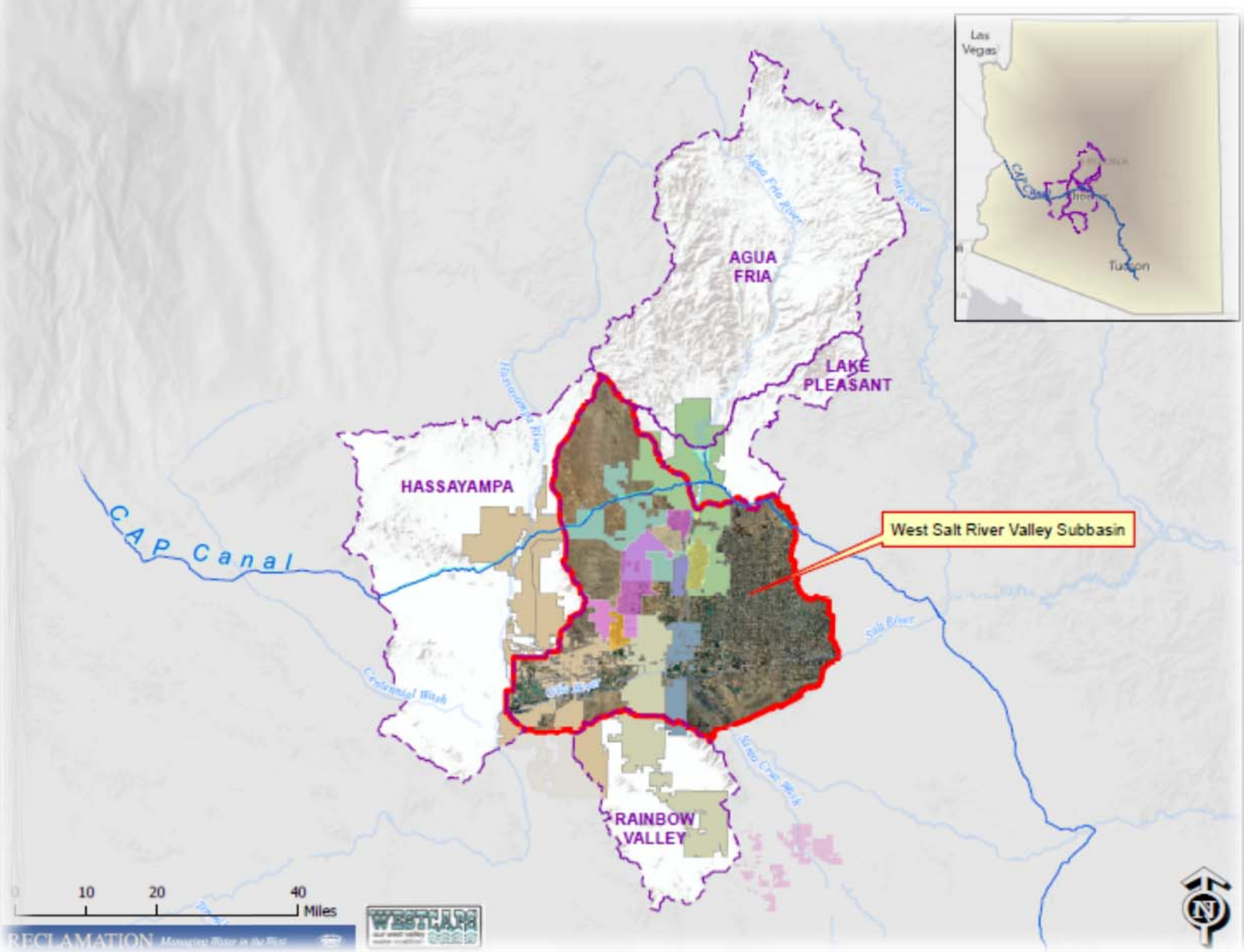
Metropolitan Phoenix

West Salt River Valley

Basin Study



Plan of Study

September 2013

Reclamation Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

"WESTCAPS is a coalition of CAP subcontractors most of whom serve drinking water to communities in the west Salt River Valley (SRV). WESTCAPS' mission is to develop workable alternatives for its members to provide their customers with a cost effective, sustainable, reliable, and high quality water supply through partnerships and cooperative efforts in regional water resource planning and management, emphasizing CAP utilization."

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I. Introduction

A. Purpose of the Study

For the past several years, WESTCAPS members have been evaluating best methods to fully utilize their surface and ground water supplies. The general planning area for WESTCAPS' members is illustrated in Figure 1. The majority of the surface water available to the WESTCAPS members comes from the Central Arizona Project (CAP). The CAP is a federal reclamation project developed and regulated by the Bureau of Reclamation (Reclamation) to deliver Colorado River water to Arizona. The primary requirement for WESTCAPS membership is to have a CAP subcontract with the Central Arizona Water Conservation District (CAWCD). The ongoing challenge for members is their inability to receive direct deliveries of their subcontract water to their service area. Many of the members are a significant distance from the CAP canal and lack the infrastructure to get their entitlement of water to their service area.

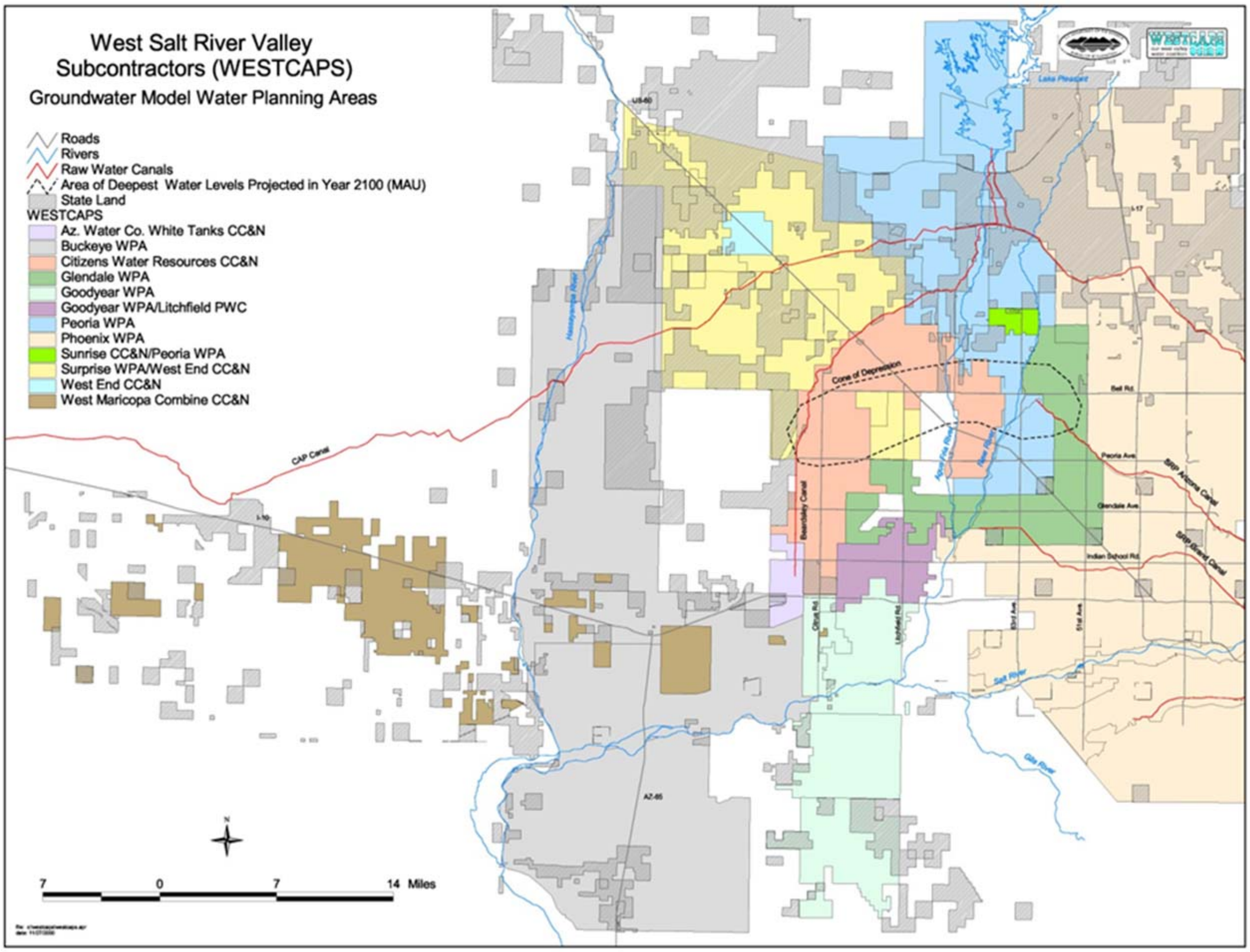


Figure 1. WESTCAPS Planning Area

Since Arizona has a junior right to waters coming from the Colorado River, there is a distinct possibility that a shortage may be declared in the future. The first state to be affected during any shortage on the Colorado River will be Arizona. This will impact deliveries coming from the Central Arizona Project to their subcontractors. Since all WESTCAPS members are subcontractors to CAP, a shortage will have a profound impact on how the members utilize their surface and groundwater supplies.

Under this study WESTCAPS members will begin developing a list of alternatives to resolve the groundwater and surface water issues in the WESTCAPS service area. Climate change issues will be considered in all identified alternatives.

B. Study Objectives

A clear understanding of the regional supply and demand and availability of groundwater and surface water supplies is critical for future water resources planning in western Maricopa County, Arizona. The impact of climate change and adaptation to these changes are potential issues which may impact existing supplies and demands along with the infrastructure for delivery. WESTCAPS needs to examine and address these potential imbalances in water supply for the citizens of the West Salt River Valley.

Under this study, WESTCAPS will identify and examine all existing water supply sources, followed by a review of the demand on these supplies. Imbalances in supply and demand with potential climate change concerns will be overlaid. Trade-off analysis studies will be applied to develop recommendations for solutions to any imbalance identified. Stakeholder input will be obtained and analyzed. A report of the findings will be developed and provided for peer review. Finally, a report will be published for dissemination to the public.

C. Description of Study Area

The WESTCAPS Basin Study area (Figure 2) covers several watersheds. The primary watershed is the West Salt River Valley (WSRV) basin (Figure 3), followed by the Hassayampa (Figure 4), Rainbow Valley (Figure 5), Agua Fria (Figure 6) and Lake Pleasant (Figure 7) watersheds.

WESTCAPS member service areas extend into all these watersheds which will impact the analysis of the proposed study. For purposes of the Plan of Study, BASIN STUDY AREA or STUDY AREA refers to these five areas, or basins, which are described in detail in the Study Description section of this Plan of Study.

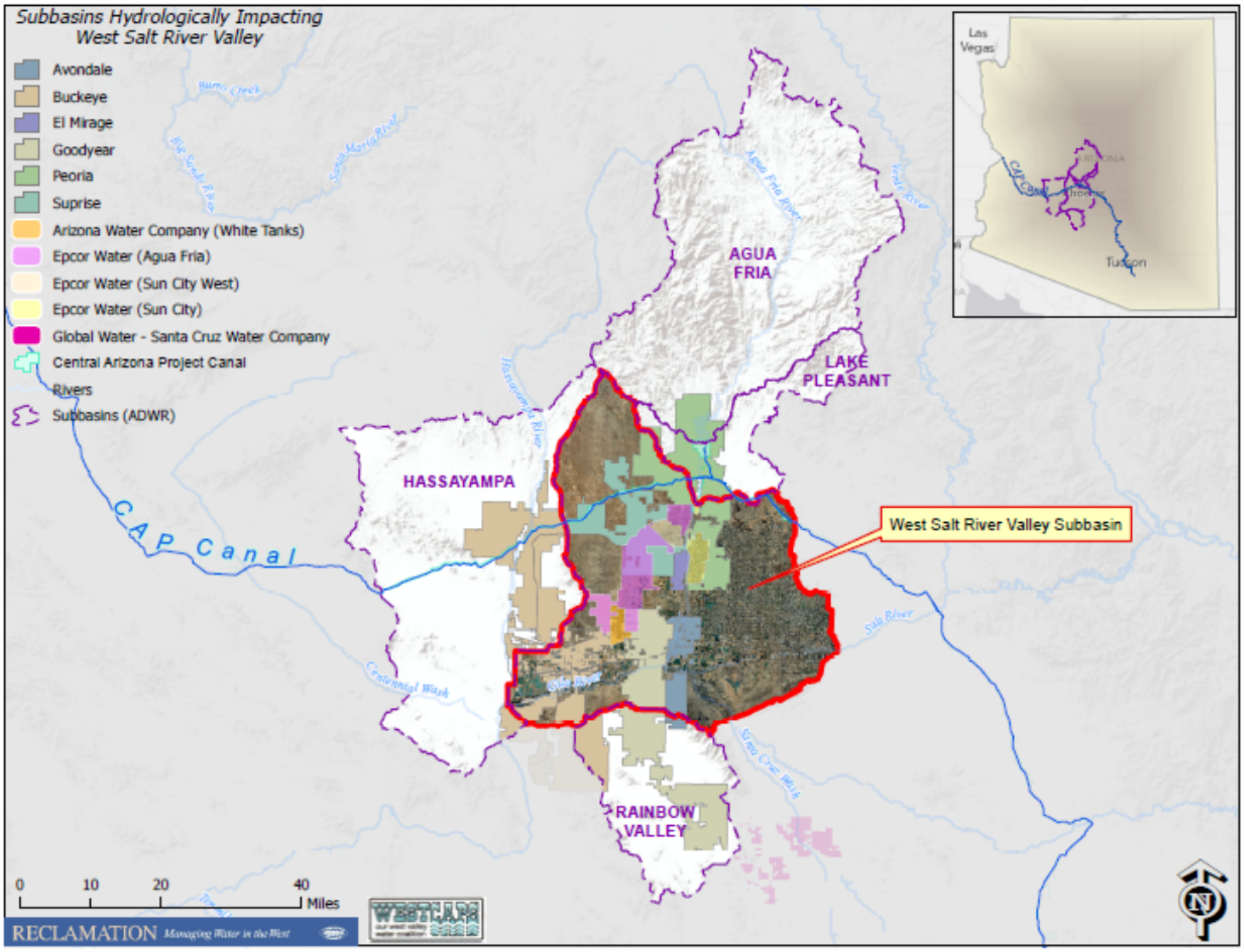


Figure 2. Basin Study Area Overall Views (Proposed Modeling Area)

D. Organization of the Plan of Study

This Plan of Study (Plan) follows the outline provided in Reclamation's "Basin Study Framework: *WaterSMART Program,"* February 2013. There are nine major tasks and associated subtasks identified to accomplish the goals of this study.

II. Study Description

A. Project Background

The West Salt River Valley (SRV), Hassayampa, Rainbow Valley (RV), Agua Fria, and Lake Pleasant Sub-basins are located in the Phoenix Active Management Area (AMA) and are the focus of this study. The Phoenix AMA is divided into seven hydrographic regions, or sub-basins, including the West Salt River Valley, Hassayampa, Rainbow Valley, Lake Pleasant, East Salt River Valley, Carefree, and Fountain Hills. Each sub-basin has its own characteristics, and a number of factors influence groundwater conditions in each. These include groundwater inflow and outflow, depth to groundwater, withdrawals and recharge, surface water conditions, subsidence potential, and quality of groundwater, with renewable water supplies being one of the most important factors in counteracting groundwater overdraft.

West Salt River Valley Sub-Basin

The West SRV Sub-basin is one of the larger sub-basins in the Phoenix AMA (1,330 square miles) and is a broad, gently sloping alluvial plain. It is bounded on the north by the Hieroglyphic Mountains and Hedgpeth Hills; on the east by Union Hills, Phoenix Mountains, and Papago Buttes; on the south by the South Mountains, the Estrella Mountains and Buckeye Hills; and on the west by the White Tank Mountains (Figure 3).

The Salt River channel meets the Gila River in the southern portion of the sub-basin. When flowing, much of the sub-basin drains from north to south into the Gila River via Skunk Creek, New River, the Agua Fria River, and Cave Creek. Skunk Creek drains into New River just east of Sun City, which subsequently flows into the Agua Fria River just south of Glendale Municipal Airport. The Agua Fria River joins the Gila River west of its confluence with the Salt River. Cave Creek flows from East SRV Sub-basin until it reaches the Arizona Canal Diversion Channel, which drains into Skunk Creek.

The West SRV Sub-basin has three hydrogeologic units recognized within the basin-fill sequence, consisting of similar unconsolidated to semi-consolidated fill deposits, including

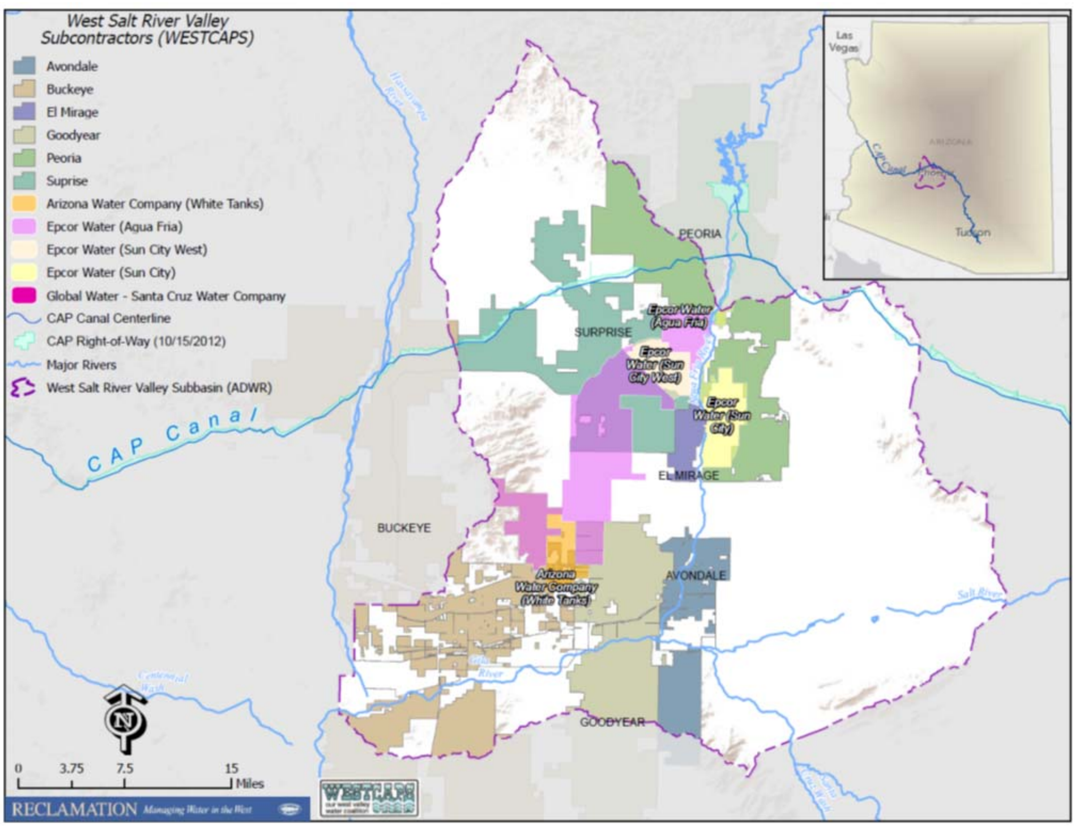


Figure 3. West Salt River Valley Basin

gravel, sand, silt, siltstone, clay, mudstone, sandstone, conglomerates, evaporates, and andesitic basalt. The upper unit is generally an unconfined aquifer and ranges in thickness from less than 100 feet near the basin margins to over 500 feet in the Luke Air Force Base area. The middle unit is unconfined to semi-confined and ranges in thickness from less than 100 feet near the basin margins to over 1,300 feet southwest of Glendale. The lower unit is semi-confined to confined, except where the middle unit is not present which can result in unconfined conditions, and ranges in thickness from less than 100 feet near the basin margins to over 10,000 feet southwest of Glendale. A large salt body, known as the Luke salt body, lies in the West SRV southeast of Luke Air Force Base and occurs at a depth of 880 feet to over 6,000 feet. Geohydrologic data indicate that the upper part of the salt body has a local effect on groundwater salinity.

Historically, groundwater entered the West SRV Sub-basin as under flow from the north, northwest, and southeast between the Sierra Estrellas and South Mountain. In addition, minor groundwater underflow entered the sub-basin from the East SRV Sub-basin between the Papago Buttes and South Mountain. Within the sub-basin, groundwater flowed toward and along the Salt and Gila Rivers and finally exited the sub-basin into the southern part of the Hassayampa Sub-basin. Historic groundwater levels in the West SRV Sub-basin ranged from 800 feet above msl along the western reaches of the Gila River to nearly 1,300 feet above msl in the north. Shallow groundwater conditions occur in the Buckeye area.

Increases in well pumping capacity, expanding agriculture, and urban development have caused increased groundwater pumping. Groundwater levels have declined significantly, with two large cones of depression created by groundwater pumping near Luke Air Force Base and in Deer Valley near the Hedgpeth Hills. In spite of extensive groundwater pumping in the area, water logging problems persist because of high volume of treated effluent discharged into the Salt River by the City of Phoenix's 91st Avenue Wastewater Treatment Plant (WWTP) and because of high volumes of water applied for agricultural irrigation to manage elevated salt levels. Although some groundwater still flows westward from the West SRV Sub-basin into the southern part of the Hassayampa Sub-basin, much of the groundwater flows toward the two large cones of depression.

The West SRV Sub-basin currently contains many water users who do not have access to many renewable supplies and rely heavily on groundwater, including municipal water providers, private water companies, numerous golf courses and agricultural users.

Hassayampa Sub-Basin

In the far western portion of the AMA, the Hassayampa Sub-basin covers 1,200 square miles and is a gently sloping alluvial plain bounded on the north by the Vulture Mountains and the Wickenburg Mountains; on the east by the White Tank Mountains; on the south by the Buckeye Hills and the Gila Bend Mountains; and on the west by the Big Horn Mountains, the Belmont Mountains, and the Palo Verde Hills (Figure 4). The area is drained by the Hassayampa River, which enters the sub-basin in the northeast and joins the Gila River east of Arlington. The Gila River, which flows perennially with effluent form the west Phoenix metropolitan area, crosses the southeastern tip of the sub-basin. Tributaries to the Hassayampa and Gila Rivers include Jackrabbit Wash and Centennial Wash, respectively.

The sequence of basin-fill sediments in the Lower Hassayampa Sub-basin consists of three hydrogeologic units designated as the upper, middle, and lower alluvium. The upper unit is 30 to 60 feet thick and consists of sand and gravel. The middle unit, 230 to 300 feet thick, consists of clay and silt. The lower unit, from 100 to more than 1,000 feet thick, consists of unconsolidated sand and moderately to well-consolidated alluvial fan deposits.

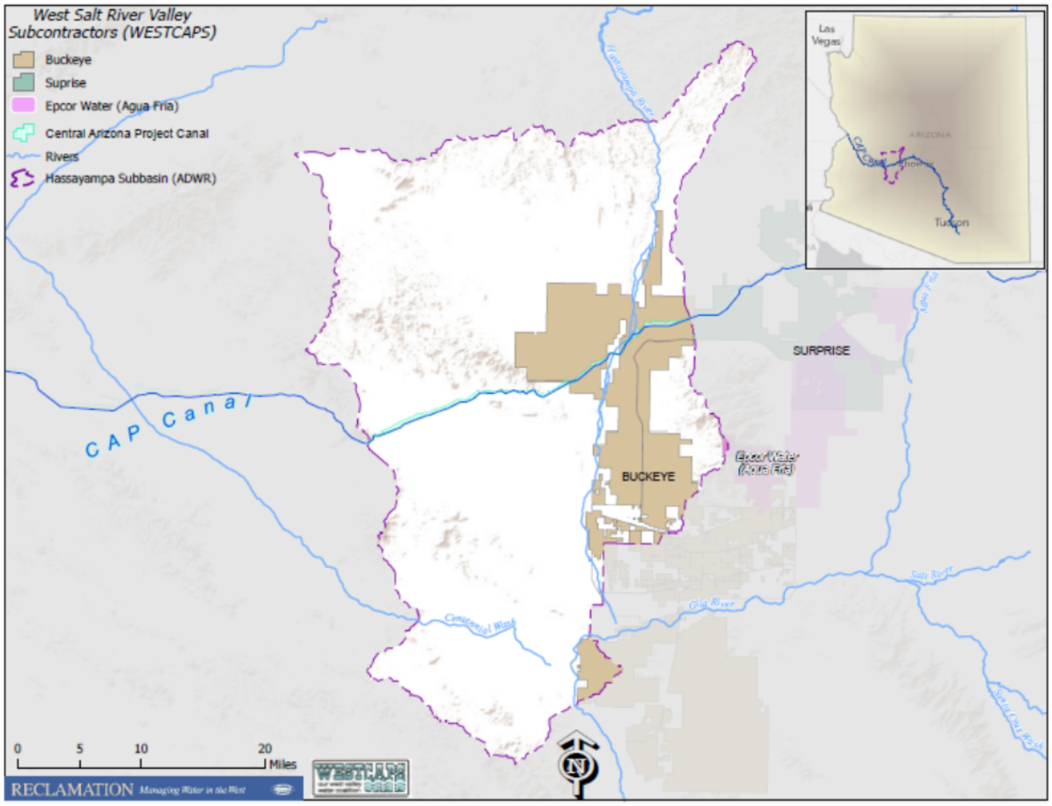


Figure 4. Hassayampa Sub-Basin

Historically, groundwater entered the Hassayampa Plain from the northeast, most of which flowed south into the Lower Hassayampa area. Groundwater also enters the southeastern part of the Lower Hassayampa area as underflow from the southern part of the West SRV Sub-basin. Groundwater levels historically ranged from 800 feet above msl in the southern area of the sub-basin to more than 1,300 feet above msl in the extreme northern reaches of the sub-basin. As a result of groundwater pumping by the agriculture community, water levels declined by as much as 70 feet in the Tonopah Desert and 90 feet in the Centennial Wash area, resulting in the creation of two large cones of depression in those areas. Also, groundwater from the RV Sub-Basin traditionally flowed to the northwest into the West SRV Sub-Basin. However, due to extensive agricultural pumping beginning in the 1950s, a cone of depression exists in the RV Sub-Basin, and groundwater no longer flows from the RV Sub-Basin into the West SRV Sub-Basin (ADWR, 1999). If agricultural pumping decreases in the future and municipal recharge occurs, groundwater conditions could change in the RV Sub-Basin.

After passing a bedrock constriction between the Belmont Mountains and the White Tank Mountains, groundwater currently flows from the northeast to southwest toward the two cones of depression in the Tonopah Desert and Centennial Wash areas. Groundwater entering the southeastern part of the Lower Hassayampa area from the southern part of the West SRV Sub-basin is largely captured by the cone of depression in the Centennial Wash area.

Rainbow Valley Sub-Basin

The Rainbow Valley (RV) Sub-Basin (Figure 5) is a gently sloping alluvial plain of about 420 square miles in area (ADWR, 1999). This sub-basin is drained by Waterman Wash, which empties into the Gila River near Buckeye (ADWR, 1999). The RV Sub-Basin adjoins the Salt River Valley at the Gila River.

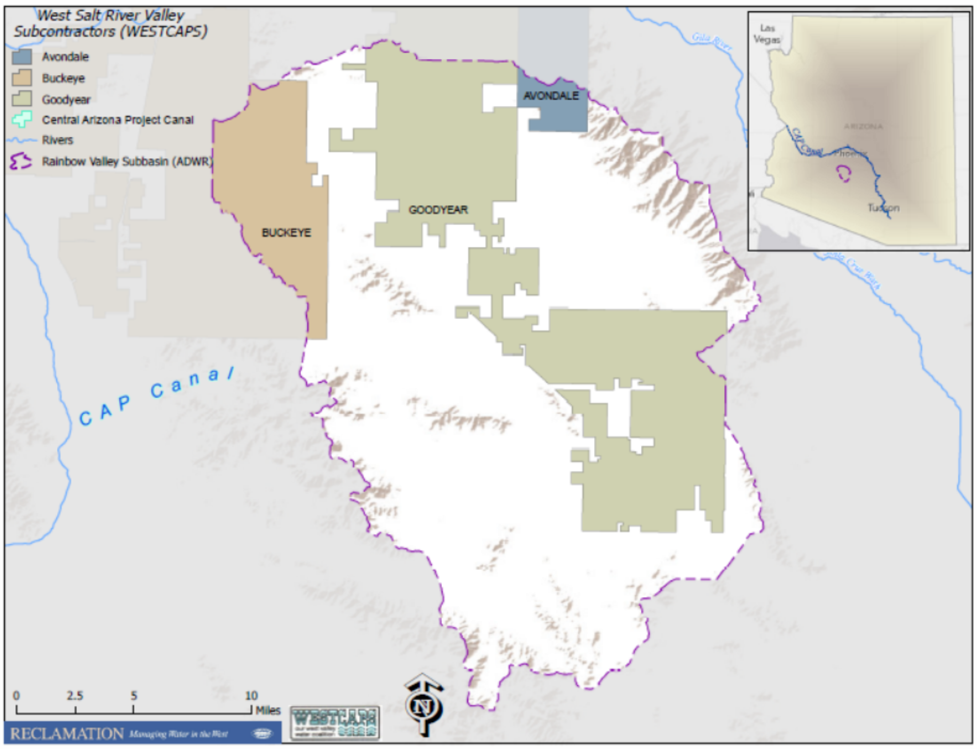


Figure 5. Rainbow Valley Sub-Basin

Historically, groundwater from the RV Sub-Basin flowed to the northwest into the West SRV Sub-Basin. However, due to extensive agricultural pumping beginning in the 1950s, a cone of depression exists in the RV Sub-Basin and groundwater no longer flows from the RV Sub-Basin into the West SRV Sub-Basin (ADWR, 1999). If agricultural pumping decreases in the future and municipal recharge occurs, groundwater conditions could change in the RV Sub-Basin.

Agua Fria Sub-Basin

The principal aquifers in the Agua Fria Sub-basin (Figure 6) are upper basin fill, which occurs under unconfined conditions, and sedimentary rock (conglomerate), which is found throughout the basin and contains the largest volume of groundwater. Water level data are sparse in the southern half of the basin. A domestic well located in unconsolidated sediments near Black Canyon City had a measured water level of 43 feet bls in 2003-04. Well yields in the unconsolidated sediments may be as high as 1,000 gpm or more although most are less than 500 gpm. The wells yield less than 20 gpm and have water levels ranging from 21 to 23 feet below ground surface.

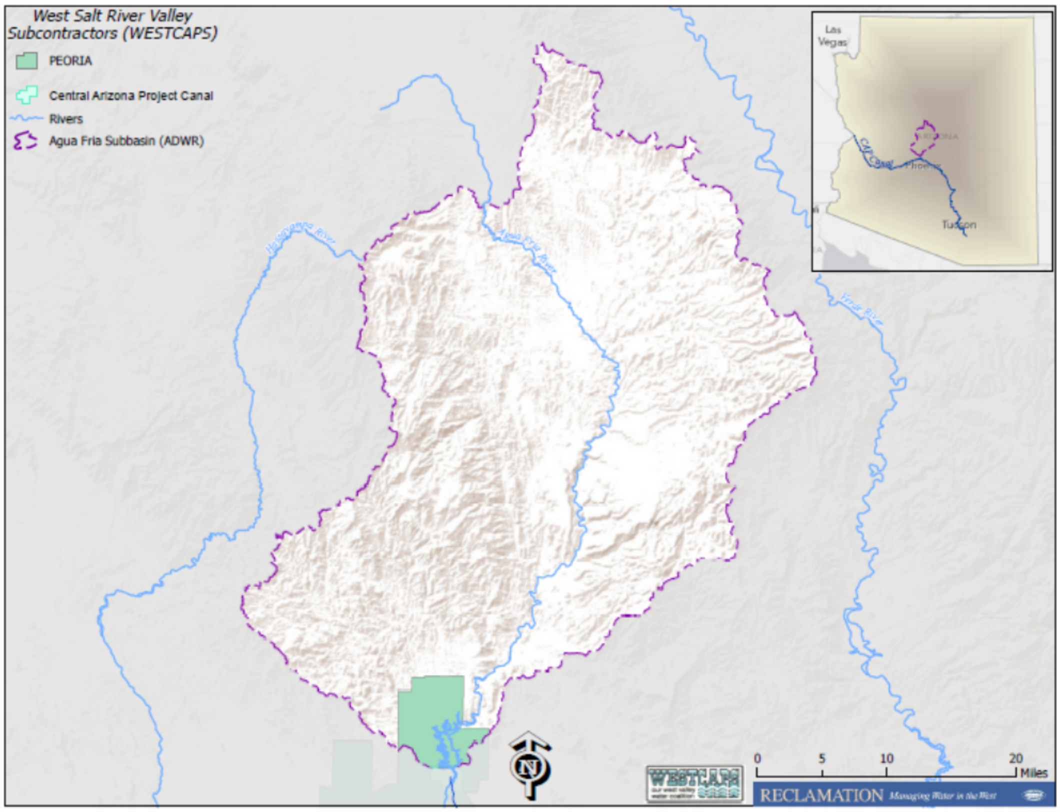


Figure 6. Agua Fria Sub-Basin

Lake Pleasant Sub-Basin

The Lake Pleasant Sub-Basin is a gently sloping alluvial plain of 240 square miles bounded on the north by an unnamed ridge southeast of the Agua Fria River (ADWR, 1999); and on the east and west by hills and low-relief mountain ranges (Figure 7). The depth to bedrock in the sub-basin ranges from a few feet near the basin margins to over 800 feet near the center of the basin. The sub-basin is drained by the lower part of the Agua Fria River, by New River, and by Skunk Creek (ADWR, 1999).

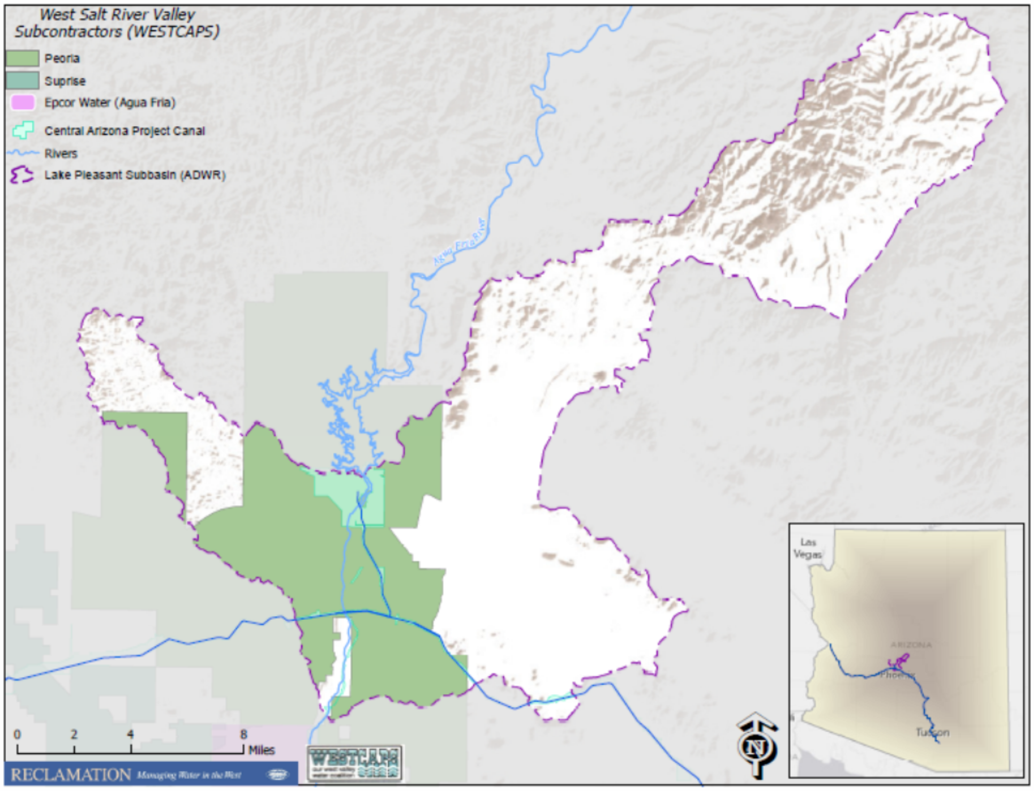


Figure 7. Lake Pleasant Sub-Basin

Groundwater flow directions suggest that the Lake Pleasant Sub-Basin is hydraulically connected with the West SRV and East SRV Sub-Basins. Long-term water level records are not available for the area. However, available information suggests that the water levels have been significantly affected by groundwater pumping. The depth to groundwater in 1998 ranged from 11 feet to nearly 300 feet (ADWR, 1999).

Lake Pleasant, which is situated at the northern boundary of the Lake Pleasant Sub-Basin, is fed by the Agua Fria River and the CAP canal. Lake Pleasant serves as a reservoir for the CAP canal.

B. Problems, Needs, and Opportunities

Management of water resources in the West SRV and Lower Hassayampa sub-basins is one of the most highly complex and controversial challenges facing water managers and users anywhere in the country. Meeting increasing regional and statewide water demands has become more difficult as dramatic changes in population, land use, and regulatory requirements have occurred. Compounding these changing conditions, temperature changes that have already occurred during the 20th century will result in decreasing snowpack, decreasing runoff, changing seasonal runoff timing, and changing peak flows. Most of these changes were not envisioned when Arizona's now aging storage and conveyance infrastructure was originally conceived and constructed in the early and mid-20th century. As increasing water demands and constraints on delivery have occurred, most water users have come to rely more heavily on the use of groundwater to meet demands in even average water supply years. Groundwater extraction continues to exceed recharge in the West SRV and Lower Hassayampa sub-basins which increases the potential for land subsidence.

Imbalances between supply and demand currently exist in the two sub-basins irrespective of water year type. These imbalances increase as hydrologic conditions become drier. Droughts, even relatively mild ones, have serious deleterious impacts on the people and economy of the Southwest Valley. Current agricultural and environmental gaps are the most significant, but future growth in population will lead to increasingly large imbalances for urban water users.

Although the full effects of climate changes have yet to be comprehensively assessed, current studies indicate that the most likely trends will involve an increase in the magnitude of the currently-projected future supply/demand imbalances. One of the principal objectives of the proposed West SRV, Hassayampa, Rainbow Valley, Agua Fria, and Lake Pleasant Sub-basin Study is to develop a comprehensive climate change impact analysis. Some of this work has been recently completed as part of Reclamation's recently completed Colorado River Basin Study (Reclamation, 2012) which provides valuable baseline information concerning the potential characteristics of climate change effects on the Central Arizona Project.

C. Previous Work and Available Data Models

In currently-funded and previous joint planning studies, Reclamation and the Arizona Department of Water Resources (ADWR) have already or are currently developing both high quality data and a suite of models that will be used to provide data and tools necessary for performing the various types of analyses needed for completing the Basin Study. The Basin Study will employ a scenario-based planning approach to evaluate the effectiveness of potential water management actions under a range of potential future uncertainties. This analytical framework was developed to evaluate the combined effects of climate and socioeconomic changes on urban, agricultural, and environmental water needs as well as other important management objectives.

The analytical framework includes the following components:

- Critical risks and scenario development
- Agricultural water demand and productivity
- Hydrology and systems analysis
- Performance-assessment tools
- Performance metrics
- Trade-off analysis
- Water management strategies
- Stakeholder interaction

Critical risks and scenario development will consist of developing a range of potential climate change futures for each of the sub-basins over the course of the 21st century. These future scenarios will build on the data and methods already developed by Reclamation and ADWR. Along with analysis of a continuation of historical hydrology, at least five representative climates will be employed to characterize a range of uncertainties. This approach is intended to be consistent with other long-term planning studies, such as the Colorado River Basin Study recently performed by Reclamation, and those of other basins and agencies. The study will analyze the effects of climate change using a suite of integrated modeling tools. These tools include analysis of climate impacts on yields of major agricultural crops grown in the Southwest Valley using the Land Atmosphere Water Simulator (LAWS) model.

A linkage between the West SRV and Hassayampa Sub-basin models will be developed which will enable basin scale assessment of climate change, and socioeconomic impacts under various regulatory constraints on the coordinated operation of the WESTCAPs systems. A great advantage of this model is that both regional (ex. infrastructure projects) and local adaption strategies (ex. water use efficiency improvements) can easily be configured in various combinations and efficiently simulated making it possible to readily evaluate a wide variety of adaptation strategies covering a wide range of future climate and socioeconomic uncertainties. Other models currently being developed which will be beneficial for this study are the City of Surprise's Integrated Water Resources Master Plan, the Town of Buckeye's Physical Availability Determination, the City of Peoria's NAUSP modeling project and the City of Goodyear's Rainbow Valley modeling project.

Anticipated studies and on-going planning efforts, which will contribute information and processes directly to the proposed West SRV, Hassayampa, Rainbow Valley, Agua Fria, and Lake Pleasant Sub-basins Study, include, but are not limited to:

- Maricopa Water District Beardsley Canal Hydraulic Capacity Analysis (Bookman-Edmonston 1999)
- Appraisal Level Study of Brackish Water Treatment Plant City of Goodyear (Brown and Caldwell 2005)
- Recharge and Reuse Inventory Report (Brown and Caldwell 2006)
- Population and Water Demand Projections for WESTCAPS Member Lands (WESTCAPS 2006)
- Phoenix AMA Redesignation Modeling (ADWR 2009)
- Our West Valley Coalition Regional Pipeline Transmission (WESTCAPS & BOR 2010)
- Computer Model Integration Salt River Valley and Lower Hassayampa Sub-basin Numerical Groundwater Models (Brown and Caldwell 2010)
- Rainbow Valley Modeling (City of Goodyear 2013)

D. Current Activities

The Partners and Reclamation propose to conduct an integrated Basin Study for West SRV, Hassayampa, Rainbow Valley, Agua Fria, and Lake Pleasant Sub-basins (Basin Study) in two major phases. Since water management issues in these basins are highly complex, the Partners and Reclamation are currently preparing a detailed Plan of Study (Plan), termed as "Phase 1," which will be completed in September 2013. The Plan includes a work program, schedule, and public involvement program designed to involve major basin stakeholders. In the fall of 2013, the Partners and Reclamation propose in Phase 2 to initiate the full Basin Study which will be guided by the content and approach described in the final approved Plan of Study.

The two-phased study approach for the Basin Study was deemed beneficial because the Partners and Reclamation are currently completing several planning studies which will provide data and modeling capabilities directly to the proposed Basin Study. In Phase 1, the Plan will include an inventory of available modeling, decision support tools and hydrologic data that will support the preparation of the Basin Study. Building on this existing information base in Phase 2, the Basin Study can then focus primarily on the developing basin and sub-basin scale climate change impact assessments and a variety of specifically-tailored adaptation strategies to address both regional and local needs. These strategies will be vetted through a comprehensive decision analysis process among the Partners and Reclamation. The decision support tools and models, developed in previous and on-going planning studies conducted by Reclamation and ADWR, will significantly improve the ability of Reclamation and its Partners to assess a wide range of climate and socioeconomic impacts on water supplies, demands, systems operations, infrastructure, water quality, agricultural productivity, and economics as well as to formulate portfolios of adaptation responses and evaluate their performance across a wide variety of potential future climate and socioeconomic conditions.

E. Resources Availability

The overall Phase 1 and 2 anticipated costs of the Basin Study are estimated to be $1.675 million in total, with the study Partners cost-sharing in a 50/50 ratio. Proposed non-Federal cost-share amounts are listed below for each Partner:

Letter of Support	Arizona Department of Water Resources
$ 63,680	Central Arizona Project
$ 149,914	City of Avondale
$ 29,440	Arizona Water Company
$ 57,180	Town of Buckeye
$ 16,000	City of El Mirage
$ 77,200	EPCOR
$ 43,680	Global Water
$ 95,626	City of Goodyear
$ 26,180	City of Peoria
$ 2,200,000	City of Surprise
$ 2,758,900	Total

The non-federal partners have offered contributions in the amount of $2,758,900 with cost share being contributed as a combination of in-kind services and monetary contributions. The total funds needed to complete the study are $1.675 million with a 50/50 match between federal and non-federal funds. Reclamation's funding contribution is $840,000, with $25,000 allocated for the development of the Plan of Study. Because many accomplishments that directly benefit the Basin Study have already occurred through Reclamation and ADWR planning studies, all of the potential contributions offered by the non-federal partners will not be required for completion of the Basin Study. However, these funds could potentially be used for additional cost-sharing in the event there are unanticipated study costs.

A major focus of the Basin Study is to provide Southwest Valley-wide, as well as basin-specific, assessments of the effects of plausible future climate changes with resulting impacts on supplies/demands, economics, water quality, hydropower, greenhouse gas emissions, environmental resources and other important management goals. A multi-scenario based approach similar to that employed in other studies will be used in order to better characterize the range of potential impacts over the course of the 21st century. This approach will provide the information necessary to characterize the uncertainty in a wide variety of performance metrics. Using these results, the basin study partners will work collaboratively to develop and evaluate a variety of adaptation strategies. These strategies will include portfolios of potential management actions such as infrastructure, technology, land use, and other options that could be implemented at the specific local planning area and basin-wide scales. Trade-off analyses will be performed to allow the partners to develop and evaluate the robustness of basin specific and system-wide portfolios of adaptation strategies addressing current and future performance risks.

F. Potential Alternatives

A preliminary list of alternatives includes:

- No action alternative
- Increased artificial recharge
- A north-south water transmission line
- A brackish water treatment plant to treat brackish groundwater
- Additional surface water treatment plant(s)
- Establishment as a special enhancement area or other regulatory designation under proposed new regulation for enhanced aquifer management

This study will also explore additional potential alternatives to address the issues identified. A literature review of water supplies alternatives will be conducted to assist in the development of these alternatives.

III. Study Approach and Interested Parties

This project is supported by a majority of the public and private municipal water providers in western Maricopa County, the Arizona Department of Water Resources and the Central Arizona Project. There is no known opposition to the study at this time.

WESTCAPS and Reclamation will develop this study using a stakeholder process through consultation with the WESTCAPS executive director and its members. The approaches to accomplishing the goals of this study are:

1. Identify water related problems that exist in the watershed.
2. Work collectively with stakeholders to develop solutions to solve the identified problems, including considerations for climate change.
3. Develop tasks that will fill in data gaps and identify solutions to the watershed problems.

4. Compile the information developed under each of the tasks.
5. Finally, prepare a report of findings using the data developed in the process.

It is anticipated the end result of this effort will be a traditional Reclamation Appraisal Study.

Reclamation, in cooperation with WESTCAPS members, will collectively develop the West Salt River Valley Basin Study. The current members of the WESTCAPS organization are:

- Arizona Water Company
- City of Avondale
- Town of Buckeye
- City of El Mirage
- EPCOR Water
- Global Water Company
- City of Goodyear
- City of Peoria
- City of Surprise

Current interested parties to the study are:

- Arizona Department of Water Resources
- Central Arizona Water Conservation District
- Salt River Project

Prospective interested parties or potential members are:

- Arizona Public Service
- Arizona State Land Department
- Central Arizona Groundwater Replenishment District
- City of Glendale
- City of Phoenix
- Gila River Indian Community
- Tohono O'odham Nation
- Maricopa Water District
- Roosevelt Irrigation District
- West Valley Groundwater Coalition
- Inter-Tribal Council of Arizona
- Others stakeholders identified through the Public Involvement process

WESTCAPS will also work to encourage participation by environmental groups, academia, agricultural interests, and Indian communities, which will be identified as the study progresses.

IV. Study Management Requirement

A. Project Management Plan

1. Study Management Structure

A Study Manager from Reclamation and WESTCAPS will be designated to oversee all activities associated with this Basin Study. Alternate managers will be designated in the occasion the Study Managers are not available.

2. Decision Making Process

Collaboration between Reclamation and WESTCAPS is the desired method for decision making. Decisions will be made on a consensus/consent basis.

3. Roles and Responsibilities

Both the Bureau of Reclamation and WESTCAPS are partners in this Basin Study. Therefore, each will play a major role and assume major responsibilities. Reclamation will assume the role of financial oversight and control. WESTCAPS will assume the role of reviewer and planner. Both entities will contribute knowledge and direction to the study from their unique perspectives.

Reclamation will receive invoices and distribute funds. In providing financial tracking over the course of the study, Reclamation will contribute to periodic progress reports in the form of financial status reports on funds expended and in what categories the funds were expended. Reclamation will provide information recently developed concerning climate change factors vital to the study and lend direction to incorporating these insights into the study. Reclamation will coordinate with WESTCAPS in all aspects of the study.

WESTCAPS will assemble information available to WESTCAPS members, such as water supply and demand information, and review modeling reports and other deliverables. WESTCAPS members will lend their unique perspectives towards developing potential modeling scenarios and constraints. WESTCAPS will coordinate with Reclamation in all aspects of the study.

4. Project Team Coordination

The Project Team will ensure that the tasks that relate to the Study are completed in a cost-effective, timely manner and are technically sound. Members of the Project Team provide the expertise, experience, and knowledge that relate to the Study's scope and objectives. Members include staff from Reclamation's PXAO, LC Region, and Technical Service Center (TSC) along with WESTCAPS members who will provide specific information, knowledge, and support. The Co-Study Managers will lead the Project Team.

5. Administrative Record

Reclamation will maintain the Administrative Record for this Basin Study. This will include:

a. All meeting minutes
b. All contract documentation
c. Report findings for each task
d. Cost share documentation
e. Final report will be included as well
f. Other documentation as will be produced for the study

6. Schedule and Cost Control

The Study will be conducted over a two-year period, beginning after the Denver Office Basin Study Management team provides approval of the Memorandum of Agreement for the study. This Study will consist of 9 tasks. Specific costs are identified in the Study Schedule and Costs section of this Plan of Study.

Schedule and cost control measures will be employed to ensure that project tasks stay on track and within budget. These measures will include quarterly reviews of the schedule and budget, and if revisions are necessary to identify schedule or budget recovery mechanisms, these will be accomplished semi-annually and reviewed by the WESTCAPS Planning Committee.

7. Quality Control Plan

Quality control will be a collaborative effort between Reclamation and WESTCAPS. Efforts will be focused on providing relevant and up-to-date information and ensuring that reports meet study objectives. At a minimum, it will involve careful editing of reports and other documentation. Also checks of information gathered during the study will be made to ensure that data does not contradict information already published by Reclamation in their 2012 Colorado River Basin Study report, except to update and refine that information for purposes of this study. Quality control points will be set to parallel important scheduling milestones during the project such that reviews become more efficient. Each WESTCAPS member submitting water demand and supply information and other data as needed will thoroughly check such information to eliminate any inconsistencies or inaccuracies. Problems with the study's progress will be identified and addressed.

8. Deliverables and Project Documentation

Status reports will be developed and provided periodically. These reports will contain the following:

1. Progress of each element identified in the plan of study
2. Timeline of each element identified in the plan of study compared to the proposed schedule
3. A report of cost share contribution by the WESTCAPS partners

At a minimum, the final Basin Study report should contain the following four elements:

1. Projections of water supply and demand, including an assessment of risks to the water supply relating to climate change as defined in §9503(b)(2) of the Secure Water Act (SWA).
   a) Changes in snowpack
   b) Changes in the timing and quantity of runoff
   c) Changes in groundwater recharge and discharge
   d) Any increase in the demand for water as a result of increasing temperatures or the rate of reservoir evaporation
2. Analysis of how existing water and power infrastructure and operations will perform I the face of changing water realities, such as population growth and climate change, including an analysis of the extent to which changes in the water supply will impact Reclamation operations and facilities as defined in §9503(b)(3) of the SWA:
   a) The ability of Reclamation to deliver water
   b) Hydroelectric power generation facilities
   c) Recreation at Reclamation facilities
   d) Fish and wildlife habitat
   e) Applicable species listed as endangered, threatened, or candidate species under the Endangered Species Act 1973 (16 U.S.C. 1531 et seq.)
   f) Water quality issues (including salinity levels)
   g) Flow and water dependent ecological resiliency
   h) Flood control management
3. Development of options to improve operations and infrastructure to supply adequate water in the future.
4. -A trade-off analysis of the options identified, findings and recommendations as appropriate. Such analysis simply examines all proposed alternatives in terms of their relative cost, environmental impact, risk, stakeholder response, or other attributes common to the alternatives. The analysis can be either quantitative or qualitative in measurement.

9. Review Process

Review of work products will be done by both Reclamation and WESTCAPS members. Additionally, the potential exists for reviews by interested parties, government agencies (such as ADWR and CAWCD) and academicians, depending on circumstances. The Reclamation and WESTCAPS project managers will be responsible for sending out work products to designated reviewers and ensuring timely return of relevant comments. Only Reclamation and WESTCAPS will have authority to change language or direction in any given work product. Reviews will occur at defined intervals throughout the project, typically at major transitions. Reviews will be oriented towards verification of facts and how well project goals are met for the given stage. Reviews will be circulated between all participants, and forwarded to any contractors for revisions as needed within 90 days of work product submission.

10. Revisions and Final Review

All revisions will be documented and added to the administrative record. The final document will be provided to the WESTCAPS Planning Committee. WESTCAPS

Planning Committee will review the final draft report and at the same time WESTCAPS will provide the final draft documentation to academia for their review as well. The final document will then be provided to Reclamation for their review and concurrence.

B. Project Communication Plan

Project communications will be vital to the process. There are many different tasks, some taking place concurrently, so it will be necessary to ensure that communications flow through and across task items to maximize information and provide the best results, particularly when task methodology or results impacts subsequent or other tasks.

All individual and stakeholder meetings will be documented with sign-in sheets and meeting notes to record any major themes and decisions from the meeting. In addition, a Basin Study update will be provided at all WESTCAPS Planning and Management Committee meetings and documented accordingly.

All communications related to the study will be provided to Reclamation as well as the WESTCAPS stakeholders to maintain and compile as part of the complete record of the effort. The basin study will include, but not be limited to, the following communication mechanisms:

- Telephonic communication as necessary to keep stakeholders and members informed of study progress.
- Website information will be updated regularly on the existing website at www.WESTCAPS.org
- E-mail information will be the primary means of communication amongst the WESTCAPS members and the stakeholder group.
- All stakeholder meetings as part of the public involvement plan will be open to the public and noticed accordingly. There will be time on each agenda for a “call to the public” to invite public input or questions for consideration.
- New releases will be provided as a courtesy to the general public in the study area.
- A mailing list and stakeholder contact list will be maintained for interested stakeholders, which will be utilized for any upcoming meetings, key milestones in project tasks, or general study progress

C. Public Involvement Plan

Reclamation and WESTCAPS agree that the basin study tasks cannot be fully successful without input, comments and consideration by stakeholders in the study area, whether or not they are WESTCAPS members. As the study addresses groundwater, as well as surface water supplies, it will be important to ensure that those potentially benefitting or impacted by the study results have the opportunity to participate throughout the process. A public involvement program will be established in coordination with the Project Communication Plan (above) for the basin study.

To that end, early on in the process, the basin study project manager will contact potentially affected interests and invite them to participate in the basin study process. In addition to current WESTCAPS members, these will include, but not be limited to, the cities of Glendale, Phoenix, Tempe, and Scottsdale, Arizona Public Service, Metropolitan Water District, Roosevelt Water Conservation District, Roosevelt Irrigation District, Arizona State Land Department, Maricopa County Farm Bureau, and the West Valley Groundwater Coalition. From this initial group of stakeholders, any additional interests that should be considered will be identified. It is anticipated that representatives from the various stakeholder groups will be assembled into a Basin Study Stakeholder Group. An initial orientation meeting will be held to provide preliminary information and explain the study purpose and objectives, stakeholder roles and responsibilities, and the purpose of the stakeholder group. The stakeholder group will then meet periodically during the process to provide input, and review and discuss results for consideration into further analysis or recommendations.

All stakeholder group meetings will be open and noticed to the public for attendance, and time on each agenda will be provided for public questions or comments to be considered in the basin study process. It is anticipated that stakeholder group meetings will be held quarterly during the basin study process; however, this may be adjusted to accommodate the study tasks or schedule.

V. Study Tasks

A. Task 1 – Project Management

Project management will be conducted through a collaborative effort between the WESTCAPS' Executive Director and Reclamation's Program Manager. Utilizing the components of the Project Management Plan, Project Communication Plan and Public Involvement Plan, in Section IV of this Plan of Study, WESTCAPS and Reclamation will coordinate the efforts of this study to ensure that progress toward action items and milestones is monitored on an ongoing basis, as well as regular tracking of project budget to stay at or below project budget levels.

B. Task 2 – Update WSRV/Hassayampa Demand Study

Demand in the West Salt River Valley can be attributed to two major classes of water users: municipal and industrial (M&I) and agricultural. Most of this demand is met from groundwater supplies, but some demand is serviced with surface water supplies. Agricultural users (mostly irrigation districts) often use both surface water and groundwater supplies. Groundwater is the primary concern of this study. Groundwater demand from industrial users utilizing their own non-exempt wells (golf courses, sand and gravel operations, other types of mines and factories) and from private users of exempt wells can be assumed to be relatively minor and constant, allowing the small amounts of water to be dropped from consideration. Groundwater demand from public and private water providers and agricultural users is the major variable to be considered.

All non-exempt groundwater users within the Phoenix Active Management Area (AMA) are required to file annual reports on water use and production with the ADWR. These reports include exact amounts of water delivered for specific purposes. Annual reports dating back 10 years should provide sufficient long-term data to evaluate water demand in the West Salt River Valley. Any shorter period will be dominated by the effects of the recent economic recession, which for some sectors severely curtailed water demand. A more accurate trend can be determined from a longer timeframe. Additionally, private water providers regulated by the Arizona Corporation Commission (ACC) are also required to file annual reports on water deliveries to that agency. Three years of reports are available on-line, and maps of Maricopa County showing active private water providers are also available on-line.

The primary data source for water demand will be the annual reports filed with ADWR over the last 10 years by M&I and agricultural users. Both public and private M&I water providers' annual reports will be collected. Additionally, ACC records will be checked for smaller private water providers (gallons sold). While the number of irrigation districts in the West Salt River Valley is not overly large, they may outnumber the M&I providers. Individual holders of Irrigation Grandfathered Rights (IGFRs) will also likely be a major data source, as many farms continue to pump groundwater under the IGFR authority. The cooperation of ADWR will be essential in gathering the information on M&I and agricultural entities. The data sources will be public information and no confidential information will be obtained. However, the cooperation of individual water providers, especially WESTCAPS members, will also be essential in compiling demand information.

Water demand for the agricultural sector can be expected to hold relatively steady over the next several years and eventually decline at ever-increasing rates. M&I demand will continue to increase, and projections of demand tied to projections of population growth will necessarily have to come from the M&I water providers, both public and private.

C. Task 3 – Update WSRV/Hassayampa Supply Study

Supplies in the West Salt River Valley consist of both surface water and groundwater. Surface water rights are primarily held by irrigation districts for the agricultural sector and by municipal water providers for the M&I sector. Production of surface water for both agricultural and M&I purposes should be reported to ADWR in annual reports. These annual reports will be the source of information on surface water supplies.

Likewise, production of groundwater is also reported annually to ADWR. However, this information is much broader in scope as it includes irrigation districts and individual farms pumping groundwater under authority of various IGFRs. Public and private M&I water providers also report groundwater production annually to ADWR. Private water providers also report to the ACC annually. Domestic exempt wells can be eliminated from the study as relatively minor and constant factors. Annual reports will again be the basic source of information for the study. It is anticipated that more information may be gathered for M&I water providers, as they are fewer in number than the total of agricultural entities. WESTCAPS members can provide production numbers from their own annual reports for the last 10 years. Retrieval of information on agricultural pumping in the last 10 years from the agricultural sector may be more difficult, and ADWR will likely be the sole source of such data.

Water production is closely tied to water demand. The same data sweeps through ADWR records for demand will produce water production numbers as well.

D. Task 4 – Update and Combine WSRV and Study Area Groundwater Models

Importance of Groundwater

Groundwater supplies are critical to many of the cities and water providers in the study area. Water supplies in this area include groundwater, Central Arizona Project (CAP) water, effluent, Salt River Project (SRP) water, and irrigation district water. Many WESTCAPS members rely heavily upon groundwater because sufficient surface water supplies are not available to these members or infrastructure has not been constructed to deliver available surface water supplies. Therefore, understanding the availability of groundwater supplies is crucial.

Essential Need for Groundwater Model

The use of an improved, more accurate numerical groundwater flow model for this study is essential to:

- Predict the depth and trends of groundwater levels
- Understand the availability of groundwater supplies
- Manage the long-term sustainability of groundwater supplies

Existing SRV and LHSB Groundwater Models

Two numerical groundwater flow models, which partially overlap and share artificial boundaries, cover portions of the study area (together these two models cover most of the study area):

1. The Salt River Valley (SRV) model covers the eastern and central portion of the study area (Figure 2); and,
2. The Lower Hassayampa Sub-Basin (LHSB) model covers the western portion of the study area (Figure 3).

There are some differences between the two models including, but not limited to, the thickness of the model layering (thickness of geologic units or aquifer layers), simulation time periods, model pumping, and hydraulic parameters (hydraulic conductivity in the overlap area, storage in the overlap area, and specific yield in the overlap area). The thickness of the model layering, which is one example of the differences between the two models, is briefly discussed below.

Example Difference between the Two Models: Thickness of Model Layers
The three geologic units or aquifer layers (Model Layers) utilized by the two models consist of the:

- Upper Alluvial Unit;
- Middle Alluvial Unit; and,
- Lower Alluvial Unit.

Although the two models utilize the same Model Layers, the assumed thickness of the Model Layers varies between the two models, with the assumed thickness of the Lower Alluvial Unit varying up to 1,000 feet or more between the two models. This is only one example of the differences between the two models. Reconciliation of the differences between the groundwater models is necessary to develop a reliable groundwater flow model which covers the study area.

Preliminary Work to Merge SRV and LHSB Groundwater Models

WESTCAPS determined it would be necessary to integrate and seam together the SRV and LHSB groundwater flow models to better understand the availability of current and future groundwater supplies. Merging the two models will require reconciliation of the differences between the two models.

In 2008, to assist WESTCAPS planning efforts, BOR authorized Brown and Caldwell to conduct the initial phase of integration of the SRV and LHSB groundwater flow models. A report completed by Brown and Caldwell in January 2010 summarized initial steps to integrate the two models, discussed preliminary findings, and recommended future steps to complete the integration and seaming of the two models (Brown and Caldwell, 2010).

When the work is completed, the combined groundwater flow model will be identified as the WESTCAPS Expansion Groundwater Model (WESTCAPS model).

Future WESTCAPS Model Development
Brown and Caldwell completed the initial steps to integrate the SRV and LHSB groundwater models into the WESTCAPS model. However, Brown and Caldwell (2010) indicated it will be necessary to address the following issues before development of the WESTCAPS model can be completed:

- Thickness of Model Layering (thickness of geologic units or aquifer layers)
- Stream package (stream channel morphology and streambed conductance)
- Model Pumping
- Hydraulic parameters
- Recharge and Evapotranspiration
- Target Water Levels
- Calibration
- Steady State Simulation

WESTCAPS proposes that the items listed above be fully addressed and that development of the WESTCAPS model be completed during the initial phase of this basin study. The completed WESTCAPS groundwater flow model will enable BOR, WESTCAPS, and ADWR to assess the availability of groundwater supplies, and plan for the long-term sustainability of the groundwater supplies.

The WESTCAPS model will be updated to include pumping demands and recharge through 2012. Updated pumping demands will include actual pumping reported to ADWR through 2012. Recharge updates will include both natural and artificial recharge. Artificial recharge will include recharge of both effluent and CAP water. Recharge by the Central Arizona Groundwater Replenishment District (CAGRD) will also be included.

In addition, while the model domains of both the SRV and the LHSB models extend across the Gila River for a short distance into the Rainbow Valley Sub-basin, neither model covers much of the Rainbow Valley Sub-basin. A regional groundwater model is needed which covers the Rainbow Valley Sub-Basin as well as the entire Lake Pleasant Sub-basin. WESTCAPS proposes that the WESTCAPS Model be expanded to include the Rainbow Valley and Lake Pleasant Sub-Basins. This would provide a significantly improved understanding of the groundwater conditions, availability of groundwater supplies, and recharge feasibility in these sub-basins. It would also provide a better understanding of the hydraulic connection between the Lake Pleasant Sub-basin and the West SRV Sub-Basin, and assist water resource and water infrastructure planning efforts by the City of Goodyear, City of Peoria, Town of Buckeye, City of Avondale, other WESTCAPS members, ADWR and BOR.

The City of Goodyear will be conducting a groundwater modeling project within the Rainbow Valley Sub-Basin in the near future. Goodyear would make technical data developed during this project available to assist efforts to incorporate the Rainbow Valley Sub-Basin into the WESTCAPS Model.

The City of Goodyear provides water and wastewater service to a portion of the Rainbow Valley Sub-Basin at Goodyear’s Estrella Mountain Ranch development, and will provide water and sewer service to additional areas within the sub-basin in the future. A portion of the Rainbow Valley Sub-Basin is also within the Town of Buckeye’s Master Planning Area. Buckeye may provide water and sewer service to a portion of the RV Sub-Basin in the future. A small portion of the Rainbow Valley Sub-Basin is also within the City of Avondale’s Master Planning Area. The City of Peoria will provide water and wastewater service to a large portion of the Lake Pleasant Sub-Basin, and as such, integration of this sub-basin into the model will provide an important planning tool.

Predictive Simulations

Once the WESTCAPS model is completed, a series of predictive simulations will be run. The predictive simulations will incorporate differing hydrologic assumptions to predict how groundwater conditions may change over the next 50 years in response to projected increases in population and water demands, variable groundwater pumping, differing natural and artificial recharge volumes and recharge locations, and variable climatic conditions including climate change, higher temperatures and drought conditions.

The predictive simulations will also account for the economic downturn which occurred between 2007 and 2012. Predictive simulations run using the WESTCAPS model will allow for a slower ramp-up of future population growth and pumping demands over the next few years before more robust growth resumes.

Various recharge scenarios will be run. Recharge scenarios will include differing recharge locations and volumes. Effluent recharge, CAP water recharge by individual water providers, and CAGRD recharge will be considered.

Predictive recharge simulations will assist recharge site feasibility assessments and aid in the selection of regional and local recharge sites. Recharge site feasibility drilling and testing will be necessary to determine the actual suitability of individual recharge sites, but the predictive recharge simulations will provide screening tools to aid the selection of candidate recharge sites. Multiple scenarios will be run to help cities and water providers with short-term and long-term planning efforts.

Climate Change in Predictive Simulations

Once the WESTCAPS model is completed, the series of predictive simulations to be run will incorporate the potential effects of climate change. Climate change assumptions may include:

- Reduced precipitation and natural recharge
- Reduced CAP water supplies available for artificial recharge
- Increased groundwater pumping to offset shortages in CAP water supplies and other surface water supplies
- Reduced effluent recharge (more effluent may be used for landscape irrigation, resulting in less available for recharge)
- Increased evapotranspiration
- Reduced outdoor water usage, due to water use restrictions, in response to drought conditions

The predictive simulations will help water planners prepare for CAP water shortages resulting from climate change. Depending on the outcome of the predictive simulations, actions such as increased recharge during non-shortage years may help water planners prepare for years when shortages may occur. A well-planned increase in recharge may ensure that sufficient groundwater supplies are available for recovery (from wells) during shortage years. The predictive simulations may also help water planners determine when to prepare for drought conditions with actions such as basin-wide conservation measures and reduction of non-essential landscape irrigation.

E. Task 5 – Update Economics Model

Updating the economic models, developed more than ten years ago, to reflect present day economic conditions is essential to fully understand the cost-benefit of potential regional strategies.

Residing within the West Salt River Valley is approximately one-third or approximately one million residents of the total Phoenix Metropolitan area. The West Salt River Valley is projected to become a future economic and residential hub. However, due to its gradual transition from agricultural to urban environments, great geographic distances from renewable water supplies, and an overall lack of renewable water resources acquisitions challenges confront the area. Similar to the gains made with the acquisition of renewable water supplies within the East Salt River Valley which have led to significant economic, environmental, and social benefits, the West Salt River Valley will need to analyze and realize the economic value tied with renewable water supplies, economy of scales realized with joint ventures and collaboration, and social benefits made possible through stable renewable water supplies.

Water is the cornerstone for success for each municipality, industry and commerce, environmental restoration and sustainability, recreation and tourism, social amenities and quality of life that may all be realized through successful water resource management. The value of water can be intrinsically calculated and quantified within each particular use within each service area. Also, the reuse of reclaimed water supplies can also be valued as part of this analysis.

Each municipality's general plan and other planning reports should be used as the foundation of current and future water resources needs. The economic analysis should minimally evaluate and analyze the following water resource uses: 1) economic development and vitality; 2) commerce; 3) environmental restoration and sustainability; 4) quality of life; 5) recreation; 6) parks and open space amenities; 7) sports; 8) tourism; 9) employment opportunities; 10) industry; 11) community beautification; 12) water reuse opportunities; 13) community activities; and 14) community financial opportunities.

The report should evaluate each community's built-out scenarios and timing with current and future water resources needs. Other data including new census and Maricopa Association of Government data should be included. Lastly, the analysis will evaluate the analysis of "do nothing" and determine the various potential impacts associated with the "do nothing" scenario for each service area and the region as a whole.

F. Task 6 – Develop Climate Change Analysis

Climate change considerations increase the uncertainty of water supply availability, and these impacts must be projected and overlaid over all potential solutions so informed decisions can be made.

Climate change is any statistical change in expected weather conditions and is typically assessed over a span of multiple decades. The Basin Studies represent Reclamation's first programmatic effort to include climate change as part of its planning studies.

Five steps for conducting a climate assessment as part of a Basin Study are proposed below.

1. Evaluate Available Climate Projection Information

The purpose of this step is to gather available climate projection information and evaluate that information for climate aspects, particularly trends in temperature and precipitation that are relevant to the Basin Study. For example, if the focus is on *seasonal to annual water supply trends*, evaluation might focus on projected changes in monthly to annual mean temperature and precipitation. Alternatively, if the focus is on *drought or extreme events*, evaluation might focus on assessing precipitation drought episodes in the projections, or identifying extreme months or periods of temperature and precipitation.

A suggested data resource is the Downscaled Climate Projections (DCP) 2 archive. This archive offers a useful starting point for surveying many climate projections and the spread of future climate possibilities over the study region. A climate projection is typically characterized by simulated temperature and precipitation conditions over time. A climate projection requires using a chosen global climate model (GCM) to simulate temperature and precipitation *responses* to a scenario of greenhouse gas (GHG) development for the atmosphere and starts from an assumed initial condition of the global climate. The GHG scenario is important for determining the global average climate while the initial condition is important for determining regional temperature and precipitation conditions and sequences within the projection. As a result, climate projections can vary significantly depending on choice of climate model, GHG scenario, and assumed initial conditions for the climate system, which can have significant impacts on basin- level assessments.

There are greater than 100 available climate projections given the multitude of available GCMs (>20), GHG scenarios, and initial condition possibilities. The most recently developed collection of projections are described in the Intergovernmental Panel on Climate Change Fourth Assessment (2007) and referred to as the World Climate Research Programme's Coupled Model Intercomparison Project phase 3 multi-model dataset (or, CMIP3 data).

CMIP3 data taken directly from GCMs are not suitable for regional (Basin) assessments as they do not offer the spatial precision needed for basin-level studies. Consequently, it is necessary to "spatially downscale" the GCM output. A number of peer-reviewed techniques exist for doing so, one of which was used to "downscale" 112 CMIP3 projections and produce the DCP archive mentioned above.

2. Determine the Appropriate Climate Projection Models to be used in the Study

As indicated in the preceding section, Basin Study teams have access to many climate projections. On the whole, these projections portray a wide range of temperature and precipitation change possibilities over time. Study teams need to decide how this "spread" of potential future climate possibilities will be represented in their particular Basin Study (e.g., either analyze all or most of the projections to represent this spread, or analyze a small set of projections that encapsulates the spread), and ultimately develop associated sets of future water supplies/demands/constraints assumptions for operations modeling.

This decision can influence approach decisions in subsequent steps. For Basin Studies, teams might discuss a preferred framework with study stakeholders. If there is a preference for portraying a future climate "snapshot," the Reclamation (2008) reference offers a rationale for choosing an encapsulating set of climate projections (e.g., low, medium, and high; wet, no change, dry; etc.), where selection is based on how they portray climate change possibilities that are relevant to the study's future period, climate metrics, and region of interest. The projection selection rationale in Reclamation (2008) also addresses the question of removing climate models from consideration, potential basis for doing so, and why ultimately no models were eliminated from consideration in that study. If study teams prefer to portray a future "developing" climate (and sequences of climate variability from the GCMs, which may differ from historical observations), the Christensen and Lettenmaier (2007) reference offers a potential outline of methods for relating a large collection of climate projections to associated natural runoff, surface water supply, and operations *projections*.

3. Model Water Supply Impacts

Climate change impacts on water supply occur when changing temperature and precipitation result in changes to watershed hydrology, runoff, and ultimately surface water supply and hydropower generation. Both Reclamation (2008) and Christensen and Lettenmaier (2007) include methods for simulating surface water hydrologic responses to climate change. The two studies feature methods common to both: (1) choose a well-calibrated surface water hydrologic model, and (2) generate weather sequences that are compatible with this model *and* consistent with the space and time structure of the climate projections selected from the DCP archive. Both studies used a similar approach for weather sequence generation, described in detail in Reclamation's 2008 *Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment*. The need to generate weather sequences stems from the fact that DCP data are monthly and regularly spaced on a grid at roughly 12km intervals. In contrast, a chosen hydrologic model may represent watershed hydrology in lumped subareas that are defined by topography rather than by a regularly spaced grid.

Likewise, the model will likely have to compute time-evolving water balances in these subareas on a daily or sub-daily time-step, which would be shorter than the monthly time-step of DCP data. Basin Study teams might anticipate the use of geographic information system (GIS) analysis in the spatial reconciliation portion of this task.

Neither of the two methods assesses groundwater supply response to climate change which may be a significant issue for some Basin Studies (e.g., trends in groundwater stocks, or trends in interaction with surface water conditions as climate changes). Basin Study teams may wish to explore methods to account for groundwater supply changes and also interactions between groundwater and surface waters.

4. Model Water Demand Impacts

Basin Study teams may feel inclined to consider climate change effects on several types of water demands affecting operations. Two categories that may be more readily analyzed are agricultural and municipal water demand.

Analysis of agricultural water demands involves both physical modeling and anticipating demand management responses under climate change (e.g., mix of crops and irrigation technologies defining "district-level" demand). Physical modeling might include crop-specific consumptive use which can analyze plant water use response to changes in future precipitation conditions (i.e., rain-fed water supply that partially satisfies crop water requirements) and future temperature conditions (i.e., atmospheric water demand driving plant evapotranspiration).

Analysis of municipal water demands might be conducted within frameworks that involve historical analysis of water use variability and statistical modeling to reveal relative importance of potential influences (e.g., weather anomalies, price changes, time of the year). The American Water Works Association offers resources to guide these types of municipal water demand evaluations (e.g., Billings and Jones 1996).

Basin Study teams may also wish to consider how climate change might affect other water demand categories (e.g., environmental water needs, hydropower generation demand and timing, reservoir "storage" demands for recreational purposes, etc.), although methods for doing so may be less straightforward or confounded by institutional or legal influences.

5. Characterize Impacts on Operating Constraints

As a final step before proceeding to operations modeling, Basin Study teams may wish to consider how climate change might affect system operational constraints independent of water supply and demand assumptions. For example, sea level rise possibilities and how that might affect "cross-Delta conveyance" constraints were featured within the methods of Reclamation (2008). Other examples, perhaps more prevalent throughout Reclamation, might include future temperature increases and their influence on the effectiveness of environmental flow constraints on reservoir release operations or increased rainfall and its impacts to flood control constraints on reservoir storage operations. Basin Study teams may wish to complement the operations analyses with sensitivity studies involving the adjustment of climate-dependent operating constraints within reasoned limits of variation under climate change.

Specific to the WESTCAPS Basin Study

WESTCAPS will attempt to answer several questions as it relates to climate change. These questions are:

1. Will surface water supplies be affected in the future by climate change?
    1.1 If so, by how much?
2. Will groundwater supplies be affected by the effects of climate change?
    2.1 If so by how much?
3. How will demand be handled?
    3.1 Low Growth
    3.2 Medium Growth
    3.3 High Growth
4. What are the historical supply and demands for the WSRV basin?
5. What are the projected supply and demands for the WSRV basin?
6. What are the gaps in these supplies and demands?
7. What are the solutions or how do we adapt to these gaps in demand and supply?
8. What are the tradeoffs that can be identified and implemented?
9. What are the periods of concern based on what we know now and what we want to know?
    9.1 1984 to 2012 period, the beginning or baseline
    9.2 2013 to 2025 period, mid term
    9.3 2026 to 2050 period, long term
    9.4 2051 and beyond

These questions will be answered by:

- Preparing a literature review.
- Developing a list of tools to use.
- Developing a baseline assessment (what has already been done) based on both the supply analysis and the demand analysis.
- Evaluating the West Wide Climate Assessment:
    - o Historical supply and demand analysis
    - o Future supply and demand analysis
- Preparing a description of the existing models including:
    - o Inputs \
    - o Boundary conditions → what are the changes
    - o Outputs /
- Including climate change assumptions.
- Finally, performing the climate change simulations and preparing a report of findings.

G. Task 7 – Develop and Explore Options

Develop options based on the efforts in the basin study, which will include a recharge suitability model as a tool to identify locations for recharge in the West Salt River Valley area. Recharge is one of the potential solutions to fully utilize the WESTCAPS member's CAP allocations. Development of potential options will also include options such as, but not limited to:

- A north-south pipeline – A long north-south pipeline will allow for enhanced delivery and additional treatment of surface water supplies.
- Brackish water treatment plant – There is the potential to augment existing supplies by treating brackish groundwater.
- Additional surface water treatment plant(s).
- Establishment of the West Valley as a special enhancement area or other designation under proposed new regulations – This may allow for additional supplies through recharge and recovery.

A review of work on supply augmentation will be conducted so that additional options can be developed. Reclamation's Colorado River Basin Study and past WESTCAPS studies such as the Strategic Plan are examples of documents that will be review in the assistance of option development.

H. Task 8 – Trade-off Analysis and Recommendation

A trade-off analysis will used by WESTCAPS in collaboration with the Bureau of Reclamation, the Central Arizona Project (operated by the Central Arizona Water Conservancy District) and the Arizona Department of Water Resources (stakeholder group) to evaluate regional trends, water resource planning scenarios, and water management strategies.

As the study evolves and information and data results become available, the stakeholder group will develop options and alternatives to analyze, model and make recommendations based on priorities. A series of stakeholder meetings scheduled at the beginning of the study will include an information exchange and dialogue regarding trade-offs between issues, alternatives, and options.

The trade-off analysis will evaluate trade-offs between regional trends, water resource planning scenarios, water management strategies, and other alternatives identified during the course of the study with a goal to decrease groundwater use, increase basin storage, improve efficiencies, reduce infrastructure depreciation, and provide a long-term sustainable water supply for the west valley communities.

Alternatives, issues and options will be discussed and a prioritization matrix will be developed for the stakeholder group to develop logical solutions and recommendations.

The analysis will include:

- Costs vs. benefits
- Regional impacts
- Impacts of climate change
- Drought management
- Recharge and reuse opportunities
- Probable legal requirements
- Exploration of standard water and/or infrastructure sharing/transfer agreements

These options could include infrastructure or structural measures, such as a new pipeline or extension of an existing pipeline, or other physical improvements. The options also could include potential water sharing arrangements during times of shortage, recharge and reuse partnerships, cost sharing, and other alternatives. The options will be modeled, performance assessed, and an analysis will be performed of the trade-offs associated with the options identified.

Preparation for water shortages (resulting from climate change) could require increased recharge in the West Salt River Valley and Hassayampa sub-basins during non-shortage years to ensure that sufficient supplies are available for recovery (from wells) during shortage years. This may include strategic siting and installation planning for recharge facilities and recovery wells. Water sharing, joint facilities and water recharge/transfer agreements may be potential options.

In response to drought conditions, actions such as basin-wide conservation measures and curtailment of non-essential landscape irrigation could be required. Conservation activities could be at a technology level requiring all new homes and irrigation systems within the WSRV & Hassayampa sub-basins to use EPA's WaterSense approved technologies. Reducing water use and the strain on water resources and infrastructure would also promote good stewardship, cost savings, and efficient water use for the west valley communities.

Monitoring of the basin will be critical to assess the availability of water supplies. Siting and planning for the installation of strategically placed water-level transducers may assist in monitoring groundwater availability and provide water-level data for groundwater model updates.

I. Task 9 – Reporting

The final report will be the culmination of all tasks identified in the Basin Study. In addition, the report will be an overall appraisal study for the West Salt River Valley with at least one identified solution to solve the imbalances in supply and demand with climate change consideration.

1. Status Reports

Status reports will be developed and provided periodically. These reports will contain the following:

1. Progress of each element identified in the plan of study
2. Timeline of each element identified in the plan of study compared to the proposed schedule
3. A report of cost share contribution by the WESTCAPS partners

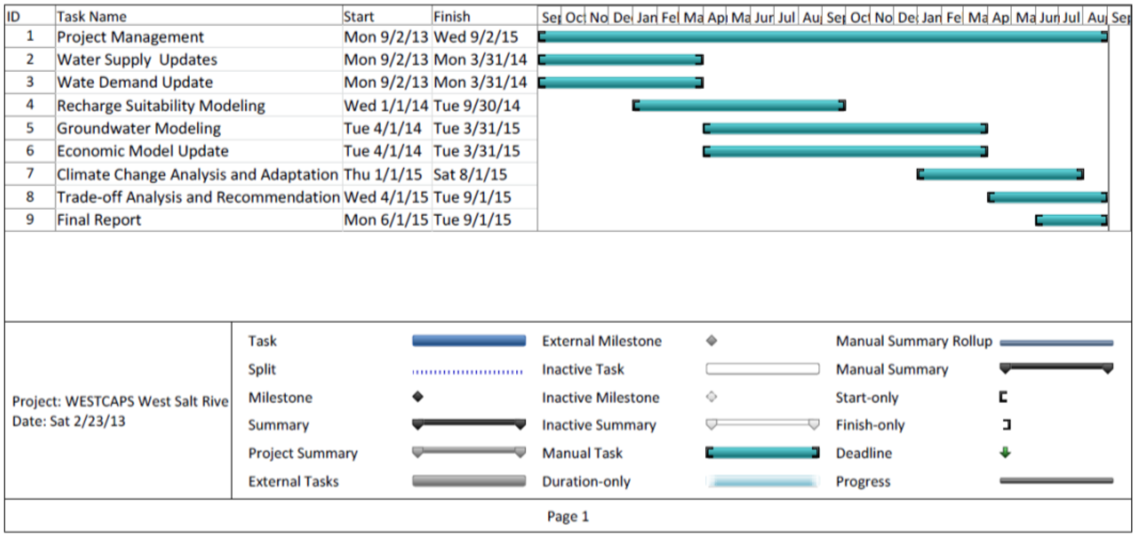
2. Basin Study Report

At a minimum the final Basin Study report should contain the following four elements:

1. Projections of water supply and demand, including an assessment of risks to the water supply relating to climate change as defined in §9503(b)(2) of the Secure Water Act (SWA).
   a) Changes in snowpack
   b) Changes in the timing and quantity of runoff
   c) Changes in groundwater recharge and discharge
   d) Any increase in the demand for water as a result of increasing temperatures or the rate of reservoir evaporation
2. Analysis of how existing water and power infrastructure and operations will perform in the face of changing water realities, such as population growth and climate change, including an analysis of the extent to which changes in the water supply will impact Reclamation operations and facilities as defined in §9503(b)(3) of the SWA:
   a) The ability of Reclamation to deliver water
   b) Hydroelectric power generation facilities
   c) Recreation at Reclamation facilities
   d) Fish and wildlife habitat
   e) Applicable species listed as endangered, threatened, or candidate species under the Endangered Species Act 1973 (16 U.S.C. 1531 et seq.)
   f) Water quality issues (including salinity levels)
   g) Flow and water dependent ecological resiliency
   h) Flood control management
3. Development of options to improve operations and infrastructure to supply adequate water in the future.
4. A trade-off analysis of the options identified, findings and recommendations as appropriate. Such analysis simply examines all proposed alternatives in terms of their relative cost, environmental impact, risk, stakeholder response, or other attributes common to the alternatives. The analysis can be either quantitative or qualitative in measurement.

VI. Study Schedule and Costs

A. Schedule



ID	Task Name	Start	Finish
1	Project Management	Mon 9/2/13	Wed 9/2/15
2	Water Supply Updates	Mon 9/2/13	Mon 3/31/14
3	Wate Demand Update	Mon 9/2/13	Mon 3/31/14
4	Recharge Suitability Modeling	Wed 1/1/14	Tue 9/30/14
5	Groundwater Modeling	Tue 4/1/14	Tue 3/31/15
6	Economic Model Update	Tue 4/1/14	Tue 3/31/15
7	Climate Change Analysis and Adaptation	Thu 1/1/15	Sat 8/1/15
8	Trade-off Analysis and Recommendation	Wed 4/1/15	Tue 9/1/15
9	Final Report	Mon 6/1/15	Tue 9/1/15

Figure 2. Study Schedule

B. Costs

Task	Task Description	Task Cost	WESTCAPS Share	Reclamation Share
1.	**Project Management**			
1.1	Stakeholder Coordination and Meetings	165,000	100,000	65,000
1.2	Study Team Coordination and Meetings	10,000	20,000	30,000
1.3	Study Administration	70,000	30,000	40,000
	Subtotal	285,000	150,000	$135,000
2.	**Update West SRV/Hassayampa Demand Study**			
2.1	Literature Review of Demand	10,000	10,000	0
2.2	Gap Analysis	20,000	20,000	0
2.3	Report Preparation	20,000	10,000	10,000
	Subtotal	50,000	40,000	10,000
3.	**Update West SRV/Hassayampa Supply Study**			
3.1	Literature Review of Supply	10,000	10,000	0
3.2	Gap Analysis	20,000	20,000	0
3.3	Report Preparation	20,000	10,000	10,000
	Subtotal	50,000	40,000	10,000
4.	**Update/Combine Ground Water Models**			
4.1	Review West SRV and Hassayampa Models	125,000	85,000	40,000
4.2	Combine models	110,000	60,000	50,000
4.3	Run Scenarios	100,000	60,000	40,000
4.4	Prepare Report	25,000	15,000	10,000
	Subtotal	360,000	220,000	140,000
5.	**Update Economics Model**			
5.1	Literature Review	70,000	40,000	30,000
5.2	Gap Analysis	80,000	40,000	40,000
5.3	Report Preparation	50,000	20,000	30,000
	Subtotal	200,000	100,000	100,000
6.	**Develop Climate Change Analysis**			
6.1	Evaluate Existing Projections of Climate Change	100,000	50,000	50,000
6.2	Incorporate Hydrologic/Groundwater modeling	120,000		120,000
6.3	Projected Gap Analysis	80,000	30,000	50,000
6.4	Prepare Report	20,000	10,000	10,000
	Subtotal	320,000	90,000	230,000
7.	**Develop Recharge Suitability Model – Explore Options**			
7.1	Data Gathering and Review	110,000	50,000	60,000
7.2	Run Suitability Model	30,000		30,000
7.3	Prepare Report	20,000	10,000	10,000
	Subtotal	160,000	60,000	100,000
8.	**Trade-off Analysis and Recommendation**			
8.1	Data Gathering and Review	50,000	40,000	10,000
8.2	Conduct Trade-off Analysis	30,000	30,000	
8.3	Prepare and Publish Report	30,000	20,000	10,000
	Subtotal	110,000	90,000	20,000
9	**Reporting**			
9.1	Interim Reporting	50,000	25,000	25,000
9.2	Draft Final Report	50,000	25,000	25,000
9.3	Final Report	40,000	20,000	20,000
	Subtotal	140,000	70,000	70,000
	STUDY TOTAL	**$1,675,000**	**$860,000**	**$815,000**

Figure 3. Study Costs

VII. Study Products

There are four required study elements which will be included in the final study report. These elements are:

I. Hydrologic Projections of Water Supply and Demand
- a. Analysis of Existing Supplies
- b. Projections of Future Water Supplies
- c. Analysis of Existing Water Demands
- d. Projections of Future Water Demands

II. Analysis of How Existing Water Infrastructure Will Perform in the Face of Changing Water Realities
- a. Baseline System Reliability Analysis
- b. Projections of Future System Reliability

III. Development of Options to Meet Future Water Supply Needs
- a. Non-Structural Changes
- b. Structural Changes
- c. Evaluation of the Options Identified

IV. Findings and Recommendations

VIII. References and Appendices

Arizona Department of Water Resources, 1999, Third Management Plan for Phoenix Active Management Area 2000-2010, Text with Figures, Tables, and Appendices.

Brown and Caldwell, 2010, Computer Model Integration: Salt River Valley and Lower Hassayampa Sub-Basin Numerical Groundwater Models; Prepared for: United States Bureau of Reclamation and West Salt River Valley CAP Contractors (WESTCAPS), January 29, 2010, Text with Figures, Tables and Appendices.