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Technical Memorandum – Final

To:	**Blaine Dwyer and Matt Brown (AECOM)**
Distribution:	**CWCB Staff**
From:	**Ben Harding (AMEC)**
Subject:	**CRWAS Phase I – Projection Selection (refinement to CRWAS Phase I Tasks 7.1, 7.2 and 7.5)**
Date:	**July 25, 2011**

Introduction

This Technical Memorandum summarizes information developed as part of the Colorado River Water Availability Study (CRWAS) Phase I.

The objective of this technical memorandum is to: *Implement data and model refinements in response to CRWAS Draft Phase I Report public comment.* This technical memorandum involves selecting five projections for the 2070 time frame that are closest to the plotting position of the five projections used for the 2040 time frame.

This technical memorandum provides an updated approach to that described in two previous CRWAS Technical Memoranda: Task 7.1, Coordination with Front Range Vulnerability Study, and Task 7.2, Climate Change Literature Review and Methods Evaluation.

Based on an approach described in the two CRWAS Technical Memoranda listed above, selection of time frames for impact assessments and selections of projections to characterize each time frame were coordinated with the Joint Front Range Climate Change Vulnerability Study (Front Range Study). The Front Range Study defined time frames and selected projections before CRWAS was initiated.

For CRWAS and the Front Range Study the time frames for impact assessments were established at 2040 and 2070. Each time frame was characterized by average conditions over a 30-year period (2025-2054 and 2055-2084, respectively). For each of those time frames, five climate projections were selected from a set of 112 readily-available downscaled projections as described in CRWAS Technical Memorandum Task 7.2 and in Woodbury, et al. (2011). Selection of projections was based not on the attributes of the projection (i.e. GCM and SRES scenario) but with the objective that the selected projections would represent approximately 80% of the range of hydrologic impacts across all of the available projections. Because the hydrologic impacts attributable to a projection could not be known without hydrologic modeling, projections were selected based on their relative position in a two-dimensional space defined by the temperature and precipitation anomalies.

In the fall of 2009, and continuing over the following winter, after the CRWAS hydrologic modeling and water resources modeling had been completed, the Bureau of Reclamation began simulating the impact of projected climate on natural flows in the Colorado River Basin as part of the Colorado River Basin Water Supply and Demand Study (Bureau of Reclamation, 2011). Reclamation developed projected natural flows for 29 points in the Colorado River Basin for all of the available 112 downscaled projections using a Variable Infiltration Capacity (VIC) model that is very similar to the model used in CRWAS. This comprehensive set of modeled flows allowed the projections selected for the Front Range Study and used in CRWAS to be compared to all of the available 112 projections in terms of hydrologic impact. This comparison revealed biases in the selection of projections. Because the CRWAS hydrologic modeling and water resources modeling had already been completed based on the original selection of projections, that modeling was not revised, but the biases were documented in the Draft Phase I CRWAS Report (CWCB, 2010).

As described below, the biases in the 2040 projections were judged to be small enough that they would not interfere with assessment of impacts for that time frame, but the biases in the 2070 projections were much larger and were judged to introduce an unacceptable bias in the assessment of hydrologic conditions at that time frame. Accordingly, the projections for 2040 were used as the principal basis for results presented in body of the Draft Phase I CRWAS Report while results based on 2070 projections were provided in the Appendices. The Draft Phase I CRWAS Report underwent a 120-day public review and comment period. Some public comments on the Report expressed concern that the projected conditions for 2070 were not given the same weight as were the projected conditions for 2040 and requested that the 2070 projections be considered in the body of the report. Following public comment on the Draft Phase I CRWAS Report and based on further assessment of the selected projections, the AECOM team suggested to the State that the selection of projections for 2070 be refined to reduce bias in assessment of hydrologic conditions for that time frame. Based on that recommendation, this technical memorandum was specified to select five projections for the 2070 time frame.

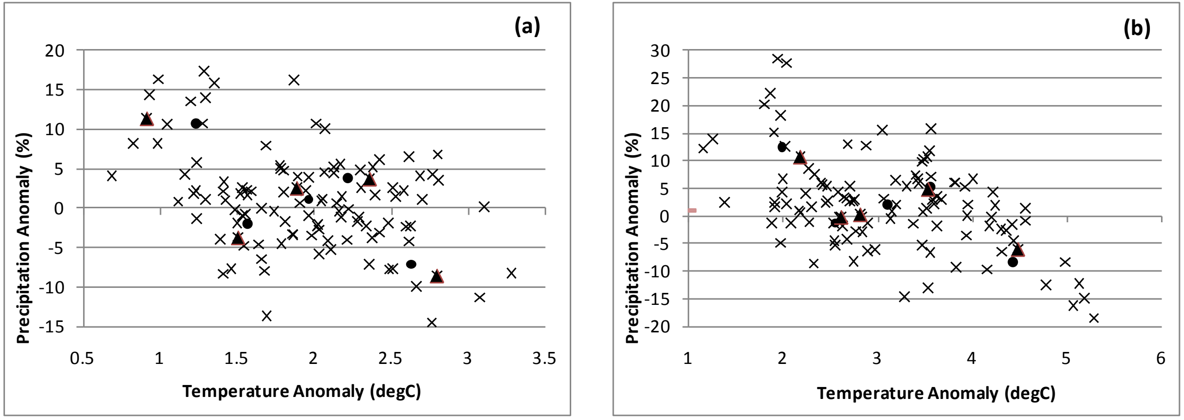
Original Selection of Projections

Projections were obtained from the bias-corrected and spatially downscaled WCRP CMIP3 Climate Projections archive (downscaled archive; served at: http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/) described by Maurer et al (2007). These projections are developed from the World Climate Research Programme's (WCRP) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset. The archive contains 112 projections of average monthly temperature and precipitation, with each projection consisting of an overlap period of 1950 through 1999 and a projection period of 2000 through 2099.

Projections were selected based on their position in a scatterplot of temperature and precipitation anomalies, with each point representing a possible future condition from one projection. The temperature anomaly was expressed in absolute terms (degrees Celsius) while the precipitation anomaly was expressed as a percent change. Five offset scenarios were defined by complementary pairs of coordinates from the 10th, 30th, 50th, 70th and 90th percentiles of the temperature and precipitation anomalies. Figure 1 shows the scatterplots for 2040 (a) and 2070 (b).

Figure 1
Temperature and precipitation anomalies and offset scenarios.

(a) 2040 projections; (b) 2070 projections; projection anomalies are designated by a cross; offset scenarios are designated by a filled circle; selected projections are designated by a filled triangle.



As noted by the filled triangles in Figure 1, five projections were selected for each time frame, one near each point representing an offset scenario (filled circles in Figure 1). At each point representing an offset scenario, the projections associated with the five closest (in Euclidean distance) anomalies (neighbors) were identified. From those five neighbors a single projection was selected for which the normalized seasonal pattern of precipitation anomalies was most similar (using a root mean square measure) to the pattern of average seasonal anomalies across the five neighbors. Table 1 shows the selected projections for both time frames.

Table 1
Selected climate projections

Time Frame	SRES Scenario	GCM	Run
2040	A2	ncar_pcm1	3
2040	A1B	ncar_ccsm3_0	2
2040	B1	cccma_cgcm3_1	2
2040	A2	mri_cgcm2_3_2a	1
2040	A2	miroc3_2_medres	1
2070	A2	ncar_pcm1	3
2070	A1B	ncar_ccsm3_0	2
2070	B1	mpi_echam5	1
2070	A1B	mri_cgcm2_3_2a	4
2070	A1B	gfdl_cm2_0	1

Analysis of Selected Projections

The five offset scenarios were qualitatively identified by the Front Range Study as:

- "warm and wet" (upper left, 10th percentile of T, 90th percentile of P)
- "warm and dry" (lower left,30th percentile of T, 30th percentile of P)
- "hot and wet" (upper right, 70th percentile of T, 70th percentile of P)
- "hot and dry" (lower right, 90th percentile of T, 10th percentile of P)
- "median" (center, 50th percentile of T, 50th percentile of P)

The intention of the selection approach was to cover roughly 80% of the projection-to-projection variability in the archive. The Front Range Study was not aware of previous use of this approach for selecting projections (personal communication, David Yates). Ruosteenoja, et al. (2003) use the method to characterize projected future climate on a regional basis and suggest that the method could be used for selection of projections. Selecting projections based on their relative position in a space defined by their temperature and precipitation anomaly assumes that the selected projections will be ordered in a useful way in terms of hydrologic impact. However, the AECOM team is not aware of reports in the literature describing any effort to validate the ability of this method to predict the ordering of hydrologic impact or the range of variability represented by the selected projections. The sensitivity of streamflow to temperature varies with the amount of precipitation, so the ability of this method to predict hydrologic impacts will also vary with precipitation. In the case of CRWAS, the availability of simulated climate-impacted flows for a number of locations in the study area, for all 112 projections in the downscaled archive, allowed evaluation of the success of the method in meeting the objective of covering approximately 80% of the variability across the available projections. This was done by placing the hydrologic impact of the selected projections in the context of the cumulative distribution function of hydrologic impacts from all available projections.

The selected projections were originally evaluated for the Colorado River near Glenwood Springs because that watershed was more representative of the smaller area used by the Front Range Study for selecting projections. The results of that evaluation were presented in the Draft Phase I CRWAS Report. Some comments received on the Report suggested that the selected projections be evaluated at Lees Ferry rather than Glenwood Springs. Because the watershed above Lees Ferry contains large areas of arid lands outside the State of Colorado, and because the focus of CRWAS is weighted toward water availability within the State of Colorado, the AECOM team elected to use an index flow that was heavily weighted toward the water-producing regions of the Colorado River Basin within Colorado. The watersheds depicted in Figure 2 were selected as the basis for the index flow because they drain a substantial portion of the Colorado River Basin within Colorado and do not drain significant areas of more arid lands outside the State. Flows at these twelve points were summed to create an index flow that is intended to represent natural water supply within the State. The Colorado River at Glenwood Springs is station 1 in Figure 2.

Figure 2.
Selected CRSS Inflow Watersheds.

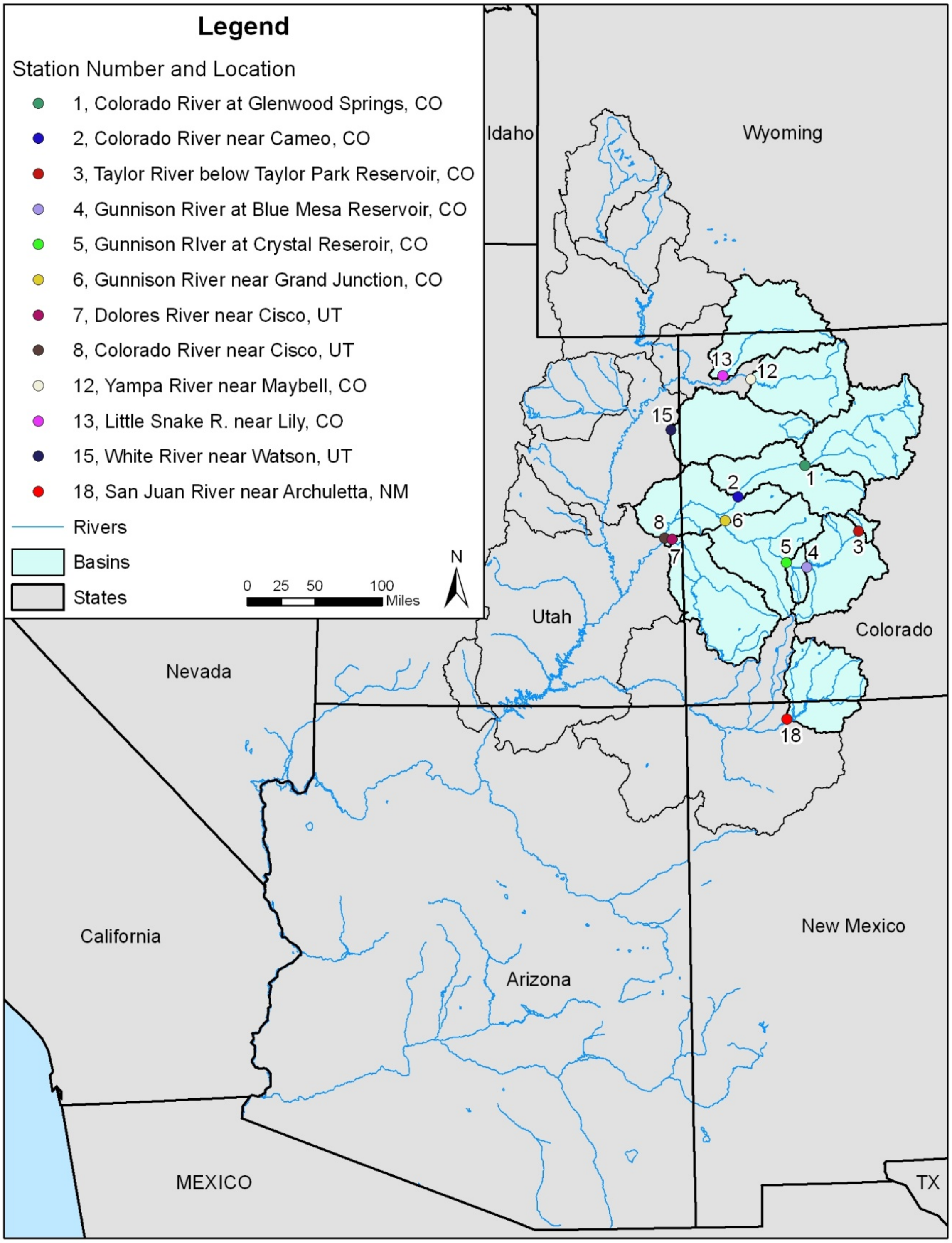


Table 2 summarizes the attributes of the selected climate projections. Figure 3 shows the selected projections in the context of the cumulative distribution of flow anomalies (expressed as percent change) for both time frames at Glenwood Springs, Colorado and for the index flow.

Table 2.
Attributes of Selected Climate Projections

	Glenwood Springs		Index Flow	
	2040	2070	2040	2070
Maximum plotting position	0.92	0.82	0.92	0.77
Minimum plotting position	0.18	0.29	0.15	0.19
Range of plotting position	0.74	0.53	0.77	0.58
Mean anomaly of all projections	-0.03	-0.03	-0.05	-0.07
Mean anomaly of selected projections	-0.01	-0.05	-0.04	-0.12

Figure 3.
Relative position of selected projections in cumulative distribution function of all 112 climate projections from the downscaled archive

a) Glenwood Springs 2040, b) Glenwood Springs 2070, c) Index flow 2040, d) Index flow 2070; solid red line represents the empirical cumulative distribution function of the flow anomaly for all of the 112 projections; yellow circles represent the plotting positions of the five selected projections; the red triangle represents the mean flow anomaly for all 112 projections and the blue square represents the mean flow anomaly for the selected projections.

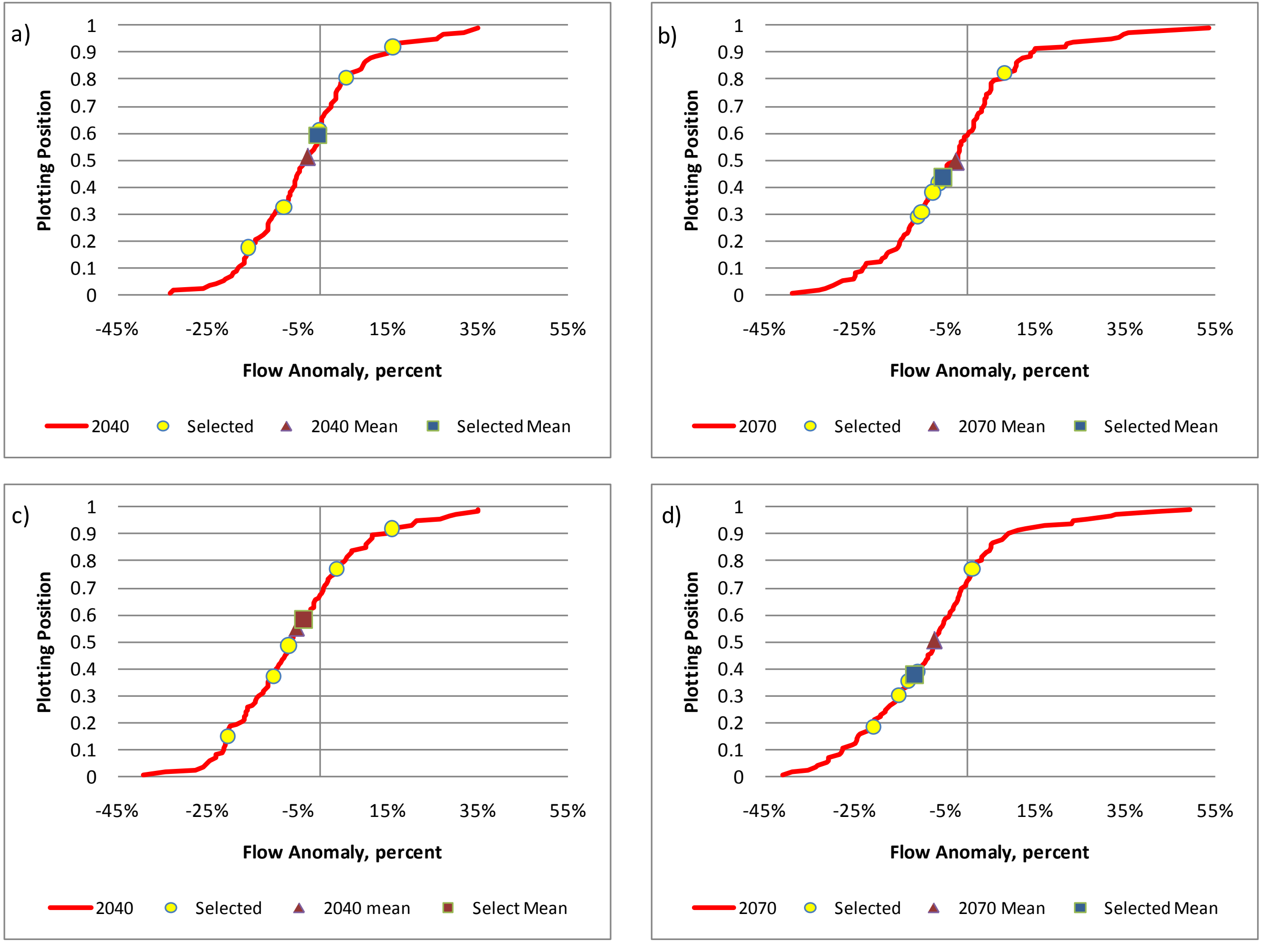


Figure 3 and Table 2 show that the initial approach used to select projections in CRWAS and the Front Range Study did not meet the objective of representing 80% of the projection-to-projection variability for either time frame. The 2040 projections represented 74% and 77% of the range of all anomalies at Glenwood Springs and the index flow, while the corresponding values for the 2070 projections were 53% and 58%. The mean flow anomaly for the 2070 projections for the index flow showed a significant dry bias relative to the mean flow anomaly for all projections.

Selection of New Projections

As discussed above, analysis indicates that the selected projections for both 2040 and 2070 failed to meet the objective of encompassing approximately 80% of the projection-to-projection variability in the large database of downscaled projections. When evaluated for the index flow representing a broad area of the Colorado River basin in Colorado, the selected projections for 2040 covered 77 percent of the range (the 15th percentile through the 92nd percentile) and the 2070 projections covered 58 percent of the range (the 19th percentile through the 77th percentile). The mean flow anomaly for the 2040 projections was one percent higher than the mean anomaly for all projections while the mean anomaly for the 2070 projections was five percent lower than the mean anomaly for all projections. The AECOM team advised the State that the bias in the 2040 projections was small, those projections came very close to meeting the nominal objective of the selection process, and they were relatively evenly distributed over the range of plotting positions. Based on this assessment, the projections for 2040 were used as the principal basis for results presented in body of the Draft Phase I CRWAS Report. Because of the bias evident in the selected 2070 projections, results based on those projections were provided in the Appendices.

Some comments received on the Draft Phase I CRWAS Report requested that the report be revised to further consider the 2070 projections. Some comments suggested that the 2040 projections were biased wet and should be refined to include projections at the 10th and 90th percentiles. The AECOM team advised the State that the selected 2070 projections exhibited greater bias (when evaluated against the index flow), covered a smaller portion of the projection-to-projection variability and were not evenly distributed over the range of plotting positions. The AECOM team further advised the state that retaining the 2040 projections as originally selected offered the advantage of consistency and comparability with the Front Range Study. The State, based on this advice, decided to select a new set of projections for 2070.

The approach to select a new set of projections for 2070 involved matching the plotting position of the 2040 projections. This was done based on flow anomalies for the index flow. The selected projections are shown in Table 3 and their attributes are summarized in Table 4 and Figure 4. All of the 2070 projections and their respective plotting positions are shown in Appendix A of this Technical Memorandum.

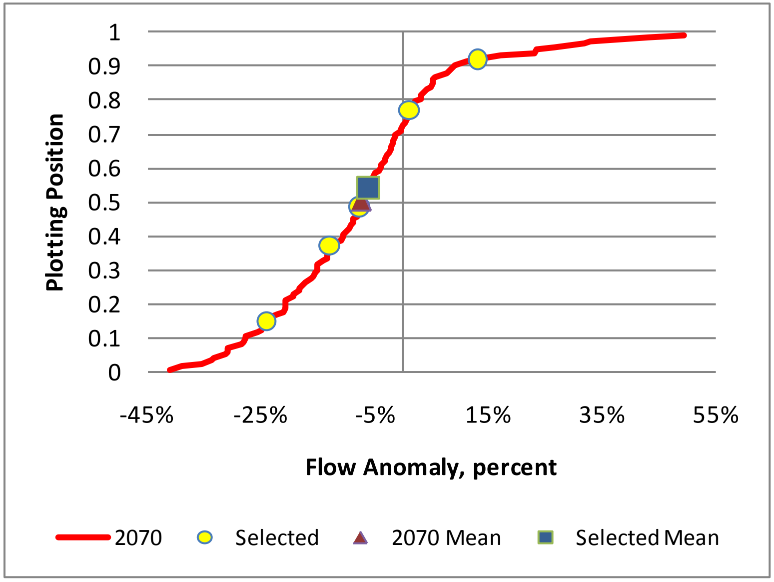
Table 3.
New Selected Climate Projections

Time Frame	SRES Scenario	GCM	Run	Flow Anomaly	Plotting Position
2070	a2	ncar_ccsm3_0	4	-24.1%	15.0%
2070	a1b	mpi_echam5	3	-13.0%	37.2%
2070	a2	mpi_echam5	1	-7.8%	48.7%
2070	a2	ncar_pcm1	3	1.0%	77.0%
2070	a2	cccma_cgcm3_1	2	13.0%	92.0%

Table 4.
Attributes of New Selected Climate Projections

	Glenwood Springs		Index Flow	
	2040	2070	2040	2070
Maximum plotting position	0.92	0.93	0.92	0.92
Minimum plotting position	0.18	0.22	0.15	0.15
Range of plotting position	0.74	0.71	0.77	0.77
Mean anomaly of all projections	-0.03	-0.03	-0.05	-0.07
Mean anomaly of selected projections	-0.01	0.01	-0.04	-0.06

Figure 4.
Relative position of new selected projections for 2070 in cumulative distribution function of all 112 climate projections from the downscaled archive.
Symbols are the same as Figure 3.



When evaluated for the index flow representing a broad area of the Colorado River basin in Colorado, the new selected projections for 2070 cover the same 77 percent of the distribution of flow anomalies as the 2040 projections and, as is the case for 2040, the mean flow anomaly for the new 2070 projections is one percent higher than the mean anomaly for all projections. When projections are selected based on 2070 flow anomalies at Glenwood Springs, the changes in the minimum plotting position and mean anomaly for the index flow are greater than the corresponding changes at Glenwood Springs when selection is based on the flow anomalies for the index flow. The results of selection based on flow anomalies at Glenwood Springs are provided in Appendix B. The index flow represents the conditions over a much larger proportion of the study area and projections selected based on the index flow exhibit less bias relative to the set of 112 projections. For these reasons, the AECOM team recommends that the projections in Table 3 be used to characterize projected conditions in 2070.

References

Bureau of Reclamation. 2011. Colorado River Basin Water Supply and Demand Study, Interim Report No. 1, Status Report. Bureau of Reclamation, U.S. Department of the Interior.

Colorado Water Conservation Board (CWCB), 2010. Colorado Water Availability Study, Draft Phase I Report. March 10, 2010.

Maurer, E. P., L. Brekke, T. Pruitt, and P. B. Duffy. 2007. Fine-resolution climate projections enhance regional climate change impact studies. Eos Trans. AGU, 88(47), 504 (online at http://www.agu.org/eos_elec/2007/47-504.html).

Ruosteenoja, K., T. Carter, K Jylha and H. Tuomenvirta. 2003. Future Climate in world regions: an Intercomparison of model-based projections for the new IPCC emissions scenarios. Finnish Environment Institute, Helsinki.

Woodbury, M., D. Yates, M. Baldo and L. Kaatz. (2011) Joint Front Range Climate Change Vulnerability Study, Draft Report. Water Research Foundation, Denver, Colorado, in preparation

Appendix A: 2070 Projections, flow anomalies and plotting position

Table A-1. Projections, 2070 flow anomalies and plotting positions for index flow.
Selected new 2070 projections are highlighted

Projection	SRES	GCM	Run	Flow Anomaly (%)	Plotting Position (%)
sresa2.miroc3_2_medres.2	a2	miroc3_2_medres.2	2	-41.0%	0.9%
sresa2.miroc3_2_medres.3	a2	miroc3_2_medres.3	3	-38.9%	1.8%
sresa1b.miroc3_2_medres.3	a1b	miroc3_2_medres.3	3	-35.6%	2.7%
sresa2.miroc3_2_medres.1	a2	miroc3_2_medres.1	1	-33.8%	3.5%
sresa2.cnrm_cm3.1	a2	cnrm_cm3.1	1	-33.4%	4.4%
sresa1b.miroc3_2_medres.1	a1b	miroc3_2_medres.1	1	-31.4%	5.3%
sresa2.miub_echo_g.3	a2	miub_echo_g.3	3	-30.9%	6.2%
sresa1b.cnrm_cm3.1	a1b	cnrm_cm3.1	1	-30.8%	7.1%
sresb1.miroc3_2_medres.3	b1	miroc3_2_medres.3	3	-28.4%	8.0%
sresa1b.miub_echo_g.2	a1b	miub_echo_g.2	2	-28.1%	8.8%
sresa1b.miub_echo_g.3	a1b	miub_echo_g.3	3	-27.8%	9.7%
sresa2.miub_echo_g.2	a2	miub_echo_g.2	2	-27.6%	10.6%
sresb1.miub_echo_g.3	b1	miub_echo_g.3	3	-25.7%	11.5%
sresb1.ncar_ccsm3_0.6	b1	ncar_ccsm3_0.6	6	-24.9%	12.4%
sresa2.miub_echo_g.1	a2	miub_echo_g.1	1	-24.8%	13.3%
sresa1b.miroc3_2_medres.2	a1b	miroc3_2_medres.2	2	-24.5%	14.2%
sresa2.ncar_ccsm3_0.4	a2	ncar_ccsm3_0.4	4	-24.1%	15.0%
sresa1b.ncar_ccsm3_0.6	a1b	ncar_ccsm3_0.6	6	-24.0%	15.9%
sresa2.bccr_bcm2_0.1	a2	bccr_bcm2_0.1	1	-22.2%	16.8%
sresb1.cnrm_cm3.1	b1	cnrm_cm3.1	1	-21.1%	17.7%
sresa1b.ncar_ccsm3_0.2	a1b	ncar_ccsm3_0.2	2	-20.9%	18.6%
sresb1.miroc3_2_medres.1	b1	miroc3_2_medres.1	1	-20.8%	19.5%
sresa1b.ncar_ccsm3_0.1	a1b	ncar_ccsm3_0.1	1	-20.8%	20.4%
sresa1b.ncar_ccsm3_0.7	a1b	ncar_ccsm3_0.7	7	-20.7%	21.2%
sresa1b.mri_cgcm2_3_2a.2	a1b	mri_cgcm2_3_2a.2	2	-19.4%	22.1%
sresa1b.bccr_bcm2_0.1	a1b	bccr_bcm2_0.1	1	-19.3%	23.0%
sresa2.mri_cgcm2_3_2a.3	a2	mri_cgcm2_3_2a.3	3	-18.2%	23.9%
sresa2.gfdl_cm2_1.1	a2	gfdl_cm2_1.1	1	-18.2%	24.8%
sresa1b.miub_echo_g.1	a1b	miub_echo_g.1	1	-17.5%	25.7%
sresb1.miub_echo_g.1	b1	miub_echo_g.1	1	-17.3%	26.5%
sresa2.ncar_ccsm3_0.2	a2	ncar_ccsm3_0.2	2	-16.3%	27.4%
sresa2.ncar_ccsm3_0.1	a2	ncar_ccsm3_0.1	1	-15.7%	28.3%
sresa2.ncar_ccsm3_0.3	a2	ncar_ccsm3_0.3	3	-15.6%	29.2%
sresa1b.mri_cgcm2_3_2a.4	a1b	mri_cgcm2_3_2a.4	4	-15.2%	30.1%
sresb1.gfdl_cm2_1.1	b1	gfdl_cm2_1.1	1	-15.2%	31.0%
sresa1b.csiro_mk3_0.1	a1b	csiro_mk3_0.1	1	-15.2%	31.9%
sresa1b.ipsl_cm4.1	a1b	ipsl_cm4.1	1	-14.2%	32.7%
sresa1b.gfdl_cm2_1.1	a1b	gfdl_cm2_1.1	1	-13.5%	33.6%
sresa2.mri_cgcm2_3_2a.2	a2	mri_cgcm2_3_2a.2	2	-13.5%	34.5%
sresa1b.gfdl_cm2_0.1	a1b	gfdl_cm2_0.1	1	-13.1%	35.4%
sresb1.giss_model_e_r.1	b1	giss_model_e_r.1	1	-13.0%	36.3%
sresa1b.mpi_echam5.3	a1b	mpi_echam5.3	3	-13.0%	37.2%
sresa2.mpi_echam5.2	a2	mpi_echam5.2	2	-12.2%	38.1%
sresb1.mpi_echam5.1	b1	mpi_echam5.1	1	-11.0%	38.9%

Projection	SRES	GCM	Run	Flow Anomaly (%)	Plotting Position (%)
sresa1b.giss_model_e_r.4	a1b	giss_model_e_r.4	4	-10.7%	39.8%
sresa2.gfdl_cm2_0.1	a2	gfdl_cm2_0.1	1	-10.6%	40.7%
sresb1.cccma_cgcm3_1.3	b1	cccma_cgcm3_1.3	3	-9.8%	41.6%
sresa2.csiro_mk3_0.1	a2	csiro_mk3_0.1	1	-9.7%	42.5%
sresb1.ukmo_hadcm3.1	b1	ukmo_hadcm3.1	1	-9.3%	43.4%
sresb1.mri_cgcm2_3_2a.5	b1	mri_cgcm2_3_2a.5	5	-8.7%	44.2%
sresb1.mpi_echam5.3	b1	mpi_echam5.3	3	-8.7%	45.1%
sresb1.miub_echo_g.2	b1	miub_echo_g.2	2	-8.0%	46.0%
sresa1b.cccma_cgcm3_1.1	a1b	cccma_cgcm3_1.1	1	-7.8%	46.9%
sresb1.ncar_ccsm3_0.2	b1	ncar_ccsm3_0.2	2	-7.8%	47.8%
sresa2.mpi_echam5.1	a2	mpi_echam5.1	1	-7.8%	48.7%
sresb1.ncar_ccsm3_0.7	b1	ncar_ccsm3_0.7	7	-7.6%	49.6%
sresb1.miroc3_2_medres.2	b1	miroc3_2_medres.2	2	-7.4%	50.4%
sresa1b.ncar_ccsm3_0.3	a1b	ncar_ccsm3_0.3	3	-7.3%	51.3%
sresb1.ncar_ccsm3_0.4	b1	ncar_ccsm3_0.4	4	-7.2%	52.2%
sresb1.bccr_bcm2_0.1	b1	bccr_bcm2_0.1	1	-6.5%	53.1%
sresb1.mpi_echam5.2	b1	mpi_echam5.2	2	-6.2%	54.0%
sresb1.ncar_ccsm3_0.1	b1	ncar_ccsm3_0.1	1	-5.9%	54.9%
sresa2.giss_model_e_r.1	a2	giss_model_e_r.1	1	-5.7%	55.8%
sresa1b.mri_cgcm2_3_2a.1	a1b	mri_cgcm2_3_2a.1	1	-5.3%	56.6%
sresa2.ipsl_cm4.1	a2	ipsl_cm4.1	1	-5.2%	57.5%
sresa1b.cccma_cgcm3_1.3	a1b	cccma_cgcm3_1.3	3	-4.8%	58.4%
sresb1.mri_cgcm2_3_2a.2	b1	mri_cgcm2_3_2a.2	2	-4.4%	59.3%
sresb1.cccma_cgcm3_1.5	b1	cccma_cgcm3_1.5	5	-4.0%	60.2%
sresb1.mri_cgcm2_3_2a.1	b1	mri_cgcm2_3_2a.1	1	-3.9%	61.1%
sresa2.cccma_cgcm3_1.5	a2	cccma_cgcm3_1.5	5	-3.4%	61.9%
sresa1b.ncar_pcm1.2	a1b	ncar_pcm1.2	2	-3.1%	62.8%
sresa2.mri_cgcm2_3_2a.4	a2	mri_cgcm2_3_2a.4	4	-3.0%	63.7%
sresa1b.ukmo_hadcm3.1	a1b	ukmo_hadcm3.1	1	-2.5%	64.6%
sresa1b.mri_cgcm2_3_2a.3	a1b	mri_cgcm2_3_2a.3	3	-2.1%	65.5%
sresb1.csiro_mk3_0.1	b1	csiro_mk3_0.1	1	-2.1%	66.4%
sresa2.mri_cgcm2_3_2a.5	a2	mri_cgcm2_3_2a.5	5	-1.7%	67.3%
sresb1.cccma_cgcm3_1.4	b1	cccma_cgcm3_1.4	4	-1.7%	68.1%
sresb1.gfdl_cm2_0.1	b1	gfdl_cm2_0.1	1	-1.5%	69.0%
sresb1.mri_cgcm2_3_2a.4	b1	mri_cgcm2_3_2a.4	4	-1.4%	69.9%
sresa2.ukmo_hadcm3.1	a2	ukmo_hadcm3.1	1	-0.4%	70.8%
sresa2.cccma_cgcm3_1.3	a2	cccma_cgcm3_1.3	3	-0.3%	71.7%
sresa2.mri_cgcm2_3_2a.1	a2	mri_cgcm2_3_2a.1	1	0.0%	72.6%
sresa1b.giss_model_e_r.2	a1b	giss_model_e_r.2	2	0.4%	73.5%
sresb1.cccma_cgcm3_1.1	b1	cccma_cgcm3_1.1	1	0.5%	74.3%
sresa2.mpi_echam5.3	a2	mpi_echam5.3	3	0.6%	75.2%
sresb1.ipsl_cm4.1	b1	ipsl_cm4.1	1	0.6%	76.1%
sresa2.ncar_pcm1.3	a2	ncar_pcm1.3	3	1.0%	77.0%
sresa1b.mpi_echam5.2	a1b	mpi_echam5.2	2	1.5%	77.9%
sresa2.inmcm3_0.1	a2	inmcm3_0.1	1	1.8%	78.8%
sresa1b.mri_cgcm2_3_2a.5	a1b	mri_cgcm2_3_2a.5	5	2.0%	79.6%
sresa1b.cccma_cgcm3_1.5	a1b	cccma_cgcm3_1.5	5	2.9%	80.5%

Projection	SRES	GCM	Run	Flow Anomaly (%)	Plotting Position (%)
sresa1b.mpi_echam5.1	a1b	mpi_echam5.1	1	3.1%	81.4%
sresb1.inmcm3_0.1	b1	inmcm3_0.1	1	3.3%	82.3%
sresb1.ncar_ccsm3_0.3	b1	ncar_ccsm3_0.3	3	4.0%	83.2%
sresa1b.ncar_ccsm3_0.5	a1b	ncar_ccsm3_0.5	5	4.8%	84.1%
sresa2.cccma_cgcm3_1.1	a2	cccma_cgcm3_1.1	1	5.3%	85.0%
sresb1.ncar_ccsm3_0.5	b1	ncar_ccsm3_0.5	5	5.3%	85.8%
sresb1.mri_cgcm2_3_2a.3	b1	mri_cgcm2_3_2a.3	3	5.4%	86.7%
sresa2.cccma_cgcm3_1.4	a2	cccma_cgcm3_1.4	4	7.5%	87.6%
sresb1.ncar_pcm1.2	b1	ncar_pcm1.2	2	8.0%	88.5%
sresb1.cccma_cgcm3_1.2	b1	cccma_cgcm3_1.2	2	8.6%	89.4%
sresa2.ncar_pcm1.2	a2	ncar_pcm1.2	2	9.2%	90.3%
sresa1b.cccma_cgcm3_1.4	a1b	cccma_cgcm3_1.4	4	11.2%	91.2%
sresa2.cccma_cgcm3_1.2	a2	cccma_cgcm3_1.2	2	13.0%	92.0%
sresa1b.ncar_pcm1.1	a1b	ncar_pcm1.1	1	17.1%	92.9%
sresb1.ncar_pcm1.3	b1	ncar_pcm1.3	3	22.9%	93.8%
sresa2.ncar_pcm1.4	a2	ncar_pcm1.4	4	23.3%	94.7%
sresa1b.cccma_cgcm3_1.2	a1b	cccma_cgcm3_1.2	2	26.6%	95.6%
sresa1b.inmcm3_0.1	a1b	inmcm3_0.1	1	31.9%	96.5%
sresa2.ncar_pcm1.1	a2	ncar_pcm1.1	1	33.0%	97.3%
sresa1b.ncar_pcm1.3	a1b	ncar_pcm1.3	3	42.9%	98.2%
sresa1b.ncar_pcm1.4	a1b	ncar_pcm1.4	4	49.1%	99.1%

Appendix B: 2070 Projections and attributes of projections selected based on flow anomalies at Glenwood Springs.

Table B-1.
Selected Climate Projections

Time Frame	SRES Scenario	GCM	Run	Flow Anomaly	Plotting Position
2070	a1b	mri_cgcm2_3_2a	2	-15.4%	17.7%
2070	a1b	ncar_ccsm3_0	7	-9.8%	32.7%
2070	a1b	cccma_cgcm3_1	3	0.8%	61.1%
2070	a1b	cccma_cgcm3_1	5	8.0%	80.5%
2070	a1b	ncar_pcm1	1	21.5%	92.0%

Table B-2.
Attributes of Selected Climate Projections

	Glenwood Springs		Index Flow	
	2040	**2070**	**2040**	**2070**
Maximum plotting position	0.92	0.92	0.92	0.93
Minimum plotting position	0.18	0.18	0.15	0.21
Range of plotting position	0.74	0.74	0.77	0.72
Mean anomaly of all projections	-0.03	-0.03	-0.05	-0.07
Mean anomaly of selected projections	-0.01	0.01	-0.04	-0.05