CENTRAL ARIZONA SALINITY STUDY --- PHASE I

Technical Appendix E

HYDROLOGIC REPORT ON THE TUCSON ACTIVE MANAGEMENT AREA

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1.0 INTRODUCTION

The Central Arizona Salinity Study (CASS) is a coalition of water and wastewater agencies evaluating salinity issues in central Arizona. The mission of CASS is to provide its members with workable alternatives for a quality, cost effective, sustainable, and reliable water supply through partnerships and cooperative efforts in regional salinity planning and management. CASS was formed in November 2001. CASS is a study group and not a legal entity.

Salinity from local and imported sources is increasing the salinity of groundwater in localized areas and the salinity of reclaimed water in central Arizona. The magnitude of the salinity issue is unclear and water providers in central Arizona decided to work together to assess the problem and, if necessary, develop regional strategies for managing it. Central Arizona water providers must work together to protect, preserve, and develop these shared resources and to respond to issues of: increasing water quality and water supply regulation; increasing reclaimed water utilization; increasing levels of salinity into water reclamation facilities; developing brine disposal strategies; deteriorating groundwater quality in localized areas; and managing costs.

If no workable solution is implemented, salinity increases may result in greater water and wastewater treatment costs, decreased agricultural production, and some water sources may become unsuitable for their intended uses.

- Increasing salinity levels may reduce the ability of water providers to use groundwater and reclaimed water to meet customer water demands. Some communities may not have enough supply to meet demand. Growth and development in these communities may become limited.

- Water reclamation plants may have water quality permit compliance problems. High salinity levels in reclaimed water supplies may make this resource unsuitable for some of its intended uses. Retrofitting water reclamation plants to manage salinity and dispose of brine may significantly increase wastewater treatment costs.

- Water customer complaints may increase due to increasing salinity of the drinking water supply. Retrofitting potable water treatment plants to manage salinity and dispose of brine may significantly increase water treatment costs.

The following white paper describes hydrologic conditions in the Tucson Active Management Area (AMA)—one of several areas within the State which has been designated by the Legislature and the Arizona Department of Water Resources as requiring active management of groundwater. This report is based on literature review of publicly available information, and site-specific fieldwork was not conducted as part of this study. The purpose of the report is to provide a general framework of the physical, geologic, and hydrologic aspects of the study area. The report will also quantitatively assess future salt loading from imported sources.

2.0 PHYSICAL SETTING

The Tucson AMA is located in southeastern Arizona within the Sonoran Desert section of the Basin and Range physiographic province. Tucson AMA covers approximately 3,900 square miles, and land surface elevation ranges from 1,860 feet to 9,453 feet above mean sea level (amsl). Broad, gently sloping alluvial basins separated by north to northwest trending block-faulted mountains characterize the land within Tucson AMA. Tucson AMA is comprised of two sub-basins: the Upper Santa Cruz Valley Sub Basin (USCVSB) north of the Pima/Santa Cruz County line, and the Avra Valley Sub Basin (AVSB).

Temperatures and precipitation vary based on season and elevation. Average high temperatures in the Tucson AMA range from 67 degrees Fahrenheit (°F) in January to 103 °F in July (ADWR, 1999). Rainfall occurs in two seasons; during the winter months from frontal storms and during summer months from convective thunderstorms or "monsoon" storms. Average precipitation ranges from approximately 11 inches per year in low elevations to 28 inches per year in the high elevations of the surrounding mountains (ADWR, 1999). Average annual evapo-transpiration rate is about 77 inches per year (ADWR, 1999).

The principal surface water drainage feature in the USCVSB is the Santa Cruz River which originates in Arizona, then flows south into Mexico before turning west and north and re-entering the United States east of Nogales, Arizona. The Santa Cruz River enters the Tucson AMA at the Santa Cruz County/Pima County line and extends 60 miles north before leaving the Tucson AMA northwest of Red Rock, Arizona. Surface flow occasionally enters the basin from the south from storm flood flows and effluent discharges from the Nogales International Wastewater Treatment Plant located 20 miles south of the county line. Perennial flow occurs along an approximate 23-mile reach of the Santa Cruz River from the discharges of effluent at Pima County's Roger Road Wastewater Treatment Plant and the Ina Road Water Pollution Control Facility. The remainder of the river is ephemeral and only flows in response to precipitation.

Principal tributaries of the Santa Cruz River include the Cañada Del Oro Wash and Rillito Creek. Tributaries to Rillito Creek include Pantano Wash and Tanque Verde Creek which in turn receive surface flow from Sabino Creek, Rincon Creek and Cienega Creek. Cienega Creek, Sabino Creek, Tanque Verde Creek, Agua Caliente Wash and Cañada Del Oro Wash have small perennial reaches in the eastern portions of the USCVSB.

In the southern portion of the AVSB, Altar Wash is the principal surface water drainage feature and becomes Brawley Wash in northern portions. Brawley Wash has a confluence with the Santa Cruz River shortly after leaving the Tucson AMA to the northwest. A small portion of Arivaca Wash is perennial within the AVSB.

3.0 GENERALIZED GEOLOGY

The AVSB and the USCVSB are alluvial basins surrounded by block-faulted mountains. Block faulting occurred as a result of the Basin and Range disturbance that began about 12 million years ago (Anderson, 1987). These mountains include the Santa Catalina, Rincon, and Santa Rita Mountains in the east portion of the USCVSB; and the Silverbell and Baboquivari Mountains in the west portion of the AVSB. The Sierrita, Tucson and Tortolita Mountains divide the two sub-basins. The alluvial basins are composed of a thick sequence of basin-fill sediments.

3.1 BEDROCK GEOLOGY

Bedrock materials of the surrounding mountains consist of andesitic to rhyolitic volcanic rocks, tuff, and agglomerate; diorite; granodioritic and mylonitic gneiss; granite; schist; and interbedded conglomerate, limestone, and sandstone (Davidson, 1973 and Reynolds, 1988). These rocks are from Precambrian to Tertiary age (Davidson, 1973). Depth to bedrock in the two sub-basins is estimated based on gravity modeling (Oppenheimer and Sumner, 1980). Depth to bedrock on the center of the USCVSB is about 11,000 feet. In the AVSB, depth to bedrock is about 9,600 feet.

3.2 BASIN GEOLOGY

The alluvial deposits in the USCVSB are separated into six distinct geologic units, referenced as the Pantano Formation, lower Tinaja beds, middle Tinaja beds, upper Tinaja beds, the Fort Lowell Formation, and stream alluvium. A brief summary of each unit is presented below:

- ***Pantano Formation.*** Overlaying and in fault contact with bedrock materials is the Pantano Formation which consist of conglomerate, sandstone, mudstone, gypsiferous mudstone, and siltstone (Anderson, 1987). This formation is highly faulted and tilted, and was deposited prior to the Basin and Range disturbance. Sediments of the formation are as much as thousands of feet thick (Anderson, 1987).

- ***Lower Tinaja Beds.*** Overlaying the Pantano Formation is the lower Tinaja beds which consist of mudstone and clay with interbedded sand, silt, and gravel. These beds were also deposited prior to the Basin and Range disturbance (Anderson, 1987).

- ***Middle Tinaja Beds.*** Middle Tinaja beds occur only in the central downfaulted portions of the USCVSB. They consist of gypsiferous and anhydritic clayey silt and mudstone (Anderson, 1987).

- ***Upper Tinaja Beds.*** Upper Tinaja beds typically consist of moderately consolidated sand, gravel, clay, and silt and are typically described as conglomerate or cemented sand and gravel in well drillers' logs. The upper, middle and lower Tinaja beds are up to 5,000 feet thick (Davidson, 1973).

- ***Fort Lowell Formation.*** The Fort Lowell Formation overlays the upper Tinja beds and consists of interbedded layers of clay, silt, sand, gravel, and boulders. The formation is about 300 to 400 feet thick in most of the basin (Davidson, 1973).

- ***Stream Alluvium.*** Unconsolidated fluvial deposits that occupy the stream bed channels of the Santa Cruz River and its tributaries characterize the stream alluvium. The stream alluvium is typically less than 100 feet thick. The stream alluvium typically consists of sand and gravel and has high infiltration capacity (Davidson, 1973).

The AVSB is separated into two distinct units, referenced as the lower and upper alluvium (Hanson, Anderson and Pool, 1990). The lower alluvium is equivalent to the Pantano Formation and Middle and Lower Tinaja beds, and the upper alluvium is equivalent to the Upper Tinaja Beds and the Fort Lowell Formation of the USCVSB.

4.0 HYDROGEOLOGIC CONDITIONS

4.1 GROUNDWATER OCCURRENCE AND MOVEMENT

The hydrogeologic system of the Tucson AMA is generally characterized by periodic recharge along the ephemeral stream channels of the Santa Cruz River and Brawley Wash and their tributaries, ground-water flow to the north-northwest through basin-fill deposits, and discharge to water supply wells and underflow to the Picacho basin to the northwest. Periodic stream flow in the ephemeral drainages occurs in response to precipitation and snow melt from the surrounding mountains. Some perennial reaches occur near the mountain fronts. Infiltration occurs through the high-permeable stream-channel deposits and flows down gradient through moderately to highly permeable basin-fill deposits.

Natural recharge to the aquifer system occurs as a result of infiltration of surface water runoff along the mountain fronts of the mountains, and stream channel recharge along the Santa Cruz River and Brawley Wash and their tributaries. Based on Osterkamp (1973), rates of groundwater recharge at the mountain fronts and stream channels in the Tucson AMA range from 0 to 850 AF per mile of mountain front or stream-channel. Average annual natural recharge in the Tucson AMA is approximately 76,600 AF/yr (ADWR, 1999).

Groundwater levels in the USCVSB have declined as much as 200 feet since 1940 (ADWR, 2003). Cones of depression are evident within Tucson Water's central well field as a result of municipal pumping and the Green Valley/Sahuarita area from agriculture and mining pumping. Typical annual declines have been in the order of 3 to 4 feet (ADWR, 2003). Since the late 1970's and early 1980's there has been some recovery of the water levels of about 80 feet in southern portions of the USCVSB. Water levels in the Cañada del Oro area in northern portions of the USCVSB have been relatively constant despite an increase in groundwater pumping.

Water levels have declined as much as 150 feet in northern portions of the AVSB creating a large cone of depression as a result of agricultural pumping. Similarly, since the late 1970's, water levels have recovered about 60 feet (ADWR, 2003).

4.2 GROUNDWATER QUALITY

Levels of Total Dissolved Solids (TDS) in groundwater in the Tucson AMA range from 101 mg/l to 752 mg/l and averages approximately 259 mg/l (Pima Association of Governments, 1994). In most areas of the Tucson AMA, groundwater is within potable drinking water standards.

5.0 Tucson AMA'S WATER SUPPLY

Total water use in the Tucson AMA in 2000 was about 336,000 acre-feet (AF) per year with groundwater resources being the primary water supply at about 90 percent (ADWR Tucson AMA, 2003). Groundwater produced from exempt wells are not accounted for in this total. Effluent is served to some golf courses, parks and schools and accounted for about 3 percent of the total use (ADWR Tucson AMA, 2003). Central Arizona Project (CAP) water is utilized to recharge the aquifer and for agriculture irrigation (in-lieu of groundwater). In 2000, approximately 49,500 AF of CAP water was recharged to the aquifer and approximately 24,000 AF was utilized for agriculture (Tucson Water, 2003b). Municipal use accounts for about 48 percent of the total water use and agricultural use accounts for about 32 percent (ADWR Tucson AMA, 2003). The remaining water use includes copper mines and other industrial well owners (ADWR Tucson AMA, 2003).

5.1 GROUNDWATER

Groundwater is used to supply potable municipal, industrial and agricultural uses. In 2000, groundwater use totaled almost 301,500 AF (ADWR Tucson AMA, 2003). Approximately 53 percent was produced for municipal uses, 27 percent for agricultural uses and the remaining 20 percent for industrial and mining uses (ADWR Tucson AMA, 2003).

5.2 RECLAIMED WATER

Approximately 70,200 AF of effluent was generated from July 2000 to June of 2001 by the two treatment plants owned and operated by Pima County (Pima County Wastewater Management Department, 2003). Some effluent was used for turf irrigation, but most was discharged into the Santa Cruz River and recharged the local groundwater aquifer.

Roger Road Wastewater Treatment Plant generated about 44,150 AF of effluent from July 2000 to June of 2001 (Pima County Wastewater Management Department, 2003). The City of Tucson reclaimed 10,400 AF of this effluent for use in its reclaimed water system and about another 680 AF for turf irrigation at the Silverbell golf course, leaving about 33,100 AF to be discharged into the Santa Cruz River (Pima County Wastewater Management Department, 2003). City of Tucson delivers the reclaimed water to golf courses, parks, schools including the University of Arizona and Pima Community College and many single-family homes.

Ina Road Water Pollution Control Facility produced about 26,100 AF/yr of effluent from July 2000 to June of 2001 (Pima County Wastewater Management Department, 2003). About 620 AF of effluent generated was used for turf irrigation at Arthur Pack golf course. Approximately 25,500 AF/yr remains and is discharged into the Santa Cruz River (Pima County Wastewater Management Department, 2003).

The City of Tucson stores effluent underground at the Sweetwater Recharge Facilities. Peak recovery of the reclaimed water occurs from May through October during periods of peak turf irrigation demands (Pima Association of Governments, 2003). The

Sweetwater Recharge Facilities has a permitted capacity of 6,500 AF/yr and for the most part operates on an annual put-and-take basis (Tucson Water, 2003). These facilities consist of 28 acres of off-channel spreading basins, six recovery wells, and the Sweetwater Wetlands (a multi-use wetland treatment system) all of which are located on the east and west banks of the Santa Cruz River (Tucson Water, 2003). These facilities utilize spreading basins to enhance infiltration, the vadose-zone profile to improve water quality through soil-aquifer treatment, and designated wells to recover the stored effluent (Pima Association of Governments, 2003). After the effluent is recovered, it is chlorinated and sent to the reclaimed distribution system (Pima Association of Governments, 2003).

The City of Tucson, in partnership with the U.S. Bureau of Reclamation, also recharges and stores effluent along a five-mile reach of the Santa Cruz River downstream from the Roger Road Wastewater Treatment Plant (Tucson Water, 2003). This permitted in-channel recharge facility is called the Santa Cruz River Managed Underground Storage Facility and is used to accrue both annual and long-term storage credits for the effluent passively recharging the aquifer between the Roger Road outfall and Ina Road. As of 2003, the City of Tucson had one recovery well associated with this facility (Tucson Water, 2003).

In addition, the City of Tucson, Town of Oro Valley, Town of Marana, Metropolitan Domestic Water Improvement District, Cortaro-Marana Irrigation District and Cortaro Water User's Association, Avra Valley Irrigation District, Flowing Wells Irrigation District and Pima County have jointly applied to obtain permits to recharge and store in-channel effluent in the Lower Santa Cruz River Managed Recharge Project (ADWR Tucson AMA, 2003). This project will allow participants to annually accrue up to 21,500 AF of effluent storage credits (which takes into account the fifty percent cut to the aquifer for managed facilities) along the Santa Cruz River between Ina Road and Trico Road. It is believed that this permit will be issued sometime in 2003.

In the future, one or more of the above entities may be interested in developing additional constructed in-channel and/or off-channel effluent storage facilities in order to accrue more effluent storage credits. In addition, municipal effluent will eventually be treated and used as a renewable water source for potable supply (Tucson Water, 2003).

5.3 CENTRAL ARIZONA PROJECT WATER

The CAP canal was completed to the Tucson area in the early 1990's to deliver a renewable supply of water from the Colorado River. For the purpose of this study, a TDS concentration 650 mg/l was utilized for this study (Tucson Water, 2003b). In 2000, 24,289 AF of CAP water was delivered and used in-lieu of groundwater for agricultural irrigation (ADWR Tucson AMA, 2003).

The CAP water allocation for the Tucson Basin's water providers and users is 215,333 AF per year and consists primarily of municipal contracts (ADWR, 1999). The City of Tucson has an allocation of 138,920 AF of this total (ADWR, 1999). Direct delivery of

Colorado River water was rejected by the public when the delivered water caused problems with the older piping of the distribution system. In response, the City of Tucson elected not to serve their CAP allotment directly but to recharge it in the Avra Valley sub-basin at the Clearwater Renewable Resource Facility (Clearwater) (Tucson Water, 2001).

Clearwater consists of a series of recharge basins and recovery wells and the facility is currently permitted to recharge and recover 60,000 AF/yr. The recovery wells produce a blend of groundwater and CAP water and convey it to a central pumping station. From the central pumping station, water is boosted to the Hayden-Udall Water Treatment Plant for chlorine disinfection and pH adjustment (Tucson Water, 2001). The water is then pumped through a tunnel to the 60 million-gallon Clearwell Reservoir. From the Clearwell Reservoir the water is distributed to the main distribution system of the City of Tucson. In the spring of 2001, City of Tucson began delivering about 18 million gallons of blended CAP water a day from the Clearwater facility. By the winter of 2003, expansion of the facility will allow the City of Tucson to deliver up to 54 million gallons per day (Tucson Water, 2001). Of all the permitted CAP water recharge facilities in Tucson AMA, only Clearwater has the “wet-water” capability to recover CAP for municipal supply (Tucson Water, 2003).

CAP water is also currently recharged in the Tucson AMA in three other constructed artificial recharge facilities but none at this time have wet-water recovery capability (Tucson Water, 2003). Recharge facilities include Pima Mine Road Recharge Project, Avra Valley Recharge Project, and the Lower Santa Cruz Recharge Project.

Pima Mine Road Recharge Project, a constructed recharge facility developed through a partnership between the City of Tucson and the Central Arizona Project, originally consisted of a single 14-acre basin, but three new basins were added in 2002 for a combined total basin area of 37 acres (Central Arizona Project, 2003). Operations began in early 1997 as a pilot project and later became a full-scale project to recharge up to 30,000 acre feet per year.

The Avra Valley Recharge Project began operations as a pilot facility in 1996 and was permitted to a full-scale facility in 1998 (Central Arizona Project, 2003). The project consists of 11 acres of spreading basins with a permit to store 11,000 acre-feet of water per year.

The Lower Santa Cruz Recharge Project is a partnership between CAP and the Pima County Flood Control District (Central Arizona Project, 2003). Construction of the full-scale facility began in 1999 and was completed in 2000. This facility consists of 33 acres of spreading basins and can recharge up to 30,000 acre-feet of water per year.

The City of Tucson, Pima County, Metropolitan Domestic Water Improvement District (MDWID), Town of Marana, Town of Oro Valley, ADWR and others have sponsored investigations in the Tucson area to study the feasibility of additional sites for recharge (ADWR Tucson AMA, 2003). These projects will allow greater amounts of contracted CAP water to be recharged into the future.

6.0 GENERALIZED SALT BALANCE

Two generalized salt balances were developed for the Tucson AMA by Tucson Water (2003b). The salt balance for the year 2000 was developed to reflect current conditions and is presented as Figure 3. The salt balance for the year 2015 was developed to reflect conditions when the full allotment of CAP water will be utilized and is presented as Figure 4. The assumptions for each item on the flow chart are included on the pages following each salt balance. Table 6.1 summarizes the salt balance flow charts and is presented below:

TABLE 6.1 GENERALIZED SALT BALANCE FOR THE TUCSON AMA

DESCRIPTION	2000	2015
Average salt inflow from the CAP Aqueduct (million tons per year)	0.0651	0.1904
Average salt inflow from groundwater (million tons per year)	0.0052	0.0052
Average salt inflow due to natural recharge (million tons per year)	0.0313	0.0313
Additional salt sources (million tons per year)	0.0290	0.0343
Total Amount of Salt Entering the Tucson AMA (million tons per year)	**0.1306**	**0.2611**
Average salt outflow in groundwater (million tons per year)	0.0137	0.0137
Average salt outflow in the Santa Cruz River (million tons per year)	0.0093	0.0419
Total Amount of Salt Leaving the Tucson AMA (million tons per year)	**0.0229**	**0.0555**
Net Salt Accumulation in the Tucson AMA (million tons per year)	**0.1076**	**0.2056**

It is estimated that by 2015, salt accumulation in the Tucson AMA will almost double from current (2000) levels. This is predominately due to utilization of the full CAP allotment. In 2000, utilization of the CAP accounted for approximately 50 percent of the salt entering the Tucson AMA; when the full allotment is utilized, the CAP will account for approximately 73 percent of the salt entering the Tucson AMA.

In 2000, approximately 107,500 tons of salt accumulated in the Tucson AMA. Utilization of the CAP accounted for approximately 50 percent of the salt entering the Tucson AMA and natural recharge accounted for approximately 24 percent. Additional salt sources from human activities (such as the application of fertilizers and municipal and industrial uses) account for approximately 22 percent of the salt entering the Tucson AMA. The amount of additional salt sources was based on values utilized in a salt balance prepared for the Phoenix AMA (CASS, 2002). Approximately 4 percent of the salt that entered the Tucson AMA was from groundwater inflow, however approximately 10 percent of the salt entering the Tucson AMA, left the Tucson AMA as groundwater outflow. Approximately 18 percent of the salt entering the Tucson AMA, leaves the AMA with groundwater and Santa Cruz River outflow.

By 2015, full allocation of the CAP is anticipated to be utilized and approximately 205,500 tons of salt will accumulate in the Tucson AMA annually. Utilization of the CAP will account for approximately 73 percent of the salt entering the Tucson AMA. Additional salt sources from human activities (such as the application of fertilizers and municipal and industrial uses) will account for approximately 13 percent of the salt entering the Tucson AMA. The amount of additional salt sources was based on values utilized in a salt balance prepared for the Phoenix AMA (CASS, 2002). Natural recharge will account for approximately 12 percent of salt entering the Tucson AMA and approximately 2 percent of the salt entering the Tucson AMA will be from groundwater inflow. Approximately 21 percent of the salt entering the Tucson AMA, will leave the AMA as groundwater and Santa Cruz River outflow.

7.0 REFERENCES

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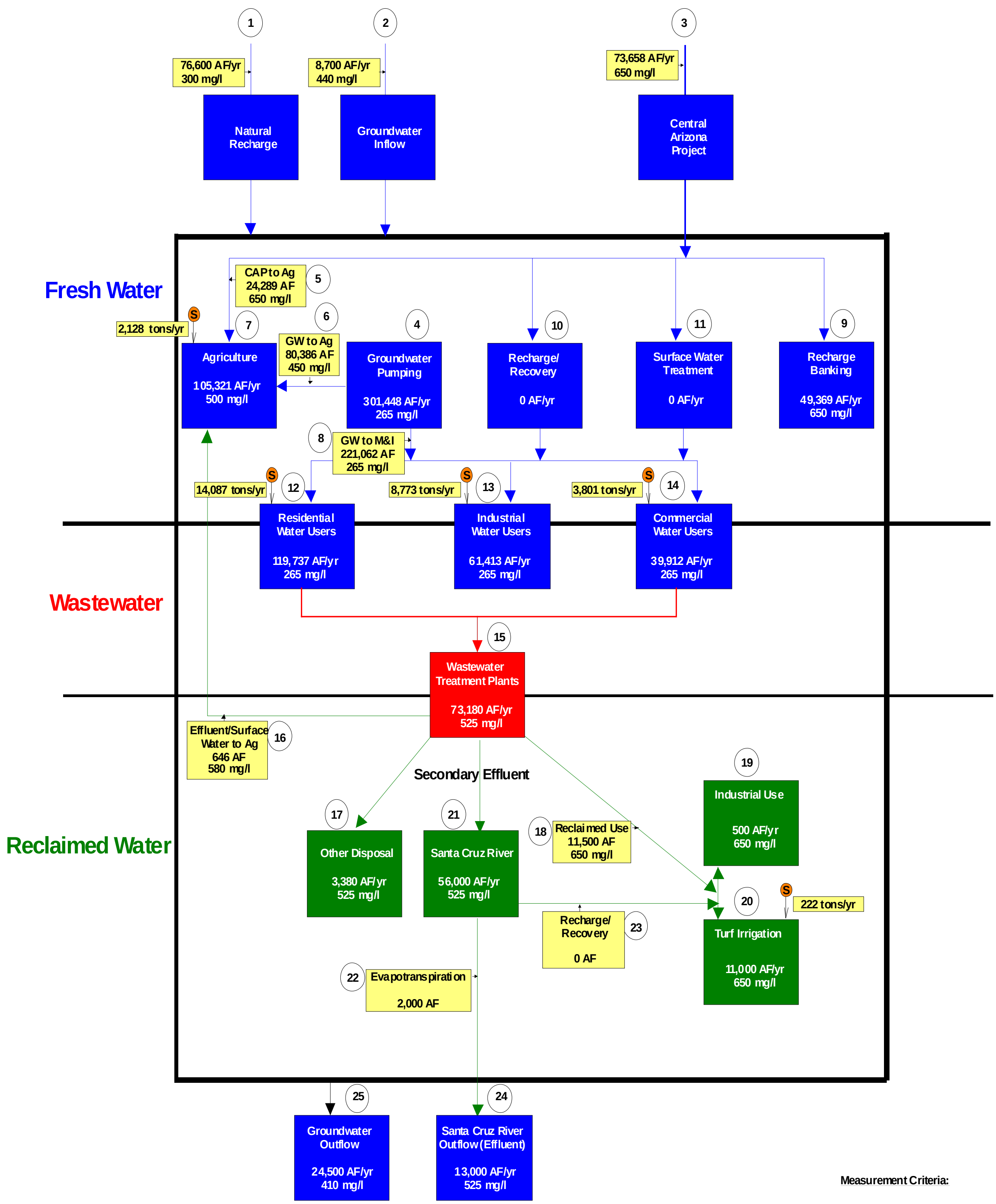
Tucson Water, 2003b. Salt Balance (Wet Water) Tucson Active Management Area 2000 and 2015.

FIGURE 3
SALT BALANCE (WET WATER)
TUCSON ACTIVE MANAGEMENT AREA
2000



Measurement Criteria:

mg/l Salinity Concentration

MAF/yr Volumetric Flow Rate

(S) Salt added (26)

(nn) Footnote

Salt Entering The Study Area: 101,573 Tons per Year
Salt Added Within the Study Area: 29,011 Tons per Year
Salt Leaving The Study Area: 22,943 Tons per Year
Salt Accumulated In The Study Area: 107,641 Tons per Year

Tucson AMA SALT BALANCE 2000 FOOTNOTES: Data Source Citations/Explanation

(1) Natural Recharge: This salt-balance component consists of natural stream-channel recharge and mountain-front recharge for the ADWR Tucson Active Management Area (Tucson AMA). The annual volumetric flow rate is based on the ADWR-Tucson AMA Third Management Plan (1999)—Page 2-16. The TDS estimate is from R.L. Laney (U.S. Geological Survey Water-Supply Paper 1939-D (1972) based on the average TDS of groundwater in the Tucson basin; it is assumed that this can credibly serve as the average TDS associated with natural recharge inputs in Tucson AMA.

(2) Groundwater Inflow: The annual volumetric flow rate based on the ADWR-Tucson AMA Third Management Plan (1999)—Page 2-16. However, ADWR plans to update the water budget for Tucson AMA based on the results of its updated groundwater model for Tucson AMA; the documentation is still in draft form and is currently under review. The groundwater inflow across this boundary is estimated to more than double the estimate that is the published in the Third Management Plan (1999). The groundwater TDS estimate along the inflow boundary is a spatially-weighted average based on TDS and electrical conductivity data obtained from ADWR-GWSI, ADEQ, and USGS databases; the electrical conductivity values were converted to TDS by applying an empirically-based factor of 0.64.

(3) Central Arizona Project Water: Volume of CAP used is based on ADWR- Tucson AMA's "2000 AMA Water Use Summary." The average TDS of raw/untreated CAP water is based on a calculation of recent data collected by Tucson Water.

(4) The volume of groundwater pumping in 2000 is based on ADWR-Tucson AMA's "2000 AMA Water Use Summary." The average TDS of pumped groundwater in Tucson AMA is approximated by using the average TDS of groundwater in City wells within and outside of the Tucson Water service area.

(5) The volume of CAP water used by agriculture in Tucson AMA for 2000 is based on ADWR-Tucson AMA's "2000 AMA Water Use Summary." The TDS of CAP water is the same as noted in (3).

(6) The volume of groundwater pumped by agriculture in 2000 is based on ADWR-Tucson AMA's "2000 AMA Water Use Summary." The summary tabulates reported pumping in 2000 losses. The average TDS of groundwater pumped in agricultural areas in Tucson AMA is based on an estimate for eastern Pima County generated by the Pima Association of Governments (September 15, 2003).

(7) The volume of water used by agriculture is the sum of (5), (6), and (16). The composite TDS concentration of the three waters used by agriculture is the volume-weighted average of (5), (6), and (16).

(8) The volume and average TDS of groundwater delivered to residential, industrial, and commercial water users in the Tucson AMA. The volume is derived from ADWR-Tucson AMA's "2000 AMA Water Use Summary". The average TDS of groundwater is the same as (4).

(9) The volume of CAP water put in storage (not recovered) in 2000 is derived from ADWR-Tucson AMA's "2000 AMA Water Use Summary", [Total CAP – Ag CAP = Banked CAP]. The TDS estimate is the same as (3).

(10) This input does not apply in 2000 since no CAP water was recovered in the Tucson AMA in 2000.

(11) There was no treatment of CAP water (the only surface water source available) in Tucson AMA in 2000.

(12) Volume (groundwater only in 2000) represents the residential portion of Tucson AMA's overall municipal use in 2000. The overall municipal use (159,649 acre-feet) is documented in ADWR-Tucson AMA's "2000 AMA Water Use Summary." The weighted average percent (75%) which is applied to the overall municipal use was calculated from information in the ADWR-Tucson AMA Third Management Plan (1999), Page 3-15. The TDS estimate is the same as (4).

(13) Volume (groundwater only in 2000) represents the industrial use (plus mining) from data in ADWR-Tucson AMA's "2000 AMA Water Use Summary." The TDS estimate is the same as (4).

(14) Volume (groundwater only in 2000) represents the commercial portion of Tucson AMA's overall municipal use in 2000. The overall municipal use is the same as noted in (12). The weighted average percent (25%) which is applied to the overall municipal use was calculated from Page 3-15 of ADWR-Tucson AMA's Third Management Plan (1999). The TDS estimate is the same as (4).

(15) The approximate total volume of wastewater effluent produced by Pima County treatment plants in 2000 is the sum of that portion of (16) relating to effluent diverted to agriculture (280AF in 2000), (17), (18), and (21). The TDS is a calculation from Tucson Water's Resource Planning Tool (2003).

(16) Volume of 280AF of effluent (reclaimed water) delivered to agriculture in 2000 is from Tucson Water. An additional 366AF of surface water for agriculture is from the ADWR-Tucson AMA's "2000 AMA Water Use Summary." The TDS is a volume weighted average.

(17) Volume refers to effluent discharged by Pima County wastewater treatment plants other than Ina Road Water Pollution Control Facility and the Roger Road Wastewater Treatment Plants; none of this volume leaves the Tucson AMA. The TDS is assumed to be the same as in (15).

(18) The volume represents the amount of reclaimed water put to reuse in 2000 including Tucson Water's reclaimed water system and effluent used at the Silverbell Golf Course and the Arthur Pack Golf Course. The TDS is the average produced by the Reclaimed Water System.

(19) This is the industrial component of (18). The TDS is the same as (18)

(20) This is the turf irrigation component of (18). The TDS is the same as (18)

(21) The volume represents secondary effluent discharged to the Santa Cruz River in 2000 by two Pima County wastewater treatment plants. The TDS is the same as in (15).

(22) Evapotranspiration estimate from effluent flows in the Santa Cruz River is derived from K. Galyean (U.S. Geological Survey Water Resources Investigations Report 96-4021) and further modified by Tucson Water for facility permitting purposes.

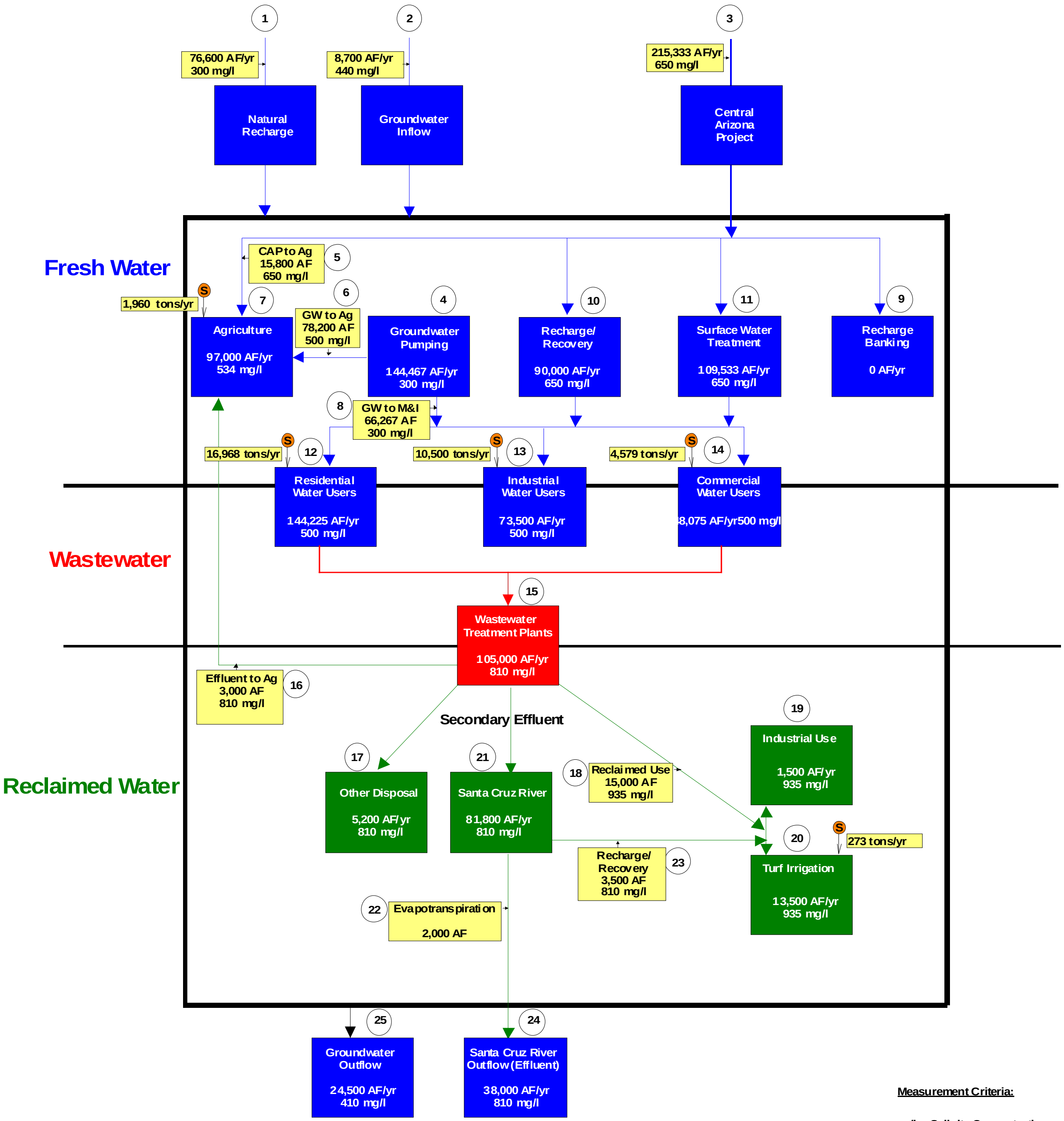
(23) There was no recovery of recharged secondary effluent associated with a managed in-channel underground storage facility permit in 2000.

(24) Volume of in-channel effluent outflow leaving the Tucson AMA as surface water is calculated as follows: (24) = (21) – [(22) + 41,000 acre-feet/yr] where 41,000 acre-feet is the volume of effluent which annually infiltrates in the Santa Cruz River channel between the two treatment plant outfalls and the Tucson AMA boundary as per the Lower Santa Cruz River Managed Recharge Project Application for an Underground Storage Facility Permit (2002) and extended to the Tucson AMA boundary. The TDS is the same as in (15).

(25) The volume of groundwater underflow leaving the Tucson AMA and entering the Pinal AMA at near Picacho as per ADWR-Tucson AMA Third Management Plan (1999), Page 2-16. However, ADWR plans to update the water budget for Tucson AMA based on the results of its updated groundwater model for Tucson AMA; the documentation is still in draft form and is currently under review. The groundwater outflow across this boundary is estimated to be about 25% less than the estimate published in the Third Management Plan. The groundwater TDS estimate along the outflow boundary is a spatially-weighted average based on TDS and electrical conductivity data obtained from ADWR-GWSI, ADEQ, and USGS databases; the electrical conductivity values were converted to TDS by applying an empirically-based factor of 0.64.

(26) Additional salt added due to human activities such as the application of fertilizers and municipal and industrial use. The amount of salt added to each item is based on the *Salt Balance Phoenix Metro Area Typical Year, Draft*, CASS, 2002. The salt added to each Tucson item was based on the volumetric proportion to the corresponding item in the Phoenix Metro Area.

FIGURE 4
SALT BALANCE (WET WATER)
TUCSON ACTIVE MANAGEMENT AREA
2015



Salt Entering The Study Area: 226,813 Tons per Year
Salt Added Within the Study Area: 34,280 Tons per Year
Salt Leaving The Study Area: 55,522 Tons per Year
Salt Accumulated In The Study Area: 205,571 Tons per Year

Tucson AMA SALT BALANCE 2015 FOOTNOTES: Data Source Citations/Explanation

(1) Natural Recharge: This salt-balance component consists of natural stream-channel recharge and mountain-front recharge for the ADWR Tucson Active Management Area (Tucson AMA). The annual volumetric flow rate is based on the ADWR-Tucson AMA Third Management Plan (1999)—Page 2-16 assumed to remain relatively constant. The TDS estimate is from R.L. Laney (U.S. Geological Survey Water-Supply Paper 1939-D (1972) based on the average TDS of groundwater in the Tucson basin; it is assumed that this can credibly serve as the average TDS associated with natural recharge inputs in Tucson AMA and will remain relatively constant.

(2) Groundwater Inflow: The annual volumetric flow rate based on the ADWR-Tucson AMA Third Management Plan (1999)—Page 2-16 assumed to remain relatively constant. However, ADWR plans to update the water budget for Tucson AMA based on the results of its updated groundwater model for Tucson AMA; the documentation is still in draft form and is currently under review. The groundwater inflow across this boundary is estimated to more than double the estimate that is the published in the Third Management Plan (1999). The groundwater TDS estimate along the inflow boundary is a spatially-weighted average based on TDS and electrical conductivity data obtained from ADWR-GWSI, ADEQ, and USGS databases; the electrical conductivity values were converted to TDS by applying an empirically-based factor of 0.64. TDS is assumed to remain relatively constant.

(10) Central Arizona Project Water: Volume of CAP used is assumed to be full utilization of all allocated CAP water within the Tucson AMA as noted in the Draft Hydrologic Report on the Tucson Active Management Area, Central Arizona Salinity Study (May 2003). The average TDS of raw/untreated CAP water is based on a calculation of recent data collected by Tucson Water and is assumed to remain constant due to on-going efforts of the Colorado River Basin Salinity Control Forum.

(11) The volume of groundwater pumping in 2015 is based on ADWR-Tucson AMA Third Management Plan (1999)—Page 11-23, as modified by Tucson Water assumption of full Tucson AMA CAP utilization. The average TDS of pumped groundwater in Tucson AMA is approximated by using the average TDS of groundwater in City wells within and outside of the Tucson Water service area. Significant reduction in Central well field usage causes a rise by 2015.

(12) The volume of CAP water used by agriculture in Tucson AMA for 2015 is based on ADWR-Tucson AMA Third Management Plan (1999)—Page 11-23. The TDS of CAP water is the same as noted in (3).

(13) The volume of groundwater pumped by agriculture in 2000 is based on ADWR-Tucson AMA Third Management Plan (1999)—Page 11-23. The average TDS of groundwater pumped in agricultural areas in Tucson AMA is based on an estimate for eastern Pima County generated by the Pima Association of Governments (September 15,2003) for the year 2000, with assumed incremental increase by 2015.

(14) The volume of water used by agriculture is the sum of (5), (6), and (16). The composite TDS concentration of the three waters used by agriculture is the volume-weighted average of (5), (6), and (16) as included in the ADWR-Tucson AMA Third Management Plan (1999)—Page 11-23.

(15) The volume and average TDS of groundwater delivered to residential, industrial, and commercial water users in the Tucson AMA. The volume is derived from ADWR-Tucson AMA Third Management Plan (1999)—Page 11-23, as modified by Tucson Water assumption of full Tucson AMA CAP utilization. The average TDS of groundwater is the same as (4).

(16) CAP Recharge Banking is not assumed to continue in a "typical year" beyond the year 2015.

(17) Volume refers to effluent discharged by Pima County wastewater treatment plants other than Ina Road Water Pollution Control Facility and the Roger Road Wastewater Treatment Plants; none of this volume leaves the Tucson AMA. The TDS is assumed to be the same as in (15).

(18) The volume represents the projected reclaimed water to be used in 2015 for turf irrigation and industrial uses including Tucson Water's reclaimed water system and effluent used at the Silverbell Golf Course and the Arthur Pack Golf Course. The TDS is projected for the Reclaimed Water System as an increase of 125 mg/L over the 2015 Wastewater TDS, similar to measured concentration for 2000.

(19) The his is the industrial component of (18). The TDS is the same as (18)

(20) This is the turf irrigation component of (18). The TDS is the same as (18)

(21) The volume represents secondary effluent projected to be discharged to the Santa Cruz River in 2015 by two Pima County wastewater treatment plants. The TDS is the same as in (15).

(22) Evapotranspiration estimate from effluent flows in the Santa Cruz River is derived from K. Galyean (U.S. Geological Survey Water Resources Investigations Report 96-4021) and further modified by Tucson Water for facility permitting purposes.

(23) The projected volume of recovered recharged secondary effluent associated with a managed in-channel underground storage facility permit in 2015. The TDS is assumed to be the same as in (15).

(24) Volume of in-channel effluent outflow leaving the Tucson AMA as surface water is calculated as follows: (24) = (21) – [(22) + 41,000 acre-feet/yr] where 41,000 acre-feet is the volume of effluent which annually infiltrates in the Santa Cruz River channel between the two treatment plant outfalls and the Tucson AMA boundary as per the Lower Santa Cruz River Managed Recharge Project Application for an Underground Storage Facility Permit (2002). The TDS is the same as in (15).

(25) The volume of groundwater underflow leaving the Tucson AMA and entering the Pinal AMA at near Picacho as per ADWR-Tucson AMA Third Management Plan (1999), Page 2-16. However, ADWR plans to update the water budget for Tucson AMA based on the results of its updated groundwater model for Tucson AMA; the documentation is still in draft form and is currently under review. The groundwater outflow across this boundary is estimated to be about 25% less than the estimate published in the Third Management Plan. The groundwater TDS estimate along the outflow boundary is a spatially-weighted average based on TDS and electrical conductivity data obtained from ADWR-GWSI, ADEQ, and USGS

databases; the electrical conductivity values were converted to TDS by applying an empirically-based factor of 0.64.

(26) Additional salt added due to human activities such as the application of fertilizers and municipal and industrial use. The amount of salt added to each item is based on the *Salt Balance Phoenix Metro Area Typical Year*, *Draft*, CASS, 2002. The salt added to each Tucson item was based on the volumetric proportion to the corresponding item in the Phoenix Metro Area.