Santa Ana Watershed Project Authority
Santa Ana River Conservation and Conjunctive Use
Project Decision Support Model
(SARCCUP DSM)

SARCCUP DSM MODEL DOCUMENTATION

DRAFT MARCH 2017

Prepared for

Prepared by

1. Introduction

The Santa Ana Watershed Project Authority (SAWPA) and its five member agencies, Eastern Municipal Water District (EMWD), Inland Empire Utilities Agency (IEUA), Orange County Water District (OCWD), San Bernardino Valley Municipal Water District (SBVMWD), and Western Municipal Water District (WMWD), collectively "Agencies" in this memorandum, are developing and implementing the Santa Ana River Conservation and Conjunctive Use Project (SARCCUP). SARCCUP is a collaborative regional program that will improve the water supply resiliency of the Santa Ana River Watershed through development of additional dry year yield, reduced water use, and improved habitat for native threatened species populations.

The primary goal of the conjunctive use element is to maximize the development and use of imported water supplies and to conjunctively manage these local and imported water supplies such that the aggregate yield and water supply reliability generated by the SARCCUP is greater than the independent management of these resources. Phase 1 of SARCCUP will develop an 180,000 acre-foot (AF) groundwater bank storage program with capacity to recharge and store 60,000 acre-feet per year (AFY) during each of three wet years in a decade and extraction facilities to withdraw 60,000 AFY in each of three dry years in a decade. SARCCUP management will also include the ability to utilize transfers and exchanges of other water supplies in lieu of recharging and extracting banked groundwater.

In support of the future development of a SARCCUP Master Plan for the conjunctive use element, the Agencies have engaged the CH2M team to develop a Santa Ana River watershed-wide decision support model (DSM) to optimize the conjunctive use element of SARCCUP. The objective of the DSM project is to simulate anticipated operations of the proposed SARCCUP facilities, identify potential constraints, optimize the operation, and quantify the benefits and the costs.

This report summarizes the development process and results of the DSM for SARCCUP and Agencies.

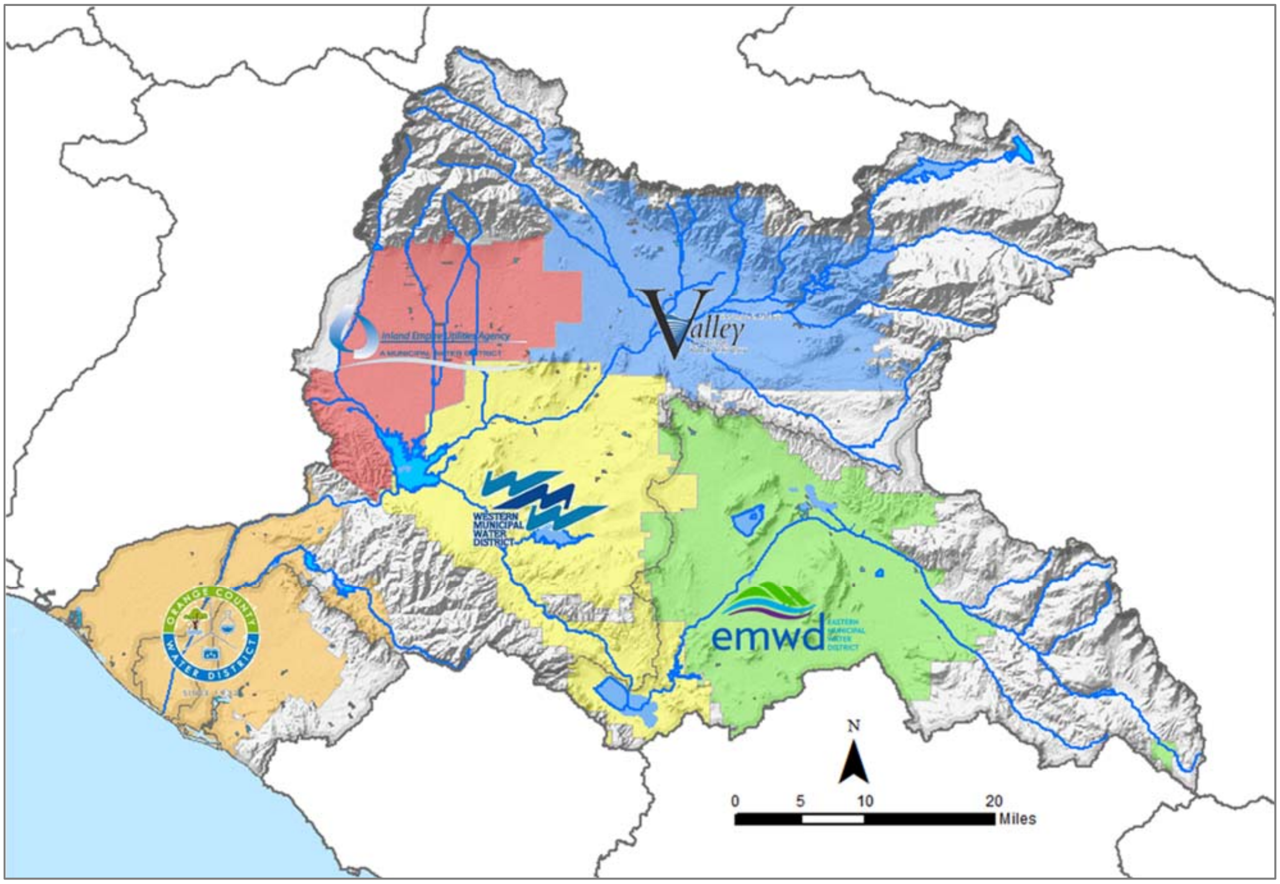
1.0. SARCCUP Agencies

This section provides an overview of the SARCCUP Agencies, their service areas, responsibilities, and local agencies served to provide context for the data collection effort. Figure 1 depicts the agencies falling within the Santa Ana River watershed.

San Bernardino Valley Municipal Water District

SBVMWD was formed in 1954 as a regional agency to plan a long-range water supply for the San Bernardino Valley. SBVMWD serves approximately 353 square miles in the San Bernardino Valley, Crafton Hills and a portion of the Yucaipa Valley, within the upper Santa Ana River watershed. SBVMWD imports water into its service area as a State Water Contractor in the State Water Project (SWP) with an annual entitlement of 102,600 AFY. SBVMWD is responsible for managing most of the groundwater basins within its boundaries and for replenishing groundwater extraction over the amount specified in the judgments. It has specific responsibilities for monitoring groundwater supplies in the San Bernardino and Colton-Rialto basins and maintaining flows at the Riverside Narrows on the Santa Ana River. SBVMWD fulfills its responsibilities in a variety of ways, including importing water through the SWP for direct delivery and groundwater recharge and by coordinating water deliveries to retail agencies throughout its service area; SBVMWD does not provide direct retail water service. Retail water agencies within the SBVMWD service area include East Valley Water District, City of Loma Linda, City of Redlands, City of Rialto, San Bernardino Municipal Water Department, Riverside Highlands Water Company, West Valley Water District, Yucaipa Valley Water District and City of Colton.

Figure 1: Agency and Watershed Boundaries



Western Municipal Water District

WMWD was formed in 1954 to bring supplemental water to growing western Riverside County and provides water and wastewater services to retail customers and wholesale agencies. WMWD water supplies include imported water from the Metropolitan Water District of Southern California (MWDSC), local groundwater, and recycled water. WMWD shares in the responsibility for management of groundwater and surface water resources in its service area and participates in four watermaster functions for the Santa Ana River, San Bernardino Basin Area, Chino Groundwater Basin and Santa Margarita River. Its specific responsibilities include replenishing groundwater extraction over the amount specified in the judgements and maintaining flows at the Prado Dam on the Santa Ana River.

Within the Santa Ana River watershed, WMWD provides retail water service to its Riverside Service Area and wholesale water service to Box Springs Mutual Water Company, City of Corona, City of Norco, City of Riverside Public Utilities, Eagle Valley Mutual Water Company, Elsinore Valley Municipal Water District, Jurupa Community Services District, and Temescal Valley Water District. In addition, Home Gardens County Water District, Riverside Highlands Water Company, Rubidoux Community Services District and Santa Ana River Water Company are located within WMWD service area but do not currently receive water from WMWD. WMWD also provides retail water service to its Murrieta Service Area and Rainbow Service Area, and wholesale water service to Rancho California Water District, which are outside the Santa Ana River watershed and are not proposed to be part of SARCCUP.

Eastern Municipal Water District

EMWD was formed in 1950, primarily supplying agricultural demand from its groundwater supplies. EMWD became a member agency to MWDSC in 1951 and, moving forward has supplemented local groundwater supplies with imported water from the Colorado Aqueduct and Northern California. EMWD services include groundwater production and desalination, water filtration, wastewater collection, and recycled water production. EMWD has individual rights as part of the Hemet-San Jacinto Watermaster along with Lake Hemet Municipal Water District, City of Hemet, City of San Jacinto and other private groundwater pumpers to Groundwater in the Canyon Subbasin, the San Jacinto Upper Pressure Subbasin downstream to Bridge Street and the Hemet Subbasin. The basins mentioned above are collectively called the Management Area and are located in the San Jacinto Valley in Riverside County, California. EMWD and Lake Hemet individually possess permitted and Pre 1914 Surface Water Rights to store, divert, and recharge Surface Water from the San Jacinto River and its tributaries.

EMWD provides water, sewer, and/or recycled water services to retail areas and provides water as a wholesaler to a handful of adjacent agencies as well. The District provides service to retail customers located within the cities of Moreno Valley, Menifee, Murrieta, and Temecula and the unincorporated communities of Good Hope, Homeland, Lakeview, Nuevo, Mead Valley, Murrieta Hot Springs, Quail Valley, Romoland, Valle Vista and Winchester. The District also supplies water on a wholesale basis to the Cities of Hemet, San Jacinto and Perris, Lake Hemet Municipal Water District, Nuevo Water Company, Elsinore Valley Municipal Water District, Western Municipal Water District and Rancho California Water District.

Inland Empire Utilities Agency

IEUA is a wholesaler distributer of imported water and a regional wastewater treatment agency. Formed in 1950, IEUA supplies supplemental imported water from MWDSC to municipalities San Bernardino County within the Chino Groundwater Basin. IEUA also performs groundwater desalination, wastewater treatment, recycled water distribution, and groundwater recharge. IEUA shares in the responsibility for management of groundwater and surface water resources in its service area and participates in watermasters for the Chino Basin and Santa Ana River. IEUA has specific responsibilities in maintaining flows at the Prado Dam on the Santa Ana River. IEUA serves over 242 square miles in western San Bernardino County and provides wholesale imported water from MWDSC to seven retail agencies, including the City of Chino, City of Chino Hills, City of Ontario, City of Upland, Monte Vista Water District, Cucamonga Valley Water District, and Fontana Water Company as well as the contracting agency San Antonio Water Company.

Orange County Water District

Since its formation in 1933 by the California State Legislature, OCWD manages and replenishes the Orange County groundwater basin, ensures water reliability and quality, prevents seawater intrusion and protects Orange County's rights to Santa Ana River water. The three water supplies in Southern California that OCWD manages are the Santa Ana River, the Orange County Groundwater basin, and the Groundwater Replenishment System (GWRS), serving residents in north and central Orange County. There are nineteen municipal water departments and special water districts that are members of OCWD and pump groundwater from the basin and retail this supply to their customers. These members include the cities of Anaheim, Buena Park, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, La Palma, Newport Beach, Orange, Santa Ana, Seal Beach, Tustin, and Westminster, East Orange County Water District, Golden State Water Company, Irvine Ranch Water District, Mesa Water District, Serrano Water District, and Yorba Linda Water District. OCWD does not retail directly to any customers.

Santa Ana Watershed Project Authority

SAWPA is a Joint Powers Authority comprised of the five member agencies described above. It focuses on developing and maintaining regional plans, programs and projects that will protect the Santa Ana River basin water resource and quality. Members plan and execute long-term projects and management programs on their own, but they work through SAWPA to provide an effective way to plan on a regional basis.

The retail and wholesale customers within each of the Agencies' service areas summarized in Table 1, along with the abbreviations for each agency.

Table 1: SARCCUP Agency & Larger Retail Agency Summary

SARCCUP Agency	Retail Agencies in Service Area	Water Service Provided by SARCCUP Agency (Water Source)	Abbreviation
SBVMWD	East Valley Water District	Wholesale (Raw Imported)	EVWD
	City of Loma Linda	None	Loma Linda
	City of Redlands	Wholesale (Raw Imported)	Redlands
	City of Rialto	Wholesale (GW)	Rialto
	San Bernardino Municipal Water Department	Wholesale (Raw Imported)	SBMWD
	Riverside Highlands Water Company	None	RHWC
	West Valley Water District	Wholesale (Raw Imported & GW)	WVWD
	Yucaipa Valley Water District	Wholesale (Raw Imported)	YVWD
	City of Colton	None	Colton
WMWD	Riverside Service Area, Murrieta Service Area and Rainbow Service Area	Retail (Treated Imported & Purchased Groundwater)	WMWD Retail
	Box Springs Mutual Water Company	Wholesale (Treated Imported)	BSMWCo
	City of Corona	Wholesale (Raw & Treated Imported)	Corona
	City of Norco	Wholesale (Desalter)	Norco
	City of Riverside	Wholesale (Treated Imported)	Riverside
	Eagle Valley Mutual Water Company	Wholesale (Raw Imported)	EVMWCo
	Elsinore Valley Municipal Water District	Wholesale (Treated Imported)	EVMWD
	Rancho California Water District	Wholesale (Raw Imported)	RCWD
	Jurupa Community Services District	None	JCSD
	Temescal Valley Water District	Wholesale (Treated Imported)	TVWD
	Home Gardens County Water District	None	HGCWD
	Riverside Highlands Water Company	None	RHWC
	Rubidoux Community Services District	None	RCSD
	Santa Ana River Water Company	None	SARWC
EMWD	EMWD retail service areas	Retail (Treated and Raw imported, locally treated, groundwater)	EMWD Retail

	City of Hemet Water Department	Wholesale	HWD
	City of Perris Water System	Wholesale	Perris
	City of San Jacinto Water Department	Wholesale	SJWD
	Lake Hemet Municipal Water District	Wholesale	LHMWD
	North Perris Water System	Wholesale	North Perris
	Nuevo Water Company	Wholesale	NWCo
	Rancho California Water District	Wholesale	RCWD
IEUA	City of Chino	Wholesale (Raw Imported and Recycled Water)	Chino
	City of Chino Hills	Wholesale (Raw Imported and Recycled Water)	Chino Hills
	City of Ontario	Wholesale (Raw Imported and Recycled Water)	Ontario
	City of Upland	Wholesale (Raw Imported and Recycled Water)	Upland
	Monte Vista Water District	Wholesale (Raw Imported and Recycled Water)	MVWD
	Cucamonga Valley Water District	Wholesale (Raw Imported and Recycled Water)	CVWD
	Fontana Water Company	Wholesale (Raw Imported and Recycled Water)	FWCo
	San Antonio Water Company	None	SAWCo
OCWD	City of Anaheim, Anaheim Public Utilities	Groundwater producer	Anaheim
	City of Buena Park	Groundwater producer	Buena Park
	East Orange County Water District	Groundwater producer	EOCWD
	City of Fountain Valley	Groundwater producer	Fountain Valley
	City of Fullerton	Groundwater producer	Fullerton
	City of Garden Grove	Groundwater producer	Garden Grove
	Golden State Water Company	Groundwater producer	GSWC
	City of Huntington Beach	Groundwater producer	Huntington Beach
	Irvine Ranch Water District	Groundwater producer	IRWD
	City of La Palma	Groundwater producer	La Palma
	Mesa Water District	Groundwater producer	Mesa Water
	City of Newport Beach	Groundwater producer	Newport Beach
	City of Orange	Groundwater producer	Orange
	City of Santa Ana	Groundwater producer	Santa Ana
	City of Seal Beach	Groundwater producer	Seal Beach

Serrano Water District	Groundwater producer	SWD
City of Tustin	Groundwater producer	Tustin
City of Westminster	Groundwater producer	Westminster
Yorba Linda Water District	Groundwater producer	YLWD

1.1. Goals and Objectives

The primary goal of the conjunctive use element is to maximize the storage of wet year imported water supplies that could be pumped during dry years to produce “dry year yield”. The DSM is used to simulate operations and demonstrate that the aggregate yield and water supply reliability generated by the SARCCUP is greater than the status quo of independent management of resources. It is also expected that the cost of water from SARCCUP is lower than the cost of independent management of resources.

Phase 1 of SARCCUP will develop an 180,000 acre-foot (AF) groundwater bank storage program with capacity to recharge and store 60,000 acre-feet per year (AFY) during each of three wet years in a decade and extraction facilities to withdraw 60,000 AFY in each of three dry years in a decade. SARCCUP management will also include the ability to utilize transfers and exchanges of other water supplies in lieu of recharging and extracting banked water.

In support of the future development of a SARCCUP Master Plan for the conjunctive use element, the Agencies have engaged CH2M to develop a Santa Ana River watershed-wide DSM to optimize the conjunctive use element of SARCCUP. The objective of the DSM project is to simulate anticipated operations of the proposed SARCCUP facilities, identify potential constraints and needed facilities, optimize the operation, and quantify the benefits and the costs.

The following document sections explain the overall modeling methodology and specific modeling logic for the key components of the DSM that is used to represent the system. Additionally, this document describes the scenarios and types of model outputs and metrics that is utilized to evaluate the performance of the SARCCUP Phase 1 facilities and operations over a range of conditions.

2. Data Collection

2.0. Data Collection Process and Database Overview

This section describes the process that was used to identify, gather, and consolidate the critical information needed to support development of the SARCCUP DSM. The data collection process was conducted in coordination with development of the model schematic to ensure integration and facilitate efficient development of the SARCCUP DSM. The data collection and schematic development process is described below and illustrated on Figure 2.

1. Provide SARCCUP database outline and draft system schematic to Agencies for review and comment. The SARCCUP database outline summarizes the data categories and time series that could be used as inputs in the model. The draft system schematic illustrates the key facilities and connections of the Agencies' systems.
2. Hold individual Agency meetings to discuss and update the draft system schematic to determine the critical facilities and model inputs for each Agency.
3. Review of Agency comments on system schematic and data provided by Agencies. Update schematic per comments and coordinate with agency staff to make necessary changes.
4. Develop SARCCUP database based on facilities included in the system schematic and data collected to date. Prepare detailed data request and updated system schematic submittal to provide to Agencies.
5. Update SARCCUP database with additional data received. Identify facility limitations and simplify or expand system schematic to ensure all critical elements are adequately represented.
6. Combine the SARCCUP database and the refined system schematic to create the inputs for the model.

During the data collection process, the CH2M team utilized a file sharing site called Box to organize data sources. Using Box, the CH2M team and the Agencies uploaded current files in the SARCCUP team folder, viewed and downloaded documents uploaded by others and added notes to specific files. A screenshot of the Box data collection tool is shown on Figure 3.

This section summarizes the types, purpose, and data sources for key data sets needed to prepare inputs for and configure the SARCCUP DSM. Information that has been collected to date is compiled in the SARCCUP Database. The SARCCUP Database includes references to data sources for key information so data can be readily validated and updated by Agency staff in the future.

The following subsections present the main categories of data that are included in the SARCCUP Database and describe the subsets of data in each category. This information is also summarized in more detail in Figure 2.

Figure 2. SARCCUP Data Collection and System Schematic Development Process

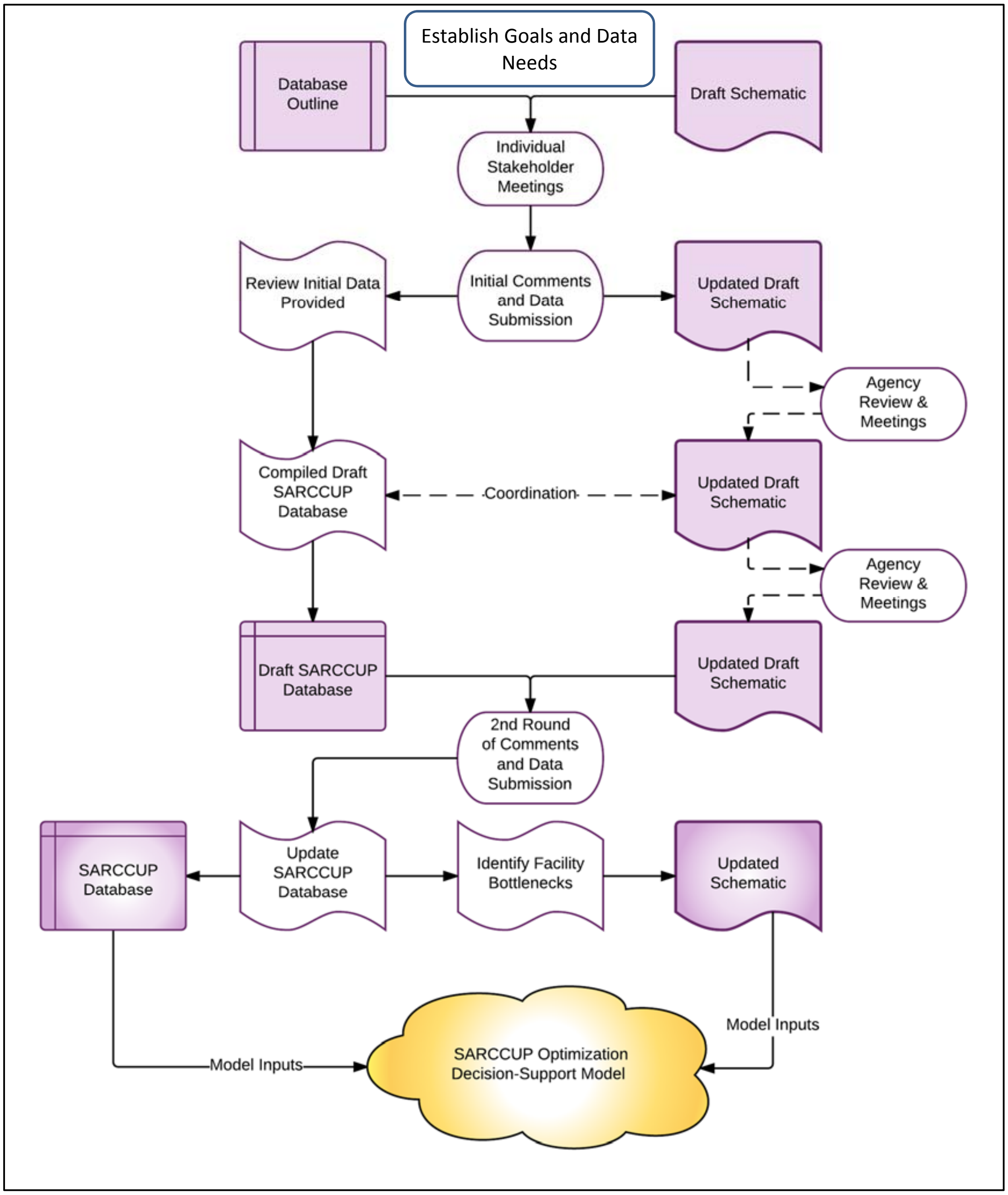
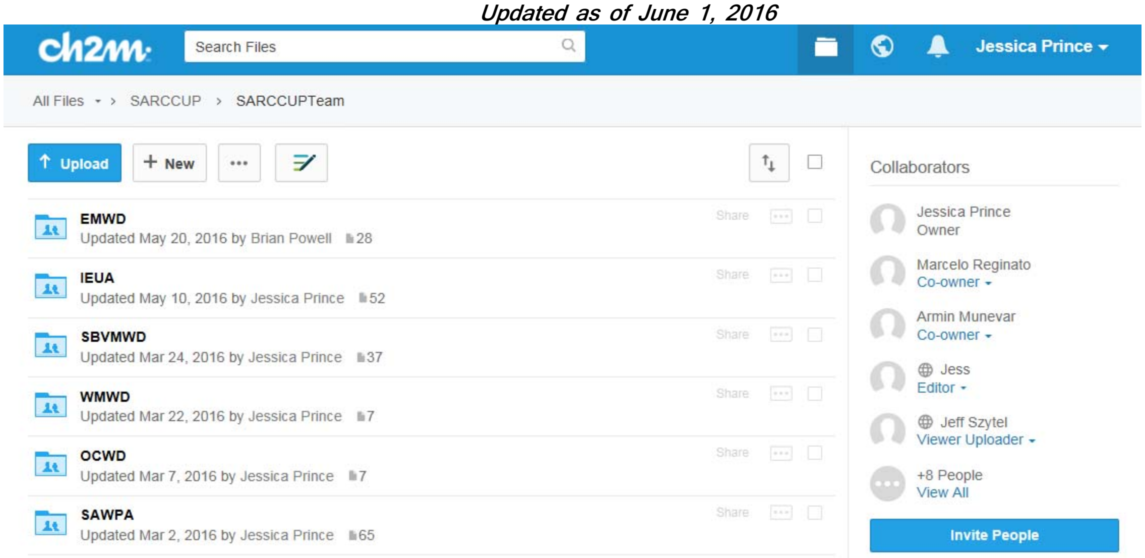


Figure 3. Screenshot of Box Data Collection Tool

Updated as of June 1, 2016



2.1. Regional Water Infrastructure

Regional water infrastructure includes key infrastructure and natural facilities that are needed to represent the physical system and could be represented in the model. This category includes both existing infrastructure and proposed SARCCUP facilities. Regional water infrastructure is necessary to be represented in the model to allow the user to simulate real-world conditions, place necessary constraints, and in turn provide results indicating bottlenecks or areas for optimization in running the SARCCUP Phase 1 project. These facilities were broken down into the following data subsets for data collection:

- Conveyance (Pipelines, Canals, Interties)
- Turnouts
- Booster Stations
- Extraction/Injection Wells
- Desalters
- Water Treatment Plants (WTP)
- Water Reclamation Facilities (WRF)
- Recharge Basins
- Surface Reservoirs

These data sets capture existing and planned capacities in 5-year increments from 2015 to 2040, as well as connection points and known constraints. Table 2 includes a breakdown of the total count of facilities shown in the SARCCUP database.

Table 2: Regional Water Infrastructure

Type	SARCCUP Database Facility Count
Conveyance	61[1]
Turnouts	28
Booster Stations	10
Extraction/Injection Wells	10
Desalters	7
Water Treatment Plants	16
Water Reclamation Facilities	20
Recharge Basins	37[2]
Surface Reservoirs	9

Note:
[1] May include multiple reaches of same conveyance.
[2] This includes all infrastructure associated with SARCCUP use of recharge at the four banks.

A major aspect of the data collection was to include capacities and gain a better understanding of the recharge basins within the study area. A list of recharge facilities (recharge basins and injection wells) were identified and captured on the model schematic and are included in full in the SARCCUP Database. Table 3 provides a summary of total recharge capacity by groundwater basin. Not all the recharge capacity (existing or expanded) in a basin will be available to SARCCUP operations, therefore a column was added on Table 3 indicating how much of the extraction is or will be available to the SARCCUP project and was modeled in the DSM.

A list of extraction facilities were identified and captured on the model schematic and are included in full in the SARCCUP Database. Table 4 provides a summary of total extraction capacity by groundwater basin. Not all the extraction capacity (existing or expanded) in a basin will be available to SARCCUP operations, therefore a column was added on Table 4 indicating how much of the extraction is or will be available to the SARCCUP project and was modeled in the DSM.

Table 5 is a summary of the system connectivity and shows how a giving basing can provide water to an agency. Inexistent connections are marked with an “x” but the model has the capability to evaluate connections between all basins and all agencies.

Table 3: Groundwater Basin Recharge Capacity

Groundwater Basin	Total Recharge Capacity (AFY)			Comments
	Existing	Expanded	DSM assumption	
Chino[1]	90,500	90,500	90,500	Data provided from A. Campbell
SBBA[2]	435,200	873,200	124,000	Data provided from B. Tincher
San Jacinto[3]	30,000 - 40,000	60,000 - 70,000	6,500	San Jacinto Water Supply Evaluation Long-Term Water Supply Scenarios
Elsinore[4]	3,000	3,000	1,500	Supply from MWD

Notes:

[1]Includes the following facilities: 8th, Banana, Brooks, College Heights, Declez, Ely, Etiwanda Debris Basin, Hickory, Jurupa, Lower Day, Montclair, RP-3, San Sevaine, Turner, Upland, and Victoria

[2]Includes the following facilities: SAR Spreading Grounds, Devil Canyon and Sweetwater Basins, Waterman Basins, East Twin Creek Spreading Grounds, Mill Creek, Cactus Basin, Patton Basins, LCN WRP Ponds, Redlands Recharge Basins, Proposed Lytle Creek Recharge Basin, Proposed Cajon Creek Recharge Basin, Proposed Cable Creek Recharge Basin, Proposed City Creek Recharge Basin, Proposed Plunge Creek Recharge Basin, Proposed Mission-Zanja Creek Recharge Basin, Proposed San Timoteo Creek Recharge Basin, and Proposed Warm Creek Recharge Basin

[3]Includes the following facilities: IRRP Ponds, Grant Ave. Ponds, Proposed Mountain Ave. West Recharge Facilities

[4]From the Draft 2015 EVMWD UWMP, Chapter 6.0

Table 4: Groundwater Basin Extraction Capacity

Groundwater Basin	Total Extraction Capacity (AFY)			Comments
	Existing	Expanded	DSM assumption	
Chino[1]	0	17,000	17,000	Data provided from A. Campbell
SBBA[2]	7,500	45,000	20,000	Data provided from B. Tincher
San Jacinto[3]	16,600	49,700	6,500	Data provided from B. Powell EMWD_DSM_SuppliesDemands02.xlsx
Elsinore	3,000	3,000	1,500	Data provided by R. Shaw

Notes:

[1]Includes the following wells: South Pressure Zone Extraction Wells

[2]Includes the following facilities: Baseline Feeder Wells, BHCUP Wells, Proposed SARCCUP SBBA Wells Existing is 2015 and fully expanded is 2020.

[3]Includes the following facilities: Hemet/San Jacinto Water Management Plan area Extraction Wells: San Jacinto Upper Pressure (EMWD and IRRP Wells), Hemet South, and Canyon. Existing is 2015 and fully expanded is 2040

Table 5: Matrix of Direct Delivery/Transfers among Agencies

		From Agency System/GW Basin			
		Elsinore GW Basin	Chino GW Basin	SBBA GW Basin	San Jacinto GW Basin
To SARCCUP Agency	OCWD	x	South Pressure Zone Extraction Wells to SAR	SBBA Extraction Wells SAR	x
	WMWD	Dual use ASR wells	x	RPU Wells unused capacity/West Riverside Canal	San Jacinto Extraction Wells Potable pipe network
	IEUA	x	South Pressure Zone Extraction Wells, Member Agency Wells	SBBA Extraction Wells 48 inch baseline feeder extension	x
	SBVMWD	x	48 inch baseline feeder extension	SARCCUP Wells RPU Wells MWDSC Inland Feeder	x
	EMWD	x	x	x	San Jacinto Extraction Wells

SARCCUP projects:

- Dual use ASR wells
- South Pressure Zone Extraction Wells
- 48 inch baseline feeder extension
- SBBA extraction wells
- Alabama st. pipeline/Redlands PS
- San Jacinto Extraction wells

2.2. Regional Water Budgets

Regional water budgets include historical and projected water supplies and demands for the Agencies and for the retail agencies in their services areas, where available. Historical supply data includes annual and monthly water supplies by source for the most recent available period, 2015. The historical supply data, associated with hydrologic conditions, is used to apply seasonal usage patterns to help identify potential bottlenecks and constraints.

The future water supply and demand projections are taken from the 2015 Urban Water Management Plans (UWMPs) for each Agency. The future water supplies and demands, as reported in the UWMPs, will form the basis for future flows for the DSM. Similar to the regional water infrastructure, this data is important in simulating the constraints and needs of the system as a whole as well as interagency support.

Water quality data collection has focused on total dissolved solids (TDS) for each of the major supply sources for SARCCUP. In the future, water quality could be used in the model to assess whether substantial changes in salinity occur due to the SARCCUP operations. The data set includes the Basin Plan Objectives for the groundwater management zones and inland surface streams. TDS concentrations for raw and treated imported water from various locations are also included. The full water quality data set can be found in the SARCCUP Database.

2.2.1. Agency Demands

The following tables summarize the total historic and future demands for each Agency. The SARCCUP database includes a breakdown of demands by customer type for each retail agency, where available.

Table 6 shows the Agency historical and future project demands, respectively. The full breakdown of demands by agency including demand type information is shown in the SARCCUP Database.

Table 6. Agency Historical Deliveries (2015) and Future Projected Demands (2020-2040), AFY

SARCCUP Agency	Year Type	Historical Deliveries	Future Projected Demands				
		2015	2020	2025	2030	2035	2040
SBVMWD	Calendar	137,046	194,791	203,452	210,825	218,940	226,369
WMWD[1]	Calendar	79,895	110,787	114,040	123,516	122,895	132,999
EMWD	Annual	145,968	197,901	218,700	235,800	252,600	268,200
IEUA[2]	2015: Normalized FY, 2020-2040: Calendar	199,702	210,588	225,923	242,732	254,721	278,017
OCWD[3]	FY	442,048	462,807	483,564	504,321	525,079	546,082
SARCCUP Total		1,000,203	1,176,874	1,245,679	1,317,194	1,374,235	1,451,667

Note:
[1] Annual totals are inclusive of demands on WMWD only, including imported water from Metropolitan and desalted groundwater. It does not include demands that would be met by other local supplies. Reference is from the WMWD Final 2015 UWMP, Table 4-7 note.
[2] Total regional demand includes imported water, which is provided by IEUA and WFA, recycled water, groundwater and local surface water. These values represent total demand from each agency that are met through several different supply sources. Recycled water demand for agriculture use is not included in these totals because it was excluded from the land use based projections.
[3] Total demand includes the use of groundwater, surface water from Santiago Creek and Irvine Lake, recycled water, and imported water. This agency demands were later updated in the model to constant 447,000 AF/yr

2.2.2. Imported and Local Supplies

The Agencies have access to multiple sources of water supply, as summarized below. The SARCCUP database included in Attachment A has a breakdown of historic and future supply sources by retail agency, where available. Supply sources include:

- Imported Water
- Local Groundwater
- Desalted Groundwater
- Local Surface Water
- Recycled Water
- Water Purchases from others

The distribution of water supplies by source, for SARCCUP Agencies is shown for 2015, 2025, and 2040 on Figures 4, 5, and 6, respectively, and numeric totals for all years in Table 7.

Figure 4. SARCCUP Agencies Supply Contribution by Source, 2015

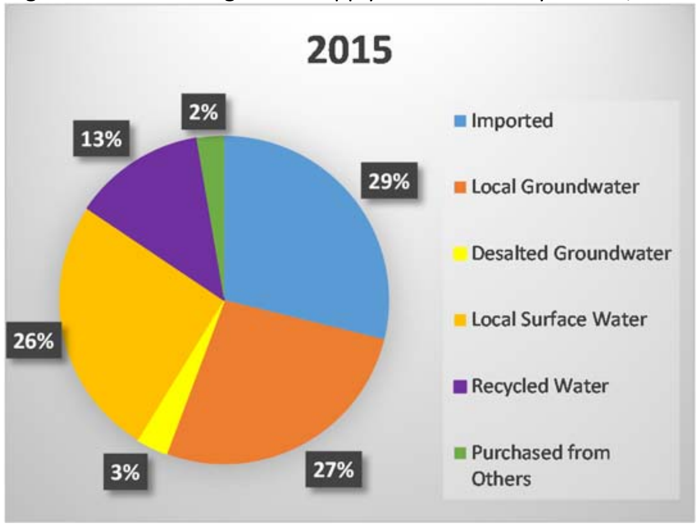


Figure 5. SARCCUP Agencies Supply Contribution by Source, 2025

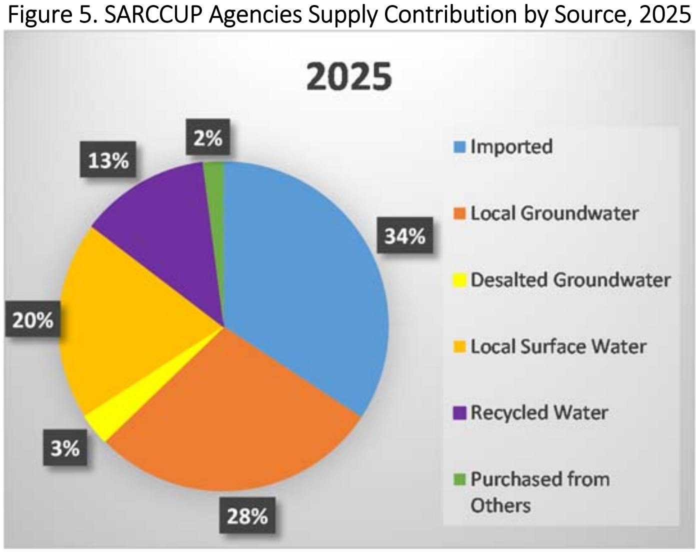


Figure 6. SARCCUP Agencies Supply Contribution by Source, 2040

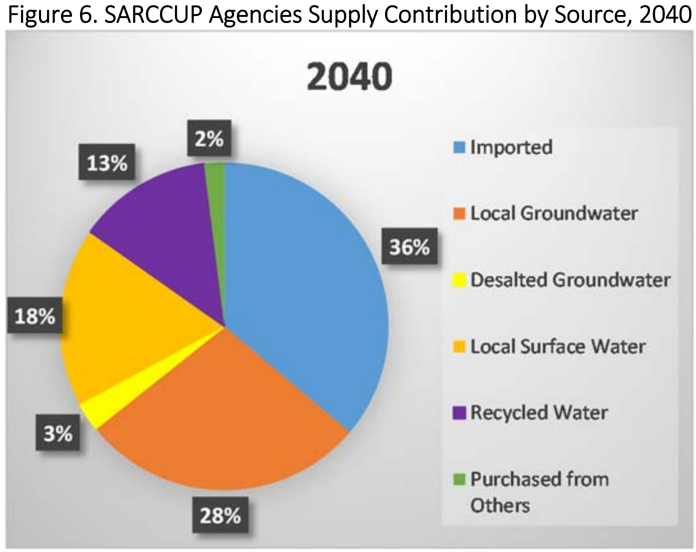


Table 7. SARCCUP Future Total Supplies (AFY)

Supply Source	2015	2020	2025	2030	2035	2040
Imported	263,067	404,983	428,278	453,958	477,979	498,515
Local Groundwater	245,009	334,963	356,016	376,804	387,564	387,564
Desalted Groundwater	27,641	35,467	38,567	38,567	38,567	38,567
Local Surface Water	234,431	243,960	243,960	243,960	243,960	243,960
Recycled Water	117,195	137,409	157,138	165,598	174,258	182,218
Purchased from Others	24,661	30,100	25,375	26,496	28,217	27,389
Total	**912,004**	**1,186,882**	**1,249,334**	**1,305,383**	**1,350,545**	**1,378,213**

SWP historical deliveries and allocation percentages are available from the SWP Analysis Office (SWPAO) from 1996 through present. Projected SWP deliveries and Table A allocations (percentage of full Table A) are available in the SWP Delivery Capability Report for a range of scenarios considering climate change projections and California Water Fix implementation. These projections, developed through DWR's CALSIM II planning model simulations, are available using adjusted hydrologic conditions for the sequence of 1922-2003. CH2M has been assisting in the development of many of these CALSIM II model simulations and has separately developed a Water Transfer Analysis tool that evaluates the capability to transfer purchased water across the Delta and through SWP facilities for any CALSIM II simulation.

2.3. Water Quality

The current version of the DSM does not model water quality, however it is a capability that can be implemented in the future is.

Water quality data collection has focused on total dissolved solids (TDS) for each of the major supply sources for SARCCUP. Water quality will be used in the model to assess whether substantial changes in salinity occur due to the SARCCUP operations. The data set includes the Basin Plan Objectives for the groundwater management zones and inland surface streams. TDS concentrations for raw and treated imported water from various locations are also included. Table 8 provides a summary of the TDS for the SARCCUP basins. The full water quality data set can be found in the SARCCUP Database, Attachment A.

Table 8. Recharge Basin Water Quality

Groundwater Basin	Management Zone	TDS Water Quality Objective, mg/L
San Bernardino Valley & Yucaipa/Beaumont Plains	Beaumont -- "max benefit"	330
	Beaumont -- "antideg"	230
	Bunker Hill-A	310
	Bunker Hill-B	330
	Lytle	260
	San Timoteo -- "max benefit"	400
	San Timoteo -- "antideg"	300
	Yucaipa -- "max benefit"	370
	Yucaipa -- "antideg"	320

San Jacinto Basins	Canyon	230
	Hemet-South	730
	Lakeview/Hemet-North	520
	Menifee	1020
	Perris-North	570
	Perris-South	1260
	San Jacinto-Lower	520
	San Jacinto-Upper --"max benefit"	500
	San Jacinto-Upper --"antideg"	320
Chino, Rialto/Colton & Riverside Basins	Chino-North -- "max benefit"	420
	Chino 1 -- "antideg"	280
	Chino 2 -- "antideg"	250
	Chino 3 -- "antideg"	260
	Chino-East	730
	Chino-South	680
	Colton	410
	Cucamonga -- "max benefit"	380
	Cucamonga -- "antideg"	210
	Rialto	230
	Riverside-A	560
	Riverside-B	290
	Riverside-C	680
	Riverside-D	810
	Riverside-E	720
	Riverside-F	660
	Prado Basin	surface water objective of 700 applies
Elsinore/Temescal Valleys	Arlington	980
	Bedford	unknown
	Coldwater	380
	Elsinore	480
	Lee Lake	unknown
	Temescal	770
	Warm Springs Valley	unknown
Orange County Basins	Irvine	910
	La Habra	unknown

Orange County	580
Santiago	unknown

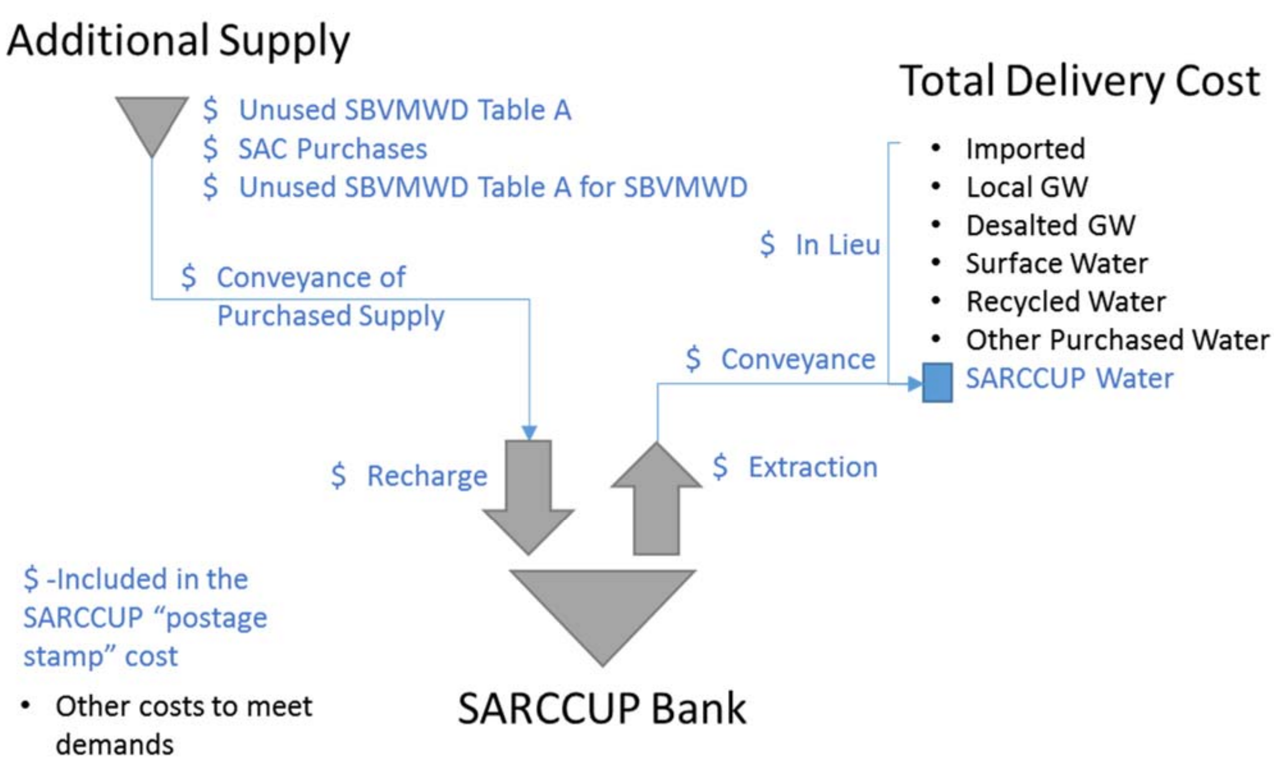
2.4. Costs

This data category includes unit costs related to SARCCUP program implementation and operation. Capital costs for new projects are not included in the DSM. The costs currently include in the DSM are the following:

- Cost of purchased supply
- Cost of recharge conveyance (O&M)
- Cost of recharge (O&M)
- Cost of extraction (O&M)
- Cost of delivery conveyance or wheeling (O&M)
- Cost of exchanges

Figure 7 illustrates all the cost associated with water moving through the system and highlights the costs associated with the SARCCUP postage stamp rate. The postage stamp rate concept estimated the average unit cost of SARCCUP water based on all the different costs associated with supplies, conveyance, recharge and extraction. The postage stamp rate concept averages the cost of SARCCUP operations for all five agencies and is estimated by model runs. The model does not apply a capital cost to the postage stamp cost, this was kept separate but should be added for a total project cost.

Figure 7: Cost associated with water moving through the system highlighting the costs associated with the SARCCUP postage stamp concept.



Costs do not include facility construction, but include energy and treatment costs, water purchases and transfers, and other O&M activities. Table 9 presents a summary of the unit costs that were developed and currently incorporated into the SARCCUP DSM. Table 9a shows the recharge and Table 9b shows the extraction costs.

A data collection summary table was produced as part of the Data Collection task (Task 1) for the SARCCUP DSM (Appendix A). The data described on the table provided critical input for the model development phase, which is discussed throughout this document. The model was developed to an appropriate level of detail to answer key SARCCUP bank operation questions. While most of the critical information has been compiled and was ready for use in the DSM not all information was used.

The critical information obtained from the data collection were system demands and supplies, recharge and extraction capacity, system connectivity, and costs.

Table 9a: SARCCUP Recharge Costs

Recharge Cost ($/AF)

From	To	Supply	Conveyance	Recharge	Total	Notes
SBVMWD Table A	SBBA (SBVMWD)	$118		$30	$148	Supply cost for SBVMWD customers is lower because SBVMWD customers pay property taxes to SBVMWD
SBVMWD Table A	SBBA (others)	$666		$30	$696	Supply cost set at 2017 untreated MWD Tier 1 rate (* RTS and capacity charges not included, but if charges occur they would be included in postage stamp rate). Recharge cost per B. Tincher.
SBVMWD Table A	Chino	$666		$40	$706	Supply cost set at 2017 untreated MWD Tier 1 rate. Recharge estimated as same as SBBA. If through recycled, then $100-125 in-lieu cost.
SBVMWD Table A	Elsinore	$979		$120	$1,099	Supply cost set at 2017 TREATED (must put treated to recharge) MWD Tier 1 rate. Recharge estimated as injection well cost.
SBVMWD Table A	San Jacinto	$666		$75	$741	Supply cost set at 2017 untreated MWD Tier 1 rate. Recharge cost per B. Powell.
SWP Transfer	SBBA	$350	$50	$30	$430	Supply cost estimated based on 50% of dry year Sacramento Valley year purchases. Conveyance estimated by B. Tincher, SBVMWD does not have a published wheeling rate. Recharge cost per B. Tincher.
SWP Transfer	Chino	$350	$413	$40	$803	Supply cost estimated based on 50% of dry year Sacramento Valley year purchases. Conveyance (Rialto Feeder, Etiwanda Pipeline, and Devil Canyon-Azusa Pipeline) assumed at MWD system access plus power rate. Recharge estimated as injection cost.
SWP Transfer	Elsinore	$663	$413	$120	$1,196	Supply cost estimated based on 50% of dry year Sacramento Valley year purchases. Plus treated surcharge. Conveyance (Etiwanda Pipeline to Lower Feeder) assumed at MWD system access plus power rate. Recharge estimated as same as SBVMWD recharge costs.

SWP Transfer	San Jacinto	$350	$413	$75	$838	Supply cost estimated based on 50% of dry year Sacramento Valley year purchases. Conveyance (Inland Feeder, Central Feeder, Alabama Pipeline) assumed at MWD system access plus power rate. Recharge cost provided by B. Powell.

Table 9b: SARCCUP Extraction Costs

From	To	Extraction	Conveyance	Wheeling	Total	Notes
SBBA	SBVMWD	$70	$50	$ -	$120	Extraction cost per B. Tincher. Assumed nominal conveyance cost, and no wheeling cost if delivered to overlying agency.
SBBA	IEUA	$185	$50	$ -	$235	Energy to extract and boost to IEUA through Baseline Feeder Extension, per B. Tincher. Valley District has no published wheeling cost.
SBBA	WMWD	$70	$131	$230	$431	Estimated cost to deliver through Riverside Public Utilities, per WMWD. Feel free to use ~$500/AF for conveyance through City of Riverside from SBBA to WMWD. Also, EVMWD confirmed that it costs $120/AF to inject and extraction capacity is 1,500 AFY However, the recharge capacity is 1,500 AFY (4,500 AF total for the full 10 year cycle of recharge).
SBBA	EMWD				$ -	No bank conveyance. MWD will not allow groundwater pumped into their system.
SBBA	OCWD	$70	$25	$ -	$95	Conveyance via Santa Ana River, assume placeholder 20-30% loss. So need to pump 1.2 AF to get 1AF. Wheeling a placeholder from B. Tincher
Chino	SBVMWD	$225	$50	$ -	$275	Extraction cost per CH2M. Assumed conveyance cost is same as SBBA-IEUA. Assumed nominal wheeling cost.
Chino	IEUA	$225	$ -	$ -	$225	Extraction cost per IEUA. Assumed nominal conveyance cost, and no wheeling cost if delivered to overlying agency.
Chino	WMWD				$ -	No bank conveyance.
Chino	EMWD				$ -	No bank conveyance.

Chino	OCWD	$100	$ -	$ -	$100	Extraction cost per CH2M. Conveyance (Santa Ana River, Or Yorba Linda Feeder or Etiwanda Pipeline) assumed at MWD system access plus power rate. Assumed nominal wheeling cost. If in SAR, loss may be 10-15%.
Elsinore	SBVMWD				$ -	No bank conveyance.
Elsinore	IEUA				$ -	No bank conveyance.
Elsinore	WMWD	$250	$ -	$ -	$250	Extraction cost per CH2M. Assumed nominal conveyance cost, and no wheeling cost if delivered to overlying agency. Per. R. Shaw.
Elsinore	EMWD				$ -	No bank conveyance.
Elsinore	OCWD				$ -	No bank conveyance.
San Jacinto	SBVMWD				$ -	No bank conveyance.
San Jacinto	IEUA				$ -	No bank conveyance.
San Jacinto	WMWD	$155	$50	$ -	$205	Extraction cost per CH2M. Assumed conveyance cost is same as SBBA-IEUA. Assumed nominal wheeling cost.
San Jacinto	EMWD	$155	$ -	$ -	$155	EVMWD confirmed that it costs $120/AF to inject/extract.
San Jacinto	OCWD			$ -	$ -	No bank conveyance.

3. Model Description

The model description is divided in seven subsections, modeling platform used, optimization approach, hydrology and water supply availability to fill SARCCUP bank, regional water conveyance, bank recharge and extraction operations, groundwater storage and accounting, and modeled deliveries.

3.0. Modeling Platform

The SARCCUP DSM is developed in the general system dynamics modeling platform named GoldSim. GoldSim is a general simulation software solution for dynamically modeling complex systems in business, engineering, and science. GoldSim supports decision and risk analysis by simulating future performance while quantitatively representing the uncertainty and risks inherent in all complex systems. Organizations worldwide use GoldSim simulation software to evaluate and compare alternative designs, plans, and policies in order to minimize risks and make better decisions under uncertainty. GoldSim, 1) can handle all the complexities of the system, 2) provides for ease of use and alternative analysis, 3) provides a state-of-the-art modeling platform so as to not become outdated in a short time, 4) allows for ease of linkage to other analysis tools used by the agencies, 5) can be enhanced by agency staff and, 6) is relatively economical.

GoldSim makes available two versions of its software, the "pro" and the "player" versions. GoldSim models are developed with the GoldSim Pro version of the software. The pro version gives the user full control of the model design and development, including model equations, inputs and outputs, and controls which variables is exposed to the user in the player version. The player version is a runtime version of the software, is free of charge, and can be downloaded from the GoldSim website. The player version allows the user to change input variables, interact with the user interfaces (dashboards), to run the model, and to view and export results. However, with the player version, the user cannot change the internal model equations or variables except those that were explicitly exposed during the model development. A "pro" version of GoldSim is provided and agency staff is trained how to use the software to enhance the model and run the model.

The GoldSim modeling platform has the ability to achieve the following objectives:

- The ability to customize operating rules or simulation procedures
- The ability to transfer information with existing external dynamic link libraries (DLLs)
- The ability to iterate within a time-step to solve non-linear problems and perform pseudo-optimization
- The ability to create submodels for subsystem partitioning or forecast-based decision-making
- The ability to perform probabilistic simulation for use in alternative proposed project analyses, climate change studies, or stochastic simulations.

Other factors that were considered important are the ability of the modeling platform to understand various hydraulic units, data exchange between other programs or spreadsheets, and the handling of array constructs.

The SARCCUP DSM model currently includes on GoldSim file. In the future is possible to link model results to Microsoft Excel spreadsheets, and a range of post processing files to facilitate the interpretation of the model results.

3.1. Optimization Approach

The SARCCUP DSM utilizes a guided optimization approach to determine the range of operations and needed facilities in order to minimize the net cost of delivery of SARCCUP supply to the Agencies. The optimization approaches include (1) an objective function that is to be minimized (or maximized), (2) decision variables that are typically adjusted to achieve optimization, and (3) constraints that provide physical or operation limits on the optimization.

For the SARCCUP DSM, the objective function can be described as to achieve recharge and extraction of SARCCUP water, while minimizing net cost of delivery of SARCCUP supply to agencies.

Some optimization is included in the DSM equations, for example, the model will recharge the cheapest basins first or during an exchange of storage it will exchange giving preference to basins where water could be extracted at lowest cost. Another optimization variable is the target storage that an agency would like to have on each basin. Although it might be intuitive that in a small bank with limited connectivity each agency would like to keep most of the storage at their correspondent groundwater bank, in a larger bank condition with multiple connectivity options the cheapest operation might not be intuitive. The SARCCUP DSM offers an optimization routine to check bank operation costs under different storage target scenarios.

SARCCUP costs are the sum of:

- Cost of Purchased Supply +
- Cost of Recharge Conveyance +
- Cost of Recharge +
- Cost of Extraction +
- Cost of Regional Conveyance or Wheeling +
- Cost of Exchanges

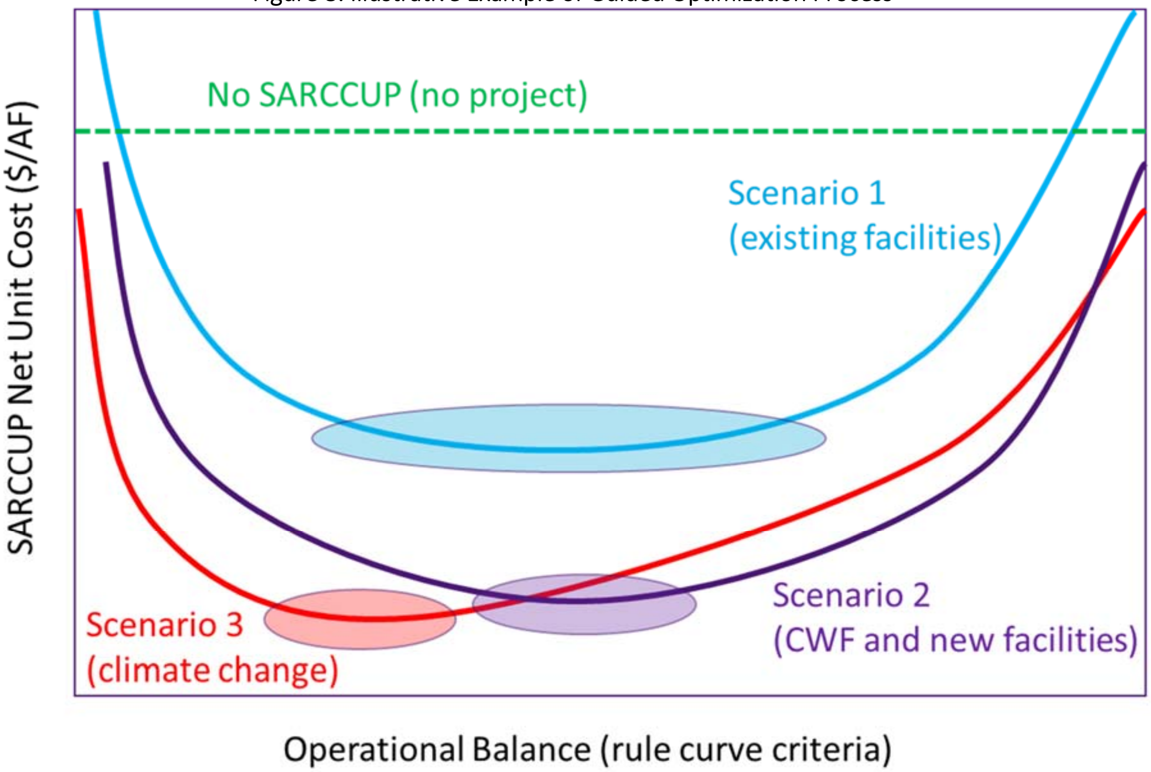
A unit net cost is computed over the time horizon of the simulation (2020-2040) as the total SARCCUP cost (sum as described above) divided by the total SARCCUP deliveries. This unit net cost (or postage stamp rate) serves as the primary objective function that was optimized through the DSM.

The optimization was guided through rule-based criteria (decision variables) that determine the amount or balance of storage to target in each SARCCUP bank storage for each agency, the bank volumes that should trigger storage exchanges, and the bank volumes that limit storage exchanges. These criteria are similar to reservoir “rule curves” that are used to target storage balancing in surface water reservoirs.

The rule curves variables and GoldSim optimization methods were utilized to search for the range of “optimal rule curves” that minimize the SARCCUP unit cost. Thousands of individual rule curves were explored through this process and automated methods narrowed these to a range that produce the lowest unit costs. This process is conceptually illustrated on Figure 8. On this figure the “optimal” regions are those shaded and may be different depending on the scenario.

The constraints are primarily related to assumed infrastructure and policy that may limit the water available for SARCCUP, the ability to recharge or extract SARCCUP water, or the ability to convey water through the regional system to deliver to SARCCUP member agencies. These are further discussed under the Regional Water Conveyance section.

Figure 8: Illustrative Example of Guided Optimization Process

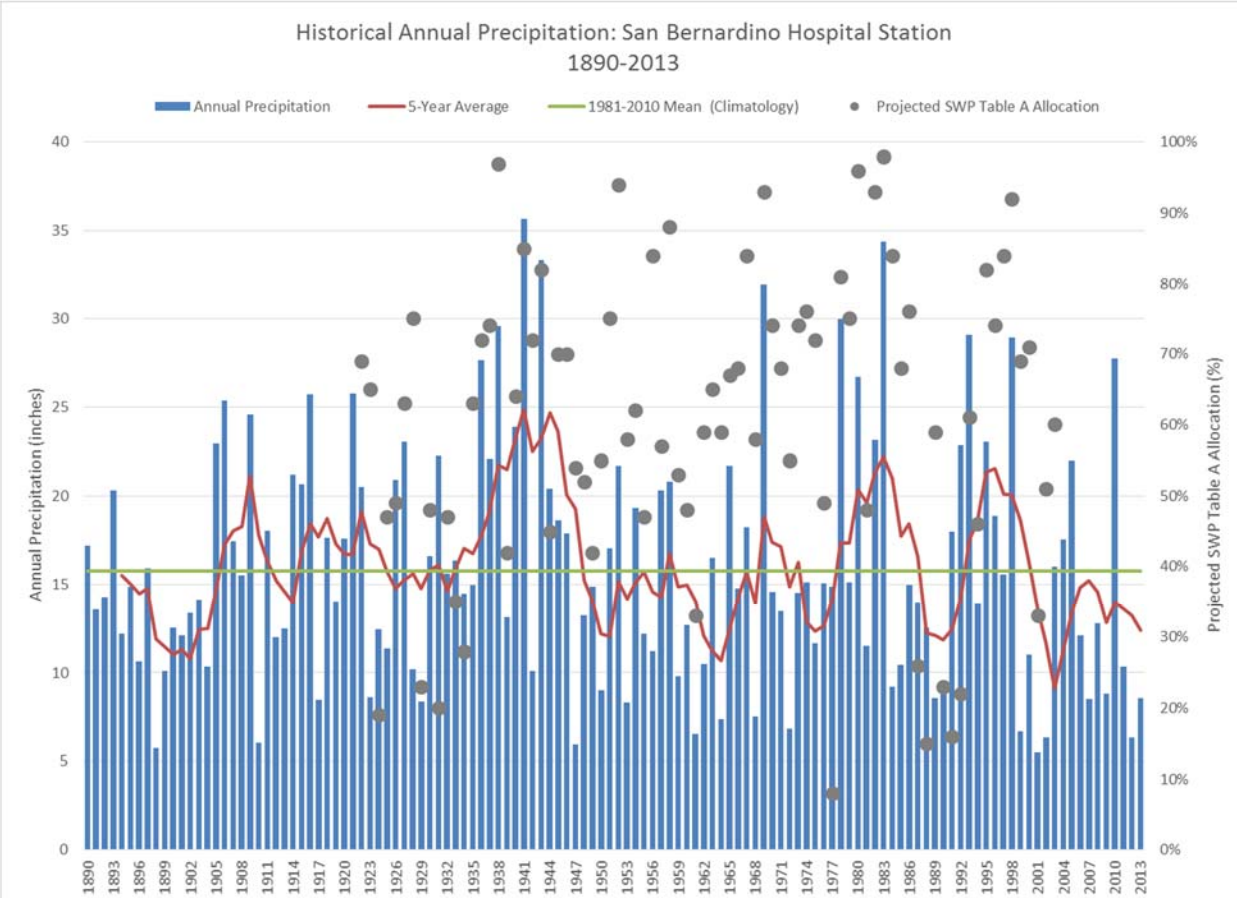


3.2. Hydrology and Availability of SARCCUP Supply

As currently envisioned, supply for SARCCUP groundwater bank would originate from water purchases from Valley District (excess SWP Table A supplies) and from willing sellers that would use the State Water Project (SWP) for conveyance. Based on recent water transfer markets, it is assumed that there would be willing sellers (pre-1914 water rights) in all wet, or above-average years, when SARCCUP would be purchasing water.

Water purchased in the Sacramento Valley must flow downstream, be transferred across the Sacramento-San Joaquin Delta, and move through the SWP system south of the Delta before delivery into the SARCCUP area. The CALSIM II model simulations performed for the Department of Water Resources 2015 SWP Delivery Capability Report is utilized to estimate both the SWP allocation in future years and the amount of SARCCUP purchased supply that could actually be transferred to southern California. Figure 9 shows the historical annual and 5-year precipitation in San Bernardino in comparison to the projected SWP Table A allocation based on the Delivery Capability Report for 1922-2003 hydrologic conditions. While in some years there is a corresponding wet year (San Bernardino) with high SWP Table A allocation, this correlation is not consistent. This poor correlation is expected, as the water supply for the SWP is generated in the Sacramento Valley with a very different hydrologic regime, than that of the service areas of SARCCUP agencies.

Figure 9: Local Hydrology and Projected SWP Table A Allocation

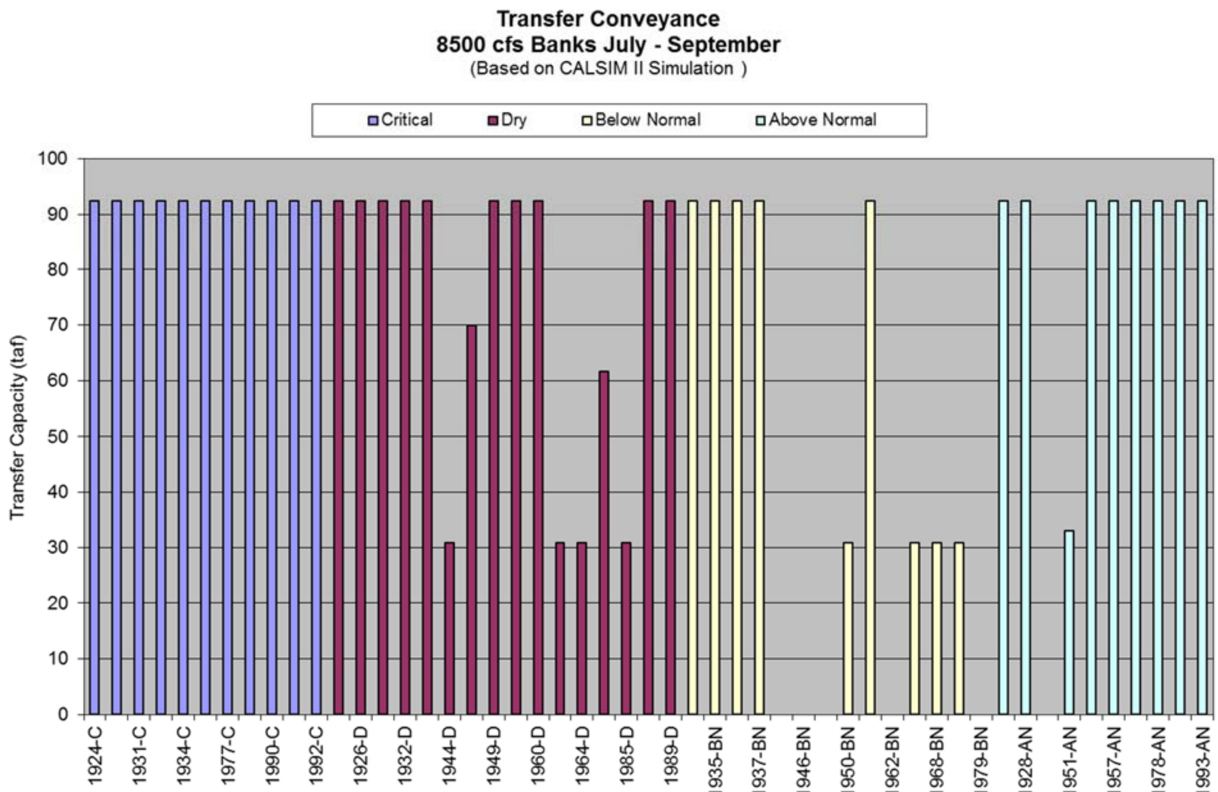


As mentioned above, the actual amount of SARCCUP supply from north of the Delta that can be conveyed into the watershed is limited to the amount of capacity available in the Delta. CH2M estimated the amount of capacity available in the Delta using an offline Water Transfer Tool developed by CH2M that operates as a post-processor to CALSIM II studies. The tool determines whether capacity is available in the Delta to transfer SARCCUP water, given the fishery and water quality regulatory conditions. Figure 10 shows an example of the results from this tool for an assumed 92,000 AFY purchase. Under some hydrologic conditions and operational assumptions, less than half of the purchased quantity was capable of being transferred due to restrictions on the SWP operations. The Water Transfer Tool was updated for the latest assumptions included in the CALSIM II modeling of the SWP Delivery Reliability Report and annual purchase supplies are limited to that which can be recharged in the SARCCUP. The annual purchase amounts are flexible inputs into the tool and can be adjusted by the user.

SWP operational scenarios include the current National Marine Fisheries Service and U.S. Fish and Wildlife Service Biological Opinions in the Delta, varying delta conveyance (existing or California Water Fix), and climate change projections.

Water that is available for import into the SARCCUP area is assumed to be available from May 1 through maximum April of the next year (12 months) and reflects some ability to regulate supplies on the SWP. Water is imported at the earliest opportunity beginning May 1, and, if not fully imported by 12 months (or the number of recharge months determined by the user) due to limits within the SARCCUP service facilities, it is assumed lost (no carryover). The loss of transferred supply is a very unlikely occurrence due to the relatively small quantities considered, and the large recharge and storage capacity available within the SARCCUP banks.

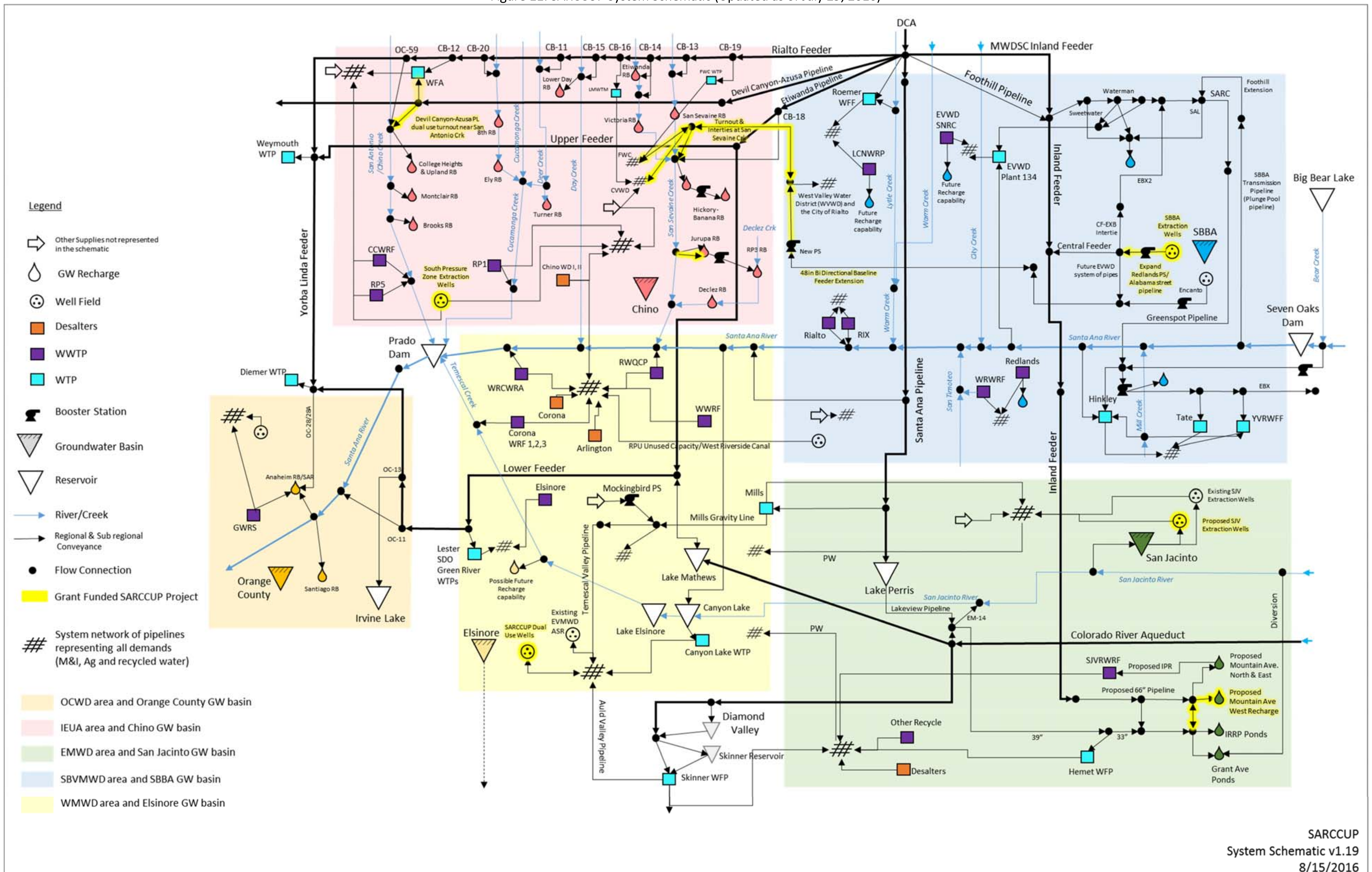
Figure 10: Illustrative Example of SWP Transfer Capacity from the Water Transfer Tool (assumed 92 TAFY purchase)



3.3. Regional Water Conveyance

The SARCCUP DSM regional water conveyance schematic is a simplified representation of the real system. The system simplification is enough to cover all the necessary features to evaluate SARCCUP operation without adding details that are either irrelevant or of minor impact to the project operations. The CH2M team developed a system schematic which demonstrates the interconnectivity of the regional infrastructure, groundwater banks, and proposed SARCCUP projects. The schematic is critical to the conceptualization of the system and the major elements involved in the decision support model. Figure 11 shows the SARCCUP system schematic which also includes facilities that are not specifically needed by SARCCUP. In general, the schematic includes the imported water interconnections, groundwater basins, and important agency water supplies that influence the ability to convey or store water.

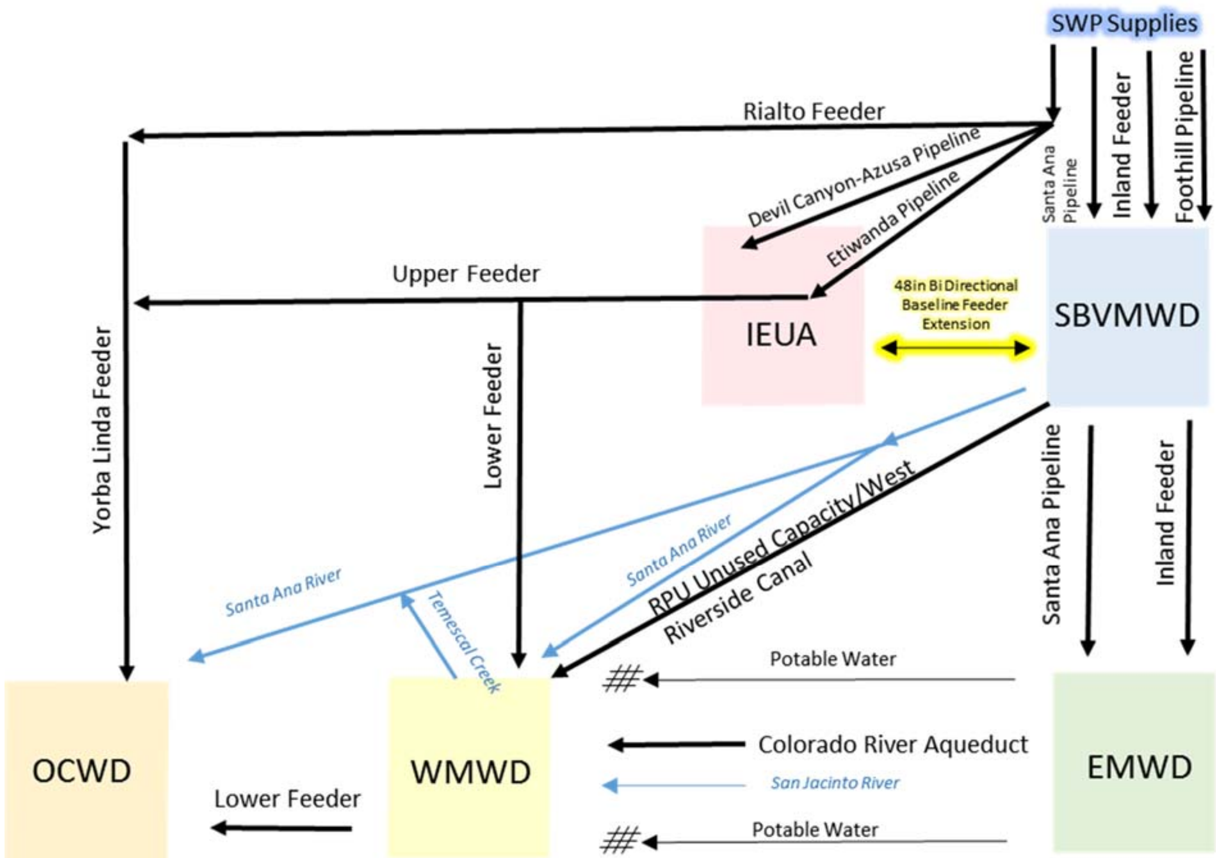
Figure 11: SARCCUP System Schematic (Updated as of July 29, 2016)



This page is intentionally left blank.

During model development, facilities that are not needed for SARCCUP were removed using a top down approach that starts by identifying the core elements (groundwater basins, main connections, grouped total extraction, and grouped recharge) and then adds detail, wherever necessary. The connectivity among the agencies that demonstrates how water can be recharged and then extracted and conveyed to the agencies is the backbone of the system. Both the connectivity and the cost of conveyance will ultimately dictate the optimal, or lower cost, operation of the groundwater bank. The resulting model is presented on Figure 12. Each link on the figure has physical and operational limitations (e.g capacity, losses, seasonality, pump stations etc.), and a cost for moving water. The cost is based on simulated operations.

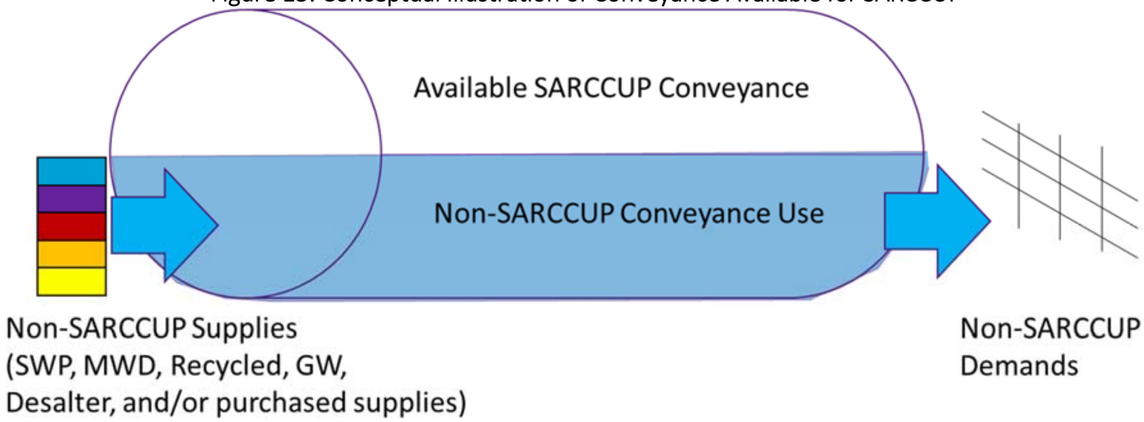
Figure 12: Simplified Conceptual System



The system presented in Figure 12 may be expanded to include additional limitations within the individual agencies which could result in a final model that looks more like Figure 11.

SARCCUP and agency conveyance capacity could limit the ability to move SARCCUP water to recharge basins or to the agencies. Local, or non-SARCCUP, water is given priority over SARCCUP water in non-SARCCUP conveyance facilities. Figure 13 graphically depicts the use of non-SARCCUP water in the regional and local conveyance system and illustrates the capacity available for SARCCUP conveyance.

Figure 13: Conceptual Illustration of Conveyance Available for SARCCUP



3.4. Recharge and Extraction

SARCCUP bank recharge and extraction availability could limit the total amount of water that can be stored or removed from individual SARCCUP groundwater banks. The following sections explain the logic for recharge and extraction of SARCCUP water.

3.4.1. Recharge

The recharge of the SARCCUP water banks is driven by available capacity, target storage, and preferences (cost or other basis). The general rule for recharge to occur is:

- MWD cannot be under curtailment (Dynamic MWD curtain logic) or water year is critical, dry, or below normal (User defined Water Year based logic)
- Water year is wet or above normal
- Sacramento Valley or SBVMWD exceeding Table A allocation supplies are available

The model offers flexibility so the three items above can be slightly changed, for example, it is possible to change parameters that define when MWD is on allocation, determine which water years will be recharge years, and what is the total supply available to recharge SARCCUP.

The default SARCCUP groundwater basin recharging operation starts on May 1st and could last until end of April of next year, the user inputs are:

- Month when recharge starts
- Number of months that the recharge will last

The model default is to use available SBVMWD Table A water first, then Sacramento Valley purchases. The model decides which basin to recharge first on a daily basis, based on recharge and conveyance costs, and limited to recharge capacity and maximum supply availability in a day (also set as a user input). The model will recharge the cheapest basin first (up to daily conveyance limit or Basin capacity), then move to the next less expensive basins.

In the DSM, when water is available for recharge, as discussed in section 3.2 Hydrology and Availability of SARCCUP Supply, recharge occurs up to the maximum recharge capacity or up to available bank storage capacity, whichever is less. Additionally, conveyance limits in the network are taken into consideration and could further limit the amount of permissible recharge.

A list of recharge facilities (recharge basins and injection wells) available to the SARCCUP were identified and captured in the model schematic. Table 3 presented under section 2 includes a summary of the recharge capacity by groundwater basin. It is assumed that water can recharge the SARCCUP groundwater banks only through these facilities and only when SARCCUP supply is available. Each facility has a maximum recharge capacity that could be changed via model dashboards. The recharge capacity is an annual input value, therefore, if basins are not allowed to recharge for one full year, a reduction in recharge capacity is expected.

In the DSM, the decision to recharge one basin over another is based on definable criteria such as the target storage levels for each groundwater banks and least cost. The target storage levels were explored and optimized to achieve the lowest unit SARCCUP cost, as discussed in the Optimization Approach section 3.1.

Every unit of water recharged at a specific basin is split equally into five accounts. The model then in a second step exchanges storage among agencies to optimize the cost of the SARCCUP operation. The storage exchange is limited to storage volumes that agencies have in the different groundwater basins and are based on target storage levels.

3.4.2. Extraction

The decision to begin a “take” (extraction) is based on the hydrological conditions (MWD curtail years or user defined dry years). SARCCUP water is extracted to meet agency-specific SARCCUP demands during “locally dry” years. These periods can be indicated in the model in two different ways:

- User defined where the user can choose to indicate hydrological year types through a user-input annual time series, or
- Metropolitan Water District of Southern California (MWD) allocation projection dynamically calculated in the model.

Currently, the user-defined annual time series builds on the criteria that were used for the SBVMWD Bunker Hill Conjunctive Use Project, if the 5-year running average precipitation is lower than the long-term mean, this is considered a “locally dry” year. MWD dynamic calculations are described below.

MWD provides water to its member agencies through water supplies from the State Water Project and the Colorado River Aqueduct. In most years, MWD can provide deliveries to meet full requests for each of its member agencies. However, under multiple dry years, it is possible that MWD must allocate its supplies to each of its member agencies. This allocation process may result in less than full delivery to members of SARCCUP, or a penalty fee if members request more than their allocated amount.

A forecasting method has been developed, which includes a dynamic computation of the frequency and amount of and MWD allocation based on time-varying inputs of Colorado River and State Water Project deliveries to MWD. Deliveries to MWD from the Colorado River are derived from the modeling performed for the Colorado River Basin Study (Reclamation 2012). Deliveries to MWD from the State Water Project are derived from the modeling performed for the Sacramento-San Joaquin Basins Study (Reclamation 2016).

This method includes a simplified GoldSim storage element to represent the cumulative MWD system storage and system demands that deplete storage. Inflows into the storage element include the State Water Project and Colorado River supplies. Water is stored in the storage element and delivered to meet MWD demands (less local supplies) as derived from MWD's Integrated Resource Plan (2015). Total MWD system storage is assumed to be approximately 2.0 MAF consisting of Diamond Valley Lake, storage in terminal reservoirs of the State Water Project, groundwater banks, and other surface storage and agreements.

During wet and normal years, the MWD supplies exceed demand and MWD storage is increased. However, during dry years, supplies are insufficient to meet demands and MWD storage is used to meet demands. When MWD storage reaches low levels, water must be allocated to member agencies at less than full delivery to protect against future dry years. The SARCCUP modeling uses an adjustable minimum target storage level to trigger the need for allocation. At present, we have assumed that any year in which projected end of year storage levels fall below 1.5 MAF, allocations would be made such that a storage does not fall below this level.

Extraction is a function of MWD curtail or hydro year, both change on a calendar year basis. If the model is run with Allocation Option 2 (Dynamic MET Allocation) selected, then extraction from the SARCCUP bank can happen only if MWD is under curtailment (MWD total supplies minus the user defined threshold is below 2 MAF).

Extraction is limited by the maximum extraction capacity of the well fields of a specific basin. The SARCCUP well fields with their respective capacity are presented on the system schematic and summarized by basin in Table 4 presented under section 2.

Extractions from a groundwater bank(s) by an agency is a function of the amount(s) the agency has in the bank(s) and on the cost to move the water from the bank(s) to the agency.

The cost to move extracted water includes: extraction, conveyance or wheeling, and exchanges.

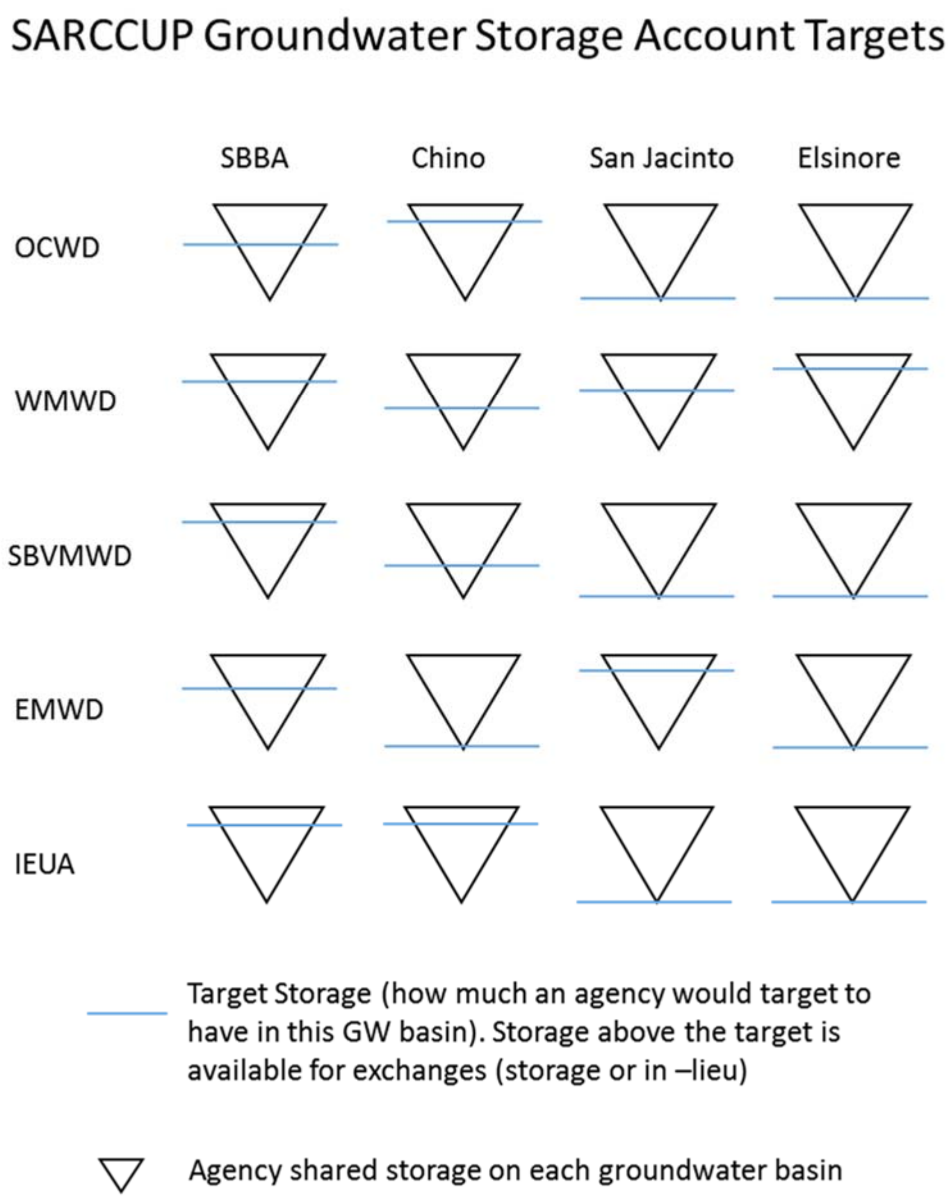
SARCCUP extraction capacity is equally shared among agencies for each model time step. This is true when demands are equal to, or exceed, the extraction capacity and all of the agencies have equal amounts stored in the banks. If an agency does not have the demand to fully utilize its extraction capacity at a specific basin, the idle capacity is equally shared among the remaining agencies, if needed. Also, it is assumed that all of the agencies will have similar extraction operations and the extraction target (60 TAF over 3 years of storage) is used during local, dry periods.

3.5. Groundwater Storage and Accounting

The model keeps track of each agency's SARCCUP supply with the use of water bank "accounts" for each agency. The first step on the implementation of the bank account was the implementation of an overall virtual SARCCUP GWB. The general virtual account is used to keep track of the total SARCCUP GWB water volume that an agency has at any point in time and to manage maximums that could be taken or stored in the SARCCUP GWB. The second step was to create five accounts in the four individual groundwater banks. The individual accounts at each groundwater banks are used to limit the water amount that can be physically drawn from a specific bank and to indicate when storage transfers or in–lieu transfers are necessary.

A system of storage targets for each agency on each groundwater basin was implemented in the DSM to facilitate the system optimization especially on model scenarios when potential different bank sizes and potential new agency connections need to be evaluated. Intuitively the overlaying agency would like to keep all its SARCCUP storage on the closest basin for extraction, however the most cost efficient alternative might require some different configuration when all costs and all agencies are taken into account. Figure 14 illustrates the concept of having target storages on each basin. The target storage determines if an agency can exchange storage (volume above target can be exchanged so another agency can achieve target).

Figure 14: Conceptual Illustration of groundwater storage accounts and triggers to determine storage exchanges



Every unit of SARCCUP supply water recharged at a SARCCUP facility goes into a virtual groundwater bank account. Every unit of SARCCUP stored water that is extracted via a SARCCUP extraction facility is deducted from the corresponding agency's account that is utilizing the supply. This virtual account keeps track of the total water volume that an agency has in the SARCCUP groundwater bank, at any given time.

A maximum SARCCUP GWB volume is determined by the five SARCCUP agencies. Initially the maximum 180,000 AF of storage proposed for SARCCUP Phase 1 is equally divided by the Agencies (36 TAF/agency). Stored water transfers are utilized, which would result in an agency having more than 36 TAF of storage in the SARCCUP GWB. A storage above 36 TAF is acceptable as long it does not interfere with recharge of other accounts. Agencies always have a guaranteed 36 TAF of storage capacity in the bank that could be later exchanged in-lieu direct MWD deliveries.

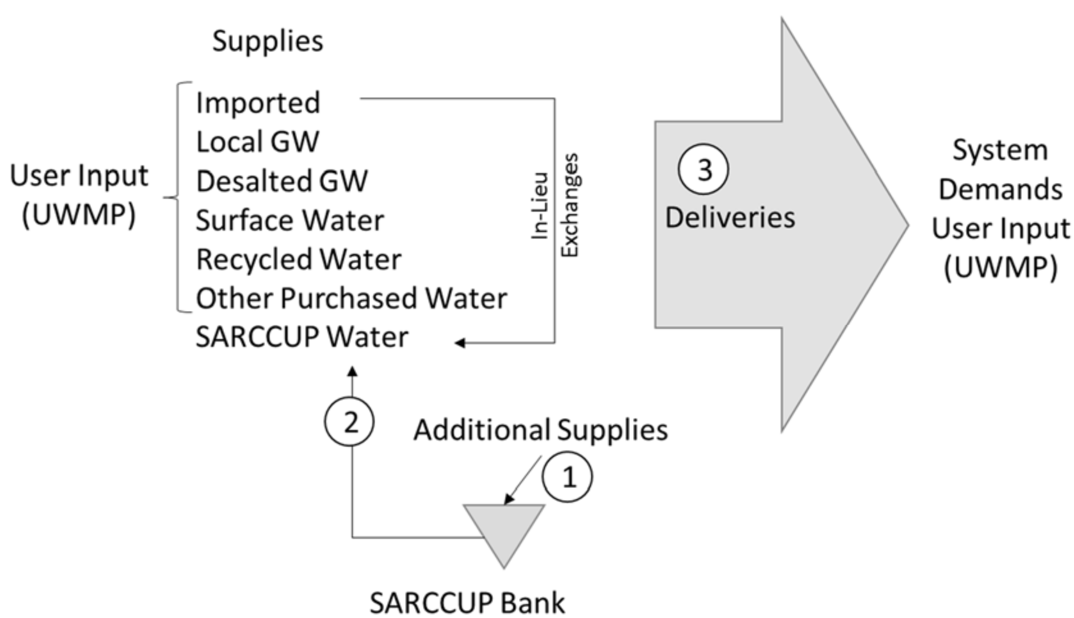
Initial conditions for the SARCCUP DSM are primarily related to the starting volumes the SARCCUP groundwater banks and hydrologic starting conditions. Preliminary DSM simulations occur with empty SARCCUP banks and hydrologic conditions that best reflect the recent sequence of dry years. Sensitivity runs were prepared to assess the impact of the initial conditions on preliminary results. If an initial storage value greater than zero is used, the user will have to also enter the cost incurred to obtain and recharge the initial storage otherwise that would enter the system as free water and skew the overall postage stamp cost of the project.

SARCCUP DSM assumes two losses in the system. First, losses are assumed during the recharge process (evapotranspiration, rejected recharge, etc). Recharge losses are assumed to be 5% of the recharge. Storage losses are not well known, but losses are likely a couple percent of the recharge volumes. The losses will charged equally to all agencies utilizing the same groundwater basin.

3.6. Deliveries

This section describes the different types of water deliveries modeled with the SARCCUP DSM. Figure 15 illustrates how an agency demand can be met by different water supplies including SARCCUP groundwater bank.

Figure 15: Summary figure showing how system demands are supplied and how the SARCCUP bank links to the system



The numbers on Figure 15 represent:

(1) Water delivered to fill SARCCUP bank (SARCCUP bank recharge)

(2) Water delivered from SARCCUP bank to agency supplies

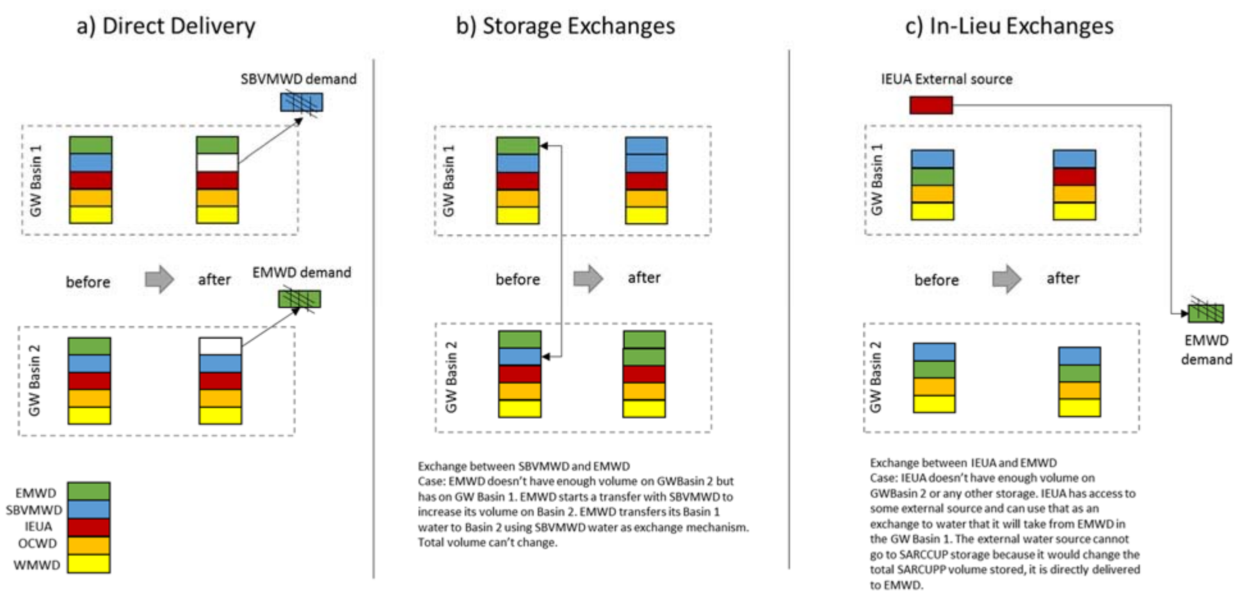
(3) Water delivered from agency supplies to system demands

The first item, water delivered to fill SARCCUP bank (recharge), was described in detail under section 3.1.1. The SARCCUP Bank water is dynamically added to the agency supplies determined by user input. The total supply amount is then used to meet the agency's system demands, which is also a user defined model input.

Water delivered from SARCCUP to agencies and from agencies to system demands is described below and illustrated as examples on Figure 16. An agency can obtain water supply by three main mechanisms:

- Direct delivery from SARCCUP bank to an agency (Figure 16a)
- Exchange of storage via agreements (Figure 16b)
- SARCCUP storage transferred from one agency to another in-lieu imported water supply. (Figure 16c)

Figure 16: Overview of the three different ways water can move out of SARCCUP storage



3.6.1.1. Direct Delivery

It is assumed that agencies that have a bank in their service area will tap into that bank first since it has the lowest extraction and conveyance cost. Each agency has a preferred groundwater bank to access (based on cost of extraction and conveyance) and extractions from that preferred bank will occur as long as the supply in its account does not have a zero balance. When an agency does not have enough storage in its own account, and no other accounts within the bank are available for a transfer, a direct delivery from another basin can occur if it is the least expensive option.

Direct deliveries from a non-local basin is constrained by conveyance connectivity and capacity. The current connectivity among agencies and groundwater basins are presented in Table 5 under section 2. Costs are assigned for each cell of Table 5 so there is a preference in case of direct deliveries among basins. In the case when groundwater storage has been exhausted for one agency, either storage exchange or in-lieu exchanges may be needed, as described in the following section.

The model offers the capability to evaluate non existing connections, to do so, the user must turn on the connection from one groundwater bank to an agency and then assign a cost to move the water through the connection.

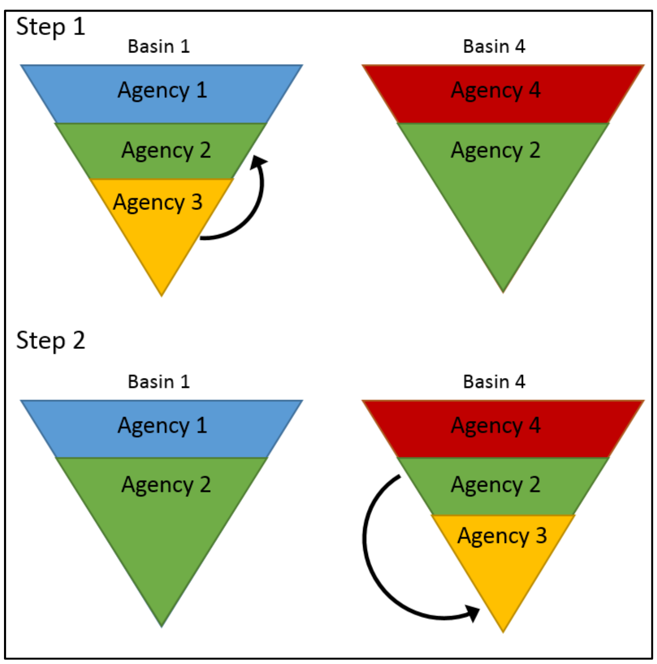
3.6.1.2. Storage Exchanges

When storage for an agency drops below a threshold (target volume in a bank defined as a user input), it will trigger the need for more water via a storage exchange. The storage exchange will move water from an account of one agency to that of another. Figure 17 illustrates an example of exchange between agencies 2 and 3. In the example the following conditions are observed:

- Agency 3 has its full storage amount above target on Basin 1 (has excess water in Basin 1)
- Agency 2 is below its storage target in Basin 1 (needs water in Basin 1)
- Agency 3 is below target on Basin 4 or is the cheapest basin for agency 3 to extract from
- Agency 2 is above its storage target on Basin 4

Under the conditions above there will be a storage exchange between agencies 2 and 3.

Figure 17: Example of a storage exchange where stored water is only exchanged between agencies form different basins



Storage exchanges between two agencies (A and B) can happen only if:

- Agency A is below its target storage in a basin and has water above its target on other basins
- Agency B is above its target on a basin so it could exchange with agency A

In Lieu exchanges can happen (described on section 3.6.2) in the case that Agency A does not have storage above target on other basins but has demand for imported water that can be transferred and direct delivered to Agency B.

The model includes logic to determine when, how much, from which agency and to which basin a storage exchange will happen and keeps an accounting. At any water transfer event there is at least 2 agencies involved, the agency in need requesting the transfers (Recipient) and the agency (or agencies) that will provide the exchange water and is compensated in another basin exchange. The four main questions to address when doing a storage transfer are:

When to do an exchange? The timing of storage transfer is reviewed annually and based on a target volume that each agency has in each groundwater basin and the threshold volume to trigger a storage exchange.

How much to exchange? The amount of exchange is limited to the volume necessary to return one agency's volume in a bank back to its target volume, the in-lieu capabilities, and the stored water available from other agencies (an agency's account is not allowed to drop below its own target to make another agency meet its target).

Which account should provide the water? Once an agency has triggered the need for an exchange (EMWD as an example in Figure 16b) and, has storage in other banks to execute the exchange, the next step decides which account will supply the exchange water. First it has to be an account that has available water for exchange (volume above its target) and second it considers the potential cost savings to an agency by doing a transfer rather than direct delivery by comparing the cost of direct extraction plus conveyance (in our Figure 16b example that agency would be SBVMWD). It is possible that more than one agency is competing for the transfer of another agency's stored. In that case the available volume is equally divided.

Where the water provider is compensated? The volume requested by an agency (EMWD on the Figure 16b example) is exchanged to another agency (SBVMWD in Figure 16b example). The exchange will start in a basin that the agency requesting exchange has storage (EMWD in Figure 16b example), which would be the most expensive basin that the agency has direct access or no direct access. It will exchange the volume with SBVMWD from that basin. In case there is not enough volume to be transferred, the agency in need will go to the next most expensive basin for direct access until it exchanges the whole volume.

The different input values for costs and storage targets determine the most efficient way to operate the system and extract water from the SARCCUP GWB.

3.6.2. In-lieu Exchanges

In-lieu exchanges is a mechanism used when an agency receives SARCCUP storage in-lieu of direct imported water deliveries. In-Lieu exchanges can occur to save the pumping cost of extractions.

The main assumptions to trigger an in lieu exchange is that one agency is below its target storage in one basin but does not have storage in other basins that can be exchanged with. That could be because the agency does not have any physical water stored on other basins or could be because the agency is at or below storage target at other basins. Also, the current model version allows in lieu transfers to move other agencies storage only to the overlaying basin agency. This is based on the assumption that only the overlaying agency would like to have all its SARCCUP storage at its basin to minimize extraction costs.

In-lieu sources do not go into SARCCUP storage, but are delivered directly. Using the example from Figure 16c, assuming that IEUA would like to have all its water on Bank 1 and IEUA does not have any volume in Bank 2 to execute a storage exchange, IEUA could purchase MWD water (external source) and deliver to the EMWD so that IEUA would receive EMWD's amount of water in Bank 1. Exchanges are the lowest cost method of moving water amongst the agencies so they are given the highest priority. In-lieu exchanges could happen automatically as the last resource to meet demands or happen based on a user defined schedule. External sources cannot be more than the imported supplies that an agency would have to use to meet its demands.

4. Scenario Analysis

The DSM model was created to evaluate and quantify the benefits of the SARCCUP project and to understand if the proposed projects were adequate planned for the system. Following is the initial list of SARCCUP projects identified:

- Dual use ASR wells providing extraction and recharge capacity to the Elsinore bank at a planned 1,500 AF/yr estimated capacity.
- South Pressure Zone Extraction Wells providing additional extraction capacity to the Chino basin, Chino basin extraction capacity was assumed to be 17,000 AF/yr.
- 48 inch baseline feeder extension providing additional connectivity between the Chino and SBBA groundwater basins.
- SBBA extraction wells providing additional extraction capabilities to the SBBA groundwater basin, the SBBA extraction capacity was set to 20,000 AF/yr.
- Alabama St. pipeline/Redlands PS providing required connectivity to the SBBA groundwater basin to convey extracted water to the system.
- San Jacinto Extraction wells providing additional extraction capacity to the San Jacinto groundwater basin, the San Jacinto extraction capacity was estimated to be 6,500 AF/yr.

Initially, four model scenarios were set up to answer key questions that are important for the success of the project. A few model sensitivity scenarios were also generated after the presentation of initial model results. Initial model results were indicating that the 48 inch Baseline Feeder extension and the Elsinore groundwater would not be crucial to the implementation of Phase 1, 180,000 AF groundwater bank. The sensitivity scenarios were created removing the 48 inch Baseline Feeder and the Elsinore groundwater bank from the system.

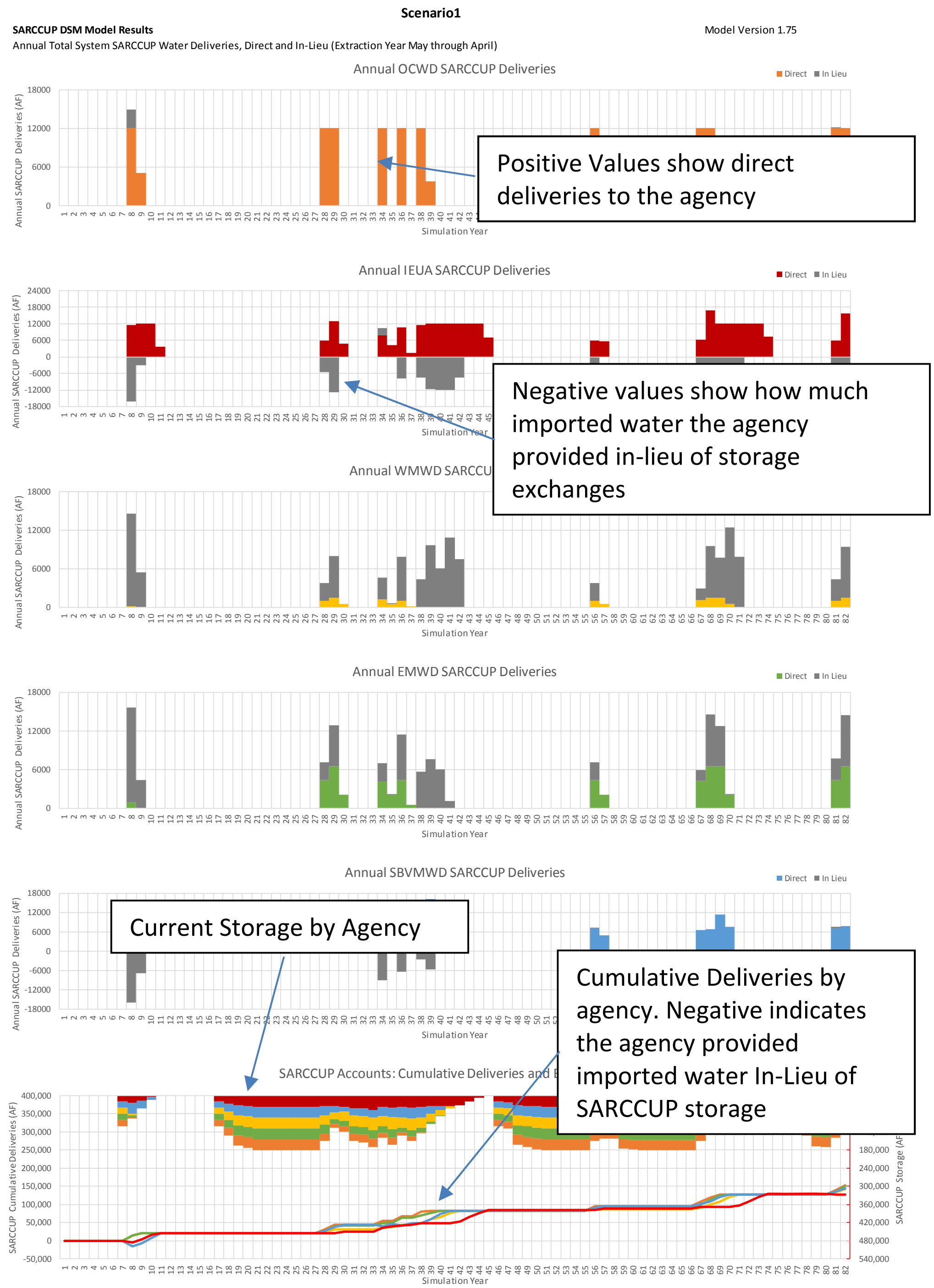
The four initial model scenarios are:

- Baseline – Baseline operations without SARCCUP (No Project scenario)
- Scenario 1 –SARCCUP planned facilities and existing SWP
- Scenario 2 – Scenario 1 with climate change assumptions. This scenario had two sensitivity runs, Scenario 2.1 without the 48 inch baseline feeder, and Scenario 2.2 without the 48 inch baseline feeder and without Elsinore groundwater bank.
- Scenario 3 – Scenario 1 with future climate change assumptions and California Water Fix
- Scenario 4 – Scenario 1 where deliveries to OCWD will be exchanges with treated wastewater being delivered to OCWD via the Santa Ana River.

Extra scenario variation were created for all Scenarios 2, expanding the bank to 500,000 AF, those were called scenarios 2a, 2a1 and 2a2.

The DSM produces a comprehensive amount of model outputs that can be accessed via dashboards. A model summary was produced for this report showing main model results. The one page summary produced for every scenario is presented on Figure 18 as an example for scenario 1. The summary shows on the top 5 charts how much SARCCUP water was delivered to each agency directly and via in-lieu. In the case an agency was the provider of imported water in-lieu of SARCCUP storage, Figure 18 will report a negative delivery. The bottom chart of Figure 18 presents the cumulative total SARCCUP deliveries for each agency and the annual SARCCUP storage by agency. The summaries for all model scenario are presented under Appendix B.

Figure 18: SARCCUP Explanation of model results summary that are presented on Appendix B



Scenario1
845 ($/AF)

End of Simulation summary (AF)

	OCWD	WMWD	SBVMWD	EMWD	IEUA	Total
Cumulative Deliveries (82 years)	152,700	142,300	143,800	150,600	126,900	716,300
End of Simulation Storage	9,700	20,200	18,600	11,800	35,600	95,900
Total	162,400	162,500	162,400	162,400	162,500	812,200

Summary table with cost, cumulative deliveries by agency and end of simulation storage

Notes:
Negative In-Lieu indicates imported water provided in lieu of SARCCUP storage. In Lieu happens in January of an extraction year.
Data is summarized based on calendar year. Extractions are allowed from May to April, therefore it is possible that more than 12,000 AF is delivered to an agency in o[...] onths
and some In-Lieu occured from January to May.

4.0. Findings from DSM Scenario Analysis

The current model findings are limited to answer the questions proposed at the beginning of the project and are related to the infrastructure needed for the first phase of the SARCCUP. The initial proposed questions with the correspondent answers are presented below.

1. **What is the cost of SARCCUP water and how does it compare to the cost of water without SARCCUP?**

The Baseline scenario (no SARCCUP bank) indicates that the cost of MWD water that could be replaced by SARCCUP water (MWD water that had to be purchased on allocation years and above Tier 1 price to meet system demands) was 1641 $/AF. The SARCCUP postage stamp cost (total expended filling, extracting and conveying bank water divided by the total water delivered) was less than $900/AF for the different model runs. It is noteworthy mention that no capital costs were included in the reported postage stamp price. Table 10 summarizes the postage stamp costs for the different model scenarios run, the cost reported is for the last year of the simulation when the bank was empty on storage:

Table 10: SARCCUP Postage Stamp cost by Scenario

Model Scenario	**SARCCUP postage stamp cost ($/AF)**
Baseline	$ -
Scenario 1	$ 845
Scenario 2	$ 856
Scenario 2.1	$ 851
Scenario 2.2	$ 827
Scenario 3	$ 833
Scenario 4	$ 845

2. **How does the California Water Fix impact SARCCUP?**

Scenario 3 evaluated the impact of the California Water Fix. It was found that the California water fix will result in a more reliable MET system, with less allocations and more chances for the SARCCUP bank to fill up. Model results indicate that the full 180,000 AF bank was not utilized as frequent as other scenarios. It is possible that increased extraction capacity and change on the rules that will trigger the bank usage could provide more benefits than what the current Scenario 3 assumptions are providing.

3. **Where are the "bottlenecks" in SARCCUP, if any? What recharge/extraction facilities would be required to alleviate specific bottlenecks?**

Model results show that the overall system has enough recharge capacity for Phase 1. The bottlenecks are on system connectivity, extraction capacity and ability to do in lieu exchanges, however none of these were strong enough to strain SARCCUP water in groundwater basins under the current set of scenarios and assumptions. Other bottlenecks that should be considered are Devil canyon 469 cfs (340,000 AF/yr) capacity and supply and conveyance availability. The model assumes that Devil Canyon's available capacity for SARCCUP was 180,000 AF/yr, a little more than half of the pipeline capacity and 3 times more than the requested at Phase 1 (60,000 AF/yr of recharge).

4. **Where in the watershed does extra recharge or extraction capacity exist without new facilities?**

A sensitivity run was prepared from Scenario 2 where the recharge and extraction capacities were set to unlimited so the model would request as much as it needed based on other system limitations and not to recharge and extraction. Table 11 presents the results of this sensitivity run comparing the existing model capacities to the maximum the model was able to use. For example, San Jacinto currently has a maximum 6,500 AF/yr of recharge capacity and the unlimited scenario apparently could use up to 20,530 AF/yr. Table 11 shows that there is plenty of recharge capacity at SBBA and Chino, but the system could use more extraction capacity (highlighted numbers) especially at San Jacinto and Elsinore groundwater basins.

Table 11: Estimated and potential maximum extraction and recharge capacities

	Recharge Capacity (AF/yr)		**Extraction Capacity (AF/yr)**	
Basin	**Assumed capacity for all model scenarios**	**Maximum verified on unlimited scenario**	**Assumed capacity for all model scenarios**	**Maximum verified on unlimited scenario**
Chino	90,500	60,630	17,000	20,870
SBBA	124,000	63,160	20,000	28,210
San Jacinto	6,500	20,530	6,500	13,750
Elsinore	1,500	4,737	1,500	4,500

5. **What facilities would be needed to increase the storage capacity to 500,000 AF and the dry year yield to 166,000 AFY?**

Sensitivity model runs 2a, 2a1 and 2a2 were prepared increasing the size of the bank to 500,000 AF. The bank expansion was on Chino and SBBA where there is room for additional groundwater storage. One limitation that might be significant to make this scenario viable is the available capacity at Devil's Canyon to move more 167 TAF/yr of water per year to recharge the groundwater banks in 3 years.

Model results show that limitations on supply availability kept the bank from filling as frequent as it filled under 180,000 AF assumptions.

The 500,000 AF bank sensitivity runs assumed increased extraction as well. Extraction capacity at SBBA was increased from 20,000 AF/yr to 33,000 AF/yr and extraction capacity at Chino was increased from 17,000 AF/yr to 125,000 AF/yr. Additional scenario runs are needed to understand if limited ability to move water out of the bank is related to in lieu limitations, extraction capacity, or maximum extraction per year per agency. The current model limits agency deliveries to 60,000 AF/yr equally divided by each agency (12,000 AF/yr per agency), what was noticed in runs that have significant amount of In lieu exchanges there could be a situation where only one agency has storage in the bank but is limited to withdraw only 12,000 AF/yr. In that case the bank would take longer to empty.

6. **What if OCWD were to only receive treated wastewater via the SAR? Would that stretch water supplies and reduce costs in the watershed?**

Under Scenario 4, a transfer of 10,000 AF of IEUA recycled water supply was transferred to OCWD groundwater supply and the same 10,000 AF from OC Imported supplies was transferred to IE imported supplies. This scenario might need extra refinement of assumptions if needed to expand to upstream agencies. The $3.5/AF cost reduction verified in this scenario was not in SARCCUP postage stamp but on the overall cost of the system to supply all system demands. This could offer substantial savings when assumed that tall agencies have to supply approximately 1.2MAF of demands per year.

Scenario 4 was simulated in a simplified way. A detailed evaluation of this scenario would require further details on specific assumptions. For example, a swap of OCWD imported demands could happen only with recycled water that is currently being delivered to customers and not water that is already being discharged to the SAR. If all current recycled water discharges to SAR were to be considered, the OCWD UWMP estimates for supply would have to be corrected. The current understanding is that only IEUA is delivering recycled water to costumers and on a limited amount. Also, the estimated OCWD imported water demand is 55TAF/yr but based on the assumption that there is a certain amount of SAR upstream flows available to recharge OCWD basin. This assumption would change in a scenario where upstream discharges to SAR are modified. A comprehensive evaluation of upstream demands and return flows to SAR and a clear ratio between imported water and return flows to the SAR would be needed. Such evaluation was beyond the scope of the model development task.

5. Model Limitations

The model accuracy is limited to the accuracy of model inputs. Future refinements on system demands, supplies, costs, connectivity and capacities could improve model accuracy.

The current model assumes inter basin connectivity, however the flow network inside each agency was not fully developed. This limitation implies that the model can answer how much water need to move across basins and agencies but it is assumed that once the water is within an agency area it will be able to reach its final destination of recharge or deliver to final demands.

The model runs in a daily time step to accommodate potential expansion of model capabilities, however, because most of the inputs like demands and capacities are set for annual values, it is appropriate to check model results in a monthly or annual time step. Placeholder monthly patterns for agency demands were used and should be refined in future versions of the model.

The optimization will not perform an efficient distribution of target storages if not all costs are input properly. For example, it was found that the model had slightly lower postage stamp cost in a scenario where the 48 inch pipe connection between Chino and SBBA was available. This would probably be not the result of an optimization run where capital costs of the new pipeline were to be considered.

6. Conclusions

The agencies now have a powerful tool to conduct what if scenarios and potentially identify projects that could bring the overall cost of SARCCUP operation down or increase the usage of the SARCCUP bank. A number of scenarios were created for the initial SARCCUP evaluation, however, further scenarios and analysis are needed to refine and answer new questions generated after the presentation of initial model results.

The SARCCUP operations cost (without capital cost investments) was estimated to be less than 900 $/AF, with a minimum (Scenario 2.2) reaching 827 $/AF. This is a substantial difference when compared to the average price of MWD supplies that would have to be used to replace SARCCUP bank water, estimated under this analysis to be 1641 $/AF.

The use of the new 48 inch baseline feeder between Chino and SBBA is not critical for the initial Phase 1 (180,000AF) bank operation, the addition of the connection does not improve bank usage. It is possible that the system would benefit from the connection under different conditions, like a larger bank or to improve system reliability.

The current model scenarios indicate that the Elsinore groundwater bank (and ASR wells) might be important for a total system reliability but it is not critical for Phase 1 operation. On an expanded bank operation scenario, any direct extraction that could be increased for WMWD or EMWD could benefit the system, but further analysis is needed to quantify these benefits.

The bank can be used more frequently if extractions are based on water year classification and not under the MWD curtailment logic. However, there are some uncertainties regarding which water year classifications should or could be used in a real bank operation. These uncertainties would have to be addressed in conjunction with MWD. The DSM tool can help guide future preferred operation of the bank since it includes both logic options. A more frequent use of the bank might also imply reduction in costs if revenues related to delivering SARCCUP water (assumed to be obtained at a cheaper cost than during critical, dry and below normal years) are greater than revenues generated by imported water.

There are some uncertainties regarding extraction capacity that will be available to SARCCUP from each agency. A test scenario with unlimited extraction and unlimited capacity to recharge was run to identify potential system bottlenecks. The most restrained basins were Elsinore followed by San Jacinto, the ideal extraction and recharge capacity for Elsinore and San Jacinto would have to be increased. Recharge capacity for Chino and SBBA are more than sufficient and probably compensating for lack of recharge on other basins. Overall it seems the system could benefit from extraction capacity for a maximum use of bank, however, the current extraction capacity seems to be enough for Phase 1 operations, so that no supplies get stranded.

7. References

(June 2011). *2010 Urban Water Management Plan for Inland Empire Utilities Agency.*

EMWD Resource Development. (2010). *2010 Urban Water Management Plan for Eastern Municipal Water District.*

Kennedy/Jenks Consultants. (May 2008). *Updated Integrated Regional Water Management Plan Report for Western Municipal Water District.*

RMC. (April 2016). *Draft 2015 Urban Water Management Plan for Western Municipal Water District.*

(January 2015). *Upper Santa Ana River Watershed Integrated Regional Water Management Plan.*

Water Systems Consulting. (2016). *Draft 2015 Urban Water Management Plan for the San Bernardino Valley.*

Appendix A: Data collection summary table

Data Category	Database Tab Name	SARCCUP Agency Applicability	Data Set Description	Data Purpose	Data Sources
Regional Water Infrastructure	Conveyance	All	Capacity in cfs for existing and proposed regional pipelines, canals and interties that maybe used for SARCCUP, transfers or exchanges of SARCCUP water. Known seasonal, jurisdiction, or capacity constraints.	Identify critical facilities and conveyance limitations to be represented in the model. Identify physical connections that may facilitate SARCCUP water transfers and exchanges.	MET System Map L1212 SARCCUP DSM - Data Request & Schematic Email from Aaron Jones - SBVMWD (4/18/16) Constraints comments from SARCCUP DSM-Data Request & Schematic email from Brian Powell (05/20/2016) SARCCUP DSM - WMWD, IEUA, EMWD Data Requests email from Tim Barr-WMWD (5/23/16) EBX Phase 1I Final EIR 2010 EVMWD UWMP - Section 3.3 2010 Corona UWMP
Regional Water Infrastructure	Turnouts	All	Capacity in cfs for existing and proposed regional turnouts to recharge basins, creeks or SAR. Known seasonal, jurisdiction, or capacity constraints.	Identify critical turnouts and limitations to be represented in the model. Identify physical connections that may facilitate SARCCUP water transfers and exchanges.	SBVMWD Turnout Capacities (Jun 2015) SARCCUP DSM-Data Request & Schematic email from Andy Campbell - IEUA (4/13/16) Capacity of OC-28 and 28A email from Greg Woodside-OCWD (4/6/16) 2010 EVMWD UWMP - Section 3.3 and 5
Regional Water Infrastructure	Boosters	All	Capacity in cfs for existing and proposed booster stations. Known seasonal, jurisdiction, or capacity constraints.	Identify critical booster stations and limitations to be represented in the model. Identify physical connections that may facilitate SARCCUP water transfers and exchanges.	2015 OWOW Program SARCCUP DSM - Data Request & Schematic Email from Aaron Jones - SBVMWD (4/18/16) SARCCUP DSM-Data Request & Schematic email from Andy Campbell - IEUA (4/13/16)
Regional Water Infrastructure	Wells	All	Capacity in gpm for existing and proposed injection and/or extraction wells. Known seasonal, jurisdiction, or capacity constraints.	Identify critical wells and limitations to be represented in the model. Identify physical connections that may facilitate SARCCUP water transfers and exchanges.	Constraints email from Bob Tincher - SBVMWD (Mar 2016) 2015 OWOW Program SARCCUP DSM - Data Request & Schematic Email from Aaron Jones - SBVMWD (4/18/16) SARCCUP DSM-Data Request & Schematic email from Andy Campbell - IEUA (4/13/16) SARCCUP DSM-Data Request & Schematic email from Brian Powell (05/20/2016), confirmed in Table 6-3 from

					2015 UWMP as well as EMWD_DSM_SuppliesDemands02.xlsx. Additional constraints in email SARCCUP DSM - WMWD Data Requests email from Tim Barr-WMWD (5/23/16) 2005 Elsinore Basin GW Management Plan
Regional Water Infrastructure	WTP	All	Capacity in MGD and supplies in AFY for existing WTP. Known seasonal, jurisdiction, or capacity constraints.	Identify physical connections that might facilitate SARCCUP water transfers and exchanges.	Data collected near SBVMWD Regional RW Concept Study (2015) 2010 IEUA's UWMP, Chapter 1 SARCCUP DSM-Data Request & Schematic email from Andy Campbell (4/13/16) 2010 IEUA UWMP, Chapter 1 2010 EVMWD UWMP 2010 Corona UWMP MWDSC Website
Regional Water Infrastructure	Desalter	All	Capacity in MGD and supplies in AFY for existing desalters. Known seasonal, jurisdiction, or capacity constraints.	Identify critical desalters and limitations to be represented in the model. Identify physical connections that may facilitate SARCCUP water transfers and exchanges.	2010 IEUA UWMP, Chapter 3.3 2010 Western UWMP - Ch 3.6.2 SARCCUP DSM-Data Request & Schematic email from Brian Powell (05/20/2016) 2010 Corona UWMP
Regional Water Infrastructure	Recharge Basins	All	Recharge Capacity in cfs, storage capacity in AF and period of operation for existing and proposed recharge basins. Known seasonal, jurisdiction, or capacity constraints.	Identify critical recharge basins and limitations to be represented in the model. Identify physical connections that may facilitate SARCCUP water transfers and exchanges.	Upper Santa Ana River Watershed IRWMP 2015, Table 2-9 Manual for Lytle Creek North RW Facilities (2005) EVWD RW Feasibility Study (2014) 2010 IEUA UWMP, Chapter 7.2 and Table 7.3 SBBA Storm Water Flow & Capture Figures & Tables pg 81 – 89

					SARCCUP-SBBA Recharge Loss email from Aaron Jones (3/18/2016), Constraints email from Bob Tincher (3/28/2016) IRWMP_2015_Table 2-9_Recharge Basins Recharge rates email from Bob Tincher - SBVMWD (4/13/16) SARCCUP DSM-Data Request & Schematic email from Andy Campbell- IEUA (4/13/16) SARCCUP DSM-Data Request & Schematic email from Brian Powell (05/20/2016) Original recharge capacity from - 2010 IEUA UWMP Chapter 7.2 and table 7.3
Regional Water Infrastructure	WRF	All	Capacity in MGD, supplies in AFY and permit/effluent TDS limits for existing WRF. Known seasonal, jurisdiction, or capacity constraints.		2010 IEUA UWMP, Chapter 6.4-6.5 2015 Valley District Draft RUWMP City of Colton 50% Draft 2015 Sewer Master Plan OWOW 2.0, Appendix C WLAM Final Report Draft RRWCS Report documents Delivery data from SARCCUP DSM-Data Request & Schematic email from Brian Powell (05/20/2016). Capacity data from UWMP table 6-7
Regional Water Infrastructure	Surface Reservoirs	All	Capacity in AF of existing surface water reservoirs. Known seasonal, jurisdiction, or capacity constraints.	Identify critical facilities and limitations to be represented in the model. Identify physical connections that may facilitate SARCCUP water transfers and exchanges.	OWOW Plan 1.0 Table 5.1-4 Orange County Flood Division website MWDSC website

Water Quality	WQ	All	TDS Water Quality Objective, 2012 Current Ambient TDS and Assimilative Capacity for TDS (all in mg/L) for existing groundwater basin management zones. TDS (mg/L) Water Quality Objective for inland surface stream. TDS (mg/L) Water Quality of imported water sources	Identify water quality of various water sources and water quality objectives to verify compliance in the DSM.	2012 Ambient Water Quality TM Santa Ana Region Basin Plan, Chapter 4 SWP 2015 Grab Samples MWDSC 2014 Annual Water Quality Report
Regional Water Budgets	Historical Supplies	SBVMWD	Monthly and annual supplies from 2011-2015 and delivery methods for the City of Colton, City of Loma Linda, City of Redlands, City of Rialto, EVWD, RHWC, SBMWD, WVWD, YVWD (combined as SBVMWD Agencies). Supply sources include untreated SWP; groundwater pumped from the Bunker Hill, Colton Rialto, North Riverside, Yucaipa, Lytle Creek and Chino basins; surface water from SAR, Mill Creek and Lytle Creek; and RW from agencies.	Identify seasonal usage p44atterns of sources for varying hydrologic years conditions.	2015 SBVMWD RUWMP Data Colton 2015 RUWMP GW production Loma Linda_2015RUWMPDataUpdated Redlands_2011-2015 RUWMP Annual Production Reports Rialto_1995-2015 production totals EVWD SWP Summary 2006-2015 EVWD_Groundwater-Surface Water Production 2009-2015
Regional Water Budgets	Historical Supplies	WMWD	Annual supplies from 2005-2015 and delivery methods for the EVMWD, JCSD, City of Norco, TVWD, BSWC, City of Corona, City of Riverside, EVMWC, RCWD, HGCWD, RCSD (combined as WMWD Agencies). Supply sources	Identify seasonal usage patterns of sources for varying hydrologic years conditions.	From WVWD 2015 Final UWMP & 2010 WMWD UWMP 2008 WMWD IRWMP

			include treated SWP; groundwater pumped from the Elsinore, Coldwater, Palomar, Bedford, Lee Lake, Warm Springs, and Temecula-Pauba basins; Chino Basin and Arlington desalters; purchased water from Meeks and Daley; and RW from agencies and regional WRF.		
Regional Water Budgets	Historical Supplies	EMWD	Aannual supplies from 2005-2015 and delivery methods for the Moreno Valley, Perris Valley, San Jacinto Valley, Temescula Valley (combined as EMWD Agencies). Supply sources include treated and untreated SWP and CRA water; groundwater pumped from the San Jacinto Upper Zone basin; Perris I, Perris II and Menifee desalters; purchased water from WMWD and EVMWD; and RW from regional WRFs.	Identify seasonal usage patterns of sources for varying hydrologic years conditions.	2015 UWMP Table 6-1, also in Table 6-18 for 2015 2015 UWMP Table 6-2, also in Table 6-19 for 2015 2015 UWMP Table 6-1, also in Table 6-11 for 2015, also in Table 6-18 for 2015 2016 UWMP Table 6-2, also in Table 6-12 for 2015, also in Table 6-19 for 2015
Regional Water Budgets	Historical Supplies	IEUA	Aannual supplies from 2005-2015 and delivery methods for the City of Chino Hills, Upland, Ontario, FWC, CVWD, Chino, MVWD, SAWC (combined as IEUA Agencies). Supply sources include imported water; groundwater pumped from the Chino and other basins; surface water; purchased water from CVWD, SAWC, West End, CDA and MVWD;	Identify seasonal usage patterns of sources for varying hydrologic years conditions.	2005 - 2010 from the 2010 UWMP and 2015 from 2015 Final UWMP

			and RW from purchased from IEUA.		
Regional Water Budgets	Future Supplies	SBVMWD	Annual future supplies from 2015 to 2040 in five year increments for normal, single dry year, multiple dry year and wet year for the SBVMWD Agencies. Known supply priority.	Identify sources that might facilitate SARCCUP water transfers and exchanges. Identify capacity limitations on critical conveyance facilities due to supplies needed.	2015 SBVMWD RUWMP Data
Regional Water Budgets	Future Supplies	WMWD	Annual future supplies from 2015 to 2040 in five year increments for normal, single dry year, multiple dry year and wet year for the WMWD Agencies. Known supply priority.	Identify sources that might facilitate SARCCUP water transfers and exchanges. Identify capacity limitations on critical conveyance facilities due to supplies needed.	Western 2015 Final UWMP
Regional Water Budgets	Future Supplies	EMWD	Annual future supplies from 2015 to 2040 in five year increments for normal, single dry year, multiple dry year and wet year for the EMWD Agencies. Known supply priority.	Identify sources that might facilitate SARCCUP water transfers and exchanges. Identify capacity limitations on critical conveyance facilities due to supplies needed.	File from B.Powell EMWD_DSM_SuppliesDemands02.xlsx Table 6-18 for 2015, Normal: Table 6-21 for 2020-2040 Table 6-20 for 2020-2040 Table 6-21 for 2020-2040 For single, 2nd, and 3rd dry year Table 7-8 and 7-9 reference.
Regional Water Budgets	Future Supplies	IEUA	Annual future supplies from 2015 to 2040 in five year increments for normal, single dry year, multiple dry year and wet year for the IEUA Agencies.	Identify sources that might facilitate SARCCUP water transfers and exchanges. Identify capacity limitations on critical conveyance	2015 Final UWMP Table 3-1

			Known supply priority.	facilities due to supplies needed.	
Regional Water Budgets	Historical Demands	SBVMWD	Annual historical demands for each customer category from 2011 to 2015 for the SBVMWD Agencies. Demands are broken per retail category.		2015 SBVMWD RUWMP
Regional Water Budgets	Historical Demands	WMWD	Annual historical demands for each customer category from 2011 to 2015 for the WMWD Agencies. Demands are broken per retail category.		Western 2015 Final UWMP Tables 4-2, 4-6, and 4-8
Regional Water Budgets	Historical Demands	EMWD	Annual historical demands for each customer category from 2011 to 2015 for the EMWD Agencies. Demands are broken per retail category.		2015 UWMP - Table 4-2 and 4-3 2015 UWMP - Table 4-5 and 4-6 2015 UWMP - Table 4-8 and 4-9
Regional Water Budgets	Historical Demands	IEUA	Annual historical demands for each customer category from 2011 to 2015 for the IEUA Agencies. Demands are broken per retail category.		2006-2010, 2010 UWMP Table 3-1 (FY Totals). 2014 from FY 13/14 and 14/15 monthly demands tables. 2015 from 2015 Final UWMP
Regional Water Budgets	Future Demands	SBVMWD	Annual future demands for each customer category from 2015 to 2040 in five year increments for the SBVMWD Agencies. Demands are broken per retail category.		2015 SBVMWD RUWMP
Regional Water Budgets	Future Demands	WMWD	Annual future demands for each customer category		Western 2015 Final UWMP Tables 4-2, 4-3, 4-5, 4-6, 4-7, and 4-8

			from 2015 to 2040 in five year increments for the WMWD Agencies. Demands are broken per retail category		
Regional Water Budgets	Future Demands	EMWD	Annual future demands for each customer category from 2015 to 2040 in five year increments for the EMWD Agencies. Demands are broken per retail category		2015 UWMP - Table 4-4, Table 4-3 2015 actual 2015 UWMP - Table 4-7 Email from BPowell 6/3/2016
Regional Water Budgets	Future Demands	IEUA	Annual future demands for each customer category from 2015 to 2040 in five year increments for the IEUA Agencies. Demands are broken per retail category		2015 Final UWMP Table 2-3 and Table 3-9
Cost	Cost	All			
Hydrologic		All			
Regulatory, Institutional, and Operational Constraints	Constraints	All	Database includes field to record known or potential facility constraints.		

Table Notes:

1. Updated as of July 28, 2016

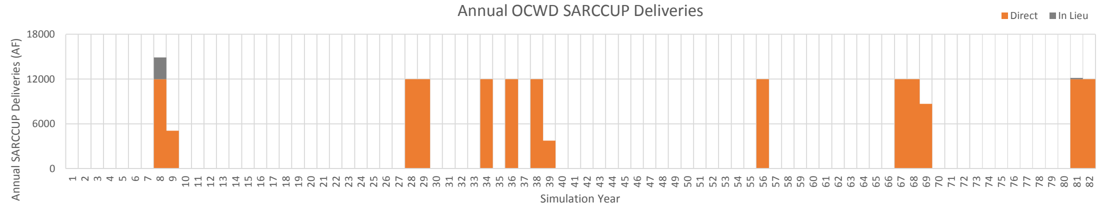
Appendix B: Summaries of Model Results

Scenario1

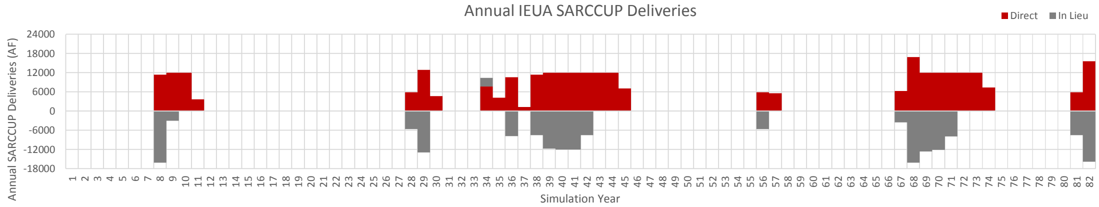
SARCCUP DSM Model Results Model Version 1.75

Annual Total System SARCCUP Water Deliveries, Direct and In-Lieu (Extraction Year May through April)

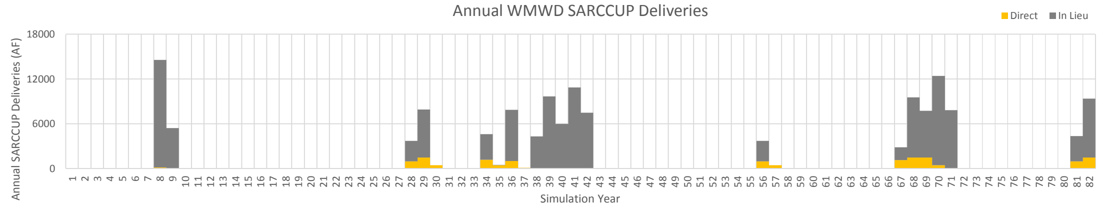
Annual OCWD SARCCUP Deliveries



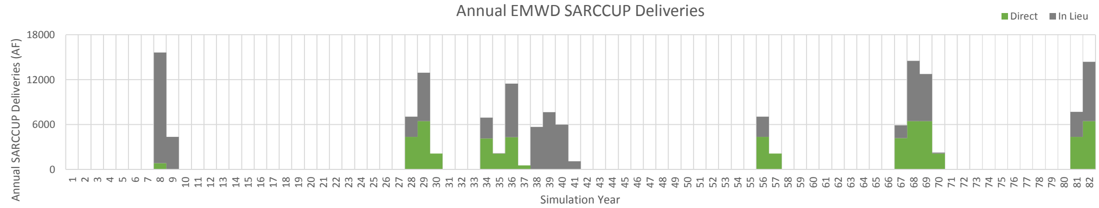
Annual IEUA SARCCUP Deliveries



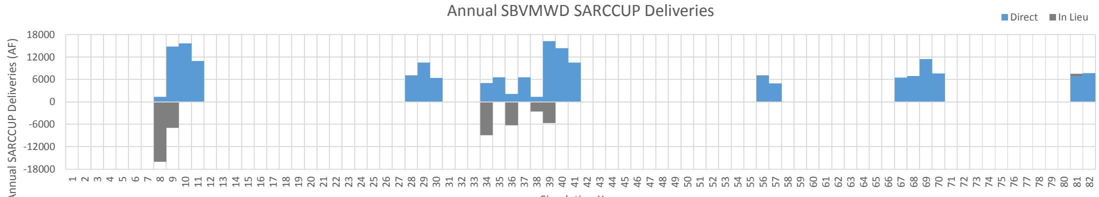
Annual WMWD SARCCUP Deliveries



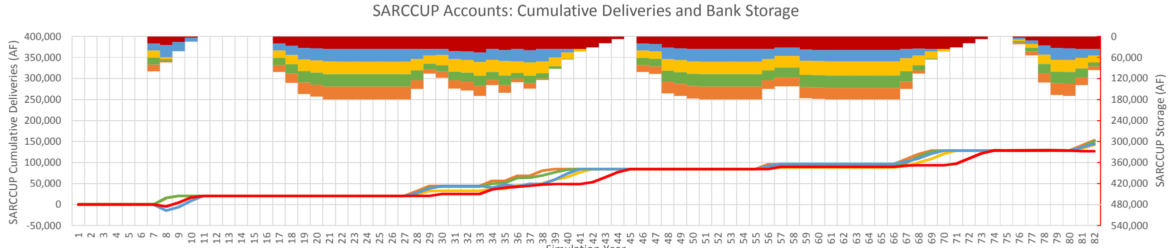
Annual EMWD SARCCUP Deliveries



Annual SBVMWD SARCCUP Deliveries



SARCCUP Accounts: Cumulative Deliveries and Bank Storage



Scenario1 **End of Simulation summary (AF)**

845 ($/AF)	OCWD	WMWD	SBVMWD	EMWD	IEUA	Total
Cumulative Deliveries (82 years)	152,700	142,300	143,800	150,600	126,900	716,300
End of Simulation Storage	9,700	20,200	18,600	11,800	35,600	95,900
Total	162,400	162,500	162,400	162,400	162,500	812,200

Notes:

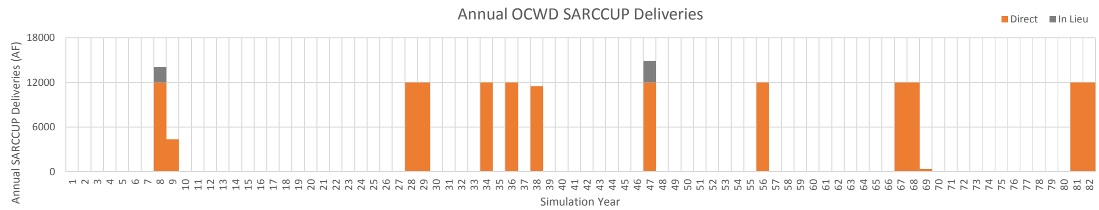
Negative In-Lieu indicates imported water provided in lieu of SARCCUP storage. In Lieu happens in January of an extraction year.

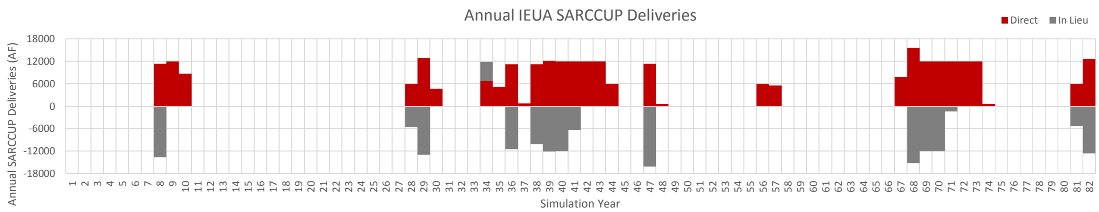
Data is summarized based on calendar year. Extractions are allowed from May to April, therefore it is possible that more than 12,000 AF is delivered to an agency in one calendar year if there was enough extraction capacity to deliver 12,000 af to an agency in less than 12 months and some In-Lieu occured from January to May.

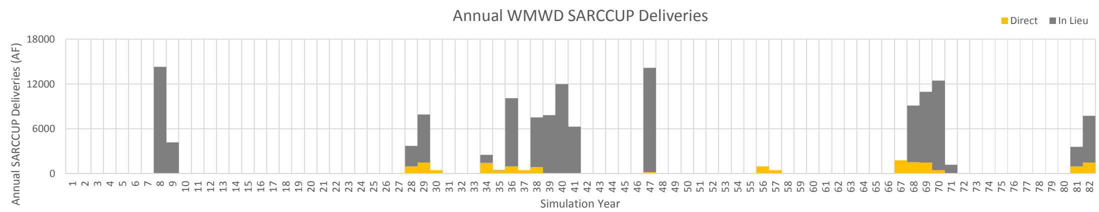
Scenario2

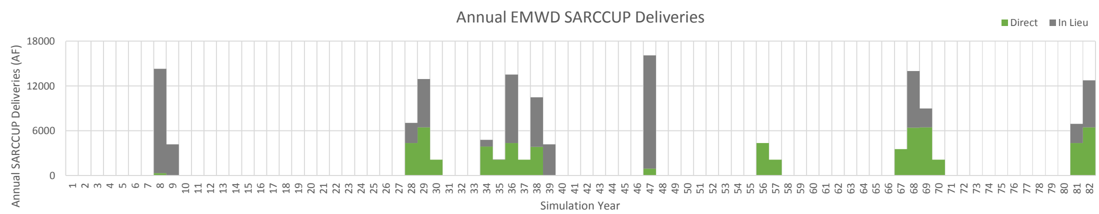
SARCCUP DSM Model Results Model Version 1.75

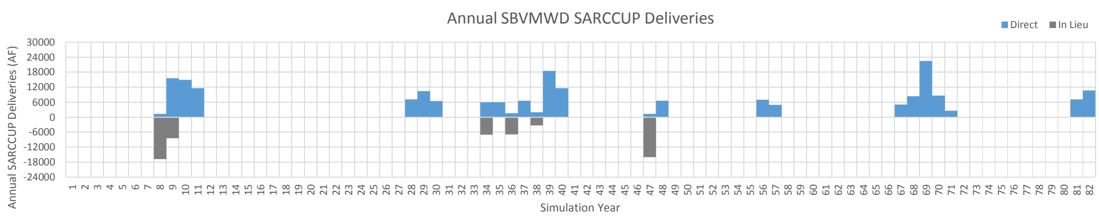
Annual Total System SARCCUP Water Deliveries, Direct and In-Lieu (Extraction Year May through April)

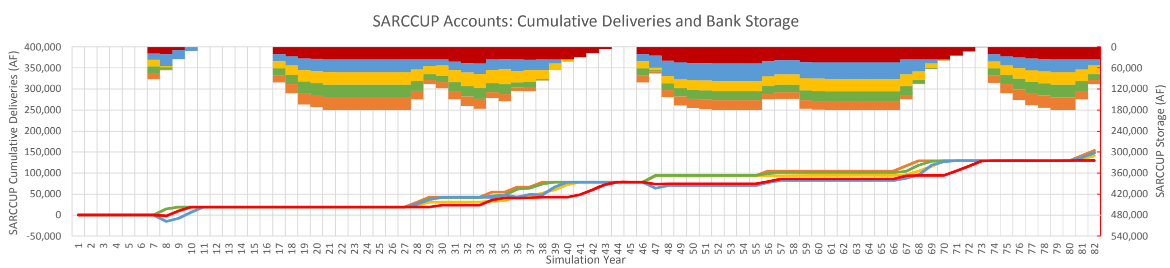












Scenario2 **End of Simulation summary (AF)**

856 ($/AF)	OCWD	WMWD	SBVMWD	EMWD	IEUA	Total
Cumulative Deliveries (82 years)	153,400	140,800	147,300	149,100	129,700	720,300
End of Simulation Storage	11,900	24,500	18,000	16,200	35,600	106,200
Total	165,300	165,300	165,300	165,300	165,300	826,500

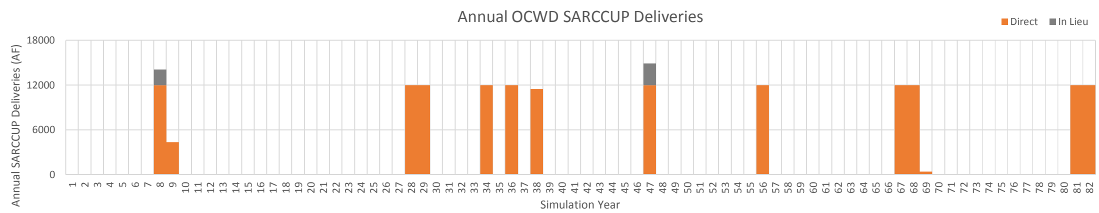
Notes:
Negative In-Lieu indicates imported water provided in lieu of SARCCUP storage. In Lieu happens in January of an extraction year.
Data is summarized based on calendar year. Extractions are allowed from May to April, therefore it is possible that more than 12,000 AF is delivered to an agency in one calendar year if there was enough extraction capacity to deliver 12,000 af to an agency in less than 12 months and some In-Lieu occured from January to May.

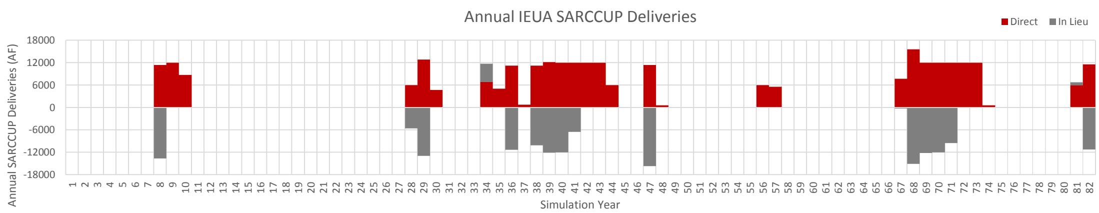
Scenario2.1

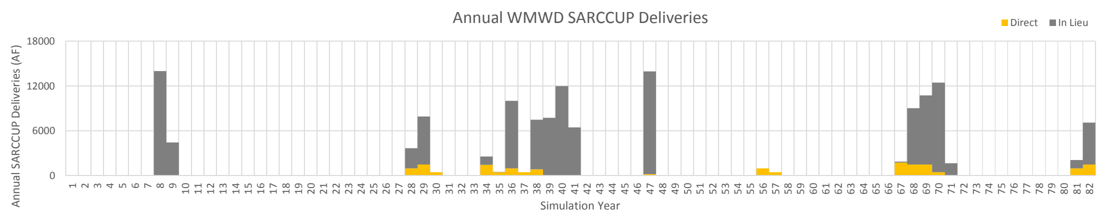
SARCCUP DSM Model Results

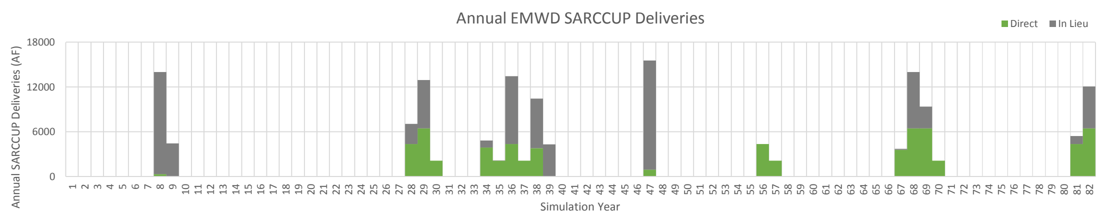
Model Version 1.75

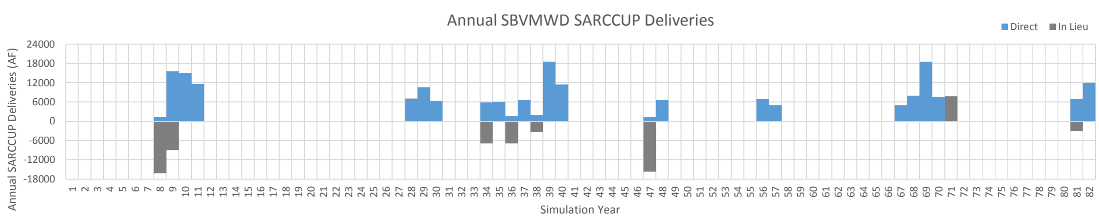
Annual Total System SARCCUP Water Deliveries, Direct and In-Lieu (Extraction Year May through April)

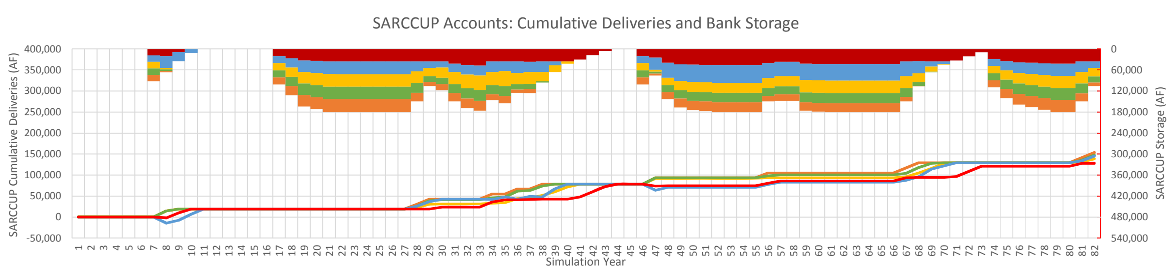












Scenario2.1

851 ($/AF)

End of Simulation summary (AF)

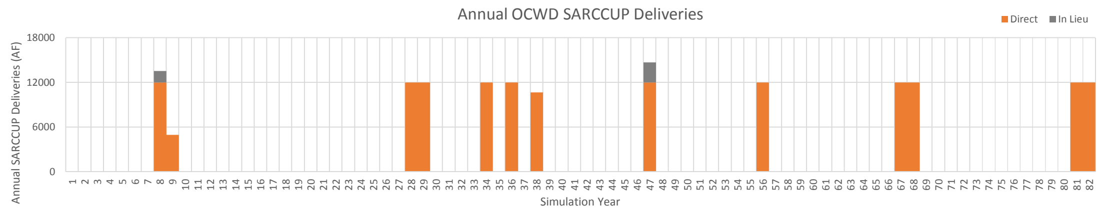
	OCWD	WMWD	SBVMWD	EMWD	IEUA	Total
Cumulative Deliveries (82 years)	153,400	138,600	145,300	146,900	128,200	712,400
End of Simulation Storage	10,300	25,100	18,400	16,800	35,500	106,100
Total	163,700	163,700	163,700	163,700	163,700	818,500

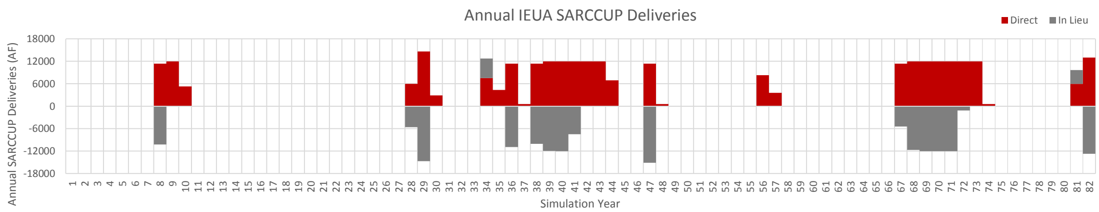
Notes:
Negative In-Lieu indicates imported water provided in lieu of SARCCUP storage. In Lieu happens in January of an extraction year.
Data is summarized based on calendar year. Extractions are allowed from May to April, therefore it is possible that more than 12,000 AF is delivered to an agency in one calendar year if there was enough extraction capacity to deliver 12,000 af to an agency in less than 12 months and some In-Lieu occured from January to May.

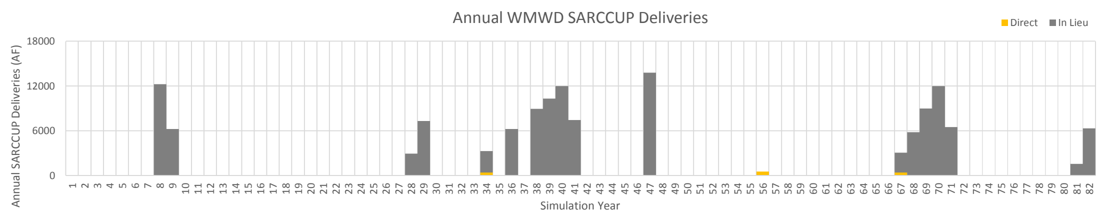
Scenario2.2

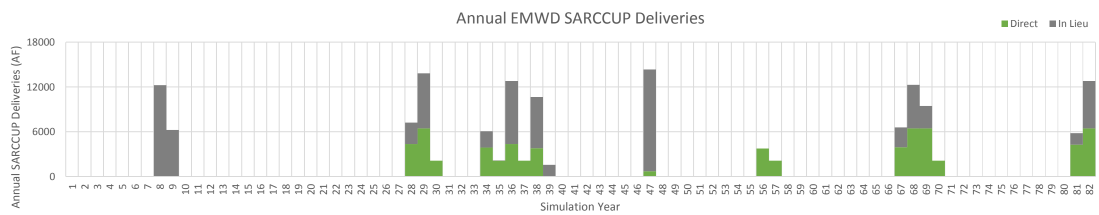
SARCCUP DSM Model Results Model Version 1.75

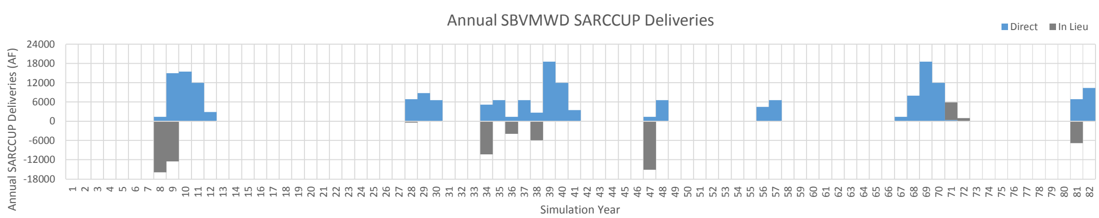
Annual Total System SARCCUP Water Deliveries, Direct and In-Lieu (Extraction Year May through April)

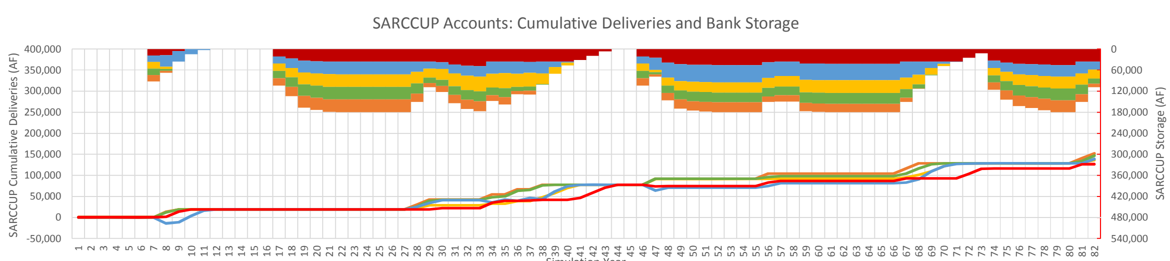












Scenario2.2 **End of Simulation summary (AF)**

827 ($/AF)	OCWD	WMWD	SBVMWD	EMWD	IEUA	Total
Cumulative Deliveries (82 years)	152,100	136,000	138,700	146,700	126,100	699,600
End of Simulation Storage	9,600	25,700	23,000	14,900	35,500	108,700
Total	161,700	161,700	161,700	161,600	161,600	808,300

Notes:

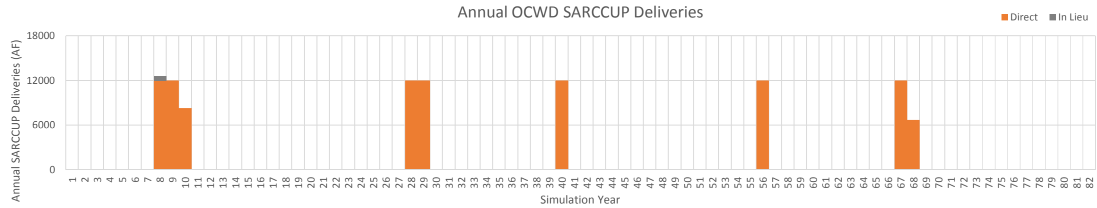
Negative In-Lieu indicates imported water provided in lieu of SARCCUP storage. In Lieu happens in January of an extraction year.

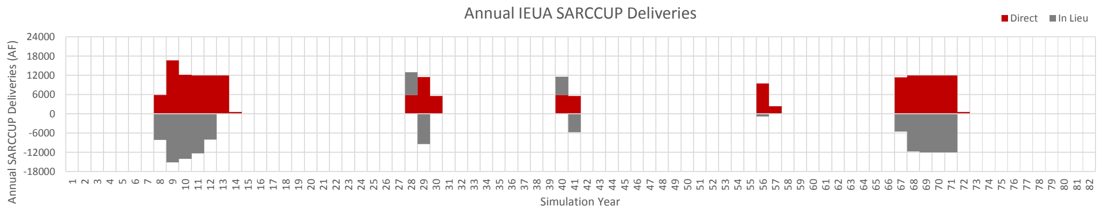
Data is summarized based on calendar year. Extractions are allowed from May to April, therefore it is possible that more than 12,000 AF is delivered to an agency in one calendar year if there was enough extraction capacity to deliver 12,000 af to an agency in less than 12 months and some In-Lieu occured from January to May.

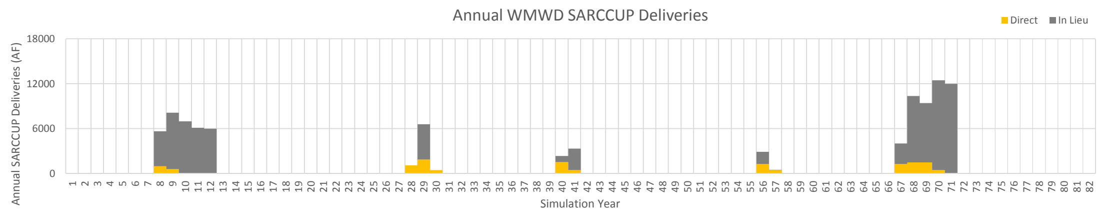
Scenario3

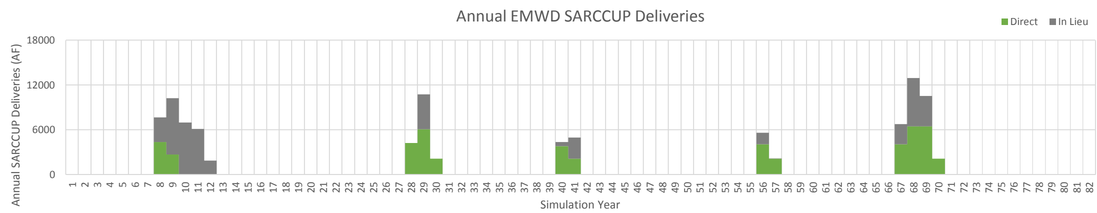
SARCCUP DSM Model Results Model Version 1.75

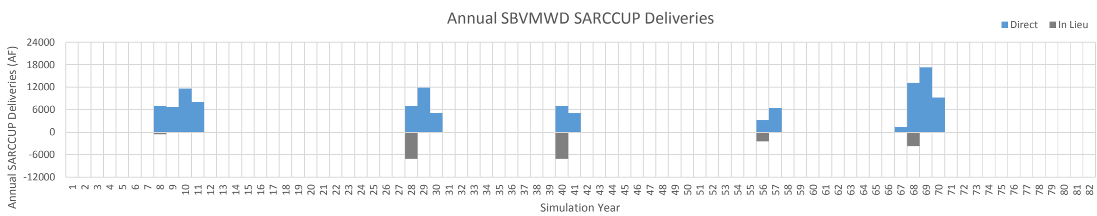
Annual Total System SARCCUP Water Deliveries, Direct and In-Lieu (Extraction Year May through April)

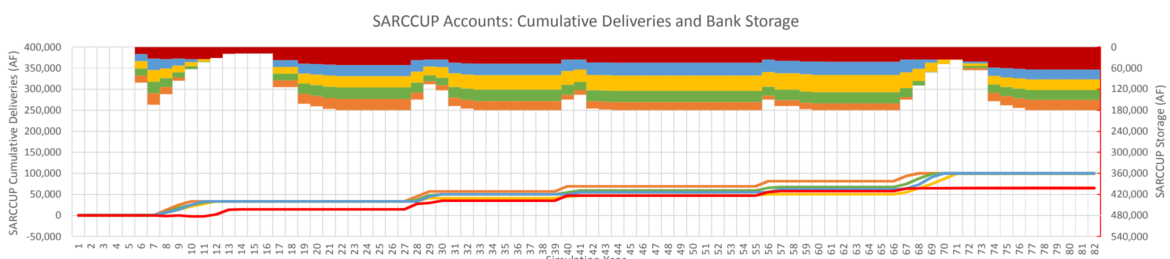












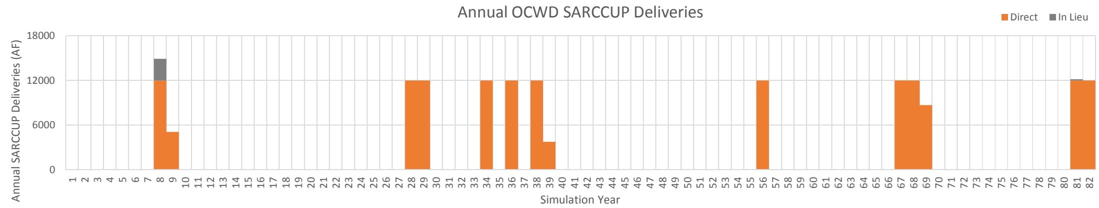
Scenario3	End of Simulation summary (AF)					
833 ($/AF)	OCWD	WMWD	SBVMWD	EMWD	IEUA	Total
Cumulative Deliveries (82 years)	99,700	98,600	99,700	99,700	64,700	462,400
End of Simulation Storage	28,800	29,900	28,800	28,800	63,700	180,000
Total	128,500	128,500	128,500	128,500	128,400	642,400

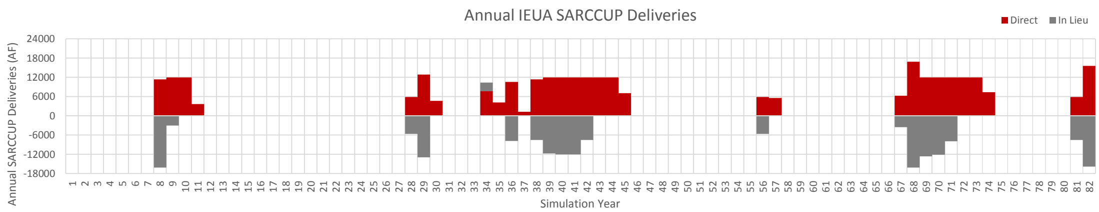
Notes:
Negative In-Lieu indicates imported water provided in lieu of SARCCUP storage. In Lieu happens in January of an extraction year.
Data is summarized based on calendar year. Extractions are allowed from May to April, therefore it is possible that more than 12,000 AF is delivered to an agency in one calendar year if there was enough extraction capacity to deliver 12,000 af to an agency in less than 12 months and some In-Lieu occured from January to May.

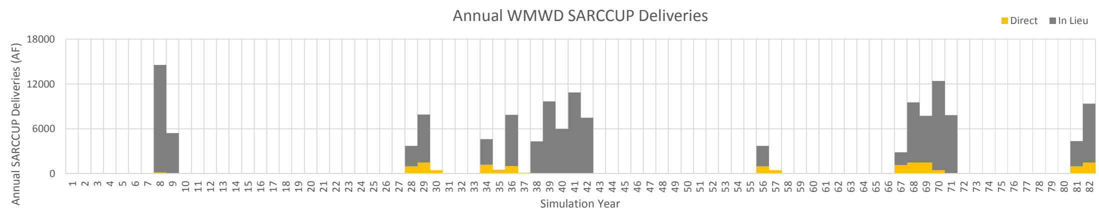
Scenario4

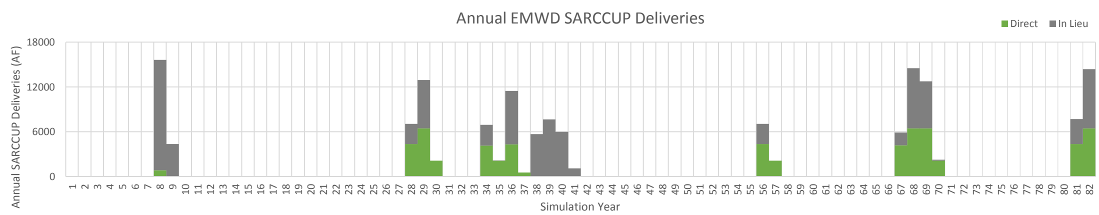
SARCCUP DSM Model Results Model Version 1.75

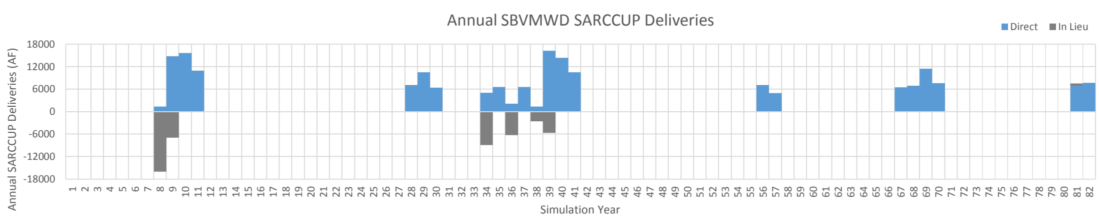
Annual Total System SARCCUP Water Deliveries, Direct and In-Lieu (Extraction Year May through April)

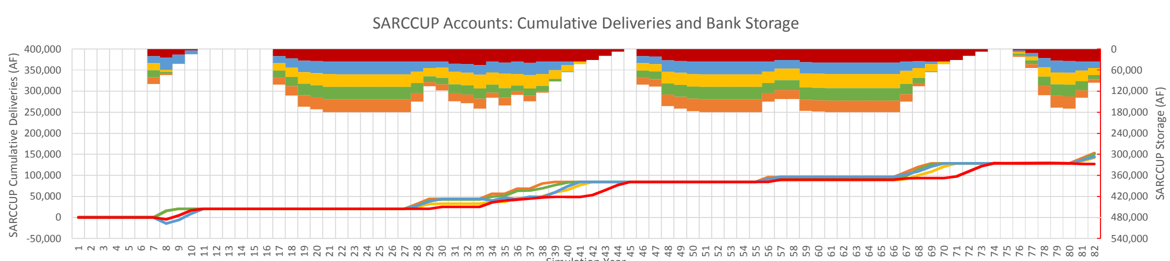












Scenario4 **End of Simulation summary (AF)**

845 ($/AF)	OCWD	WMWD	SBVMWD	EMWD	IEUA	Total
Cumulative Deliveries (82 years)	152,700	142,300	143,800	150,600	126,900	716,300
End of Simulation Storage	9,700	20,200	18,600	11,800	35,600	95,900
Total	162,400	162,500	162,400	162,400	162,500	812,200

Notes:
Negative In-Lieu indicates imported water provided in lieu of SARCCUP storage. In Lieu happens in January of an extraction year.
Data is summarized based on calendar year. Extractions are allowed from May to April, therefore it is possible that more than 12,000 AF is delivered to an agency in one calendar year if there was enough extraction capacity to deliver 12,000 af to an agency in less than 12 months and some In-Lieu occured from January to May.