2023 COASTAL MASTER PLAN

MISSISSIPPI RIVER HYDROGRAPHS

SUPPLEMENTAL MATERIAL B2.3

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COASTAL PROTECTION AND
RESTORATION AUTHORITY
150 TERRACE AVENUE
BATON ROUGE, LA 70802
WWW.COASTAL.LA.GOV

COASTAL PROTECTION AND RESTORATION AUTHORITY

This document was developed in support of the 2023 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every six years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

CITATION

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OVERVIEW

This document was developed as part of a partner project between CPRA and the US Army Corp of Engineers Engineer Research and Development Center (USACE-ERDC). This document contains a technical report entitled “Mississippi River Climate Model-Based Hydrograph Projections at the Tarbert Landing Location” prepared through USACE-ERDC for CPRA.

ERDC/CHL TR-23-5

Coastal and Hydraulics Laboratory

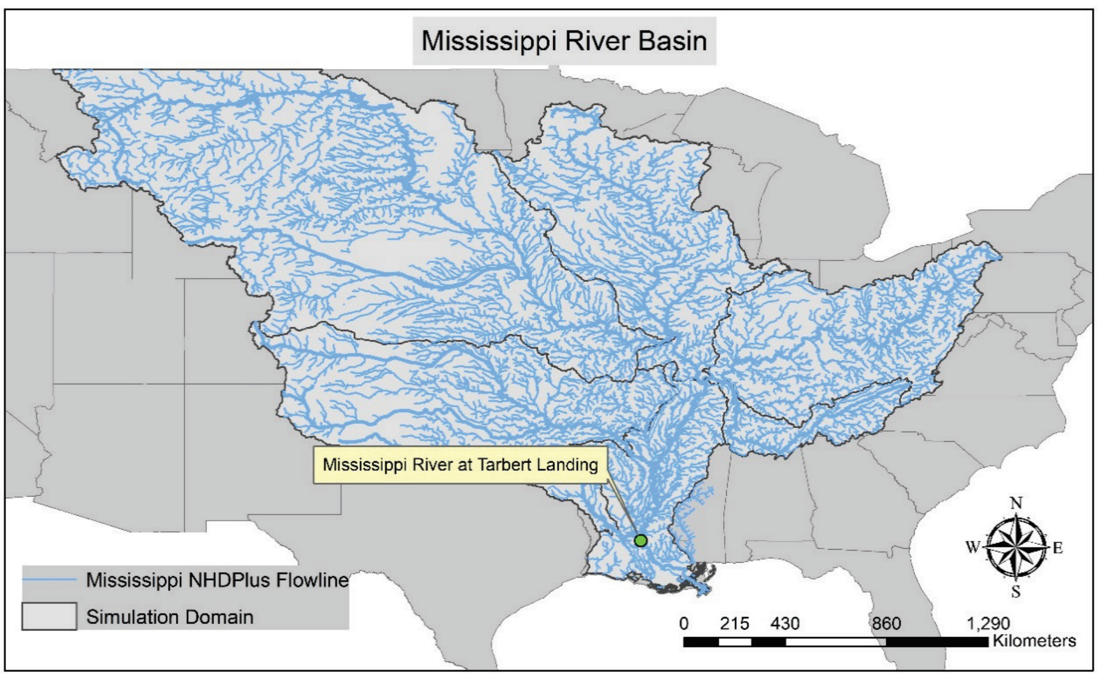
US Army Corps of Engineers®
Engineer Research and Development Center

Lowermost Mississippi River Management Program (LMRMP)

Mississippi River Climate Model–Based Hydrograph Projections at the Tarbert Landing Location

W. Clay LaHatte, Ahmad A. Tavakoly, Sara E. Lytle, and James W. Lewis

May 2023



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Coastal and Hydraulics Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Prepared for State of Louisiana Coastal Protection and Restoration Authority
150 Terrace Ave
Baton Rouge, LA 70802

Under Funding Account Code U4381454; AMSCO Code 081900

Abstract

To better understand and prepare for the possible effects associated with potential climate changes on the lower Mississippi River, the State of Louisiana Coastal Protection and Restoration Authority sought information on the historical, current, and projected future hydrodynamics of the Mississippi River. To this end, flow duration curves (FDC) for the Tarbert Landing location were generated, based on climate models derived from two of the four scenarios of the Coupled Model Intercomparison Project, Phase 5 (CMIP5), multimodel ensemble representative concentration pathways (RCPs). The global CMIP5 datasets were used by the variable infiltration capacity land surface model to produce a runoff dataset, using a bias-correction spatial disaggregation approach. The runoff datasets were then applied to simulate streamflow using the Routing Application for Parallel computatIon of Discharge (RAPID) river routing model. Based on the streamflow, FDCs were calculated for 16 CMIP5 as well as observed historical data at the Tarbert Landing location. Key observations from the results are that the 90th percentile exceedance of the simulated versus the observed flows is more frequent for the RCP 8.5 scenario than for the RCP 4.5 scenario and that the maximum annual flows for the RCP 8.5 scenario are generally smaller than for the RCP 4.5 scenario.

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Preface

This study was conducted for the State of Louisiana Coastal Protection and Restoration Authority under Funding Account Code U4381454; AMSCO Code 081900.

The work was performed by the River and Estuarine Engineering Branch of the Flood and Storm Protection Division, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL). At the time of publication of this report, Mr. Casey Mayne was acting branch chief; Dr. Cary A. Talbot was division chief; and Dr. Julie Rosati was the technical director, Flood & Coastal Risk Management R&D. The deputy director of ERDC-CHL was Mr. Keith W. Flowers, and the director was Dr. Ty V. Wamsley.

The authors acknowledge the World Climate Research Programme's Working Group on Coupled Modelling, which is responsible for the Coupled Model Intercomparison Project (CMIP), and also thank the climate modeling groups (listed in Table 2 of this report) for producing and making available their model output. For CMIP, the US Department of Energy's Program for Climate Model Diagnosis and Intercomparison provided coordinating support and led development of software infrastructure in partnership with the Global Organization for Earth System Science Portals.

The commander of ERDC was COL Christian Patterson, and the director was Dr. David W. Pittman.

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1 Introduction

The Mississippi River system is critical to the infrastructure of the United States and serves as a vital means of transporting goods. A changing climate has the potential to impact the hydrodynamics of the Mississippi River for years to come by way of increased and stronger occurrences of large river flow events. Recent understandings of weather impacts associated with a changing climate have brought the need for an updated understanding of how the river system may perform due to such increases in flows within the Mississippi River Basin (MRB) (Jha et al. 2006; Krysanova et al. 2018; Zaherpour et al. 2018). To better understand and prepare for the possible effects on the lower Mississippi River associated with possible climate changes, the State of Louisiana's Coastal Protection and Restoration Authority (CPRA) seeks information on the historical, current, and projected future hydrodynamics of the Mississippi River.

To this end, flow duration curves have been generated, based on climate models derived from two of the four scenarios of representative concentration pathways (RCPs), (described in Section 1.2), for the Tarbert Landing location. This report documents the investigation of these concerns.

1.1 Background

The CPRA manages several planning efforts that are directly impacted by understanding of the historical, current, and future hydrodynamics of the Mississippi River. As part of the larger Lowermost Mississippi River Management Program (LMRMP), and building upon previous work by the US Army Engineer Research and Development Center (Lewis et al. 2019) for representative concentration pathway 4.5 (RCP 4.5), CPRA sought improved estimates of future Mississippi River hydrographs projected by the RCP 8.5 Coupled Model Intercomparison Project, phase 5 (CMIP5) model ensemble.

1.2 Climate Projections via Representative Concentration Pathways (RCPs)

The investigation described in this report made use of flow duration curves (FDCs) created based on predictions about how the climate may change in the future. These predictions are global climate scenarios referred to as RCPs, which are projections of the radiative forcings in the atmosphere due to relative concentrations of greenhouse gasses that have accumulated at the year 2100.

Four RCP scenarios have been defined via the World Climate Research Programme, each of which prescribes a potential amount of global warming based on a given level of concentration of greenhouse gasses at year 2100. These global climate projections are from the CMIP5 multimodel ensemble. These RCP scenarios are shown in Table 1, where the RCP scenario number represents the global warming in *watts per square meter* averaged over the planet.

Table 1. RCP scenario levels.

RCP Scenario	When Emissions Peak	Potential Warming (°C)*
2.6	Between 2010 and 2020	0.9–2.3
4.5	2040s	1.7–3.2
6.0	2070s to 2080s	2.0–3.7
8.5	2100+	3.2–5.4

* Temperature source: Climate Nexus, n.d.

Two of these scenarios were considered for the Louisiana CPRA investigation, namely the RCP 4.5 and RCP 8.5 (SOS 2023a, RCP 4.5; SOS 2023b, RCP 8.5).

1.3 Objective

The objective of the investigation described in this report was to obtain flow hydrographs and assess a range of FDCs at Tarbert Landing in the MRB with consideration of RCP 4.5 and RCP 8.5 climate projections.

1.4 Approach

River flow occurring at Tarbert Landing was simulated using a Routing Application for Parallel computatIon of Discharge (RAPID) model of the entire Mississippi River Basin (David et al. 2011; Tavakoly et al. 2017, 2021). The RAPID numerical model is an open-source river-routing model that computes river discharge. RAPID has been developed and validated over more than 15 yr[1]. The RAPID numerical model is fully parallelized and solves a matrix version of the Muskingum method in river networks with hundreds of thousands of river reaches. RAPID routes combined surface and subsurface runoff generated by a land surface model and simulates streamflow for every river reach in the river network.

The model of the MRB was created as vector-based stream segments. The simulations were driven by climate models that estimate the state of the climate through 2099, namely the CMIP5 climate models that include the greenhouse gas concentration scenarios RCP 4.5 and RCP 8.5 (Section 1.2).

Daily hydrographs and FDCs were generated for the Tarbert Landing location based on 16-member CMIP5 model ensembles under both RCP 4.5 and RCP 8.5 atmospheric conditions. All ensemble-run outputs used in this study span the time frame between 1950 through 2099. FDCs were created from the RAPID outputs using Microsoft Excel via a standard method of ranking flow values from largest to smallest.

1.5 Scope

The investigation discussed in this report is based on the CMIP5 RCP 4.5 and RCP 8.5 atmospheric conditions. It is a continuation from previous work that was based on CMIP5 RCP 4.5 atmospheric conditions (Lewis et al. 2019).

[1] For a full list of the spelled-out forms of the units of measure and unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248–52 and 345–7, respectively. https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

2 Methodology

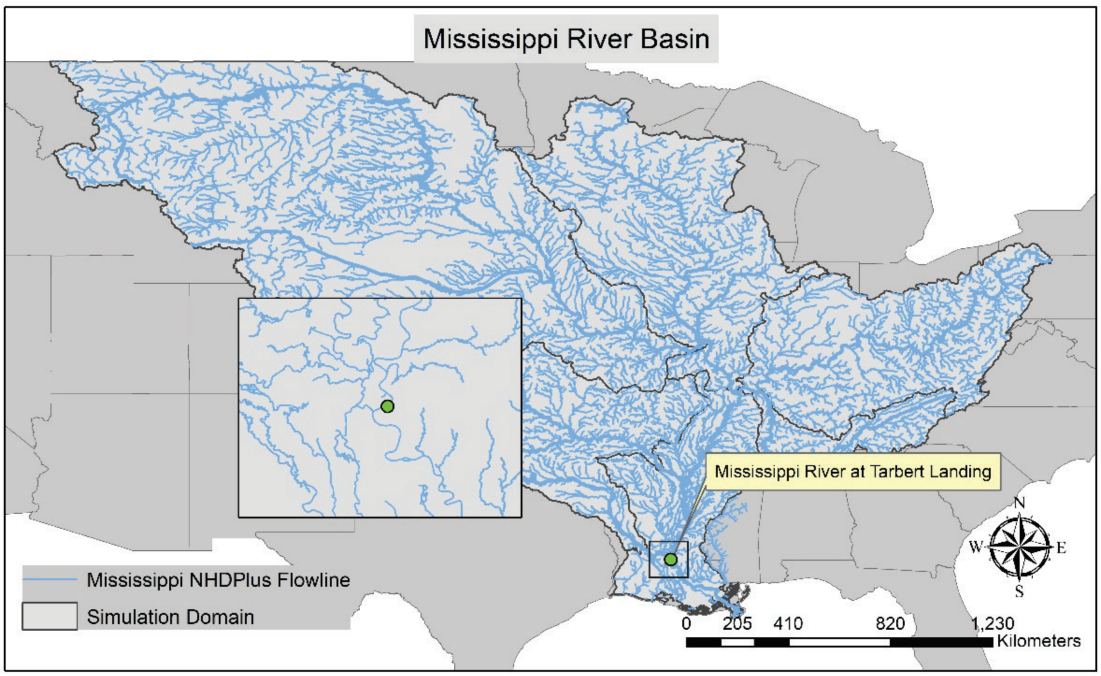
The Tarbert Landing is located on the Mississippi River at river mile 306.3, approximately 4 mi upstream of Red River Landing (Figure 1). The Tarbert Landing gauge currently serves as an upstream boundary condition for several of the State of Louisiana's Mississippi River numerical models. The United States Geological Survey gauge at this site is in Wilkinson County, Mississippi, and has an elevation of 0.0 ft, National Geodetic Vertical Datum of 1929. The drainage area contributing to the site is 1,124,900 mi^2 (Water Quality Portal, n.d.).

Figure 1. Location of Tarbert Landing.

2.1 Simulation

This investigation is based on CMIP5 RCP climate prediction scenarios, specifically RCP 4.5 and RCP 8.5. These predictions of climate forcings were used to drive the RAPID model of the MRB to obtain streamflow. The MRB model was created as vector-based stream segments obtained via the National Hydrography Dataset Plus (NHDPlus) V2 dataset (Figure 2). The geospatial hydrography river network for entire MRB encompasses 1,240,697 NHDPlus river reaches with an average length of 1.9 km. A Python utility code called RAPIDpy was used to preprocess data to be used as inputs for the RAPID model.

Figure 2. The Mississippi River Basin (MRB) and the Tarbert Landing location. The river network is produced based on the National Hydrography Dataset Plus (NHDPlus) dataset.



To obtain streamflow values from the climate projections, the variable infiltration capacity hydrology model, version 4.1.2, was used to generate daily total runoff from 1950 through 2099 (University of Washington Computational Hydrology Group 2021). Sixteen climate models were selected for this study and are shown in Table 2.

Table 2. List of the 16 climate models selected.

CMIP5 Climate Model ID	CMIP5 Climate Modeling Group*
bcc-csm1-1	Beijing Climate Center, China Meteorological Administration
bcc-csm1-1-m	
can-esm2	Canadian Centre for Climate Modelling and Analysis
ccsm4	National Center for Atmospheric Research
cesm1-bgc	Community Earth System Model Contributors
csiro-mk3-6-0	Commonwealth Scientific and Industrial Research Organization, Queensland Climate Change Centre of
fgoals-g2	Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences, and Center for Earth System Science, Tsinghua University
gfdl-cm3	NOAA Geophysical Fluid Dynamics Laboratory
gfdl-esm2g	
giss-e2-r	NASA Goddard Institute for Space Studies
ispl-cm5a-mr	Institut Pierre-Simon Laplace
miroc5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
mpi-esm-lr	Max-Planck-Institut für Meteorologie (Max Planck Institute for Meteorology)
mpi-esm-mr	
mri-cgcm3	Meteorological Research Institute
nor-esm1-m	Norwegian Climate Centre

*Program for Climate Model Diagnosis & Intercomparison, n.d.

Daily hydrographs were simulated by the RAPID model for all 16 CMIP5 climate models and all river reaches in the MRB for 1950–2099. Using daily streamflow, the FDCs were then generated at the Tarbert Landing location based on 16-member CMIP5 model ensembles under both RCP 4.5 and RCP 8.5 atmospheric conditions. All ensemble run outputs used in this study span the time frame between 1950 through 2099.

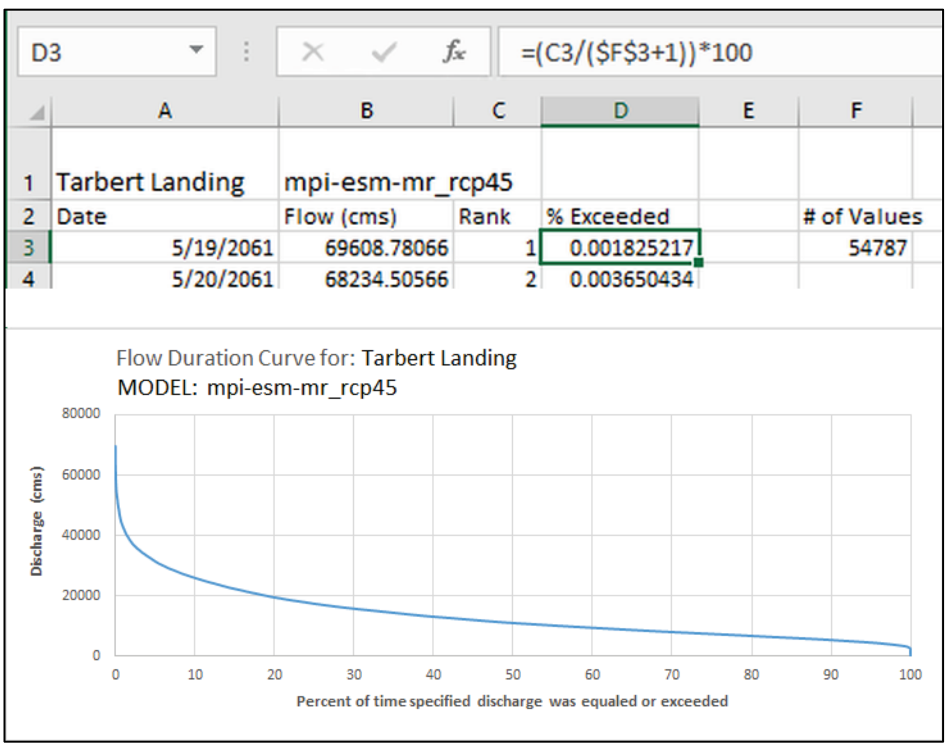
2.2 Daily Hydrographs at Tarbert Landing

Tarbert Landing is located downstream of the Old River Control Complex, which regulates the flow of water between the Mississippi River and the Atchafalaya River. In 1954, the US Congress authorized the construction of the Old River Control Project to maintain the distribution of flow between the two rivers as they existed at that time (US Congress 1954). Therefore, the flow is regulated such that 70% of the flow goes down the Mississippi River while 30% of the flow goes down the Atchafalaya River. Using the NHDPlus V2 stream network, streamflows were extracted in the two segments just upstream of this regulation location, one in the Mississippi River and one in the Lower Red River below the confluence with the Black River. The time series of daily streamflows for each model and each RCP at these two stream segments were extracted for 1950–2099 into Excel. For each simulation, the Mississippi and Red Rivers streamflows were summed together in Excel. The Tarbert Landing streamflows were calculated as 70% of that total flow, according to the regulation of flow described above. These Tarbert Landing streamflows were used in the following sections.

2.3 Flow Duration Curves (FDCs)

The FDCs for the model results were produced in Microsoft Excel via a standard method of ranking the period flows from largest to smallest flow value and plotting the ranked values versus the percent of exceedance as related to the entire period of interest. The percentage of exceedance of a given flow value is the rank of that value divided by the total number of flow values recorded (Figure 3).

Figure 3. Example of how the flow duration curves (FDCs) were created.



3 Results

3.1 Flow Hydrographs

Hydrographs for the individual climate models were created and are provided in Appendix A. To facilitate comparison of the RCP 4.5 and RCP 8.5 scenarios per climate model, each of the hydrograph plots is a combination of these two climate scenarios.

3.2 FDCs

For this investigation, FDCs were created from the RAPID results for each of the 32 climate models (16 each for RCP 4.5 and RCP 8.5) that were used in the study, as well as from the observed flow data. The observed flow data obtained for this study spans the period between 1950 through 2005. The model results were compared with observations for the time period 1950 to 2005 because CMIP5 climate models used observed climate forcings in this time period. The FDCs for the individual climate models are provided in Appendix B.

To discover which of the climate models yield the closest match to the observed data, the FDCs from the models were compared with the FDC derived from the observed data. The time span for the FDC comparison covers the period where the modeled results and observed data overlap—between 1950 and 2005. One climate model each for the RCP 4.5 and RCP 8.5 scenarios that most closely matched the observed FDC was found. For each climate model, the determination of the best matches for the curves was made by choosing the smallest resulting value obtained when squaring the difference between the maximum simulated flow and the maximum observed flow. The closest matches were BCC-CSM1-1-m for RCP 4.5 and CSIRO-MK3-6-0 for RCP 8.5. The hydrographs for these models are shown in Figure 4 and Figure 6. The FDCs for these closest matches are shown in Figure 5. The single climate model that had the closest FDC match to the observed for both RCP 4.5 and RCP 8.5 together was BCC-CSM1-1-m (Figure 7).

The FDCs for all climate models plotted together are provided. Figure 8 and Figure 9 show the FDCs for the RCP 4.5 climate models, and Figure 10 and Figure 11 show the FDCs for the RCP 8.5 models.

Figure 4. Hydrographs for the closest matching climate model FDCs (one match each for representative concentration pathway [RCP] 4.5 and RCP 8.5) to the FDC of the observed flow data for the period 1950–2005.

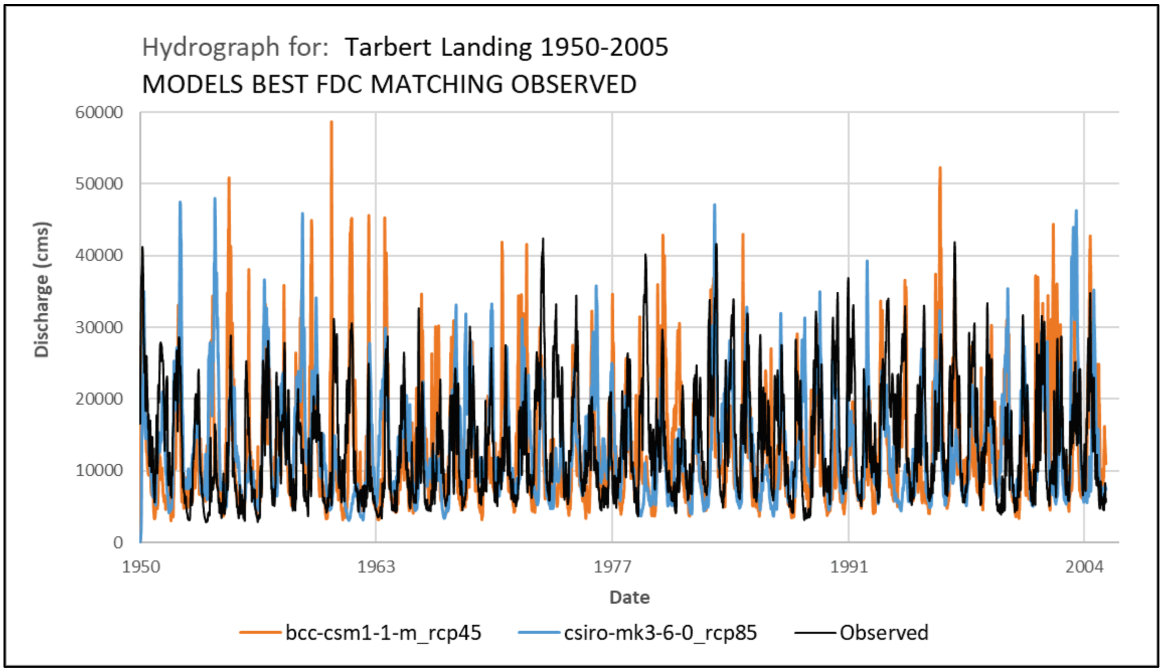


Figure 5. The closest matching climate model FDCs (one match each for RCP 4.5 and RCP 8.5) to the FDC of the observed flow data.

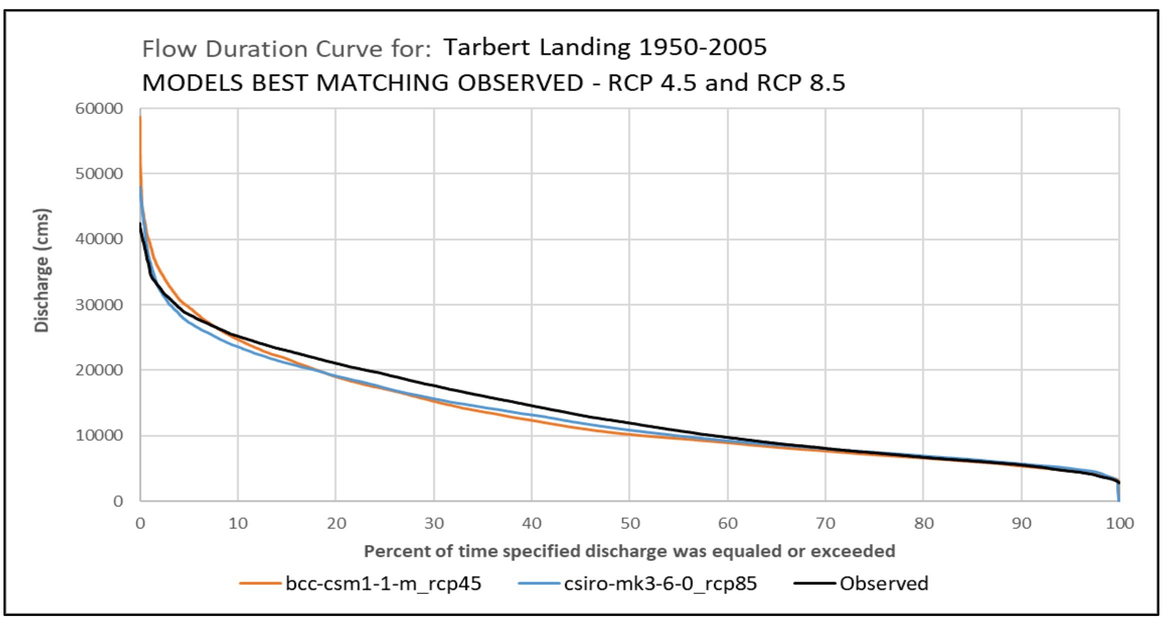


Figure 6. Hydrographs for the closest matching climate model FDCs (one match each for RCP 4.5 and RCP 8.5) to the FDC of the observed flow data for the period 1950–2099.

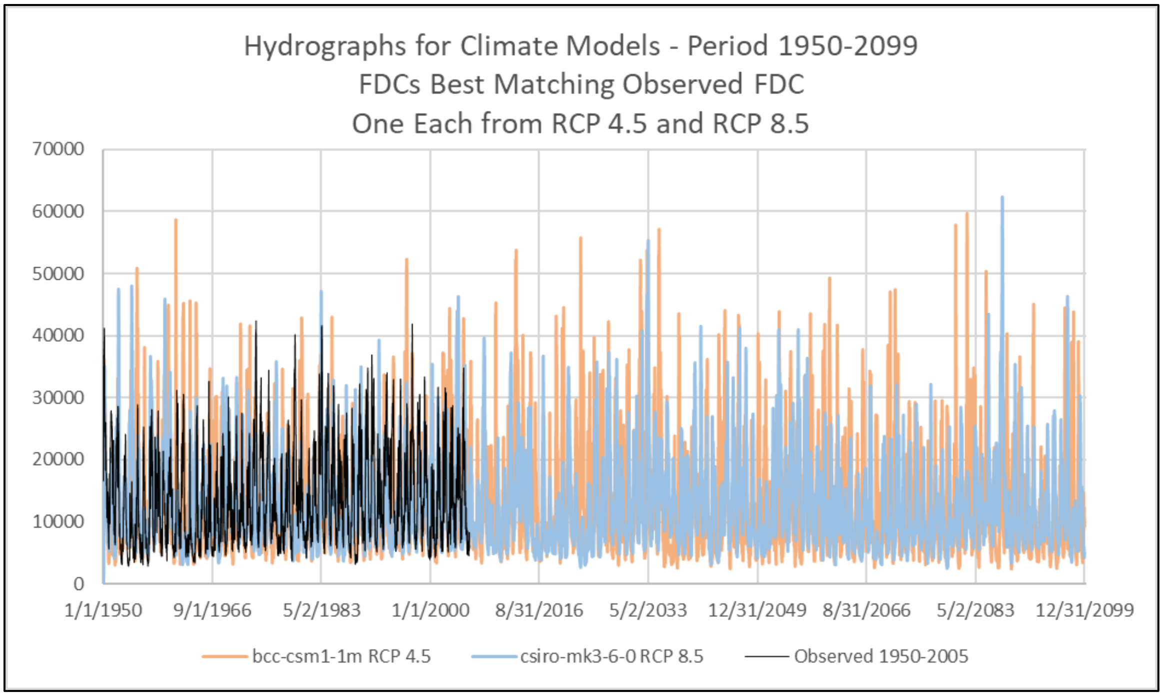


Figure 7. The climate model that most closely matched the observed flows for RCP 4.5 and RCP 8.5 together was bcc-csm1-1-m.

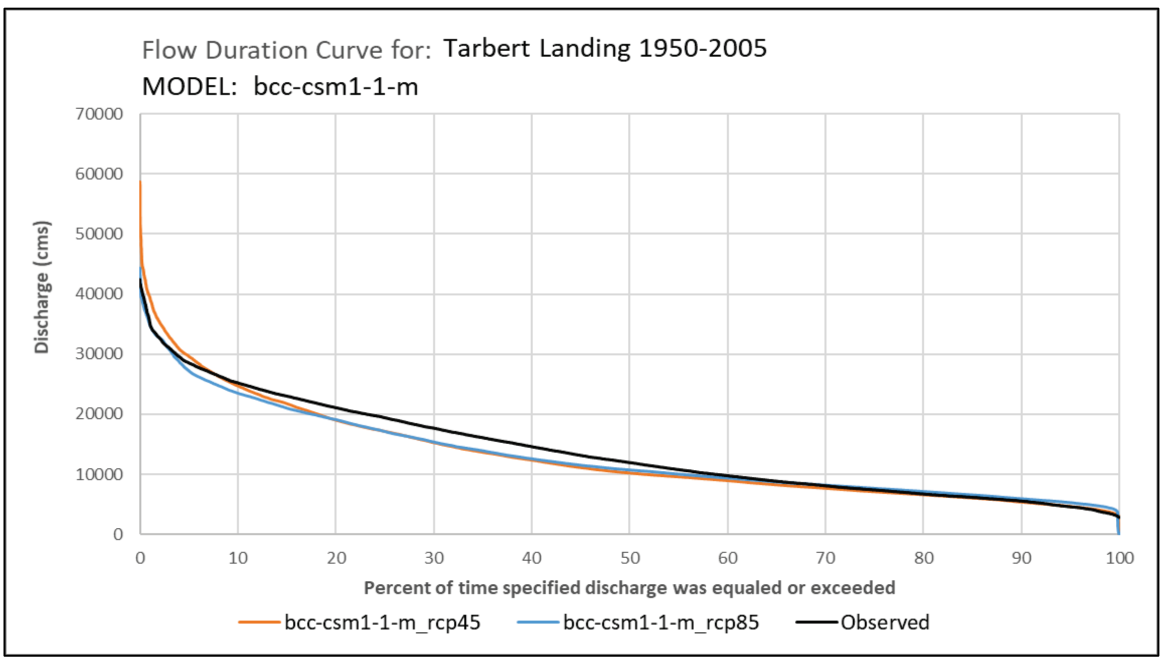


Figure 8. RCP 4.5, all climate model FDCs with the FDC for the observed flow data. All FDCs 1950–2005.

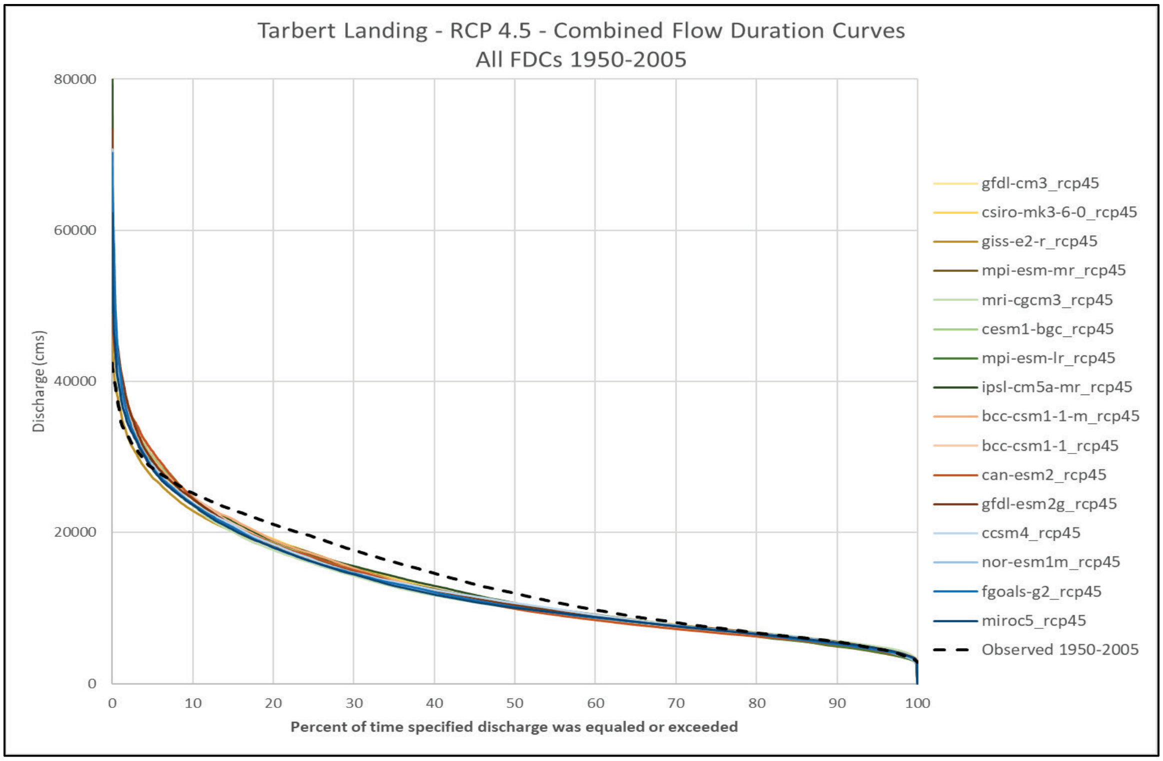


Figure 9. RCP 4.5, all climate model FDCs with the FDC for the observed flow data. All modeled FDCs 1950–2099. Observed 1950–2005.

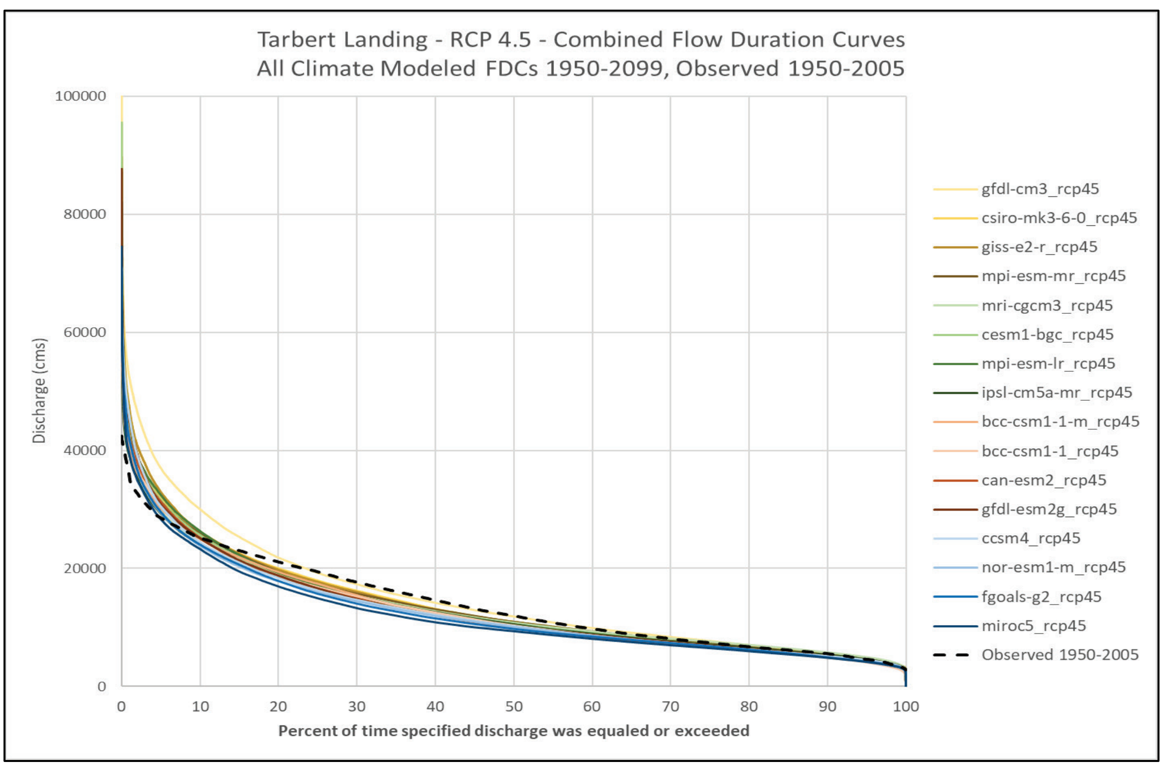


Figure 10. RCP 8.5, all climate model FDCs with the FDC for the observed flow data. All FDCs 1950–2005.

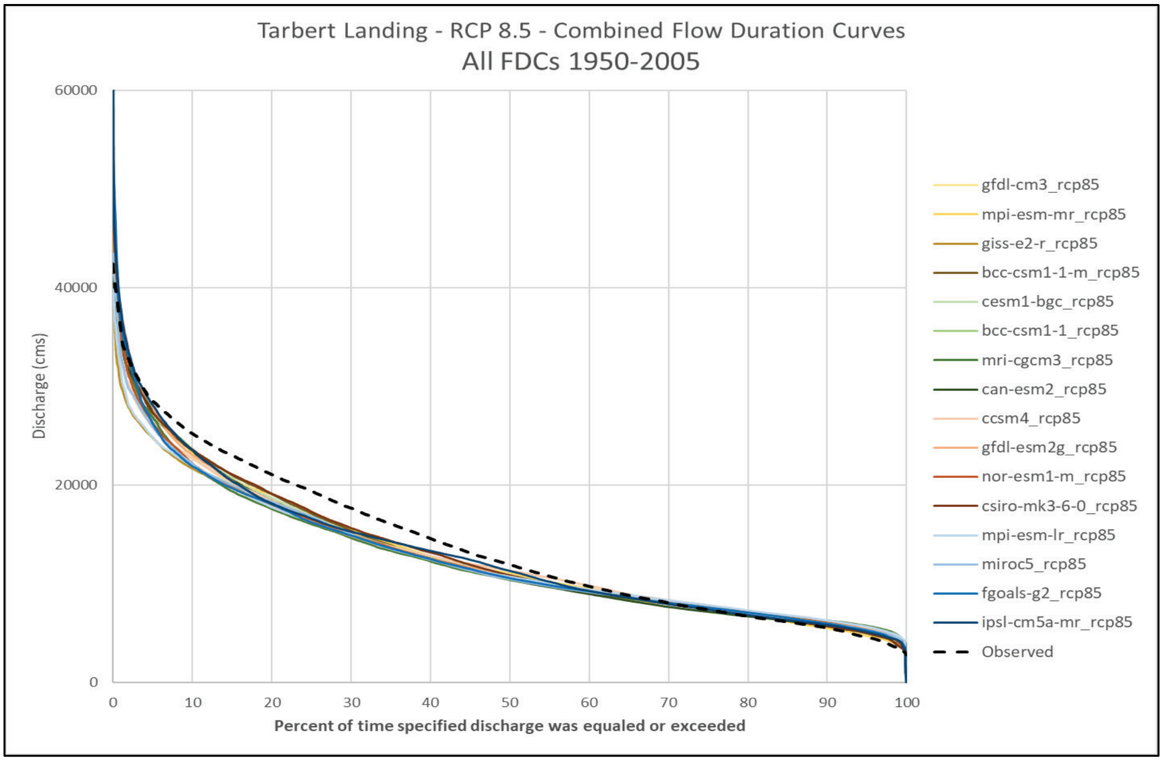
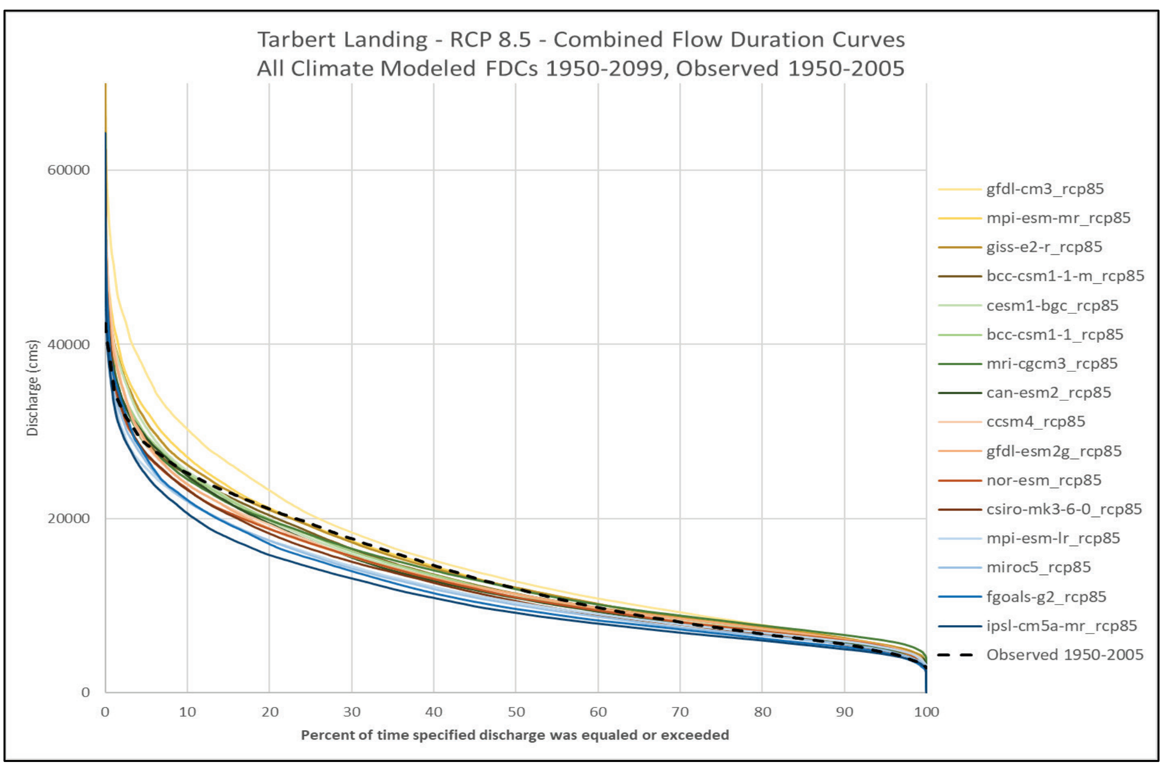


Figure 11. RCP 8.5, all climate model FDCs with the FDC for the observed flow data. All modeled FDCs 1950–2099. Observed 1950–2005.



3.3 90th Percentile Exceedance Values

From the FDCs, the 90th percentile exceedance values were extracted and are provided in Figure 12 through Figure 15. The exceedance values are shown for both the observed period span of 1950–2005 and include the projected period, 1950–2099. The two RCP 4.5 and 12 RCP 8.5 climate models that exceeded the observed at the 90th percentile for the simulation period of 1950–2099 are shown below.

3.3.1 RCP 4.5 Climate Models Exceeding Observed at 90th Percentile

The two RCP 4.5 climate models exceeding the observed at the 90th percentile for the period 1950–2099 are

- giss-e2-r
- mri-cgcm3.

3.3.2 RCP 8.5 Climate Models Exceeding Observed at 90th Percentile

The 12 RCP 8.5 climate models exceeding the observed at the 90th percentile for the period 1950–2099 are

- bcc-csm1
- bcc-csm1-1m
- can-esm2
- ccsm4
- cesm1-bgc
- gfdl-cm3
- gfdl-esm2g
- giss-e2-r
- mpi-esm-lr
- mpi-esm-mr
- mri-cgcm3
- nor-esm1-m.

Figure 12. The 90th percentile exceedance flow values for RCP 4.5 based on data spanning 1950–2005.

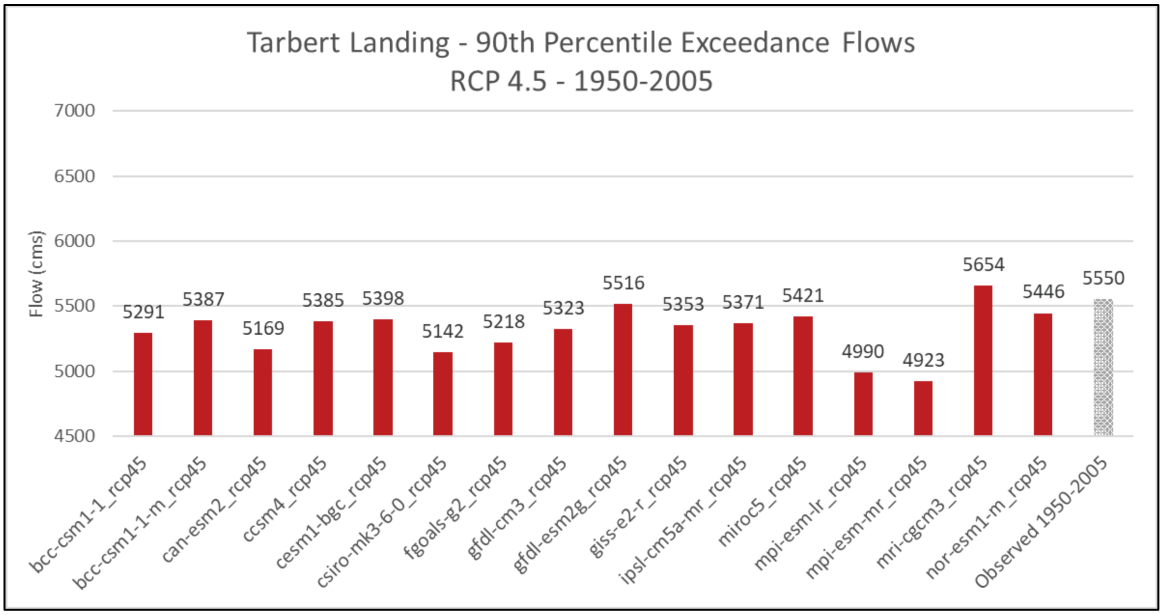


Figure 13. The 90th percentile exceedance flow values for RCP 4.5 based on data spanning 1950–2099.

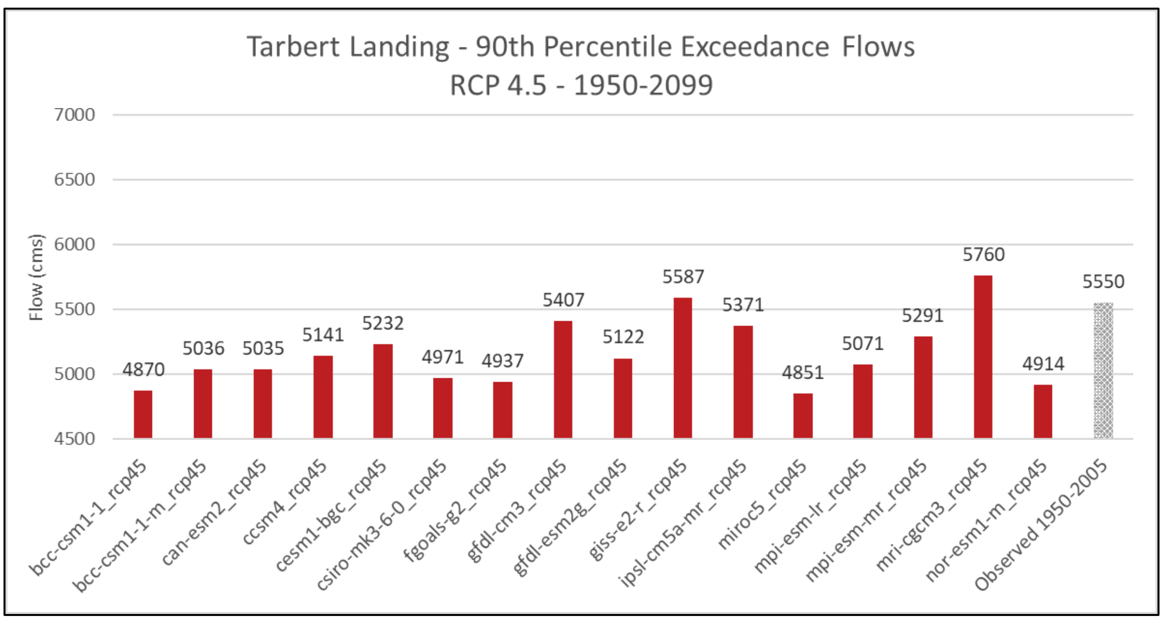


Figure 14. The 90th percentile exceedance flow values for RCP 8.5 based on data spanning 1950–2005.

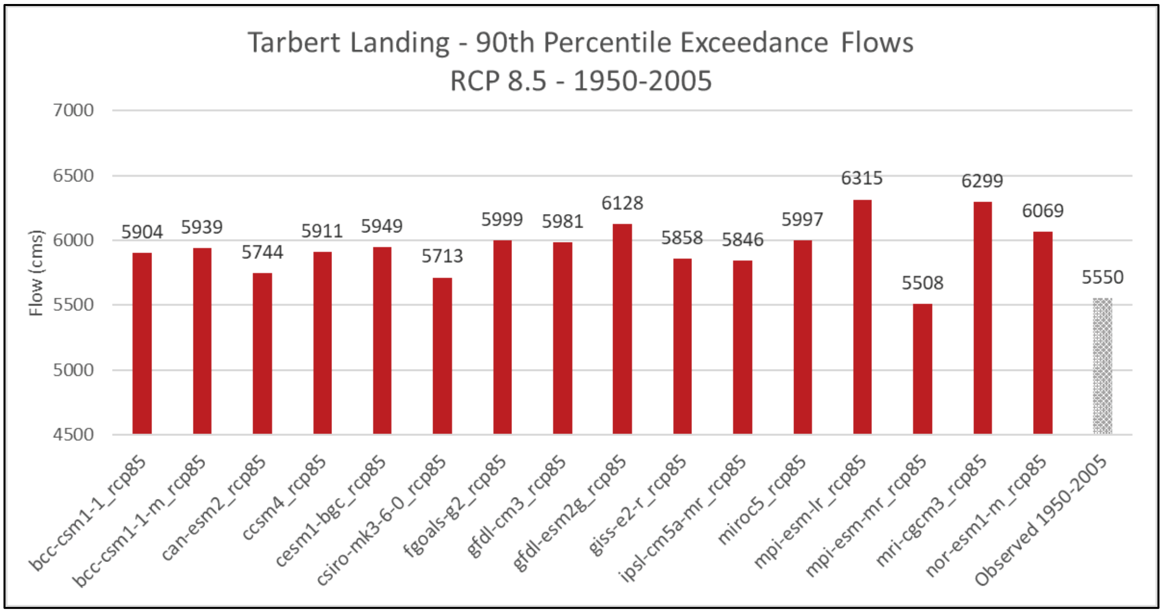
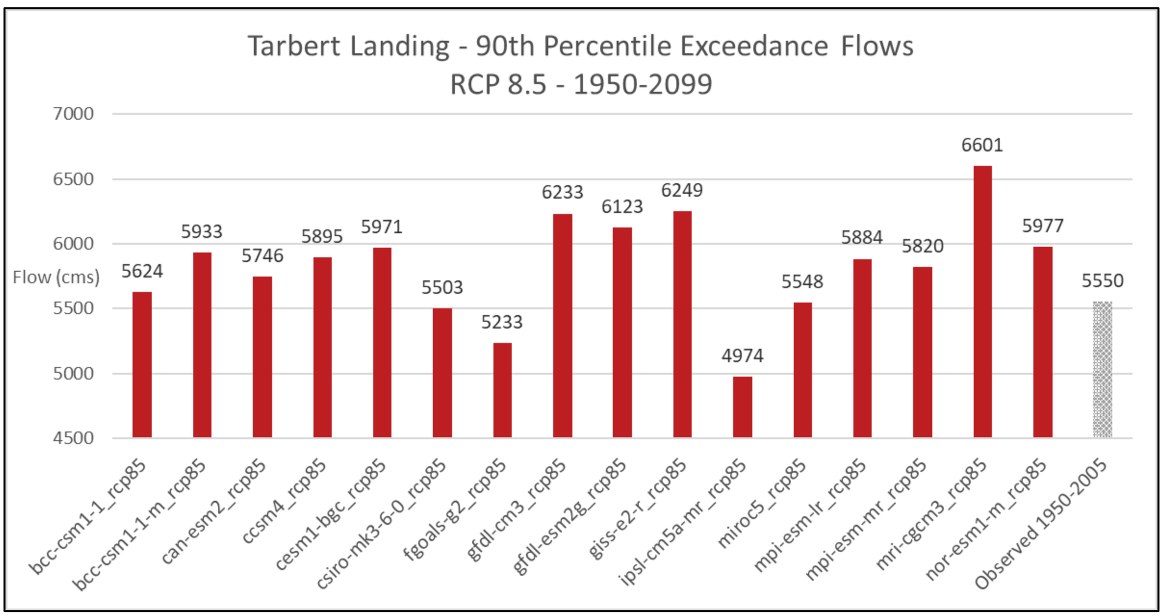


Figure 15. The 90th percentile exceedance flow values for RCP 8.5 based on data spanning 1950–2099.



3.4 Maximum Annual Flows

The yearly median of the maximum yearly flows of all the 16 climate models is shown in Figure 16 and Figure 17, along with the maximum flows for all models. The climate model simulations span 1950–2099. The observed data span 1950–2005. From these plots, it is observed that the maximum flow values resulting from the RCP 4.5 simulations generally exceed the maximum simulated flows resulting from the RCP 8.5 scenario.

Figure 16. For the RCP 4.5 climate models—maximum annual flows and the median of the yearly maximum flows. The R^2 is for the trend of the median of all combined climate model flow results at Tarbert Landing for the RCP 4.5 scenario.

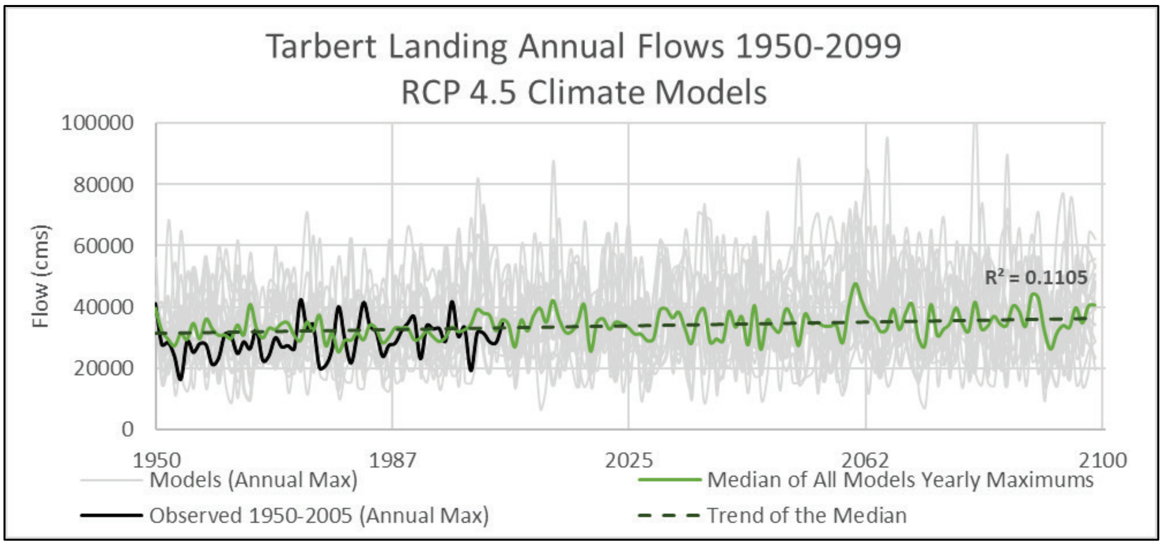
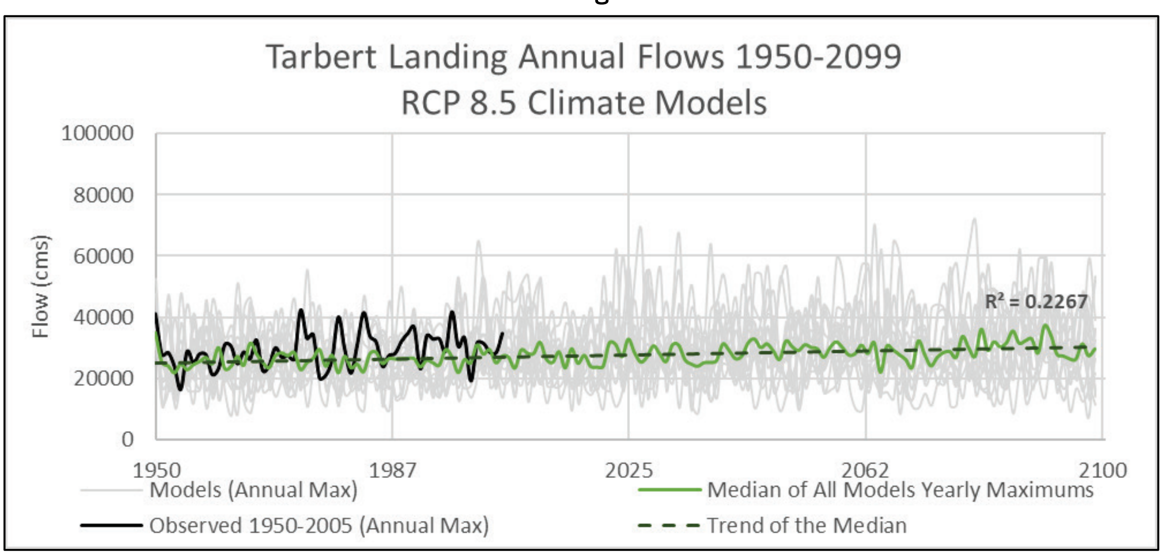


Figure 17. For the RCP 8.5 climate models—maximum annual flows, and the median of the yearly maximum flows. The R^2 is for the trend of the median of all combined climate model flow results at Tarbert Landing for the RCP 8.5 scenario.



4 Conclusions and Recommendations

The RAPID numerical model was used to simulate CMIP5 climate scenarios RCP 4.5 and RCP 8.5 for the MRB stream network for the time period 1950–2099. FDCs and hydrographs for each of 16 climate models were created from the model results for the RCP 4.5 and RCP 8.5 scenarios at the Tarbert Landing location. The following conclusions can be drawn from this investigation:

- There is a large amount of uncertainty in the streamflow projections. Improvement is needed in the climate and hydrological modeling framework to continue reducing uncertainty.
- Model results are not intended to predict the flow at any particular time. An FDC approach was used here to evaluate the distribution of flows. Comparisons of relative changes in the model results can also be useful.
- Analysis of the results based on the annual maximum flows, as well as the 90th percentile exceedance, indicates that the flow values obtained from the climate model results exceed the flows recorded in the observations. The reason for those differences should be investigated further.
- The analysis of the FDCs from the modeling indicates that the climate models that most closely match the observed flows are bcc-csm1-1-m for the RCP 4.5 scenario and csiro-mk3-6-0 for the RCP 8.5 scenario.
- The climate model that most closely matched the observed flows for both RCP 4.5 and RCP 8.5 scenarios together was bcc-csm1-1-m.
- Analysis of the 90th percentile exceedance of the modeled results compared with the observed flow, for the period 1950–2099, indicates that there were two climate models that exceeded the observed flow for the RCP 4.5 scenario (GFDL-CM3 and MRI-CGCM3) and 12 climate models that exceeded the observed flow for the RCP 8.5 scenario.
- Analysis of the simulated maximum flows indicates that the annual maximum flows for RCP 4.5 scenarios tend to exceed those of the RCP 8.5 scenarios. This should be investigated further.
- The streamflow data produced in this project can be used as boundary condition to study the response of river network under varying potential management strategies across a range of future environmental conditions.
- The rapid evolution of climate change science and the need to address an ever-expanding range of scientific questions arising from more and

more research communities necessitate revisiting of CMIP project. The latest CMIP 6 has been recently released to meet those gaps and needs. The streamflow simulations using CMIP6 can be considered for future work.

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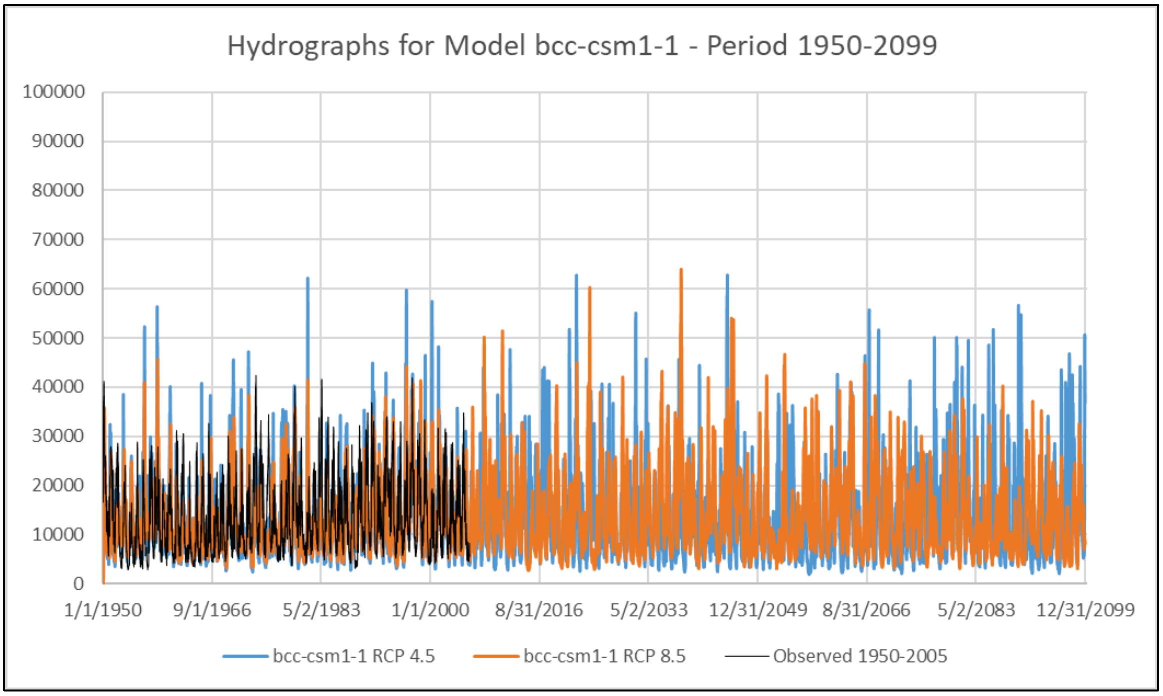
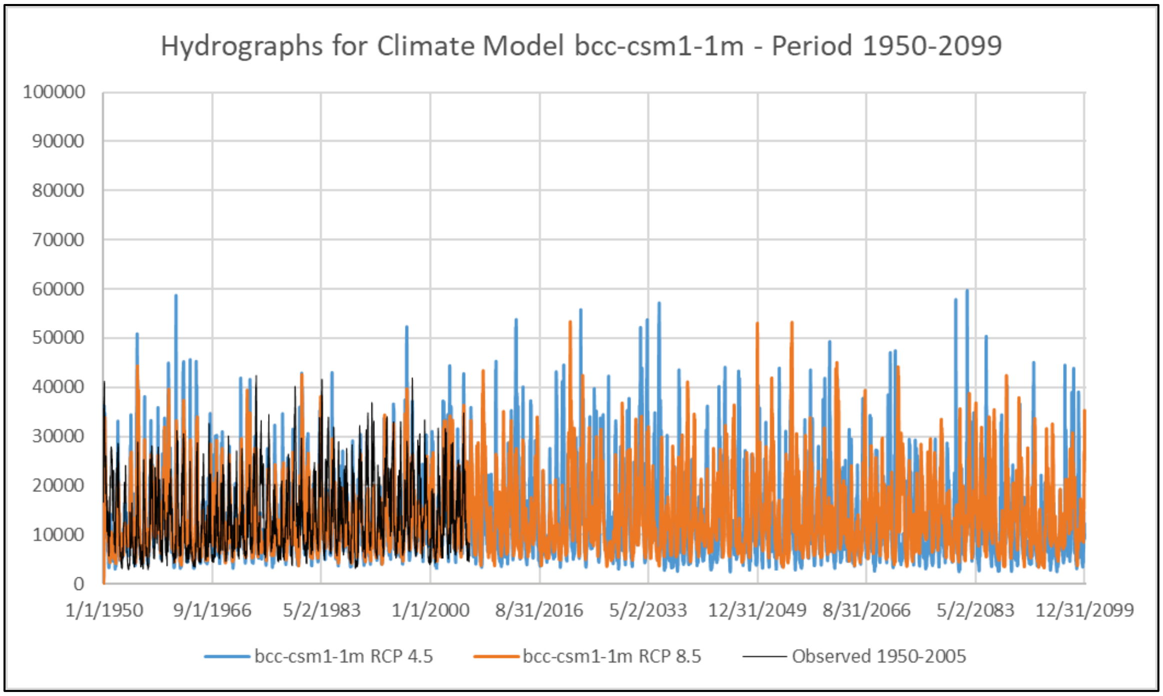
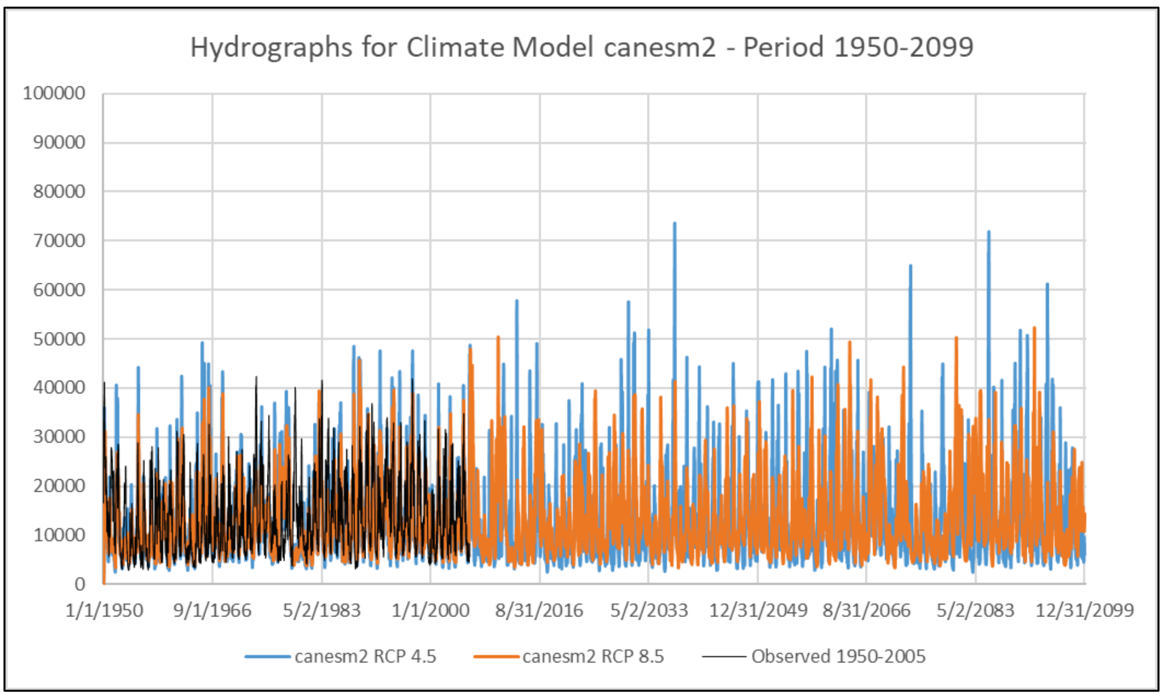
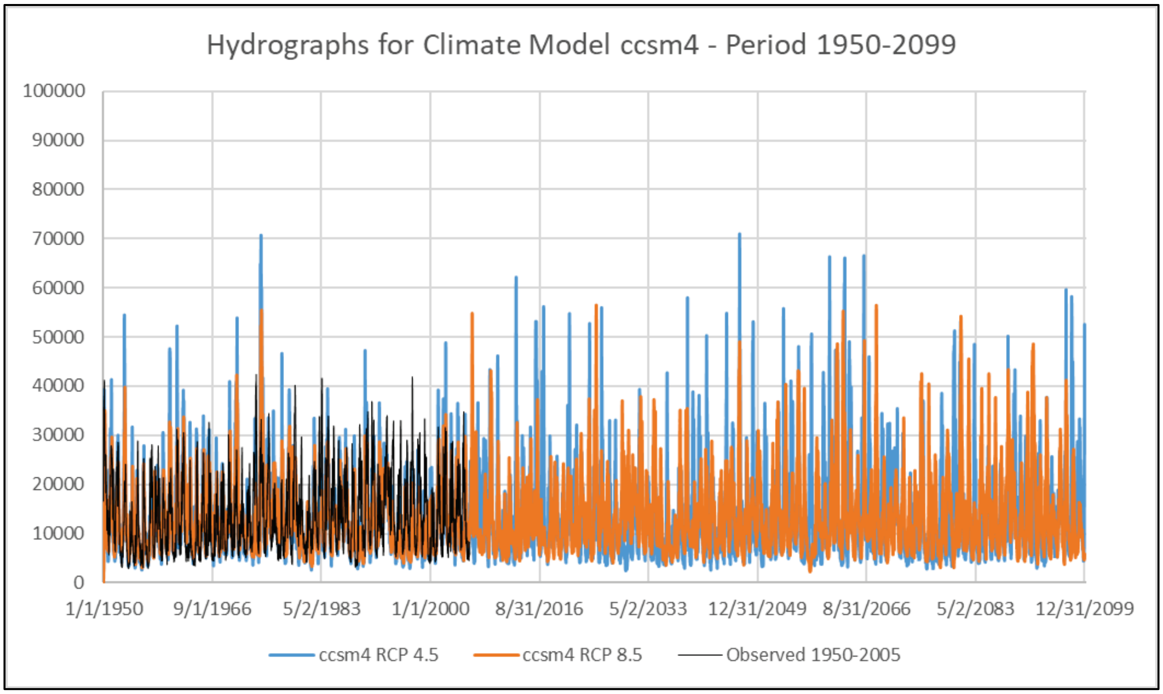
Appendix A: Flow Hydrographs per Climate Model

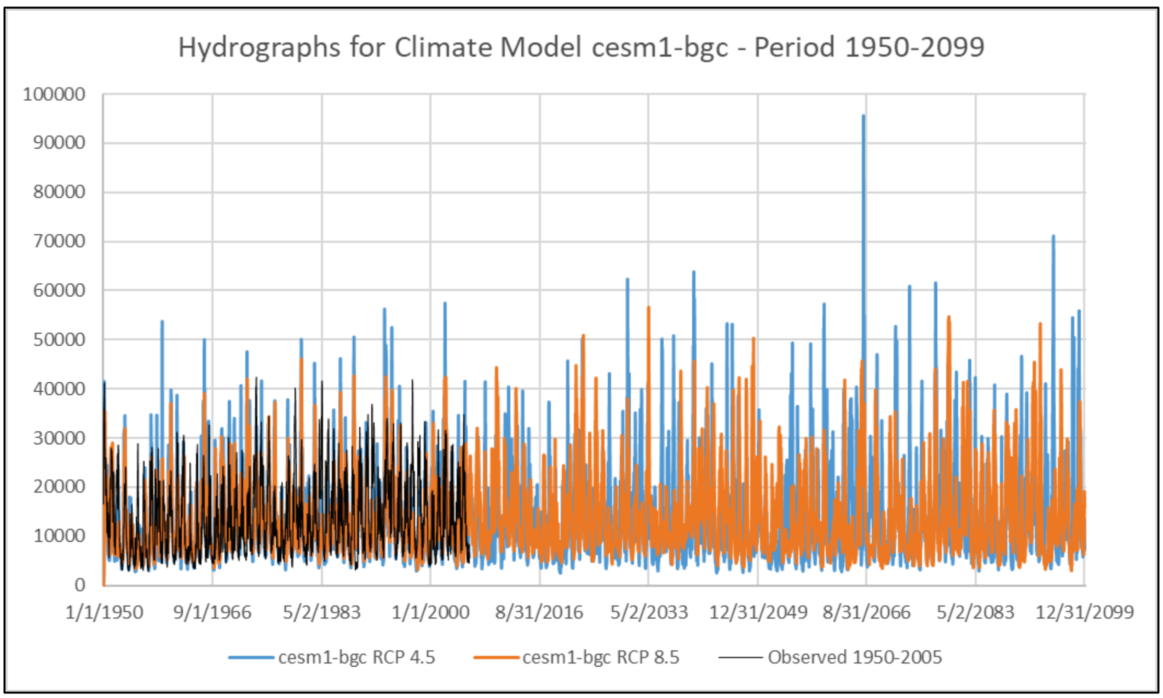
The following figures present the flow hydrographs for each of the 16 climate models, with RCP 4.5 and RCP 8.5 combined, together with the observed flow hydrograph, for the simulation period spanning 1950–2099. All plots use the same *y*-axis range to facilitate comparisons across charts.

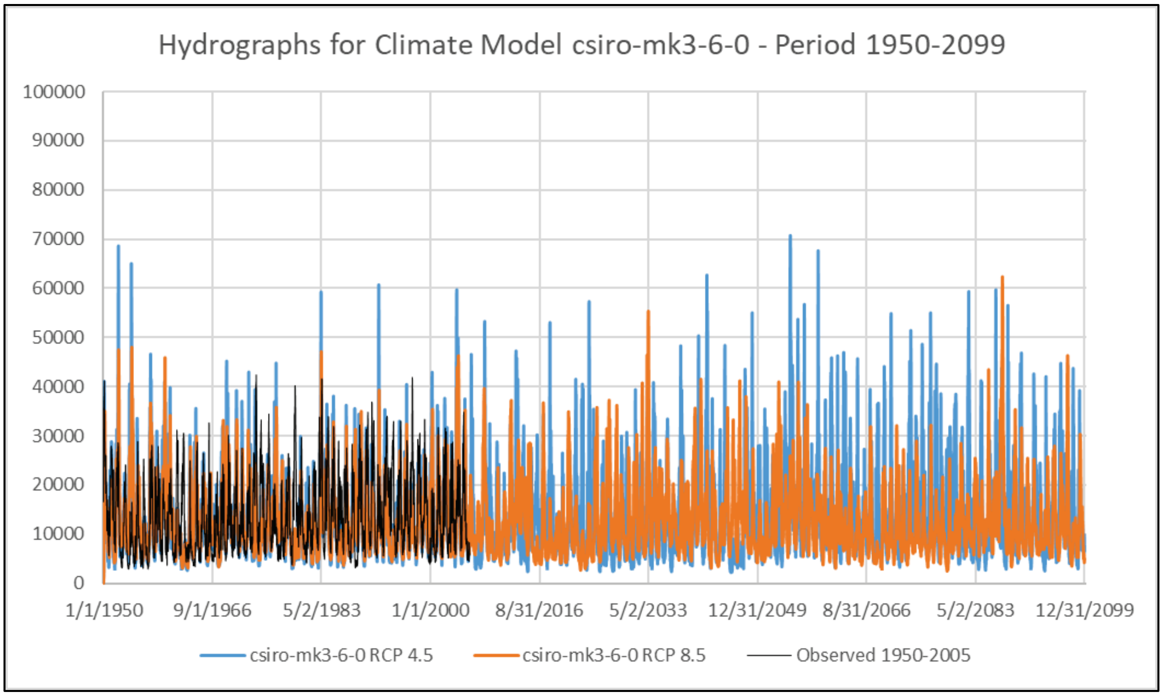


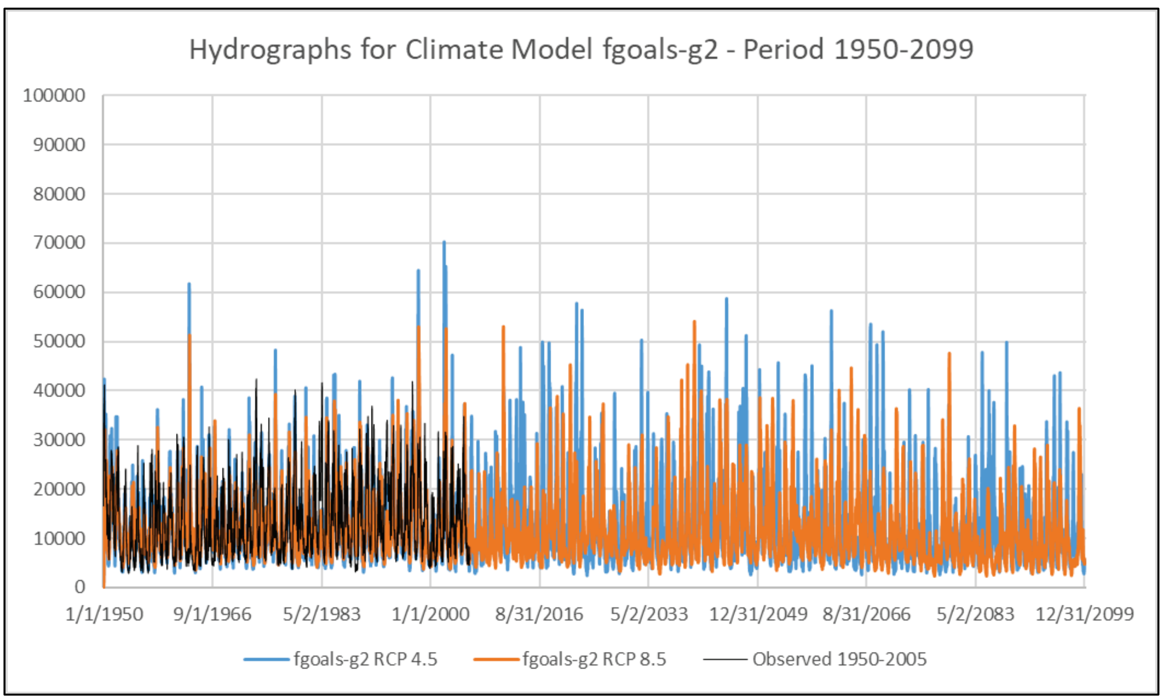

Hydrographs for Climate Model bcc-csm1-1m - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
bcc-csm1-1m RCP 4.5
bcc-csm1-1m RCP 8.5
Observed 1950-2005

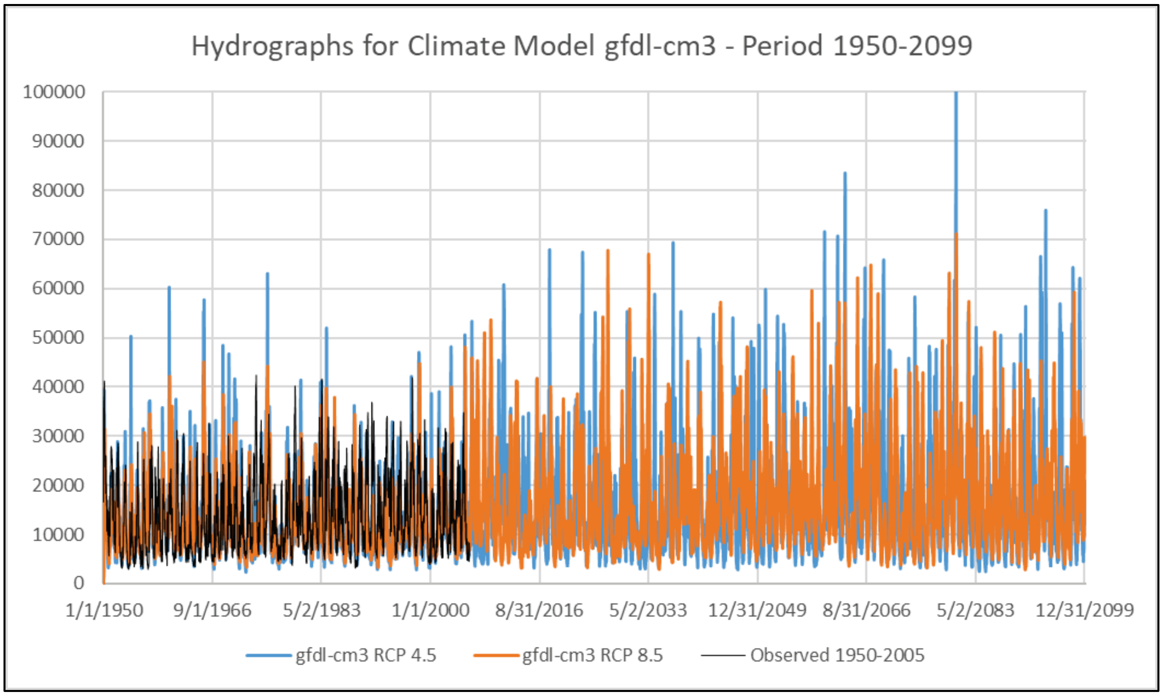

Hydrographs for Climate Model canesm2 - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
canesm2 RCP 4.5
canesm2 RCP 8.5
Observed 1950-2005

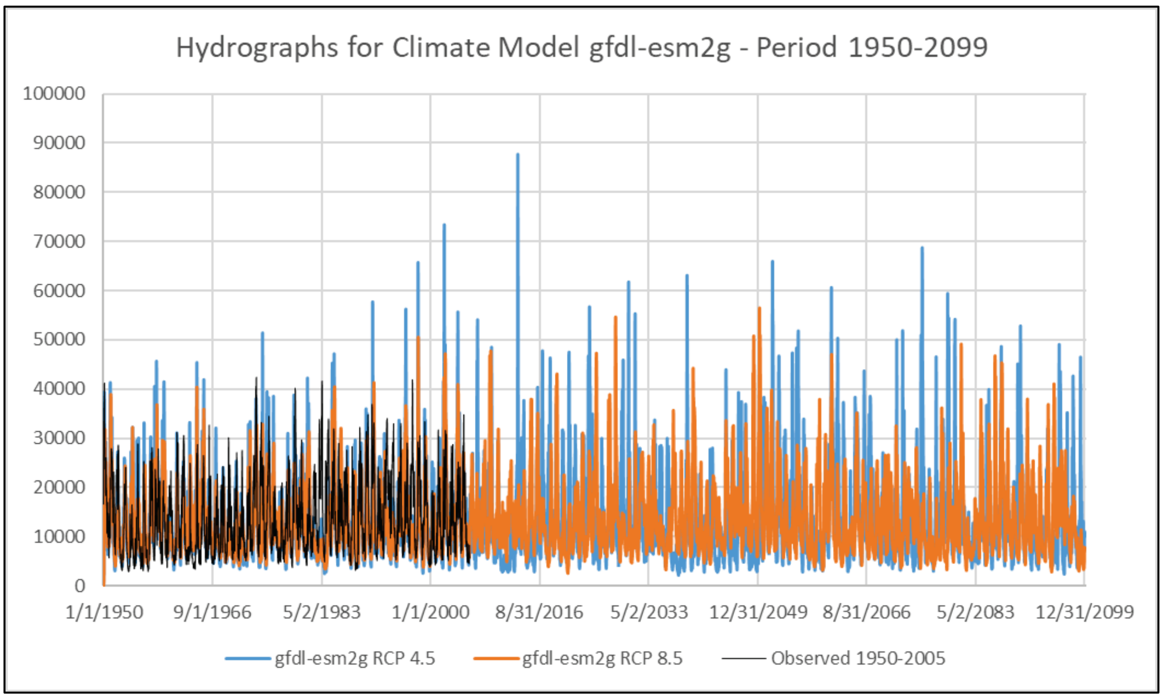

Hydrographs for Climate Model ccsm4 - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
ccsm4 RCP 4.5
ccsm4 RCP 8.5
Observed 1950-2005

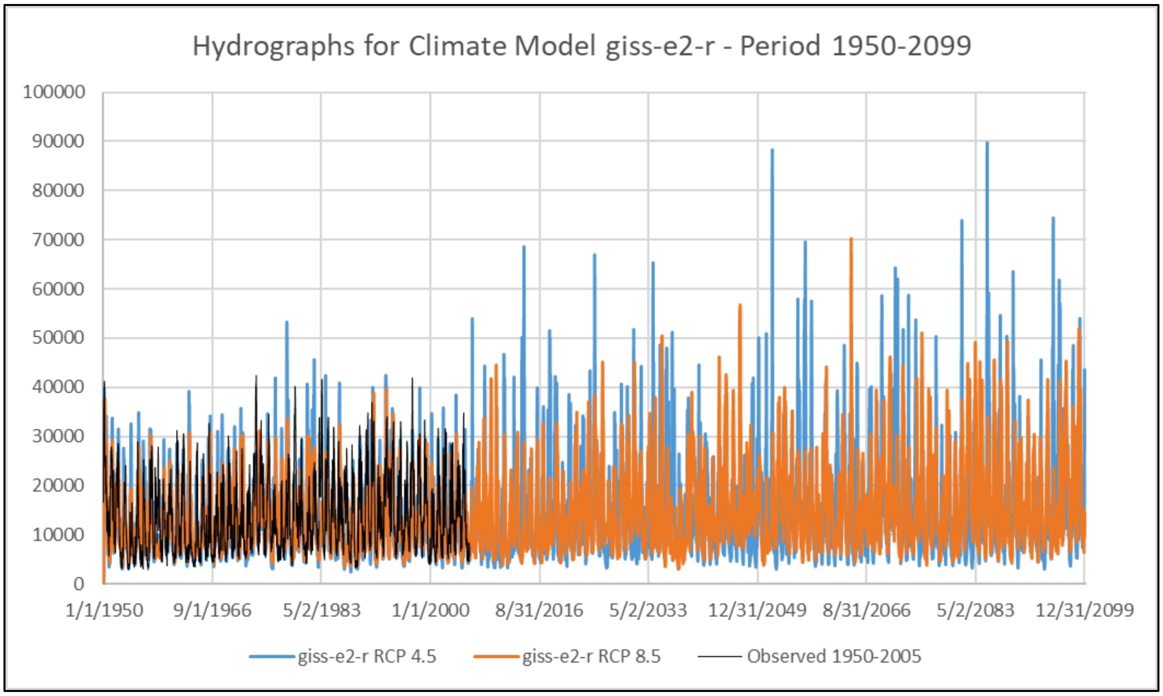

Hydrographs for Climate Model cesm1-bgc - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
cesm1-bgc RCP 4.5
cesm1-bgc RCP 8.5
Observed 1950-2005


Hydrographs for Climate Model csiro-mk3-6-0 - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
csiro-mk3-6-0 RCP 4.5
csiro-mk3-6-0 RCP 8.5
Observed 1950-2005

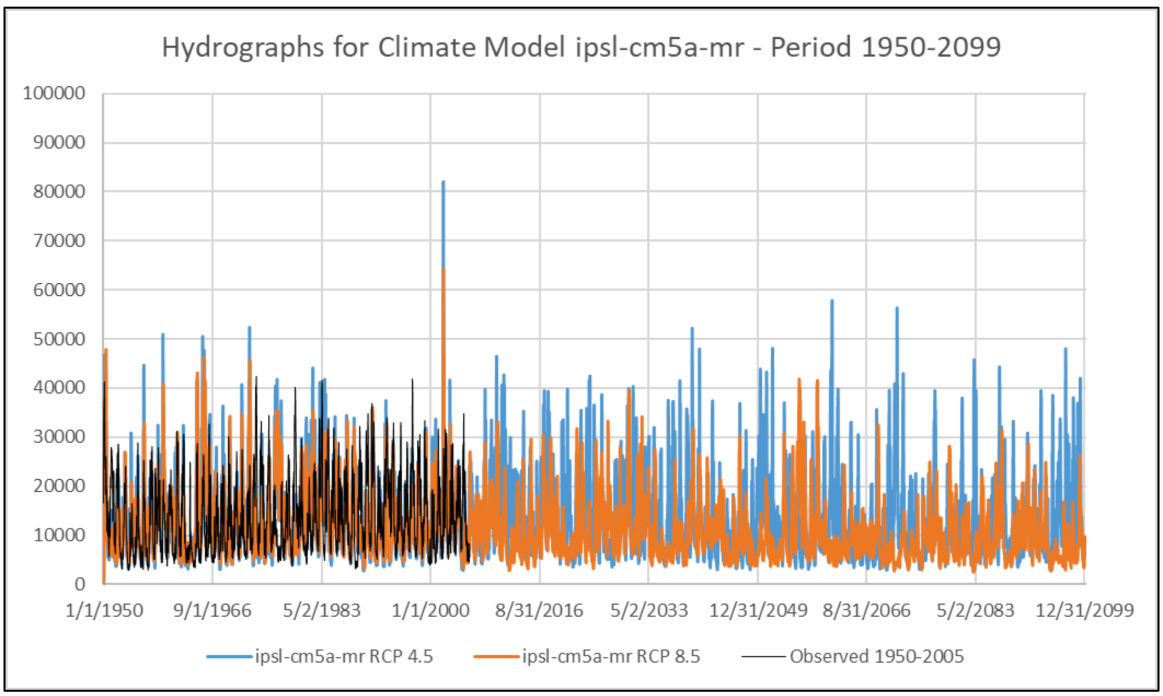

Hydrographs for Climate Model fgoals-g2 - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
fgoals-g2 RCP 4.5
fgoals-g2 RCP 8.5
Observed 1950-2005


Hydrographs for Climate Model gfdl-cm3 - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
gfdl-cm3 RCP 4.5
gfdl-cm3 RCP 8.5
Observed 1950-2005

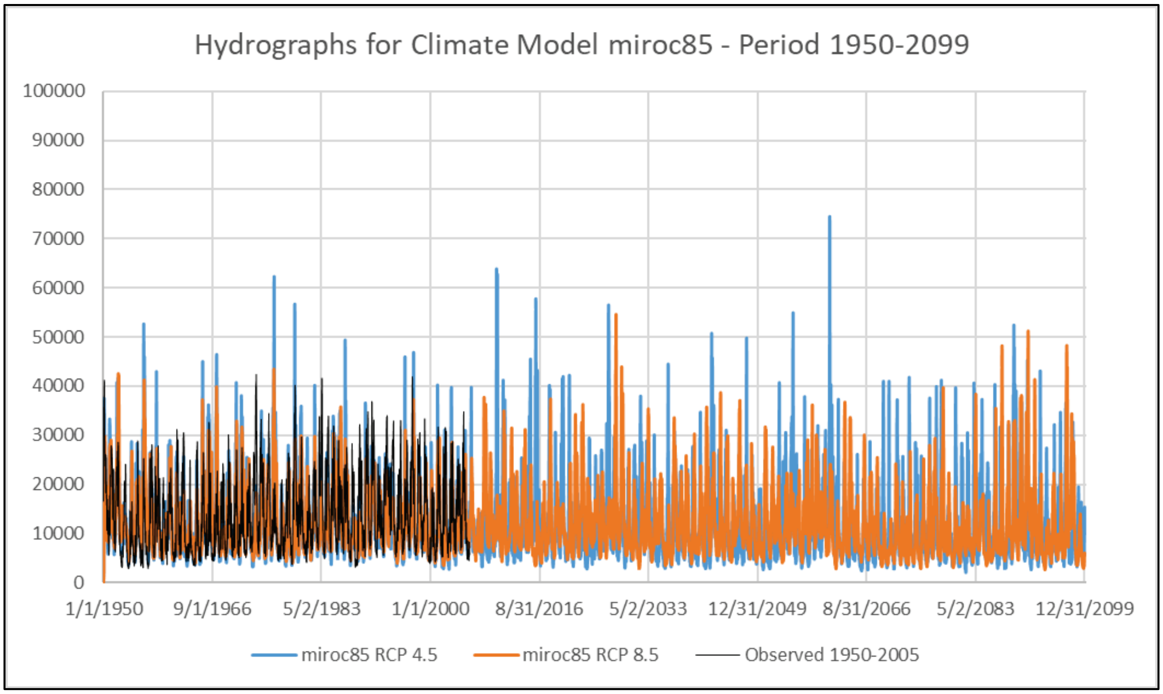

Hydrographs for Climate Model gfdl-esm2g - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
gfdl-esm2g RCP 4.5
gfdl-esm2g RCP 8.5
Observed 1950-2005

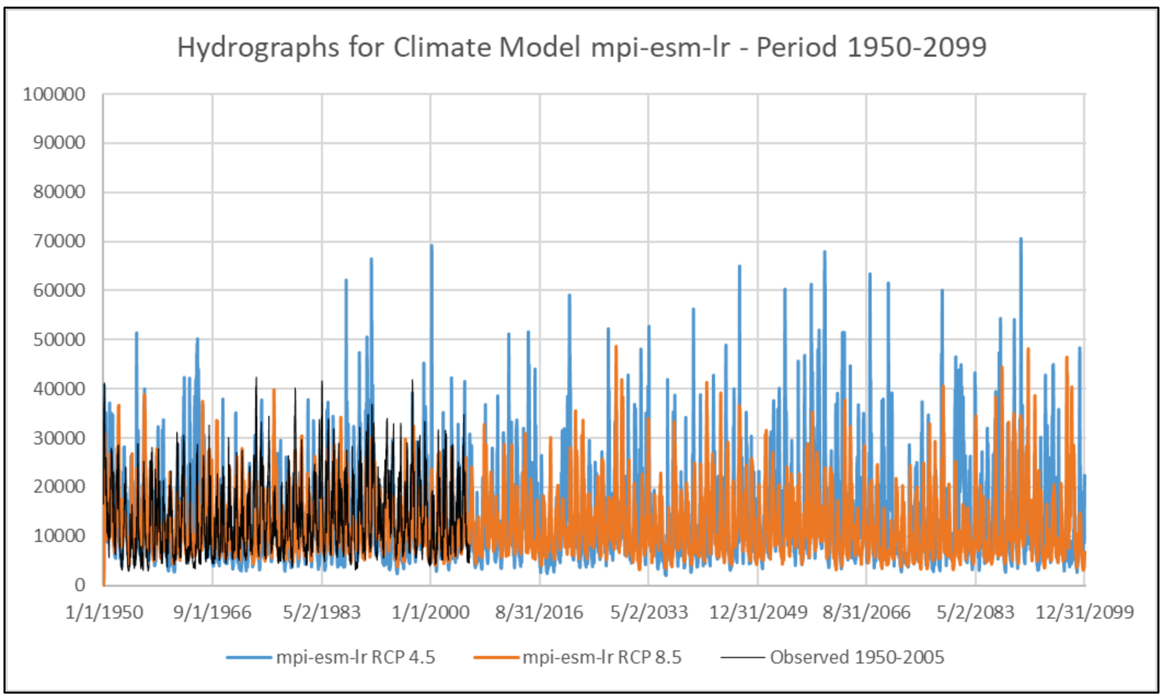


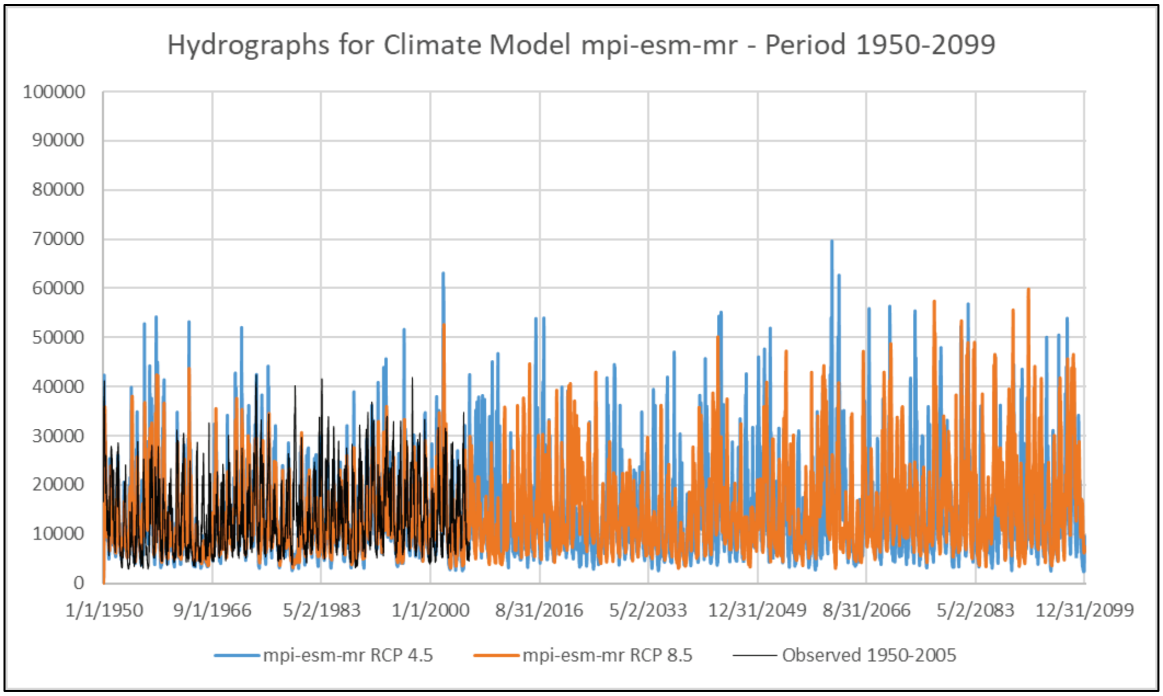
Hydrographs for Climate Model giss-e2-r - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
giss-e2-r RCP 4.5
giss-e2-r RCP 8.5
Observed 1950-2005

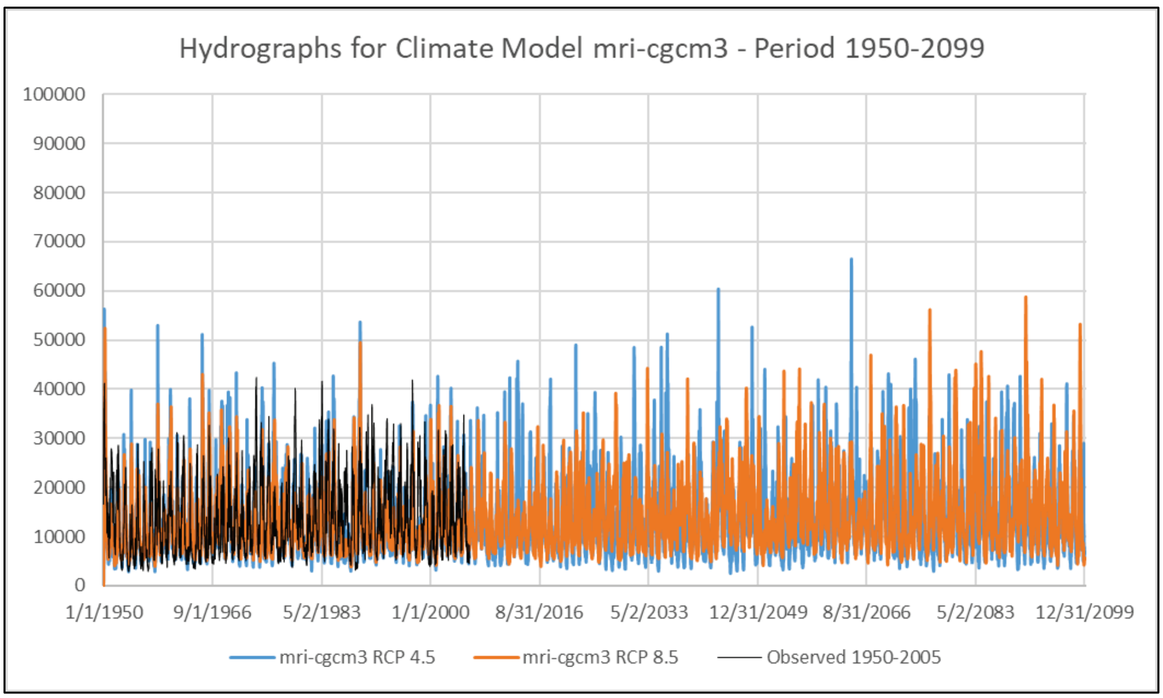


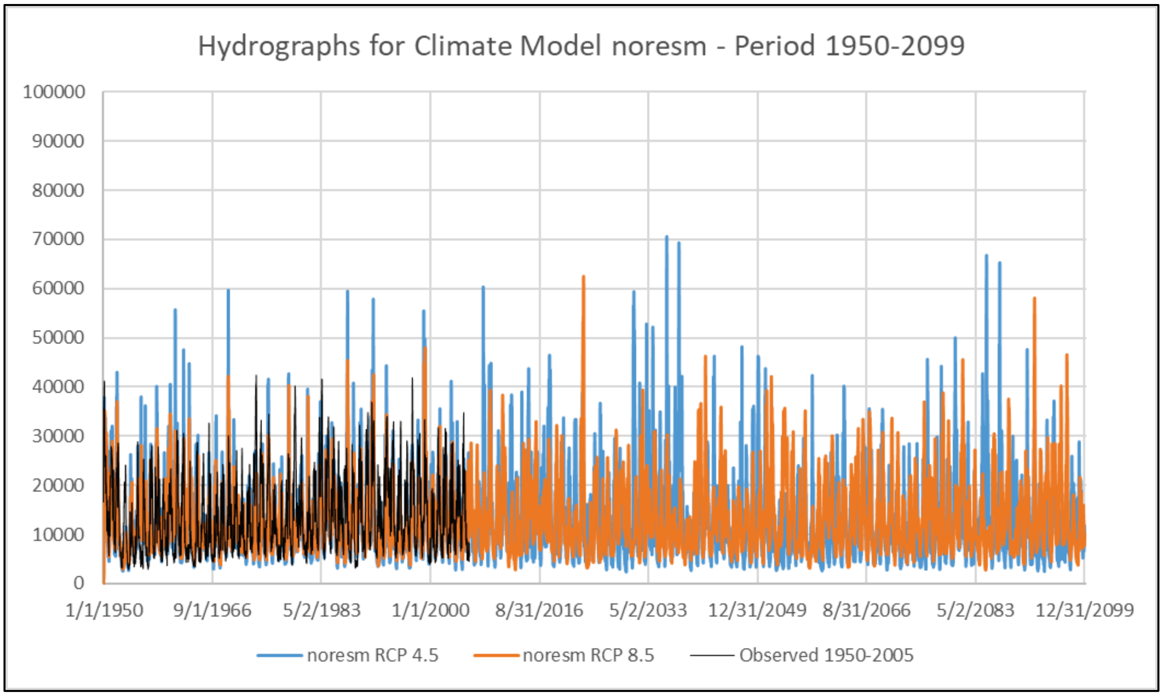
Hydrographs for Climate Model ipsl-cm5a-mr - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
ipsl-cm5a-mr RCP 4.5
ipsl-cm5a-mr RCP 8.5
Observed 1950-2005


Hydrographs for Climate Model miroc85 - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
miroc85 RCP 4.5
miroc85 RCP 8.5
Observed 1950-2005


Hydrographs for Climate Model mpi-esm-lr - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
mpi-esm-lr RCP 4.5
mpi-esm-lr RCP 8.5
Observed 1950-2005


Hydrographs for Climate Model mpi-esm-mr - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
mpi-esm-mr RCP 4.5
mpi-esm-mr RCP 8.5
Observed 1950-2005

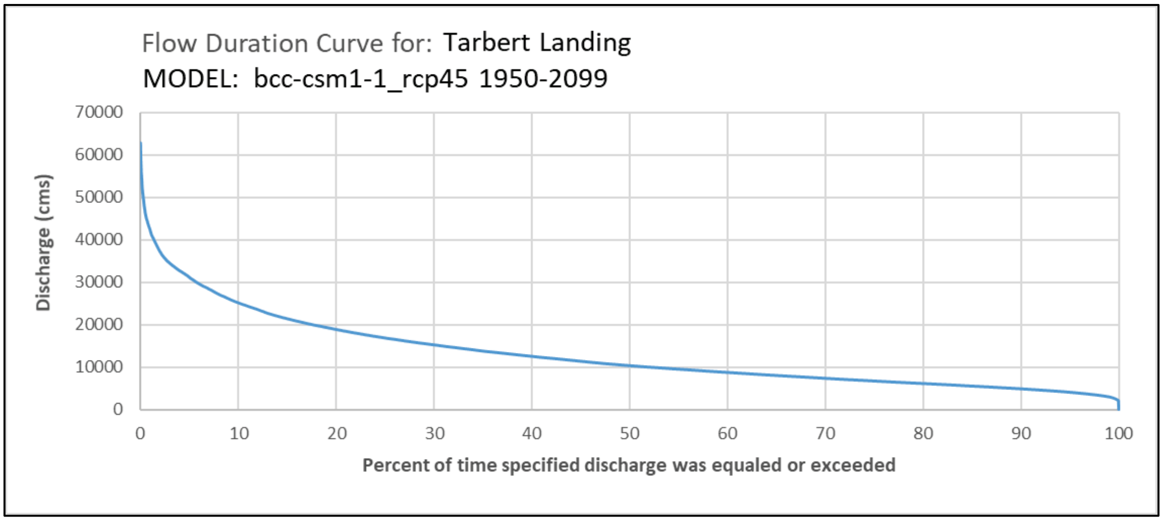

Hydrographs for Climate Model mri-cgcm3 - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
mri-cgcm3 RCP 4.5
mri-cgcm3 RCP 8.5
Observed 1950-2005

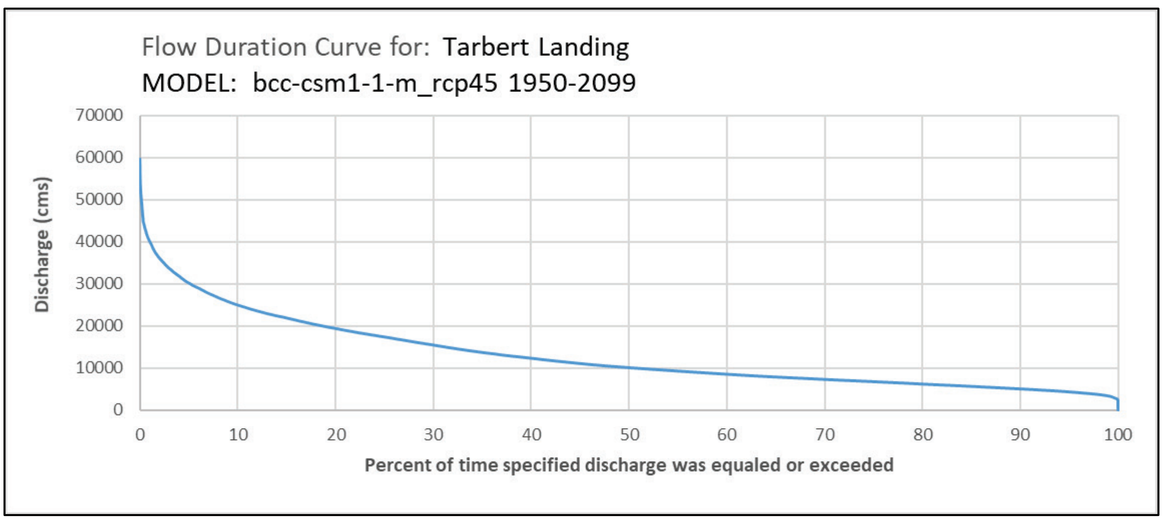

Hydrographs for Climate Model noresm - Period 1950-2099
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1/1/1950
9/1/1966
5/2/1983
1/1/2000
8/31/2016
5/2/2033
12/31/2049
8/31/2066
5/2/2083
12/31/2099
noresm RCP 4.5
noresm RCP 8.5
Observed 1950-2005

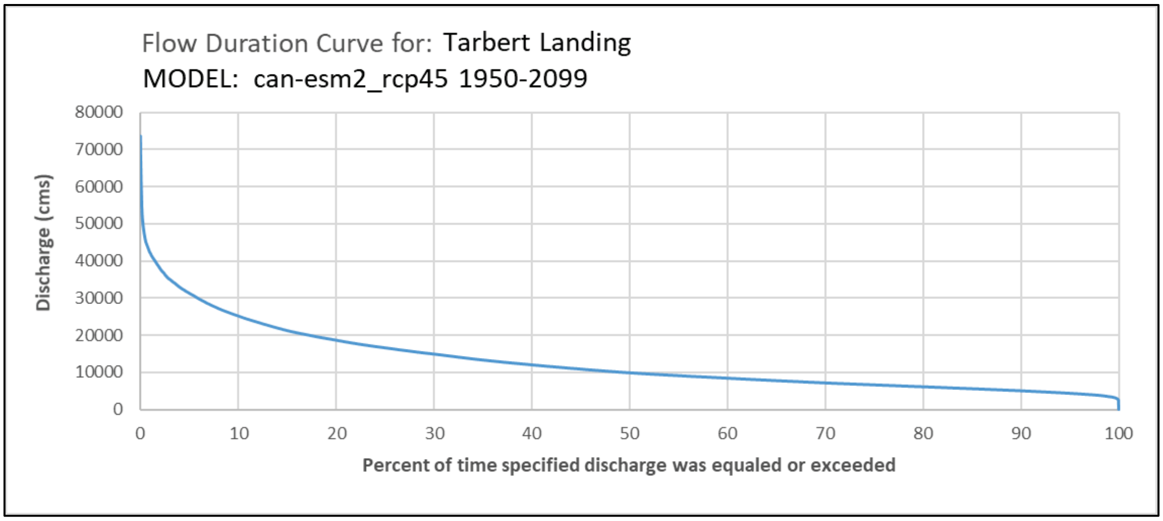
Appendix B: FDCs per Climate Model

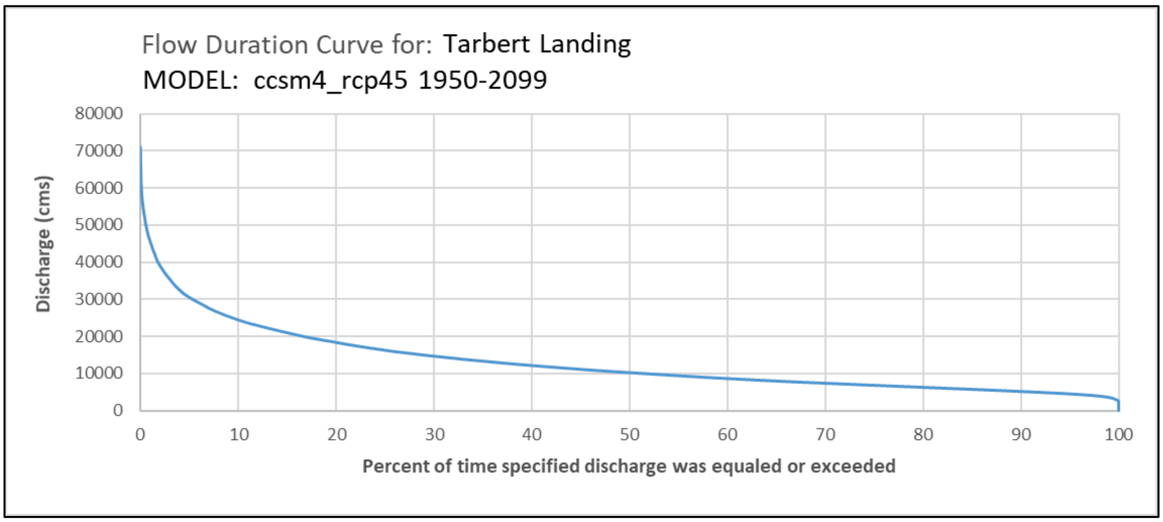
The following figures present the FDCs for each of the 32 climate models (16 each for RCP 4.5 and RCP 8.5) for the simulation period spanning 1950–2099.

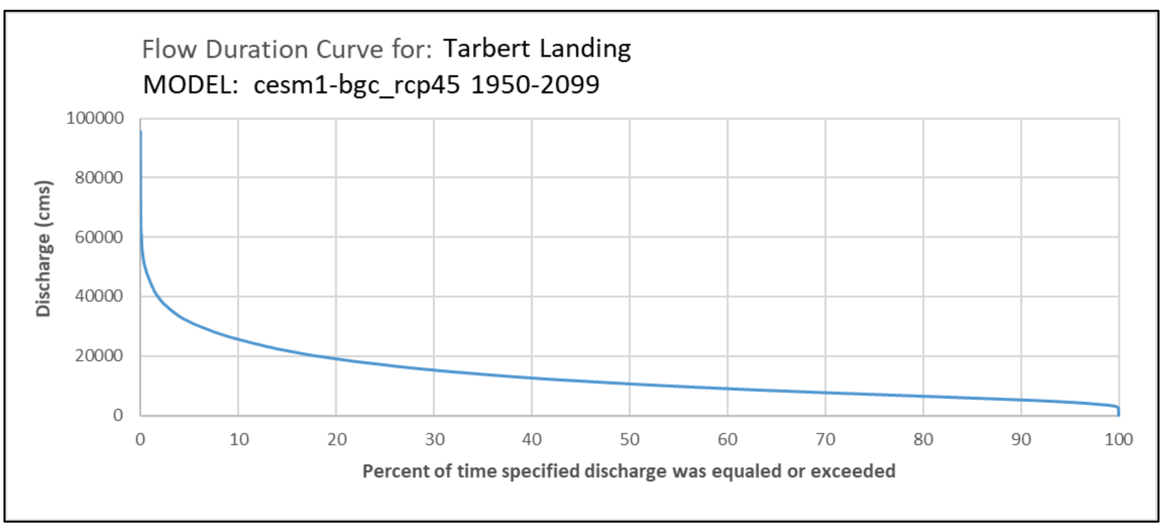
RCP 4.5

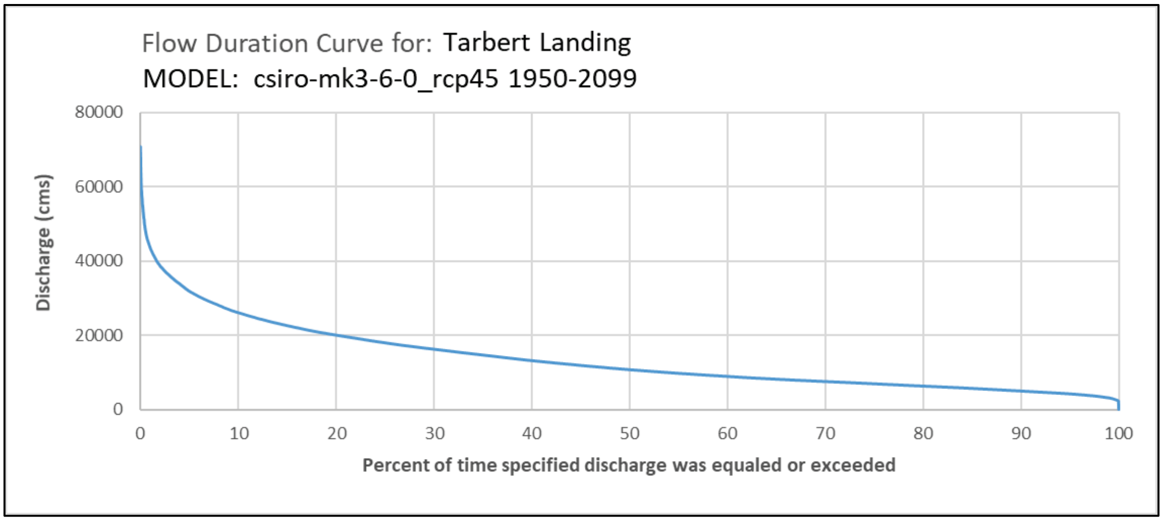


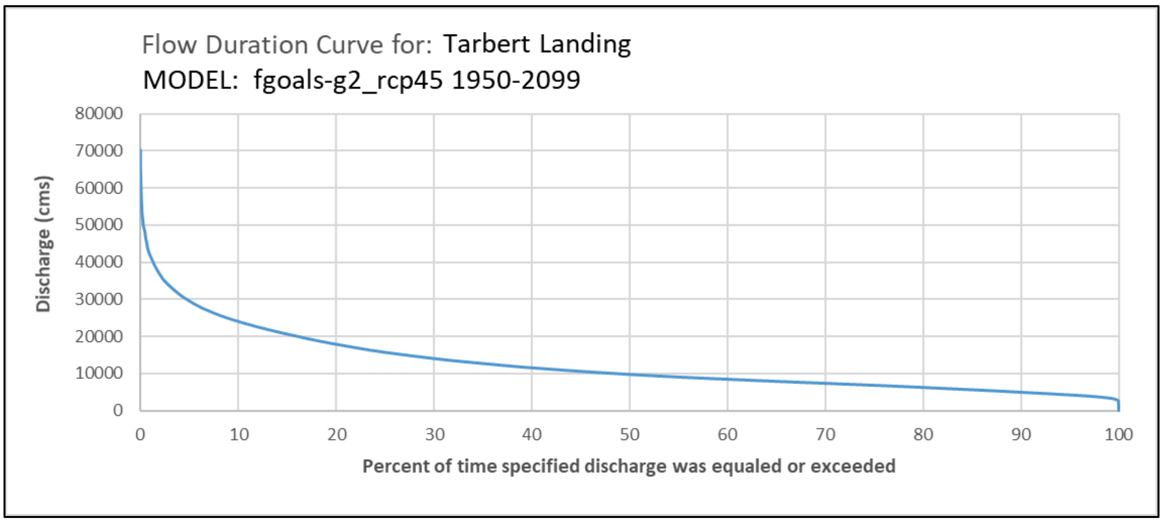


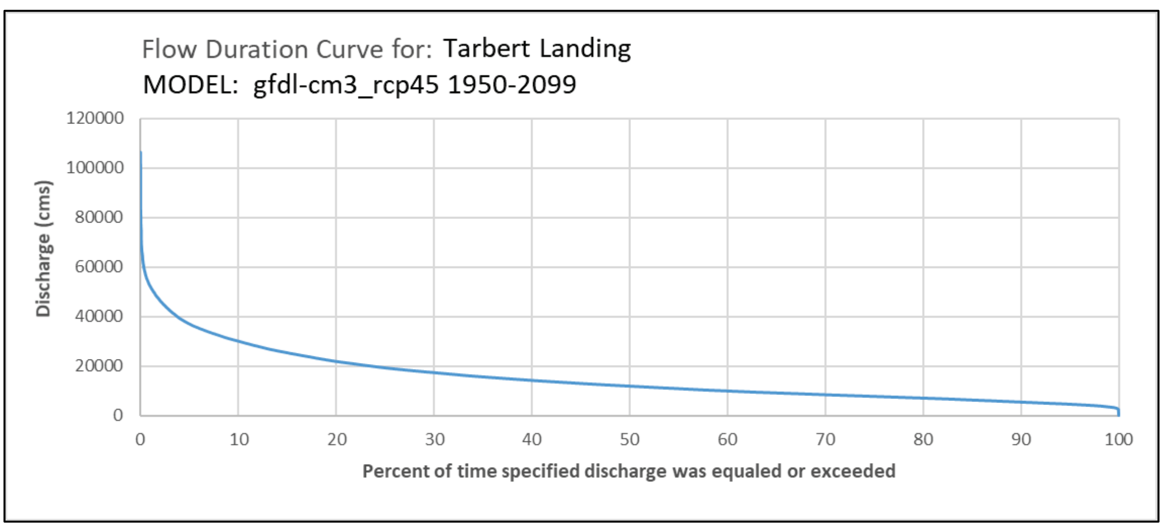

Flow Duration Curve for: Tarbert Landing
MODEL: can-esm2_rcp45 1950-2099
Discharge (cms)
80000
70000
60000
50000
40000
30000
20000
10000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

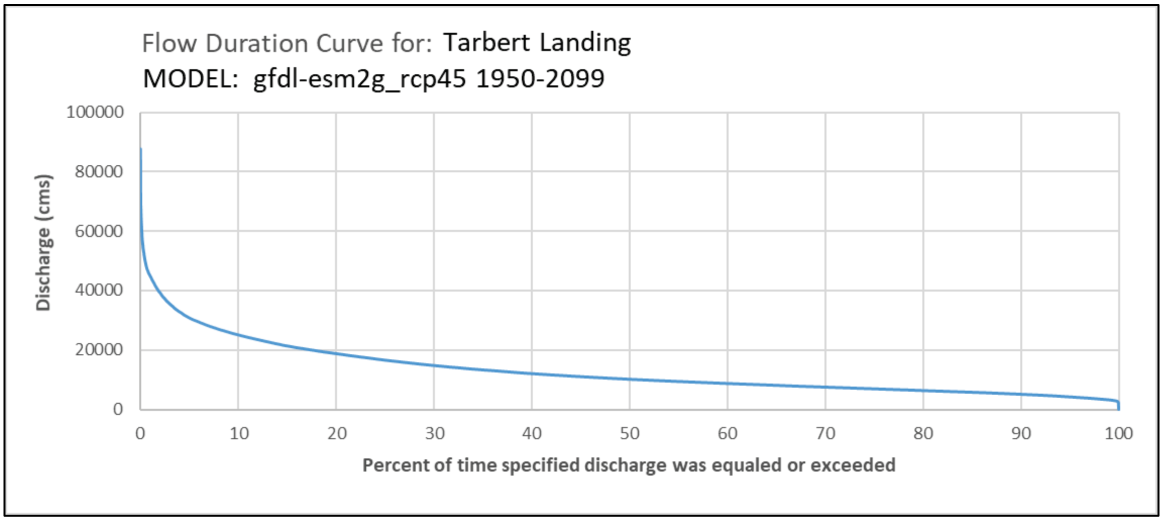

Flow Duration Curve for: Tarbert Landing
MODEL: ccsm4_rcp45 1950-2099
Discharge (cms)
80000
70000
60000
50000
40000
30000
20000
10000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

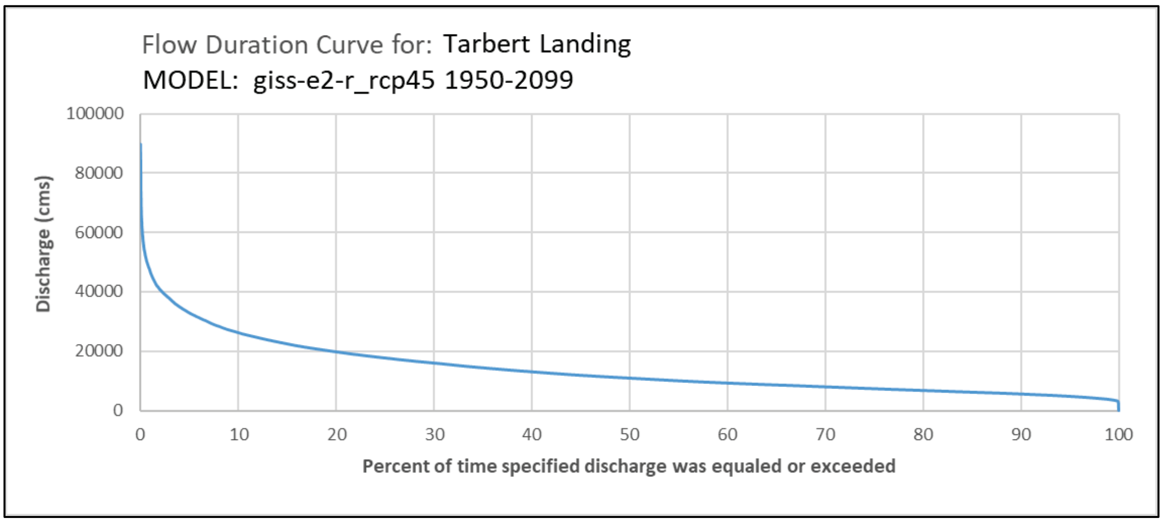

Flow Duration Curve for: Tarbert Landing
MODEL: cesm1-bgc_rcp45 1950-2099
Discharge (cms)
100000
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

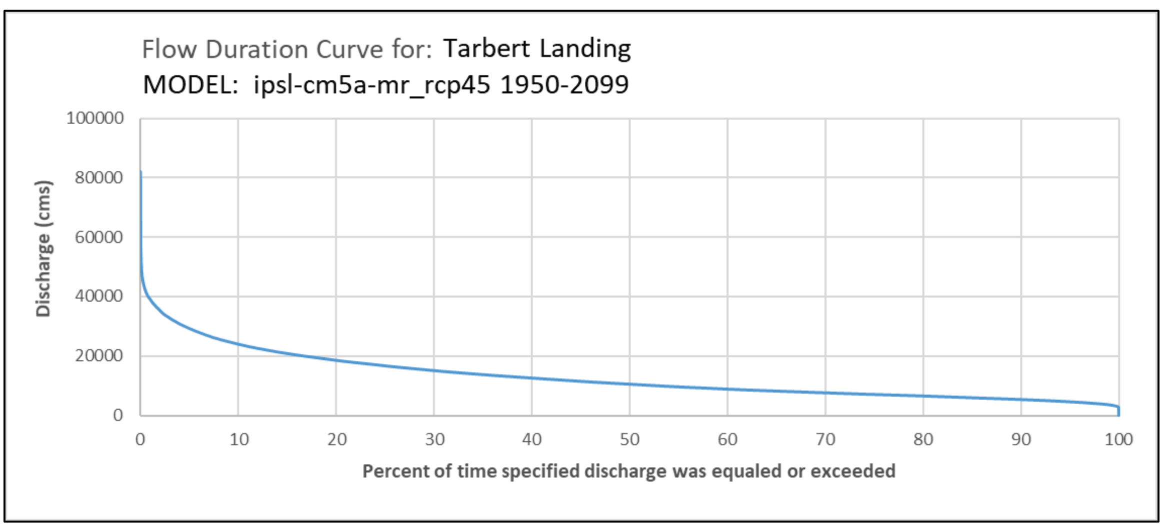

Flow Duration Curve for: Tarbert Landing
MODEL: csiro-mk3-6-0_rcp45 1950-2099
Discharge (cms)
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

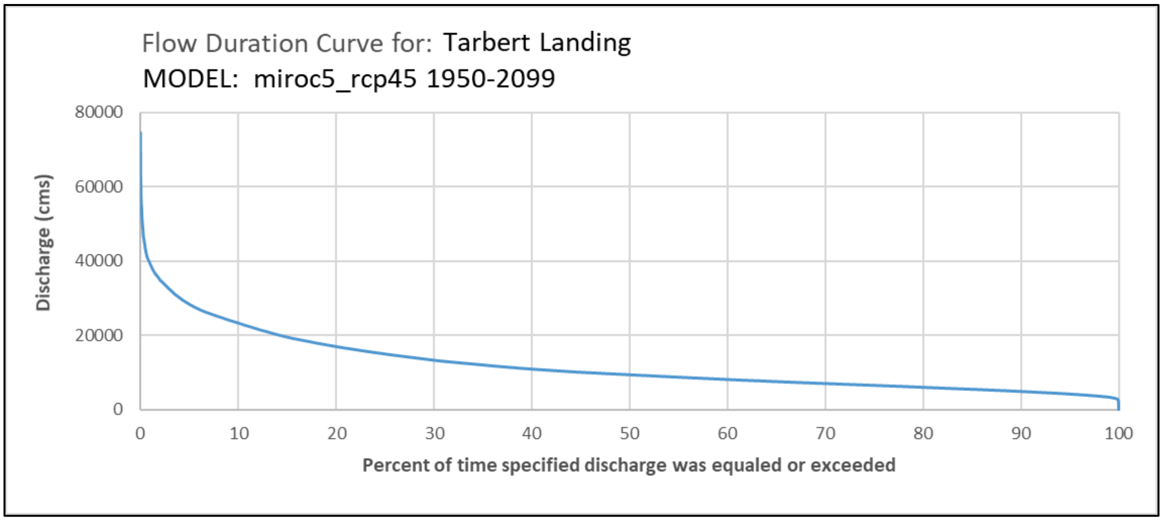

Flow Duration Curve for: Tarbert Landing
MODEL: fgoals-g2_rcp45 1950-2099
Discharge (cms)
80000
70000
60000
50000
40000
30000
20000
10000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

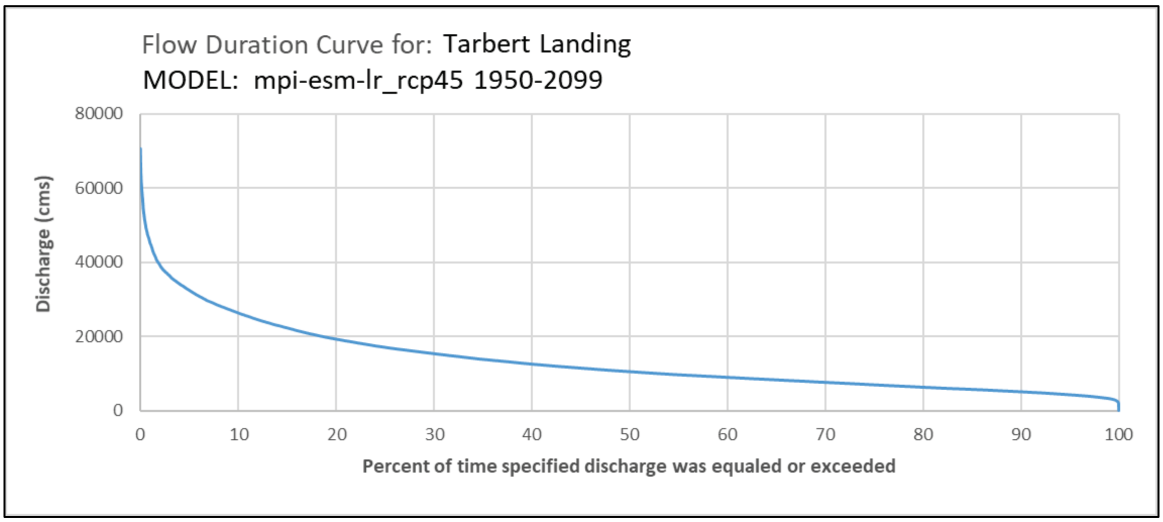

Flow Duration Curve for: Tarbert Landing
MODEL: gfdl-cm3_rcp45 1950-2099
Discharge (cms)
120000
100000
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

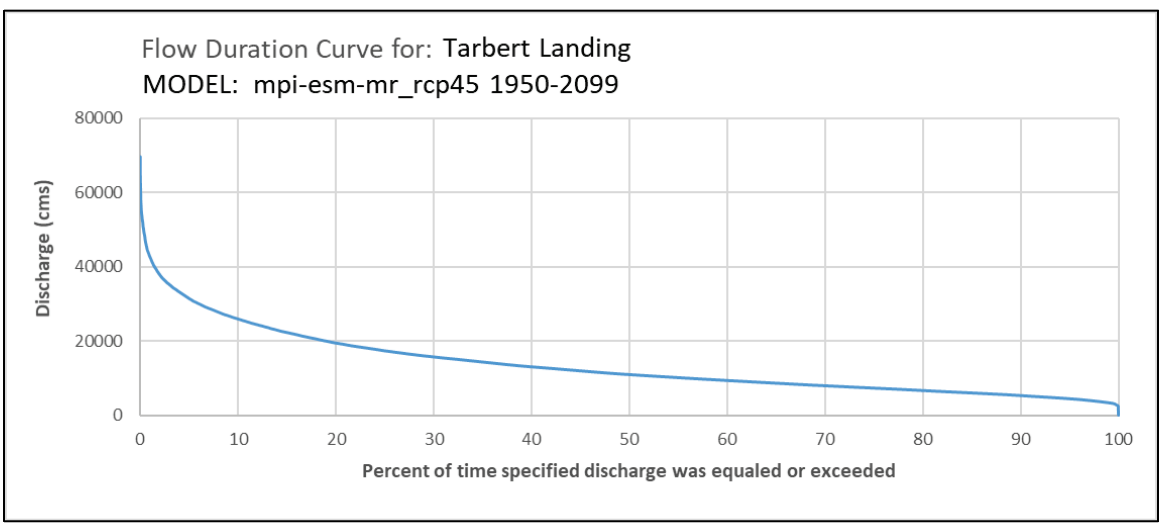

Flow Duration Curve for: Tarbert Landing
MODEL: gfdl-esm2g_rcp45 1950-2099
Discharge (cms)
100000
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

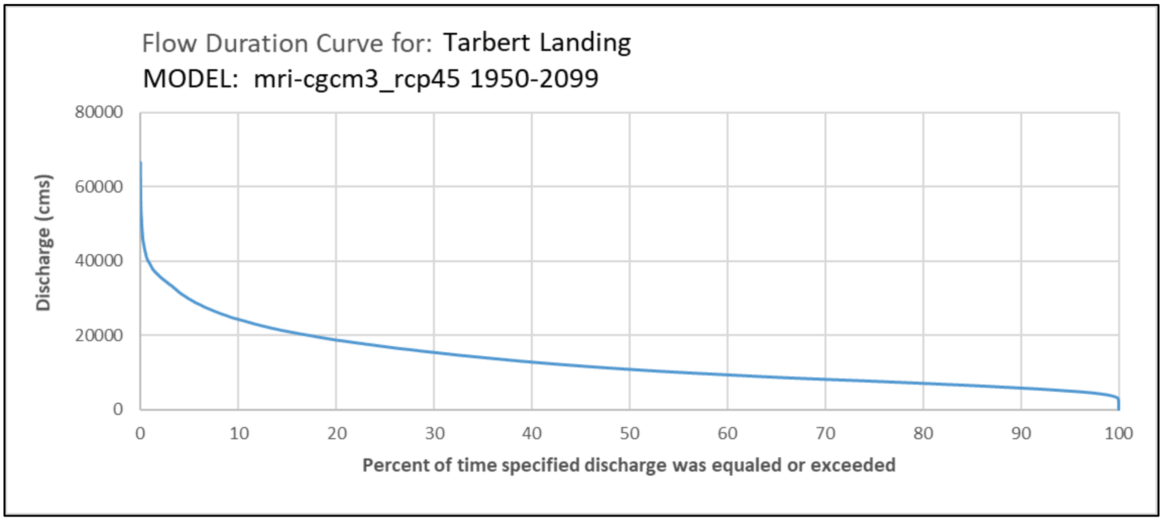

Flow Duration Curve for: Tarbert Landing
MODEL: giss-e2-r_rcp45 1950-2099
Discharge (cms)
100000
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
MODEL: ipsl-cm5a-mr_rcp45 1950-2099
Discharge (cms)
100000
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
MODEL: miroc5_rcp45 1950-2099
Discharge (cms)
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
MODEL: mpi-esm-lr_rcp45 1950-2099
Discharge (cms)
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
MODEL: mpi-esm-mr_rcp45 1950-2099
Discharge (cms)
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
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Discharge (cms)
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0
10
20
30
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50
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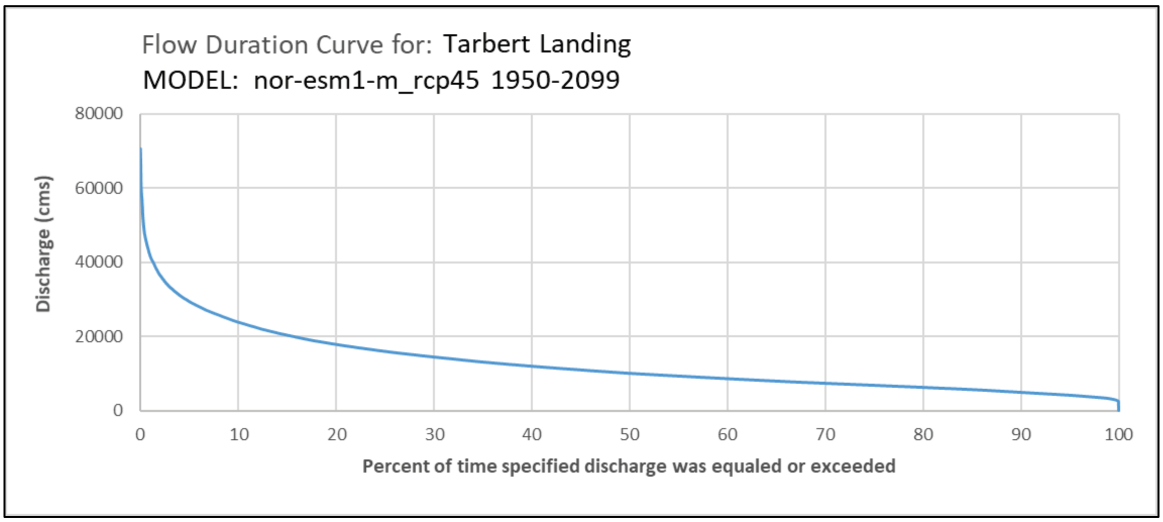
90
100
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
MODEL: nor-esm1-m_rcp45 1950-2099
Discharge (cms)
80000
60000
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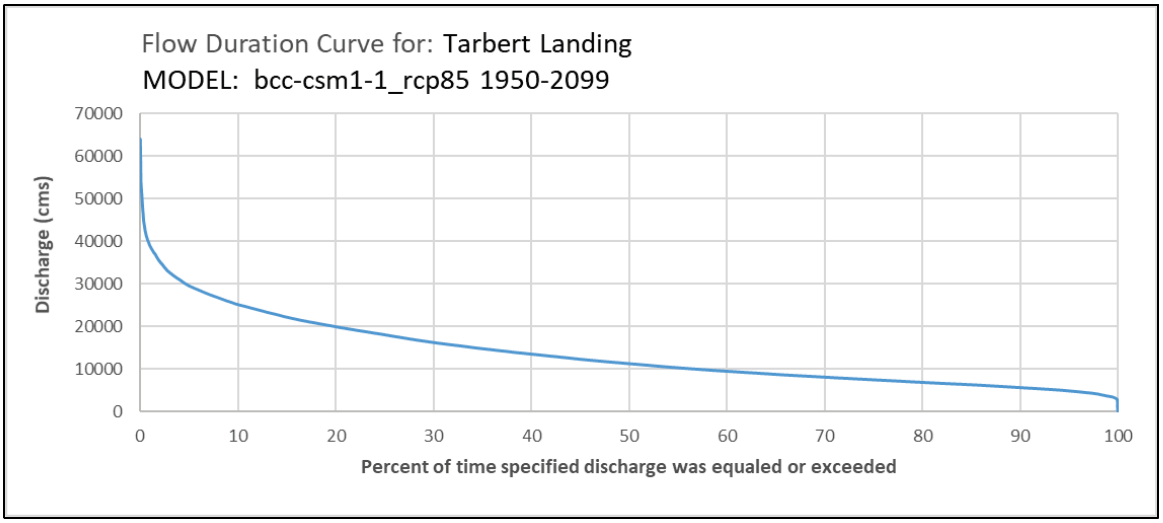
0
10
20
30
40
50
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

RCP 8.5


Flow Duration Curve for: Tarbert Landing
MODEL: bcc-csm1-1_rcp85 1950-2099
Discharge (cms)
70000
60000
50000
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20000
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0
0
10
20
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70
80
90
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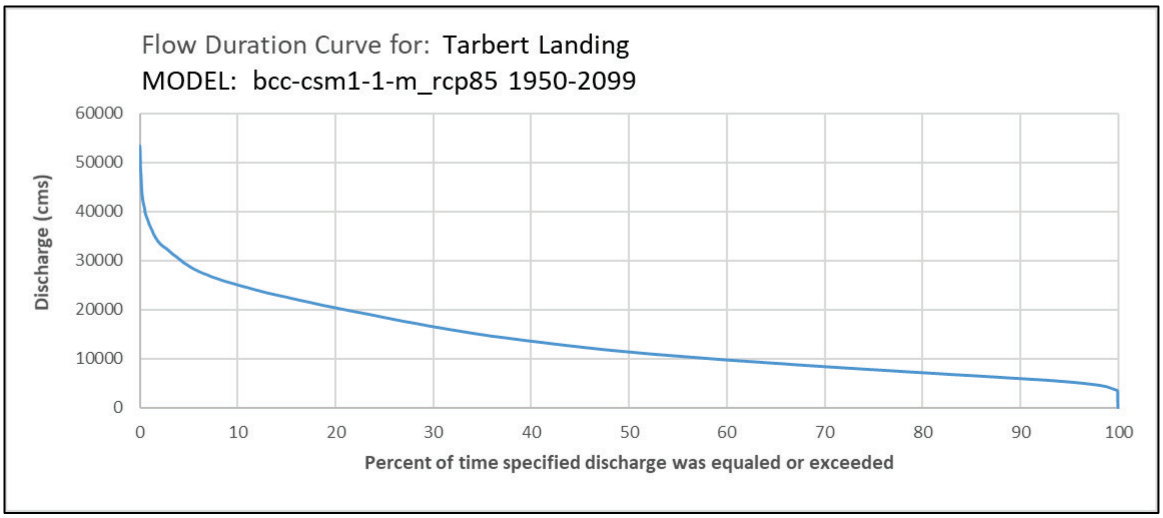
Percent of time specified discharge was equaled or exceeded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Discharge (cms)
60000
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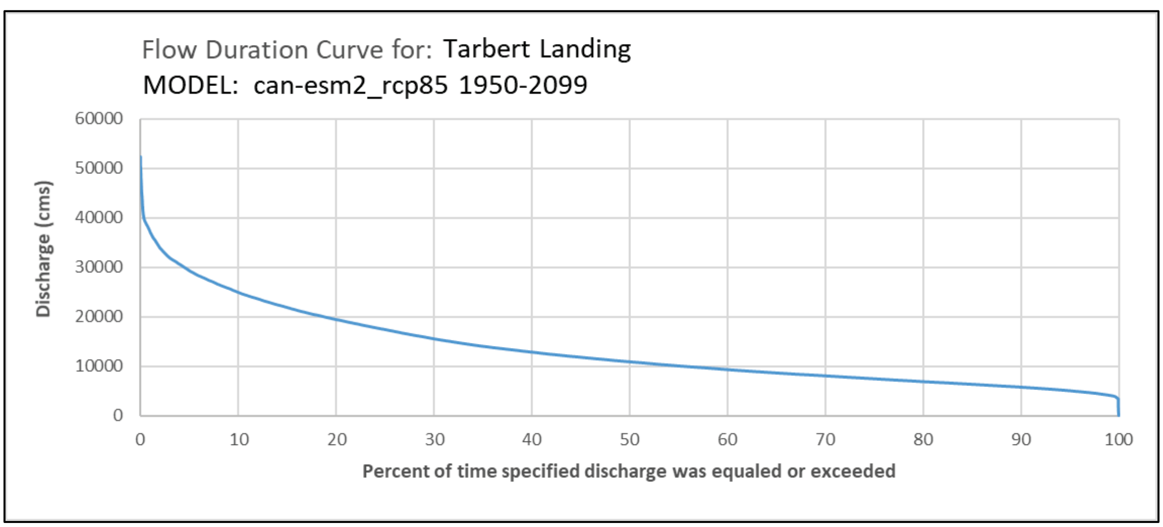
70
80
90
100
Percent of time specified discharge was equaled or exceeded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MODEL: can-esm2_rcp85 1950-2099
Discharge (cms)
60000
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0
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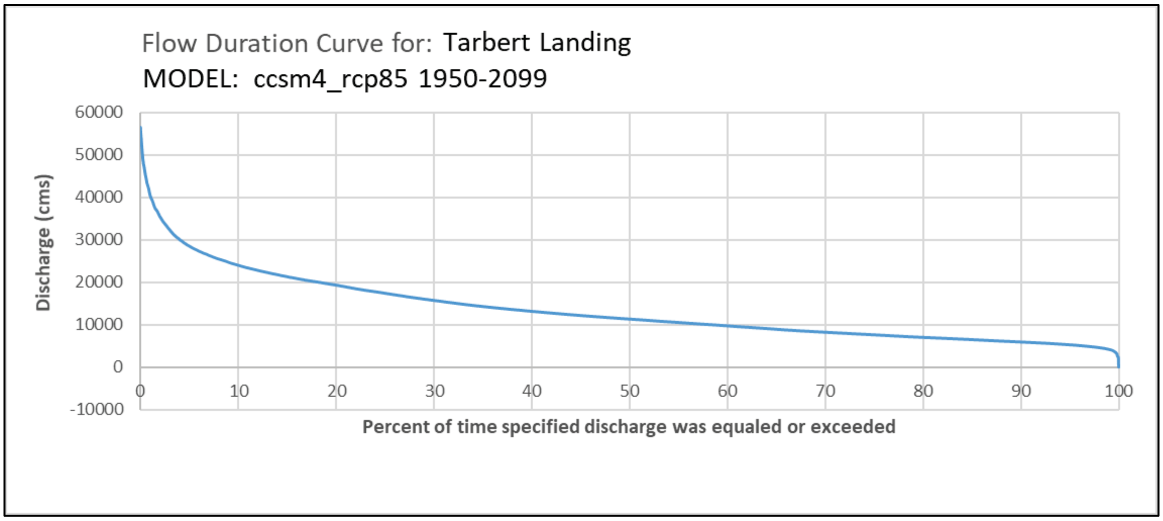
Percent of time specified discharge was equaled or exceeded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MODEL: ccsm4_rcp85 1950-2099
Discharge (cms)
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40000
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-10000
0
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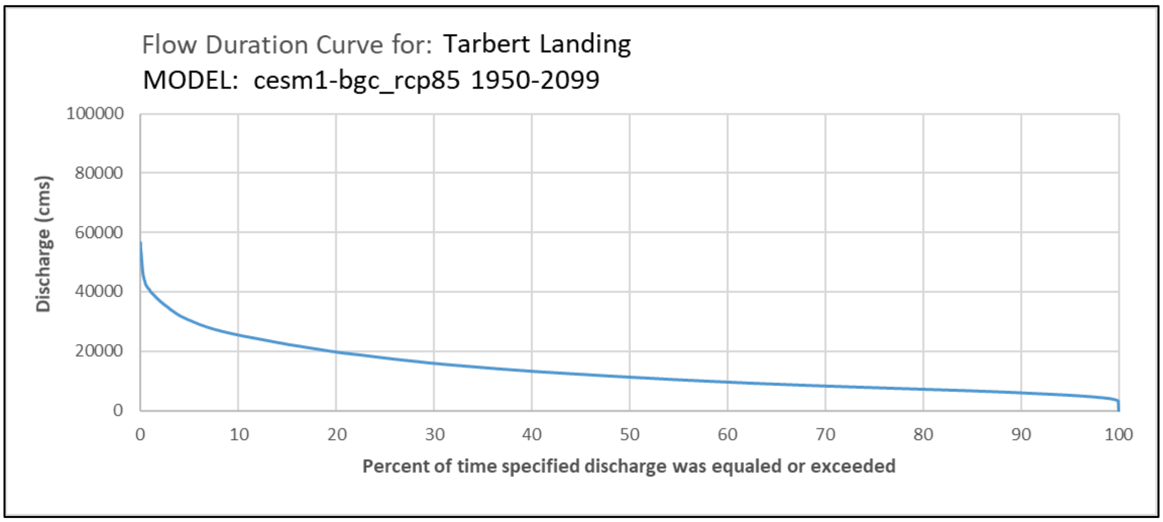
70
80
90
100
Percent of time specified discharge was equaled or exceeded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80
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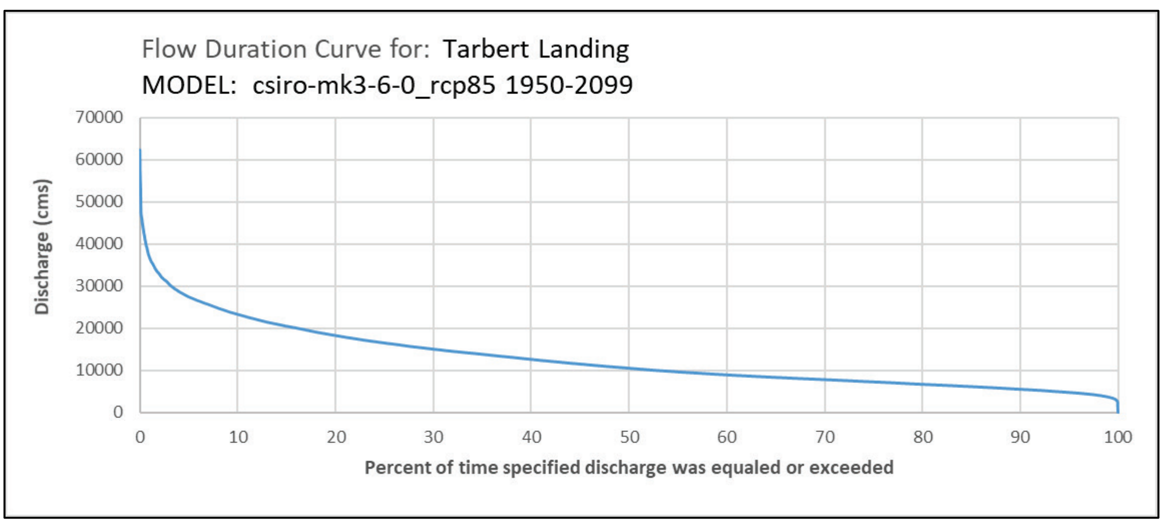
Percent of time specified discharge was equaled or exceeded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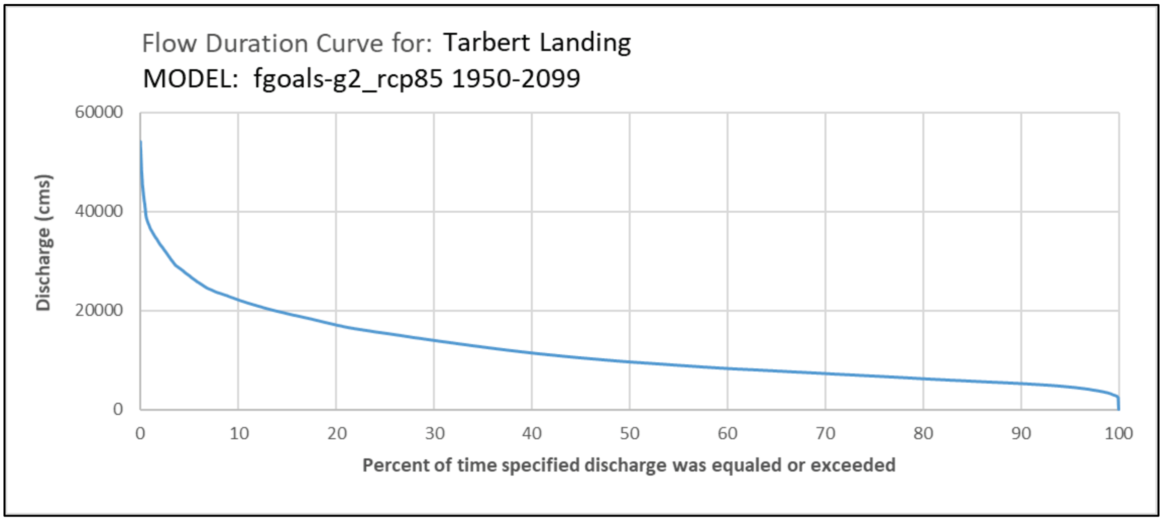
Percent of time specified discharge was equaled or exceeded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Discharge (cms)
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90
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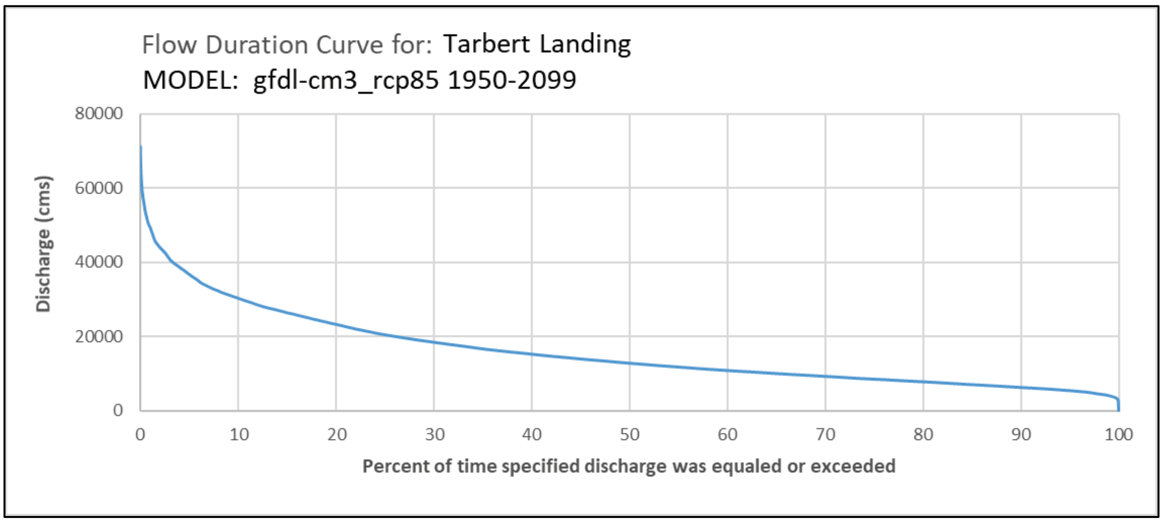
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
MODEL: gfdl-cm3_rcp85 1950-2099
Discharge (cms)
80000
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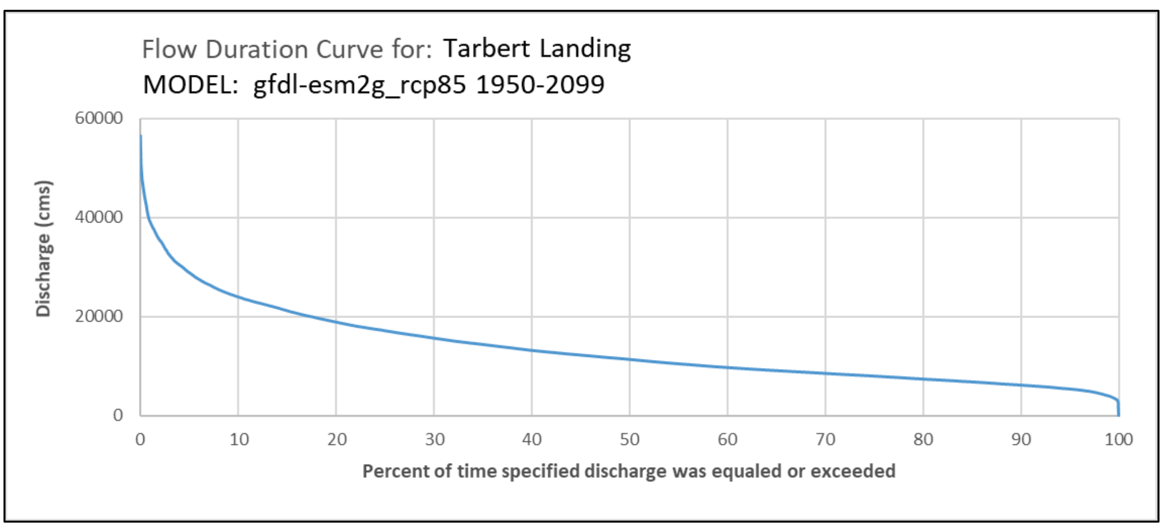
60
70
80
90
100
Percent of time specified discharge was equaled or exceeded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Discharge (cms)
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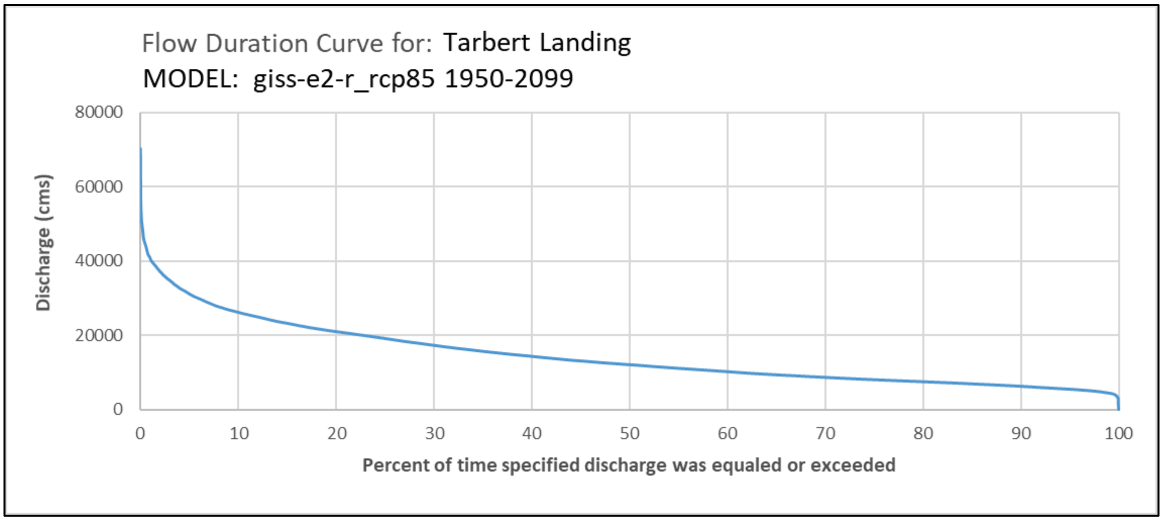
Percent of time specified discharge was equaled or exceeded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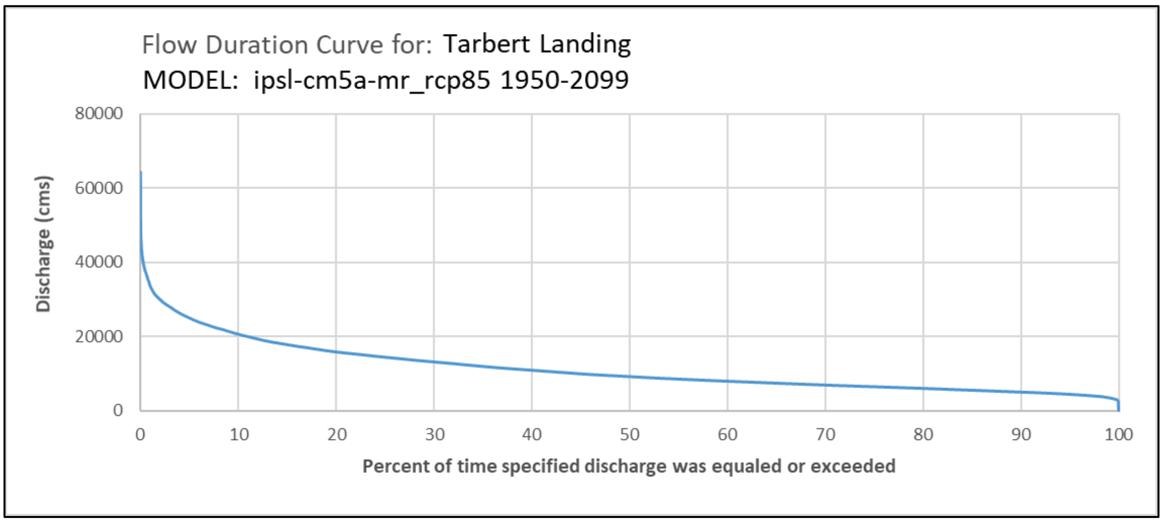
Percent of time specified discharge was equaled or exceeded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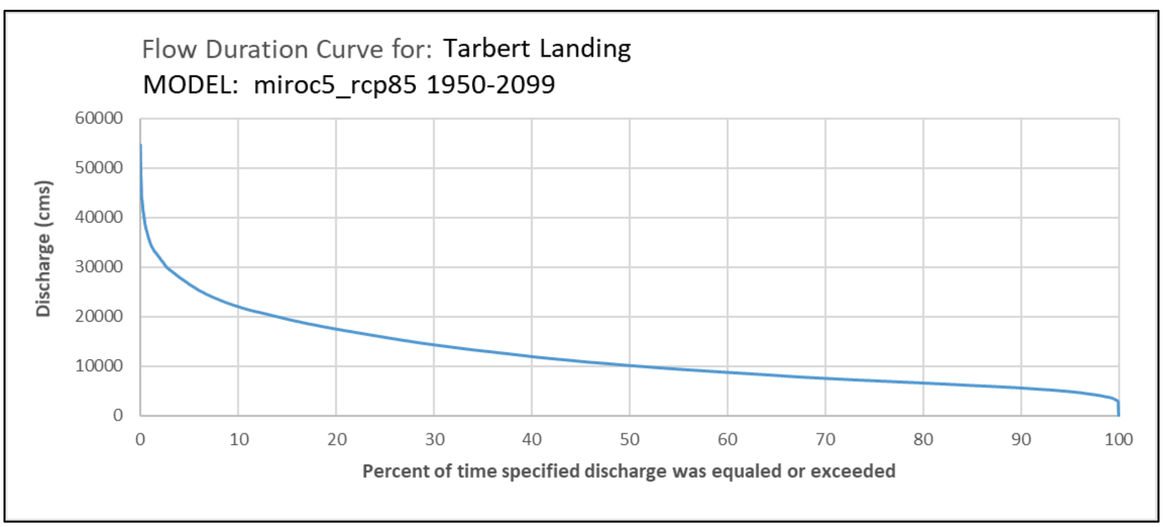
Percent of time specified discharge was equaled or exceeded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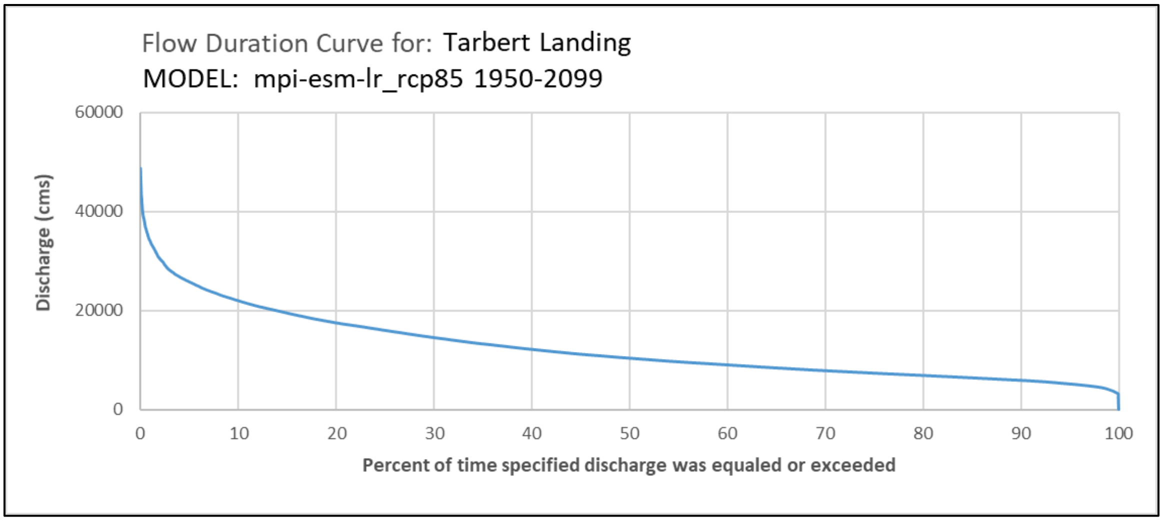
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
MODEL: mpi-esm-lr_rcp85 1950-2099
60000
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Discharge (cms)
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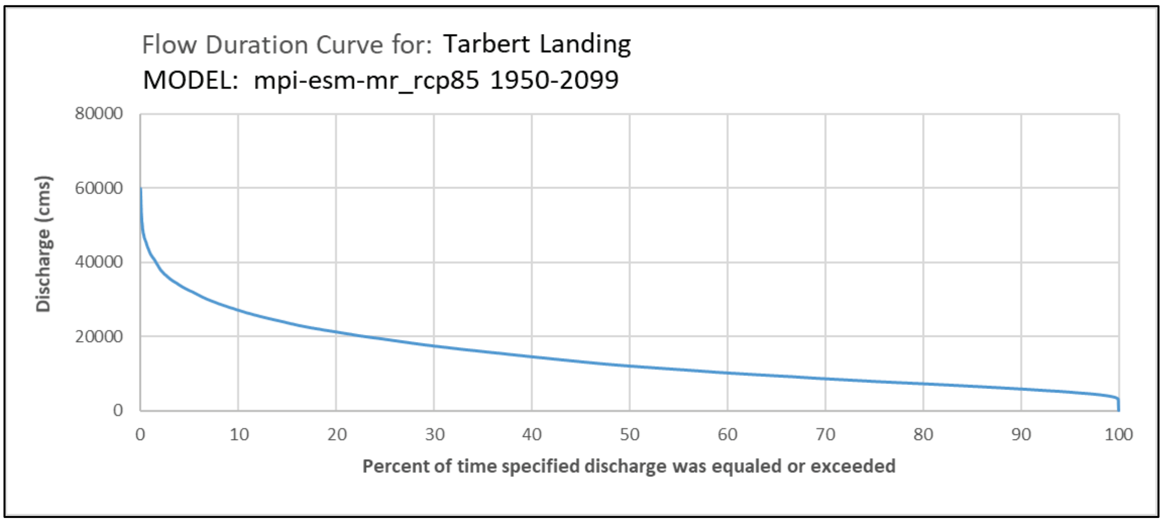
Percent of time specified discharge was equaled or exceeded


Flow Duration Curve for: Tarbert Landing
MODEL: mpi-esm-mr_rcp85 1950-2099
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Discharge (cms)
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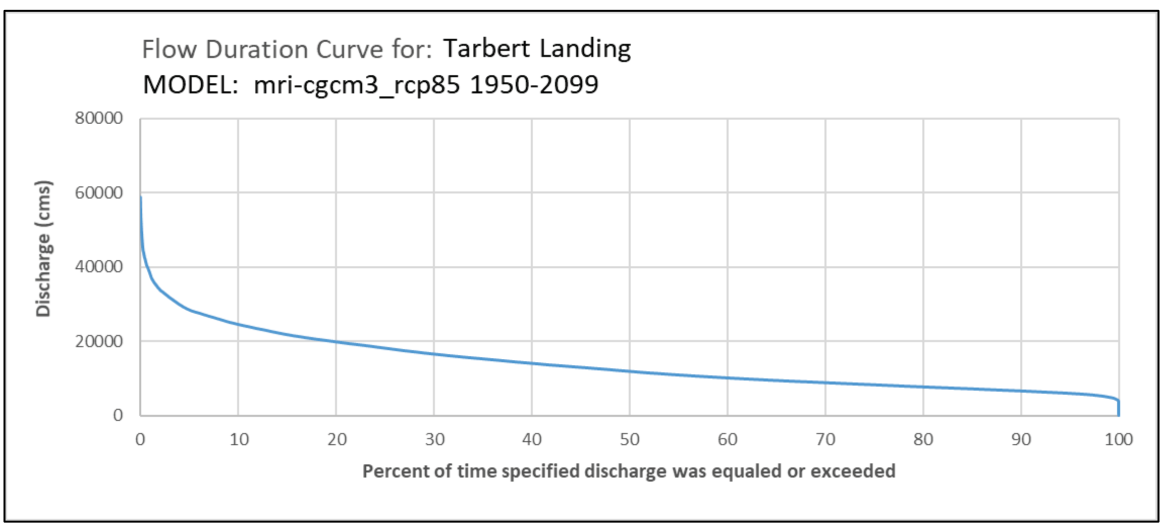
Percent of time specified discharge was equaled or exceeded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MODEL: mri-cgcm3_rcp85 1950-2099
80000
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Discharge (cms)
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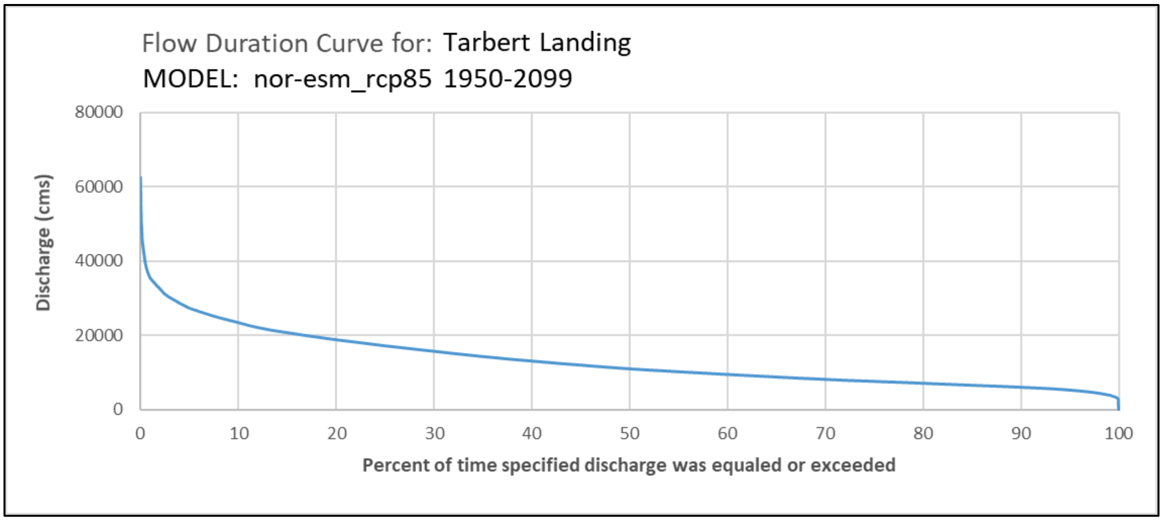
100
Percent of time specified discharge was equaled or exceeded



Flow Duration Curve for: Tarbert Landing
MODEL: nor-esm_rcp85 1950-2099
Discharge (cms)
80000
60000
40000
20000
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40
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60
70
80
90
100
Percent of time specified discharge was equaled or exceeded

Abbreviations

CMIP5	Coupled Model Intercomparison Project, Phase 5
CPRA	Coastal Protection and Restoration Authority
FDC	Flow duration curve
LMRMP	Lowermost Mississippi River Management Program
MRB	Mississippi River Basin
NHDPlus	National Hydrography Dataset Plus
RAPID	Routing Application for Parallel computatIon of Discharge
RCP	Representative concentration pathways

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5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**

6. AUTHOR(S)
W. Clay LaHatte, Ahmad A. Tavakoly, Sara E. Lytle, and James W. Lewis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Engineer Research and Development Center (ERDC)
Coastal and Hydraulics Laboratory (CHL)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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14. ABSTRACT
To better understand and prepare for the possible effects associated with potential climate changes on the lower Mississippi River, the State of Louisiana Coastal Protection and Restoration Authority sought information on the historical, current, and projected future hydrodynamics of the Mississippi River. To this end, flow duration curves (FDC) for the Tarbert Landing location were generated, based on climate models derived from two of the four scenarios of the Coupled Model Intercomparison Project, Phase 5 (CMIP5), multimodel ensemble representative concentration pathways (RCPs). The global CMIP5 datasets were used by the variable infiltration capacity land surface model to produce a runoff dataset, using a bias-correction spatial disaggregation approach. The runoff datasets were then applied to simulate streamflow using the Routing Application for Parallel computatIon of Discharge (RAPID) river routing model. Based on the streamflow, FDCs were calculated for 16 CMIP5 as well as observed historical data at the Tarbert Landing location. Key observations from the results are that the 90th percentile exceedance of the simulated versus the observed flows is more frequent for the RCP 8.5 scenario than for the RCP 4.5 scenario and that the maximum annual flows for the RCP 8.5 scenario are generally smaller than for the RCP 4.5 scenario.

15. SUBJECT TERMS
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19a. NAME OF RESPONSIBLE PERSON	19b. TELEPHONE NUMBER (include area code)
W. Clay LaHatte	601-634-3350