MOJAVE RIVER TRANSITION ZONE RECHARGE PROJECT

PHASE II REPORT

GROUNDWATER SUPPLY AND DEMAND IN THE TRANSITION ZONE

June 13, 2003

URS Corporation
10723 Bell Court
Rancho Cucamonga, CA 91730

Mojave Water Agency
22450 Headquarters Ave
Apple Valley, CA 92307

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EXECUTIVE SUMMARY

This report is the culmination of Phase II of the Mojave River Transition Zone Recharge Project. Phase II, Supply and Demand in the Transition Zone (TZ) was conducted to assess current and future water supply and demand conditions within the within the Transition Zone (TZ) and estimate the market for imported water and viability of recharge projects in the TZ. The Phase II report builds on the Phase I Report, TZ Hydrogeology (URS, 2003). The four phases of the Mojave River TZ Recharge Project identified by Mojave Water Agency are:

Phase I	Define Transition Zone Hydrogeology,
Phase II	Assess Current Supply and Demand & Project Future Demand,
Phase III	Perform Candidate Recharge Site Analysis, and
Phase IV	Assess Current Regulatory Environment in Relation to the Proposed Recharge Activity and Prepare Environmental Documentation.

WATER BUDGET

The balanced water budget is developed to evaluate future regional supply and demand scenarios by modifying individual components of the budget. The TZ water budget summarizes annual inflow and outflow and indicates over the past 10 years, the TZ water budget is in balance with an average annual water inflow of 61,150 AFY and average annual water outflow of 61,336 AFY. The difference between inflow and outflow is 186 AFY and is within the variability and estimating precision of the data. While the water budget is considered balanced from the perspective of long-term historical water supply and demand, and while annual water elevations are generally consistent, recently observed increases in summer groundwater depths in the southern area of the Floodplain aquifer are greater than can be tolerated by riparian vegetation.

WATER MANAGEMENT

Water resources management in the Mojave Basin Area is governed by the physical solution of the Judgment. The physical solution controls FPA Ramp Down, accounts for groundwater production, and provides methods to purchase water for replacement and Make Up Water obligations. MWA has developed a long-term regional water management plan to enhance supply, reduce consumption, and develop funding for purchasing imported water. By law (California State Water Code, 1959) MWA has the responsibility to ensure sufficient water is available for beneficial uses within its service area. Under current conditions, that responsibility is best fulfilled by balancing water supply and water demand. From the projected market for imported water, additional water management by MWA (through recharge or in lieu programs) will be required to maintain that balance. This may be achieved by either TZ recharge efforts, FPA Ramp Down, and/or introduction of imported water in the upper Alto Subarea.

GROUNDWATER SUPPLY

Projections indicate future water supply to the TZ may increase at a rate dependent on projected increases in VVWRA discharge and the future recovery of Mojave River base flow. VVWRA has begun processes to allow it to limit future discharge to the river channel at current levels and allow future increases to be diverted for reclaimed use elsewhere. Base flow recovery could begin as soon as overdraft in the upper Alto Subarea is reversed. The halt of overdraft in the upper Alto Subarea is estimated by the Watermaster to occur at approximately 60 percent to 65 percent Ramp Down of FPA.

For the 2000-01 WY, total water supply to the TZ was approximately 58,720 AFY. With no base flow recovery and VVWRA discharges tied to growth, total water supply is projected to be approximately 64,485 AFY by the 2019-20 WY. With no base flow recovery and VVWRA discharges limited at 9,700 AFY, projected total water supply is estimated at approximately 53,351 AFY by the 2019-20 WY. With base flow recovery and VVWRA discharges tied to growth, total water supply is projected to be approximately 80,411 AFY by the 2019-20 WY. With base flow recovery and VVWRA discharges limited at 9,700 AFY, projected total water supply is estimated at approximately 69,277 AFY by the 2019-20 WY.

GROUNDWATER DEMAND

Projections indicate future water demand in the TZ is increasing due largely to potential increases in municipal and industrial use. For the 2000-01 WY, total water demand in the TZ was approximately 60,709 AFY. The 2000-01 WY pumping water demand in the TZ was approximately 14,188 AFY. Pumping demand by the 2019-20 WY is projected to be approximately 28,979 AFY and exceeds the TZ BAP established by the Judgment (24,145 AFY for the original parties) and the TZ BAP reduced by producers dismissed from the Judgment (23,030 AFY). Depending on various scenarios of continued FPA Ramp Down, future TZ water demand could exceed TZ FPA by the 2003-04 WY.

MARKET FOR IMPORTED WATER

The projected market for imported water in the TZ is dependent of four main variables: water supply, water demand, recovery of Mojave River base flow, and limitations on VVWRA discharges. Without recovery of Mojave River base flow, the market for imported water in the TZ is projected to increase from about 3,300 AFY in the 2001-02 WY to between 8,800 AFY and 20,000 AFY by the 2019-20 WY. With continued FPA Ramp Down and success of water management practices, recovery of Mojave River base flow is predicted by the Watermaster to beginning at 65 to 60 percent FPA or approximately in the 2005-06 WY. With recovered base flow beginning in approximately the 2005-06 WY and with VVWRA discharges limited to 9,700 AFY, the market for imported water in the TZ would be approximately 4,000 AFY in the 2019-20 WY. With both recover of Mojave River base flow beginning in the 2005-06 WY and no limitations on growth-linked VVWRA discharge, the market for imported water in the TZ would be 0 AF in the 2010-11 WY through the 2019-20 WY limit of the study.

The market for imported water will also be driven by groundwater production exceeding FPA Ramp Down in addition to balancing total water supply and demand. Assuming current trends, annual Ramp Down of FPA for all water users, and projected future increases in pumping demand indicate future groundwater pumping demand in the TZ will exceed FPA Ramp Down at 70 percent for all producers and will exceed the total BAP by the 2012-13 WY.

MWA is currently entitled to a maximum of 75,800 AFY of imported water from the State Water Project water through the California Aqueduct. DWR currently estimates that on average MWA can expect 78 percent of that entitlement available due to limitations on the State Water Project. The market for imported water or any other interruptible water has a limited potential for maintaining riparian vegetation.

POTENTIAL RECHARGE PROGRAMS

The market exists for potential TZ recharge programs with varying objectives. Objectives of a TZ artificial recharge program could satisfy different water demand needs including supply to riparian vegetation, replenishing groundwater production, banking groundwater for short and long terms, and maintaining water level in TZ outflow areas.

Riparian vegetation and production replenishment objectives are best served by discharges to the river along the Mojave River in the southern TZ. Banking groundwater would be more suitable in areas of the Regional aquifer using injection wells or recharge basins. Maintaining water levels in outflow areas may be more suitable to recharge basins located in the vicinity of the Helendale fault than in the southern TZ.

VIABILITY OF POTENTIAL RECHARGE PROGRAMS

Recharge programs are viable in the TZ due to several factors, including demand based funding (the Judgment), available imported water supply, available groundwater storage, and available land for recharge facilities. Recharge programs may also be driven by increasing demand, base flow insufficient to meet riparian vegetation needs, maintaining key well water levels, and the potential limiting of VVWRA effluent discharges. Should recovery of Mojave River base flow occur as projected and VVWRA discharge remain tied to growth, then recharge programs in the TZ would not be required to balance total supply and demand. However, as with any regional water budget, separation of water supply from the demand may still require local recharge programs to protect local needs.

INTRODUCTION

Phase II of the *Mojave River Transition Zone Recharge Project* was conducted to assess current and future water supply and demand conditions within the within the Transition Zone (TZ) and estimate the market for imported water and viability of recharge projects in the TZ. The aerial extent of the TZ is defined in Exhibit A of *Judgment After Trial* (Riverside County Superior Court, 1996). *Judgment After Trial* (Riverside County Superior Court, 1996) is commonly referred to as the Mojave Basin Area Adjudication or the Judgment. The TZ boundaries are shown on Figure 1 and Figure 2 and are described in detail in the Mojave River Transition Zone Recharge Project Phase I report (URS, 2003). Figure 1 also shows the five water management subareas defined by the Judgment, namely the Alto, Centro, Baja, Oeste, and Este Subareas. The TZ, as defined by the Judgment, occupies approximately the northern 40 percent of the Alto Subarea. Throughout the remainder of this report, the portion of the Alto Subarea that excludes the TZ is referred to as the upper Alto Subarea.

The Phase II report on supply and demand is intended to be a document that will serve as the basis for Phase III and IV evaluations. The objectives of Phase II are to:

(1) Compile basic water supply and demand information,
(2) Prepare projections of future water supply and demand,
(3) Determine the magnitude of any imbalance between the current and future supply and demand, and
(4) Evaluate potential artificial recharge needs.

The four phases of the Mojave River TZ Recharge Project as defined by MWA are:

Phase I	Define Transition Zone Hydrogeology
Phase II	Assessment of Current Supply and Demand, Projection of Future Demand.
Phase III	Candidate Recharge Site Analysis.

Phase IV Assessment of the Current Regulatory Environment in Relation to the Proposed Recharge Activity and Preparation of Environmental Documentation.

SCOPE OF WORK

MWA defined the tasks completed under Phase II. The specific tasks are listed in Appendix A. In general, the tasks included

Task II-1 Summarize current status of water management in the TZ.
Task II-2 Assemble and organize all relevant data and information.
- 2 (a) Review recent ground water level and ground water production data.
- 2 (b) Determine water supply needs of existing water users.
- 2 (c) Determine future water supply plans.
- 2 (d) Determine potential for imported water demand resulting from implementation of the Judgment.
- 2 (e) Compile accumulated data in electronic format.

Task II-3 Present MWA with a Phase II summary report including findings regarding the viability of a recharge project within the TZ.

PROJECT UNDERSTANDING

The Judgment declared the Mojave Basin Area and each of the five subareas to be in overdraft and established base annual production rights for groundwater producers within each subarea. The Riverside County Superior Court recognized the importance of the link between the Alto Subarea and the Centro Subarea as it sought to determine water rights within the Mojave Basin Area (City of Barstow et. al. vs. City of Adelanto et. al., Case No. 208568). The term "Mojave Basin Area" is used in this report to refer to the adjudicated portions of the Mojave River Basin and the Lucerne and El Mirage Valleys. The term "Mojave River Basin" is used in this report to refer to the drainage area of the Mojave River. In the Judgment, the Riverside County Superior Court found hydrogeologic conditions in the TZ serve to convey groundwater and surface water from the Alto Subarea to the Centro Subarea. The Court described this TZ function as a "water bridge". Water supply and demand within the TZ form a critical link with TZ

hydrogeology to facilitate groundwater and surface water flow from the upper Alto Subarea to the Centro Subarea. The hydrologic subareas are interrelated, and receive at least some of their annual water supply as outflow from an up-gradient adjoining subarea. The Phase I evaluation (URS, 2003) was conducted to determine the hydrogeologic framework of the TZ and to identify factors critical to the TZ water bridge function. The purpose of the Phase II investigation is to assess potential future water demand within the TZ, identify a potential market for imported State Project Water and investigate the viability of artificial recharge within the TZ.

For the Alto Subarea producers, the Judgment established a minimum subarea obligation of 23,000 acre-feet per year (AFY) combined Mojave River base flow (21,000 AFY) and subsurface flow (2,000 AFY) flow to the TZ (Riverside County Superior Court, 1996). The Judgment assumes that if these conditions are met and water levels within the TZ are maintained at appropriate levels as determined by the Court, then the same amount of water would be capable of flowing through the TZ downstream to the Centro Subarea as had historically occurred. Various requirements of the Judgment relevant to water supply and the function of the TZ as a water bridge are discussed in the water management section.

PHYSIOGRAPHY

The TZ physiography is presented as background to understanding the aerial distribution of water supply and land use features. The TZ occupies approximately 296 square miles within the northernmost portion of the Alto Subarea. Key physiographic features of the TZ are shown on Figure 2.

TOPOGRAPHY

The TZ is bounded to the east and west by several low mountain ranges. Along the eastern boundary lie Quartzite and Silver Mountains. Quartzite Mountain, the farther south of the two, rises 1,300 feet above the Mojave River channel over a distance of about 2 miles to an elevation of 3900 feet above mean sea level (MSL). Silver Mountain rises 1,700 feet above the Mojave River channel over a distance of about 4 miles to an elevation of 4251 feet MSL. Along the western TZ boundary, the Shadow Mountains lie 8 to 10 miles west of the Mojave River channel and rise to a maximum elevation of 4120 feet MSL. Between the mountains of the eastern and western boundaries, the elevation of the alluvial plain ranges between 2600 and 2900 feet MSL.

DRAINAGE PATTERNS

The alluvial plain is incised by drainages of the Mojave River, Fremont Wash, and Buckthorn Wash. The Mojave River originates outside of the TZ about 20 miles to the south on north-facing slopes of the San Bernardino Mountains. A bedrock constriction of the Mojave River referred to as the Lower Narrows marks the entrance of the Mojave River into the TZ at an elevation of approximately 2660 feet MSL. Within the TZ, the Mojave River channel arcs northwest then northeast sloping approximately 17 feet per mile or about 0.3 percent. Approximately 16 miles down stream of the Lower Narrows, the Mojave River leaves the TZ crossing the Helendale fault at an elevation of approximately 2390 feet MSL.

The Fremont and Buckthorn Washes are large washes, west of the Mojave River, that drain the TZ alluvial plain towards the Mojave River channel. Fremont Wash, originating near the southern extent of the Shadow Mountains, collects several small unnamed washes originating in the foothills of the San Gabriel Mountains southwest of the TZ and drains northeast into the Mojave River channel near the community of Silver Lakes. Buckthorn Wash collects runoff from both the southern slopes of the Kramer Hills, approximately 6 miles northwest of the TZ, and the northern portion of the Shadow Mountains and drains southeast into the Mojave River channel near the community of Silver Lakes.

CLIMATE

The TZ climate is typical of a rain-shadow desert. Precipitation in the TZ and the Mojave Desert is limited by the rain shadow of the San Bernardino, San Gabriel, and Sierra Nevada mountains ranges, which are partial barriers to storms originating along the California coast. Consequently, the TZ is arid and experiences long, hot summers and relatively short, mild winters. Summer temperatures commonly exceed 100° F, while winter temperatures can be below 30° F, based on a 62-year precipitation record obtained from the National Oceanic Atmospheric Administration (NOAA, 2002) for Victorville Pumping Plant No. 4. The Victorville Pumping Plant is located approximately 3.5 miles upstream of the Lower Narrows and 0.5 miles west of the Mojave River channel, and is the closest rain gage to the TZ with a significant historical record. The TZ receives approximately 5.6 inches of precipitation per year. USGS (1996) estimated evaporation rates in the TZ range between 60 and 75 inches per year.

LAND USE

Principal land uses within the TZ include agriculture, ranching, urban, mining, industrial, air transport, land transportation, a prison, and undeveloped private land. The Federal government administers some undeveloped portions of the TZ through the Bureau of

Land Management. Undeveloped private land consists mostly of open desert that has been used historically for homesteading or grazing, but little else.

Agriculture and Ranching

Agriculture and ranching have historically been the dominant land use within the TZ. Much of the fertile and easily irrigated lands along the Mojave River bottom are, or have been at one time, under cultivation with alfalfa or other crops. These and slightly higher elevation areas west of the Mojave River have been used as pasture or to support livestock. Undeveloped lands west of the Mojave River channel are mostly privately owned and are used at least on an intermittent basis for grazing sheep.

Urban

The 2000 U.S. Census indicates that communities within the TZ have a combined population of nearly 24,000 (U.S. Census Bureau, 2002). The TZ population has grown significantly in the past 50 years and is expected to continue growing in the future. Population data are presented in Table 1. The 2000 Census indicates the City of Adelanto has a population of approximately 18,130 and is the largest population center within the TZ (U.S. Census Bureau, 2002). The former George Air Force Base (AFB) and limited surrounding undeveloped areas have been annexed by the City of Victorville. Several smaller, unincorporated communities also exist within the TZ, namely Oro Grande, Bryman, La Delta, Silver Lakes, and Helendale and are located adjacent the Mojave River channel. Silver Lakes is a large master planned community within the community of Helendale. The 2000 Census indicates that Helendale has a population of 4,936 and Oro Grande has a population of 895. The populations of Bryman and La Delta are included in the Oro Grande census track population estimate.

Mining

The largest mining land use in the TZ supports cement manufacturing. Limestone and aggregate are mined on Sparkhule and Quartzite mountains and are transported to the cement operations located in the community of Oro Grande. Within the TZ, other mining claims exist on Quartzite Mountain, Sparkhule Mountain, Silver Mountain, and in the Shadow Mountains. Most of these claims are small and are worked only on an intermittent basis.

Industrial

Historically, cement manufacturing has been the largest industrial land use within the TZ. The cement operations, located near Oro Grande have been in operation continuously since the early 1900s under a succession of owners and names. The operations manufacture cement from limestone mined on Sparkhule and Quartzite mountains and are the largest industrial water user in the TZ. Several businesses in the Adelanto area are involved in manufacturing, but are not large water users. Because the City of Adelanto provides water to small industrial sites within its city limits, industrial water use in the Adelanto area is accounted for as municipal water use (Mr. Jack Stonesifer, City of Adelanto Director of Public Utilities, personal communication, October 2002).

Air Transport

In the southern TZ, George AFB has been deactivated as a military base and is operated by the City of Victorville-sponsored Southern California Logistics Airport (SCLA) Authority. The SCLA is the location of an airliner refurbishment and scrapping business, the High Desert Power Project, a road to air cargo transfer point, and a proposed rail intermodal facility.

Land Transportation

Transportation has been an important land use within the TZ since the mid 1880s, when the railroad laid tracks along the Mojave River to connect San Bernardino with Barstow (Upland Savings & Loan Association, 1973). Since then, the railroad industry has continued to play a major part in the TZ economy by providing transportation to market for mined materials and cement manufactured in Oro Grande.

National Trails Highway (formerly Route 66) follows the railroad route through the TZ. Traffic through the TZ on Route 66 diminished when Interstate 15 was constructed several miles to the east. In the western TZ, Highway 395 is a major north-south transportation corridor connecting the desert communities of Victorville, Adelanto, Boron, Ridgecrest, and eastern California communities within Owens Valley.

Import Water Supply Infrastructure

Existing water supply infrastructure that provides or potentially provides imported water within the TZ consists of the Victor Valley Wastewater Reclamation Authority (VVWRA) wastewater reclamation plant and the Mojave River Pipeline. The location of the VVWRA treatment plant and Mojave River Pipeline are shown on Figure 2. VVWRA is neither a groundwater producer nor a party to the Judgment. The Mojave River Pipeline takes water from a siphon on the California Aqueduct in the upper Alto Subarea and passes northward through the TZ to recharge facilities located in the Centro Subarea. In the future, this pipeline may be used to supply recharge facilities within the TZ. Pending State Water Project water availability, MWA is entitled to up to 75,800 AFY of water from the State Water Project through the California Aqueduct (MWA, 2002). The Department of Water Resources currently estimates that on average MWA can expect to have 78 percent of that entitlement available due to limitations on the State Water Project.

The VVWRA wastewater reclamation plant, located on the west bank of the Mojave River north of the SCLA, receives wastewater from SCLA, the Federal Prison located south of SCLA, and several Victor Valley communities. These communities include Victorville, Hesperia, Apple Valley and San Bernardino County Service Area (CSA) 42 (Oro Grande) and CSA 64 (Spring Valley Lake). Treated water is recharged to both the Regional and Floodplain aquifer adjacent the treatment plant. Discharge from the VVWRA plant is counted in the minimum subarea obligation of the Alto Subarea as measured entering the TZ. With continued development of the upper Alto Subarea and expansion of municipal sewer systems, future VVWRA discharges could increase. VVWRA staff has indicated that they intend to pursue development of reclamation opportunities that may have the effect of reducing future flow quantities from VVWRA into the TZ. Northwest of the City of Adelanto, the City of Adelanto discharges wastewater to ponds (Figure 2) overlying a perched zone of the Regional aquifer. North of Helendale, the community of Silver Lakes discharges treated wastewater to a percolation pond overlying the Floodplain aquifer (Figure 2). These reclaimed waters are not counted in the minimum subarea obligation, but are accounted for as pumping return flow from municipal water use and consequently are considered an additional water recharge source in the TZ.

PREVIOUS INVESTIGATIONS

Many documents and reports have been prepared as management tools to address water demand, anticipated increases in future demand, and upper Alto subarea overdraft. This section presents a chronological summary of available water management documents reviewed as pertinent to the Phase II evaluation.

Alternative Water Supply for the Mojave Water Agency (California Department of Water Resources (DWR, 1981)) develops water resource management plans through the year 2000. DWR (1981) includes estimated groundwater and imported water use in the Mojave River Basin, an inventory of water supplies, major issues to be addressed, methods of active conservation, and direct application of reclaimed wastewater to reduce groundwater overdraft. The report includes a projection of population and total water demand from the mid 1980s to 2000.

Historic and Present Conditions, Upper Mojave River Basin (J.S. Murk Engineers and Leroy Crandall & Associates, 1985) addresses groundwater conditions in the area now referred to as the Alto Subarea. The report includes TZ-specific information including: groundwater production, riparian water use, surface water flow, water quality, a well location map, geologic maps, and geologic cross sections.

Mojave River Basin Design for Water Management (California State Polytechnic University, Pomona, 1987) was prepared as a guide for water resource managers to determine areas suitable for groundwater recharge in the Mojave River Basin. This report suggests measures for replenishing aquifers and stopping basin wide groundwater overdraft. This report contains historical population data and per capita water consumption values for communities located in the TZ.

Mojave River Basin Groundwater Recharge Study, Volumes 1 and 2 (Malcom Pirnie, 1988) explores the potential for artificial recharge programs and suggests candidate sites for recharge facilities. This report includes geologic maps, cross sections, and land use maps.

Master Plan for the Delivery of Imported Water, Final Report (Malcolm Pirnie, 1990) describes the facilities needed and costs associated with supplying the MWA service area with supplemental water from the California Aqueduct. In the course of this master planning process, historical groundwater demand was evaluated and future groundwater demand was projected to the year 2010.

Mojave River Groundwater Basin Demonstration Project (Bechtel, 1992) was prepared to evaluate the feasibility of recharging water purchased from the California Aqueduct into overdrafted groundwater basins within the MWA service area. The report suggests options for recharging groundwater basins in the upper Alto Subarea and the Centro Subarea. This report includes historical groundwater demand data and the historical rate of increase of groundwater demand.

Urban Water Use in California, Bulletin 166-4 (DWR, 1994) includes a forecast of water demand throughout the state. The bulletin is periodically updated to reflect changes in water use patterns and water supplies throughout the state. The bulletin includes per capita water consumption and population values specific to the South Lahontan Region of the State Regional Water Quality Control Board (RWQCB), which includes the TZ.

Regional Water Management Plan (Bookman-Edmonston, 1994) was developed for MWA to evaluate alternative management strategies to address water supply and demand issues within the agency service area. The plan identified trends in urban and agricultural consumptive use, annual water supply, estimated storage capacity, and rate of overdraft.

The plan includes historical population values, population growth rates, and average per capita groundwater consumption.

Judgment After Trial (Riverside County Superior Court, 1996), the Judgment, governs the use, transfer, and discharge of groundwater within the Mojave Basin Area and sets forth the methodology by which the free production allowance, Replacement Water, and Make Up Water obligations are calculated. The Judgment also establishes the minimal subarea obligation of each hydrologic subarea to the adjoining downstream subarea. The Judgment is discussed in greater detail in the follow section titled, *Water Management.*

Consumptive Water Use and Update of Production Safe Yield Calculations for the Mojave Basin Area, (Albert A. Webb Associates, 2000) updates safe yield calculations consistent with requirements of the Judgment. Included in this report are values for surface water flow across the Helendale Fault, subsurface flow into the TZ from the upper Alto Subarea, and TZ-specific consumptive use values.

Regional Water Management Plan Update, Phase I Report (Saracino Kirby Snow, 2002) was prepared for MWA as an update to the *Regional Water Management Plan* (Bookman-Edmonston, 1994). The update was needed to reassess MWA programs and policies and to update projections of future water demand based on population growth data from the 2000 Census and water use trends. As part of Phase II of the Regional Water Management Plan Update (Saracino Kirby Snow, 2003), water use projections to year 2020 were modeled to develop an aggregate of management scenarios that could be implemented to bring the entire MWA management area into water supply balance. In the Phase II update, data from Phase II were used to compare the projection of current trends through year 2020 to modeled groundwater basin overdraft elevations and recovery trends.

WATER MANAGEMENT

With the task of managing water resources of California, DWR released the California Water Plan (DWR, 1957). The plan stated there was a critical water shortage in the Mojave Desert and that action must be taken immediately or "consequences may be disastrous". In 1959 the California State Legislature passed SB 1068, enabling the creation of the MWA. Pursuant to this act, MWA was established in 1960 "*to do any and every act necessary . . . so that sufficient water may be available for any present or future beneficial use of the lands and inhabitants of the agency"* (California State Water Code, 1959). Prior to establishment of DWR and MWA, water resources of the Mojave River Basin were utilized solely by competing individual water users and purveyors.

In the early 1960s, it was widely recognized that Mojave River Basin had been in overdraft since the early 1950s. The problem was sufficiently severe in 1960 that the California State Real Estate Commissioner ordered real estate developers and builders to cease and desist until water resources of the Mojave River aquifer (sic) could be determined (MWA, 2002). Although the order was unenforceable, the need to determine water rights and sustainable yield were clear. In an effort to curb the problem, MWA put forward the first adjudication attempt in 1964 (MWA, 2002). Although early adjudication efforts failed, they set the stage and established some of the basic concepts necessary to make later adjudication efforts successful.

Portions of the Mojave River Basin and the Lucerne and El Mirage Valleys were adjudicated as the "Mojave Basin Area" following a suit filed in May of 1990 by the City of Barstow against upstream water users (Riverside County Superior Court, 1996). The *Judgment After Trial*, commonly referred to as the Judgment, was entered on January 10, 1996. The Judgment is the principal water resource management tool to control groundwater overdraft and water use within the adjudicated portion of the MWA service

area. The Judgment defines a "physical solution" for arresting groundwater overdraft in the subareas of the Mojave Basin Area. The following paragraphs describe policies, programs (Ramp Down, Make Up Water, Replacement Water, and carry over rights), the regional water management plan, water management infrastructure, and institutional configuration.

POLICIES

Prior to the Judgment, water production and use were unregulated within the Mojave Basin Area. The concepts that govern production, use, and transfer of groundwater within the TZ are outlined in the Judgment and provide the foundation for the Rules and Regulations of the Mojave Basin Area Watermaster. These concepts include: Base Annual Production, Free Production Allowance, Ramp Down of production rights, Make Up Water, Replacement Water, transfer of production rights, and carry over rights. Water quality is regulated through the South Lahontan RWQCB.

BASE ANNUAL PRODUCTION

The Judgment established the Base Annual Production right (BAP) for each user within each subarea of the Mojave Basin Area. The BAP values are equal to the maximum annual production verified for that user between 1986 and 1990 (Mojave Basin Area Watermaster, 2002). BAP is used to determine each producer's share of the water supply available within a subarea. The TZ BAP from the Judgment is 24,145 AFY. Two parties to the Judgment, Fitzwater and Palisades Ranch, having a combined FPA of 1,115 AFY, were let out of the Judgment by the California Supreme Court. Without these two parties, the TZ FPA is 23,030 AFY.

FREE PRODUCTION ALLOWANCE

The physical solution requires that the Watermaster establish a percentage of the BAP that each water user would be allowed to produce from each subarea each year. That percentage is referred to as the Free Production Allowance (FPA).

RAMP DOWN OF FPA

The physical solution required that the FPA initially be reduced to 80 percent for all subareas during the period between the 1993-94 Water Year (WY) to the 1997-98 WY in increments of 5 percent per year (Riverside County Superior Court, 1996). This reduction in FPA is referred to as Ramp Down of FPA. After the initial ramp down period, the Watermaster is required to make annual recommendations to the Court for FPA reductions or increases in the FPA for each subarea. Watermaster recommendations are limited to increments of 5 percent per year. Within the Alto Subarea, which includes the TZ, FPA is currently set at 80 percent of BAP for agricultural users and 70 percent for municipal users. The Ramp Down of FPA can be expected to continue until overdraft conditions in the Alto Subarea stabilize. Watermaster staff currently estimate that unless cultural conditions affecting water use are substantially modified, the BAP in the Alto Subarea could continue to be ramped down to 65 or 60 percent to achieve balance between supply and demand.

MAKE UP WATER

The Judgment established minimum subarea obligations of either a groundwater flow or a combined surface water and groundwater flow for each subarea to the next downstream subarea (Riverside County Superior Court, 1996). The minimum obligations consist of the volume of water that must pass from one subarea to the next downstream subarea. If the minimum obligation is not met, a Make Up Water obligation is assessed against the water users of the subarea that did not meet the minimum subarea obligation. The makeup assessments are applied proportionately against all producers within the subarea

having an obligation. The funds collected are used to provide imported water to the down stream subarea that is owed makeup water. Producers with a makeup obligation also have the option to transfer (but not produce) twice the quantity of the Make Up Water from producers having unused FPA in the down stream subarea owed Make Up Water.

The 2,000-AFY subsurface flow component of the minimum subarea obligation was determined from average historical conditions using technical data available at the time. The Judgment requires that MWA provide an update of the estimates of subsurface flow between subareas and develop methods to monitor annual change in these flows. The base flow obligation of 21,000 AFY measured at the Lower Narrows Gage was determined from historical averages but was negotiated as a key settlement point between parties in the Alto and Centro subareas.

REPLACEMENT WATER

Individual water users that pump groundwater in excess of their annual FPA are required under the physical solution to pay an assessment for the purchase of Replacement Water (Riverside County Superior Court, 1996). Alternatively, producers can transfer the equivalent amount of unused FPA from another producer within the same subarea. Each spring, the Watermaster determines the Replacement Water obligation for each user based on verified production for the previous water year.

KEY WELLS

There are specific provisions for Replacement Water obligation that apply to the TZ due to its function as a water bridge in the context of the Physical Solution. MWA is required to establish key wells to be used to monitor groundwater levels in the TZ, and subject to approval by the Court, the Watermaster is required to establish minimum water levels to be maintained in the key wells. After these water levels have been established, the

Watermaster is required to provide Replacement Water in the Transition Zone as necessary to maintain the minimum water levels. If water levels in key wells are being met, water purchased with Replacement Water assessments paid by TZ producers may be provided elsewhere in the Alto Subarea.

Key wells have not been established and minimum water levels have not been recommended to the Court. Until then, the Judgment requires Watermaster to provide Replacement Water in the TZ equal to annual TZ production in excess of the collective TZ producers' share of the Alto Subarea FPA. Since implementation of the physical solution, the water users in the TZ have not pumped in excess of the TZ share of the Alto Subarea FPA, and consequently there has not been a requirement for Replacement Water in the TZ.

CARRY OVER RIGHT

Individual water users that pump less groundwater than their FPA are allowed to produce that water the following water year as a carry over right from the previous year. Under provisions of the Judgment, the first water produced the following year is considered to be the carry over from the previous water year. The carry over right expires if it is not used the following water year (Riverside County Superior Court, 1996).

REGIONAL WATER MANAGEMENT PLAN

MWA is responsible for ensuring that sufficient water is available for beneficial uses within its service area. To help fulfill this responsibility, MWA prepared a Regional Water Management Plan (Bookman Edmonston, 1994), which includes projections of water demand and discussion of key water management issues.

An update to this plan (Saracino Kirby Snow, 2002) includes recommendations to help MWA identify and adopt a long-term water management strategy. Development of the Regional Water Management Plan Update is being conducted in 3 phases, namely:

- Phase 1 - Review and revise, as necessary, previous estimates of water supply and demand,
- Phase 2 - Identify and solicit input from stakeholders with interest in long-term reliable water supplies for the region.
- Phase 3 - Identity a suite of preliminary alternatives that may help MWA achieve its goals in regional water supply management.

MWA has currently concluded Phase 2 and is preparing to begin Phase 3. Phase 1 of the Plan identified three basic management categories, namely supply enhancement, water conservation, and water allocation/pricing. Supply enhancement includes purchases of State Water Project water, construction of the Mojave River pipeline, construction of injection wells and recharge basins, and construction of imported water delivery and treatment facilities. Water conservation includes mechanism to reduce consumption. Water allocation and pricing include development of alternative sources of revenue for payment for imported water such as zones of benefit assessments, groundwater production assessments, and the direct sale of water. Phase 1 also identified a series of project alternatives to be screened for development of recommended projects (Phase 2) to the MWA Board of Directors. During April 2003, the MWA Board of Directors adopted Phase 2 of the Regional Water Management Plan Update. Phase 2 outlines an aggregate of various recharge projects and management scenarios that balance water supply and demand for the entire MWA management area through year 2020. Two water management alternatives (which include both projects and management actions) were chosen by a Technical Advisory Committee made up of local stakeholders from throughout the MWA service area and presented to the MWA Board for consideration.

INSTITUTIONAL CONFIGURATION

Water resources within the TZ are under the control of three types of institutions: water purveyors, wastewater reclamation entities, and water resource management entities.

Water purveyors within the TZ are both private and public water producers, including the City of Adelanto, the Victor Valley Water District, Silver Lakes Association, CSA 42 and CSA 70C, agricultural uses, industrial users, and small producers. The City of Adelanto operates 14 wells to service approximately 4,300 connections. The City of Victorville provides water to facilities located on the SCLA. CSA 42 operates four wells to provide water to 429 connections in the Oro Grande area. CSA 70C operates seven wells to provide water to 2,160 connections in the Helendale and Silver Lakes area (MWA, 2001). The Silver Lakes Association uses up to eight wells to maintain surface water in the Silver Lakes. The distribution of water production in the TZ is shown in Appendix E (Figures E-4 and E-5) of the Phase I report (URS, 2003).

Wastewater produced in the upper Alto Subarea that is not discharged to local septic systems is conveyed to the VVWRA plant. VVWRA discharges treated wastewater to the Mojave River near Oro Grande. All wastewater produced within the City of Adelanto that is not discharged to septic systems is processed by the City and recharged to groundwater through recharge basins located on the west side of the SCLA (Figure 2). Water quality of waters discharged from wastewater reclamation facilities is subject to regulation by the Lahontan RWQCB. VVWRA discharges have been increasing steadily since first released in the early 1980s. VVWRA has been negotiating with the California Department of Fish and Game (CDFG) to establish a mutually agreeable discharge level that will allow the VVWRA to limit future discharge to the river channel and allow future increases to be diverted for reclaimed use elsewhere, without impacting the river environment. The most recent discussions anticipated that VVWRA limit effluent discharges to the river at 9,700 AFY and utilize incremental excess flows up to 1,680

AFY for use on the golf course on the SCLA, with possible consideration of some incremental growth flows being dedicated to river discharges. The VVWRA is also pursuing the development of satellite wastewater reclamation facilities upstream of the VVWRA plant, which may also influence future discharges at the current location (Mr. Norm Caouette, MWA Assistant General Manager, personal communication, February 2003).

Water resource management entities include MWA and the Mojave Basin Area Watermaster. MWA is responsible for ensuring that adequate water resources are available for use within its service area both through conservation measures and acquisition of new resources. As such, MWA is in a position to work with water purveyors to anticipate growth and future water use. MWA was appointed Watermaster by the Riverside County Superior Court through the Judgment to administer the physical solution set forth in the Judgment. The Watermaster is responsible for making recommendations to the Court regarding changes in FPA. The Watermaster also administers transfers, Replacement Water, and Make Up Water obligations and consequently must monitor water production by individual purveyors.

WATER BUDGET

In the Phase I report (URS, 2003), TZ water inflow (supply or sources) and TZ water outflow (demand or sinks) components were identified for both surface water and groundwater in order to understand the dynamics of the groundwater basin and to develop a TZ-specific water budget. The water budget can be used to evaluate surpluses or deficits in TZ water supply and to predict imported water market for future scenarios of varying supply and demand. The water budget describes average annual conditions and does not describe seasonal variations. The individual water budget components and the methods used to compile them are described in Appendix B of this report. The water budget was compiled from existing data contained in previous reports that specifically address water resources in the Alto Subarea. Unless otherwise noted, the TZ-specific water budget generally uses representative values available from the past 10 years and includes equal time before and after implementation of the Judgment. Longer historical trends and especially anticipated future trends of the water budget components are discussed in this report in the sections titled, *Groundwater Supply* and *Groundwater Demand*.

Inflow components of the water budget include Mojave River base flow, Mojave River storm flow, precipitation, VVWRA discharge, ungaged tributaries, pumping return flows, and subsurface inflows. Outflow components of the water budget include evaporation, riparian transpiration, surface outflow across the Helendale fault, and groundwater pumping. Surface and subsurface inflow components total 61,150 AFY (Appendix B). Surface and subsurface outflow components total 61,336 AFY (Appendix B). The difference between the estimated annual inflow and annual outflow components is a relatively small number (186 AFY) and is balanced within the precision of several of the estimated parameter values.

Historical groundwater elevations from wells within the TZ show annual water table stability although seasonal fluctuations are observed in the southern portion of the TZ (URS, 2003). With annual inflow and outflow in balance and with groundwater elevations within the TZ being annually consistent, the water budget is concluded to generally be in balance on an annual basis. Although the annual water budget and annual water elevations indicate a balance over the past 10 years, seasonal groundwater fluctuations exist that can impact riparian vegetation and pumping lifts. This is especially true within the Floodplain aquifer in the southern TZ when during recent years, summer-time water levels have been deeper than in previous years, only to recover by the following spring.

GROUNDWATER SUPPLY

Groundwater is currently the only supply of water to domestic, agricultural and industrial users in the TZ. Current water supply and projected future water supply through the 2019-20 WY are described in this section. Future supply will be compared later with future demand to evaluate the need for import and recharge of additional water in the TZ. Water supply components are described in a TZ-specific water budget in the Phase I report (URS, 2003), which is included as Appendix B of this Phase II report. Water supply component values are listed in Table 2. Historical and projected future water supply are graphed on Figure 3 and Figure 5, respectively. On a large scale, the water supply components include groundwater storage, subsurface groundwater flow, and groundwater recharge by surface water. These components are summarized below as they relate to current and future water supply.

GROUNDWATER STORAGE

Within the TZ, groundwater is produced from both the Regional and Floodplain aquifers. These aquifers are described in Phase I report (URS, 2003). Aquifers within the TZ act not only to transmit but also to store groundwater. Groundwater storage acts as a reservoir from which water can be withdrawn in time of need and replenished in times of surplus. Effective groundwater management strategies utilize groundwater storage as a buffer for variations in supply and demand. Planned drawdown and recovery can increase the safe yield of a groundwater basin. The volume of groundwater in storage can be dynamic depending on the supply and demand.

The Phase I report presented estimates of the volume of groundwater in storage. Since the early 1990s, groundwater storage has been fairly constant. Groundwater storage experiences seasonal fluctuation with more water withdrawal in summer and replenishment in winter. URS (2003) estimated the Regional and Floodplain aquifers

within the TZ contain approximately 6.6 million AF and 710,000 AF of groundwater storage, respectively. A large portion of this water in the Regional aquifer may be unavailable for use due to reasons associated with pumping water from perched zones or deep aquifers. Such reasons include lower yields and larger drawdowns in the more consolidated sediments, greater energy requirements needed to lift the water over large drawdowns, and potentially poorer quality water from shallow perched or deeper and older more consolidated formations. Bookman-Edmonston (1994) assumed groundwater stored in the upper 100 feet of aquifers in the Mojave River Basin is economically available for use. However, as water resources are depleted, the costs associated with pumping water from great depths will be less of a barrier to production. Based on 1998 water levels, URS (2003) estimated the upper 100 feet of the Regional and Floodplain aquifers contain approximately 1.1 million and 300,000 AF, respectively. The permanent extraction of this quantity of groundwater and subsequent drawdown would seriously impact the water bridge function of the TZ and potentially damage or destroy riparian habitat.

GROUNDWATER INFLOW

Groundwater flows across the southern TZ boundary, through the Regional aquifer into the TZ. In compiling the TZ-specific water budget, URS (2003) estimated that approximately 4,890 AFY of groundwater flows across the Adelanto and Shadow Mountains faults and enters the TZ. This value was calculated using 1998 water level data and transmissivity data published by USGS (1971). A discussion of historical groundwater inflow and outflow estimates is presented in the Phase I report Appendix H (URS, 2003). Inflow can change as groundwater elevations and flow gradients change across the southern TZ boundary. No significant long-term change in groundwater inflow to the TZ would likely occur without significant dewatering of the Regional aquifer south of TZ. Based on a review of existing groundwater elevation maps constructed over the past 10 years (USGS, 1992, 1996a, and 1998), groundwater

elevation in the northern upper Alto Subarea and groundwater inflow to the TZ have been fairly constant. Natural groundwater outflow from the TZ was also estimated in the Phase I report at approximately 4,580 AFY. Thus without significant changes in groundwater elevations, the net water supply to the TZ from subsurface inflow is approximately 310 AFY.

GROUNDWATER RECHARGE BY SURFACE WATER

The largest available water supply to the TZ originates as groundwater recharge from surface water. Surface water exists in the TZ as Mojave River base flow and storm flow, VVWRA discharges, precipitation, flow in ungaged tributaries, and pumping return flows. How each of these components has changed historically is critical to understanding current and future TZ water supply. Historical and predicted future trends of these supply components are described below.

Imported Water

The TZ has not historically received imported water. The Mojave River Pipeline (Figure 2) runs northward through the TZ and is currently used to deliver imported water to the Centro Subarea. The pipeline could also be used to deliver imported water to compensate for any future supply deficiencies within the TZ. Pipeline facilities were completed in the beginning of 2003 to provide State Water Project water to the SCLA for use by the High Desert Power Plant.

Base Flow

Mojave River flow enters the TZ at the Lower Narrows. Base flow and storm flow values compiled by the Watermaster (MWA, 1996 to 2001) are graphed on Figure 4. For storm flow periods, the Watermaster determines the simultaneously occurring base flow and storm flow components of total gaged flow. During large storm flows, a portion of the measured base flow exits the TZ across the Helendale fault with the storm flow

(Webb, 2000). Although several annual storm flow values graph greater than the limit of the y-axis of Figure 4, they are shown on this figure to illustrate the occurrence and relative frequency of wet years and their correlation with changes in base flow. During dry years, base flow percolates to groundwater within the southern TZ.

Mojave River base flow has declined since the mid 1950s. The early 1950s saw a sharp increase in population, urban development, and groundwater demand in the Victor Valley area. The increased groundwater demand soon resulted in overdraft of portions of the upper Alto Subarea. The decline of base flow in the 1990s can be roughly correlated with increased overdraft in the upper Alto Subarea (Todd, 1999). Todd (1999) supports this correlation by showing that declining base flows in the 1990s have not rebounded following recent years of high precipitation. Consequently, these declines cannot be strictly drought related. Recent trends of urban development, population growth, and water demand in the Victor Valley area are not expected to slow in the near future. With groundwater demand in the upper Alto Subarea continuing to increase, base flow at the Lower Narrows would continue to decrease, and ultimately, base flow at the Lower Narrows would potentially occur only on a seasonal or intermittent basis that is linked to storm flow recharge above the Lower Narrows. The declining base flow trend could be stabilized or reversed by the annual introduction of sufficient quantities of imported water into the upper Alto Subarea (USGS, 2002), as well as continued reduction of FPA through the Judgment.

Prior to 1957, annual base flow at the Lower Narrows gage did not fall below 20,000 AFY. Base flow averaged as high as 23,100 AFY during the 1900-31 through 1956-57 WYs. Through the 1960s, base flow fell as low as 16,000 AFY, but recovered to above 20,000 AFY in the late 1970s and early 1980s following several successive wet years. In the mid 1980s, with renewed urban growth and increased groundwater demand in the upper Alto Subarea, base flow at the Lower Narrows began a trend of decline that continues to the present. Except during unusually wet years, (1994 and 1998) base flow

at the Lower Narrows has not exceeded 10,000 AFY since 1989. The 2000-01 WY base flow of 5,345 AF was the lowest annual base flow on record.

From the 1980-81 to 1990-91 WYs, base flow declined an average rate of 1,412 AFY. This decline is the result of heavy pumping during very dry years from 1985 to 1991 following very wet years in the late 1970s and mid 1980s. For long-term base flow projections, the rate of decline between 1981 and 1991 is not appropriate, as it is a result of two extremes in relatively rapid succession. The rate of decline during the late 1980s was also influenced by renewed population growth and urban development. If the 1980s rate of decline were projected into the future from 2001, base flow would be nonexistent by the 2005 WY.

Between the 1990-91 and 2000-01 WYs, base flows declined, at an average rate of 219 AFY (based on a linear regression analysis). The rate of base flow decline may have slowed during the 1990s due to a combination of restrictions implemented by the Judgment, water conservation awareness, and the occurrence of three wet years when total flow of the Mojave River at the Lower Narrows exceeded 70,000 AFY. During this 10-year period, annual water elevations in a USGS multi-depth monitoring well (05N/04W-14D1-4) were fairly consistent showing season variations and deeper summer elevations beginning in 1998 (URS, 2003). The deeper summer elevations at this well did not correspond to a lower annual base flow.

For a continuation of the existing trend in declining base flow, the 1976-77 to 2000-01 WYs appears to be more appropriate for use in predicting future base flow as these years reflect a period of development, intermittent occurrence of both dry and wet years, and groundwater production since implementation of the Judgment. A linear regression of annual base flow values from these years indicates a base flow decline of approximately 916 AFY with an R^2 value of 0.856. Using any constant base flow decline rate, base flow values would gradually approach no flow. No base flow would suggests that water levels

in the upper Alto Subarea have been drawn down such that no groundwater rises to form surface water in the Mojave River upstream of the Upper Narrows, and that the water levels drawn down by production are not later replenished by lateral groundwater flow or the recharge of other water (storm flow or imported water) to bring the water table back up to levels where surface water can formed. A total lack of base flow is not likely to occur due to recharge of storm flows in the area of the Upper and Lower Narrows creating some brief period of minimum base flow in the months following storm flows.

In years with long-duration and large storm flow, base flow may temporarily return. In a hypothetical future dry year if base flow ceased to exist at the Lower Narrows, the Mojave River through the Lower Narrows would be a dry stream bed with no groundwater rising to become base flow. At a hypothetical later time if the Mojave River flowed again during a long-duration and large storm event on the magnitude of the historical average (33,107 AFY), infiltration would occur to aquifers both up stream, at, and downstream of the Upper Narrows. During this condition, storm flow would rapidly fill the Floodplain aquifer between the Upper and Lower Narrows and temporarily reestablish base flow as rising groundwater during and after the storm. After the storm had passed and water had left bank storage, base flow would likely be measurable until conditions again lowered water levels at the Lower Narrows to below ground surface.

The first scenario of future base flow predictions are a continuation of recent trends of decreasing base flow and do not include base flow recovery The scenario of no base flow recovery use in part the 916-AFY rate of decline between the 1976-77 and 2000-01 WYs. If this rate of base flow decline were projected into the future from the 2000-01 WY, base flow would be nonexistent in any given year without storm flow by the 2006-07 WY. However, under this scenario long-term average base flow predictions are not allowed to approach zero flow, but are kept at a minimum flow required to transmit the (decreasing) long-term average storm flow through the TZ. Webb (2000) estimated that on average 105 percent of the volume of large storm flows passes through the TZ into the Centro

Subarea. The 5 percent of storm flow over 100 percent is made up of base flow carrying the storm flow. In this situation, the net water supply gained in the TZ during large storm flow from storm flow is 0 percent, and the net water supply gained from base flow is total base flow minus 5 percent of storm flow. For example, with a long-term storm flow average of 33,107 AFY at the Lower Narrows, 34,762 AFY would exit the TZ at the Helendale fault with 1,655 AFY (5 percent of 33,107 AFY) originating from total base flow. If base flow during this hypothetical water year were 10,000 AF, then base flow remaining in the TZ would be 10,000 AF minus 1,655 AF.

The no-base-flow recovery scenario of future annual base flow prediction allows base flow to decline at historical rates and then holds base flow at a minimum level equal to the flow required to "carry" the long-term average storm flow from the Lower Narrows to the Helendale fault. For this evaluation, this minimum base flow is assumed to recharge in the TZ and not leave the TZ with storm flow. The minimal base flow can be thought of as complete base flow infiltration (estimated at 5 percent of storm flow) occurring during storm flow with 100 percent of storm flow leaving the TZ. This estimation of minimum base flow during storm flow does not change the storm flow value, but is simply approximated from it.

The second scenario of future base flow predication includes a reversal of recent trends (base flow recovery). For a reversal of the 1976-77 to 2000-01 WYs declining base flow trend, a reversal of the annual overdraft of the upper Alto Subarea would be necessary. Annual overdraft of the upper Alto Subarea could be mitigated with continued Ramp Down of FPA and recharge or direct use of import water from the State Water Project water (USGS, 2001). A halt or reversal of upper Alto Subarea overdraft is estimated by the Watermaster to occur at approximately 60 percent to 65 percent Ramp Down of FPA in the Alto Subarea. The Alto Subarea FPA is currently at 70 percent. For this scenario, base flow recovery is assumed to occur in the water year following a production Ramp Down of FPA to 65 percent and is assumed to occur at opposite the historical rate of base

flow decline (916 AFY) observed between the 1976-77 and 2000-01 WYs. Although it is impossible to predict court rulings in regards to continued implementation of the Judgment (Ramp Down) as well as the construction and subsequent utilization of various future recharge projects, a scenario of base flow recovery may be a useful tool to compare the anticipated rate of potential base flow recovery.

Storm Flow

The Judgment does not credit annual storm flow measured at the Lower Narrows towards the minimum subarea obligation of the Alto Subarea. Water that is counted towards the obligation includes base flow at the Lower Narrows, subsurface groundwater inflow, and current VVWRA discharges. The long-term average storm flow value of 33,107 AFY used in the water budget includes the entire period of record from the 1930-31 to 2000-01 WYs. This average number is appropriate for evaluation of historical conditions. However, as future base flow declines, an increasing portion of future storm flow (rather than base flow) will infiltrate into the Floodplain aquifer within the upper Alto Subarea where the river was once a gaining stream (see Transition Zone Phase I report, Appendix F-2, URS, 2003). As quantified below, increased infiltration of storm flow in the upper Alto Subarea would reduce storm flow passing across the Lower Narrows into the TZ and across the Helendale fault into the Centro Subarea. Average storm flows at the Lower Narrows are predicted to decline as base flow declines. Webb (2000) presented a correlation of historical cumulative Mojave River storm flows at the Upper Forks stream gage versus the Lower Narrows stream gage. Between 1950 and 1997, the ratio of these flows declined on average 15.7 percent (approximately 0.33404 percent per year) from pre-1950 conditions. This decline was attributed to increased infiltration of storm flow in the upper Alto Subarea due to cultural changes. To predict future average storm flow at the Lower Narrows as base flow declines, the long-term storm flow average of 33,107 AFY was reduced by 111 AFY (0.33404 percent per year times 33,107 AFY). At this rate, the average annual storm flow entering the TZ at the Lower Narrows would be

30,998 AFY by the 2019-20 WY. For the future water supply scenario that includes recovery of base flow towards historical conditions, average storm flow values are not reduced by this factor.

VVWRA Discharge

In 1977, VVWRA began discharging reclaimed water using a series of infiltration ponds at its treatment plant located adjacent the Mojave River in the southern TZ. At that time, the majority of water users in the Victor Valley area discharged wastewater to domestic septic systems. Since 1981, there has been a concentrated effort in the communities of Victorville, Apple Valley, and Hesperia to connect new commercial and residential construction to municipal sewer systems. These municipal sewer systems are used to deliver wastewater for treatment at the VVWRA plant. In 1981, VVWRA began discharging reclaimed wastewater to the Mojave River channel from its treatment plant northeast of the SCLA along the west bank of the river. Discharge of reclaimed wastewater to the Mojave River recharges the groundwater beneath the river channel. The City of Adelanto initially contributed wastewater to VVWRA, but has subsequently established an independent treatment facility that discharges reclaimed water to a perched zone of the Regional Aquifer.

The new sewer connections resulted in greater volumes of wastewater treated by VVWRA and increased discharges of secondary and tertiary-treated reclaimed wastewater from VVWRA. Between the 1990-91 and 2000-01 WYs, VVWRA discharges have ranged from 7,276 to 9,286 AFY. Recent trends of urban expansion and population increase in the Victor Valley area are expected to continue in the future. The population of the Victor Valley is anticipated to continue growing with new construction being connected to existing and expanding municipal sewer systems. VVWRA (2000) estimates that municipal sewer systems currently serve approximately 94,268 people and that by 2020, that number will rise to approximately 183,022 people. VVWRA (2000)

estimates it will be discharging 18.6 million gallons per day (mgd) or 20,834 AFY by 2020 (VVWRA, 2000). This represents an average increase of approximately 608 AFY from the 9,286 AFY discharged in the TZ in the 2000-01 WY. The current treatment plant in the TZ is rated at 11.0 mgd (12,320 AFY), and cannot currently treat and discharge the projected quantities of water. Plant upgrades that allow a discharge capacity up to 14.5 mgd have been planned, but the construction of several sub-regional treatment plants in the Alto Subarea may preclude future expansion of the current facilities.

Future reclaimed water releases above the current capacity may come from sub-regional treatment plants constructed in the upper Alto Subarea or from the expansion of existing facilities within the TZ. If diverted VVWRA discharges are used within the TZ, then their use may replace another water supply (pumped groundwater) with no net impact on total water supply predictions compared to discharging effluent to the Mojave River. If diverted VVWRA discharges are used outside the TZ, then the projected increase would not be part of the TZ water supply. As shown on Figure 5, two future supply scenarios of future VVWRA discharges are considered. For the first scenario, discharge is kept at 9,700 AFY. VVWRA discharges currently exceed this level. For the second scenario, discharge is allowed to increase annually by approximately 608 AFY without limitation. Reality will lie somewhere between these two scenarios and will depend on VVWRA identifying TZ reclaimed water customers as rapidly as its treatment capacity.

Ungaged Tributaries

Several ephemeral washes contribute surface water flow to the TZ. Webb (2000) estimates that approximately 320 AFY of surface water flow is contributed to the TZ by ungaged tributaries from the upper Alto Subarea. The water budget assumes that because this flow occurs only during intense storms that none of the flow is lost to evaporation and that 100 percent is recharged either in a tributary channel or in the Mojave River

channel. No long-term change in average precipitation is anticipated. Consequently, the future average annual water supply infiltrating to groundwater due to surface water flow in ungaged tributaries is assumed to be relatively constant. Water supply sources that are considered relatively constants (ungaged tributaries, precipitation, and subsurface inflow) are graphed together on Figure 5.

Pumping Return Flow

Pumping return flow consists of groundwater that is pumped, applied to its intended use, and subsequently infiltrated to groundwater. Within the TZ, pumping return flows occur through infiltration of excess irrigation water and septic system water. Webb (2000) performed a detailed consumptive use study of the Mojave Basin Area based on data from the 1996-97 WY. The consumptive use value determined by Webb (2000) for all groundwater uses within the TZ is approximately 60 percent of verified production. Thus, in the water budget prepared under Phase I (Appendix B), pumping return flow is estimated at 40 percent of all groundwater pumped within the TZ. The pumping return flow estimate includes municipal, domestic, agricultural and industrial uses. A complete shift from agricultural to domestic water use may cause pumping return flow to increase from 40 percent to the domestic rate of 50 percent assumed by Webb (2000). In recent years, agricultural water use has declined within the TZ and municipal water use has increased (Watermaster, 2002). In the 2001-02 WY, agricultural production (Table 3) represented approximately 18 percent of total verified production. As discussed later for water demand, agricultural demand in AFY is anticipated to remain relatively constant, but decrease as a percentage of total water demand as total demand in AFY increases. By the 2019-20 WY, agricultural demand is predicted to represent only 7 percent of total demand. As agricultural demand in AFY is predicted to remain relatively constant, its predicted future demand will not directly influence the TZ pumping return flow rate.

Increases in industrial demand will have a large impact on the TZ pumping return flow rate. Webb (2000) assumed industrial demand is 100 percent consumed (0 percent pumping return flow). In the 2000-01 WY, industrial production (Table 3) represented approximately 13 percent of total verified production. As discussed later for water demand, industrial demand in AFY is anticipated to increase significantly. By the 2019-20 WY, industrial demand is predicted to represent nearly half of total demand. With significant increases in industrial water demand being 100 percent consumed, the pumping return flow rate will decrease from 40 percent by the inverse of industrial growth rate. For future supply predictions, because industrial demand is projected to equal nearly 40 percent of all demand in the 2019-20 WY, the pumping return flow rate is assumed here to decrease linearly from 40 percent in the 2001-02 WY to 20 percent in the 2019-20 WY (as shown in Table 2, adjacent total pumping).

It is important to note that return flow water is typically poorer in quality than the produced source water. Repeated use of groundwater can have adverse effects on groundwater and may limit perpetual reuse with out management of salt accumulation. Regional plans are underway for a future salt balance study to evaluate the long-term effects of salt loading in the Mojave River Basin (Mr. Jehiel Cass, RWQCB Lahontan Region, written communication to MWA, 2003)

Precipitation

Long-term precipitation data (1939 through 2001) indicate that an average of 5.61 inches falls in the TZ (NOAA, 2002). Most precipitation falling on the TZ is lost quickly to evaporation or transpiration. With the exception of surface runoff into the Mojave River channel and precipitation falling on open water bodies, direct precipitation does not recharge groundwater in the TZ under normal conditions (USGS, 1996b). As previously discussed, surface runoff of precipitation into the Mojave River channel is accounted for in the water budget as either storm flow at the Lower Narrows gage, flow from ungaged

tributaries, or percolation of precipitation falling on open (unlined) bodies of water. As shown in the water budget, approximately 96 AFY is contributed to the TZ water supply by precipitation falling on open bodies of water. No long-term change in average precipitation is anticipated. Other than recharge basins that may be developed for a TZ recharge project, development of additional large open water bodies is not anticipated within the TZ. The average annual water supply due to precipitation falling on open bodies of water is assumed to be constant. Water supply sources that are considered relatively constants (ungaged tributaries, precipitation, and subsurface inflow) are graphed together on Figure 5.

GROUNDWATER SUPPLY THROUGH THE 2019-20 WY

Future projection of historical water supply trends provides a basis for estimating future water supply conditions through the 2019-20 WY. Future availability of each water supply components of the water budget directly impacts future total groundwater supply. Although all supply components follow some trend, annual VVWRA discharge and base flow may both vary between two extremes. Future VVWRA discharge depends on the location of future treatment plant expansion, future effluent discharge locations, discharge style (pond or river discharge), and quantity of future reclaimed water. Future base flow depends on the implementation and success of water management strategies in the Alto Subarea towards recovery of overdraft. The water supply components of storm flow, precipitation, ungaged tributaries, and subsurface inflow are not anticipated to change significantly over the next 20 years. These water supply components should be fairly predictable based on historical trends.

For this study, future water supply is evaluated with two scenarios each for base flow and VVWRA discharge. For base flow, a continuation of the existing trend is evaluated as is base flow recovery in 2005-06 WY. Base flow reversal is anticipated due to water importation as outlined in the Regional Water Management Update and continued FPA

Ramp Down. For VVWRA discharge, a continuation of the existing trend tied to growth is evaluated as is a limitation of VVWRA discharge at 9,700 AFY. As discussed later in the section titled, *Market of Imported Water*, continued production Ramp Down of FPA is also evaluated with existing demand to predict when total water demand will exceed FPA.

Continuation of Recent Historical Trends

Projected future water supply based on continuation of recent historical trends is shown in Table 2 and on Figure 5. With the continuation of recent trends, changes in Mojave River base flow, pumping return flow, and VVWRA discharge are predicted to have the greatest affect on future water supply within the TZ. Recent trends indicate that base flow is declining while VVWRA discharges and pumping return flows are increasing. Since 1977, Mojave River base flow at the Lower Narrows has been declining by approximately 916 AFY. If this trend continues, base flow could be reduced to 0 AFY in any give year by the 2006-07 WY. For long-term predictions, a no base flow recovery scenario assumes minimum base flow (or base flow infiltration during storm flow) is held at 5 percent of long-term average storm flow. If water production continues to increase in the future for predominately industrial uses, pumping return flows would decrease from 40 percent to 20 percent while total production increases. The combined impact of decreased pumping return, increased total production, and increased industrial demand is a nonlinear variation in pumping return flow that increase about 60 AFY from 2001-02 to 2009-10 WYs and decreased approximately 60 AFY from 2009-10 to 2019-20 WYs.

VVWRA discharge has historically increased based on increased population growth and sewer system build out within the Alto Subarea. Although VVWRA predicts expansion and increased treatment effluent of up to 20,834 AFY (VVWRA, 2000) in 2019-20, VVWRA may limit future discharges to the Mojave River at is current discharge rate of approximately 9,700 AFY or less. Sale or transfer of future VVWRA discharge within

the TZ may not impact the TZ water budget if it meets a predicted water demand. VVWRA discharge is anticipated to increase approximately 608 AFY from 9,286 in the 2000-01 WY to its peak capacity of 10,650 AFY in the 2003-04 WY. Future increase in VVWRA discharge above peak capacity will require additional treatment capacity, which may or may not physically occur in the TZ.

Two VVWRA discharge scenarios are evaluated, one limit at 9,700 AFY and the second tied to growth. For the 2000-01 WY, total water supply to the TZ was approximately 58,720 AFY. With no base flow recovery and VVWRA discharges tied to growth, total water supply is projected to be approximately 64,485 AFY by the 2019-20 WY. With no base flow recovery and VVWRA discharges limited at 9,700 AFY, projected total water supply is estimated at approximately 53,351 AFY by the 2019-20 WY.

Reversal of Upper Alto Subarea Overdraft

The Alto Subarea is generally recognized to be in a state of overdraft and has been so since the early 1950s. Todd (1999) estimated that groundwater storage in the upper Alto Subarea has been depleted by approximately 750,000 AF between 1951 and 1997. Annual overdraft in the Alto Subarea was approximately 19,900 AFY in 1990 (Bookman Edmonston, 1994), 16,800 in 2000 (Saracino Kirby Snow, 2002) but may reach 45,100 AFY by 2020 (Saracino Kirby Snow, 2002).

To halt overdraft in the upper Alto Subarea, groundwater supply and demand would need to be in balance. Some groundwater management alternatives being considered to mitigate the effects of overdraft include using State Water Project Water for artificial recharge and for supply in-lieu of production. USGS (2002) simulated various 20-year duration artificial recharge and in-lieu scenarios for the upper Alto Subarea that utilized imported water rates ranging from 8,000 to 30,000 AFY. An alternative modeled by USGS (2002) included 3,800 AFY in-lieu water use with in the TZ for 20 years, and predicted a 5 to 30-foot increase in TZ water elevations. In addition, modeling work

associated the Phase II Regional Water Management Plan Update (Saracino Kirby Snow, 2003) shows that all projected 2020 future water demands for the Transition Zone can be met for year 2020 assuming implementation of the Judgment and the development and utilization of multiple recharge projects.

If overdraft of the upper Alto Subarea is halted, but groundwater storage is not replaced, base flow at the Lower Narrows may stabilize, but would not likely increase. With stabilized base flow, the projected future base flow trend would become a constant rather than a declining value. If overdraft were reversed, it is possible that base flow at the Lower Narrows would recover. As used, reversal of overdraft means that supply is in balance with demand and some level of depleted storage is replaced.

Groundwater elevations trends over the last 10 years (URS, 2003) indicate annual winter water levels in the Regional aquifer near the southern TZ are fairly consistent. This finding indicates that overdraft of the upper Alto Subarea has not reduced the amount of water entering the TZ as subsurface groundwater inflow over this 10-year period. If upper Alto Subarea overdraft were to continue, it may eventually threaten the amount of subsurface water entering the TZ by intercepting water that would currently flow northward into the TZ. If overdraft of the upper Alto Subarea were reversed, future subsurface inflow could increase slightly, but base flow would be expected to experience larger increases towards historical levels.

Projected future water supply based on reversal of overdraft and recovery of base flow is shown in Table 2 and on Figure 5. For the 2001-02 WY, total water supply to the TZ is estimated at approximately 58,720 AFY. With base flow recovery and VVWRA discharges tied to growth, total water supply is projected to be approximately 80,411 AFY by the 2019-20 WY, assuming current trends. With base flow recovery and VVWRA discharges limited at 9,700 AFY, projected total water supply is estimated at approximately 69,277 AFY by the 2019-20 WY.

GROUNDWATER DEMAND

Current water demand and projected future water demand through the 2019-20 WY are described in this section. Future demand will be compared later with future supply to evaluate the need for import and recharge of additional water in the TZ. Water demand components are described in a TZ-specific water budget in the Phase I report (URS, 2003), which is included as Appendix B of this Phase II report. Water demand component values are listed in Table 3. Historical and projected future water demand are graphed on Figure 6 and Figure 8, respectively. On a large scale, the water demand components include groundwater production, subsurface groundwater outflow, storm flow leaving the TZ, and evapotranspiration. These components are summarized below as they relate to current and future water supply.

GROUNDWATER PRODUCTION

Historical groundwater production in the TZ began with the arrival of the earliest inhabitants of the region. Native Americans and early settlers dug shallow wells in or near the Mojave River channel to satisfy their water need (USGS, 2001). Early irrigation along the Mojave River was accomplished primarily by diversion of surface water from the river. By the early 1920s, wells were used increasingly for irrigation during dry periods or when available surface water diminished in response to demand (Thompson, 1921). Wells were initially constructed near the Mojave River channel where groundwater was near the surface and aquifer characteristics are favorable. Since the 1920s groundwater pumping has spread out from the river in response to increased population and demand (USGS, 2001).

Historical groundwater production data used in this evaluation were obtained from the Watermaster (1995 to 2002) and USGS (2001). The Watermaster is responsible for verification of groundwater production within the adjudicated area of the Mojave River Basin, and has published annual reports containing verified production values since the

1994-95 WY. The verified production data are the best available data for the 1993-94 to 2000-01 WYs. Prior to 1993, groundwater production data were not verified on a regular basis. In preparation for regional modeling of groundwater flow through the Mojave River Basin, USGS (2001) estimated groundwater production between the 1930-31 and 1998-99 WYs from published data, field surveys, and communication with the Watermaster Engineer, Robert Wagner. USGS groundwater production estimates represent the best available information for the period before the 1992-93 WY. Groundwater production data obtained from USGS (2001) for the 1993-94 to 2000-01 WYs are based on values generated by the Watermaster, but includes an estimated component intended to compensate for years that verification may not have included every water user in the TZ. Because no imported water is delivered to the TZ, it is assumed for this evaluation that water demand equals groundwater production. Estimated and verified historical water demands are both shown in Table 3 and are graphed on Figure 6.

Groundwater production within the TZ is comprised of agricultural, municipal, domestic, and industrial components. Between the 1930-31 and 1944-45 WYs, groundwater production in the TZ was less than 10,000 AFY (Figure 6), yet was increasing steadily. In the late 1940s and early 1950s, groundwater production in the TZ increased sharply to about 25,000 AFY then stayed between 25,000 and 32,000 AFY until the late 1960s. After the 1967-68 WY, a decline in groundwater production occurred through the early 1980s. The USGS data show a linear interpolation between the 1972-73 and 1985-86 WYs. With the exception of a slight increase during the late 1980s, the decline continues to the present (Table 3). Historic agricultural, municipal, domestic, military and industrial groundwater production has changed in response to development and cultural changes within the TZ.

Historically, greater groundwater demand occurs along the Mojave River than away from it, as the river sediments in and along the river have relatively shallower groundwater and

greater transmissive properties that allow for high capacity wells. Recent verified production trends indicate changes in groundwater use are occurring within the TZ. The TZ can sustain some change in water use type and pumping location without cumulative impact to the water budget. However, concentration of demand to more limited areas and well fields may locally stress aquifers to the point that recharge with imported water may be required to maintain the availability of the groundwater resource, and as indicated by the Judgment to maintain groundwater elevations in key wells yet to be identified.

Agricultural Demand

Historically, agriculture has been the largest single water use within the TZ. Between the 1930-31 and 1948-49 WYs, agriculture accounted for 96 percent of annual groundwater production within the TZ (USGS, 2001). Agricultural demand rose sharply in the late 1940s and early 1950s as the use of turbine pumps in deep wells allowed farming away from the immediate Mojave River channel (USGS, 2001). Agricultural demand peaked at approximately 27,112 AFY in the 1954-55 WY (approximately, 90 percent of groundwater demand for that year) and remained between 20,000 AFY and 25,000 AFY throughout the remainder of the 1950s and 1960s. In the 1968-69 WY, the Silver Lakes residential and recreational community began development, signaling cultural changes that would reduce agricultural water use and increase municipal water use within the TZ. Agricultural water use in the TZ has undergone a long-term steady decline from approximately 24,106 AFY in the 1967-68 WY to 2,120 AFY in the 2000-01 WY. During this time, agricultural water demand dropped from approximately 80 percent to approximately 15 percent of TZ total production.

Municipal and Domestic Demand

Municipal and domestic groundwater demands are described together here because they are both closely related to population. Between the 1930-31 and 1948-49 WYs, municipal demand accounted for approximately 4 percent of total annual groundwater

production in the TZ. Like the Victor Valley area, the TZ experienced significant population growth beginning in the early 1950s, that has continued to present. Municipal and domestic demand increased from approximately 5 percent of total TZ production in the early 1950s to approximately 48 percent in the 2000-01 WY. Significant population growth is expected to continue in the TZ (Figure 7). Domestic water use represented by the minimal producers will not likely increase significantly. Minimal producers pump groundwater at a rate less than 10 AFY and are not party to the Judgment. Municipal water use growth will likely dwarf potential growth in minimal producer demand. Current TZ municipal demand is approximately 6,700 AFY, while minimal producer demand is estimated to range between 100 and 200 AFY .

Military Demand

Military groundwater demand in the TZ has historically been generated entirely by use at the Victorville Army Airfield and later George AFB. The Victorville Army Airfield opened in 1941. George AFB closed in 1992. Future water use at the former base for the SCLA will likely be industrial. Based on state well records, within the first year of operation, three production wells were drilled in the Mojave River channel to support the base. The Victorville Army Airfield, which later became George AFB, developed a well field in the Mojave River channel within Section 30 of Township 6 North, Range 4 West of the San Bernardino Baseline and Meridian. The wells located in the Section 30 well field were turned over to the City of Adelanto. A total of eight wells were turned over from the Air Force to the City of Adelanto, one of which is currently inactive (Mr. Jack Stonesifer, City of Adelanto Director of Public Utilities, personal communication, February 2002). The remaining seven wells are used by the City of Adelanto and have a total production capacity of 5,500 gpm. The City of Adelanto has an agreement with Victorville to supply water to the prison located directly south of the Former George AFB. Prison water demand is accounted against Adelanto FPA.

Industrial Demand

Current industrial water demand within the TZ is generated almost completely by the cement plant and mining operations that exist near the community of Oro Grande. Other industrial water users exist in the Adelanto area but are not involved in high water demand processes. Industries in the Adelanto area include manufacturing and distribution. Industrial water demand within the TZ has averaged 2,224 AFY over the period for which production has been verified (1993-94 to 2000-01 WYs). Industrial water use prior to this period was estimated by USGS (2001) and combined with municipal water use. Consequently, there are no separate estimates of industrial and municipal water use prior to the 1993-94 WY.

Base Annual Production and Free Production Allowance

The TZ BAP from the Judgment is 24,145 AFY. Two parties to the Judgment, Fitzwater and Palisades Ranch, having a combined FPA of 1,115 AFY, were let out of the Judgment by the California Supreme Court. Without these two parties, the TZ FPA is 23,030 AFY. Within the Alto Subarea, the Watermaster reduced FPA by 5 percent per year beginning in the 1994-95 WY to 80 percent by the 97-98 WY, consistent with the terms of the Judgment. Until the 2002-03 WY, the Court has held FPA at 80 percent since the 1997-98 WY. In the 2003-04 WY, the Court approved an FPA Ramp Down to 70 percent for municipal producers only and opted to leave agricultural producers at 80 percent. Considering current cultural conditions, the Watermaster estimates that it may be necessary to reduce the Alto Subarea FPA to 60 to 65 percent of BAP to achieve balance between FPA and renewable water supply. Changes in FPA are not considered to have an impact on water demand by this evaluation. The difference between demand and FPA is instead considered as the market for imported water. Water use is not limited by the FPA as water demand can either be supplemented by Replacement Water or water transfers arranged through MWA and the Watermaster, respectively. In reality, the

higher cost of water demand above the FPA may in fact reduce the projected growth in water demand.

Natural Demands

Natural demands are water demands that are predicted to not be significantly influenced by groundwater production. These include evapotranspiration, subsurface outflow, and storm flow leaving the TZ. Evaporation from open, unlined bodies of water within the TZ was estimated in the Phase I report to be approximately 1,159 AFY (URS, 2003). Riparian vegetation within the TZ is estimated to transpire approximately 6,000 AFY in an average year (USGS, 1996b). URS (2003) estimated that approximately 4,600 AFY of groundwater leave the TZ across the Helendale fault based on 1998 groundwater gradients. Transpiration from riparian vegetation, evaporation from open water bodies, and subsurface outflow combine to form a constant demand of approximately 11,759 AFY that will continue into the future. In the evaluated demand scenarios, storm flows are assumed to pass entirely through the TZ, consistent with assumptions of Webb (2000). During the long-term average storm flow, groundwater recharge is assumed to originate entirely from base flow, with all storm flow passing through the TZ and exit across the Helendale fault.

GROUNDWATER DEMAND THROUGH THE 2019-20 WY

Projected future demand through the 2019-20 WY is described in this section. Current and future demand will be compared later in this report with current and future supply to evaluate the market for imported water the TZ. Historical and future water demand components are listed in Table 3. Water demand components include agriculture, industrial, Silver Lakes Association, municipal and domestic uses. Constant, non-anthropogenic groundwater demand includes evaporation, riparian transpiration, storm outflow, and subsurface outflow.

Future Agricultural Demand

If agricultural water use continues to decline at the rate observed in the recent past, agricultural water use would eventually reach negligible levels. At 2,120 AFY, 2001-02 WY agricultural demand is about 8 percent of its peak historical demand of 27,112 AFY. Agricultural water use will not likely disappear entirely from the TZ because the Mojave River bottomlands are agriculturally productive and probably cannot be developed for other uses due to the floodplain hazard. For this evaluation, it is assumed that agricultural water demand will not decline below 2001-02 WY demand, or approximately 2,100 AFY. Using alfalfa irrigation as an example, 2,100 AFY could be used to irrigate 525 acres using 4 AFY per acre (Webb, 2000) of irrigation water. This agricultural demand is assumed to be constant in the future as agricultural interests are not likely to purchase imported water due to economic limitations associated with marketing their crops. The California Supreme Court found that some agricultural users have overlying riparian rights that do not fall within the adjudication. These riparian rights are not limited but are bound by the guidelines of beneficial use. For the purposes of this evaluation, the agricultural demand of these riparian rights holders is assumed to be separate from the projected future agricultural demand. For a conservatively high estimate of future agricultural demand, the former BAP of the Fitzwater and Palisades Ranches (1,115 AFY) was added to the existing agricultural demand (2,100 AFY) to generate the future agricultural demand constant (3,215 AFY) shown on Figure 8.

Future Municipal and Domestic Demand

As the TZ population continues to grow, more land will be developed for residential and municipal use, thus increasing municipal water use. U.S. Census data from 1990 and 2000 are combined with Southern California Association of Governments (SCAG) data in Table 1 and on Figure 7 to illustrate the recent and projected future total population of the TZ. SCAG produced a projection of population for the City of Adelanto (SCAG, 2003) but not for other areas of the TZ. To estimate population growth for the

communities of Oro Grande and Helendale (including Silver Lakes), the SCAG growth rates for unincorporated areas of San Bernardino County were applied to the 2000 Census population values of these communities. Table 1 and Figure 7 show that total TZ population is expected to be approximately 41,330 by the 2019-20 WY. This is an approximately 80 percent growth over the next 18 years.

Historically, as population has increased, groundwater demand for municipal and domestic uses has increased proportionately. DWR (1981) estimated that residents in the Adelanto and Oro Grande areas use approximately 225 gallons per day (GPD) per capita and residents of the Silver Lakes and Helendale areas use approximately 252 GPD per capita. These per capita usage values were also used by Malcom Pirnie for the 1990 MWA Master Plan. Using 2000 census data and confirmed production, per capita consumption is approximately 240 GPD per capita. Using the 41,330-person population projection for the 2019-20 WY and 240 GPD per capita, estimated domestic and municipal water use would be approximately 11,120 AFY in the 2019-20 WY. It is possible however, that per capita use rates may be reduced in the future by conservation,

Future Military Demand

Historical military water demand within the TZ has been significant part of municipal production estimates. However, closure of George AFB has reduced military water demand to insignificant levels. Although, there is still a military presence at the former Air Force Base, it is very small and water use is negligible. The U.S. Army currently has a reserve helicopter wing stationed at the SCLA, and the base is currently used as a transfer point for Army troops flying in to Fort Irwin north of Barstow. Troops are flown into the SCLA and loaded onto busses or trucks for the remainder of the trip to Fort Irwin. Troops and aircrews occasionally spend one or two nights at the SCLA. The U.S. Army plans to relocate the current functions from the SCLA to Daggett east of Barstow when modifications to the Daggett Airport are complete (globalsecurity.org, 2002).

Water use by these troops and aircrews is limited to domestic type uses and does not significantly impact TZ water demand. Water is supplied to these troops at the former base by the City of Victorville from a single well located on the former base. Seven wells formerly operated by the Air Force to supply George AFB have been turned over to, and are still in service with, the City of Adelanto. Military water use at the SCLA will not likely increase in the future and will likely decrease from the already low levels supplied by the City of Victorville.

Future Industrial Demand

Industrial water use associated with the ongoing mining and cement manufacturing activities in the Oro Grande area is not expected to increase significantly in the future. The availability of water has not been a limiting factor to these industries, and consequently the industries have grown based on mineral availability and market potential for their products. As stated previously, average water consumption by these mining and cement industries has been approximately 2,224 AFY over the period of record and is expected to remain relatively constant through the 2019-20 WY based on continuation of historical trends and limitation of mineral resources supporting those industries.

Other Industrial water uses may increase significantly in the TZ with the addition of new businesses to the City of Adelanto and the SCLA. The City of Victorville, which controls the SCLA, has acquired 1,700 AFY of BAP and estimates a demand of up to 9,000 AFY to support anticipated commercial and industrial development at the SCLA (Ms. K. Cox, City of Victorville, personal communication, March 2003). The High Desert Power Project (HDPP) is a new industry moving into the TZ. The HDPP is a 700 megawatt combined cycle gas fired power plant that is currently under construction on the northeast corner of the SCLA. Although the HDPP is being constructed within the TZ, its primary water source will be the State Water Project (up to 4,000 AFY) delivered

through the California Aqueduct and a MWA pipeline (power-technology.com, 2002). As the HDPP will be supplied with imported water it will not increase TZ water demand. A portion of the water purchased from the State Water Project will be treated to drinking water standards and injected in the upper Alto Subarea a few miles south of the TZ for subsequent recovery by the HDPP when backup water is needed. As much as 13,000 acre-feet are required by the California Energy Commission to be injected and stored in the upper Alto Subarea for use by the HDPP (power-technology.com, 2002).

Projected industrial water demand through the 2019-20 WY is shown in Table 3 and graphed on Figure 8. Industrial water use was projected to increase to the sum of the existing average demand and the total demand projected by the City of Victorville for industrial development of the SCLA. With a demand growth to 9,000 AFY at the SCLA, industrial water demand is anticipated to increase from an average of 2,224 AFY (average verified production from 1993-94 to 2000-01 WYs) to 11,224 AFY by the 2019-20 WY. This represents an annual industrial demand increase of approximately 493 AFY.

Total Pumping Demand by the 2019-20 WY

Significant population and industrial growth are anticipated within the TZ by the 2019-20 WY. Growth in these sectors will result in increased water demand. Based on recent trends and cultural changes within the TZ, agricultural water use is the only water use not projected to increase by the 2019-20 WY. As shown in Table 3 and on Figure 8, total pumping demand within the TZ (comprised of agricultural, municipal, domestic, military and industrial water demands) is projected to be approximately 28,979 AFY in the 2019-20 WY.

Natural Demands

Future changes in the natural water demands are not anticipated or readily quantified. Consequently, natural demands are assumed to be relatively constant for the period of projection. Evaporation is controlled by the amount of available surface area of open bodies of water, and will change in proportion to available surface area. Riparian transpiration is largely controlled by the availability of water (USGS, 1996b) and will increase or decrease based on expansion or contraction of riparian plant communities with the availability of water. Subsurface outflow across the Helendale fault is primarily controlled by groundwater gradients immediately upstream of the fault in the Regional and Floodplain aquifers. Evaporation, evapotranspiration, and subsurface outflow are assumed to continue into the future with little to no change. These three demands total approximately 11,759 AFY and are graphed together on Figure 8. Storm flow leaving the TZ is also assumed to be constant, but is graphed separately on Figure 8 because it is allowed to decrease during the supply scenario having no base flow recovery. Various natural groundwater demands are discussed in the Water Budget included as Appendix B of this report.

MARKET FOR IMPORTED WATER

The market for imported water in the TZ is expressed as water demand exceeding water supply and total pumping exceeding FPA Ramp Down of BAP. The differences between predictions of future supply and demand are shown in Table 4 and on Figure 9. The difference between projected total pumping demand and projected FPA Ramp Down is shown in Table 5 and on Figure 10. The 2001-02 WY difference between supply and demand shown in Table 4 is greater than the difference presented in the water budget (Appendix B) because the water budget generally reflects average conditions occurring over the past 10 years and the 2001-02 WY values in Table 4 reflect single water year values. Depending on the various water supply and demand scenarios, the import water demand in the TZ is predicted to increase from approximately 3,300 in the 2001-02 WY to between 4,000 and 20,000 AFY in the 2019-20 WY. Alternatively, import water may not be required in the 2019-20 WY should Mojave River base flow at the Lower Narrows recovery and VVWRA discharges be tied to population growth. With demand exceeding supply, most of the major TZ water demands (sinks or outflow) have the potential to become a market for imported water. These major potential markets include riparian vegetation, groundwater production, and subsurface outflow.

RIPARIAN VEGETATION

Surface and subsurface water in the Mojave River supports a corridor of riparian vegetation within the TZ. If groundwater levels are allowed to decline below the minimum depth required for survival of the riparian vegetation, the vegetation will die and the habitat that it supports will be lost. Fluctuation of water levels in some areas of the TZ has already threatened localized riparian vegetation. Additional threats may include increased future groundwater demand within limited areas of the TZ, continued base flow declines, or loss of current VVWRA discharges. No riparian vegetation goal

has yet been stated and consequently, the volume of water required to restore or to maintain riparian vegetation has not been determined. The Judgment provides for the establishment of a trust fund to maintain riparian vegetation along the Mojave River. The trust fund is funded through assessments against all water users under the Judgment, and is managed by CDFG. However, the CDFG has historically indicated that maintenance of habitat with imported water is not the preferred alternative because of the intermittent nature in this supply.

GROUNDWATER PRODUCTION

With increased population growth, significant increases in municipal and industrial groundwater use are anticipated within the TZ. By the 2019-20 WY, growth is predicted to result in a pumping water demand of approximately 28,979 AFY (Table 3). In particular, the City of Adelanto expects to double its water use over the next 10 years (Mr. Jack Stonesifer, City of Adelanto Director of Public Utilities, personal communication, November 2002). By the 2019-20 WY, industrial water demand is projected to increase five fold within the TZ based on current estimates by City of Victorville for industrial development at the SCLA.

Municipal water purveyors are well equipped to finance infrastructure or generate the necessary revenue to purchase imported water through rate increases or usage assessments and consequently make up a market of greater potential than individual smaller volume producers or individual domestic users (minimal producers). Under MWA Ordinance 11, the purchase of imported water by minimal producers would be limited to an annual Replacement Water assessment of 1 acre-foot of water for new minimal producers after April 1, 2000. Otherwise, no mechanism now exists to fund the purchase of imported water by the minimal producers or individual domestic users, unless they pump more than 10 acre-feet, which would then require that they become parties to the Judgment.

The majority of anticipated growth in industrial water demand would be generated by development of a portion of the SCLA into an industrial park. As planned, the City of Victorville is seeking to accumulate more than 10,000 AFY of BAP rights for use at the SCLA. No means currently exists within the Judgment to prevent a water user from concentrating purchased BAP in a relatively small area, and thus creating a large area of depressed groundwater due to overlapping pumping cones of depression. The projected growth of industrial water use within the TZ does however signify an influx of financial resources that may augment the market for imported water.

Although agriculture has historically been the largest volume water use within the TZ, based on recent trends, the market for agricultural use of imported water is limited. As stated previously agricultural water use has been declining steadily since the late 1960s, for reasons commonly referred to as "cultural changes" (Webb, 2000). These changes have resulted in a general reduction in the number of acres under cultivation and a reduction in the total water demand to irrigate these lands. Consequently, many of the production rights associated with agricultural production have been transferred to municipalities. It is not likely that the agricultural community would have sufficient resources available for the purchase of imported water and the associated infrastructure unless such expenditure would reduce the unit cost of water enough to enhance the profitability of smaller farms. The cost of imported water will likely be greater than the cost of energy necessary to pump local groundwater.

In addition to balancing total water supply and demand (Figure 9) to maintain the TZ water bridge function, the market for imported water will be driven by groundwater production exceeding the ramped-down FPA. Since implementation of the Judgment, FPA has been differentially ramped down from 100 percent to 80 percent for agricultural uses and to 70 percent for non-agricultural uses for the 2003-04 WY. At 70 percent, the groundwater producers in the TZ are projected to pump in excess of the TZ FPA.

However, production demand in excess of FPA will result as future Ramp Down of FPA continues and future groundwater demand increases.

Ramp Down of FPA is limited to 5 percent annual increments until overdraft conditions in the upper Alto Subarea stabilize. The court recently ruled and held FPA at 80 percent for agricultural users and 70 percent of municipal and industrial users for the 2003-04 WY. Table 5 lists a hypothetical 5-percent annual Ramp Down of FPA for all water users and the projected future pumping demand (listed in Table 3). These values graphed on Figure 10 indicate future pumping demand will exceed an FPA held at the current 70 percent rate, and will exceed the BAP (100 percent FPA) in the 2012-13 WY. The Judgment requires producers pumping in excess of FPA to be assessed a Make Up Water obligation. Import water would be purchased by the Watermaster to replenish excess production subsequent to payment of the assessment by producers. If import water in-lieu of groundwater production were a supply option for TZ producers, the timing and method of using import water would be driven by available import water infrastructure and the cost difference between either 1) the groundwater production costs and the Replacement Water assessment or 2) the cost of import water and the delivery fees.

SUBSURFACE OUTFLOW

In the Phase I report, URS (2003) estimated that subsurface groundwater outflow across the Helendale fault is approximately 4,600 AFY. The groundwater gradient immediately upstream from the Helendale fault is a key factor in maintaining flow across the fault. If the gradient is reduced due to increased groundwater pumping upstream from the fault, the amount of groundwater flow across the fault may be reduced. It is critical that the water levels directly up gradient of the Helendale fault be maintained to ensure that sufficient water flows into the Centro Subarea to meet the needs of downstream users. The market for imported water to maintain subsurface flow would be determined by water levels in Key Wells, as required by the Judgment, some of which may potentially be located immediately up gradient from the Helendale fault.

POTENTIAL RECHARGE PROGRAMS

Potential recharge programs within the TZ may be designed to meet several objectives. Each objective would satisfy the needs of a different water demand. Figure 11 shows areas for potential recharge projects based on the following objectives of TZ artificial recharge programs:

- Supplying water to riparian vegetation,
- Replenishing groundwater production,
- Banking or storing groundwater for short or long-terms, and
- Maintaining water levels in key wells and in outflow areas.

These objectives serve to replenish TZ groundwater when and where demand exceeds supply either regionally or locally. It should be noted that there could be instances when water supply and demand are in balance for the TZ as a region, but are not in balance locally (e.g. large pumping depressions and areas of riparian vegetation).

SUPPLY RIPARIAN VEGETATION

Maintaining groundwater elevations for riparian vegetation is an objective of the Judgment (Riverside County Superior Court, 1996). Exhibit H of the Judgment provides a funding method that can be used to purchase supplemental water if implementation of the Judgment does not maintain groundwater elevations in areas of riparian vegetation. Areas of dense riparian vegetation in the TZ have been mapped by USGS and CDFG (USGS, 1996b). Findings of the Phase I report (URS, 2003) indicate that groundwater elevations directly beneath the surface in areas of riparian habitat can not only be influenced by groundwater supply and demand but also by the presence of low permeability sandy clay lenses within the Floodplain aquifer. Appendix F of the Phase I

report includes an assessment of surface water flow lengths, clay lenses in the Floodplain aquifer, and occurrence of dense riparian vegetation in the Mojave River. From Oro Grande to Bryman, clay lenses at depths ranging from 75 to 100 feet can be used to differentiate deep and shallow zones within the Floodplain aquifer. Supply of water to riparian vegetation would call for maintaining groundwater elevations in the Floodplain aquifer shallow zone above these clay layers in very specific areas of the Mojave River channel. CDFG prefers TZ groundwater elevations be maintained by the recovery of base flow into the TZ to historical levels through recharge in the upper Alto Subarea (Personal Communication, Mr. Tom Bilhorn, CDFG, 2003). However, because the purpose of this evaluation is to determine the potential for artificial recharge within the TZ, recharge locations up stream of the Lower Narrows and the TZ were not considered.

To effectively supply water to riparian vegetation, artificial recharge would have to take place upstream or in the immediate vicinity of the vegetation to be restored. In the TZ, the recharge method to maintain water levels in riparian areas would likely be surface discharge to the Mojave River. The benefits of this method include minimal maintenance of recharge facilities, flow of discharge water over a large area of the river, and direct infiltration to the target aquifer. Discharge to the surface of the Mojave River should consider the occurrence of shallow, low permeability, clay lenses that would tend to maintain recharge water within depths available to riparian vegetation. Surface recharge away from such lenses would tend to percolate to deeper depths. Figure 11 shows areas of greater surface infiltration rate as discussed in Appendix F of the Phase I report. Supply of recharge water for riparian vegetation would increase evapotranspiration and effectively increase TZ water demand. Thus recharge objectives in riparian areas may require a greater than 1:1 ratio of recharge volume to riparian demand volume.

REPLENISH GROUNDWATER PRODUCTION

Replenishing groundwater production may be necessary as demand begins to exceed supply. Centers of concentrated production in the TZ are located along the Mojave River and are shown on Figure 11 based on 2001 verified production data. Greater detail of water production in the TZ is shown in Appendix E (Figures E-4 and E-5) of the Phase I report (URS, 2003). The Judgment requires that Replacement Water be purchased for an individual water producer exceeding its FPA. The Judgment specifies that Replacement Water for overproduction of FPA in the TZ (prior to establishing minimal water levels) must be replaced in the TZ under certain conditions in order to maintain the TZ water bridge function. After the minimal water levels have been set, if water levels are not met, Alto Subarea Replacement Water is required to be placed in the TZ. If water levels are met, water can be placed elsewhere in the Alto Subarea. Replacement Water has typically been purchased in the water year following the excess production.

Although not currently practiced, Replacement Water could conceivably be purchased and recharged prior to the actual production excesses and then be credited towards Replacement Water. The Judgment does allow for MWA and parties to the Judgment to bank water in this manner with a storage agreement with the Watermaster. Purchase and recharge of Replacement Water in anticipation of production in excess of FPA could be an option to some seasonally high volume producers with the ability to fund water purchases. Such a replenishment program would likely be seasonal in nature. As documented in the Phase I report, the majority of TZ production occurs along the Mojave River and the largest seasonal drawdown occurs near Oro Grande in the Section 30 well field. As water demand increases in the TZ, competition for groundwater resources may force resource development away from the Mojave River into areas underlain by the Regional aquifer.

To effectively replenish groundwater production, the method of recharge would likely be discharge to the Mojave River in the Floodplain aquifer forebay for wells constructed in the Floodplain aquifer and injection wells or recharge basins for wells constructed away from the river in the Regional aquifer. The Floodplain aquifer forebay is described in the Phase I report. Discharge of recharge water directly to the river may not be suitable if evapotranspiration losses are not acceptable. Water recharged outside the forebay would be more likely to stay in the shallow zone and out of the deep zone where most production from the Floodplain aquifer occurs.

Injection wells or recharge basins would need to be located either at or up gradient of the extraction location, depending on the time duration between the recharge water supply and production water demand. The use of recharge basins would be precluded in areas of the Regional aquifer where low permeable clays may perch recharge water above the targeted production depths such as in the vicinity of the SCLA. As the Regional aquifer is partially consolidated, injection into it will be limited to areas with acceptable transmissivity. Acceptable transmissivity values will depend on required injection rates, injection duration, and available injection head. The choice of injection wells or recharge basins will also depend on the quality and source of the recharge water. Water that is relatively higher in turbidity would be better recharged in basins where maintenance is easier. Reclaimed water recharge may also have regulatory requirements that preclude direct injection near points of extraction.

BANKING GROUNDWATER

Banking or storing groundwater for short and long-term storage programs could be implemented as water becomes seasonally available from the California Aqueduct and the Mojave River Pipeline. A short-term banking program would likely be executed as described above for storage to meet future groundwater production. The difference between meeting current demand and future demand is that annual recharge could exceed

current seasonal or annual demand in anticipation of a greater future demand. The potential for recharge of import water would likely occur during wet years when flows may already exist in the Mojave River. In this case, groundwater banking recharge programs would be preferable in areas off the immediate river channel. Alternatively, a wet year in northern California coupled with a dry year in southern California may present available imported water for recharge directly in the river channel.

Water banking would likely be conducted in areas where available storage exists and groundwater demand is low. The storage area would be near pipeline facilities such as the Mojave River Pipeline so that the stored water can be removed and transferred to demand areas when required. Figure 11 shows areas near the Mojave River Pipeline that may be suitable for short or long-term banking programs in the Regional aquifer. Although the Regional aquifer has less favorable aquifer properties than the Floodplain aquifer, the Regional aquifer has more available storage and is currently less utilized for production. Methods of recharge for water banking would likely include injection wells with the same aquifer and location limitations as discussed previously for replenishing groundwater production.

MAINTAINING WATER LEVELS

As discussed in the Phase I Report (URS, 2003), maintaining water elevations in key wells and in outflow areas is a key to maintaining the TZ water bridge function. Groundwater elevation contours for the Regional and Floodplain aquifers are shown in the Phase I report on Figure 6 and Figure 7, respectively. TZ subsurface groundwater outflow occurs along the Helendale fault. Maintaining water levels and historical groundwater gradients from the TZ at the Helendale fault would serve to maintain groundwater flow from the TZ to the Centro Subarea. With the Alto Subarea minimal obligation met and with the water bridge function maintained, the Judgment assumes sufficient water flow reaches the Centro Subarea. As indicated on Figure 11, TZ

subsurface outflow along the Helendale fault in the area of the Mojave River channel flows towards the Barstow area of the Centro Subarea, while TZ outflow northwest of the channel flows towards the Harper Dry Lake area of the Centro Subarea. Recharge water could be applied in these areas to target the intended downstream demand.

The method of recharge for maintaining water levels in out flow areas would likely be recharge basins constructed near Helendale within the limits of the Floodplain aquifer. Discharge to the river at this location would likely flow at or near the surface, cross the Helendale fault, and exit the TZ into the Centro Subarea, and not meet the objective of maintaining TZ water levels. Recharge away from the river to the west in the Regional aquifer would tend to maintain outflow to the Harper Dry Lake area. Recharge near or east of the river would tend to maintain outflow towards Barstow, which is more preferable than towards Harper Lake due to the greater production from the Barstow area of the Centro Subarea.

DOWNSTREAM OBLIGATIONS

The Judgment requires Make Up Water be purchased by a subarea when its minimal subarea obligation to the downstream subareas is not met. Consequently, one of the potential objectives of a recharge program would be to ensure that the obligation of the Alto Subarea is met. Alto Subarea Makeup Water owed to the Centro Subarea is delivered to recharge facilities in the Centro Subarea.

VIABILITY OF POTENTIAL RECHARGE PROGRAMS

The viability of potential TZ recharge programs is dependent on the availability of a water supply, underground storage, and land for suitable recharge facilities.

Water supply for potential TZ recharge programs includes imported water and VVWRA discharge. Although not currently used to supply water to the TZ, the Mojave River

Pipeline travels northward near the Mojave River and could be used to supply future recharge projects. Large supply components of the TZ water budget include storm flow, base flow, and VVWRA discharges. The Judgment requires that storm flows be allowed to recharge naturally and not be captured for artificial recharge. Up to 18 cubic feet per second (approximately 13,000 AFY) of daily base flow entering the TZ can recharge naturally prior to exiting the forebay and meeting discharges from VVWRA (See Phase I report, Appendix F-1). Annual base flows measured at the Lower Narrows have been decreasing and may not be a reliable water supply in the near future. As suggested by CDFG, the return and stabilization of base flow may be a preferred alternative to recharge for preserving riparian vegetation in the TZ. VVWRA discharges may continue increasing, and may require expansion of existing discharge facilities if this resource continues to grow. VVWRA has indicated it plans to maintain its discharge at current levels and redirect future flows from new connections to a system for reclaimed water uses.

Funding of water purchases for potential recharge programs is provided for by the Judgment. Funding can be raised through Replacement Water obligations when producers exceed their FPA. The users likely to fund Replacement Water purchases include municipal and industrial users, both of which are projected to experience the largest increases in water demand. As discussed earlier, TZ municipal water use is projected to increase from approximately 6,796 AFY in the 2000-01 WY to approximately 11,119 AFY in the 2019-20 WY. Industrial water demand is anticipated to increase from approximately 1,856 AFY in the 2000-01 WY to nearly 11,224 AFY in the 2019-20 WY. The projected increases by municipal and industrial users should provide financial resource to facilitate artificial recharge programs

Exhibit H of the Judgment provides for a $1,000,000 (in 1993 dollars) Biological Resources Trust Fund to maintain riparian habitat and requires minimum water levels be set for the maintenance of riparian habitat. Among other uses, the trust fund may be

utilized to purchase supplemental water or purchase/lease BAP to maintain riparian vegetation along portions of the Mojave River channel if minimum water levels are not maintained. CDFG has stated it prefers reestablishing hydrologic conditions that support riparian habitat rather than artificially maintaining locally high water levels with an irregular supply of water (Mr. Tom Bilhorn, CDFG, personal communication, December 2002). The entire Mojave River channel in the TZ is eligible for use of this fund by CDFG. The municipal, industrial, and biological markets offer the potential to bring together diverse interests to pool resources and operate recharge programs that meets multiple objectives.

For TZ recharge programs to be viable, available storage must exist above the water table in the aquifer into which recharge water is to be placed. A balance must be maintained between the need for available storage and maintaining water levels to support the water bridge function. Available storage was discussed in more detail in the Phase I report (URS, 2003) with respect to the Floodplain and Regional aquifers. In the Floodplain aquifer beneath the Mojave River, groundwater storage exists predominately in the southern TZ where groundwater production and seasonal fluctuations are greatest, as shown in Appendix E and Plate 3 of the Phase I report (URS, 2003). In the Floodplain aquifer north of VVWRA, groundwater levels are closer to the surface and would limit locally available storage. Unlike recharge basins of limited area, recharge through the river channel is advantageous for certain recharge objectives. As has occurred historically, it is from the Floodplain aquifer that future demand is likely to be sought due to its relatively high production capacity. In the river channel, as storage is filled locally, surface flow conveys recharge water to the next downstream available area having available storage. In the Regional aquifer, available storage occurs throughout most of the TZ. However, as groundwater moves relatively slowly in the Regional aquifer, artificial recharge programs in this aquifer should be either near the intended future use or should be for a long-term objective. Recharge to the Regional aquifer in areas located

near the banks of the Mojave River can be used to provide water more slowly and deeper in the Floodplain aquifer than would direct recharge in the river channel.

For TZ recharge programs to be viable, future recharge facilities should be maintained at locations that meet the selected recharge objectives stated at the beginning of this section. The TZ contains large areas of undeveloped land over the Floodplain and Regional aquifers that can be developed for recharge programs. Land in the river channel is not likely to be developed and should be available for future recharge projects similar to that currently conducted by VVWRA. Although much of the land over the Regional aquifer is undeveloped, the nature of the Regional aquifer may preclude its blanket use for artificial recharge basins. The relatively lower transmissivity and locally perched conditions of the Regional aquifer may limit recharge operations to direct injection for future extraction. Recharge basins overlying the Regional aquifer may be developed in areas without perching layers and where recharged water will follow groundwater flow paths towards to intended water recipient. Potential locations considered for construction of recharge facilities should be fully characterized before facilities are constructed to ensure that the aquifer in that location can support the intended recharge and that the intended objectives will be met.

FINDINGS

Summarized below are the findings of the Mojave River TZ Recharge Project Phase II evaluation of groundwater supply and demand in the TZ.

WATER BUDGET

The TZ water budget summarizes annual inflow and outflow and is essentially balanced for water supply purposes based on representative average annual conditions over the past 10 years. The water budget indicates that under recent conditions, the TZ has an average annual water inflow of 61,150 AFY and average annual water outflow of 61,336 AFY. The difference between inflow and outflow is 186 AFY and is within the variability and estimating precision of the data. The balanced water budget can be used to evaluate future regional supply and demand scenarios by modifying individual components of the budget. While the water budget is considered balanced from the perspective of long-term historical water supply and demand, and while annual water elevations are generally consistent, recently observed increases in summer groundwater depths in the southern area of the Floodplain aquifer are greater than can be tolerated by riparian vegetation.

WATER MANAGEMENT

Water resources management in the Mojave Basin Area is governed by the physical solution presented in the Judgment. The physical solution controls Ramp Down of FPA, accounts for groundwater production, and provides methods to purchase water for both replacement and Make Up Water obligations. Although the Judgment is the primary water management instrument within the TZ, several parties within the TZ have been exempted to the conditions of the Judgment and produce riparian water rights along the Mojave River for agricultural use. MWA has developed a long-term regional water management plan to enhance supply, reduce consumption, and develop funding for

purchase of imported water. By law (California State Water Code, 1959) MWA has the responsibility to ensure that sufficient water is available for beneficial uses within its service area. Under current conditions, that responsibility is best fulfilled by balancing water supply and water demand. From the projected market for imported water, additional water management by MWA (through recharge or in lieu programs) will be required to maintain the balance of supply and demand. This may be achieved by either recharge efforts in the TZ, Ramp Down of pumping, and/or introduction of quantities of imported water in the upper Alto Subarea. Current TZ production is less than the current FPA set by the Judgment.

GROUNDWATER SUPPLY

Projections indicate future water supply to the TZ may increase at a rate dependent on projected increases in VVWRA discharge and the future recovery of Mojave River base flow. VVWRA has begun processes to allow it to limit future discharge to the river channel at current levels and allow future increases to be diverted for reclaimed use elsewhere. If diverted VVWRA discharges are used within the TZ, then their use may replace another water supply (groundwater) with no net change in the water budget. Base flow recovery could begin as soon as overdraft in the upper Alto Subarea is reversed. The halt of overdraft in the upper Alto Subarea is estimated by the Watermaster to occur at approximately 60 percent to 65 percent Ramp Down of FPA for Alto Subarea producers.

For the 2000-01 WY, total water supply to the TZ was approximately 58,720 AFY. With no base flow recovery and VVWRA discharges tied to growth, total water supply is projected to be approximately 64,485 AFY by the 2019-20 WY. With no base flow recovery and VVWRA discharges limited at 9,700 AFY, projected total water supply is estimated at approximately 53,351 AFY by the 2019-20 WY. With base flow recovery and VVWRA discharges tied to growth, total water supply is projected to be

approximately 80,411 AFY by the 2019-20 WY. With base flow recovery and VVWRA discharges limited at 9,700 AFY, projected total water supply is estimated at approximately 69,277 AFY by the 2019-20 WY.

GROUNDWATER DEMAND

Projections indicate future water demand in the TZ is increasing due largely to potential increases in municipal and industrial use. For the 2000-01 WY, total water demand in the TZ was approximately 60,709 AFY. The 2000-01 WY pumping water demand in the TZ was approximately 14,188 AFY. Pumping demand by the 2019-20 WY is projected to be approximately 28,979 AFY and exceeds the TZ BAP established by the Judgment (24,145 AFY for the original parties) and the TZ BAP reduced by producers dismissed from the Judgment (23,030 AFY). Depending on various scenarios of continued FPA Ramp Down, future TZ water demand could exceed TZ FPA by the 2003-04 WY (Figure 10).

MARKET FOR IMPORTED WATER

The projected market for imported water in the TZ is dependent of four main variables: water supply, water demand, recovery of Mojave River base flow, and limitations on VVWRA discharges. Without recovery of Mojave River base flow, the market for imported water in the TZ is projected to increase from about 3,300 AFY in the 2001-02 WY to between 8,800 AFY and 20,000 AFY by the 2019-20 WY. The difference in the 2019-20 WY projected values is linked mainly to potential limitations on VVWRA discharge. With VVWRA discharge limited at 9,700 AFY, the import water demand would be greater.

With continued FPA Ramp Down and success of water management practices, recovery of Mojave River base flow is predicted by the Watermaster to beginning at 65 to 60 percent FPA or approximately in the 2005-06 WY. With base flow recovery, the market

for imported water in the TZ is projected to decrease from the year that increased base flow is observed. Until that time, the market for imported water will increase by between 800 and 1,600 AFY. With recovered base flow beginning in approximally the 2005-06 WY and with VVWRA discharges limited to 9,700 AFY, the market for imported water in the TZ would by approximately 4,000 AFY in the 2019-20 WY. With both recover of Mojave River base flow beginning in the 2005-06 WY and no limitations on growth-linked VVWRA discharge, the market for imported water in the TZ would be 0 AF in the 2010-11 WY through the 2019-20 WY (limit of the study)

The market for imported water will also be driven by groundwater production exceeding FPA Ramp Down in addition to balancing total water supply and demand (Figure 9). Assuming current trends, annual Ramp Down of FPA for all water users, and projected future increases in pumping demand indicate future groundwater pumping demand in the TZ will exceed FPA Ramp Down at 70 percent for all producers and will exceed the total BAP by the 2012-13 WY. The projected dates are conservative, as the Court has recently approved differential Ramp Down for agriculture and municipal water users. With projected increases in pumping demand coupled with FPA Ramp Down to 60 percent, the market for imported water in the TZ is projected to be approximately 15,161 AFY in the 2019-20 WY (Table 5 and Figure 10).

MWA is currently entitled to a maximum of 75,800 AFY of imported water from the State Water Project water deliverable through the California Aqueduct. DWR currently estimates that on average MWA can expect to have 78 percent of that entitlement available due to limitations on the State Water Project. The Mojave River Pipeline runs northward through the TZ near the Mojave River. The market for imported water or any other interruptible and similarly priced water has a limited potential for maintaining riparian vegetation.

POTENTIAL RECHARGE PROGRAMS

The market exists for potential TZ recharge programs with varying objectives. Objectives of a TZ artificial recharge program could satisfy the needs of different water demands including: supplying riparian vegetation, replenishing groundwater production, banking groundwater, and maintaining water level in TZ outflow areas.

Riparian vegetation and production replenishment objectives are best served by discharges to the river along the Mojave River in the southern TZ. Banking groundwater for short and long terms would be more suitable in areas of the Regional aquifer using injection wells or recharge basins. Maintaining water levels in outflow areas is more suitable to recharge basins in the vicinity of the Helendale fault than in the southern TZ.

Depending on the recharge objectives, imported water to meet future demand could be either introduced directly into the TZ or potentially introduced up gradient of the TZ. Recharge up gradient of the TZ would be to maintain or slightly increase subsurface flow into the TZ and to maintain or increase base flow into the TZ.

VIABILITY OF POTENTIAL RECHARGE PROGRAMS

Recharge programs are viable in the TZ due to several factors, including demand based funding (the Judgment), available imported water supply, available groundwater storage, and available land for recharge facilities. Recharge programs may also be driven by increasing demand, base flow insufficient to meet riparian vegetation needs, maintaining key well water levels, and the potential limiting of VVWRA effluent discharges. Should recovery of Mojave River base flow occur as projected and VVWRA discharge remain tied to growth, then recharge programs in the TZ would not be required to balance total supply and demand. However, as with any regional water budget, separation of water supply from the demand may still require local recharge programs to protect local needs

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