Nevada Irrigation District

Staff Report

TO: Board of Directors

FROM: Jennifer Hanson, General Manager
Doug Roderick, Director of Engineering

DATE: October 10, 2023

SUBJECT: **Plan for Water**

ADMINISTRATION

RECOMMENDATION:

Discuss and provide Reservoir Operations Modelling Results Summary Climate Change Scenarios.

BACKGROUND:

The purpose of this staff report is to provide background information related to the Plan for Water (PFW) Reservoir Operations Modelling Results Summary, Climate Change Scenarios presentation. The presentation provides an overview of the modelling results from the Hec-ResSim 3 Reservoir Operations Model. Hec-ResSim 3.3 is the reservoir operations model that is software developed by the United States Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center (HEC). This model is used to simulate reservoir operations at one or more reservoirs.

In order to provide additional context and information for the data presented in the presentation, notes have been added for each of the slides in the presentation. This document is included as an attachment to the presentation.

This information was presented to the PFW Stakeholder group. Two main comments were presented during that process:

1. Request to consider reduced reservoir carryover targets during dry periods.

2. Request to evaluate median unmet demands in addition to average unmet demands.

Both comments will be discussed further during the presentation.

The final steps in the process will consist of:

- Select modeling scenarios to move forward to model strategic alternatives
- Select strategic Alternatives studies
- Perform strategic alternatives studies
- Final documentation

The bulk of this work will be completed in October and November with the final document being completed soon thereafter.

BUDGETARY IMPACT: N/A

Attachments: (2)
- Presentation
- Presentation with Notes

NID PFW Reservoir Operations Modeling Results Summary

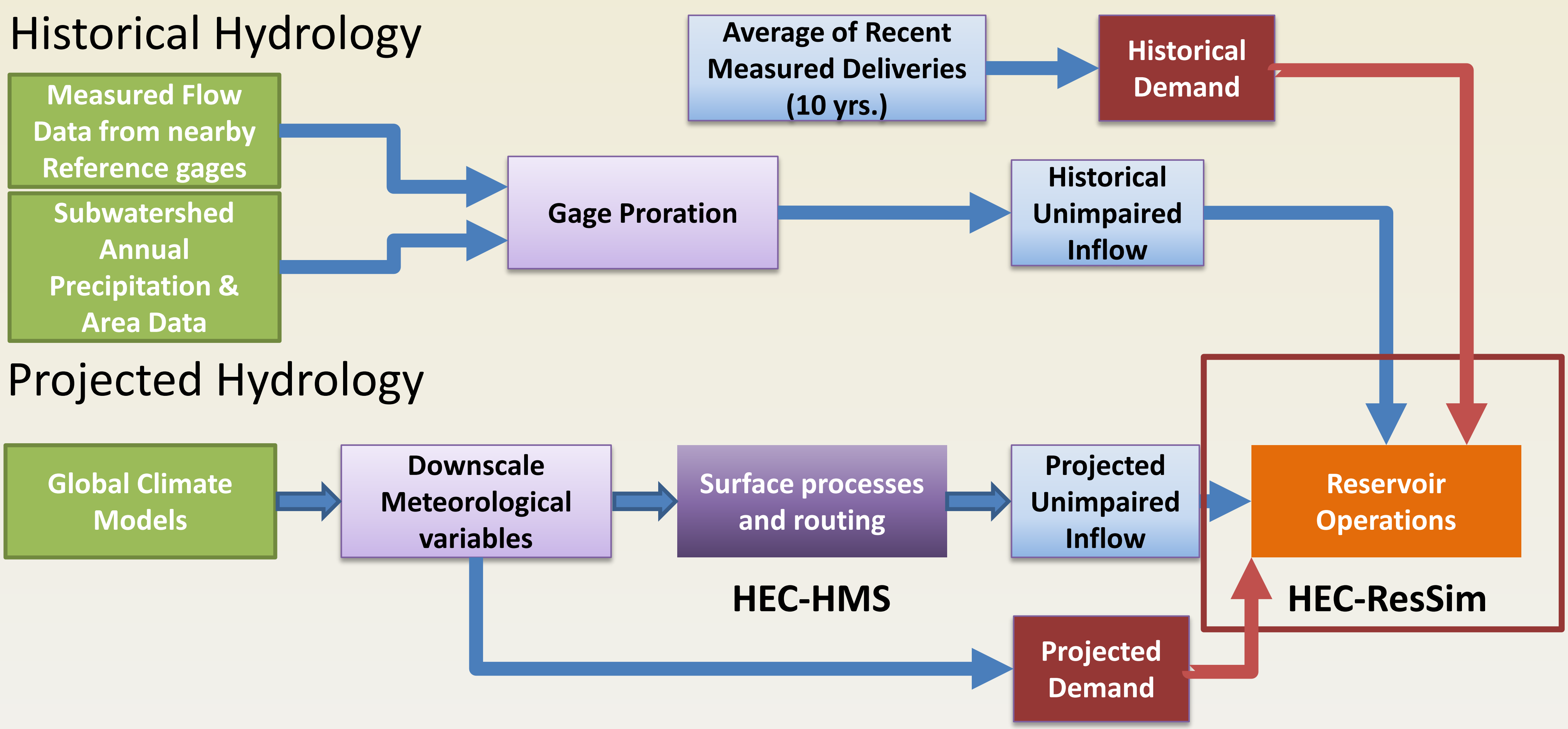
Climate Change Scenarios

10/10/2023

Agenda

- HEC-ResSim
- Projected hydrology
- Projected demands
- Scenario overview
- Summary of model results
- Selection of bookend scenarios
- Strategic alternatives
- Next steps

Introduction

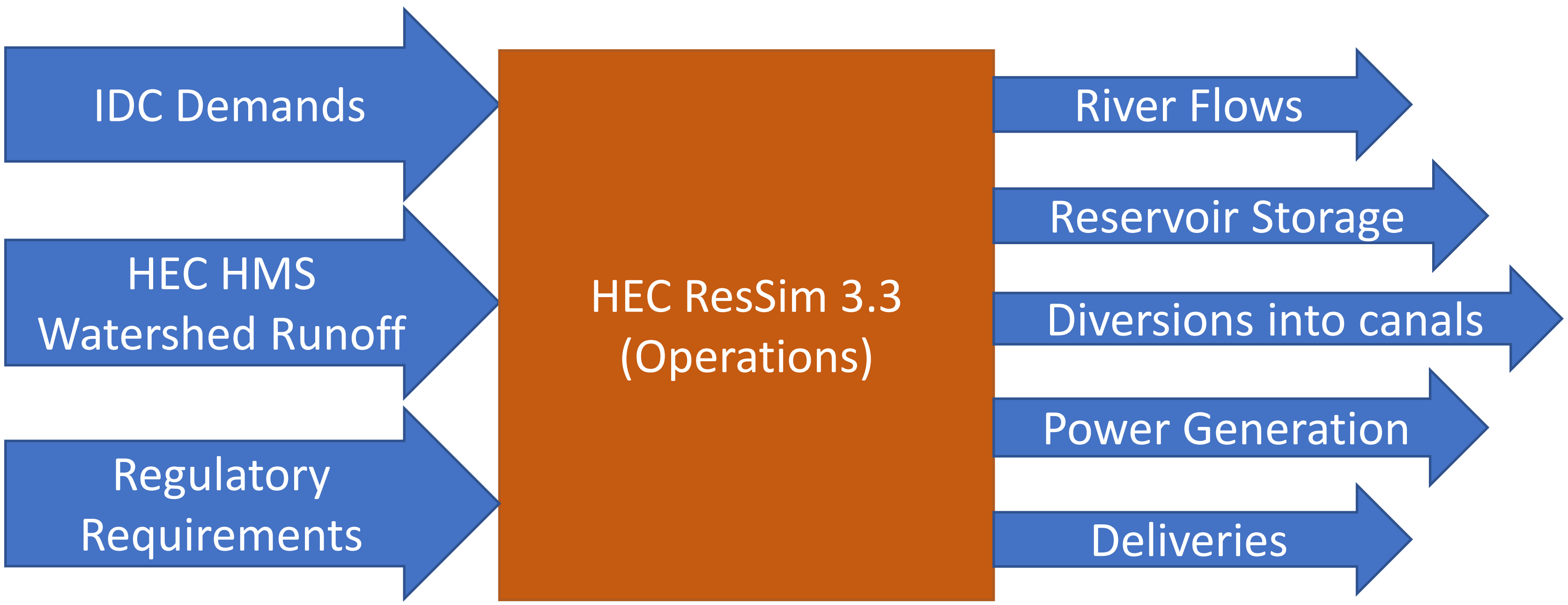


Reservoir Operations Model

US Army Corps
of Engineers
Hydrologic Engineering Center

HEC-ResSim

Reservoir System Simulation



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Projected Hydrology

Projected Scenarios

Climate Models Selected for Use

Scenarios	Models and Emissions
High Bookend (Wet)	**EC-Earth3-Veg_ssp370**
Median	**CNRM-ESM2 1_ssp245**
Low Bookend (Dry)	**CESM2-LENS_ssp370**

Projected

2022 → 2071

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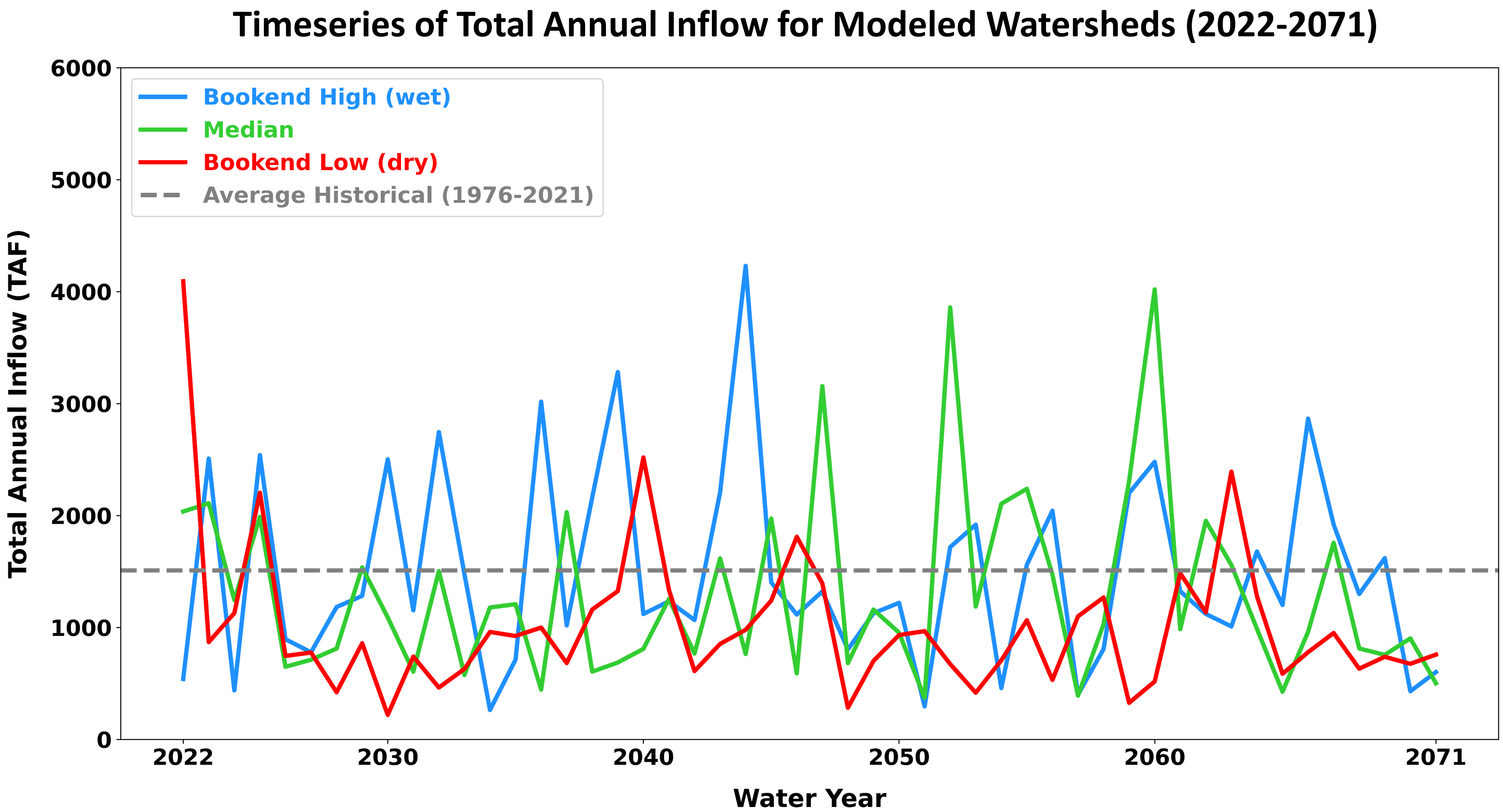
Climate Change Inflow



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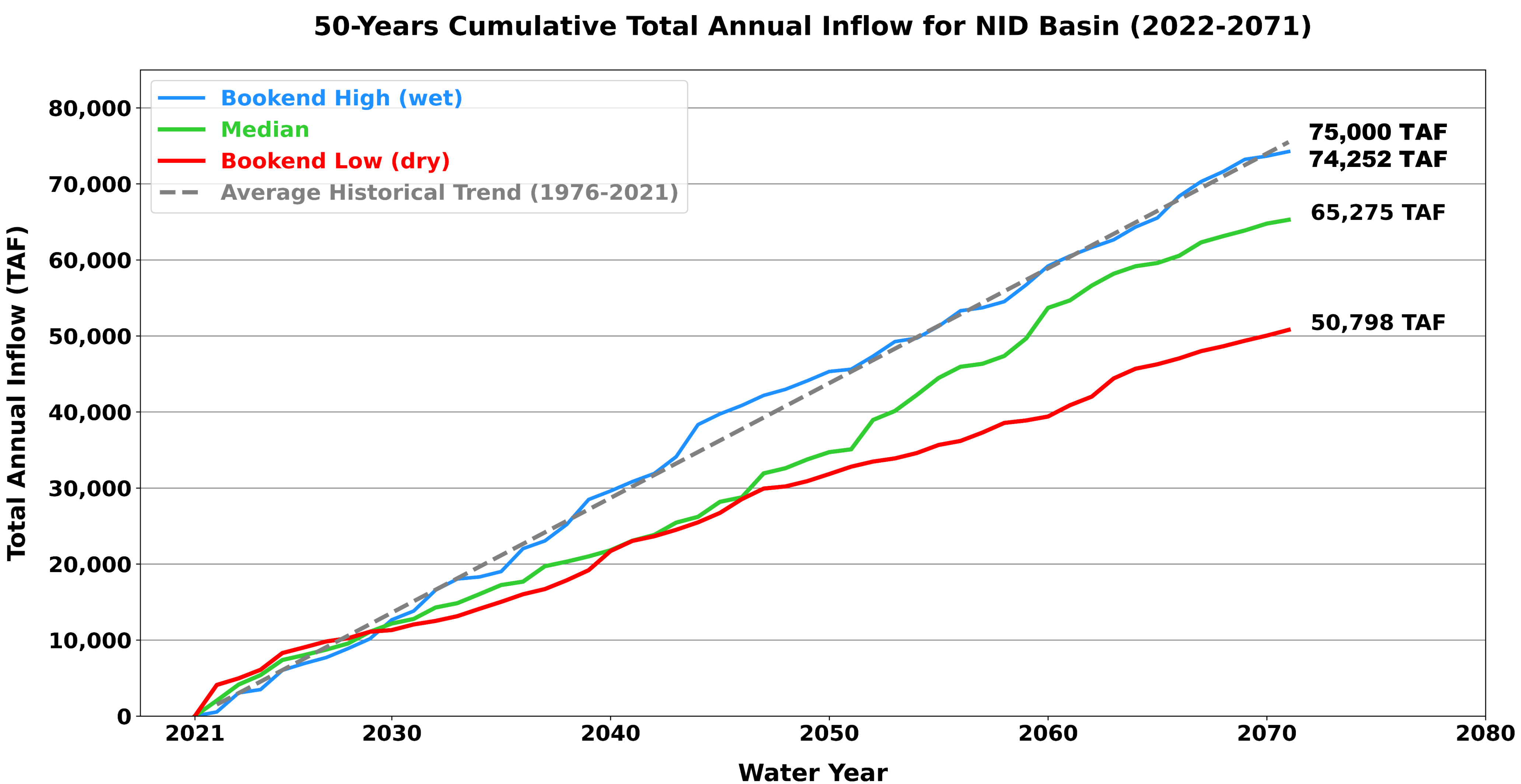
Climate Change Cumulative Inflow



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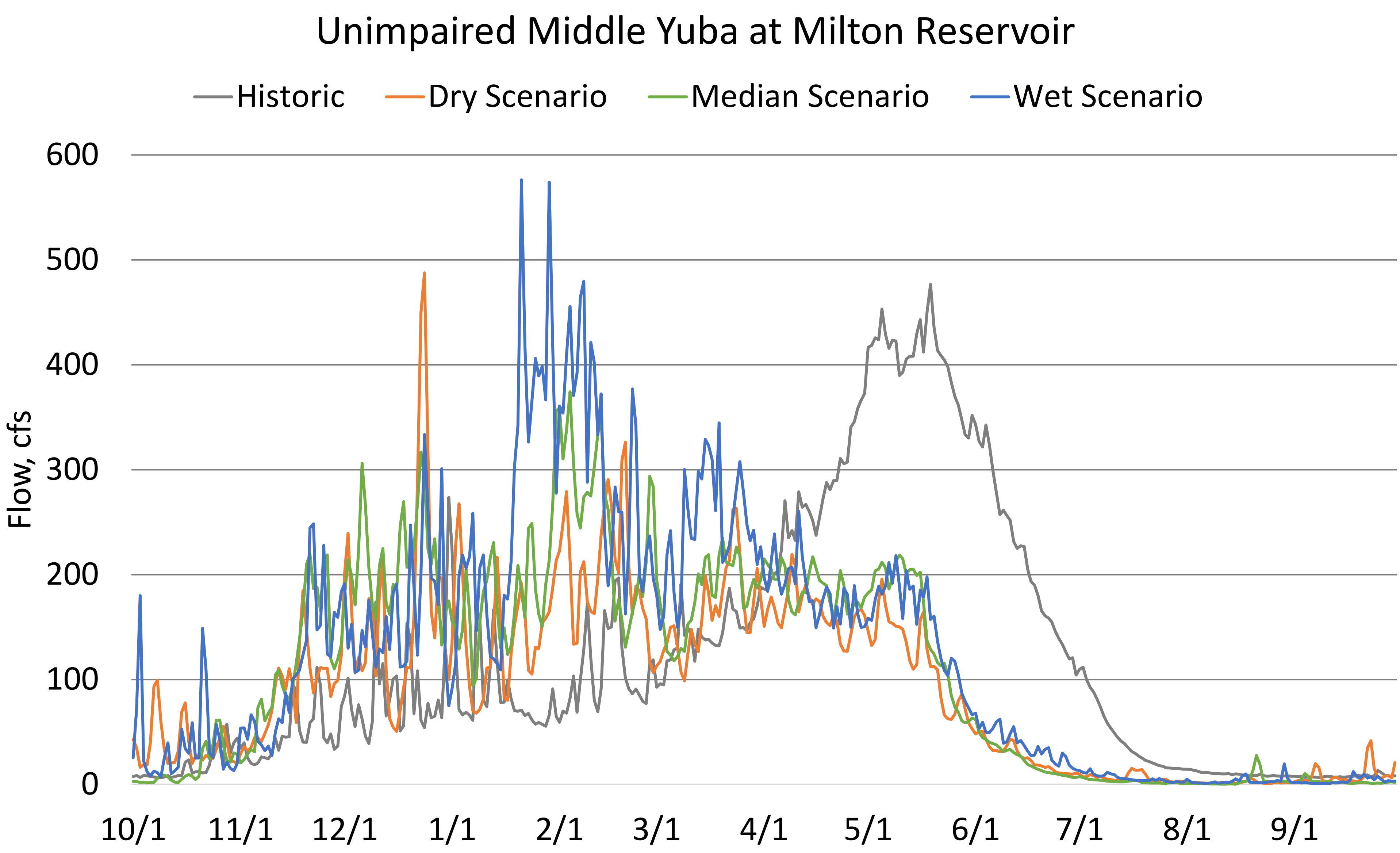
Climate Change Inflow



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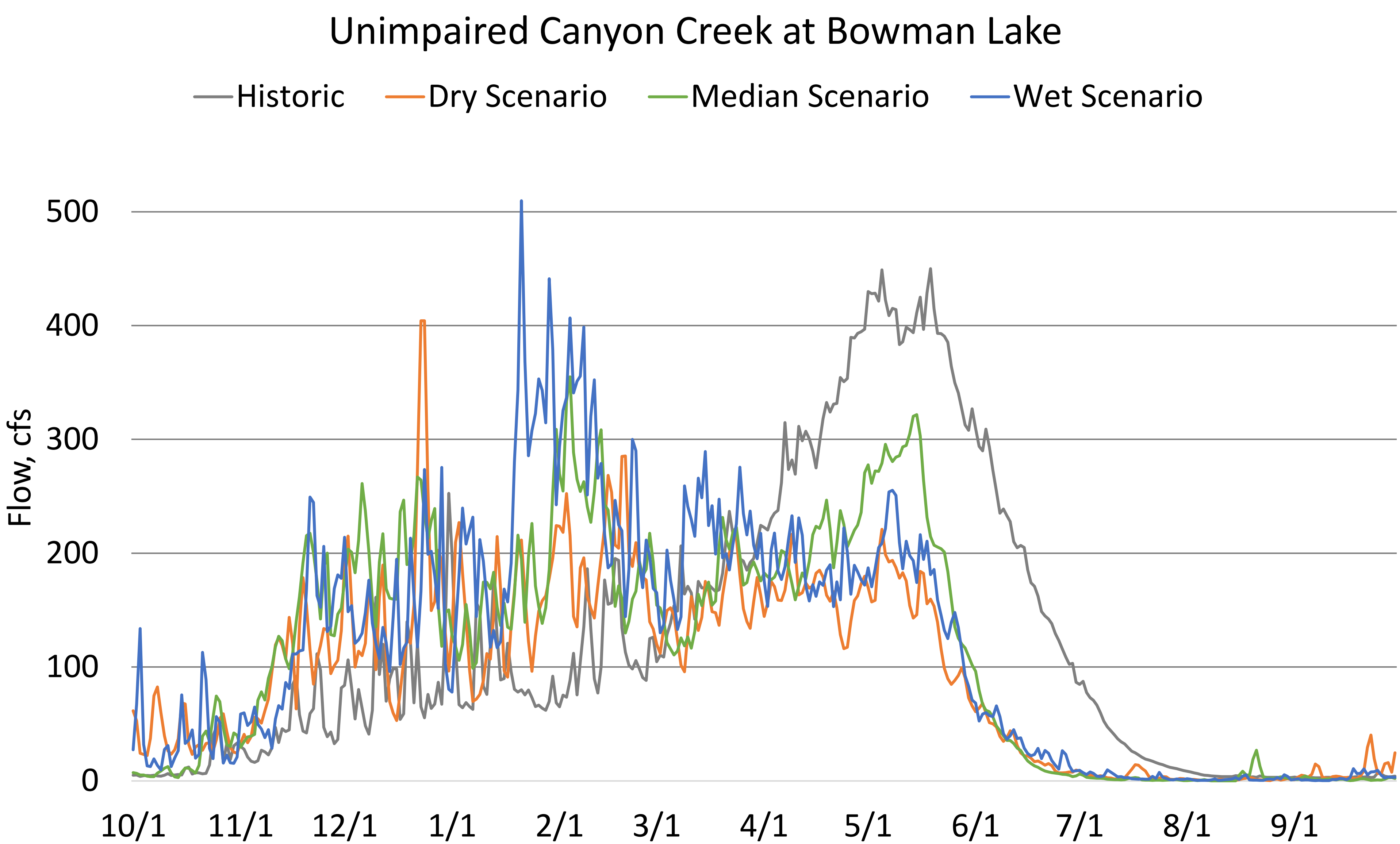
Climate Change Inflow



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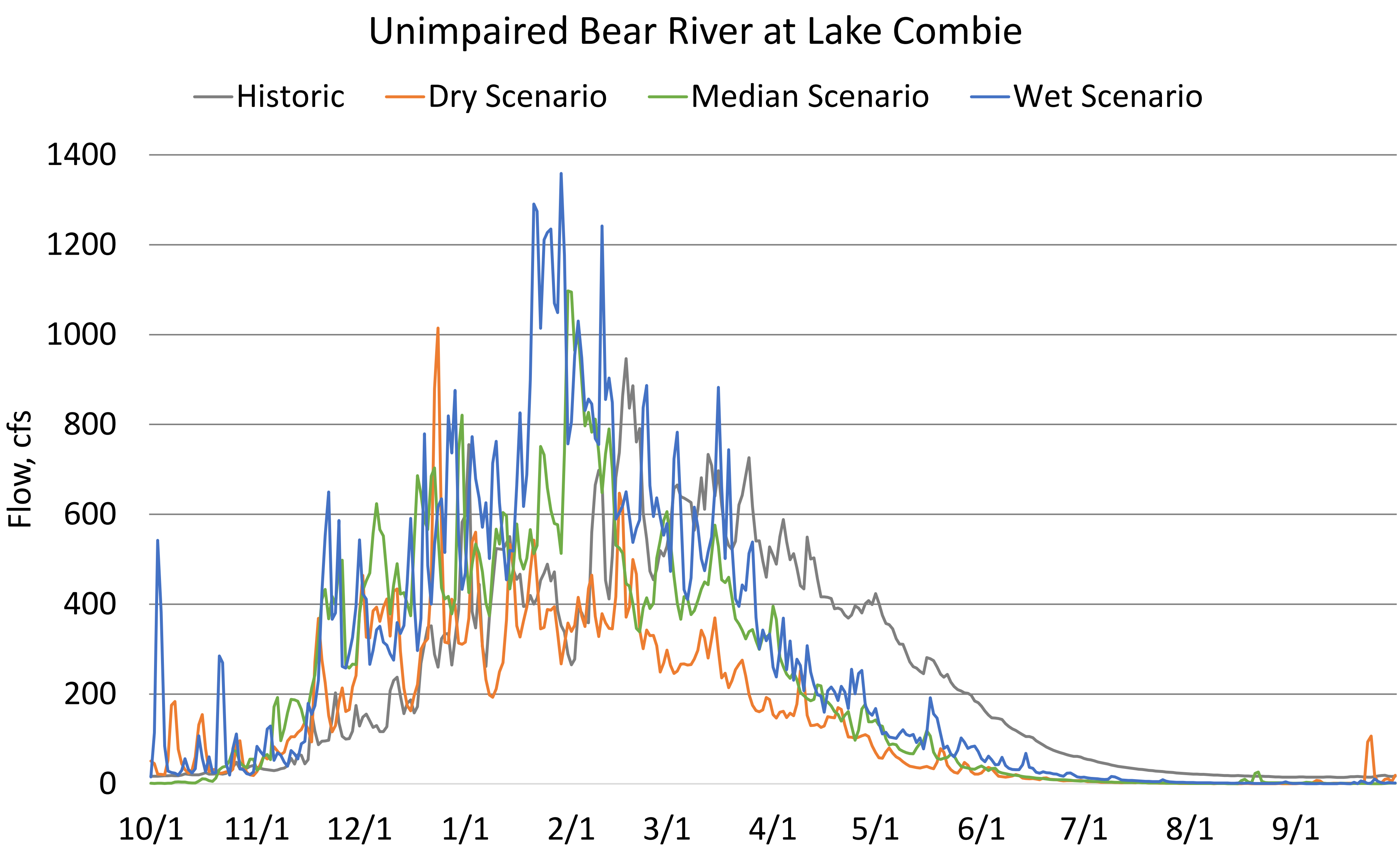
Climate Change Inflow



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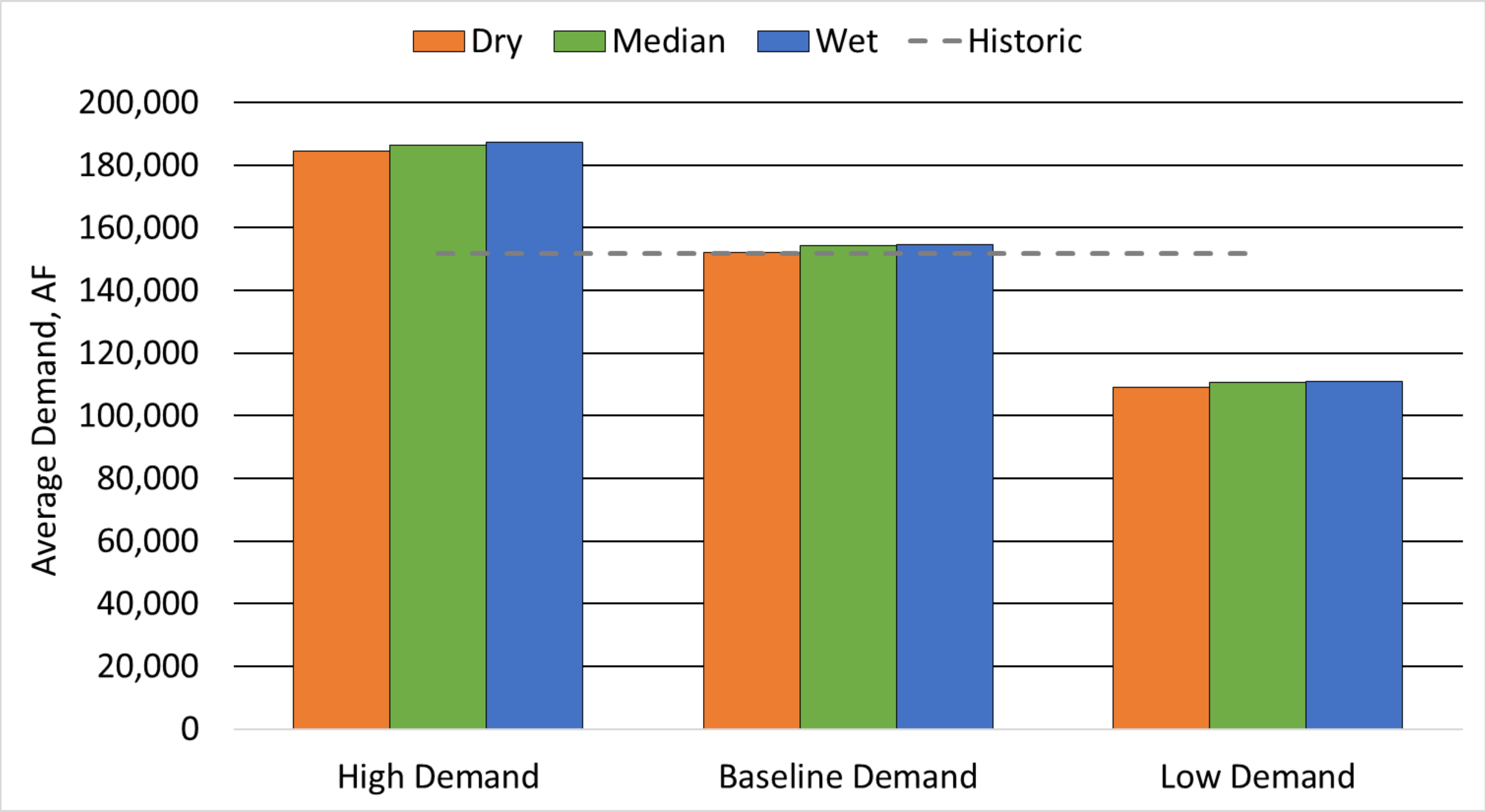
NID Demands

Average Annual NID Demands



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Reservoir Operations Model

- 10 baseline scenarios
- 3 scenarios for strategic alternatives analysis
- Assess strategies for addressing shortages

Climate Change Simulations	Demand Scenarios			
Hydrology Scenario	High	Median	Low	Constant Baseline
CESM2-LENS_ssp370 (Dry)	1	4	7	
CNRM-ESM2-1_ssp245 (Median)	2	5	8	10
EC-Earth3-Veg_ssp370 (Wet)	3	6	9	

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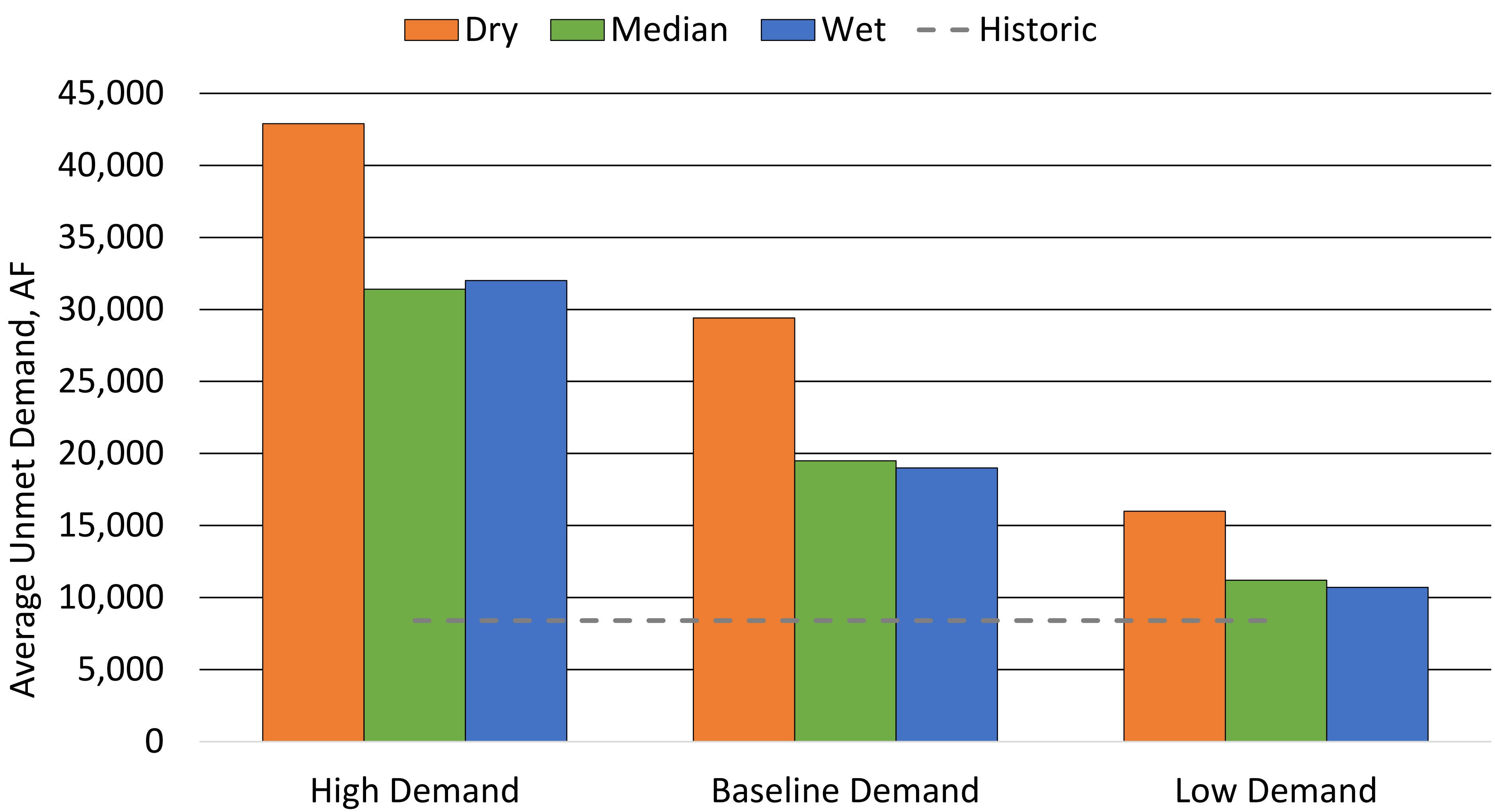
Reservoir Operations Model

- Metrics
    - Unmet Demands
    - Carryover Storage
    - Minimum Flow Requirements
        - All NID Minimum Flows are met in all studies

Unmet Demands

Average Annual Unmet Demand



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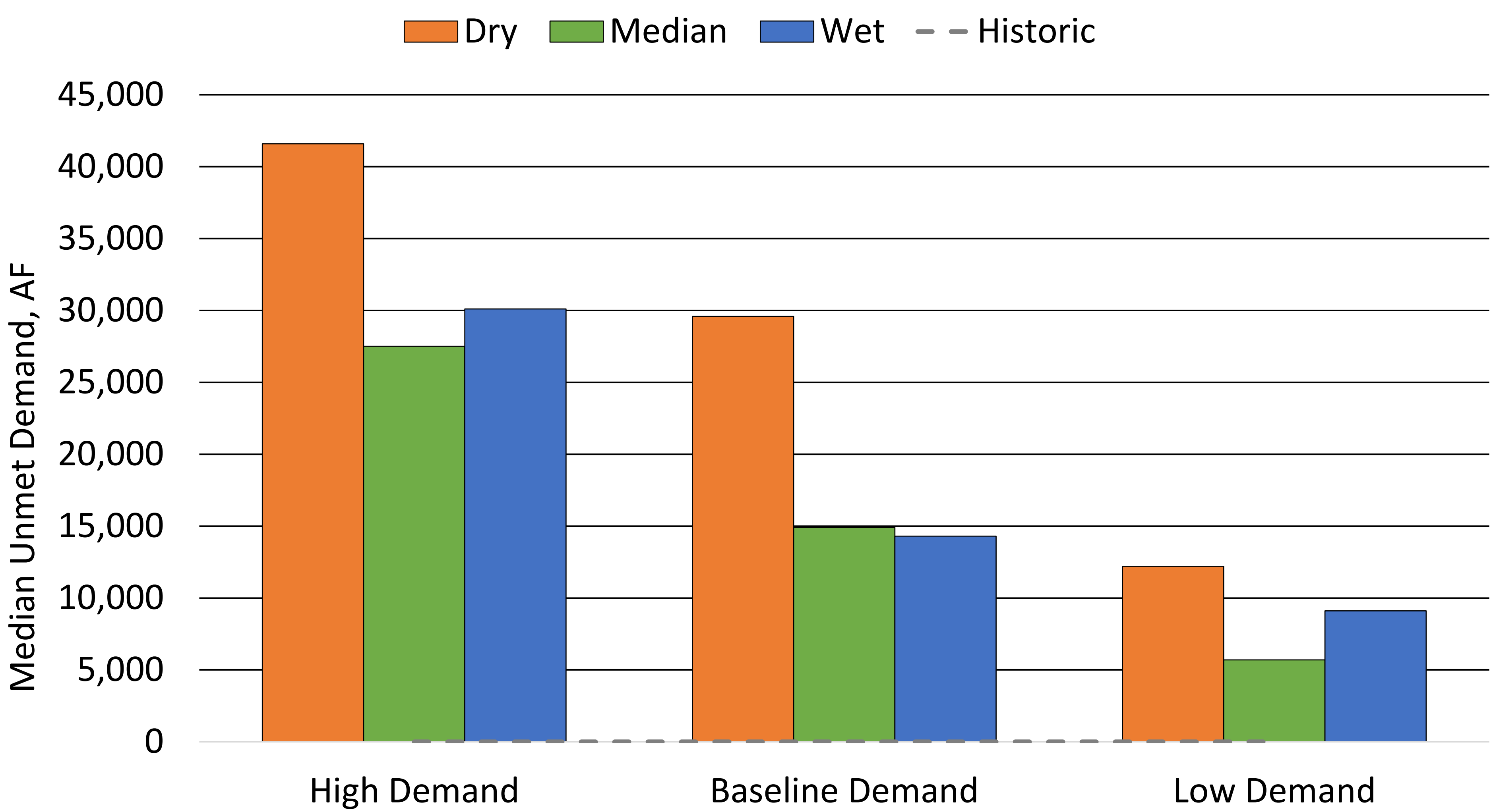
Unmet Demands

Median Unmet Demand



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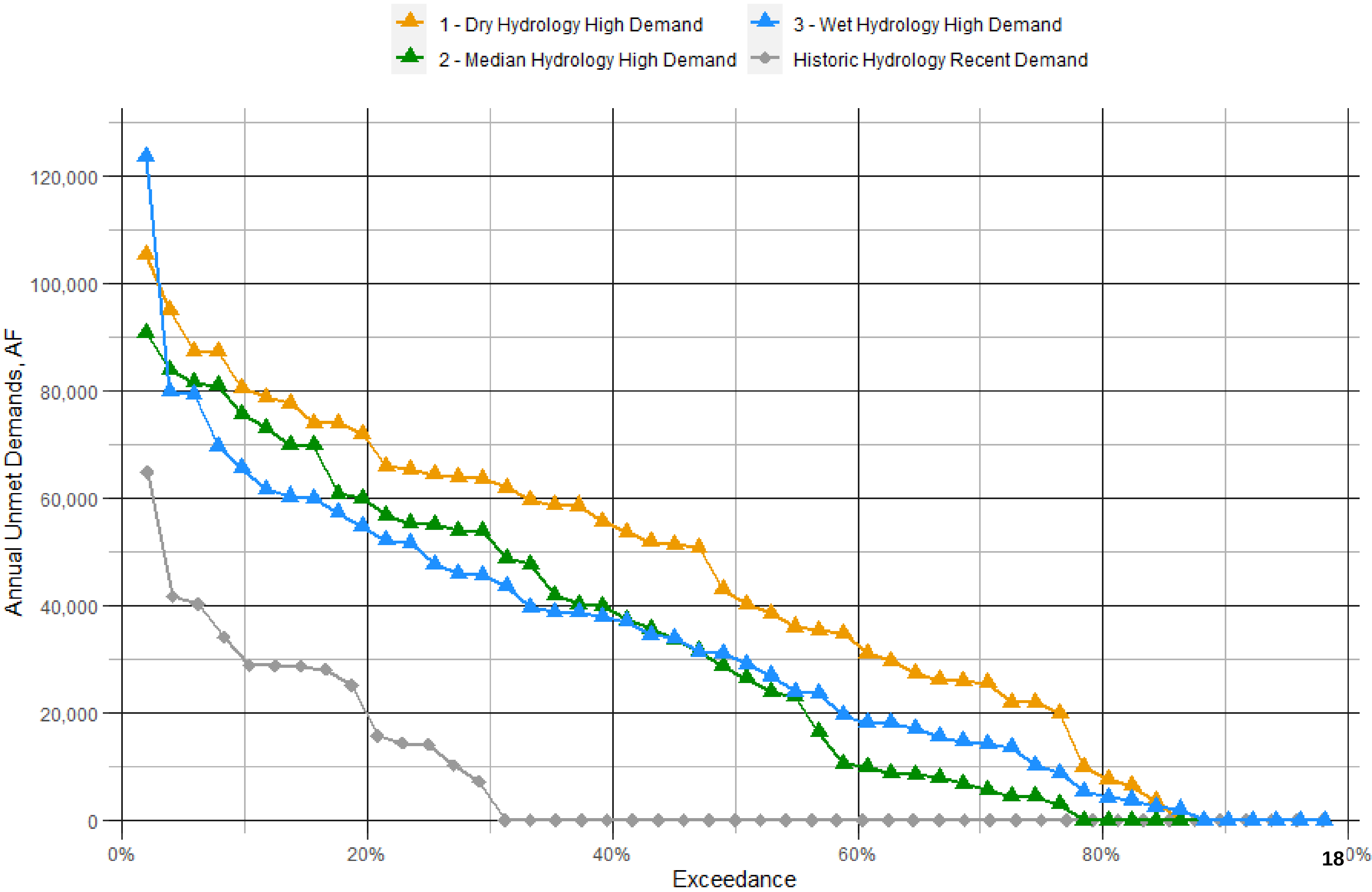
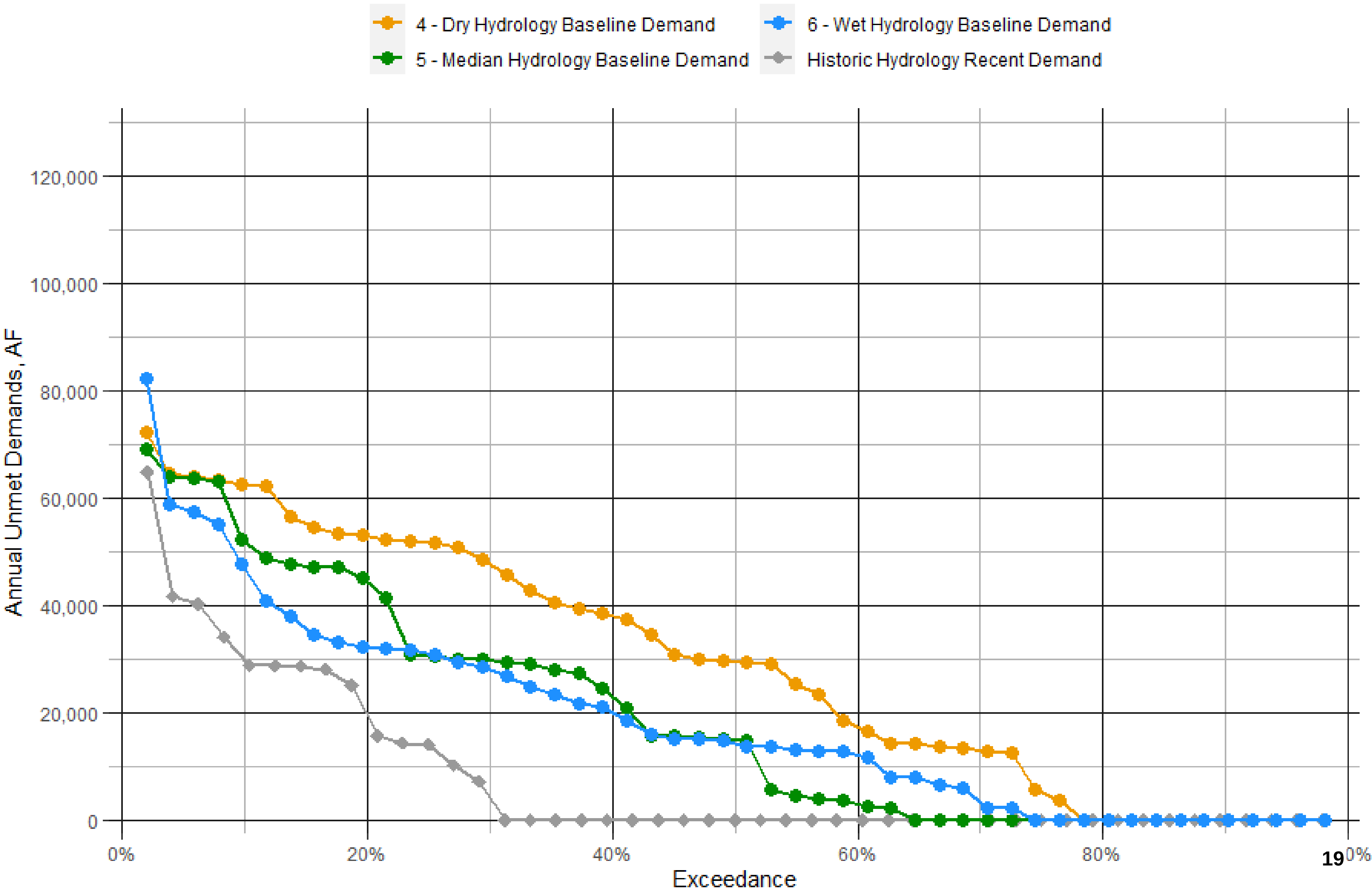
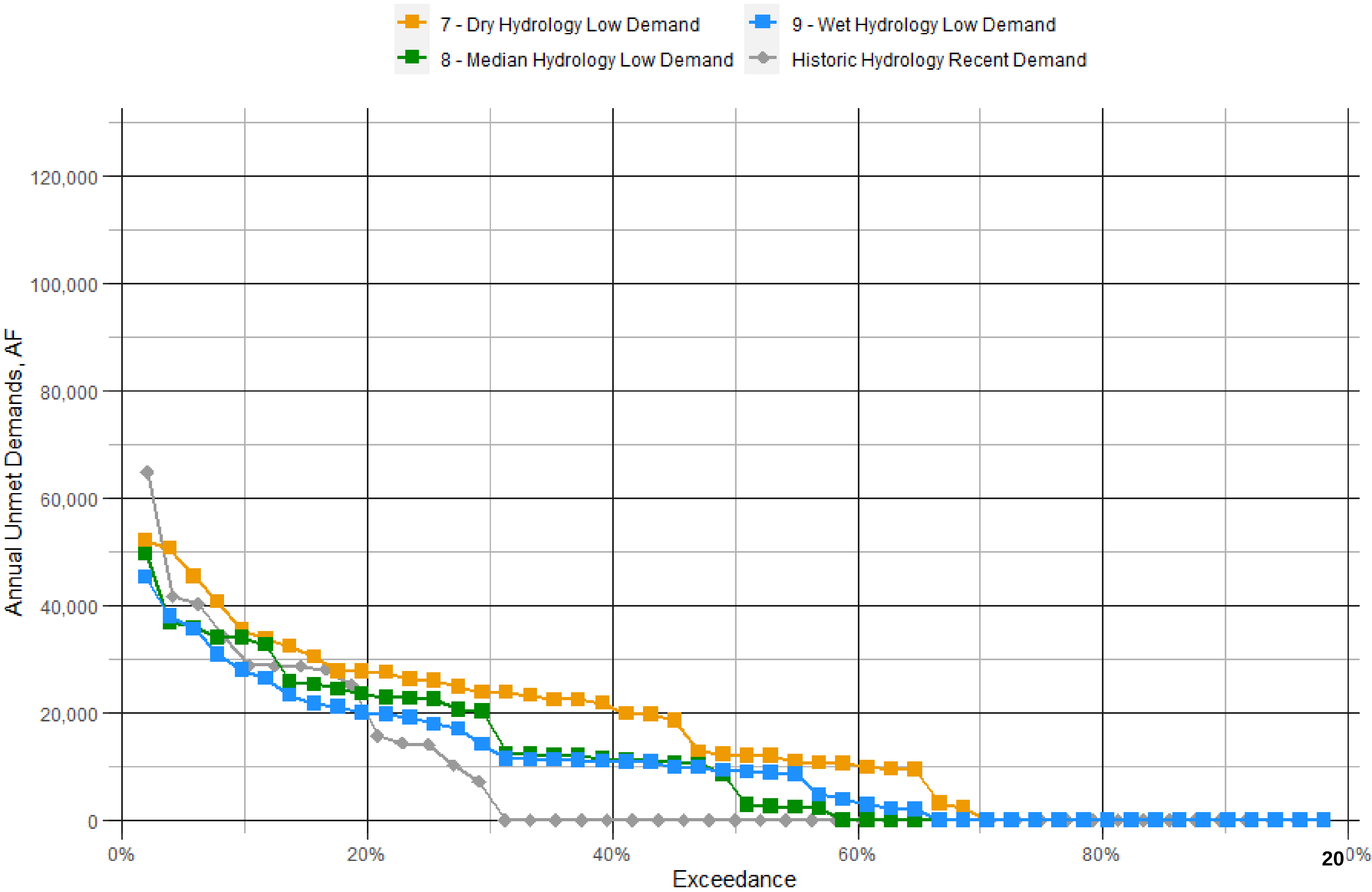
Unmet Demands – Annual Exceedance



Unmet Demands – Annual Exceedance



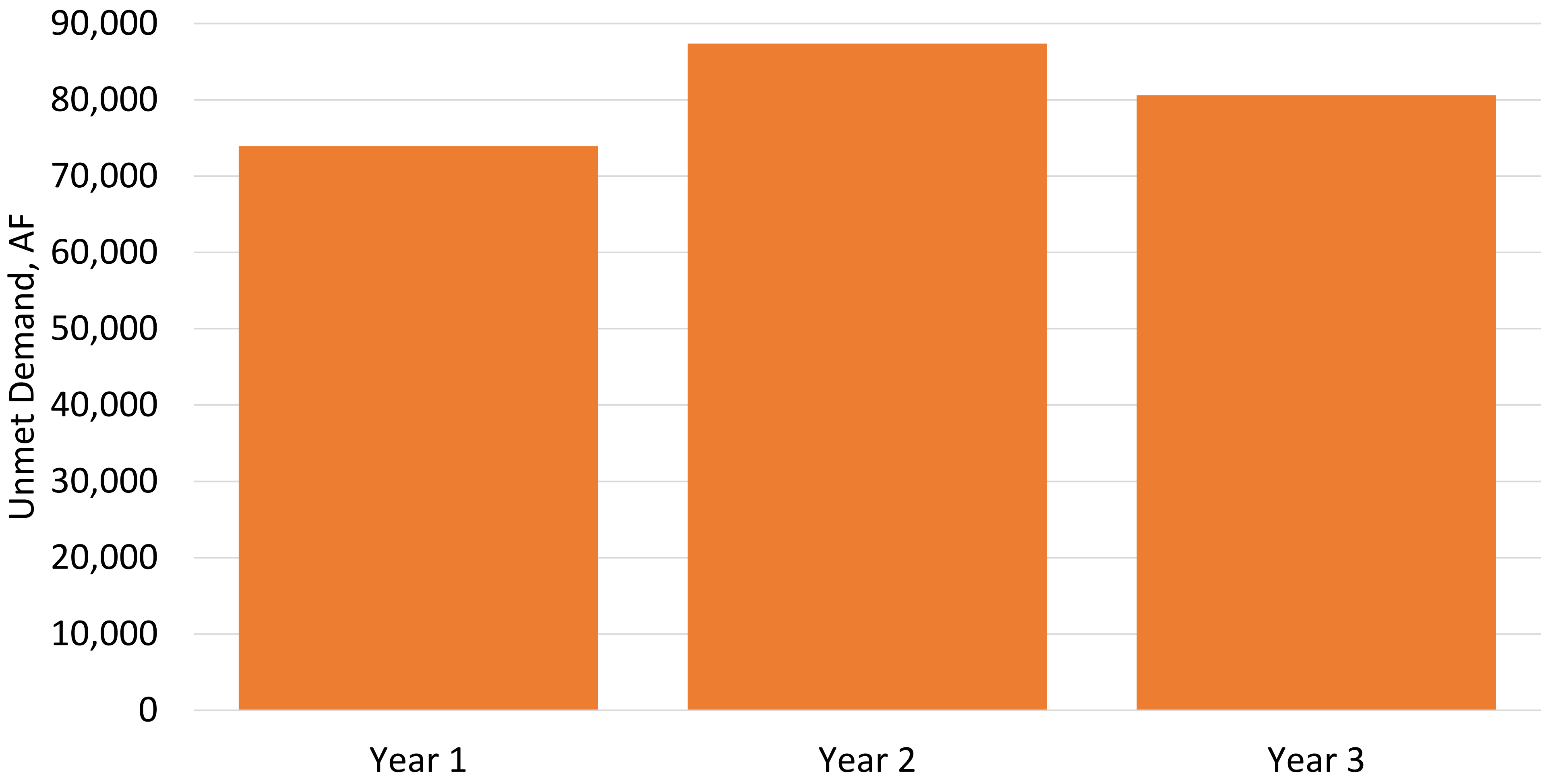
Unmet Demands – Annual Exceedance



Unmet Demands

Worst 3-year consecutive drought

Scenario 1 – Dry Climate High Demand



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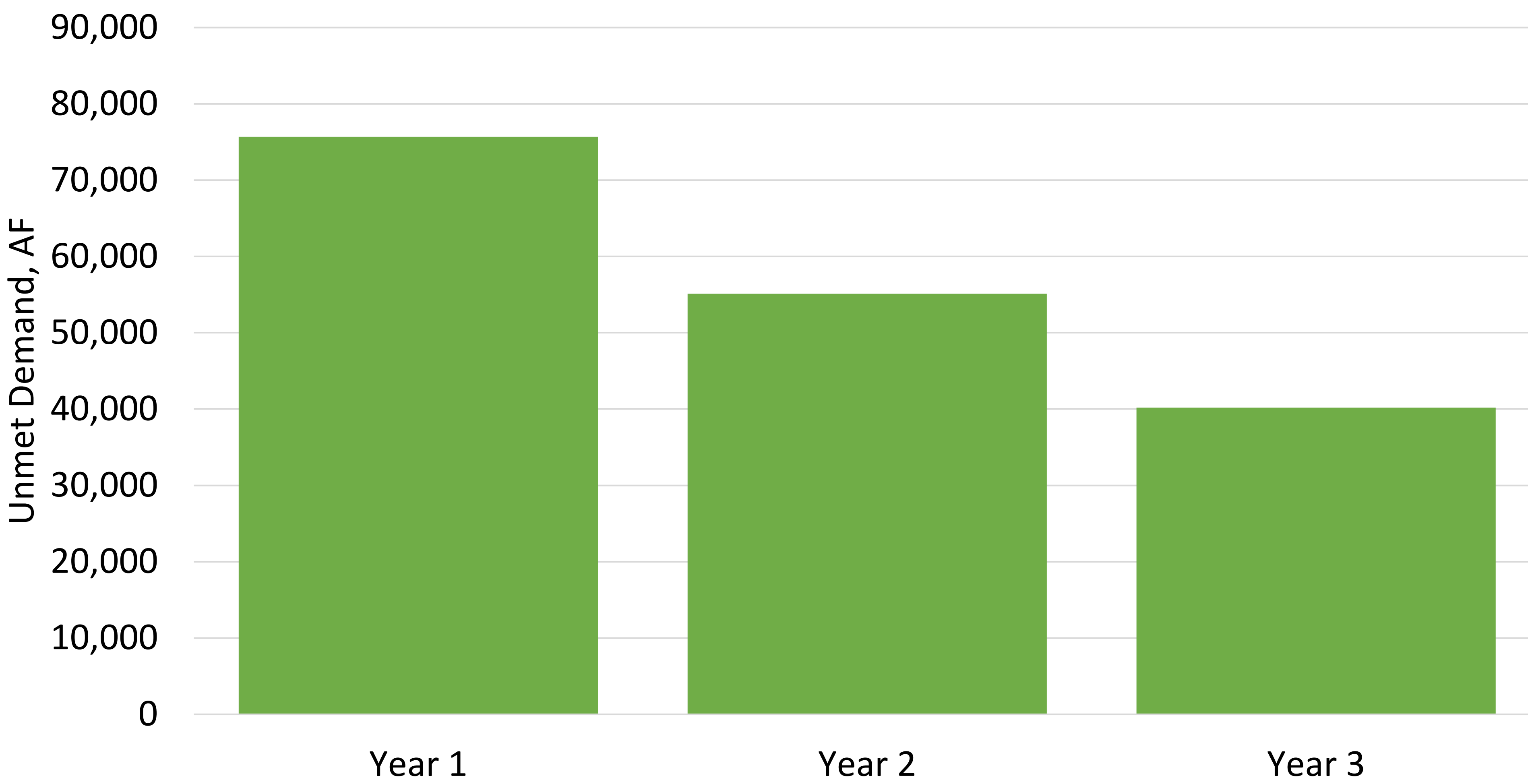
Unmet Demands

Worst 3-year consecutive drought

Scenario 2 – Median Climate High Demand



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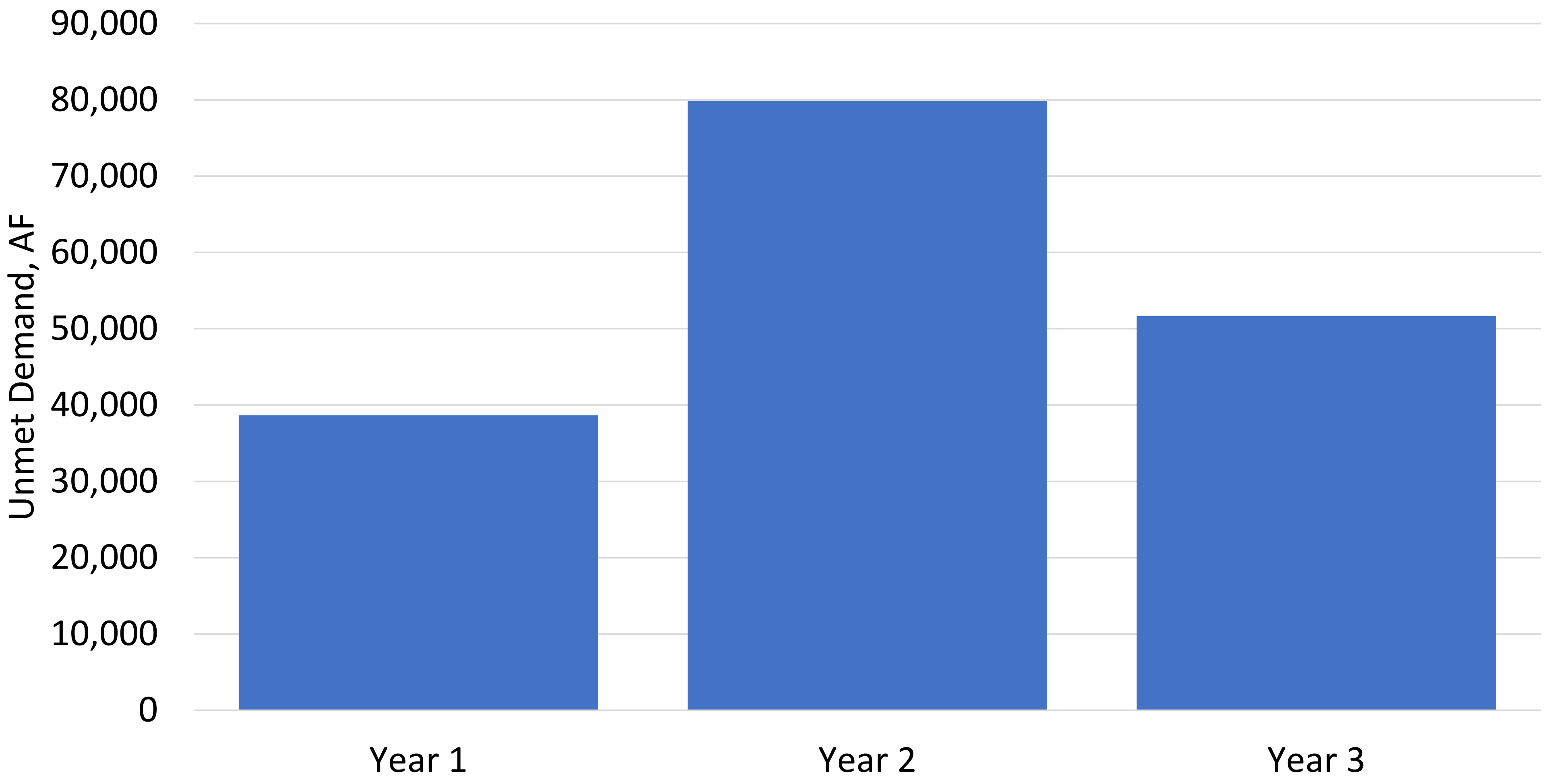
Unmet Demands

Worst 3-year consecutive drought

Scenario 3 – Wet Climate High Demand



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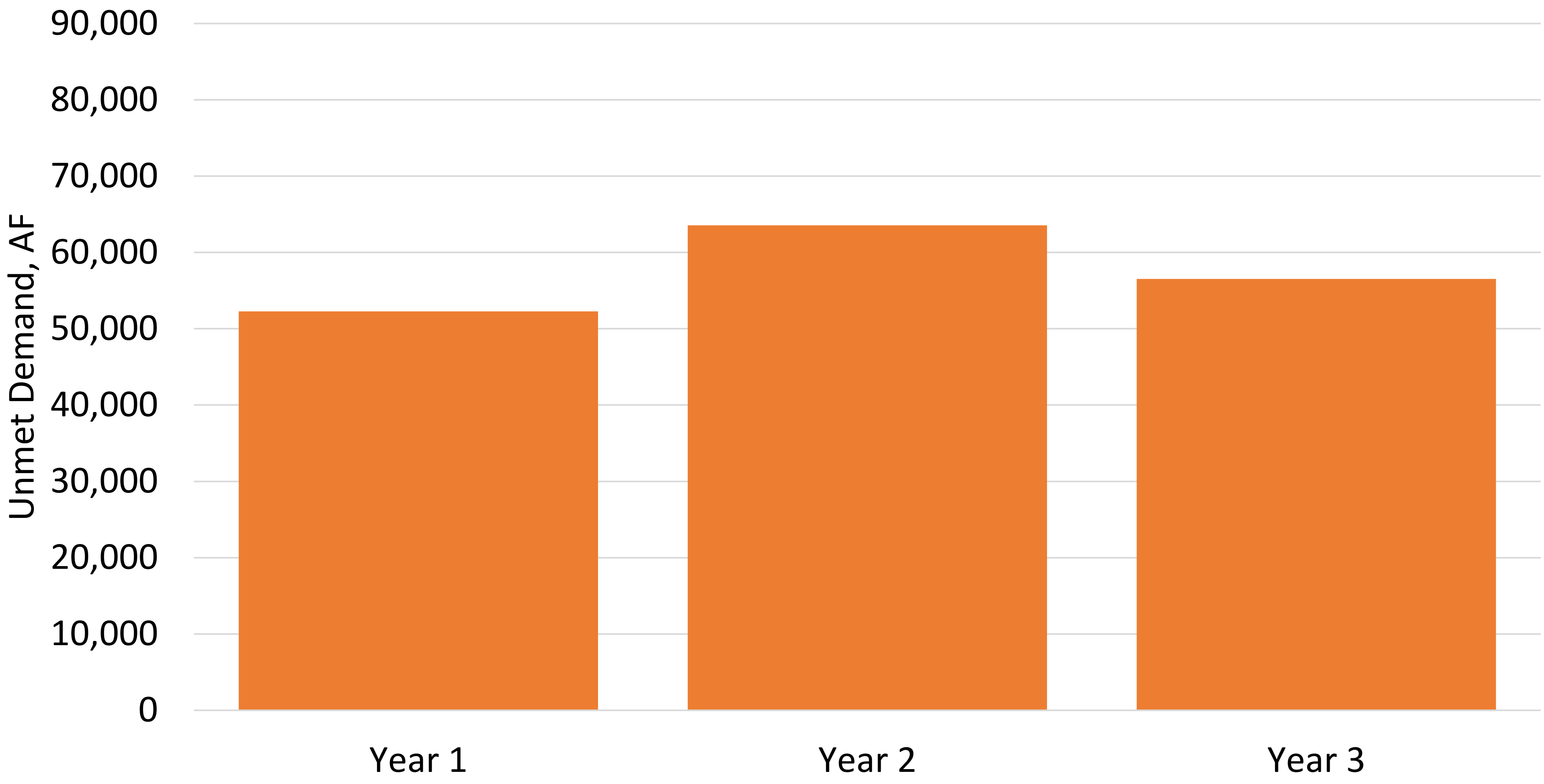
Unmet Demands

Worst 3-year consecutive drought

Scenario 4 – Dry Climate Baseline Demand



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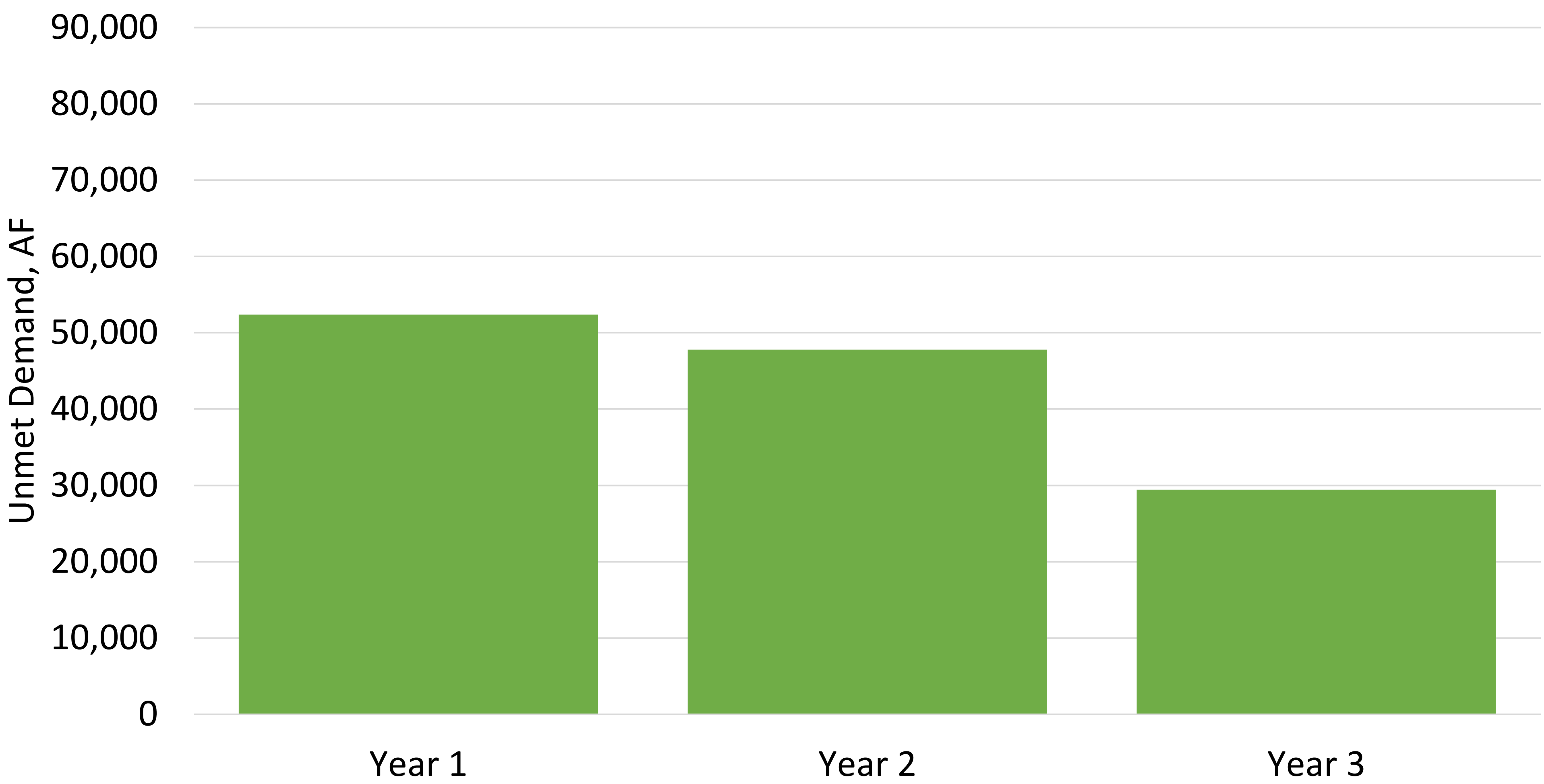
Unmet Demands

Worst 3-year consecutive drought

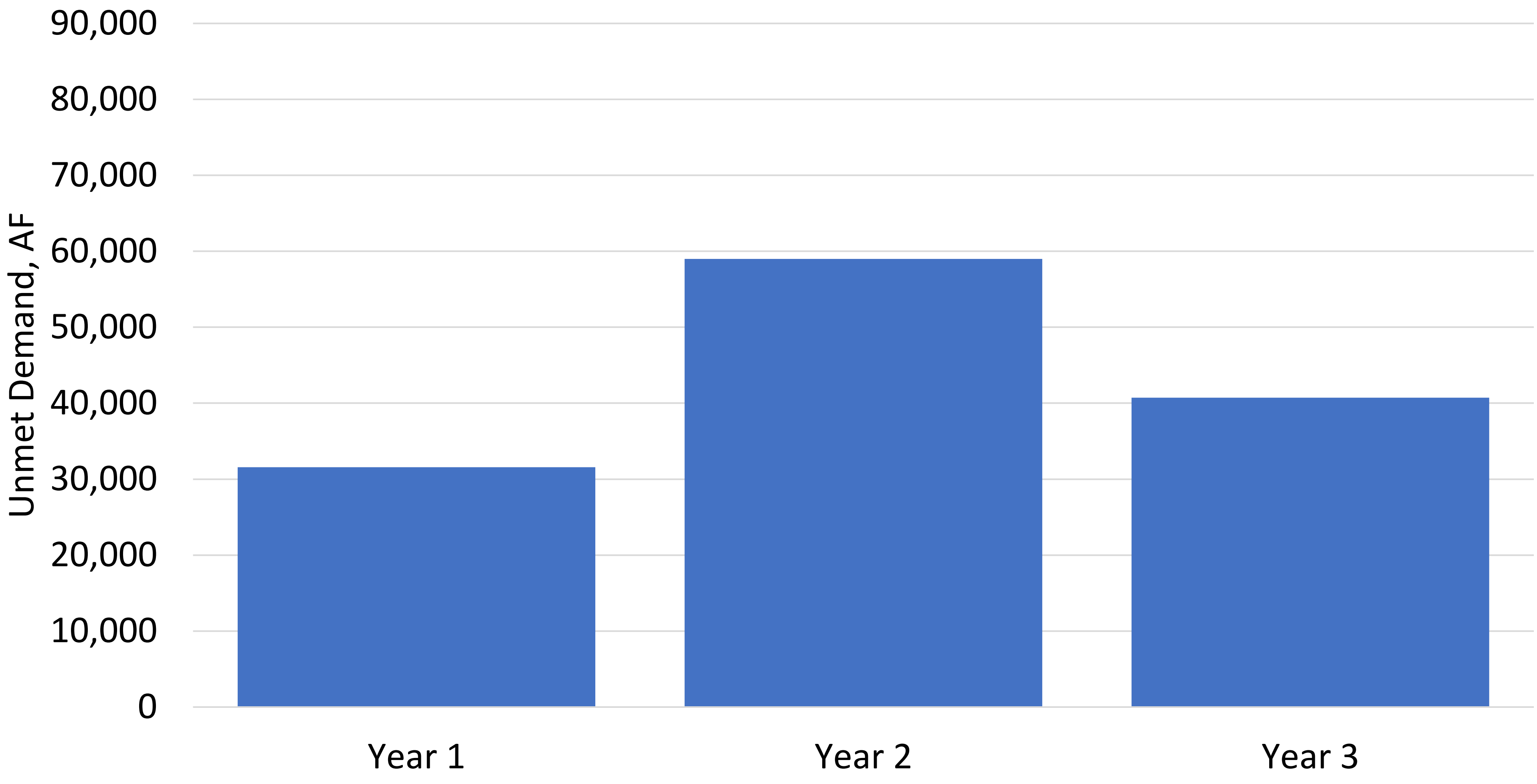
Scenario 5 – Median Climate Baseline Demand



Unmet Demands

Worst 3-year consecutive drought

Scenario 6 – Wet Climate Baseline Demand



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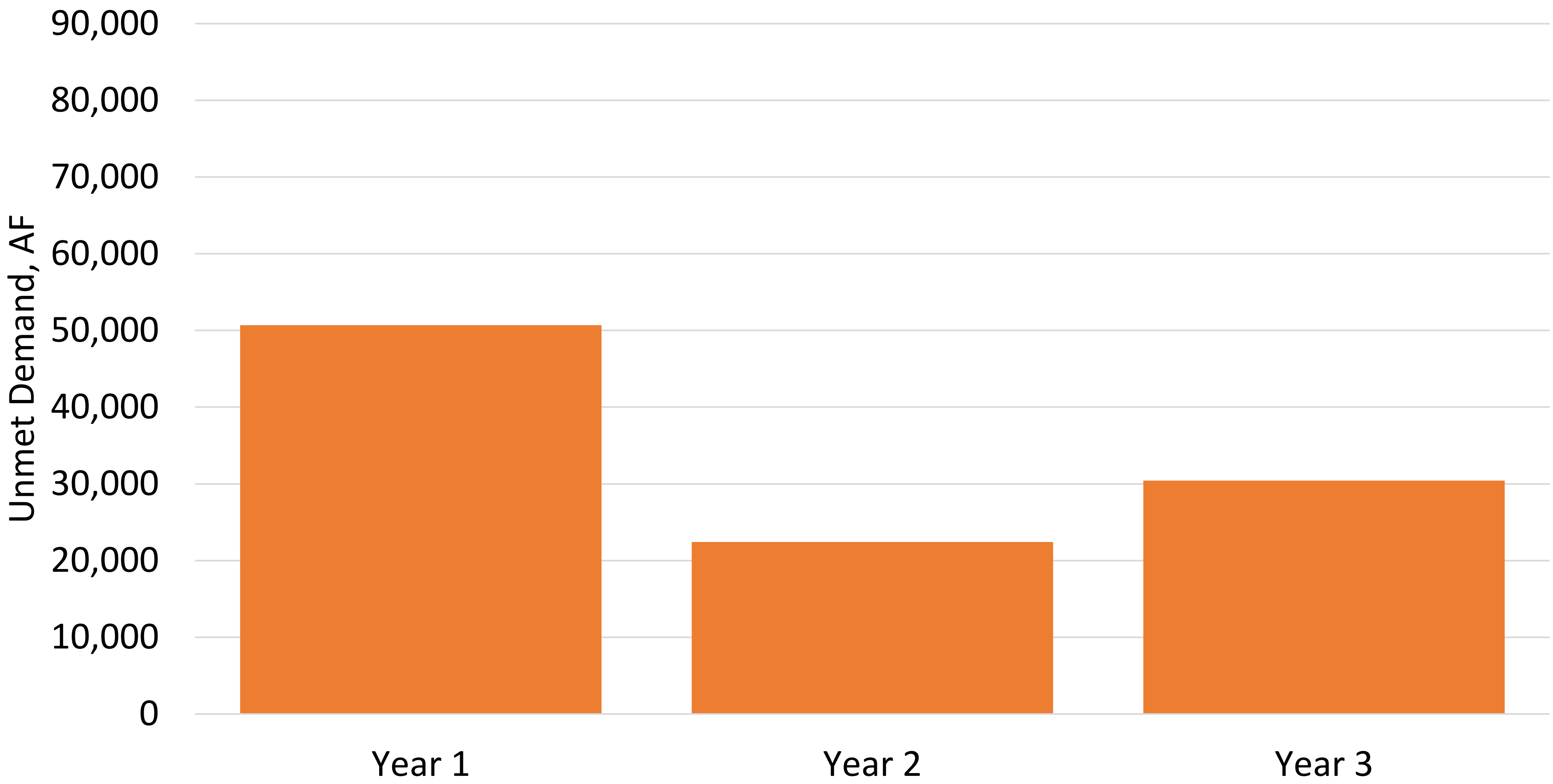
Unmet Demands

Worst 3-year consecutive drought

Scenario 7 – Dry Climate Low Demand



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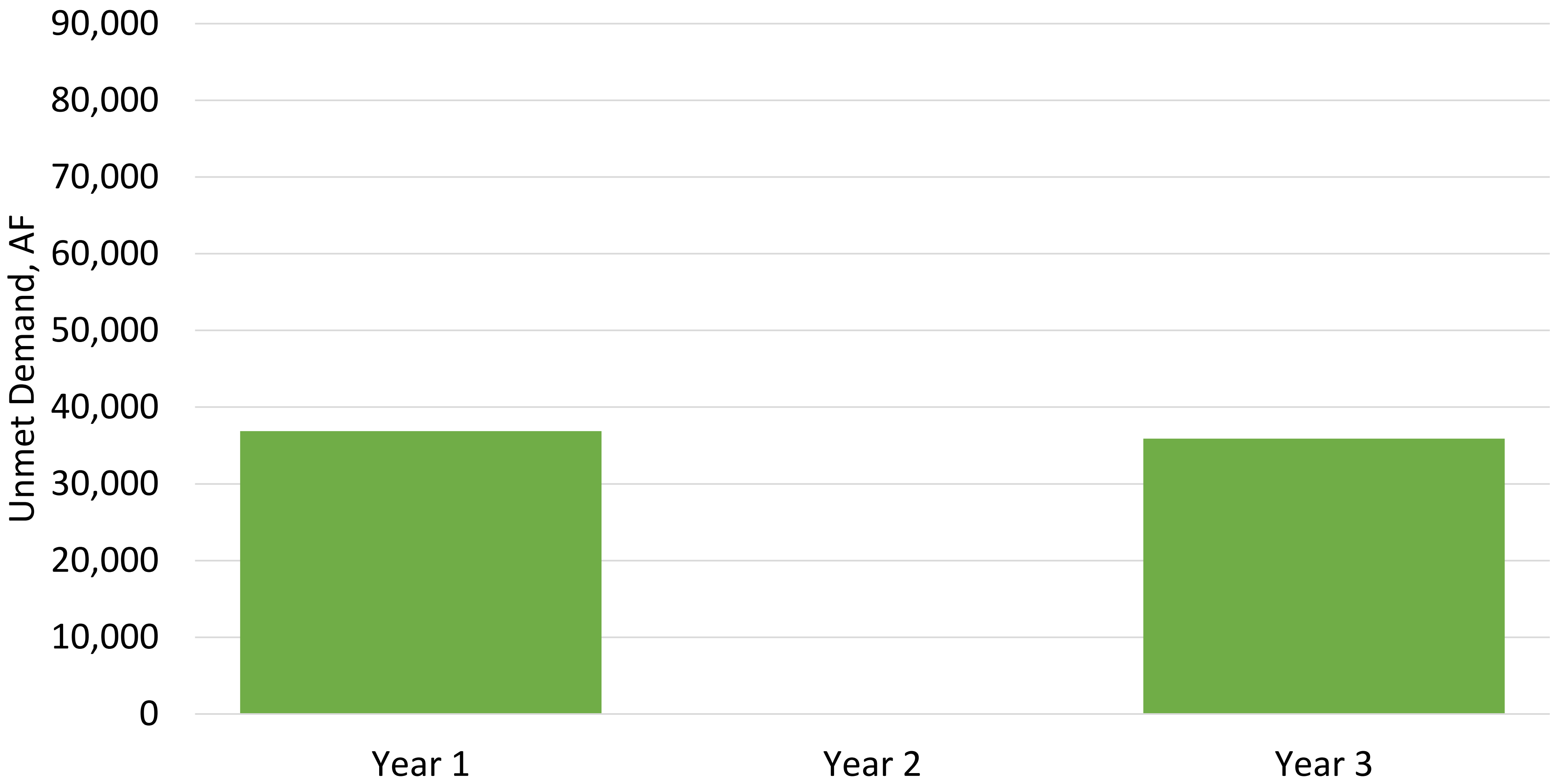
Unmet Demands

Worst 3-year consecutive drought

Scenario 8 – Median Climate Low Demand



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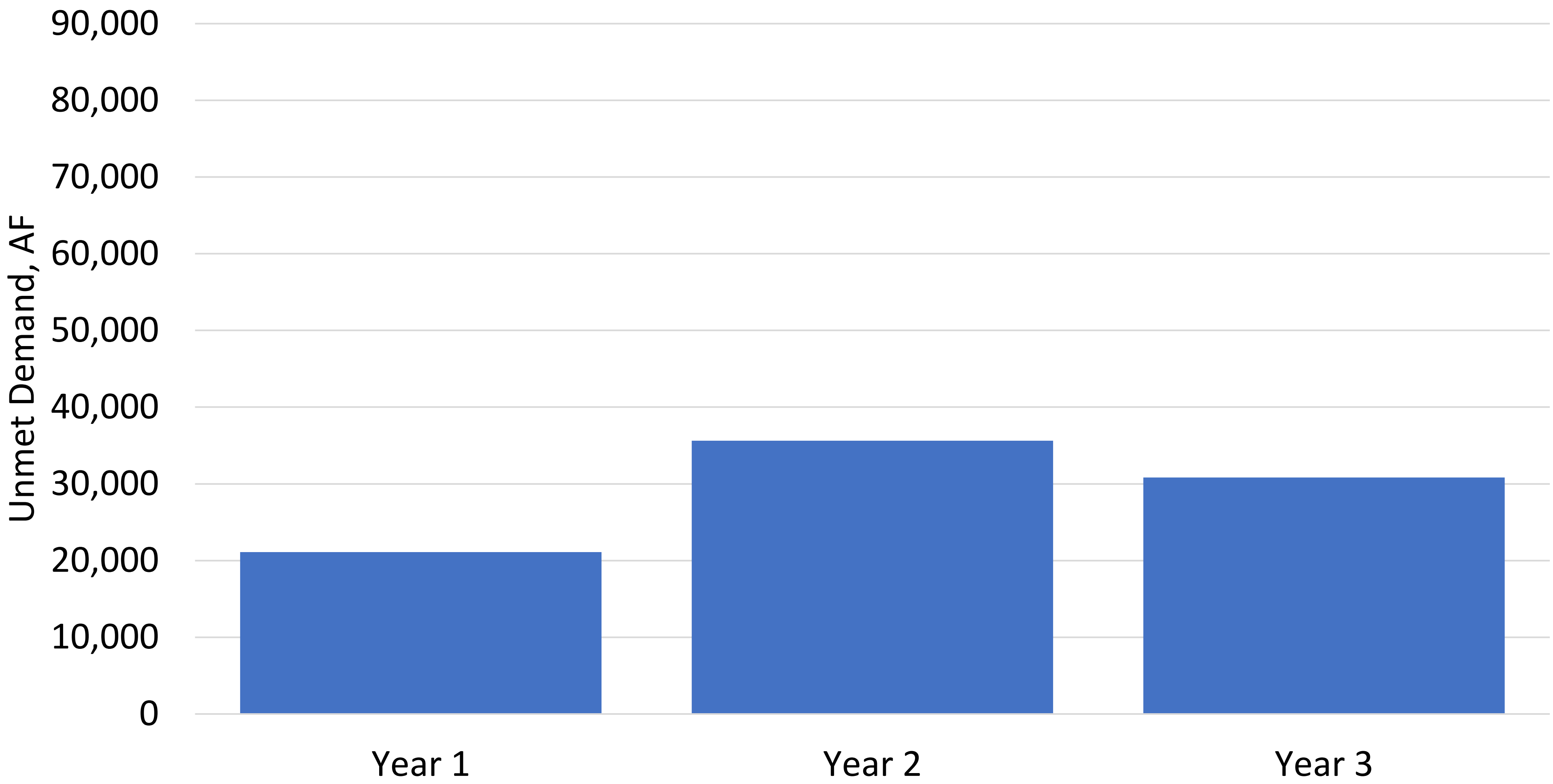
Unmet Demands

Worst 3-year consecutive drought

Scenario 9 – Wet Climate Low Demand



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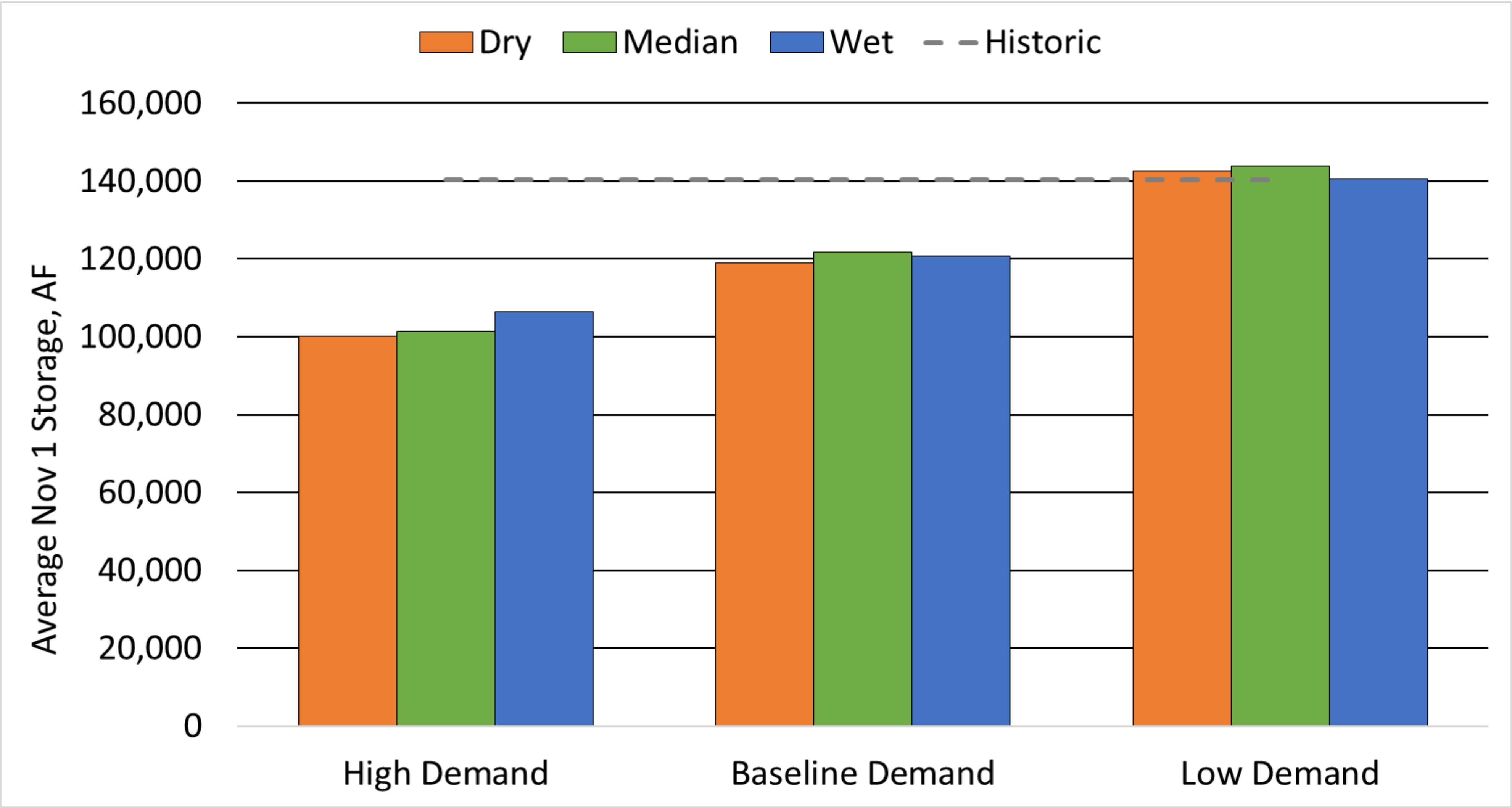
November 1 Carryover Storage at NID Reservoirs



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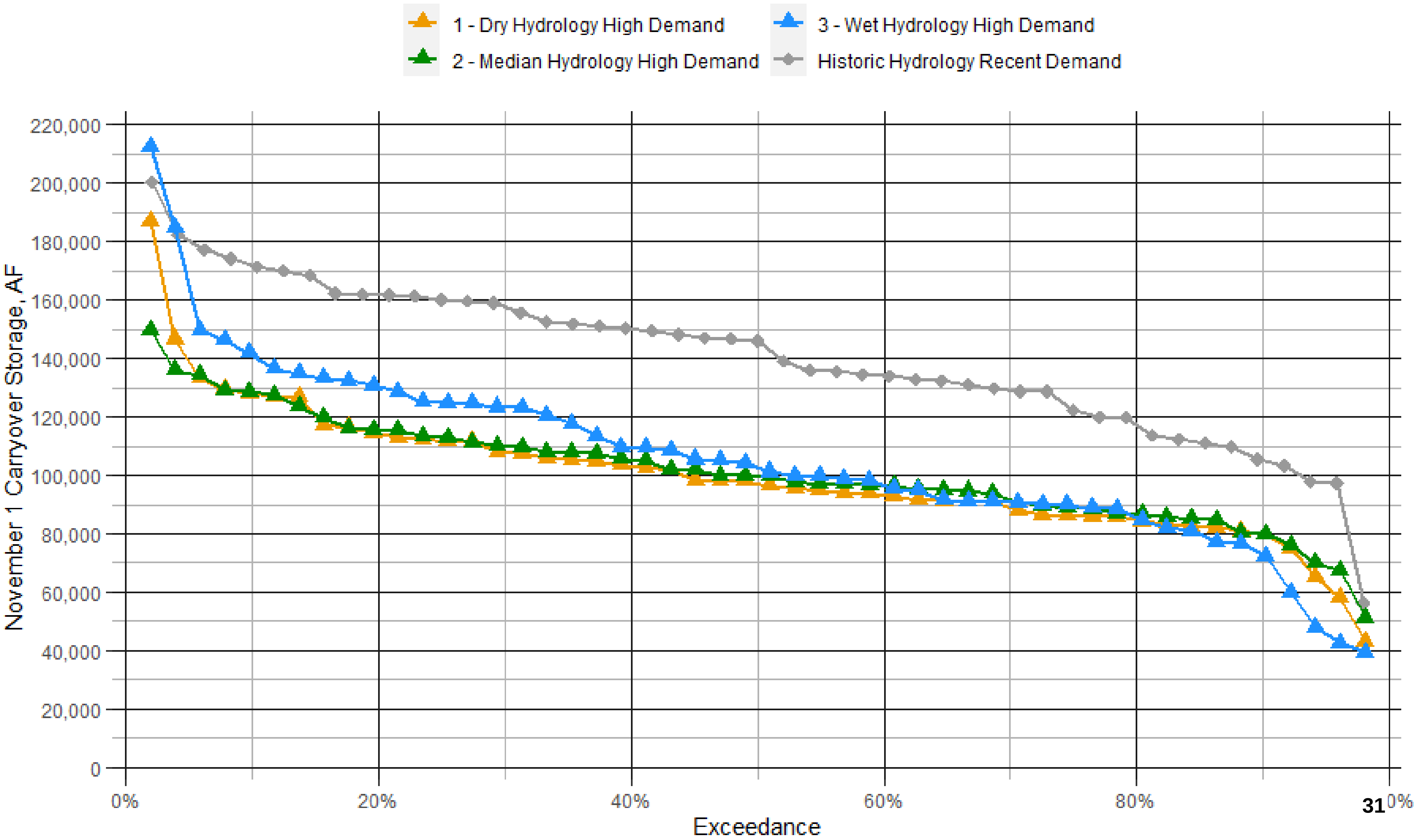
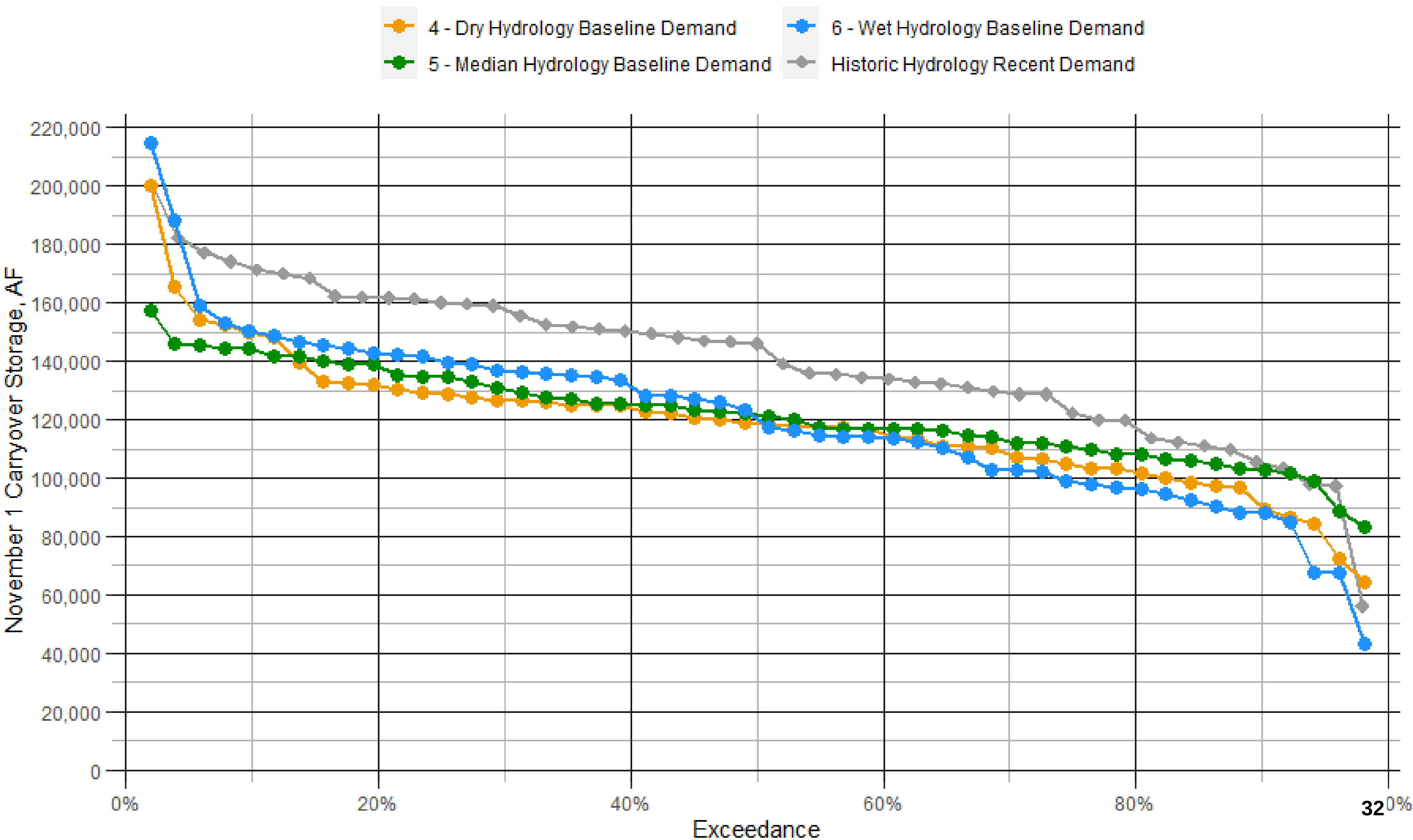
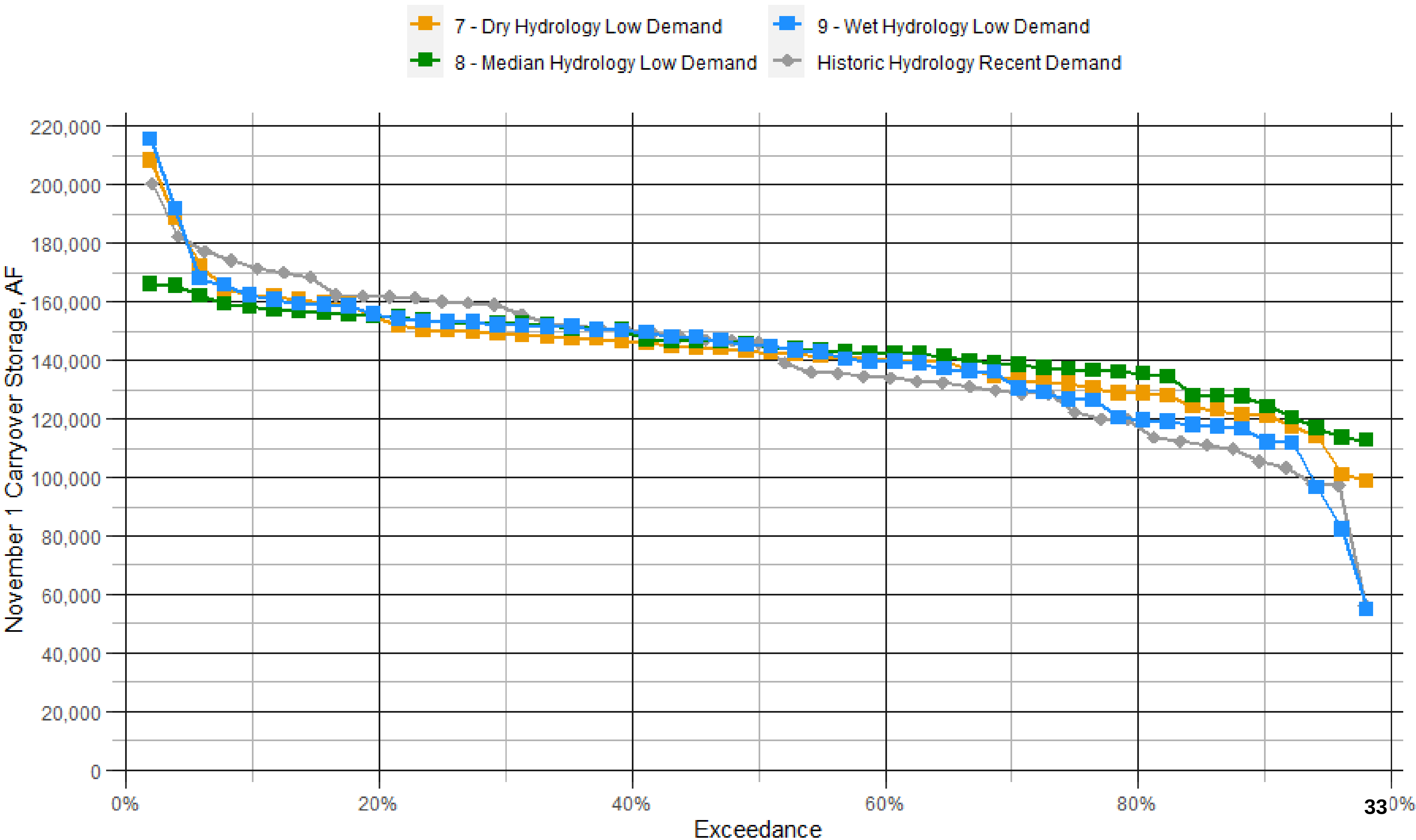
November 1 Carryover Storage at NID Reservoirs



November 1 Carryover Storage at NID Reservoirs



November 1 Carryover Storage at NID Reservoirs



Potential Strategic Alternatives

- Canal improvements to reduce losses
- Optimized operations
  - Increase reservoir carryover storage
  - Additional purchase contracts
  - Reoperate existing facilities
- Storage augmentation
  - Sediment removal
  - Increase storage
- Demand side management

Other Potential Analysis

- Extended Irrigation Season
- Increased Regulatory Requirements
  - Higher Release Requirements
  - Water Budgets
  - Curtailments

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Next Steps

- Select modeling scenarios to move forward to model Strategic Alternatives
- Select Strategic Alternatives studies
- Perform Strategic Alternatives studies
- Final documentation

Board Action Items

- Select 3 Scenarios for strategic alternative analysis
- Select which types of alternative require modeling vs. financial cost/benefit

Climate Change Simulations	Demand Scenarios			
Hydrology Scenario	High	Median	Low	Constant Baseline
CESM2-LENS_ssp370 (Dry)	1	4	7	
CNRM-ESM2-1_ssp245 (Median)	2	5	8	10
EC-Earth3-Veg_ssp370 (Wet)	3	6	9	

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Interactive Unmet Demands

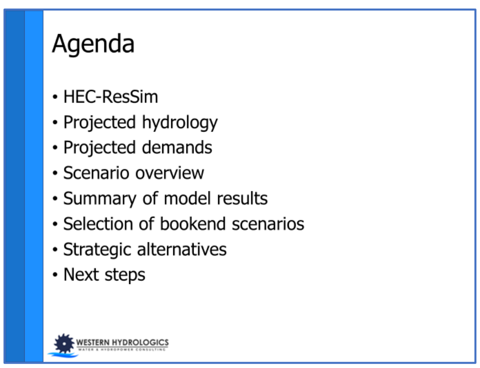
Nevada Irrigation District - Plan for Water

NID PFW Reservoir Operations Modeling Results Summary
Climate Change Scenarios - Commentary

October 10, 2023

<u>Title Page – No commentary</u>

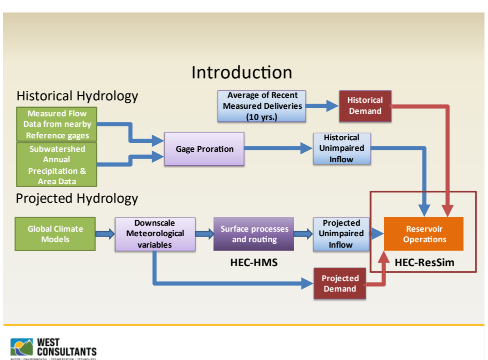
This commentary will be included in the presentation.



<u>Slide 2 – Agenda</u>

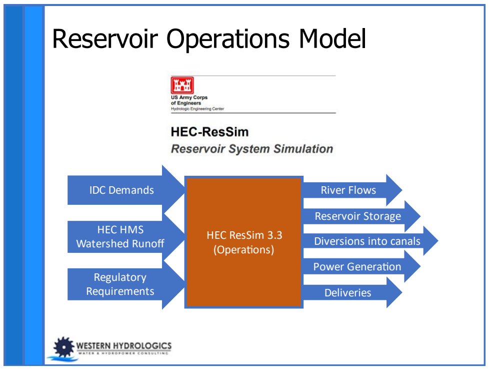
The first four bullets are review materials.

The last four bullets are new materials focused on ResSim results and development of strategic alternatives.



<u>Slide 3 – Process Flowchart</u>

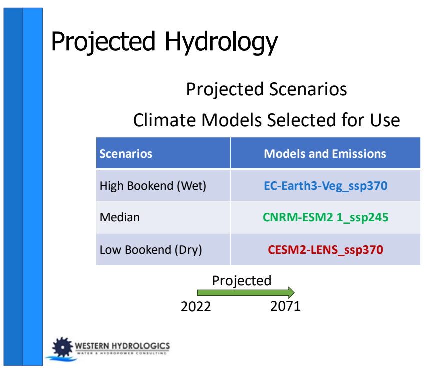
There are four processes that are outlined: Historical Hydrology, Historical Demands, Projected Hydrology and Projected Demands. These four processes produced the inputs required to run HEC-Res-Sim. The Projected Hydrology and Demands inputs include consideration of climate change. Three models are used: (1) IDC (IWFM Demand Calculator): calculates historical and projected demands, (2) HEC-HMS: hydrological model that calculates historical and projected unimpaired inflows, and (3) HEC-ResSim: simulates reservoirs operations (historical and multiple scenarios of projected operations). Currently we are at the reservoir operations simulation stage.



Slide 4 – Reservoir Operations Model

HEC-ResSim software was developed by the U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center (HEC). The software simulates reservoir operations for a variety of operational goals. HEC-ResSIM has been applied to the NID reservoir system for the NID PFW project. The software uses the inputs as described in Slide 3. Additional inputs include regulatory requirements such as FERC fish flows and minimum pool requirements.

The model outputs are shown in the right-side arrows and include, but not limited to, river flows, reservoirs storage, diversions into canals, power generation, and deliveries. The output is obtained in daily quantities for the time period of the simulation.

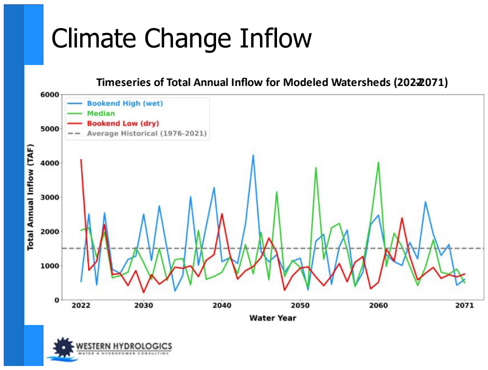


Slide 5 –Projected Hydrology

The three scenarios represent two bookends and one middle of the road hydrologic scenario. The scenarios represent a reasonable range of possible outcomes for future hydrology. These three scenarios include precipitation and temperature data that were used as input to the IDC and the HMS models to develop inflows and demands. Inflows and demands are the input to the Res-Sim model.

The three hydrology scenarios cover a range of possible outcomes. The bookends represent low inflows and high inflows, and there is a middle inflow included in the possible outcomes for analysis. It is important to note that from a statistical perspective, the scenarios are not normally distributed, but you can consider them to have equal probability of occurring. If you take a six-sided dice, the high bookend probability of occurrence would be represented by a 5 and a 6; the middle would be a 3 and a 4; and the low bookend would be a 1 and a 2. If you roll the dice once, the middle of the road scenario is just as likely to occur as the wet or dry bookend conditions. The middle of the road scenario is not necessarily the most likely to occur.

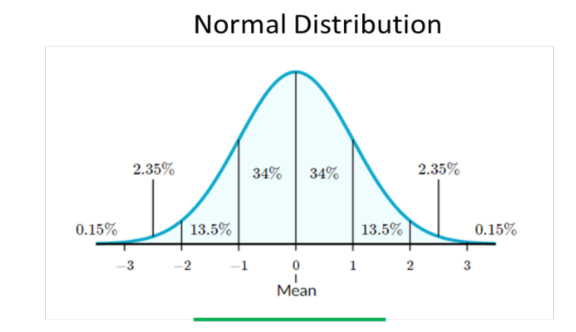
For actual future conditions, the inflow pattern would be expected to be between the low and the high bookends, without preference of any scenario. Which specific pattern will be experienced depends on unknown conditions such as policies, innovations, and socio-economic changes, non-linearities in climate, and other conditions. Those changes will determine how hydro-climatic variables, such as temperature and precipitation, will change in the future.

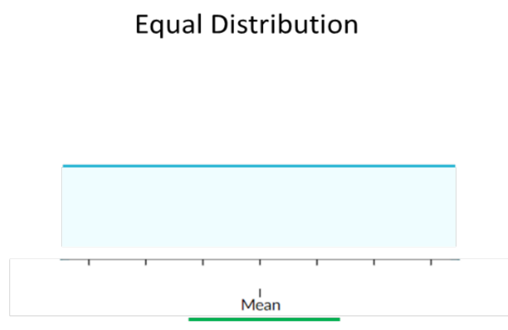


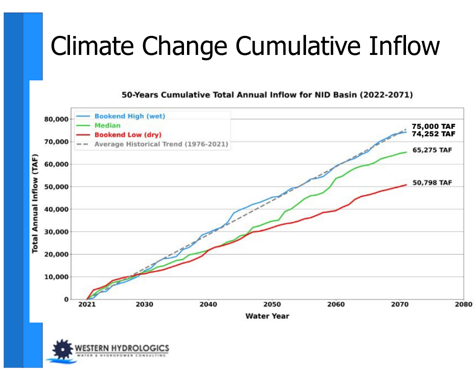
<u>Slide 6 – Climate Change inflow</u>

From the selected climate change scenarios (as show in Slide 5), this slide shows the resulting annual inflows for the modeled watershed from 2022 to 2071. The graphs include inflows for the two bookends and the middle of the road scenario. These inflows are outputs from the HMS model that was developed for NID (see Slide 3). The y axis is in TAF or Thousand-Acre-Feet.

The wet bookend is blue, the dry bookend is red, and the middle of the road scenario is green. The wet bookend has the greatest number of high inflow events, but also has occurrences of drought conditions. The dry bookend has the greatest number of drought conditions, but also has some occurrences of high inflow events. The middle of the road scenario has some high inflow events and some drought events, but not as significant as the bookends. Again, as explained in Slide 5, from a statistical perspective, the three scenarios are not normally distributed, but you can consider them to have equal probability of occurring.

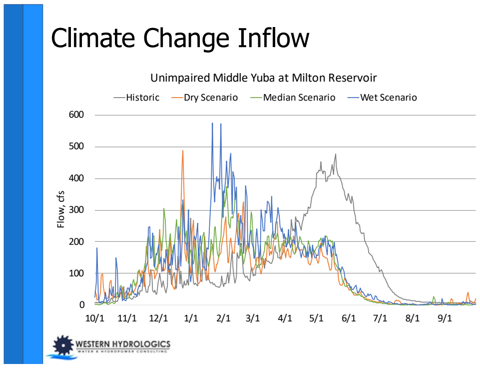






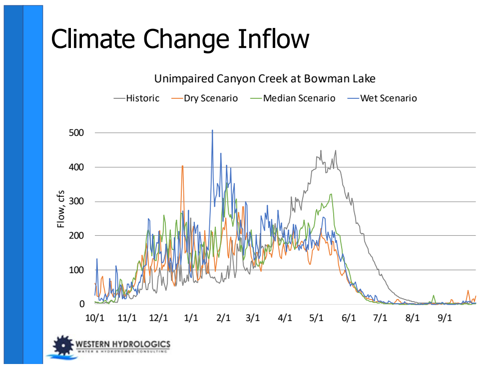
<u>Slide 7 – Climate Change Cumulative Inflow</u>

This slide is similar to the previous slide, but it has the data in cumulative format. Cumulative means the total inflow to NID reservoirs over time. This graph shows that over the 50-year projection of inflows, the cumulative values lie in the proper order. The wet has the highest cumulative total inflow after the 50-year projection, the dry has the lowest, and the middle of the road is in the middle. The black dashed line takes the average annual inflow value of 1,444 TAF from the historical dataset of 1976-2021 and creates a cumulative trend line using this average value. This was included for comparison purposes only. One takeaway is that even the wet bookend has less total inflow than historical values for the 50-year projection.



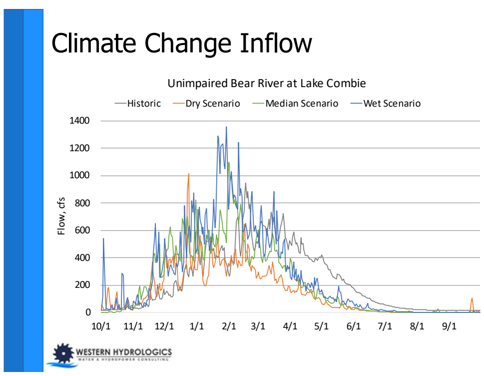
Slide 8 – Climate Change Inflows at Milton Reservoir

This slide shows average inflows over the 50-year projection at each day of the water year at Milton Reservoir. The graph clearly shows that the inflow patterns are changing with climate change. Inflows are occurring earlier in the year as compared to historical patterns.



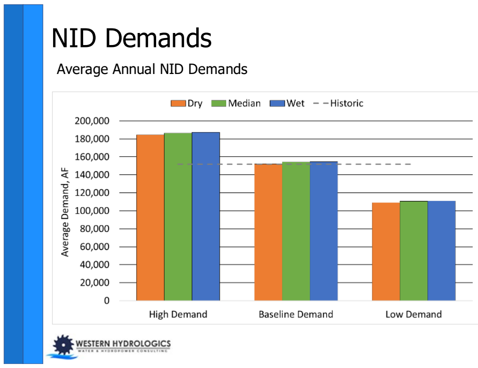
Slide 9 – Climate Change Inflows at Bowman Lake

Same as Slide 8 but at Bowman Lake.



Slide 10 – Climate Change Inflows at Lake Combie

Same as Slide 8 but at Lake Combie.

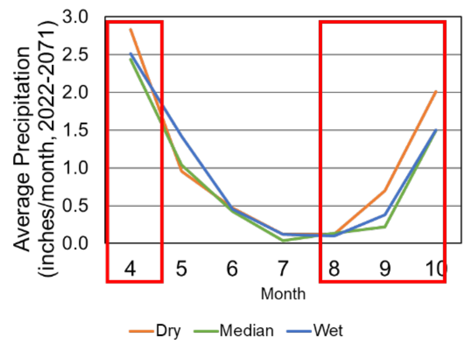


Slide 11 – NID Consumptive Demands

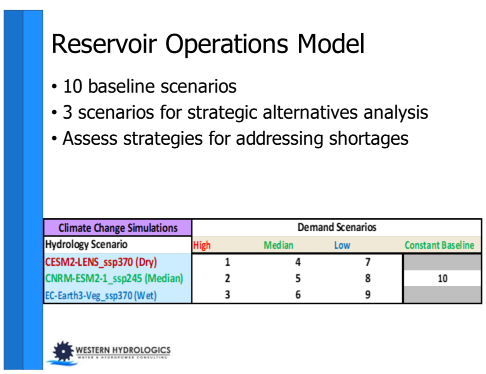
These bar graphs show the approximate range of customer demands for NID. These are not total demands since FERC and regulatory requirements are not included; the other demands are included as part of the ResSim model simulations. The NID Demands in this graph include raw and treated water demands, system losses, ET and other parameters as simulated by the IDC model.

There are three levels of demands, high and low bookends, and a baseline level. These demand levels were previously selected and coordinated with the stakeholder group and authorized by the Board.

Within each demand level there are three representative scenarios. These scenarios represent hydrological inflow bookends and middle of the road hydrological inflow. The very far left orange bar represents dry hydrological inflows with a high level of demand.



The green, middle of the road hydrological inflow scenarios, can have larger demand levels than both the wet and the dry scenarios. This occurs because the middle of the road hydrology has less precipitation during the irrigation season resulting in higher demands. The adjacent graph shows that the orange dry simulations can have more non-zero precipitation days than the green middle of the road simulations.

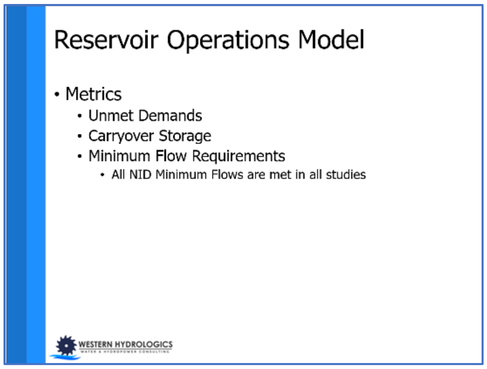


Slide 12 – Reservoir Operations Model

Ten climate models, known to perform well for California's climate, were evaluated and ranked according to the median annual reservoir inflows. Three of the models represent a low bookend (i.e., dry), middle of the road, and high bookend (i.e., wet) future hydrologic conditions.

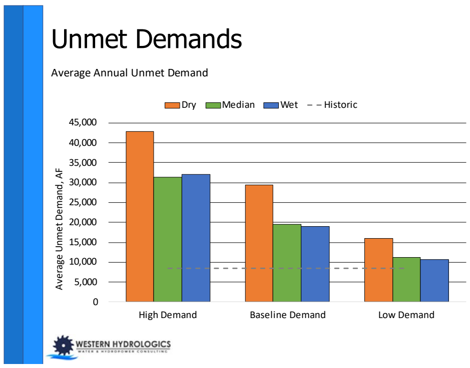
The wide bookends are necessary considering the high variability in California's climate. Further, California's climate can drift into persistently wet conditions or persistently dry conditions for decades at a time. The thirty-year average annual precipitation in central California can vary +/- 30-40%. These persistent multi-decadal variations are on the same time scale as the NID Plan for Water and must be considered.

Each of the three future hydrologic conditions were matched with three future demand scenarios, high, baseline, and low projected demand scenarios. This yields a total of nine future scenarios to evaluate potential supply shortages and examine strategies for meeting unmet demands. A constant baseline scenario representing historic hydrology with future demand held to current levels is provided for comparison.



Slide 13 – Reservoir Operations Model

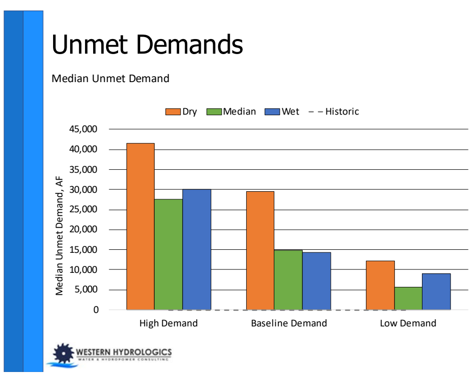
Slide defines the metrics used to measure system performance.



Slide 14 – Unmet Demands

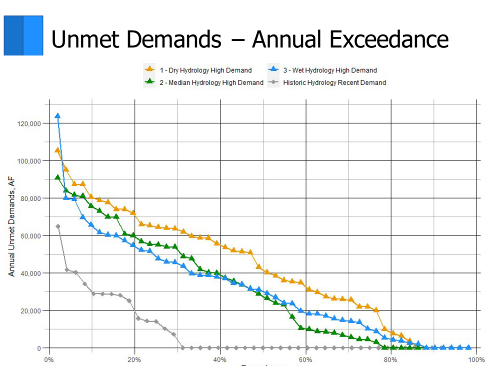
Slide 14 summarizes average annual unmet demands for the nine combinations of future hydrologic conditions and future demands. All future scenarios show average annual unmet demand. Further, all future scenarios exhibit more average annual unmet demand than the baseline of historical hydrology with current demand held constant into the future.

Average annual unmet demands range from about 45,000 AF for the dry future hydrology coupled with high future demands to a low of 11,000 AF in average annual unmet demands for the wet future hydrology with low future demands. The baseline shows average annual unmet demands of about 9,000 AF.



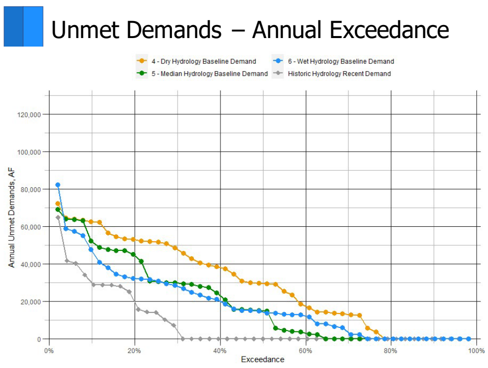
Slide 15 – Unmet Demands

Same as above except using median unmet demands. Median unmet demands range from about 42,000 AF for the dry future hydrology coupled with high future demands to a low of 5,000 AF in the low demand with median hydrology. The baseline historical unmet demand is 0 AF because historically, demands have been met more than 50% of the time.



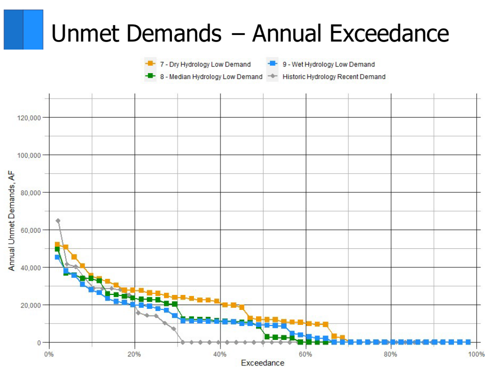
Slide 16– Unmet Demands - Annual Exceedance

Unmet demands under the high future demands are indicated in Slide 12 whenever the curves are above zero. The gray line representing historic hydrology coupled with recent demand levels indicates that unmet demands occur, on average, a bit more than 20% of the time. With the high future demand scenario, unmet demands occurred, more than 85% of the time. Unmet demands in the range of 20-45,000 AF occurred about 50% of the time.



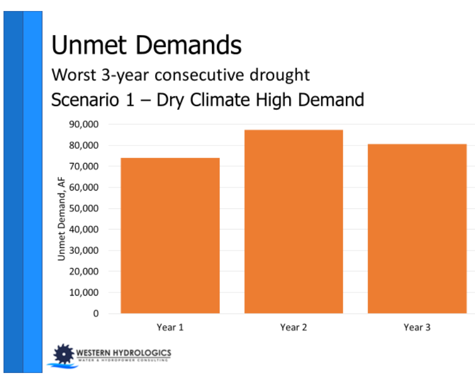
Slide 17 – Unmet Demands - Annual Exceedance

Considering the baseline or current demand projected into the future, unmet demands occurred at least 60% of the time and up to 80% of the time under drier future hydrology.



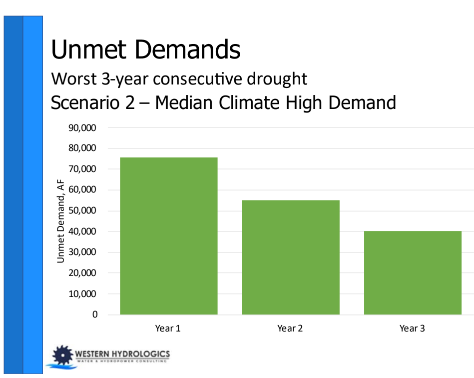
Slide 18 – Unmet Demands - Annual Exceedance

Even under low future demands, some unmet demands occurred more than 60% of the time for all future hydrologies. However, the magnitudes of the unmet demands are lower due to the lower projected demands.



Slide 19 – Unmet Demands

For the dry future hydrology with high demand, the worst 3-year consecutive drought over the period 2022-2071 was determined. The three-year sequence is shown in Slide 18. Single year unmet demands ranged from about 70,000 AF to about 85,000 AF. Total unmet demand over the worst 3-year period is more than 225,000 AF.



Slide 20 – Unmet Demands

For the middle of the road future hydrology coupled with high demand, the worst 3-year drought was identified. Unmet demands totaled nearly 250,000 AF over the three-year period.

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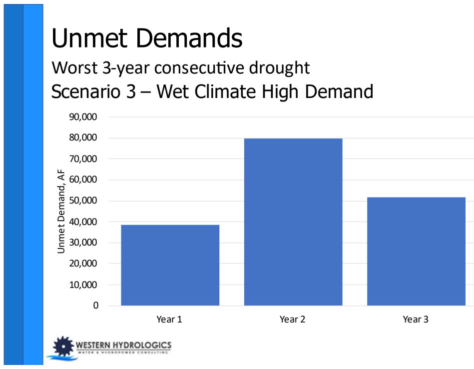
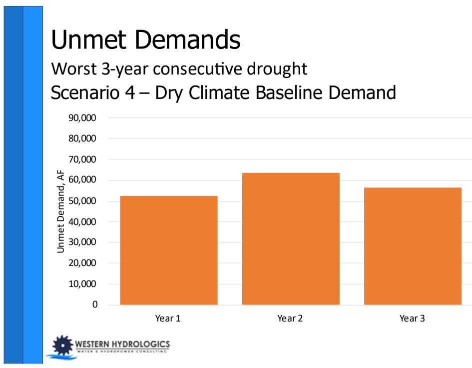


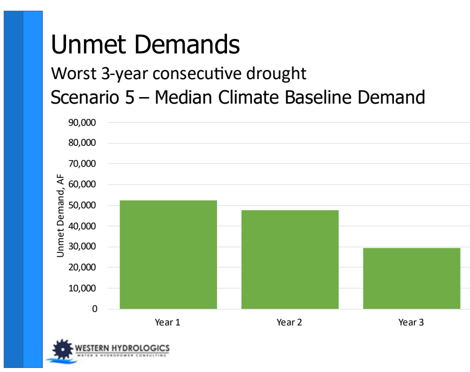
Slide 21 – Unmet Demands

For the wet future hydrology coupled with high demand, the worst 3-year drought was identified. Unmet demands totaled about 170,000 AF over the three-year period.



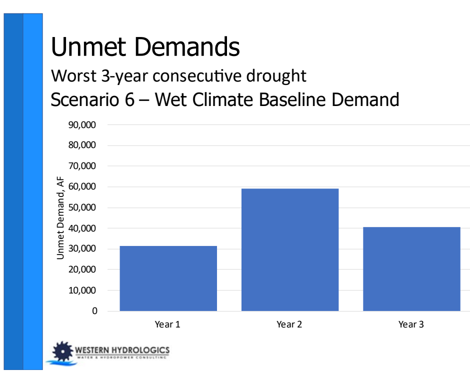
Slide 22 – Unmet Demands

For the dry future hydrology coupled with baseline demand, the worst 3-year drought was identified. Unmet demands totaled about 170,000 AF over the three-year period.



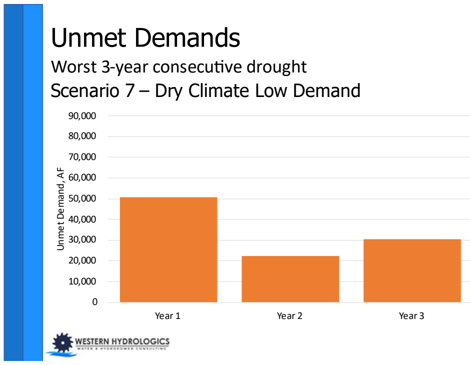
Slide 23 – Unmet Demands

For the middle of the road future hydrology coupled with baseline demand, the worst 3-year drought was identified. Unmet demands totaled about 120,000 AF over the three-year period.



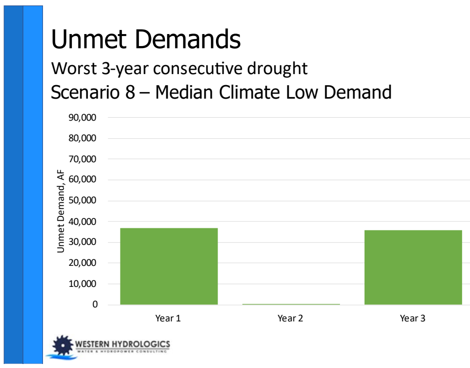
Slide 24 – Unmet Demands

For the wet future hydrology coupled with baseline demand, the worst 3-year drought was identified. Unmet demands totaled about 130,000 AF over the three-year period.



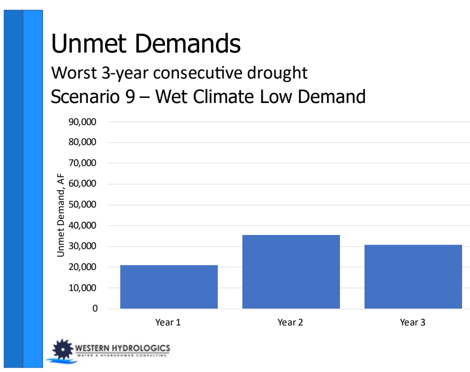
Slide 25 – Unmet Demands

For the dry future hydrology coupled with low demand, the worst 3-year drought was identified. Unmet demands totaled about 100,000 AF over the three-year period.



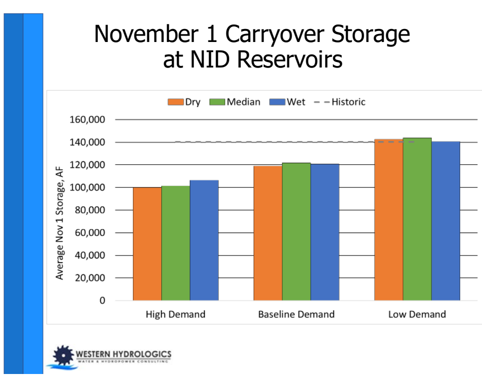
Slide 26 – Unmet Demands

For the middle of the road future hydrology coupled with low demand, the worst 3-year drought was identified. Unmet demands totaled about 70,000 AF over the three-year period. The second year has zero unmet demand, but the three years together add up to the highest worst 3-year unmet demands for this scenario.



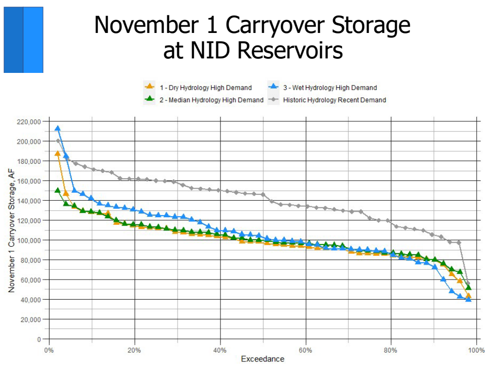
Slide 27 – Unmet Demands

For the wet future hydrology coupled with low demand, the worst 3-year drought was identified. Unmet demands totaled about 85,000 AF over the three-year period.



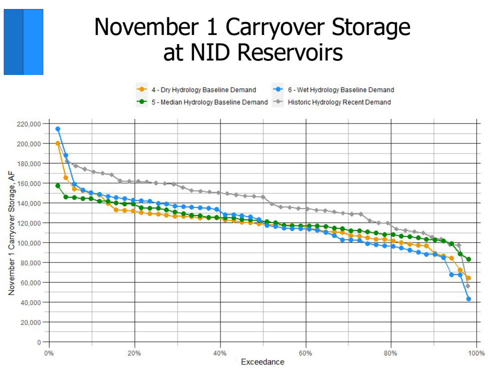
Slide 28 – November 1 Carryover Storage at NID Reservoirs

Average November 1 carryover storage for the three future hydrology scenarios coupled with three demand scenarios. The baseline November 1 carryover storage is shown as the horizontal gray dashed line. Only the low demand scenarios come close to the baseline carryover storage. The remaining carryover storages range from about 20,000 to about 40,000 less than the baseline carryover.



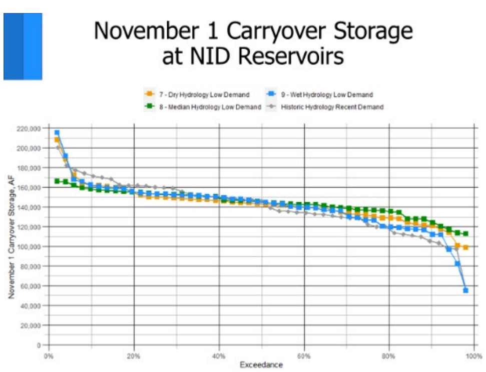
<u>Slide 29 – November 1 Carryover Storage at NID Reservoirs</u>

This slide shows the estimated frequency of carryover storage for the high demand condition. As with earlier charts, the gray line represents historic hydrology coupled with the most recent demand. With current demand coupled with historic hydrology, more than 100,000 AF of carryover storage occurred 50% of the time. Under existing conditions, about 80,000 AF of November 1 carryover storage occurred 20% of the time. Conversely more than 120,000 AF of carryover storage occurred 80% of the time. As you might expect, carryover storage for the high demand conditions is significantly lower for the future climate scenarios.



<u>Slide 30 – November 1 Carryover Storage at NID Reservoirs</u>

For the baseline demand condition, November 1 carryover storage was 20-40,000 AF less than the baseline condition. For all future hydrologic conditions, about 120,000 AF of November 1 carryover occurred. Carryover was simulated as a high priority target storage and these operational criteria could be relaxed in future strategic studies to reduce unmet demands.



<u>Slide 31 – November 1 Carryover Storage at NID Reservoirs</u>

Low demand November 1 carryover storage under all future hydrologic conditions were virtually the same as the historic hydrologic conditions with current demand. Basically, the lowered demand offsets the lower expected future reservoir inflows resulting in similar carryover storage profiles.

Potential Strategic Alternatives

- Canal improvements to reduce losses
- Optimized operations
  - Increase reservoir carryover storage
  - Additional purchase contracts
  - Reoperate existing facilities
- Storage augmentation
  - Sediment removal
  - Increase storage
- Demand side management

WESTERN HYDROLOGICS

<u>Slide 32 – Potential Strategic Alternatives</u>

Potential strategic alternatives to mitigate unmet demand.

Other Potential Analysis

- Extended Irrigation Season
- Increased Regulatory Requirements
  - Higher Release Requirements
  - Water Budgets
  - Curtailments

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<u>Slide 33 - Other Potential Analyses</u>

Further potential assessments

Next Steps

- Select modeling scenarios to move forward to model Strategic Alternatives
- Select Strategic Alternatives studies
- Perform Strategic Alternatives studies
- Final documentation

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<u>Step 34 – Next Steps</u>

What is next?

Board Action Items

- Select 3 Scenarios for strategic alternative analysis
- Select which types of alternative require modeling vs. financial cost/benefit

Climate Change Simulations	Demand Scenarios			
Hydrology Scenario	High	Median	Low	Constant Baseline
CESM2-LENS_ssp370 (Dry)	1	4	7	
CNRM-ESM2-1_ssp245 (Median)	2	5	8	10
EC-Earth3-Veg_ssp370 (Wet)	3	6	9	

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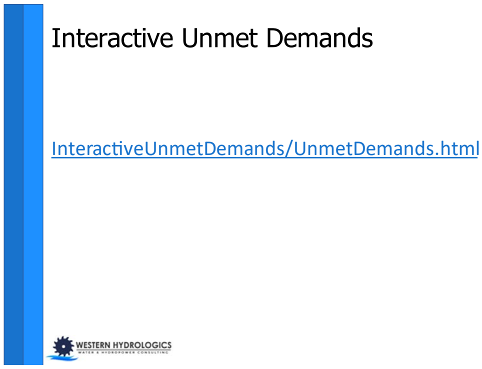
<u>Slide 35 – Board Action Items</u>

Action items that must be completed prior to commencement of the next step in the Plan for Water study.



Slide 36 – Interactive Unmet Demands

This slide is linked to an interactive unmet demand graph shown below. The graph has a clickable legend that can turn on or off the unmet demand for each scenario. This tool is useful to visualize sets of unmet demands. You can compare different sets of scenarios such as 1-5-9, or 3-5-7.