RECLAMATION
Managing Water in the West

DRAFT Hood River Basin Study:
Climate Change Analysis Technical Memorandum

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Pacific Northwest Regional Office
Boise, Idaho

February 2014

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The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

Mission of the Bureau of Reclamation

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1.0 INTRODUCTION

In 2009, Congress enacted the Science and Engineering to Comprehensively Understand and Responsibly Enhance (SECURE) Water Act to establish a climate change adaptation program. The legislation authorizes the Bureau of Reclamation (Reclamation) to determine the impacts of climate change on water supply, demands, and reservoir evaporation. It further authorizes Reclamation to evaluate those impacts on water delivery, power production, flood management, and ecological resources (e.g., ecological resiliency).

To implement the SECURE Water Act, the Department of Interior (DOI) established the Sustain and Manage America's Resources for Tomorrow Program (WaterSMART) in 2010. This program enabled all bureaus of DOI to collaborate with States, Tribes, and local agencies to determine the impacts of climate change and develop mitigation and adaptation strategies to address those impacts. WaterSMART grants were established to facilitate these collaborative efforts. These grants, including basin studies, are provided every year based on a competitive process with the requirement that non-Federal entities cost-share the effort 50/50.

In 2011, Hood River County submitted a proposal to conduct a basin study in the Hood River basin and was awarded funding in 2012. Hood River County and Reclamation will collaborate on addressing four main components, including:

1. Define current and future basin water supply and demands, with consideration of potential climate change impacts.

2. Determine through analysis the potential impacts of climate change on the performance of current water delivery systems (e.g., infrastructure and operations).

3. Develop structural and non-structural options to maintain viable water delivery systems for adequate water supplies in the future.

4. Conduct a tradeoff analysis of the options developed, summarize the findings, and make recommendations on preferred options.

This Technical Memorandum is to document the methods used to select the climate change projections and conduct the analysis of historical and future climate used in the Hood River Basin Study. In addition, results from the selection process and analysis are provided.

Hood River is located in northern Oregon (Figure 1). This basin faces potentially serious future water supply issues given that the glaciers from Mount Hood supply baseflows to two of the three major tributaries to the Hood River, which flows into the Columbia River.

Increasing temperatures over the last century have caused the glaciers to shrink, which is a pattern that is expected to continue over the next century given the projections of continued warming due to climate change. Therefore, a better understanding of what to expect in terms of potential changes in snowpack and the timing and quantity of runoff is needed.

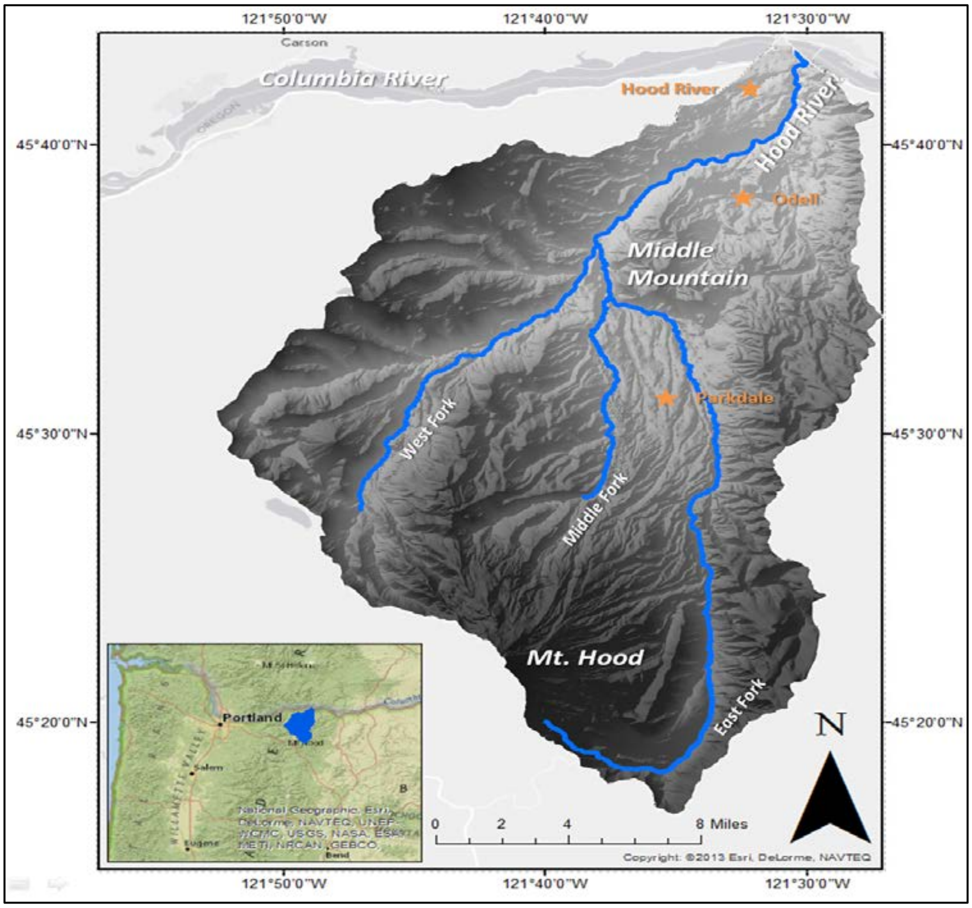

Figure 1. Shaded relief map of the Hood River Basin study area.

1.1 Purpose and Scope

The purpose of this technical memorandum is to document the methodology and results for the climate change analysis for the Hood River basin. This technical memorandum describes the process of defining the climate change scenarios, the multiple decision points involved with the projection selection, the methodology used in processing the selected projections, and the rationale behind each of these decisions. The results of the climate change analysis using this methodology are also presented. The application of the climate change scenarios and simulation of the climate change conditions on surface water and groundwater flows are addressed specifically in the hydrologic and groundwater modeling technical memorandums.

2.0 DEFINING CLIMATE CHANGE SCENARIOS

2.1 Available Climate Change Projections

The climate change projections and datasets used for this study are the same ones used in multiple other scientific, international, and Reclamation studies that deal with climate change (Wood et al. 2002; Wigley 2004, Meehl et al. 2007; Maurer et al. 2007; IPCC 2007; Reclamation 2009; and Reclamation 2010). The datasets were generated through the third iteration of the Coupled Model Inter-comparison Project (CMIP3) which is available online at the Bias-Corrected and Downscaled CMIP3 Climate Projections website under the Downscaled Climate Projections (DCP).[1]

The DCP archive data were used as the initial set of climate projections considered for defining climate change scenarios in this study. Each climate projection is specified on a monthly time step from 1950 to 2099 and at roughly a 12-kilometer (km) (1/8-degree [º]) spatial resolution over the contiguous United States. In Figure 2, the thicker red line surrounding the grids shows the spatial extent that climate change data (e.g., temperature, precipitation) were downloaded. Each cell contains downscaled climate change data stored in the DCP archive servers.

[1] URL: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html

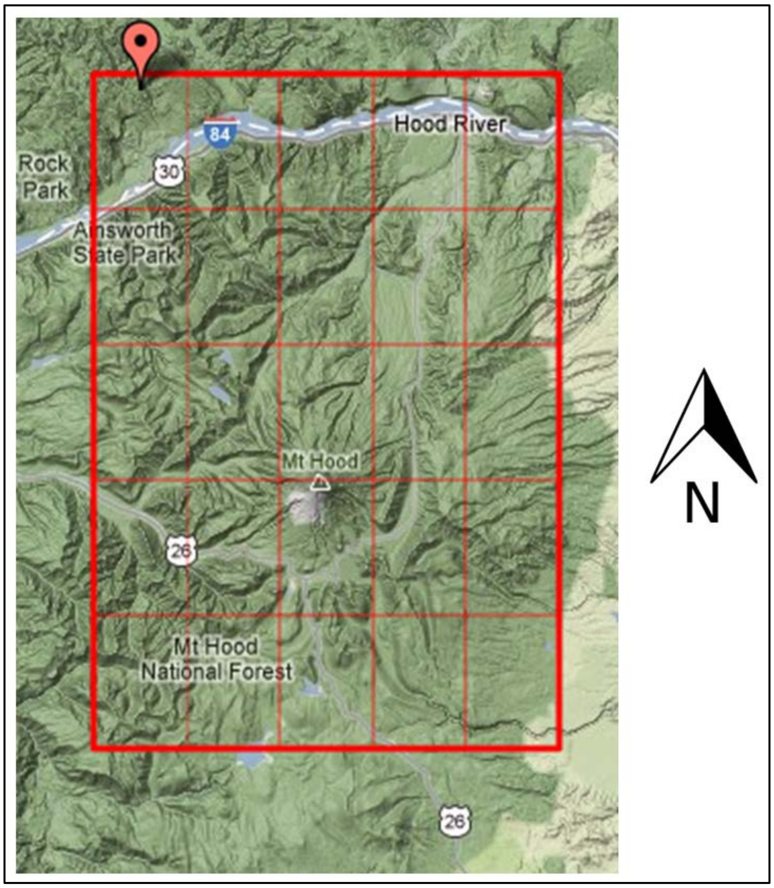

Figure 2. Climate change dataset extent.

A total of 112 projections were downloaded from the DCP archive for the time period between January 1950 and December 2099 composed of the 1/8-degree (roughly 12 kilometers) spatial averages for both monthly precipitation (P) and average monthly air temperatures (T).

A time series representation of the downloaded CMIP3 projection data converted to U.S. customary units is shown in Figure 3. The top panel shows the mean annual change in precipitation (in inches) between 1950 and 2099 and the bottom panel reflects the change in mean annual temperature (in degrees Fahrenheit) for the same time period. The shaded areas represent the envelope that contains the average annual values for the climate change simulated precipitation and temperature. The dark line in the center of each of the shaded areas represents the average for all 112 member projections.

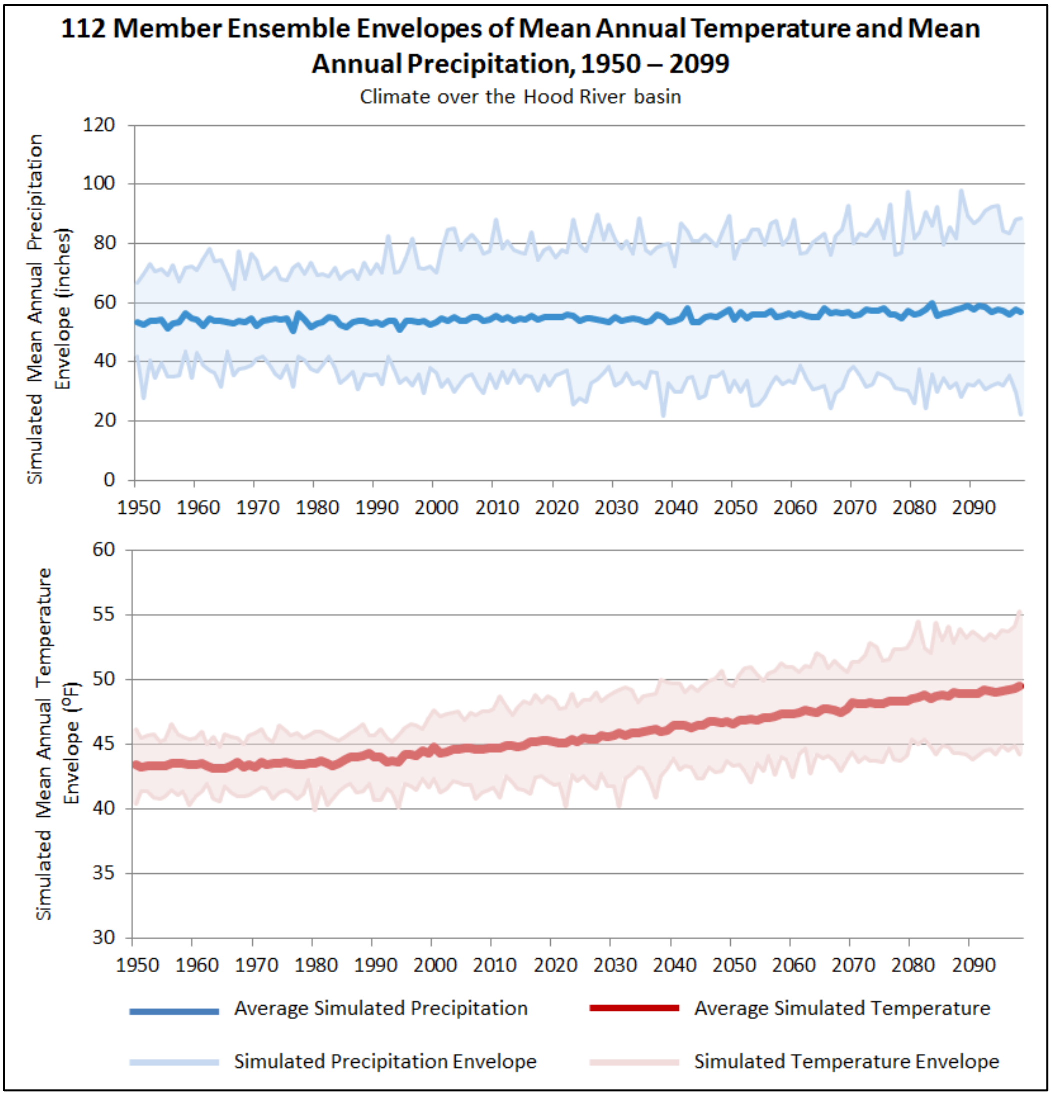

Figure 3. CMIP3 112-member ensemble envelopes of mean annual temperature and precipitation.

Analysis of Figure 3 above in terms of the plotted envelope suggests that through time, the level of uncertainty in the projections of precipitation and temperature regimes increases as reflected by the slightly widening envelope bounds. The wider envelope not only signifies increases in the uncertainties within the precipitation and temperature regimes, but also in the severity of both precipitation and temperature extremes. A wider envelope means that wet and dry extreme events, floods and droughts respectively, are projected to become more extreme (floods become more wet, droughts become more dry). In terms of the plotted average for all 112 projections between 1950 and 2099, the basin is projected to experience an average annual increase of 5 inches per year for precipitation and an annual average increase of 6 degrees Fahrenheit for air temperatures.

2.2 Climate Projection Processing Methodology

Because each one of the 112 climate change projections is just as likely to occur as any other, a methodology for selecting and grouping climate change projections that represent a broad range of potential future climate in the Hood River basin is required. The outcome from this methodology is distilled into a set of adjustment factors that represent the trend that the climate is projected to take. To generate the climate change adjustment factors, these key decision points needed to be addressed and are discussed in the following sections:

1. Climate change dataset selection
2. Temporal ranges for comparison
3. Climate uncertainty characterization
4. Projection processing technique selection

2.2.1 Climate Change Dataset Selection

The CMIP3 climate dataset was selected for this study as it has more precedent in terms of usage in similar water resources planning studies. In addition, several studies in the Pacific Northwest, including ones conducted around the Hood River basin, had taken advantage of these data. Although the CMIP5 dataset is deemed to be equally valid, its more recent publication and release has not allowed it to be as thoroughly vetted as the CMIP3 dataset.

2.2.2 Historical and Future Temporal Ranges Selected for Comparison

To project climate change, two 30-year periods are identified, one for historical conditions and one for future conditions. The historical period is represented by the 30-year period between 1980 and 2010. The selected historical period was analyzed and determined to be representative of historical conditions when compared to the entire period of record that was available from the long-term weather station located at the Hood River Experiment Station located near the City of Hood River (1928-2005). Also, by selecting the most recent 30-year period, current conditions in the Hood River basin are better represented. If using the entire period of record, some of the more recent patterns may have been attenuated. The future period is represented by the years between 2030 and 2060 because this future window was deemed relevant by the larger working group for long-term watershed planning.

Figure 4 shows a percentile distribution comparison that spans a majority of the selected historical period (1980 - 2005) and the entire period of record (1928 - 2005) for precipitation and temperature in the Hood River basin at the Hood River Experiment Station. The available historical data at the experiment station is limited to the years between 1928 through 2005 so this analysis cannot cover the entire historical period between 1980 through 2010.

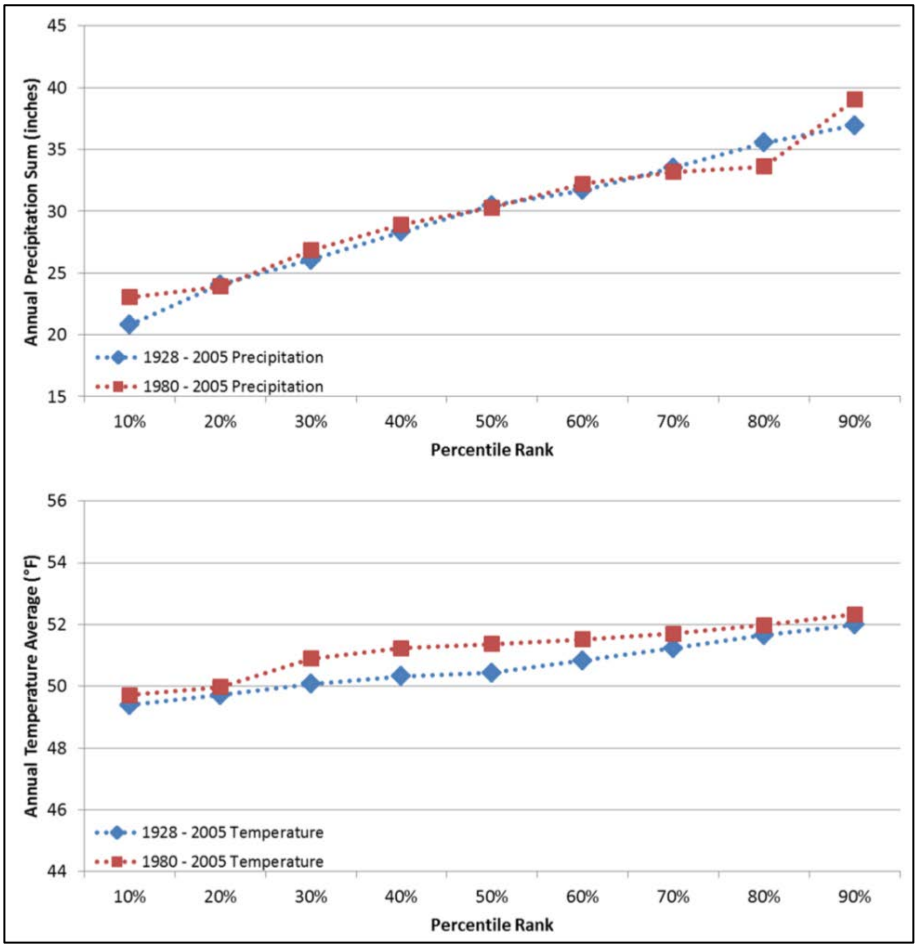

Figure 4. Percentile comparison between annual average temperature and precipitation for the entire period of record and the selected historical period.

Figure 4 shows that the selected historical period closely mimics the percentile rank distribution of the entire period of record in terms of both temperature and precipitation. The selected historical period successfully captures extremes in both annual average temperatures and precipitation as shown by the end points of the curves in Figure 4. Precipitation extremes for the selected historical period are biased towards wetter conditions as evidenced by the higher annual precipitation sum at the 10th and 90th percentile ranks. The annual temperature averages for the selected historical period are biased towards higher temperatures throughout the range of percentile ranks, but this is likely due to historical climate change and not data error.

2.2.3 Climate Change Uncertainty Characterization

Before characterizing uncertainty in the climate change dataset, it is important to understand that each climate change projection has an equal likelihood of occurrence as the other projections in the entire dataset. Each projection imposes varying magnitudes of change between historical and future temperatures and precipitation. Given that there are 112 projections in the CMIP3 dataset, the change magnitudes among all 112 of the projections will have some degree of spread, and there may even be groups of projections (subsets of the 112) that have similar projected change magnitudes. The uncertainty that is characterized in the climate projection selection methodology has to do with the spread and grouping of climate change projections in terms of changes to temperature and precipitation.

To determine the change between the historical period of record and the future period of record, a “change factor” is calculated based on annual averages for both temperature and precipitation. These change factors are reported as an absolute change in the case of air temperatures (i.e., the difference between two values) and as a relative change in terms of precipitation (i.e., the percent change between two values).

As an example, the historical condition for a particular projection, CCCMA_CGCM3_1.1.SRESB1, shows that the average annual temperature and average annual total precipitation is 6.92°C and 4.75 inches, respectively. The future condition for the same projection results in an average annual temperature and average annual total precipitation of 8.16°C and 4.92 inches, respectively. The calculated change factors for this projection are therefore equivalent to 1.24°C (8.16 - 4.92) and 0.04 (4.92/4.75 - 1) or 4 percent for temperature and precipitation respectively. In the case of this projection, climate change is projecting a 1.24°C increase in temperatures along with a 3-percent increase in precipitation. This process is repeated for each projection in the climate change dataset and the corresponding results are then ranked in terms of percentiles; this is represented in Plots A and B of Figure 5. The results of the temperature and precipitation percentile plots are then combined and plotted against each other which results in Plot C as shown in Figure 5. Figure 5 also shows the projection example, CCCMA_CGCM3_1.1.SRESB1, which happens to be the 50th percentile for both temperature and precipitation.

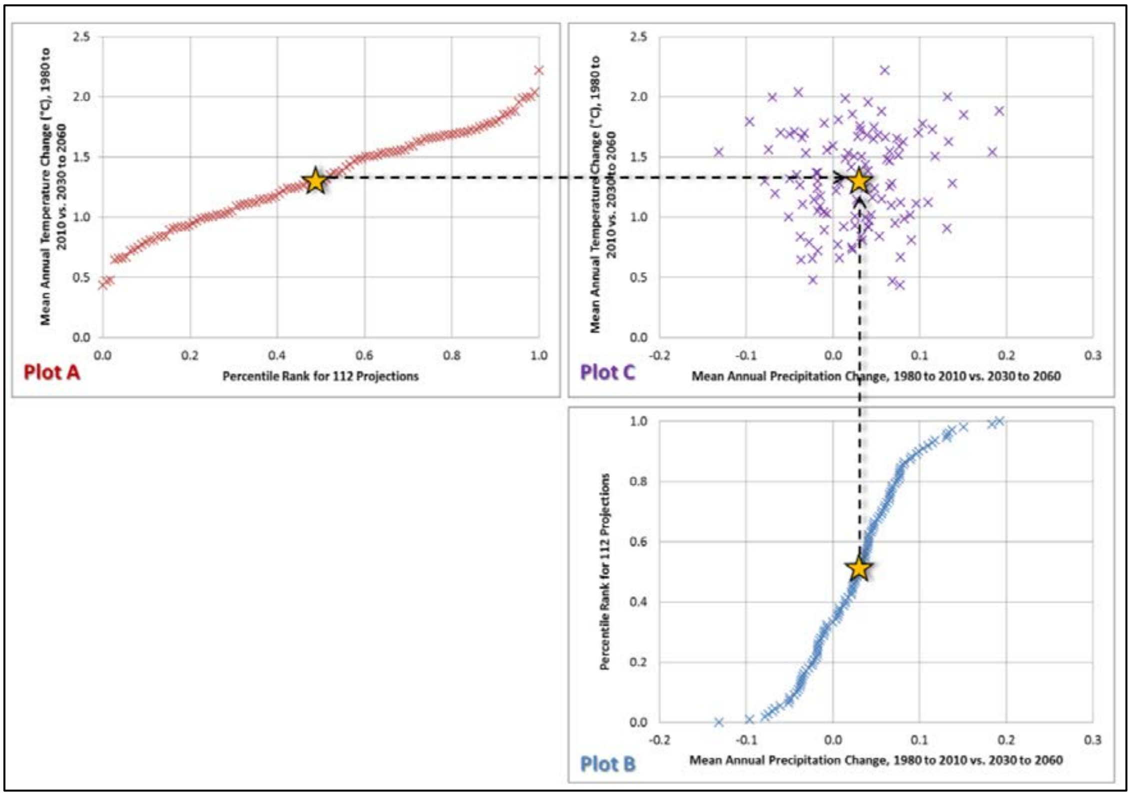

Figure 5. Mean annual temperature and precipitation adjustment factor comparison.

Once the changes factors are determined, the next step in characterizing uncertainty is the selection percentile changes that best capture a wide range of potential future climate change conditions in the Hood River basin. The 50th percentile represents the median tendency of all the change factors calculated for all of the projections. By defining uncertainty using percentile rankings, the entire dataset can be leveraged to determine which projections or group of projections best represent a wide range of future potential conditions. As an example, projections in and near the lower left quadrant of Plot C in Figure 5 are showing change factors that have future conditions with high temperatures and less precipitation relative to historical conditions. Conversely, the upper right quadrant of the same plot contains projections that have higher temperatures and more precipitation in relation to historical conditions.

The uncertainty percentiles selected for the Hood River Basin Study were those representing the 20th, 50th, and 80th percentiles. The selected percentile range is appropriate for a planning-level study as it results in a wide spread of projected temperature and precipitation change, but excludes the effects of projections that may be considered outliers or more extreme. In contrast, selecting the 10th, 50th, and 90th or more extreme percentiles would likely be more appropriate for evaluating reliability and failure studies (e.g., dam construction or those with large infrastructure investments).

As a convention for characterizing climate uncertainty, the different percentile groups identified in the previous paragraph are referred to by the respective effects to temperature and precipitation. A shorthand designation for each of these percentile groups is outlined in Table 1. As an example, the 50th percentile for both the temperature and precipitation change identified in a previous example is designated as the median (MED) climate change scenario. As mentioned earlier, the upper right quadrant contained projections that have higher temperatures and more precipitation than historical conditions. The projections in that quadrant are referred to as More Warming/Wetter (MW/W) climate change scenario.

Table 1. Climate change scenario definitions.

Climate Change Scenario	Percentile in terms of temperature change	Percentile in terms of precipitation change
More Warming – Drier (MW/D)	80	20
More Warming – Wetter (MW/W)	80	80
Median (MED)	50	50
Less Warming – Drier (LW/D)	20	20
Less Warming – Wetter (LW/W)	20	80

The MW/D, MED, and LW/W climate change scenarios were selected for the basin study. The MED climate change scenario was selected as it captures the median tendency of the entire climate change dataset. The MW/D and LW/W scenarios were selected based on early hydrologic modeling results that showed that the extremes in terms of summer decreases to streamflows are best captured by these scenarios. Studies (Hamlet et al. 1999; Littell et al. 2009; Snover et al. 2013) conducted in the Pacific Northwest region have shown that during the winter months, streamflows can increase significantly and peak flows can shift to earlier in the year when compared to historical patterns. During the summer months, streamflows are generally much less than historical conditions. Because specific impacts to ecological resources, water delivery, or power production are better understood by evaluating these changes using a seasonal time period, climate change impacts on summer streamflow was considered to be more important to analyzing the effects of climate change in the Hood River basin.

Once the climate change scenarios have been chosen, the next step is the selection of projections that represent the different scenarios to be used in the climate change analysis. This selection is made using the framework discussed earlier in this section that organizes the effects of the entire climate change dataset in terms of temperature and precipitation change percentiles between the historical and future periods of record. Figure 6 below shows the selected climate change scenario percentile ranges.

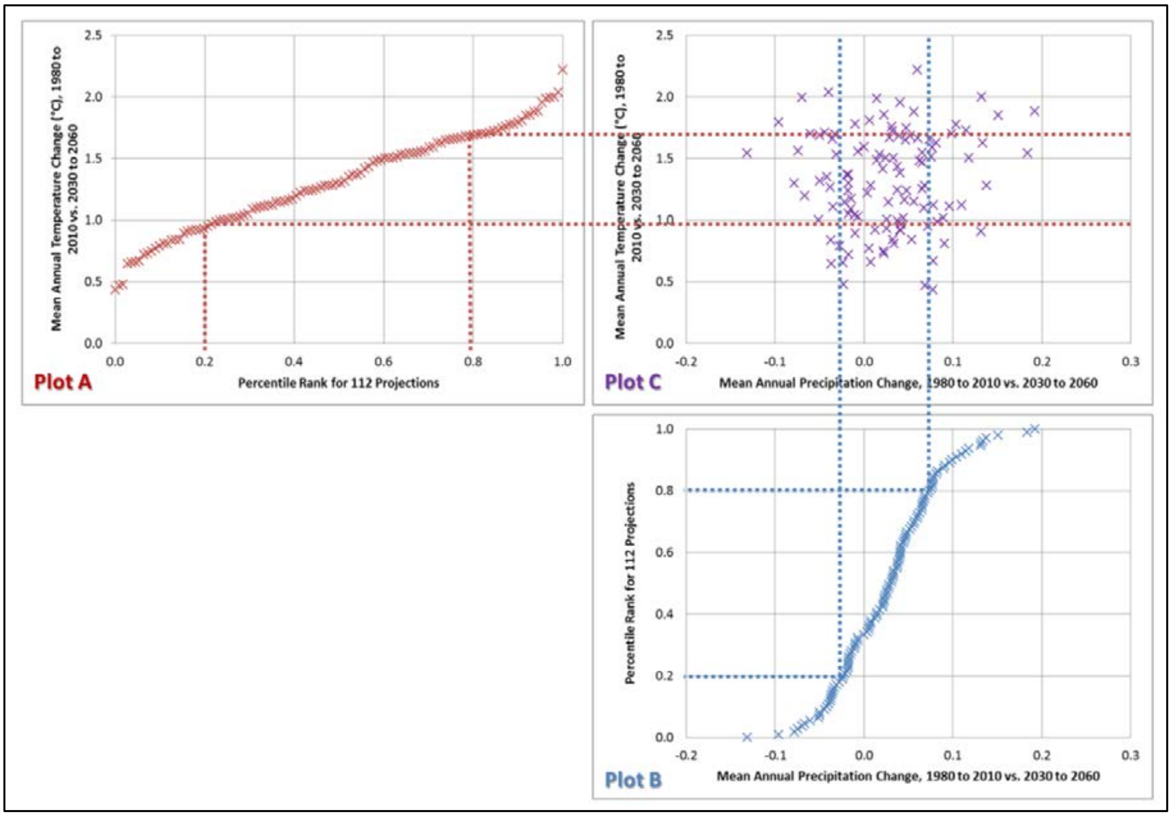

Figure 6. Climate change projection selection using climate scenario percentiles.

Using Figure 6 above, projection selections are made based on relative proximity to the intersections of the precipitation and temperature percentiles on Plot C. A selection of a single projection that lines up with the percentile intersections or the selection of an ensemble of projections (e.g., a group of ten or so projections closest to the intersection) for each percentile may be made. The selection of an ensemble would be based on each projection's relative distance to the intersection representing the range of percentiles selected. As an example, an ensemble selection of five projections for the MW/D climate change scenario would result in the five projections in the upper-left quadrant of Plot C that are closest to the intersection of the 80th percentile line (more-warming) originating from Plot A and the 20th percentile line (dry) originating from Plot B.

Projection selections for this study were made using an ensemble of 10 projections for each climate change scenario. An advantage to using an ensemble of projections is the smoothing effect it has on the climate adjustment factors. Figure 7 shows a figure from the cited 2010 Reclamation study that compares the precipitation adjustment factors generated using a single projection (Hybrid-Delta) versus adjustment factors that were generated using 34 projections (Ensemble Hybrid-Delta) using climate change projections over part of the Oklahoma River basin. It is evident that the adjustment factors generated using a single projection has more "noise" throughout the percentile range. This noise results in adjustment factors that are contrary to the climate change scenario that best represents a robust range of future climate change.

As an example, in the lower percentile ranges of the Hybrid-Delta technique (top panel), the MW/D adjustment factors show precipitation increases of up to 50 percent while the MW/W adjustment factor shows a precipitation decrease of up to 25 percent. This is contrary to what may be expected in that a drier projection in this example is projecting greater precipitation than the wetter condition. The same can be said in comparing the MED condition to the LW/W condition for the Hybrid-Delta technique.

These discrepancies are minimized in the Ensemble Hybrid-Delta technique (lower panel) also shown in Figure 7. The drier condition (MW/D) is consistently dry and the wetter condition is consistently wet, which is what would be expected.

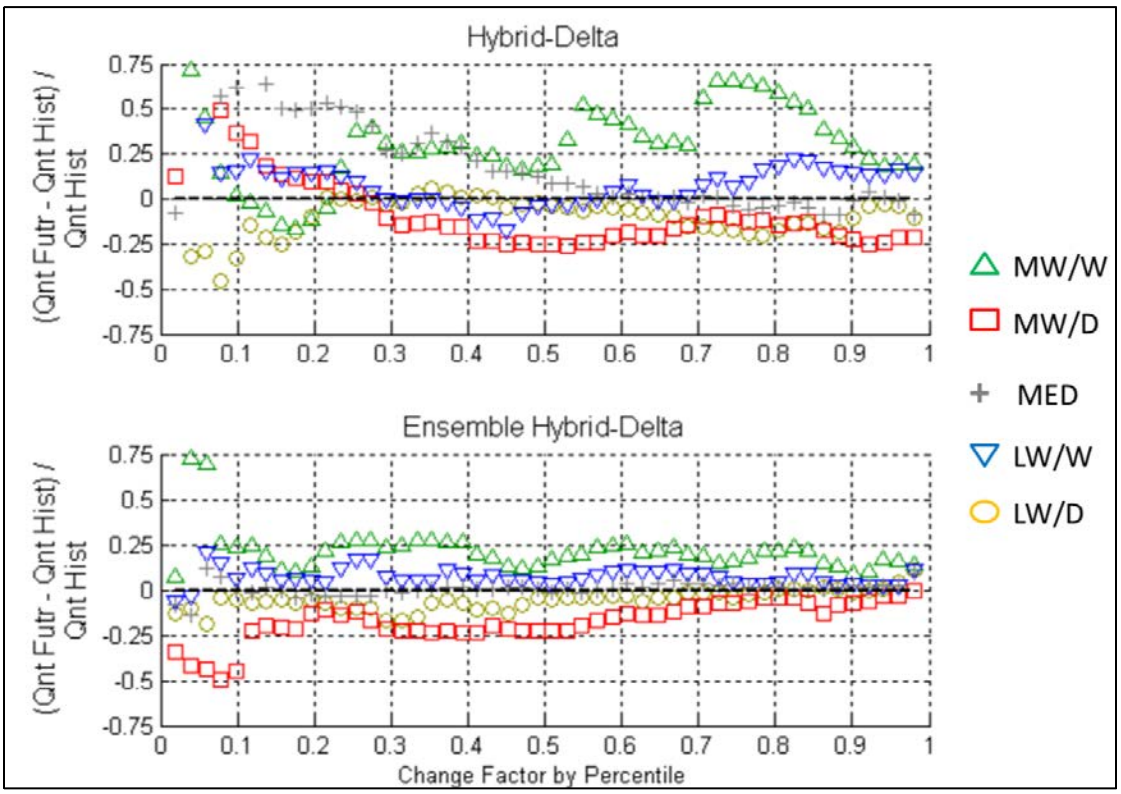

Figure 7. May precipitation adjustment factors by percentile value (Reclamation 2010).

The noise is inherent in every climate change projection due to the nature of the variability between monthly modeled values for both temperature and precipitation. By using a single projection, the noise is directly transferred to the adjustment factors via the calculation procedure used to generate said adjustment factors. By using an ensemble of projections, the dataset is expanded and the noise is smoothed not only in the dataset, but also for the generated adjustment factors. The result is that the adjustment factors are more representative of the climate scenario because the factors are generated based on the consensus of the projection ensembles. Because of these reasons, the ensemble Hybrid-Delta method was selected for use in analyzing the future climate in the Hood River Basin Study.

2.2.4 Projection Processing Technique Selection

There are several techniques that may be used to generate the climate change adjustment factors, but one technique generates consistent, time-varying climate change adjustment factors (Reclamation 2010). The Hybrid Delta Ensemble (HDe) technique has been shown to produce adjustment factors that more adequately reflect the climate change signal of future projections by smoothing the noise inherent in single climate change projections. To understand how this is done in the HDe technique, an explanation of how climate change adjustment factors are generated is provided.

Adjustment factors are used to modify historical observed datasets that are in turn used in water resources simulation models. To generate adjustment factors, the previous steps outlined in this document that relate to the selection of a temporal range and climate uncertainty range have to be completed. The "ensemble" portion of the HDe technique results from the selection of a multiple projections rather than a single projection in defining future climate change scenarios.

The Hybrid Delta technique relies on the change in probabilistic likelihood for a given adjustment magnitude within the climate change dataset. The adjustment factor is generated through the steps that follow:

1. Group projection data by month for each time period.
2. Assign exceedance percentiles for each value, for each month, for each time period.
3. Calculate the change (adjustment factor) between each corresponding percentile value between the two time periods.
4. Interpolate the adjustment factors in between calculated percentile values.

As an example, to calculate the 50th percentile adjustment factor for the month of May, the 50th percentile value for all May values in the historical period (1980-2010) and the 50th percentile value for the future period (2030-2060) are compared to each other. The resulting change between the two time periods is designated as the 50th percentile adjustment factor for the month of May. This is repeated until the entire range of percentile values (0.02 to 0.98) for each month has been processed.

Selecting an ensemble of projections rather than just one reduces the noise in the generated adjustment factors. By selecting an ensemble of projections to inform each climate characteristic, the dataset that is used to define the range and magnitude of the calculated percentile values are expanded and therefore normalized to better reflect the climate signal. An ensemble of 10 projections per climate change scenario was selected for this study.

3.0 CLIMATE CHANGE RESULTS

3.1 Selected Climate Change Projections

The projection selection process was used to identify historical and future date ranges, determine the uncertainty percentiles, and select the number of projection members for each ensemble.

The selected projections indicate a potential increase in annual temperature compared to the historical period that ranged from between 0.5 to 2.2 degree Celsius (Table 2). The 20th, 50th, and 80th percentile temperature changes were approximately 0.9° C, 1.3° C, and 1.7° C, respectively. The projections also show a change in precipitation that ranges between -10 to 20 percent with the 20th, 50th, and 80th percentile values at -2, 3, and 7 percent, respectively.

The results from the selection process are shown graphically in Figure 8 and are tabulated in Table 2. Table 2 lists the selected individual projections that comprise each ensemble, the change in T and P, and the ranking of each individual projection based on its proximity to the intersection of interest. The projection description in includes the GCM name, initial condition run number, and emission scenario (e.g., ukmo_hadcm3.1.sresb1 is GCM ukmo_hadcm3, run number 1, emission scenario from the Special Report on Emission Scenarios [SRES] B1). In some cases, GCMs were run with up to five different initial condition settings.

Table 2. Selected projections per climate scenario.

Climate Change Scenario	Projection	Average Annual Precipitation Change Factor	Average Annual Temperature Change Factor	Rank
More Warming – Dry (MW/D)	ukmo_hadcm3.1.sresb1	-2.80	1.66	1
	ncar_ccsm3_0.3.sresa2	-3.32	1.74	2
	miub_echo_g.1.sresa1b	-0.85	1.77	3
	mpi_echam5.2.sresa1b	-1.47	1.55	4
	ncar_ccsm3_0.5.sresb1	-3.35	1.52	5
	miub_echo_g.1.sresa2	-5.11	1.72	6
	ncar_ccsm3_0.2.sresa2	0.58	1.59	7
	ncar_ccsm3_0.3.sresa1b	0.38	1.85	8
	ukmo_hadcm3.1.sresa2	-6.12	1.69	9
	miroc3_2_medres.2.sresa2	0.81	1.53	10
Median (MED)	cccma_cgcm3_1.4.sresb1	3.66	1.24	1
	mri_cgcm2_3_2a.3.sresa1b	4.17	1.43	2
	cnrm_cm3.1.sresa1b	4.63	1.22	3
	ncar_pcm1.3.sresa1b	1.75	1.40	4
	ncar_ccsm3_0.7.sresb1	3.73	1.46	5
	gfdl_cm2_1.1.sresb1	0.97	1.24	6
	cccma_cgcm3_1.4.sresa1b	3.01	1.49	7
	miroc3_2_medres.1.sresb1	3.38	1.49	8
	gfdl_cm2_0.1.sresb1	4.51	1.15	9
	mpi_echam5.1.sresa2	2.58	1.11	10
Less Warming – Wet (LW/W)	cccma_cgcm3_1.2.sresb1	7.50	1.02	1
	mri_cgcm2_3_2a.5.sresa1b	8.25	0.99	2
	mri_cgcm2_3_2a.2.sresa1b	8.74	1.04	3
	mri_cgcm2_3_2a.2.sresa2	8.57	0.84	4
	mri_cgcm2_3_2a.5.sresa2	5.39	0.83	5
	ncar_ccsm3_0.1.sresb1	4.45	0.93	6
	mpi_echam5.3.sresa2	4.56	1.00	7
	mri_cgcm2_3_2a.1.sresa1b	6.47	1.14	8
	bccr_bcm2_0.1.sresa2	4.38	0.91	9
	mpi_echam5.1.sresb1	4.40	0.98	10

Each ensemble projection represents the 10 projections that are closest to the intersection of the indicated percentile of the change in temperature and precipitation. The 10 projections nearest the intersection of the 20th percentile for both temperature and precipitation represents the LW/D ensemble projection (highlighted blue triangles in Figure 8), the 10 projections nearest to the intersection of the 50th percentile represents the MED ensemble projection (highlighted red asterisks in Figure 8) , and the 10 projections nearest to the intersection of the 80th percentile represents the MW/W ensemble projection (highlighted in green upside down triangles in Figure 8).

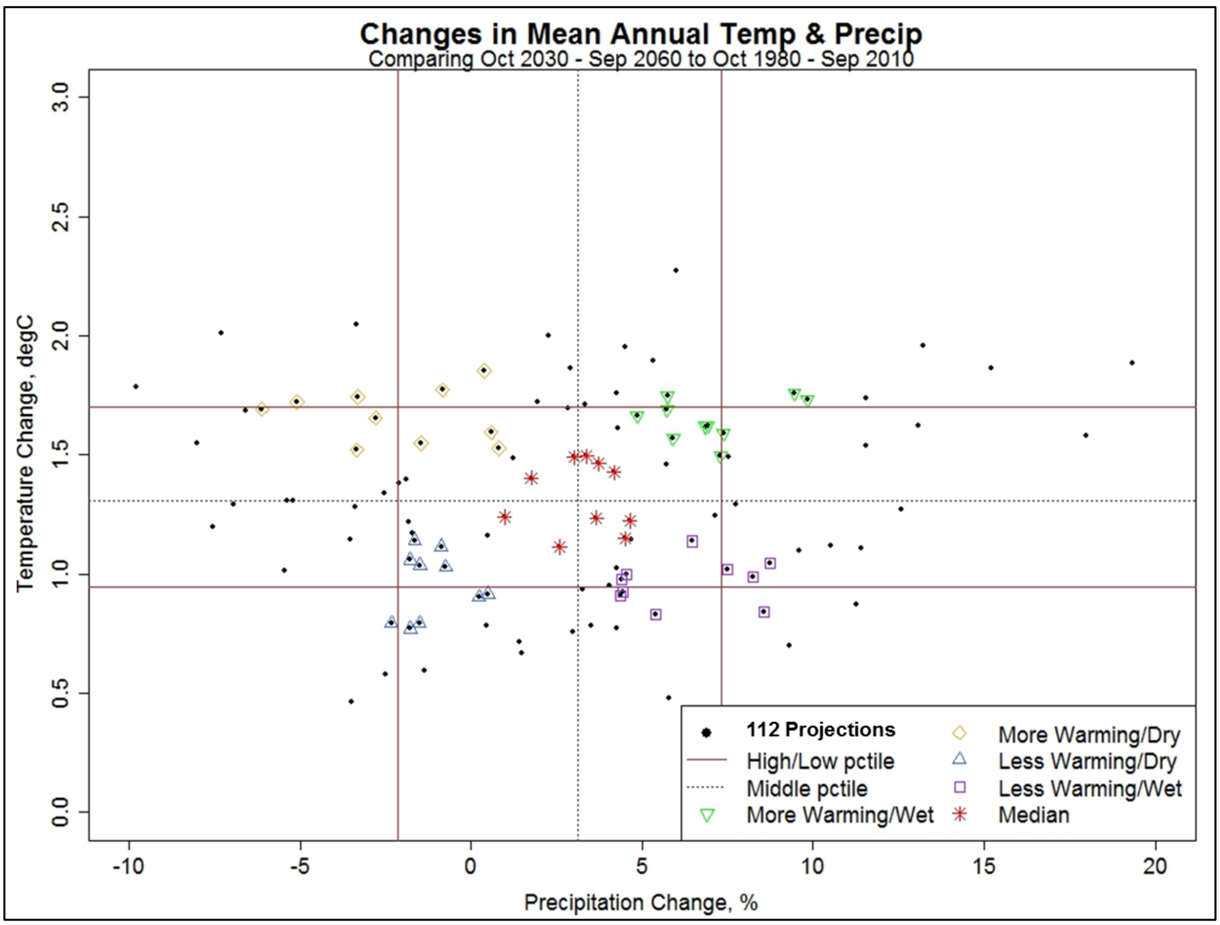

Figure 8. Climate change projection selection results.

3.2 Hybrid-Delta Ensemble Processing Results

Like the projection selection process, the results for generating the HDe results were also automated. Results from the HDe processing technique are shown in Figure 9 and are shown for each selected climate change scenario with its corresponding change in precipitation and temperature. At the bottom of the figure, the change in precipitation (percentage) and in temperature (°C) is shown for each percentile (e.g., 0.02, 0.08) that was evaluated. Each month of the year is shown on the vertical axis. Together these plots help identify trends in temperature and precipitation changes due to climate change in the basin. Plots are paired with precipitation on the left column and temperature on the right column for each climate change scenario. The colors reflect the range of change in precipitation (percentage) and as an absolute change in temperature (°C).

In the upper right panel of Figure 9, the LW/W precipitation plot projects a general increase up to 15 percent in precipitation during the winter (December through February or DJF), spring (March through May or MAM), and fall (September through November or SON) seasons (shown in light blue in the panel). During the summer months (June through August or JJA), a decrease in precipitation of up to 45 percent is projected (shown in purple and green). On average (near the 50th percentile, 50 percent), the LW/W plot is projecting an increase in precipitation during the winter, spring, and fall seasons while projecting a decrease in precipitation during the summer.

A similar analysis as the one presented in the previous paragraph was made for the other climate change scenarios and the results are summarized and quantified in Table 3 below. Increases are shown with plus signs while decreases are shown as negative numbers.

Table 3. Hybrid-Delta ensemble adjustment factor seasonal trends.

Climate Characteristic	Average Precipitation Change (%)				Average Temperature Change (°C)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
More Warming Dry (MW/D)	-3	-7	-33	+4	+1.2	+1.5	+2.4	+1.5
Median (MED)	+7	0	-14	+3	+1.2	+1.1	+1.5	+1.2
Less Warming Wet (LW/W)	+5	0	-15	+12	+0.8	+0.7	+1.3	+0.9

The results and trends shown in Table 3 above are consistent with the three selected climate change scenarios. Annual temperature projections increase from LW/W to MW/D climate change scenario while annual precipitation projections have a general increasing trend from MW/D to LW/W. Temperature increases are highest during the summer while precipitation changes vary with respect to each season. The precipitation projections show a discernible trend in the seasonality of the change with the most extreme cases (either above or below historical conditions) occurring during the fall and winter months and decreases mostly being felt in the summer months.

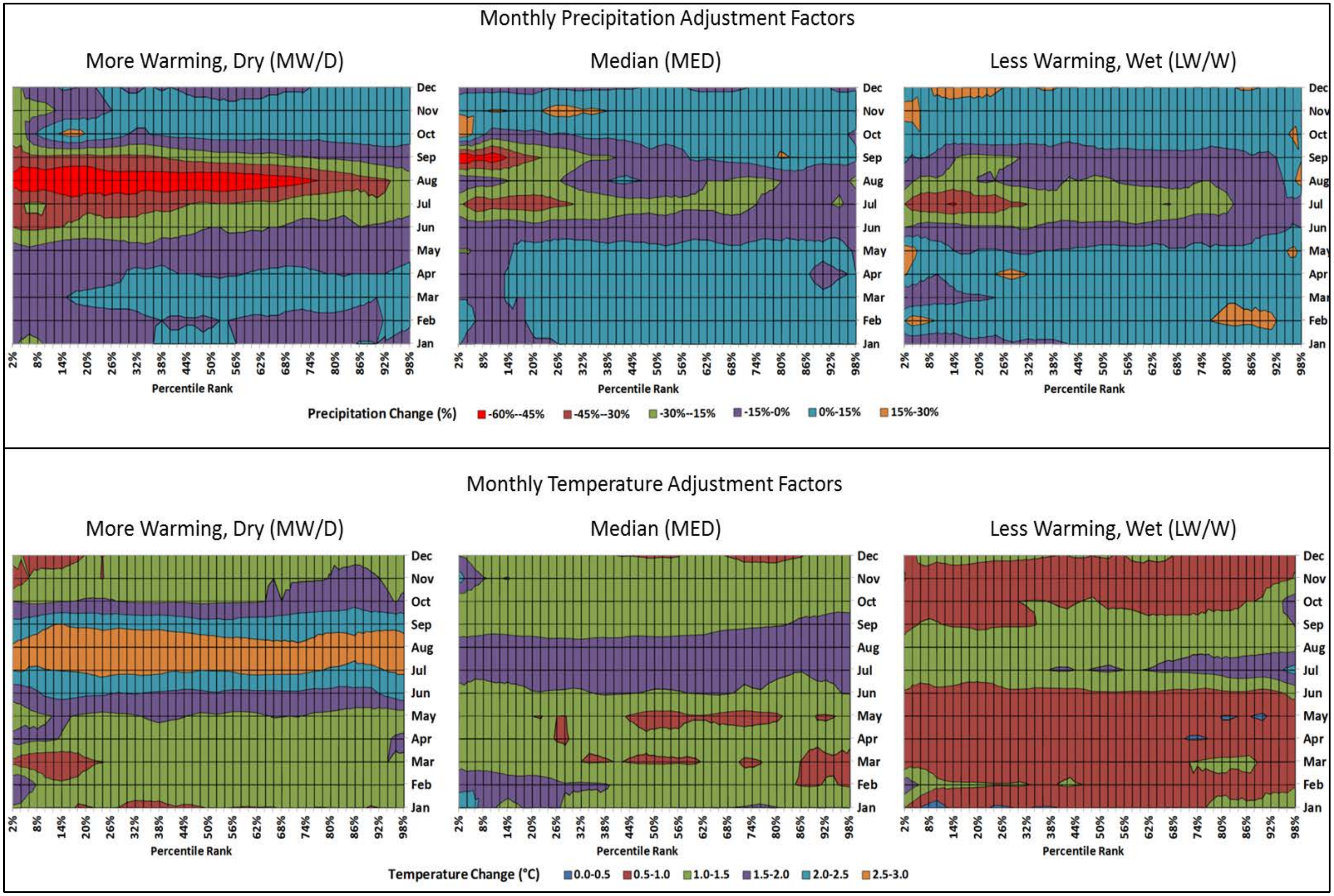

Figure 9. Hybrid-Delta ensemble generated adjustment factors.

4.0 CONCLUSIONS

The methodology for selecting climate change projections are consistent with methods used elsewhere in Reclamation for incorporating climate change information to water resources planning studies. The climate change analysis was conducted in collaboration with Hood River County stakeholders to provide the county and others the widest range of projected climate change effects to summer streamflows and glacial snowmelt. Adjustment factors calculated for temperature and precipitation can be used to adjust historical weather data that serve to inform hydrologic and water resources models. Caution should be exercised in using the results for purposes other than its designed objectives.

5.0 LITERATURE CITED

Parenthetical Reference	Bibliographic Citation
Hamlet and Lettenmaier 1999	Hamlet, A.F. and D.P. Lettenmaier. 1999. "Effects of Climate Change on Hydrology and Water Resources in the Columbia River Basin." *Journal of the American Water Resources Association* 35(6):1597-1623
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