CENTRAL ARIZONA SALINITY STUDY --- PHASE I

Technical Appendix D

HYDROLOGIC REPORT ON THE GILA BEND BASIN

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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 Gila Bend Basin. 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 basin. The report will also discuss groundwater quality and surface water quality over time, with a primary focus on salinity.

2.0 PHYSICAL SETTING

The Gila Bend Basin is located in southwestern Arizona within the Sonoran Desert section of the Basin and Range physiographic province (Figure 1). The basin is adjacent to the Phoenix Active Management Area (AMA) to the north, Pinal AMA to the east, San Simon Wash Basin to the south, and Lower Gila Basin to the west. The Gila Bend Basin comprises approximately 1,300 square miles, and land surface elevation ranges from 524 feet to 4,084 feet above mean sea level (amsl). Precipitation in the basin averages approximately 6 inches per year, and the average daily mean temperature is 72.4 degrees Fahrenheit (°F). The principal surface drainage feature is the Gila River, which enters the basin at Gillespie Dam to the north, and exits the basin at Painted Rock Dam to the west (Figure 2).

3.0 GENERALIZED GEOLOGY

The Gila Bend Basin is thought to have formed during the Tertiary Basin and Range Disturbance. During this disturbance, widespread extensional deformation in southern and western Arizona resulted in northwest trending mountain ranges separated by alluvial filled troughs. Subsequent to the faulting and alluvial deposition, volcanic eruptions produced lava flows that likely diverted and dammed the Gila River, altering its course over time.

3.1 BEDROCK GEOLOGY

The Gila Bend Basin is bounded by the Gila Bend Mountains and Buckeye Hills on the north, the Maricopa Mountains on the east, the Sand Tank and Sauceda Mountains on the south, and the Painted Rock Mountains and White Hills on the west (Figure 2). The bounding mountain ranges are predominantly comprised of Precambrian granite and metamorphic rocks, Tertiary to Late Cretaceous granite, Tertiary volcanics and basalt, Tertiary sedimentary rocks, and Quaternary to Tertiary basalt (Reynolds, 1988). In general, the Precambrian granite and metamorphic rocks primarily occur in the northeastern portion of the basin, and the volcanics and basalt dominate the bedrock geology elsewhere in the basin.

3.2 BASIN GEOLOGY

The Gila Bend Basin is comprised of two northwest trending structural troughs that are separated by the Gila Bend and Sand Tank Mountains. Based on gravity modeling (Oppenheimer and Sumner, 1980), the depth to bedrock in the majority of the basin is 800 to 1,600 feet below land surface (bls). However, the gravity modeling also suggests a deeper portion of the basin southwest of Gila Bend with a depth to bedrock of 1,600 to 3,200 feet bls, and a low point in the basin near Gila Bend, with a depth to bedrock of 4,800 to 6,400 feet bls. Sebenik (1981) reported that the thickest alluvial deposits occur in the central portion of the basin (near Gila Bend), and are greater than 2,000 feet thick. Rascona (1996) reported that the alluvial deposits in the trough northeast of Gila Bend are generally not greater than 1,000 feet in thickness, and that the alluvial deposits in the trough southwest of Gila Bend are up to 1,480 feet thick. Although differences in depth to bedrock values are noted in each study, the deepest portion of the basin appears to be near Gila Bend, and the trough southwest of Gila Bend appears to be deeper than the trough northeast of Gila Bend.

Based on the study by Rascona (1996), the alluvial deposits in the Gila Bend Basin are separated into three distinct units, referenced as the stream alluvium, upper basin fill, and lower basin fill. A brief summary of each unit is presented below:

- ***Stream Alluvium.*** Unconsolidated fluvial deposits that are late Pliocene to Holocene in age characterize the stream alluvium. The extent of the stream alluvium deposits is restricted to the Gila River and its tributaries.

- ***Upper Basin Fill.*** The upper basin fill is characterized by unconsolidated to moderately cemented alluvial deposits. The upper basin fill deposits were likely deposited in an integrated (through-flowing) drainage basin.

- ***Lower Basin Fill.*** The lower basin fill primarily consists of weakly to highly consolidated gravel, sand, silt, and clay that were likely deposited in a closed interior drainage basin. West of Gila Bend, the lower basin fill also includes an extensive fine-grained deposit that achieves a maximum thickness of between 700 and 900 feet.

4.0 HYDROGEOLOGIC CONDITIONS

4.1 GROUNDWATER OCCURRENCE AND MOVEMENT

The upper basin fill and lower basin fill alluvial units represent the principal aquifer in the Gila Bend Basin. In general, groundwater in the upper and lower basin fill deposits is unconfined to semi-confined, although local perched conditions and confined conditions exist in areas with extensive clay layers. Based on estimates by the Arizona Department of Water Resources (ADWR) in 1988, the Gila Bend Basin contains approximately 27.6 million acre-feet of recoverable groundwater to a depth of 1,200 feet. The primary source of groundwater recharge (inflow) to the basin is stream losses (infiltration) from the Gila River and its tributaries. Additional sources of recharge include irrigation seepage and underflow from the Lower Hassayampa Basin. The primary source of outflow from the basin is groundwater pumpage (for crop irrigation) and evapotranspiration. Approximately 50 wells pump into the Gila Bend Canal (Sebenik, 1981), where the groundwater is conveyed for irrigation purposes.

Based on predevelopment hydrologic conditions in the Gila Bend Basin, groundwater flowed south from the Gillespie Dam area and generally followed the Gila River drainage before exiting the basin as underflow near the Painted Rock Dam area (Freethey and Anderson, 1986). However, major groundwater development of the basin began in 1935, altering the groundwater flow regime. Sebenik (1981) reported that groundwater did not flow toward Painted Rock Dam as occurred during predevelopment conditions, and instead noted several cones of depression due to pumping that apparently changed the groundwater flow direction. According to Rascona (1996), groundwater in the basin northeast of Gila Bend generally flowed toward the east due to extensive pumping and shallow bedrock. Near Gila Bend, the groundwater flow direction changes abruptly to the southwest, where it likely exits the basin south of the Painted Rock Mountains. The study by Rascona (1996) also indicated that no significant cones of depression or groundwater mounds were observed as in the previous report by Sebenik (1981). Although historic groundwater declines up to 100 feet have been noted in the Gila Bend Basin (Schumann and Genualdi, 1986), Sebenik observed groundwater level rises up to 65 feet during 1973 to 1979, likely due to recharge following significant flooding.

4.2 GROUNDWATER QUALITY

The United States Geological Survey (USGS) conducted the initial water quality study in the Gila Bend Basin in 1946. Based on this study, groundwater throughout the basin was generally unsatisfactory for most agricultural uses, and had a high total dissolved solids (TDS) content. In particular, the groundwater contained high concentrations of sodium and chloride. The study conducted by Sebenik (1981) reported TDS concentrations in groundwater ranging from 900 to 5,100 milligrams per liter (mg/l), with sodium and chloride as the major ions. Sebenik noted that the highest TDS concentrations were generally northeast of Gila Bend (1,200 to 4,920 mg/l), and that wells southwest of Gila Bend typically produced groundwater with TDS concentrations less than 1,200 mg/l. Northwest of Gila Bend, near the area inundated by the Painted Rock Reservoir, two likely perched zones were sampled with TDS concentrations of 3,900 and

5,100 mg/l. The map showing TDS content of groundwater in Arizona by Daniel (1981) indicated TDS concentrations ranging from 1,000 to 5,000 mg/l in the majority of the basin, and TDS concentrations greater than 10,000 mg/l near portions of the Gila River.

The study conducted by Rascona (1996) included comprehensive water quality sampling from 1991 to 1993. In general, Rascona concluded that groundwater quality has not changed significantly since the initial USGS study in 1946, nor has it changed significantly since the Sebenik study from 1976 to 1993. TDS concentrations northeast of Gila Bend averaged 2,100 mg/l, and TDS concentrations southwest of Gila Bend averaged 1,380 mg/l. In addition, fluoride concentrations averaged 2.1 mg/l northeast of Gila Bend, and averaged 4.9 mg/l southwest of Gila Bend. However, Rascona noted that most of the wells northeast of Gila Bend are perforated above 1,000 feet, whereas the majority of the wells southwest of Gila Bend are perforated below 1,000 feet, primarily due to alluvium thickness. Therefore, an apparent relationship exists between TDS and fluoride concentrations with well depth. Rascona also noted increased sulfate and alkalinity concentrations northeast of Gila Bend, and relatively high concentrations of boron and selenium in the groundwater samples throughout the basin.

Initial interpretations in 1948 predicted a continual increase in groundwater TDS concentrations over time due to the highly mineralized nature of the Gila River surface flows. The predictions were based on infiltrated Gila River water replacing the groundwater withdrawn from the aquifer during extensive irrigation pumping. However, the majority of groundwater recharge apparently occurs during high flow (flood) events, and the Gila River water is significantly less mineralized during these events. Therefore, according to Rascona, the TDS concentrations in the Gila Bend Basin are not expected to increase unless significant recharge occurs during highly mineralized Gila River flows.

5.0 SURFACE WATER CONDITIONS

5.1 SURFACE WATER OCCURRENCE

The principal surface water feature in the Gila Bend Basin is the Gila River, which enters the basin at Gillespie Dam (Figure 2). Gillespie Dam is located at a narrow passage between the Buckeye Hills and Gila Bend Mountains, and was constructed in 1921 to divert all non-flood flows into two canals to supply irrigation water. Below Gillespie Dam, the Gila River traverses a distance of approximately 36 miles around the Gila Bend Mountains to Painted Rock Dam, where the river exits the basin. Painted Rock Dam is located at a narrow passage between the Gila Bend Mountains and Painted Rock Mountains, and was constructed in 1959 to control upstream floodwaters and to protect downstream areas.

Upstream of Gillespie Dam, the Gila River is perennial due to treated effluent discharge from the City of Phoenix 91st Avenue Wastewater Treatment Facility and from irrigation return flow and groundwater pumped for drainage by the Buckeye Irrigation District. Within the Gila Bend Basin, the Gila River is ephemeral and flows only in response to precipitation events or releases from Gillespie Dam. The Gila River below Painted Rock Dam is also ephemeral, and surface water is only released from the dam during flood events. According to Rascona (1996), the net surface water (Gillespie Dam inflow minus Painted Rock Dam outflow) entering the Gila Bend Basin from 1976 to 1993 was approximately 4.6 million acre-feet, exceeding the groundwater pumpage of approximately 3.9 million acre-feet during this period.

5.2 SURFACE WATER QUALITY

Based on the study by Rascona (1996), surface water in the Gila River is highly mineralized with calcium and sodium, and high (flood) flows are considerably less mineralized than low (normal) flows. This observation correlates well with USGS streamflow and water quality data for the Gila River at Gillespie Dam (USGS Site No. 09518000). USGS data at this site represents Gila River surface flows prior to diversion into the two canals for irrigation purposes. USGS data for this site was utilized to illustrate TDS concentrations (Figure 3) and annual surface flow (Figure 4) for the period 1960 to 2001. The annual surface flow below Painted Rock Dam (USGS Site No. 09519800) for the same time period is presented as Figure 5. Due to limited water quality data (1973 through 1976, 1979), TDS concentrations below Painted Rock Dam could not be properly evaluated.

The time period from 1960 to 2001 can be divided into three distinct intervals on the basis of annual surface flows. The period from 1960 to 1977 represents relatively low flows in the Gila River, with the exception of a minor flood event in 1966. By contrast, the period from 1978 to 1995 represents significant surface flows, including two major flood events. The recent drought conditions are reflected in the 1996 to 2001 interval, and the corresponding flows are relatively low to normal. The relationship between average annual surface flows and TDS concentrations is illustrated below in Table 1.

TABLE 1. AVERAGE ANNUAL FLOW AND TDS CONCENTRATIONS IN THE GILA RIVER

DESCRIPTION	1960 TO 1977	1978 TO 1995	1996 TO 2001
Average annual flow above Gillespie Dam diversions (acre-feet)	60,480	1,017,741	118,610
Average TDS concentration above Gillespie Dam diversions (mg/l)	4,225	2,225	2,872
Average annual flow below Painted Rock Dam (acre-feet)	47,435	740,254	3,798
Average annual net surface water entering the Gila Bend Basin (acre-feet)	13,045	277,487	114,812

6.0 GENERALIZED SALT BALANCE

Based on USGS streamflow and water quality data, a generalized salt balance was calculated for the Gila Bend Basin. Results of the salt balance are presented in Table 2, and assumptions utilized in the salt balance are listed below:

TABLE 2. GENERALIZED SALT BALANCE FOR THE GILA BEND BASIN

DESCRIPTION	1960 TO 1977	1978 TO 1995	1996 TO 2001
Average salt inflow from Gillespie Dam inflows (million tons per year)	0.40	2.67	0.46
Average salt outflow from Painted Rock Dam outflows (million tons per year)	0.19	1.86	0.01
Average salt accumulation in the Gila Bend Basin (million tons per year)	0.21	0.81	0.45

- The difference in groundwater inflow to the basin and groundwater outflow from the basin is negligible.

- The additional salt load resulting from agricultural irrigation practices is considered to be negligible.

- The TDS concentration of surface water outflow below Painted Rock Dam is equal to the TDS concentration of surface water inflow at Gillespie Dam.

- The average salt contribution is based on surface water inflows at Gillespie Dam, and the average salt removal, is based on surface water outflows below Painted Rock Dam.

The primary source of salt contribution in the Gila Bend Basin is from surface flows of the Gila River at Gillespie Dam. According to the ADWR Assessment in 1993, municipal and industrial water demands in the basin are met entirely by groundwater, and no additional sources of surface water are utilized in the basin. Rascona (1996) estimated that approximately 600 acre-feet per year of groundwater entered the basin as underflow from the Lower Hassayampa Basin to the north. However, the amount of groundwater underflow is considerably less than 1 percent of the average surface flow at Gillespie Dam, and the difference between groundwater inflow and outflow from the basin is considered to be negligible for the purposes of this salt balance. Groundwater pumpage for crop irrigation averaged approximately 233,000 acre-feet per year between 1971 and 1990 (ADWR, 1993). Based on previous salt contribution calculations from irrigation in the Salt River Valley, the crop irrigation in the Gila Bend Basin would result in approximately 0.005 million tons of salt per year, and is thus considered to be negligible for the purposes of this balance.

The primary source of salt outflow from the Gila Bend Basin is from surface flows below Painted Rock Dam during high flow (flood) events. Due to limited water quality data, the TDS concentration of surface water below Painted Rock Dam is assumed to be equal to the TDS concentration of surface water entering the basin at Gillespie Dam. This assumption is also based on the minimal residence time of the surface water in the basin during high flow events, which represents the majority of outflow and salt discharge from the basin. Since Painted Rock Dam is designed to retain non-flood flows, the Gila Bend Basin is essentially a closed basin during normal flow on the Gila River. Therefore, groundwater pumpage, treated wastewater flow, and irrigation return flows are not considered in the salt balance, as they originate and terminate within the basin.

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