RECLAMATION

Managing Water in the West

Mogollon Rim Water Resources
Appendices

Appendices

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ATTACHMENT 1

(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Hydrogeologic Framework and review of Alternative Water Solutions for the Mogollon Rim Water Resources Management Study Area by HydroSystems, Inc., April, 2008

Hydrogeologic Framework and Review of Alternative Water Supplies for the Mogollon Rim Water Resources Management Study Area

Prepared for:

Mogollon Rim Water Resources Management Study

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Expires 12/31/08

May 2008

03-343

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1.0 INTRODUCTION

The Mogollon Rim Water Resources Management Study (Study) is a regional assessment of water resources and water use alternatives for the growing communities along the Mogollon Rim in Gila County as shown in ***Figure 1***. The Study region is located within the area bounded by the Colorado Plateau to the north, Fossil Creek and the Verde River to the west, Christopher and Tonto Creeks to the east, and an arbitrary east-west line roughly connecting North Peak in the Mazatzal Wilderness with "Ox-Bow Hill", north of Rye. The Study area is entirely within the central Transition Zone physiographic province and because of its diverse geology and topography climate; it is one of the most complex hydrogeological areas within the State of Arizona.

To meet the needs of the Study, an in-depth evaluation of the region's geology, groundwater chemistry, and isotope geochemistry was commissioned. The hydrogeologic framework presented herein is based heavily on three primary resources. Gaeaorama Inc. developed the geological mapping and much of the geographic data used in this document's figures and plates. Dr. Chris Eastoe of the University of Arizona analyzed significant hydrologic relationships between precipitation and groundwater based on isotopic geochemistry of springs and wells in the area. HydroSystems, Inc. further developed the hydrogeologic relationships of wells and springs in the area using general water chemistry analyses. Additional references include work performed by the Town of Payson, the US Geological Survey (USGS), and data available from the Arizona Department of Water Resources (ADWR). This report is an evaluation of the data and resources developed for this Study and briefly summarize the findings into an information baseline for water resources planning. This report provides a conceptual hydrogeological framework of the Study area and a review of possible alternative water resource solutions as a guide for future water management.

2.0 HYDROGEOLOGICAL FRAMEWORK

The topographic feature known as the Mogollon Rim, along the southern edge of the Colorado Plateau, extends southeast to northwest nearly 200 miles across central Arizona. Exposed along the southern portion of the Rim is a series of Paleozoic sedimentary units nearly 3,000 feet thick. The highest elevations along the Mogollon Rim are in excess of 7,000 feet above mean sea level. The rocks of the Paleozoic sedimentary sequence are composed of interbedded sandstone, shale, and limestone. In many areas, the Paleozoic sequence is capped by Tertiary basalt. Topography along the Rim area is notably rugged, with steep cliffs and hills, covered in most portions of the Study area with thick forest. The topography south of the Mogollon Rim is characteristically rugged, but with less topographic relief. South of the Mogollon Rim, the Paleozoic rock sequence has been eroded away, revealing significant exposures of Precambrian (a.k.a. Proterozoic) rock units. The Proterozoic units consist of granite, diorite, rhyolite, gabbro, and a plethora of metamorphic rocks.

Adding significant complexity to the region are numerous faults and fractures which offset and cross-cut the rock units, leaving a patchwork of geologic discontinuity. Because the Study region is diverse and complex, the area has been broken into four different sub-regions (displayed in ***Figure 2***) for discussion. Each sub-region has generally similar hydrogeologic characteristics and complexities. Because of the size of the Study area, groundwater elevation contours along with flow directions, are presented at this larger (1:24,000) sub-region scale. Upon conclusion of these sub-regional hydrogeologic discussions, the regional groundwater flow system is presented as a composite of the four sub-regions at a smaller 1:45,000 scale.

For additional understanding of the geologic units discussed in this report, ***Figure 3*** displays a generalized/composite stratigraphic cross section across the Study area. This figure shows the presence of the Paleozoic sedimentary sequence, the Proterozoic units beneath, and the numerous younger Tertiary and Quaternary units covering them.

2.1 Sub-Region 1

The Sub-Region 1 encompasses the area south of the Mogollon Rim, along the southern perimeter of the Colorado Plateau, and north of the Diamond Rim Fault. Due to the elongated nature of this sub-region, it is divided and displayed on two plates; ***Plate 1*** (West) and ***Plate 2***

(East). Sub-Region 1 is characterized by the exposure of significant portions of Paleozoic sedimentary rock units of the Colorado Plateau. Although not in the Study area, the Colorado Plateau is extremely influential in regard to both its geology and hydrology.

The Colorado Plateau, just north of the Study area, is the primary recharge zone for the regional groundwater systems that exist both south and north of the Mogollon Rim. Groundwater moving south of the Rim's crest represents the primary groundwater inflow into the Study area. This groundwater recharge represents water from precipitation events infiltrating along the southern fringe of the C aquifer system through the Coconino Sandstone and layers of the Upper Supai Formation down to the Lower Supai Formation (see ***Figure 3***). In this study, the base of the C aquifer is defined as the top of the Lower Supai Formation. The groundwater gradient within the C aquifer south of the Mogollon Rim is steep and groundwater flow is generally southward from the Mogollon Rim.

Numerous springs exist along the south face of the Mogollon Rim. Named springs include: Fossil, Parsnip, Dripping, Red Rock, Pine, Turkey, Bear, Washington, Pieper Hatchery, Fish Hatchery, Horton, and Nappa Springs. The C aquifer's groundwater elevation rises from Fossil Springs in the west part of the sub-region towards the northeast. The discharge from some of the springs displays high variability (Flora, 2004). Some of the larger springs are: Pieper Springs at the headwaters of the East Verde River and the Hatchery and Horton Springs at the headwaters of Tonto Creek in the uppermost northeastern portion of the Study area. These headwater springs discharge groundwater that is relatively young from the C aquifer and consists of the most recently recharged water of the regional C aquifer whereas Fossil Springs discharges groundwater that appears to be much older but has a similar C aquifer source.

The age and source of groundwater is determined based on the isotopic and ionic composition of the water. Isotopes considered as part of the Study's evaluation included stable isotopes of oxygen and hydrogen as well as sulfur, strontium, and tritium (Eastoe, 2006; Flora, 2004). The evaluation of ionic composition incorporates analyses of dissolved materials found within the water and a determination of the rocks and geologic formations, which may have contributed those materials (HSI, 2006).

Fossil Springs are located at the junction of Sub-Region 1 and Sub-Region 2 and are the largest springs in the Study area discharging 32,838 acre-feet per year (afy) or 20,345 gpm (Parker et al, 2005; NAU, 2005). The discharge emanates predominantly along the north side of the Diamond Rim Fault system and issues from between a thick shale and resistant limestone layer in the lower Naco Formation. The majority of the discharge issues from the west side of Fossil Creek Canyon, below a large travertine deposit, itself the result of ancient spring discharge. The occurrence of Fossil Springs is likely due to an interaction of the Diamond Rim Fault system, the Fossil Springs Fault, and the exposure of highly transmissive, fractured limestone at this location. The discharge of groundwater at Fossil Springs is likely a release of significant pressures, as water is confined by the fine-grained units of the Naco Formation.

Groundwater flow in the fine-grained units of this sub-region tends to have a significantly steep vertical gradient (as observed in several wells). The more transmissive units in the area are relatively thin (<10 feet), and wells in the area have calculated transmissivities below 2,000 gallons per day per foot (gpd/ft), low storage coefficients typical of confined systems, and low water production (HWRC, 2005). Wells in the region typically pump less than 30 gpm with specific capacities of less than 1 gallon per minute per foot of drawdown (gpm/ft) (Morrison, 2003).

Although the fine-grained geologic units typically have very low hydraulic conductivities, the fractures and faults through these units appear to be acting locally as sub-vertical conduits and drains for local recharge. This facilitates leakage from the C aquifer, as the structures transmit groundwater from along and beneath the Colorado Plateau into the lower section of Paleozoic strata (through Sub-Region 1) and ultimately into the Precambrian rocks below. Springs along the face of the Mogollon Rim are likely a result of groundwater moving along these fractures and permeable layers of rock as they intercept the land surface. Additionally, fractures appear to promote not only leakage of older C aquifer groundwater but also conduct recent locally recharged groundwater to the springs. This behavior is recognized in water quality data, which indicates mixed water sources in the springs (i.e. Webber Springs). Also, the physical performance of the springs often displays increased flow after precipitation events (Eastoe, 2006).

Our understanding of the nature of fracture and fault systems is mainly derived from their surface expressions and from limited well drilling records. These structures are often presented on geological maps as lineaments, faults, or fracture traces. Water quality sampling has revealed isotopic and chemical differences that indicate these structures act as conduits for leakage of the C aquifer and may act as barriers to lateral flow. Fossil and Hatchery Springs are good examples of this behavior as water is discharged from the regional aquifer in locations where faults cut across low permeability shale sequences.

Finding the location of small-scale transmissive units and understanding their variable connectivity through faults and fractures creates a challenge for developing water resources in many parts of Sub-Region 1. Wells constructed in the dominantly fine-grained sedimentary units in the Pine and Strawberry area (***Plate 1***) display seasonal variation in groundwater elevations and yield. Water levels observed in these well also exhibit a nearly vertical groundwater gradient within the fine-grained units. In the Pine and Strawberry area, there appear to be at least four isolated transmissive units, each possessing different heads (HWRC, 2006a; ERM, 2006). Therefore, the occurrence of water producing zones is highly dependent on depth and local geologic constraints.

A deeper transmissive unit (approaching a depth of 1,000 feet) has not yet been tapped in the Strawberry area except for the 1,870-foot Water Plan Alliance borehole drilled in 2001. However, this interval of the well was sealed with cement grout because of lost circulation during drilling. It is likely that this lower zone is the same transmissive unit that yields groundwater in Pine at a depth between 200 and 300 feet (HWRC, 2006a).

Groundwater moves through the fine-grained layers of the Supai Group and Naco Formation down into the Redwall Limestone and Martin Formation below. The Redwall Limestone and the stratigraphically lower units of this sub-region are also recharged by local precipitation in addition to groundwater inflow from the C aquifer to the north. Isotope and other water chemistry data indicate mixing of recently recharged groundwater with older groundwater coming from the C aquifer, particularly in exposed areas of the Redwall Limestone and Martin Formations. Recharge from precipitation is facilitated by the significant secondary permeability of the limestone and dolomite, with significant fracturing at the surface providing direct infiltration paths to the groundwater system. Significant stream losses coincident with faults and exposures of these units are also observed along segments of Pine Creek, East Verde River, Horton Creek, and Christopher Creek. Spring locations are also affiliated with faults intersecting these units in low-lying exposures.

Secondary permeability (caused by faulting, fracturing, and fluid solution) is the dominant flow mechanism in the Redwall Limestone; whereas there is some primary permeability (interconnected depositional pore spaces) in sandy layers within the Martin Formation, Tapeats Sandstone, and weathered portions of the Precambrian rocks. In many of the Study documents, this portion of the regional aquifer system has been referred to as "RMX" (roughly equivalent to **R**edwall, **M**artin, and Proterozoic units) and includes the relatively thin Cambrian aged Tapeats Sandstone. The Proterozoic units are often labeled on geologic maps using an **X**. These aquifer units are displayed on ***Figure 3***. Although small in comparison to the other units, the Tapeats Sandstone appears to have a significant capacity for groundwater movement. Its higher hydraulic conductivity is likely due to both primary porosity (depositional pore spaces) and enhanced secondary porosity (caused by faulting and fracturing) of the unit. The Tapeats Sandstone can be utilized as an aquifer in areas where the Redwall Limestone or Martin Formations have limited saturation (HWRC, 2005; 2006b).

Just as with groundwater moving from the C aquifer into the lower Paleozoic units, water quality analyses indicate leakage from the Paleozoic units down into the Proterozoic units (Eastoe, 2006). The Proterozoic rock units consist of granite, diorite, gabbro, basalt, and metamorphic rocks of the East Verde River formation that include quartzite, silty quartzite or greywacke, slate and others (Gaearama, 2006). Structural features in the Proterozoic units carry groundwater under semi-confined to confined conditions resulting in some locations having groundwater moving as upward flow in wells within Sub-Region 1 (HWRC, 2005; 2006b).

Unfortunately, there is limited data available on the hydraulic characteristics of the aquifer units, within Sub-Region 1, outside of the Pine and Strawberry area. Data available from a deep well in Pine at Strawberry Hollow, a deep well in central Pine (Milk Ranch LLC.), and another deep well at Ellison Creek Summer homes provides some hydrologic data from the Martin Formation, Tapeats Sandstone, and local Proterozoic units at greater depth. Transmissivity estimates from the Strawberry Hollow and Ellison Creek wells have values approaching 10,000 gpd/ft with relatively high specific capacities; greater than 2 gpm/ft of drawdown (HWRC, 2000; 2005; 2006b). Each of these wells produces significant quantities of very fine sand and silt. This characteristic may be due to the existence of silt and sand in cavernous and fractured areas as well as sandy layers within the dolomite of the Martin Formation and the Tapeats Sandstone units. Anecdotal evidence also indicates that springs discharging from these aquifer units also experience increases in turbidity with precipitation events (Cold, Whispering Pines, Camp Tontozona, and Indian Gardens springs).

2.2 Sub-Region 2

Sub-Region 2 is an area northwest of the East Verde River and south of the Diamond Rim Fault and is displayed in ***Plate 3***. Much of this sub-region is covered by Tertiary basalt units and is sparsely populated. The basalt units covering much of the sub-region range in thickness up to more than 1,500 feet. The basalt, together with the other Tertiary units, overlay some of the same Paleozoic units exposed along the Mogollon Rim, which have been vertically offset by the Diamond Rim Fault as displayed in ***Figure 3***.

Several springs exist within Sub-Region 2, including Indian, Oak, LP, Cane, Whiterock, Walnut, South Walnut, Horse, and Tonto Natural Bridge Springs. Many of these springs exist along the periphery of the large Tertiary basalt units associated with Hardscrabble Mesa and Cane Springs Mountain. As noted previously, Fossil Springs appears roughly at the intersection of the Diamond Rim Fault and Fossil Springs Fault (displayed on ***Plate 1***). Based on water quality data obtained from Fossil Springs; Fossil Springs' discharge is likely a composite of groundwater recharged along the Colorado Plateau and potentially water recharged through the basalt units of Sub-Region 2. It appears that some of the groundwater that flows towards the Diamond Rim Fault is diverted to move along the fault zone. The Diamond Rim Fault provides a conduit for groundwater flow; ushering significant quantities of groundwater towards Fossil Springs where it discharges at a relatively consistent rate.

Groundwater flow in Sub-Region 2 is generally southward from the Diamond Rim Fault. However, there may be significant recharge within the sub-region, as precipitation may quickly infiltrate through the basalts. The fractured and jointed nature of the extensive basalt cap, in addition to its relatively flat topography, provides ideal conditions for groundwater recharge from precipitation. As a result of this recharge, groundwater flow would likely move in a somewhat radial fashion away from the recharge area beneath the basalt covered mesas as displayed on ***Plate 3***. With only 53 registered wells located in Sub-Region 2, most of which are along its periphery, the direction and magnitude of groundwater flow through the sub-region is uncertain. The springs discharging along the outside edge of the basalt are likely an indication of groundwater recharged in the area. However, the basalt also may conceal faults and fractures in the underlying sedimentary units that could transmit unknown quantities of groundwater elsewhere in the Study area.

As water moves southward from Sub-Region 1 into Sub-Region 2, through the Diamond Rim Fault zone, it moves predominantly out of the sedimentary Paleozoic units and down into the Proterozoic igneous rock units. This groundwater enters a tortuous path flowing through systems of fractures, which transmits groundwater southward within the Precambrian rocks that make up the lowermost portion of the regional aquifer system.

2.3 Sub-Region 3

Sub-Region 3 is located in the southeast portion of the Study area, and encompasses the communities of Payson and Star Valley and is displayed in ***Plate 4***. The geology of Sub-Region 3 is predominantly comprised of Proterozoic rock units, except in the northern western portion of the sub-region, where Proterozoic rocks are covered by remnants of the lower Paleozoic sedimentary units. The Proterozoic units, as noted previously, consist primarily of crystalline igneous and metamorphic rocks. Notably, the Payson granite and surrounding igneous rocks have been studied extensively as a result of Payson's groundwater use and exploration programs.

The groundwater flow through Sub-Region 3 is generally towards the southwest. Water moves into the sub-region along its northeast boundary through the Diamond Rim Fault. The primary groundwater flow paths are inferred to be the faults and fractures. In many areas, the fracturing and weathering of the rock units provide greater interconnection for groundwater flow in shallower intervals. At greater depths, fractures often become more isolated and less transmissive. The age of faults and their associated fractures provide some indication of the potential transmission of groundwater. Many of the older faults in this sub-region have been sealed over time due to mineralization, while many of the fractures associated with more recent Tertiary extensional faulting may have greater open area and interconnectivity.

Groundwater appears to exit the sub-region in a radial fashion towards the east, south, and west; away from the topographic high of the Payson area. The radial movement of groundwater away from the Payson area is likely reflective of significant recharge occurring throughout the Payson area. Most of the wells in the sub-region are relatively shallow and observe significant changes in water levels due to local precipitation variations, which is also indicative of the local recharge to the aquifer. Deeper wells display less water level variability with regard to local recharge, and are more reflective of the larger regional movement of groundwater through the Study area.

Wells constructed in Sub-Region 3 have variable groundwater production capacity. The yield from wells in this sub-region is almost exclusively a factor of fracture size and interconnection near the individual wells. Unlike the Paleozoic sedimentary sequences, the crystalline Proterozoic rock units (characteristic of the RMX aquifer in this sub-region) have almost no primary permeability. Secondary permeability of these units is associated with weathering (chemical and mechanical) and fractures of variable magnitude and interconnection. However, the crystalline rock composition does not promote the formation of solution channels such as those found in many of the limestone units discussed previously. As a result, hydraulic conductivity and storage coefficients determined from wells tested in this sub-region are generally very small. Also, with lower storage capacity, water levels tend to have greater variability in response to local precipitation events.

As the largest community in the Study area, Payson has managed the greatest volume of groundwater use and has observed the most change in water levels over time. Gradual water level declines in excess of 50 feet have been displayed over the last decade in some wells. These negative changes in water levels are a result of a reduction in aquifer storage volumes as well as the decreased recharge associated with regional drought conditions. However, as precipitation and snowfall increases, water levels in some wells have displayed stabilization and rise (Payson, 2006).

Drought conditions are also a cause of some of the spring discharge variability throughout the study area. Springs located in Sub-Region 3 include: Big, Blue, Gilmore, Grapevine, Grimes, Hidden, Lion, Mud, Peach Orchard, Summit, Turkey, Water, and Willow Springs. It is likely that the springs located in this sub-region are discharging both local and distantly recharged groundwater however; no long-term, consistent sampling has been performed on springs discharging from this sub-region to confirm this hypothesis.

Groundwater flow is uncertain in the southeastern portion of Sub-Region 3, which includes Green Valley and the Green Valley Hills. Surface water drainage is into the Tonto Creek however; only 3 registered wells and a single unnamed spring have been identified in this part of Sub-Region 3.

2.4 Sub-Region 4

Sub-Region 4 is located in the southwestern corner of the Study area, south of the East Verde River and is displayed in ***Plate 5***. The sub-region includes a portion of the Mazatzal Wilderness and a portion of the Rye Creek valley along Cypress Thicket. The portion of Rye Creek in the Study area is ephemeral, although it becomes perennial above its confluence with Tonto Creek.

In the eastern portion of the sub-region, groundwater flows west from Sub-Region 3 into Sub-Region 4 and diverges near the Verde River and Tonto Creek watershed divide. Part of the groundwater flow continues moving west along the East Verde River. The other portion of the groundwater moves southwards through the Rye Creek Valley, primarily through the Tertiary sedimentary deposits of the valley; generally following the surface drainage of Rye Creek. Springs discharging along the eastern edge of Sub-Region 4 include: Pig, Larsen, Gould, and Hanging Rock Springs. These springs all appear to be associated with mapped faults and their discharge is likely derived from recharge occurring in Sub-Region 3 as well as more distant sources. However, these springs have not been sampled for any water chemistry confirmation.

Shallow wells constructed in the Rye Creek Valley obtain water from the saturated sedimentary deposits of the basin. The water chemistry of shallow wells sampled in the valley is very similar to the chemistry of local precipitation. However, water quality data from wells screened in deeper intervals, below the Tertiary gravels, indicate a more remote (spatial and/or temporal) water source. The groundwater source may be remotely related to water recharged along the Mogollon Rim and Colorado Plateau but is chemically distinct from water in the Payson area, as the Rye Creek Valley groundwater is higher in sodium, chloride and sulfate (Payson, 2004; HSI, 2006).

The Mazatzal Wilderness in the western portion of Sub-Region 4 (the northernmost end of the Mazatzal Mountains) has very limited hydrogeologic information. The rugged terrain and its classification as a Wilderness Area place tight constraints on any future hydrogeologic data gathering in the area. Only two registered wells exist in the Mazatzal Wilderness, one of which is abandoned. Both wells were drilled into Proterozoic rock units and like much of the Study area, groundwater movement is likely restricted to fractures and faults. Due to the area's higher elevation, it is likely a source of recharge to the surrounding alluvial valleys; including the Rye Creek Valley and Verde River Valley. There may also be some groundwater contribution to streamflow of the East Verde River to the north. Springs discharging from this Mazatzal Wilderness are likely a result of localized recharge in the Mazatzal Mountains. Named springs present in the area include: Cedar Basin, Red Metal, Bullfrog, Old Thicket, Barnett, Pole Hollow, Mineral, Dennis, House Place, and Mine Road Springs along with Fuller and Childers Seeps.

3.0 STUDY AREA GROUNDWATER FLOW

A regional scale compilation of the hydrologic and geologic structural information discussed above is displayed in ***Plate 6.*** This plate is a composite of the groundwater flow maps presented in ***Plates 1*** through ***Plate 5***. The groundwater contours and flow directions appear to represent a complex interconnected regional aquifer system. This section presents the hydrogeology of the Study area as a singular mechanism with its several parts. As discussed in the previous sections, groundwater flow in the Study area is generally from northeast to southwest. Recharge to groundwater occurs throughout the Study area. However, the predominant recharge location is along the Colorado Plateau and the Mogollon Rim through the more permeable sedimentary units of the C aquifer. Recharge contributions are from both regional precipitation and snowmelt during the winter, and more localized precipitation events in the summer, which is typical throughout most of Arizona. As precipitation is a function of elevation, so also is recharge. The higher elevations in the Study area along the Mogollon Rim and northward along the Colorado Plateau tend to have greater rainfall and snow totals. This in turn provides greater volumes of recharge to the regional groundwater systems both north and south of the Mogollon Rim. ***Figure 4*** displays a geologic cross section with water level elevations extending from the Mogollon Rim to the East Verde River, delineated as F to F' on ***Plate 6***.

Recharge capability in some areas is significantly enhanced by faults and fractures. As recharge water reaches the saturated portion of the C aquifer it begins to move with the groundwater gradient. The groundwater gradient north of the Mogollon Rim tends to be shallow through the more conductive Coconino Sandstone and upper Supai sandstone units. Moving south of the Mogollon Rim, the groundwater encounters the fine-grained units of the Lower Supai and Naco Formation; and the gradient becomes very steep as a result of the typically low hydraulic conductivities associated with fine-grained shale and limestone. Near vertical flow through these less permeable units is also promoted by abundant faults and fractures, which provide conduits for groundwater flow.

The locations and discharge rates of springs are regulated by both lithologic and structural controls. Faults and fractures intercepting the ground surface provide conduits to the land surface and result in the formation of springs along the Mogollon Rim. Also, as permeable layers (typically coarse-grained intervals bounded by shale rich layers) intercept the surface; these too may result in the formation of springs. Many of the monitored and sampled springs in the area indicate highly variable discharge rates individually, and have contributions from both local and far removed sources (based on the water's isotopic and ionic composition). In some locations, spring discharge increases substantially after precipitation events, while in other locations, springs show a more tempered response depending upon local hydrogeologic constraints. The increase in discharge may be the result of recharging precipitation increasing head pressures. As recharge occurs at even a great distance, newly recharged groundwater will "push" older groundwater out of the system ahead of the recharge front.

Wells too can display high variability with respect to production capacity and hydraulic characteristics as a result of lithologic and structural controls. Wells developed in the fine-grained units of the Supai and Naco Formations exhibit significant variability in water level elevation and typically, the geologic units supplying water to the screens have very low hydraulic conductivities. As mentioned above, the fine-grained units tend to have very steep downward gradients.

As groundwater moves down through the Naco Formation and into the limestone units of the Redwall and Martin Formation, fractures and solution channels become the dominant mechanism for flow. The surface exposures of these units north of the Diamond Rim fault are recharged by precipitation events as well as by the capture of stream flow (often fed from above by spring discharge along the Mogollon Rim).

The Diamond Rim fault zone potentially represents the most influential structural feature with regard to groundwater flow in the Study area but with limited data in its vicinity, the true relationship between the fault and groundwater flow is uncertain. However, some reasonable inferences can be made. The locality and discharge rate of Fossil Springs appears to be controlled in some great degree by the Diamond Rim fault. Other springs in the Study area appear to be both directly and indirectly related to the presence of this fault. Locally, this fault may act as a barrier or a conduit to groundwater flow; likely a conduit in the case of Fossil Springs.

South of the Diamond Rim fault zone, groundwater exits the Paleozoic sedimentary units and flows down into the Proterozoic igneous and metamorphic units below. The area beneath Hardscrabble Mesa may be an exception to this general statement in that there may be a saturated sequence of Paleozoic sedimentary units (primarily the Redwall Limestone and Martin Formation) preserved below the Tertiary basalt and conglomerate cover.

Groundwater flow through the Proterozoic units (like much of the Paleozoic units) relies primarily upon the secondary porosity and permeability of faults and fractures. The faults and fractures provide avenues for localized precipitation to recharge the aquifer in addition to providing pathways for regional groundwater flow. The uppermost portions of the Proterozoic units tend to have greater hydraulic connections relative to deeper fractured areas. Water levels observed in wells penetrating these units exhibit strong variability associated with localized recharge events. The presence of springs and gaining reaches along the East Verde River and Tonto Creek, along the periphery of Sub-Region 3, appears indicative of groundwater discharging from the regional aquifer system.

The groundwater within the Study area is an interconnected aquifer system flowing through several different geologic units. Continuity of groundwater flow is disrupted by recharge zones, faults, fractures, and by the lithologic variability of the sedimentary units in the area. However, connection between and through these various units is facilitated by the broken and fractured nature of the Study area. Viewing the Study area as a regional groundwater system appears to be supported by water levels observed in wells, spring elevations, and by water chemistry data. This regional aquifer system provides a large canvas upon which the several communities and water resource managers can plan and develop water resources for the area.

4.0 SUSTAINABILITY OF REGIONAL GROUNDWATER RESOURCES

Determination of water needs and availability for sustaining the current and future population within the Study area requires evaluation of the renewable water resources (groundwater recharge and safe yield), water resources in storage (reservoir and aquifer storage), as well as the current and future water demands.

4.1 Groundwater Budget

The conceptual groundwater water budget presented here provides a generalized and simplified account of the groundwater inflow and outflow of the Study area, but does not address the volume of groundwater in storage. In order to evaluate the water budget in any greater depth requires significantly more temporal and spatial hydrologic information for the Study area. Because of the extreme variations in hydrologic and geologic conditions encountered throughout the Study area, analysis of more localized water budgets may vary substantially from the more universal water budget presented here.

The strategy used in developing a groundwater budget for the Study area was adapted from the more expansive USGS report on the Mogollon Highlands (Parker et al, 2005). Although the Mogollon Highlands Study encompasses a larger 4,855 square miles (compared to this Study with 632 square miles) a significant portion of the Mogollon Highlands water budget moves through and is recharged within the Study area. Groundwater inflow includes recharge occurring within the Study area as well as groundwater inflow from the C aquifer north of the Study area. The outflow includes base-flow to streams, spring discharge, as well as groundwater discharging out of the Study area towards the south. ***Figure 5*** provides an overview of the groundwater budget components and the locations of primary springs and stream gages used to estimate groundwater outflow from the Study area.

4.1.1 Groundwater Inflow to the Study Area

The primary contributor to groundwater inflow to the Study area is the C aquifer. The inflow from the C aquifer according to the Mogollon Highlands report was calculated using a precipitation rate of 374,400 acre-feet per year (afy), and allowed for 17% infiltration; thus giving a total inflow of 63,600 afy into the Mogollon Highlands. The current Study area obtains approximately half of that C aquifer inflow (31,500 afy) based on the groundwater flow directions displayed on ***Plate 6*** and in relation to the C aquifer contribution discussed in the Mogollon Highlands report (Parker et al, 2005).

Recharge estimates for the Study area were calculated from areal precipitation totals using Parameter-elevation Regressions on Independent Slopes Model (PRISM) shapefiles. The PRISM shapefiles are contoured annual precipitation rates that have been generated using point data and digital elevation models to simulate the spatial distribution of precipitation (Parker et al, 2005). In order to calculate area-weighted annual precipitation within the Study, PRISM regions denoted as having the same precipitation rate were broken into polygons where the area of each polygon was used to weight the average annual precipitation. The area weighted precipitation for the Study area is 766,703 afy. Factors that inversely influence recharge to the aquifer in the study area include steep sloping areas and typical thin soil horizons overlying low permeability rock units. However, significant areas of exposed karstic limestone units, thick units of weathered granite and Tertiary aged gravel units accept recharge at a much higher rate locally (Payson, 2005; Gookin, 1992; Southwest Ground-water, 1998; Gæaorama Inc., 2003; Clear Creek, 2007). Considering the variability and influence of near surface conditions on groundwater recharge, it is estimated that between 4-5% of precipitation results in recharge (30,700 to 38,300 afy) to the aquifer. These percentages are consistent with the initial estimates discussed in the Mogollon Highlands report (Parker et al, 2005). The groundwater inflows to the Study area are displayed in ***Table 1***.

Table 1. Groundwater Inflow to Study Area

C Aquifer Inflow	31,800
Precipitation	766,703
Percent Infiltration	4 - 5
Total Recharge from Precipitation	30,700 – 38,300
Total Groundwater Inflow	62,500 – 70,100

4.1.2 Groundwater Outflow from the Study Area

Groundwater leaves the Study area directly, as stream base-flow, and as spring discharge. Base-flow leaving the Study area though streams was estimated by using streamflow records obtained from the USGS Surface-Water Data for the Nation website. Tonto Creek, East Verde River, and Fossil Creek provide the primary drainages from the Study area and were used to estimate groundwater outflows. The portion of the Study area not within these drainages (namely the

Mazatzal Wilderness in Sub-Region 4) does not appear to provide significant spring discharge or baseflow to streams leaving the Study area. Although Mazatzal Wilderness in Sub-Region 4 may provide an undefined volume of groundwater flow out of the Study, it is not specifically addressed as part of this conceptual groundwater budget.

Stream gauge data for Tonto Creek was obtained from the USGS gauging station (9499000) located outside the Study area above Gun Creek. Records for this station include approximately 10 years of average daily discharge rates. Stream gauge data for the East Verde River was obtained from near the Study area boundary at the USGS gauging station (9507980) near Childs. This gauging station was selected based on its long-term records of daily stream discharge as well as its convenient location near the Study area boundary. Stream flow within Fossil Creek was gleaned from the Mogollon Highlands report (Parker et al, 2005) as well as Northern Arizona University (2005).

Average annual base-flow for each of the streams was estimated as the median low-flow daily discharge rates for the month of January. This estimate assumes minimal runoff contributions from precipitation as well as no evapotranspiration losses due to low seasonal temperatures. It is also assumed that spring discharge is a component of these average annual base-flow estimates. (In the case of Fossil Creek, it was assumed that base-flow to the stream and discharge from Fossil Springs is equal.) In order to calculate the net base-flow from each stream, the average annual discharge from springs within the watershed were removed from the annual average base-flow. Lastly, the net base-flow from each watershed was reduced based on the percentage of the contributing watershed within the boundary of the Study area. (This assumes that the baseflow contribution for each stream is proportional to the contributing watershed area. Without better understanding of groundwater behavior outside of the Study area, and based on the conceptual nature of the groundwater budget, this seemed a reasonable assumption.) The difference between the annual average base-flow and the average annual discharge for each stream represents the average annual runoff from the watershed. The stream discharge rates and baseflow contributions are displayed in ***Table 2***.

Table 2. Baseflow Calculations for Major Watersheds in the Study Area

Stream Name	USGS Stream Gauge Site No.	Avg. Annual Discharge (cfs)	Avg. Annual Discharge (afy)	Avg. Annual Runoff (afy)	Avg. Annual Baseflow (afy)	Avg. Annual Spring Flow (afy)	Net Baseflow (afy)	Watershed Percentage within Study Area	Net Baseflow from Study Area (afy)
East Verde River	9507980	44.5	32218	17738	14480	5406	9074	94.2%	8548
Tonto Creek	9499000	114.9	83188	46988	36200	4442	31758	46.9%	14895
Fossil Creek	*	62.4	45200	12362	32838	32838	0	47.0%	0
Total (rounded to nearest hundred)		222	145700	70500	77700	42700	35000	87.8%	18000

*(Parker et al, 2005; NAU, 2005)

Table 3. Discharge Rates for Major Springs in the Study Area

Spring Name	Drainage	Spring Discharge (gpm)	Avg. Annual Spring Discharge (afy)
Bear	East Verde River	100	161
Big	East Verde River	138	223
Big	Tonto Creek	175	282
Cold	East Verde River	1060	1711
Fish Hatchery	Tonto Creek	1291	2084
Fossil	Fossil Creek	20345	32838
Geronimo	East Verde River	14	23
Horton	Tonto Creek	1100	1776
Indian Gardens	Tonto Creek	57.5	93
Nappa	Tonto Creek	70	113
Pieper Hatchery	East Verde River	125	202
Spring (Unnamed)	East Verde River	75	121
Tonto Bridge	East Verde River	841	1357
Webber	East Verde River	996	1608
Wildcat	Tonto Creek	58.5	94
Total (rounded to nearest hundred)		26400	42700

Spring discharge removed from the net base-flow noted above included only those springs with an average annual discharge rate in excess of 10 gpm (16 afy). ***Table 3*** lists the springs used in the groundwater budget calculations, their annual discharge rate, and their respective watershed. Each of the springs listed in ***Table 3*** drain into one of three streams (Fossil Creek, Tonto Creek, and the East Verde River). Many of the springs displayed on ***Plate 6*** do not have annual discharge rates due to imprecise measurements and lack of data. The methods used in removing spring discharge from the baseflow of streams are consistent with the Mogollon Highlands report (Parker et al, 2005).

Evapotranspiration as an outflow from groundwater system is assumed to be derived exclusively from shallow groundwater available along active stream channels and near spring discharge locations. Baseflow estimates were made using winter stream discharge in order to more accurately isolate the groundwater component of streams without the influence of significant evaporation or evapotranspiration by riparian vegetation (in addition to avoiding surface runoff from precipitation events). In simple terms, this Study assumes evapotranspiration is a component of the groundwater baseflow estimates and spring discharge from the system.

Direct groundwater outflow was estimated by the amount of groundwater flow through the Proterozoic rocks and the alluvium of the Rye Creek Valley exiting the Study Area towards the south that was not included in the base-flow calculations. The flow of groundwater directly out of the Study area is estimated to be between 1,800 to 9,400 afy. This range of flux out of the Study area represents the water remaining unaccounted for as part of the groundwater budget that is not discharged to streams or springs. The Total Groundwater Outflow is displayed in ***Table 4***.

Table 4. Groundwater Outflow from Study Area

Stream Base-flow	18,000
Spring Discharge	42,700
Direct Groundwater Outflow	1,800 – 9,400
Total Groundwater Outflow	62,500 – 70,100

4.2 Recharge and Watershed Health

The majority of the surface area available for natural recharge to the region's aquifer system is contained within the public lands of the Tonto National Forest. The relatively small amount of private land in comparison to the size of the region's watershed and recharge areas, coupled with strict rules governing the use of groundwater from Federal Lands and National Forests, limits the development of groundwater resources and therefore minimizes potential impacts to groundwater in most areas as well as minimizing impacts to stream flow and springs.

One item which may limit recharge to the regional aquifer system is the overgrowth of forest vegetation across the public and private lands of the Study Area. The overgrowth of vegetation is a result of many factors including decades of thwarting the natural effect of wildfire in the Study area. As a result, the overgrowth maintains a higher consumptive use of available water resources. A small increase in vegetation cover over the entire Study area can be a large consumer in terms of the overall water budget. When coupled with growing domestic use, this situation should be evaluated with regard to potential impacts for long-term sustainability of water resources. There is a balance to be maintained in that vegetation slows watershed run-off and controls erosion, but without proper management, the increased vegetation cover may pose a threat for water resources and wildfire management. A large-scale wildfire would be devastating to groundwater recharge as well as uncontrolled watershed run-off and erosion.

The determination and protection of focused groundwater recharge locations is also essential for the long-term viability of the regional aquifer system. This includes land protection for groundwater recharge preservation as well as protection from potential contamination. Just as seasonal precipitation reaches the aquifer system quickly, so too can potential contaminants. Examples of potential contaminants include on-site waste water systems, industrial wastes, or hazardous spills along transportation avenues. Because of the direct interconnection of many fracture networks, a small-scale contamination event could become disastrous as water moves very quickly along some of these pathways. Also, this same scenario should be considered closely in terms of effectiveness of soil-aquifer treatment in managing on-site treatment facilities and the recharge of treated effluent in more populated areas.

4.3 Hydrologic Capture and Safe Yield Estimates for Population Centers

In order to understand the potential long term impacts associated with groundwater use requires a basic understanding of hydrologic capture. In order to understand the concept of capture, we will start by discussing the attributes of an undisturbed natural groundwater system. In an undisturbed natural groundwater system, it is assumed that the groundwater system has come into a long term balance or equilibrium which has been established over thousands of years. This balance requires that the same volume of water added to the groundwater system also leaves the groundwater system. The system acts as a conduit where new water comes in and old water leaves, while the conduit itself maintains the same volume of water. The groundwater budget for the Study area discussed previously assumes this same long-term equilibrium. New water comes into the system through inflow from the C aquifer and recharge from precipitation; old water moves out of the system through direct groundwater outflow, discharge from springs, and base-flow to streams.

When a disruption to the groundwater balance occurs as a result of groundwater pumping, the groundwater system compensates for this disruption by doing one or more of the following: increase inflow, decrease outflow, or change the volume of groundwater in storage. These changes may be observed as increased losses from streams (increased inflow); decreased groundwater outflow, reduced base-flow and spring discharge (decreased outflow); and/or lowering groundwater levels (change in groundwater storage). The volume of water taken as increased inflow, decreased outflow, and change in storage is "captured" from the groundwater system. The effects of these changes may be minor or significant and may be localized or regional depending upon the magnitude of the disruption. However, regardless of magnitude, there are impacts to the groundwater system once groundwater pumping starts.

Historically, the groundwater resource evaluations and impact assessments within the Study area have been developed around the idea of "safe yield." This concept is based only on the estimates of groundwater recharge for a specific locality. The volume of groundwater deemed "safe" for use in a given year is roughly equal to the average annual volume recharged to the aquifer for that locality. As these estimates relate to the groundwater system locally, it has been observed that many of the springs discharging within the Study area respond rapidly to precipitation. Groundwater elevations in many wells within the Study area also respond rapidly to precipitation. At any given time, local variations in water level elevations and spring discharge may reflect localized variations of recharge. In other words, the groundwater resources in many areas are readily recharged, have relatively low storage capacity, and are highly susceptible to climatic changes (drought sensitive).

Safe yield estimates are calculated from annual average recharge over a 50 to 100 year time frame. Because of this, observed impacts from groundwater pumping in any single year may not appear to behave in an "average" manner. However, using safe yield estimates for groundwater management and development is an attempt to reduce potential long-term impacts associated with groundwater pumping and the removal of groundwater from storage.

Localized calculations developed for the Town of Payson indicate a safe yield of 1,826 afy (Southwest, 1998). Sustainable withdrawal rates have been estimated to be 10-16% of annual precipitation (17-20 inches per year as a conservative estimate) (Gookin, 1992). The calculation methods are believed to be conservative in that much of the groundwater flowing through the Study area was recharged outside of its boundary, and appears to have a groundwater flux in excess of the safe yield calculations.

Applying the same localized assumptions that lead to Payson's estimate of safe yield to the communities of Pine and Strawberry; the deep aquifer accessible below those communities can be estimated to yield no less than 900 afy within a renewable state or "Safe Yield". When used conjunctively with existing shallow resources this number may be as high as 1,200 afy. Utilizing precipitation values, the safe yield of the entire Pine and Strawberry area should range between 1,200 afy to 1,780 afy (Payson, 2005).

The area immediately surrounding Star Valley has recently been evaluated to determine groundwater consumption and safe yield estimates. The estimated safe yield is 4,300 afy, with a current use of approximately 380 afy. As a practical measure, not all of the water is capable of being utilized. So assuming a maximum potential use of 80%, the practical safe yield for Star Valley would be 3,440 afy (Clear Creek, 2007).

In comparison to the groundwater budget components discussed previously, the groundwater available for use by the three major population centers (as derived from Safe Yield estimates) represents 10 to 11% of the total groundwater inflow into the Study area.

4.4 Future Water Demands for the Study Area

In calculating the potential water available for future development, the Study has developed a demand analyses for "build-out" water demand projections from 2002-2040. According to the Study's demand analysis, the 2002 population in the Study area was approximately 21,300. By 2040, the population is projected to increase to approximately 73,200. As population increases, so will the water demands. The current (2002) water demands for the Study area are computed to be nearly 2,600 afy whereas water demands by 2040 are expected to increase to approximately 11,000 afy.

As noted previously, the Town of Payson is currently the largest community in the Study area with a population of approximately 14,500 and by 2040, the population is expected to be within its build out range of 35,000 to 45,000. Thus, Payson is expected to remain the largest community and therefore the largest water consumer in the Study. Using a conservative value of 120 gallons per capita per day, estimated water demands by Payson will be 6,000 afy by 2040. Approximately 1,200 afy will be required to supply the communities of Pine and Strawberry at build-out (by 2040). This estimate was based on a build-out population of 7,259 with a range of demand between 120 and 250 gpcd (gallons per capita day). As a practical matter, actual gpcd values in the region are typically less than 120 gpcd and could be maintained at or below this number via demand-side management.

On a regional scale, it appears that groundwater supplies could easily provide for the expected population increases. However, because of the local variability associated with hydrogeologic conditions or accessibility problems, groundwater may not be the best solution to meet water demands in all communities, if only population demands are factored.

The importation of surface water from C.C. Cragin (formerly Blue Ridge) Reservoir would dramatically offset future demands on the overall groundwater system at the largest population center in the Payson area. Early in its future use, the C.C. Cragin Reservoir water may be used directly, or recharged in the Payson area to offset seasonal demands. Later, the reservoir's water will be used directly, and may require supplemental groundwater pumping to meet peak demands. The addition of a surface water resource will help to eliminate some of the potential impacts associated with localized aquifer pumping. However, the quantity of C.C. Cragin Reservoir water is limited and expensive to distribute, thus many areas throughout the Study area will still rely exclusively on groundwater. The many smaller county island communities do not represent significant groundwater use commitments; therefore, these locations may be able to supplement their growing water demands with limited groundwater from public lands with minimal potential for negative impacts to groundwater and forest resources in the Study area. Nevertheless, it should be noted that the U.S. Forest Service typically requires that all alternative water resource options have been exhausted prior to permitting the installation of wells on Federal lands.

5.0 ALTERNATIVE WATER RESOURCES SOLUTIONS

Developing new water supplies for existing and future developments within the Study area presents many interesting challenges. Matrices of four alternatives have been identified, with each one having its own set of challenges. Each of these alternatives represents a grouping of ideas as possible solutions to finding alternative water supplies. These alternatives are not listed in any specific order but do include the following: 1) surface water and water exchanges, 2) groundwater, 3) reclaimed water (effluent), 4) water conservation including loss reduction.

5.1 Surface Water and Water Exchanges

The surface water and water exchange option could have many components that relate to the use of surface water as one possible water resource solution. Any additional use of surface water will likely require a water exchange agreement involving the Salt River Project (SRP) and possibly a site or several sites having the ability to store the newly acquired surface water supply. By developing a water exchange agreement with the SRP, several options open up whereby additional C.C. Cragin water can be delivered to facilitate a water exchange.

One example of a water exchange would be to acquire (purchase or lease) CAP water rights from the Gila River Indian Tribe, Tonto Apache Indian Tribe and/or from Brooke Utilities. These rights could be exchanged with SRP for C.C. Cragin Reservoir water. Assuming exchange is the means utilized to obtain water (rights) from C.C. Cragin (because direct purchase is found not to be feasible), the keys to this option would be: 1) acquiring the rights to the water, 2) acquiring an exchange agreement with SRP, 3) having a place to store the additional surface water (CAP or C.C. Cragin), and 4) facilitating expansion of proposed distribution infrastructure.

Another possibility might include the capture of storm water runoff within the incorporated boundary of the Town or other development that would otherwise be diverted to local washes and pass through the incorporated area. This could be an additional means of obtaining an intermittent surface water supply during the runoff season. The capturing of this water could be accomplished by stream modification techniques to slow down and store the storm water that would have normally flowed out of the incorporated area and down the watershed. This alternative would require water rights exchanges with downstream appropriators. This alternative could also provide possible recharge sites for excess CAP and C.C. Cragin water. The keys to this option would be: 1) securing water rights, 2) diverting the water, 3) capturing the water and 4) treating and storing the water.

The C.C. Cragin Reservoir presently stores local runoff water from the winter storm season. The reservoir is unlined and likely has a component of leakage that could be recaptured if wells were drilled down gradient within the reservoir's influence. Since this leakage water is presently not accounted for as part of the watershed runoff and it has not been determined where this water ends up, it may therefore be available for use downstream to augment existing water supplies. The keys to this option would be: 1) the rights to this water, 2) the ability to capture the leakage water, 3) the operation of the capture facility and 4) obtaining permits.

5.2 Groundwater

The second option involves the further development of existing groundwater resources on private lands. Currently, most of Gila County is dependent on groundwater supplies as the major source of water. Much of the groundwater comes from fractured rock aquifers, making it difficult to estimate the volume of groundwater in storage. Due to the fractured nature of the rock aquifers, production wells may need to be drilled far from where the water will be used. Therefore, wells need to be located where sufficient fracturing occurs which may be on public lands. The public land sites pose challenges because of the various permits required for water extraction and because of citizens' concerns. Expanding groundwater development programs may require a significant capital expenditure to drill wells and build pipelines to deliver water to where it is needed.

Table 5 below provides a rough estimate regarding construction costs for small-scale domestic wells on privately owned land and the table provides a scalable cost associated with well depth. Significant increases in costs for permitting and NEPA process would be required for wells installed on public lands. Such costs would be project specific and are therefore not included here.

Fortunately, the quality of the groundwater encountered is good and requires little or no treatment other than disinfection and possibly handling localized radon and/or arsenic treatment. The keys to this option would be: 1) finding suitable sites for drilling, 2) acquiring the necessary permits, 3) addressing citizens' concerns, and 4) ensuring continuous access to groundwater resources developed on public lands.

Table 5. Estimated Domestic Well Construction Costs (private lands) (2007)

	Well Construction Costs for Average Well*	Well Construction Costs per Well Foot
Field Drilling and Installation Cost	13,000.00	37.14
Unlisted Items (15%)	1,950.00	5.57
Subtotal	14,950.00	42.71
Contingency (25%)	3,737.50	10.68
Subtotal	18,687.50	53.39
Indirect Costs (25%)	4,671.88	13.35
Subtotal	23,359.38	66.74
Interest During Construction (4.875%)	948.97	2.71
Total	**$24,308.35**	**$69.45**

(*Average well of 350 feet deep, 5-inch PVC casing, without pump)

5.3 Reclaimed Water

The third option involves the further development and use of reclaimed effluent from the treatment of wastewater flows. This alternative could be more challenging for the smaller developments since most of these developments are presently on septic systems and the cost of installing wastewater infrastructure may be prohibitively expensive. However, the use of reclaimed water from the larger developments makes sense because of the larger volume of effluent generated. The use of reclaimed water will also reduce the risk of contamination from septic tank flows migrating downward to the groundwater table. Reclaimed effluent can readily be used on turf areas such as parks, roadways, and golf courses to minimize the additional need for pumping more groundwater. The keys to this option would be: 1) collecting the sewage flows for treatment, 2) constructing and operating a wastewater system and 3) converting irrigated turf to the use of effluent.

5.4 Water Conservation

The fourth option deals with water conservation including loss reduction. This option does not involve the development of a new water supply but involves becoming a better steward of the water that is available. With the recent successes enjoyed by the Town of Payson from its water conservation program, some of the conservation ideas could be applied to the smaller communities outside of the Payson area. Water conservation is such a visible concern that there presently is an Arizona Statute for Water System Planning that deals with the issue.

Part of this option would include evaluating the municipal water distribution system for lost and unaccounted-for-water as another potential water saving strategy. By locating and repairing leaks in the system, waste is reduced which maximizes the efficient use of the supplies available. This option requires metering of most uses within the distribution system, and the metering costs are made up in increased revenue for accurate water deliveries.

This fourth option should be applied even if one or more of the other options are selected. Water conservation and loss reduction programs can be employed by all communities and all people in the State of Arizona no matter their location or source of water used. Water rate-based incentives could be employed to reward those users who conserve. The keys to this option would be: 1) developing a water conservation and loss reduction program that makes sense for each community, 2) educating the community to apply these conservation measures and 3) establishing some level of enforcement or rate-based incentives to ensure communities comply.

6.0 RECOMMENDATIONS

As this Study is a regional assessment of water supplies, this section lists several recommendations to assist in more accurately determining water supplies in the future. As a general statement, given the large Study area, gathering additional data is the first recommendation. Several inferences and subsequent calculations have been made regarding the water resources for the area however; these are based on both temporally and spatially sparse data. The data gathered should encompass both groundwater and surface water supplies.

Groundwater and spring monitoring should include regular water level and discharge measurements and sampling for the entire Study area. As has been discussed in this report, water levels and spring discharge in many areas are seasonally variable. Quantifying the water resources for the study area should include consideration of this variability and how it can be managed. The time frame for collection would be yearly for the most remote areas and quarterly for the well and spring locations nearest the communities. This water level data collection may be promoted in conjunction with the Groundwater Site Inventory (GWSI) water level measurement program of the ADWR. The GWSI consists of field verified data collected by personnel from the ADWR Hydrology Division and/or the U.S. Geological Survey. This information is continually being updated by ongoing field investigations and through a statewide network of water level and water quality monitoring sites.

Stream gauging and water quality sampling for the perennial reaches of streams will provide information regarding the groundwater contribution to these locations. Also provided as part of stream flow monitoring, is an assessment of water volumes recharged into the underlying aquifer unit. Stream gauges also assist in quantifying precipitation distribution during storm events, further enabling the determination of recharge to the groundwater system. Stream gauging in addition to meteorological data also will assist in overall watershed management by the Salt River Project. Stream gauging and water quality sampling stations would be beneficial at multiple locations along Tonto Creek and the East Verde River as well as down gradient of the major spring locations, namely Webber Springs, Cold Springs, Pieper Hatchery Spring, Horton Spring, Tonto (Fish Hatchery) Spring, Tonto Bridge, Big Spring, Indian Gardens Spring, and Wildcat Spring.

The conceptual geology and hydrology developed as part of this Study should be further investigated. Subsurface hydrologic and geologic information should be developed in those critical areas with influence upon future groundwater and surface water resources. It has been speculated within this study that Hardscrabble Mesa in Sub-Region 2 may have significant recharge potential for the regional system, and may contribute water to Fossil Springs. This hypothesis should be confirmed with surface geophysics and the drilling of at least three deep exploration boreholes converted into monitor/piezometer wells on Hardscrabble Mesa. The goals for the drilling and well construction are to confirm groundwater flow direction(s) and water quality components. Further, drilling through Hardscrabble Mesa will provide confirmation of subsurface geology with regard to the presence of Paleozoic rock units below the basalts and their potential transmission of groundwater from recharge on Hardscrabble Mesa or from along the Colorado Plateau.

Additional areas for hydrologic and geologic data gathering through deep drilling exploration include the geologic transition zone between the Paleozoic rock units and the underlying Proterozoic rock units. Understanding this transition is valuable to determining the direction of groundwater flow, the volume of water moving through this transition, as well as for up-gradient groundwater monitoring for the groundwater users in the Study area. Also located along the Paleozoic/Proterozoic unit transition is the Diamond Rim Fault. A determination of groundwater flow across (or along) the fault will aid in understanding the contribution of Colorado Plateau recharge and for long-range management of groundwater supplies. There are eight recommended areas for exploration borehole drilling and monitor/piezometer well construction along the transition zone. These areas are: Buckhead Mesa, near Cedar Mesa, and north of Webber Spring in Sub Region 2; the area south of Milk Ranch Point but north of the Diamond Rim Fault, within Hells Half Acre north of the Diamond Rim fault, and along the control road approximately 2 miles north of the Little Diamond Rim in Sub-Region 1 (West); 2 miles east of Cold Spring near Ellison Creek in Sub-Region 2 (East); north of Houston Mesa just west of Mesa Del Caballo development in Sub-Region 3.

The areas recommended above for additional data gathering represent only a few of the significant spatial gaps in hydrogeological knowledge within the Study area. By gathering information in these areas, much of the conceptual hydrogeologic model presented in this report will be better constrained. This information may then be utilized in creating a numerical groundwater/surface water flow model. The model would allow for the testing and revision of the numerous ideas presented in the Study, including refinement of the overall regional water budget. A numerical model provides a tool for the assessment of potential impacts – temporally and spatially – of the different water resource alternatives presented. The development of a numerical model would also assist in guiding future data collection efforts as well as provide a tool for evaluating and designating wellhead and spring head protection areas. The protection of the groundwater recharge areas is essential for the long-term viability of individual wells and the entire aquifer system. Because many of the areas within the aquifer system are recharged quickly, wells should be protected from potential contamination.

With the observed temporal variation in isotope and Tritium data, quarterly sampling of major springs and a sub-set of wells in the region is also recommended. This effort would help to better understand recharge events, mechanisms, volumes, and local vs. regional groundwater behavior and relationships.

As groundwater is the primary water source for most of the region, the development of additional, reliable groundwater resources would be extremely beneficial. To do this, a groundwater exploratory program in support of the most resource limited communities such as Geronimo Estates, Tonto Village, Wonder Valley / Freedom Acres and Hardscrabble Mesa should be considered. Funding for the investigations may include both public and private components. This program could include a significant surface geophysical survey component as well as an exploratory drilling program with a goal of finding more stable, long-term groundwater supplies. In addition to providing additional supplies, the hydrogeologic information developed as part of the program would likely provide valuable confirmation (or not) of the conceptual hydrogeologic system developed as part of this Study.

The understanding of the fractured nature of the rock units as they relate to groundwater flow in the Study area cannot be overstated. In a study conducted by Maini and Hocking (1977) (as discussed in Marsily, 1986), they relate the characteristics of the flow from a single fracture to flow through a much larger equivalent unit of porous material. The Maini and Hocking study indicated that flow from a single fracture with an aperture less than ¼ inch could yield an equivalent hydraulic conductivity of approximately 283 ft/day. This is equivalent to a transmissivity value of nearly 700,000 gpd/ft in an aquifer 328 feet (100 meters) in thickness. Thus given the capability of a single fracture, determining the location of the fracture networks may be imperative to the development and management of water resources in the Study area. The geologic mapping conducted as part of this Study has indicated several areas where significant faulting is observed at the land surface. A program using surface geophysical methods to identify fractures and faulting at depth (where they intercept groundwater) may be very beneficial for the small outlying communities in the Study area which are in close proximity to mapped faults and fractures.

7.0 CONCLUSIONS

With the information developed in support of and by the Study effort, reasonable solutions to the water resources problems that have historically plagued the communities along the Mogollon Rim have now been identified. The single most important solution appears to be the implementation of the C.C. Cragin surface water project. Implementation of this solution will minimize groundwater use within the study area by importing a renewable surface water source to the primary population center of the region. Thus, groundwater demand then would be limited to only the smaller outlying communities where build-out demand for water should be well within the limits of regional sustainability; given the size of the watershed relative to dispersed demand. Utilization of groundwater in such areas, alongside responsible management strategies, is one way to ensure that the above statement rings true. Ultimately, the “toolbox” of alternative water resource solutions and suggested recommendations can be used as a basis for further study in detail and lead to considerations of feasibility for those wishing to proceed.

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Figure 1. Mogollon Rim Water Resources Management Study Area

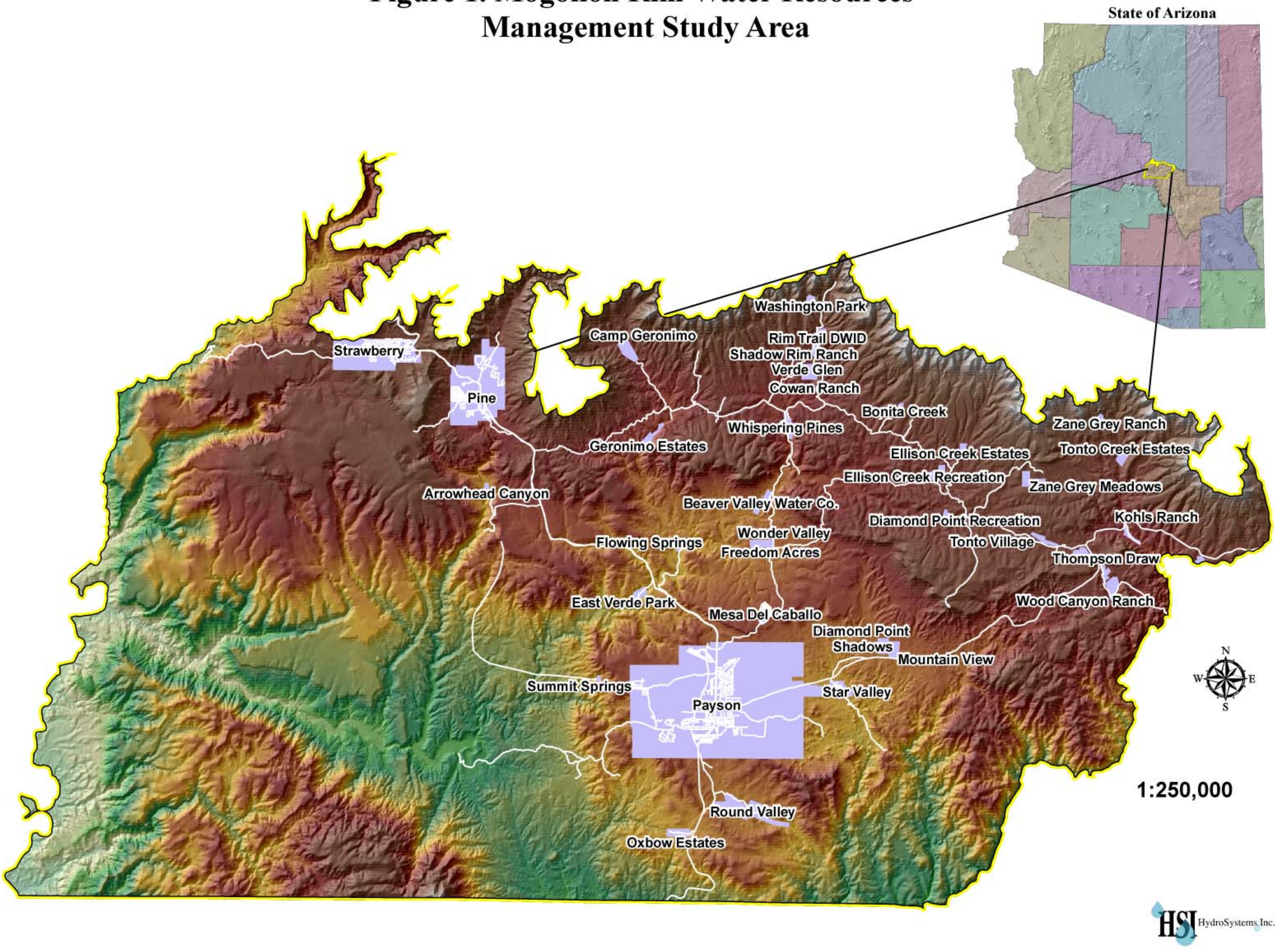
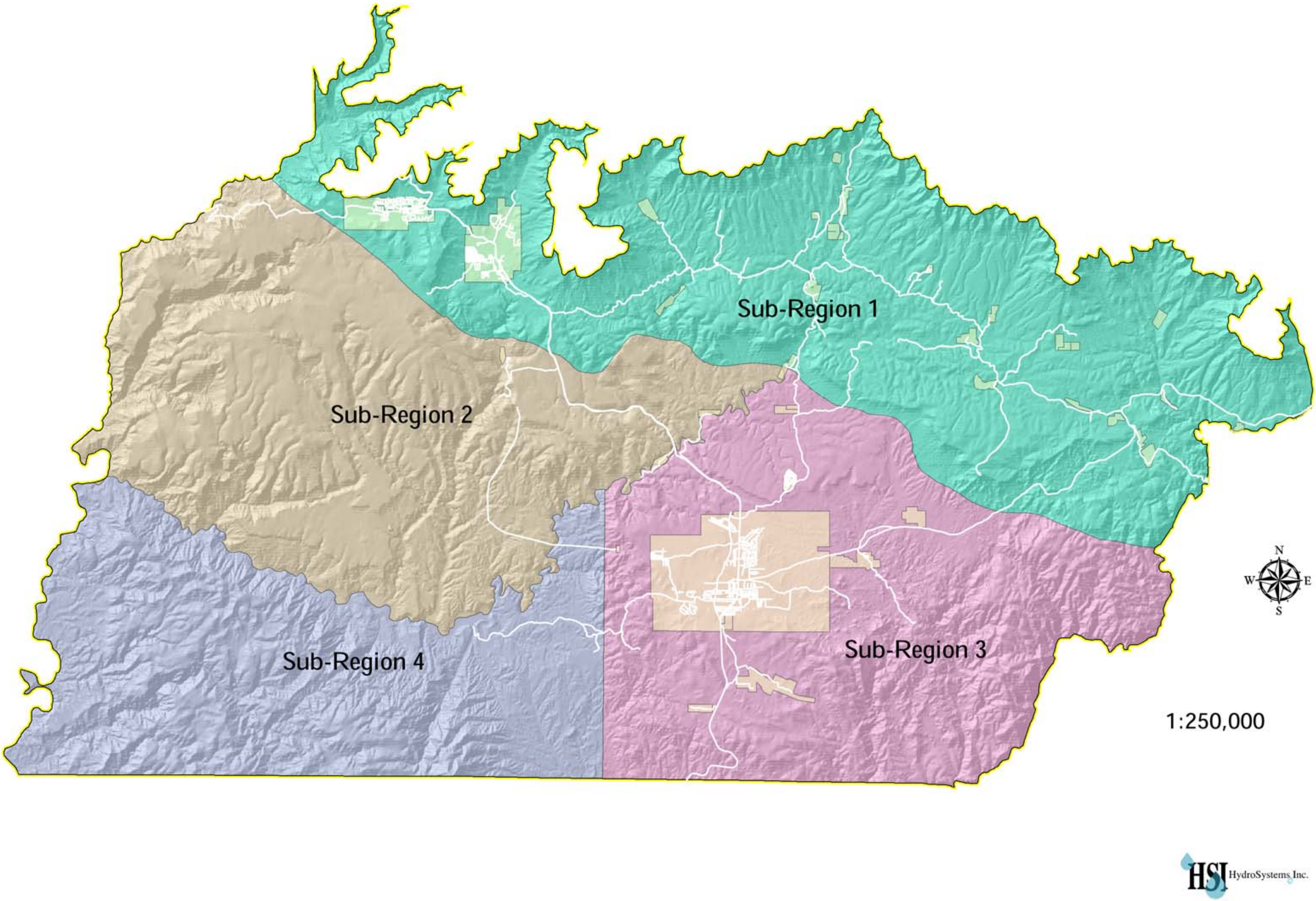
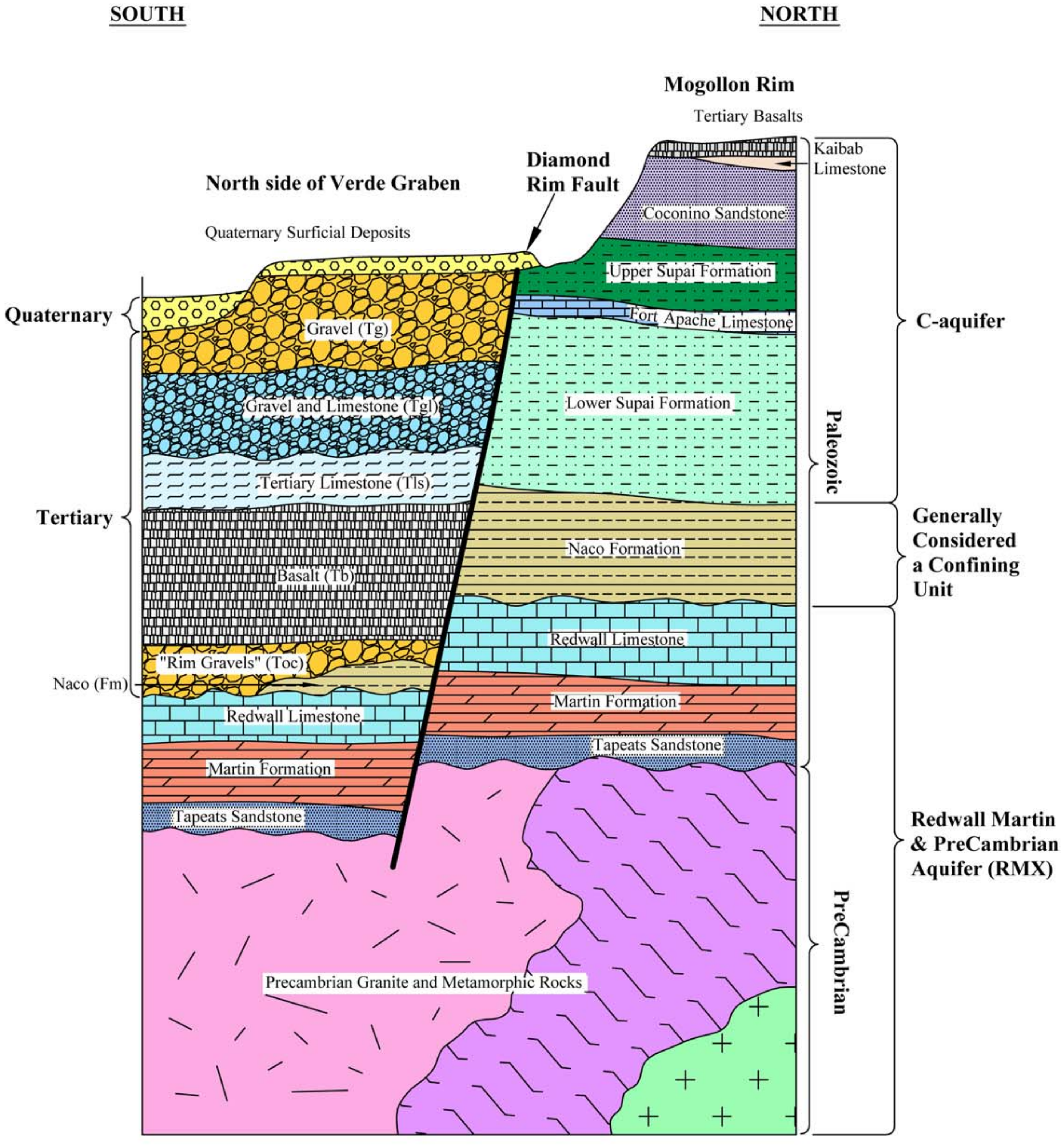


Figure 2. Sub-Regions of the Mogollon Rim Water Resources Management Study Area





Note: Thicknesses are shown diagramatically and are not exact.

HSI HydroSystems, Inc.	Composite, Generalized Stratigraphic Section for the Study Area. Looking west along the Diamond Rim fault across the northern part of the Verde Graben, west of Payson	Figure 3

S:\03-343 City of Payson\MRWRMS\Hydrogeologic Summary Report\Figures\Figure 3.dwg, 7/17/2007 3:17:57 PM

ATTACHMENT 1A
(Supplemental Documentation to the: Mogollon Rim Water Resource, Management Study Report of Findings)

Geology and Structural Controls of Groundwater, Mogollon Rim Water Resources Management Study by Gaeaorama, Inc., July, 2006

GEOLOGY AND STRUCTURAL CONTROLS OF GROUNDWATER, MOGOLLON RIM WATER RESOURCES MANAGEMENT STUDY

Prepared for the

Bureau of Reclamation

GÆAORAMA, INC.
Blanding, Utah

DRAFT FOR REVIEW
22 July 2006

CONTENTS

EXECUTIVE SUMMARY

As part of the Mogollon Rim Water Resources Management Study (MRWRMS), Gæaorama has produced a geologic map of the entire MRWRMS area and has done a geologic structural analysis to evaluate structural controls on groundwater. All data – geology, springs, wells, water chemistry sites, private property boundaries – have been compiled in Geographic Information Systems (GIS), utilizing ArcGIS software by Environmental Systems Research Institute (ESRI). The data can be utilized at any scale either on-screen or by hard-copy prints. Map data can be viewed or printed on any desired base, including 7.5 minute or 30 x 60 minute topographic maps or on DEM shaded relief or remote imagery.

A large amount of new mapping was done for this study in the central to northwestern parts of the area. The emphasis was on extending the Diamond Rim fault system from just north of Payson to the Fossil Springs area on Fossil Creek. Extensive new mapping and integration with earlier mapping was done in the Pine-Strawberry area. The upper drainage basin region of the East Verde River was mapping in reconnaissance. Compilation of mapping from many sources, including recent mapping for the Town of Payson, was utilized for the compilation. This work involved correlation of map units across the area and creating a customized set of geologic units for the study. Comprehensive descriptions of these map units are given as a section in the report; those units underlying areas of greatest groundwater interest for this study were given considerably more attention than other units and their descriptions include details in lithologic and stratigraphic variation and in thickness changes.

Faults in the region are primarily of Early Proterozoic (~1.65 billion years) or late Tertiary age (mostly younger than about 12 million years). The older faults, which trend mostly northeasterly are largely sealed due to formation deep in the earth under great pressure or to vein-filling during hydrothermal events. They are not conducive to water production. Tertiary faults of several trends but mostly northwesterly, on the other hand, commonly contain open space, thus providing secondary porosity and permeability, and can provide excellent targets for groundwater. Some Tertiary faults are in line with northeast-trending Proterozoic faults and in a few cases appear to have formed through reactivation of the old faults.

Fossil Springs lie at the intersection of the Diamond Rim fault and the Fossil Springs fault, the latter apparently being a reactivation of the Proterozoic Moore Gulch fault. The northeast-trending Fossil Springs fault is apparently a conduit for the spring water, whereas the Diamond Rim fault is a dam and has been for perhaps a few million years as evidenced by the enormous dissected travertine dam 400 feet above the canyon bottom. Fossil Springs and other large springs of the area derive their water almost entirely from the deep regional aquifer up-gradient beneath the Mogollon Rim. Some faults serve as barriers to groundwater passage, many do not. It can be argued, for instance, that spring water from Tonto Bridge spring and Webber spring have flowed across/through the Diamond Rim fault.

Most of the 124 springs in the study area are small, intermittent, and derive their water from perched tables containing mostly local recharge. Only very few springs in the region can be reliably used to created any sort of a meaningful water elevation map. Actually only one such map could be drawn anyway – the water elevation map for the deep regional aquifer. And at this point it can only be very tentatively created only locally because there are so few data points (wells and deep regional aquifer springs) in the northern MRWRMS area.

The water levels in the few deep wells (>1000 feet) in the region and the elevations of some large springs suggest the presence of a pervasive deep regional aquifer. In the Pine-Strawberry region this water table (about 4,400' - 4,600' elevation) is a matter of only about 50 to 200 feet higher in elevation than Fossil Springs and at about the same elevation as Tonto Bridge spring and Webber spring. The elevation of the deep regional aquifer in the north part of the Town of Payson is about 4,300 feet, based on 'old' water encountered at that elevation in the Goat Camp # 1 well.

We put forward as a conceptual model - as a working hypothesis - that the water of the deep regional aquifer in the structurally disrupted region in the northeastern part of the Verde graben (basically from the Mogollon Rim to the valley bottoms) has no specific lithologic host and has no effective confining layers. This aquifer is basically an unconfined fractured system reservoir that crosses many lithologic boundaries from the higher Paleozoic rocks down into the Proterozoic crystalline rocks. The standard aquifer systems of the Colorado Plateau country to the north - the C aquifer and the 'limestone' aquifer – break down in this highly fractured region which also has terrific topographic relief. The main control on the groundwater elevation of this deep regional aquifer is surface elevation. The water table roughly follows the surface form but ranges from perhaps 1500 feet to 0 feet (at springs) from the surface – 500 feet to 1200 feet is probably common.

Numerous Tertiary faults in the region, and particularly fault intersections can no doubt be profitably explored at these depths to obtain water from the practically limitless supply (relative to very few inhabitants) of water in the deep regional aquifer. Many of these faults are in or close to county subdivisions and thus feasibly are immediate water sources for these communities. The numerous faults and fracture systems in Pine and Strawberry, in particular, are inviting targets for water production in those water-starved communities.

INTRODUCTION

Gæaorama, or its principle, Clay Conway, working earlier for Southwest Ground-water Consultants, produced a number of reports (Southwest Ground-water Consultants, 1997, 1998; Gæaorama, 1999, 2003) in support of Payson's groundwater exploration program over the past 8 years. Each of these has involved geologic mapping, analysis of geologic structural controls on groundwater, and an assessment of groundwater potential. The Town of Payson has drilled numerous wells, and has discovered significant new groundwater resources, based in part on these studies. In particular, these studies have concentrated on an area in and near the Town, on the upper Rye Valley area southwest of the Town, and on an area beneath the Diamond Rim northeast of the Town. Numerous wellsites in the latter area were recommended to the Town but none have yet been drilled.

There is much in these reports on the local and regional geology, with an emphasis on hydrogeology, that is pertinent to the present study. The reader is therefore referred to these reports; it is not the purpose of the present report to repeat or to review the findings of these earlier reports. Rather it is the primary objective of this report to present a comprehensive portrayal of the hydrogeology of northernmost Gila County – the area defined by the Bureau of Reclamation for the Mogollon Rim Water Resources Management Study (MRWRMS), of which this report is a part. This portrayal is primarily through the creation of a geological spatial database using GIS software.

For the present study, the above mapping as well as other published and unpublished mapping (none previously digitized) in the MRWRMS study area was all integrated geologically and digitally to create the comprehensive geological spatial database as described in the next section.

Much of the study area was previously unmapped, or mapped in reconnaissance fashion. In particular, the area of greatest interest, a belt extending from Payson northwestward to the area of Fossil Springs, was at the outset of this study very poorly known. Likewise much of the area north of Payson to the Mogollon Rim was unmapped. It was therefore a necessary and most important part of this study to conduct new geologic mapping in these regions. Mapping by Gæaorama for this study occupied 48 field days, mostly in the fall of 2004. Mapping was done on aerial photographs and GPS was utilized. Hand compilation of the new mapping data was done on 1:24,000 topographic maps. This was then scanned and digitized in ArcGIS. The office and computer work related to the new mapping occupied many months of time.

As the new mapping and compilation progressed, pre-existing mapping, published and unpublished was scanned and digitized. This covered most of the area, with a few conspicuous gaps. Once mapping for the entire MRWRMS study was digitized, the challenging tasks of correlating and systematizing geologic units across the entire area and 'blending' the mapping at map area boundaries was undertaken. This was a huge job which relied both on the many years of field study in the region by C. Conway and also on extensive study of the geologic literature of the region. Many months were also consumed in this work.

Geologic structural analysis of the Fossil Creek-Strawberry-Pine (FSP) area was also a major undertaking of this study and involved painstaking, tightly-controlled construction of five geologic cross-sections (Plate 4). Hand construction and CAD rendering of these cross-sections also occupied several months time. A number of new faults were discovered and mapped in the FSP area in the course of the new mapping. Additionally, several faults were hypothesized from photolineaments, alignments of springs, or other geological considerations. Constraints from the construction of the 'correlated' cross-sections actually demonstrated the presence of several of these faults, notably the LoMia fault. By 'correlated' cross-sections is meant that the sections are drawn to agree with one another at their numerous intersections. Drawing involves, most importantly, precise rendering of topographic profiles, careful placement of mapped contacts and faults, and utilization of depths of formational contacts as determined in well logging. Numerous uncertainties remained, however, and many of these were gradually worked out in the iterative, trial-and-error correlative construction of the sections. Ultimately revealed through the mutual constraints of the various intersecting sections were such things as variations in unit thickness, variations in dispositions of beds (strike and dip), and even the existence and sense of offset of some faults. Understanding the structural geology, notably the fault locations and dispositions, will be important to future groundwater exploration (siting of wells).

One objective of this study was to complete the mapping of the Diamond Rim fault system, *the* major northeastern break in that part of the Verde graben that passes through the MRWRMS study area (Plate 2). This objective was met, primarily in the mapping of the belt of interest between Payson and Fossil Creek. We now know that understanding this fault is one key to understanding the groundwater regime in the MRWRMS study area. Until this study, the lateral extent of this fault, the magnitude of its vertical throw, and the fact that it controls the location of Fossil Springs were not known, although they had been anticipated for some years by C. M. Conway, as expressed to Mike Ploughe, Town of Payson, and others. Fault segments of the complex Diamond Rim fault system are key sites for groundwater potential. The numerous sites recommended for drilling (Gæaorama, 2003) beneath the Diamond Rim, northeast of Payson, are all on various strands of this fault system.

Regarding the actual deliverables to the MRWRMS project, the two most important products of Gæaorama's study are the GIS Database (explained in the next section), from which the maps of this report were prepared, and the Description of Map Units (DMU) which constitutes the major portion of this textual report. The DMU is a comprehensive 'geologic shorthand' description of the geologic units of the study area. It relies not only on the original field observations of the current study, and on observations and writings of C. M. Conway made in numerous studies in the MRWRMS area since 1976, but it also relies heavily on the extensively published and unpublished mapped and written information on the geology of the study area and surrounding regions. In previous studies made by Conway for the Town of Payson, reports have relied largely on personal knowledge and on field observations made in the course of the study at hand. In a departure from this, the DMU for the current study includes information gained from an extensive and careful excursion into the literature of the region. The DMU, however, is not in scientific balance. Much more careful attention was paid to geologic units in areas of greatest hydrogeological interest. Thus, for example, the Paleozoic units, of importance in the FSP area, have much more extensive descriptions in the DMU than various Proterozoic units in southwestern and southeastern parts of the study area (much in Wilderness areas) where there is little current practical interest in hydrogeology. The actual detailed descriptions of the geologic units, along with extensive reference to the literature, provide a fundamental lithologic framework for understanding the hydrogeology of the region.

The DMU further represents an attempt to make geological correlations within the region of study. This aspect of the DMU, in itself, required extensive study and analysis of descriptions of lithologies, facies, stratigraphy, and structure provided by the various authors and made at various stages in the scientific studies of the region over the past 7 decades. It has led in this study, for example, to a first-ever attempt to correlate, describe, and define so-called 'rim gravels' in this region *beneath* 'the rim' (Mogollon Rim). We postulate, from extensive evidence, that the consistently oldest Tertiary unit throughout the MRWRMS area, a basal gravel (Toc, Tertiary older conglomerate) is equivalent to the so-called 'rim gravel' of Mogollon Rim Formation (Potochnick, 1989) widespread on the Colorado Plateau in the Mogollon Rim region. This is important to aspects of the study relating to structural controls of groundwater.

Gæaorama's part of the MRWRMS project is a comprehensive study, incorporating the creation of a geospatial database, of the geology of the region with an emphasis on structural geology. It does not, in itself, focus on the hydrogeology although it clearly provides a strong foundation for the understanding of the hydrogeology. And, at this foundational stage, it leads directly to a number of important preliminary conclusions about groundwater, new questions regarding hydrogeology, and points to areas of groundwater potential in and near various subdivisions in Gila County. These are discussed in the report; directions are suggested for further hydrogeologic work and groundwater exploration that can be built on this foundation.

GIS DATABASE

Earlier studies by Gæaorama and Southwest Ground-water Consultants in the Payson area, first presented maps drafted by conventional means, then digital maps created in CANVAS, and finally maps created in ArcVIEW 3 and finalized in Adobe Illustrator for cartographic purposes. No other geologic mapping in the MRWRMS study area had been previously digitized.

The current study migrates previous digital products into a state-of-the-art geospatial database. Mapping of other authors has been digitized and incorporated into this regional database for the MRWRMS area. Gæaorama is currently doing this work in Environmental Science Research Institute's (ESRI) ArcGIS 9.1. We also make extensive use of Autodesk's AutodeskMAP which is AutoCAD with an added GIS module. The cross-sections of Plate 4 were done in AutoCAD.

The complete Geodatabase, including metadata, and a digital version of this text report are including in a CD with each printed and bound copy of the final report. The complete digital product standing alone on CD is available to any party on request to Gæaorama, to the Town of Payson, or to the Bureau of Reclamation. *(check to confirm this)*

At this stage, the geologic database of the MRWRMS area is deficient in that little of the extensive bedding, foliation, and joint attitude data has been incorporated due to time constraints. Extensive local use of this structural data (particularly in the FSP area) was made in evaluating structural geology for the current study, but time has not permitted digitization of the data. Otherwise the digital geology is nearly complete. The database can be expanded and improved in other ways. For example, descriptions of map units, tables of water chemistry, or photographs could be integrated digitally so they can be individually viewed by clicking on a polygon, data point, or waypoint of interest.

This digital geologic database provide a foundation for the region. It can be built upon geologically, it can be integrated with other GIS data, and it will prove to be useful not only for future hydrogeologic work in the region, but for purposes relating to geologic hazards, environmental studies, natural resources, engineering, etc. It should prove useful to various governmental agencies and private industry as well.

There is currently great interest in Fossil Creek as a result of the recent decommisioning of the two APS hydropower plants and the return of full stream flow into the drainage below Fossil Springs. There are studies underway pertaining to the environment and the habitat of Fossil Creek. This, and current attempts at deep groundwater development in the Pine-

Strawberry area, have brought considerable interest to Fossil Springs itself, which has never been subject to much hydrogeologic investigation. The new findings of this report regarding the localization of the springs on the Diamond Rim fault and particularly the geospatial database of this study will be integrated into a study underway at Northern Arizona University under the direction of Professor Abe Springer. Gæaorama is collaborating with Springer and his student Megan Green for integration of our geodatabase into a three-dimensional digital model intended to illustrate the geology and hydrogeology of the greater Fossil Creek area.

FAULTS AND FAULT SYSTEMS

Geologic structures, mainly faults, of three distinct ages are present in the MRWRMS study area: Early Proterozoic, late Cretaceous to Paleocene (Laramide), and Miocene to possibly Pliocene. These will be referred to in this report respectively as Proterozoic, Laramide, and Tertiary structures. There are numerous Proterozoic and Tertiary faults but very few Laramide faults and monoclines. The overall characteristics of these types of structures and their pertinent geologic histories in the central Arizona region are discussed extensively in Appendix A of Southwest Ground-water Consultants, 1998, and details will not be reviewed here.

In this report, the minor Laramide structures will be mentioned only incidentally. Regionally, the faults are readily categorized as Proterozoic and Tertiary (Figure 2). On Plate 2, where more detail can be shown, the faults are further subdivided into four classes:

1. Proterozoic faults
2. Re-activated Proterozoic faults
3. Post-Paleozoic faults of likely Proterozoic inheritance
4. Tertiary faults

Proterozoic Faults

These are north- to northeast-trending faults that occur only in Proterozoic rocks and which themselves are about 1.65 million years old. They originated mostly or entirely in an Early Proterozoic tectonic event called the Mazatzal orogeny. These are shown in blue in Figure 2 and in Plate 2 in southerly parts of the study area. They trend northeast to north and tend to be arcuate, swinging from northeasterly to northerly. The motion on these faults was largely left-lateral with variable vertical components of movement. Two of the faults, the Agate Mountain fault and The Buttes fault, are thrust faults. All formed in a compressional tectonic regime at considerable depth in the earth's crust; deformation was largely ductile but locally brittle especially in the thrust faults. Hydrothermal solutions moving along the faults in both Proterozoic and Tertiary time have extensively cemented these faults, largely with silica, leaving them with very little porosity and permeability. Proterozoic faults, therefore, generally do not provide much passageway for the movement of groundwater and are poor targets for groundwater production. To a large extent they are sealed.

Re-activated Proterozoic faults

On several Proterozoic faults there has been re-activation that is likely of Tertiary age. The best example is the Rumsey Park fault (see Appendix A, Southwest Ground-water

Consultants, 1998) which passes northeastward through western and northern parts of the Town of Payson. Re-activation on this Proterozoic fault has resulted in creation of open space in fault breccia. Some of Payson's best wells, including Woodland # 1 and Goat Camp # 1, occur at intersections of this fault with northwest-trending Tertiary faults.

An un-named re-activated Proterozoic fault lies immediately south of Pine. It is the western of two northeast-trending faults within quartzite of the Mazatzal Group. Its reactivation is demonstrated by offset of lower Paleozoic strata.

Time of re-activation of these faults is constrained from field relations to be younger than Tapeats Sandstone for the Rumsey Park fault and younger than Redwall Formation for the fault south of Pine. The northeast trend of these faults suggests they belong to one of the systems of Tertiary faults (see below).

There is undoubtedly re-activation on other Proterozoic faults – either unrecognized at present or of little import to this study. For example, in the complex intersection of the Proterozoic Deadman Creek fault and the Verde fault in the northern Mazatzal Mountains, a strand of the Verde fault turns southward and appears to join a strand of the Deadman Creek fault. Clearly the Deadman Creek fault has exercised some control on fault topologies of the Verde fault system.

Post-Paleozoic faults of likely Proterozoic inheritance

Inheritance, or control, from Proterozoic faults can be argued for a number of northeast-trending faults (lavender on Plate 2) that are largely in Paleozoic strata. Re-activation is implied, as in the previous category, but for faults of this group there is no Proterozoic fault exposed nearby. In the case of the small Natural Bridge fault (at Tonto Natural Bridge State Park), the fault pre-dates overlying Eocene Tertiary gravel (Toc) and is therefore likely Laramide. Location of this fault could be controlled by re-activation along northward extensions of either the Houston Creek fault or the Deadman Creek fault system. This fault is important to the study because it is likely the conduit for the spring at Tonto Natural Bridge State Park.

The other faults in this category (see Plate 2) are likely faults of Tertiary age; some clearly cut Tertiary strata. Fossil Creek fault is the best example of this type of fault; it is on trend with the Proterozoic Moore Gulch fault to the southwest (Figure 2). It is almost surely a Tertiary reactivation of the buried northeast extension of the Moore Gulch fault, one of the greatest Proterozoic faults in Arizona (Conway and others, 1987). It is not likely a coincidence that the Fossil Creek fault and Fossil Canyon are directly on trend with the Moore Gulch fault. This Fossil Creek fault is also very important to the study because Fossil Springs appear to be structurally controlled by the intersection of Fossil Creek fault with the Diamond Rim fault.

A number of other northeast-trending faults in the northern part of the study area could possibly have of Proterozoic inheritance. They include the Dripping Spring fault, Bear Spring fault, Webber Creek fault, and Horton Campground fault, among others. These faults are sub-parallel and they have basically the same trend as the Proterozoic faults of the region. This suggests Proterozoic inheritance, although, unlike the Fossil Springs fault, they are not as readily tied to specific Proterozoic faults.

Tertiary fault systems

There are fundamentally three Tertiary fault systems – two older systems, one east- to northeast-trending and the other north-trending, and a younger system of generally northwest-trending but locally north-trending faults. The relative ages of the two older systems is not known, but faults of both these systems are cut by the younger northwest-trending faults. This youngest system consists of the numerous major and minor faults of the Verde graben which cuts across the study area and is more or less continuous with other basins for 250 miles northwest-southeast in Arizona's Transition Zone and into southwesternmost New Mexico.

The paucity of faults in the west-central part of the study area (between Deadman Mesa and Polles Mesa, Plates 1 and 2) is likely only apparent. Tertiary faults on all sides trend toward this area which is underlain entirely by thick basalt flows. Faults are likely as abundant here as in surrounding areas, but they are difficult to recognize and map with nothing but basalt on the mesas and in the canyon walls. The same is true of the basalt mesas north of Fossil Canyon.

The Tertiary fault systems all developed under tensional tectonic conditions. They are often complex in terms of bifurcatons, irregular surfaces, and variable dips, all of which lead at least locally to much broken ground and much open space. This is ideal for secondary porosity and secondary permeability, the latter being by far the most important for development of a high-production well.

Verde graben system

The Verde graben is a major structural system on the southwest margin of the Colorado Plateau and it results in profound complications to the regional groundwater regimes.

The graben is assymetrical. It has fewer faults and greater displacments on its southwest margin and many more faults and overall less displacement on the northeast margin. The northeast margin east of the Verde Valley (Figure 2) is a faulted hinge across which Paleozoic strata form an arch – dipping northeastward northeast of the hinge and dipping southwestward on the southwest side of the hinge. The faults on the northeast margin are mostly down-to-the-southwest, but there are also down-to-the-northeast faults; faults of opposing movement form numerous small grabens, and in some cases nested grabens, and scarce horsts. Southward from the Verde Valley into the MRWRMS area the scenario changes in that there is a major break – the Diamond Rim fault - on the northeast margin of the graben along with the numerous minor faults.

The graben is relatively simple and narrow between the lower East Verde River-Limestone Hills area and the Pine-Strawberry area – the major bounding breaks being the Verde fault and the Diamond Rim fault. Displacement in this stretch on the Diamond Rim fault varies from about 500 feet south of Pine to about 2000 feet in the vicinity of Fossil Springs. South and east of this, the graben widens dramatically; it is very complex and includes a number of minor grabens. East-side-down displacements on the northeast side of the graben are taken up by many faults and the Diamond Rim fault dies out just before it reaches the eastern margin of the MRWRMS area.

It would appear that the graben also widens and becomes more complex northwest of the narrow area discussed in the previous paragraph. The Diamond Rim fault was mapped in the current study as far northwest as Fossil Canyon. In Fossil Canyon it apparently begins to swing northward. We speculate that this swing is pronounced and that the two major strands in Fossil Canyon arc northward then northeastward and join faults mapped by Weir and others (1989) in the Sedona quadrangle (see Figure 2). The easternmost of these two faults is here given the name Apache Maid fault. Should it be demonstrated that the faults are actually continuous this name should probably be dropped in favor of Diamond Rim fault.

Numerous faults of the Verde graben system have been the subject of detailed structural analysis and groundwater targeting in the vicinity of Payson over the past 10 years. An excellent well, Goat Camp #1, was located on the Goat Camp fault (Plates 1 & 2) at its intersection with the Rumsey Park fault. These studies have shown that Payson's historically best wells occurred on or near northwest-trending Tertiary faults. As a result of these recent studies, and the discovery of large amounts of water at greater depths (700-800 feet) than previously encountered (or previously drilled), the Town of Payson deepened many old wells and thereby greatly increased water production in many of these wells.

In the complex Lion Springs graben, along the Diamond Rim fault about 5 miles northeast of Payson (Plate 2), more than 30 well sites were picked based on detailed structural mapping (Gæaorama, 2003) and on audio-frequency magnetotelluric (resistivity) surveys (Zonge Engineering, 2004). At this date no drilling has been done at these sites.

East- to northeast-trending system

In central to northern parts of the study area are a number of Tertiary faults that trend east to northeast, commonly arcing from eastward to northeastward. Some of the more prominent easterly faults are Mayberry Spring fault, Pyeatt Draw fault, Ash Creek fault, Shannon Gulch fault and Strawberry fault. This group would probably also include all or most of the northeasterly faults discussed earlier as having potential Proterozoic inheritance; most are likely Tertiary although, as discussed above, some are Laramide.

The Mayberry Spring fault is cut by northwesterly faults of the Lion Spring graben. It is likely that most of the east-west faulting predates the formation of the Verde graben system.

North-trending system

A number of faults, mostly in westerly parts of the MRWRMS area, trend northward. These include Canyon Creek, Tangle Peak and other faults to the southwest (Plate 2 and Figure 2) and a number of mostly minor faults in the upper Fossil Canyon region. It also includes the bounding faults of the Cedar Bench horst and the LF Ranch horst near the Verde fault on the East Verde River. These faults all appear to predate the Verde graben system. It is uncertain whether north-south faults (e.g. Snowstorm Mountain, Table Mountain, Pole Hollow) in the south-central part of the study area, actually belong to the north-trending system. They are in an area of complex nested north-south grabens where the Verde fault turns southward and they may just be part of the Verde graben system itself.

REGIONAL DISTRIBUTION OF PALEOZOIC STRATA

Paleozoic strata of the Mogollon Rim region dip generally northeastward as shown by structural contours at the base of the Fort Apache Limestone Member of the Supai Formation (Fig. 3). Faulting in the region of the Verde graben has disrupted what is otherwise a simple homoclinal pattern in the distribution of these strata. As discussed above, the northeast margin of the assymetrical Verde graben is basically a faulted hinge. Southwest of this hinge the strata are dropped down on faults and in places dip to the north, northwest, or west. There are irregular rotations of strata in the various blocks bounded by Tertiary faults. These disruptions are evident in the Fort Apache elevation data (Fig. 3) in the vicinity of Pine and Strawberry.

In the region of 'STRUCTURAL DISRUPTIONS' (Fig. 3), structural contour data could only be properly drawn if the faulting is taken into account; contours would be continuous and have closure only within individual fault blocks. The short black dashed contour lines in Figure 3 show how the 5000', 6000', and 6500' contour lines would be drawn ignoring faults, which would be incorrect. Faulting is so minor it can be ignored in the broad region of the red contour lines. The western limit of these red contour lines in Figure 3 is approximately the western limit to which the contour lines can be meaningfully drawn at the scale of figure 3 and without taking into account the faulting.

A point to be drawn from this discussion and from Figure 3 is that Paleozoic strata in the Pine-Strawberry area do not dip simply to the northwest toward Fossil Springs as shown by structural contour lines at the top of the Redwall Limestone in Figure 6-4 of Morrison Maierle (2003). The strata have variable dips in the various fault blocks and a given horizon drops down toward Fossil Springs by steps on the numerous Tertiary faults (Plates 3 & 4).

MOGOLLON RIM FORMATION – DISTRIBUTIONS AND IMPLICATIONS

Mogollon Rim Formation is the name given by Potochnik (1989) to Eocene gravels widespread on the plateau north of the Mogollon Rim and also on south slopes of the rim in the area between Show Low and the Salt River. These were long informally called 'rim gravels' (e.g. Peirce and others, 1979). The older conglomerate unit (Toc) of this study (Plate 1) is in part, and perhaps entirely, equivalent to the Mogollon Rim Formation. Thus in Figure 2 we show Toc, which is all south of the rim in the MRWRMS area, and conglomerate of the Mogollon Rim Formation in the Blue Ridge area as being equivalent (Tertiary conglomerate of Fig. 2). Previous studies of these units (Wrucke and Conway, 1987; Conway, 1990) show that certain distinctive clasts of Proterozoic rocks, from the New River Mountains/Mazatzal Mountains region are common to gravels of Toc and to the gravels in the Blue Ridge area.

These distinctive gravels are key to understanding the faulting on the Diamond Rim fault in Fossil Creek. They are present at canyon bottom on the western down-thrown side of the southwestern strand of the Diamond Rim fault (Plate 3). They also occur about three-fourths the way up the north and south canyon walls between the strands of the Diamond Rim fault (Plates 3 and 4). The gravels and a great deal of Paleozoic rock and Tertiary basalt have been eroded away on the east side of the Diamond Rim fault. It is not certain whether basalts capping high places (e.g. Nash Point) northeast of the fault are remnants of 'old' basalt on Eocene erosional surfaces where the gravel was not deposited or whether they are 'young' basalts deposited after gravel and 'old' basalts were eroded away in the late Tertiary. In any case, rim gravel and overlying 'old' basalt are not found northeast of the fault until the East Clear Creek area – a distance of about 15 miles. If the basalt capping Nash Peak is 'old' and sitting on an Eocene erosional surface, presumably in a site of non-deposition of the gravels, projecting this surface to the fault constrains displacement on the fault to be about 2000 feet.

Conglomerate of the Mogollon Rim Formation was not deposited continuously across the Eocene erosional surface in central to northern Arizona. In Fig. 2 where the unit 'Tertiary sedimentary and volcanic rocks' lies directly on Paleozoic or Early Proterozoic rocks, the Mogollon Rim Formation is missing. Either it was never deposited or was eroded away prior to the onset of basalt volcanism in the region about 15-20 Ma. The conglomerate may have been deposited in two broad northeast-trending belts – one in the northwestern corner of Fig. 2 and one extending between the Mazatzal Mountains and the E. Clear Creek/Blue Ridge reservoir area. Sediment transport direction was generally northeastward away from the Laramide Mogollon Highlands which occupied the area now underlain by the Basin and Range province in central to southwestern Arizona.

Mogollon Rim Formation is deposited in a very low angle unconformity across the region. It lies on Proterozoic rocks in the Mazatzal Mountains vicinity in southern parts of Figure 2. Northward it lies on succeedingly stratigraphically higher Paleozoic units until finally in the vicinity of Blue Ridge Reservoir it rests on Triassic Moenkopi Formation. In southerly parts clast are entirely of Proterozoic material, largely granite and rhyolite, with locally abundant quartzite. Northward, once the gravel rests on Paleozoic strata it begins to pick up pebbles and cobbles of sandstone and limestone. These clasts of sedimentary rock become increasingly more abundant northward and come from increasingly higher in the Paleozoic section. Still, even in the Blue Ridge area, Proteorozic clasts are far more abundant than Paleozoic clasts.

Strontium isotope studies show that water from the regional aquifer in the Flagstaff area (Bills and others, 2000) is much less radiogenic than from the Mogollon Rim region (C. Eastoe and M. Ploughe, MRWRMS report, in prep.; Parker and others, 2004). Among the potential reasons for the difference is the possibility that rain and snow recharge waters may pick up radiogenic strontium passing through the highly radiogenic felsic clastic rocks of the Mogollon Rim Formation which is present on the Mogollon Rim but not in the Flagstaff area. These gravels are up to several hundred feet thick.

RELATION OF SPRINGS TO FAULTS

Springs, wells, gaging stations, water tanks, and windmills plotted on Plate 2 are taken almost wholly from 7.5 minute quadrangle maps of the MRWRMS area and vicinity. This is a very nearly complete data set for spring locations, but probably a rather poor representation of wells, gaging stations, water tanks, and windmills. For example, there are a number of water tanks in the Town of Payson that are not shown. The spring locations are important to this section; the other data is incidental. Most of the spring locations are shown with a blue-circled 'S'. A few (Fish Hatchery, Cold, Webber,Tonto Bridge, Fossil), for which chemical and isotopic data were obtained for this study, are located with a red star.

Associated with each spring location is the name of the spring, or the word Spring if un-named, and elevation of the spring in feet.

Shown on Plate 2 are the locations of 124 springs. Sixteen are outside the geologic map and cannot therefore be evaluated in the following discussion. Springs classified as 'near' a fault in the next few paragraphs are within 500 feet of the fault – an arbitrary classification.

Of the 108 springs that can be related to geology, only 3 springs lie on or near Proterozoic faults in the study area. These are Bootleg spring 5356 (to distinguish from Bootleg spring 4923) and Spring 5025 both on the Bear Flat fault in the far eastern part of the study area, and Spring 4881 on the Lousy Gulch fault one mile south of the Town of Payson. Bootleg spring 4923 is actually in Paleozoic rocks, likely in a break 'above' the fault suggesting that a reactivation has occurred on the Bear Flat fault. Likewise Lousy Gulch fault could have some reactivation; this is suggested by the presence of two small exposures of Tapeats Sandstone between two branches of the Lousy Gulch fault which may be preserved by downdrop in a little graben. Of the remaining 105 springs, 59 lie on or near Tertiary faults or pronounced lineaments that are either faults or joints. An additional 6 springs (between Gilmore and Brushy Basin springs) aligned east-west at the south-central border of the map are likely on a basin-bounding Tertiary fault(s). Many of the remaining springs are close to faults and could lie on unmapped breaks parallel to nearby faults. Faults commonly have closely-spaced allied breaks that are not all readily mappable.

It is clear that there is extensive structural control of groundwater by Tertiary faults, but not by Proterozoic faults. As discussed above, the Proterozoic faults are largely 'sealed' – they do not carry water – they could, however serve as water barriers or aquitards, but we see little evidence of that in the study area.

The Tertiary faults in the study area are largely and probably entirely normal faults; they are tensional in nature – that is they are basically pull-apart faults. Certainly all the faults related to the Verde graben are normal faults. Faults formed under tension tend to have relatively large amounts of open space in which water can reside and along which water can travel quite rapidly. Such open space provides for what is called secondary porosity and secondary permeability. This is enhanced porosity and permeability above that provided in normal pore space between grains in sandstones and between crystals in limestones.

However, there are heterogeneities in the Tertiary faults. They can in places have little or no permeability and porosity due largely to the presence of clay-rich fault gouge or to veins that have filled the fault. The presence or absence of clay-rich fault gouge is a function of both local fault topology and of rock type. Because fault geometries can be very complicated due to fault irregularities, not all parts of normal faults are purely pull-apart. Some can have compressional characterisitics thus yielding minimal open space. Hard quartz-, feldspar- and calcite-rich rocks tend to rupture brittlely preferentially yielding breccia with relatively more open space. Soft rocks, particularly clay-rich rocks (shales, shaly and silty sandstones) lend to the formation of fine-grained fault gouge with little porosity and permeability. Formation of clay and/or calcite upon chemical decomposition of fault wallrock may also result in impermeable fault zones. Basalt, common in the study area, is a rock type that would readily form clay and calcite.

Thus faults, or portions of faults, can be impervious, preventing water from either passing along the fault or passing through the fault. Many springs occur along faults whose trace is more or less parallel to contours on slopes (common in the margins of the Verde graben and nested grabens) where it is clear that water has been dammed thus raising the local water table and resulting in formation of a spring. [Such instances must be carefully evaluated before they are used in the formation of a regional water table map – they can represent local perched aquifers and not the regional water table of interest.]

With the exception of Fish Hatchery spring, all the major springs in the study area lie on Tertiary faults. This includes, from west to east, Fossil Springs, Tonto Bridge Spring, Webber Spring, Cold Springs, and Pieper Hatchery Spring. The structural geologic settings of some of these springs are discussed below.

Fossil Springs

Fossil Springs consists of several dozen individual orifices, with the great bulk of the discharge coming from about a half dozen. These are distributed over a distance of about 300 yards either in the bed of Fossil Creek or in the north ledgy wall of the east-west section of the creek. Five individual springs are shown on the USGS Strawberry 7.5' topographic map; these are all actually in the lower part of the spring array. The biggest spring is the furthest upstream; it and two other springs, one large and one small, apparently issue from the Fossil Springs fault. These three springs are disposed on a straight line having an azimuth of 72°, which is essentially identical to the strike of the mapped Fossil Springs fault, and they lie on the extrapolation of the fault into the alluvium of the drainage bottom.

The other springs, to the southwest and on the south side of the Fossil Springs fault, issue mostly from a single horizon in the Naco Formation – a shaly layer between massive limestone beds. Likely these springs are fed also from the Fossil Springs fault which is only a few hundred feet to the north. These Naco beds lie perhaps 30 to 80 feet stratigraphically above the contact with the underlying Redwall Limestone which is exposed in the vicinity of the dam only another quarter mile to the west. On the north side of the north-side-down Fossil Springs fault the Redwall would be perhaps another 50 to 100 feet deeper. Detailed mapping and some cross-section constructions in the vicinity could considerably further constrain the stratigraphic and structural relations.

It seems likely that the Fossil Springs fault serves as a conduit to bring groundwater from the east-northeast to Fossil Springs. It seems likely also that the channelway is more complex than simply open space in the fault. Given that the wallrock of the fault is limestone of the Naco Formation and, at very shallow depth, limestone of the Redwall Formation, it is possible that solution passageways in the limestones also play a role in the water transmission.

A complex nexus of the Fossil Springs fault, the Flume fault, and the three strands of the Diamond Rim fault lies about a quarter mile west of Fossil Springs and beneath a great travertine bench. This travertine mass, no doubt deposited by ancestral Fossil Springs, is ¾ mile by ½ mile in lateral dimension and up to perhaps 200 feet thick. The top of the ledge is approximately 400 feet up a shear cliff from the canyon bottom. This travertine deposit is found only on the north side of the creek. It post-dates the faults and the various geologic units – Naco Formation, Supai Formation, and Tertiary basalt – that are juxtaposed on the faults and which lie beneath it.

The canyon bottom has been deepened by at least 200 feet since the travertine bench was deposited. The bench is the remnant of a great travertine dam which stretched from wall to wall across Fossil Canyon. There is no radiometric date on the travertine, but the geomorphological relationships suggest that it may be on the order of hundreds of thousands to several million years old.

It would appear that the Diamond Rim fault has long served as a barrier, at this site, to groundwater draining generally westward to southwestward away from the deep regional aquifer groundwater divide about 20 miles to the east (Fig. 2). Clay minerals and calcite formed both mechanically and chemically along the fault, largely from breakdown of the Tertiary basalt, have likely caused the subterranean damming. The spring waters have historically been, and still are, oversaturated with $CaCO_3$ which resulted not only in subaerial precipitation of calcium carbonate in the form of travertine/tufa, but perhaps also in the build-up of calcite veins in the faults. Whether the latter is feasible from a purely chemical perspective is beyond the scope of this report. Empirically, however, spring position has migrated not only downward with deepening of the canyon, but also upstream implying eastward build-up of minerals (veining) in the Fossil Creek fault.

Tonto Bridge Spring

Tonto Bridge spring lies in a developed area at the eastern margin of a large meadow atop the travertine bridge at Tonto Natural Bridge State Park. Exposure at the spring is poor. It appears there are two possible structural controls on the spring – unconformity and fault. The spring lies on or near the northward projection of the unconformable contact of the Martin Formation resting on Proterozoic rhyolite porphyry (Xdrp, Plate 1). The Tapeats Formation is missing at this location. Also, the spring lies at or near the projected intersection of two faults (Plate 2) - the Natural Bridge fault and a minor northwest-trending fault. The northeasterly Natural Bridge fault appears to be overlain by rim gravels (Toc); thus it may be a Laramide fault.

The Tonto Bridge Spring has a number of things in common with Fossil Springs – build-up of huge travertine dam, downcutting of canyon since travertine dam formation, similar water geochemistry including Sr isotopes (C. Eastoe and M. Ploughe, MRWRMS report, in prep.; Parker and others, 2004; Hydro Systems Inc., MRWRMS report, in prep.), and a fairly consistent historical discharge rate. Differences between the two springs are a huge difference in discharge rate (Fossil ~20,000 gpm; Tonto Bridge ~800 gpm), and geologic setting. Whereas Fossil Springs discharge from the Naco, and presumably the upper Redwall, Tonto Bridge Spring discharges from the very base of the Paleozoic section and possibly right at the unconformity. Yet, the spring water at Tonto Bridge does not 'see' the Precambrian rocks isotopically. This has implications for the role of several faults in the area, as explained in following paragraph.

Parker and others (2004) found in doing strontium isotope analyses (entirely in the MRWRMS area) that in most cases $^{87}Sr/^{86}Sr$ values in spring water were extremely close to $^{87}Sr/^{86}Sr$ values in wall rocks of the spring. The Tonto Bridge Spring is a major exception. Tapeats Sandstone at Tonto Bridge (Parker and others, 2004, Table 11; there is uncertainty of unit sampled – perhaps a basal sandy facies of Martin) gives the most radiogenic value (.71233) of any rock or water sample in the region either from MRWRMS data or from Parker and others (2004). This value is likely a reflection of detritus from Proterozoic granite and rhyolite in the 'Tapeats' sample. Yet the Tonto Bridge spring water (.70912) is similar to values obtained from the Redwall, Naco, and Supai rocks and also from Fossil Springs. It is clear also that the Natural Bridge spring water is not 'seeing' either the rim gravels (highly radiogenic) or the Tertiary basalt (non-radiogenic) which combine to make a cap several hundred feet thick on Buckhead mesa immediately to the east of the Spring. It would appear that the source of the spring water at Tonto Bridge is the middle to lower part of the Paleozoic section of the Mogollon Rim and that the water has passed through the Diamond Rim fault (2 miles to the northeast) and under Buckhead Mesa.

On hydrogeologic grounds alone, one can readily make the argument that Tonto Bridge Spring must have a source north of Buckhead Mesa and therefore north of the Diamond Rim fault. This spring, with not too much variation in flow at around 800 gpm basically year-round, cannot have its source in re-charge to Buckhead Mesa south of the Diamond Rim fault, a rather small area of only 6-8 square miles immediately east of the spring. Similar, much larger mesas in the area, for example west of Pine Creek, contain only tiny springs and seeps.

The strontium isotopic data confirms what was ascertained from geological arguments and provides powerful evidence that the source of spring water at Fossil Springs and at Tonto Bridge Spring is the same – what we call in this report the deep regional aquifer. They are on opposite sides, however, of a secondary groundwater drainage divide which runs northeastward from about Strawberry Mountain to the regional drainage divide beneath the East Clear Creek area (see Fig. 2).

Whereas at Fossil Springs the Diamond Rim fault is fundamentally impenetrable by groundwater, at Buckhead Mesa the same fault permits an 800-gpm-flow-through which breaches the surface at Tonto Bridge Spring. The northeast-trending Natural Bridge fault may be the channelway for the flow beneath Buckhead Mesa; as such it would be the only known Laramide fault in the study area with from which a spring issues. Alternatively, and less likely, the water could be moving along the unconformity and just happen to emanate at the intersection of the two faults.

Weber Spring and Flowing Spring

Weber Springs and the two un-named springs (Spring 4654 and Spring 4650) at the Flowing Springs subdivision (Plate 2) are in an area of complex Tertiary faulting along the East Verde River about 4 miles north of Payson. They are also near the base of the Paleozoic section. The un-named springs are within and perhaps near the top of the Tapeats Sandstone (poor exposure). Webber Spring, ½ mile northeast of the un-named springs, issues from several horizons within the Martin Formation.

The two un-named springs are near the intersection of the north-trending Flowing Springs fault and an east-west fault extending eastward from the small Cherry Spring graben. The northern of these two springs flows well during wet seasons and stops flowing in dry times. It was not flowing when investigated in summer 2004. The other spring has a very small consistent flow and keeps a pond full on private property. Obviously these two springs, even though close, are controlled by separate channelways.

Weber Spring discharge rates have varied in three measurements from 1,570 gpm to 996 gpm (Parker and others, 2004). Chris Miller (pers. comm., summer 2004), who has lived in Fossil Springs subdivision for many years, reports marked variations in flow from dry to wet periods. This spring, which lies close to an small auxiliary fault of the Weber Spring fault, is dependant to a large extent on annual recharge for its water source. Its highly radiogenic $^{87}Sr/^{86}Sr$ (.71132) indicates, however, that a substantial portion of its water has equilibrated with Proterozoic granitic rocks. It is likely that much of its water has come from the north, across the Diamond Rim fault. Only 1-1/2 miles to the northeast, immediately on the north side of the fault, is a large mass of coarse porphyritic granite (unit XYg). It seems likely this granite and/or other high-potassium Proterozoic rocks buried just north of the Diamond Rim have imparted an isotopic character to water moving downslope in the deep regional aquifer which manifests itself in waters of Webber Spring.

As at Tonto Bridge Spring, spring water at Webber has surely passed through the Diamond Rim fault. Webber Spring is another point of discharge for the deep regional aquifer.

Cold Spring

Cold Spring is somewhat analogous in its setting to Tonto Bridge spring – it is on both a fault and the regional unconformity. The relations are more clear, however, at Cold Spring. The spring lies near the west end of the 9-mile-long east-west Ellison Creek fault. It would appear that the fault has served to at least partially dam the water and that the water has traveled westward down-gradient along the fault. It is somewhat puzzling that the spring did not form further west where the Ellison Creek fault drops down into the East Verde River drainage. An explanation may be that a change in rock type beneath the unconformity resulted, for some reason, in impermeable fault gouge. Thus water moved westward along the fault through Paleozoic rocks then discharged where the Precambrian basement became exposed on the fault.

Three discharge measurements from 1952 (Parker and others, 2004) give 830, 1,060, and 4,200 gpm. It now generally runs about 2,000 gpm (M. Ploughe, 2004, pers. comm.) but is strongly influenced by variations in precipitation. Moderately radiogenic strontium (.71057; E. Eastoe and M. Ploughe, MRWRMS report, in prep.) is similar to water and to Supai 'wall rock' at the Tonto Fish Hatchery Spring and is also similar to surface water at Blue Ridge Reservoir. It may be that surface water in this area might not be readily distinguished from groundwater equilibrated with middle to lower Paleozoic strata. The isotopic data suggests, however, that unlike Webber spring, the water of Cold Spring has not pickup up significant radiogenic strontium from passage through Proterozoic basement. This is consistent with the observation in the previous paragraph that water was not able to move down along the fault into the Proterozoic rocks.

Thus it appears that Cold Sring is fault controlled and also unconformity controlled. Ellison Creek fault dammed the water to a certain extent and provided passage for the water. How leakey this 'dam' was cannot be ascertained at this point.

FOSSIL CANYON-STRAWBERRY-PINE AREA

A geologic map (Plate 3) and geologic cross-sections (Plate 4) provide details at 1:24,000 scale) of the structure and stratigraphy of the Fossil Canyon-Strawberry-Pine area. Through extensive new mapping, the current study adds considerably to previously published maps – notably in identification of new faults and particularly in extending the Diamond Rim fault from Pine Creek northwestward to Fossil Creek.

The Diamond Rim fault at Pine Creek has a south-side-down displacement of about 500 feet (cross-section A-A’). Displacement in the northeast margin of the Verde graben in this area is partly distributed to faults further south along Pine Creek. Northwest from Pine Creek, the fault bifurcates so that there are three strands in Fossil Creek. As discussed earlier, in the section on the Mogollon Rim Formation, there is approximately 2,000 feet of total displacement on the fault in Fossil Creek.

Strata of the Supai Formation on the Hardscrabble road southwest of Pine have highly variable dips due to much minor faulting on the northeast side of the Diamond Rim fault. But a rough average dip is gently to moderately to the northeast. From this and other structural data, it appears that the Paleozoic beds have been somewhat upturned in the vicinity of Strawberry Mountain. The Fort Apache Limestone was truncated by erosion, presumably in the Laramide orogeny, under southern Strawberry Mountain and also at Nash Pasture Tank at the west end of Strawberry valley. The line of truncation parallels the Diamond Rim fault immediately off the fault to the northeast. This may suggest that 1) this was a zone of Laramide uplift with a possible monocline trending northwestward and dipping northeastward, and 2) that the local position of the Diamond Rim fault may be controlled by the Laramide structure. In other words, the Diamond Rim fault could be a re-activated Laramide structure, with the opposite sense of movement.

The east-west Strawberry valley owes its presence largely to preferential erosion along the Strawberry fault. The Strawberry fault could actually consist of a number of parallel breaks even though it is shown on Plate 3 as being a single fault. The fault appears to bifurcate on its eastern end (Plate 3). Several generally north-trending faults were also mapped in this study across Strawberry valley. These are part of the same north-south fault system mapped by Weir and Beard (1997) crossing Calf Pen Canyon and Sandrock Canyon to the north of Strawberry. Offsets on these faults range from perhaps 25’ to 100’ and are mostly down to the west (cross-section B-B’. Preferential erosion on parts of these faults has resulted in roughly north-south drainages and divides in the higher terrain north and south of Strawberry valley.

Similarly, the basin occupied by the village of Pine owes its existence to preferential erosion along faults, primarily the LoMia fault and the Strawberry Hollow fault. The water courses of Pine Creek and Strawberry Hollow closely follow these two faults. The upper part of The Narrows through which Pine Creek leaves the Pine basin is also structurally controlled; the drainage follows the Strawberry Hollow fault for more than half a mile. Dripping Spring fault is down to the north as determined primarily by the offset of a thin, probably discontinuous limestone unit (Psll) in the lower part of the Supai Formation in the Hardscrabble road area.

Dripping Springs on the west face of Milk Ranch Point lie on the Dripping Springs fault and owe their presence to water being carried down along the fault zone from recharge areas atop Milk Ranch Point. They are an example of a perched aquifer, dependant entirely upon annual recharge for replenishment.

Preferential erosion along the various faults in Pine and Strawberry is instructive. It indicates that the fault zones are soft zones, that they are not occupied by resistant vein material. They are soft zones, easily weathered and eroded, because they contain broken-up material. This material may be as small as clay-rich fault gouge or as coarse as blocky fault breccia with individual clasts and open space as large as inches to perhaps locally feet. This bodes well for the presence of groundwater in these zones and for the potential in these zones of excellent secondary permeability. A nexus of faults in the south part of Pine provides a superior target area for groundwater.

On the south margin of the Pine basin is a resistant somewhat high-standing mass of quartzite; this quartzite belongs to the regionally widespread Early Proterozoic Mazatzal Group. This rock is almost pure quartz and is exceedingly hard. Mapping shows that this quartzite exposure, like a number of others in the central Arizona region was a monadnock on a regional peneplane when shallow seas flooded the continent and Paleozoic sedimentation began. When the area was covered with shallow early Paleozoic seas it may have stood emergent as an island. From all directions the lower Paleozoic units lapped out against this resistant quartzite mass. Tapeats Sandstone is entirely missing near the quartzite. Overlying Paleozoic Formations, as high as the Naco rest directly on the quartzite. This relationship is shown best in cross-section E-E' but also in cross-sections A-A' and B-B.' Redwall Limestone rests on the quartzite in the south Part of Pine (Plate 3) and Naco Formation rests on the quartzite at the southernmost end of cross-section A-A' just south across the Diamond Rim fault. The steep westward dip of the base of the quartzite (near Hwy 87) and distribution of attitudes within the quartzite suggest it is distributed in a syncline as shown in cross-section B-B.' Note that a well penetrates the quartzite giving some control in the construction of this part of cross-section B-B.' The well in the southern part of cross-section E-E,' which bottoms in Martin Formation constrains the northern paleoslope away from the quartzite prominence to be quite steep. Proterozoic units Xe (East Verde River Formation) and Xu (Undivided) are best guesses at what type of Proterozoic rock might lie beneath the cross sections of the Pine-Strawberry area. It is unlikely that quartzite will be encountered by drilling except in southernmost parts of Pine.

Thicknesses of Paleozoic units as shown in the cross-sections (Plate 4) are probably accurate in most places to ±20 feet and relatively minor lateral changes in thickness as shown are for the most part real. Some of these thickness changes are described in the Description of Map Units. The unusually wavy contact line between the Naco Formation and the Redwall Formation is intended to reflect the irregular nature of this contact in space. The irregularity is due to a karst topography which developed on the surface of the Redwall prior to deposition of the Naco. Because of this, thicknesses of the Redwall and Naco are quite unpredictable; again see the Description of Map Units for details. The total thickness of the Redwall plus Naco is better controlled and this was used for construction of the cross-sections.

Logs of four wells were extremely useful in constraining the cross-sections. These are logs for the Strawberry borehole of the Northern Gila County Water Plan Alliance (Corkhill, 2000); for the Strawberry Hollow well (M. Ploughe, 2004, pers. comm., ADWR Application No. 22-401908); for a preliminary 740-foot boring in southcentral Pine (Highland Water Resources Consulting, 2005; ADWR Application No. 55-205322); and for a boring that bottomed in quartzite (need to locate file on this). Schematics of these wells, with formational boundaries and depth to water table, are shown in various cross-sections of Plate 4. Plate 4 also contains an explanation of the well schematics.

The numerous cross-sections drawn through Pine closely constrain the actual attitudes and thicknesses of the various units and also the offsets on the faults. There is a huge amount of information and spatial data in these carefully constructed sections which could never be fully or properly explained by tens of hundreds of pages of text, but which can visualized, understood, and appreciated to a great extent by thorough study of the cross-sections and maps in tandem.

SPECULATIONS ON AQUIFER SYSTEMS

Except in a small area of thin basin-fill sand and gravel a few miles southwest of Payson, groundwater in the MRWRMS area is hosted in bedrock; the only significant water resources are in bedrock. The bedrock groundwater systems are exceedingly complex because the physiography and geology are complex.

The study area contains the great escarpment of the Mogollon Rim. Elevations range from 7,500 feet on the rim down to almost 3,500 feet on Tonto Creek in the southern part of the area. The topography is rugged, resulting in numerous minor surface drainage divides. The area contains parts of three regional drainage basins: Little Colorado River north of the Mogollon Rim; Salt River including Tonto Creek and its tributaries; and Verde River including Verde River, East Verde River and their tributaries. Groundwater divides mimic the surface divides. Groundwater gradients are locally very steep (see Fig 2).

Rain and snowmelt recharge waters percolate down, variably, through Tertiary volcanic and sedimentary rocks, Tertiary gravels of the Mogollon Rim Formation, sandstone and limestone of the Paleozoic section, and through Proterozoic rocks such as granite, gabbro, and metamorphic rocks (see Figure 2). Inherent porosities and permeabilities are highly variable in these rocks; superimposed on that are the strong controls on groundwater of the Proterozoic and Tertiary fault systems in the area. The classic notion of an aquifer as a distinct sedimentary layer or group of layers having relatively high porosity and permeability is of very limited applicability in the study area. The best known and simplest of the aquifers, the C aquifer, consisting of the Coconino Sandstone and the Supai Formation, really loses its definition where these formations are exposed in the slopes beneath the Mogollon Rim.

Likewise, the concept of a limited recharge area - where the strata of an aquifer are exposed - also has very limited applicability. Certainly the exposures of Coconino Sandstone and Supai Formation on the slopes beneath the Mogollon Rim provide *no* recharge to the C aquifer extending northward beneath the Little Colorado River region. Recharge received in these formations in the study area either remains shallow and issues as springs not far downslope or it percolates down to the water table in lower Paleozoic strata or Proterozoic rocks. Recharge occurs throughout the area although it is far more effective in some rocks than others. For example, in the Payson area, Payson Granite readily accepts recharge whereas the gabbro/diorite of the Gibson Creek Intrusive Suite does not (see Appendix A, Southwest Ground-water Consultants, 1998).

What appears to be emerging from the limited 'deep' drilling in the area and from isotopic data is that below a certain depth, the rocks (of whatever rock formation) are saturated with mostly 'old' water that has moved southward to westward from the drainage divide of the deep regional aquifer (see Fig. 2). Currently, if this water is in the Coconino or Supai Formations it is said to be in the C aquifer; if it is in the Redwall or Martin formations it is said to be in the 'limestone aquifer;' if it is in Proterozoic rocks it is said to be in the X aquifer. We suggest this is all quite meaningless in the current study area and we present the following conceptual model for a deep regional aquifer. This is modeled somewhat after Bills and others (2000) who use the term regional aquifer basically for the C aquifer but modify it to include important variations such as local 'mounds' of water up into the Kaibab Limestone.

We suggest that throughout much of the study area a certain fraction of the recharge water moves virtually unimpeaded downward through the extensive Tertiary fracture and fault systems of the region to a deep regional aquifer. There is much greater precipitation and much greater recharge from the plateau country north of the Mogollon Rim. The relatively continuous groundwater surface in this aquifer lies generally at depths on the order of, perhaps, 500 feet to 2000 feet; depth from place to place is highly variable because of locally great topographic relief. Beneath this level the rocks are everywhere saturated. This groundwater surface mimics the earth surface to a certain extent, being, for example, very steep beneath the steep slopes below the Mogollon Rim. This is not a potentiometric surface because there is no real confining layer, although, locally, unusual conditions may cause water to rise under a hydrostatic head to a level in a well above the regional water table. This deep regional aquifer is not defined by rock type – it is defined fundamentally by distance from the earth's surface, and its geometric properties are permitted by the extensive fractures in the region. The fractures are the key. Structural disruptions on the northeast margin of the Verde graben (see Fig. 2, 3) permit ready downward percolation almost everywhere and make this system an unconfined aquifer. We call it the deep regional aquifer. We argue it is pointless to attempt division of this deep regional aquifer in the study area into other aquifers such as C aquifer, 'limestone' aquifer, or X aquifer. Northeast of the Verde graben, however, the deep regional aquifer changes into the different classical bedrock aquifers of the southernmost Colorado Plateau.

Above this deep regional aquifer are countless more or less perched tiny to fairly large 'aquifers.' These are controlled by rock type and by faults. They are more common along faults. In places they exist on slopes as water dammed behind impermeable faults. The great majority of springs in the region are from these highly variable perched aquifers. Because of this it is quite meaningless to use spring elevations in an attempt to draw a groundwater elevation map. There is little or no continuity between these perched aquifers. The only groundwater elevation map that can have any meaning must be drawn on the deep regional aquifer and it can only be drawn from well data and from the few, generally large, springs that can be demonstrated to have their origin from the deep regional aquifer.

GROUNDWATER POTENTIAL

It is not the purpose of this report to actually determine specific sites for water well drilling. Nevertheless, a number of potential target areas have become obvious and merit discussion in this report. Loosely, these target areas are faults or fault intersections in or near tracts of unincorporated private property – county subdivisions. Payson will not be discussed in this section as it has been the subject of an earlier report (Southwest Ground-water Consultants, 1998)

The thesis underlying the groundwater potential here discussed is that significant to pronounced secondary permeability may be encountered in faults and fractures. The objective would be to drill into such zones of secondary permeability within the deep regional aquifer which can typically be reached at about 1000 feet, in many places shallower. The idea would be to construct relatively large-capacity wells to provide for subdivisions. This report should not be taken as a guide for drilling on individual private parcels. For these small parcels, low-budget shallow wells might better target perched aquifers away from faults. Fault and fracture systems at shallow depths might be dry because the water could readily drain down to the deep regional aquifer.

Ideally, detailed exploration should be undertaken to determine optimal drill sites. This could involve more detailed geologic structural analysis to better locate the faults and could also involve geophysical techniques to image the subsurface. Audio-magnetotellurics (AMT, a resistivity method) has been employed with considerable success in recent years in Arizona. For example, the drilling of a deep well (>2,000 feet) into a fault zone in the Supai Formation in the Belmont area west of Flagstaff (Gary Small, Hydro Systems, Inc., pers. comm., 2005) was guided by AMT. Two previous unsuccessful wells (11 and 23 gpm) failed to intercept the fault. Two wells guided by AMT did encounter the fault zone and produced 73 and 371 gpm. One of the successful locations was only 300 feet from one of the first, unsuccessful, wells (Norm Carlson, Zonge Engineering, written comm., 2006). Optimal well siting and then carefully controlled penetration of fractures beneath the water table are absolutely essential to ensure successful drilling.

Pine-Strawberry area

Strawberry valley is traversed by an east-west fault system and numerous north-south faults. Thus there are a number of potential targets; fault intersections should be given top priority. Wells will ideally be drilled to depths of 1800 to 2000 feet and the water level will be about 1400 feet, based on the one deep well drilled so far (Corkhill, 2000). A number of faults traverse Pine; they, and particularly their intersections, present a number of targets within the community. They are advantageous compared to Strawberry targets in that the water table will be at about 600-800 feet and the wells need be drilled only to about 1200-1400 feet. Locally, the Redwall Limestone may be partly beneath the water table (see cross-sections, Plate 4). Wells sited in such places would have a possible added advantage in that cavernous areas within the Redwall could be intercepted, providing potentially huge secondary permeability. This should not be a primary consideration, however, in siting the wells. Water can potentially be produced in large quantities from any rock unit, including granites and other rock types of the Proterozoic basement, provided fault systems are properly intercepted within the deep regional aquifer.

Geronimo Estates

The Webber Creek fault passes through a considerable part of the Geronimo Estates subdivision along its southeast margin. This normal fault dips to the northwest, beneath the subdivision, thus providing excellent potential drill sites within the subdivision. Shannon Gulch fault also passes through the subdivision and it has an intersection within the subdivision with a minor fault. This fault, and particularly the fault intersection, present good groundwater possibilities.

Whispering Pines

The Dude Creek fault and the Brody Hills fault intersect in the northernmost part of the Whispering Pines subdivision. Production of water from this point would be ideal as it could be gravity fed downhill to the rest of the subdivision. Displacements on these two faults, particularly the Dude Creek fault, may be small, however, and so open space in the fault might not be so well developed. The Willow Spring fault, with considerably more displacement (several hundred feet), lies only one-quarter mile west of the subdivision. Its intersections with the Dude Creek fault and the Brody Hills fault are also potential target areas for the Whispering Pines subdivision.

Other subdivisions

The Mayfield Canyon fault cuts across the southwestern part of Dealer's Choice and the Diamond Point Shadows fault cuts across the northern part of Diamond Point Shadows. These faults offer excellent opportunities for groundwater from the deep regional aquifer.

Star Valley is transected by a number of faults and contains several fault intersections.

Mead Ranch subdivision is transected by the east-west Ellison Creek fault.

A number of small subdivisions in the Kohls Ranch area are transected by faults or are close to faults.

DESCRIPTION OF MAP UNITS

(For Plates 1-3)

Quaternary Sediments and Sedimentary Rocks

Qa1 **Alluvium (Holocene)**—Unconsolidated clay, silt, sand, and gravel. Mapped chiefly along major drainages. Locally includes terrace deposits at higher levels than drainage bottoms. Includes fine-grained materials, including moderately developed soils, in large flats. Includes extensive granite grus where underlain by Payson Granite.

Qc **Colluvium (Holocene)**—Veneer of unconsolidated materials, generally containing large amounts of silt, sand, and fine angular gravel on slopes. Deposited largely by masswasting processes. Shown as mapped widely by Weir and Beard (1997) in Fossil Creek as well as locally elsewhere on the map.

Q1 **Landslide deposits (Holocene and Pleistocene?)**—Broken and dislocated slump masses and debris flows. Common on steep walls of canyons and steep slopes of mesas where Tertiary basalt caps softer sedimentary strata. Locally consists of glide blocks of broken but stratigraphically coherent Paleozoic strata. Includes some talus.

Qt **Talus deposits (Holocene and Pleistocene?)**—Blocky rubble on steep slopes. Generally contains small amounts of clay-, silt-, and sand-size particles.

Qtc **Talus and colluvium (Pleistocene)**—Widely varying unconsolidated material, primarily immediately west of the Snowstorm Mountain fault. Ranges from pre-fault to post-fault deposits.

Qg **Gravel (Pleistocene)**—Unconsolidated and weakly consolidated gravel, sand, and silt in terrace deposits along drainages, and poorly sorted pebble to cobble and locally boulder alluvium in isolated patches and old fan deposits. Highly variable. Commonly dissected. Some could be Tertiary.

Qtr **Travertine and tufa (Holocene, Pleistocene and possibly Pliocene)**—Generally light- to medium-gray to yellowish-gray, dense to porous carbonate deposited by springs; in part cavernous. Main occurrences are the deposits of the huge travertine bench above Fossil Springs in Fossil Creek (Weir and Beard, 1997), and the travertine bridge at Tonto Natural Bridge State Park in Pine Creek (Wrucke and Conway, 1987). A number of smaller deposits in the area commonly associated with springs. Woody plant material and angular talus rocks commonly imbedded in the calcareous deposits.

Travertine at Fossil Springs as much as 120 feet thick; forms conspicuous bench about 0.7 mi wide and 1 mile long (Weir and Beard, 1997).

Qp **Pediment alluvium (Pleistocene or Pliocene)**—Loosely consolidated sand and gravel on pediment surfaces. Primarily in upper Rye Creek drainage basin and on knobs in the northern parts of community of Pine.

Tertiary Sedimentary and Volcanic Rocks

Tg **Gravel (Miocene)**—Weakly consolidated, poorly sorted, crudely stratified pebble to boulder alluvium locally containing thin beds and lenses of pebbly sandstone. Deeply dissected. Forms cliffs and gentle to steep slopes strewn with pebbles and cobbles. Mapped chiefly on ridges in the vicinity of the confluence of Pine Creek and the East Verde River and in the Lion Spring graben under the Diamond Rim and in the Houston Pocket area. In the latter area clasts tend to be coarse and angular and are derived from Proterozoic and Paleozoic outcrops to the north. In general, rocks of this unit were derived as a result of latest faulting and basin subsidence in the region. Could be roughly equivalent to Tyc, but is likely younger. Thickness up to perhaps several hundred feet.

Tls **Limestone (Pliocene of Miocene)**—Light-gray to yellow-gray, thick-bedded massive limestone that rests on basalt (Tb) on Polles Mesa and Whiterock Mesa in west-central part of map area. Contains abundant irregular vugs 1-10 mm across, partly lined with secondary calcite. Closely resembles limestone of the Tertiary gravel and limestone unit (Tgl), with which it is likely correlative. Weathers medium gray. Maximum thickness about 120 feet.

Tgl **Tertiary gravel and limestone (Miocene)**—Gravel, sandstone, and interbedded limestone primarily in the upper Rye Creek area; smaller isolated deposits near Payson and eastward. Deposited on a middle Tertiary erosional surface having local relief up to several hundred feet. Deposited in closed basin prior to downdropping of graben between the Snowstorm Mountain fault and the Verde fault.

In Rye Creek, heavily cemented with calcite in lower parts that are well consolidated; otherwise poorly cemented and weakly to moderately consolidated. Abundant breccia in lower parts composed largely of diorite and gabbro derived locally from unit Xgc. In thicker parts to the west, upper half of section contains quartzite and rhyolite clasts derived from the Mazatzal Mountains nearby to the west and coarse porphyritic granite possibly from regions to the south. Lacustrine limestone beds in upper parts of the thicker western section south of the Verde River contain plant fossils. These pale orange, medium-gray weathering limestone are in beds up to 10 feet. Upper gravel beds in northerly exposures south of East Verde River possibly equivalent to gravel of unit Tg. More than 600 feet thick in boreholes near the Baby Doll ranch (Town of Payson Water Department, 2004).

Unit includes ‘gray gravels’ (Tgg, Gæaorama, 2003) of the Lion Springs graben that contain abundant limestone, dolomite and sandstone clasts from the Paleozoic strata of the Diamond Rim. These gray gravels contain widespread abundant carbonate cement but no continuous limestone layers; they contain minor clasts derived from underlying older conglomerate (Toc).

Tst **Siliceous tuff (Miocene)**—White to tan tuff and tuff breccia interbedded with Tertiary basalt (Tb) at Fossil Creek, Hardscrabble Creek, Squaw Butte, and further south along the Verde River. Notable for soft white pumice fragments and for angular lithic clasts; latter are Tertiary silicic volcanics. Single bed about 50 feet thick in Fossil Creek near Fossil Springs. Two closely spaced beds in lower Fossil Creek and Hardscrabble Creek. Age at Black Ridge (west of study area 1.5 miles northwest of confluence of Verde River and Fossil Creek) as dated by K-Ar methods is 11.0 ± 0.6 Ma (Wrucke and Conway, 1987).

Ttg **Tuffaceous gravel (Miocene)**—White to light gray gravel interbedded with basalt (Tg) about a mile downstream from Fossil Springs along flume road. Distinctly different from siliceous tuff (Tst) higher in the basalt section. Contains light-colored pumice fragments, light-gray obsidian, and other Tertiary volcanic fragments including basalt (up to 6 inches). Also contains up to 5% fragments of Proterozoic rock types – primarily hornblende-biotite-granodiorite. Thickness perhaps about 50 feet.

Tb **Basalt (Miocene)**—Medium- to dark-gray mostly olivine basalt throughout the study area north of the Limestone Hills (basically, north of the Verde fault) and east of the Mazatzal Mountains. Includes Tbu of Wrucke and Conway (1987). Probably largely equivalent to older basalt (Tob) of the area south of the East Verde River gorge in the Mazatzal Wilderness, but may locally contain equivalent of younger basalt (Tyb). Consists of flows 5 to 100 feet thick that contain olivine phenocrysts 1-2 mm long, commonly altered to iddingsite and, in some flows, conspicuous phenocrysts of a dark-green pyroxene, in an intergranular groundmass. Flows high in the unit capping the eastern parts of Polles Mesa and parts of Hardscrabble Mesa contain abundant prominent augite phenocrysts 2-6 mm in size. Deeply embayed quartz phenocrysts and large blocky plagioclase crystals locally are abundant in flows of the lower third of the unit. Vesicles are common and locally are partly lined with a zeolite; calcite amygdules and veins are abundant. Contains locally conspicuous interbeds of basaltic sand and scoria.

Forms cliffs and steep slopes commonly mantled with talus and landslide deposits. Great thicknesses exposed in deep gorges of East Verde River, Hardscrabble Creek, and Fossil Creek. Caps Buckhead Mesa and smaller mesas east of Buckhead Mesa. Thin scattered basalt remnants in central to eastern parts of map area. Also caps parts of the Mogollon Rim where it lies on a gently southward dipping erosional surface. Source of most of the basalt is likely at or near the northwestern margin of the study area, perhaps in the volcanic complex of the Hackberry Mountains area (Lewis, 1983; Scott, 1974). Section thins from more than 1,200 feet to less than 100 feet from western parts to the central part of the study area.

K-Ar ages on basalts of unit Tb (Tbu of Wrucke and Conway, 1987) in the Mazatzal Wilderness range from 9.9 ± 0.5 Ma in the Limestone Hills to 13.4 ± 0.8 Ma at the base of the unit on the East Verde River, 2.5 km east of the confluence with the Verde River (Wrucke and Conway, 1987). Peirce and others (1979) report whole-rock K-Ar ages of 12.1 ± 0.4 Ma for basalt of Buckhead Mesa and 11.4 ± 0.27 Ma for basalt of Bakers Butte on the Mogollon Rim just north of Milk Ranch Point. Peirce and others (1979) also determined K-Ar whole-rock ages of 9.30 ± 0.40 and 10.16 ± 0.22 Ma for uppermost flows of Fossil Creek. Weisman and Weir (1990) report: "A feldspar-groundmass concentrate from a sample of basalt from the base of the topmost flow on the south end of Milk Ranch Point yielded a K-Ar date of 14.25 ± 0.74 Ma (Sample number UAKA 77-79, Muhammad Shafiqullah, Laboratory of Isotope Geochemistry, University of Arizona, and H. Wesley Peirce, Geologist, Arizona Bureau of Geology and Mineral Technology, oral and written communs., 1988)."

Ta **Andesite (Miocene)**—Small occurrences along upper Tonto Creek above Kohls Ranch. Taken from mapping by Satterthwaite (1951). Not examined in this study. Age relation to other volcanic rocks unknown.

Tcb **Conglomerate and basalt (Miocene)**—Gray to brown conglomerate and sandstone and interlayered basalt in the valley of the Verde River south of Squaw Butte (Wrucke and Conway, 1987). The sedimentary deposits are equivalent to the younger conglomerate (Tyc) and the basalt is equivalent to the younger basalt (Tyb). Rests on younger conglomerate, silicious tuff (Tst), and older basalt (Toc). Maximum preserved thickness about 360 feet.

Tyb **Younger basalt (Miocene)**—Dark-gray to dark greenish-brown, massive to vesicular flows in the valley of the Verde (Wrucke and Conway, 1987). Consists mostly of olivine basalt but contains minor amounts of andesite. Vesicular basalt is common and generally is light- to medium-gray and deuterically altered. Olivine phenocrysts are ubiquitous but are mostly converted to iddingsite in the lighter-colored rocks. Pyroxene phenocrysts are rare. Red scoriaceous basaltic sands form rare but conspicuous interbeds. Commonly forms steep slopes and cliffs in which individual flows are fairly distinct. Separated from older basalt (Tob) by younger conglomerate (Tyc). Highest flow identified, several miles south of the study area, dated by K-Ar methods as 8.3±2.6 Ma (Wrucke and Conway, 1987). Maximum thickness about 330 feet.

Tyc **Younger conglomerate (Miocene)**—Weakly to moderately consolidated medium-gray pebble to cobble conglomerate along the valley of the Verde River (Wrucke and Conway, 1987). Clasts are 80-90 percent gray to black Tertiary olivine basalt, 0-5 percent red basalt scoria, 0-3 percent Tertiary volcanic rocks of intermediate composition, and locally 5-10 percent Proterozoic granite, granophyre, rhyolite quartzite and a few Paleozoic rocks. Most clasts are pebbles, but cobbles are common. The matrix is poorly sorted, fine- to coarse- grained, sandy volcanic debris. May contain basalt flows. Maximum thickness 750 feet south of study area (Wrucke and Conway, 1987) but probably less than 200 feet within study area.

Tvs **Volcanic sandstone (Miocene)**—Minor beds of mostly fine reworkd volcanic sands interbedded in Tob in far southwestern corner of map area.

Tob **Older basalt (Miocene)**—Light to dark-gray and dark-brown massive to vesicular flows of olivine basalt exposed from the Mazatzal Mountains west to the Verde River (Wrucke and Conway, 1987). Has abundant olivine phenocrysts mostly converted to iddingsite. Pyroxene phenocrysts are present in most flows and are abundant in some. Contains sparse bytownite phenocrysts and rare partly resorbed quartz phenocrysts. Calcite amygdules and veins abundant in upper parts of the unit. Has conspicuous subordinate interbeds of red-brown to yellow-brown scoriaceous basaltic debris containing crystals of green pyroxene. Unit may include andesitic rocks. Commonly forms gentle to steep slopes in which individual flows are difficult to identify.

K-Ar ages for this unit south of the study area range from 12.3 ± 0.8 Ma to 16.1 ± 0.15 Ma. Maximum thickness at least 1200 feet.

Toc **Older conglomerate (Eocene)**—Moderately consolidated cobble to pebble conglomerate and sandstone. Interlayered fine- to coarse-grained, thin- to medium-bedded sandstone containing lenses and beds of arkosic grit and fine pebbles forms as much as three-fourths of the unit. Clasts are principally of Proterozoic rocks, the main types being quartzite, rhyolite, granophyre, and granite. Clast types and proportions vary widely across the study area, depending on the source area which is generally to the south to southwest relative to a given locality. In Lion Spring graben area, clasts are primarily from Green Valley Hills Granophyre and Hells Gate Rhyolite to the southeast. Elsewhere clasts from quartzite of the Mazatzal Group and Payson Granite are common. In western exposures, there are also black rhyolite clasts from the New River Mountains. Locally there are also clasts of the Tapeats Sandstone, a distinctive trachyte porphyry (unit Tit), or other local distinct rock types from source areas. Deposited on irregular surface carved in Paleozoic and Proterozoic rocks. Thickness up to about 400 feet.

Unit includes 'red gravels' (Tgr, Gæaorama, 2003) of the Lion Springs graben area.

Occurs in areas east and north of Payson beneath the Diamond Rim, in the Buckhead Mesa/Pine Creek area, in the Limestone Hills, and in Fossil Creek. Also occurs north of the study area at various places north of the Mogollon Rim (Conway, 1990). These conglomerates are equivalent to the so-called 'rim gravels' of Cooley and Davidson (1963). The 'rim gravels' east of the study area between Young and Showlow were extensively studied by Potochnik (1989) who assigned to them the informal name Mogollon Rim formation. Two air-fall biotite tuff samples from the upper part of the Mogollon Rim formation yielded K-Ar ages of 37.6 ± 0.8 and 37.5 ± 0.8 Ma (Potochnik, 1989).

Tertiary Intrusive Rocks

Tis **Siliceous plugs and dikes (Miocene)**—Gray to tan and dark-brown, dacite to rhyodacite porphyry (Wrucke and Conway, 1987). The unit forms plugs into basalt (Tb) in western Hardscrabble Mesa and at Squaw Butte at southwestern edge of map area. Also forms dikes on the Ikes Backbone about 1.5 miles west of study area. Consists of plagioclase and subordinate hornblende and biotite plenocrysts in a matrix of devitrified glass and rarely of glass. Plagioclase phenocrysts are blocky euhedral to subhedral crystals and broken fragments of complexly twinned and, in some rocks, oscillatory zoned andesine and subordinate oligoclase. Plagioclase in a few rocks is spongy because of included myriad blebs of glass. Hornblende consists of brown prisms that locally enclose biotite, which also occurs separately as equant books. Hornblende and biotite exhibit varying stages of alteration. Accessory minerals are magnetite, apatite, and zircon. [Above petrographic description may not wholly apply; it was written to include plugs at Lion Mountain, many miles south of the study area.] Mostly massive but locally flow banded. As dated by the K-Ar method, the plug at Squaw butte is 8.9 ± 0.6 Ma (Wrucke and Conway, 1987).

Tib **Basalt plugs and dikes (Miocene)**—Basalt plugs, dikes, and sills. Sills and dikes in Tapeats Sandstone and Martin Formation in the western part of the Limestone Hills are greenish-black, fine-grained, olivine basalt comprising euhedral olivine in crystals as large as 1mm long in an intergranular matrix of calcic plagioclase, augite, and accessory biotite with late albite and zeolites concentrated in scattered pools 1-3 mm across (Conway and Wrucke, 1987). Sills and dikes intrude older basalt (Tob) south of the study area in the Mazatzal Wilderness (Wrucke and Conway, 1987). Occurs as plugs in Proterozoic gneissic granitoids (Xn) in northern Star Valley area and as a sill in Martin Formation on the eastern margin of Walnut Flat. Generally poorly exposed. Dike and sill width 2-30 feet.

Tit **Trachyte sill (Tertiary?)**—Brown, massive trachyte porphyry (Conway and Wrucke, 1987). Contains alkali feldspar phenocrysts 5-10 mm long in an aphanitic to phaneritic groundmass. Small vugs containing black and green alteration products common in the groundmass and particularly in the feldspar phenocrysts. Forms sill 600 feet thick in Tapeats Sandstone (Ct) in southwestern part of study area. Found only here and as dikes further south on the west side of the Verde River (Wrucke and Conway, 1987). This unusual and rare rock type is not demonstrably Tertiary. It could be as old as early Paleozoic. Presence of this distinctive rock type in older conglomerate (Toc) in the Fossil Creek area and in gravels atop the Mogollon Rim clearly reveals the provenance of the gravel as being south to southwest of depositional sites.

Paleozoic Sedimentary Rocks

Pk **Kaibab Formation (Lower Permian)**—Limestone, dolomite, and sandstone. Limestone and dolomite are yellowish-gray to light-gray, very fine- to fine-grained and locally sandy; commonly contain irregular nodules, about 1 in. across of reddish-brown and medium-gray chert. Fossils are sparse to common, in part silicified, in part as casts and molds, and consist mostly of whole and fragmented brachiopods, crinoid columnals, and fragments of sponges, bryozoans, and gastropods.

Sandstone is light-brown to pinkish-gray, calcareous, and spotted with limonite. Occurs at base of formation as a 2-foot-thick bed, and higher in section as thinner beds interlayered with dolomite and limestone. Stratification generally obscure because of bioturbation; composed of well-sorted, very fine to fine grains of subangular quartz and minor amounts of microcline, plagioclase, hornblende, and muscovite.

Formation weathers to a sandy residuum of chert and silicified fossils. Base, generally covered by colluvial chert, is a regional unconformity commonly having relief of less than 3 feet in 300 feet. Attains greatest thickness of about 350 feet in the north-central part of Pine quadrangle.

The Kaibab Formation is a shallow marine limestone commonly containing abundant shelly fossils.

Found only on top of Mogollon Rim and not closely examined in this study. Above description modified from Weisman and Weir (1990).

Pc **Coconino Sandstone (Lower Permian)**—Well-indurated sandstone, very light grayish-orange to pale-orange; generally weathers grayish orange. Composed mostly of very fine to fine grains of quartz and trace amounts of feldspar, chert, and mica; moderately well cemented by silica. In planar and more rarely in trough sets, commonly about 4 feet thick, of low- to high-angle crossbeds interstratified with a few thin horizontal beds. Rare straight, flat-topped ripple marks on crossbed surfaces. Wind-blown sand deposit having its origin as a vast sand sea (erg) in a Permian desert environment.

Steep cliff-forming unit at or near the top of the Mogollon Rim across the northern boundary of the study area and in upper parts of Fossil Creek canyon. Contact with underlying Supai Formation generally marked by a sharp break in slope; softer Supai Formation weathers to form a much gentler slope. At basal contact, for up to 100 feet, sandstone of Coconino is interlayered with silty redbeds of the Supai. Sharp break in slope mapped as the contact in this study.

Thickness ranges from about 1000 feet in northern parts (vicinity of Calf Pen Canyon) to as little as 800 feet in southern exposures. Coconino is entirely cut out on the pre-basalt erosional surface at the south end of Milk Ranch Point (Weisman and Weir, 1990).

Cliffs yield abundant debris of sandstone that commonly form a thick talus or colluvial cover on underlying formations beneath the steep cliffs of the Mogollon Rim or canyons that cut into the Rim. Locally, this material forms more distal fluvial gravel deposits, some of which are mapped as unit Qg.

Not examined closely in this study. Above description modified from Weisman and Weir (1990) and Weir and Beard (1997).

Supai Formation (Lower Permian and Upper Pennsylvanian)—In this report, all strata between the Coconino Sandstone and the Naco Formation belong to the Supai Formation. As a matter of practicality, for mapping purposes, this report divides the Supai into an upper member, the Fort Apache Member, and the lower member. This report follows the usage of Weisman and Weir (1990), Weir and Beard (1997), Ostrander (1950), and Satterthwaite (1951) which is similar to that of Huddle and Dobrovolny (1945). Blakey (1990) proposed the name Schnebly Hill Formation which encompasses the upper member, the Fort Apache Member, and the upper part of the lower member of the Supai as mapped in this study. We agree with Weir and Beard (1997) that: "Comparison of the units proposed by Blakey (1990, Fig. 2) with the units in this quadrangle (Strawberry 7.5' quad) shows large differences." The main difficulty would be to locate and map the base of the Schnebly Hill within the lower member. The lower member, as used in this study, is not amenable to division for mapping purposes; there is no readily discernible lithologic break to mark the base of the Schnebly Hill. Though not a study of stratigraphy, the current mapping and structural work nevertheless suggests that some of the units of the Schnebly Hill, as proposed by Blakey (1990) are simply not readily mappable, if mappable at all, in the study area. Likewise, the formational subdivisions of Peirce (1989) for his Supai Group do not lend themselves to mapping in the study area. Controversies of the Pennsylvanian-Permian stratigraphy of the region continue to the present and are beyond the scope of this study.

Overall, the Supai Formation is a classical Permian 'red bed' sequence. It is composed almost entirely of highly oxidized fine-grained sediments that were deposited in a warm continental environment primarily by fluvial processes, but with intermittent and local marine and eolian conditions.

Supai Formation exposed continuously beneath the Mogollon Rim across the northern part of the study area from Promontory Butte on the east to the canyon of

Fossil Creek on the west. According to Ostrander (1950) and Satterthwaite (1951), the overall Supai Formation thins eastward from uppermost East Verde River area (~1900 feet) to the west side of Promontory Butte (~1400 feet). Thicknesses for members in the Strawberry-Pine-Fossil Creek area given below.

Descriptions below from field observations in this study and from modifications of Weisman and Weir (1990), Weir and Beard (1997), Ostrander (1950), and Satterthwaite (1951).

Ps **Supai, undivided (Permian)**—In fault slices within the Diamond Rim fault zone in Fossil Canyon. Could also include some Naco Formation.

Psu **Upper Member (Lower Permian)**—Siltstone, shale, sandstone, and minor limestone. Siltstone, shale, and sandstone are all reddish-brown, varying to brownish-gray and grayish-orange. Siltstone, shale, and sandstone are irregularly interbedded throughout. Siltstone and shale clayey to very fine sandy, in laminated to thin-bedded layers commonly 0.5 to 5 feet thick; form slopes. Sandstone very fine- to medium-grained, micaceous, well-cemented by calcite and iron oxides. Sandstone mostly in thin-bedded layers 1 to 10 feet thick, but near top of section includes layers with high-angle crossbeds similar to Coconino Sandstone; forms weak, discontinuous ledges.

Limestone in one or more thin (1-20 feet), discontinuous layers in the lower part of the section; rarely in the upper part of the section. Limestone constitutes perhaps 1-2% of the upper member. Locally a relatively continuous limestone ledge in lower part of unit is nearly half as thick as the Fort Apache Member. Light to medium tan or gray, fine-grained, and thin-bedded; locally ledge forming. Silicified mollusks and other fossils give a Leonardian (Early Permian) age (Weisman and Weir, 1990; Weir and Beard, 1997).

Thickness increases eastward from about 220 feet west of Strawberry in the vicinity of Nash Point to as much as 340 feet on Milk Ranch Point. Thickness not determined east of Milk Ranch Point.

Generally poorly exposed due to cover by colluvium and talus derived from overlying Coconino Sandstone.

Psuf **Upper member and Fort Apache Member (Lower Permian)**—These two members form one map unit where Fort Apache was not mapped in the current study – basically east of Pine Canyon. Fort Apache not mapped as a separate unit by previous workers.

Psf **Fort Apache Member (Lower Permian)**—Mostly limestone; medium to light tan to gray, locally silty to sandy, and micro- to fine-grained. Locally dolomitic. Wavy tabular beds 0.5 to 5 feet thick with pale red siltstone partings common between the beds. Kaolinite most abundant clay mineral; illite and mixed layer illite-smectite are common (Weisman, 1984).

Fossils in eastern Arizona (Winters, 1963, p. 15) and conodonts in central part of study area (Wardlaw cited by Peirce, 1989) yield early to middle Leonardian (early Permian) age. Ostrander (1950) reports scattered altered brachipods in northeastern part of study area.

Named by Stoyanow (1936) for section in the Fort Apache Indian Reservation more than 100 feet thick. Thins east to west across study area; about 60 feet on east margin and as little as 30 feet in far western parts. In Pine-Strawberry area typically 40-50 feet thick.

Forms striking 'white' intermittent cliffs on moderately steep reddish Supai slopes; largely covered with colluvium, especially on more gentle slopes.

Psl **Lower Member (Lower Permian and upper and middle Pennsylvanian)**—Siltstone, shale, sandstone, conglomerate, dolomite, limestone, and carbonaceous rocks. Siltstone, shale, and sandstone are red beds similar in character to clastic rocks in the upper member; occur irregularly interbedded throughout the lower member. Commonly calcareous.

Dolomite, mostly reddish brown, very fine-grained and locally silty, found in 1-foot discontinuous beds near top and base. Rare, tan to light-gray, 1-20-foot limestone beds found both high and low in the member across the study area. One such limestone bed mapped separately (Psll, see below). Limestones similar to that of Fort Apache Member.

Conglomerates composed of carbonate clasts near the bottom of section. In Pine area, conglomerates consist chiefly of clasts up to 8 inches of sandy limestone or limy siltstone in a matrix of similar composition; generally in lenses 1-15 feet thick, up to a hundred feet in length, with up to 7 lenses in vertical sequence (Weisman and Weir, 1990). Conglomerates layers less abundant in eastern part of study area. In vicinity of Kohls Ranch, single persistent 6-foot marker bed of conglomerate about 70 feet from base of section (Gæaorama, 1998). Ostrander (1950, p. 48) reported a basal conglomerate 6-32 feet thick.

Thin coaly beds and gray beds with plant fragments occur regionally, but sporadically, in the lower part of the lower member and are commonly associated with conglomerate (Peirce and others, 1977). Uranium and copper mineralization associated with these beds; largest uranium prospect in the region beneath Promontory Butte near Christopher Creek about 900 feet beneath the Fort Apache Member (Peirce and others, 1977; McGoon, 1962; Blazey, 1971). Satterthwaite (1951, p. 103) reported plant fragments in sandstones about 350 feet from base of section. Similar occurrence of carbonaceous siltstone and shale with coaly fragments and impressions of plant material and with uranium and copper minerals in southeast wall of Fossil Creek Canyon (Peirce and others, 1977; McGoon, 1962). Fossils late Pennsylvanian to early Permian in age (Peirce and others, 1977).

About 1120 feet thick on the rim of Fossil Creek canyon in vicinity of Nash Point. Thins eastward through Strawberry and Pine areas to about 950 feet in vicinity of Milk Ranch Point.

Lower member in the study area divided into two or three units by earlier workers doing stratigraphy; these units never actually mapped. Weir and Beard (1997) state that lower member in Strawberry quadrangle is naturally divisible into two parts, but cannot be mapped because of poor exposure and because of irregularly intergrading and intertonguing.

Psll **Limestone in lower member (Pennsylvanian)**—Buff limestone bed up to about 20 feet thick within lower member of Supai southwest of Pine. Caps ridge (named Limestone Point in this report) about 2 miles southwest of 'downtown' Pine and crops out along road from Pine to Hardscrabble Mesa. Key unit in determining direction and amount of displacement on Dripping Springs fault.

Pn **Naco Formation (Pennsylvanian)**—Limestone, dolomite, shale/mudstone, siltstone, sandstone, and conglomerate. Limestone much more abundant than dolomite; minor sandstone and conglomerate. Characterized by interbedding of primarily gray to light red-brown mudstone and siltstone with gray to reddish-gray commonly mottled limestone; detailed stratigraphy in vicinity of Kohls Ranch given in Gæaorama (1998). Also characterized by unusual and distinctive red-brown to orange chert in upper one-third to upper two-thirds of section, depending on locality. Chert occurs as scattered irregular nodules and lenses in limestone layers and as partial to complete replacement of shelly fossils in limestone layers. Two semi-continuous 1-5-foot layers of chert as lenses, nodules, and beads (resembling sandstones) in Kohls Ranch area (Gæaorama, 1998). Commonly contains one or more thin carbonate-clast conglomerate beds at (Gæaorama, 1998) or near (Satterthwaite, 1951) the base of the formation.

Generally highly fossiliferous, though Weisman and Weir (1990) found only a few broken ostracode tests and unidentifiable comminute shelly material in the Pine quadrangle. Fossils include foraminifers, brachiopods, crinoids, bryozoans, and sharks teeth. A gray shaly bed near Kohls Ranch contains abundant hard calciferous brachiopods, bryozoans, crinoids stems, and sharks teeth that weather out whole (Gæaorama, 1998). Brew (1965) determined from fusilinid foramininfers that the Naco in central Arizona is Desmoinesian (late Middle Pennsylvanian) in age.

Contact with overlying Supai Formation in most places readily mapped within about 20 stratigraphic feet. In Kohls Ranch area, gray mudstone and limestone characteristic of Naco and red beds characteristic of Supai are interbedded over an interval of 20 to 40 feet (Gæaorama, 1998). Contact in this study mapped as being about midway in this transitional interval.

Ostrander (1950) and Satterthwaite (1951) report variable thicknesses for the Naco between 400 and 530 feet in the area between Promontory Butte and Dude Creek beneath the Mogollon Rim and each report gives one measured section. Gæaorama (1998), however, measured the section at only 250 feet in the Kohls Ranch area; relative thinness may be due to proximity to the Christopher Mountain paleohigh. According to Weismann and Weir (1990), thickness in the Pine quadrangle varies between 200 and 300 feet, but Weir and Beard (1997) give 360 feet for the thickness in the adjoining Strawberry quadrangle. From our mapping and cross-section construction in the Pine-Strawberry area, the thickness of the Naco and Redwall combined is quite constant between about 550 and 600 feet. We estimate thickness of the Naco in this area to range between about 300 and 450 feet, the variation due primarily to the relief on the Pre-Naco karsted surface. Thicknesses given by other workers, above, include terra rossa breccia beneath the formation; our thicknesses do not (see description of Redwall Limestone).

Naco formation distributed across the northern part of the area in lower slopes beneath the Mogollon Rim as far west as Pine. Exposed also in Fossil Creek canyon in the vicinity of Fossil Springs. Numerous springs there issue largely from a single horizon in the lowermost part of the Naco Formation.

Redwall Limestone (Mississippian)—Thick-bedded massive limestone in lower part of section; terra rossa breccia/conglomerate in upper part of section.

Terra rossa unit should, ideally, be a formation separate from either Naco or Redwall, in the manner of the Surprise Canyon Formation which lies between the Redwall and the Naco in the Grand Canyon (Billingsley and Beus, 1986; Beus, 1990). This unique unit in the Paleozoic section of the Mogollon Rim region formed as a result of terrestrial karstification during an approximately 30 million year period between the end of the deposition of the Redwall and the beginning of the deposition of the Naco

With the inclusion of the terra rossa/breccia in the Redwall, there is still considerable relief on the pre-Naco surface; inclusion of the terra rossa in the Naco would result in pronounced relief and mapping the contact would be a formidable task indeed. Terra rossa complex typically on the order of 10 to 40 feet thick; ranges up to about 150 feet; rarely, is missing. Total thickness of Redwall in Pine-Strawberry area from 100 feet to 300 feet, probably generally 200 to 250 feet. Redwall south of Pine laps out against paleohigh underlain by quartzite of the Mazatzal Group. Lower limestone 189 feet thick along Highway 87 from 3.7 to 11 miles north of the bridge over the East Verde River (Huddle and Dobrovolny,1952). Thickness from cross-section construction in Kohls Ranch area about 100 feet (Gæaorama (1998, Plate 2); as with Naco, thinness may be due to proximity to Christopher Mountain paleohigh. Laps out against this paleohigh on steep north slopes of Christopher Mountain.

Distributed in semi-continuous east-west belt between Christopher Creek and central Pine Creek, mostly north of Diamond Rim fault. Exposures in Buckhead Mesa area south of Diamond Rim fault. Small exposures in Fossil Creek on west side of Diamond Rim fault.

Mrt **Terra Rossa upper part of Redwall Limestone**—Thick section mapped separately, southwest corner of Buckhead Mesa (Conway, 1980). It is mappable in most places at 1:24,000 or larger scale, but such mapping was only done locally in this study and only shown on Buckhead Mesa.

Terra rossa breccia/conglomerate consists of generally angular fragments of limestone and chert in a matrix of red-brown locally formed clay-silt-sandstone detritus. Much of this highly oxidized detritus is residue from the solution and removal of probably hundreds of feet of limestone. In lower chaotic parts, limestone blocks are abundant; they decrease upward, giving way to chert and the terra rossa 'soil.' Uppermost parts become stratified and clasts become somewhat rounded clearly indicating fluvial activity on the karst surface. Commonly at the very top of the section, highly indurated chert pebble conglomerate beds are present. Chert-rich uppermost parts of terra rossa member locally mined for road metal. Many gravel pits along Control Road between Highway 260 and Highway 87.

Terra rossa/breccia genetically and lithologically distinct from either the underlying limestone of the Redwall or the overlying marine mudstones and limestones of the Naco. Some workers include the terra rossa in the Naco Formation; we include it in the Redwall for several reasons: 1) its fragments are derived entirely from the physical and chemical breakdown of the limestone, 2) terra rossa commonly grades down into less and less modified limestone, and 3) it is far easier to map the terra rossa as part of the Redwall than as part of the Naco.

Mr **Limestone lower part of Redwall Limestone**—Limestone light gray to rarely pinkish gray; upper parts commonly yellowish, particularly in association with terra rossa material, either the upper terra rossa member or irregular red sandy masses within the limestone. Yellow tints clearly distinguish Redwall from limestone of the Naco which is never yellowish. Limestone fine- to coarse-grained. Irregular chert nodules, more abundant in upper parts, are typically reddish- to dark-gray and commonly somewhat mottled; vary in color to brown and locally a yellow color similar to that of yellowed limestone. Irregular masses of dark red-brown unsorted siltstone/sandstone, locally common in upper parts, within limestone. These masses related to karsting processes wherein solutioning created openings (sometimes cavernous) into which fine terra rossa clastic particles fell. Sparse to locally concentrated fossils include horn corals, colonial corals, brachiopods, and fusulinid foraminifers. Latter indicate an Osagean (Early Mississippian) age (Skip, 1969, p. 179, 181). Outcrops near Pine quadrangle (Weisman and Weir, 1990) assigned to Mooney Falls Member of Redwall by McKee and Gutschick (1969).

Limestone locally cavernous. Hix (1978) describes 18” crevice in the Redwall on east side of the highway just south of Pine (from Morrison Maierle, 2003). Modern sinkholes several miles west of Kohls Ranch (Gæaorama,1998) where15-foot cavern discovered in borings for highway construction (Ken Ricker, RAM Associates, 1999, oral communication). Cavernous character important for groundwater considerations where below water table (Morrison Maierle, 2003).

Tan unsorted sandstone in basal parts where formation laps out against Pine Creek paleohigh; south margins of town of Pine and near highway just north of Buckhead Mesa and elsewhere. Thickness few feet to perhaps 30 feet.

As mentioned above, this map unit throughout most of the area also includes the terra rossa member, which ideally should be mapped separately.

Dm **Martin Formation (Upper and Middle? Devonian)**—Consists of upper Jerome and lower Beckers Butte members named by Teichert (1965) for type sections in Jerome and in Salt River Canyon. Both members widespread in central Arizona, including study area. Much variation in facies, particularly near Pine Creek and Christopher Mountain paleohighs. Entire formation laps out against the two paleohighs. Several of Teichert’s (1965) measured sections in the study area. The two members not mapped separately in this study, except that in some places the Beckers Butte Member is mapped with the Tapeats Sandstone (see below).

Jerome Member (Upper Devonian)—Dolomite, sandy dolomite, subordinate limestone and sandstone. Medium- to pinkish-gray, fine- to medium-grained, thin- to medium-bedded, commonly laminated dolomite and subordinate limestone. Sandy dolomite layers sparse to locally abundant; contain fine to coarse, clear to clouded quartz grains. Dolomitic sandstone also present locally. Brown thin-bedded limy dolomite beds (~25 feet) at or near base of unit emit petroliferous odor when broken. Gray to white chert nodules occur throughout the member and are particularly common in the lower half. Abundant bryozoans, corals and brachiopods locally in upper part of the member. Forms ledgy slopes, rarely cliffy.

Fairly consistent in character through middle parts of study area – roughly between Tonto Village on the east and Webber Creek on the west. West and east of this central area, section becomes much sandier (mostly sandy dolomites) approaching the Pine Creek and Christopher Mountain paleohighs. Brown unsorted sandstone common at base of section resting on Precambrian rocks of paleohighs, as with Redwall Limestone. Pronounced lithologic changes in section near Christopher Mountain paleohigh (Conway, 1980; Gæaorama, 1998). Lower half of section near Control Road turnoff from Highway 260 (Thompson Wash area) mostly sandstone with minor siltstone, mudstone, marly sandstone, dolomite and limestone; includes 85-foot-interval of medium-grained tan clean quartz sandstone (Gæaorama, 1998); lowermost fetid unit not recognized. Ostrander (1950) and Satterthwaite (1951) report that Martin in northeastern parts of study area is entirely limestone and that there are sinkholes in the area. These northeastern strata are certainly mostly dolomite and the existence of sinkholes is questionable. Extensive mapping of the Martin in the region (this study; Gæaorama, 1998, 2003; Wrucke and Conway, 1987) has revealed no sinkholes.

Jerome Member subdivided into three mappable sub-units on south slopes of Buckhead Mesa (Dml, Dmm, Dmu; Conway, 1980) and in Thompson Wash area (Gæaorama, 1998). But the units are different in these two areas, and in neither case do they correspond to Teichert's (1965) three units of the Jerome Member. Extensive facies changes, particularly near the paleohighs, and discontinuity of lenses would likely preclude continuous mapping of any subunits across the study area.

Beckers Butte Member (Upper and Middle? Devonian)—Lower parts mostly soft calcareous sandstone and minor sandy dolomite; minor local medium-gray aphanitic dolomite in uppermost parts. Commonly mottled pale red-purple to pale red, locally reddish brownish-orange; colorations distinctive and consistent. Sandstone is fine- to medium-grained, commonly containing 5-20 percent scattered rounded quartz grains 1-2 mm across. Bedding poorly expressed but generally thin locally emphasized by lenticular laminations of very coarse quartz grains and chert fragments. Pebble conglomerate (~8 feet) at base in Limestone Hills contains clasts of rhyolite, quartzite, and chert (Wrucke and Conway, 1989). Light-gray, medium-grained, well indurated sandstone as much as 1.2 m thick occurs at top of sandstone part of the member.

Beckers Butte poorly exposed slope forming unit 0 to 35 feet thick. Fairly persistent in thickness and character throughout much of central part of study area. Not recognized by Teichert (1965) or Gæaorama (1998) in Thompson Wash area.

Total thickness of Martin 350 to 190 feet in northeastern part of study area (Ostrander, 1950; Satterthwaite, 1951). At Thompson Wash Teichert (1965) measured 282 feet, in which he included Tapeats Sandstone, whereas, from detailed mapping and cross-section construction, Gæaorama (1998) measured 380 feet excluding 60 feet of Tapeats. At five places between Diamond Point and Tonto Natural Bridge Teichert measured 448, 437, 437, 467, and 389 feet; his Beckers Butte, which mistakenly included Tapeats Sandstone in the first four, measured 90, 84, 68, and 65 feet. At the fifth section, at Natural Bridge, the Tapeats and Beckers Butte are missing. Incomplete section in Limestone Hills up to about 200 feet. Martin in Pine-Strawberry area from limited drilling data may be about 300 feet thick (see cross-sections E-E' and B-B'). Thins to 0 feet against Pine Creek and Christopher Mountains paleohighs.

Martin Formation widespread in central to eastern parts of study area both north and south of Diamond Rim fault system. Intermittent exposures in Limestone Hills in southwestern part of study area.

Ct **Tapeats Sandstone (Middle? Cambrian)**—Generally reddish-purple to reddish-brown, coarse-grained, cross-stratified arkosic sandstone to granular and pebble conglomerate. Forms prominent cliffs and steep slopes.

Tapeats is basal formation of Tonto Group of Grand Canyon, extended into central Arizona as far south as Roosevelt Lake (Middleton, 1989). Teichert (1965) included the Tapeats of the study area in his Beckers Butte Member of the Martin, but Hereford (1977) demonstrated its equivalence to Tapeats northwest of the study area in the Pine Mountain and Black Hills areas.

Mapped unit in places includes Beckers Butte Member of Martin Formation with upper contact at change in slope from soft Beckers Butte to hard ledgy fetid dolomite. Together, Tapeats and Beckers Butte (both sandstones) make logical map unit given that Tapeats commonly forms single vertical cliff difficult to represent on a topographic map.

Basal resistant unit of Paleozoic section; deposited on generally very smoothly peneplaned Early Proterozoic rocks (about 1.7 Ga). Throughout most of area maintains fairly consistent thickness of 90 to 110 feet, but laps out against Pine Creek and Christopher Mountain paleohighs. Near paleohighs contains coarser sediment, notably one or more pebble-cobble conglomerate layers.

Section measured by R. Hereford (Wrucke and Conway, 1987) in central Limestone Hills: upper 12 feet white, coarse-grained, cross-bedded, arkosic sandstone containing scattered lenses of pebbles and cobbles of granite, argillite, and quartzite; next 51 feet reddish-purple, generally very coarse-grained, cross-bedded arkosic sandstone to fine-pebble conglomerate in beds 50-120 cm thick, commonly showing scour relations to one another; basal 33 feet reddish-purple granule to small-pebble conglomerate in beds 8 feet thick separated by thinner beds of very coarse-grained arkosic sandstone. Only the lower unit is preserved at most localities.

Sixty-foot section in Thompson Wash, from surface mapping and drill core (Gæaorama, 1998) divided into five units: basal conglomeratic arkose (0-10 feet); pebble-cobble conglomerate containing mostly quartzite of the Mazatzal Group (10-25 feet); coarse-grained arkosic sandstone characteristic of Tapeats regionally (~20 feet), dark red-brown siltstone (~20 feet); pebble-cobble conglomerate similar to lower conglomerate (~5 feet).

Crops out across central part of area from Thompson Wash on east to Webber Creek and Pine Creek on the west; also in Limestone Hills, southwestern part of study area. Locally caps broad mesas, with or without generally thin mantle of Martin Formation, e.g. on Houston Mesa north of Payson. Caps knobs south and southwest of Payson, remnants on early Tertiary erosional surface.

Ctc **Conglomerate member**—Pebble to cobble conglomerate and fine- to medium-grained, medium-bedded arkose; clasts from Proterozoic metamorphic and granitic rocks. Abundant iron oxides give red, brown and purple hues. Small exposures. Beneath Martin Formation north of East Verde River and west of Polles Mesa; beneath normal Tapeats in eastern Limestone Hills. Thickness up to 75 feet.

Middle Proterozoic Rocks

Yd **Diabase**—Small masses of gabbro that intrude intrude Payson Granite beneath the Diamond Rim. Distinctive ophitic texture suggests these bodies belong to the widespread diabase of the Southwest that intrudes as sills in the Apache Group (Shride, 1967) and as dikes in Proterozoic crystalline rocks (Conway and Gonzales, 1995).

Apache Group—Siltstone, conglomerate, and arkosic sandstone capping Christopher Mountain, far eastern part of the study area, mapped by Satterthwaite (1951) as lower Pioneer Shale, and the Barnes Conglomerate Member and Arkose member of the overlying Dripping Springs Quartzite. Total thickness perhaps on order of 200 feet.

From implications of publications (Gastil, 1958; Shride, 1967; Granger and Raup, 1964) following that of Satterthwaite (1951), it is questionable that Pioneer Shale and Barnes Conglomerate Member actually exist atop Christopher Mountain. Satterthwaite's mapping is nevertheless followed for the current map. Following general unit descriptions abbreviated from Shride (1967).

Dripping Springs Quartzite

Yad **Arkose middle member and/or siltstone upper member**—Arkose member: Thin- to thick-bedded massive-cropping arkose and feldspathic quartzite. Crossbedding characteristic but obscure. Siltstone member: Thin-parting feldspathic siltstone and subordinate quartzitic arkose.

Yab **Barnes Conglomerate Member**—Mainly quartzite pebbles in arkosic matrix.

Yap **Pioneer Shale**—Mostly grayish-red tuffaceous siltstone or silty mudstone.

Early or Middle Proterozoic Rocks

XYg **Granite**—Coarse-grained porphyritic granite in vicinity of 'First Crossing' on East Verde River (just north of Beaver Valley Estates). Potassium feldspar phenocrysts up to ~1 inch. Apparently massive and unfoliated. Presumably intrudes gneissic granitoids (Xn). Probably one of regional ~1.4-Ga granites with which it has lithologic affinity. Less likely is ~1.7-Ga granite. Nearest known granites of this character are Ruin Granite (Globe-Roosevelt Lake region) and Sunflower Granite (southern Mazatzal Mountains).

Early Proterozoic Rocks

Southern parts of the study area are underlain by representatives of several regionally important lithostratigraphic and lithodemic groupings (North American Commission of Stratigraphic Nomenclature, 1983) of Early Proterozoic rocks (Conway and Silver, 1989; Conway and others, 1987; Anderson, 1989; Karlstrom, 1991). These rocks are widely exposed in the overall Tonto Basin-Mazatzal Mountains (TBMM) region. [Tonto Basin in TBMM refers to the upper Tonto Creek drainage basin including the major tributaries Christopher Creek, Haigler Creek, Spring Creek, Green Valley Creek and Houston Creek.]

Strata of the Tonto Basin Supergroup rest unconformably on the East Verde River Formation (Wrucke and Conway, 1987; Conway, 1995). Intrusive rocks of the Diamond Rim Intrusive Suite are broadly coeval with strata of the central part of the Tonto Basin Supergroup; basically they are the hypabyssal equivalents of the rhyolites of the Red Rock Group (Conway, 1976; Conway and Silver, 1989). East Verde River Formation overlies the Gibson Creek Intrusive Suite (Dann, 1992, 1997; Conway, 1995). Mafic plutonic rocks and sheeted dikes of the Gibson Creek Intrusive Suite along with overlying pillow lavas at the base of the East Verde River Formation are interpreted by Dann (1992, 1997) and Dann and Bowring (1996) to be parts of their Payson ophiolite. The gneissic granitoids unit is undated and its physical relation to the other units remains uncertain except that it is intruded by Payson Granite of the Diamond Rim Intrusive Suite. Based on pervasive foliation gneissic granitoids is likely older than the only very weakly foliated Gibson Creek Intrusive Suite.

Early Proterozoic rocks of the region are generally metamorphosed in the greenschist facies but, with one exception, metamorphic terminology is not used in this report (i.e. rhyolite used instead of meta-rhyolite, etc.). The exception is the use of quartzite which has been historically used for metamorphosed quartz sandstone (meta-quartzite) of the Mazatzal Group, earlier formally known as Mazatzal Quartzite. Metamorphism is more readily detected in the mafic rocks, by the presence of epidote, chlorite, albite and secondary amphibole, than in the felsic rocks which are little changed mineralogically. Metamorphism is accompanied by weak to strong foliation in softer strata, but by little to no foliation in large massive resistant bodies of quartzite, rhyolite, and plutonic rocks.

Tonto Basin Supergroup—Volcanic and sedimentary strata approximately 1710-1700 Ma in the TBMM region (Conway and Silver, 1989; Silver and others, 1986; Conway, 1976; Wrucke and Conway, 1987). Sedimentary, volcaniclastic, and volcanic strata in lowermost Alder Group; mostly ash-flow rhyolite, but with minor mafic volcanics in middle Red Rock Group; mostly quartz arenite, but with minor shale and with a few rhyolite flows near the base in the Mazatzal Group.

Red Rock Group, up to 9,000 feet thick, *conformably* overlies a comparable thickness of the Alder Group in southern parts of the TBMM area. Northward, however, into the current study area, Alder Formation is missing or very thin (southwestern part of study area) and a relatively thin section of the Red Rock *unconformably* overlies the East Verde River Formation in the Limestone Hills and perhaps in the Pine Creek area, where there is also massive rhyolite beneath the unconformity. In the vicinity of North Peak, both the Alder Group and the Red Rock Group are missing and the Mazatzal Group rests unconformably on folded strata of the East Verde River Formation.

Mazatzal Group—Thick quartzite sequences with minor siltstone, shale and conglomerate underlying central parts of Pine Creek, Christopher Mountain, and North Peak area of the Mazatzal Mountains. Divided into Mazatzal Peak Quartzite, Maverick Shale, and Deadman Quartzite (Wilson, 1939; Anderson and Wirth, 1981; Wrucke and Conway, 1987;) in the Mazatzal Mountains; descriptions of these formations largely from Wrucke and Conway (1987). Uppermost Hopi Springs Shale (Doe and Karlstrom, 1991) occurs south of study area in the Mazatzal Mountains. Total thickness on the order of 3,500 feet.

Quartzite of the Mazatzal Group is quartz sandstone widely cemented with quartz and somewhat recrystallized metamorphically. Consisting almost entirely of quartz, this quartzite is by far the most resistant rock type in the study area. Prior to the deposition of Paleozoic formations, the Proterozoic rocks of the region were beveled by erosion to a smooth peneplain, the exception being that quartzite masses stood as erosional remnants, or monadnocks, on this plain. Such monadnocks stood at Pine Creek, at Christopher Mountain, and almost certainly at Mazatzal Mountains. Paleozoic strata, up through the Naco Formation, lapped out against these ancient monadnocks.

Mazatzal Peak Quartzite—Contains in descending order: White quartzite member and Red quartzite member

Xmpw **White quartzite member**—Light-gray or pinkish to white, commonly medium- to coarse-grained, locally gritty, crossbedded quartzite in beds generally 1.5-3 feet thick. Crops out in cliffs and steep slopes in high parts of the Mazatzal Mountains. Thickness up to 1,050 feet.

Xmpr **Red quartzite member**—Pale-brown to reddish-brown, fine- to coarse-grained quartzite commonly with a distinctive purplish hue. Beds planar to cross stratified, locally ripple marked, and are a few inches to 6 feet thick. Contains minor amount of interbedded red-brown, silty shale. Exposed in highest parts of the Mazatzal Mountains where it forms jagged cliffs and steep ledgy slopes. Thickness 600-1,000 feet.

Xmm **Maverick Shale**—Greenish-gray to reddish brown, silty and sandy shale and minor sandstone exposed on the flanks of North Peak. Shale consists of 25-40 percent quartz grains, 0.03-0.1 mm in size, in a matrix of very fine grained white mica and black to red-brown iron oxides in laminated, thin, hard, weakly fissile beds. Some beds ripple marked. Locally has weak cleavage. Sandstone in planar to cross-laminated beds 1-24 inches thick forms less than 5 percent of the unit. Thickness 390-750 feet.

Xmd **Deadman Quartzite**—Grayish red-purple to reddish-brown, fine- to medium-grained, crossbedded quartzite containing minor amounts of hematitic shale and argillaceous sandstone. Local basal conglomerate up to 20 feet thick (thickens to 300 feet at Cactus Ridge south of the study area) consists of angular and subangular pebbles, chiefly of red-brown rhyolite. Thickness in North Peak area up to about 200 feet.

Xmq **Quartzite, siltstone, conglomerate**—Rocks of the Mazatzal Group at Pine Creek and Christopher Mountain. Light to dark purplish red-brown, medium- to coarse-grained, and locally pebbly; in all essential characteristics similar to red quartzite of Mazatzal Peak or upper part of Deadman. Very minor silty, shaly, or conglomeratic beds; clasts in latter grit to small pebble size. Has thin interbedded rhyolite flow (Xrr) near base of section at Pine Creek; U-Pb zircon age same as for rhyolites of Red Rock Group (Silver and others, 1986; Conway and Silver, 1989).

Xms **Silty quartzite**—Reddish-brown to tan and grayish-green, thin-bedded, fine-grained sandstone, siltstone and minor shale as a single layer within lower part of quartzite (Xm) in Pine Creek area. Possibly equivalent to Maverick Shale, but much thinner and considerably different in facies. Thickness about 150 feet.

Xmc **Conglomerate**—Pebble to boulder conglomerate at base of Mazatzal Group in Pine Creek near Natural Bridge. Grades upward into lithic-rich sandstone which in turn grades into quartz sandstone of unit Xm. Consists entirely of rhyolite clasts probably derived from Red Rock Group. Equivalent to conglomerate at base of Deadman Quartzite.

Red Rock Group—Light to dark reddish-brown rhyolite ash-flow tuff, flows, tuff and breccia. From area to area contains variable, but generally very small, amounts of intermediate and mafic volcanic rocks, sandstone, shale and conglomerate. Clastic rocks are virtually all volcanogenic. Major exposures of Red Rock Group, containing formational subdivisions, are out of study area in central Mazatzal Mountains (Wilson, 1939; Ludwig, 1974; Wrucke and Conway, 1987) and in Tonto Basin (Gastil, 1958; Conway, 1976). Regional correlations are proposed for strata of the Red Rock Group in Conway and Silver (1989).

It is uncertain how proposed Red Rock strata (Wrucke and Conway, 1989) in the Limestone Hills (Xrab, Xry, Xra, and Xrh), southwestern part of the current study area, and at Pine Creek (Xrr) correlate with major Red Rock formations elsewhere. The Limestone Hills section has an unusually high proportion of mafic flows and an overwhelming amount of conglomerate. The units (Xrr, Xrm and Xrs) along Tonto Creek in the eastern part of the area are likely part of the Haigler Formation (Conway, 1976; Conway and Silver, 1989).

Xrr **Rhyolite**—Variable rhyolite and minor other volcanic and volcanogenic rocks. May include rhyolite flows, ash-flows, breccias and tuffs. Quartz, potassium feldspar, and albite occur as phenocrysts in varying amounts and sizes. Typically extensive oxidized. Locally has abundant lithophysae. Includes a thin (~50 feet) rhyolite ash flow in lower part of Mazatzal quartzite (Xm) at Pine Creek and a thin rhyolite section beneath this quartzite. Also includes rhyolite in fault slice in far eastern part of study area.

Xrm **Mafic volcanic rocks**—Small bodies associated with Xrr in far eastern part of study area.

Xrs **Sedimentary rocks**—Small exposure north of Kohls Ranch (Satterthwaite, 1951).

Following four units in Limestone Hills in stratigraphic order, top to bottom (descriptions from Wrucke and Conway, 1989). Probably part of Red Rock Group; less likely an up-section continuation of East Verde River Formation.

Xrab **Andesitic basalt**—Grayish-red and dark greenish-gray, porphyritic and nonporphyritic flows along East Verde River north of Limestone Hills. Consists of plagioclase laths (altered to albite) 0.1-0.4 mm long in a completely altered matrix of chlorite, calcite, iron oxides, and minor quartz. Porphyritic rocks have abundant euhedral plagioclase phenocrysts 1-2 mm long, commonly arranged in clusters. Has amygdules filled with chlorite, quartz, calcite, and epidote. Unconformable on rhyolite ash-flow tuff (Xry). Variable thickness up to 275 feet.

Xry **Rhyolite ash-flow tuff**—Welded ash-flow tuff exposed along the East Verde River north of Limestone Hills. Consists of massive to finely laminated tuffs. Locally has abundant lithophysae a few millimeters to a few centimeters in diameter. Interlayered with rhyolite and andesite unit (Xra) and hematitic rhyolite conglomerate (Xrh). Thickness about 450 feet.

Xra **Rhyolite and andesite**—Dark grayish-brown to very dark-gray andesite flows interlayered with lesser amounts of dark brownish-gray rhyolite ash-flow tuff. Andesite is aphanitic, largely metamorphic, intergrowth of albite, white mica, chlorite, quartz, and opaque iron oxides showing little original texture other than locally preserved fine groundmass plagioclase needles and sparse plagioclase phenocrysts (now partly sericitized albite) 3 mm or less in length. The interlayered tuffs are densely welded and closely resemble rocks in the overlying rhyolite ash-flow tuff (Xry). Thickness 80-110 feet.

Xrh **Hematitic rhyolite conglomerate**—Grayish-red, reddish-purple, and brownish-red conglomerate, lithic sandstone, siltstone, grit, and rhyolite. Conglomerate consists of subangular to rounded pebbles and sparse cobbles of rhyolite, argillite, and jasper in a hematite-rich matrix of lithic, commonly gritty sandstone composed of the same rock types as the pebbles. Beds many feet thick and poorly defined. Interlayered with thin to medium-thick beds of lithic sandstone in sequences as thick as 60 feet and with unmapped rhyolite of the rhyolite ash-flow tuff (Xry). Rests in apparent slight angular unconformity on upper graywacke unit (Xeug) of the East Verde River Formation. Thickness about 2000 feet.

Alder Group(?)—Sedimentary rocks in the far southwestern part of the study area which have lithologic affinity to strata of the Alder Group in the central Mazatzal Mountains.

Xaq **Quartzite**—Gray to tan, medium- to coarse- grained, crossbedded quartz sandstone and dark-gray to brown, medium-bedded lithic sandstone south of Squaw Butte. Probably part of Alder Group. Thickness about 900 feet.

Diamond Rim Intrusive Suite—Granite, granophyre, rhyolite and minor mafic rocks intruded at 1705-1695 Ma (Conway and Silver, 1989; Silver and others, 1986; Conway, 1976). Hypabyssal equivalents of overlying volcanics of the Red Rock Group formed in caldera ash-flow events. Generally leucocratic high-silica, high-alkali rocks of anorogenic character. In gently southeastward to southwestward dipping sheets between Payson and Christopher Mountain. This great sill complex intrusive into strata of Tonto Basin Supergroup and between the Supergroup and planar upper surface of gneissic granitoids unit (Xn). In sub-horizontal sheets between the northern Mazatzal Mountains and the Verde River in the southwestern part of the study area; sheets intrude East Verde River Formation at high angle to stratification.

Xdb **Bear Flat Alaskite**—Tan to reddish-brown, fine- to medium-grained, biotite alkali granite containing accessory opaque oxides, fluorite, and zircon. Biotite strongly to totally altered to hematite and muscovite; rare trace of amphibole in least altered parts. Feldspars albite and perthite (K-feldspar with exsolved albite lamellae). Locally porphyritic and micrographic along upper contacts. Forms sills along southern margins of the Payson Granite between the Green Valley Hills and Bear Flat in Tonto Creek and along Gibson Rim south of Payson. Occurs also as plugs in Payson Granite east of Payson. Intrudes Payson Granite, Green Valley Hills Granophyre, and Gibson Creek batholith (Conway, 1976).

Xdt **Tourmaline granite**—Biotite alkali granite similar to Bear Flat Alaskite (included in Bear Flat Alaskite by Conway and Silver, 1989) except for its widespread, locally abundant tourmaline pods and stringers and common pale pea-green color of albite.

Sheet intrusive into upper part of Payson Granite in vicinity of Mud Spring in Green Valley Creek.

Xdtp **Tourmaline-bearing porphyry**—Tan to white porphyritic rhyolite in dike 12 feet wide in upper Clover Creek, located on the south side of Limestone Hills (Wrucke and Conway, 1987). Has bursts and clots of black tourmaline and conspicuous 5-6-mm-long quartz phenocrysts. Broken into large float blocks north of Clover Creek.

Xdg **Green Valley Hills Granophyre**—Classical 'red-rock granophyre;' pervasively highly oxidized with almost all iron as hematite. Feldspars commonly brick red from hematite 'dust' throughout the crystals. Porphyritic, commonly miarolitic, and micrographic to spherulitic; in deeper bodies coarsens to granular texture. Phenocryst and groundmass sodic pyroxene and amphibole preserved only in rare gray or grayish-red rocks. Phenocrysts are resorbed quartz and mesoperthite which serve as substrate to micrographic or spherulitic domains of intergrown quartz and feldspar. Accessory minerals are fluorite, sphene, zircon, allanite(?), and garnet(?). Minor, mostly secondary minerals (from oxidation of rocks) are hematite, magnetite, muscovite, biotite, and rare albite. Secondary minerals commonly found in miarolitic cavities.

Commonly lies as irregular sills between Payson Granite or Bear Flat Alaskite and structurally overlying units, including Hells Gate Rhyolite and Gibson Creek batholith in Tonto Basin region (Conway, 1976) and East Verde River Formation in the northern Mazatzal Wilderness (Conway, 1995, p. 28). Sheets intrude Payson Granite and overlying units. Numerous plugs and irregular masses in Payson Granite (likely much more than mapped) between Star Valley and Green Valley Creek likely feeders to sills at roof of Payson Granite. Small mass near North Peak.

Consists of Mescal Ridge, Thompson Wash and King Ridge sills and aplite selvages in Tonto Basin, described below; shown as map unit Xdg where not subdivided. Not mapped separately in Mazatzal Wilderness, but included with Payson Granite as unit Xdpg.

Composite thickness of intrusive sheets a few hundred feet to as much as 6,000 feet.

Xdgt **Thompson Wash sill**—Granophyre sheet extending from Bear Mountain fault on east to McDonald Mountain fault on west (in eastern part of study area). Generally about 900 to 1,200 feet thick, but nearly pinches out on west end. Contains 5-10% 1-3 mm alkali feldspar phenocrysts and about 2% quartz phenocyrsts less an 1 mm. Intrudes both overlying King Ridge sill and underlying Mescal Ridge sill.

Xdgk **King Ridge sill**—Apparently bulbous sill on either side of Tonto Creek in King Ridge area in east-central part of study area; up to 3,000 feet thick. Consisting of granophyre in lower parts grading upward into spherulitic rhyolite in uppermost parts. Intrudes Salt Lick Canyon sill of Hells Gate Rhyolite; intrudes rhyolite of Red Rock Group. Two distinctive phenocryst generations of alkali feldspar, plagioclase, and quartz persist throughout the sill.

Xdgm **Mescal Ridge sill**—Granophyre sheet extending from Bear Mountain fault on east to Green Valley Creek fault on west; from 300 to 3,000 feet thick, generally around 1,800 feet. Intrudes Payson Granite. Intrudes Blue Dog Ridge sill of Hells Gate Rhyolite. Most coarse-grained phase of Green Valley Hills Granophyre; 5-10% each of 2-3 mm roundish quartz and alkali feldspar phenocrysts; micrographic texture coarsens with depth into sub-equigranular texture locally at base.

Xdga **Aplite phase**—Aplite selvages (small sheets) at upper contact of Mescal Ridge sill. Locally gradational into granophyre of Mescal Ridge sill; probably represents magma, without phenocrysts and micrograhic domains, differentiated from the Mescal Ridge granophyre.

Hells Gate Rhyolite—Intrusive rhyolite occupying a large area mostly between the Green Valley Hills and Tonto Creek in the southeastern part of the study area (Conway, 1976). Two closely related irregular sills, one with abundant mafic xenoliths, of generally massive, columnar jointed rhyolite porphyry. Both sills contain 10-15% phenocrysts of partially resorbed quartz (1-3 mm) and mesoperthitic alkali feldspar (2-4 mm) in approximately equal amounts. Pyroxene phenocrysts rarely preserved; usually altered to pseudomorphic clots of opaque minerals, chlorite(?), and calcite. Rocks oxidized and thereby reddened with ubiquitous hematite, but generally not as strongly as Green Valley Hills Granophyre.

Cumulative thicknesses from 1,500 feet to 7,500 feet, but highly irregular. Intruded complexly and semi-concordantly into Haigler Formation of the Red Rock Group and quartzite of the Mazatzal Group east and southeast of the study area (see cross-sections in Conway, 1976). Columnar joints pass continuously across contacts of the two phases, indicating the two sills probably cooled together.

Xdhb **Blue Dog Ridge sill**—Extensively contaminated sill with two kinds of mafic inclusions: 1) gabbro or diorite xenoliths rarely up to a foot in diameter, generally only an inch or two, and as small as clusters of several phagioclase and hornblende crystals, and 2) mafite porphyry (Conway, 1976) which is basically a fine-grained basaltic porphyry with plagioclase megacrysts up to 1.5 inches. Mafite porphyry xenoliths range in size from 0.5 inches to 3 feet. Intrudes overlying Salt Lick Canyon sill. Very fine-grained matrix (0.1-0.3 mm) in upper parts, but coarsens in lower parts to 0.3 mm and becomes micrographic to vermicular near lower contacts.

Xdhs **Salt Lick Canyon sill**—Generally uncontaminated to locally only slightly contaminated sill. Uppermost and thinnest of the two sills; complexly intruded into extrusive rhyolite of the Red Rock Group. Weakly flow-banded near uppermost margins. Contaminated parts contain xenoliths up to a foot in length of mafite porphyry as described above under Blue Dog Ridge sill; plagioclase megacrysts very rare. Inclusions are commonly platy to swirled; they may represent small amounts of mafic magma mixed into the rhyolitic magma.

Xdrp **Rhyolite porphyry**—Red-brown massive to rarely flow-foliated rhyolite porphyry in vicinity of Natural Bridge in Pine Creek. Quartz, plagioclase, and K-feldspar phenocrysts and very fine-grained mafic clots, all about 3-8 mm in size, total 25-35% percent of the rock. Western exposures along Pine Creek where overlain by rhyolite (Xrr) of Red Rock Group extensively altered. Relatively unaltered and weakly columnar jointed in eastern exposures on south slope of Buckhead Mesa. Possibly intrusive into siltstone of upper graywacke (Xeug) of East Verde River Formation. Includes dike on northeast part of Buckhead Mesa immediately north of Diamond Rim fault.

Xdp **Payson Granite**—Reddish-brown to tan, medium- to coarse-grained, hypidiomorphic granular alkali biotite-amphibole granite widespread between Payson and Kohls Ranch areas (Conway, 1976; Southwest Ground-water Consultants, 1998). Constitutes a gently (10° to 30°) southward-dipping mega-sill; upper southern contacts described by Conway (1976); northern basal contact, between lower Mayfield Canyon and southern Houston Mesa, described by Southwest Ground-water Consultants (1998) and Gæaorama (2003). Sill about 5,000 feet thick between Gibson Rim and Star Valley; could be two to three times thicker in areas eastward.

Superficially homogeneous, but with subtle changes from base to roof (Conway, 1976). Uppermost leucocratic parts, similar to Bear Flat Alaskite, are biotite alkali granite in which biotite is commonly altered to hematite and muscovite. Amphibole (probably ferrohastingsite) in trace amounts in upper parts and increasing to several percent in lower parts. Plagioclase/K-feldspar ratio increases with depth in the body and plagioclase (albite to sodic oligoclase in upper parts) becomes more calcic (intermediate oligoclase in lower parts). K-feldspar in upper parts usually coarsely perthitic microcline; at depth is clear, weakly exsolved orthoclase with rims of coarsely exsolved microcline or orthoclase. Uppermost parts extensively altered deuterically and/or hydrothermally.

Slightly to well developed rapakivi texture (plagioclase mantling K-feldspar) pervasive in middle to lower parts; absent in uppermost parts. Textural variants in uppermost parts: seriate porphyritic, porphyritic, miarolitic, rare micrographic.

Deeply weathered mechanically; very little weathered chemically. Common loose mantle (grus) of mostly quartz and alkali feldspar crystals with very little clay. Generally poorly exposed in areas of little relief. Local bold bedrock in drainages and on steep slopes; good rocky exposures in southeastern parts of area in deeply incised tributaries to Tonto Creek. Unweathered, really hard, hammer-ringing rock extremely rare.

Three major lithologic types within the Payson Granite: 1) Granophyre plugs and irregular bodies. Discussed above under Green Valley Hills Granophyre. 2) Irregular masses of leucocratic granite virtually free of mafic minerals and plagioclase; form resistant ridges and knobs. Relatively small masses generally in upper parts of the mega-sill. Probably a late highly differentiated, cross-cutting phase of the Payson Granite. Not mapped separately. 3) Variable generally dark masses of mostly intermediate to mafic plutonic rocks and very minor metamorphosed strata; commonly foliated. Found mostly in lower parts of mega-sill. Interpreted as screens (large inclusions) incorporated from gneissic granitoids unit (Xn); a few masses mapped immediately south of Diamond Point.

Sparse dikes of Payson Granite (a few mapped) intrude gneissic granitoids unit (Xn). Texturally variable felsic dikes (unmapped) above the megasill in the Gibson Creek batholith (Xgc) are likely from Payson Granite and from Green Valley Hills Granophyre.

Texturally homogeneous; foliated (or brecciated) only in near vicinity of major Proterozoic faults (e.g. Green Valley Hills fault; Agate Mountain thrust fault) and along base where foliation is parallel to sub-planar contact with gneissic granitoids unit (Xn). In both cases foliation is due to shearing related to fault movement (Conway, 1976; Gæaorama, 2003).

Xdpq **Pegmatite and/or quartz vein**—Small masses on far eastern Diamond Rim just west of Thompson Wash (Satterthwaite, 1951). Probably related to Payson Granite or to post-granite faulting.

Xdpg **Payson Granite and Green Valley Hills Granophyre**—Widespread granite and less abundant granophyre in northern part of Mazatzal Wilderness south of the East Verde River (Wrucke and Conway, 1987). Lithologically similar to Payson Granite and Green Valley Hills Granophyre in central to eastern part of study area. Granophyre occurs as one or more sheets lying structurally above the granite; sub-horizontal contacts particularly well-exposed in Wet Bottom Creek (Wrucke and Conway, 1987). Structural relation entirely analogous to the sill-above-sill-relationship in the area east of Payson.

Xddg **Diorite and gabbro (Early Proterozoic)**—Brownish-green to gray, fine- to coarse-grained, massive hornblende diorite and pyroxene-hornblende gabbro in vicinity of Limestone Hills and Squaw Butte, southwestern part of study area. Gabbro locally has igneous laminations. Intrudes East Verde River Formation and rocks as young as hematitic rhyolite conglomerate (Xrh) of Tonto Basin Supergroup.

Xds **Syenite**—Massive intrusive rock in Limestone Hills similar to associated diorite and gabbro in overall character, but with much more abundant K-feldspar.

East Verde River Formation—Very thick section (minimum 25,000 feet) of lower mafic volcanic rocks, central thin sequence of siltstone/shale and rhyodacite/jasper, and upper classical turbidite graywacke (Wrucke and Conway, 1987; Conway and others, 1987). Section appears to be entirely submarine. Group status warranted because of great thickness and lithologic variability, but would require more work to define constituent formations and their type sections.

Entire west-dipping and mostly west-facing sequence exposed between North Peak and the western Limestone Hills; central to lower parts of sequence exposed also on slopes of Buckhead Mesa/Crackerjack Mesa and locally northeastward into south slopes of the Diamond Rim in the vicinity of Webber Creek and eastward.

Tuff beds in lower part of graywacke section dated by U-Pb zircon methods at about 1710 Ma (Dann, 1997; Dann and others, 1989).

Xeug **Upper graywacke**—Gray to maroon, unfoliated, thin- to thick- bedded, fine-to coarse-grained graywacke, maroon siltstone, and conglomerate on south side of East Verde River. Graded graywacke beds contain more quartz than lower graywacke unit (Xelg). Siltstone is similar to siltstone units (Xeus and Xels). Conglomerate near the top of the unit contains dacite pebbles, cobbles, and boulders. Thickness about 3,500 feet.

Xeus **Upper Siltstone—**Dark bluish-gray, thin-bedded siltstone and minor sandstone. Thickness about 200 feet.

Xec **Conglomerate**—Gray to green, unfoliated, granule to boulder conglomerate, breccia, and gray to tan graywacke and siltstone. Conglomerate clasts are mostly graywacke but also consist of jasper and various types of volcanic rocks. Many breccia beds are composed only of chaotic ripped-up clasts of graywacke of all Bouma cycle lithologies. Tan graywacke is richer in quartz and felsic volcanic material than gray graywacke. Thickness about 1,900 feet.

Xels **Lower siltstone**—Dark bluish-gray, thin-bedded siltstone and subordinate sandstone. Siltstone similar to fine-grained tops of graded sequences in graywacke units (Xeug and Xelg). Unit incompletely studied and may be more heterogeneous then described. Thickness about 2,600 feet.

Xelg **Lower graywacke**—Bluish–gray to maroon and brown graywacke, siltstone, and pebble conglomerate exposed in Bull Spring Mesa area on south slopes of East Verde River canyon and on northern and eastern slopes of North Peak. Thin- to thick-bedded and massive. Unfoliated to weakly foliated. Bluish-gray graywacke predominates. Reddish-brown rocks occur mostly at base of the unit. Consists of innumerable turbidite graded-bed cycles from a few inches up to about ten feet thick. Graded beds range from pebble to medium-grained sandstone at the base and from fine-grained sandstone to siltstone at the top. Coarse basal portions of beds commonly contain ripped-up, dark-gray siltstone fragments from the top of the underlying bed. Graywacke usually consists of 10-15 percent quartz, 30-60 percent clouded sericitized plagioclase, and 10-50 percent lithic clasts. Lithic clasts are graywacke, jasper, and felsic to mafic volcanic rocks. Groundmass minerals are quartz, feldspar, sericite, magnetite, hematite, epidote, chlorite, blue-green amphibole, and rare zircon. Sericite, epidote, chlorite, and amphibole are metamorphic minerals. Mafic clasts are difficult to identify because of metamorphic modification. Thickness about 8000 feet.

Xes **Siltstone and shale**—Red, maroon, tan, and green thin-bedded siltstone and shale and minor thin, resistant beds of fine-to medium-grained green to tan basaltic to rhyodacitic tuff and tuffaceous quartz-bearing sandstone. Small-scale, low-angle crossbeds occur in some siltstone beds. Sparse graded beds occur in silty to sandy layers. Main exposures in lower City Creek and vicinity approximately equivalent to City Creek series of Wilson (1939); here and in Buckhead Canyon area thickness as much as 600 feet. Much thinner section (~70 feet) south of East Verde River in Houston Creek-Bullfrog Canyon area.

Xerj **Rhyodacite and jasper**—Gray to greenish-gray rhyodacite or dacite pumice breccia and massive to laminated jasper in same exposure areas as given above for Xes but also on lower eastern slopes of North Peak area. Has slightly flattened and irregularly oriented pumice clasts of granule to cobble size. Jasper lenses as much as 60 feet thick. At City Creek unit also has massive brown rhyolite or rhyodacite flows(?) that contain elongate quartz amygdules, interlayered conglomerate, and brown to maroon siltstone. Felsic volcanic rocks all contain plagioclase phenocrysts; no quartz phenocrysts identified. Clasts in the conglomerate are of amygdaloidal and pumice breccia rocks of the unit. Forms distinctive marker unit in the East Verde River Formation. Thickness from about 75 to 500 feet.

Xem **Mafic volcanic rocks**—Andesite and basalt flows, pyroclastics, and epiclastics and felsic volcanic and sedimentary rocks. Mafic volcanic rocks are mostly green to greenish-brown and consist of pillow flows, massive amygdaloidal flows, agglomerate, breccia, conglomerate, and volcanic sandstone and graywacke. Andesite containing abundant plagioclase and or pyroxene phenocrysts probably more abundant than basalt. Jasper common as lenses and irregular masses in the flows and as clasts in the clastic rocks. Light greenish-gray, massive andesite or dacite containing completely sericitized plagioclase phenocrysts and a percent of two each of quartz and clinopyroxene phenocrysts crops out extensively in lower Boardinghouse Canyon. Unit includes rare tan to gray or green rhyolite to dacite tuffs. Gray to green, thin-bedded siliceous shale and shaly chert locally interbedded with mafic detrital rocks. Flows probably constitute less than one-half of the unit. Much of the unit is massive and poorly bedded. Finer detrital material commonly well bedded and contains internal sedimentary structures. Primary textures are moderately well preserved in the mafic rocks, but in general only the greenschist facies minerals albite, chlorite, epidote, actinolite-tremolite, sericite, calcite, and magnetite are present. Generally unfoliated except near major faults. Variations in attitude suggest the presence of folds in the large mass west of City Creek.

Thickness uncertain but may be from 10,000 to 20,000 feet.

Main exposures on eastern and northern lower slopes of the North Peak area, including area west of confluence of Pine Creek and East Verde River, thence westward on south slopes of East Verde River canyon to Bullfrog Canyon. Widely exposed also on south slopes of Crackerjack Mesa, immediately north of Buckhead Mesa, and in area between confluence of Shannon Gulch with Webber Creek and Hells Half Acre.

Descriptions above from Wrucke and Conway (1987) for exposures in the northern Mazatzal Mountains-East Verde River area, but likely have general application to the northerly exposures where reconnaissance mapping was done for this study.

Lowermost exposures of mafic section (Xem) on east flank of the northern Mazatzal Mountains found by Dann (1992, 1997) to consist almost entirely of sheeted dikes perpendicular to layering of mafic strata. These dikes, also present eastward into plutons of the Gibson Creek Intrusive Suite, are key to Dann's definition of the Payson ophiolite.

Xeft **Felsic tuff**—Light-tan to olive-gray sequence of incompletely mapped felsic tuff within the mafic volcanics (Xem) about 3 miles northwest of North Peak. With or without sparse 0.1-0.6-mm quartz and plagioclase phenocrysts in weakly laminated aggregate of shards recrystallized to very fine-grained mass of white mica, quartz, and feldspar. Thickness about 300 feet.

Gibson Creek Intrusive Suite and Gneissic Granitoids—Mafic plutonic complex south and southwest of Payson comprises the Gibson Creek Intrusive Suite, a name here used to replace Gibson Creek batholith (Conway and others, 1987). Batholith may not be appropriate name for this plutonic complex for two reasons: 1) According to Dann's (1992, 1997) ophiolite model, the Gibson Creek may be part of an arc-rift complex; batholiths are generally huge plutonic complexes emplaced in continental crust, commonly above subduction zones. 2) The Gibson Creek has a very small exposure area (<80 square miles) compared to typically huge batholithic terrains (e.g. Sierra Nevada batholith, Idaho batholith).

U-Pb zircon ages of the Gibson Creek range from about 1710 to 1735 Ma (Dann and others, 1989, 1993, 1996; Conway and others, 1987).

The various phases of Gibson Creek combined with the lower mafic volcanic section of the East Verde River Formation constitute the Payson ophiolite (Dann, 1991, 1992, 1997).

Gneissic granitoids an interim informal name for a distinct body of rocks found between Town of Payson and Diamond Rim. May correlate with screens of granitic rocks and strata found within the Gibson Creek Intrusive Suite. Granite of the screens dated at 1751 ± 3 Ma (Dann and others, 1989).

The Gibson Creek and gneissic granitoids units only briefly described in this report, compared with other map units. Gibson Creek contains a number of map units (Dann, 1992) which could be added to the map and descriptions for these units derived from Dann's thesis and publications. Much additional work would be required to properly describe the various units within the gneissic granitoid unit and to make comparisons and possible correlations with screens of granitoids and metamorphic rock mapped by Dann (1992) within the Gibson Creek Intrusive Suite.

Xgc **Gibson Creek Intrusive Suite**—Mostly mafic plutonic rocks and sheeted dikes studied extensively by Dann (1991, 1992, 1997), Dann and Bowring (1996), and Dann and others (1989, 1993). Lowermost parts layered pyroxene gabbro and hornblende gabbro and diorite in general area between Payson and Oxbow Hill (Conway, 1976). Diorite and granophyric tonalite present in uppermost parts between lower Oxbow Hill and East Verde River 4-5 miles west of Payson. Central to uppermost parts cut by west- to northwest-striking dikes which westward become mutually intrusive sheeted dikes overlain orthogonally by mafic volcanics of the East Verde River Formation on the east flank of the Mazatzal Mountains. Dikes of highly variable intermediate to mafic composition. Dikes cut by a late gabbro body.

Contains numerous distinct intrusive bodies. Slightly to locally moderately foliated. Contains extensive veins, many in fault zones, of quartz, epidote and local gold-bearing sulfide minerals. Structurally overlies Payson Granite and is intruded by the Payson Granite. Locally contains granite/granophyre dikes probably derived from the Payson Granite or Green Valley Hills Granophyre.

Gibson Creek rocks mapped by Southwest Ground-water Consultants (1997, 1998) but not subdivided for mapping purposes. Additional general descriptions in these reports.

Xgg **Granodiorite**—Sphene-bearing weakly foliated granodiorite along the East Verde River between East Verde Park and Crackerjack Mine area. May or may not be properly included with the Gibson Creek Intrusive Suite. Dated by L. T. Silver at 1709 Ma (Conway and others, 1987).

Xn **Gneissic granitoids**—Primarily granodiorite, but also granite, diorite, and minor gabbro with probably small amounts of stratified rock. Pervasive weak to strong foliation; foliation locally strongly contorted. Gneissic in many places; augen gneiss present. Intruded by small sheets and plugs of Payson Granite mostly near the contact with Payson Granite. Generally deeply weathered and poorly exposed.

Crops out in a belt bounded by Diamond Rim and the Diamond Rim fault (Gæaorama, 2003); also north of Star Valley between Payson Granite and Houston Mesa/Walnut Flat (Southwest Ground-water Consultants, 1998;Gæaorama, 1999). Additional descriptive material in these reports.

May be equivalent to small pendants/screens of granitoids and stratified rocks within Gibson Creek Intrusive Suite. These stratified rocks, consisting primarily of intermediate to felsic volcanics and volcaniclastics, given the name Larson Spring Formation by Dann (1992).

Following two units small bodies within gneissic granitoids 0.5-1 mile east of Beaver Valley Estates (Gæaorama, 2003).

Xnl **Leucogranite**—Small mass of boldly cropping leucogranite.

Xnd **Diorite**—Small mass of melanocratic diorite and granodiorite

Xpe **Pendant**—Small pendant of volcanic and volcaniclastic rocks within Gibson Creek Intrusive Suite near Gisela, south-central part of map area (Conway, 1976). Dann (1997) includes these strata in his Larson Spring Formation.

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ATTACHMENT 1B

(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Evaluation of the Source Water Chemistry from the Major Springs and Select Wells in the Mogollon Rim Water Resources Management Study Area by Hydrosystems Inc., February 2006

Evaluation of the Source Water Chemistry from the Major Springs and Select Wells in the Mogollon Rim Water Resources Management Study Area

DRAFT

Prepared for:

Town of Payson Water Department

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03-343

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Evaluation of the Source Water Chemistry from the Major Springs and Select Wells in the Mogollon Rim Water Resources Management Study Area

Prepared for
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Introduction

To help characterize and constrain the origin(s) of groundwater in the Mogollon Rim Water Resources Management Study (MRWRMS) area, including the Towns of Payson, Pine, Strawberry, and Star Valley, several water samples have been collected from springs, surface waters, and wells for general inorganic chemical analysis. All samples were analyzed for total dissolved solids (TDS) and the major ions of calcium, magnesium, sodium, alkalinity, chloride, fluoride, nitrate, and sulfate. Most were also analyzed for potassium and silica and had field parameters collected for temperature, conductivity, and pH. Some general chemistry data and hydrogeologic descriptions of the study area were also referenced from other sources as part of this investigation, including Kaczmarek (2003) for the Pine-Strawberry area; Southwest Ground-water Consultants, Inc. (2004), and AGRA Earth & Environmental (1999) for the Star Valley area; and Feth, 1954; Bills et al., 2000; Parker et al., 2005; and USGS, 2005 for the Mogollon Rim and Colorado Plateau study area.

The hydrogeologic units that are referred to in this document are summarized briefly here for an explanation of terms. The regional aquifer of the Colorado Plateau, referred to as the C aquifer, occurs within Paleozoic strata, including the Kaibab limestone, Coconino sandstone, Schnebly Hill formation, and upper to middle Supai formation. The C aquifer is separated to some extent from the underlying RMX aquifer by the lower Supai formation. The RMX aquifer is comprised of the Redwall limestone, Martin formations (primarily carbonate rock), and underlying Proterozoic rock (granitoids, intrusive gabbro, metamorphics). The water in this aquifer flows primarily through fractures and dissolution cavities within the host rock, and in some cases there may be little contribution to or from the underlying Proterozoic rocks, particularly in areas of lesser fracturing and faulting. Farther south of the Mogollon Rim, the X aquifer is also a fractured rock aquifer, and refers to similar Proterozoic rock, where the Redwall and Martin formations are absent. Groundwater is also present in smaller aquifers of valley-fill sediment and/or decomposed granitoids, as will be discussed primarily in the context of the Payson area and Star Valley. The Rye basin, located at the southern end of the study area is also discussed and includes both shallow and deep valley fill aquifer systems.

The general chemistry of most groundwater, spring water, and surface water samples in the MRWRMS area is dominated by calcium, magnesium, and bicarbonate, as illustrated in *Figures 1 and 2*. These figures illustrate the chemical variability of the aquifer systems compositionally (*Figure 1*) and spatially (*Figure 2*), and will be discussed throughout this document. Springs and wells tapping regional groundwater sources tend to be higher in solute concentrations due to longer exposure time of the groundwater with the surrounding rock and aquifer materials and larger source areas which have allowed the water to evolve along its travel path. Conversely, springs and wells that tap shallow groundwater and surface runoff tend to be significantly more dilute compared to regional sources. Exceptions occur, predominantly when land-use practices alter the shallow aquifer system, including reclaimed water use for irrigation, septic tank leach fields, and solvent leaks, as have occurred in the Payson area. This investigation will take a closer look at the general chemistry of five major springs in the MRWRMS area, as well as nearby groundwater and surface water samples collected within their hydrologic basins. By analyzing the general chemistry of these samples in the context of the local and regional hydrogeology, we can better understand the sources of water contributing to the major springs and wells of interest.

Spring Water Chemistry

Fossil Springs

Fossil Springs is the source of the Fossil Creek drainage system and the largest set of springs in the study area. It has the highest total dissolved solids (TDS) concentration of all the measured springs in this study (380 to 420 mg/L). Given discharge from the Naco formation, the source of this spring is likely to be dominated by the C aquifer. This is supported by the high TDS and high, stable flow rates, which are indicative of long residence times and the C aquifer's large discharge area. Previous investigations have suggested there is significant contribution from the Redwall limestone through fractures and dissolution cavities of the Redwall and Naco (Kaczmarek, 2003; Parker et al., 2005). On the basis of several samples collected from Fossil Springs (at three locations and from 1952-2004; *Table 1*), the calcium, magnesium bicarbonate chemistry is fairly consistent and indicative of C aquifer groundwater (*Figure 1*).

Also of interest, Fossil Springs is surrounded by large travertine deposits, both as extensive older terraces and as lesser active deposits. The formation of travertine requires supersaturation of calcium bicarbonate typically associated with a drop from high to low pressure and large supplies of carbon dioxide and calcium bicarbonate. Early research (Feth et al., 1954) suggested that these conditions were met in the Mogollon Rim area through deep-seated limestone aquifers. More recently, Crossey et al. (2006) showed that travertine formation at springs in the Grand Canyon results from active upper mantle degassing contributing large amounts of carbon dioxide to the aquifer system. The extensive volcanic deposition over the Fossil Springs area suggests a similar scenario may be possible for the travertine formation there.

Tonto Natural Bridge Spring

Heading east from Fossil Springs, Tonto Natural Bridge Spring is the next large spring in the MRWRMS area, and is located within the Diamond Rim Basin (*Figure 2*). It discharges water of a similar chemistry, though more dilute (TDS = 320 mg/L), to that of Fossil Springs.

Our interpretation of the geology indicates the discharge of the spring is from the Martin formation (regional RMX aquifer), although others (Feth and Hem, 1963; Parker et al., 2005) have suggested it is from the Tapeats sandstone. Discerning the Martin from the Tapeats has been discussed by Teichert (1965) and Hereford (1977). Although some portion of the C aquifer is contributing to the regional RMX aquifer directly and through re-infiltration of spring discharges along the rim, the RMX aquifer is also diluted by local recharge through large fractures and dissolution caverns. This helps to explain the similar but diluted chemistry of Tonto Natural Bridge Spring compared to Fossil Springs. Tonto Natural Bridge Spring is likely receiving a direct contribution from local recharge, as shown by a relatively higher silica concentration (19 mg/L) that might be attributed to the adjacent cliffs, capped with Rim Gravels and basalt (Parker et al., 2005). Like at Fossil Springs, the volcanics here may be indicative of upwelling carbon dioxide gas being related to the active deposition of travertine (Crossey et al., 2006). The natural bridge itself is an older travertine terrace that spans Pine Creek about 180 feet above creek level (Feth, 1954).

Webber Spring

Continuing east along the Diamond Rim Fault area, the next large spring is Webber Spring, which is located in the East Verde River drainage basin (*Figure 2*). This spring also discharges from the Martin formation, and continues to show similar calcium, magnesium bicarbonate chemistry that is consistent with the RMX aquifer, but even further diluted than Tonto Natural Bridge Spring. The TDS ranged between 220 and 280 mg/L between August and October of 2004. Its water temperature was as low as 14°C, which is 5 degrees warmer than Tonto Natural Bridge Spring. This suggests that Webber Spring has a larger component of local recharge that has rapidly infiltrated the fractured rock and had little water-rock interaction time to pick up dissolved constituents.

Cold Spring

Cold Spring is on the upthrown side of the Diamond Rim Fault, less than 5 miles east of Webber Spring (*Figure 2*). It discharges from the RMX aquifer with a variable flow rate that upon first glance would indicate low storage and most of its contribution from local recharge. However, the TDS concentration of Cold Spring is 350 to 370 mg/L, which is greater than that of Webber Spring, having greater concentrations of calcium and bicarbonate. It is quite comparable to the chemistry of Indian Gardens Spring (Parker et al., 2005), which is on the same side of the Diamond Rim Fault, but in the Tonto Creek watershed. The chemistry from both of these springs is chemically more evolved and indicates longer travel times and water-rock interaction times than springs discharging from the rim face (Parker et al., 2005) or discharge waters that are dominated by local recharge. Also, when comparing the two samples collected from Cold Spring in April and August 2004, there is only minor dilution of the April sample in dissolved constituents during the wetter winter/spring season. The water temperature from Cold Spring is slightly lower (13°C) than Webber Spring (14 - 21°C), but apparently more stable. Given this chemical evidence and isotopic evidence (C. Eastoe, this report) for a significant contribution of regional RMX groundwater to Cold Spring, and its generally large volume of discharge, the suggestion of a large local recharge contribution to this spring is in question. However, due to the lack of historical data collected from Cold

Spring, additional seasonal sampling and flow monitoring is necessary to determine if the chemical data presented here are consistent over time and support a significant regional aquifer contribution, or if the water chemistry shows to vary with discharge volume and climatic changes.

For additional comparison, in October of 2004 a water sample was also collected from Ellison Creek Well, nearly 4 miles east of Cold Spring, but presumably on the same fault. This well is drilled to 560 feet and withdrawals water from the Martin formation and underlying fractured granite. The chemistry of the groundwater is similar to Cold Spring but slightly more diluted, having a TDS of 290 mg/L. The similar but diluted chemistry to Cold Spring suggests more local recharge is being received by the well than by the neighboring spring. This reflects the local variations in fractures, dissolution channels, and related hydrogeologic properties of the RMX aquifer that affect the influence of local recharge and groundwater flow.

Tonto Hatchery Spring

Tonto Hatchery Spring is located at the head of Tonto Creek, near the rim face on the eastern side of the MRWRMS area (*Figure 2*). It has a comparatively low TDS of 60 to 104 mg/L which is interpreted to result from discharging a blend of local recharge and C aquifer water from the Colorado Plateau. In comparison to Fossil Springs, this water has had minimal water-rock interaction due to the short distance from its regional source in clean Coconino sandstone and rapid travel time allotted by the fractured rock. Feth (1954) believed that the Coconino sandstone was so pure in this area because it had been partly leached of soluble matter by active groundwater circulation along the rim. Although Tonto Hatchery Spring discharges a dominantly calcium, magnesium bicarbonate water, it differs from the waters that have interacted with the limestone aquifer by having a greater molar calcium-magnesium ratio (> 2), which supports the concept that this water originated in and flowed through clastic rocks such as the Coconino sandstone and Schnebly Hill formation (Parker et al., 2005). Likewise, the low temperature (9°C) and low silica concentration (6.8 mg/L) of Tonto Hatchery Spring water suggests little chemical evolution and rapid infiltration of recharge through the fractured rock system. Also in comparison to Fossil Springs, not only is the chemistry from Tonto Hatchery Spring significantly diluted, it is also more variable. The observed variations are based on a similar time span (from 1952-2004; *Table 1*), and are illustrated in the expanded view of the trilinear diagram in *Figure 1*.

Well Water Chemistry

Strawberry – Pine Area

The Strawberry – Pine area, located on the crest of the Mogollon Rim in the northwestern part of the MRWRMS area, has been characterized has having local aquifers in the Schnebly Hill formation and Supai formation that share a common restricted recharge zone (Parker et al., 2005). Kaczmarek (2003) indicates that the Schnebly Hill formation with its greater primary permeability and storage allows wells in Strawberry to be generally more productive and less prone to climate changes than wells in Pine which are drilled in the Supai formation with tighter siltstones and very fine sandstones. Deeper wells have also been successfully constructed down into the Redwall-Martin, which offer additional water supply from the regional RMX aquifer.

The groundwater chemistry sampled from wells in the Pine-Strawberry area is generally indicative of the RMX or C aquifers, which are difficult to distinguish using only general chemistry parameters (*Table 2; Figures 1 and 2*). Of the wells that have been sampled in and around the Towns of Strawberry and Pine as part of this and previous investigations (Kaczmarec, 2003; Ploughe, 2005), only one differs significantly in water chemistry. That well is the shallow Strawberry Hollow well, SH-2 (55-579973), located in northwest Pine. This shallow well is screened in the Lower C aquifer and is located next to the Strawberry Hollow Fault. The water chemistry is higher in TDS, notably in calcium, magnesium, bicarbonate and sulfate, but its composition is similar to surface water samples collected in the area that are lower in TDS. Therefore its composition is interpreted to be a blend of regional C aquifer and local recharge.

Otherwise, the chemistry of the Strawberry and Pine wells are fairly indistinguishable from each other and the nearby Dripping Springs. Parker et al. (2005) distinguishes Dripping Springs from other springs along the rim based on its higher silica concentration, to which they attribute volcanics that cap the rim at Milk Ranch Point. Silica concentrations in the well water samples range from 8.9 to 34 mg/L, suggesting varying influences from the volcanic rocks and/or contributions from local recharge.

Payson Area

Several wells have been sampled within and around the Town of Payson between 1998 and 2005 that are considered in this investigation (*Table 2*). Most of the wells in this area are drilled entirely in fractured and decomposed Payson granite of Proterozoic age, whereas others are drilled in other Proterozoic igneous and metamorphic rocks that are also fractured and offer little primary capacity. *Figure 1* demonstrates that chemical distinctions can be made between these waters from the X aquifer and the upgradient RMX aquifer, depending on the size of the fracture system and length of time the groundwater has had to interact with the host rock. Similarly, there are chemical differences between the wells that discharge locally recharged groundwater and the wells that primarily discharge groundwater from the regional aquifer system. In the Payson area, the regional groundwater flows through fractured granite and other igneous and metamorphic rocks, but the predominant calcium, magnesium bicarbonate signature can ultimately be tied to upgradient sources in the RMX and C aquifers.

Regional Aquifer

The geology of the X aquifer in the Payson area is primarily comprised of fractured Payson granite and Gibson diorite/gabbro. Some of the faults and fractures are of limited extent and result in relatively isolated systems that are sometimes more dependent on local recharge, whereas others are deeper more extensive fault and fracture systems supplying larger reliable water volumes to multiple wells. The water chemistry of groundwater in the regional aquifer north and northwest of Payson is more evolved than local recharge, having higher concentrations of dissolved solids, primarily as calcium, magnesium, bicarbonate, and silica. The Skypark (55- 568624), Summit (55-576872), NP-2 (55-577329), and Goat Camp #1 (55-565426) wells are all examples of this type of groundwater, as shown in *Figure 3*. Their measured TDS concentrations range from 220 to 400 mg/L. Slight variations in the chemical composition are likely attributed to variations in the flow path and geological conditions. For example, the Skypark well produces water from the Birch Mesa Fault which is in contact with Payson granite and older gneissic granite; Summit well produces water from Gibson diorite and gabbro, with some influence from the down-dropped Martin formation via the Summit Mine Fault; and NP-2 and Goat Camp #1 produce water from Payson and gneissic granite in an area of northeast Tertiary and northwest Precambrian faults.

There is some chemical evidence to support mixing of groundwater in the regional system, between different but connected fault and fracture systems. In a hypothetical mixing scenario, the water chemistry of Skypark well resembles a 2:1 mixture of water from NP-2 and Summit well, respectively. Spatially in support of this, Skypark well is also located between these two wells (*Figure 3*). The exception to this mixing scenario is chloride, which is greater in Skypark well than either NP-2 or Summit well. In the absence of contamination, increasing chloride concentrations in groundwater may be an indication of dissolution of chloride from the rocks through which the groundwater is moving and may be attributed to a longer residence time of water in the aquifer.

The Payson Pines 4 well (55-564016), also sampled north of Payson, has aquifer testing and isotope results that suggest little local recharge, yet a short residence time for its groundwater derived from the regional aquifer (M. Ploughe, personal communication; C. Eastoe, this report). Water chemistry results indicate it is more dilute than neighboring wells (*Figure 3*), which could be indicative of the influence of local recharge. However, given the other test results, the reduced TDS may be indicative of the short residence time and rapid flow that minimizes water-rock interaction and dissolution of minerals. It may also be indicative of more open and less mineralized fractures.

Local Recharge

In the Payson area, the chemical evidence for groundwater influenced by local recharge appears in two different ways. One way that local recharge can be confirmed chemically is through dilution, as seen in the springs and wells in other parts of the MRWRMS area. At least three wells that are centrally located in Payson have shallow to deep screened intervals and exhibit generally similar water chemistry types to deeper regional wells; however, they are relatively diluted in TDS, primarily through reductions in calcium and bicarbonate. These include the Beeline (55-620867), Woodland #1 (55-503323), and McKamey (55-509870) wells. In comparison to the northern Payson wells that primarily discharge X aquifer groundwater, this blend of local and regional groundwater has measured TDS concentrations that are lower, ranging from 190 to 230 mg/L, and plots at a higher sodium, chloride and sulfate position on the trilinear diagram in *Figure 1*.

The other way that shallow recharge is recognized is through surficial contamination or land-use impacts such as that caused by shallow recharge and irrigation with reclaimed wastewater. Reclaimed wastewater from the Gila County Sanitary District is slightly elevated in TDS (440 mg/L), primarily as added sodium and chloride. Because sodium and chloride are naturally low in the regional groundwater system, addition of these constituents as artificial recharge and irrigation can be traced in samples from nearby wells. Specifically, Country Club Well #3 (55-565297), Lake Drive Well (55-558391), and Mt. View Well (55-512759), which are all shallow screened wells located in southern Payson near the recharge facility and exhibit elevated sodium, chloride, and TDS concentrations. These wells also plot separately from the regional and shallow aquifer wells on the trilinear diagram in *Figure 1*. Well CPN-13 (55-544348), located near a golf course receiving reclaimed irrigation water in eastern Payson, is also proportionally higher in sodium and chloride (*Figure 1*), but has a lower TDS of 250 mg/L.

Other sources of contamination that indicate local recharge include septic leach fields, as shown by elevated nitrate concentrations in the Luke Well (55-575304), northwest of Payson, and PCE contamination in southern Payson as monitored by TOP Well 19 (55-519459).

Shallow aquifers thought to be dominated by local recharge have been sampled in neighboring communities of Payson, including Star Valley to the east. The Star Valley wells, Milky Way (55-605247), Sky Run (PW-1), and Landfill (MW-1) are of relatively shallow depths (120 to 300 feet) that penetrate thin alluvium and fractured granite, and have shallow water levels that tend to fluctuate significantly with respect to local recharge. The isotope results for Milky Way (oxygen-18, deuterium, and tritium) also support local recharge as a primary source. The water chemistry results from these shallow aquifer systems are more difficult to differentiate from regional groundwater for the following reasons: 1. The water chemistry from shallow wells is similar to northern Payson wells that are interpreted to discharge water primarily from the regional X aquifer (*Figures 1 and 3*); 2. Water chemistry data available from a deeper well (Sky Run PW-2, 1,000 feet) are incomplete for major ions and were collected prior to deepening the well (407 feet); 3. Water chemistry data available from the shallow wells represent one point in time for each well and cannot demonstrate if there are seasonal changes. Therefore, at this time little can be interpreted from the water chemistry data from Star Valley other than the shallow aquifer system here may be chemically similar to the deeper X aquifer.

The shallow aquifer systems of Round Valley, south of Payson, and Doll Baby Ranch, east of Payson, have a similar chemistry to the blended local and regional groundwater in central Payson (*Figure 1*), but are higher in TDS (320 to 400 mg/L). Of possible significance, both of these aquifer systems overlie fractured Gibson diorite/gabbro, though in the case of Doll Baby Ranch, the deeper Gibson diorite/gabbro aquifer appears to be confined from the shallow aquifer that is composed of Tertiary gravels. This confined aquifer is of significantly different quality than the regional system, having a large component of sodium sulfate not seen in any other wells in this study. Feth (1954) hypothesized sources of significant sodium sulfate in the southwestern part of the Verde Basin, including deep-water basins having a continuous influx of salty waters, the relict part of a desiccating lake, as well as leaching of igneous and metamorphic rocks with copper mineralization. This deeper water source may also be connected to the deep groundwater found in the Rye Basin, near the southern end of the MRWRMS area. The groundwater in Rye is much more saline due to potential connate sources within the Tertiary gravels and clay rich sediments which underlie that location.

Conclusions

1. Groundwater in the C and RMX aquifers is generally similar in chemical composition within the study area, comprised primarily of calcium, magnesium, and bicarbonate and suggesting that the RMX aquifer is fed by downward leakage and re-infiltration of spring waters from the C aquifer.
2. The relative contribution of local recharge to springs along the Mogollon Rim has been interpreted based on the following criteria: 1. TDS, where a higher TDS is indicative of longer residence times and water-rock interaction and lower TDS is attributed to rapid local recharge through vertical fractures and minimal water-rock interaction. 2. Water temperature, where lower temperature may be indicative of more local recharge, but variation in temperatures is also a consideration. 3. Silica concentration, where silica concentrations may be higher in local recharge if volcanics or gravels are present above the spring discharge area. Silica may also be significantly low in local recharge water that has undergone rapid infiltration. Using these criteria, Webber Spring and Tonto Hatchery Spring are thought to have significant contributions from local recharge. Cold Spring also receives local recharge, but its evolved chemistry seems to indicate perhaps less than originally thought.
3. Wells located north and northwest of Payson are producing groundwater that is dominantly from the regional X aquifer. This groundwater likely originated from the RMX and C aquifers along the Mogollon Rim based on a similar but evolved chemistry and the extensive faults and fractures that appear to connect them.
4. Groundwater in central Payson is a blend of local recharge and regional X aquifer groundwater. This water is more dilute and chemically distinct from regional groundwater that has not been significantly influenced by local recharge.
5. Wells located south of Payson show the impact of local recharge through chemical mixing of reclaimed water (artificially recharged) and groundwater. Other chemical tracers have also been used to identify contributions from local recharge, including elevated nitrate associated with septic leach fields and PCE contamination.
6. Groundwater in the Proterozoic rock beneath Doll Baby Ranch and in the deep alluvium of the Rye Basin is chemically distinct from the regional X aquifer in the Payson area, being significantly higher in sodium, chloride, and sulfate.

Recommendations

1. The water chemistry data provided for this report primarily offer one or two points in time, which limits the ability to make inferences on the stability or variability of water chemistry over time and with changes in season. Collection of water samples

on a seasonal (quarterly) basis for a few years would be worthwhile to observe whether or not there are seasonal or other temporal trends in water chemistry data.

2. More water chemistry data is needed from the Star Valley area, particularly from deeper wells to better differentiate regional versus local groundwater contributions.
3. C-14 testing of the Payson Pines 4 well north of Payson suggested short flow times (decades) for water reaching the X aquifer from the regional C and RMX aquifers (C. Eastoe, this report). However, this well was slightly anomalous in chemical composition, being comparatively dilute from other wells in the area that discharge regional groundwater from the X aquifer. If higher TDS is indicative of longer water-rock interaction times, then additional C-14 testing of some of these other wells (Skypark, Summit, Goat Camp 1) should indicate longer flow times.

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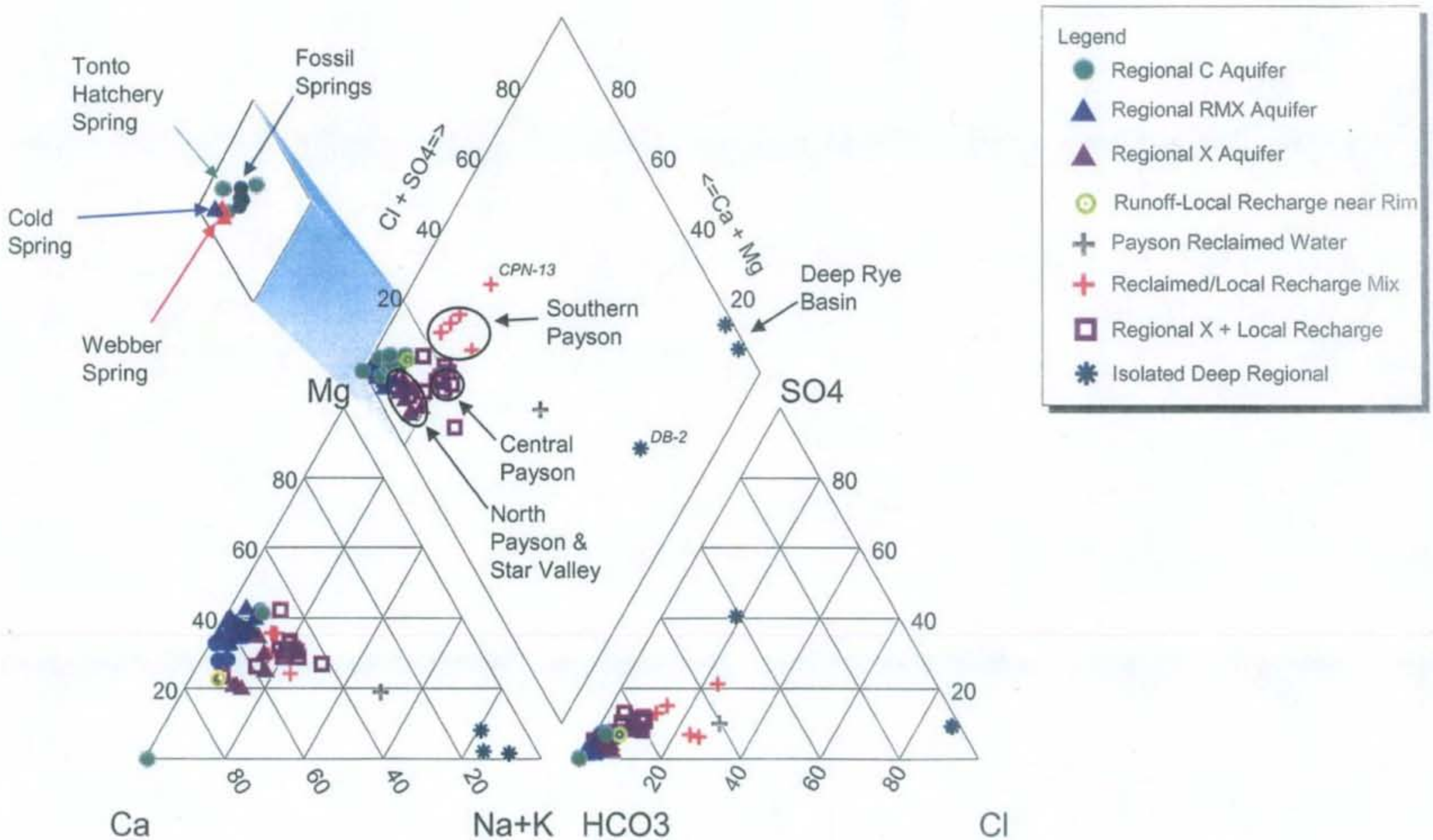
Figure 1. Piper Diagram Indicating Water Chemistry Differences between Regional Groundwater Aquifers and Local Recharge



HSI HydroSystems, Inc.

Figure 2. Chemical Variability of Spring, Surface and Well Waters as Shown by Stiff Diagrams
(Colors indicate regional aquifer contribution and shapes generally vary according to amount of local recharge)

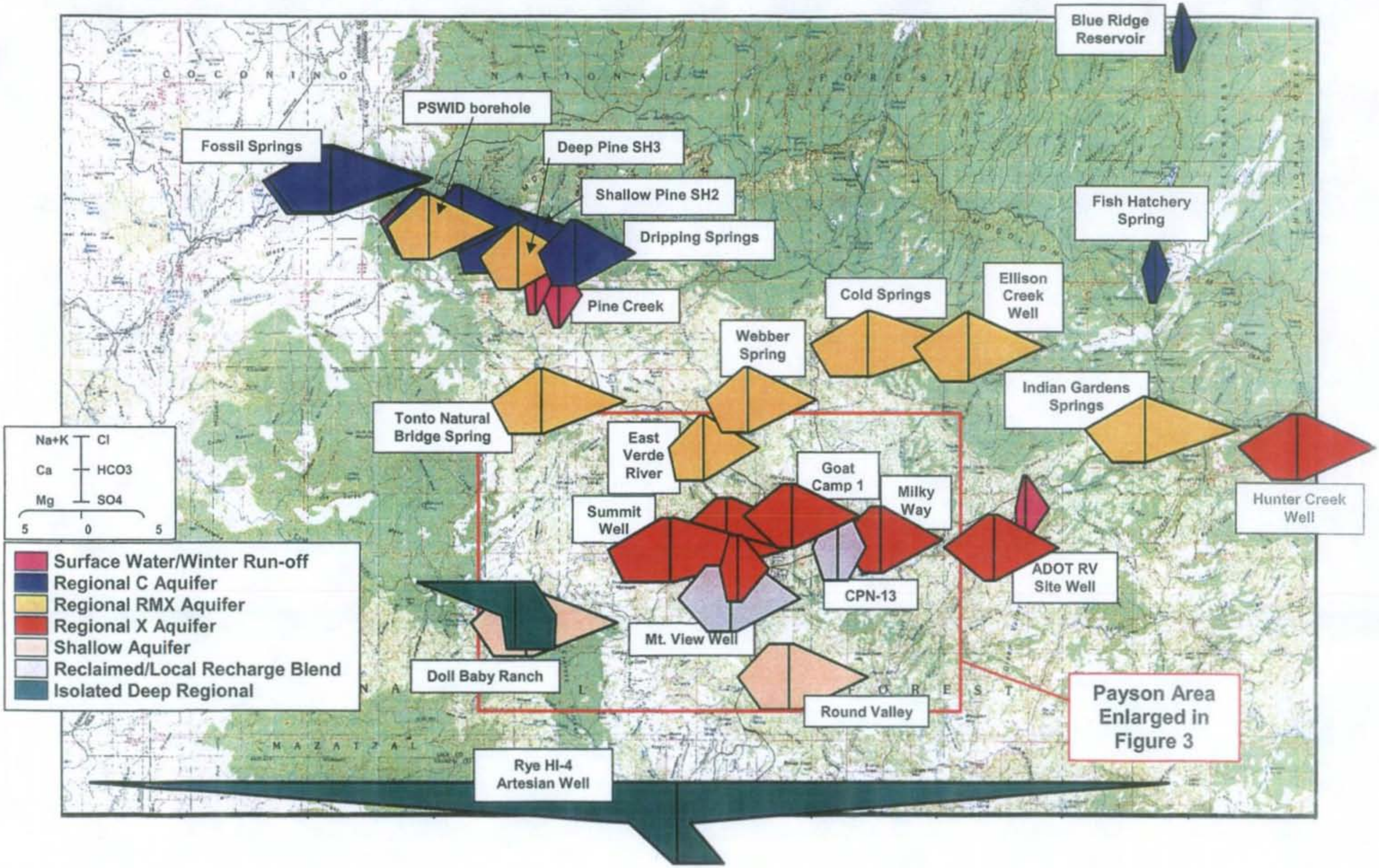


Figure 3. Variations in Payson Area Surface and Groundwater Chemistry due to Local Recharge, Regional Aquifer Contributions and Reclaimed Wastewater Recharge/Reuse

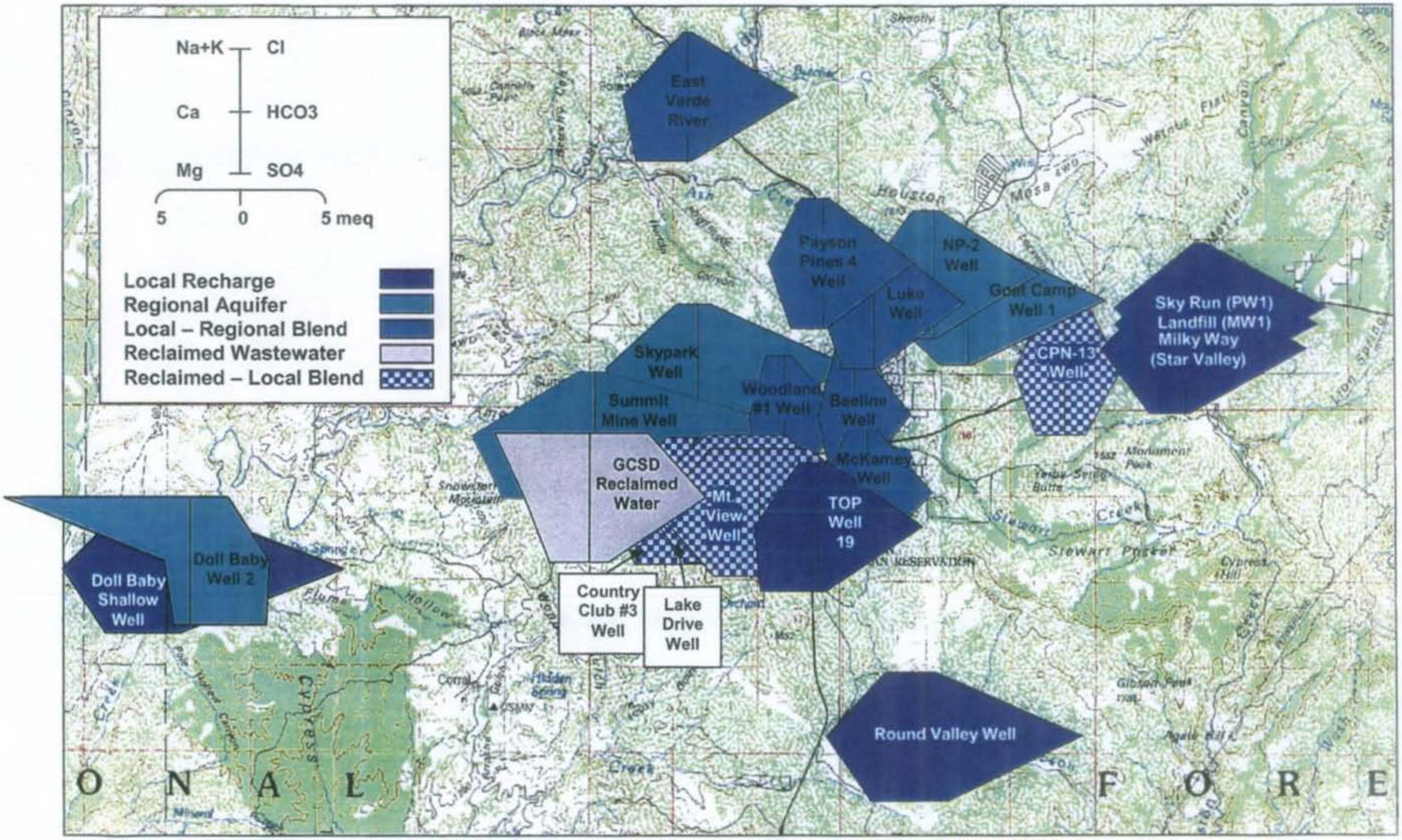


Table 1.
MRWRMS Spring and Surface Water Chemistry Data Summary

Site Name	Site* Type	Aquifer*** Geology	Water Source	Data Source	Sample Date	pH	Cond uS/cm	Temp °C	Alkalinity mg/l	TDS mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	Fe mg/l	F mg/l	Cl mg/l	HCO3 mg/l	NO3 mg/l	SO4 mg/l	SiO2 mg/l
Cold Springs	SP	Redwall-Martin	Regional w/ Minor Local	1	4/21/2004	7.56	610	13	350	370	3.4	<2	83	33	<0.05	<0.4	2.5	427	2.26	5.5	8.9
				1	8/11/2004	7.31	374	13.4	390	350	3.8	<2	93	38	<0.05	<0.4	3.4	475.5	2.17	6.4	9.7
Dripping Springs	SP	Lower C Aquifer/ Volcanics	Blend	4	10/24/2002	6.9	452	13.3	234		8.2	0.7	56	21		0.1	6.3	285		2.2	31
Fish Hatchery Spring	SP	Younger C Aquifer System	Blend	2	10/17/1952		174	9	91	104	0.7	<0.7	26	7.6		0.2	2	111	0.3	3.1	8.7
				4	7/31/1997	7.1	145	9	66		1.32	0.83	18.8	4.51	0.04	<0.1	1.05	80.5	0.53	1.7	7.1
				1	11/17/2004	7	153.9	9.1	66	60	<2	<1	19	4.8	0.08	<0.4	3	66	1.77	3.3	6.8
Fossil Springs (unsurveyed)	SP	Lower C Aquifer	Deep Regional	2	2/16/1952		753	21.5		440	6.9	<6.9	104	40		0.1	9	485	0.5	27	14
				4	8/7/1998	7	720	21	385		10.6	1.85	96.4	34.9		0.2	7.14	469	0.6	22.9	11.9
				5	1/22/2003	6.8	710		399	423	12	2	94	36	<0.03	0.17	8	486	0.62	19	
Fossil Springs Upper	SP	Lower C Aquifer	Deep Regional	1	4/27/2004	7.51	730		380	410	11	<2	96	35	<0.05	<0.4	7.1	463.3	2.52	24	13
				1	10/20/2004				390	420	12	2	97	37	<0.05	0.57	7.5	475.5	2.52	24	13
Lower				1	8/18/2004	6.81	712	21	400	380	12	<2	98	37	<0.05	0.44	7.6	488	2.12	24	13
Indian Garden	SP	Lower Paleozoic	Regional w/ Minor Local	4	7/30/1997	7.1	645	14.5	362		3.23	0.72	92.3	30.5		0.1	3.52	441	0.32	2.7	10.4
Tonto Natural Bridge Spring	SP	Martin	Blend	3	8/19/1997	7.4	620	20	336	350	6.4	0.94	79	32		0.16	6.1	410		3.2	19
				1	10/20/2004	7	580	19.1	330	320	6.3	<2	78	31	<0.05	0.57	6.2	402	3.01	5	19
Webber Spring	SP	Martin/ X (Granite)	Local w/ Minor Regional	4	10/22/2002	7.3	459	21	247		4.2	0.7	62	22		0.2	3.6	301		5.2	10
				1	8/11/2004	7.14	499	14.1	270	220	5.7	<2	67	25	<0.05	<0.4	2.8	329	2.08	5.1	12
				1	10/20/2004	7	489	14.1	270	280	5	<2	68	26	<0.05	0.55	3.3	329	2.52	6.6	11
87 and Cavern	SW	to Redwall	Surface Water	1	4/14/2004				90	110	2.4	<2	27	5.1	<0.05	<0.4	3.2	109.7	<0.8	4.9	20
Pine Creek	SW	to Naco	Surface Water	1	4/14/2004				72	97	2.8	<2	18	6.9	0.12	<0.4	4.1	83	<0.8	4.4	13
Blue Ridge Reservoir	SW	to Upper C	Surface Water	1	10/26/2004	7.62	70	4.3	19.68	47.7	<2	<2	6	2.7	0.21	<0.4	<0.2	24	0.54	3.2	3.1
				1	10/20/2005	7.44	99	6.7	48	52	<2	<2	12	4.8	0.52	<0.4	<2	58.5	<0.8	3.5	5.6

* SP= Spring, SW= Surface Water

** 1 = MRWRMS, 2 = Feth, 1954; 3 = Parker et al., 2005; 4 = USGS NWIS Database, 2005; 5 = Kaczmarek, 2003; 6 = AGRA, 1999 - ADOT Study

*** Any Precambrian Geology Producing Groundwater May be Considered as an "X" Aquifer, For example, Payson Granite is a member of the X aquifer system

Table 2.
MRWRMS Well Water Chemistry Summary

Site Name	Well Depth	ADWR No.	Aquifer Geology	Water* Source	Data Source	Sampling Date	pH	Cond uS/cm	Temp °C	Alkalin. mg/l	TDS mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	Fe mg/l	F mg/l	Cl mg/l	HCO3 mg/l	NO3 mg/l	SO4 mg/l	SiO2 mg/l
Payson Area Wells																						
Beeline	1004	620867	X Payson Granite	Blend	1	2/9/2004	7.1		18	114	200	17		29	11	<0.01	0.85	10	139	4.43	10	
CC #3 Well	760	565297	X Payson Granite/ Gibson Diorite	Recent	1	1/6/2003	6.27	590	15.7	240	360	22	<2	67	28	0.06	0.41	31	293	5.8	37	30
					1	4/22/2004	7.54	600	16	230	360	24	<2	66	28	1.3	0.44	35	280	7.97	44	24
CPN-13 Well	400	544348	X Granite/ Reclaimed Reuse	Recent	1	4/21/2004	6.88	300	15.8	110	250	18	<2	40	14	0.7	0.8	35	134	2.74	39	38
Goat Camp #1 Well	925	565426	X Gneissic Granite	Deep Regional	1	2/11/2004	7.7			274	300	17		77	14	0.05	0.28	9.5	334	3.5	5.5	
					1	12/18/2001	6.9	529	16.6	270	320	18	<2	81	15	0.18	0.48	12	329	3.5	5.3	27
Lake Drive Well	500	558391	X Granite/ Reclaimed Reuse	Recent	1	1/6/2003	6.13	662	15.3	240	400	28	<2	79	25	0.07	0.4	70	293	1.8	18	29
Luke Well	860	575304	X Payson Granite	Blend	1	1/6/2003	6.26	393	18.7	170	250	21	<2	44	18	<0.05	0.53	14	207	22.6	15	32
					1	12/18/2001	7.1	300	17.5	170	300	23	<2	48	20	1	0.71	18	207	29.7	20	32
McKamey	860	509870	X Payson Granite	Blend	1	1/6/2003	6.15	340	16.3	150	230	18	<2	39	14	<0.05	1.3	15	183	7.1	13	40
					1	3/16/2004	7		18	131	210	18		36	13	0.1	1.3	14	160	5.3	11	
Mt. View Well	280	512759	X Granite/ Reclaimed Recharge	Recent	1	1/6/2003	6.62	691	16.8	270	430	45	<2	81	22	<0.5	0.43	69	329	3.45	22	32
NP-2 Well	1000	577329	X Payson Granite	Deep Regional	1	11/13/2001	7		18	210	240	19	<2	54	14	<0.05	0.64	8.5	256	1.95	3.8	27
					1	10/22/2001	7.6	427	18	240	253	19		50	13		0.6	8.5	293	1.3	3.8	
Payson Pines 4 Well	400	564016	X Payson Granite	Deep Regional	1	4/21/2004	6.9	260	18	180	200	19	<2	42	15	0.39	0.51	9.4	219	2.74	6.8	36
Reclaimed Water			Recharge/ Reuse Golf Courses	Reclaimed	1	1/6/2003	6.22	695	14	230	440	86	17	51	19	0.27	0.56	83	280	3.14	36	35
Skypark Well	815	568624	X Payson Granite	Deep Regional	1	2/12/2004	7.4		18	314	350	19		73	28	3.0	0.44	19	383	3.14	5.9	
Summit Mine Well	970	576872	X Gibson Diorite/ Gabbro	Deep Regional	1	12/18/2001	7.2	400	16.7	380	400	15	<2	85	39	<0.05	0.52	7.3	463	3.4	3.7	31
TOP-19 Well	340	519459	X Payson Granite	Recent	1	1/6/2003	6.15	475	15.4	210	290	16	<2	49	27	0.16	<0.4	18	256	15	18	31
Woodland #1 Well	925	503323	X Payson Granite	Blend	1	4/21/2004	7.3	400	16.5	120	190	16	<2	28	10	<0.05	0.86	11	146	6.6	15	40
Star Valley Area																						
RV Site Well R-2	~500	???	X Payson Granite	Recent	2	10/22/1998				260	320	12	<2	78	10		0.95	12	317	1.24	4.3	35
RV Site Well R-4	~500	???	X Payson Granite	Recent	2	10/26/1998				240	300	14	<2	75	11		0.78	9.3	293	0.62	4.6	38
Landfill MW-1	100	???	X Payson Granite	Recent	1	7/18/2005	6.74	430	15	240	340	9.1	<2	71	14	5.5	<0.4	2.6	293	7.97	10	49
Landfill MW-2	110	???	X Payson Granite	Recent?	1	7/18/2005	6.35	174	18.1	71	130	11	<2	14	5.2	0.27	0.44	3.5	86.6	3.59	7.4	47
Sky Run Well (PW2)	407	???	X Payson Granite	Blend?	3	8/25/2004				230	263	18	<2	64	13		0.5		280	3.54	<5.0	
Sky Run Well (PW1)	300	???	X Payson Granite	Blend?	3	3/23/2004	7.3		18.5	240	270	17	<2	67	12		0.59	8.8	292.6	3.94	5.4	
Milky Way Well	120	605247	X Payson Granite	Recent?	1	11/17/2004	7.7	480	7.4	240	280	19	<2	66	17	<0.01	0.49	8.6	292.6	4.87	8.6	26
Pine / Strawberry Wells																						
Deep Pine SH-3 Well	1320	587628	Martin-X	Blend	1	4/21/2004	7.3	420	11.2	230	320	5.3	<2	60	19	<0.05	<0.4	4.4	280	3.94	6.2	13
Deep Strawberry Well	700	203413	Supai - Lower C	Blend	1	10/25/2004	7.27	470	13.4	250	290	7.8	<2	63	22	0.49	<0.4	4.7	304.8	3.14	6.8	22
PSWID Strawberry	1872	581081	Redwall-Martin	Blend	1	4/11/2005	7.9	470	16.4	270	280	9.6	<2	65	25	<0.05	<0.4	7	329.2	3.1	7	24
Shallow Pine SH-2 Well	240	579973	Supai - Lower C	Blend	1	4/21/2004	7.4	780	11	370	460	16	2.6	84	42	0.06	<0.4	10	451	2.39	26	17
Strawberry Shallow Well	400	588181	Supai - Lower C	Blend	1	10/25/2004	7.38	461	14.3	260	250	9.7	<2	58	23	<0.05	<0.4	5	317	2.7	3.6	23
Other Wells																						
DB-2	992	597574	X Gibson Diorite/ Gabbro (confined)	Deep Regional	1	11/19/2003	7.3	560	22	130	380	140	4.5	17	6.6	0.32	1.8	44	158.5	<0.3	120	26
DB-Shallow	80	???	TG Gravels	Recent	1	11/19/2003	6.9	465	16	290	320	29	<2	70	25	2.1	0.4	14	353.6	4.87	21	26
Ellison Creek Well	560	581836	Martin - X Granite	Blend	1	10/21/2004	7.11	509	13	290	290	2.4	<2	78	24	<0.05	0.5	5.5	353.6	2.43	5.2	8.5
Hunter Creek Well	95	508554	Alluvium - Upper X Quartzite	Recent	1	11/18/2004	7.1	644	9.9	300	330	10	<2	91	24	<0.05	<0.4	21	365.8	2.26	18	10
Round Valley Well	160	???	X Gibson Diorite/ Gabbro	Recent	1	4/15/2004	7.2	450	16.5	310	400	36	<2	79	26	0.91	<0.4	14	378	6.64	43	26
Rye HI-4 Well	840	590440	X Gibson Diorite/ Gabbro	Deep Regional or Connate	1	1/6/2003	7.55	4280	21.1	40	2300	850	19	60	3.1	0.43	5.8	1100	48.8	<0.8	140	23

* 1 = MRWRMS or Town of Payson Publication, 2 = AGRA, 1999 - ADOT Study; 3 = SWGC, 2004

ATTACHMENT 1C
(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Report on an Isotope Study of Groundwater from the Mogollon Highlands Area and Adjacent Mogollon Rim, Gila County, Arizona

By: Chris Eastoe Ph.D., University of Arizona., October 2007

REPORT ON AN ISOTOPE STUDY OF GROUNDWATER FROM THE MOGOLLON HIGHLANDS AREA AND ADJACENT MOGOLLON RIM, GILA COUNTY, ARIZONA

Prepared for the Town of Payson Water Department

by C.J.Eastoe, Ph.D., University of Arizona

October 23, 2007

Introduction

As part of the MRWRMS investigation of groundwater in the area around Payson, several sets of groundwater, rainwater and surface water samples were collected for isotopic analysis. All samples were analyzed for stable oxygen and hydrogen isotopes, and many were analyzed for stable sulfur isotopes, strontium isotopes and tritium. Three samples were analyzed for carbon-14. The goals of the isotope study were to characterize local precipitation, and to constrain the origin(s) and the residence time(s) of the groundwater. Sets of isotope data are available for groundwater and precipitation along the Mogollon Rim to the west of the Payson area, and these data are compared with the new data generated for this study.

The geology and hydrogeology of the study area are described in detail elsewhere in the MRWRMS reports. Earlier descriptions of the hydrogeology of the Pine-Strawberry area were given by Highland Water Resources Consulting Inc. (2005) and Kaczmarek (2003). Bills et al. (2000) described the hydrogeology of the Flagstaff area, where the Colorado Plateau strata are similar. A brief summary only is given here to explain terms that will be used in this section.

The strata of the Colorado Plateau, including capping Tertiary basalt, contain two principal aquifer systems: (1) a perched aquifer, present locally in Tertiary volcanic rock; and (2) the Regional aquifer, occurring within Paleozoic strata and underlying Proterozoic rocks. The Regional aquifer can be divided into units that are separated by the impermeable lower Supai redbeds. Above that horizon, the water is present in the primary porosity of sandstone units, principally in the Coconino sandstone and the Schnebly Hill formation, and in fractures. This unit has been termed the C aquifer. Below the Supai group, water is present in fractures and open spaces of the Redwall and Martin formations (largely carbonate rock) and underlying Proterozoic rock, and is here termed the RMX aquifer (cf. Highland Water Resources Consulting Inc., 2005). Evidence presented in these reports suggests that the C and RMX aquifers are connected locally. Groundwater discharges from the C and RMX aquifers in a series of springs along the base of the Mogollon Rim.

South of the Mogollon Rim, another major aquifer, here termed the X aquifer, occupies fracture permeability within granitoids and other intrusive rocks of Proterozoic age. Groundwater is also discharging from downfaulted parts of the Martin formation south of the Rim. The aquifer(s) in this case may or may not be connected to the Regional aquifer of the Colorado Plateau; any connection must be through fractured Proterozoic rock. For the purposes of this study, they will be grouped as the M aquifer. Groundwater is also present in minor aquifers hosted by valley-fill sediment in the Rye basin, at Star Valley and adjacent to other streams.

Potential Usefulness of Stable Isotope Data

Stable isotope data are measured as ratios, for instance $^{2}H/^{1}H$ (or D/H), $^{18}O/^{16}O$ and $^{34}S/^{32}S$. The results are expressed using δ-notation, e.g.:

$$\delta D = \left(\frac{R(sample)}{R(s\tan dard)} - 1\right)x1000$$

where R = D/H and the standard is Vienna Standard Mean Ocean Water.

The definition of $\delta^{18}O$ is analogous, with $R = {}^{18}O/{}^{16}O$ for oxygen, and for $*^{34}S$, $R = {}^{34}S/{}^{32}S$. For $\delta^{34}S$, the standard is CDT, Cañon Diablo troilite.

Values of δD and $\delta^{18}O$ are usually presented in a plot such as Fig. 1 in which annually-averaged precipitation from around the globe plots along a straight line (the global meteoric water line, GMWL) with slope = 8. Groundwater at a given site usually bears the time-averaged isotopic signature of precipitation in the areas where it fell as precipitation, unless evaporation or exchange with rock oxygen have taken place. In Fig. 1, point A represents a hypothetical local average precipitation. Exchange of O isotopes between water and rock leads to horizontal shifts to the right of the GMWL (e.g. line AD) and evaporation leads to trends with slope 3 to 5, also to the right of the GMWL (e.g. line AC, composition C being the water left over from intense evaporation of composition A) . The mixing of waters of different isotopic composition results in straight-line trends on the diagram, so that point B on the evaporation trend in Fig 1 could represent mixing of compositions A and C.

An advantage of using hydrogen and oxygen isotopes in groundwater is that they label the water molecules themselves (rather than solute ions or molecules) and are conservative in groundwater under typical conditions.

As groundwater passes through rock, it may dissolve sulfate minerals (usually gypsum) or oxidize sulfide minerals (commonly pyrite). If these minerals have characteristic sulfur isotope compositions, the sulfur isotope composition of the sulfate dissolved in the water may give useful information about the flow-path of water. In the study area, Permian gypsum with $\delta^{34}S$ values of 11-14‰ (Claypool et al., 1980) in the Kaibab formation and Supai group, and possibly igneous sulfide, near 0‰, are the most likely sources of high concentrations of dissolved sulfate.

Strontium isotopes, like sulfur isotopes, are labeled according to the source of solute, in this case the cations. ^{87}Sr originates from the decay of radioactive ^{87}Rb, while ^{86}Sr is unchanging. Rocks such as granite that have high Rb concentrations therefore develop high $^{87}Sr/^{86}Sr$, particularly in the case of ancient rocks such as the Proterozoic granitoids of the Payson area. Rocks such as basalt that have low initial ^{87}Rb retain low $^{87}Sr/^{86}Sr$ ratios. Marine carbonates and calcium sulfate evaporites have $^{87}Sr/^{86}Sr$ ratios reflecting those of the oceans from which they formed, the ratios varying with time (Burke et al., 1982). Rock $^{87}Sr/^{86}Sr$ ratios are imparted to groundwater in contact with the rock. In the Mogollon Rim area, the Kaibab, Naco, Supai (evaporitic facies) and Martin formations will impart marine Sr isotope ratios to groundwater, while the clastic elements of Coconino, Schnebly Hill and Supai formations may impart the Sr isotope signatures of reworked fragments of other rock types.

Tritium is continuously generated in the upper atmosphere as a result of nuclear reactions caused by cosmic rays. In Tucson, the level of cosmogenic tritium in rainwater is about 6 TU (tritium units; 1 TU = 1 atom of tritium per 10^{18} atoms of hydrogen) (Eastoe et al., 2004). Similar, but not identical, levels are expected elsewhere in the southwest USA. In addition, a pulse of tritium was added to the atmosphere between 1955 and 1975 as a result of atmospheric testing of nuclear weapons. In 1963-64, tritium levels rose briefly to about 1000 TU. The half-life of tritium is 12.4 years, so that pre-bomb tritium has now decayed to less than the level of detection, 0.6 TU in our laboratory. Bomb tritium is still present in aquifers recharged with rainwater since about 1955. We therefore use tritium to distinguish between water containing tritium below detection, which must have recharged before about 1955, and water containing tritium above detection, which must contain some water that fell as rain since 1955.

Carbon-14 can be measured in dissolved inorganic carbon species (usually bicarbonate) in groundwater. The carbon comes from two sources: carbon dioxide gas in soil or near-surface sediment through which the recharging water passes, and from carbonate minerals like calcite in rock. The soil gas has ^{14}C content near that of the atmosphere, currently about 108 pMC (percent modern carbon). Like tritium, ^{14}C is generated in the upper atmosphere and in nuclear explosions in the atmosphere. Pre-bomb levels were near 100 pMC, and during the 1960s, levels near 200 pMC were reached for a few years. Rock carbon contains no ^{14}C. The half life of ^{14}C is 5730 years, so that ^{14}C measurements enable us to estimate water ages in the range of hundreds to thousands of years. The mixing of carbon types precludes exact age determinations. If infiltrating water dissolved *only* carbon from soil gas, and then resided in an aquifer, we can calculate an age based on ^{14}C decay. But if the water also dissolved carbon from rock, the calculated age will be too old. Nonetheless, ^{14}C content in water can give useful comparative age information. In general, higher (lower) pMC indicates groundwater of shorter (longer) residence time.

Hypothetical O and H Data Arrays

The study area and potential recharge areas stretch from the Mogollon Rim to Rye, with an altitude difference of more than 1000 m. Three cases for recharge and flow of groundwater seem likely (see Fig. 2):

1. Recharge important at high elevations, where precipitation is heaviest, and unimportant at low elevations; regional groundwater flow to lower elevations. Water undergoes little evaporation prior to recharge, and does not change in isotope composition down-gradient in the aquifer. The entire aquifer will therefore contain water with a high-altitude isotope signature. Water at low

elevations is older than that at high altitude, so that tritium will be observed to decrease down-gradient.

2. Recharge and groundwater flow are mainly local, and recharge occurs rapidly from stream beds. In a given area, the source of recharge is precipitation in that area. The altitude effect in rainwater isotopes will be reflected in groundwater; high-altitude groundwater will have low δ-values, and low-altitude groundwater will have high δ-values. Young water, with detectable tritium, is found at all altitudes. Low-altitude rainwater tends to be slightly evaporated, so that the slope of a data array will be between 6 and 8.

3. Recharge occurs at all altitudes, but the source of water is at high altitude. At low altitude, some groundwater derives from regional groundwater flow from high altitude, and shows no isotopic shift due to evaporation. This may mix with water recharged at low altitude, but mainly derived from high elevations and supplied as surface water. Such water will be subject to evaporation. Mixtures of the two kinds of water will give a linear data trend with a slope between 3 and 5. Tritium will be present throughout.

A graph of $\delta^{18}O$ vs. altitude of sampling would show no altitude dependence in case 1; a clear linear relationship in case 2; and an indistinct relationship in case 3. If case 3 applies, there may be an observable isotope effect of evaporation in groundwater sampled close to major drainages.

Stable O and H Isotope Data

The new data for the study area are listed in a table in the hydrology section of the MRWRMS reports.

1. *Payson Rainwater*. Seasonal bulk samples, weighted for amount, were collected in Payson at an altitude near 5000 ft./1500 m. above sea level between Winter 2002-2003 and Summer 2007. These are not sufficient to characterize average rainfall in the area; annual variability is likely to be great, as in Tucson, where the data set extends over 24 years (Wright, 2001). The data are compared with long-term mean data for the Tucson area in Fig. 3, and demonstrate: (1) That bulk precipitation in Payson plots close to the GMWL (more closely than in Tucson, where summer precipitation at 2500 ft./750 m.a.s.l. is more evaporated than in Payson, and winter precipitation at 7400 ft/2242 m.a.s.l. shows a greater shift above the GMWL than in Payson); and (2) That the difference between summer and winter precipitation is generally similar to that in Tucson.

2. *Surface Water*. The linear array of data (Fig. 4A) generally follows the GMWL, and several points coincide with the field of groundwater. An exception is surface water from Blue Ridge reservoir, which has an isotope composition consistent with evaporation.

3. *Groundwater.* On a δD vs $\delta^{18}O$ plot, most of the data form a linear array (Fig. 4A) with a slope close to 5. Certain samples do not conform to the linear trend: (1) Samples from well HI-4 at Rye and the Doll Baby ranch, where the groundwater may be very old (see ^{14}C data, below); (2) A sample from shallow alluvium at Hunter Creek. The Hunter Creek sample is the only sample in which summer precipitation is clearly present. This is a local effect in a small pocket

of alluvium, and is not present to the same extent in the principal aquifers in fractured rock. (3) the C aquifer samples from Fossil Springs (Fig. 4B).

The linear trend can be explained in two ways.

Hypothesis 1: The trend is as expected for Case 3, above. The single trend suggests strongly that most recharge in the study area plots in a limited field on the diagram, at the left-hand end of the trend, near $\delta^{18}O = -11.5‰$. The source or recharge is predominantly winter precipitation, and the trend is generated by evaporation. Scatter about the trend might represent the incorporation of small amounts of summer precipitation. The identification of the linear trend as an evaporation trend is reinforced by two observations. First, the samples with highest δ-values are from the Lake Drive, Mountain View, CC-3 and CPN-13 wells, which are near the Green Valley Park Lake or various golf course ponds, and are influenced by recharge from the ponds, or from irrigation reflux (Fig. 5A). Second, Blue Ridge reservoir water plots close to the trend (Fig. 4A). The reservoir is on the Colorado Plateau at 6700 ft./2030 m. elevation, and is fed by runoff from the highest part of the Mogollon Rim in this area. The second observation suggests further that the source of recharge in the Payson area is high-elevation precipitation; a mean $\delta^{18}O$ value of -11.5‰ in winter precipitation at the Rim summit (7000 ft./2100 m. elevation) is consistent with the $\delta^{18}O$ vs altitude data of Blasch et al. (2005).

Hypothesis 2: Case 2 is the operative case, but is not indicated clearly on the δD vs. $\delta^{18}O$ plot because average recharge at the elevation of Payson (AREP) plots in the middle of a single linear trend of data. Local recharge clearly occurs to the X aquifer where evaporated water is available (Fig. 5A), and therefore probably occurs where non-evaporated runoff is available. The field of AREP indicated in Fig. 4B is based on the data for three wells, Round Valley (in Round Valley) and Quail Valley and Milky Way (in Star Valley). All three are drilled through valley-bottom alluvium overlying Proterozoic granitoid; in all cases the water table is shallow (25 and 40 feet below the surface, respectively). Both valleys receive only lower-elevation runoff: Gibson Creek in Round Valley rises at the south end of Payson, and the drainages entering Star Valley rise on Diamond Rim or at lower elevation. *Assuming that much of the recharge near these two wells is from the nearby streams,* the water samples should represent AREP. This is plausible: groundwater is shallow in both cases, and in both cases, total dissolved solids are low (see the MRWRMS Water Chemistry report). At Round Valley, the well screen starts 30 feet below the surface, and at Milky Way, the screen starts at 20 feet. According to this hypothesis, the trend of O and H isotope data to the right of the AREP field is an evaporation trend. To the left of the AREP field, however, the trend reflects mixing between AREP and water from the C and RMX aquifers, with a slope that is near 5 by coincidence.

In Fig. 5B, groundwater samples are grouped according to the aquifer sampled. Three of the samples from the C aquifer lie at the lower end of the evaporation trend. The lowest $\delta^{18}O$ and δD values are from the C aquifer at Fossil Springs, at the western end of the study area, and match the upper end of the field of data for the regional aquifer (equivalent to the C aquifer) beneath Flagstaff (Bills et al., 2000 –see below). The fifth sample, from Fish Hatchery Spring at the eastern end of the field area, is distinctively light. A scattering of similar samples was found in the regional aquifer beneath Flagstaff by Bills et al. (2000). Samples from the RMX aquifer conform to the mixing/evaporation trend; the least evaporated of these samples match the C aquifer samples. Samples from the M aquifer either coincide with the AREP field (Webber Spring) or fall on the mixing/evaporation trend (Tonto Natural Bridge Spring). In the X aquifer, a group of samples (Summit, Payson Pines 4, Turtle Rock, Goat Camp and Luke wells, shown as "Summit etc." in Fig. 5B) also plots on the mixing/evaporation trend to the left of the AREP field. These locations are 3 to 5 km north and west of Payson, and are separated from the base of the Mogollon Rim by the canyon of the East Verde River.

The plot of $\delta^{18}O$ vs. sampling elevation (Fig. 6) shows a linear trend including most of the groundwater samples from the Payson-Pine area. Samples from the C, RMX and M aquifers and from Rye Basin do not conform to the trend. The slope of the trend is much lower than the slopes of $\delta^{18}O$ vs. altitude trends for the region (Tucson and Santa Catalina Mts. – Wright, 2001; Verde Valley to Flagstaff – Blasch, 2005). The trend is clearly not governed mainly by the altitude isotope effect. Note that sampling altitude does not necessarily correspond with average recharge altitude, which cannot be estimated for the sample sites in this study, given the possibility of long-distance flow of groundwater. The least evaporated samples (lowest $\delta^{18}O$) on the linear trend correspond with average precipitation from about 400 m higher according to Blasch's (2005) data. The correspondence between the most evaporated samples (highest $\delta^{18}O$) and Blasch's altitude trend is coincidental. The apparent linear trend may simply reflect the fact that ponds are constructed in topographic depressions.

Fig. 7A is a map of $\delta^{18}O$ values at sample sites in the X aquifer near Payson. The association of high $\delta^{18}O$ values (indicating evaporation) with central Payson shows clearly, and can be explained by the local recharge of reclaimed water from ponds and lakes in Payson. Groundwater from north Payson has lower $\delta^{18}O$ values.

The linear δD vs. $\delta^{18}O$ trend in the Payson area (the "Payson trend", below) is compared with other data from the region in Fig. 8. Data reported by Flora (2004) and Parker et al. (2004) for springs along the base of the Mogollon Rim are largely consistent with the Payson trend. Exceptions include springs near Camp Verde and Sedona, and as far east as Blue Spring on the Verde River near Childs; these plot below the Payson trend. Data reported by Bills et al. (2000) for groundwater in the Flagstaff area differ significantly from the Payson trend. Data from perched aquifers in the volcanic rock of the San Francisco Peaks may define an evaporation trend like that at Payson, but originating at a lower $\delta^{18}O$ value, consistent with the higher altitude of the Peaks. Springs from the Sedona-Camp Verde area fall on this trend (Fig. 8). Data from the regional aquifer in the Paleozoic section underlying Flagstaff plot near the GMWL and at lower δ-values $\delta^{18}O$ between -11.9 and -12.4‰, but with scattered higher values) than in the C aquifer near Payson; presumably the lower $\delta^{18}O$ values reflect recharge from high-altitude areas of the San Francisco Peaks. Unpublished data reported to the Arizona Department of Transportation for an area along State Route 260 east of Lion Springs scatter more widely than the other data sets, and may for this reason not be accurate. Particularly suspect are the data points plotting above the GMWL. No comparable values have been observed in the other studies in the region. Water with such $\delta^{18}O$ and δD values can be generated from snow banks that have undergone sublimation prior to melting, but it seems unlikely that such an effect would be limited to the Lion Spring area.

Tritium and Carbon-14

Tritium in average precipitation from the study area appears to be close to 5 TU on the basis of 5 measurements for seasonal rain samples. The value is comparable to that for Tucson (5-7 TU) where long-term records have been kept. There has been no bomb-tritium in Tucson precipitation (or, by implication, in Mogollon Rim precipitation) since 1992 (Eastoe et al., 2004). Groundwater samples from the study area almost all contain tritium at levels between 1 and 6 TU, consistent with various degrees of mixing of recent precipitation with pre-bomb water throughout the area. Only a few wells, Turtle Rock, Rye HI-4, Doll Baby 2) yield groundwater of < 1 TU, and therefore have little to no post-bomb rainwater component. The distribution of tritium in the X aquifer is shown in Fig. 7B Values greater than 2.5 TU correlate with high $\delta^{18}O$ in Payson; presumably some tritium from rainwater is recharging with the reclaimed water. This zone contrasts with a zone of low tritium in north Payson. Tritium levels > 2.5 TU were also found at sites CPN13, Milky Way and Round Valley, where local recharge is thought to occur, as explained above.

Four ^{14}C measurements are available. Average residence times of groundwater are indicated in a semi-quantitative way by tritium and C14 data in combination, as follows.

Rye-HI4 well (2.6 pMC, 0.6 TU) yields water of long average residence time, and post-bomb recharge is insignificant. Residence times in the thousands of years are probable, and consistent with the low $\delta^{18}O$ and δD values. Late Pleistocene and early Holocene rainwater are thought to have had lower mean $\delta^{18}O$ and δD values than those of present-day rainwater (e.g. Plummer et al., 2004).

Tonto Natural Bridge spring (74.2 pMC, 2.0 TU) yields a mixture of post-bomb and pre-bomb water.

Payson Pines 4 well (82.4 pMC, 0.6 to 1.4 TU) occurs in an area of little post-bomb recharge, as noted above. The ^{14}C data, however, are consistent with pre-bomb recharge in the few decades prior to 1950.

Fossil Springs (69.2 pMC, 0.6 TU; pMC from unpublished data of A. Springer) is similar to Tonto Natural Bridge Spring, but the proportion of post-bomb water is smaller.

Sulfur Isotopes

Sulfur isotopes have been measured in a selection of samples. In Fig. 9, the data for those samples with known sulfate concentrations plot in a triangular array typical of groundwater in the region – e.g. in Tucson basin (Gu, 2005). Mixing trends on this plot are straight lines. The data therefore indicate a minimum of three sulfate sources: 1. High $\delta^{34}S$ (12-13‰) and high sulfate, corresponding to Permian marine evaporites; 2. Low $\delta^{34}S$ (near 0‰) and high sulfate, most likely corresponding to oxidized igneous sulfide; and 3. Values of $\delta^{34}S$ of 6 to 8‰ and low sulfate, corresponding to sulfate in rain and dust. The evaporite end-member might be expected mainly in C-aquifer and RMX-aquifer water, and the igneous end-member in the X aquifer, if sulfate were locally derived. No such pattern is evident. Sulfate in X-aquifer water resembles evaporitic sulfate in some cases, and there is a strong signal of rain+dust sulfate in sulfate in water from Paleozoic rocks, including the C aquifer. It is possible that other sulfate sources, of lower $\delta^{34}S$, exist in Paleozoic strata. The identification of end-member 3 as fallout is supported by the data from two runoff samples, in which this type of sulfur predominates. The lower $\delta^{34}S$ values (relative to data for groundwater in the area) may reflect industrial sulfur in the atmosphere; in Tucson basin, Gu (2005) concluded that rainwater sulfate of the last few decades has lower $\delta^{34}S$ values than earlier rainwater sulfate for this reason.

The samples approaching the end-member compositions may be informative.

End-member	Samples
Evaporite	Lake, Hunter Creek, Mountain View, Rye HI-4
Igneous	Round Valley, CC#3
Rain+dust	Webber, Shallow Strawberry

In fact, little can be concluded. The low $\delta^{34}S$ values at Round Valley and CC#3 may indicate concentrations of sulfide in the granites in these areas. The Lake well is influenced by recharge from Green Valley Park Lake on the basis of O and H isotopes, but the $\delta^{34}S$ value (13.3‰) is quite different from that of reclaimed water (6.1‰). A possible explanation is that partial sulfate reduction, leading to an increase in $\delta^{34}S$ of the residual sulfate, is occurring in the bottom sediment of the lake. This effect may also be responsible for the $\delta^{34}S$ value, 12.2‰, at the Mountain View well. In the case of the Rye HI-4 sample, sulfate reduction is almost certainly responsible for the high $\delta^{34}S$ value, because water from this well smells of H_2S. These three samples excluded, there is little remaining indication of evaporitic sulfate in the data set; only the Hunter Creek well at the far eastern end of the study area contains such sulfate.

Strontium Isotopes

Fig. 10 shows $^{87}Sr/^{86}Sr$ data for groundwater in the Payson area in relation to data from the literature: (1) groundwater from the regional aquifer near Flagstaff (Bills et al., 2000); (2) expected $^{87}Sr/^{86}Sr$ ratios for limestone and evaporite units in the Paleozoic section (Burke et al., 1982); (3) Neogene and Quaternary volcanic rocks of the Hickey basalt and the San Francisco Peaks (Scott, 1974); (4) Paleozoic strata of the study area (Parker et al., 2005); and (5) 1.4 to 1.7 Ga Proterozoic granites sampled as xenoliths in volcanic vents in the Four Corners area (Condie et al., 1999).

The data for groundwater near Flagstaff are classified according to flow-path rock type, and show clearly the influence of lithology on $^{87}Sr/^{86}Sr$ in groundwater solutes. The range of $^{87}Sr/^{86}Sr$ in solutes is consistent with $^{87}Sr/^{86}Sr$ ranges of limestone (Kaibab and Martin/Redwall formations) and volcanics. There is no indication of addition of strontium from radiogenic detritus in clastic sedimentary units in this area.

Samples from the Mogollon Rim near Payson differ according to the formation from which the water emerges or is drawn. Water from the Supai group has $^{87}Sr/^{86}Sr$ ratios slightly higher than those expected or measured in the Kaibab formation and the Supai group. The Tonto and Fish Hatchery samples have particularly high ratios. The Fish Hatchery spring discharges from the Fort Apache Limestone, part of the Supai Group. Two $^{87}Sr/^{86}Sr$ measurements on the he Fort

Apache Limestone gave conflicting results: one (0.7104; Parker et al., 2005) almost as high as the measurement for the Fish Hatchery sample (0.7107), but another (0.7080; this study) much lower. Water emerging from the Martin formation has distinctly higher $^{87}Sr/^{86}Sr$ ratios that water from the Supai formation. The highest $^{87}Sr/^{86}Sr$ ratios were measured in water from Proterozoic granitoid and Quaternary detritus of granitoid derivation at the Milky Way site, and from basin-fill, which must contain a large fraction of granitic detritus, at Rye ($^{87}Sr/^{86}Sr = 0.7128$, not shown in Fig. 10). Both ratios are consistent with the $^{87}Sr/^{86}Sr$ ratios for Proterozoic granitoids.

The difference in $^{87}Sr/^{86}Sr$ ratios between groundwater from the C and RMX aquifers is of interest here. All of the samples are from the Rim itself, not from downfaulted Paleozoic strata in the area immediately south of the Rim. Therefore the processes responsible for the ratios must be taking place in the Colorado Plateau. Two hypotheses can be advanced.

> (1) Groundwater from the Martin Formation is a mixture of recharge from the crest of the Mogollon Rim with upwelling water that has circulated through underlying Proterozoic granitoids and metamorphic rocks and is focused along major fractures. Crossey et al. (2006) showed that such mixtures are responsible for travertine formation at springs in the Grand Canyon. Groundwater from Proterozoic rock is more likely to affect the lower aquifer(s) in the Paleozoic section, but might locally mix with the C aquifer if suitable fractures exist. Upwelling in such a case may occur if the water is heated as it circulates through the Proterozoic rocks, or if there is a positive hydrologic head difference between the zones of recharge and discharge zones.
>
> (2) Groundwater from the RMX aquifer has been exposed to radiogenic detritius (e.g. eroded from Proterozoic rocks) in clastic units below the C aquifer host strata, or by recharge through the Eocene Rim Gravels.

Rim Gravels occurs north and south of the Mogollon Rim in the study area, but not on the face or the crest of the Rim. The first occurrence of Rim Gravel to the north of the summit is at a distance of several miles from the crest. Recharge through Rim Gravel is therefore unlikely to add radiogenic Sr to groundwater discharging at the base of the Rim in this area. Derivation of radiogenic Sr from ancient granitic detritus in the clastic strata of the Colorado Plateau is also unlikely. Similar clastic strata occur in the Flagstaff area, but $^{87}Sr/^{86}Sr$ ratios are much lower in groundwater that has been in contact with them. There is no reason to suppose a facies change with concomitant variation in the fraction of Proterozoic-derived detritus in the clastic strata (C. Conway, personal communication). The first hypothesis therefore seems more tenable as an explanation of high $^{87}Sr/^{86}Sr$ ratios in the RMX aquifer. The impermeable lower Supai strata would insulate the C aquifer from this effect. The Strawberry Shallow well and the Fish Hatchery Spring (both C aquifer), however, with relatively high $^{87}Sr/^{86}Sr$ ratios, do not conform to this explanation. Groundwater in both is associated with the Fort Apache Limestone. The Sr isotope data suggest that the groundwater in these instances may be in contact with a localized body of rock containing radiogenic Sr, or that a fracture may be conveying water of deep derivation locally as far as the C aquifer. The second possibility seems unlikely for the Fish Hatchery Spring, which is near the Rim crest. If the first possibility is operative, the Fort Apache Limestone may have an unusual $^{87}Sr/^{86}Sr$ ratio. During the Permian and Pennsylvanian, two short-duration spikes in marine $^{87}Sr/^{86}Sr$ ratios are present according to the data of Burke et al. (1982), with values as high as 0.7090. This is insufficient to explain the value of 0.7107 in the Fish Hatchery sample, but suggests at least that high $^{87}Sr/^{86}Sr$ ratios are possible in certain marine limestone units.

The upwelling of water that has passed though Proterozoic granite might conceivably add water of different $\delta^{18}O$ and δD to the RMX aquifer. Such an effect is not visible in the present data set (Fig. 5B). This observation suggests that the water circulating deeply through the Proterozoic granites beneath the Colorado Plateau is of the same origin as other water in the C and RMX aquifers.

Discussion

1. Variation in $\delta^{18}O$ and δD of Mogollon Rim springs. The low $\delta^{18}O$ and δD values of springs to the west of the study area (Flora, 2004), in combination with the perched-aquifer isotope data from Bills et al. (2000), confirm the regional importance of high-altitude winter precipitation as a source of recharge for groundwater south of the Mogollon Rim. The elevation of the Rim itself is about the same from Sedona to Payson, so that snowmelt from the Rim summit should have the same average isotope content throughout. Groundwater near Flagstaff and Sedona most likely has lower $\delta^{18}O$ and δD values because recharge from the high-altitude area of the San Francisco Peaks contributes to groundwater in that area. The lower $\delta^{18}O$ and δD values are clearly present in the perched groundwater near Flagstaff, and in the C aquifer from Flagstaff to Fossil Springs. Higher $\delta^{18}O$ and δD values are found in C aquifer wells and springs directly north of Payson, and much higher values at the Fish Hatchery spring northeast of Payson.

The presence of a distinctive evaporation trend in the data of Bills et al. (2000) and Flora (2004) demonstrates that part of the recharge in these areas is evaporated water. For the Mogollon Rim springs, the regional data are therefore consistent with Hypothesis 1 (outlined above in the section on O and H isotopes), except possibly for springs from the RMX aquifer near Payson (see below).

2. Payson groundwater: Hypothesis 1 or Hypothesis 2? The two hypotheses are illustrated schematically in Fig. 11. Hypothesis 2 has the advantage of allowing for local recharge at the altitude of Payson. Local recharge can clearly be traced to artificial ponds in and near Payson. If pond water can infiltrate the X aquifer , it is reasonable to suppose that natural winter snowmelt can also infiltrate in that area. Hypothesis 1 has the disadvantage (in this area) of requiring recharge of evaporated stream water to the X aquifer in areas where the streams draining the Rim are deeply incised. If the $\delta^{18}O$ and δD values of local recharge (AREP) have been correctly characterized, the most plausible interpretation of the O and H isotope data is that given in Fig. 12. That the evaporation and mixing trends that diverge from the AREP fields have similar slopes is strictly coincidental. The AREP isotope composition is consistent with winter precipitation as the principal source of recharge. Hypothesis 2 is the preferred explanation for the O and H isotope data in the X aquifer near Payson. Local recharge around Payson would mask any evidence of recharge consistent with hypothesis 1, which may therefore also still explain some of the replenishment of the X aquifer near Payson; this cannot be proven or excluded using the present data set.

According to this interpretation, the shallow groundwater from wells near central Payson (Fig. 7), which have been pumped for many decades, is a mixture of local recharge and evaporated pond/lake/irrigation water. The North Payson wells have been pumped for a shorter time, and yield water that is a mixture of local recharge with water from the Mogollon Rim. This apparently requires upwelling of Rim-derived water into the fractured granite beneath North Payson, which is physically possible for high altitude of recharge into fractured rock at the Rim crest.

3. RMX aquifer. The $\delta^{18}O$ and δD values of RMX samples coincide with values for the C aquifer near Payson (Fig. 5B), except for Ellison well, which has higher values. The data are consistent with leakage of water from the C aquifer to the RMX aquifer, but at Ellison well some of the recharge is either evaporated runoff from the Rim crest or AREP water.

4. M aquifer. Webber Spring and Tonto Natural Bridge (TNB) Spring discharge water that has values of $\delta^{18}O$ and δD higher than those of the water in the RMX aquifer. Local recharge appears to contribute. At Webber Spring, only water of the AREP composition is required; there is no evidence for mixing with RMX water. The presence of a rain/dust $\delta^{34}S$ signature rather than a evaporite $\delta^{34}S$ signature, and chemical data presented elsewhere in the MRWRMS reports, are consistent with this interpretation. Recharge is probably limited to the area between Little Diamond Rim and the spring. At TNB spring, the sample appears to be a mixture of RMX and AREP water, the latter presumably recharging on Buckhead Mesa. The TNB spring varies greatly in discharge with time, but has been observed to vary by less than 0.5 ‰ on $\delta^{18}O$ in four samples taken between 2002 and 2004 (Flora, 2004; this study). The C-14 content is consistent with mixing of pre-bomb and post-bomb water.

4. Rye Basin samples. The Doll Baby shallow sample plots in the AREP field, and presumably represents locally derived winter precipitation. Doll Baby deep and Rye HI4 yield water that resembles C aquifer water from Flagstaff. Given the low C-14 content of the HI-4 water, however, and the remoteness of this site from the Mogollon Rim, it is more likely that the low $\delta^{18}O$ and δD values represent a colder climate regime some thousands of years ago.

5. *Residence time of water reaching the X aquifer from the Rim crest.* The North Payson wells that have low tritium and $\delta^{18}O$ and δD values matching those of the C aquifer are (up till the present, at least) replenished mainly from the Regional aquifer of the Colorado Plateau by flow through fractured rock. The Payson Pines 4 sample has a tritium content of about 1 TU, consistent with little local recharge, and a C-14 content of 82.4 pMC, suggesting a short residence time (decades to 100 years?) for the groundwater derived from the Regional aquifer, despite its remote origin.

Principal Conclusions

1. Natural replenishment of groundwater in the study area is almost entirely from winter precipitation.
2. Groundwater from the Colorado Plateau Regional aquifer is replenished from high-altitude winter precipitation. Evidence for recharge from the San Francisco Peaks is observed in the area west of (and including) Fossil Springs. Part of the recharge water evaporates before infiltration.
3. Groundwater in the X aquifer near Payson is a mixture of local recharge and groundwater from the Regional aquifer. Where pumping has continued for longest, local recharge, including evaporated water from ponds and irrigation reflux, is prominent.
4. Post-bomb precipitation has contributed to (but is not necessarily predominant in) groundwater currently being pumped throughout the study area.
5. One C-14 data point suggests short flow times (decades) for water reaching the X aquifer from the Regional aquifer.
6. On the evidence of Sr isotopes, upwelling water that has circulated through Proterozoic rock beneath the Colorado Plateau is added to the RMX aquifer, as in Muav aquifer springs in the Grand Canyon.
7. Groundwater in the C and RMX aquifers is similar isotope composition in the study area, suggesting that the RMX aquifer is fed by downward leakage from the C aquifer.
8. M aquifer groundwater is distinct from RMX groundwater in receiving a larger proportion of local, low-elevation recharge.
9. Groundwater in alluvium of the Rye Basin is isotopically lighter than groundwater in the X aquifer, and appears to be thousands of years older.

Suggestions for further work

In this study, unanswered questions remain concerning the water sources in certain springs, in particular Fossil Springs and Tonto Natural Bridge Spring where discharge is observed to increase after a wet season such as Winter 2004-2005. The implied changes in the balance of local and more remote water sources may not be reflected immediately as isotope changes. The water source for the Fish Hatchery Spring is not understood. Quarterly sampling of these locations for oxygen and hydrogen stable isotopes and tritium would most likely add greatly to the present understanding of the regional hydrology, particularly after the effects of the present (2005-2006) winter drought propagate through the aquifers. The behavior of strontium isotopes is not understood in the case of water emerging from the Fort Apache Limestone, and further study of this problem is warranted, including further measurement of $^{87}Sr/^{86}Sr$ in the limestone. Lastly, groundwater systems are dynamic, and will change with time in response to heavy pumping. Periodic (every 5 years?) sampling of Payson wells for oxygen and hydrogen stable isotopes would provide useful information on the evolution of the X aquifer.

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Figure Captions:

1. Plot of δD vs. $\delta^{18}O$, illustrating the global Meteoric Water Line (GMWL) and trends due to evaporation and exchange with oxygen from rock. See text for explanation of points A, B, C, D.

2. Plots of δD vs. $\delta^{18}O$, showing different possible arrays of data in groundwater. #1: regional groundwater flow, with recharge at high elevations only; #2: Local groundwater flow and local recharge only; #3. Recharge at high and low elevations from streams fed at high elevation. H and L indicate the predicted fields of waters sampled at high and low elevations, respectively.

3. Plot of δD vs. $\delta^{18}O$, showing data for seasonal weighted average precipitation from Payson (red symbols) in comparison with 23-year means (Wright, 2001) for precipitation from Tucson basin and the Santa Catalina Mountains (yellow symbols). W, A, S signify winter, all, summer respectively.

4. A: Plot of δD vs. $\delta^{18}O$, showing all data from this study for precipitation, groundwater, surface water and reclaimed municipal water. B. Plot of δD vs. $\delta^{18}O$ for groundwater (and the Blue Ridge reservoir), with groundwater data classified according to aquifer.

5. Plot of δD vs. $\delta^{18}O$, showing data for groundwater from the study area. A: distinguishing samples from wells near recharge ponds and irrigated land in parks in and near Payson; B: classifying samples according to the aquifer sampled. The group of blue data symbols shown as "Summit etc." includes the Summit, Payson Pines 4, Turtle Rock, Goat Camp and Luke wells.

6. Plot of $\delta^{18}O$ vs. altitude of sampling, compared with measured altitude dependences in Tucson (Wright, 2001, orange line) and Flagstaff to Prescott (Blasch et al., 2005, solid purple line). The dashed purple line is a likely altitude dependence line in the Payson area, passing through the data points for the Milky Way and Round Valley wells.

7. A. Map of the Payson area showing the distribution of $\delta^{18}O$ in groundwater. B. Map of the Payson area showing the distribution of tritium in groundwater.

8. Plot of δD vs. $\delta^{18}O$, including published data from Flora (2004), Bills et al. (2000) and Parker et al. (2004), and unpublished data reported to the Arizona Department of Transportation, for spring and well samples along the Mogollon Rim between Sedona and Payson. Green line: evaporation trend of Payson area groundwater. Red dotted line: suggested evaporation line for Flagstaff-Sedona area groundwater. "Perched" refers to the perched aquifer in volcanic rocks in the Flagstaff area; "regional" to the regional aquifer in Paleozoic strata in that area.

9. Plot of $\delta^{34}S$ vs. $1/SO_4$ ($L\ mg^{-1}$) groundwater samples from this study, in relation to likely end-member compositions.

10. Plot of $^{87}Sr/^{86}Sr$ ratios in groundwater from the study area), in relation to the field of data from the regional aquifer in Colorado Plateau strata near Flagstaff (Bills et al., 2000), the ratios in Neogene Hickey basalt and Quaternary San Francisco volcanics (blue bar, from Scott, 1974), the ratios in Devonian to Permian marine carbonates (black bar, from Burke at al., 1982), the ratios in Proterozoic granitoids (red bars, from Condie et al., 1999), and measured ratios in rock units from the study area (Parker et al., 2005). K, S and M indicate the likely $^{87}Sr/^{86}Sr$ ranges in the limestone and evaporite elements of the Kaibab, Supai and Martin formations respectively. Groundwater data are shown as colored diamonds (enclosed in a blue rectangle) and are classified according to aquifer host rock in the case of Payson area data, and lithology of recharge zones in the case of Flagstaff data. Circled data points are rock data set are rock data for the Fort Apache Limestone member of the Supai formation, and groundwater data for Fish Hatchery spring.

11. Schematic block diagram of the Mogollon Rim and Payson area, showing possible recharge sites and flow paths of groundwater to a well in the central highlands.

12. Summary δD vs. $\delta^{18}O$ plot, showing the principal processes affecting groundwater in the study area and the Flagstaff-Sedona area.

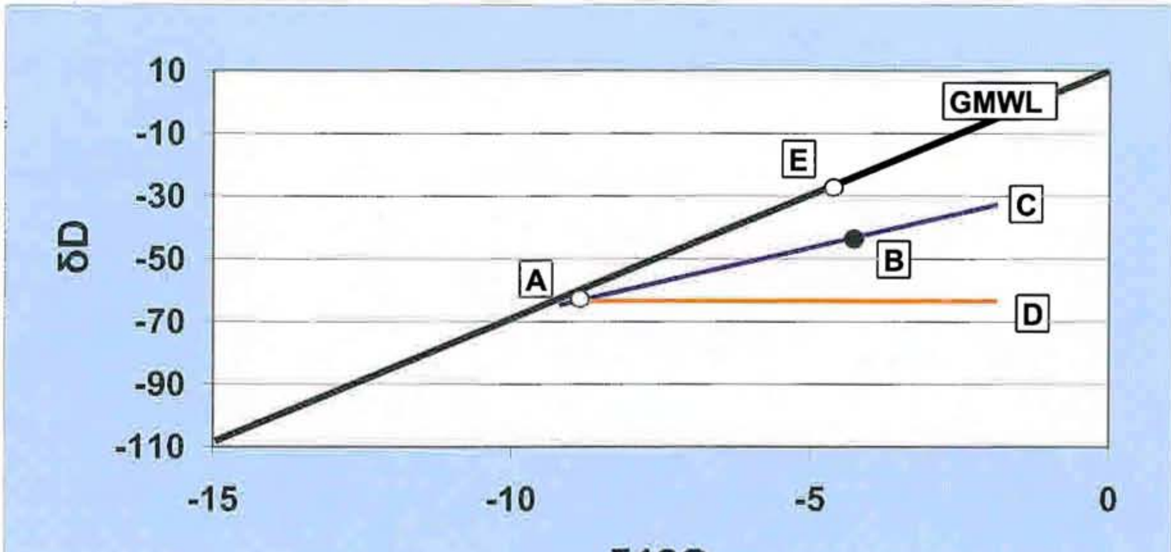
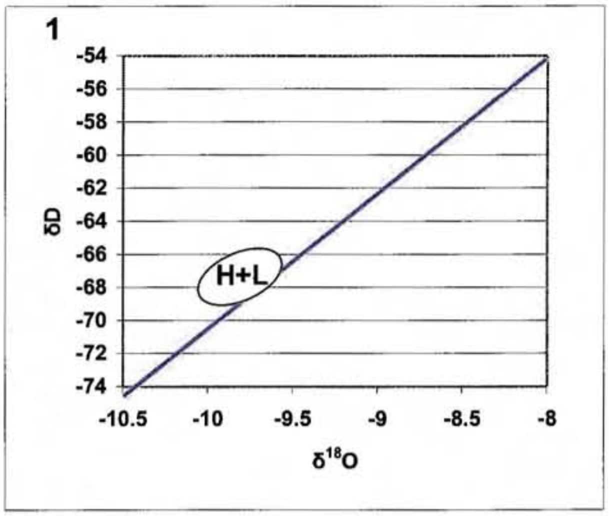
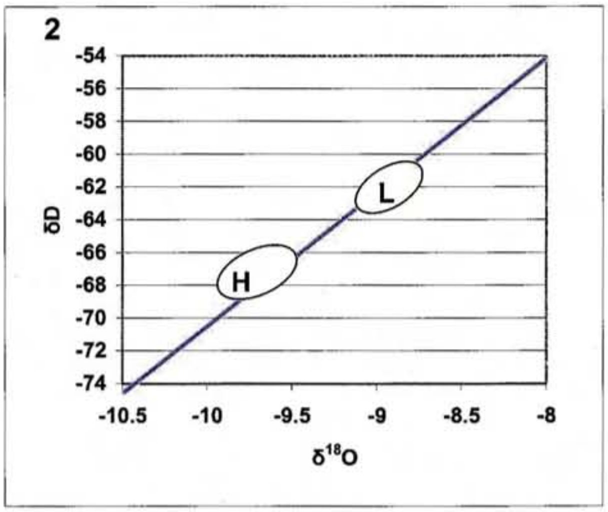


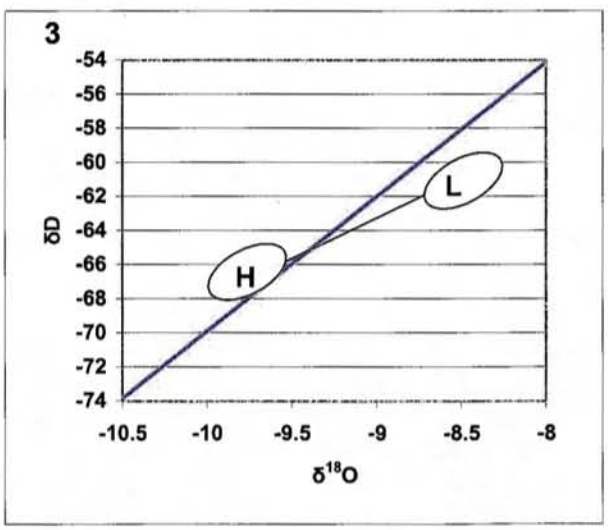
Fig. 1



tritium decreases downgradient
no change in isotopes of groundwater with altitude

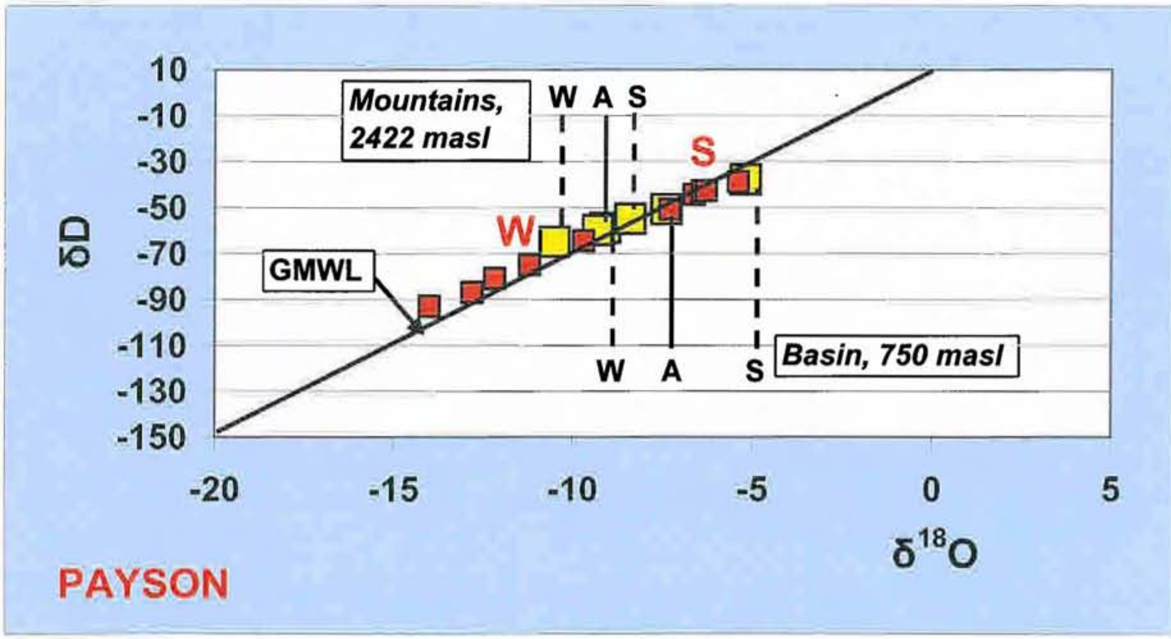


tritium present throughout.
trend slope 7-8
clear altitude dependence of isotopes



tritium present throughout
trend slope 3-5
altitude effect blurred

Fig. 2



PAYSON
δD
δ18O
Mountains, 2422 masl
Basin, 750 masl
GMWL
W A S
W A S
W
S
10
-10
-30
-50
-70
-90
-110
-130
-150
-20
-15
-10
-5
0
5

Fig. 3

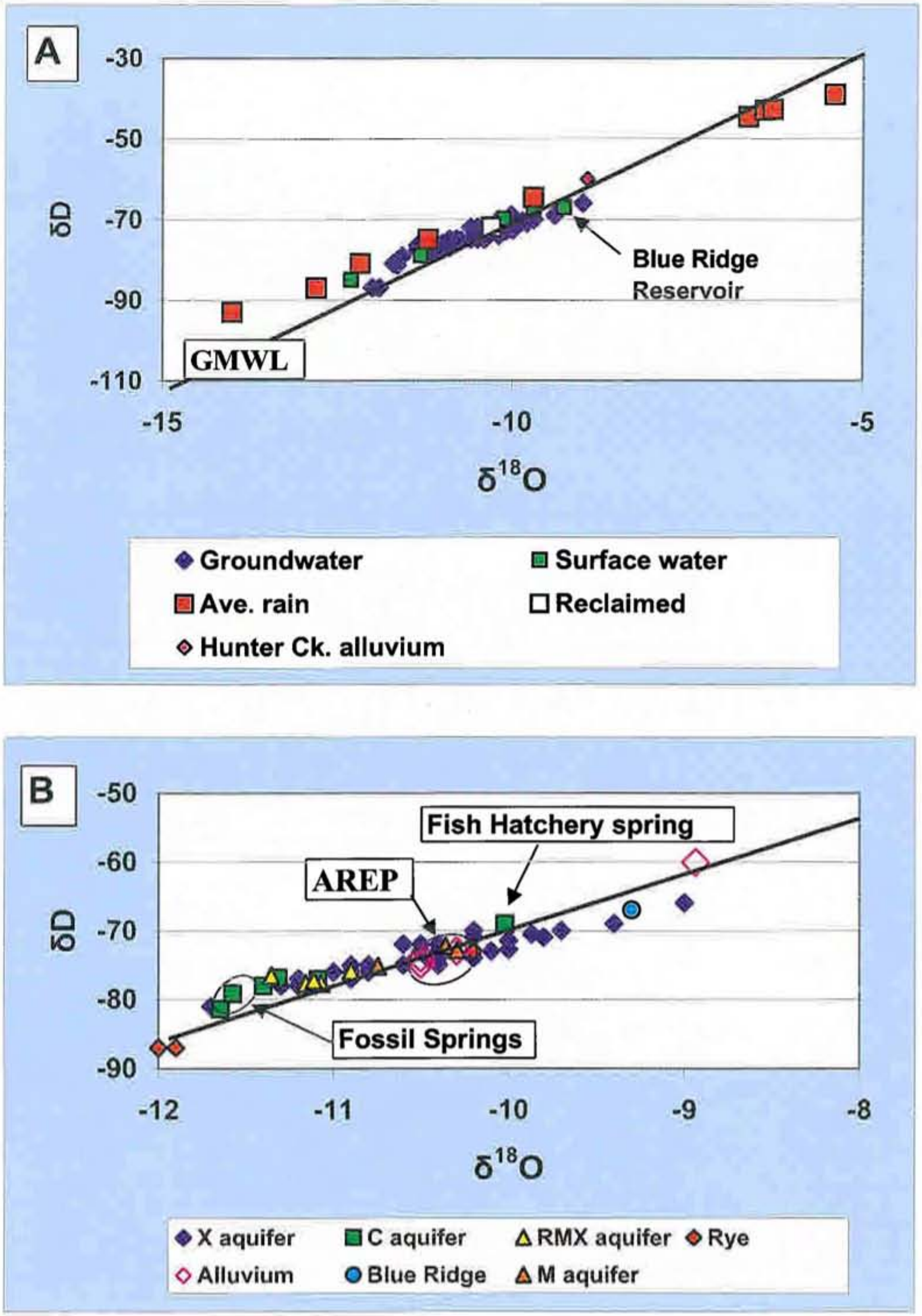
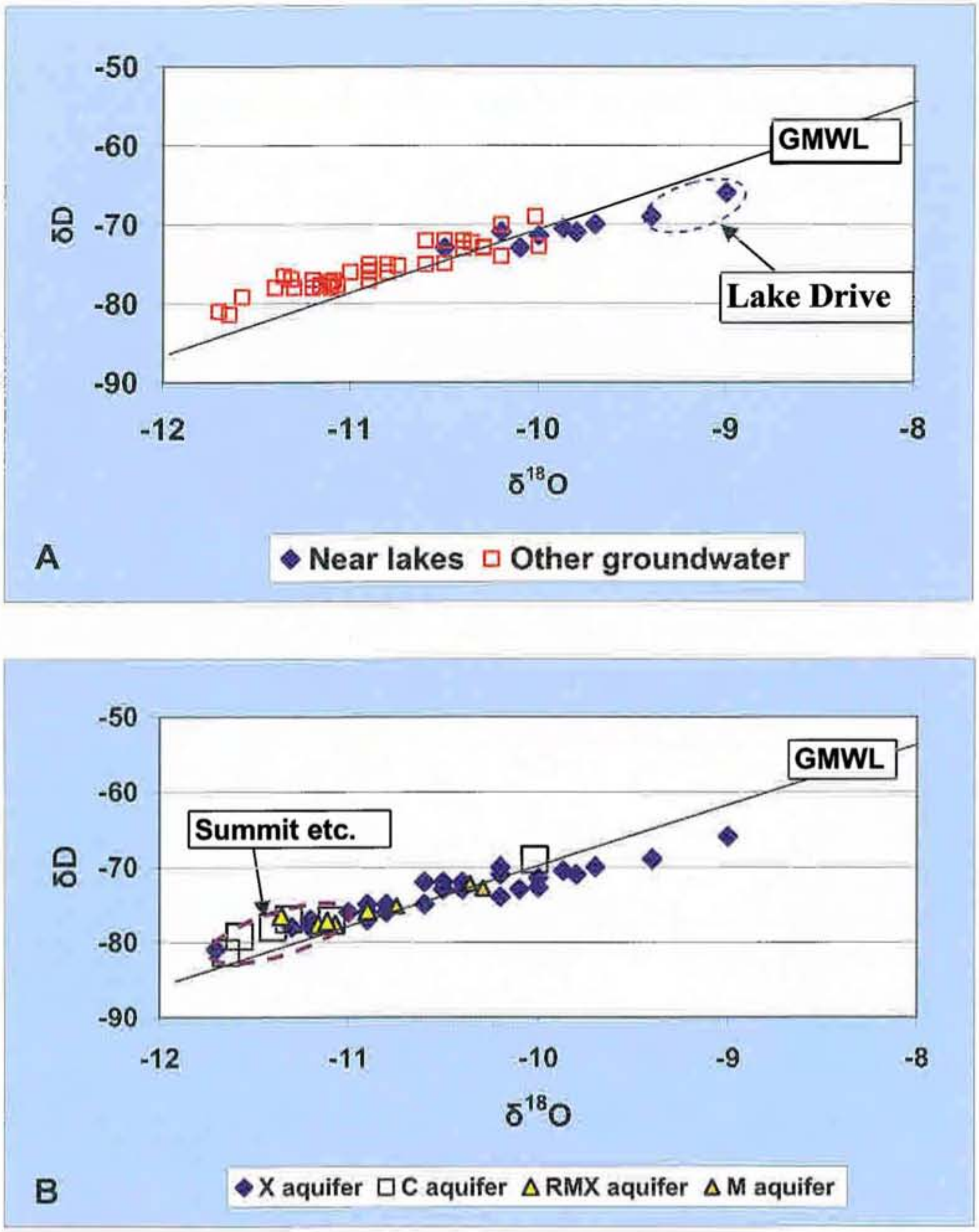

A
B
GMWL
Blue Ridge Reservoir
δD
δ18O
Groundwater
Surface water
Ave. rain
Reclaimed
Hunter Ck. alluvium
Fish Hatchery spring
AREP
Fossil Springs
X aquifer
C aquifer
RMX aquifer
Rye
Alluvium
Blue Ridge
M aquifer

Fig. 4



-50
-60
-70
-80
-90
δD
GMWL
Lake Drive
-12
-11
-10
-9
-8
δ18O
A
Near lakes
Other groundwater
-50
-60
-70
-80
-90
δD
GMWL
Summit etc.
-12
-11
-10
-9
-8
δ18O
B
X aquifer
C aquifer
RMX aquifer
M aquifer

Fig. 5

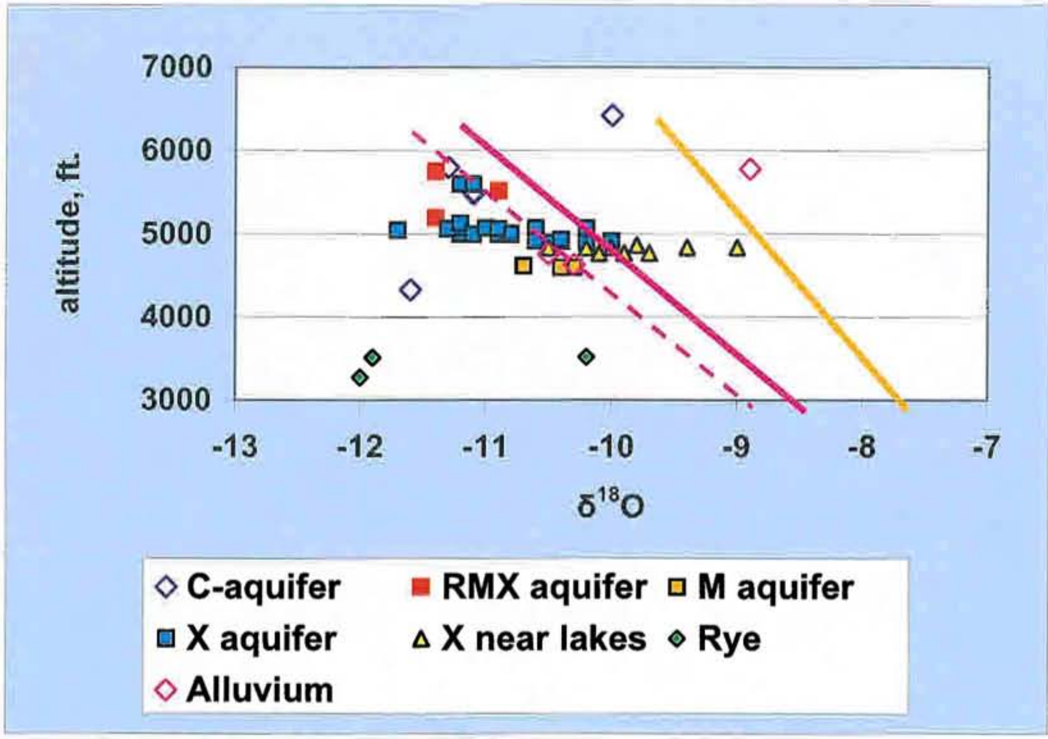

7000
6000
5000
4000
3000
altitude, ft.
-13
-12
-11
-10
-9
-8
-7
δ18O
C-aquifer
RMX aquifer
M aquifer
X aquifer
X near lakes
Rye
Alluvium

Fig. 6

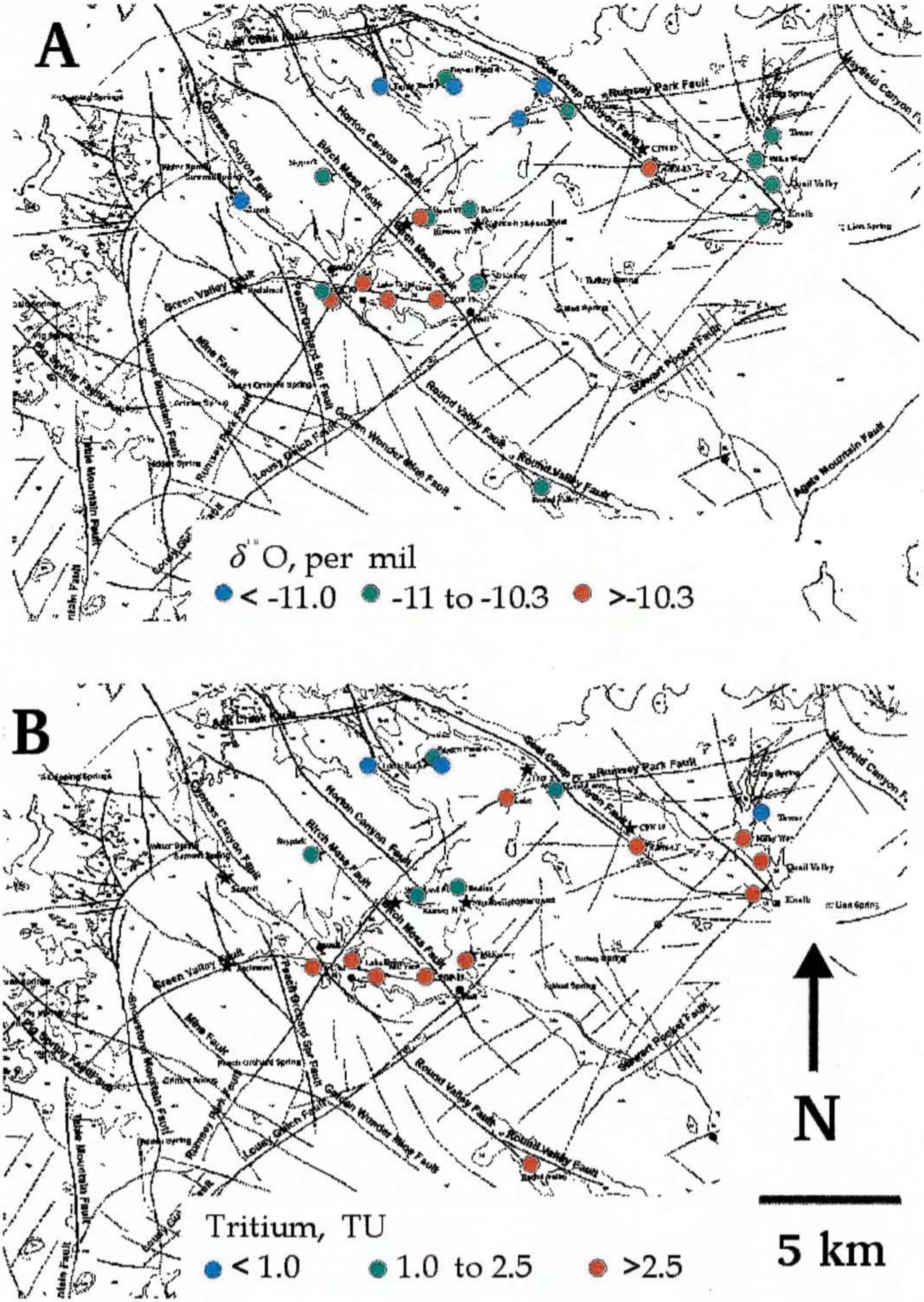
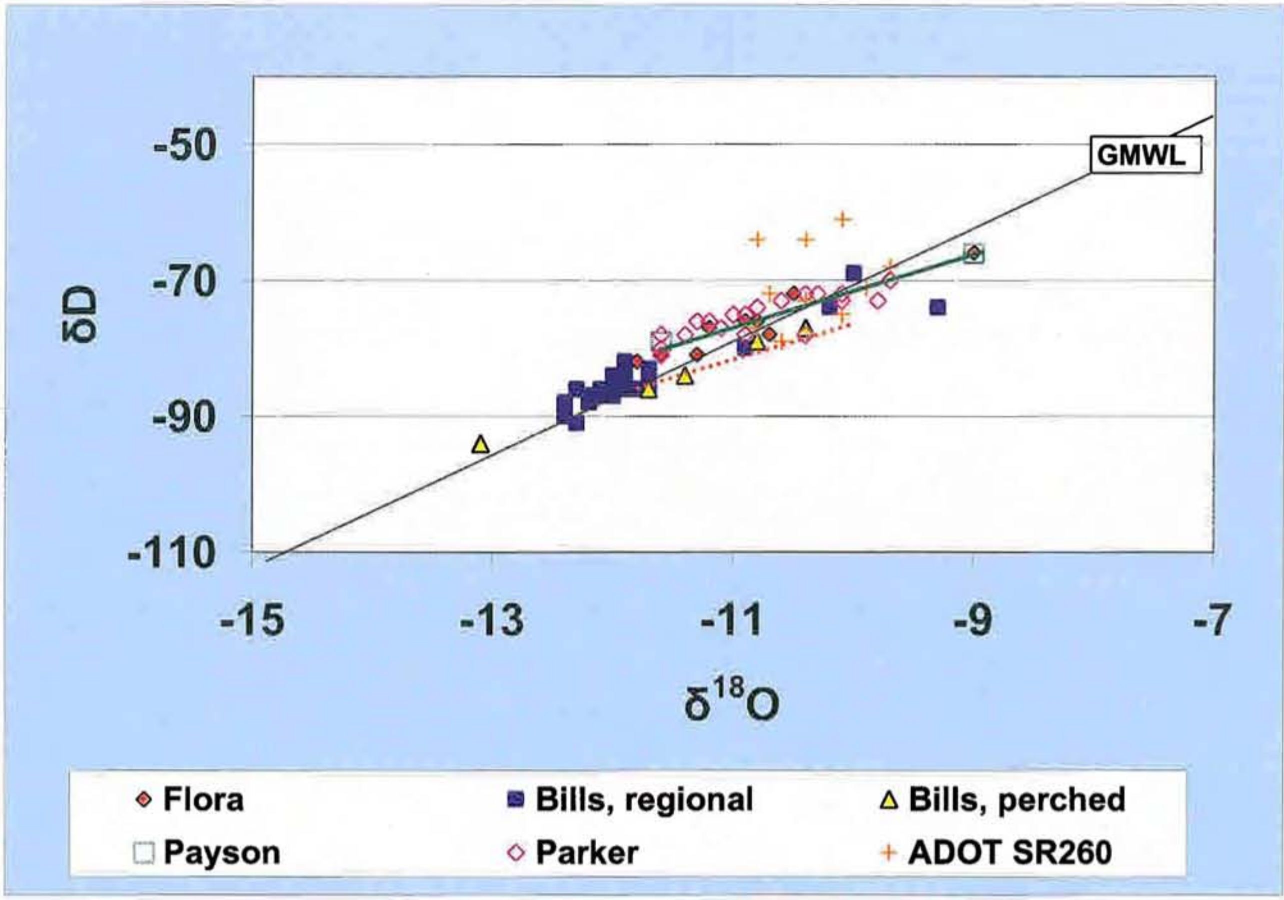
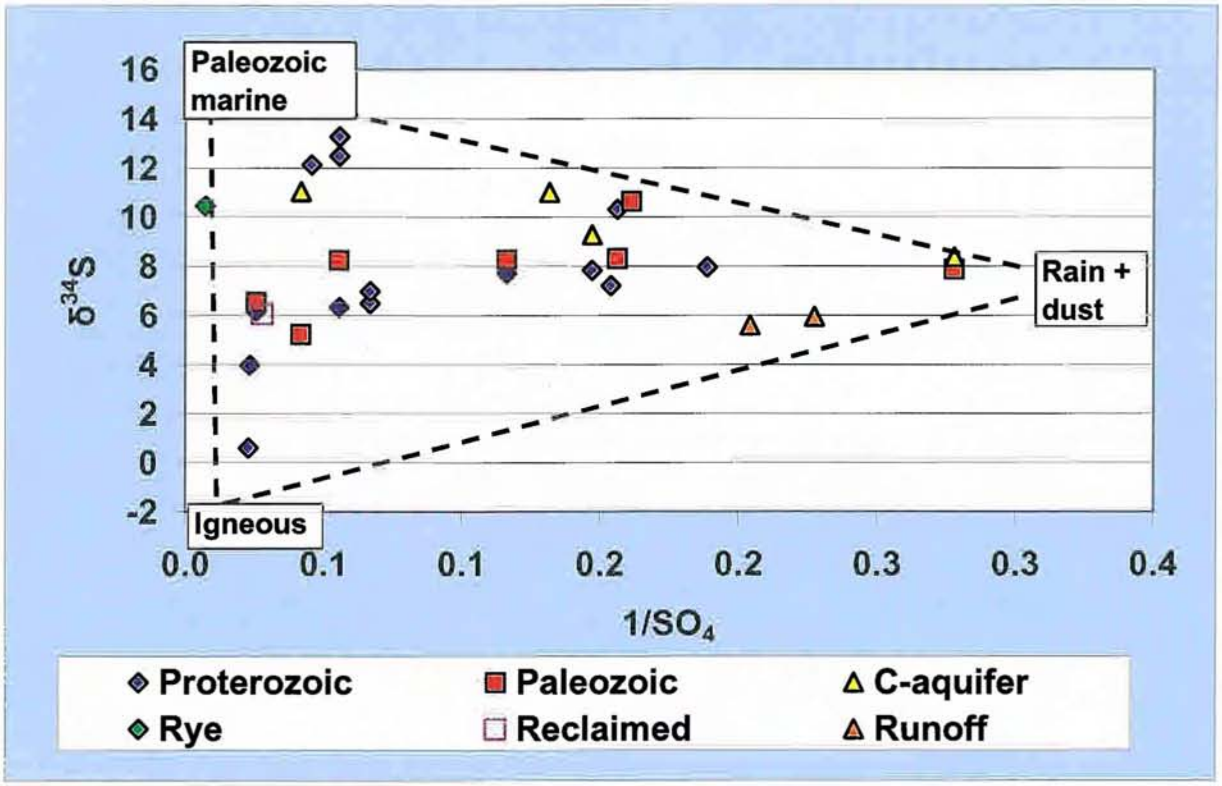

A
Ash Creek Fault
Horton Canyon Fault
Birch Mesa Fault
Rumsey Park Fault
Goat Camp Canyon Fault
Green Valley Fault
Mine Fault
Round Valley Fault
Stewart Pocket Fault
Agate Mountain Fault
Garden Wonder Mine Fault
Lousy Gulch Fault
Table Mountain Fault
Tower
Quail Valley
Knoll
Lion Spring
$\delta^{18}O$, per mil
< -11.0
-11 to -10.3
>-10.3
B
Tritium, TU
< 1.0
1.0 to 2.5
>2.5
N
5 km

Fig. 7



-50
-70
-90
-110
δD
GMWL
-15
-13
-11
-9
-7
δ18O
Flora
Bills, regional
Bills, perched
Payson
Parker
ADOT SR260

Fig. 8



Paleozoic marine
Rain + dust
Igneous
δ34S
1/SO4
16
14
12
10
8
6
4
2
0
-2
0.0
0.1
0.1
0.2
0.2
0.3
0.3
0.4
Proterozoic
Paleozoic
C-aquifer
Rye
Reclaimed
Runoff

Fig. 9

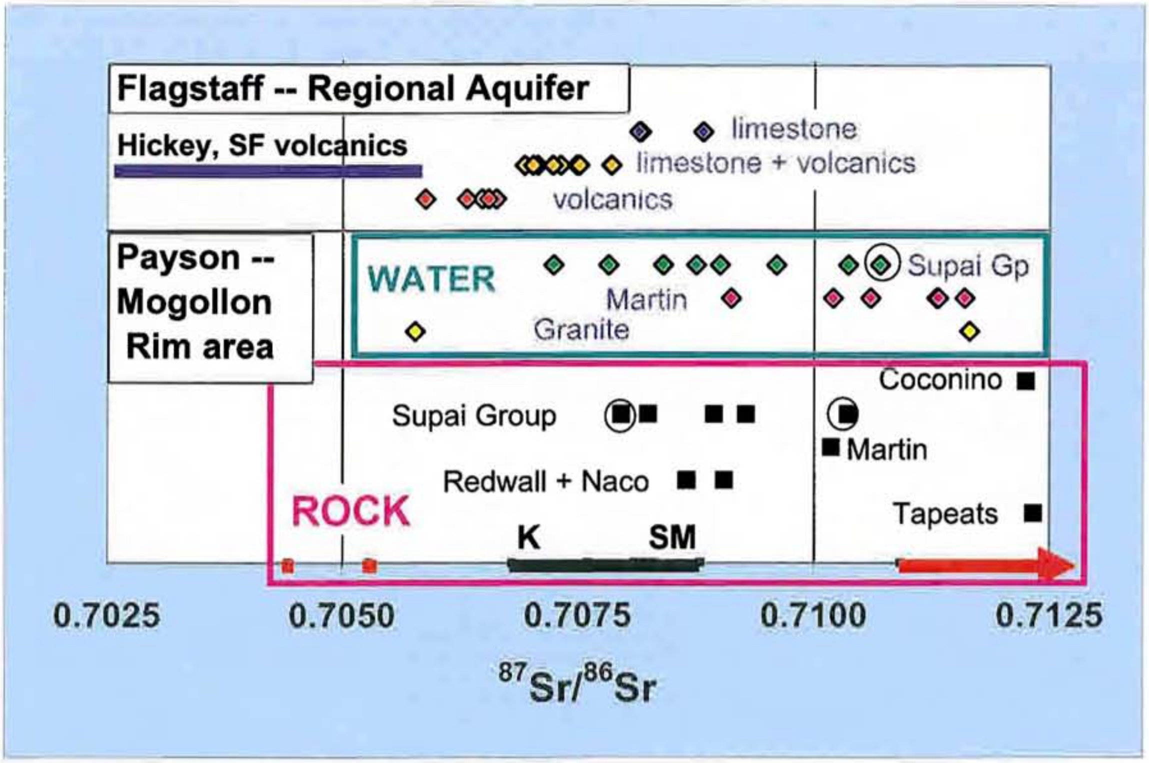

Flagstaff -- Regional Aquifer
Hickey, SF volcanics
limestone
limestone + volcanics
volcanics
Payson -- Mogollon Rim area
WATER
Supai Gp
Martin
Granite
ROCK
Coconino
Supai Group
Martin
Redwall + Naco
Tapeats
K
SM
0.7025
0.7050
0.7075
0.7100
0.7125
$^{87}Sr/^{86}Sr$

Fig. 10

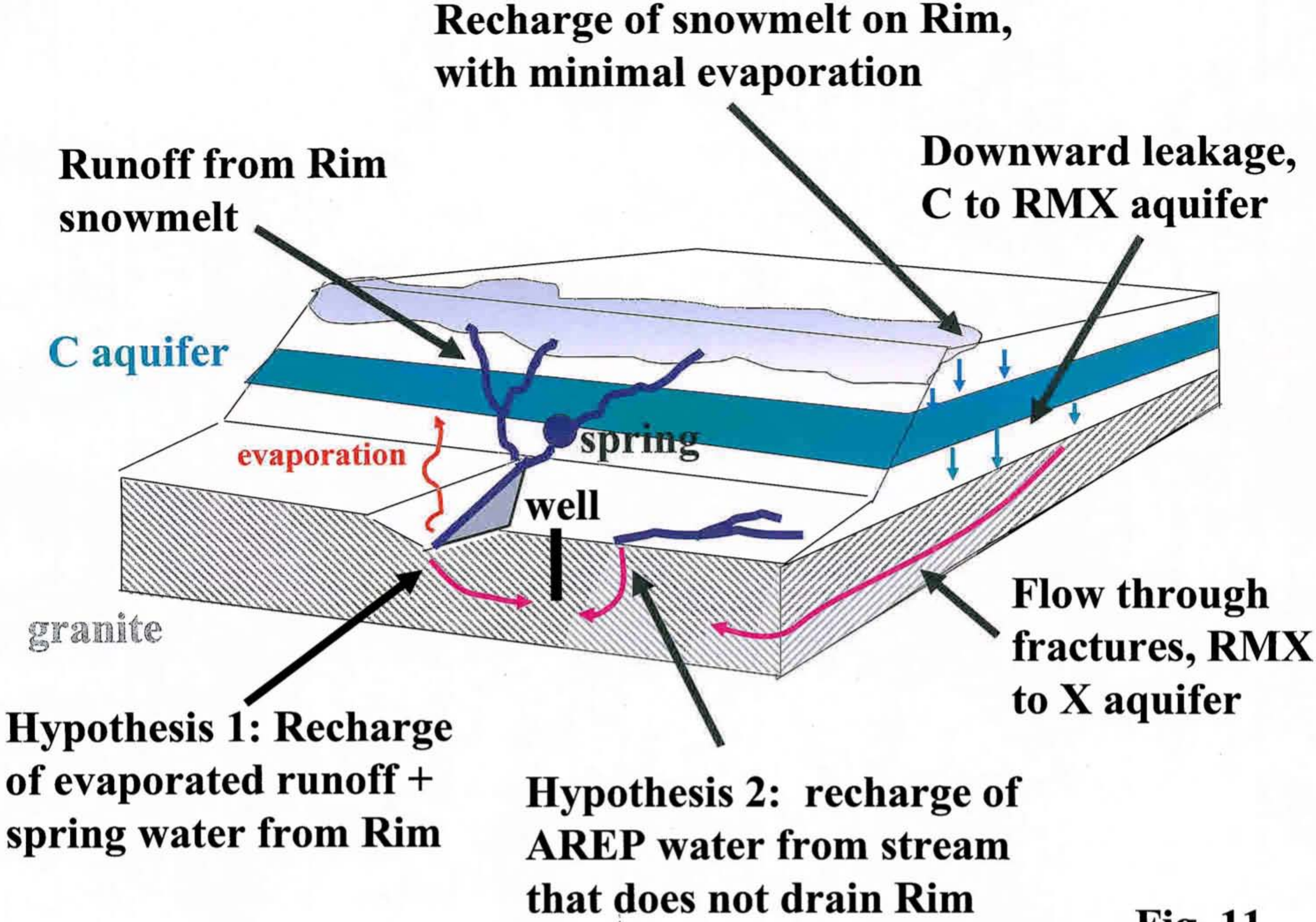
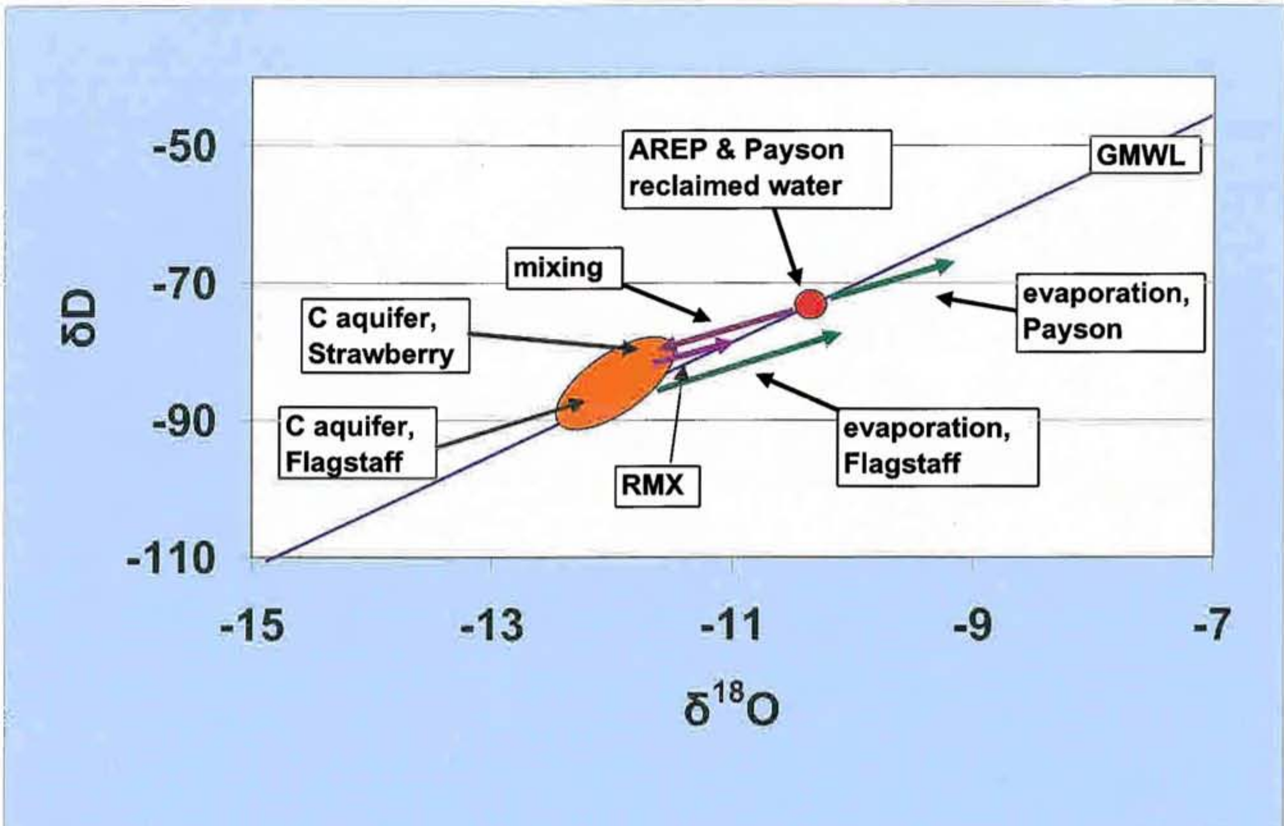

Recharge of snowmelt on Rim,
with minimal evaporation
Runoff from Rim
snowmelt
Downward leakage,
C to RMX aquifer
C aquifer
evaporation
spring
well
granite
Flow through
fractures, RMX
to X aquifer
Hypothesis 1: Recharge
of evaporated runoff +
spring water from Rim
Hypothesis 2: recharge of
AREP water from stream
that does not drain Rim

Fig. 11



δD
-50
-70
-90
-110
-15
-13
-11
-9
-7
δ18O
AREP & Payson reclaimed water
GMWL
mixing
C aquifer, Strawberry
evaporation, Payson
C aquifer, Flagstaff
RMX
evaporation, Flagstaff

Fig. 12

ATTACHMENT 2

(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Mogollon Rim Water Resources Management Study-Demand Analysis, Bureau of Reclamation, Phoenix Area Office

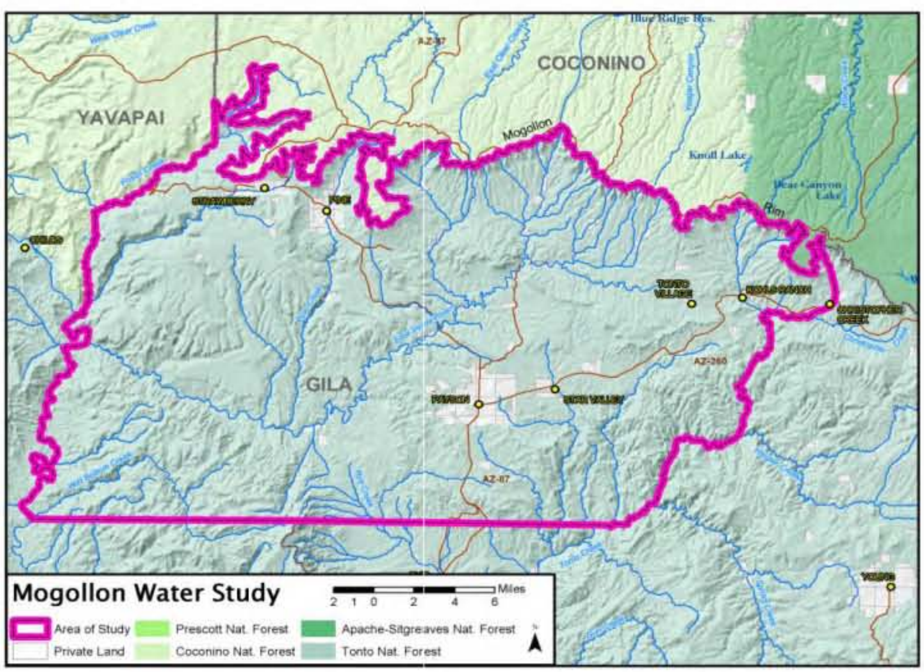
Mogollon Rim Water Resources Management Study Demand Analysis

I. Introduction

The Mogollon Rim Water Resources Management Study (MRWRMS) is an appraisal level assessment of the present water use and future water needs of the communities in northern Gila County, Arizona. The major emphasis of the study will be the development of water supply alternatives to meet the identified future demands. In order to evaluate needs, this Demand Analysis (Analysis) has been developed to identify stakeholders and present population and water use in the study area. The Analysis will use the present data and project it to the year 2040. The resultant information will be used as the basis for the development of water supply strategies and alternatives.

A. Background

The MRWRMS is located in northern Gila County. The study area is bordered on the west by the Gila County boundary and on the north by the county boundary and the Mogollon Rim. The eastern boundary is Christopher and Tonto Creeks and the southern boundary is at Latitude N34^{o} 09'.



The study partners are the town of Payson, Gila County, and the Bureau of Reclamation. Gila County represents the unincorporated communities within the study area. Other participating agencies include the Arizona Department of Water Resources, the U.S. Forest Service, the Salt River Project, the Tonto Apache Tribe, and Brooke Utilities, a private water company in the study area.

B. Water Supplies

Ground water. Currently, most of the water provided to users in the study area is ground water. Wells produce water from the underlying geology or aquifer, which is composed of fractured bedrock. The water storage capacity of this type of aquifer is dependent on fractures and weathered zones located within the bedrock.

Surface Water. Surface water in the study area is regulated under the doctrine of prior appropriation, and for many years, has been appropriated by senior water rights holders. Those water rights holders include shareholders of the Salt River Project, the city of Phoenix, the Salt River Pima-Maricopa Indian Community, and the Fort McDowell Indian Community, and others. Few entities within the study area have surface water rights and thus legal access to surface water supplies to meet the water demands on their lands.

Effluent. The Northern Gila County Sanitary District that serves parts of Payson and Mesa Del Caballo operates the only significant wastewater treatment plant in the study area. The effluent provided is used to irrigate golf courses and parks and to supply the town of Payson Green Valley Park Lake and recharge project.

Drought. The southwestern United States is considered to be in the midst of a prolonged and severe drought period. Eight of the past ten years have been unusually dry, and Arizona experienced its sixth consecutive dry winter in 2003-04. The area has experienced severe deficits in precipitation since 1989 and has observed consecutive declines in the local aquifer levels. The long-term forecast is for continued drought conditions. Although an issue, the Analysis does not take into account drought as a factor when determining future water demands.

C. Objectives and Methodology

The objective of this Analysis is to establish long-term water demands for the communities within the study area. The Analysis examines the time period 2002 to 2040, i.e. 38 years. It is expected that the study area will be fully built out by 2040.

The analysis will:

- Identify current population levels within each service area within the study area.
- Identify current water demand within each service area on a per capita basis.
- Forecast future populations for each service area within the study area over the time period 2002 - 2040.
- Project future water demands, on a per capita and “build-out” basis, over the time period 2002 – 2040 for each service area within the study area.

- Consolidate all service area water demands into a combined study area water demand forecast for the year 2040.

Determining Present Population - Present population is based on the 2000 census data obtained from Gila County, recorded by voting precinct.

Determining Present Water Demand, Seasonal Use, and Water Losses – Present water demand for the town of Payson is based on actual water use and was provided by the town's Water Department. Specific data for the major private regulated water providers: 1. Pine Water Company; 2. Strawberry Water Company; and 3. Payson Water Company (East Verde Park, Flowing Springs, Geronimo Estates, Mead Ranch, Mesa Del Caballo, Star Valley A & B, and Whispering Pines) is interpreted from the 2002 Arizona Corporation Commission Annual Reports. Data for all other water systems was collected through personal interviews with system operators.

Present values for gallons per capita per day (GPCD) are based on historical usages that vary significantly from service area to service area depending on horse population, rapid swings in temporary residency (summer camps, etc.), various levels of perceived or actual water availability, and differences in water conservation practices or conservation enforceability. Rapid changes in demand (weekend and/or seasonal use) is accounted for by consolidating those demand spikes into annual totals that are then divided by the total permanent population to determine per capita use. In the summary section of this report, all demand estimates (based on sales of water) are adjusted for an estimated water loss percentage to reflect estimated supply requirements.

Land Use – The total number of land parcels, both developed and undeveloped, are based on Gila County Assessor's tax rolls.

Methodology for Projected Population and Water Demands - Future water demands are calculated using estimated future populations assuming water use of 120 – 300 GPCD. The GPCD numbers are estimates that encompass all types of water use expected by each service area, e.g., residential, commercial, industrial, institutional, or government.

Future population projections are calculated using a build-out scenario. The land expected to be built out is the undeveloped subdivided and unsubdivided lands remaining within the study area. This method, known as the housing unit method, calculates the expected population associated with each parcel remaining to be fully developed. Land Exchanges between the U.S. Forest Service and the unincorporated communities that create more private land tracts are expected to net zero new developable acres. Any anticipated exchanges between the Forest Service and the Town of Payson are included in the Town's general plan and reflected in the future population estimates.

The housing unit method is based upon the following concept: A dwelling unit count is used to make population estimates. (In this study, parcels remaining to be built out will be substituted for a housing unit.) The future population is estimated by multiplying the expected number of occupied households by the average number persons per household (assumed to be 2.4 unless noted).

In summary, the primary method for projecting water demand is a per capita value established for each water service area within the study area. The per capita model simply calculates the estimated consumption per capita at a specified point in time, multiplied times the estimated population at the same point in time.

D. Assumptions

- No estimates of private well water use were used to determine the 2002 demand, other than private wells that are used to directly supply the included systems (i.e. private wells that supply water direct to Pine Water Co. or Strawberry Water Co.)
- Estimates are for residential and commercial potable water only. No nonpotable irrigation water used for golf courses, pastures, orchards, etc. is included.
- No evaluations of the legality of water use or ownership of water are included. Virtually all water included is ground water; however, minor amounts of surface water is included.
- Water demands are based on estimated sales and do not reflect water pumped from supply sources. Appropriate amounts for water losses need to be added to estimated sales of water reported.
- Future population estimates assume a shift from part-time to full-time residency for communities within the study area.
- The number of estimated new parcels was from interviews with water operators, U.S. Forest Service personnel, real estate developers, and from land use studies and zoning maps, including the 2003 Comprehensive Master Plan and the 2002 Inventory and Analysis Reports prepared by Gila County.
- The estimates of gallons used per capita per day were based on current demand levels, sometimes adjusted for the fact that past water use restrictions were or were not in place, and from trends of full-time versus part-time residency.
- All un-metered water users within service areas are assumed to become metered water users by 2040.
- The volume of water taken from private wells that serve individual or commercial consumers (not sold or supplied to the utility) has not been completely estimated; however it has been accounted for when multiplying future population estimates times average water usage per capita for the service area.

E. Water Service Providers and Consumption

Table 1 lists the water source for each provider in the study area.

Table 1. List of Water Service Providers			
	System Owned And Operated Wells	Private Wells Not Tied To System	Surface Water Used (Acre-ft) And Source
Public – Municipal			
Town of Payson (includes the Tonto Apache Tribe)	37	300	-
Public - Domestic Water Improvement Districts			
Pine: Solitude Trails DWID	2	-	-
Pine: Strawberry Hollow DWID	2	-	-
Pine: Pine Water Association DWID	-	?	10.7 - A
Pine: Pine Creek Canyon DWID (Portals 4)	2	-	-
Rim Trail DWID	1	1	7.1 - B
Private – Unregulated Cooperatives/Homeowners Associations, etc.			
Arrowhead Ranch	-	5	-
Bear Flat	-	20	-
Bonita Creek	-	-	3.7 - D
Camp Geronimo Boy Scout Camp	-	-	6.4 - C
Collins Ranch	2	6	-
Cowan Ranch	1	2	-
Diamond Point Recreation	1	-	-
Diamond Point Shadows	-	260	-
Ellison Creek Estates	-	?	-
Ellison Creek Recreation	-	-	-
Freedom Acres	1	10	-
Hunter Creek	2	-	-
Kohl's Ranch	3	-	-
Oxbow Estates	-	?	-
Pine Meadows	5	-	-
R-C Boy Scout Camp	2	-	-
Round Valley	-	?	-
Shadow Rim Girl Scout Camp	2	-	-
Summit Springs	-	-	-
Thompson Draw I & II	2	-	-
Verde Glen	2	1	-
Washington Park	-	-	.3 - E
Wonder Valley	2	12	-
Zane Grey Meadows	-	5	-
Private – Regulated Utility Firms – Brooke Utilities			
East Verde Park - Payson Water Co.	3	11	-
Flowing Springs – Payson Water Co.	1	-	-
Geronimo Estates – Payson Water Co.	2	13	-

Table 1. List of Water Service Providers			
	System Owned And Operated Wells	Private Wells Not Tied To System	Surface Water Used (Acre-ft) And Source
Mead Ranch – Payson Water Co.	1	-	-
Mesa Del Caballo – Payson Water Co.	7	-	-
Pine Water Co.	21	105	-
Star Valley A&B - Payson Water Co.	2	?	-
Strawberry Water Co.	9	25	-
Whispering Pines – Payson Water Co.	2	10	-
Private – Regulated Utility Firms – Other			
Beaver Valley Water Co.	1	2	22.1 - B
Christopher Creek Haven Water Co.	4	?	-
Strawberry Water Co. (Lufkin Hunt Water Co.)	?	?	-
Tonto Creek Estates Water Co.	3	?	-
Tonto Village Water Co.	1	-	-

A – Pine Creek
B – East Verde River
C – Poison Spring and Herron Spring (on Tonto)
D – Bonita Creek
E – Mail Creek Spring

F. Present Water Demand and Population

The town of Payson's annual ground-water consumption in 2002 was 588,100,000 gallons or 1,805 acre-feet. The Town has established an estimate of aquifer Safe Yield (Safe Yield – Attain and thereafter maintain a long-term balance between the annual amount of ground water withdrawn, ground water discharged, and the annual amount of natural and artificial recharge) based upon recent hydrogeologic studies of the local aquifer underlying the incorporated boundaries of the town. Safe Yield for Payson is estimated to be 1,826 acre-feet/year. In 2002, the Town's ground-water usage was at 99 percent of Safe Yield. Table 2 presents Payson's 2002 ground water consumption in tabular form.

Table 2. Actual Ground-Water Consumption – Town of Payson – Gila County – 2002.		
Incorporated Area – Gila County	Million Gallons Per Year	Acre-Feet per Annum
Town of Payson	588.1	1,805

A safe yield value has not been determined for those communities that are unincorporated within the study area. Table 3 summarizes 2002 water use for the unincorporated communities within the study area.

Table 3. Estimated Potable Water Consumption – Unincorporated Areas – Gila County – Study Area, 2002.

Unincorporated Communities – Gila County	Million Gallons Per Year	Acre-Feet per Year
Pine (Pine Water Co., Solitude Trails DWID, Strawberry Hollow DWID, Pine Water Assoc. DWID, Pine Creek Canyon/Portal IV DWID)	60	183
Strawberry (Strawberry Water Co. and Lufkin Hunt)	37	115
Other Unincorporated Areas	163	494
Total	260	792

G. Future Water Demand and Population

Table 4 summarizes total estimated potable water consumption for all communities in the study area.

Table 4. Estimated Potable Water Consumption – All Areas Within Study Area – Gila County – 2002 to 2040, Acre-Feet per Annum.

Community	2002		2040	
	Population	Acre-Feet per Year	Population	Acre-Feet per Year
Town of Payson	14,500	1,805	44,637	6,000
Pine (Pine Water Co., Solitude Trails DWID, Strawberry Hollow DWID, Pine Water Assoc. DWID, Pine Creek Canyon/Portal IV DWID)	1,981	183	9,317	1,346
Strawberry (Strawberry Water Co. and Lufkin Hunt)	1,062	115	5,170	878
Other Unincorporated Areas of Study Area	3,798	494	14,061	2,428
Total	21,341	2,597	73,185	10,652

H. Summary

Based on 10 percent estimated losses for the town of Payson and 15 percent estimated losses for all other water service providers, the total acre-feet of water required to supply the study area at build out, as shown in Table 5, is estimated to be 11,949 acre-feet per year.

Table 5. Future Water Demand, 2040 Including Losses

Community	Estimated Losses (%)	Total Annual Water Demand (AF)
Payson	10	6,600
Pine (Pine Water Co., Solitude Trails DWID, Strawberry Hollow DWID, Pine Water Assoc. DWID, Pine Creek Canyon/Portal IV DWID)	15	1,548
Strawberry (Strawberry Water Co. and Lufkin Hunt)	15	1010
Other Unincorporated Areas of Study Area	15	2,792
Total		11,950

Table 6. Mogollon Rim Water Resources Management – Population and Water Demands – 2002 & 2040																
			2002						2040							
											Low Demand			High Demand		
Map No.	Grp.	Location	Population	Developed Parcels	Total Parcel	Gallons per Capita per Day	Million Gallons per Year	Acre-Feet per Year	Population	Total Parcels (Developed)	Gallons per Capita per Day	Million Gallons per Year	Acre-Feet per Year	Gallons per Capita per Day	Million Gallons per Year	Acre-Feet per Year
		Public - Municipal														
39	1-1	Town of Payson (includes Tonto Apache Tribe)	14,500	7,254	9747	111	588	1805	44637	19594	120	1955	6000	120	1955	6000
		Public – Domestic Water Improvement District														
29	2-1	Pine: Solitude Trails DWID	22	34	78	149	1	4	187	78	120	8	25	150	10	31
31	2-2	Pine: Strawberry Hollow DWID	0	12	41	0	0	1	173	72	120	8	23	150	9	29
23	2-3	Pine: Pine Water Association DWID[1]	50	47	55	192	4	11	132	55	120	6	18	250	12	37
22	2-4	Pine: Pine Creek Canyon DWID (Portals4)	20	70	170	342	3	8	432	180	120	19	58	250	39	121
26	1-3	Rim Trail Estates DWID	44	108	149	218	4	11	358	149	120	16	48	218	28	87
		Private Unregulated Cooperatives/Homeowners Associations, etc.														
1	5-7	Arrowhead Canyon	10	5	8	100	0	1	19	8	120	1	3	140	1	3
2	3-1	Bear Flat	12	61	144	250	1	3	346	144	120	15	46	200	25	77
4	5-2	Bonita Creek [1]	30	30	84	110	1	4	202	84	120	9	27	150	11	34
5	5-6	Camp Geronimo Boy Scout Camp [3]	60	1	1	96	2	6	68	1	120	3	9	120	3	9
7	3-2	Collins Ranch	11	35	38	199	1	2	84	38	120	4	11	150	5	14
8	1-20	Cowan Ranch	5	19	21	164	0	1	50	21	120	2	7	164	3	9
9	5-3	Diamond Point Recreation	4	45	45	137	0	1	108	45	120	5	15	150	6	18
10	1-14	Diamond Point Shadows	140	181	197	250	13	39	473	197	120	21	64	250	43	132
12	5-4	Ellison Creek Estates	30	50	80	130	1	4	192	80	120	8	26	150	11	32
13	5-5	Ellison Creek Recreation	10	60	60	137	1	2	144	60	120	6	19	140	7	23
15	1-19	Freedom Acres	29	21	21	283	3	9	50	21	120	2	7	283	5	16
17	4-2	Hunter Creek	35	75	166	571	7	22	398	166	120	17	54	300	44	134
18	3-3	Kohl's Ranch [1]	270	134	192	70	7	21	461	192	120	20	62	120	20	62
21	1-16	Oxbow Estates [2]	240	70	75	120	11	32	250	75	120	11	34	150	14	42
25	4-3	R-C Boy Scout Camp [3]	20	1	1	96	1	2	23	1	120	1	3	120	1	3
27	1-15	Round Valley	300	178	202	230	25	77	581	242	120	25	78	230	49	150
28	1-17	Shadow Rim Ranch Girl Scout Camp [3]	12	1	1	96	0	1	14	1	120	1	2	120	1	2
34	1-10	Summit Springs	0	0	27	0	0	0	65	27	120	3	9	150	4	11
35	3-6	Thompson Draw I & II	5	85	85	657	1	4	204	85	120	9	27	200	15	46
40	1-5	Verde Glen	16	66	108	137	1	2	274	114	120	12	37	175	17	54
41	1-18	Washington Park	1	14	14	150	0 (0.1)	0 (0.3)	34	14	120	1	5	150	2	6
43	1-8	Wonder Valley	40	20	23	69	1	3	58	24	120	3	8	225	5	15
44	3-5	Wood Canyon Ranch	0	0	260	0	0	0	624	260	120	27	84	150	34	105
45	3-9	Zane Grey Meadows	4	5	20	180	0	1	48	20	120	2	6	180	3	10
		Sub-total	**15,920**				**677**	**2077**	**50689**			**2220**	**6815**		**2382**	**7312**

Table 6. Mogollon Rim Water Resources Management – Population and Water Demands – 2002 & 2040																
			2002						**2040**							
										Low Demand			**High Demand**			
		Private – Regulated Utility Firms														
11	1-11	Payson Water Co. East Verde Estates (Brooke Utilities)	180	164	246	79	5	16	590	246	120	26	79	130	28	86
14	1-12	Payson Water Co. Flowing Springs (Brooke Utilities)	40	42	73	137	2	6	192	80	120	8	26	150	11	32
16	5-1	Payson Water Co. Geronimo Estates (Brooke Utilities)	35	109	252	141	2	6	624	260	120	27	84	150	34	105
19	3-4	Payson Water Co. Mead Ranch (Brooke Utilities)	25	85	126	99	1	3	302	126	120	13	41	130	14	44
20	1-9	Payson Water Co. Mesa Del Caballo (Brooke Utilities)	640	409	455	92	22	66	1092	455	120	48	147	130	52	159
24	2-5	Pine Water Co. (Brooke Utilities)	1,889	2,111	2798	75	52	159	8393	3497	120	368	1128	120	368	1128
30	1-13	Payson Water Co. Star Valley A&B (Brooke Utilities)	700	461	708	84	22	66	2378	991	120	104	320	120	104	320
33	2-6	Strawberry Water Co. (Brooke Utilities)	1,002	1,199	1667	90	33	101	5002	2084	120	219	672	150	274	840
42	1-6	Payson Water Co. Whispering Pines (Brooke Utilities)	80	171	228	195	6	17	547	228	120	24	74	200	40	123
3	1-7	Beaver Valley Water Co. [1]	240	231	351	82	7	22	842	351	120	37	113	150	46	142
6	4-1	Christopher Creek Haven Water Co.	150	342	528	73	4	12	1363	568	120	60	183	120	60	183
32	2-7	Strawberry Water Co. (Hunt Water)	60	49	60	200	4	14	168	70	120	7	23	200	12	38
37	3-7	Tonto Creek Estates Water Co.	30	65	65	137	2	5	156	65	120	7	21	150	9	26
38	3-8	Tonto Village Water Co.	350	303	353	68	9	27	847	353	120	37	114	120	37	114
		Sub-total	**5,421**				**171**	**520**	**22496**			**985**	**3025**		**1089**	**3340**
		Total	**21,341**				**848**	**2597**	**73185**			**3205**	**9840**		**3471**	**10652**

[1] Uses a combination of surface and ground water.
[2] Oxbow Estates present population density exceeds the assumed future density of 2.4; therefore, the future population is based on an assumed density of 3.4 people per parcel.
[3] Population for seasonal camps represents a full time equivalent.

ATTACHMENT 3

(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

A Summary of the Town of Payson's 2006 Water Quality Analysis

Attachment 3

A SUMMARY OF THE TOWN OF PAYSON'S 2006 WATER QUALITY ANALYSIS

The Town of Payson performs an annual Water Quality Survey of it drinking water sources – groundwater, as required by Arizona Department of Environmental Quality. Similarly, other water service providers, in the Study Area, are required to provide their customers with an annual Consumer Confidence Reports that reports similar water quality information as found in Payson's Annual Water Quality Survey. It is assumed that the water quality of Payson's groundwater is similar to the groundwater quality throughout the Study Area since most groundwater sources are taken from the same geologic formations. The one item that the Town tests for and will not be repeated in the table immediately below is the data gathered for biological monitoring. The smaller communities' wastewater is processed by septic systems. These systems may contaminate local water supplies. Hence, the biological condition of a community's water supply should be established on a community by community basis. Table I.-1. presents a summary of the 2006 water quality analysis of the Town's water supply.

TableI.-1. A Summary of the Town of Payson's 2006 Water Quality Analysis.

Primary Drinking Water Standards – Mandatory Health-Related Levels Established by EPA and ADEQ					
Parameter	**Unit**	**MCL**	**MCLG**	**Remarks**	
Lead & Copper	Ppb/ppb	---	---	Town-wide source level range = <0.5 – 19; Town-wide source level range = <0.0002 – 0.25	
Radiochemical Monitoring				Highest Average	Range
Gross Alpha	pCi/l			13.9	1.8 – 13.9
Combined Radium	pCi/l			1.6	N.D. – 1.6
Regulated Inorganic Compounds				Highest Detected Level	Range
Arsenic	ppb	10	0	40	N.D. – 40
Barium	ppm	2	2	0.14	0.04 – 0.14
Chromium	ppb	100	100	5	N.D. – 5
Fluoride	ppm	4	4	1.8	0.2 – 1.8
Nitrate (as N)	ppm	10	10	4.8	N.D. – 4.8
Regulated Organic Compounds				Highest Detected Level	Range
Di(2-EthylHexyl) Phthalate	ppb	20	20	0.8	N.D. – 0.8
Tetrachloroethylene	ppb	5	0	1.4	N.D. – 1.4
Toluene	ppm	1	1	0.003	N.D. – 0.003

Xylenes, Total	ppm	10	10	0.003	N.D. – 0.003
Disinfection Byproduct Monitoring				Highest Average	Range
Total Trihalomethane	ppb	80	0	9.1	N.D. – 12.5
Haloacetic Acids	ppb	60	N/A	1.9	N.D. – 2.7
Secondary Drinking Water Standards – Aesthetic Levels Established by EPA and ADEQ					
Unregulated Inorganic Compounds				Range	
Alkalinity	ppm	--	--	103 – 353	
Calcium	ppm	--	--	28 – 84	
Chloride	ppm	--	--	7.5 – 77	
Hardness, total	ppm	--	--	111 – 325	
Iron	ppm	--	--	N.D. – 4.9	
Magnesium	ppm	--	--	10 –31	
Manganese	ppm	--	--	N.D. – 0.31	
Nickel	ppm	--	--	N.D. – 0.011	
pH	SU	--	--	6.9 – 7.7	
Sodium	ppm	--	--	13 – 45	
Sulfate	ppm	--	--	5.2 – 22	
Total Dissolved Solids	ppm	--	--	190 – 440	
Zinc	ppm	--	--	0.005 – 3.3	
Key to Table					
MCL – Maximum Contaminant Level MCLG – Maximum Contaminant Level Goal (<) Less than the amount indicated		Limits are not set for these parameters. Range – Low to high measurements reported during the year pCi/l – PicoCuries per liter		N.D. Not Detected ppm -- Parts per million ppb – Parts per billion	

The Town of Payson Water Department tested all active water sources during 2001, for the following contaminants:

2,4 – Dinitrotoluene
2,6 -- Dinitrotoluene
Acetochlor
DCPA Mono-acid degradate
DCPA Di-acid degradate
4,4' – DDE
EPTC
Molinate
MTBE
Nitrobenzene
Perchlorate
Terbacil

Payson has reported that none of these contaminants were detected in its drinking water.

A potential water quality issue that may exist in those communities that are totally on septic or similar type waste water treatment and disposal systems. The issue is that there is a potential for water supply impairment. The water supply impairment could be caused by the percolation of human and other waste entering into the local ground water supply. A study should be undertaken to determine if human waste is impairing a local ground water supply.

ATTACHMENT 4

(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Legal and Institutional Considerations

ATTACHMENT 4
LEGAL AND INSTITUTIONAL CONSIDERATIONS

There are many administrative considerations, both legal and institutional, that place restrictive limitations on water related issues. These limitations will be considered during the development of the various proposed alternative solutions to water problems in the Study Area. The legal issues include Federal, State, county, and town laws, statutes, ordinances related to surface water rights, groundwater rights, private property rights, pubic health and safety, environmental concerns, and resource conservation. Institutional limitations relate to powers and authorities vested within Federal departments, State agencies, and counties and towns. Included are such institutions as Federal departments of Agriculture, Interior, and Homeland Security; State agencies such as the Arizona Departments of Water Resources (ADWR) and Environmental Quality (ADEQ); county and town departments such as health, planning and zoning, and building. A summary of these legal and institutional considerations, and how they may apply to the various alternative solutions to water problems in the Study Area, are presented immediately below and summarized in Table I.-1:

Legal Considerations:

Arizona water law is based on the doctrine of prior appropriation. Surface water and groundwater are regulated separately. Thus, the applicable law is dependent on a determination of what type of water is being used. Surface water is “all sources flowing in streams, canyons, or ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, floodwaters, wastewaters, or surplus water, and of lakes, ponds, and springs on the surface (Arizona Revised Statutes 45-101). Ground water is all other waters. Water law in Arizona is administered by the ADWR, with a major division of regulation occurring between Active Management Areas (AMA) and non-AMA areas. Five AMA’s (Phoenix, Pinal, Tucson, Santa Cruz, and Prescott) are located in the major population centers of the State. There are no AMAs in Gila County.

Water rights in Arizona can be held by all types of legal entities such as government agencies, corporations, individuals, groups, etc.

Surface Water Laws and Rights

The doctrine of prior appropriation that governs surface water is based on the tenet of “first in time, first in right” which is interpreted to mean that the party that first consumes water for a beneficial use acquires a right that is superior to those that are later appropriators. Under A.R.S. Title 45 Waters, Chapter 1, Administration and General Provisions, Article 5 Appropriation of Water; a person must obtain a permit in order to appropriate surface water. Points of diversion, places of use, and the ultimate use of the water are key elements of surface water rights. Surface water rights are attached to specific land parcels, and may only be transferred by a transfer and sever process approved by ADWR. Changes of use of the surface water must also be approved by ADWR.

Senior water right holders in the Phoenix area have previously appropriated most of the surface water in the Salt and Verde watersheds. Some of these water right holders include shareholders of the Salt River Project, the City of Phoenix, the Salt River Pima Maricopa, Fort McDowell, and Gila River Indian Communities, the Roosevelt Water Conservation District and the Buckeye Irrigation Company. Pine Water Company and the Tonto Apache Tribe have Central Arizona Project ("CAP") water allocations (161 a/f and 128 a/f respectively) which are currently undeliverable to either entity, but might be available through water right exchanges with Salt River Project. Other surface water supplies in the Study Area, such as C.C. Cragin Reservoir, Fossil Springs/Creek, East Verde River, and Tonto Creek have been appropriated for many years.

C.C. Cragin Reservoir: A major source of surface water in the Study Area is C. C. Cragin Reservoir, located 25 miles north of Payson on top of the Mogollon Rim. A water pumping and nine mile pipeline system from the reservoir to the headwaters of the East Verde River has been used since 1964 to transfer water to the metropolitan Phoenix area. Phelps Dodge Corporation's rights to C. C. Cragin (formerly known as Blue Ridge) water that had been covered under an exchange agreement between Phelps Dodge and Salt River Project for over 40 years, were severed and transferred fully to SRP during 2006. The Arizona Water Settlement Act of 2004, established an annual water supply of 3,500 ac-ft of water from C.C. Cragin Reservoir to be used in northern Gila County, Arizona.

East Verde River: Currently, only the rural communities in the Study Area of Rim Trail, Verde Glen, and Beaver Valley draw a historical water right from the East Verde River. Because SRP will be adding substantial volumes of C. C. Cragin water to the East Verde streambed in future years, they are currently evaluating other potentially unauthorized users in order to minimize water losses they might incur as they transport water down the river toward metropolitan Phoenix.

Fossil Creek/Springs: For over 100 years, the surface water in Fossil Creek had been subject to power generation permits (issued by the Federal Energy Regulation Commission--FERC-- to Arizona Public Service--APS), for power generation at Childs and Irving power generation facilities constructed in the waterway. No water consumption was allowed. FERC permits were surrendered in October, 2004, In 1999, APS in concert with the Yavapai-Apache Nation, American Rivers, Arizona Riparian Council, the Center for Biological Diversity, The Nature Conservancy, and Northern Arizona Audubon Society, agreed to decommission the Childs and Irving hydroelectric power plants and restore full flow to Fossil Creek. FERC permits were surrendered in October, 2004, and on June 18, 2005 APS restored full flow to 14 miles of the Fossil Creek wetland ecosystem, returning the area to a "natural and scenic" waterway. The return of the previously diverted flows from Fossil Springs back to Fossil Creek are being used to restore and enhance environmental habitat and riparian areas, to preserve in-stream flows for the benefit of establishing travertine dam and deposits, to enrich a popular recreation area, and to provide sufficient flow conditions for native fish.

Tonto Creek: Waters from Tonto Creek are nearly fully allocated to several agricultural users between the headwaters and Roosevelt Lake, and to SRP and other downstream users in the Phoenix metropolitan area. SRP has issued notices of unauthorized diversions to numerous users along the creek. Some major concerns exist along this creek with contamination levels from septic systems, a problem for which Gila County has been obtaining grants to help residents mitigate effects of leaky septic systems near the creek's edge.

Groundwater Laws and Rights:

ADWR administers ground water under three levels. There are special rules for AMAs (where overdraft of groundwater has been most severe) and for Irrigation Non-Expansion Areas ("INAs"). Outside AMAs and INAs groundwater may be withdrawn and used for reasonable and beneficial use, although a Notice of Intent" to drill requires a permit. Well drillers must report initial results of drillings. Basically, within Arizona, groundwater is owned by the public and controlled by ADWR, but is available to property owners that can extract water under their property and put it to a reasonable and beneficial use.

Institutional Considerations:

Various powers and authorities that effect water in northern Gila County are vested in various Federal departments, State agencies, County divisions, Town departments, and Native American tribes.

Federal Institutions.

The Department of Agriculture, Tonto National Forest, Payson Ranger District is responsible for:

- Protection of the watershed, for the benefit of Salt River Project
- Environmental issues that may affect the Forest
- Wilderness designations and protections must be observed. Research for additional potential environmental issues is required since this is only a partial listing of the environmental issues that need to be address prior to the construction of any infrastructure required to deliver water from any alternative.
- Endangered species issues to be evaluated during the formulation of any water supply project. Department of Interior, U.S. Fish and Wildlife Service is responsible for In-stream flow conditions for sustained balanced aquatic conditions.

Two Department of the Interior bureaus, Bureau of Reclamation, who is responsible for water development in the west and holds some Indian trust responsibilities; and the Bureau of Indian Affairs who also has Indian trust responsibilities.

Federal Law

Show immediately below is a partial listing of the Federal Laws that will be considered during the course of any project planning:

Antiquities Act of 1906, American Indian Religious Freedom Act of 1978, Archaeological Resources Protection Act of 1979, as amended, Archaeological and Historic Preservation Act of 1974, Clean Air Act of 1970, as amended, Endangered Species Act of 1973, amended in 1979, 1982, and 1988, Federal Water Pollution Control Act (commonly referred to as the Clean Water Act), Fish and Wildlife Coordination Act of 1958, as amended, Historic Sites Act of 1935, National Environmental Policy Act of 1969, National Historical Preservation At of 1966, as amended, Native American Graves Protection and Repatriation Act of 1990, Noise Control Act of 1972, amended in 1978, Occupational Safety and Health Administration, Hazard Communication Standards, Resource Conservation and Recovery Act, Rivers and Harbors Act of 1899, and the Safe Drinking Water Act, Title 28, Public Law 89-72, as amended.

Executive Orders – EO 11988 -- Floodplain Management, EO 11990 – Protection of Wetlands, EO 12875 – Enhancing the Intergovernmental Partnership, and EO 12898 – Federal Actions to Address Environmental Justice.

The laws and executive orders offered immediately above is only a partial listing of federal laws and executive orders that may pertain to the implementation of any of the proposed alternatives identified by this Study. Additional research will be required to identify other federal law that pertains to any project alternative that may be selected for further study as a result of this current study effort.

State Institutions:

Arizona Department of Water Resources: ADWR has a variety of responsibilities that must be considered when planning, developing, or managing water resources:

Adequacy of water supply is a responsibility of ADEQ: In 1973, the Arizona Legislature enacted a statewide water adequacy statute as consumer protection measure in response to the marketing of lots without available water supplies. The Water Adequacy Program requires subdivision developers to obtain a determination from the State regarding the availability of water supplies prior to marketing lots. Developers are required to disclose any "inadequacy" of the supply to potential buyers. This law applies to new subdivisions outside of AMAs. For a new subdivision outside of AMAs, a water adequacy determination is required before a plat can be approved by a city of county. The determination is also needed before the Department of Real Estate will authorize the sale of lots.

The ADWR has established criteria for meeting water adequacy. First, the water must be physically, legally and continuously available. Physical availability of the water supply is typically demonstrated through a hydrologic study. For groundwater, the study must consider demands of current and committed uses for a 100 year period, and the supply must meet depth limitation specific in the Assured and Adequate Water Supply Rules. The depth-to-water cannot exceed 1,200 feet after 100 years for subdivision served by a water company. For dry lot subdivision, the maximum depth-to-water cannot exceed 400 feet after 100 years. For all sources of water, legal rights must exist, and adequate delivery, storage, and treatment works must be either in place or financed. The second criterion is water quality. Proposed sources of water must satisfy state water quality standards as well as other water quality standards applicable to the proposed use after treatment.

The Department, upon review of the developer's water demand projections, the proposed subdivision plat, and a hydrologic study will make a determination, based upon the quality, quantity and dependability of the water supply, as to whether the water supply is either adequate or inadequate to meet 100 years of projected water demand.

Underground storage facilities and recovery, of stored water is a responsibility of ADEQ: In 1986, the Arizona Legislature established the Underground Water Storage and Recovery program to allow persons with surplus supplies of water to store that water underground and recover it at a later time for the storer's use. In 1994, the Legislature enacted the Underground Water Storage, Savings, and Replenishment Act, which further defined the recharge program. The recharge program is administered by ADWR.

The Department encourages the direct use of renewable water supplies. The recharge program restricts the type of water that may be stored long-term to renewable sources that cannot be used directly. Persons who wish to store water through the recharge program must apply to ADWR for the appropriate permits. All permit holders are required to file annual reports with the Department regarding the volume of water they stored and/or recovered pursuant to their permits.

When eligible water is stored underground for more than one year, long-term storage credits may be issued. Long-term Storage Credits are credits earned in the process of storing water. These credits can be recovered in the future to be used for approved and permitted uses.

Rural Water monitoring and development is part of ADWR's responsibility: The Department' Water Resource Planning Section role for participating in rural water issues is primarily limited to providing planning and technical assistance to rural Arizona. The issues that motivate participation, by this Section, are the knowledge that they have regarding the impacts that the expanding population growth is having on several of the rural communities, including Towns. The Department is concerned with the impacts of limited groundwater resources to support the ~~noted~~ growth, drought management and water conservation; and they also have concern for unique environmental factors that are being impacted by this increasing population growth. As a partial requirement for this section to participate in the development of a degree of understanding on how to understand and address these issues, the Department has published a statewide drought and conservation plan for the Governor's Drought Task Force to address the growing concerns about water shortages. Additionally, the heightened concerns about Arizona's water resources led to the passage of legislation that requires all community water systems to annually report water uses, prepare water system plans to ensure continuously available water supplies and prepare water conservation plans. ADWR is required to assist the communities with the reporting and plans to ensure that the water supplies for all of Arizona are monitored and managed.

In summary, the Arizona Revised Statutes Title 45 *Water* is the State statute that provides legal guidance for the development and management of water resources throughout the State of Arizona. This specific statute contains several provisions that should be considered during the development of any implementation plan for a proposed project alternative. Those chapters that should be considered include, but are not limited to, the following chapters and noted articles:

Chapter 1: Administration and General Provisions (includes several articles that reference surface water rights and appropriation)

Chapter 2: Groundwater Code (including an article discussing the legal elements associated with Wells)

Chapter 3: Underground Water Storage, Savings and Replenishment (including articles regarding Storage Facility Permits, Water Storage Permits and Recovery Well Permits, Use of stored water, Indian Water Rights Settlement, and Accounting)

Chapter 4: Water Exchanges

Chapter 6: Dams and Reservoirs (there are articles in this Chapter that discuss the legal considerations associated with the following considerations: Supervision of Dams, Reservoirs and Project, Flood Control, and Weather Control and Cloud Modification)

Arizona Department of Environmental Quality

The mission of the ADEQ's Water Quality Division is to protect and enhance public health and the environment by ensuring safe drinking water and reducing the impact of pollutants discharged to surface and groundwater.

The Water Quality Division's core responsibilities include:

- Ensuring that Arizona's public water systems deliver safe drinking water.
- Managing the quality of water resources through partnerships within the natural boundaries of the state's watersheds.
- Regulating the discharge and treatment of wastewater.
- Monitoring and assessing the quality of surface and groundwater throughout the state.
- Identifying water pollution problems and establishing standards to address them.
- Issuing permits to protect Arizona waters from point sources of pollution.
- Investigating complaints and violations of Arizona's water quality laws, rules and permits.

The materials contained in this section refer to the responsibilities of the Water Quality Division of ADEQ. The Water Quality Division is responsible for administering and enforcing most state laws protecting the state's water resources. The state water quality laws include the following actions:

- Adoption of water quality standards within the state, in general, for navigable waters and for aquifers, along with water quality monitoring to determine compliance with applicable water quality standards;
- Administration of the Aquifer Protection Permit Program, including the adoption of best management practices for regulated agricultural activities;
- Remedial actions involving the release of hazardous substances which impact state waters;
- Drinking water system regulation;
- Regulation of wastewater collection and treatment systems; and

- Financing of the construction, rehabilitation and/or improvement of drinking water, wastewater, wastewater reclamation, and other water quality facilities/projects, i.e. Water Infrastructure Financing Authority (WIFA).

Watershed In summary, ADEQ manages the quality of Arizona's water resources by working within the natural boundaries of the state's watershed rather than administrative or jurisdictional boundaries such as county lines and national forest boundaries. This approach recognizes the complex interrelationships between water quality and quantity, surface water and groundwater, and the needs of local communities whose livelihoods depend on having enough clean water.

The Arizona Revised Statutes Title 49 *The Environment* is the State statute that provides legal guidance for the management of water quality control throughout the State of Arizona. This specific statute contains provisions that should be considered during the development of any implementation plan for a proposed project alternative. Those chapters that should be considered include, but are not limited to, the following chapters and noted articles:

Chapter 2: Water Quality Control (Water Quality, Total Maximum Daily Loads, Aquifer Protection Permits, Arizona Pollutant Discharge Elimination System Program, and Potable Water Systems)

Chapter 3: Air Quality (State Air Pollution Control, County Air Pollution,)

Chapter 4: Solid Waste Management (Regulation of Solid Waste and Management of Special Waste)

Chapter 5: Hazardous Waste Disposal (Hazardous Waste Disposal at State Sites, Hazardous Waste Management, Sites for Waste Facilities; Notification, and Pollution Prevention)

Chapter 6: Underground Storage Tank Regulation

Chapter 8: Water Infrastructure Finance Program (Financial Provisions)

<u>Arizona Corporation Commission (ACC):</u> Article 15 of the Arizona Constitution establishes the ACC. By virtue of the Arizona Constitution, the Commission is overseen by elected Commissioners. The Commissioners function in an *executive* capacity, they adopt rules and regulations thereby functioning in a *legislative* capacity, and they also act in a *judicial* capacity sitting as a tribunal and making decisions in contested matters. The Commissioners have the ultimate responsibility for final decisions on granting

or denying rate adjustments, enforcing safety and public service requirements, and approving securities matters.

The Commission staff is organized into six divisions: Administration, Hearings, Utilities, Securities, Corporations, and Legal. The division of most interest in this Study is the Utilities Division.

The Commission has jurisdiction over the quality of service and rates charged by public service utilities (includes private water and sewer companies). By state law, public service utilities are regulated monopolies given the opportunity to earn fair and reasonable return on their investments. The Utilities Division makes specific recommendations to the Commissioners to assist them in reaching decisions regarding public utility rates, utility finance and quality of service.

Arizona Department of Real Estate: The purpose of the department in is to protect the public interest through licensure and regulation of the real estate profession in Arizona. The Real Estate division is responsible for making sure buyers of properties are aware of the status of water adequacy for any new subdivisions. The first buyers in a newly platted subdivision must be informed in writing as to whether the property has been granted a 100 year water adequacy designation or not. Most subdivisions are deemed to be inadequate, however sales can be made anyway since the required long-term testing for adequacy has not been started or ever completed. After the first buyers are notified, no additional notification to future buyers is required.

Arizona Game and Fish Department (AZGFD): State Game and Fish is responsible for

County, Municipality, Improvement Districts: Numerous departments and divisions of local governments have legal responsibility for water development, quality, and conservation.

Northern Gila County Sanitary District. Within the Town of Payson and in the community of Mesa Del Caballo, the Sanitary District, a political subdivision of Gila County, is responsible for wastewater disposal, recycling and/or reuse.

Town of Payson: The Community Development Department and the Water Department of Payson exercise considerable control over the quantity of building permits issued and programs for conservation of water resources. Payson has a strong demand management program for water conservation and significant ordinances related enforcement of a conservation stage that is set once per year.

The Town's water conservation policy is built on the premise that the Town has a limited water supply. The Town has taken the position that it is necessary to protect its limited water supply to allocate and monitor water use to existing, pending, and future development within its jurisdictional boundaries to ensure the continuing economic development and stability of the Town. Further, the Town has determined that is necessary to require that the Town implement conservation measures and to require that water is utilized in the maximum beneficial way and that waste, unreasonable use or unreasonable methods of use (misting systems, etc.) of water be prevented. By applying this policy for water conservation the Town believes that it has protected the interests of the Town and its citizens and promoted the general welfare of the community. The policy is expected to apply to all water whether potable or effluent and to all citizens, businesses, and governmental entities within the corporate limits of the Town and all customers of the Water Department, wherever situated.

Salt River Project: Surface water from both Fossil Creek and Tonto Creek are fully protected, preserved, and put to beneficial use by SRP, thus any alternatives dealing with surface water, must carefully consider the rights and controls that SRP may have on water flows, water rights, severs and transfers, and changes of use where acknowledge rights are held by others.

Brooke Utilities: Through three different wholly owned subsidiaries, Brooke Utilities holds the Certificates of Convenience and Necessity issued by the ACC. As such, water development, line extensions, meter moratoriums, conservation requirements, water rates etc. (except as carried out on a single individuals private property, and not sold to others) must all be coordinated with the Brooke Utilities operations, and if necessary be approved by the ACC. Probably the most notable area where Brooke Utilities has had to exercise the most activity associated with water conservation is for the area served by the Pine Water Company. However, they do exercise some level of water conservation in their other water services areas as well, with full meter moratoriums in place in both Pine and Geronimo Estates. Brooke Utilities' water conservation programs comply with water conservation staging levels as dictated by the ACC. Brooke Utilities' water conservation stages are generally based upon the status of water in storage. The water conservation plan establishes mandatory measures at Stages 3, 4, and 5, prohibiting, irrigation of outdoors lawns, shrubs or plants; washing vehicles; using water to control dust or clean outdoors; dripping or misting systems; and filling swimming pools, spas, fountains or ornamental ponds. In stage 5, Brooke Utilities can exercise regulatory restrictions in the form of moratoriums, curtailment orders, meter disconnection without notice or the like. It is possible that while one or more water service areas of Brooke Utilities are at Stage 1, one or more other water service areas may be at Stage 5. For Brooke Utility service areas, water conservation programs cannot be expected to reduce demand much further as a method to extend a water supply. Future water supplies for most of Brooke Utilities’ areas will probably be developed from additional groundwater reserves, if they are ultimately required by the ACC to meet the growing water demands for their respective communities. No information is currently available concerning a Brooke Utilities Master Plan for water supply development for each of the water companies providing service within the Study Area.

Table I.-1
Legal and Institutional Considerations for Various Alternative Solutions

	Ground Water Alternatives	Surface Water Alternatives	Effluent Water Alternatives	Conservation Water Alternatives
Legal and Institutional Considerations for Communities Within the Study Area				
AZ Ground Water Laws	Yes	No	No	Yes
AZ Surface Water Laws	No	Yes	No	Yes
ADWR General Rules and Regulations	Yes	Yes	Yes	Yes
ADEQ General Rules and Regulations	Yes	Yes	Yes	Yes
ACC General Rules and Regulations	Yes	Yes	No	Yes
AZ Department of Real Estate GeneralRules and Regulations	Yes	Yes	No	No
AZGFD General Rules and Regulations	No	Yes	No	Yes
Gila County Department of Health General Rules and Regulations	Yes	Yes	Yes	No
Gila County Planning and Zoning	No	Yes	Yes	No
Payson Community Development and Water Department Ordinances.	Yes	No	No	Yes
Star Valley Town Ordinances	NA	NA	NA	NA
Salt River Project Exchanges	Yes	Yes	No	No
Brooke Utilities Rules and Regulations	Yes	No	No	Yes

Table ??. Legal and Institutional Considerations

Institution(s)	Town of Payson	Town of Star Valley	Private Water Companies	Water Improvement Districts	Unincorporated & Incorporated Communities	Private Well Owners
Salt River Project	Water Rights – Sever and Transfer Agreements and Operation Agreements		Water Rights – Severe and Transfer Agreements and Operation Agreements	Water Rights – Severe and Transfer Agreements and Operation Agreements	Water Right Claims Settlements	Water Right Claims Settlements
Tonto Apache Tribe	Water Service Agreements and Other Agreements as Required	None	None	None	None	None
Town of Payson	Compliance with Town's Ordinances, Regulation, and Codes	Current or proposed Joint-Power Agreements	Construction, Wheeling, and Operation Agreements	Construction, Wheeling, and Operation Agreements	Water Resource Management Issues	Unresolved Issues as Identified for Resolution
Town of Star Valley	Current or proposed Joint-Power Agreements	Compliance with Town's Ordinances, Regulation, and Codes	None	Water Resource Management Issues	Water Resource Management Issues	Unresolved Issues as Identified for Resolution
Gila County	Compliance with County Ordinances, Regulations and Codes	Compliance with County Ordinances, Regulations and Codes	Compliance with County Ordinances, Regulations and Codes	Compliance with County Ordinances, Regulations and Codes	Compliance with County Ordinances, Regulations and Codes	Compliance with County Ordinances, Regulations and Codes
Water Improvement Districts (all)	Construction, Wheeling, and Operation Agreements		Water Supply and/or Operation Agreements – Past, Present, & Future	Compliance with County Ordinances and State Law	Compliance with Existing Agreements; County Ordinance and State Law	Unresolved Issues as Identified for Resolution
ADWR	Arizona Revised Statutes Title 45 – Waters (all pertinent sections) and Arizona		Arizona Revised Statutes Title 45 – Waters (all pertinent sections) and Arizona	Arizona Revised Statutes Title 45 – Waters (all pertinent sections) and Arizona	Arizona Revised Statutes Title 45 – Waters (all pertinent sections) and Arizona	Arizona Revised Statutes Title 45 – Waters (all pertinent sections) and Arizona Administrative Code Title 12,

	Administrative Code Title 12, Chapter 15		Administrative Code Title 12, Chapter 15	Administrative Code Title 12, Chapter 15	Administrative Code Title 12, Chapter 15	Chapter 15
ADEQ	Arizona Revised Statutes Title 49 – The Environment (all pertinent sections) and Arizona Administrative Code Title 18 Environmental Quality Chapter 4 DEQ Safe Drinking Water; Chapter 9 DEQ Water Pollution Control; Chapter 14 DEQ Water Quality Standards; Permits and Compliance Fees; and Chapter 15 DEQ Water Infrastructure Finance Authority of Arizona		Arizona Revised Statutes Title 49 – The Environment (all pertinent sections) and Arizona Administrative Code Title 18 Environmental Quality Chapter 4 DEQ Safe Drinking Water; Chapter 9 DEQ Water Pollution Control; Chapter 14 DEQ Water Quality Standards; Permits and Compliance Fees; and Chapter 15 DEQ Water Infrastructure Finance Authority of Arizona	Arizona Revised Statutes Title 49 – The Environment (all pertinent sections) and Arizona Administrative Code Title 18 Environmental Quality Chapter 4 DEQ Safe Drinking Water; Chapter 9 DEQ Water Pollution Control; Chapter 14 DEQ Water Quality Standards; Permits and Compliance Fees; and Chapter 15 DEQ Water Infrastructure Finance Authority of Arizona	Arizona Revised Statutes Title 49 – The Environment (all pertinent sections) and Arizona Administrative Code Title 18 Environmental Quality Chapter 4 DEQ Safe Drinking Water; Chapter 9 DEQ Water Pollution Control; Chapter 14 DEQ Water Quality Standards; Permits and Compliance Fees; and Chapter 15 DEQ Water Infrastructure Finance Authority of Arizona	Arizona Revised Statutes Title 49 – The Environment (all pertinent sections) and Arizona Administrative Code Title 18 Environmental Quality Chapter 4 DEQ Safe Drinking Water; Chapter 9 DEQ Water Pollution Control; Chapter 14 DEQ Water Quality Standards; Permits and Compliance Fees; and Chapter 15 DEQ Water Infrastructure Finance Authority of Arizona
Tonto National Forest & Payson Ranger District	Special Use Permits		Special Use Permits	Special Use Permits	Special Use Permits	Special Use Permit
U.S. Fish and Wildlife Service & AZGFD	Threatened and Endangered Species and natural streamflow					
Private Well Owners						
Others	To Be Determined (TBD)		TBD	TBD	TBD	TBD

Note: ADEQ – Arizona Department of Environmental Quality

ATTACHMENT 5

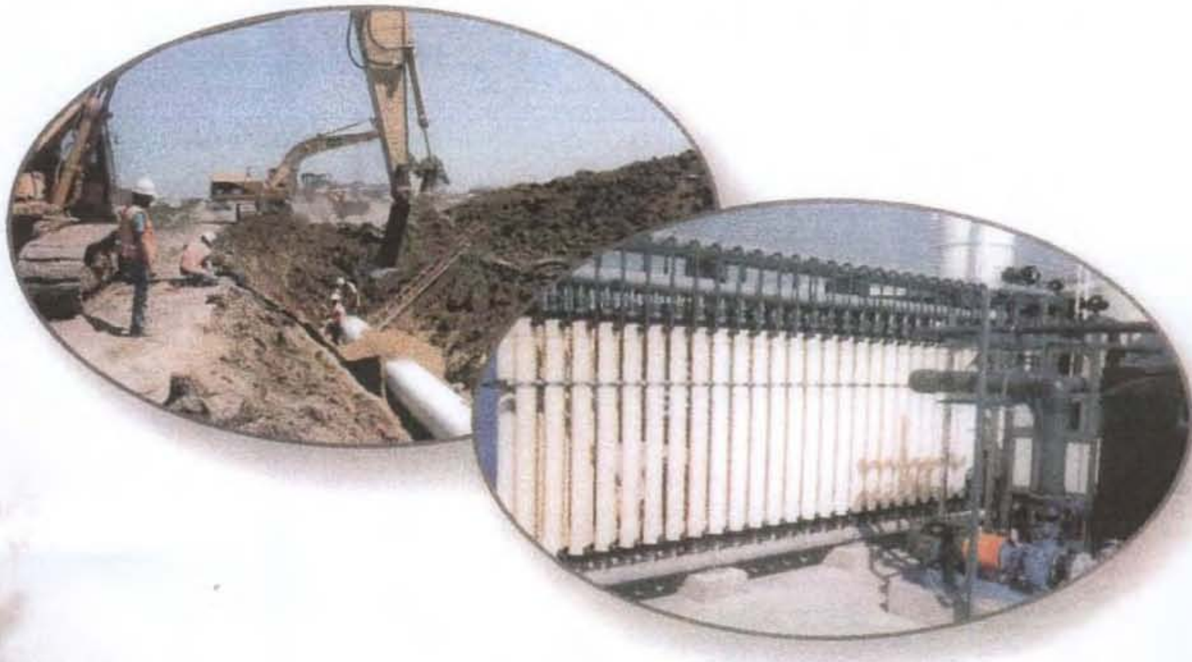
(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Town of Payson: Blue Ridge Reservoir Water Supply Pipeline and Treatment Plant, 2007

Payson

Town of Payson

Blue Ridge Reservoir Water Supply Pipeline and Treatment Plant



Final

REGISTERED PROFESSIONAL ENGINEER (CIVIL)
CERTIFICATE NO.
15695
B. E.
HEMKEN
Date Signed 2-10-06
ARIZONA, U.S.A.
BEHemken

building a world of difference ™

BLACK & VEATCH

BLACK & VEATCH

2850 E. Camelback Road
Suite 240
Phoenix, AZ 85016 USA

Tel: (602) 381-4400

Black & Veatch Corporation

Town of Payson, Arizona
Blue Ridge Reservoir Water Supply
Pipeline and Treatment Plant

B&V Project 141789
February 10,2006

Mr. Buzz Walker
Town of Payson
303 N. Beeline Highway
Payson, AZ 85541-4306

Dear Mr. Walker:

Enclosed you will find five (5) copies of the final report entitled "Blue Ridge Reservoir Water Supply Pipeline and Treatment Plant." Please review and contact me if you have any questions or comments concerning the report. We are available to discuss the details of the report in person at your convenience.

Very truly yours,

BLACK & VEATCH

Brad Hemken

Brad E. Hemken
Project Manager

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Appendices

Tables

Figures

1.0 INTRODUCTION

The Town of Payson has secured a 3,000 ac. ft annual allocation of water from the Blue Ridge Reservoir. The Town plans to divert it's allocation from the Blue Ridge Power Plant, operated by the Salt River Project (SRP), on the downstream side of the power generation turbine. A pipeline approximately 14.5 miles in length would deliver raw water to Payson. The alignment would generally follow the Houston Mesa Road. A water treatment plant (WTP) would be constructed in Payson to treat the raw water to drinking water standards prior to delivery to the Town's potable water distribution system. For the purpose of this analysis a membrane filtration plant will be assumed. The Town will take it's Blue Ridge Reservoir allocation continuously over the nine months that SRP operates the turbine. During periods of low water demand the excess water will be used to recharge the local aquifer. This analysis will also take into consideration a potential 250 ac. ft allocation for the Tonto Indian Community to be delivered through the pipeline to the WTP in Payson.

The community of Pine may secure a potential 500 ac. ft annual allocation of water from the Blue Ridge Reservoir. Pine plans to divert it's allocation from the Blue Ridge Power Plant in a common pipeline with Payson. Where the alignment to Pine diverges from that for Payson, the Pine Extension will start and convey Pine's allocation to the community along Forest Road (FR) 64 and State Route 87. For the purpose of this analysis it is assumed that Pine will only take it's Blue Ridge Reservoir allocation concurrent with Payson. It is also assumed for this analysis that a membrane filtration plant will be provided to treat the raw water to drinking water standards prior to delivery to Pine's potable water distribution system.

The purpose of the feasibility study is to develop sizing criteria and preliminary cost estimates for the pipelines and treatment facilities.

1.1 Hydraulic Capacity

Table 1-1 presents the design flows for a nine month delivery period of the Town's 3,000 ac. ft annual allocation, the Tonto Indian Community's 250 ac. ft annual allocation and Pine's potential 500 ac. ft annual allocation.

Table 1-1
Raw Water Main / WTP Design Capacity

Entity	Annual Allocation (ac-ft/yr)	Capacity (gpm)	Capacity (mgd)
Town of Payson	3,000	2,515	3.6
Tonto Indian Community	250	210	0.3
Pine	500	420	0.6
Total	**3,750**	**3,145**	**4.5**

The raw water main will be sized to deliver the combined design flow of 4.5 mgd for the initial length with the Pine Extension taking 0.6 mgd and the remaining length sized to deliver a flow of 3.9 mgd. The Payson WTP will be designed to initially treat the Town's water allocation with a design capacity of 3.6 mgd. However, the WTP will be designed to allow expansion to an ultimate capacity of 3.9 mgd for treatment of the Tonto Indian Community's potential water allocation. The Pine WTP will be designed to treat the community's water allocation with a design capacity of 0.6 mgd.

2.0 PAYSON RAW WATER MAIN

2.1 Location and Alignment

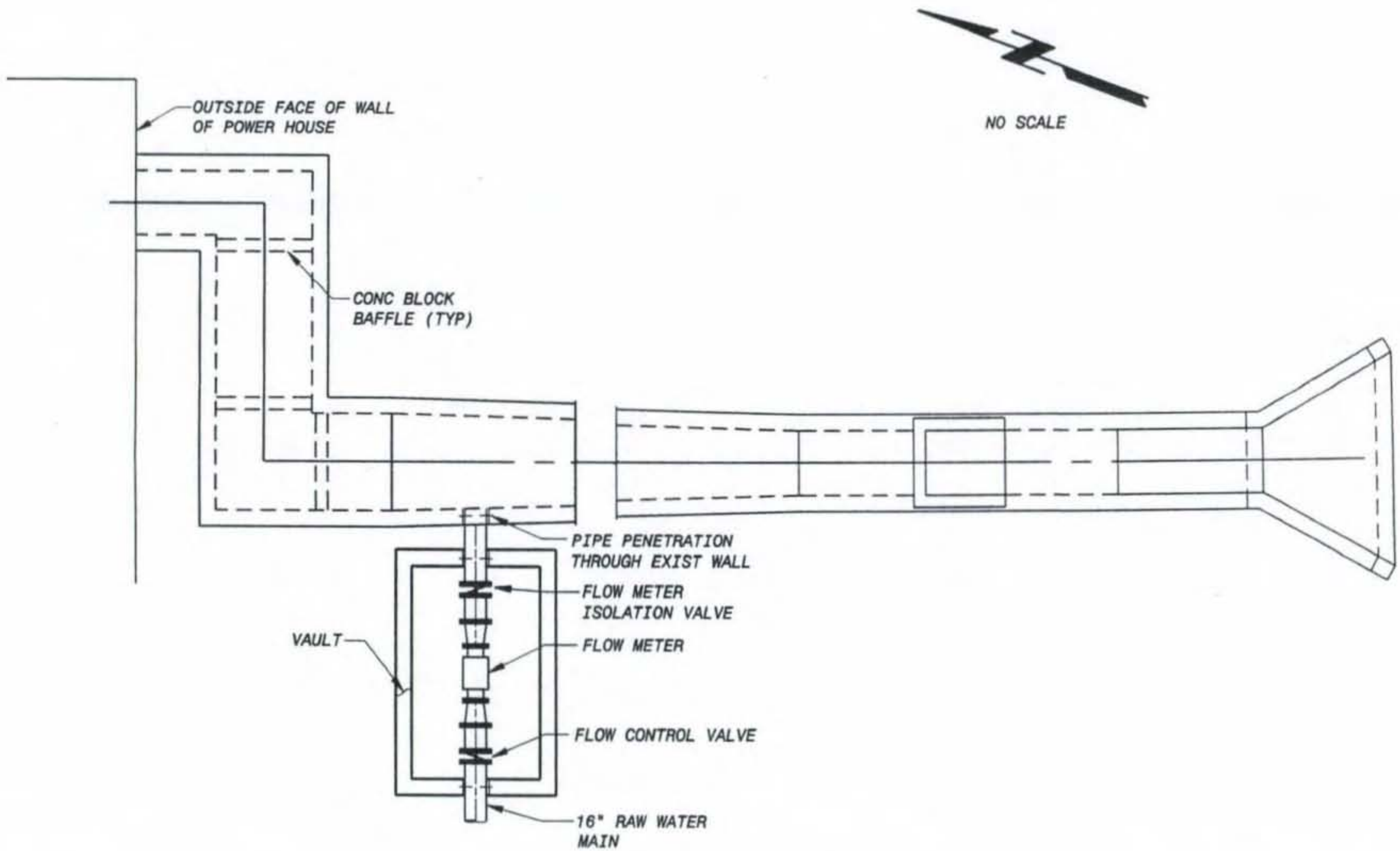
The raw water main will begin at the Blue Ridge Power Plant and follow the alignment of the Houston Mesa Road to the WTP location within the Town of Payson. Two potential alignments were initially evaluated: 1) Houston Mesa Road and 2) powerline utility easement. The powerline easement provided a shorter pipeline length, however, permitting concerns and construction issues associated with the rugged topography negated any advantage of a shorter alignment. The alignment along the Houston Mesa Road was selected to minimize permitting issues, such as environmental impact statements and 404 permits, and facilitate ease of construction. One disadvantage of the Houston Mesa Road alignment would be traffic control during construction. However, the pipeline can be constructed within the existing roadway easement along the edge of the road to minimize the impact.

The raw water main will penetrate the tailrace conduit downstream of the Blue Ridge Power Plant turbine, as shown in **Figure 2-1**, prior to discharge to the East Verde River. A flowmeter and flow control valve will be installed in the pipe to control and meter the flow in the raw water main.

The raw water main alignment along the Houston Mesa Road will run in a southwesterly direction from the Blue Ridge Power Plant to the Town. **Figure 2-2** presents the proposed alignment of the raw water main. An alternate alignment is also shown, which follows a powerline alignment through a small community adjacent to the Blue Ridge Power Plant. The proposed alignment along the Houston Mesa Road has a slight elevation gain at the beginning, which would require an increased pipe trench depth to maintain gravity flow. The alternate alignment has a negative slope from the start and would require less excavation. However, a detailed survey and easement search would be required to evaluate this option. It is recommended that the alternate alignment be evaluated further in the design stage of this project. The Pine extension turnout will be located at the intersection of Houston Mesa Road and FR 64 at Station 183+00.

2.2 Design Criteria

The raw water main was sized to satisfy two conditions: 1) gravity flow along the length of the pipeline alignment and 2) sufficient pressure at the end of pipe to drive the membrane filtration process without the use of booster pumps. Several different pipe sizes were evaluated. **Table 2-1** presents the resulting pressure along the length of the alignment for five different pipe diameters ranging from 14 to 24-inches. The resulting pressure along the length of the alignment between Station 0+00 and Station 183+00 was based on a design flow of 4.5 mgd. The resulting pressure along the remaining alignment was based on a design flow of 3.9 mgd.



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PROJECT NO. 141789

TOWN OF PAYSON

BLUE RIDGE RESERVOIR WATER SUPPLY PIPELINE AND TREATMENT PLANT

TAILRACE CONDUIT MODIFICATIONS

FIGURE NO. 2-1

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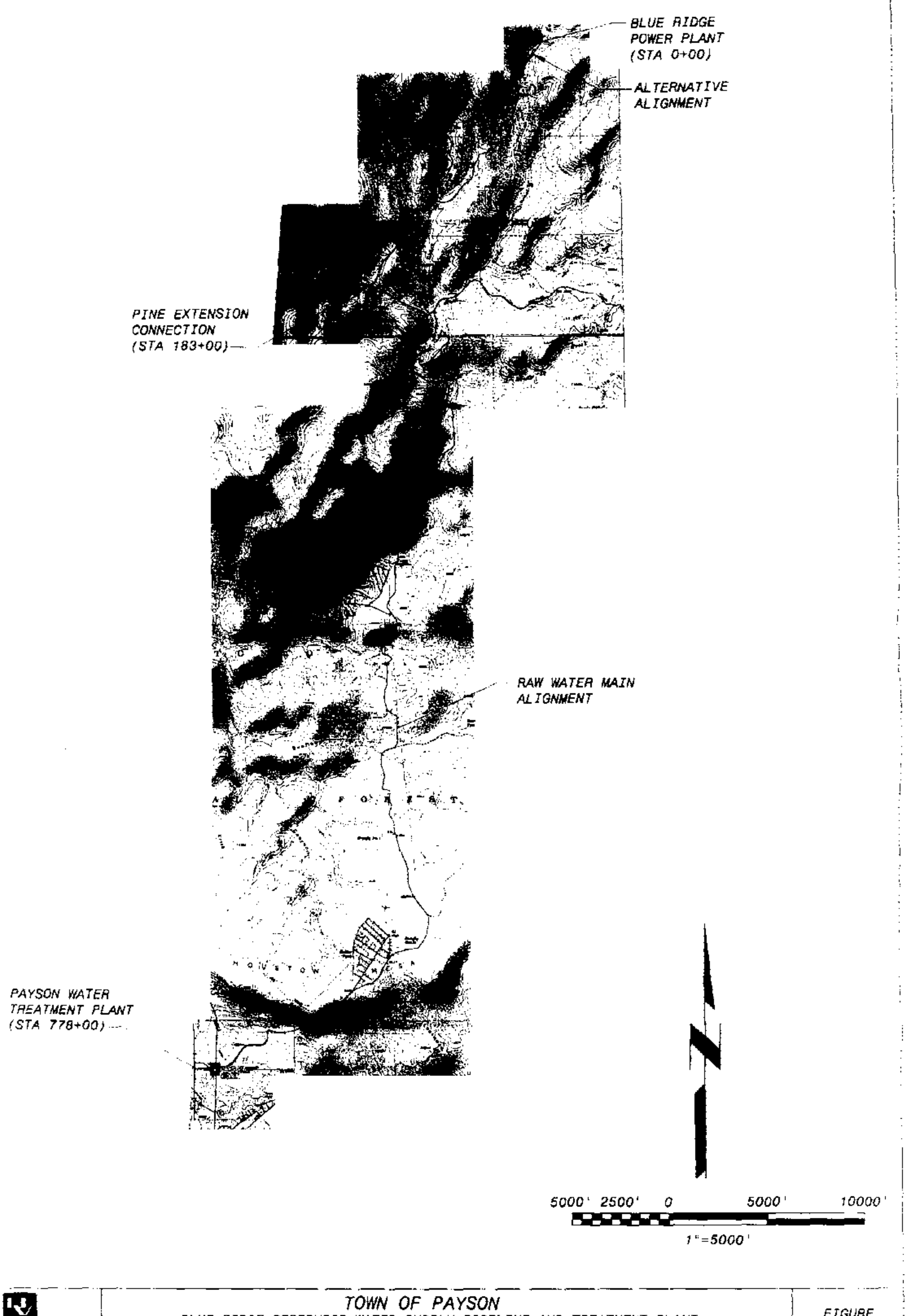

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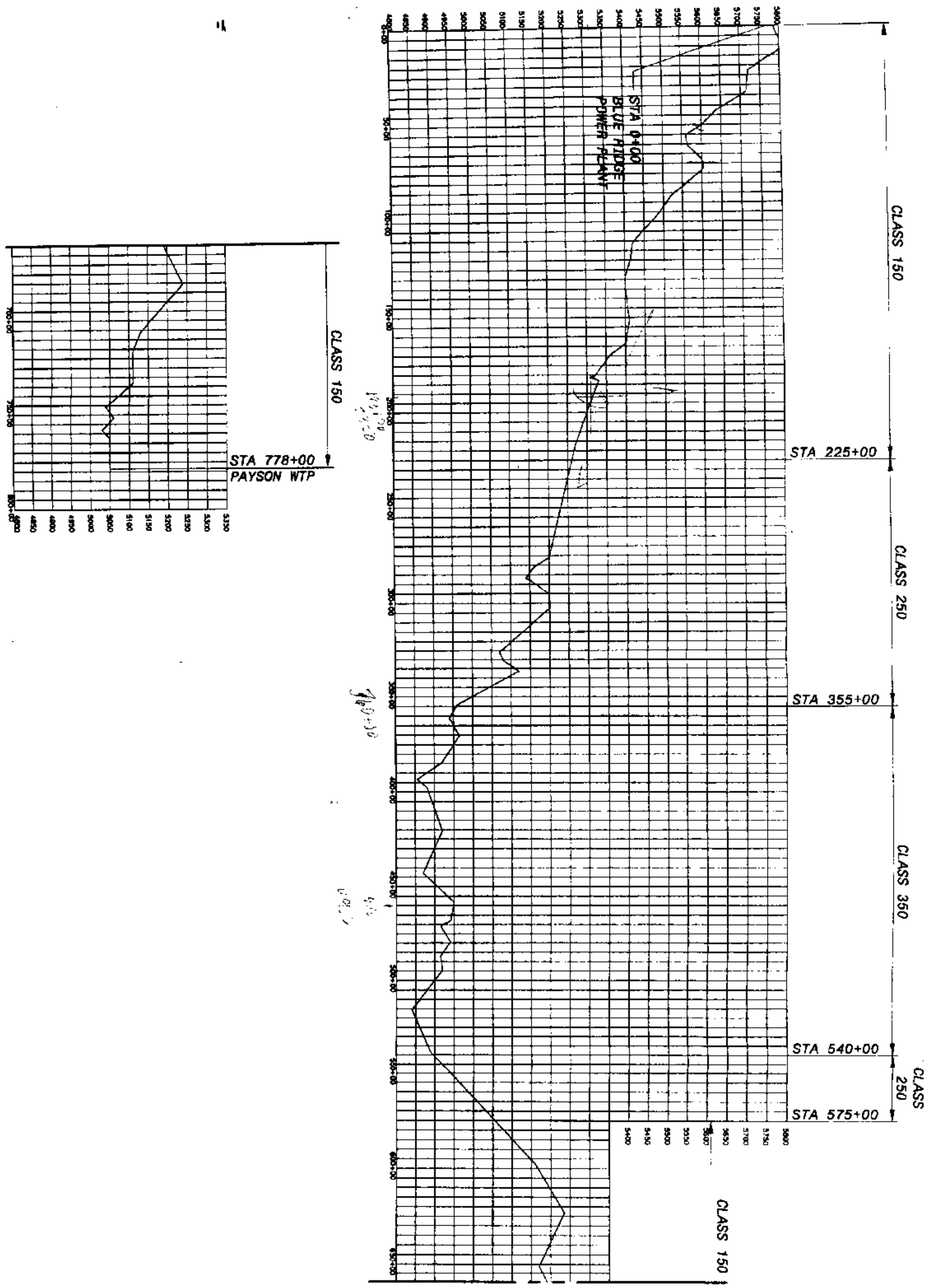
PROJECT NO. 141789

TOWN OF PAYSON

BLUE RIDGE RESERVOIR WATER SUPPLY PIPELINE AND TREATMENT PLANT

RAW WATER MAIN ALIGNMENT

FIGURE NO. 2-2



BLACK & VEATCH Corporation PROJECT NO. 141789	TOWN OF PAYSON BLUE RIDGE RESERVOIR WATER SUPPLY PIPELINE AND TREATMENT PLANT RAW WATER MAIN PIPE CLASS	FIGURE NO. 2-3

Table 2-1
Pipe Diameter versus Pressure

Station	Pipeline Pressure (psi)				
	14-inch	16-inch	18-inch	20-inch	24-inch
0+00	0	0	0	0	0
33+00	5	16	21	24	27
55+00	59	77	86	91	95
71+00	29	52	63	69	74
130+00	76	119	140	151	160
164+00	52	107	133	147	158
183+00	69	130	160	175	188
225+00	77	149	183	201	216
275+00	76	161	201	222	241
287+00	95	183	225	247	266
295+00	64	154	197	219	238
326+00	105	203	249	273	295
336+00	78	178	226	251	273
370+00	128	238	250	317	341
393+00	161	277	331	360	385
420+00	119	241	299	329	356
458+00	85	218	280	312	342
495+00	78	220	287	322	353
515+00	102	249	318	354	387
575+00	-24	139	215	255	292
623+00	-128	47	129	172	211
652+00	-115	68	153	198	239
680+00	-161	30	118	165	207
634+00	-79	99	182	226	265
758+00	-112	99	196	248	295
778+00	-131	84	184	238	286

The pressure within the pipeline along the alignment was calculated based on elevation head minus friction loss. In order to minimize the cost of the pipeline the smallest pipe diameter meeting the design criteria will be used. As shown in **Table 2-1**, a 14 inch diameter pipe would result in a negative pressure in the pipeline and would require an intermediate pump station. The smallest pipe diameter meeting the design criteria is a 16-inch pipe diameter. This will ensure gravity flow along the pipe alignment and provide a residual pressure of 84 psi at the WTP. A larger diameter pipe could be used, however this would increase the working pressure due to decreased friction loss and increase the cost.

2.3 Pipe Materials

Pipe materials were evaluated based on a 16-inch diameter pipe with a maximum working pressure of 277 psi. Investigation into the pipe materials resulted in two potential pipe materials, ductile iron pipe (DIP) and steel. Both pipe materials are suitable for the required working pressure and cost effective for a 16-inch diameter pipe. Other pipe material were evaluated including prestressed concrete cylinder pipe (PCCP) and PVC. However, PVC pipe is not suited for the high pressures that will occur in the pipeline and PCCP is cost prohibitive in pipe diameters below 30-inches.

Ductile iron pipe is available in three pressure classes, Class 150, 250 and 350. The pressure class is based on working pressure and has a test pressure of twice the working pressure plus 100 psi for surge, for example Class 350 DIP would have a test pressure of 800 psig. DIP has a benefit for installations in areas where a significant amount of rock is present because it requires a lower class of bedding material than for steel pipe, which reduces installation cost.

Steel pipe is designed based on working pressure by varying the pipe wall thickness to accommodate the design pressure. Steel pipe requires a full pipe embedment with a higher class bedding material required in installations with a significant amount of rock to decrease the point loads that occur from surrounding rock. Additionally, the standard coating system comprising of a tape wrap is delicate and not suited for rocky installations. A more durable coating system of either concrete mortar or fusion bonded epoxy would be required for this project.

It is recommended that DIP be used for this project. DIP provides a cost effective material that would be suitable for installation under the existing geotechnical conditions. **Figure 2-3** presents the required DIP pressure class along the length of the pipeline. Steel pipe can be bid against DIP to ensure a competitive environment to obtain the lowest price for the pipeline.

3.0 PINE EXTENSION

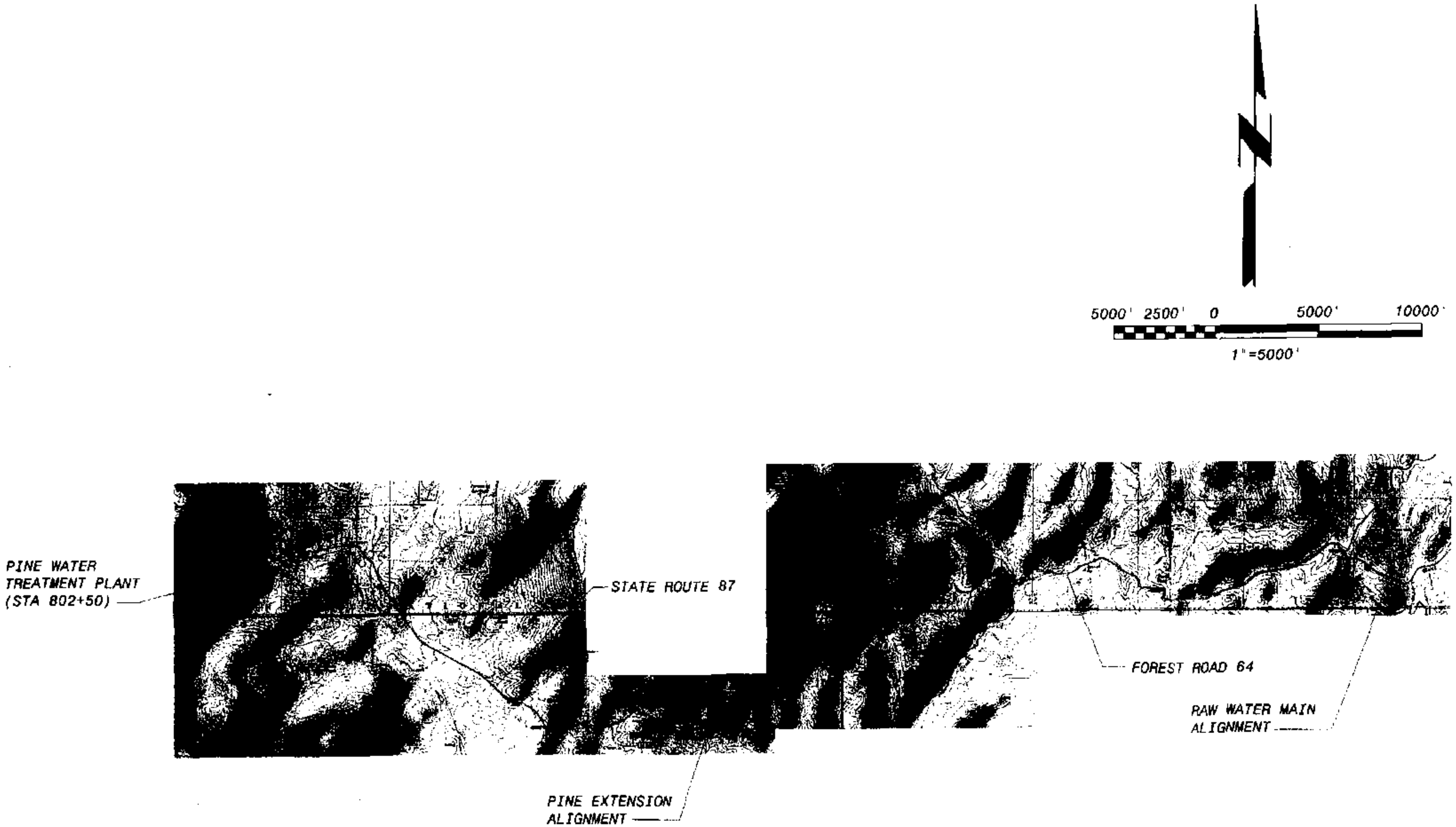
3.1 Location and Alignment

The Pine extension will begin at Station 183+00 of the raw water main alignment at the intersection of Houston Mesa Road and FR 64. **Figure 3-1** presents the proposed alignment of the Pine extension. The Pine extension will run east along FR 64 to the intersection of State Route 87 and then northwesterly along State Route 87 to the Pine WTP. A flowmeter and flow control valve will be installed at the beginning of the Pine extension to control and meter the flow in the pipeline.

The proposed alignment crosses several hills and climbs up to the community of Pine at the base of the Mogollon Rim. Therefore, intermediate pump stations will be required, which will be discussed further in the following section. The pipeline will be constructed within the roadway alignment along FR 64 and within the roadway easement along State Route 87. The alignment along FR 64 and State Route 87 was selected to minimize permitting issues, such as environmental impact statements and 404 permits, and facilitate ease of construction. One disadvantage of the State Route 87 alignment would be traffic control during construction. However, the pipeline can be constructed within the existing roadway easement along the edge of the road to minimize the impact.

3.2 Design Criteria

The Pine extension will consist of the pipeline and intermediate booster pump stations to convey the design flow to the Pine WTP. The system was designed to provide sufficient pressure at the end of the pipe to drive the membrane filtration process without the use of on-site booster pumps.



TOWN OF PAYSON
BLUE RIDGE RESERVOIR WATER SUPPLY PIPELINE AND TREATMENT PLANT

PINE EXTENSION
ALIGNMENT

FIGURE NO. 3-1

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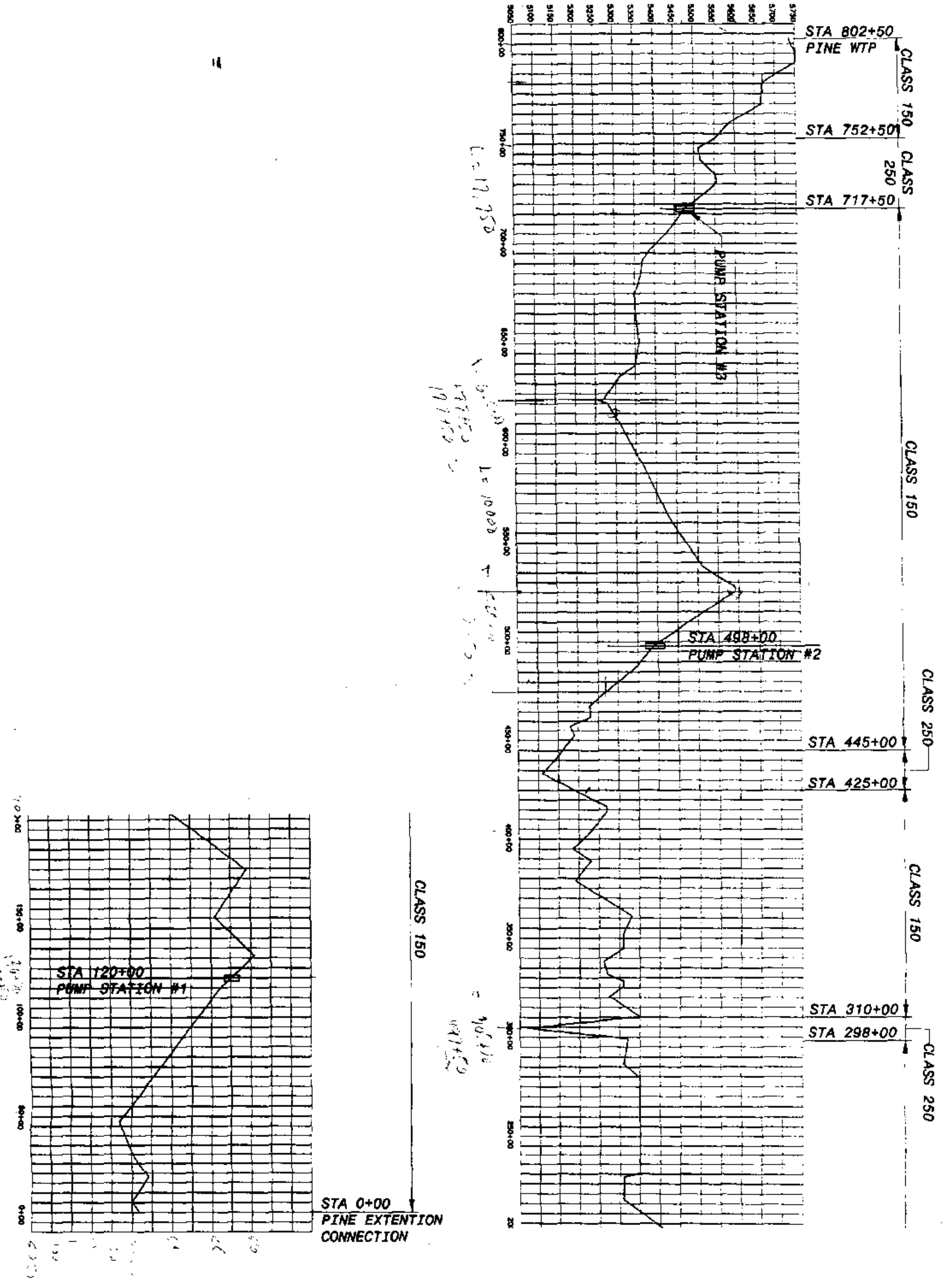
Corporation

PROJECT NO.



BLACK & VEATCH Corporation

PROJECT NO. 141789

TOWN OF PAYSON

BLUE RIDGE RESERVOIR WATER SUPPLY PIPELINE AND TREATMENT PLANT

PINE EXTENSION

PIPE CLASS AND PUMP STATION LOCATIONS

FIGURE NO. 3-2

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Several different pipe sizes were evaluated, including 6-inch, 8-inch and 10-inch diameter. A cost optimization was performed for each of the three pipe diameters based on pipeline and booster pump station cost. Based on pipeline cost and number of booster pump stations required, an 8-inch pipeline is the most cost-effective.

Table 3-1 presents the resulting pressure along the length of the alignment and proposed booster pump station locations for an 8-inch diameter pipeline. The resulting pressure along the length of the alignment was based on a design flow of 0.6 mgd.

Table 3-1
Pipe Pressure and Pump Station Locations

Station	Pipeline Pressure (psi)	Station	Pipeline Pressure (psi)
0+00	130.4	457+00	114.1
6+00	141.9	462+00	91.2
17+50	121.6	468+00	89.6
47+50	142.1	487+50	32.7
113+00	23.6	**498+00**	**105.0**
120+00	**40.0**	520+00	30.1
125+00	25.7	525+00	11.5
130+00	11.5	527+50	10.9
150+00	49.7	537+50	43.0
170+00	9.9	560+50	71.7
217+50	119.0	620+00	121.5
227+50	116.4	622+00	129.6
230+00	98.5	623+00	125.0
280+00	85.7	632+50	107.4
286+00	101.5	638+00	86.6
298+00	94.1	651+00	78.9
303+00	201.1	667+50	79.0
310+00	78.1	672+50	77.7
320+00	108.0	682+50	68.7
325+00	91.5	691+00	64.4
327+50	90.9	**717+50**	**175.0**
332+00	107.1	730+00	139.3
337+50	110.0	735+00	140.2
345+00	86.4	742+00	153.6
352+50	84.5	747+50	154.4
362+00	75.6	752+50	135.8
377+00	128.0	762+00	113.9
388+00	110.1	768+00	82.0
395+00	125.6	780+00	76.8
413+00	86.4	790+00	39.6
417+00	85.4	797+00	37.8
433+00	150.5	802+50	42.9
452+00	111.0		

Notes:
(1) Pump Station locations are shown in bold.

The pressure within the pipeline along the alignment was calculated based on elevation head minus friction loss. Booster pump stations were located along the alignment to boost the pressure within the pipeline to convey the raw water to the Pine WTP. Three booster pump stations are provided as follows:

Pump Station #1	
Location	Station 120+00
No. Pumps	1 (plus 1 standby)
Type	Centrifugal
Capacity, gpm	420
TDH, ft	92
Motor, hp	20

Pump Station #2	
Location	Station 498+00
No. Pumps	1 (plus 1 standby)
Type	Centrifugal
Capacity, gpm	420
TDH, ft	245
Motor, hp	50

Pump Station #3	
Location	717+50
No. Pumps	1 (plus 1 standby)
Type	Centrifugal
Capacity, gpm	420
TDH, ft	405
Motor, hp	75

3.3 Pipe Materials

Pipe materials were evaluated based on an 8-inch diameter pipe with a maximum working pressure of 201 psi. Investigation into the pipe materials resulted in two potential pipe materials, ductile iron pipe (DIP) and steel. Both pipe materials are suitable for the required working pressure and cost effective for a 8-inch diameter pipe. Other materials were evaluated including prestressed concrete cylinder pipe (PCCP) and PVC. However, PVC pipe is not suited for the high pressure that will occur in the pipeline and PCCP is cost prohibitive in pipe diameters below 30-inches.

Ductile iron pipe is available in three pressure classes, Class 150, 250 and 350. The pressure class is based on working pressure and has a test pressure of twice the working pressure plus 100 psi for surge, for example Class 350 DIP would have a test pressure of 800 psig. DIP has a benefit for installations in areas where a significant amount of rock is present because it requires a lower class of bedding material than for steel pipe, which reduces installation cost.

Steel pipe is designed based on working pressure by varying the pipe wall thickness to accommodate the design pressure. Steel pipe requires a full pipe embedment with a higher class bedding material required in installations with a significant amount of rock to decrease the point loads that occur from surrounding rock. Additionally, the standard coating system comprising of a tape wrap is delicate and not suited for rocky installations. A more durable coating system of either concrete mortar or fusion bonded epoxy would be required for this project.

It is recommended that DIP be used for this project. DIP provides a cost effective material that would be suitable for installation under the existing geotechnical conditions. **Figure 3-2** presents the required DIP pressure class along the length of the pipeline. Steel pipe can be bid against DIP to ensure a competitive environment to obtain the lowest price for the pipeline.

4.0 WATER TREATMENT PLANTS

The water treatment plants (WTP) for this project will be located within the limits of the Town of Payson and the community of Pine. The WTPs will consist of microfiltration treatment followed by disinfection. An on-site finished water reservoir and pump station will be constructed for storage and distribution of treated water. The following sections will present an overview of the microfiltration process, design criteria for the treatment processes and cost estimate. A preliminary site layout for the Payson WTP is presented in **Figure 4-1**. The Pine WTP site layout will be similar to that of the Payson WTP, only at a smaller scale.

4.1 The Microfiltration Process

Microfiltration (MF) membranes provide an effective barrier to particles, bacteria, cryptosporidium and giardia in the influent stream in a small footprint technology. In a cartridge configuration the membranes are housed in a pressure vessel and feed water is delivered to the membranes at approximately 35psi. Raw water is fed to the membranes in an outside-in mode. Permeate is withdrawn leaving solids to accumulate in the vessel. Solids are removed via periodic backwashing, air scrubbing and chemical cleaning.

4.2 Payson WTP

The following presents the design criteria for the WTP processes. Raw water will be delivered to the WTP on a continuous basis during a nine month period. Finished water will be delivered into the potable water distribution system or used to recharge the local aquifer during periods of low demand. The Town will use wells for peaking and for the drinking water supply in the remaining three months of the year.

It was assumed that the residual pressure in the raw water main will be sufficient to drive the MF process. Excess pressure can be relieved through pressure regulating valves (PRV) prior to the process. An alternative to PRVs would be an in-line power generation turbine. This option would alleviate some of the power cost of the WTP and further examination of this option is suggested during the design phase.

4.2.1 *MF Process*. Prefilter strainers will be provided as a barrier to larger particles to protect the membranes. Flow will then pass through the MF membranes and into the reservoir.

The design criteria for the MF process are as follows:

Prefilter Strainers	
Number of units	1 (plus 1 standby)
Mesh opening, micron	500
MF Membranes	
Manufacturer	Pall Corporation
Number at assembly trains	2
Type	Microza hollow fiber
Number of modules	130
Flux rate, gfd	55
Module area, m^2	50/27 (O.D/I.D.)
Membrane rating	0.1 micron

4.2.2 *Reservoir and Pump Station*. An at-grade steel reservoir will be constructed to provide on-site storage and system control flexibility. The reservoir will store finished water for delivery to the potable water distribution system and off-site storage tanks. During periods of low water demand the water level within the reservoir will rise and initiate recharge to the local aquifer. The pump station will be constructed adjacent to the reservoir to deliver finished water to the distribution system.

The design criteria for the reservoir and pump station are as follows:

Reservoir	
Type	At-grade, steel
Volume, MG	1.0
SWD, ft	24
Diameter, ft	85
Pump Station	
Number of units	2 (plus 1 standby)
Type	Vertical turbine, canned
Capacity, gpm	1,260

4.2.3 *Disinfection*. Disinfection will occur via on-site sodium hypochlorite generation. On-site generation passes a salt and water solution through an electrical field to produce sodium hypochlorite and hydrogen. The process is comprised of a water softener to prevent scaling in the process, a brine tank to generate a salt water solution, an electrolytic cell to generate sodium hypochlorite and stand pipe to vent hydrogen to atmosphere. Two storage tanks will be required to meet Arizona regulations pertaining to critical chemicals for potable water systems. A hydrogen dilution blower will be located at the storage tanks to prevent hydrogen buildup within the tanks and prevent explosions. Sodium hypochlorite will be fed to the permeate stream prior to the reservoir.

The design criteria for the disinfection system are as follows:

<u>Storage Tank</u>	
Number	2
Type	FRP
Volume, gal	2,500
Storage capacity, days	3

<u>Chemical Feed Pumps</u>	
Number of units	1 (plus 1 standby)
Type	Diaphragm

4.3 Pine WTP

The following presents the design criteria for the WTP processes. Raw water will be delivered to the WTP on a continuous basis during a nine month period. Finished water will be delivered into the potable water distribution system. It was assumed that the residual pressure in the raw water main will be sufficient to drive the MF process. Excess pressure can be relieved through pressure regulating valves (PRV) prior to the process.

4.3.1 *<u>MF Process</u>*. A skid mounted MF membrane will be provided to treat the raw water. The skid mounted unit will consist of the prefilter strainers, MF membranes, clean-in-place (CIP) system and required instrumentation and controls. Flow will pass through the prefilter strainers and MF membranes and into the Finished Water Reservoir.

The design criteria for the MF process are as follows:

<u>MF Membranes</u>	
Manufacturer	Pall Corporation
Model	Aria AP-6
Number of units	1
Type	Microza hollow fiber
Number of modules	30
Flux rate, gfd	55
Module area, m^2	50/27 (O.D/I.D.)
Membrane rating	0.1 micron

4.3.2 *<u>Reservoir and Pump Station</u>*. An at-grade steel reservoir will be constructed to provide on-site storage and system control flexibility. The pump station will be constructed adjacent to the reservoir to deliver finished water to the distribution system.

The design criteria for the reservoir and pump station are as follows:

<u>Finished Water Reservoir</u>	
Type	At-grade, steel
Volume, MG	0.2
SWD, ft	24
Diameter, ft	40

<u>Pump Station</u>	
Number of units	1 (plus 1 standby)
Type	Horizontal, split case
Capacity, gpm	420

4.3.3 <u>Disinfection</u>. A tablet chlorination system will be provided for disinfection. Tablet chlorination systems comprise of a package system that is easily delivered and installed and requires minimal operator attention and maintenance for proper operation. Solid chlorine tablets are dissolved into a chlorine solution that will be delivered to the storage tanks. Two storage tanks will be required to meet Arizona regulations pertaining to critical chemicals for potable water systems. From the storage tanks, the chlorine solution will be fed to the permeate from the MF membranes via chemical feed pumps prior to the Finished Water Reservoir.

The design criteria for the disinfection system are as follows:

<u>Storage Tank</u>	
Number	2
Type	FRP
Volume, gal	500
Storage capacity, days	3
<u>Chemical Feed Pumps</u>	
Number of units	1 (plus 1 standby)
Type	Diaphragm

5.0 COST

The following presents the cost for the pipelines and water treatment plants. All cost data is presented in 2006 dollars.

5.1 Raw Water Main

The estimated construction cost for the pipeline will include the modifications to the existing tailrace conduit and pipe installation. Several assumptions were made in order to establish a cost for the pipeline, including:

- Seventy-five percent of the pipeline alignment will be in the road and require pavement replacement. Pavement replacement will occur only within the limits of the pipe trench.
- Half of the pipe trench depth along seventy-five percent of the pipeline alignment will be through hard rock and require blasting.
- Traffic control will comprise of two flagmen during construction activities along with the required traffic control signage.
- Construction schedule of 10 months based on installation of 400 linear feet of pipe per day.
- Cost does not include land acquisition, surveying or engineering services.

Table 5-1 presents the estimated construction cost for the raw water main.

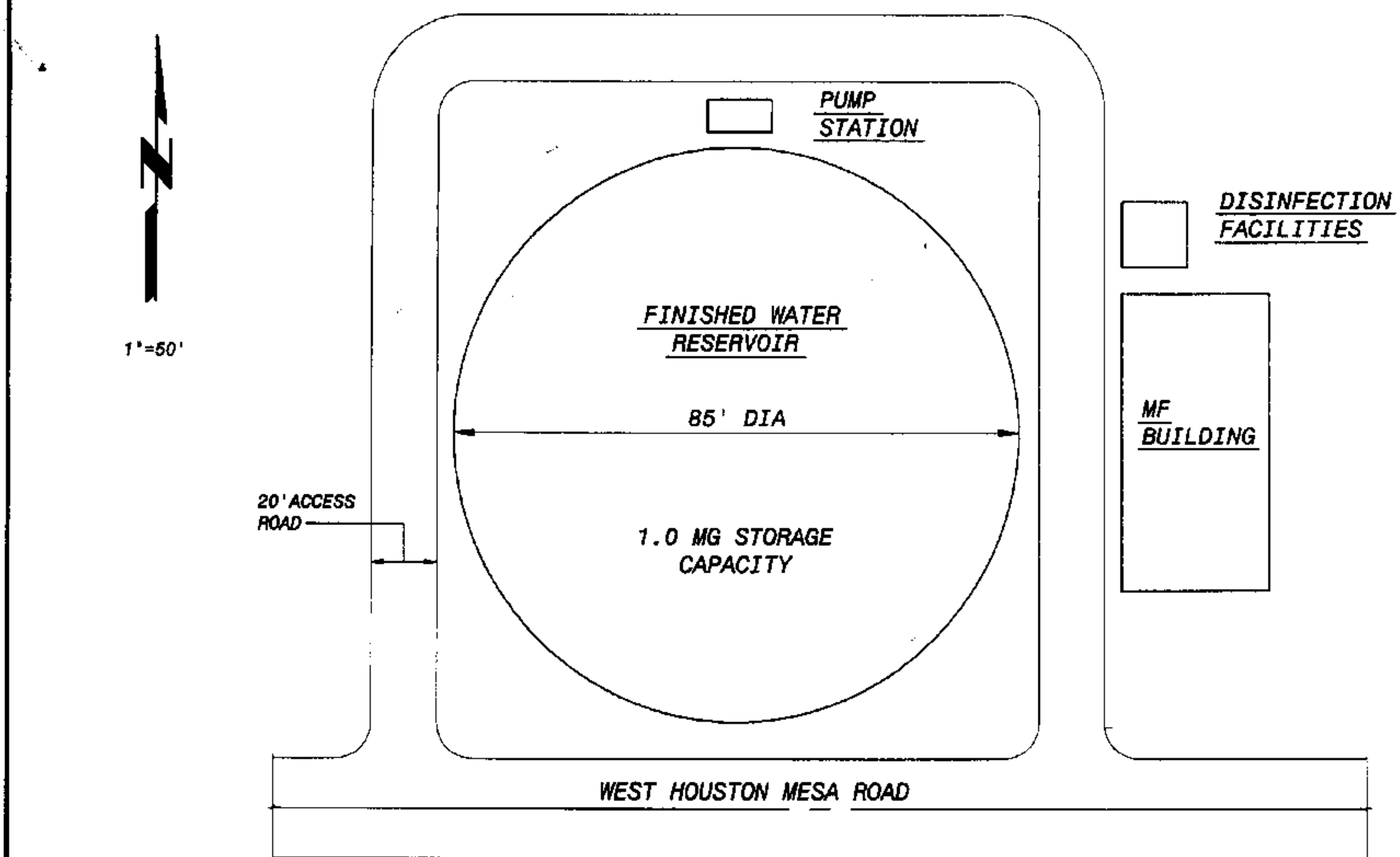
Table 5-1
Raw Water Main Construction Cost Estimate

Item	Units	Unit Cost	Subtotal
Tailrace Modifications	1	Lump Sum	$55,000
Raw Water Main			
Pipeline	14.5 miles	$7.50/in-dia/lf	$9,187,200
Pavement Replacement	57,420 lf	$40/lf	$2,296,800
Rock Excavation	29,774 cy	$45/cy	$1,339,830
Water/ Wash Crossings	16	$45,000	$720,000
Traffic Control		Lump Sum	$170,000
Subtotal			$13,768,830
Contingency (25%)			$3,442,207
Total			**$17,211,037**

5.2 Pine Extention

The estimated construction cost for the pipeline will include the three booster pump stations and pipe installation. Several assumptions were made in order to establish a cost for the project, including:

- Seventy-five percent of the pipeline alignment will be in the road and require pavement replacement. Pavement replacement will occur only within the limits of the pipe trench.
- Half of the trench depth along seventy-five percent of the pipeline alignment will be through hard rock and require blasting.
- Traffic control will comprise of two flagman during construction along with the required traffic control signage.
- Construction schedule of 10 months based on installation of 400 linear feet of pipe per day.
- Each pump station will consist of a building to house pumps and other equipment. Surge control will consist of an air chamber on the pumps discharge header and small reservoir on the pump suction.
- Cost does not include land acquisition, surveying or engineering services.



BLACK & VEATCH Corporation

PROJECT NO. 141789

TOWN OF PAYSON

BLUE RIDGE RESERVOIR WATER SUPPLY PIPELINE AND TREATMENT PLANT

WTP SITE PLAN

FIGURE NO. 4-1

141789/FIGURE 3-1 07/05/2005 14:02:32

Table 5-2 presents the estimated cost for the pipeline and booster pump stations.

Table 5-2
Pine Extension Construction Cost Estimate

Item	**Units**	**Unit Cost**	**Subtotal**
Pipeline	15.2 miles	$7.50/in-dia/lf	$4,815,000
Pavement Replacement	60,200 lf	$40/lf	$2,408,000
Rock Excavation	30,000 cy	$45/cy	$1,350,000
Water / Wash Crossings	20	$45,000	$900,000
Traffic Control		Lump Sum	$200,000
Booster Pump Stations	3	$825,000	$2,475,000
Subtotal			$12,148,000
Contingency (25%)			$3,037,000
Total			**$15,185,000**

5.3 Water Treatment Plants

The estimated cost for the WTP's is presented in **Table 5-3**.

Table 5-3
WTP Construction Cost Estimate

Item	**Payson WTP**	**Pine WTP**
General Requirements (9%)	$288,000	$72,000
Sitework (20%)	$640,000	$160,000
MF Building (1,600 sq ft)	$176,000	$88,000
MF Equipment	$1,780,000	$415,000
Disinfection	$275,000	$50,000
Finished Water Reservoir (@ $0.75/gal)	$750,000	$150,000
Pump Station	$215,000	$100,000
Electrical / I&C (20%)	$703,000	$177,000
HVAC / Plumbing (5%)	$176,000	$44,000
Subtotal	$5,003,000	$1,336,000
Contingency (25%)	$1,250,750	$334,000
Total Capital	**$6,253,750**	**$1,670,000**
Cost per 1,000 Gallons Treatment Capacity ($/kgal)	**$6.40**	**$10.25**

5.4 Payson Cost Summary

The following presents the total cost of the project, including both capital and operating expenses. The total capital cost of the project is $23,464,784. The annual cost of the project amortized over a period of 20 years at a 7% interest rate is $2,214,910. The estimated yearly operation and maintenance cost including power, chemicals, membrane replacement, waste disposal and full-time operator is $168,433. Therefore, the total annual cost of the project (annual capital plus yearly operation and maintenance) is $2,383,343, or $2.44 for every thousand gallons treated over a 20 year period. **Table 5-4** summarizes the cost information.

Table 5-4
Payson Cost Summary

Item	Cost
Raw Water Main	$17,211,037
Water Treatment Plant	$6,253,750
Total Capital Cost	$23,464,787
Amortized (20 years)	$2,214,910
Operation & Maintenance ($/year)	$168,433
Total Annual Cost	**$2,383,343**
Cost per 1,000 Gallons ($/kgal)	**$2.44**

5.5 Pine Cost Summary

The following presents the total cost of the project, including both capital and operating expenses. The total capital cost of the project is $16,855,000. The annual cost of the project amortized over a period of 20 years at a 7% interest rate is $1,590,993. The estimated yearly operation and maintenance cost including power, chemicals, membrane replacement, waste disposal and full-time operator is $162,262. Therefore, the total annual cost of the project (annual capital plus yearly operation and maintenance) is $1,753,255, or $10.76 for every thousand gallons treated over a 20 year period. **Table 5-5** summarizes the cost information.

Table 5-5
Pine Cost Summary

Item	Cost
Raw Water Main	$15,185,000
Water Treatment Plant	$1,670,000
Total Capital Cost	$16,855,000
Amortized (20 years)	$1,590,993
Operation & Maintenance ($/year)	$162,262
Total Annual Cost	**$1,753,255**
Cost per 1,000 Gallons ($/kgal)	**$10.76**

APPENDIX A

Pall Microfiltration System

Preliminary
Design Information

for

Payson Arizona

And

Black & Veatch

June 6, 2005

Submitted by:
Pall Corporation
2200 Northern Boulevard
East Hills, New York 11548

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Microfiltration System Equipment
Preliminary Design Information

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1.0 OVERVIEW OF PALL CORPORATION

1.1 Qualifications

Pall Corporation is the world's largest supplier of membrane filters, filter systems and fluid purification equipment. We focus our strengths on advancing the state-of-the-art in separation technology in thousands of diverse applications. We owe our success to developing products that offer our customers optimal value and economy of use.

Pall Corporation offers our Microza hollow fiber filters that are available in ultrafiltration and microfiltration ratings. The enclosed information is built upon our 0.1 micron PVDF hollow fiber filter.

The first membrane filtration plant was installed in Japan in April 1993. The first municipal water treatment plant using Pall's membrane was installed in Japan in October 1993. Since then, over a hundred membrane plants have been installed. All of these projects have shown excellent performance, reliability, and cost-effectiveness.

As shown in these tables, Pall microfilters have been successfully tested and installed in a wide range of applications, including:

- Surface waters (reservoirs, lakes, and rivers)
- Coagulated and clarified surface water
- Ground water with iron, manganese and arsenic
- Waste filter washwater from conventional granular filters
- Drinking water from an open, finished storage reservoir
- Secondary Wastewater Effluent (pretreatment to RO)

In addition to the over one hundred hollow fiber membrane systems, we also supplied a 44 MGD coarse membrane system to protect nanofilters for the City of Paris for drinking water, and over 1,600 specialty Reverse Osmosis membrane systems that produce drinking water from seawater for ships and resorts.

For the treatment of surface waters for potable use, Pall Corporation offers our Microza hollow fiber filters that are available in ultrafiltration and microfiltration ratings. Our proposal is built upon our 0.1 micron PVDF hollow fiber filter.

Microza filters are currently installed and operating at over one hundred drinking water sites around the world. See Section 6, for additional qualifications.

Membrane Filtration systems are operating or on order for the following microfiltration water applications:

- Pittsburgh, Pennsylvania
- Holladay, Utah
- Meeteetse, Wyoming
- Travis County WC&ID 17 & 18, TX
- Point Hope, Alaska
- Wainwright, Alaska
- Alamitos Barrier, California
- City of Chandler, Arizona
- San Patricio Municipal Water District, TX
- Beverly Beach, Oregon
- Bullard's Beach, Oregon
- Abilene, TX
- San Diego, California
- Atqasuk, Alaska
- Point Lay, Alaska
- Young's River, Oregon
- Solano Irrigation District, CA
- Fountain Hill Sanitation District, AZ
- Upper Eagle Regional Water Authority – Edwards, CO

And over 100 additional UF installations worldwide!

1.2 Corporate Philosophy

Pall is a billion-dollar corporation with manufacturing, sales, marketing, engineering and technical support throughout the world. We have over 50 years of experience in thousands of successful installations using state-of-the-art filters to remove contaminants from liquid and gas streams. The cornerstone of Pall's philosophy is service to customers. This extends beyond product quality and prompt delivery to problem solving, system recommendations and the sharing of scientific information.

Our charter is clearly stated in our latest Annual Report. "Pall Corporation is committed to being the preeminent supplier of filtration products within each geographic area and industry it serves. We enter only those markets where we can provide superior products that are recognized by our customers as delivering clear and compelling benefits. Pall products and support services provide users with the most economical and reliable solution to their filtration and separation requirements. We call this standard ***"Absolute Performance."***

We serve customers who must remove contaminants from gases and liquids used to produce their products. Across a wide array of industries we adopt a "systems" approach to filtration that takes into account ever tightening environmental regulations, with economy of use and the push for finer particle removal. By design, our filters minimize waste and reduce operator exposure to hazardous materials.

New orders in our fiscal year 1999 totaled over a billion dollars, which makes us the largest manufacturer of filters, on a global basis. Since filters and filter systems are our only business, we provide our customers with the highest value and economy of use.

We design and manufacture our own media, elements, vessels and fully integrated separation systems. We provide expert engineering, applications and system design assistance and technical support. Since we supply the broadest array of polymeric, glass, metallic and ceramic filters to industry, we select the optimum filter medium that meets specific customer requirements. Our internal research and development organizations are continually developing and testing advanced filtration membranes for new and challenging applications.

While our strategies for meeting customer requirements may vary in different parts of the world, our guiding philosophy is consistent. Our global network of employees, sales distributors and manufacturing facilities is made up of highly trained professionals with a focus on ***Absolute Performance.*** Each Pall manufacturing facility adheres to uniform manufacturing procedures. Our manufacturing facilities, research and development and scientific laboratories in

Europe and the USA have been granted International Standard Organization (ISO) certification to the ISO 9001 Quality Management System. No matter where in the world you order Pall filters, you can be assured they will perform exactly as specified.

Pall maintains a global network of support and service with top management headquarters in East Hills, New York; Portsmouth, England and Tokyo, Japan. In many different markets, Pall Corporation has formed alliances with leading companies to provide advanced solutions to customers' purification challenges. We design and build products that offer our customers superior performance and economical operation. Through strategic alliances, we can provide customers unique value that makes our alliance partners more competitive. For ultrafiltration and microfiltration hollow fiber systems, Pall has an alliance with Asahi Chemical to supply systems that are more economical than other available technology. The strengths of both companies ensure a successful system design with good operational performance.

Many alliance partners select Pall as an alliance partner because we are the leading filter manufacturer in the world. Not only are we the leading manufacturer of high technology filter products, but Pall also has the resources and the commitment to continually developing new leading edge products.

1.3 Pall Microfiltration Modules

Our Microza microfiltration modules employ homogeneous (polyvinylidenefluoride) PVDF hollow fiber membranes. Our PVDF product is unequaled in strength and chemical compatibility. The fiber porosity is double that of most competing membranes resulting in higher sustainable unit flow rates.

1.4 Pall Microfiltration System

All Pall filtration systems for water applications are manufactured in our factory in Cortland, New York. Cortland is located 30 miles South of Syracuse, New York. Our engineers have designed a wide range of membrane filtration systems for use in diverse water applications. Reference Section 2.0 for a description and the operation of the Pall microfiltration system.

2.0 PROCESS DESCRIPTION

2.1 Description of the Pall Filtration Systems

The Pall MF system will treat surface water, with an estimated recovery of 92-97%. The system is comprised of Pall Microza Microfiltration modules, along with all required pumps, tanks, piping, valves, instrumentation, and controls required for a complete and functional system. Installation of the system is usually by others with construction technical advice provided by Pall. The system includes the components as identified in our P&ID and Scope of Supply.

Pall Microza Microfiltration modules are specially designed for water processing applications. These modules use proprietary PVDF (Polyvinylidenefluoride) hollow fiber membrane technology with high and stable flux rates and advanced bonding techniques for an exceptionally strong module design.

The Microza Modules operate in an outside-in mode with a small amount of recirculation. In conventional or single pass filtration, the membrane filter is perpendicular to feed flow direction. Solids are dead end filtered by the media and are generally removed when the filters are backwashed. For Microza modules, the membranes are places parallel to the feed direction and only clean liquid passes through the membrane. Two exit streams are produced during filtration: filtrate or permeate and the recirculation. The filtrate is the processed water and the recirculation is a small portion of the flow that is returned to the feed stream. This flow stream is taken from the top of the module and ensures complete utilization of the available filter area by increasing the velocities in the upper end of the module. Solids retained on the filter are removed via periodic backwashing, air scrubbing and chemical cleaning.

Microza Hollow Fiber membrane provide:

- A very high filter area per module
- A small footprint,
- Low energy requirements,
- Low system hold-up and efficient regeneration.

2.2 Pall Microfiltration System Operation

Typical Operating Processes:

Water is pumped through backwashable strainers into the microfiltration system, then through the supply manifold to the module racks holding the Microza Modules. Each module is fed an equivalent flow rate.

- *Forward Flow –*

The pressure-reducing valve reduces the incoming feed to maintain a constant pressure. As water flows through each module, the module will gradually foul, and the valve will automatically adjust the feed pressure as required to maintain the set-point. A control valve on each control block will automatically adjust to maintain a constant level in the filtered water tank. A set of excess recirculation pumps, controlled by a VFD and flowmeter will maintain a constant recirculation percentage.

- *Reverse Filtration -*

Approximately every 30 - 60 minutes, the module racks will go through a reverse filtration (RF) cycle that cleans the modules. First isolation valves are closed. The RF backwash valves open. The RF control valve, which takes filtrate from between the module racks and the filtrate control valve, modulates to maintain the RF flow set-point, at which time about 150% the normal forward flow is forced through the module filaments in the reverse direction. This flow is maintained for about 15 -30 seconds and is diverted to the drain. At the end of this time period, the RF control valve closes and the other valves revert to their normal operating positions.

As required to prevent biological fouling, a chemical injection system pumps a small amount of chlorine into the reverse filtration water as it is being fed into the modules. The amount of chlorine required varies based on feed-water conditions.

- *Air Scrub -*

The reverse filtration cycle will restore the modules to near clean condition but once every thirty 40 - 120 minutes a second cleaning will be required. This cleaning cycle is called air scrubbing, and involves injecting instrument grade compressed air into the feed side of the module rack while maintaining feed water flow through the modules. The air scrub mode is maintained for one hundred and twenty (120) seconds, 30 seconds with air and 90 seconds with air and water.

- *Clean-In-Place -*

Periodically, the system will require a more thorough cleaning than RF or air scrubbing can provide. Cleaning chemicals will be added to the system and recirculated as required to regenerate the modules. The clean in place (CIP) operation happens infrequently, it is designed to be an automatic operation, which the operator manually initiates when indicated by the control system. Included in this section is a more detailed description of the cleaning procedure.

- *Integrity Test Method -*

Integrity testing of hollow fiber microfiltration modules specified in the proposed water filtration system is conducted in accordance with standardized procedures developed at Pall Corporation. These methods have been optimized for modular installations and have proven successful in detecting an integrity breach in system modules consisting of over a half of a million hollow fibers.

In operation, the filtrate quality is constantly monitored to immediately detect a performance change at the system level while an off line pressure hold test provides the ability to isolate and identify a questionable module. These easily implemented procedures ensure system reliability without adding an extensive cost (capital or operating) and maintenance burden on users.

2.3 Design Philosophy and Equipment Selection

Pall proposes to offer the following microfiltration systems with an average continuous treated water output of approximately **3.6 MGD.**

The equipment proposed is designed for simplicity of operation. All plant operations are automatically controlled via a PLC and a distributed control system. There are no routine operations that require manual operation of valves etc. The system design philosophy is to reduce as far as possible the potential for system problems caused by operator error.

Pall Microfiltration System Components

The following outlines the general scope of supply for the proposed microfiltration system: (See section 3 for detailed description)

- Microza Microfiltration Modules
- Module Rack System
- Valve Rack System
- Reverse Filtration System
- Clean-In-Place System
- Air Compressor System
- System Valves & Piping
- Instrumentation & Controls

The Membrane Filtration Equipment

Complete Membrane System.

The Microfiltration MF System includes Module Rack Assemblies consisting of Microza Microfiltration modules. The system also includes all tanks, piping, valvès, instrumentation, and controls required for a complete and functional microfiltration system.

Membrane Design

The design flux is based on previously pilot and plant experience.

Hollow-Fiber Membrane Design Flux & Hydraulic Capacity

Membrane Flux Rate	*55 gfd*
Membrane Module Area*	50 m^2 / 27 m^2 (O.D. / I.D)
Membrane Rating	0.1 micron

All aspects of performance and materials are identical to the piloted module and are operating in Pall's existing microfiltration plants.

Membrane Clean-In-Place Equipment

CIP System.

A Clean-In-Place (CIP) System is included with the proposal. The CIP system is designed to clean one module rack at a time. Therefore, the CIP system proposed for the demonstration unit will be incorporated into the full-scale system.

Reverse Filtration System

Reverse Filtration System.

The system periodically undergoes an automated procedure for cleaning the membranes. Filtrate is directed backward through the filtrate valve into the membranes in the reverse direction to dislodge any particles that may be fouling the membranes, and then to drain. The flow reversal is of short duration - usually about 15-30 seconds every 15 – 30 minutes. The fluid used for the Reverse Flow is treated filtrate diverted from the pressurized filtrate line. Chlorine is typically introduced to the reverse flow to assist the cleaning process.

Air Supply System

Air Compressor and Related Equipment.

The air supply system will have two air compressor units and will be supplied complete with an air receiver tank, air drier unit and discharge air pressure filter regulators and filters to ensure clean, oil-free process air.

Chemical Feed System

Chemical feed systems are included in the above systems and consist of small storage/mixing/feed tanks and metering pumps with appropriate redundancy.

Integrity Testing System

Integrity testing of hollow fiber microfiltration is conducted in accordance with standardized procedures developed at Pall Corporation. The Pressure Decay Test has been optimized for modular installations and has proven successful in detecting an integrity breach in system modules. An automatic procedure, programmed into the HMI, will be initiated automatically at a pre-set time or initiated by an operator at any time.

2.4 Features & Benefits of the Pall Microfiltration System

- ***High Quality Treated Water***

  Pall's Microfiltration System is a cost-effective method for the removal of micro-solids and is particularly recommended for a wide range of water filtration applications.

- ***Pall System Certification (DHS, NSF and TNRCC)***

  CA- Department of Health
  In January 1999, Pall completed the test program for certification by California Department of Health Services of its 0.1 micron microfiltration system. As of October 1999, the CA-DHS has accepted the Pall Microza Microfiltration System as an alternative SWTR filtration technology granting **4-log** removal for Giardia and Cryptosporidium.

  NSF-61 Certification
  The Pall family of microfilter assemblies for water treatment is certified to ANSI/NSF 61. National Sanitation Foundation International issued the NSF 61 certification to Pall on July 14, 1999. For more information please contact NSF or Pall Corporation.

  TNRCC
  Pall Corporation has furnished a 7.8 MGD Membrane Filtration System to San Patricio Municipal Water District in Ingelside, Texas. Performance data has been collected and submitted through Malcolm Pirnie, Inc. and SPMWD to the TNRCC for the operation in Texas.

- ***Advantages of Microza Hollow Fiber (MF) "Outside-In" Membrane***

1. The rating of the medium assures the finest protection for the downstream systems, reduced downtime and maintenance costs. The membrane provides narrow pore size distribution for excellent effluent quality.

2. The hollow fiber membranes have extremely high permeability which facilitates automated, clean-in-place regeneration via reverse flushing, and permits operation at high flux thereby reducing equipment cost.

3. The membranes permit operation at high chlorine residuals to minimize biofouling rates and extend process time between chemical cleanings.

4. The outside-in flow configuration tends to minimize any contamination to the filtrate water resulting from an integrity breach.

- ***Chemical Resistance – Oxidant Resistant (Chlorine Dioxide)***

  The MF membrane is resistant to chlorine in concentrations as high as 5000 mg/L during cleaning. Pre-chlorination of the raw water is acceptable. This precludes the need for adding chemical such as bisulfite in a subsequent de-chlorination step. Chlorine resistance also allows for easy disinfection of the membrane and the system should this be required.

  The 0.1 micron PVDF membrane has been tested and is compatible with the following, chemical additives:

- Ozone, ***Chlorine Dioxide***, Alum, Ferric Chloride, PACL, and PAC.

Pall Microfiltration / Membrane Compatibility

Chemical	Condition		Compatibility
	Concentration	Temperature	
Sodium hypochlorite	1 %	25	Excellent
Hydrogen peroxide	2 %	25	Excellent
Formaldehyde	3 %	25	Excellent
Ethanol	100 %	25	Good[1]
Caustic soda	1 N	25	Excellent[2]
Caustic soda and sodium hypochlorite	NaOH (1N) NaClO (0.5%)	25	Excellent
Nitric acid	1 N	25	Excellent
Hydrochloric acid	1 N	25	Excellent
Sulfuric acid	1 N	25	Excellent
Glycerin	100 %	25	Excellent
Chlorinated solvents		25	Not compatible
Aromatic base solvent		25	Not compatible
Ester base solvents		25	Not compatible
Ether base solvents		25	Not compatible
Ketone base solvents		25	Not compatible

NOTE: 1 Compatible up to 30 days exposure

2 Use of caustic soda alone will result in the slight discoloration of the membrane and extraction of F^- ion, however, there is no deterioration in the physical properties of membrane. Therefore, the cleaning of module by caustic soda alone should be limited and use of caustic soda with sodium hypochlorite is recommended.

- ***Robust Membrane: Sturdy Module***

The microfiltration modules use a proprietary PVDF hollow fiber membrane technology and advanced bonding techniques. This creates an exceptionally robust membrane and sturdy module.

- ***Operational Flexibility***

The Pall system is designed to produce a consistent quality of water irrespective of seasonal and weather related variations in the source raw water quality.

- ***Operational Simplicity***

The microfiltration process is an easy and inexpensive system to operate both in terms of maintenance costs and manpower requirement. The operators are required to ensure they maintain proper membrane permeating conditions.

- ***Flexible Modular Design***

The Pall Microfiltration System is modular in design. Plant expansion, if required, can be done by progressively adding Module Racks and control blocks with treated water pumping capacity. As demand incrementally increases, the plant is incrementally expanded.

- ***Compact System Footprint***

The Pall Microfiltration System is physically compact. This allows the purchaser to realize savings in physical plant size and hence construction costs.

3.0 TECHNICAL SPECIFICATIONS

3.1 Process Design

The equipment proposed is designed for simplicity of operation. All plant operations are automatically controlled via networked PLC's and a PC-based Human Machine Interface software system. There are no routine operations that require manual operation of valves, etc. The system design philosophy is to reduce as far as possible the potential for system problems caused by operator error.

The filtration system is designed with several skid mounted packaged units to minimize field assembly. The valve rack is completely assembled and the module rack is easily field assembled. The system PLC control panel will mounted adjacent to the plant and the operator control station will be located in a separate control room.

Pall Microfiltration System Components

The following outlines the general scope of supply for the proposed microfiltration system:

- Microza Hollow Fiber Membrane Modules
- Module and Valve Rack Assemblies
- Prefilter Strainer
- Clean-In-Place (CIP) System
- Reverse Filtration System
- Compressed Air System
- System Valve and Piping
- Process Instruments & Controls

Pumping Equipment

The Excess Feed recirculation pumps are ANSI centrifugal type with variable frequency drives. The chemical injection pumps are electric diaphragm pumps with adjustable output. The CIP circulation pumps are horizontal end suction ANSI pumps. The CIP drainage pump and chemical transfer pumps air operated diaphragm type.

Piping and Valves

Process valves equal to or less than 1" are ball valves and greater than 1" are butterfly valves.

Instrumentation and Control Processes

Instrumentation can include:

- Level Transmitters and Switch
- Pressure Transmitters and Switch
- Temperature Transmitters
- Flow Sensor and meters
- Conductivity Analyzer and Transmitter
- pH Analyzer and Transmitter

Remote Monitoring

The Pall Microfiltration System is outfitted with our remote monitoring equipment. This equipment monitors critical process variables 24 hours a day and tabulates this data over time to allow for trending of variables that are critical to the performance of the filter system. The performance data are available via advanced communication technology to the client or Pall personnel who are assigned to monitor the Pall filter system. Using this system, Pall personnel have the ability to view the data real-time, or to view the data as recorded over time. The same data is also available to process operators at the site.

Membrane Integrity

Integrity testing of hollow fiber microfiltration is conducted in accordance with standardized procedures developed at Pall Corporation. The Pressure Decay Test has been optimized for modular installations and has proven successful in detecting an integrity breach in system modules. If a broken fiber, or fibers, is present, the row of modules will be isolated for a brief period of time while an air leak test is performed on the modules. For the air leak test, air is introduced into the feed side while a test is conducted visually. When air on the filtrate side is detected in a module, the identified module is further tested with air to identify the individual broken fibers. The broken fibers are repaired by inserting a straight stainless steel pin or approved epoxy into the upstream end of the fiber to plug off filtrate flow. Once repairs are completed the row of modules is put back into service.

The Pressure Decay Test offers the advantage of high sensitivity, not being affected by changes in feed water quality.

3.2 Technical Specifications

3.2.1 Scope of Supply of MF System

The main equipment included with the Microfiltration System is listed briefly as follows. Detailed equipment specifications are included within this section.

- One Pall Microfiltration System with a continuous design treated water capacity output per below. All MF Systems include one train of redundancy:

System Design (MGD)	**3.6**
Total Number of Modules	130
Number of Assembly Trains / Racks	2

Scope of Supply by Pall:

- Microza Membrane Hollow Fiber Modules
- Module Rack Systems (per above)
- Assembly Block Systems
- Prefilter Strainer
- Integral Clean-In-Place (CIP) System
- Reverse Filtration System
- Compressor Air System
- System Valves
- Instrumentation & Controls
- Process Instrumentation
- Valve Rack Control Panel
- Anchor bolts, adhesive anchors, and expansion anchors materials for supporting the MF system equipment, piping, tanks, electrical.
- Equipment General Arrangement and Layout Drawings
- Operating & Maintenance Manuals
- Site visits and personnel training as required (TBD)
- Spare Parts List
- Start-Up Assistance

3.2.2 Scope of Supply - OTHERS

The following items are for supply by Others and includes but is not limited to:

- Final Plant Design
- Review of equipment drawings and specifications. (Pall & Client)
- Equipment foundations, civil work, equipment mounting pads, buildings etc.
- Unloading of delivered equipment at plant site (or other mutually agreed FOB point).
- Receiving and safe storage of equipment until ready for installation.
- Treated water discharge piping from MF system to the treated water storage.
- Backwash / drain water piping from the MF system to the disposal or storage point.
- Electrical wiring, conduit and other appurtenances required to provide power connections as needed from the electrical power source to the PALL control panels, VFDs and other equipment and from the terminal boxes on the skids to the main plant panels.
- Instrumentation wiring, conduit and other appurtenances required to provide connections as needed between the terminal boxes on the skids, and to other equipment the PALL control panel.
- Air piping, supports etc. from the air compressor systems to the main instrument air supply header located on the skids.
- Bulk chemical storage facilities
- Laboratory Services, Operating and Maintenance Personnel during equipment Checkout, Start-Up and Operation.
- Any on-site painting or touch-up painting of equipment supplied.
- Approval Permits
- Interconnecting piping between Pall supplied equipment

3.3 Equipment Selection

The following sections provide a description and specifications of major components incorporated into the Pall Microfiltration Systems.

3.3.1 Membrane Modules and Module Rack Assembly

The microfiltration includes Microza Hollow Fiber Modules.

Microfiltration Module:

Module	Microza Hollow Fiber Modules
Dimensions:	6" diameter x 80" long
Removal Rating:	0.1 μm
Membrane Material:	PVDF

Microfiltration Module and Valve Rack:

Model Number:	PMDM Series
Operation:	Single Block Operation
Dimensions:	Reference Layout Drawing
Material:	HDPE

3.3.2 Prefilter – Bachwashable Strainers

Automatic backwashable strainer rated at 400 micron.

3.3.3 Clean-In-Place (CIP) System

CIP System.
System includes a CIP tanks and accessories, CIP pumps, CIP tank heater control panel, heater and controls, citric acid dose system, sodium hypochlorite dose system, sodium hydroxide dose system, cleaning solution dose pumps, instrumentation, interconnecting piping and valves. Below briefly describes some of the system components.

- Acid Feed System
- Caustic Feed System
- CIP Circulating Pump

3.3.4 Reverse Filtration System

Reverse Filtration System.
The membrane periodically undergoes an automated procedure for cleaning the membranes. Flow is directed through the Reverse Filtration

control valve to the membranes in the reverse direction to dislodge any particles that may be fouling the membranes.

3.3.5 Compressed Air System

Compressed Air System
The Compressed Air System will supply air to the various pneumatically actuated valves included with the Microfiltration System, and supply Air Scrub air.

The compressed air system will consist of compressors with integral dryers and outlet filters; supply air filter assemblies; one air receiver with accessories; process air regulator assembly; control air regulator assembly; pneumatic control panel; instrumentation and controls.

3.3.6 Excess Feed Recirculation System

Excess Feed Recirculation System
The EF pumping system includes pumps supplied with suction and discharge piping manifolds, valves, pressure gauges and other associated ancillary equipment.

3.3.7 System Valves and Piping Specifications

Process Valves
The following is a general list of main valves used on Microfiltration system. The following specifications do not include miscellaneous small bore valves for isolating instruments, seal water line isolation etc. (Automatic butterfly, non-cyclic butterfly, check-valves, and ball valves)

3.3.8 Process Instruments and Controls

The following process instruments and controls are included with the MF systems.

- Electromagnetic Flowmeters
- Level Transmitters
- Pressure Transmitters
- Temperature Transmitters
- Turbidity meters

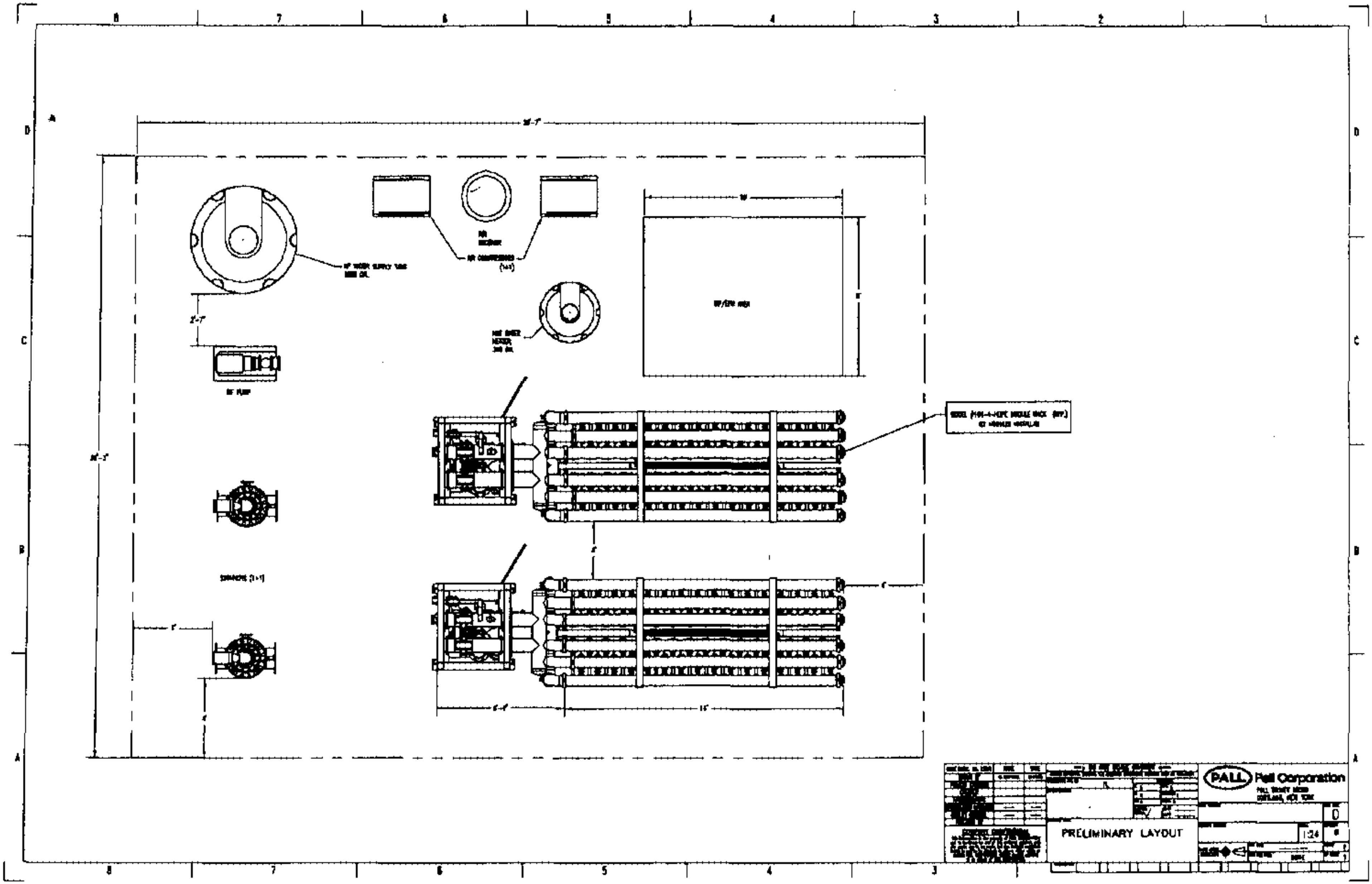
Control Panel

The microfiltration system is controlled by a PLC based control system, which monitors process variables and provide the control functionality.

The microfiltration system is supplied with an Allen Bradley SLC –5/04 PLC based distributed Field I/O control system. The control enclosures have terminal block connections for all PALL supplied instrumentation (flow, level and turbidity etc.) and outputs for control of the pumps, control valves etc.

All valves and control devices are interlocked through the PLC to allow smooth and continuous automatic operation. Valves will open/close and or modulate depending on signals from the PLC. These signals are predetermined through the PLC programming and allow the system to operate at optimal conditions.

All operating parameters are continuously monitored by the PLC and if an alarm or emergency condition occurs the PLC program will instruct the various components to change operation conditions and/or shut down the system and alert the operator. The system control logic will be designed with the ability to shut down the system in the event of an alarm condition that could be detrimental to the equipment.



Pall Corporation
PRELIMINARY LAYOUT
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ATTACHMENT 6

(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Blue Ridge (C.C. Cragin) Reservoir Drinking Water Source Financial Feasibility Study, Tetra Tech Inc.

Blue Ridge (C.C. Cragin) Reservoir Drinking Water Source Financial Feasibility Study

Prepared for

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ABBREVIATIONS & ACRONYMS

AAC	Arizona Administrative Code
ACC	Arizona Corporation Commission
AC-FT	Acre-feet
ADC	Arizona Department of Commerce
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ARS	Arizona Revised Statutes
ASCE	American Society of Civil Engineers
AWS	Assured Water Supply
AWWA	American Water Works Association
BGS	Below Ground Surface
CC&N	Certificate of Convenience and Necessity
CFS	Cubic feet per second
CWA	Clean Water Act
DIP	Ductile Iron Pipe
DU	Dwelling Unit
DWID	Domestic Water Improvement District
DWRF	Drinking Water Revolving Fund
FPS	Feet per second
FR	Forest Road
GADA	Greater Arizona Development Authority
GPD	Gallons per day
GPM	Gallons per minute
HOA	Home Owners Association
HP	Horsepower
Kgal	One thousand gallons
MAG	Maricopa Association of Governments
MRWRMS	Mogollon Rim Water Resources Management Study
PWS	Public Water Supply
PVC	Polyvinyl Chloride
RPM	Revolutions per minute
SDWA	Safe Drinking Water Act
SRP	Salt River Project
TDH	Total Dynamic Head
WIFA	Water Infrastructure Finance Authority
WTP	Water Treatment Plant

EXECUTIVE SUMMARY

This Financial Feasibility Study of the Blue Ridge (C.C. Cragin) Reservoir Drinking Water Source (Study) has been developed for Gila County, Arizona, under the Water Infrastructure and Finance Authority (WIFA) of Arizona Technical Assistance (TA) program, Grant Number TA-DW001-2007. The Study identifies the need for, and quantifies the associated financial conditions associated with the use of the C. C. Cragin Reservoir ("Reservoir") to augment local water supply in an area of Northern Gila County, below the Mogollon Rim.

The C.C. Cragin Reservoir (formerly known as the Blue Ridge Reservoir) is located near Clint's Well, on the Mogollon Rim in Coconino County, about 25 miles north of Payson, Arizona. The reservoir has a storage capacity of 15,000 acre-feet, and is physically located within the Coconino National Forest. As a part of the Arizona Water Settlement Act, the Salt River Project (SRP) acquired the C.C. Cragin Reservoir and water transfer system from Phelps Dodge Corporation in February of 2005. Ownership of the reservoir has been transferred as of 2007 to the Bureau of Reclamation, with the SRP operating the reservoir under the provisions of the Salt River Federal Project. As a part of the acquisition agreement, a portion of the water is to be delivered to the Gila River Indian Community in accordance with the Comprehensive Gila River Settlement (Tetra Tech, 2007).

In addition, the agreement also set aside 3,500 acre-feet of water per year to be used to improve water supply in northern Gila County. Of this amount, 3,000 acre-feet has been designated for use by for the Town of Payson; the remaining 500 acre-feet are planned to serve other communities in northern Gila County. Surface water from the reservoir is currently conveyed from the pump station located near the reservoir through an existing pipeline to the headwaters of the East Verde River near Washington Park where the existing electrical generator is located. A new 16-inch diameter pipeline is proposed to transfer water from Washington Park to the Payson area.

The Town of Payson will construct, own, and operate the pipeline extension and will, in its sole and absolute discretion, make all decisions related to use of the pipeline extension to deliver any Gila County allocated water to rural communities adjacent to the pipeline, or near the Town of Payson. This Study does not consider any delivery fee or connection fee that may be charged by the Town of Payson to Gila County or to other Town approved users of the pipeline extension. These Town of Payson related charges will be an additional cost to the non-Payson users of the C.C. Cragin water. This Study does not include any Salt River Project costs of allocated water that will be charged to the Gila County C.C. Cragin water users that are located in the rural areas outside the Town of Payson.

There are over 15 identified rural communities that are located near the proposed pipeline, or near the Town of Payson that may be able to use the 500 acre-feet non-Payson reservoir allotment (Tetra Tech, 2007). Gila County, under an envisioned Northern Gila County Water Authority entity, has proposed a joint use agreement with the Town of Payson to transport ("wheel") the County's allocation of water to the various rural communities that commit to purchase water needed to serve their private lands. Therefore, if any rural communities commit to access the C.C. Cragin water via the Payson pipeline, the Town will need to engineer infrastructure capacity and ultimately approve any agreements for the joint use of the pipeline by any rural communities, water improvement districts, homeowner associations, regulated water utilities, etc.

This Study is focused on assessing the financial viability of possible pipeline water use by the affected rural communities in Northern Gila County. The report is intended to be a decision-making tool for Gila County, the Town of Payson, and the affected communities to assist with establishing water supply priorities relative to the C.C. Cragin (Blue Ridge) Pipeline Project. The Study identifies which of the rural communities can readily demonstrate a need for additional water supply from the pipeline, whether water service from the pipeline is appropriate for these communities, and if the communities can reasonably assume the capital and annual operations and maintenance (O&M) costs associated with this water supply. The study is based upon population projections, and other capacity data from the Mogollon Rim Water Resources Management Study (MRWRMS), and capital and O&M costs from the recent Blue Ridge Reservoir Water Supply Pipeline and Treatment Plant study commissioned by the Town of Payson and completed by Black & Veatch (Black & Veatch, 2006).

The financial evaluation of water supply alternatives are summarized herein, including the construction cost analyses for pipeline connections and water treatment facilities, relative water treatment O&M evaluation, and identified debt repayment scenarios. The Summary of Findings (Table A on the following page) indicates that, with very few exceptions, most of the communities studied herein could benefit from additional water supply from the pipeline, and again, with few exceptions, most of the projects appear to be financially viable.

Blue Ridge (C.C. Cragin) Reservoir Drinking Water Source Financial Feasibility Study
December 21, 2007

Table A. Summary of Financial Feasibility Study Results

Community	Existing Capacity (Ac-ft)	2002 Demand (Ac-Ft)	2040 Average Demand[4] (Ac-Ft)	Average Additional Demand[5] (Ac-Ft)	Existing Capacity/ 2040 Avg Demand Ratio	Connection Cost	WTP Cost	Total Capital Cost	Construction Cost/ 2002 Connections	Annual O&M	Annual Capital Payment[6]	Total Annual Payment	Cost $/1000 gallons
Washington Park	3.2	0.2	4.5	1.3	0.7	$305,300	$4,300	$309,600	$25,800	$410	$29,200	$29,600	$70.5
Rim Trail DWID	14.5	10.7	66.0	51	0.2	$96,700	$172,000	$268,700	$2,889	$16,700	$25,400	$42,100	$2.5
Verde Glen	11.6	2.8	32.5	22	0.4	$638,100	$73,700	$711,800	$14,829	$7,160	$67,200	$74,400	$10.3
Cowan Ranch[7]	12.1	0.9	8.0	0.0	1.5	$102,800	$0	$102,800	$5,411	$0	$9,700	$9,700	$0.0
Shadow Rim Ranch GS Camp[7]	8.1	1.2	2.0	0.0	4.0	$295,600	$0	$295,600	$36,950	$0	$27,900	$27,900	$0.0
Whispering Pines[1]	32.3	17.5	98.5	66	0.3	$209,500	$221,200	$430,700	$2,519	$21,500	$40,700	$62,200	$2.9
Beaver Valley	22.6	22.0	74.5	52	0.3	$185,000	$173,400	$358,400	$2,172	$16,800	$33,800	$50,600	$3.0
Freedom Acres[3]	9.2	9.2	11.5	3.4	0.8	$176,365	$11,400	$187,700	$14,438	$1,100	$17,700	$18,800	$17.1
Wonder Valley[7]	16.9	3.0	9.5	0.0	1.8	$81,050	$0	$81,050	$6,235	$0	$7,700	$7,700	$0.0
Sunflower Mesa[3]	2.0	2.0	5.0	3.0	0.4	$75,900	$9,983	$85,900	$10,738	$970	$8,100	$9,100	$9.1
Mesa del Caballo[1]	28.2	66.0	153.0	125	0.2	$56,900	$416,700	$473,600	$1,158	$40,500	$44,700	$85,200	$2.1
East Verde Estates[1,2]	16.1	15.9	82.5	66	0.2	$1,680,300	$138,400	$1,818,700	$11,090	$3,440	$171,700	$175,100	$8.1
Flowing Springs[2]	7.3	6.1	29.0	22	0.3	$972,600	$45,300	$1,017,900	$24,236	$1,130	$96,100	$97,200	$13.7
Star Valley[2]	153.8	153.8	490.9	337	0.3	$0	$621,550	$621,600	$1,348	$15,450	$58,700	$74,200	$0.8
Round Valley[1,2,3]	77.3	77.3	113.5	36	0.7	$1,761,200	$75,500	$1,836,700	$10,319	$1,880	$173,400	$175,300	$14.9
Oxbow Estates[1,2,3]	32.2	32.2	38.0	6	0.8	$877,550	$12,100	$889,700	$12,710	$300	$84,000	$84,300	$44.4
TOTALS:	**447.4**	**420.9**	**1,218.9**	**791.2**		**$7,514,900**	**$1,975,500**	**$9,490,500**			**$896,000**	**$1,023,400**	**$199**

Table Notes:

[1] *Community with undependable or drought-sensitive aquifer per ADEQ/MRWRMS*

[2] *Could be served by the Town of Payson Water Treatment Plant*

[3] *Existing Capacity derived from privately owned wells; combined capacity unknown; Current Water Demand shown as capacity*

[4] *2040 Average Demand = Average of future estimates of low and high water consumption in gpcd as presented in the MRWRMS*

[5] *Average Additional Demand (Design Value) = Difference between actual 2002 capacity and future average demand (averaged between "low" and "high" gpcd).*

[6] *Annual Capital Payment is the annual capital recovery cost of connection and treatment amortized over a 20 year period at an interest rate of 7%. The capital recovery equation was used, where:*

A = P[i(1+i)n/(1+i)n-1], where

A = annual capital payment

P = present value of water treatment and connection costs

i = is the inflation rate in %/100% (in this case, 7%)

n = lifetime of payment schedule (in this case, 20 years)

Cost per 1,000 gal = (Annual O&M + Annual Capital Payment)/1,000 gallons treated per year

[7] *Existing capacity meets/exceeds future demand; additional water from pipeline extension may not be warranted, connection and capital costs shown for information only.*

Denotes Community with capacity/demand ratio less than 1 - this community can demonstrate a need for additional water supply

Denotes Construction Cost/Connection less than $5000; and thus "scorable" with respect to WIFA Cost-effectiveness criteria

See Footnote #7

1.0 INTRODUCTION

This Financial Feasibility Study of the Blue Ridge (C.C. Cragin) Reservoir Drinking Water Source (Study) has been developed for Gila County, Arizona, under the Water Infrastructure and Finance Authority (WIFA) of Arizona Technical Assistance (TA) program, Grant Number TA-DW001-2007. The Study identifies the need for, and quantifies the associated financial conditions associated with the County's use of the C. C. Cragin Reservoir (the "reservoir") to augment local water supply in an area of Northern Gila County, below the Mogollon Rim in conjunction with the Town of Payson.

The C.C. Cragin Reservoir (formerly known as the Blue Ridge Reservoir) is located near Clint's Well, on the Mogollon Rim in Coconino County, about 25 miles north of Payson, Arizona. **Figure 1**, the Project Location Map, shows Payson, about 80 miles north of Phoenix. The Reservoir has a storage capacity of 15,000 acre-feet, and is physically located within the Coconino National Forest. As a part of the Arizona Water Settlement Act, the Salt River Project (SRP) acquired the C.C. Cragin Reservoir and water transfer system from Phelps Dodge Corporation in February of 2005. Ownership of the reservoir has been transferred to the Bureau of Reclamation, with the SRP operating the reservoir under the provisions of the Salt River Federal Project. As a part of the acquisition agreement, a portion of the water is to be delivered to the Gila River Indian Community in accordance with the Comprehensive Gila River Settlement (MRWMRS, 2007).

In addition, the agreement also set aside 3,500 acre-feet of water to be used to improve water supply in northern Gila County. Of this amount, 3,000 acre-feet has been designated for use by for the Town of Payson; the remaining 500 acre-feet are planned to serve other communities in northern Gila County. Surface water from the reservoir is currently conveyed from the pump station located near the reservoir through an existing pipeline to the headwaters of the East Verde River near Washington Park, a small private community surrounded by the Tonto National Forest. As shown in **Figure 2**, a new 16-inch diameter pipeline is proposed to be constructed, owned and operated by the Town of Payson to transfer about one-third of the annual water supply of C. C. Cragin Reservoir from the Washington Park generator to the Town of Payson. The other two-thirds of the water will flow down the East Verde River to its confluence with the Verde River.

It is important to note that the Town of Payson will construct, own, and operate the pipeline extension and will, in its sole and absolute discretion, make all decisions related to use of the pipeline extension to deliver any Gila County allocated water to rural communities adjacent to the pipeline, or near the Town of Payson. This Study does not consider any delivery fee or connection fee that may be charged by the Town of Payson to Gila County or to other Town approved users of the pipeline extension. These Town of Payson related charges will be an additional cost to the non-Payson users of the C.C. Cragin water. This Study does not include any Salt River Project costs of allocated water that will be charged to the C.C. Cragin water users that are located in the rural areas of Gila County that are outside of the Town of Payson.

There are over 15 identified rural communities that are located near the proposed pipeline, or near the Town of Payson that may be able to use the 500 acre-feet non-Payson reservoir allotment (Tetra Tech, 2007). Gila County, under an envisioned Northern Gila County Water Authority entity, has proposed a joint use agreement with the Town of Payson to transport ("wheel") the County's allocation of water to the various rural communities that commit to purchase water needed to serve their private lands. Therefore, if any rural communities commit to access the C.C. Cragin water via the Payson pipeline, the Town will need to engineer infrastructure capacity and ultimately approve any agreements for the joint use of the pipeline by any rural communities, water improvement districts, homeowner associations, regulated water utilities, etc. Several of these communities have experienced chronic water supply shortages related to drought, and other issues. Table 1 includes a summary of the affected communities and their water suppliers included in this study as identified by County personnel.

Table 1 - Community Water Systems along/near Pipeline

Community	Water Supplier	Community	Water Supplier
• Washington Park -	Home Owners Association	• Wonder Valley -	Home Owners Association
• Rim Trail -	Rim Trail DWID	• Mesa Del Caballo -	Brooke-Payson Water Co.
• Verde Glen -	Home Owners Association	• Flowing Springs -	Brooke-Payson Water Co.
• Cowan Ranch -	Home Owners Association	• East Verde Estates -	Brooke-Payson Water Co.
• Shadow Rim Ranch – Girl Scout Camp-	Cactus Pine Council of GSA (Private wells)	• Oxbow Estates -	Private wells
• Whispering Pines -	Brooke Utilities/Payson Water Co. Div.	• Round Valley -	Private wells
• Beaver Valley -	Beaver Valley Water Company	• Star Valley -	Private Wells & Brook-Payson Water Co.
• Freedom Acres -	Private wells		

This report is intended to be a decision-making tool to Gila County in establishing water supply priorities relative to the C.C. Cragin/Blue Ridge Pipeline Project. Therefore, the purposes of this Study are to determine:

- If the above identified rural communities adjacent to or near the proposed Town of Payson/ C.C. Cragin Reservoir pipeline need, and can effectively utilize a potential new source of water from the existing C.C. Cragin Reservoir;
- The costs of constructing the pipelines, possible pumping stations, and treatment plants necessary to provide water to these communities from this potential water source; and
- If the communities can reasonably assume the capital costs and annual operations and maintenance (O&M) costs associated with the use of this water supply.

This report summarizes the findings of the financial feasibility study, includes a discussion of the potential growth in the Mogollon Rim Water Resources Management Study (MRWRMS) area, and a summary of the rural community-specific needs for water supply from the proposed pipeline. The MRWRMS regional water supply study is conducted by the United States Bureau of Reclamation, the Town of Payson and Gila County. An infrastructure needs assessment for northern Gila County is discussed and specific water supply alternatives for rural communities are identified in the MRWRMS study. The financial evaluation of water supply alternatives for the 15 rural communities are summarized herein, including the construction cost analyses for pipeline connections and water treatment facilities, relative water treatment O&M evaluation, and identified debt repayment scenarios. Lastly, this report provides an assessment of whether the identified rural communities along the pipeline alignment can demonstrate a need for additional water supply from the pipeline, whether water service from the pipeline is appropriate for those communities with demonstrated need, and if these communities can reasonably assume the capital costs and annual O&M maintenance costs associated with the use of this water supply.

1.1 Previous Work by Others

This study makes use of, and augments other ongoing planning efforts by Town of Payson, the Bureau of Reclamation, the SRP, the Coconino and Tonto National Forests, Gila County, and other stakeholders, related to the C.C. Cragin (Blue Ridge) Pipeline Project.

1.1.1 Mogollon Rim Water Resources Management Study (MRWRMS)

As a part of the ongoing Mogollon Rim Water Resources Management Study (MRWRMS), a 2006 draft section entitled, "Mogollon Rim Water Supply Study: Future "Without' Available Alternatives", was provided as background data to support this Study (Murray and Jones, 2006). The MRWRMS provides data on existing and future populations, existing system water capacity, alternative water supplies and water service demand. The MRWRMS also describes the Mogollon Rim study area's potential future water supply situation, particularly if no alternative solutions are pursued and if no federal action is taken to address the area's water shortage issues (Murray and Jones 2006). The study area includes 48 communities, many of which have already experienced water supply shortages. Drought conditions have existed in the study area since the early 1990s. Only 3 to 4 of these communities have a right to use surface water as a primary water source. The other communities, including the Town of Payson, rely solely on groundwater for water supplies. This study proposes surface water delivery from the Blue Ridge Reservoir (now called C.C. Cragin Reservoir) or development of local groundwater supplies as the best options to meet future water supply needs, with surface water delivery from the Blue Ridge Reservoir as the primary option (Murray and Jones, 2006).

If no new water resources are identified for the Town of Payson and the surrounding communities, then in the future, severe growth and conservation limitations will be necessary. The MRWRMS recommends the construction of a pipeline extension from the existing Blue Ridge Reservoir Pipeline as the best option for Payson. Tapping into this pipeline extension, with the approval of the Town of Payson is a viable approach for additional supply for the other affected area communities (Murray and Jones, 2006).

1.1.2 Blue Ridge Reservoir Water Supply Pipeline and Treatment Plant (Pipeline Study)

Most of the cost-estimating methodology, and unit costs used for the financial analyses within this Study were obtained from the "*Town of Payson, Blue Ridge Reservoir Water Supply Pipeline and Treatment Plant*", (Pipeline Study) (Black & Veatch, 2006). The Pipeline Study report discusses proposed pipelines from the Blue Ridge Reservoir (now called C.C. Cragin Reservoir) to the Town of Payson and the community of Pine, as well as proposed treatment to address requirements for surface water treatment for both areas (Black & Veatch, 2006).

The Pipeline Study includes a discussion of a proposed 14.7-mile raw water pipeline extension from the Washington Park generator to Payson, as well as a micro-filtration-type treatment plant for this water source. A second proposed pipeline trunk off the main Payson line to serve the community of Pine, Arizona, is evaluated in the report, along with plans for a corresponding micro-filtration (membrane) type water treatment plant. The initial length of the raw water main will be sized to deliver a combined design flow of 4.5 million gallons per day (mgd) (considering 0.6 mgd for the Pine Extension and 3.9 mgd for the remaining length for Payson). The optimum pipe diameter for the Payson raw water main was determined to be 16-inches; ductile iron pipe (DIP) was determined to be the best choice for pipe material. However, if more than Payson's 3,000 acre feet per year are to be transported in the Payson pipeline to communities in or near Payson, then the pipeline size may be increased to eighteen inches in diameter. The proposed Pine Extension consists of an 8-inch DIP pipeline that is 15.2 miles long, with three intermediate booster pump stations (Black & Veatch, 2006).

The proposed Payson raw water pipeline runs in a south-southwesterly direction, beginning at the Washington Park generator and mainly following the Houston Mesa Road to the proposed water treatment plant within or near the Town of Payson. The Pipeline Study introduces two possible alignments for a portion of the pipeline: one follows an existing powerline easement; the other follows the FR 199 (Houston Mesa Road) alignment. Both alignments are currently being evaluated by the Town of

Payson, as part of the Environmental Assessment process under the National Environmental Protection Act (NEPA) (Walker, 2007). Both alignments are shown on the attached Plate 1.

The proposed Pine extension (previously determined to not be feasible due to excesive cost) begins at Station 183+00 of the Payson raw water pipeline alignment at the intersection of Forest Road (FR) 32 and FR 64 (Control Road). The proposed pipeline runs west along Forest Route (FR) 64 to the intersection of State Route 87, then northwesterly along State Route 87 to the proposed Pine treatment plant (Black & Veatch, 2006).

The proposed water treatment plants for the Town of Payson and community of Pine involve microfiltration treatment followed by disinfection. At both areas, an on-site finished water reservoir and pump station are proposed to be constructed for treated water storage and distribution (Black & Veatch, 2006). Using Year 2006 unit costs, the Pipeline Study includes estimates of probable capital and O&M costs for both the Pine and Payson pipeline and water treatment plants. Table 2 provides a summary of the total costs for the proposed Payson raw water pipeline and treatment plant.

Table 2 - Cost Summary
Proposed Payson Raw Water Main and Treatment Plant

Item	Cost
16-inch raw water main	$17,211,037
Water treatment plant	$6,253,750
Total capital cost	$23,464,787
Amortized Cost per Year (20 year period)	$2,214,910
Operation & maintenance ($/year)	$168,433
Total annual cost	**$2,383,343**
Cost per 1,000 gallons ($/kgal)	**$2.44**
Table Source: Black & Veatch, 2006	

Table 3 provides a summary of the total costs for the proposed Pine raw water pipeline and treatment plant.

Table 3 - Cost Summary
Proposed Pine Raw Water Main and Treatment Plant

Item	Cost
Raw water main	$15,185,000
Water treatment plant	$1,670,000
Total capital cost	**$16,855,000**
Amortized Cost per Year (20 year period)	$1,590,993
Operation & maintenance ($/year)	$162,262
Total annual cost	**$1,753,255**
Cost per 1,000 gallons ($/kgal)	**$10.76**
Table Source: Black & Veatch, 2006	

1.2 Design Criteria

All work has been developed to be consistent with the requirements for surface water sources as set forth in Arizona Administrative Code (AAC) Title 18, Chapter 4, Article 3 (R18-4-301), and design guidance for drinking water systems as outlined in ADEQ Bulletin 10. In addition, debt repayment scenarios are evaluated using methods that are consistent with the WIFA loan evaluation guidelines as set forth in AAC Title 18, Chapter 15, Article 3. Other applicable design criteria are listed in Appendix A.

2.0 BACKGROUND AND GENERAL SITE CONDITIONS

The Study Area including the Town of Payson is located in northern Gila County, approximately 25 miles south of the C.C. Cragin Reservoir, 93 miles northeast of Phoenix and 183 miles north of Tucson. Figure 2 provides a general project vicinity map. This area is described as having a high quality of life and has retirement, construction, and tourism as its main economic focus, as well as growth in service firms and manufacturing.

2.1 Topography

The area encompassed by the Salt and Verde River Basins (which includes Gila County) contains mid-elevation mountain ranges, valleys, and areas of higher elevation along the north-central boundary. Vegetation includes semi-desert grasslands, Sonoran desert scrub, chapparal, montane and woodland conifer forests (ADWR, 2007). Most of the study area is comprised of scrub-shrub juniper and conifer forest-type cover.

The most prominent topographic feature in the study area is the Mogollon Rim, a rock escarpment which is 200 miles long and 7,000 feet high (Arizona Department of Commerce, 2007). The Mogollon Rim escarpment, which is the boundary between the Plateau uplands province and the Central highlands province, is a steeply sloping cliff that rises 1,000 to 2,000 feet above Payson to altitudes of 5,500 to 7,500 feet (National Geodetic Vertical Datum of 1929) at the upper edge of the escarpment. The rim is cut by steepened canyons, and south of the rim is a landscape of buttes and mesas. Elevations in the study area range from about 4,500 feet in and near Payson, up to over 7,000 feet at the Mogollon Rim. Slopes are generally north-to-south from the Rim, and range from flat in valley sections to over 20 percent nearer the Rim (Owen-Joyce, 2000).

2.2 Climate

The Mogollon Rim influences the climate of the area. Moisture-laden airmasses, upon encountering these topographic features, rise, cool, and precipitate moisture. Annual precipitation ranges from 18 to 26 inches near the rim and in the Plateau uplands with the highest values occur along the rim. Annual snowfall is about 40 to 85 in along the edge and top of the Mogollon Rim, and 24.1 inches in Payson (WRCC, 2007 and Owen-Joyce, 2000). Precipitation is seasonal; during the winter, storms associated with frontal systems bringing moisture from the Pacific Ocean traverse the area from west to east. These storms spread rainfall of light to moderate intensity across large parts of the southwestern United States from late October through April. Precipitation often occurs as rain at the lower elevations near Payson and as snow at higher elevations along the Mogollon Rim, and on the plateau. Winter storms have been the cause of many of the major floods in this area, particularly when warm rain falls on snow. The highest runoff during a year commonly occurs in March and April as a result of snowmelt. High flows are less common in May and early June between the winter and summer storm seasons than during any other part of the year. The second precipitation season is during the summer when moist tropical air sweeps in from the south. Precipitation at this time of year often occurs as short-duration, locally intense thunderstorms that are common from late June through early October and often cause local flash flooding.

2.3 Geology and Soils

The Mogollon Rim presents the primary geologic feature of the area. A 3,000- to 4,000-foot sequence of early to late Paleozoic sedimentary rocks forms the generally south-facing scarp of the Mogollon Rim. The area adjacent to the edge of the Mogollon Rim is an "erosional landscape of rolling, step-like terrain exposing Proterozoic metamorphic and granitic rocks. Farther south, the Sierra Ancha and Mazatzal Mountain ranges, which are composed of various Proterozoic rocks, flank an alluvial basin filled with late Cenozoic sediments and volcanic flows" (Parker, et al, 2004).

Most of the soils found at higher elevations are derived from weathered granite and basaltic rocks. Granitic soils have sandy textures surface horizons with weak soil structure and loose consistency, making them susceptible to wind, and water erosion. Soils derived from basalt have a medium to fine-textured surface horizon, and clayey-subsoils. Soils on the hills and mountains of the Verde watershed can be generally classified as having a high runoff potential, with very low infiltration rates (Woodhouse et al, 2002 and Blasch, et al, 2005).

2.4 Surface Water Hydrology and Hydraulics

For water planning purposes, the Arizona Department of Water Resources (ADWR) has grouped this portion of Gila County into the Verde River Basin (**Figure 3**). Within the Verde River basin, there are 7 large reservoirs (500 acre-feet and greater) and 6 other reservoirs (50 acre-feet and greater) (**Figure 4**) (ADWR 2007). Eight streams with perennial to intermittent to ephemeral flow drain upland regions of the Mogollon Rim and flow into the Salt River on the southern boundary or the Verde River on the western boundary. These tributaries drain the region north and east of the Verde River and flow in a southwesterly direction toward the Verde River. Perennial flow in the Verde River and its major tributaries is maintained by ground-water discharge. Stream channels are largely controlled by geologic features, such as regional joint or fault systems. Flashy runoff in the mainly bedrock stream channels is typical (Parker, 2004). There are numerous streams and washes throughout the pipeline corridor. In the upper portions of the watershed, above an elevation of 5,000 feet, most of the streams are perennial; nearer to the Town of Payson, the streams reflect intermittent flow conditions.

Springs are distributed throughout the region, typically discharging at or above the contact of variably permeable formations along the face of the Mogollon Rim with a scattering of low-discharge springs (Parker, et al, 2004 and ADWR, 2007).

2.5 Hydrogeology

The project area is located within the Mogollon Highlands, an area of 4,855 square miles of rugged, mountainous terrain at the southern edge of the Colorado Plateau. This area is characterized by a "bedrock-dominated hydrologic system that results in an incompletely integrated regional ground-water system, flashy stream flow, and various local water-bearing zones that are sensitive to drought" (Parker et al, 2004). Ground-water flow is generally controlled by large-scale fracture systems or by karst features in carbonate rocks. Precipitation, which shows considerable variability in amount and intensity, recharges the ground-water system along the crest of the Mogollon Rim and to a lesser extent along the crests and flanks of the rim and the Mazatzal Mountains and Sierra Ancha (Parker et al, 2004). Local, generally shallow aquifers of variable productivity occur in plateau and mesa-capping basalts in the sedimentary rocks of the Schnebly Hill and Supai Formations, in fractured zones of the Proterozoic Payson granite, and in the alluvium of the lower Tonto Creek Basin. These water-bearing zones are sensitive to short-term climatic fluctuations, such as the current drought (Parker, et al, 2004).

Well yields near the Payson pipeline route and the Town of Payson range from less than 1-2 gpm to over 500 gpm, with most wells yielding less than 35 gpm (ADWR, 2007). **Figure 5** depicts groundwater resources in the Verde River Basin, and areas where there has been a recent reduction in well capacity. The ADWR 55 Well Inventory was used to obtain general information on area wells, including depths, static water levels, and pumping capacity (ADWR, 2007a). This information indicates several hundred groundwater wells throughout the basin, and that many of the homes and businesses within the study area rely on individual private wells for their water supply (ADWR, 2007). Water quality is generally high; however, in Payson, several wells exceed standards for arsenic, beryllium, cadmium, lead, selenium, and volatile organic compounds (ADWR, 2007).

2.6 Land Use and Population Estimate

Throughout the MRWRMS study area, about 97% of the land is federally managed National Forest and Wilderness areas or Tribal lands; only about 3% of the land is privately owned (MRWRMS, 2007). Land uses include limited commercial and industrial properties, generally in- or near the Town of Payson, along with minimal agricultural property, limited mining property, and significant recreational land (mainly weekend cabin property that is steadily transforming to full time homes). With the proximity to Phoenix, there has been increasing pressure for growth – primarily residential growth; however, property use and growth has been significantly limited because of major concerns with water availability, with local controls on land use and growth in the form of water staging use-restrictions and moratoriums on new meters and main extensions. In 2000, Gila County reported a population of 51,335. By 2006, the population had grown to over 56,800, a growth rate of only 10 per cent over a six year period. As a part of the MRWRMS, population and associated water demands were projected from 2002 through 2040, by water service provider groups. By 2040, all developed and developable land within the study area are expected to have been built-out and occupied by full-time residents (Murray and Jones 2006). Current (2002) and projected populations for the study area are provided in **Table 4.**

Table 4 - Present and Projected Population Summaries

Water Service Provider Groups	Present Population (2002)	Projected Future Build-Out Population (2040)	Incremental Increase in Population
Town of Payson*	14,500	44,637	30,137
Private regulated water utilities**	5,650	20,550	14,900
Domestic water improvement districts	192	1,253	1,061
Cooperatives/home owner associations/non-profits***	1,986	6,696	4,710
Total All Groups	**22,328**	**73,136**	**50,808**

Data Source: Murray and Jones, 2006

* Includes Tonto Apache Tribe.

** Includes the Brooke Utilities, Inc. Star Valley A&B portions of the Town of Star Valley.

*** Includes the Diamond Point Shadows portion and the non-Brooke Utilities portion of the new Town of Star Valley.

As shown in **Table 4**, the current (2002) population of the study area is approximately 22,000. By 2040, the study area population is expected to increase to approximately 73,000. About 61 percent of this population is within Payson. The major growth outside of Payson is anticipated to occur in areas served by regulated water utilities. To date, growth has been limited by strict water conservation restrictions, including a basic lack of potable water in many areas (Murray and Jones, 2006).

3.0 INFRASTRUCTURE NEEDS ASSESSMENT

An infrastructure needs assessment has been performed to evaluate the existing and future water demands with respect to the capacity and reliability of the existing water infrastructure to meet these demands. This assessment was based upon the population planning estimates from the MRWRMS, with average per capita water use rates from communities with known water use.

The infrastructure needs assessment included a review of known and projected annual demand, (converted to acre-feet), for the affected communities located adjacent to or near the proposed Town of Payson pipeline. The needs determination has been developed using a spreadsheet that can be used to compare the demand to the capacity of the existing supply, as a way of assessing the ability of the current water sources to meet the short- and long-term water needs for the area. Communities with existing or anticipated future water supply issues are identified, along with the additional water supply requirements.

3.1 Estimates of Water Demand

Estimates of existing and future water demand were obtained from the MRWRMS, as provided for use in this Study (Murray and Jones, 2006). These estimates are based upon current water use in gallons per capita, per day (gpcd), and projected future use under two different water scenarios. The MRWRMS includes an estimate of future water use under a "low" water use rate that reflects implementation of various water conservation practices, and a "high" rate that reflects a "worse case scenario".

In order to streamline the evaluation of infrastructure needs for this Study, the "high" and "low" future demands, as calculated in the MRWRMS, were averaged to reflect an average future water use rate within this range. These water demand values reflect the Average Daily Demand, as is typical for water supply planning. However, as ADEQ Bulletin 10 recommends using the Peak Daily Demand for the design of wells, pumps, and pipelines, a peaking factor of two was used to develop an estimate for the existing and future Peak Day Demand (ADEQ, 1978).

These calculations are provided in **Appendix B**. A summary of existing and future water demands for each community is provided in **Table 5**, on the following page.

Table 5 - Table of Existing and Future Water Demand

Community	Demand				Average Additional Demand (Design Value) (ac-ft)*
	2002		2040		
	No. of connections	2002 (ac-ft)	No. of connections	2040 Avg of High & Low Estimate (ac-ft)	
Washington Park	12	0.2	12	5	1.3
Rim Trail DWID	93	10.7	137	66	51
Verde Glen	48	2.8	89	33	22
Cowan Ranch	19	0.9	21	8	0
Shadow Rim Ranch GS Camp	8	1.2	8	2	0
Whispering Pines	171	17.5	228	99	66
Beaver Valley	165	22.0	205	75	52
Freedom Acres	13	9.2	21	12	3
Wonder Valley	13	3.0	15	10	0
Sunflower Mesa	8	2	10	5	3
Mesa del Caballo	409	66.0	455	153	125
East Verde Estates	164	15.9	246	83	66
Flowing Springs	42	6.1	80	29	22
Star Valley	461	153.8	1101	491	337
Round Valley	178	77.3	242	114	36
Oxbow Estates	70	32.2	75	38	6
TOTALS:	**1,874**	**420.9**	**2,945**	**1,219**	**791**

Data Source: MRWRMS, 2007; * Reflects difference between existing capacity and average future demand

3.2 Current Water Capacity

The current capacity of the public water systems that serve the communities identified in this Study was obtained through a review of the information provide in the MRWRMS (Murray and Jones 2006), and from well information included in the ADWR 55 Wells database (ADWR, 2007) It should be noted that the data concerning well capacities within the ADWR well database are obtained from the original well driller's reports. While these data generally reflect production capacity at the time of well development; they may or may not reflect current well capacity, thus some estimates of production capacity have been made through interviews with system operators. **Table 6** provides a summary of the existing public water system capacity for each of the communities identified in this study. (NOTE: This section deals with current supply, not with demand, and does not include private well capacities. See Section 3.1 above for estimates of demand).

Table 6– Existing Public Water System Capacity

Community	Surface Water	Distribution System	# of Public System-Wells	Total System Output (gpm)	Gpd[4]	Capacity ac- ft/year[5]
Washington Park	No	Yes	Spring	4[1]	2,880	3.2
Rim Trail DWID	Yes	Yes	1	18	12,960	14.5
Verde Glen	No	Yes	1	14	10,080	11.6
Cowan Ranch	No	Yes	1	15	10,800	12.1
Shadow Rim Ranch GS Camp	No	Yes	2	10	7,200	8.1
Whispering Pines	No	Yes	2	40	28,800	32.3
Beaver Valley	Yes	Yes	1	28	20,160	22.6
Freedom Acres	No	Yes	1	14	10,080	9.2
Wonder Valley	No	Yes	2	21	15,120	16.9
Sunflower Mesa[2]	No	No	0	0	0	2.0
Mesa del Caballo	No	Yes	10	35	25,200	28.2
East Verde Estates	No	Yes	3	20	14,400	16.1
Flowing Springs	No	Yes	1	9	6,480	7.3
Star Valley[3,6]	No	Yes	5	155	111,600	153.8
Round Valley[2]	No	No	0	0	0	77.3
Oxbow Estates[2]	No	No	0	0	0	32.2

Data Sources: MRWRMS (Preliminary Draft), system operators, and ADWR 55 Wells Database; available online at http://www.sahra.arizona.edu

[1] Spring steady 24 hours per day. [2]Served by Private Wells; [3]Parts of Star Valley served by private wells.

[4] Gpd based upon supply provided over a 12-hour day. [5] If no public wells or distribution system exist, the Ac-ft capacity is based upon the MRWRMS estimated 2002 demand.

[6] Parts of Star Valley are served by both private wells and Brooke Utilities (excludes the Diamond Point Shadows area recently incorporated into the new Town of Star Valley)

3.3 Pipeline Supply Needs Evaluation

For planning and study purposes, a preliminary ranking of initial water infrastructure priorities can be developed using a simple ratio of available supply-to-demand (e.g. a ratio of more than one is ok; less than one indicates a community that may need additional water supply). In addition, the recent draft Water Atlas for the Verde River watershed has identified several communities that do not have an adequate water supply (ADWR, 2007). These communities are annotated within this table along with those that the MRWRMS have identified as having chronic water shortages.

Table 7, on the following page, provides a summary comparison of water supply and existing system capacity, based upon the average daily demand. **Appendix B** includes these calculations, as well as the evaluation of these systems with respect to the ability to meet Peak Daily Demand.

Table 7. Comparison of Water Demand Versus Supply.

Community	2002					2040	
	Existing Supply (Ac-ft)	Average Demand (Ac-ft/Yr)	Capacity/ Demand Ratio	Peak Demand (Ac-Ft)	Capacity/ Demand Ratio	Average Demand (Ac-ft)	Capacity/ Demand Ratio
Washington Park	3.2	0.2	16.1	0.4	8.1	4.5	0.7
Rim Trail DWID	14.5	10.7	1.4	21.4	0.7	66.0	0.2
Verde Glen	11.6	2.8	4.1	5.6	2.1	32.5	0.4
Cowan Ranch	12.1	0.9	13.4	1.8	6.7	8.0	1.5
Shadow Rim Ranch GS Camp	8.1	1.2	6.7	2.4	3.4	2.0	4.0
Whispering Pines	32.3	17.5	1.8	35.0	0.9	98.5	0.3
Beaver Valley	22.6	22.0	1.0	44.0	0.5	74.5	0.3
Freedom Acres	9.2	9.2	1.0	18.5	0.6	11.5	1.0
Wonder Valley	16.9	3.0	5.6	6.0	2.8	9.5	1.8
Sunflower Mesa	2.0	1.2	1.0	4	0.5	5.0	0.3
Mesa del Caballo	28.2	66.0	0.4	132.0	0.2	153.0	0.2
East Verde Estates*	16.1	15.9	1.0	31.8	0.5	82.5	0.2
Flowing Springs*	7.3	6.1	1.2	12.2	0.6	29.0	0.3
Star Valley*	153.8	153.8	1.0	307.6	0.6	490.9	0.4
Round Valley*	77.3	77.3	1.0	154.6	0.5	113.5	0.7
Oxbow Estates*	32.2	32.2	1.0	64.4	0.5	38.0	0.9
TOTALS:	**447.4**	**420.7**		**841.7**		**1,218.9**	

** Community systems that may be served by Town of Payson Water Treatment Plant ("WTP"). The additional total demand for the Payson WTP equals 467.2 Ac-ft, which is the difference between average demand in 2040 and the 2002 existing supply for these five communities. This anticipated additional demand from these five communities would require an 11% increase in the planned Payson pipeline capacity.*

As shown in Table 7, many of the communities within the study area have constrained water resources under existing conditions, and most will require additional water supply by the Year 2040.

3.4 Alternative Water Supply

For communities with identified water supply issues, the water supply alternatives as presented in the MRWRMS study have been reviewed to identify possible non-C.C. Cragin (Blue Ridge) water supply options. As discussed in the MRWRMS report, these potential alternative water supplies include surface water, rainwater harvesting, possible wastewater reuse, and de-salination.

Most of the communities within the study area rely on groundwater and many residences rely on private wells, rather than a community water system. Only three or four of the communities within this Study rely on surface water. Because surface water requires filtration to meet the requirements of the Safe Drinking Water Act (SDWA), it is more expensive to produce; thus many of these communities use surface water only to augment groundwater supplies.

Rainwater harvesting is used in some areas of the United States as a means of augmenting water supplies. This is often relied upon on a very localized home-by-home basis to augment the water supplies used for outside washing and irrigation purposes (e.g. non-potable), and to reduce the potential for stormwater quality issues downstream. Unfortunately, the volumes and frequencies of precipitation in the study area may not be sufficient to allow rainwater harvesting to be relied upon to augment water supply.

In most communities in the study area, wastewater is not collected for treatment or disposal. Because of the distances involved, converting the existing onsite wastewater facilities (septic tanks with drainfields) to the community systems that would allow wastewater capture for reuse would be prohibitively expensive. The Town of Payson, Mesa del Caballo, and the Tonto Apache Tribe are the only communities within the project study area where wastewater is presently collected for treatment. A portion of the effluent in Payson is currently being used for groundwater recharge in the Green Valley Park (Payson, 2007). However, effluent generated by the Town and Mesa del Caballo is owned by the Northern Gila County Sanitary District. Over the next 10 to 15 years, this effluent is not anticipated to be a useable alternative water supply for the Town because this water source is presently over-committed to other end re-uses, and because currently Payson generates less effluent than expected due to low water use by Town residents. In addition, the Tonto Apache Tribe has constructed a wastewater treatment plant and will no longer use the current Northern Gila County Sanitary District treatment facility (Murray and Jones, 2006).

In reviewing the total number of connections, and the community layout with respect to potential for economic collection of wastewater for treatment and effluent reclamation and reuse, Star Valley may have enough connections in close proximity, so that that evaluation of a centralized wastewater treatment facility with water reclamation may be merited, especially in light of the ability to avoid potential contamination of groundwater resources that are currently used for potable water. As communities develop from primarily rural land uses to the higher development densities found in towns and cities, the discharge from onsite wastewater treatment systems (septic tanks and drainfields) can increase to the point where the collective discharge from these systems to groundwater becomes problematic. Thus, consideration of community wastewater treatment may be warranted, to allow capture and potential reuse of the effluent, and as a water source protection measure.

Desalination is a very effective way of treating water sources with limited water quality to allow use as a drinking water supply. This technology is gaining acceptance and use in coastal areas, and in arid areas such as the Rio Grande valley, where there are water shortages and saline ground- and surface water supplies. While this technology is proven, and is gaining more widespread use in the United States, desalination plants can be expensive to implement, and are generally considered to be more cost-effective for larger capacity systems (20 to 50 MGD) with a viable (saline) water supply (Tetravision, 2007). The communities within this study would generally be considered to be small, with concerns related to limited water supply rather than the supply's water quality. Thus, this option is not really feasible for this area.

Because of the remote nature of the majority of these communities, these alternatives may not adequately meet the requirements as "long term, uninterruptible water supplies that may be relied upon for drinking water". **Table 8,** on the following page provides a matrix that summarizes the general availability of these options to each community.

Table 8 – Alternative Water Sources.

Community	Present Source	Groundwater	Surface Water	Wastewater Reuse	Desalination
Washington Park	Spring	✓	✓		
Rim Trail DWID	1 Well &Surface Water	✓	✓		
Verde Glen	2 Wells	✓			
Cowan Ranch	1 Well	✓			
Shadow Rim Ranch GS Camp	2 Wells	✓	✓		
Whispering Pines[1]	2 Wells	✓			
Beaver Valley[2]	1 Well & Surface Water	✓	✓		
Freedom Acres	1 Well	✓			
Wonder Valley	2 Wells	✓			
Sunflower Mesa	Private Wells	✓			
Mesa del Caballo,[1,2]	10 Wells	✓			
East Verde Estates[1]	3 Wells	✓			
Flowing Springs	1 Well	✓			
Star Valley	5 public wells; private wells	✓		✓	
Round Valley	Private wells	✓			
Oxbow Estates	Private Wells	✓			

Data Source: MRWSS, 2006;
Notes: [1] Identified by MRWSS as having chronic water shortages
[2] Included in Table 5.5-10, Arizona Water Atlas for Verde Watershed as having an "Inadequate" ADWR Adequacy Determination.
✓ Possible alternative water supply

4.0 PIPELINE CONNECTIONS

For communities where there are no other viable water supply options, an estimate of probable cost for the required pipeline connection has been developed.

The Town of Payson will construct, own, and operate the pipeline extension and will, in its sole and absolute discretion, make all decisions related to use of the pipeline extension to deliver any Gila County allocated water to rural communities adjacent to the pipeline, or near the Town of Payson. This Study does not consider any delivery fee or connection fee that may be charged by the Town of Payson to Gila County or to other Town approved users of the pipeline extension. These Town of Payson related charges will be an additional cost to the non-Payson users of the C.C. Cragin water. This Study does not include any Salt

River Project costs of allocated water that will be charged to the Gila County C.C. Cragin water users that are located in the rural areas outside the Town of Payson.

4.1 Methodology and Pipeline Connection Layout

The proposed pipeline connection locations have been identified through field reconnaissance of each community facility, and a review of the Pipeline Study and MRWRMS. The field reconnaissance effort included visits to each of the affected communities, obtaining Geospatial Positioning System (GPS) coordinates and elevation data, obtaining photographs, and general system assessment concerning current system condition. A copy of the field summary is included in **Appendix B**.

A preliminary "redline" schematic map that shows the pipeline connection locations was provided to Gila County, the Town of Payson, and other stakeholders for input, to verify that the proposed layouts accurately reflect local concepts, concerns and preferences concerning optimal pipeline connection location for each community. This schematic map that incorporates the Town and Gila County comments is included in this report as Plate 1. The pipeline extension alignments as shown in Plate 1 form the basis of the estimates of probable cost as developed for this project. The pipeline design assumes waterline connection sizes will be developed in accordance with water design guidance for Gila County, Town of Payson, and Arizona Department of Environmental Quality (ADEQ) Engineering Bulletin 10. However, the minimum diameter for waterlines longer than 500 feet is 6-inches; and thus this becomes the minimum waterline diameter used for these pipeline extensions. Pipeline extensions less than 500 feet in length were sized as necessary to meet projected build out demand. The estimate of probable costs will be developed for 6-inch and 8-inch diameter ductile iron pipe (DIP) to the Town of Payson 16-inch diameter DIP Pipeline. All piping is assumed to be provided in accordance with the requirements of the American National Standards Institute (ANSI)/ American Water Works Association (AWWA) Specification C150/A21.50, which includes a standard minimum pressure rating of 350 pounds per square inch (psi).

4.3 Cost Estimates

For communities where there are no other viable water supply options, an estimate of probable cost for the required pipeline connection has been developed. Because there are few communities where there are other viable water supply options, cost estimating has been provided for all of the communities, as a tool to support local decision-making. Estimates of probable cost have been developed for each of the pipeline connections as independent projects. For consistency with prior cost estimates developed for the Blue Ridge (now C.C. Cragin) Pipeline Study, the unit costs from the Pipeline Study have been used to develop the estimates of probable cost for each pipeline extension project. Consistent with this study, these estimates are based upon Year 2006 construction costs.

These pipeline extension project costs have then been allocated to the communities proposed to be receiving service by a ratio of community demand to total water volume proposed to be delivered through that pipeline service extension. Booster pump stations have been included in locations where there is negative slope, or insufficient pipeline velocity. The costs for these pump stations have been pro-rated from the cost estimates in the Pipeline Study on the basis of pump station capacity. These estimates include costs for pipeline and bedding, booster pump stations, rock excavation, pavement replacement, wash crossings and traffic control. A 25 per cent contingency is also included to cover other general construction items such as tapping sleeves and valves, any clearing and grubbing, mobilization and demobilization, Stormwater Pollution Prevention Plans (SWPPPs), permits, labor, equipment, miscellaneous contingencies and other appurtenances required for complete installation. **Table 9**, on the following page includes a summary of the proposed pipeline service extensions, the communities served, and the associated total lengths of 6-inch and 8-inch diameter pipeline associated with these community pipeline extensions.

C.C. Cragin Reservoir Financial Feasibility Study

Blue Ridge (C.C. Cragin) Reservoir Drinking Water Source Financial Feasibility Study

Table 9 - Summary of Estimates of Preliminary Cost for Water Line Extensions

Extension	Start	Terminus	Communities Served	Length	Diameter	Wash Crossings	Pump Stations: Number	Pump Stations: Capacity (gpm)	Pump Stations: ~TDH	Segment Cost
Rim Trail DWID	Pipeline	Rim Trail WTP	Rim Trail DWID, Washington Park, Verde Glen, Cowan Ranch, Shadow Rim Ranch Girl Scout Camp	250	6	1	0			$ 96,700
Washington Park	Rim Trail WTP	Washington Park	Washington Park	2,500	6	2	1	1.6	235 ft	$ 305,300
Verde Glen Extension	Rim Trail WTP	Verde Glen	Verde Glen, Cowan Ranch	7,800	6	1	0			$ 638,100
Cowan Ranch Extension	Verde Glen	Cowan Ranch	Cowan Ranch	500	6	1	1	0.0	30 ft	$ 102,800
Shadow Rim Ranch Extension	Verde Glen Extension	Shadow Rim GS	Shadow Rim Ranch GS Camp	2,400	6	2	0			$ 295,600
Beaver Valley	Pipeline	Beaver Valley	Beaver Valley	1,200	6	1	0			$ 185,000
Whispering Pines	Pipeline	Whispering Pines	Whispering Pines	400	6	1	0			$ 209,500
Wonder Valley Extension	Pipeline	Wonder Valley	Freedom Acres, Wonder Valley & Sunflower Mesa	50	6	1	0			$ -
Sunflower Extension	Wonder Valley	Sunflower Mesa	Sunflower Mesa & Freedom Acres	200	6	1	0			$ 75,900
Freedom Acres Extension	Sunflower Mesa	Freedom Acres	Freedom Acres	800	6	1	0			$ 176,400
Mesa del Caballo	Pipeline	Mesa del Caballo	Mesa del Caballo	200	6	0	0			$ 56,900
E. Verde Main Pipeline Extension	Payson WTP	Split to E. Verde & Flowing Springs	East Verde Estates & Flowing Springs	14,800	8	3	0			$ 1,623,900
East Verde Estates Pipeline	E. Verde Main Pipeline	E. Verde Estates	E. Verde Estates	4,500	6	2	0			$ 457,100
Flowing Springs Pipeline	E. Verde Main Pipeline	Flowing Springs	Flowing Springs	5,000	6	1	1	27.0	80	$ 571,900
Star Valley	Payson 260 Pipeline Te	Star Valley System	Star Valley	0	8	2	1	369.5	100	$ -
Round Valley Main Pipeline Extension	Payson 260 Pipeline Te	Round Valley	Round Valley & Oxbow Estates	9,800	8	1	1	52.1	50	$ 1,292,000
Round Valley Pipeline	RV Main Pipeline @ 2	Round Valley	Round Valley	4,500	8	1	1	44.9	50	$ 647,600
Oxbow Estates Pipeline	RV Main Pipeline @ 2	Oxbow Estates	Oxbow Estates	6,650	6	2	1	7.2	50	$ 699,200
			Total Pipeline:	61,550	116	24	7			**$ 7,433,900**
			Total, 6-inch diameter waterline:	32,450						
			Total, 8-inch diameter waterline:	29,100						

5.0 WATER TREATMENT

The Federal Safe Drinking Water Act (SDWA) requires surface water treatment by filtration prior to its use as a drinking water supply. In accordance with the SDWA and AAC Section R18-4-301, water treatment plants ("WTP") are included to provide filtration, and chlorination, and necessary storage of the "finished water" prior to use by each community. This section describes the methodology used, system locations and cost estimates associated with the water treatment facilities necessary to use the C.C. Cragin Reservoir water source.

5.1 Methodology and Layout

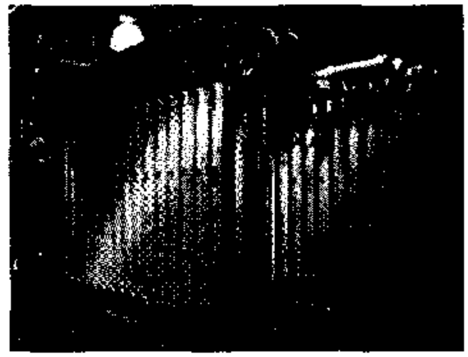
During the field reconnaissance and subsequent pipeline extension layout and map review process, a general layout was developed so that it would be possible to serve several communities within close proximity to each other by a single WTP. This allows some potential cost savings through economies of scale, particularly with respect to reducing O&M and in serving a greater number of connections to share in the annual expenses. In addition, the communities of Star Valley, Round Valley, Oxbow Estates, East Verde Estates, and Flowing Springs are located downstream of the Town of Payson Pipeline terminus and WTP. So the additional water supply necessary to serve these communities would likely be obtained through the Town of Payson WTP and water system (or through County owned or community owned water main extensions), rather than directly from the proposed Payson Pipeline extension.

The proposed location for each WTP was located centrally within the proposed treatment area, and as close to the Pipeline as practicable in order to reduce pipeline extension costs. In addition, the GPS elevation data were also used to locate each facility to reduce the overall number of required pump stations. As shown on Plate 1, a total of five WTPs (in addition to the Payson WTP) are proposed to serve the 15 communities of this study. These are generally located:

- Rim Trail DWID
- Beaver Valley
- Whispering Pines
- Wonder Valley
- Mesa del Caballo

In order to be consistent with the WTPs proposed in the Pipeline Study, it is assumed that the WTPs would also be a similar microfiltration technology as manufactured by Pall Corporation, or equal. This would allow for consistent parts, O&M requirements, and possibly shared operators between these systems. Similar to the microfiltration plants proposed in the Pipeline Study proposed for Pine and Payson, the WTPs for this study will consist of microfiltration followed by disinfection (chlorination). An onsite finished water reservoir and pump station would also be included for storage and distribution of treated water, where required.

Microfiltration membranes provide an effective barrier to particles, bacteria, cryptosporidium and giardia within a small footprint. The membranes are provided in cartridges that are housed in a pressure vessel. Feed water is delivered to the membranes at about 35 pounds per square inch (psi) pressure. The permeate is drawn from the outside into the membrane, and out, leaving the solids to accumulate within the pressure vessel. These solids are removed through periodic backwashing, air scrubbing and chemical cleaning. Some, or all, of the WTPs will require a method to dispose of the backwash materials removed from the raw water that flows in the Payson pipeline extension.



It is assumed that raw water will be delivered to each WTP when the Town of Payson Pipeline is in use, about nine months of each year. Finished water will be delivered to the storage tank, and then into the distribution systems. Each system will also include a pre-strainer to filter out larger particles, and disinfection. General specifications for the treatment equipment are:

- Pre-filter strainers: at least one per WTP site; mesh opening at 500 microns
- MF Membranes: Pall Corporation, or approved equal: Microza hollow fiber; flux rate of 55 gfd; module area of 50 meters square Outside Diameter/ 27 square meters Inside Diameter
- Membrane Rating: 0.1 micron;
- Disinfection: On-site chlorine generators or hypochlorinators will be used for disinfection.

The number of microfiltration process modules to be provided for each WTP is a function of the overall capacity required for that particular unit.

5.2 Cost Estimates

Estimates of probable cost have been developed as independent projects for each of the surface water treatment facilities necessary to meet the requirements of the SDWA, and AAC Section R18-4-301. For consistency with prior cost estimates developed for the Town of Payson Blue Ridge (now C.C. Cragin) Pipeline Study, the unit costs from the Pipeline Study have been used to develop the estimates of probable cost for each WTP project. These costs have been developed to include general requirements, site work, the microfiltration building and equipment, disinfection, a finished water reservoir (ground storage tank), disinfection, mechanical, electrical, plumbing and controls (Black and Veatch, 2006). A 25 per cent contingency is also included. Consistent with the Pipeline Study, the costs are based upon Year 2006 construction costs.

The costs for these WTP projects have then been allocated to each of the 15 communities receiving service by a ratio of community demand to total water volume treated by the water treatment plant connected to that community. The nominal cost of water treatment facilities for most of the communities has been developed as a ratio of the required average flow rate to the actual flow rates and costs associated with the Pine micro-filtration water treatment plant (WTP) rather than the Payson WTP since the proposed Pine WTP capacity is closer to the anticipated capacity of the new community WTPs considered herein. The total adjusted cost was then divided by the current plant capacity in acre-feet per year and gallons per minute (gpm) to obtain a multiplier as a function of cost per capacity unit (Acre-feet and gpm). A simple spreadsheet was then used to multiply the required pipeline delivery rate (and surface water treatment capacity) for each affected community by the adjusted unit cost for treatment. Those communities that can be served by the Town of Payson WTP (Star Valley, Round Valley, Oxbow Estates, East Verde Estates, and Flowing Springs) may ultimately incur a different formula for allocation of treatment and O&M costs.

For the other communities, because the Pine unit costs are a little higher, they reflect the decreased economies of scale associated with a smaller plant, and thus provide a level of conservativeness to these estimates. This provides a realistic relative water treatment infrastructure cost for each community. Consistent with the Pipeline Study, capital costs were amortized over a 20-year period at a seven percent interest rate in order to obtain an annual payment requirement. Costs per 1000 gallons treated, and costs per connection were also estimated to allow a basis of comparison. Detailed cost estimates are included in **Appendix C**. **Table 10** provides a summary of the WTPs proposed for the communities on or near the Pipeline.

Table 10. Summary of Proposed Water Treatment Plants

Plant #	WTP Location	Communities Served	WTP Capacity (kgal/year)	WTP Capacity (gpd)	Capital Costs
1	Rim Trail WTP	Rim Trail DWID, Washington Park, Verde Glen, Cowan Ranch, Shadow Rim Ranch Girl Scout Camp	24,400	66,800	$ 250,100
2	Whispering Pines WTP	Whispering Pines	21,600	59,100	$ 221,400
3	Beaver Valley WTP	Beaver Valley	16,900	46,300	$ 173,230
4	Freedom Acres WTP	Freedom Acres, Sunflower Mesa and Wonder Valley	2,100	5,700	$ 21,530
5	Mesa del Caballo WTP	Mesa del Caballo	40,700	111,400	$ 417,180
Payson	Payson WTP**	Town of Payson, Tonto Apache Tribe*	1,059,000	3,900,000	$ 6,253,750
		Star Valley, Oxbow Estates, Round Valley, East Verde Estates and Flowing Springs	152,237	417,089	$ 974,320
		Total, Proposed Payson Plant	1,211,237	4,317,089	$ 7,228,070

See **Appendix C** for Detailed Cost Estimates
* Currently served by Town of Payson
**Original Payson WTP capacity per Black & Veatch Report is 3.9 mgd
Estimated increase in capacity is 11%

A similar approach has been used to develop the estimate of prototypical O&M costs for the water treatment facilities. O&M estimates from the Pipeline Study for the Payson and Pine WTPs were used to estimate the required annual O&M budget. The O&M costs within the Pipeline Study include power, chemicals, membrane replacement, waste disposal and a full-time operator (Black & Veatch, 2006). The costs were adjusted to provide a multiplier for acre-feet per year, and gpm minute treated. This cost formula was then used with the required water demands associated with the affected communities, to develop the relative O&M costs associated with each facility.

As another important cost consideration, it is important to note that the Town of Payson will construct, own, and operate the pipeline extension and will, in its sole and absolute discretion, make all decisions related to use of the pipeline extension to deliver any Gila County allocated water to rural communities adjacent to the pipeline, or near the Town of Payson. This Study does not consider any delivery fee or connection fee that may be charged by the Town of Payson to Gila County or to other Town approved users of the pipeline extension. These Town of Payson related charges will be an additional cost to the non-Payson users of the C.C. Cragin water. This Study does not include any Salt River Project costs of allocated water that will be charged to the Gila County C.C. Cragin water users that are located in the rural areas outside the Town of Payson.

6.0 EVALUATION OF FINANCIAL FEASIBILITY

The evaluation of financial feasibility includes an assessment on a community-by-community basis of the ability to initially fund construction, and to support ongoing debt repayment and O&M costs.

6.1 Community Cost Assessment

Population and system demand data from the MRWRMS, were used with unit cost from the Pipeline Study to develop an estimate of preliminary cost for the pipeline extensions and WTPs necessary to augment the existing water supply for the 15 communities within this study. These costs were then prorated per community using a ratio of the individual community demand to overall WTP demand. Costs per 1000 gallons served, and cost per connection were also calculated in order to allow a basis for comparison. **Table 11**, on the next page, provides a summary of the prorated pipeline extension cost, WTP cost, and annual costs (including debt repayment and O&M) for each community within the study area.

The cost for (a) Gila County or individual rural communities to transport ("wheel") water through the Payson pipeline, (b) the cost of the raw reservoir water from Salt River Project, and (c) the cost of Gila County or individual communities to operate the WTPs, will all be determined at a later date. It is assumed herein that it is likely Gila County will ultimately form a northern Gila County Water Authority to construct the infrastructure, operate the WTPs, and possibly coordinate joint bonding, etc. to minimize the duplication of efforts and costs to the various communities that "sign-on" to the use of C.C. Cragin water.

As shown **on Table 11**, these total initial capital costs range from $81,050 for Wonder Valley to $1.8 Million for East Verde Estates and Round Valley. Total annual payments range from $7,700 for Wonder Valley to $173,400 for Round Valley. For some communities where the residents may be on limited incomes, the upper range of these annual costs, when allocated to individual water users, may be prohibitive. Generally, infrastructure costs are often easier to finance for systems with a greater number of connections. In order to evaluate whether jointly financed systems would provide cost savings with respect to annual payment requirements, the costs were also evaluated assuming a joint finance scenario.

Table 11. Summary of Financial Feasibility of C.C. Cragin Drinking Water Source

	Demand				Additional Capacity from Reservoir - Average Additional Demand		Cost Summary								
	2002		2040												
Community	No. of connections	2002 (ac-ft)	No. of connections	2040 High (ac-ft)	(kgal)	(ac-ft)**	Capital Connect Cost	WTP Cost	Total Initial Capital	Cost per Connect 2002	Amortized Annual Capital Payment	Annual O&M	Annual O&M + Capital Costs	Cost per 1,000 ($/kgal) gallons	Annual Cost per Connect 2040
Washington Park	12	0.2	12	5	420	1.3	$305,300	$4,300	$309,600	$25,800	$29,200	$410	$29,600	$70.48	$2,470
Rim Trail DWID	93	10.7	137	88	16,800	51.5	$96,700	$172,000	$268,700	$2,689	$25,400	$16,700	$42,100	$2.51	$310
Verde Glen	48	2.8	89	44	7,200	22.0	$638,100	$73,700	$711,800	$14,829	$67,200	$7,160	$74,400	$10.33	$840
Cowan Ranch	19	0.9	21.0	9	0	0.0	$102,800	$0	$102,800	$5,411	$9,700	$0	$9,700	$0.00	$460
Shadow Rim Ranch GS Camp	8	1.2	8	2	0	0.0	$295,600	$0	$295,600	$36,950	$27,900	$0	$27,900	$0.00	$3,490
Whispering Pines	171	17.5	228	123	21,600	66.2	$209,500	$221,200	$430,700	$2,519	$40,700	$21,500	$62,200	$2.88	$270
Beaver Valley	165	22.0	205	83	16,900	51.9	$185,000	$173,400	$358,400	$2,172	$33,800	$16,800	$50,600	$2.99	$250
Freedom Acres	13	9.2	21	16	1,100	3.4	$176,365	$11,356	$187,700	$14,438	$17,700	$1,100	$18,800	$17.09	$900
Wonder Valley	13	3.0	15	12	0	0.0	$81,050	$0	$81,050	$6,235	$7,700	$0	$7,700	$0.00	$510
Sunflower Mesa	8	2.0	10	7	1,000	3.0	$75,900	$9,983	$85,900	$10,738	$8,100	$970	$9,100	$9.10	$910
Mesa del Caballo	409	66.0	455	159	40,700	124.8	$56,900	$416,700	$473,600	$1,158	$44,700	$40,500	$85,200	$2.09	$190
East Verde Estates	164	15.9	246	86	21,600	66.4	$1,680,300	$138,400	$1,818,700	$11,090	$171,700	$3,440	$175,100	$8.11	$710
Flowing Springs	42	6.1	80	32	7,100	21.7	$972,600	$45,300	$1,017,900	$24,236	$96,100	$1,130	$97,200	$13.69	$1,220
Star Valley	461	153.8	1101	573	97,100	337.0	$0	$621,550	$621,600	$1,348	$58,700	$15,450	$74,200	$0.76	$70
Round Valley	178	77.3	242	149	11,800	36.2	$1,761,200	$75,500	$1,836,700	$10,319	$173,400	$1,880	$175,300	$14.86	$720
Oxbow Estates	70	32.2	75	42	1,900	5.8	$877,550	$12,100	$889,700	$12,710	$84,000	$300	$84,300	$44.37	$1,120
TOTALS:	1,874	420.9	2,945	1,430	245,220	791	$7,514,900	$1,975,500	$9,490,500	$11,428	$896,000	$127,340	$1,023,400	$12	$903
										(Average)				(Average)	(Average)

Table 12, on the following page, presents the joint finance scenario. Supporting calculations and documentation for the estimates of probable cost are presented in **Appendix C.**

In addition, it is important to note that these estimates of probable costs reflect a general order of magnitude based upon the anticipated costs of the pipeline extension and WTPs only, and do not include the costs for delivered raw water through the main pipeline. The costs of use of the Pipeline by communities other than Payson will be determined at a later date by the Town of Payson.

The Town of Payson will construct, own, and operate the pipeline extension and will, in its sole and absolute discretion, make all decisions related to use of the pipeline extension to deliver any Gila County allocated water to rural communities adjacent to the pipeline, or near the Town of Payson. This Study does not consider any delivery fee or connection fee that may be charged by the Town of Payson to Gila County or to other Town approved users of the pipeline extension. These Town of Payson related charges will be an additional cost to the non-Payson users of the C.C. Cragin water. This Study does not include any Salt River Project costs of allocated water that will be charged to the Gila County C.C. Cragin water users that are located in the rural areas outside the Town of Payson.

In terms of cost comparisons, the individual communities must consider that the cost for (a) Gila County or individual rural communities to transport ("wheel") water through the Payson pipeline, (b) the cost of the raw reservoir water from Salt River Project, and (c) the cost of Gila County or individual communities to operate the WTPs will all be determined at a later date. It is assumed herein that it is likely Gila County will ultimately form a northern Gila County Water Authority to construct the infrastructure, operate the WTPs, and possibly coordinate joint bonding, etc. to minimize the duplication of efforts and costs to the various communities that "sign-on" to the use of C.C. Cragin water.

Table 12. Summary of Financial Feasibility of C.C. Cragin Drinking Water Source Using Joint Financing

Community	Demand				Additional Capacity from Reservoir - Average Additional Demand		Cost Summary								
	2002		2040												
	No. of connections	2002 (ac-ft)	No. of connections	2040 High (ac-ft)	(kgal)	(ac-ft)**	Capital Connect Cost	WTP Cost	Total Initial Capital	Cost per Connect 2002	Amortized Annual Capital Payment	Annual O&M	Annual O&M + Capital Costs	Annual Cost per 1,000 ($/kgal) gallons	Annual Cost per Connect 2040
Washington Park/Rim Trail	105	10.9	149	93	17,220	52.8	$ 402,000	$ 176,300	$ 578,300	$ 5,508	$ 54,600	$ 17,110	$ 71,700	$ 4	$ 480
Verde Glen/Cowan Ranch	67	3.7	110	53	7,200	22.0	$ 740,900	$ 73,700	$ 814,600	$ 12,158	$ 76,900	$ 7,160	$ 84,100	$ 12	$ 760
Shadow Rim Ranch GS Camp	8	1.2	8	2	-	0.0	$ 295,600	$ -	$ 295,600	$ 36,950	$ 27,900	$ -	$ 27,900	$ -	$ 3,490
Whispering Pines	171	17.5	228	123	21,600	66.2	$ 209,500	$ 221,200	$ 430,700	$ 2,519	$ 40,700	$ 21,500	$ 62,300	$ 3	$ 270
Beaver Valley	165	22.0	205	83	16,900	51.9	$ 185,000	$ 173,400	$ 358,400	$ 2,172	$ 33,800	$ 16,800	$ 50,600	$ 3	$ 250
Freedom Acres/Wonder Valley/Sunflower Mesa	34	14.3	46	35	2,100	6.4	$ 333,315	$ 21,339	$ 354,650	$ 10,431	$ 33,500	$ 2,070	$ 35,600	$ 17	$ 770
Mesa del Caballo	409	66.0	455	159	40,700	124.8	$ 56,900	$ 416,700	$ 473,600	$ 1,158	$ 44,700	$ 40,500	$ 85,200	$ 2	$ 190
East Verde Estates/Flowing Spr	206	22.0	326	118	28,700	88.1	$ 2,652,900	$ 183,700	$ 2,836,600	$ 13,770	$ 267,800	$ 4,570	$ 272,300	$ 9	$ 840
Star Valley	461	153.8	1,101	573	97,100	337.0	$ -	$ 621,550	$ 621,600	$ 1,348	$ 58,700	$ 15,450	$ 74,200	$ 1	$ 70
Round Valley/Oxbow Estates	248	109.5	317	191	13,700	42.0	$ 2,638,750	$ 87,600	$ 2,726,400	$ 10,994	$ 257,400	$ 2,180	$ 259,600	$ 19	$ 820
PROJECT TOTALS	**1,874**	**420.9**	**2,945**	**1,430**	**245,220**	**791**	**$ 7,514,900**	**$ 1,975,500**	**$ 9,490,500**	**$ 9,701**	**$ 896,000**	**$ 127,300**	**$ 1,023,400**	**$ 7**	**$ 794**
										(Average)				(Average)	(Average)

6.2 Project Finance Options

Project implementation for utility infrastructure projects is usually heavily dependent upon identifying and securing the necessary project funding. General funding methods used for public infrastructure include finance mechanisms necessary for initial project capital, and revenue sources necessary for repayment. Finance mechanisms are often used by a community to basically get the project implemented. These generally involve the initial capital expenditures for permitting, project administration, design and construction. Examples of finance mechanisms that may be considered by these communities for infrastructure improvements includes, but are not limited to:

- **General Fund**: Many communities that have an established water and wastewater utility, budget for, and use a portion of their General Fund to finance capital improvements for infrastructure. Typically, a Capital Improvements Plan is prepared every 5 years that proactively outlines these expenditures. The downside to this may be that water improvements may have to compete with other programs for a limited budget.

- **Revenue Bonds**: Cities, utility districts, and other political bodies with bonding authority may sell revenue bonds to raise necessary capital for various identified public improvements. Depending upon the total amount being bonded, revenue bonds may require public (voter) approval prior to implementation. Counsel from a municipal bonding specialist, and legal counsel is recommended. Most bond programs have an extended repayment period (20 to 30 years is typical).

- **General Obligation Bonds**: General obligation bonds are similar to revenue bonds, except that the proceeds from the bond sale are placed in the General Fund, and may not necessarily be ear-marked for a specific project.

- **Local Improvement Assessments**: Local improvement assessments can be used to levy necessary project funding from the landowners that may potentially reap the greatest benefit from a project. Local improvement assessments typically require approval of the affected property owners. While theoretically a viable source of funding, actual implementation of local improvement assessments may be challenging.

- **Local Impact Fees:** Local impact fees are a good way of leveraging revenue to support capital improvements, and are generally regarded as a good method of "growth paying for growth". These fees are typically developed through an impact fee study that evaluates both local market conditions, and the overall cost of the proposed capital improvements. Impact fees are generally viewed as a "free" revenue source, as they may be voted in without an election, usually only apply to new development, and are perceived to exclude current taxpayers. Collected impact fees must be expended within about 6 years of collection (Tischler, 2002).

- **Utility Extension Agreements:** In Arizona, many private utilities and Domestic Water Improvement Districts (DWIDs) use utility extension agreements in order to expedite system expansion. These agreements form a contract between the interested developer and the utility whereby the developer agrees to design and install the infrastructure necessary to serve their project, with future ownership and operation by the utility. The utility typically retains design approval and construction oversight authority. The utility then agrees to repay the developer, all, or a portion of the associated project costs at a certain rate over an agreed upon timeframe (usually 10 percent over ten years). This may be useful for new developments within the project area, but may not adequately address the existing situation or in-fill type development.

- **Revolving Loan Funds**: Revolving loan funds are available from state and federal sources. These funds are typically low-interest loans that may be available to support water and wastewater infrastructure needs; other revolving loan funds are established to implement the water and wastewater improvements necessary to support local economic development. Loan repayment is reinvested in the revolving loan fund to support other projects. Many of these loans require a local match of other funding, or in-kind services.

- **Federal Loan and/Grant Programs**: Federal loan and grant programs may also be available to support project development. The ability to use a loan versus a grant is typically dependent upon project need, and local demographics (median household income, % below poverty level, minority population, etc). In addition, several programs promote grants for project planning and design efforts as a means of leveraging loans for construction costs. These funds are typically low-interest loans that may be available to support water and wastewater infrastructure needs; other revolving loan funds are also available to implement water and wastewater improvements necessary to support local economic development. Many of these loans require a local match of other funding, or in-kind services.

- **State Loan and Grant Programs**: Arizona administers several state loan and grant programs through the Arizona Water Infrastructure Finance Authority (WIFA), and the Arizona Department of Economic Security (ADEC), Greater Arizona Development Authority (GADA) and others. These programs vary in the amount provided, the ability to fund infrastructure need, versus economic development needs, and in terms of repayment.

- **Rural Water Infrastructure Committee (RWIC)**: WIFA and GADA have convened a committee to coordinate Arizona and Federal infrastructure financing entities that have programs directed towards rural infrastructure finance. The RWIC may serve as a "one stop shop" for project funding. A community can make arrangements to make a presentation to the RWIC concerning the project infrastructure needs, description, and cost estimates. The funding participants can then provide the community with a road map of the best route(s) available towards obtaining necessary funding for a particular project.

Revenue sources are funding mechanisms that may be used to support ongoing system O&M, program management and administration, and to repay project financial obligations over time. Revenue sources that may be considered by these communities include, but are not limited to:

- **User charges (utility rates):** Most utilities develop monthly user charges (or utility rates) in order to obtain necessary revenues for utility operation, capital reserves, and repayment of debt obligation. Monthly utility rates for both water and wastewater use, are typically developed and billed as a function of water meter size and water use. There is publically available software that may be used by a utility to establish appropriate rate structures or a formal rate study by a trained utility economist may also be used to justify proposed utility rates.

- **System development charges (impact fees):** System development charges or impact fees are another way of leveraging revenue to support ongoing utility service. These fees are typically developed through an impact fee study that evaluates local market conditions, potential future land values, and the overall cost of the proposed capital improvements. Impact fees are generally viewed as a "free" revenue source, as they may be voted in without an election, usually only apply to new development, and are perceived to exclude current taxpayers. Collected impact fees must be expended within about 6 years of collection (Tischler, 2002).

- **Connection charges:** Many utilities charge connection charges to new development/ or new service addresses as a way of recuperating costs for the infrastructure upgrades necessary to serve the additional area. Depending on local growth, political climate concerning that growth, financial need and other factors, connection charges can range from a few hundred dollars per connection, to several thousand dollars. High connection charges may serve to slow development, and associated economic growth.

- **Inspection fees:** Inspection fees on new utility construction, or upgrades to existing construction can also be used to offset costs of utility operation. These fees are typically used with impact fees, and other primary revenue streams.

- **Property, or other taxes:** Property, and other tax assessments can be used to levy necessary project funding. Tax assessments typically require approval of the affected property owners, and while theoretically a viable source of funding, actual implementation may also be challenging.

Gila County and the affected communities may want to explore other options for developing revenue to support project implementation through a more detailed utility rate study. This rate study should be focused on the development of a municipal infrastructure financial program that addresses the anticipated infrastructure costs and implementation schedule as outlined in this report.

6.3 Debt Repayment Scenarios

As it is anticipated that these projects will likely apply to WIFA for a loan under the Capacity Development sections of the Drinking Water State Revolving Loan program. A debt repayment scenario was developed based upon using the current initial debt ratios, current loan interest rates, and appropriate discount rates. A schematic that illustrates the WIFA loan process is included in Appendix C.

In general, publicly-held community drinking water systems (excluding federal facilities) are eligible for financial assistance under WIFA's Drinking Water Revolving Fund (DWRF). A community water system is defined as a water system that serves 25 or more people (and at least 15 service connections) year round. Nonprofit, non-community water systems, such as schools and church camps, are also eligible, although they must meet all other WIFA financial assistance requirements. Systems qualified under DWRF also include cities, towns, special districts, domestic water improvement districts, co-ops and nonprofit associations. Privately-held community drinking water systems are also eligible, however loans to private systems may will be charged a higher interest rate.

Projects are evaluated by WIFA for available funding based upon priority, existing system conditions, project benefits, including consolidation and regionalization, and local fiscal capacity. Fiscal capacity includes a review of construction cost per connection: projects with costs per connection that are less than $2,500 are scored higher; projects with costs greater than $5,000 connection get no points. This would also encourage joint project development. Projects applying for funding under this WIFA DWSRF program will need to be able to demonstrate the following:

- Legal capability under AAC Section R18-15-103;
- Financial Capability under AAC Section R18-15-104;
- Technical Capability under AAC Section R18-15-105;
- Managerial and Institutional Capability under AAC Section R18-15-105;
- Completion of Environmental Review Process under R18-15-107.

In addition, the projects need to be "ready-to-implement". WIFA has the authority to establish the interest rates for these loans, and thus the interest rate may be variable; however, they are generally considered to be lower interest rate loans.

The spreadsheets developed under Tables 11 and 12 (above) provide an assessment of debt repayment scenarios over a twenty year period based upon a conservative seven (7) percent interest rate, over a twenty year period. The time frame is consistent with WIFA requirements; the interest rate may be higher than current rates, but is consistent with the prior cost estimates, and may reflect a "worse-case" future scenario with respect to project financing. These analyses will include initial construction costs, the annual O&M requirements, debt repayment and capital (debt) reserve.

7.0 CONCLUSIONS

In reviewing the infrastructure needs analyses, and the financial evaluation of the proposed pipeline extensions and WTPs necessary to serve the communities located in, or near the Pipeline, one can draw the following conclusions:

- The total difference between existing supply, and future average demand can be met by the proposed Town of Payson Pipeline;
- Most of the communities in the study have a very strong current need for additional water supply and/or for improved infrastructure necessary to treat, store, and deliver new or current water supplies.
- All communities currently need the redundancy of supply available from the Payson Pipeline to reduce the risk of single source of supply (one well, groundwater only, etc.), and to periodically rest ground water wells and aquifers for hours, days, or years, so that adequate recharge occurs.
- All communities, except the Shadow Rim Ranch Girl Scout Camp, Wonder Valley and Cowan Ranch will need additional water supply by the Year 2040.
- The Town of Payson Pipeline and WTP may provide service to Star Valley, Round Valley, Oxbow Estates, East Verde Estates, and Flowing Springs through pipeline extensions; this would require about a 11 percent increase in the Payson Pipeline and WTP capacity.
- Existing groundwater supply may not be sufficient to serve the needs of all study area communities.
- With the exception of exploring wastewater reclamation and reuse to augment non-potable water supply within Star Valley, available waste water supplies may not present a viable alternative to surface water as a means of augmenting water supplies.
- The relatively high initial and annual costs for the project for Washington Park may discourage the project consideration by these communities.
- Many of the projects may be feasible for their intended communities, and would be considered to be "cost-effective" under WIFA project guidelines (AAC R18-15-305).
- Joint project cost-sharing may provide initial and annual cost savings by decreasing the per connection charges

- The estimates of probable costs reflect a general order of magnitude based upon the anticipated costs of the pipeline extension and WTPs only, and do not include the costs for delivered raw water through the main pipeline. The costs of use of the Pipeline by communities other than Payson are to be determined at a later date by the Town of Payson.

- So, in terms of cost comparisons, the individual communities must consider that the cost for (a) Gila County or individual rural communities to transport ("wheel") water through the Payson pipeline, (b) the cost of the raw reservoir water from Salt River Project, and (c) the cost of Gila County or individual communities to operate the WTPs will all be determined at a later date.

- It is assumed herein that it is likely Gila County will ultimately form a northern Gila County Water Authority to construct the infrastructure, operate the WTPs, and possibly coordinate joint bonding, etc. to minimize the duplication of efforts and costs to the various communities that "sign-on" to the use of C.C. Cragin water.

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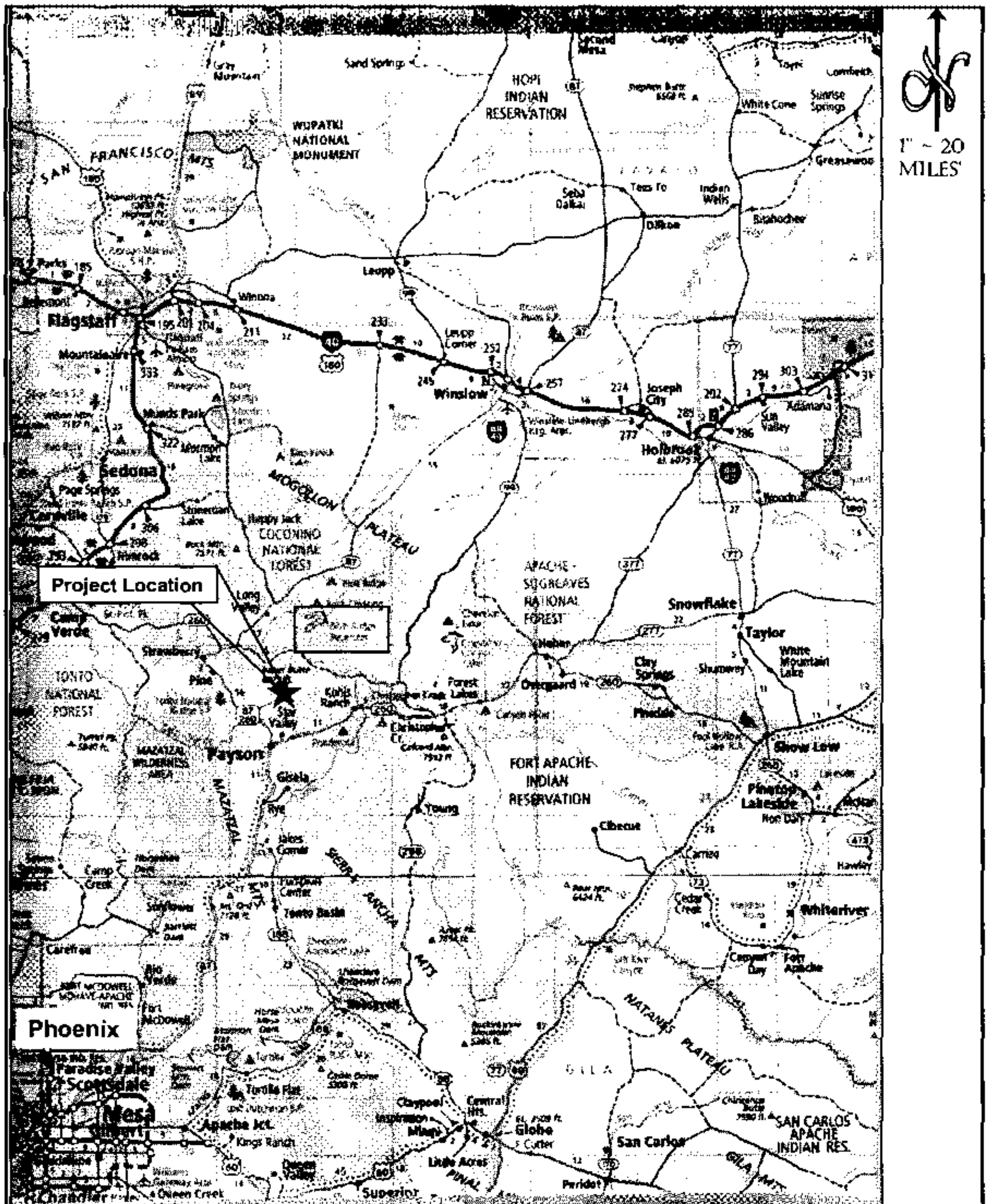
FIGURES



Map Source: Rand McNally, 2006

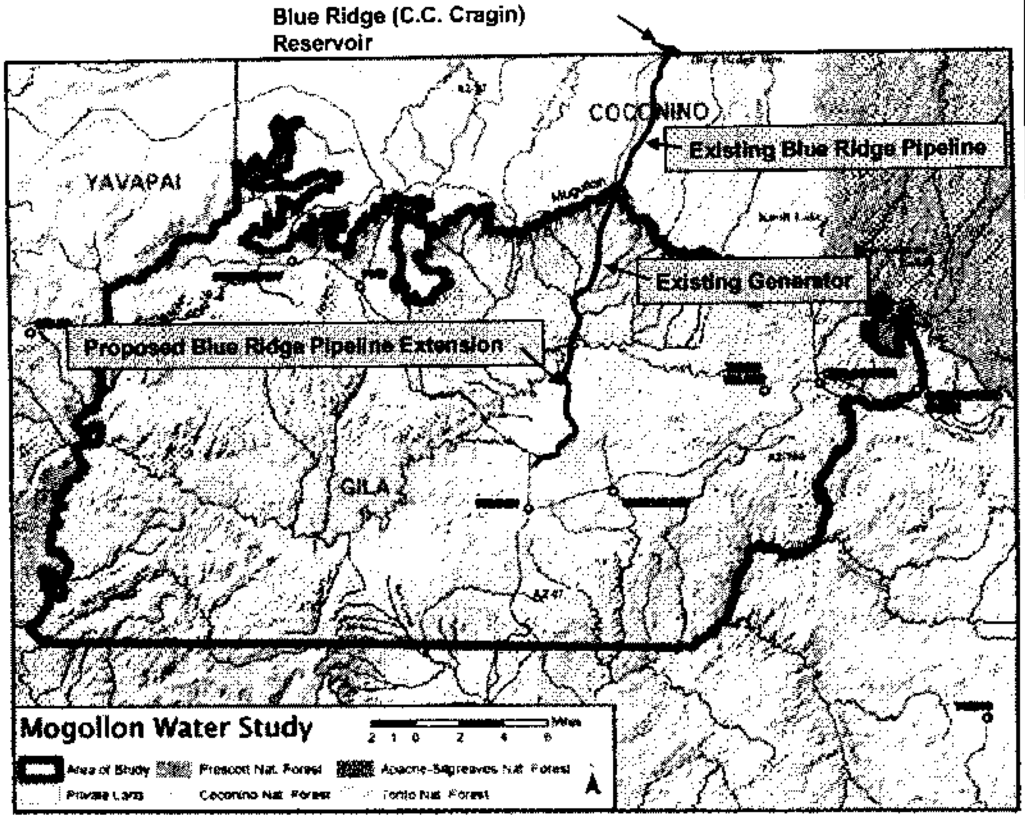
C.C. Cragin Reservoir Financial Feasibility Report

Gila County, Arizona

Figure 1 – Project Location Map

TETRA TECH

Blue Ridge (C.C. Cragin) Reservoir



Map Source: Draft MRWRMS, 2007

C.C. Cragin Reservoir Financial Feasibility Report
Gila County, Arizona
Figure 2 – Pipeline Location Map

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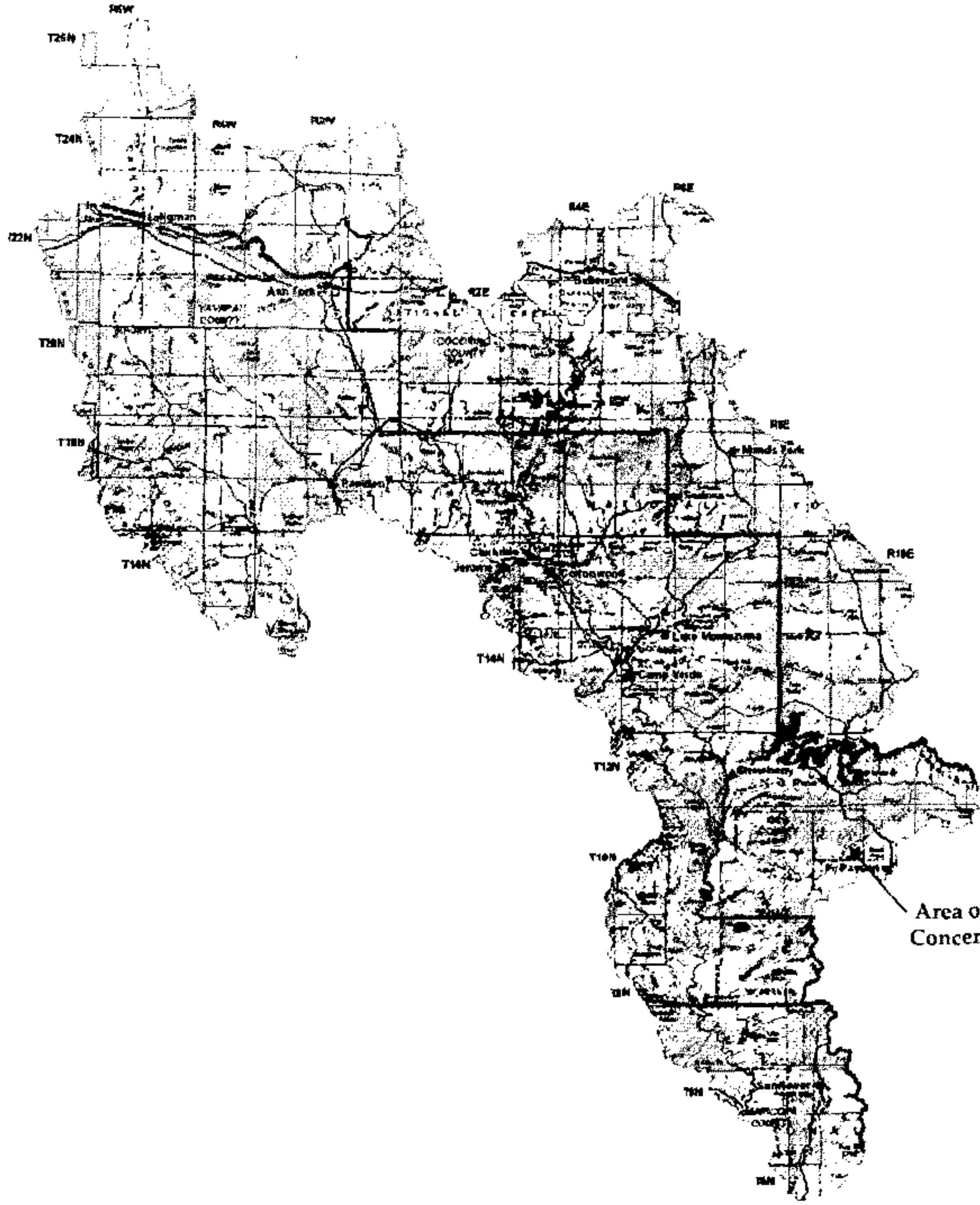
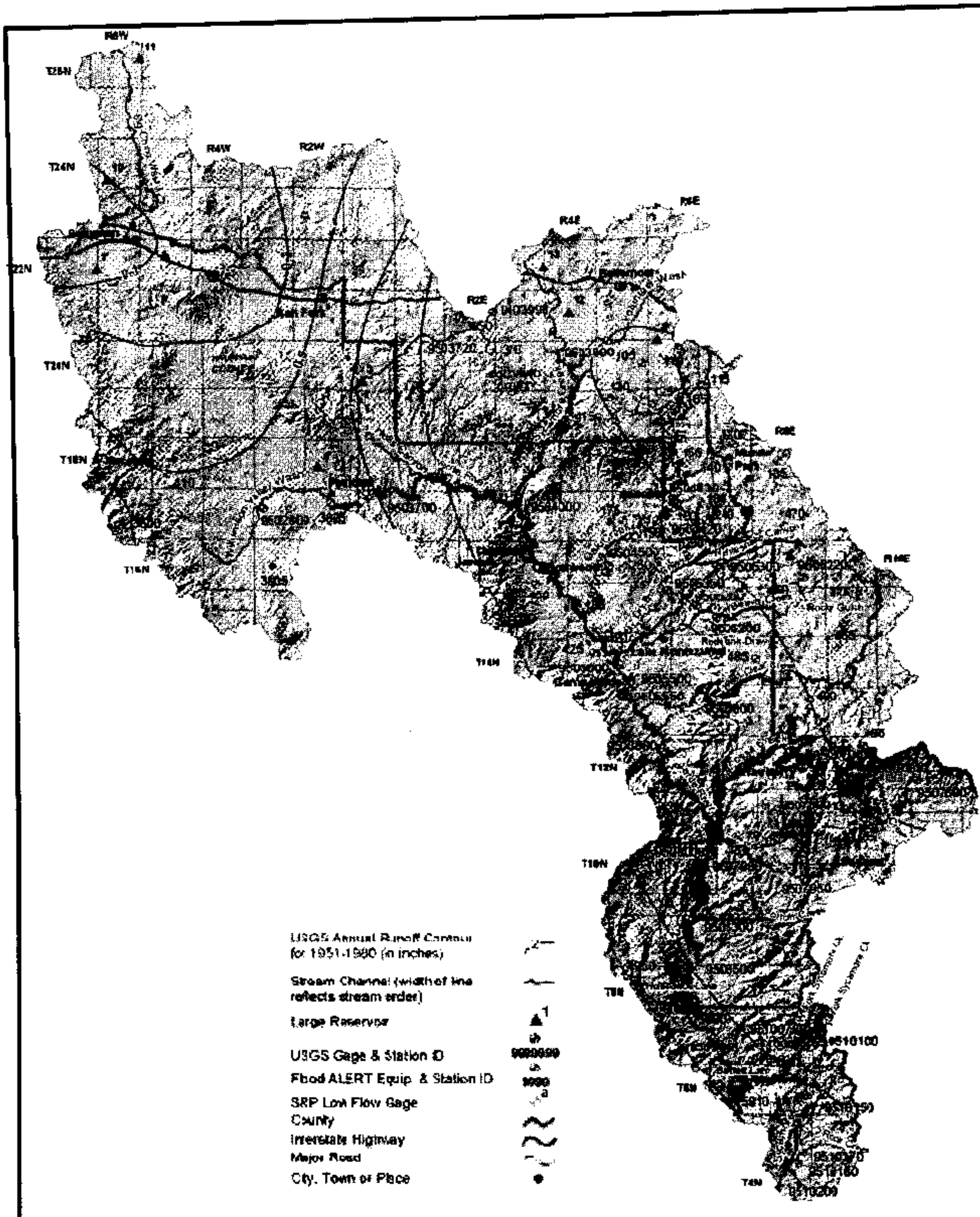


Map Source: ADWR 2007

C.C. Cragin Reservoir Financial Feasibility Report
Gila County, Arizona
Figure 3– Verde River Basin Map

TETRA TECH



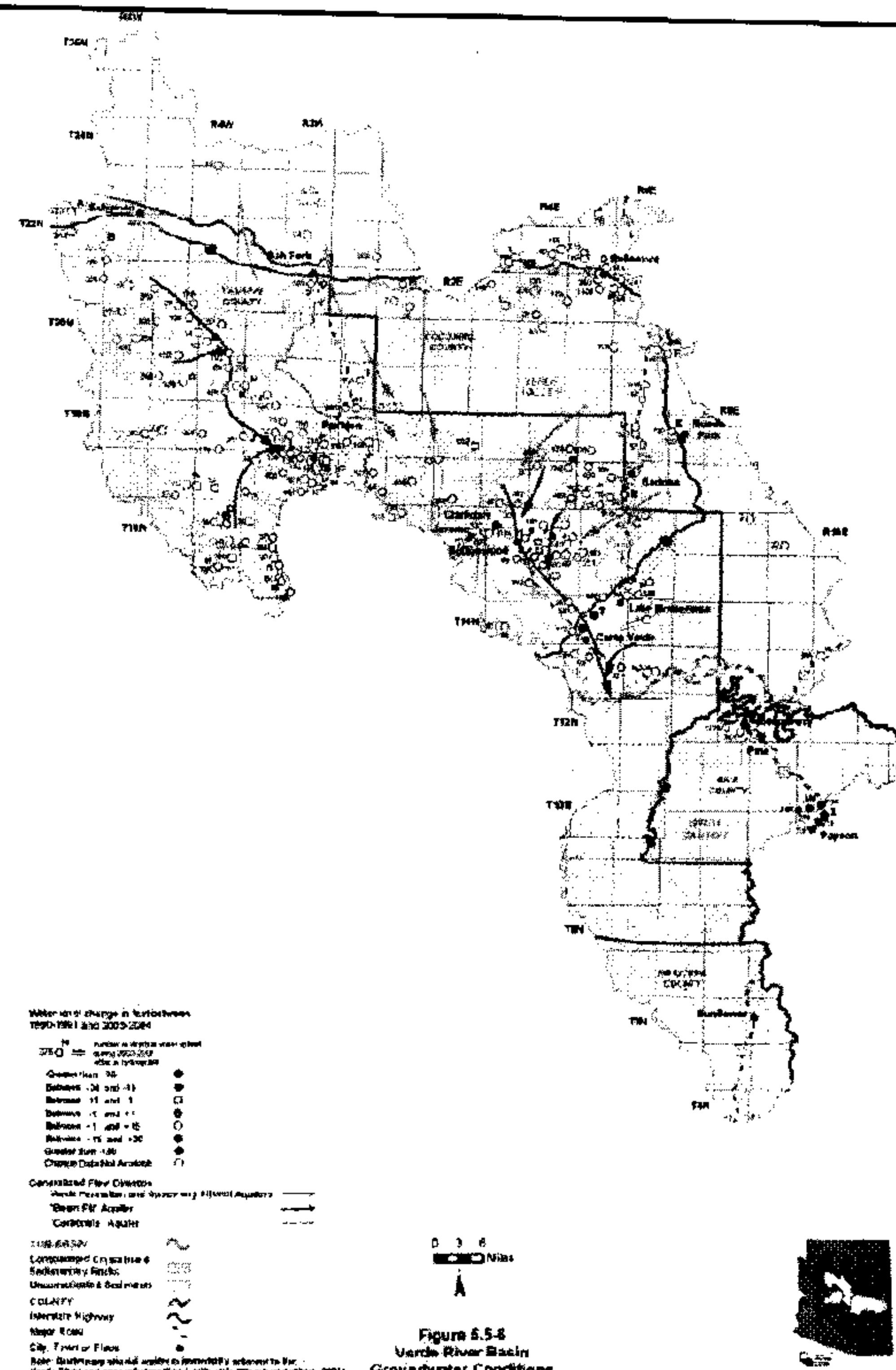
Map Source: ADWR 2007

C.C. Cragin Reservoir Financial Feasibility Report

Gila County, Arizona

Figure 4 – Verde River Basin Surface Water

TETRA TECH



Map Source: ADWR 2007

C.C. Cragin Reservoir Financial Feasibility Report

Gila County, Arizona

Figure 5– Verde River Basin Groundwater

TETRA TECH

APPENDIX A

SUMMARY OF DESIGN CRITERIA

Federal Requirements

Archaeological Resources Protection Act of 1979 (16 U.S.C. 470 aa-11; 43 CFR 7) – Requires protection for any archaeological resources uncovered during the project construction.

Clean Water Act, Section 304(a), National Recommended Water Quality Criteria – Permits for discharges to waters of the United States, including jurisdictional wetlands, must ensure that the discharges will not cause or contribute to a violation of water quality criteria or impair designated uses in the receiving water or downstream waters.

Clean Water Act, Section 401 Certification – For discharges to waters of the United States to certify that the project will not violate water quality standards; this certification must come from the State or authorized Tribe (or EPA for "unauthorized" Tribes) in whose geographic jurisdiction the discharge would occur; States or Tribes may place conditions on its certification that are intended to prevent such violation; in addition, States and Tribes may waive certification (USEPA, 2000a).

Clean Water Act, Section 402 (NPDES) – The National Pollutant Discharge Elimination System (NPDES) regulates the discharge of pollutants from point sources into waters of the United States. This may apply for either point discharge from a treatment system to waters of the United States, or for stormwater discharges during construction from projects affecting an area greater than 5 acres (USEPA, 2000a).

Clean Water Act Section 404 – Section 404 of the clean water act pertains to projects that involve the discharge of dredged or fill material to waters of the United States; This might occur if flood control measures were constructed to protect a treatment system, or if a historical wetlands location were to be converted to a treatment wetlands (generally discouraged unless the wetlands had been previously degraded) (USEPA, 2000a).

Endangered Species Act (16 U.S.C. 1531, et seq. 50 CFR 402; 40 CFR 6.302 (h)) – Projects cannot results in adverse impacts to species listed as threatened or endangered.

Fish and Wildlife Conservation Act (16 U.S.C. 2901 et seq. and 50 CFR 83) – Projects cannot results in adverse impacts to fish and wildlife habitat.

Protection of Wetlands (Executive Order 11990) – Projects cannot result in overall adverse impacts to jurisdictional wetlands.

National Historic Preservation Act (16 U.S.C. 470) – Requires appropriate documentation and if appropriate, preservation of any and all resources with historic or prehistoric significance encountered during construction.

Native American Grave Protection and Repatriation Act (Public Law 101-601) – Requires documentation, protection and appropriate repatriation of any human remains of Native American origin encountered during construction.

Safe Drinking Water Act (42 U.S.C. 300f-300j-25) – Concerns use of surface water sources for drinking water supply.

National Environmental Policy Act (NEPA) (42 U.S.C. 4321 to 4370d; 40 CFR 1500-1508) – For projects that involve a federal action with the potential to significantly affect the environment.

State Requirements

State requirements may be considered in the development of this project; however, in general, the Federal requirements are considered to be more stringent. State Regulations to be considered include, but are not limited to:

- Arizona Department of Environmental Quality (ADEQ). 2005. Arizona Administrative Code – Environmental Reviews and Certification. Title 18, Chapter 5. March 31.
- Arizona Department of Environmental Quality, 1978, Engineering Bulletin No. 10, Guidelines for the Constructionf Water Systems; Prepared by the Arizona Department of Health Services, May.
- Arizona Department of Environmental Quality, 1978a, Engineering Bulletin No. 8 Disinfection of Water Systems. Prepared by the Arizona Department of Health Services, June.

APPENDIX B

DEMAND ESTIMATIONS AND OTHER CALCULATIONS

APPENDIX B - Infrastructure Needs Analyses

			Existing System Capacity						002 Demar	2040 Demand							
										Average Daily Demand (gpd)				Peak Daily Demand (gpd)			
WTP No.	Location	MRWRMS #	Surface Water?	Dist'n System?	# of System-Wells	Total Well Output* (gpm)	Gallons per Day****	Ac-ft/Year	Capacity/ Demand Ratio	Low	High	Average	Capacity/ Demand Ratio	Low	High	Average	Capacity/ Demand Ratio
1	**Rim Trail WTP**				5	61	44,186	49.5	1.6	76,200	132,286	104,243	0.42	152,400	264,572	208,486	0.21
	Washington Park	41	No	Yes	Spring	4	2,880	3.2	9.6	3,480	4,350	3,915	0.74	6,960	8,700	7,830	0.37
	Rim Trail DWID	26	Yes	Yes	1	18	12,960	14.5	0.7	39,480	78,631	59,056	0.22	78,960	157,262	118,111	0.11
	Verde Glen	40	No	Yes	1	14	10,080	11.3	2.4	15,240	22,225	18,733	0.54	30,480	44,450	37,465	0.27
	Verde Glen - Other**	47	No	No	0	0	268	0.3	0.3	10,320	17,200	13,760	0.02	20,640	34,400	27,520	0.01
	Cowan Ranch	8	No	Yes	1	15	10,800	12.1	6.6	6,000	8,200	7,100	1.52	12,000	16,400	14,200	0.76
	Shadow Rim Girl Scout Ranch	28	No	Yes	2	10	7,200	8.1	3.1	1,680	1,680	1,680	4.29	3,360	3,360	3,360	2.14
2	**Whispering Pines WTP**	**42**	No	Yes	2	40	28,800	32.3	0.9	65,640	109,400	87,520	0.33	131,280	218,800	175,040	0.16
3	**Beaver Valley WTP**	**3**	Yes	Yes	1	28	20,160	22.6	0.6	59,040	73,800	66,420	0.30	118,080	147,600	132,840	0.15
4	**Freedom/Wonder WTP**				3	35	26,995	28.1	7.9	14,640	30,710	22,675	0.65	29,280	61,420	45,350	0.60
	Freedom Acres	15	No	Yes	1	14	10,080	9.2	4.6	6,000	14,150	10,075	1.00	12,000	28,300	20,150	0.50
	Wonder Valley	43	No	Yes	2	21	15,120	16.9	21.0	5,760	10,800	8,280	1.83	11,520	21,600	16,560	0.91
	Sunflower Mesa**	48	No	No	0	0	1,795	2.0	3.7	2,880	5,760	4,320	0.42	5,760	11,520	8,640	0.21
5	**Mesa del Caballo WTP**	20	No	Yes	10	35	25,200	28.2	0.2	131,040	141,960	136,500	0.18	262,080	283,920	273,000	0.09
***	**Flowing Springs/East Verde WTP**				4	29	20,880	23	0.5	93,840	105,500	99,670	0.21	187,680	211,000	199,340	0.10
	Flowing Springs	14	No	Yes	1	9	6,480	7.3	0.6	23,040	28,800	25,920	0.25	46,080	57,600	51,840	0.13
	East Verde Estates	11	No	Yes	3	20	14,400	16.1	0.5	70,800	76,700	73,750	0.20	141,600	153,400	147,500	0.10
***	**Star Valley**				5	155	172,128	154	1.2	409,560	511,950	460,755	0.37	819,120	1,023,900	921,510	0.19
	Star Valley A & B	30	No	Yes	5	155	111,600	125.0	0.7	148,800	186,000	167,400	0.67	297,600	372,000	334,800	0.33
	Star Valley - Other**	46	No	No	0	0	60,528	67.8	0.5	260,760	325,950	293,355	0.21	521,520	651,900	586,710	0.10
***	**Oxbow/Round Valley**				-	-	97,755	110	0.5	99,720	171,130	135,425	0.72	199,440	342,260	270,850	0.36
	Oxbow Estates**	21	No	No	0	0	28,746	32.2	0.5	30,000	37,500	33,750	0.85	60,000	75,000	67,500	0.43
	Round Valley**	27	No	No	0	0	69,009	77.3	0.5	69,720	133,630	101,675	0.68	139,440	267,260	203,350	0.34

* Data from ADWR 55 Wells Database; available online at http://www.sahra.arizona.edu

** Served by Private Wells; capacity is assumed to meet existing demand

*** May be served through Town of Payson System

**** Assumes water replenishment over a 12-hour day

Appendix [illegible] - Demand Calculations

WTP No.	Location	[illegible] Map Location #	2002 Population	2002 Demand Avg Daily (gpcd)	2002 Demand Peak Daily (gpcd)	2002 Demand Avg Annual (ac-ft)	2002 Demand Average Daily Demand (gpd)	2002 Demand Peak Daily (gpd)	2040 Population	2040 Avg Daily (gpcd) Low	2040 Avg Daily (gpcd) High	2040 Peak Daily (gpcd) Low	2040 Peak Daily (gpcd) High
1	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Washington Park	41	1	150	300	[illegible]	150	300	[illegible]	[illegible]	190	[illegible]	[illegible]
	[illegible]	26	45	[illegible]	[illegible]	[illegible]	[illegible]	19,121	[illegible]	[illegible]	[illegible]	240	[illegible]
	[illegible]	[illegible]	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	127	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	47	2	200	400	[illegible]	400	800	[illegible]	[illegible]	201	280	400
	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	1,440	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	29	12	96	192	[illegible]	1,152	2,304	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	Whispering Pines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Valley	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Acres/[illegible] Valley		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible] Acres	15	[illegible]	[illegible]	76	[illegible]	[illegible]	[illegible]	30	[illegible]	[illegible]	240	[illegible]
	[illegible]	30	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	240	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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	[illegible] Springs	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible] Valley		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible] Valley [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible] Valley [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	150	[illegible]	[illegible]
[illegible]	[illegible] Valley		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible] Valley	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Location	2040 Avg (gpd) Low	2040 Avg (gpd) High	2040 Peak Day (gpd) Low	2040 Peak Day (gpd) High	2040 Avg annual (ac-ft) Low	2040 Avg annual (ac-ft) High	2040 Avg annual (ac-ft) Avg	Difference Low (ac-ft/yr)	Difference High (ac-ft/yr)	Difference Average (ac-ft/yr)	Difference Avg (gpd)	MGD Future High	MGD Difference High	Annual Demand (kgal)	Unit Cost based on	Unit Cost ($/kgal)	2040 High Flow Cost Estimate	O&M Unit cost ($/kgal)	O&M Total Annual Cost
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Washington Park	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
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[illegible]	6,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
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Whispering Pines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible] Acres/[illegible] Valley	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Acres	[illegible]	[illegible]	12,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
[illegible]	[illegible]	[illegible]	11,520	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
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Blue Ridge (C.C. Cragin) Reservoir Pipeline Financial Feasibility Study
Appendix B - Distribution System Details

Description	Length (ft)	dH (ft)	Slope	Demand (gpm)	Flow (cfs)	V (fps)	Design Q, cfs	# of Pumps	Wash Crossings	Pipe Size	Notes
Washington Park	2,500	-320	-12.8	1.58	0.004	0.02	1.42	1	2	6	Pump Required - TDH=235 ft
To Wash 1	2,500	-160	-		Pipefull V =	7.23	OK			6	Pump Required
End	0	-80	-							0	Pump Required
Rim Trail Extension	250	40	16.0	93	0.21	1.05	2.41	0	1	6	
(pipeline to RT DWID WTP)					Pipefull V =	12.30	OK				PRV required
Verde Glen Extension	7,600	151	1.9	27	0.06	0.31	0.84	0	1	6	
RT DWID to Verde Glen	8,000	151			Pipefull V =	4.28	OK				
Capacity = Verde Glen & Cowan Ranch											
Cowan Ranch Extension	500	-8	-1.6	0	0.00	0.00	0.15	1	1	6	Pump required, TDH = 30 feet
Verde Glen to Cowan Ranch					Pipefull V =	7.53	OK				
Shadow Rim Ranch Extension	2,400	125	5.21	0	0.00	0.00	1.38	0	2	6	2 wash crossings
Pipeline to Shadow Rim GS Ranch					Pipefull V =	7.02	OK				
Beaver Valley	1,200	40	3.33	64	0.14	0.73	1.10	0	1	6	
Pipeline to Beaver Valley Plant					Pipefull V =	5.61	OK				
Wonder Valley Extension	50	3	6.00	8	0.02	0.09	1.48	0	1	6	
Pipeline to Wonder Valley					Pipefull V =	7.53	OK				
(size for Sunflower Mesa, Wonder Valley & Freedom Acres)											
Sunflower Mesa	200	43	21.50	1	0.00	0.01	2.80	0	1	6	
Freedom Acres to Sunflower Mesa					Pipefull V =	14.26	OK				
(Size for Sunflower Mesa & Wonder Valley)											
Freedom Acres	800	5	0.63	0	0.00	0.00	0.48	0	1	6	
Sunflower Mesa to Freedom Acres					Pipefull V =	2.43	OK				
Whispering Pines	400	4	1.00	19	0.04	0.21	0.60	1	0	6	Pump required, TDH = 30 feet
Pipeline to Whispering Pines Plant					Pipefull V =	3.07	OK				
Mesa del Caballo	200	2	1.00	82	0.18	0.93	0.60	0	0	6	
Pipeline to MdC Plant					Pipefull V =	3.07	OK				

Blue Ridge (C.C. Cragin) Reservoir Pipeline Financial Feasibility Study
Appendix B - Distribution System Details

Description	Length (ft)	dH (ft)	Slope	Demand (gpm)	Flow (cfs)	V (fps)	Design Q, cfs	# of Pumps	Wash Crossings	Pipe Size	Notes
E. Verde Main Pipeline Extension	14,800	300	2.0	109.3	0.24	0.70	1.85	0	3	8	to split, 3 wash crossings
From pipeline to Split					Pipefull V =	5.31	OK				
To Wash 1	2,300	50	2.2						1	8	
To Wash 2	1,200	40	3.3						1	8	
To Wash 3	10,500	240	2.3						1	8	
To Split	800	80	10.0							8	
E. Verde Estates Extension	4,500	153	3.4	82.3	0.18	0.93	1.11	0	2	6	2 wash crossing
To Wash 1	2,200	160	7.3		Pipefull V =	5.67	OK		1	6	
To Wash 2	2,200	20	0.9						1	6	
To End	100	0	0.0							6	
To Flowing Springs	5,000	-27	-0.54	52.1	0.12	0.59	0.76	1	1	6	Pump Required, TDH= 80 ft
To Wash 1	3,600	120	3.3		Pipefull V =	3.89	OK				
To End	1,400	0	0.5 to 1								
Star Valley	0	266	0.0	417.9	0.93	2.67	0.00	1	2	8	2 wash crossings
Star Valley will be served from existing pipeline					Pipefull V =	0.00	OK		1	8	
								1	1	8	Pump Required, TDH=50
Round Valley Pipeline	9,800	200	2.0	52.1	0.12	0.33	1.86	1	1	8	
From Payson Pipeline @ Tonto Apache Tribe		200			Pipefull V =	5.33	OK			8	1 wash crossing
To Wash 1	4,300	0	0.0					1	1	8	Pump Required
To Split	5,500	160	2.9							8	
To Round Valley	4,500	1	Flat!	45	0.10	0.29	1.94	1	1	8	Pump required, TDH=50'
					Pipefull V =	5.56	OK				
To Oxbow	6,650	160	2.4	7.2	0.02	0.08	0.90	1	2	6	2 wash crossings.
To Wash 1	3,600	120	3.3		Pipefull V =	4.58	OK	1	1	6	Pump Required; TDH=50ft.
To Wash 2	2,400	40	1.7						1	6	Pump Required
To End	650	0	0.0							6	Pump Required

Design Assumptions: V >= 3fps **Diameter** >= 8 inches

APPENDIX C

ESTIMATES OF PROBABLE COMMUNITY COSTS

Blue Ridge (C.C. Cragin) Reservoir Pipeline Financial Feasibility Study
Appendix C - 2006 Unit Costs from
Blue Ridge Reservoir Pipeline Study

2006 Pipe Unit Construction Costs[A]		
Description	**Unit Cost**	**Unit**
Pipeline	$7.50	/in-dia/lf
Pavement Replacement	$40	/lf
Rock Excavation	$45	/cy
Water/Wash Crossings	$45,000	/crossing
Traffic Control	$170,000	/Lump Sum
Booster Pump Stations	$1,650	/station/acft/yr

2006 WTP Construction Costs[A]		
	Community	
Description	**Payson**	**Pine**
General Requirements (9%)	$288,000	$72,000
Sitework (20%)	$640,000	$160,000
MF Building (1600 sq ft)	$176,000	$88,000
MF Equipment	$1,780,000	$415,000
Disinfection	$275,000	$50,000
Finished Water Reservoir (@ $0.75/gal)	$750,000	$150,000
Pump Station	$215,000	$100,000
Electrical / I&C (20%)	$703,000	$177,000
HVAC / Plumbing (5%)	$176,000	$44,000
Subtotal	$5,003,000	$1,336,000
Contingency (25%)	$1,250,750	$334,000
Total Capital	$6,253,750	$1,670,000
Cost per 1,000 Gallons Treatment Capacity ($/kgal)	$6.40	$10.25

Cost Summary		
Item	**Payson Cost**	**Pine Cost**
Raw Water Main	$17,211,037	$15,185,000
Water Treatment Plant	$6,253,750	$1,670,000
Total Capital Cost	$23,464,787	$16,855,000
Amortized (20 years)	$2,214,910	$1,590,993
Operations & Maintenance ($/year)	$168,433	$162,262
Total Annual Cost	**$2,383,343**	**$1,753,255**
Cost per 1,000 Gallons ($/kgal)	**$2.44**	**$10.76**
O&M ($/kgal)	$0.16	$1.00
Design Capacity (mgd)	3.9	0.6
Design Capacity (ac-ft/year)	3250	500
Design Capacity (kgal/year)	1,059,017	162,926

[A] Black and Veatch. February 10, 2006. Blue Ridge Reservoir Water Supply Pipeline and Treatment Plant - Final. Town of Payson, Arizona.

December 21, 2007

Cost Assumptions: Costs are developed for each of the identified communities within this financial feasibility study. Costs for shared pipeline extensions (a pipeline that serves more than one community) are prorated to each community as a percentage of total pipeline extension capacity provided to each community. Costs for water treatment and O&M are prorated on the basis of average future volume of water treated. Costs are based upon the Unit Costs for pipeline, microfiltration, and O&M as presented in the Blue Ridge Reservoir Water Supply Pipeline and Treatment Plant (Black & Veatch, 2006). Pipeline costs include piping, pipe fitting, bedding, backfill and compaction, and may reflect a "conservative-high" estimate. Water treatment and O&M costs for most communities are based upon unit costs for Pine as presented in the Black& Veach report, as the Pine system is closer in scale to those required by these systems. Communities served by the Town of Payson (Flowing Springs, East Verde Oxbow Estates, and Round Valley) are based upon the Payson rates. Consistent with the costs presented within the prior study, costs are provided on a FY 2006 basis, and include a 25% contingency. Capital Recovery is based upon a period of 20 years, and a 7% interest rate. Present Value is based upon period of 20 years, and a 7% discount rate.

n = 20 years
i = 7%

Capital Recovery: $A = P[i(1+i)^n/(1+i)^n-1]$

WASHINGTON PARK COSTS					
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Pipeline Extension					
Pipeline - 6"	2,500	lf	$7.50	in-dia/lf	$112,500
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	625	lf	$40	lf	$25,000
Rock Excavation*	139	cy	$45	cy	$6,200
Water/Wash Crossings	2	crossing	$45,000	crossing	$90,000
Traffic Control	0.05	lump sum	$170,000	lump sum	$8,500
Booster Pump Stations	1	stations	$2,000	station	$2,000
				Subtotal, Extension Costs	$244,200
				Contingencies @25%	$61,100
				Total Extension Cost	***$305,300***
Portion of Rim Trail WTP	415	kgallons	$10.25	kgallons	$4,260
				Total Capital Costs	**$309,600**
				Amortized Capital Costs	$29,200
Annual Operations and Maintenance	415	kgallons	$1.00	$/kgal	$410
				Total Annual Costs for Washington Park	**$29,600**
Present Value of O&M over 20 years, at 7% rate					**$4,400**
TOTAL Life-Cycle Costs, Washington Park:					**$315,100**
No. of connections, 2002	12			**Cost/connection, 2002:**	**$26,260**
No. of connections, 2040	12			**Cost/connection, 2040:**	**$26,260**

RIM TRAIL DWID COSTS					
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Pipeline Extension					
Pipeline - 6"	250	lf	$7.50	in-dia/lf	$11,250
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	63	lf	$40	lf	$2,500
6-inch Diameter Pressure Reducing Valve & box	1	ea	$1,000	ea	$1,000
Rock Excavation*	14	cy	$45	cy	$600
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.1	lump sum	$170,000	lump sum	$17,000
Booster Pump Stations	0	stations	$0	station	$0
				Subtotal, Extension Costs	$77,350
				Contingencies @25%	$19,300
				Total Extension Cost	***$96,700***
Portion of Rim Trail WTP	16,776	kgallons	$10.25	kgallons	$172,000
				Total Capital Costs	**$268,700**
				Amortized Capital Costs	$25,400
Annual Operations and Maintenance	16,776	kgallons	$1.00	$/kgal	$16,700
				Total Annual Costs for Rim Trail DWID	**$42,100**
Present Value of O&M over 20 years, at 7% rate					**$177,800**
TOTAL Life-Cycle Costs, Rim Trail, DWID					**$448,200**
No. of connections, 2002	93			**Cost/connection, 2002:**	**$4,820**
No. of connections, 2040	137			**Cost/connection, 2040:**	**$3,270**

Verde Glen Water Extension - ***serves communities of Verde Glen, Verde Glen "Other" & Cowan Ranch from Rim Trail DWID WTP***					
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Pipeline Extension					
Pipeline - 6"	7,800	lf	$7.50	in-dia/lf	$351,000
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	1,950	lf	$40	lf	$78,000
Rock Excavation*	433	cy	$45	cy	$19,500
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.1	lump sum	$170,000	lump sum	$17,000
Booster Pump Stations	0	stations	$0	station	$0
				Subtotal, Verde Glen Extension Cost	$510,500
				Contingencies @25%	$127,600
				Total Extension Cost	***$638,100***
VERDE GLEN COSTS					
Annual Water Demand, kgal:	7,186				
Total Water Demand for Extension, kgal:	7,186				
Percentage per Verde Glen:	100%				
Portion of Verde Glen Extension Costs:					$ 638,100
Portion of Rim Trail WTP	7,186	kgallons	$10.25	kgallons	$73,700
				Total Capital Costs	**$711,800**
				Amortized Capital Costs	$67,200
Annual Operations and Maintenance	7,186	kgallons	$1.00	$/kgal	$7,160
				Total Annual Costs for Verde Glen	**$74,400**
Present Value of O&M over 20 years, at 7% rate					**$76,200**
TOTAL Life-Cycle Costs,Verde Glen:					**$792,000**
No. of connections, 2002	48			**Cost/connection, 2002:**	**$16,500**
No. of connections, 2040	89			**Cost/connection, 2040:**	**$8,900**

COWAN RANCH COSTS

Annual Water Demand, kgal:	0
Total Water Demand for Extension, kgal:	7,186
Percentage per Verde Glen:	0%
Portion of Verde Glen Extension Costs:	$ -

Description	Quantity	Unit	Unit Cost	Unit	Cost
Cowan Ranch Pipeline Extension from Verde Glen					
Pipeline - 6"	500	lf	$7.50	in-dia/lf	$22,500
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Surface Pavement Replacement	125	lf	$40	lf	$5,000
Rock Excavation*	28	cy	$45	cy	$1,200
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.05	lump sum	$170,000	lump sum	$8,500
Booster Pump Stations	1	stations	$0	station	$0
			Subtotal, Verde Glen Extension Cost		$82,200
			Contingencies @25%		$20,600
			Total Extension Cost		*$102,800*
			Total Costs, Extension to Cowan Ranch		$ 102,800
Portion of Rim Trail WTP	-	kgallons	$10.25	kgallons	$0
			Total Capital Costs		$102,800
			Amortized Capital Costs		$9,700
Annual Operations and Maintenance	-	kgallons	$1.00	$/kgal	$0
			Total Annual Costs for Cowan Ranch		$9,700
Present Value of O&M over 20 years, at 7% rate					$0
TOTAL Life-Cycle Costs,Cowan Ranch					$103,300
No. of connections, 2002	19		**Cost/connection, 2002:**		$5,440
No. of connections, 2040	21		**Cost/connection, 2040:**		$4,920

SHADOW RIM RANCH GIRL SCOUT CAMP COSTS

Description	Quantity	Unit	Unit Cost	Unit	Cost
Pipeline Extension					
Pipeline - 6"	2,400	lf	$7.50	in-dia/lf	$108,000
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	600	lf	$40	lf	$24,000
Rock Excavation*	133	cy	$45	cy	$6,000
Water/Wash Crossings	2	crossing	$45,000	crossing	$90,000
Traffic Control	0.05	lump sum	$170,000	lump sum	$8,500
Booster Pump Stations	0	stations	$0	station	$0
			Subtotal, Extension Costs		$236,500
			Contingencies @25%		$59,100
			Total Extension Cost		*$295,600*
Portion of Rim Trail WTP	-	kgallons	$10.25	kgallons	$0
			Total Capital Costs		$295,600
			Amortized Capital Costs		$27,900
Annual Operations and Maintenance	-	kgallons	$1.00	$/kgal	$0
			Total Annual Costs for Shadow Rim		$27,900
Present Value of O&M over 20 years, at 7% rate					$0
TOTAL Life-Cycle Costs, Shadow Rim:					$297,000
No. of connections, 2002	1		**Cost/connection, 2002:**		$297,000
No. of connections, 2040	1		**Cost/connection, 2040:**		$297,000

BEAVER VALLEY COSTS					
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Pipeline Extension					
Pipeline - 6"	1,200	lf	$7.50	in-dia/lf	$54,000
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	300	lf	$40	lf	$12,000
Rock Excavation*	67	cy	$45	cy	$3,000
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.2	lump sum	$170,000	lump sum	$34,000
Booster Pump Stations	0	stations	$0	station	$0
				Subtotal, Extension Costs	**$148,000**
				Contingencies @25%	$37,000
				Total Extension Cost	***$185,000***
Beaver Valley WTP	16,917	kgallons	$10.25	kgallons	$173,400
				Total Capital Costs	**$358,400**
				Amortized Capital Costs	$33,800
Annual Operations and Maintenance	16,917	kgallons	$1.00	$/kgal	$16,800
				Total Annual Costs for Beaver Valley	**$50,600**
Present Value of O&M over 20 years, at 7% rate					**$178,800**
TOTAL Life-Cycle Costs, Beaver Valley					**$538,600**
No. of connections, 2002	165			**Cost/connection, 2002:**	**$3,260**
No. of connections, 2040	205			**Cost/connection, 2040:**	**$2,630**

WHISPERING PINES COSTS					
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Pipeline Extension					
Pipeline - 6"	400	lf	$7.50	in-dia/lf	$18,000
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	100	lf	$40	lf	$4,000
Rock Excavation*	22	cy	$45	cy	$1,000
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.2	lump sum	$170,000	lump sum	$34,000
Booster Pump Stations	1	stations	$65,600	station	$65,600
				Subtotal, Extension Costs	$167,600
				Contingencies @25%	$41,900
				Total Extension Cost	***$209,500***
Whispering Pines WTP	21,584	kgallons	$10.25	kgallons	$221,200
				Total Capital Costs	**$430,700**
				Amortized Capital Costs	$40,700
Annual Operations and Maintenance	21,584	kgallons	$1.00	$/kgal	$21,500
				Total Annual Costs for Whispering Pines	**$62,200**
Present Value of O&M over 20 years, at 7% rate					**$228,900**
TOTAL Life-Cycle Costs, Whispering Pines					**$662,100**
No. of connections, 2002	171			**Cost/connection, 2002:**	**$3,870**
No. of connections, 2040	228			**Cost/connection, 2040:**	**$2,900**

Wonder Valley Main Extension - *serves communities of Freedom Acres, Sunflower Mesa and Wonder Valley from Wonder Valley WTP*					
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Main Pipeline Extension					
Pipeline - 6"	50	lf	$7.50	in-dia/lf	$2,250
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	13	lf	$40	lf	$500
Rock Excavation*	3	cy	$45	cy	$100
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.1	lump sum	$170,000	lump sum	$17,000
Booster Pump Stations	0	stations	$0	station	$0
			Subtotal, Wonder Valley Extension Cost		$64,850
				Contingencies @25%	$16,200
				Total Extension Cost	***$81,050***
WONDER VALLEY COSTS					
Annual Water Demand, kgal:	0				
Total Water Demand for Extension, kgal:	2,082				
Percentage per Wonder Valley:	0%				
Portion of Wonder Valley Extension Costs:				**$**	-
Portion of Wonder Valley WTP	-	kgallons	$10.25	kgallons	$0
				Total Capital Costs	**$81,050**
				Amortized Capital Costs	$7,700
Annual Operations and Maintenance	-	kgallons	$1.00	$/kgal	$0
			Total Annual Costs for Wonder Valley		**$7,700**
Present Value of O&M over 20 years, at 7% rate					**$0**
TOTAL Life-Cycle Costs,Wonder Valley:					**$82,000**
No. of connections, 2002	13			Cost/connection, 2002:	**$6,230**
No. of connections, 2040	15			Cost/connection, 2040:	**$5,400**

SUNFLOWER MESA COSTS					
Annual Water Demand, kgal:	974				
Total Water Demand for Wonder Valley, kgal:	2,082				
Percentage per Sunflower Mesa:	47%				
Portion of Wonder Valley Extension Costs:				$	37,900.00
Sunflower Mesa Pipeline Extension	(Pipeline from Freedom Acres to Sunflower Mesa, split costs with Wonder Valley)				
Pipeline - 6"	200	lf	$7.50	in-dia/lf	$9,000
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	50	lf	$40	lf	$2,000
Rock Excavation*	11	cy	$45	cy	$500
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.05	lump sum	$170,000	lump sum	$8,500
Booster Pump Stations	0	stations	$0	station	$0
			Subtotal, Sunflower Mesa Extension Cost		$65,000
				Contingencies @25%	$16,300
			Total Sunflower Extension Cost		***$81,300***
Annual Water Demand, kgal:	974				
Total Water Demand for Sunflower Extension, kgal:	2,082				
Percentage per Sunflower Mesa:	47%				
Portion of Sunflower Mesa Costs:				$	38,000.00
			Total Costs, Extension to Sunflower Mesa	$	75,900
Portion of Wonder Valley WTP	974	kgallons	$10.25	kgallons	$9,983
				Total Capital Costs	**$85,900**
				Amortized Capital Costs	$8,100
Annual Operations and Maintenance	974	kgallons	$1.00	$/kgal	$970
			Total Annual Costs for Sunflower Mesa		**$9,100**
Present Value of O&M over 20 years, at 7% rate					**$10,300**
TOTAL Life-Cycle Costs,Sunflower Mesa					**$96,900**
No. of connections, 2002	8			**Cost/connection, 2002:**	**$10,740**
No. of connections, 2040	10			**Cost/connection, 2040:**	**$8,590**

FREEDOM ACRES COSTS					
Annual Water Demand, kgal:	1,108				
Total Water Demand, kgal:	2,082				
Percentage per Freedom Acres:	53%				
Portion of Freedom Acres Extension Costs:				$	8,700.00
Annual Water Demand, kgal:	1,108				
Total Water Demand for Sunflower Extension, kgal:	2,082				
Percentage per Freedom Acres:	53%				
Portion of Sunflower Mesa Extension Costs:				$	43,265.12
Freedom Acres Pipeline Extension	(Pipeline from Sunflower Mesa to Freedom Acres)				
Pipeline - 6"	800	lf	$7.50	in-dia/lf	$36,000
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	200	lf	$40	lf	$8,000
Rock Excavation*	44	cy	$45	cy	$2,000
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.05	lump sum	$170,000	lump sum	$8,500
Booster Pump Stations	0	stations	$0	station	$0
				Subtotal, Freedom Acres Extension Cost	$99,500
				Contingencies @25%	$24,900
				Total Freedom Acres Extension Cost	*$124,400*
				Total Costs, Extension to Freedom Acres $	176,365
Portion of Wonder Valley WTP	1,108	kgallons	$10.25	kgallons	$11,356
				Total Capital Costs	**$187,700**
				Amortized Capital Costs	$17,700
Annual Operations and Maintenance	1,108	kgallons	$1.00	$/kgal	$1,100
				Total Annual Costs for Freedom Acres	**$18,800**
Present Value of O&M over 20 years, at 7% rate					**$11,700**
TOTAL Life-Cycle Costs,Freedom Acres					**$200,100**
No. of connections, 2002	13			**Cost/connection, 2002:**	**$14,440**
No. of connections, 2040	21			**Cost/connection, 2040:**	**$8,940**

East Verde Estates Water Extension - *serves communities of East Verde Estates and Flowing Springs*

Description	Quantity	Unit	Unit Cost	Unit	Cost
Main Pipeline Extension					
Pipeline - 6"	0	lf	$7.50	in-dia/lf	$0
Pipeline - 8"	14,800	lf	$7.50	in-dia/lf	$888,000
Pavement Surface Replacement	3,700	lf	$40	lf	$148,000
Rock Excavation*	958	cy	$45	cy	$43,100
Water/Wash Crossings	3	crossing	$45,000	crossing	$135,000
Traffic Control	0.5	lump sum	$170,000	lump sum	$85,000
Booster Pump Stations	0	stations	$0	station	$0
		Subtotal, East Verde Estates Main Extension Cost			$1,299,100
				Contingencies @25%	$324,800
				Total Extension Cost	***$1,623,900***
EAST VERDE ESTATES COSTS					
Annual Water Demand, kgal:	21,627				
Total Water Demand for Extension, kgal:	28,711				
Percentage per Verde Glen:	75%				
Portion of East Verde Main Extension Costs:					$ 1,223,200

Description	Quantity	Unit	Unit Cost	Unit	Cost
East Verde Pipeline Extension					
Pipeline - 6"	4,500	lf	$7.50	in-dia/lf	$202,500
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	1,125	lf	$40	lf	$45,000
Rock Excavation*	250	cy	$45	cy	$11,200
Water/Wash Crossings	2	crossing	$45,000	crossing	$90,000
Traffic Control	0.1	lump sum	$170,000	lump sum	$17,000
Booster Pump Stations	0	stations	$0	station	$0
		Subtotal, East Verde Estates Extension Cost			$365,700
				Contingencies @25%	$91,400
				Total Extension Cost	***$457,100***
				Total costs for connection to East Verde	***$1,680,300***
Portion of Payson WTP	21,627	kgallons	$6.40	kgallons	$138,410
				Total Capital Costs	**$1,818,700**
				Amortized Capital Costs	$171,700
Annual Operations and Maintenance	21,627	kgallons	$0.16	$/kgal	$3,440
		Total Annual Costs for East Verde Estates			**$175,100**
Present Value of O&M over 20 years, at 7% rate					**$36,600**
TOTAL Life-Cycle Costs,East Verde Estates					**$1,863,900**
No. of connections, 2002	164			Cost/connection, 2002:	**$11,090**
No. of connections, 2040	246			Cost/connection, 2040:	**$7,390**

FLOWING SPRINGS COSTS					
Annual Water Demand, kgal:	7,084				
Total Water Demand for Extension, kgal:	28,711				
Percentage per Verde Glen:	25%				
Portion of East Verde Main Extension Costs:					$ 400,700.00
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Flowing Springs Pipeline Extension					
Pipeline - 6"	5,000	lf	$7.50	in-dia/lf	$225,000
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	1,250	lf	$40	lf	$50,000
Rock Excavation*	278	cy	$45	cy	$12,500
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.1	lump sum	$170,000	lump sum	$17,000
Booster Pump Stations	1	stations	$108,000	station	$108,000
			Subtotal, Flowing Springs Extension Cost		$457,500
				Contingencies @25%	$114,400
				Total Extension Cost	***$571,900***
			Total Cost of Connection to Flowing Springs:		***$972,600***
Portion of Payson WTP	7,084	kgallons	$6.40	kgallons	$45,341
				Total Capital Costs	**$1,017,900**
				Amortized Capital Costs	$96,100
Annual Operations and Maintenance	7,084	kgallons	$0.16	$/kgal	$1,130
			Total Annual Costs for Flowing Springs		**$97,200**
Present Value of O&M over 20 years, at 7% rate					**$12,000**
TOTAL Life-Cycle Costs,Flowing Springs					**$1,034,700**
No. of connections, 2002	42			**Cost/connection, 2002:**	**$24,240**
No. of connections, 2040	80			**Cost/connection, 2040:**	**$12,720**

MESA DEL CABALLO COSTS					
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Pipeline Extension					
Pipeline - 6"	200	lf	$7.50	in-dia/lf	$9,000
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	50	lf	$40	lf	$2,000
Rock Excavation*	11	cy	$45	cy	$500
Water/Wash Crossings	0	crossing	$45,000	crossing	$0
Traffic Control	0.2	lump sum	$170,000	lump sum	$34,000
Booster Pump Stations	0	stations	$0	station	$0
				Subtotal, Extension Costs	**$45,500**
				Contingencies @25%	$11,400
				Total Extension Cost	***$56,900***
Mesa del Caballo WTP	40,657	kgallons	$10.25	kgallons	$416,700
				Total Capital Costs	**$473,600**
				Amortized Capital Costs	$44,700
Annual Operations and Maintenance	40,657	kgallons	$1.00	$/kgal	$40,500
			Total Annual Costs for Mesa del Caballo:		**$85,200**
Present Value of O&M over 20 years, at 7% rate					**$431,100**
TOTAL Life-Cycle Costs, Mesa del Caballo					**$907,000**
No. of connections, 2002	409			**Cost/connection, 2002:**	**$1,160**
No. of connections, 2040	455			**Cost/connection, 2040:**	**$1,040**

STAR VALLEY COSTS - Will assume use of existing Pipeline					
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Pipeline Extension					
Pipeline - 6"	0	lf	$7.50	in-dia/lf	$0
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	0	lf	$40	lf	$0
Rock Excavation*	0	cy	$45	cy	$0
Water/Wash Crossings	0	crossing	$45,000	crossing	$0
Traffic Control	0	lump sum	$170,000	lump sum	$0
Booster Pump Stations	0	stations	$556,000	station	$0
				Subtotal, Extension Costs	$0
				Contingencies @25%	$0
				Total Extension Cost	**$0**
Portion of Payson WTP	97,117	kgallons	$6.40	kgallons	$621,550
				Total Capital Costs	**$621,600**
				Amortized Capital Costs	$58,700
Annual Operations and Maintenance	97,117	kgallons	$0.16	$/kgal	$15,450
				Total Annual Costs for Star Valley	**$74,200**
Present Value of O&M over 20 years, at 7% rate					**$164,500**
TOTAL Life-Cycle Costs, Star Valley:					**$789,900**
No. of connections, 2002	461			**Cost/connection, 2002:**	**$1,350**
No. of connections, 2040	1,101			**Cost/connection, 2040:**	**$560**

Description	Quantity	Unit	Unit Cost	Unit	Cost
Round Valley Main Extension - *serves communities of Round Valley and Oxbow Estates from Town of Payson system*					
Main Pipeline Extension					
Pipeline - 6"	0	lf	$7.50	in-dia/lf	$0
Pipeline - 8"	9,800	lf	$7.50	in-dia/lf	$588,000
Pavement Surface Replacement	2,450	lf	$40	lf	$98,000
Rock Excavation*	635	cy	$45	cy	$28,600
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	1	lump sum	$170,000	lump sum	$170,000
Booster Pump Stations	1	stations	$104,000	station	$104,000
			Subtotal, Round Valley Main Extension Cost		$1,033,600
				Contingencies @25%	$258,400
				Total Extension Cost	***$1,292,000***
ROUND VALLEY COSTS					
Annual Water Demand, kgal:	11,796				
Total Water Demand for Extension, kgal:	13,686				
Percentage per Verde Glen:	86%				
Portion of Round Valley Extension Costs:			$60	$	1,113,600
Description	**Quantity**	**Unit**	**Unit Cost**	**Unit**	**Cost**
Round Valley Pipeline Extension					
Pipeline - 6"	0	lf	$7.50	in-dia/lf	$0
Pipeline - 8"	4,500	lf	$7.50	in-dia/lf	$270,000
Pavement Surface Replacement	1,125	lf	$40	lf	$45,000
Rock Excavation*	291	cy	$45	cy	$13,100
Water/Wash Crossings	1	crossing	$45,000	crossing	$45,000
Traffic Control	0.5	lump sum	$170,000	lump sum	$85,000
Booster Pump Stations	1	stations	$60,000	station	$60,000
			Subtotal, Round Valley Extension Cost		$518,100
				Contingencies @25%	$129,500
				Total Extension Cost	***$647,600***
			Total cost of connection to Round Valley:		***$1,761,200***
Portion of Payson WTP	11,796	kgallons	$6.40	kgallons	$75,500
				Total Capital Costs	**$1,836,700**
				Amortized Capital Costs	$173,400
Annual Operations and Maintenance	11,796	kgallons	$0.16	$/kgal	$1,880
			Total Annual Costs for Round Valley		**$175,300**
Present Value of O&M over 20 years, at 7% rate					**$20,000**
TOTAL Life-Cycle Costs,Round Valley:					**$1,866,100**
No. of connections, 2002	178			**Cost/connection, 2002:**	**$10,320**
No. of connections, 2040	242			**Cost/connection, 2040:**	**$7,590**

OXBOW ESTATES COSTS

Annual Water Demand, kgal:	1,890				
Total Water Demand for Extension, kgal:	13,686				
Percentage per Oxbow Estates:	14%				
Portion of Round Valley Main Extension Costs:				$	178,400

Description	Quantity	Unit	Unit Cost	Unit	Cost
Oxbow Estates Pipeline Extension					
Pipeline - 6"	6,650	lf	$7.50	in-dia/lf	$299,250
Pipeline - 8"	0	lf	$7.50	in-dia/lf	$0
Pavement Surface Replacement	1,663	lf	$40	lf	$66,500
Rock Excavation*	369	cy	$45	cy	$16,600
Water/Wash Crossings	2	crossing	$45,000	crossing	$90,000
Traffic Control	0.4	lump sum	$170,000	lump sum	$68,000
Booster Pump Stations	1	stations	$19,000	station	$19,000
			Subtotal, Oxbow Estates Extension Cost		$559,350
				Contingencies @25%	$139,800
				Total Extension Cost	***$699,150***
			Total cost of connection to Oxbow estates		***$877,550***
Portion of Payson WTP	1,890	kgallons	$6.40	kgallons	$12,100
				Total Capital Costs	**$889,700**
				Amortized Capital Costs	$84,000
Annual Operations and Maintenance	1,890	kgallons	$0.16	$/kgal	$300
			Total Annual Costs for Oxbow Estates		**$84,300**
Present Value of O&M over 20 years, at 7% rate					**$3,200**
TOTAL Life-Cycle Costs,Oxbow Estates					**$897,400**
No. of connections, 2002	70			**Cost/connection, 2002:**	**$12,710**
No. of connections, 2040	75			**Cost/connection, 2040:**	**$11,860**

ATTACHMENT 7

(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Social Assessment and Environmental Justice – Mogollon Rim Water Resource Management Study

MOGOLLON RIM WATER RESOURCE MANAGEMENT STUDY

SOCIAL ASSESSMENT AND ENVIRONMENTAL JUSTICE

A. Social Assessment

Social analysis is the process of considering impacts on humans, and social assessment is the product of the analysis (the results needed to describe the impacts on the human community from the action.

The goals of social analysis are to:

- Contribute to making projects more sound and sustainable by ensuring that projects fit the individuals and communities served and affected.
- Ensure project effectiveness by increasing support and tailoring institutional arrangements to the local culture.
- Make projects more inclusive by involving not only selected stakeholders but the larger, more diverse community

An extensive Social Analysis was not performed during this study. Rather an attempt has been made to identify significant area of social concern that could require additional research, analysis, and evaluation in subsequent studies. Social Assessment considerations for the Study Area include the following issues:

- Environmental Justice -- Distribution of minority population and low income populations of the Study Area within Gila County.
- Probable economic impacts – restrictive limits on growth for all economic units associated residential, commercial and industrial development and expansion.
- Reduced quality of life, changes in lifestyle, increased poverty in general, population migrations, reduction or modifications of recreation activities.
- Reevaluation of social values – growth vs. no-growth, community appearance, and cultural resources preservation and protection
- Public dissatisfaction with government water resource development and community growth policies and strategies -- moratorium on the issuance of water meters for community development (all considerations) and the introduction and application of restrictions on all community's planning and zoning policies and codes.
- Perceptions of inequity related to socioeconomic status, ethnicity, age, gender, and seniority, particularly with respect to water service rates.
- Recognition of institutional restraints on water use. Surface Water Rights
- Increased Restrictions and Conflicts -- Water user, Political, and Management (Community Fire Protection and Water Conservation), and (Other social conflicts?)
- Institutional Formation – Legal requirements and institutional organization

B. Environmental Justice

is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including a racial, ethnic, or a socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal and commercial operations or the execution of federal, state, local, and tribal programs and policies. Meaningful involvement means that; (1) potentially affected community residents have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision; (3) the concerns al all participants involved will be considered in the decision making process; and (4) the decision makers seek out and facilitate the involvement of those potentially affected.

In sum, environmental justice is the goal to be achieved for all communities and persons across this Nation. Environmental justice is achieved when everyone, regardless of race, culture, or income, enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.

Environmental justice must be considered and where required appropriate mitigation measures will be established that will not create disproportionately high and adverse human health or environmental effects of federal programs, policies, and activities on minority populations and low-income populations in the Study Area.

The populations that could be affected in the Study Area are minority and low income populations in the Study Area are, in general, Black or African Americans, American Indian and Alaska Native, Asian, Native Hawaiian and other Pacific Islander, and Hispanic or Latino. The minorities population distribution, by population centers and estimation are shown in Table A.

Table A Minority Population Distribution by Town and Census Designated Place (CDP)--- 2000.

Table A

Population Distribution Center	Gila County	Town of Payson	Pine CDP	Strawberry CDP
Minority Groups	**Population***	**Population***	**Population***	**Population***
Black or African American	197	36	3	1
American Indian and Alaska Native	6,630	257	10	6
Asian	220	72	2	7
Native Hawaiian and Other Pacific Islander	28	7	0	0
Some Other Race	3,385	183	21	10
Hispanic or Latino	8,546	708	34	32
Total	19,006	1,263	70	56

*2000 U. S. Bureau Census Data

The population distribution of minorities in the residual population of the Study Area's unincorporated community population, 4,762, is unknown, but mostly likely would be similar to the population distribution of minorities in the Pine and Strawberry Census Designated Places (CDP).

Low-Income populations are persons of low-income status. This status is based on U.S. Bureau of the Census definitions of individuals living below the poverty line, as defined by a statistical threshold that considers family size and income. Poverty levels census data -- 2000, in the Study Area, have been developed several ways, however, only two poverty status levels are presented in TableB., i.e. Families and Individuals.

Table B.

The Poverty Status of Families and Individuals in the Study Area. – 2000.

Population Distribution Center	Gila County	Town of Payson	Pine CDP	Strawberry CDP
Below Poverty Level	**Numbers**	**Numbers**	**Numbers**	**Numbers**
Families	1,785	274	31	24
Individuals	8,752	1,360	176	111

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There are enough population in both minorities and low-income groups to flag these population groups as being groups that will require further considerations regarding environmental justice with respect to any proposed action associated with any or all of the proposed alternative prior to its implementation, including the Future Without alternative.

Probable economic impacts – The local economy is dominated by the tourism, in-migrating retirees, and seasonal residents are the primary drivers of the Payson and surrounding area economy. Government provides the most employment of any sector in Payson area. Another significant area of the local economy is the construction industries. There is a growing emphasis on manufacturing and service firms. Also encouraged is light industry and high tech operations compatible with the community's "High Quality of Life."

With the overall water supply being limited in both Payson and the surrounding area, the potential for the placement of restrictive limits on growth or expansion, e.g. moratorium on the sale of water meters or limitations on the issuance of building permits, could occur and hinder all future residential, commercial and industrial economic growth. The placement of restrictive growth limits would have a serious economic impact upon the construction industry as well as having a trickle down effect on the rest of the supporting economic sectors in the area.

As certain economic sectors are impacted the expected results would be a reduced quality of life, changes in lifestyle, increased poverty in general, population migrations, reduction or modifications of recreation activities to identify a few of the potential impacts.

Reevaluation of social values – Payson and the surrounding communities and unincorporated areas could settle the ongoing argument concerning growth vs. no-growth. If the water supply is limited and the safe yield limits have been identified and perhaps encroached upon, it most likely that a political scenario would be developed that implements no-growth policies for Payson and the surrounding areas. Water currently used to maintain each community's appearance could be seriously reduced and perhaps eliminated from use. Other areas where water could be used but restricted or eliminated could include cultural resources preservation and protection and recreation facilities.

Public dissatisfaction with local government -- for past several years, water resource development and community growth policies and strategies have been hot topics with the citizens of Payson and the surrounding areas. Issues that have been regularly discussed over the years are growth and no-growth. In fact, election of mayors and council persons frequently revolve around this specific issue. Secondary to the growth and no-growth issues is water resource development. Issues associated with special use permits, for groundwater exploration and development in the National Forest, have been quite difficult to acquire by the Town of Payson. It is expected that acquisition of special use permits by others will be equally difficult. Discussions that evolve around moratoriums, whether zoning or water supply availability, i.e. water meters; create heated and divisive discussions within the community.

Perceptions of inequity related to the cost of water services and water supply development and their impact upon the socioeconomic status, ethnicity, age, gender, and seniority of Payson's citizens and the surrounding unincorporated communities will require additional study. The concerns over the issues of inequity may become may require special deliberations with respect to their impacts upon each group's or grouping's quality of life.

Recognition of institutional restraints on water use -- As noted through out this Report, surface water rights in the Study Area can generally be regarded as owned by the Salt River Project. Land ownership is also an institutional restraint in a geographic area that is primarily owned by Federal and State governments. Very little private land is available for developing well sites and other water system facilities needed system development, particularly groundwater wells and associated pipelines.

Increased Restrictions and Conflicts – As each community's water supply reaches its "Safe Yield" limitations, the challenge will be to establish a process for sustainable water supply management that will protect both the supply and serve the water user. Groundwater has been the primary water resource for this are for several years. However, this supply is susceptible to drought conditions. As the aquifer storage is diminished and the assumptions associated with "Safe Yield" are violated; the impacts and conflicts between and among groundwater users will increase. Impacts that could be noticed are the reduction in available fire protection, increased use of restrictive water conservation measures – including policing of water use. Efforts to mitigate these impacts could include use of effluent for as a source to provide fire protection, persistent application of water conservation measures rather than seasonal application of those same measures.

Drought may be another area that creates water use restrictions and conflicts. As aquifer deplete and recharge and aquifer recovery fails to provide for an adequate water supply for a community conflicts between water resource managers and water users will increase. There will be a need to focus upon the issues of water demand management and supplement water supplies to alleviate these shortages.

Institutional Formation – Legal requirements and institutional organization – The only known formation of a legal institutional arrangement is between the Town of Payson and the Tonto Apache Tribe. This action is an extension of previous service agreements between the Town and the Tribe.

All considered alternatives are on or near Federal lands. The probability of the any project being impacted by one or more Federal laws is quite high, i.e. it should be expected that some type of Federal impact will occur to either a community or the environment. What has been presented here is a preliminary social assessment. Certainly, more intense research, analysis, and evaluation would be required prior to the implementation of any proposed projects. Even the activities associated with Future Without Alternative would have to have the same level of investigation prior to the implementation of this Alternative, particularly where the projects implemented traverse Federal lands.

ATTACHMENT 8
(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

Estimation Work Sheets

MOGOLLON RIM WATER RESOURCE MANAGEMENT STUDY

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BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET__1__ OF __1__

FEATURE:	PROJECT:
C. C. Cragin Reservoir Water Supply Alternative Payson and Tonto Apache Tribe Only -- Raw Water Transmission Pipeline and Water Treatment Plant Cost Summary (Annual Water Supply = 3,7250 acre-feet per year	**Mogollon Rim Water Resource Management Study**
	WOID:
	ESTIMATE LEVEL: Appraisal
	REGION: LC
	PRICE LEVEL: 1st quarter 2008
	FILE: U:\PaysonAppraisalReport\Attach. 8\[C.C.Cragin Res to Payson Table IV29.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Tailrace Modifications		1	Lump Sum	$55,000	$55,000
		Raw Water Main Pipeline					
		Pipeline -- 18"		76,560	lf	$135	$10,335,600
		Pavement Replacement		57,420	lf	$40	$2,296,800
		Rock Excavation		29,774	cy	$45	$1,339,800
		Water/Wash Crossing		16	Crossing	$45,000	$720,000
		Traffic Control			Lump Sum	$170,000	$170,000
		Booster Pump Stations		0	Stations	$825,000	0
		Subtotal					$14,917,200
		Mobilization @ 5%					$745,900
		Subtotal with Mobilization					$15,663,100
		Unlisted Items @ 15%					$2,349,500
		Contract Cost					$18,012,600
		Contingencies @ 25%					$4,503,100
		Field Cost (1st qtr 2006)					$22,515,700
		Water Treatment Plant					
		General Requirements					$288,000
		Sitework					$640,000
		Microfiltration Building (1,600 sq ft)					$176,000
		Microfiltration Equipment					$1,780,000
		Disinfection					$275,000
		Finished Water Reservoir					$750,000
		Pump Station					$215,000
		Electrical					$703,000
		HVAC/Plumbing					$176,000
		Subtotal					$5,753,400
		Mobilization @ 5%					$287,700
		Subtotal with Mobilization					$6,041,100
		Unlisted Items @ 15%					$906,200
		Contract Cost					$6,974,300
		Contingencies @ 25%					$1,736,800
		Field Cost (1st qtr 2006)					$8,684,400
		Total Field Cost (1st qtr 2006)					$31,199,800
		Adjusted Field Cost (1st qtr 2008)					**$33,861,900**
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET__1__ OF __1__

FEATURE:	PROJECT:
C. C. Cragin Reservoir Water Supply Alternative	**Mogollon Rim Water Resource Management Study**
Pine Only with CAP--Raw WaterTransmission	
Pipeline and Water Treatment Plant	**WOID:** / **ESTIMATE LEVEL:** **Appraisal**
Annual Water Supply = 500 acre-feet per year	**REGION:** **LC** / **PRICE LEVEL:** **1st quarter 2008**
	FILE: U:\PaysonAppraisalReport\Attach. 8\[CCCraginPineStrawExtTableIV33.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Raw Water Main Pipeline					
		Pipeline -- 8"		80,256	lf	$60	$4,815,400
		Pavement Replacement		60,200	lf	$40	$2,408,000
		Rock Excavation		30,000	cy	$45	$1,350,000
		Water/Wash Crossing		16	Crossing	$45,000	$720,000
		Traffic Control			Lump Sum	$200,000	$200,000
		Booster Pump Stations		3	Stations	$825,000	$2,475,000
		Subtotal					$11,968,400
		Mobilization @ 5%					$598,400
		Subtotal with Mobilization					$12,566,800
		Unlisted Items @ 15%					$1,885,000
		Contract Cost					$14,451,800
		Contingencies @ 25%					$3,612,900
		Field Cost					**$18,064,700**
		Field Cost: Water Treatment Cost (see Pine Raw					**$1,895,800**
		Water Transmission Pipeline and Water Treatment					
		Plant Cost Summary)					
		Total Field Cost (1st qtr 2006)					**$19,960,500**
		Adjusted Field Cost (1st qtr 2008)					**$21,663,600**
		Annual Cost					
		Amortized Annual Cost (20 yrs @ 4,875%)					$1,719,900
		Annual Operation & Maintenance Cost @ 8%					$1,733,100
		of Field Cost					
		Total Annual Cost					$3,453,000
		Annual Cost per Acre-Foot					$6,906
		Annual Cost per 1,000 gallons					$21.19
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED June 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:	PROJECT:
C. C. Cragin Reservoir Water Supply Alternative *Tetra Tech's Group -- Houston Mesa Road and* *beyond to Round Valley and Oxbow Estates* *Field Cost Summary* *Source: Tetra Tech -- Base Cost*	**Mogollon Rim Water Resource Management Study** WOID: ESTIMATE LEVEL: **Appraisal** REGION: **LC** PRICE LEVEL: **1st quarter 2008** FILE: U:\PaysonAppraisalReport\Attach. 8\[Communities along HMRoad Table IVc32.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Washington Park					
		Subtotal (includes pipeline and WTP)					$248,500
		Mobilization @ 5%					$12,400
		Subtotal with Mobilization					$260,900
		Unlisted Items @ 15%					$39,100
		Contract Cost					$300,000
		Contingencies @ 25%					$75,000
		Field Cost (1st qtr 2006)					$375,000
		Adjusted Field Cost (1st qtr 2008)					$377,400
		Rim Trail DWID					
		Subtotal (includes pipeline and WTP)					$249,400
		Mobilization @ 5%					$12,500
		Subtotal with Mobilization					$261,800
		Unlisted Items @ 15%					$39,300
		Contract Cost					$301,100
		Contingencies @ 25%					$75,300
		Field Cost (1st qtr 2006)					$376,400
		Adjusted Field Cost (1st qtr 2008)					$378,700
		Verde Glen					
		Subtotal (includes pipeline and WTP)					$584,200
		Mobilization @ 5%					$29,200
		Subtotal with Mobilization					$613,400
		Unlisted Items @ 15%					$92,000
		Contract Cost					$705,400
		Contingencies @ 25%					$176,400
		Field Cost (1st qtr 2006)					$881,800
		Adjusted Field Cost (1st qtr 2008)					$887,300
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 30, 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:	PROJECT:
C. C. Cragin Reservoir Water Supply Alternative *Tetra Tech's Group -- Houston Mesa Road and* *beyond to Round Valley and Oxbow Estates* *Field Cost Summary* *Source: Tetra Tech -- Base Cost*	**Mogollon Rim Water Resource Management Study** WOID: ; ESTIMATE LEVEL: **Appraisal** REGION: **LC** ; PRICE LEVEL: **1st quarter 2008** FILE: U:\PaysonAppraisalReport\Attach. 8\[Communities along HMRoad Table IVc32.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Cowan Ranch					
		Subtotal (includes pipeline and WTP)					$82,200
		Mobilization @ 5%					$4,100
		Subtotal with Mobilization					$86,300
		Unlisted Items @ 15%					$13,000
		Contract Cost					$99,300
		Contingencies @ 25%					$24,800
		Field Cost (1st qtr 2006)					$124,100
		Adjusted Field Cost (1st qtr 2008)					$124,900
		Shadow Rim Ranch Girl Scout Camp					
		Subtotal (includes pipeline and WTP)					$236,500
		Mobilization @ 5%					$11,800
		Subtotal with Mobilization					$248,300
		Unlisted Items @ 15%					$37,200
		Contract Cost					$285,600
		Contingencies @ 25%					$71,400
		Field Cost (1st qtr 2006)					$357,000
		Adjusted Field Cost (1st qtr 2008)					$359,200
		Whispering Pines					
		Subtotal (includes pipeline and WTP)					$388,800
		Mobilization @ 5%					$19,400
		Subtotal with Mobilization					$408,200
		Unlisted Items @ 15%					$61,200
		Contract Cost					$469,500
		Contingencies @ 25%					$117,400
		Field Cost (1st qtr 2006)					$586,800
		Adjusted Field Cost (1st qtr 2008)					$590,500
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 30, 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

C. C. Cragin Reservoir Water Supply Alternative
Tetra Tech's Group -- Houston Mesa Road and
beyond to Round Valley and Oxbow Estates
Field Cost Summary
Source: Tetra Tech -- Base Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION: **LC**

PRICE LEVEL: **1st qtr 2008**

FILE: U:\PaysonAppraisalReport\Attach. 8\[Communities along HMRoad Table IVc32.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Beaver Valley					
		Subtotal (includes pipeline and WTP)					$322,200
		Mobilization @ 5%					$16,100
		Subtotal with Mobilization					$338,300
		Unlisted Items @ 15%					$50,700
		Contract Cost					$389,100
		Contingencies @ 25%					$97,300
		Field Cost (1st qtr 2006)					$486,300
		Adjusted Field Cost (1st qtr 2008)					$489,400
		Freedom Acres					
		Subtotal (includes pipeline and WTP)					$110,900
		Mobilization @ 5%					$5,500
		Subtotal with Mobilization					$116,400
		Unlisted Items @ 15%					$17,500
		Contract Cost					$133,900
		Contingencies @ 25%					$33,500
		Field Cost (1st qtr 2006)					$167,300
		Adjusted Field Cost (1st qtr 2008)					$168,400
		Wonder Valley					
		Subtotal (includes pipeline and WTP)					$64,900
		Mobilization @ 5%					$3,200
		Subtotal with Mobilization					$68,100
		Unlisted Items @ 15%					$10,200
		Contract Cost					$78,300
		Contingencies @ 25%					$19,600
		Field Cost (1st qtr 2006)					$97,900
		Adjusted Field Cost (1st qtr 2008)					$98,500
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 30, 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

C. C. Cragin Reservoir Water Supply Alternative
Tetra Tech's Group -- Houston Mesa Road and
beyond to Round Valley and Oxbow Estates
Field Cost Summary
Source: Tetra Tech -- Base Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION: **LC**

PRICE LEVEL: **1st quarter 2008**

FILE: U:\PaysonAppraisalReport\Attach. 8\[Communities along HMRoad Table IVc32.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Sunflower Mesa					
		Subtotal (includes pipeline and WTP)					$75,000
		Mobilization @ 5%					$3,700
		Subtotal with Mobilization					$78,700
		Unlisted Items @ 15%					$11,800
		Contract Cost					$90,500
		Contingencies @ 25%					$22,600
		Field Cost (1st qtr 2006)					$113,200
		Adjusted Field Cost (1st qtr 2008)					$113,900
		Mesa del Caballo					
		Subtotal (includes pipeline and WTP)					$462,200
		Mobilization @ 5%					$23,100
		Subtotal with Mobilization					$485,300
		Unlisted Items @ 15%					$72,800
		Contract Cost					$558,100
		Contingencies @ 25%					$139,500
		Field Cost (1st qtr 2006)					$697,600
		Adjusted Field Cost (1st qtr 2008)					$702,000
		East Verde Estates					
		Subtotal (includes pipeline and WTP)					$504,100
		Mobilization @ 5%					$25,200
		Subtotal with Mobilization					$529,300
		Unlisted Items @ 15%					$79,400
		Contract Cost					$608,700
		Contingencies @ 25%					$152,200
		Field Cost (1st qtr 2006)					$760,900
		Adjusted Field Cost (1st qtr 2008)					$765,700
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY **Marvin Murray**	CHECKED	BY	CHECKED
DATE PREPARED **April 30 2008**	PEER REVIEW	DATE PREPARED	PEER REVIEW

ESTIMATE WORKSHEET

FEATURE:

C. C. Cragin Reservoir Water Supply Alternative
Tetra Tech's Group -- Houston Mesa Road and
beyond to Round Valley and Oxbow Estates
Field Cost Summary
Source: Tetra Tech -- Base Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL: **1st qtr 2008**

FILE: U:\PaysonAppraisalReport\Attach. 8\[Communities along HMRoad Table IVc32.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Flowing Springs					
		Subtotal (includes pipeline and WTP)					$502,800
		Mobilization @ 5%					$25,100
		Subtotal with Mobilization					$528,000
		Unlisted Items @ 15%					$79,200
		Contract Cost					$607,200
		Contingencies @ 25%					$151,800
		Field Cost (1st qtr 2006)					$759,000
		Adjusted Field Cost (1st qtr 2008)					$763,800
		Town of Payson					
		Subtotal (includes pipeline and WTP)					$20,670,700
		Mobilization @ 5%					$1,033,500
		Subtotal with Mobilization					$21,704,200
		Unlisted Items @ 15%					$3,255,600
		Contract Cost					$24,959,800
		Contingencies @ 25%					$6,240,000
		Field Cost (1st qtr 2006)					$31,199,800
		Adjusted Field Cost (1st qtr 2008)					$33,861,900
		Town of Star Valley					
		Subtotal (includes pipeline and WTP)					$621,600
		Mobilization @ 5%					$31,100
		Subtotal with Mobilization					$652,600
		Unlisted Items @ 15%					$97,900
		Contract Cost					$750,500
		Contingencies @ 25%					$187,600
		Field Cost (1st qtr 2006)					$938,200
		Adjusted Field Cost (1st qtr 2008)					$944,100
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY: Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED: April 30, 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

C. C. Cragin Reservoir Water Supply Alternative
Tetra Tech's Group -- Houston Mesa Road and beyond to Round Valley and Oxbow Estates
Field Cost Summary
Source: Tetra Tech -- Base Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL: **1st qtr 2008**

FILE: U:\PaysonAppraisalReport\Attach. 8\[Communities along HMRoad Table IVc32.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Round Valley					
		Subtotal (includes pipeline and WTP)					$1,523,200
		Mobilization @ 5%					$76,200
		Subtotal with Mobilization					$1,599,400
		Unlisted Items @ 15%					$239,900
		Contract Cost					$1,839,300
		Contingencies @ 25%					$459,800
		Field Cost (1st qtr 2006)					$2,299,100
		Adjusted Field Cost (1st qtr 2008)					$2,313,600
		Oxbow Estates					
		Subtotal (includes pipeline and WTP)					$571,400
		Mobilization @ 5%					$28,600
		Subtotal with Mobilization					$600,000
		Unlisted Items @ 15%					$90,000
		Contract Cost					$690,000
		Contingencies @ 25%					$172,500
		Field Cost (1st qtr 2006)					$862,500
		Adjusted Field Cost (1st qtr 2008)					$868,000
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 30 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET__1__ OF __ 1__

FEATURE:	PROJECT:
Installation of wells near C. C. Cragin Reservoir	Mogollon Rim Water Resource Management Study
	WOID: — ESTIMATE LEVEL: Appraisal
Annual Groundwater Production = 3500 acre-feet	REGION: — PRICE LEVEL: 1st quarter 2008
	FILE:

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Well Field Cost		6	well	$500,000	$3,000,000
		Amortized -- 20 yrs @ 4,875%					$238,200
		Annual Operation & Maintenance Cost @ 8%					$240,000
		of Field Cost					$478,200
		Total Annual Cost					
		Annual Cost per Acre Foot					$137
		Annual Cost per 1,000 gallons					$0.42
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 30 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET__1__ OF __1__

FEATURE:

Central Arizona Project Water Supply Alternative
Option: Pine Creek
(Annual Water Volume = 161 acre-feet per year)
CAP Waters Only

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION: **LC**

PRICE LEVEL: **1st quarter 2008**

FILE: U:\PaysonAppraisalReport\Attach. 8\[PineWaterCoTableIV36&TableIV37.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Pine Creek Water Supply					
		Pipeline System					
		Diversion Structure		1	Lump Sum	$250,000	$250,000
		Pipeline -- 10"		2,640	lf	$75	$198,000
		Pavement Replacement		250	lf	$40	$10,000
		Rock Excavation		250	cy	$45	$67,500
		Water/Wash Crossing		1	Crossing	$45,000	$45,000
		Traffic Control		0.2	Lump Sum	$170,000	$42,500
		Booster Pump Station(s)		0	Stations	$104,000	0
		Subtotal					$613,000
		Mobilization @ 5%					$30,600
		Subtotal with Mobilization					$643,700
		Unlisted @ 15%					$96,600
		Contract Cost					$740,200
		Contingencies @ 25%					$185,000
		Field Cost (1st qtr 2006)					$925,200
		Water Treatment Plant					$649,300
		Finished Water Storage					$1,143,400
		Field Cost (1st Qtr 2006)					$1,792,700
		Total Field Cost (1st qtr 2006)					$2,717,900
		Adjusted Total Field Cost (1st qtr 2008) TFC					**$2,885,000**
		Annual Cost					
		Amortized (20 yrs @ 4.875%; CRF = 0.07939)					$229,000
		Operation & Maintenance @ 8% TFC					$230,800
		Total Annual Cost					**$459,800**
		Annual Cost per Acre-Foot					$2,856
		Annual Cost per 1,000 gallons					$8.76
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 30 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Central Arizona Project Water Supply Alternative
East Verde River Option
(Annual Water Supply = 161 acre-feet per year)

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION: **LC**

PRICE LEVEL: **1st qtr 2008**

FILE: U:\PaysonAppraisalReport\Attach. 8\[PineWaterCoTableIV36&TableIV37.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		East Verde River Water Supply					
		Water Delivery System					
		Diversion Structure		1	Lump Sum	$500,000	$500,000
		Pipeline -- 6"		52,272	lf	$45	$2,352,200
		Pavement Replacement		52,272	lf	$40	$2,090,900
		Rock Excavation		20,000	cy	$45	$900,000
		Water/Wash Crossing		5	Crossing	$45,000	$225,000
		Traffic Control		1	Lump Sum	$170,000	$170,000
		Booster Pump Station(s)		3	Stations	$882,000	$2,646,000
		Subtotal					$8,384,100
		Mobilization @ 5%					$419,200
		Subtotal with Mobilization					$8,803,300
		Unlisted @ 15%					$1,320,500
		Contract Cost					$10,123,800
		Contingencies @ 25%					$2,531,000
		Field Cost (1st qtr 2006)					$12,654,800
		Water Treatment Plant					$649,300
		Finished Water Storage					$1,143,400
							$1,792,700
		Total Field Cost (1st qtr 2006)					$14,447,500
		Adjusted Total Field Cost (1st qtr 2008) TFC					**$15,680,200**
		Annual Cost					
		Amortized (20 yrs @ 4.875%; CRF = 0.07939)					$1,150,000
		Operation & Maintenance @ 8% TFC					$1,254,400
		Total Annual Cost					**$2,404,400**
		Annual Cost per Acre-Foot					$14,934
		Annual Cost per 1,000 gallons					$45.83
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 30, 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Central Arizona Project Water Supply Alternative
East Verde River Option
(Annual Water Supply = 661 acre-feet per year)

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION: **LC**

PRICE LEVEL: **1st qtr 2008**

FILE: U:\PaysonAppraisalReport\Attach. 8\[PineWaterCoTableIV36&TableIV37.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		East Verde River Water Supply					
		Water Delivery System					
		Diversion Structure		1	Lump Sum	$500,000	$500,000
		Pipeline -- 8"		52,272	lf	$45	$3,136,300
		Pavement Replacement		52,272	lf	$40	$2,090,900
		Rock Excavation		20,000	cy	$45	$900,000
		Water/Wash Crossing		5	Crossing	$45,000	$225,000
		Traffic Control		1	Lump Sum	$170,000	$170,000
		Booster Pump Station(s)		3	Stations	$882,000	$2,646,000
		Subtotal					$9,668,200
		Mobilization @ 5%					$483,400
		Subtotal with Mobilization					$10,151,600
		Unlisted @ 15%					$1,522,700
		Contract Cost					$11,374,400
		Contingencies @ 25%					$2,918,600
		Field Cost (1 qtr 2006)					$14,592,900
		Water Treatment Plant					$649,300
		Finished Water Storage					$1,143,400
							$1,792,700
		Total Field Cost (1st qtr 2006)					$21,960,900
		Adjusted Total Field Cost (1st qtr 2008)					$23,834,700
		Annual Cost					
		Amortized (20 yrs @ 4.875%; CRF = 0.07939)					$1,897,245
		Operation & Maintenance @ 8% TFC					$1,906,800
		Total Annual Cost					**$3,804,000**
		Annual Cost per Acre-Foot					$5,755
		Annual Cost per 1,000 gallons					$17.66
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY: Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED: April 30, 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET__1__ OF __1__

FEATURE: ***ADOT HWY 260 Surface Water Diversion***

Station 0+00 is located at or near Lion Springs @ HWY 260
Pipeline Terminus is at or near Kohl's Ranch @ HWY 260
Communities that could be served include Kohl's Ranch, Pine Meado, Thompson Draw I & II, and Tonto Village. One or more of these communities can use all of the expected water supply from this source, i.e 100 acre-feet per annum

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION **LC**

PRICE LEVEL: **1st quarter 2008**

FILE:

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		HWY 260 Transmission Pipeline					
		Pipeline -- 6" (dip -- 350 psi class)		54,542	lf	$45.00	$ 2,454,400
		Pipeline -- 8" (dip -- 350 psi class)		0	lf	$60.00	$ 0
		Pavement Surface Replacement		10,560	lf	$40.00	$ 422,400
		Rock Excavation		14,667	cy	$45.00	$ 660,000
		Water/Wash Crossing		10	Crossing	$45,000	$ 450,000
		Traffic Control		1	Lump Sum	$170,000	$ 170,000
		Booster Pump Stations		1	Stations	$167,000	$ 167,000
		Subtotal					$ 4,323,800
		Mobilization @ 5%					$ 216,200
		Subtotal with Mobilization					$ 4,540,000
		Unlisted Items @ 15%					$ 681,000
		Contract Cost					$ 5,221,000
		Contingencies @ 25%					$ 1,305,200
		Field Cost (1st qtr 2006)					$ 6,526,200
		Probable Purchase Cost of Existing Facilites					$ 2,500,000
		Assumption: water treatment facilities, storage, and					
		recovery, and disinfection systems are included					
		and operable.					
		Field Cost with ADOT Facilities					$ 9,583,000
		Field Cost adjusted to 1st qtr. 2008 -- FC					
		Annual Cost					
		Amortized @ 20 yrs, I = 4.875%; CRF = 0.07939					$ 760,800
		Operation & Maintenance @ 8% FC					$ 766,600
		Total Annual Cost					$ 1,527,400
		Annual Cost per Acre-Foot					$ 15,274
		Annual Cost per 1,000 gallons					$ 46.87
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	**CHECKED**	**BY**	**CHECKED**
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ESTIMATE WORKSHEET

FEATURE:	**PROJECT:**
Sub-Regional Groundwater Alternative Individual, Cluster and Group Field Cost and Associated Annual Cost	**Mogollon Rim Water Resource Management Study**
	WOID:
	ESTIMATE LEVEL: **Appraisal**
	REGION:
	PRICE LEVEL: **1st quarter 2008**
	FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Non-Cluster Communities						
	Camp Geronimo						
		2040 Annual Low Water Demand = 19 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$322
		Annual Cost per 1,000 gallons					$0.99
	Geronimo Estates						
		2040 Annual Low Water Demand = 84 af/yr					
		Low volume production well(s)		3	20 gpm	$38,400	$115,200
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$115,200
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$9,100
		Annual O & M Cost @ 8% of FC					$9,200
		Total Annual Cost					$18,400
		Annual Cost per Acre-Foot					$219
		Annual Cost per 1,000 gallons					$0.67
	Bonita Creek						
		2040 Annual Low Water Demand = 27 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$227
		Annual Cost per 1,000 gallons					$0.70
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		**PRICES**	
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PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Non-Cluster Communities						
	Diamond Point Recreation						
		2040 Annual Low Water Demand = 15 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$408
		Annual Cost per 1,000 gallons					$1.25
	Kohl's Ranch						
		2040 Annual Low Water Demand = 62 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$197
		Annual Cost per 1,000 gallons					$0.61
	Tonto Creek Estates						
		2040 Annual Low Water Demand = 21 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$291
		Annual Cost per 1,000 gallons					$0.89
	Note: The estimate does not include Non-contract costs.						

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FEATURE:

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PROJECT: **Mogollon Rim Water Resource Management Study**

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FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 1						
	Pine Water Company						
		2040 Annual Low Water Demand = 1128 af/yr					
		Low volume production well(s)		5	20 gpm	$38,400	$192,000
		High volume production well(s)		4	150 gpm	$350,000	$1,400,000
		Field Cost (FC)					$1,592,000
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$126,400
		Annual O & M Cost @ 8% of FC					$127,400
		Total Annual Cost					$253,700
		Annual Cost per Acre-Foot					$225
		Annual Cost per 1,000 gallons					$0.69
	Pine Creek Canyon DWID						
		2040 Annual Low Water Demand = 58 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$211
		Annual Cost per 1,000 gallons					$0.65
	Pine Water Association DWID						
		2040 Annual Low Water Demand = 18 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$340
		Annual Cost per 1,000 gallons					$1.04
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
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	WOID:
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	PRICE LEVEL: 1st quarter 2008
	FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 1						
	Solitude Trails DWID						
		2040 Annual Low Water Demand = 25 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	38,400
		High volume production well(s)		0	150 gpm	$350,000	0
		Field Cost (FC)					38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$245
		Annual Cost per 1,000 gallons					$0.75
	Strawberry Hollow DWID						
		2040 Annual Low Water Demand= 23 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$266
		Annual Cost per 1,000 gallons					$0.82
	Strawberry Water Company (Brooke)						
		2040 Annual Low Water Demand = 672 af/yr					
		Low volume production well(s)		0	20 gpm	$38,400	$0
		High volume production well(s)		3	150 gpm	$350,000	$1,050,000
		Field Cost (FC)					$1,050,000
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$83,400
		Annual O & M Cost @ 8% of FC					$84,000
		Total Annual Cost					$167,400
		Annual Cost per Acre-Foot					$249
		Annual Cost per 1,000 gallons					$0.76
	Note: The estimate does include Non-contract costs.						

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PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 1						
	Strawberry Water Company						
		2040 Annual Low Water Demand = 23 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$266
		Annual Cost per 1,000 gallons					$0.82
	Cluster 1 -- Sub-Regional System						
		2040 Annual Low Water Demand=1,947 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		8	150 gpm	$350,000	$2,800,000
		Field Cost (FC)					$2,838,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$225,300
		Annual O & M Cost @ 8% of FC					$227,100
		Total Annual Cost					$452,400
		Annual Cost per Acre-Foot					$232
		Annual Cost per 1,000 gallons					$0.71
	Note: The estimate does include Non-contract costs.						

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PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 2						
	Washington Park						
		2040 Annual Low Water Demand = 5 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$1,224
		Annual Cost per 1,000 gallons					$3.76
	Rim Trail DWID						
		2040 Annual Low Water Demand = 48 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$255
		Annual Cost per 1,000 gallons					$0.78
	Shadow Rim Ranch						
		2040 Annual Low Water Demand = 7 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	38,400
		High volume production well(s)		0	150 gpm	$350,000	0
		Field Cost (FC)					38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					3,000
		Annual O & M Cost @ 8% of FC					3,100
		Total Annual Cost					6,100
		Annual Cost per Acre-Foot					874
		Annual Cost per 1,000 gallons					$2.68
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
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PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 2						
	Whispering Pines						
		2040 Annual Low Water Demand = 74 af/yr					
		Low volume production well(s)		3	20 gpm	$38,400	$115,200
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$115,200
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$9,100
		Annual O & M Cost @ 8% of FC					$9,200
		Total Annual Cost					$18,400
		Annual Cost per Acre-Foot					$248
		Annual Cost per 1,000 gallons					$0.76
	Cowan Ranch						
		2040 Annual Low Water Demand = 7 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$874
		Annual Cost per 1,000 gallons					$2.68
	Verde Glen						
		2040 Annual Low Water Demand = 37 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$331
		Annual Cost per 1,000 gallons					$1.02
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
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PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 2						
	Cluster 2 -- Sub-Regional System						
		2040 Annual Low Water Demand = 178 af/yr					
		Low volume production well(s)		6	20 gpm	$38,400	$230,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$230,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$18,300
		Annual O & M Cost @ 8% of FC					$18,400
		Total Annual Cost					$36,700
		Annual Cost per Acre-Foot					$206
		Annual Cost per 1,000 gallons					$0.63
	Sub-Region One - Cluster 3						
	Zane Grey Meadows						
		2040 Annual Low Water Demand = 6 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$1,020
		Annual Cost per 1,000 gallons					$3.13
	Collins Ranch						
		2040 Annual Low Water Demand = 11 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$556
		Annual Cost per 1,000 gallons					$1.71
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
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PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 3						
	Mead Ranch						
		2040 Annual Low Water Demand = 41 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$299
		Annual Cost per 1,000 gallons					$0.92
	Cluster 3 -- Sub-Regional System						
		2040 Annual Low Water Demand = 58 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$211
		Annual Cost per 1,000 gallons					$0.65
	Sub-Region One - Cluster 4						
	Ellison Creek Recreation						
		2040 Annual Low Water Demand = 19 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$322
		Annual Cost per 1,000 gallons					$0.99
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
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PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 4						
	Ellison Creek Estates						
		2040 Annual Low Water Demand = 26 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$235
		Annual Cost per 1,000 gallons					$0.72
	Cluster 4 -- Sub-Regional System						
		2040 Annual Low Water Demand = 45 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$272
		Annual Cost per 1,000 gallons					$0.83
	Note: The estimate does not include Non-contract costs.						

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PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 5						
	Thompson Draw I&II						
		2040 Annual Low Water Demand = 27 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$227
		Annual Cost per 1,000 gallons					$0.70
	Tonto Village						
		2040 Annual Low Water Demand = 114 af/yr					
		Low volume production well(s)		4	20 gpm	$38,400	$153,600
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$153,600
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$12,200
		Annual O & M Cost @ 8% of FC					$12,300
		Total Annual Cost					$24,500
		Annual Cost per Acre-Foot					$215
		Annual Cost per 1,000 gallons					$0.66
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
BY Marvin Murray	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED April 30 2008	**PEER REVIEW**	**DATE PREPARED**	**PEER REVIEW**

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET__12__ OF __18 __

FEATURE:

Sub-Regional Groundwater Alternative
Individual, Cluster and Group Field Cost and
Associated Annual Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL: **1st quarter 2008**

FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 5						
	Wood Canyon Ranch						
		2040 Annual Low Water Demand = 84 af/yr					
		Low volume production well(s)		3	20 gpm	$38,400	$115,200
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$115,200
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$9,100
		Annual O & M Cost @ 8% of FC					$9,200
		Total Annual Cost					$18,400
		Annual Cost per Acre-Foot					$219
		Annual Cost per 1,000 gallons					$0.67
	Cluster 5 -- Sub-Regional System						
		2040 Annual Low Water Demand = 225 af/yr					
		Low volume production well(s)		7	20 gpm	$38,400	$268,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$268,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$21,300
		Annual O & M Cost @ 8% of FC					$21,500
		Total Annual Cost					$42,800
		Annual Cost per Acre-Foot					$190
		Annual Cost per 1,000 gallons					$0.58
	Sub-Region One - Cluster 6						
	Bear Flat						
		2040 Annual Low Water Demand = 46 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$266
		Annual Cost per 1,000 gallons					$0.82
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
BY Marvin Murray	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED April 30 2008	**PEER REVIEW**	**DATE PREPARED**	**PEER REVIEW**

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Sub-Regional Groundwater Alternative
Individual, Cluster and Group Field Cost and
Associated Annual Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL: **1st quarter 2008**

FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 6						
	Christopher Creek						
		2040 Annual Low Water Demand = 183 af/yr					
		Low volume production well(s)		6	20 gpm	$38,400	$230,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$230,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$18,300
		Annual O & M Cost @ 8% of FC					$18,400
		Total Annual Cost					$36,700
		Annual Cost per Acre-Foot					$201
		Annual Cost per 1,000 gallons					$0.62
	Hunter Creek						
		2040 Annual Low Water Demand = 54 af/yr					
		Low volume production well(s)		2	20 gpm	$38,400	$76,800
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$76,800
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$6,100
		Annual O & M Cost @ 8% of FC					$6,100
		Total Annual Cost					$12,200
		Annual Cost per Acre-Foot					$227
		Annual Cost per 1,000 gallons					$0.70
	R Bar C Boy Scout Camp						
		2040 Annual Low Water Demand = 3 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$2,040
		Annual Cost per 1,000 gallons					$6.26
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
BY Marvin Murray	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED April 30 2008	**PEER REVIEW**	**DATE PREPARED**	**PEER REVIEW**

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Sub-Regional Groundwater Alternative
Individual, Cluster and Group Field Cost and
Associated Annual Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL: **1st quarter 2008**

FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region One - Cluster 6						
	Cluster 6 - Sub-Regional System						
		2040 Annual Low Water Demand = 286 af/yr					
		Low volume production well(s)		9	20 gpm	$38,400	$345,600
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$345,600
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$27,400
		Annual O & M Cost @ 8% of FC					$27,600
		Total Annual Cost					$55,100
		Annual Cost per Acre-Foot					$193
		Annual Cost per 1,000 gallons					$0.59
	Sub-Region Two						
	Arrowhead Canyon						
		2040 Annual Low Water Demand = 3 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$2,040
		Annual Cost per 1,000 gallons					$6.26
	Sub-Region Three - Individual Communities						
	Mesa Del Caballo						
		2040 Annual Low Water Demand = 147 af/yr					
		Low volume production well(s)		5	20 gpm	$38,400	$192,000
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$192,000
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$15,200
		Annual O & M Cost @ 8% of FC					$15,400
		Total Annual Cost					$30,600
		Annual Cost per Acre-Foot					$208
		Annual Cost per 1,000 gallons					$0.64
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
BY **Marvin Murray**	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED **April 30 2008**	**PEER REVIEW**	**DATE PREPARED**	**PEER REVIEW**

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Sub-Regional Groundwater Alternative Individual, Cluster and Group Field Cost and Associated Annual Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL: **1st quarter 2008**

FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region Three - Individual Communities						
	Flowing Springs						
		2040 Annual Low Water Demand = 26 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$235
		Annual Cost per 1,000 gallons					$0.72
	East Verde Estates						
		2040 Annual Low Water Demand = 79 af/yr					
		Low volume production well(s)		3	20 gpm	$38,400	$115,200
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$115,200
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$9,100
		Annual O & M Cost @ 8% of FC					$9,200
		Total Annual Cost					$18,400
		Annual Cost per Acre-Foot					$232
		Annual Cost per 1,000 gallons					$0.71
	Summit Springs						
		2040 Annual Low Water Demand = 9 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$680
		Annual Cost per 1,000 gallons					$2.09
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
BY Marvin Murray	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED April 30 2008	**PEER REVIEW**	**DATE PREPARED**	**PEER REVIEW**

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Sub-Regional Groundwater Alternative
Individual, Cluster and Group Field Cost and
Associated Annual Cost

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL: **1st quarter 2008**

FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region Three - Individual Communities						
	Star Valley						
		2040 Annual Low Water Demand = 509 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		2	150 gpm	$350,000	$700,000
		Field Cost (FC)					$738,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$58,600
		Annual O & M Cost @ 8% of FC					$59,100
		Total Annual Cost					$117,700
		Annual Cost per Acre-Foot					$231
		Annual Cost per 1,000 gallons					$0.71
	Sub-Region Three - Group 7						
	Beaver Valley						
		2040 Annual Low Water Demand = 113 af/yr					
		Low volume production well(s)		4	20 gpm	$38,400	$153,600
		High volume production well(s)		0	150 gpm	$350,000	
		Field Cost (FC)					$153,600
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$12,200
		Annual O & M Cost @ 8% of FC					$12,300
		Total Annual Cost					$24,500
		Annual Cost per Acre-Foot					$217
		Annual Cost per 1,000 gallons					$0.66
	Freedom Acres						
		2040 Annual Low Water Demand = 7 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$874
		Annual Cost per 1,000 gallons					$2.68
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
BY Marvin Murray	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED April 30 2008	**PEER REVIEW**	**DATE PREPARED**	**PEER REVIEW**

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Sub-Regional Groundwater Alternative
Individual, Cluster and Group Field Cost and
Associated Annual Cost

PROJECT: 1

Mogollon Rim Water Resource Management Study

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL: **1st quarter 2008**

FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region Three - Group 7						
	Wonder Valley						
		2040 Annual Low Water Demand = 8 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$765
		Annual Cost per 1,000 gallons					$2.35
	Group 7 - Sub-Regional System						
		2040 Annual Low Water Demand = 128 af/yr					
		Low volume production well(s)		4	20 gpm	$38,400	$153,600
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$153,600
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$12,200
		Annual O & M Cost @ 8% of FC					$12,300
		Total Annual Cost					$24,500
		Annual Cost per Acre-Foot					$191
		Annual Cost per 1,000 gallons					$0.59
	Sub-Region Three - Group 8						
	Round Valley						
		2040 Annual Low Water Demand = 78 af/yr					
		Low volume production well(s)		3	20 gpm	$38,400	$115,200
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$115,200
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$9,100
		Annual O & M Cost @ 8% of FC					$9,200
		Total Annual Cost					$18,400
		Annual Cost per Acre-Foot					$235
		Annual Cost per 1,000 gallons					$0.72
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
BY **Marvin Murray**	CHECKED	BY	CHECKED
DATE PREPARED **April 30 2008**	PEER REVIEW	DATE PREPARED	PEER REVIEW

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Sub-Regional Groundwater Alternative
Individual, Cluster and Group Field Cost and
Associated Annual Cost

PROJECT: Mogollon Rim Water Resource Management Study

WOID:

ESTIMATE LEVEL: Appraisal

REGION:

PRICE LEVEL: 1st quarter 2008

FILE:

PLANT ACCOUNT	PAY ITEM		CODE	QUANTITY	UNIT	UNIT PRICE	FIELD COSTAMOUNT
	Sub-Region Three - Group 8						
	Oxbow Estates						
		2040 Annual Low Water Demand = 34 af/yr					
		Low volume production well(s)		1	20 gpm	$38,400	$38,400
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$38,400
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$3,000
		Annual O & M Cost @ 8% of FC					$3,100
		Total Annual Cost					$6,100
		Annual Cost per Acre-Foot					$182
		Annual Cost per 1,000 gallons					$0.56
	Group 8 - Sub-Regional System						
		2040 Annual Low Water Demand = 112 af/yr					
		Low volume production well(s)		4	20 gpm	$38,400	$153,600
		High volume production well(s)		0	150 gpm	$350,000	$0
		Field Cost (FC)					$153,600
		Annual Cost					
		Amortization: n = 20 yrs; I = 4.875%					$12,200
		Annual O & M Cost @ 8% of FC					$12,300
		Total Annual Cost					$24,500
		Annual Cost per Acre-Foot					$219
		Annual Cost per 1,000 gallons					$0.67
	Note: The estimate does not include Non-contract costs.						

QUANTITIES		PRICES	
BY Marvin Murray	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED April 30 2008	**PEER REVIEW**	**DATE PREPARED**	**PEER REVIEW**

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET__1_ OF __1 __

FEATURE:

Tonto Apache Tribe
Roosevelt Lake Option
(Annual Water Supply = 128 acre-feet per year)
Reclamation Construction Cost Trend Adjusted

Original Cost:Gookin Engineers 1992

PROJECT: **Mogollon Rim Water Resource Management Study**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION: **LC**

PRICE LEVEL: **1st qtr 2008**

FILE: U:\PaysonAppraisalReport\Attach. 8\[TontoRooseveltTableIV37.xls]Sheet1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	Original Price -- 3rd Qtr 1992	Index Adjusted Price -- 1st Qtr 2008
		Roosevelt Lake Option					
		Water Delivery System					
		Pipeline		253,440	lf	$29,146,100	$48,477,700
		Intake Facility		1	unit	$10,000	$16,600
		Pump Houses (2 pumps per unit)		22	unit	$2,530,000	$4,208,100
		Water Treatment Plant (7mgd)		1	mgd	$3,500,000	$2,521,400
		Storage (1 mg)		1	mgd	$200,000	$332,600
		Electric Lines & Substations		Varies	lf	$5,481,500	$9,117,200
		O&M Equipment		Varies	System	$34,000	$56,551
		Subtotal				$40,901,600	$68,030,200
		Mobilization @ 5%				$2,045,100	$3,401,200
		Subtotal with Mobilization				$42,946,700	$71,430,800
		Unlisted Items @ 15%				$6,442,000	$10,714,800
		Contract Cost				$49,388,700	$82,146,500
		Contingencies @ 25%				$12,347,200	$20,536,600
		Field Cost				**$60,735,900**	**$101,581,400**
		Annual Cost					
		Amortized 20yr @ 8.5%; 0.10568)				$6,523,800	$0
		Amortized 20yr @ 4.875%; 0.07939)				$0	$8,064,600
		Operation & Maintenance @ 8% FC				$4,938,870	$8,126,500
		Total Annual Cost				**$11,462,600**	**$16,191,100**
		Annual Cost per Acre-Foot				$71,196	$126,493
		Annual Cost per 1,000 gallons				218.49	388.19
		Note: The estimate does not include Non-contract costs.					

QUANTITIES		PRICES	
BY Marvin Murray	CHECKED	BY	CHECKED
DATE PREPARED April 30, 2008	PEER REVIEW	DATE PREPARED	PEER REVIEW

ATTACHMENT 9

(Supplemental Documentation to the: Mogollon Rim Water Resource Management Study Report of Findings)

A review of Water Resource Investigations and Other related Information for the Mogollon Rim Water Resource Management study

MOGOLLON RIM WATER SUPPLY STUDY

Introduction

While the recorded and evidential history for the study area goes back to the 16th century, the focus of this report will be upon the history or water resource development within the study area since the beginning of the 20th century. There is an extensive history of water supply development in the study area of the Mogollon Rim Water Supply Study. The water resource development history starts near the beginning of the twentieth century with the development of the Salt River Project.

Once the planning for the project was completed, the U.S. Congress authorized the Project and appropriated funds for its construction. In terms of water resource development this action by the Congress was an important decision to support a water project for the Salt River Valley, which includes Phoenix and surrounding communities.

When this project was constructed and placed into operation, the capture and delivery of this water into the Salt River Valley created a major impact upon the total water resources of the entire study area. The first impact on the watershed was the construction of the facilities required to support the Project. The second impact was the assignment of water rights to the Project; and thirdly, the associated establishment of the Tonto National Forest to preserve and protect the watershed, as well as for other purposes, to sustain the development of the watershed's water resources for the Project.

The Town of Payson and the unincorporated communities of Pine and Strawberry were founded in 1884 with the establishment of local post offices. Payson was incorporated as a Town in 1973. Pine and Strawberry do not intend to become incorporated communities at any time in the foreseeable future (2004).

Offered below is a review of the water resource development studies completed by Payson, Pine and Strawberry for the time period 1971 to the present. Other portions of the historic review reflect early time periods associated with the establishment of the Salt River Project, Tonto National Forest, and the Central Arizona Project.

A. History of Water Supply Development and Management in the Study Area

It is important to start with some relationship to the timing of events that have led to the planning efforts associated with the Mogollon Rim Water Supply Study. The first event will be a brief review of the establishment of the Salt River Project and the Tonto National Forest. The rest of the historical review will focus upon the water resource development efforts of the Town of Payson, the Pine and Strawberry Water Improvement District, and other water resource studies prepared by Gila County, in association with the Arizona Department of Water Resources.

B. Salt River Project

The Salt River Project (SRP) includes a water service area of about 250,000 acres in Maricopa County. The member lands within SRP are provided water annually for irrigation, municipal and industrial uses. Surface water is derived from the 13,000 square mile watersheds of the Salt and Verde Rivers. Supplemental water is provided from 250 groundwater wells within the water service area. SRP also provides power within a 2,900 square mile service area spanning Maricopa, Gila and Pinal counties in Central Arizona.

SRP was created in 1903 when landowners in the Salt River Valley (Phoenix area) formed the Salt River Valley Water Users' Association, in accordance with the National Reclamation Act (Act). Individual property owners within the water service area pledged their land as collateral for a federal government loan to build Theodore Roosevelt Dam, the cornerstone of SRP's water operations. SRP was the nation's first multipurpose reclamation project authorized under the Act.

In its early days, the Salt River Valley Water User's Association was an uneasy alliance. Disputes about water rights were common. The Articles of Incorporation of the Salt River Valley Water User's Association (Association) did not determine the prior water rights of individual landowner's nor were these rights defined in the contract between the Association and the federal government.

Before the federal government would invest money to build storage facilities to capture flood flows on the Salt River as contemplated by the Act, a system would have to be in place to distribute the natural or normal flow, of the Salt River and its tributaries. Washington officials wanted shareholders to settle these water rights claims to the use of the normal flow of the Salt River and its tributaries to avoid future conflicts between the users of stored water and the owners of prior vested water rights.

In 1905, Judge Kibbey filed an action to quiet title the water rights of Patrick T. Hurley against Charles Abbott and other Salt River Valley landowners. As one of the prime movers of the Association, Hurley volunteered to file the friendly suit to force a decision on water rights issues. On March 1, 1910, after five years of gathering and studying evidence, Judge Edward Kent sitting as the district judge, handed down a decision that endures even today.

The Kent Decree established the relative rights of the Association lands to the normal flow of water of the Salt River and its tributaries. The decree formally stated the principle of normal-flow rights and prior appropriation, and reaffirmed the principle of appurtenancy, thus tying water to the land. Kent's ruling concerns lands that used water from the Salt River from 1869 through 1909 diverted at or above the Joint Head Dam (on the Salt River near what is now 48th Street.)

With the issuance of the Kent Decree that recognized the water rights within the Salt River Project, and the creation of several national Forests, the regional surface water rights were established and protected. The remaining funding was released from the federal government for the construction of Roosevelt Dam and the dam was completed in 1911. While creating a water storage facility for SRP, the communities that lie within the

Salt and Verde watersheds were either not in existence or so small those available resources were sufficient to meet their water demands. Over the past few decades water demand in smaller watershed communities has boomed, requiring the importation of new water supplies or significant capital expenditures in search of alternative water supplies.

C. Tonto National Forest

The Tonto National Forest owes its existence to a singular historic event that took place shortly after the turn of the (20^{th}) century -- the building of Roosevelt Dam to control the Salt River and ensure the water supply of what was then the heavily agricultural cities of Phoenix, Mesa, and Tempe in the Salt River Valley.

The National Forest was created in 1905 to protect the watersheds of the Salt and Verde rivers. This continues to be a central focus of the Tonto National Forest; however all of the mandates for managing the Forest for all resource values and uses are still applicable to the Tonto (National Forest). In response to the growing need for water to support community needs while still protecting the forest environment, the Southwestern Region of the Forest Service adopted a policy, on September 5, 2001, that gives specific direction for consideration of consumptive use of water uses and development from National Forest lands.

The major focus for the current management direction of the Forest is the improvement of Forest health and fuels reduction. The ongoing drought situation has exacerbated the mortality from insect infestation as well as presented nearly unprecedented fire hazards to western Forests and communities. Efforts are now underway to use prescribed fire and mechanical treatments to thin the Forests to pre-settlement era levels to mimic conditions when natural fire played the predominant role in the ecosystem. The thinned forest is reasonably expected to have the added benefit of increasing watershed shed runoff.

D. Town of Payson

There are numerous water resource studies which have been performed regarding Payson's portion of the Study Area between 1972 and 2004. A summary presentation of all of the reports is offered immediately below:

E, Background

The Town of Payson is dependent on a water supply produced from groundwater wells located within the Town's boundaries. These wells produce water from the underlying geology or aquifer, which is composed of fractured bedrock. The water storage capacity of this type of aquifer is dependent upon fractures and weathered zones located within the bedrock. The Town has invested in many water studies in an effort to affectively and responsibly mange its water supplies. These efforts have afforded the Town's ability to grow to its current size while also resulting in the adoption of a Safe Yield ground water supply management objective. As such, it has been identified that little to no additional growth can be supported with the existing ground water supply. Moreover, the development of a groundwater reserve for drought mitigation is clearly needed.

Efforts to explore for and develop additional supplies of both ground water and surface water for use conjunctively are on-going and directly relate to the study at hand. A surface water source has always been a desire for the Town of Payson. The realization of such supplies via exchange, purchase, or other means, has been complicated by environmental issues, limited water rights, and monetary infeasibility.

Making Payson's 1984 CAP water allocation "wet", in Payson, in time to meet increasing demands was simply not possible. Particularly when considered in light of the State's on-going adjudication process and lengthy Federal Indian water rights settlements.

Faced with this reality, the Town of Payson elected to sell its original CAP water allocation of 4,995 ac/ft and set aside the funds in trust for the future development of yet undetermined alternative surface water sources and/or ground water development and management actions. These funds have essentially financed the majority of the ground water development and exploration actions described below in addition to ongoing surface water negotiations such as Blue Ridge Reservoir.

F. Previous Studies

Offered immediately below is a summary of the water resource related investigations that the Town has pursued since 1971.

Manera and Associates, Inc., 1975 (3), prepared a report concerning the water available to Payson North. They concluded that a sufficient groundwater supply was available to supply the project growth of Payson North for a minimum period of 35 years (2010) with an acceptable rate of decline in the static water level. It was further noted that the Town of Payson was studying methods of purchasing United Utilities Company. In addition, the Town of Payson had applied for an allocation of Central Arizona Project (CAP) water. The delivery of CAP water would require an exchange with either SRP or others prior to it being available to Payson. Delivery of the exchanged water would probably be by capturing and diverting from the East Verde River. Further, it was expected that when these transactions were completed Payson North as well as the Town of Payson would be supplied with CAP water, the remaining groundwater acting as a supplement supply.

The Payson's Master Water Plan, 1981 (4), prepared by the engineering firm (Dashney, Steele & Jensen, Inc.) was primarily a report discussing the infrastructure needs of Payson. However, there were two items that related to Payson's water resource development program. The two items were as follows: (1) "Payson should continue with the use of underground water. Central Arizona Project water will be expensive and should not be used as the main source of water supply unless the ground water supply is found to be inadequate or insufficient to meet future needs…"; and (2) "The top priority in a program for improving the Payson waterworks is to conduct a systematic investigation of the groundwater resources in the study area (Payson). Present sources must be modified and new sources found and integrated with the distribution system as soon as possible. This proposed Master Water Plan was entirely dependent on the assumption that the underground water supply would be sufficient to meet the ultimate needs of the study area."

W. S. Gookin & Associates in cooperation with Dashney & Associates (Gookin), 1984 (5), concluded in their CAP feasibility study for Payson that "it is apparent that the cost of CAP water will significantly exceed the cost of ground water for the Town of Payson. Therefore, CAP water should only be utilized as an alternative to ground water and not as the replacement. If sufficient ground water supplies can be located, it probably will not be desirable for Payson to pursue CAP supplies. Given the uncertain nature of water supplies in the area and the restrictive nature of the ground water code, substantial evidence of a dependable ground water supply should be obtained prior to abandoning the CAP option. If additional ground water supplies cannot be economically developed, then it will be necessary to proceed with the CAP diversion project."

In the section entitled "Future Activities", the Gookin Report notes the following: "The Town of Payson is facing a limitation under the subcontract (CAP water service subcontract) of "Take and/or Pay for Water" in 1990. If the Town of Payson has not taken (CAP) water by 1990, the Town will have to pay capacity, advalorem, and nonpumping Operation and Maintenance charges anyway."

The Gookin Report recommended that the Town of Payson continue all activities that were being undertaken at that time to contract for CAP waters by 1990. These activities included infrastructure plans, a Notice of Intent, Loan Application, an Environmental Assessment, Exchange Contract, Bonding, M&I Water Service Subcontract, Repayment Contract, Design and Survey, and Construction Program.

Further, Gookin recommended that the CAP diversion from the East Verde River be made at a Beaver Valley site because it is economically and probably environmentally superior. Gookin also noted that the diversions should be done pursuant to a tripartite exchange agreement between the Town of Payson and Salt River Project and Phelps Dodge Corporation.

Additionally, Gookin identified several alternatives for additional water sources. Payson could purchase valid water rights along the East Verde River and divert the water; groundwater development; Blue Ridge Reservoir diversions and a CAP exchange.

In Payson's Master Water Plan update for the waterworks system serving the Town of Payson, 1989 (7), the Engineers (Burgess & Niple Engineers and Architects) noted that Payson should continue with the use of underground water unless the groundwater supply is found to be inadequate or insufficient to meet future needs. Continuing the existing systematic investigation, including test drilling and pumping is recommended for exploration and evaluation of higher yielding groundwater resources in the Payson area and surrounding areas. Recharging of the groundwater resources via the proposed Green Valley Lake project by the Town of Payson is a viable method of insuring an adequate groundwater supply.

The Town of Payson performed a water exploration project from 1984 – 1987 (6). The work was done under the direction of hydrologist, E. L. Gillespie. Mr. Gillespie observed, in early 1985, that the exploratory drilling program conducted during 1984 produced fair results. The estimated total new water discovered was 960 g.p.m. In the following years exploratory program, Mr. Gillespie noted that the 1985 Exploration Project appeared to be quite discouraging as so many sites proved to be unsuccessful (less than 100 g.p.m.) but overall we arrived at a total new water slightly less than last year (1984, 960 g.p.m.) compared to this year of 880 g.p.m. with a (combined) total for both years (1984 and 1985) of 1,840 g.p.m.

Mr. Gillespie encouraged Payson to explore additional areas within the Payson Town site, Land Developer's project lands, USFS Trades, Star Valley and Granite Dells area, as well as some sites within Payson proper. He felt that investigating some of the outlying areas would be wise—not only to spread the well fields further apart, but also for future Payson water services to areas now being served (1986).

In Mr. Gillespie's final report (1987), he notes the 1986 exploration project completed with a good success—after appearing so "bleak" during most of the project.

The pumping test on the four (4) successful exploration wells resulted in 1,065 g.p.m. of "new water" for the Town of Payson's growth.

He further notes that it now appears that the exploratory program would be limited in test sites within the town, unless some exploration could be obtained in the lower Country Club area and along the edge of the valley south of Main Street.

Gookin's Report, 1992 (9), reiterates a recommendation from their 1984 report (see above). (1) Payson should not rely solely on groundwater to meet its future requirements. In the 1992 Report, Gookin recommends two alternatives to meet their future demand. These are the CAP exchange and a recharge project. Their final recommendation was that when faced with the decision of accepting CAP water; it should be contracted for unless the recharge program has produced positive results.

Town of Payson Recharge Studies: Green Valley, Rumsey Park, and Other

Sargent, Hauskins & Beckwith—Consulting Geotechnical Engineers (SHB) prepared a hydrogeologic evaluation of the proposed groundwater recharge project, Green Valley Park May 1992 (11). Their report included the results of their geologic and hydrogeologic investigations, evaluations and analyses for the proposed recharge project and they included a recommended preliminary design for a pilot recharge project.

The Green Valley Park Governing Board commissioned a study (November 1992—Study results were developed from 1991 data.) to evaluate the water pumping facilities which would be needed to serve the Green Valley Park Lake system. In the study, it was reported that the original design of the American Gulch Wastewater Treatment Plant (WWTP) was capable of treating the average daily flows of the Town of Payson up 1.7 mgd. The original land area and hydraulic provisions for the subsequent expansion of facilities was sufficient in size to ultimately treat average daily flows of 2.55 mgd.

During the period of the study, the WWTP was treating an average daily flow of 1.0193 mgd. Northern Gila County Sanitary District (Sanitary District) was operating these facilities in 1991. The Sanitary District has been the operating agency for these from the initial operations until the present (2004).

During 1991 the Sanitary District provided 56.32 million gallons of treated effluent to five users for irrigation (approximately 15% of the total flow). The total effluent production for the year 1991 was 372.0625 million gallons. The five effluent users were the Payson Golf Course, Jones, Llama Ranch, Payson West, and Payson High School.

In a late 1992 report (10), Gookin notes the following water supply alternatives for Payson:

1. Rely on existing groundwater supplies and future, local groundwater wells.
2. CAP water via Roosevelt Dam.
3. CAP water via the East Verde.
4. Develop waters from the Tonto National Forest.
5. Groundwater recharge using wastewater effluent.
6. CAP exchange/funds with the City of Scottsdale.

In and around 1993, Errol L. Montgomery & Associates (Montgomery) (13) was commissioned by the Town of Payson to perform a hydrogeologic investigation to identify and evaluate potential groundwater development areas in the vicinity of the Town of Payson. Their study area in east central Arizona was approximately 700 square miles in size. They were to study three areas within the project area. The three areas were Hardscrabble Mesa, Star Valley/Mogollon Rim, and Rye Creek basin. The principal water-bearing units in the study area are: floodplain alluvium, basin-fill deposits, basalt and related volcanic rocks, consolidated sedimentary rocks, and igneous and metamorphic complex.

Montgomery's findings were as follows: Hardscrabble Mesa – The quantity of groundwater data for Hardscrabble Mesa is small, and because the probability is small that a substantial volume of groundwater is stored in or recharged to the basalt and related volcanic rocks in the area, Hardscrabble Mesa was considered to be favorable for groundwater exploration and development. Star Valley/Mogollon Rim—the principal aquifers in the Star Valley/Mogollon Rim area are the igneous and metamorphic basement complex and consolidated sedimentary rocks. The principal source of groundwater in the Star Valley/Mogollon Rim area is recharge from precipitation on the Mogollon Plateau. The Star Valley/Mogollon Rim area was considered a favorable area for potential groundwater development. Rye Creek Basin (outside of the study area) – The principal aquifers in the Rye Creek basin are floodplain alluvium and basin –fill deposits. The floodplain alluvium is generally more transmissive and has larger specific yield than the basin-fill deposits, but areal extent and thickness of the floodplain alluvium are small. Basin-fill deposits in Rye Creek basin store a large volume of groundwater relative to other aquifer units in the study area. Rye Creek basin was considered the most favorable area, of the three area studied, for groundwater development. The chemical quality of groundwater in the project area was observed to be generally good.

In 1994, Errol L. Montgomery & Associates, Inc. (Montgomery) (14) were engaged by Payson to prepare a report regarding the hydrogeologic conditions in the Jacks Canyon, Clear Creek, and Chevelon Creek watersheds located in Coconino and Navajo counties, Arizona. The purpose of this study was to provide background information relative to the adjudication of water rights in the Little Colorado watershed. As part of the proposed adjudication settlement, it had been proposed that watersheds of Jacks Canyon, Clear Creek, and Chevelon Creek on the Colorado Plateau be closed to all further surface water and groundwater development. This area was being considered by the Payson for possible future development of groundwater for a supplemental supply to serve the growing population of Payson. The purpose of this report was to document groundwater conditions in the aquifers that underlie the three watersheds.

Montgomery also provided the following assessment of the groundwater development and use in these three watersheds:

> "Withdrawals of groundwater from the Coconino Aquifer consist of pumping for livestock, domestic, and public-supply uses. Amounts of groundwater that have been developed in the Jacks Canyon, Clear Creek, and Chevelon Creek watersheds have been small except for the Winslow public-supply wells. The major withdrawal occurs in the vicinity of Winslow for public-supply wells and probably does not exceed 2,000 acre-feet per year at present (1994). Withdrawals for other uses in the three watersheds are probably are less than 200 acre-feet per year…."
>
> Because withdrawal of groundwater in the area is small and does not exceed recharge, water levels generally show no decline. Altitude of groundwater levels in the Coconino aquifer has not changed except in the vicinity of the Winslow well-field.

George V. Sabol Consulting Engineers (Sabol), December 1994 (15), prepared the Rumsey Park Addition – Stormwater Drainage and Aquifer Recharge Facilities report. In the Conclusions and Summary section of the report, Sabol noted that aquifer recharge in the Rumsey Park addition may be feasible. Sabol noted that this was due to the favorable soil and aquifer properties in the area and because there is significant groundwater withdrawal that provides opportunity for aquifer recharge.

Sabol also noted that aquifer recharge can be achieved with reuse water that is generated by the North Gila County Sanitation District's Wastewater Treatment Plant. Quality aspects must also be considered, including the quality of the WWTP reuse water and the expected quality improvements obtained when the reuse water infiltrates into the sand fill of the seepage trench and moves through the alluvium and decomposed granite. Once the reuse water has moved into the fractures of the granite, additional quality improvements should not be expected. Early discussions with ADEQ and ADWR are needed to make sure that the proposed recharge with reuse water meets regulatory requirements and that the necessary permits can be obtained. Other water quality concerns were address with respect to the reuse water's impact upon on groundwater quality for potable use.

Sabol indicated that two aquifer recharge facilities could be constructed: either an aquifer recharge pond or an aquifer recharge channel. Sabol further noted that both recharge facilities can be developed to enhance recreational and environmental consideration for Rumsey Park.

In 1997 (18), the Town of Payson prepared a groundwater exploration report concerning, the Snowstorm Mountain Exploration Area. The results of that effort were that the groundwater potential in the Gibson Creek Batholith is marginal and likely limited in extent due to abundant secondary mineralization. In recently faulted areas a higher potential for groundwater may exist and especially in areas where more felsic rocks are present. The erosion of both the Mazatzal Mountains and the Snowstorm-Oxbow Range has deposited a substantial thickness of alluvial fan and freshwater limestone deposits from Simonton Flat towards Cypress Thicket and Rye. These deposits may offer a potential for productive deep sand and gravel aquifers. The land area over which this study was conducted was Federal lands administered by the U.S. Forest Service.

ASL Consulting Engineers, in their 1998 reconnaissance hydraulic evaluation report of the Hancock/Winslow irrigation system and McHood Reservoir (19), Winslow, Arizona, noted that the existing irrigation delivery system appears to be hydraulically capable of delivering 5,456 acre-feet of water per year. However, the system has probably been delivering a maximum of approximately 4,000 acre-feet per year. The report further stated that the actual average annual amount delivered is probably less than 2,000 acre-feet per year.

Southwest Ground-water Consultants, Inc. (SWC), 1998 (17), prepared a long-term management program of the Town of Payson's water resources. They noted that the potential future water resources available to the Town of Payson consist of:

- Effluent (direct use and recharge);
- Ground water within a 5-mile radius of the Town;
- Ground water outside a 5-mile radius of the Town; and,
- Water Conservation.

The SWC report included the following Long-Term Management Recommendations to help insure the long-term water supply for the Town of Payson:

1. "Develop and implement an in-depth water conservation plan that will reduce the summer peak month and peak day demands, as well as the overall year-round Town water use. This plan should include the development of water rates that will discourage waste and/or overuse.
2. Re-use directly or indirectly all available effluent from the North Gila County Sanitary District (NGCSD) wastewater treatment plant.

3. Explore for potential ground-water resources north and east of Town in particular and other areas outside of Town in general.
4. Continue the periodic monitoring of all Town production, observation, and exploratory wells for depth to water, water production, and water quality.
5. Continue the periodic monitoring of water users, and develop a better understanding of water use by customer classification.
6. Continue the monthly monitoring and evaluation of the effects of precipitation on ground-water levels on a seasonal and annual basis.
7. Continue the policy of requiring all new developments to "bring" water with them in order to obtain project approval and building permits, and provide options to developers to co-develop/cost share with the Town for ground-water exploration and development. This policy should remain in effect until such time as the Town has located and proven additional long-term water supplies. At that time, adjust water development fees to reflect the cost of development of these supplies."

In a May 1999 report, Rumsey Park Recharge (20), the Town of Payson proposed to recharge treated effluent into the northern part of American Gulch as part of a potential aquifer storage and aquifer project.

In September 2000 (24), the Town of Payson continued its groundwater exploration program. A study of the North Payson Area was prepared with the following results: In November 1999 the Town of Payson initiated Phase II of its Federal lands groundwater exploration program in an area referred to as the North Payson area. The study area is located just North and East of the Town of Payson, in the Tonto National Forest. A total of 15 exploratory well sites were selected following the completion of initial geological investigations. The land area over which this study was conducted was Federal lands administered by the U.S. Forest Service.

An estimated total of 316 gallons per minute (g.p.m.) of potential well yield was identified by the project. No "dry holes were drilled. The Northeast portion of the North Payson study area can be described as an area of moderate to low groundwater production potential. Unless, new information warrants, the development of water supplies in this area is not feasible for municipal supplies. While the estimated total of 316 gpm would make a positive increase in the Town's water supplies, there was still a need for the Town to continue its investigations for additional groundwater supplies.

In the Town's 2001 Ground-Water Management Status Report (29), the following was noted: Ground-water well development and rehabilitation efforts since late 1997 have increased production capabilities by 1,313 or 1.9 mgd. A significant proportion of this increase was gained in 2001 with ongoing well rehabilitation and deepening efforts. In addition, the total above does not include a well located in the Tonto National Forest which is expected to produce $\approx$ 150 gpm (NP-2). At the time of the writing of this Report, the USDA Forest Service was requiring further testing and permitting before the NP-2 well could be utilized as a public water supply. It had been estimated by others (Southwest Ground-Water Consultants) that the safe yield of the useable groundwater supply is 1,826 afy and 89 gpcd if the Town were to supply a population of 18,600, including commercial uses. At the time of the writing of this Report the author (M. Ploughe) notes the Town was rapidly approaching its safe yield estimate.

The Town of Payson continued its exploration and development work in the North Payson Area by performing NP-2 Aquifer Testing and Analysis, March, 2002 (31). A special use permit was obtained from USDA Forest Service in January 2001. The obtaining of this permit was necessary to facilitate the testing of the NP-2 well. In order to estimate the true long-term capacity of the NP-2 well, the natural flux or flow of groundwater available to the well was considered. The natural flux available to sustain pumping from NP-2 is estimated to be 107 gpm. Approximately two thirds of this existing natural flux is however, currently being captured or will be captured with existing Town of Payson and private wells. As a result, no more than approximately 35 gpm can be considered "new water" to Payson. Water quality samples collected from NP-2 met all drinking water quality standards. In concluding the recommendations of the Report it was recommended that using the NP-2 well at a pumping rate of 150 gpm was proposed. Under normal circumstances the actual well use would not be continuous, but would likely be less than a twelve-hour per day overall annual pumping average. As a result, the potential impacts to existing Town wells and nearby private wells are minimized and the natural flux is not exceeded. Most importantly, utilizing this pumping rate will help maintain the Town's abilities to meet future peak summer demands while improving overall well field efficiency.

The Forest Service, however still has reservations about issuing a production well permit for NP2 due to indications from the initial pump tests that nearby private wells could be affected. Additional analysis will be required before a final determination would be made (2004).

The 2002 Status Report (32) on the Town's groundwater management noted the efforts to investigate potential water supplies on private lands and the national forest public lands will continue. The deepening of existing wells and installation of new wells in areas that can increase well field efficiency will continue to be pursued. The current production (2002) capabilities were sufficient to meet the demands for the 2002 summer season even when amidst the worst winter drought recorded. As such, the need for drought emergency plan to aid in managing the water supply via conservation requirements in times of drought has been identified and would be addressed. With annual demand approaching safe yield, planned depletion projection results indicate that the aquifer could conservatively sustain overdraft until the year 2021. However, the Town's abilities to meet peak demands will become increasingly difficult as aquifer storage declines.

In addition, the results of test drilling on private lands in the Rye area were presented. The purpose was to explore the potential for sand and gravel aquifers within the Rye Creek Basin, as theorized in the 1993 Montgomery Report. Upper alluvial sediments were found to be less than 20 feet thick and were unsaturated. The lower Tertiary sediments were found to be of variable thickness not exceeding 600 feet and were comprised of clay and silt rich sediments. Ground water yields, though, were very low at less than 20 gpm while the quality was found to be quite poor.

The Town's 2003 Water Resources Management Status Report (34) notes that Payson, and the southwestern United States, is in the midst of a prolonged and severe drought period. The Town is rapidly converging upon it safe yield target, as previously expressed above. Without additional water supply developed outside of the Town's limits, Payson is limited to producing water from existing wells located in the local aquifer. It is the policy of the Town that the Town will make attempts to manage its water supply and take efforts relating to water development and water conservation to achieve "Safe Yield" water supply goals each year. Additionally, the Town conducted drilling exploration for additional groundwater supplies on private lands in and near the Town's limits and in areas remote to the Town's limits. The Town has also conducted drilling exploration on public lands near the Town's limits. These efforts have revealed only limited potential for new water supplies and have not been pursued for water supply development. Special use permits were requested and pending at the time of the Report's preparation. Efforts to secure a surface water source from Blue Ridge Reservoir were also ongoing as were efforts to develop a local groundwater recharge project utilizing reclaimed (see Rumsey Park Recharge Project). Until additional water supplies are developed for use within the Town, Payson will utilize strategies to reduce the consumption of local water supplies by conservation methods.

Black & Veatch prepared an Aquifer Recharge Feasibility Study, in July 2003 (36). The essence of the Report was to outline the design details for effluent treatment pilot plant to study the best operations and processes to apply to effluent for it to be recharged into the local aquifer. The report also identifies that only limited reclaimed water is available for a pilot study at this time. The operation of a pilot treatment and injection facility with current effluent availability would require numerous shut down and restarts of the facility which is not feasible. Reclaimed water availability is most desired to be consistently available in excess of 100 gpm. No action regarding the final development of this pilot project has been reported at this time (November 2003).

The Town had GǼAORAMA prepare a report concerning the Structural Geology and Groundwater Potential, Diamond Rim Study Area, August 2003 (36). The consultant notes that the Town has been successfully producing water in the Payson Granite for a number of decades. In recent years it has been determined that the best wells are along Tertiary faults. Recent groundwater exploration efforts leading to drilling on Tertiary faults in Payson Granite have been successful. Moreover, recent drilling has produced appreciable water at depths approaching 1,000 feet, much deeper than was previously thought possible in the Payson Granite. Geologic mapping for the Diamond Rim Study Area has successfully delineated and carefully located numerous Tertiary faults involving 'basement' crystalline rocks (Payson Granite and gneissic granitoids) and overlying sedimentary rocks of Tertiary and Paleozoic age. These faults have high potential for rapid transmittal of groundwater to wells that are sited to drill into the fault zones beneath the groundwater table and at depths from 500 to 1,000 feet. Thirty-six potential drill sites, largely along faults and at intersection of faults, have been located by this study. The Town is awaiting approval from the Forest Service before moving on into this exploratory drilling program.

During three different short periods in October, November, and December of 2003 (39), HydroSystems, Inc. incorporation with Zonge Engeneering & Research Organization, Inc. performed a geophysical survey of the Diamond Rim project area. The geophysical survey was performed using a process known as Natural Source Audio-frequency magnetotellurics (NSAMT).

The Diamond Rim project area is very complex topographically and geologically, containing steep topography and numerous mapped faults. In general, background resistivities are very high, as is normally the case in areas dominated by the presence of granitic rock. In addition, many of the geologically mapped faults and contacts are clearly evident in the survey results. The geophysical data also show several faults that are not evident in surface geologic mapping.

The geophysical data gathered during the study appears to be consistent with the surface geologic mapping and hydrologic of previous studies. The data also appear to have provided additional new subsurface information. Some well sites that were proposed prior to the geophysical survey have been modified or re-prioritized by the Town of Payson and HydroSystems, Inc. These modifications were not made simply on the basis of the geophysics, but also on the basis of background geological and hydrological data, as well as on drilling concerns and access. Based on the data and other considerations, the Diamond Rim Fault is considered to be an attractive drilling target for future ground water exploration.

Payson's 2004 Water Resources Management Status Report (41) discussed several water resource management issues that were causing impacts upon the "Safe Yield" policy of the Town. Those water resource management issues are discussed in the following paragraphs.

First, the Town of Payson is dependent on a water supply produced from groundwater wells located solely within the town limits. These wells produce water from the underlying aquifer, which is composed of fractured bedrock. The water storage capacity of this type of aquifer is dependent upon fractures and weathered zones located within the bedrock. As a practical matter, it is desirable that water withdrawn from the aquifer for public use is replaced on a yearly basis by rain and snowfall that falls within the town limits and seeps through the overlying soils into the aquifer. This ideal situation is referred to as "Safe Yield" wherein the amount of water that seeps into the local aquifer on a yearly basis is equal to, or great than, the amount that is withdrawn for local water supply. Safe Yield for Payson has been estimated to be 1,826 ac-ft/yr (not including artificial recharge).

The southwestern United States, in which Payson is located, is generally considered to be in the midst of a prolonged and severe drought period. Payson has endured significant deficits in precipitation since 1989 and has observed consecutive declines in the local aquifer water levels since the El Nino weather cycle of 1997-1998. A yearly decline in aquifer water levels indicates that Payson is not in the ideal situation of "Safe Yield" but is using water stored within the aquifer that may or may not be replaced in future years.

Without additional water supplies developed outside of the town limits, Payson is limited to producing water from existing wells located in the local aquifer that is currently in a state of reduced water storage. It is the policy of the Town of Payson local government that the town will make attempts to manage its water supply and take efforts relating to water development and water conservation to achieve "Safe Yield" water supply goals each year. In 2003, Payson residents consume local groundwater resources in an amount equal to 92% of "Safe Yield". The fact that water consumption for 2003 was reduced by 7%, from a 2002 annual consumption of 99% of safe yield, is a sign that the Town's award winning water conservation programs are working successfully.

Until additional water supplies are developed for use within the town, Payson will continue to utilize strategies to reduce the consumption of local water supplies by conservation methods. Since March 2003, the Town's most recent conservation ordinance has been utilized to mandate water conservation methods for new and existing businesses and homes. A key component of this ordinance is the possible institution of water use restrictions each spring in order to achieve reduced water consumption. These efforts in combination with increased water conservation education, special conservation programs, and the assistance provided to the public water system homes and businesses are a meaningful attempt by the town government to achieve the town's goals of "Safe Yield" in the management of its public water supply.

Defining the viable water resources options for the Town continue to be a priority for the Water Department. Within this context, the potential for a surface water source from Blue Ridge Reservoir continues to be a priority for the Town of Payson along side exploration on public lands as well as effort to develop a local ground water recharge project utilizing reclaimed wastewater and/or future surplus surface water sources.

In recent years, the Town of Payson has conducted drilling exploration for additional ground water supplies on private lands in and near the town limits and in areas remote to the town limits. In addition, the Town has also conducted exploration projects on public lands near the town limits. These past efforts revealed only limited potential for new water supplies and have not been pursued for water supply development. More recently, investigations conducted at Doll Baby Ranch have been concluded with similar results, while a new well installed on property of the Northern Gila Sanitary District shows some promise. In addition, permit applications for additional ground water exploration in much more promising areas of the public lands northeast of Payson are pending at this time (April 2004).

Efforts to investigate potential water supplies on private lands and the national forest public lands will continue. However, private lands close to the Town and available for exploration are few. The 2003—2004 recharge season was another below average period of precipitation for Payson. No significant recharge was observed over the 2003-2004 water year and ground water levels continue to decline. Longer periods of wet weather are clearly needed to ease the impact of drought in the region. The Town's water conservation programs appear to be addressing the lack of precipitation by successfully limiting annual water consumption to less than the long-term safe yield of the aquifer. In addition, production capabilities are expected to be sufficient to meet demands for the 2004 summer season even amidst the likelihood of continued drought.

H. Town of Payson's Recharge Projects

Payson has either studied or studied and constructed two recharge facilities within the Town's boundaries. The Green Valley Park Reuse Facilities have been constructed and are being operated by the Town.

Green Valley Park Lakes Groundwater Recharge Project

Green Valley Park is a cooperative water reclamation project between the Northern Gila County Sanitary District and the Town of Payson. This award-winning park has been designed to recharge the town's water table through passive percolation of treated effluent and excess storm-water runoff through the bottom of the lakes into the groundwater aquifer. The lakes also provide storage of the effluent for reuse customers throughout town and for watering of landscaping in the park. Monitoring of water levels in wells located around the edges of the Park allow the town to assess the effectiveness of the recharge process.

The town is partners with the Arizona Game and Fish Department in providing an urban fishing program. In October, 1996, the lakes were stocked initially with 1,250 pounds of rainbow trout. The Town continues to work with the Game and Fish Department to stock the lakes with rainbow trout from October through May each year. The lake is currently stocked at a rate of approximately 450 pounds of trout every three weeks. Approximately 300,000 gal/day is passively recharged to the Payson granite aquifer via the Green Valley Recharge project.

The second recharge facility that has been studied is the Rumsey Park Recharge Project. Observation wells have installed within the area in which the recharge could occur. A study of surface drainage and other pertinent items was completed by George V. Sabol Consulting Engineers, Inc. in 1994 (15). To date (January 2004) this project has not been built. See Black and Veatch study, 2003 (35), above.

I. Town of Payson's Infrastructure Studies and Associated Projects

Currently Payson's water supply and delivery system is located within the Town itself. Master Water Plans were prepared in both 1981 (4) and 1989 (7) concerning Payson's water system infrastructure. Since both reports were concerned with the water supply and distribution system within the Town's boundaries, no additional reporting will be provided concerning the adequacy of the Town's interior infrastructure in this Report.

In 1999 (21), both Reclamation and Payson computed preliminary estimates for an infrastructure system to bring Blue Ridge Reservoir waters into Payson. No copy of the work done by Payson's consultant, Burgess and Niple, has been made available to Reclamation for summarization in this study.

In March 1999, there was a Payson Road Reconnaissance Geology Study (22) with respect to potential pipeline locations for bringing surface from the Phelps Dodge's power generation stations located, near Rim Trail and Washington Park, on the East Verde River. The purpose of the reconnaissance was to investigate the feasibility of the routes for placement of a pipeline in the roadbed from the power generating plant to the Town of Payson. The Study provides field reconnaissance of several pipeline routes and the routes associated geology

Reclamation's prepared a preliminary engineering study concerning the same project. Reclamation's report was prepared in draft form only. A summary of the draft results are offered below:

The Town of Payson, November 1998 (??), had prepared, by ASL Consulting Engineers, a preliminary estimate of construction and operation costs for an East Verde River Water Transfer System (Transfer System). The Transfer System included two different water treatment options to treat 6,100 acre-feet per year. The two treatment options considered were (1) conventional treatment and (2) membrane treatment. The Transfer System includes 18" transmission pipeline with needed appurtenances, treatment plant system and land acquisition costs. The preliminary estimates for the Transfer System was $13,792,710.

A draft report, prepared by the Bureau of Reclamation, February 1999, entitled "Blue Ridge Dam and Reservoir, Water Supply Alternative—Pipeline Options for Payson, Strawberry & Pine, Preliminary Cost Estimates" (21). The report presented a preliminary look at several options to move water from the Blue Ridge Reservoir to the communities of Payson, Pine and Strawberry. Included in the report were several options to transport 3,000 acre-feet/yr of water to the communities of Payson, Pine and Strawberry. There were several cost items that were not included in the probable opinion of construction costs. The list of cost items that were not included are land purchase, rights-of-ways, safety, reliability, geology, utility relocations, pump selection and configuration, and associated social problems. In addition, the study addressed the initial costs for an Environmental Impact Statement. Unforeseen (unpredictable) costs of environmental problems, mitigation or litigation were not calculated. The report provided only a level or magnitude of the construction costs for various piping options under the Blue Ridge Dam and Reservoir Water Supply Alternative.

There were four (4) options for pipeline locations developed in the draft report. Those options were as follows: Control Road, Instream Diversion, Rim Road and Highway 87.

The Control Road option takes water directly from Phelps Dodge's power plant pipeline and follows Control Road west along the base of the Mogollon Rim. A 3,000 acre-foot reservoir would be located near Buckhead Mesa, along with 2.5 million gallons a day (mg/d) water treatment facility and a 10 million gallon (mg) clear well. Water would then be pumped north to Pine and Strawberry to 0.5 mg storage tanks and use gravity flow south to Payson to storage. The probable opinion of cost for this option is $73,100,000.

The Instream Diversion option puts the water in the East Verde River at Phelps Dodge's power plant. The water is then taken out of the river near the Houston Mesa Road crossing. A small ogee dam would be built to get the depth required for the infiltration diversion system. Water would be pumped up a pipeline aligned along Houston Mesa Road into a 3,000 acre-foot reservoir located at Sunflower Mesa. The water would then be pumped through an 18 inch pipeline aligned along the Houston Mesa Road to near Highway 87 where a 2.5 mg/d water treatment facility and a 10 mg clear well would be located for Payson's needs. The water would then be pumped through an 8 inch PVC line aligned along Highway 87 to holding tanks for Strawberry and Pine. . The probable opinion of cost for this option is $53,500,000.

The Rim Road option splits the supply of water to Payson and to Strawberry and Pine in two separate pipelines. The water to Payson is taken directly from the Phelps Dodge power plant and follows Houston Mesa Road via an 18 inch steel pipeline to a reservoir located at Sunflower Mesa. A pump station would then pump the water to a 2.5 mg/d water treatment plant and 10 mg clear well located near Payson. The water for Strawberry and Pine would be diverted form the Phelps Dodge pipeline on top of the Mogollon Rim. It would be pumped through an 8 inch PVC pipeline along the Rim Road to Highway 87. The pipeline would then follow Highway 87 down to a small water treatment plant located near Pine and then be gravity feed to final storage near Strawberry. . The probable opinion of cost for this option is $72,000,000.

The Highway 87 option pumps water out of Blue Ridge Reservoir along a forest road directly to Highway 87 via an 18 inch steel pipeline. The pipeline then follows Highway 87 south, down the Mogollon, past Strawberry, through Pine to a 3,000 acre-foot reservoir located northwest of the Highway 87 and Control Road intersection. The water would then be treated at a 2.5 mg water treatment plant and stored in a 10 mg clear well before being pumped south to Payson and back north to Strawberry and Pine. The probable opinion of cost for this option is $91,100,000.

J. Northern Gila County Watershed Alliance

The Northern Gila County Watershed Alliance's Technical Committee prepared (1998) a Report entitled Northern Gila County Water Plan (16). It was observed in this Report that the current water usage in the Northern Gila Country area (includes Payson, Pine, Strawberry, and Star Valley) is estimated to be less than 2,000 afy. This usage is probably low, however, considering the water shortages and conservation efforts that have been on going for several years. The majority of residents in the area take great care in utilizing this precious resource. The study area's primary source of water is groundwater drawn from public and private wells. Overdraft of groundwater in the Payson area has produced declining water levels in the Town's network of supply wells. Water quality, in some wells, has also has an impact. In the Pine/Strawberry area, a lack of high producing water wells and under-developed infrastructure combine to create frequent inadequate or unavailable water supply for residents. Recreational use by tourist and seasonal visitors also severely impact the study area's water supplies. Population projections developed for this report, indicate between 38,000 and 48,000 residents by the 2050. Serving this population will require and additional 4,500 to 5,500 afy of water (based on 150 gallons per day, per capita). With adequate storage capability these quantities should be able to serve the recreational users as well. Several potential water sources were discussed as possible solutions to future water needs. Among the most discussed were Blue Ridge Reservoir, new water wells, greater and more effective use of reclaimed water and miscellaneous area water rights. Additional hydrogeological, legal and cost/benefit information will be required before final informed decisions could be made.

The Northern Gila County Water Plan offers a list of possible sources for additional water. The list contains the following surface and groundwater sources:

Table J.1. Potential Water Supply Sources That Require Additional Investigation (16).

Below the (Mogollon) Rim	**Above the (Mogollon) Rim**
Tonto Creek Water Rights	Blue Ridge Reservoir
Gisela Area Water Rights	Long Valley—Clints Well Area
C-Aquifer (Portion below the Rim)	Hay Lake Ranch
Rye Creek Water Rights	
Indian Springs at Kohl's Ranch Water Rights	
Pine Creek Water Rights	**Other Options**
Fossil Springs Water Rights	Better Utilization of Currently Reclaimed Water
Verde Valley Water Rights	Stronger Conservation Measures
Existing CAP Allocations/Trades	Development of Ordinances and Building Code to Regulate Water Usage
Recycled and Reclaimed Water	
Surface Water Impoundment(s)	
Ground Water Exploration	
Horizontal Drilling (at Rim)	
Flowing Springs Water Rights	

K. Pine and Strawberry Water Resources Study Information

During the time period, May 18 – June 2, 2000 (23), an exploratory borehole was drilled near Strawberry, Arizona. The borehole was drilled to a total depth of 1,872 feet below land surface. Although the total depth of the hole was 1,872 feet, "lost" circulation problems combined with unstable borehole conditions the onsite geologist was not able to gather and collect drill samples from depths below 970 feet, and limited the depth of geophysical logs to 1,773 feet.

The major geologic units penetrated by the borehole include the lower member of the Supai Formation, the Naco Formation, the Redwall Limestone, and possibly the Martin Formation and/or the Tapeats Sandstone. A shallow groundwater zone that produced a small, unquantified amount of water into the borehole was encountered in the lower member of the Supai Formation at a depth of about 170 feet. The water level of the regional aquifer system was encountered in the Redwall Limestone at a depth of about 1,380 feet (about 4,400 feet in elevation above mean sea level). Based on interpretation of the geophysical logs it does not appear that basement rock (such as, granite or quartzite) was penetrated by the borehole.

L. Pine and Strawberry Water Improvement District

The Consultant's report, (2003) – Morrison Maierle, Inc (38), concerns the investigation of groundwater availability for the Pine/Strawberry Water Improvement District notes the following:

The communities of Pine and Strawberry have historically experienced severe water shortages in the summer months. Recent investigations conducted by the Pine/Strawberry Water Improvement District (PSWID) reveal that the water supply shortages caused by seasonal decreases in well yields are the result of limitations inherent in the hydraulic properties of the fractured rock aquifers that supply water to wells in the PSWID area. The limitations of groundwater flow through the fractured rocks to pumped wells will cause predictable decreases in well yields as pumping time increase. Although drought or below average precipitation conditions exacerbate the seasonal groundwater shortages, they are not the fundamental cause of the shortages, a conclusion supported by the fact that water shortages have historically occurred at the end of as many as 12 consecutive years of above average precipitation. The investigations show the currently utilized groundwater sources, in the Schnebly Hill and Supai strata, are inadequate to support existing demands let alone future growth.

The report continues to state: Investigation of the PSWID area of alternative sources of groundwater supplies has identified a deep aquifer in the Redwall Limestone and associated strata as the most favorable groundwater resource from which to develop additional sustainable water supplies for the area.

M. Pine and Strawberry Water Improvement District

The District was formed and approved to function during the mid-1990s. The purpose of the District was to perform those studies and related activities that would lead to the identification of additional water supplies to supplement the existing water resources of both Pine and Strawberry. Further, the purpose of this effort was to find water supplies that were both reliable and sustainable since the existing water supply was prone to have shortages during the summer months of each year.

The District joined the North Gila County Watershed Alliance to work on the solution to their water supply needs from a regional context. That Alliance has been integrated in to the current Study. The District has returned its power to the County. The County now represents not only the Pine and Strawberry Water Improvement District in the study; but several other districts and unincorporated communities/subdivisions as well.

Prior to the District dissolution they had established a water plan to use in the development of a strategy for accomplishing their goal of finding additional waters to firm up their existing but tentative water supply. A presentation and current status of each element is reviewed below.

N. The Pine and Strawberry Water Improvement District's 2002 Long Range Water Plan

Purpose: The Development Of A Water Resources Plan With The Goal Of Assuring An Adequate Long Term Groundwater Supply Is Available To Meet The Reasonable Needs Of Both The Area Residents And Property Owners (current and future)

The Plan

- Northern Gila County Water Plan Alliance. Continue as members of the NGCWPA Steering and Technical committees in its efforts to provide studies of the Northern Gila County water issues and assist the community, county, state and federal decision-makers in pursuing solutions. The Northern Gila County Water Plan Alliance no longer exists. This Alliance has been reorganized by Gila County into a study partner in the Mogollon Rim Water Supply Study.
- Water supply and demand model**.** Define a water consumption factor that can be used to estimate quantity of water that will be required to provide the Pine/Strawberry area with an adequate long-term supply of water. This effort was completed during the current study. A report entitled "Demand Analysis", Mogollon Rim Water Resources Management Study has been prepared an it is incorporated as part of the general report for the study.
- Maintain an outreach program. Communicate efficient recycling and water conservation programs. This work has been transferred back to the County
- Expand web sites**.** Prepare handouts for distribution. Have a booth at the Crafts Fair to share information with general public. Sponsor a contest with school children for ideas to communicate information on water conservation. Never end the process to communicate effectively. The web site for the District is no longer available for public viewing.
- USGS study**.** Participate with USGS and other participants in a study of the geology, surface and sub-surface hydrology of the greater Northern Gila County area. All USGS studies in the area have either been completed or terminated.

- Explore costs and feasibility of a deep production well**.** If this proves to be appropriate and ultimately successful, request that Gila County transfer the well site(s) to PSWID. There was an exploratory borehole drilled in the Strawberry area in the early part the first decade of the new century. See Strawberry test hole for additional comments.
- Strawberry test hole**.** Continue monitoring to determine feasibility of sub-surface water source development in the Strawberry area. A preliminary report regarding the data developed during the borehole drilling, limited geophysical testing, and other borehole studies has been prepared. No additional monitoring is being performed.
- Solicit participation from other local water districts/suppliers to work on common goals and objectives**.** PSWID, Portal 4, Solitude Trails, and others, may benefit by meeting frequently to share thoughts, current positions/status, and direction. This effort is no longer being pursued by the District.
- Investigate feasibility of developing a Mogollon Rim Well Field and pipeline**.** This effort is a part of the Mogollon Rim water supply study.
- Investigate feasibility to transfer local CAP allocations to PSWID and research methods and agreements to allow collection of surface water**.** A winter storage lake could be a wetlands or habitat; basins could be built to capture rainfall; and other water harvesting concepts should be investigated. Explore the feasibility of utilizing the Blue Ridge Reservoir and proposed back up Well Field to supply water to the Pine/Strawberry area. This alternative will consider during the alternative formulation phase of the study.
- Investigate feasibility of becoming the water supplier/company to the communities of Pine and Strawberry. The District, when it existed made efforts toward formalizing this concept. No action or final decisions have made toward confirming and formalizing this concept.

O. Central Arizona Project

During the early 1900's, the seven states of the Colorado River Basin: Arizona, California, Nevada, New Mexico, Wyoming, Colorado, and Utah negotiated for shares of Colorado River water. In 1922, representatives from the seven states and the United States government created the Colorado River Compact, which divided the states into lower and upper basins and gave each basin 7.5 million acre-feet of water to apportion. Arizona, California, and Nevada were sectioned into the lower basin, and were instructed to divide their 7.5 million acre-foot allotment among themselves.

Arizona was in dispute over its share of the river, however, and was the last state to approve the Compact in 1944. Today in the Lower Basin, Arizona has rights to 2.8 million acre feet of Colorado River water per year, California is entitled to 4.4 million acre feet per year and Nevada has annual allocation of 300,000 acre feet.

In 1946, the Central Arizona Project Association was formed to educate Arizonans about the need for CAP and to lobby Congress to authorize its construction. It took the next 22 years to do so, and in 1968, President Lyndon B. Johnson signed a bill approving construction of CAP. The bill provided for the Bureau of Reclamation of the Department of the Interior to fund and construct CAP and for another entity to repay the federal government for certain costs of construction when the system was complete.

In 1971, the Central Arizona Water Conservation District was created to provide a means for Arizona to repay the federal government for the reimbursable costs of construction and to manage and operate CAP. Construction began at Lake Havasu in 1973 and was completed over twenty years later south of Tucson.

The Town of Payson, Pine Water Company, and the Tonto Apache Tribe have either had or have a CAP water allocation. In 1983, the Secretary of the Interior (Secretary) allocated CAP municipal and industrial (M&I) to Payson (4,995 acre-feet per year water per year), E&R Water Company (161 acre-feet per year), and the Tonto Apache Tribe (128 acre feet per year). In the early 1990s, Payson entered into a transfer agreement with the City of Scottsdale for the severance of Payson's water allocation to the City of Scottsdale, Arizona.

In August of 1999, E&R Water Company transferred it CAP water allocation to the Pine Water Company/Brooke Utilities. The Pine Water Company still retains its CAP water allocation to date (2004). No action has been taken by either the Pine Water Company or the Secretary, acting through the Bureau of Reclamation, to deliver "wet" water to the Pine Water Company's defined service area.

The Secretary (of Interior), 1983, acting upon his trust authority to Indian tribes allocated 128 acre-feet per year to the Tonto-Apache Tribe (Tribe) for use on their Tribal Reservation (29). The Tribe still retains its CAP water allocation to date (2004). No action has been taken by either the Tribe or the Secretary, acting through the Bureau of Reclamation, to deliver "wet" water to the Tribe's Tribal Homelands. The Tribe has proposed a land exchange with the Forest Service for the purpose of expanding the boundaries of their current 85 acre Reservation by an additional 278 acres. The actual size of the final land exchange acreage will be determined by an appraisal of all the lands involved in the exchange. That appraisal is expected to be completed by late summer 2004 and a decision on the exchange likely by the end of the calendar year (2004).

The Regional Director, Lower Colorado Region, U. S. Bureau of Reclamation, in a memorandum to the Assistant Commissioner – Program, Budget, and Liaison (Bureau of Reclamation), June 11, 1993 (12), shared the following background information concerning the Town of Payson Central Arizona Project Water Exchange with the City of Scottsdale:

"In 1968, the Arizona congressional delegation provided a means for the water-short communities located in the upstream portions of the Salt and Verde Rivers watersheds to participate in and benefit from CAP through indirect access to water from the construction of CAP…

In 1983, the Secretary of the Interior allocated to Payson 4,995 acre-feet of CAP municipal and industrial (M&I) water per year…

In 1992, Payson, the United States, and the Central Arizona Water Conservation District (CAWCD) entered into a water service subcontract for delivery of 4,995 acre-feet of CAP water. The subcontract contains language which allows for assignment of the subcontract to another entity.

The East Verde River is the only surface water source available to Payson for direct exchange of its CAP water. Significant environmental obstacles have arisen concerning Payson's use, through exchange, of the waters of the East Verde River. Studies continuing since 1984 have resulted in the conclusion that an exchange involving East Verde River water is not legally, physically, or economically feasible.

Since the passage of the Basin Act in 1968, Payson has grown rapidly to a 1993 population of over 8,000 residents. Payson's present water supply, developed from multiple wells tapping shallow ground water in fractured granite beneath Payson, is no longer adequate to meet the increasing needs of the residents.

Payson has concluded that the development of an alternative water source, such as effluent reuse system and a new well field, is preferable to attempting a direct exchange of its CAP water."

Payson's CAP water allocation was subsequently transferred to the City of Scottsdale. Funds received from the transfer process of the CAP water allocation have been used by Payson to fund both groundwater exploration programs and other development projects to increase local water supplies.

In the U. S. Fish and Wildlife Coordination Act Substantiating Report, Central Arizona Project, Verde and East Verde River water diversions, 1989 (8), the Fish and Wildlife Service (Service) identified both issues and recommendations concerning proposed CAP exchange diversions from the East Verde River. Presented immediately below are some of the more significant observations and recommendations noted by the USFWS:

(Note: The Substantiating Report was written to cover eight holders of CAP water allocations to exchange their allocations with water right holders on the Verde and East Verde Rivers and withdraw water directly from the rivers.)

"The Verde and East Verde Rivers support 165 miles of high quality aquatic and riparian resources… These rivers support an important remnant native fish community. Populations of three species [spikedace (Meda fulgida), bald eagle (Haliaeetus leucocephalus), and peregrine falcon (Falco peregrinus)] that are federally and State listed as threatened or endangered are found with the Verde and East Verde River area, as well as nine other State listed species. Recreational use is high along portions of the two rivers."

The Report furthers states "Flow reductions from the diversions (see Table ?? below), as originally proposed, would be significant in some reaches and would result in a loss of about one-half the normal flow in the headwater reaches of the Verde River and about two-thirds in the East Verde River. Propose flow changes would have adverse effects on riparian and aquatic species, particularly native fishes. Quantity and quality of the aquatic resources would be directly reduced for native fish species and increased for some undesirable non-native species such red shiner. Long-term effects from changes in riparian zone width, stream channel morphology, water temperature and chemistry, flow patterns, and nutrient cycles would accrue to fish, wildlife, and riparian resources. Impacts would be greatest in the headwaters of the Verde River and in the East Verde Rivers and lowest in the Verde River downstream from Camp Verde. Indirect impacts would occur from residential, recreational, and commercial growth due to increased water availability."

The Service made several recommendations, the pertinent ones recommendations 3 through 6 concerning the water supply study are listed below:

"3) Minimum flows presented in Table 9 (see???) should be maintained in respective Reaches of the East Verde River. During periods of non-trans-basin water diversion, when natural stream flow is less than the indicated amount, the natural stream flow should be provided.

4) Maximum allowable diversion rates for the proposed diversions on the East Verde River should not exceed 1 cubic feet per second (cfs) for Tonto Apache Indian Reservation and the E & R Water Company (now Pine Water Company) and 4 cfs for the City (Town) of Payson. (Note: The flow restriction of a maximum diversion flow of 4 cfs for the Town of Payson, to preserve minimum stream flow in the East Verde River, would not allow them to receive their full CAP allocation of 4,995 AF/YR, i.e., 6.9 cfs.)

5) Long-term monitoring of riparian and aquatic resources should be conducted on the East Verde River. Monitoring procedures should be developed in cooperation with the Forest Service, AGFD (Arizona Game and Fish Department), and Service. Monitoring should begin prior to initiation of any diversions or construction of diversion facilities and be continued throughout the life of the project.

6) Changes in proposed/conceptual diversion plans or any additional proposed diversions or impoundments should be re-analyzed by the Service as appropriate."

Exchange diversions, as originally proposed are as follows:

Table O.1 Central Arizona Project Probable Exchange Diversions (8).

Entity	E & R Water Company (Pine Water Company) Pine and Strawberry	Tonto Apache Tribe	City (Town) of Payson
CAP Allocation	161 AF/YR	128 AF/YR	2,606 AF/YR (4,995

							AF/YR?)		
Month	AF	CFS	Peak	AF	CFS	Peak	AF	CFS	Peak
January	8	0.14	0.21	0	0	0	217	3.6	N/A
February	11	0.19	0.29	0	0	0	217	3.6	N/A
March	10	0.16	0.24	4	0.07	0.14	217	3.6	N/A
April	13	0.22	0.33	14	0.24	0.48	217	3.6	N/A
May	14	0.25	.038	20	0.35	0.7	217	3.6	N/A
June	31	.52	0.78	24	0.41	0.82	217	3.6	N/A
July	21	0.35	0.53	26	0.43	0.86	217	3.6	N/A
August	16	0.27	0.41	23	0.39	0.78	217	3.6	N/A
September	11	0.19	0.29	14	0.24	0.48	217	3.6	N/A
October	10	0.16	0.24	3	0.04	0.08	217	3.6	N/A
November	8	0.14	0.21	0	0	0	217	3.6	N/A
December	8	0.14	0.21	0	0	0	217	3.6	N/A

Table ??9??. Recommended minimum instream flows (cfs) for the East Verde River (8).

Month	Reach 8*	Reach 9 and 10**
Jan	9	11
Feb	8	15
Mar	14	28
Apr	19	27
May	20	21
June	16	16
July	16	16
Aug	15	16
Sept	15	16
Oct	12	12
Nov	11	12
Dec	9	10

* Measured at Highway 87 crossing.
** Measured at Childs gage.

P. Water Conservation Programs—Brooke Utilities

The Arizona Corporation Commission’s (ACC) decision No.’s 61076 and 61072 ordered water conservation staging levels for Pine Water Company in 1998 and remain these orders remain applicable to date, September 2004. During periods of low water supply periods all customers are encouraged to strictly observe the water conservation measures in effect at all times. The following five (5) stages of water conservation have been adopted by Brooke’s Utilities, Inc., in concurrence with ACC, for the Pine Water Company

Stage 1 – No water conservation measures are in effect.

Stage 2 – Voluntary customer water conservation measures should be employed to reduce daily consumption by ten percent (10%). Outside watering on weekends and holidays should be curtailed. Outside vegetation watering may occur during weekday periods on even days of the month for even-numbered lots and odd numbered days for odd numbered lots.

Stage 3 -- Voluntary water conservation should be employed to reduce daily consumption by approximately twenty-five percent (25%). Outside watering should be completely curtailed except for permitted livestock. Indoor water conservation techniques should be employed wherever possible. Restaurant patrons should be served water only upon request

Stage 4 -- Voluntary water conservation measures should be employed to reduce daily consumption by approximately forty percent (40%). Outside watering should be completely curtailed and livestock should be watered only when necessary. Mandatory indoor water conservation techniques should be employed throughout customer residences. Restaurant patrons should be served water only upon request.

Stage 5 -- Mandatory water conservation restrictions are currently in effect pursuant to regulatory enforcement proceedings. Such regulatory restrictions may be in the forms of moratoriums, curtailment orders, meter disconnection without notice or the like. Customers should confine themselves to not more than one-half of their usual indoor daily water consumption except for permitted livestock. No outside watering should be conducted. Restaurant patrons should be served water only upon request.

Q. Water Conservation Programs—Town of Payson

Town of Payson Code of Ordinances (25) provides a clear expression of the Town's Water Conservation Guidelines as follows:

Q.1 DECLARATION OF POLICY for Water Conservation.

A) The Town of Payson has a limited water supply.
B) It is necessary for the town to protect its limited water supply to allocate and monitor water use to existing, pending and future development within its jurisdictional boundaries to ensure the continuing economic development and stability of the town.
C) It is necessary to require that the town implement conservation measures and to require that water is utilized in the maximum beneficial way and that waste, unreasonable use, or unreasonable methods of use of water be prevented.
D) This subchapter is a fair and reasonable means of achieving, and substantially advances, the public purposes set forth in this subchapter, and has been drafted to provide the controls necessary to accomplish the stated public purposes.
E) Conservation of water is in the interests of the town and its citizens and promotes the public welfare.
F) This subchapter is adopted pursuant to the authority vested in the Town of Payson by the Arizona Revised Statutes to maintain and operate a water system and provide the town with water.

G) This subchapter shall apply to all water whether potable or effluent and all citizens, businesses and governmental entities within the corporate limits of the town and all customers of the Water Department wherever situated. All provisions of this subchapter related to water surcharges shall apply to all persons, customers, and property served by the Water Department wherever situated.

Q.2. RESTRICTIONS DURING WATER SHORTAGE.

A) The Town Manager, upon the recommendation of the Public Works Director, is hereby authorized to declare or rescind Water Conservation Levels in conformity with and based upon the Resource Status Levels set forth herein below which assess the relationship between water demand and municipal safe production capability. Safe production capability is 90% of the total available water resources, based upon distribution components, storage reserves, weather conditions and historic data.

B) The following Resource Status Levels are hereby prescribed:

    1. *Resource Status I:* When water demand is equal to or less than safe production capability. Resource Status I shall correspond with Water Conservation Level I. When Resource Status I is reached, Water Conservation Level I shall be declared.
    2. *Resource Status II:* When demand is greater than safe production capability for three consecutive days. Resource Status II shall correspond with Water Conservation Level II. When Resource Status II is reached, Water Conservation Level II shall be declared.
    3. *Resource Status III:* When demand is greater than safe production capability for two consecutive weeks. Resource Status III shall correspond with Water Conservation Level III. When Resource Status III is reached, Water Conservation Level III shall be declared.
    4. *Resource Status IV:* When water demand exceeds total production capability. Resource Status IV shall correspond with Water Conservation Level IV. When Resource Status IV is reached, Water Conservation Level IV shall be declared.

C) The following Water Conservation Levels shall govern the use of water by customers of the Payson Water Department, as prescribed below:

    1. *Water Conservation Level I:* Water awareness. Water users are specifically encouraged to minimize waste in water used for irrigation, vehicle and pavement washing, construction and other water consuming activities. No person shall wash paved areas such as drives, sidewalks, or tennis courts, except for health or safety.
    2. *Water Conservation Level II:* Water restrictions. The following water uses are restricted or prohibited. In addition to the restrictions set forth in subsection (1) above, no person shall:
        a) Irrigate, wash vehicles, fill or refill pools, spas, or wading pools except as provided in this subchapter and subject to the restrictions contained in § 50.83.

b) Wash vehicles on the allowed days unless a bucket and hose with a positive cutoff nozzle is used. No restrictions apply to vehicles that must be washed for public health, safety or welfare purposes, or to commercial car washes.
c) Irrigate golf courses except before 9:00 a.m. and after 6:00 p.m. No restrictions apply if treated effluent is used.
d) Use ornamental fountains except if equipped with a recycling pump.
e) Use water from a fire hydrant except for emergencies or upon the written approval of the Public Works Director and Fire Chief; and except for such use associated with firefighting activities, public health, safety or welfare.

3. *Water Conservation Level III:* Water reductions. In addition to the restrictions set forth in subsections (1) and (2) above, the following water uses are further restricted or prohibited. No person shall:
   a) Fill or refill swimming pools, spas or wading pools.
   b) Irrigate golf courses. No restrictions apply if treated effluent is used.
   c) Wash vehicles, paved areas, or use fire hydrants on a non-emergency basis without written approval of the Public Works Director and Fire Chief. No restrictions apply to vehicles that must be washed for public health, safety or welfare, or to commercial car washes.
   d) Irrigate outdoors except as permitted pursuant to § 50.83.

4. *Water Conservation Level IV: Water curtailments. The following water uses are restricted* or prohibited. No person shall:
   a) Do any of the acts prescribed in subsections (1) through (3) above.
   b) Use any potable water for irrigation.
   c) Use fire hydrants, wash pavements, fill or refill pools or spas or fountains unless for public health, safety or welfare.
   d) Use potable water for dust control on public or private streets or capital improvement projects.
   e) Use potable water in violation of any other restriction deemed necessary by the Town Council for the purpose of protecting the welfare of the citizens of the town.

5. *Reduction in anticipated water use.* The foregoing water conservation levels shall be utilized to achieve the following respective reductions in anticipated water use:
   a) Water Conservation Level I: 0% reduction in anticipated water use
   b) Water Conservation Level II: 5% reduction in anticipated water use
   c) Water Conservation Level III: 10% reduction in anticipated water use
   d) Water Conservation Level IV: 30% reduction in anticipated water use

D) The Town Council may, from time to time, change the established water conservation level or enact additional water conservation or water use reduction measures as may be necessary or appropriate to achieve a desired reduction in water use.

E) In addition to the restrictions set forth above, the town shall establish yearly water conservation goals and implement such water conservation measures as may be appropriate for any year in which precipitation levels for the previous year fall below 22 inches of precipitation as measured by the National Weather Service. On or before May 1 of each year, the Water Department shall report to the Town Council the amount of precipitation, as measured by the National Weather Service, for the immediately previous 12 month period. The Water Department shall report the amount of precipitation for such period, whether it is above or below 22 inches for the period, and the percentage variation from 22 inches of precipitation for each such 12 month period. In the event that the precipitation level for any such yearly period is less than 22 inches, the water restrictions provided for in this section, or so many of such restrictions as may be necessary, shall be implemented immediately to reduce water demand, defined as a percentage, in an amount equal to the reported percentage shortfall of precipitation.

F) In addition to the provisions set forth in divisions (A) through (D) above, the Water Department shall report on a quarterly basis to the Town Council and shall furnish to the Town Council, as part of such report, the amount of precipitation and water usage for such quarterly period, and shall make such recommendations as may be appropriate regarding water restrictions based upon the information presented. The Town Council shall review quarterly precipitation and water usage and such other information as is presented by the Water Department and may take such action as is necessary or appropriate to implement water restrictions or modify water restrictions then in effect at such time.

In addition to the Town's water conservation policy, the staff of Payson's Water Department has proposed new water conservation measures for increasing residential on-site recharge and reuse. The new measures are on-site rainwater harvesting for recharge and reuse of gray water. It is expected that potential implementation of these measure would be helpful in augmenting the Towns' water supplies. In anticipation of employing these two technologies to augment local water supplies, the Town's water department staff is preparing a rainwater harvesting brochure to assist community residents in applying this technology at their residential home sites. By applying rainwater harvesting it is expected that the average (Mogollon) Rim resident can double the amount of rainwater that percolates into the ground on their property.

R. The Tonto Apache Tribe of Payson

The Tonto Apache Tribe of Payson (Tribe) were recognized in 1972 by the Federal Government and given 85 acres which comprises the current reservation. Tribal leaders reasoned that there were 85 members and each member should have one acre. Tribal population has grown since that time to 110 (January 2002).

The Tribe is, currently (2004), seeking the expansion of their reservation. At present, the Tribe has approximately one half the housing needed for current tribal members because of the Reservation's limited size. Many houses on the Reservation are crowded and contain two families. Some contain three. The Tribal Chairperson estimates a need for 25 additional houses to accommodate the present needs. At the time the 85-acre reservation was created, tribal membership comprised 85 people. Present tribal membership comprises 110 people and there are an additional 20 non-tribal living on the Reservation.

In the Environmental Assessment Proposed Tonto Apache Land Exchange (EA) (29) the following was noted concerning water availability to the Tribe's Reservation: "Surface waters such as springs, seeps, and streams, are limited in the immediate vicinity of Payson. There is no surface water available on the Payson parcel. (Payson parcel is approximately 278 acres located adjacent to the existing Reservation. T.10N., R. 10E., and sections 9 & 10, Tonto National Forest, Payson Ranger District) As a result, water needed for future development of this tract will in all probability be derived from groundwater located underneath the parcel itself or in the immediate vicinity of the parcel. The Payson aquifer is the primary source of water for the entire area. It consists primarily of Payson granite and to a lesser extent the Gibson Creek batholith, gneissic granitoids (granite-like), and basaltic dikes. Water is found throughout the upper 300 to 800 feet of this aquifer, primarily in joints, fractures and faults. Payson estimates that the aquifer underlying the Town can provide 1,826 acre-feet annually on a sustained basis.

Water needed for potential development of the Tonto Apache's Payson parcel would fall into two categories: residential and commercial.

Residential water needs: the amount of additional water needed for residential purposes would not be significant. The Reservation population has increased from 85 to 130 individuals over the past 29 years, or an average growth rate of about one and half people per year. The Tribe currently estimates that 25 additional new houses are needed in order to accommodate the existing population. There are very few lawns at the existing Reservation homes. The Tribe has stated that members might like to have gardens and some ornamental plantings. The Town's daily per capita water use of 95 gallons per capita per day reflects an increase in water usage that the Town attributes to an increase in outdoor watering. The Town uses an average 2.4 capita per service connection (2.4 people people per household) which would be consistent with the number of people per household with 25 homes added on the Reservation.

Commercial water needs: of the 278-acre Federal parcel being proposed for exchange to the Tribe, there are approximate 28 acres suitable for commercial development. That acreage includes 19 acres that lie west of Highway 87 and south of the Town of Payson's Event Center and in a narrow (241 feet wide) strip along the south edge of the existing Reservation boundary. There are five acres within the easement for the highway that are not useable. In addition, if the Tribe does acquire the Payson, the opportunity would exist for the Tribe to replace the existing 34 homes on the Reservation by moving or rebuilding them on the acquired Federal parcel. That would make an additional 35 acres of the existing Reservation, where homes now sit, potentially available for commercial development.

The exact nature of any future commercial development on the Reservation is currently unknown. In order to estimate the potential water demand of any such development, the water use for existing commercial development in the Town of Payson can be utilized.

Payson reports a current average use of 95 gallons of water per person per day from the Town's water system. The Town has a current population of 13,620 people. For usage projections the Town has converted the commercial use into equivalent gallons per capita per day (gpcd) of an additional 1,850 people. Using the Town's formula, the existing commercial water usage in Payson is 175,750 gallons/day. There 447 acres of developed commercial and industrial properties in Payson (number derived from the 1997 Payson Land Use Plan, pages 25 & 27). Using the Payson water usage formula, the average water use per acre of developed commercial lands is 393 gallons/day. The same average number applied to the potential commercial properties on the Reservation, that could be available as a result of a land exchange (63 acres), would be 24,760 gallons/day or 27.7 acre feet per year. For comparison purposes, water use on the Reservation in the year 2000, for both residential and commercial use (casino, store and service station), was 25,113 gallons per day.

In November 1998 (Brad Prudhom, Geologist, personal communication) the Bureau of Reclamation made a preliminary field hydrogeologic investigation to locate well sites for exploratory drilling. The purpose for these exploratory drill holes was to establish if there was a potential to develop an independent groundwater supply for the Tribe if their Tribal lands were expanded. An application to drill these exploratory wells was submitted in February 1999. To date, the application to drill has not been approved. No further action to implement this proposed drilling program is expected at this time.

If new lawns and/or gardens become part of the landscape of new homes to be built on land acquired through a land exchange, water demand could increase by one acre-foot per annum for a total increase of 29 acre-feet per annum.

In order to identify a water supply to meet any commercial development that may occur, the Tonto Apache Tribe's attorney has identified the following potential sources:

- A Tribal well in the Southeast quarter of Section 9 with a historic capacity of 50 gallons per minute.
- A well on property owned by or on behalf of the Tribe located within the Northwest quarter of Section 9 with an undocumented capacity.
- A potential well site located within the Northwest quarter of Section 9 with an unknown capacity.

The Tonto Apache Tribe has also filed claims for various surface water rights and has a contract for 128 acre feet of Central Arizona Project water. Those surface water rights may have value to trade for more available ground water or be developed to bring surface water into Payson. These prospects are vague at the present and are not considered, for the purpose of this analysis, to have potential in the foreseeable future."

S. Private Water Companies and Other Water Service Areas

About 30 water companies deliver almost 3,500 acre-feet per year to commercial and domestic customers in the study area. Presented below is a partial listing of Gila County water providers that are believed to be located with the Study area (as provided by ADWR 2001). (Note there may be included in this list water companies which lie outside of the study area. Additionally, there may water companies not listed because of the uncertainty as to where their Certificate of Convenience and Necessity service areas are located.)

Table S.1. Gila County Water Providers Located Within the Study Area (circa 2000).

Company Name	Service Connections	Amount of Water Delivered (gallons pumped per year)
Beaver Valley	154	?5,611,700,000?
Bonita Creek Land & Homeowners Association	37	572,468
J.N.J. Enterprises, L.L.C.	249	5,704,350
Kohl's Ranch Water Company	123	5,338,918
Payson Water Company		
Deer Creek	116	8,094,920
East Verde Estates	139	5,152,860
Flowing Springs	25	1,951,610
Geronimo	68	1,777,400
Gisela	178	1,417,867
Mead's Ranch	64	873,160
Mesa del Caballo	346	21,323,070
Star Valley	266	21,451,950
Whispering Pines	151	5,655,020
Pine Water Company, Inc.	1,887	43,711,000
E&R Water Company		
United		
Williamson Waterworks		
Strawberry Water Co., Inc.	1,016	50,151,790
Strawberry Water Co.	49	Flat rate unmetered

The Arizona Corporation Commission maintains regulatory authority over private water companies and private sewer companies throughout Arizona.

Several other agencies also have jurisdiction over aspects of running a reliable water system. Two divisions within the Arizona Department of Environmental Quality have regulatory authority. ADEQ's Waste Programs Division deals with solid waste treatment and disposal, and therefore is concerned with sewer systems. ADEQ's Water Quality Division has the responsibility of ensuring the safety of drinking water from public water systems.

County health authorities also oversee public health issues associated with water and sewer systems.

Private water companies and water cooperatives are regulated by the ACC. Raising or restructuring rates requires ACC approval in a rate hearing. Private companies generally are not allowed to raise rates to recover future costs. For example, if ADWR requires conservation programs, the ACC may refuse a rate increase to cover the costs until after the money has been spent and the program proven to be effective. Similarly, a small water company cannot increase rates to build a new well or a treatment system. Instead, it must build the well or the treatment system, then recover the costs. Also ACC does not allow water companies to recover CAP holding costs. These are costs for CAP water rights not presently being used.

As a result, private water companies and water cooperatives may find themselves in a regulatory bind. ACC's goal is to keep rates low to benefit consumers; the ADWR goal is to conserve water within AMAs; and an ADEQ goal is to ensure safe drinking water quality. A private water company confronting these varied regulatory goals may have problems initiating conservation programs. Without the power to borrow money or float bonds, a small water company's very survival may be threatened when major capital improvements are needed.

T. Water Rights

Arizona has separate water rights systems for groundwater and surface water. Groundwater rights are based on the reasonable use doctrine and are not quantified outside AMAs. Within AMAs, grandfathered rights are quantified on the basis of use prior to the designation and establishment of the AMA.

Surface water rights are based on the doctrine of prior appropriation. Predominant in the West, the doctrine protects early appropriators and is summarized by the tenet "first in time, first in right." In other words, the first person to put the water to beneficial use acquires a right superior to later appropriators.

In addition to rights for typical beneficial uses (e.g., irrigation, domestic, stock watering, etc.), surface water rights can be issued for instream-flow. Instream rights maintain a flow at specified levels, times, and reaches along a river for environmental or wildlife benefits. The specifications of the right depend on the needs of the particular use, along with water availability, and other appropriations.

U. Privately Owned Wells

Ground water is the source of almost all water for human uses except recreation in the study area. A recent review of the USGS's National Water Information System (NWIS) (27) ground water data base shows approximately 1,200 wells in the study area. Most of the wells in the study area are in bedrock aquifers.

Most of the 1,200 wells, excluding production wells for the Town of Payson and Private Water Companies are assumed to be considered to be under private ownership and are described as exempt wells under Arizona's water law. (An exempt well, per Arizona Department of Water Resources' definition, is a well that has a maximum pump capacity of 35 gallons per minute (50,400 gpd). Typical exempt well uses include non-irrigation purposes, noncommercial irrigation of less than 2 acres of land and watering stock. Most exempt well are used for residences and are more than adequate for household use.

A coalition of private well owners, Diamond Star Citizen's Action Coalition (Coalition), was formed, 2001, to challenge the efforts of the Town of Payson to develop ground water sites on Forest Service lands in and near both Star Valley and Diamond Point communities (??). The Coalition was formed to focus on the following issue: (1) encourage wise growth within the Study Area guided by staying within the limits of a specified annual water budget; and (2) monitor and comment on any project to promote the exploration and drilling of new wells to develop new ground water supplies in or near Star Valley and Diamond Point Shadows and adjacent areas; and (3) discourage any "encroachment" upon previously developed private groundwater supplies

V. Private Surface Water Rights

In Gookin's Feasibility Study regarding the Central Arizona Project (5), they incorporated a table (Table 10 -- not included in this Report) entitled Surface Water Rights on the East Verde River. Gookin states in the text preceding Table 10 the following: "The Town of Payson has two water sources available to it: surface water and ground water. If the CAP allocation is not taken via an exchange agreement, the Town of Payson probably could not get a new surface water right to the East Verde River. Salt River Project protests all new applications for new water rights in the Salt and Verde water sheds. It is likely that Salt River Project would be successful in preventing a new water right certificate from being issued due to the legal and financial resources of the Project.

Even if Payson did get a surface water right, it would be junior to all other surface water rights along the East Verde River, the shareholders of the Salt River Project, the City of Phoenix and the Salt River Pima Maricopa and Fort McDowell Indian Communities. These senior water right holders would have priority to surface water and the remaining flow would not provide sufficient water for Payson's demands at any time during the year.

The Town of Payson could purchase water rights along the East Verde River as other cities in Arizona have done for surface and ground water supplies, but there are no large volume water rights along the East Verde to purchase. The data in Table 10 shows that the Doll Baby Ranch has the largest water right claim but that only amounts to 310 acre feet per year. (The surface water rights holders are not listed since it is generally unlikely that Payson will pursue the small amounts of surface water rights that may be available for Payson's acquisition.)

The total surface water rights on file at the Arizona Department of Water Resources for the East Verde River are 580.1 acre feet per year, per Gookin Study 1984. The water rights associated with the Doll Baby Ranch represent nearly 54 % of the water rights existing in the Payson area.

W. Surface Water

Surface water sources in or near the Study Area include East Clear Creek, in the Little Colorado River watershed; East Verde River and Fossil Creek, Gila River watershed; and Tonto Creek, Salt River watershed. Each of these surface water sources will be briefly described below.

X. East Clear Creek -- Blue Ridge Dam and Reservoir

In 1963 (1), the Phelps-Dodge Mining Company completed the construction of the Blue Ridge Reservoir dam, on East Clear Creek, along the Mogollon Rim approximately 50 miles southeast of Flagstaff (Arizona) and 90 miles northeast of Phoenix. The dam site and reservoir are located within the Coconino National Forest, Arizona. The dam, a concrete monolith, stands 160 feet high and 14 feet thick at its base. East Clear Creek is an intermittent stream that drains northeastward into the Little Colorado River.

Blue Ridge Reservoir has a storage capacity of about 15,000 acre-feet and receives seasonal and other runoff from 71 square miles of contributing watershed. The Blue Ridge system consists of a dam to store water on East Clear Creek, a pumping station, a two-million gallon priming reservoir, a 10-mile steel-reinforced concrete cylinder pipeline, an 11-mile electrical transmission line within the pipeline right-of-way, and a 3mW hydropower generator which is used only to provide electricity for the pumping station. The water from the Reservoir is pumped from the Reservoir through the pipeline across the Mogollon Rim to the East Verde River, which is a tributary to the Verde River. First exports were made in October 1965.

The purpose of the Reservoir and associated facilities has been to deliver water to SRP in exchange for diversions of water from Black River on the Salt River Watershed by Phelps Dodge for use for mining purposes at its Morenci, Arizona copper mine.

In 1962, Phelps Dodge and the SRP entered into an Exchange Agreement which provided that Phelps Dodge must provide SRP with water from Blue Ridge equivalent in quantity and quality to the water diverted from the Black River by Phelps Dodge for use in Morenci. Historical deliveries of Blue Ridge water to the East Verde from 1996 through 1990 were about 9,630 A.F. and average annual credits to Phelps Dodge were approximately 5,775 .A.F. net of evaporation and other losses.

In 1997, a settlement agreement between Phelps Dodge and the San Carlos Apache Tribe, which was ratified by Congress, required Phelps Dodge to discontinue the use of Blue Ridge water for the Black River Exchange. Instead, Phelps Dodge is now leasing CAP water from the Tribe for delivery to SRP in the exchange.

Historical withdrawals from the Reservoir have been approximately 9,300 acre-feet annually to balance withdrawals on the Black River (on the Salt River watershed) by Phelps Dodge for mining operations at their Morenci Copper Mine. Since the implementation of the Black River/CAP Exchange Agreement in early 2002, the pumping and power generation components of Blue Ridge reservoir have not been operated.

The water rights for Blue Ridge reservoir are currently unadjudicated and are the subject of the Little Colorado River Basin Water Rights Adjudication and Negotiations. Blue Ridge water has also been identified as a water supply source in the Arizona Water Rights Settlement legislation (which includes the Gila River Indian Community Settlement), and have been considered in the Payson Area Water Supply Study.

Y. East Verde River

The East Verde River flows in a generally westerly direction from the Mogollon Rim in central Arizona. The East Verde River is located in both Gila and Yavapai Counties, Arizona. The East Verde River is tributary to the Verde River which is tributary to the Salt River and is part of the Colorado River System.

The headwaters of the East Verde are of high gradient and flow through steep rocky canyons with some small broad valleys. Moving downstream, the river alternately flows in narrow boulder-filled channels with steep gradient, and lower gradient areas with sand and gravel substrate.

Groundwater discharge maintains perennial flow in the East Verde River. The East Verde River enters the main stem Verde River from the east, about 25 miles upstream from Horseshoe Reservoir, and has a perennial length of about 40 miles.

Flows within the East Verde River may be affected if groundwater pumping increases substantially in the vicinity of the river. Since 1966, water has been added to the East Verde River about 50 percent of the year at the rate of approximately 30 cfs. This water is imported by pipeline from East Clear Creek in the Little Colorado River basin a result of a water exchange agreement between the Phelps-Dodge Corporation (Phelps-Dodge) and the Salt River Project. Phelps-Dodge pumps water from the Black River (in the Gila River drainage) in eastern Arizona on a when-needed basis for use in its Morenci operations. They then transfer a similar amount of water from East Clear Creek (Little Colorado River drainage) to the East Verde River (Gila River drainage) to replace the Black River water. As a result of the river diversions being placed on a when-needed basis, flows in the East Verde River fluctuate widely and occasionally little or no flow is recorded. This was the type of exchange and diversion operation that existed between the years of 1966 and 1999.

In 1999, Phelps-Dodge ceased to divert waters from the Blue Ridge reservoir to meet its exchange agreement regarding diversions from the Black River. Instead Phelps-Dodge began using Central Arizona Project waters to meet its exchange conditions with Salt River Project.

The East Verde River, in the past, has received intermittent trans-basin diversions of water from the Blue Ridge Reservoir, located on East Clear Creek, in the Little Colorado River basin, as part of a water exchange agreement between Phelps Dodge Corporation and the Salt River Project. The average annual flow diverted by Phelps Dodge Corporation, 1965 – 1990, was 9,990 acre-feet. The recorded annual low flow for this same period was 3,110 acre-feet. Again, since 1999, diversion flows from Blue Ridge reservoir have gone to zero. This major reduction in diversion flows has created a significant reduction in the in stream flow volumes of the East Verde River.

Currently, the water stored in Blue Ridge Reservoir is being considered as part of the Navajo Nations' and the Gila River Indian Community's water settlements. There is also some consideration being given by the U.S. Congress to sit aside a portion of the average annual water supply to communities of northwest Gila County.

Z. Tonto Creek

Tonto Creek originates in the Mogollon Rim country northeast of Payson, Arizona, and flows southward into Roosevelt. The 955 square-mile Tonto Creek basin is in the Central highlands water province of central Arizona and is entirely in Gila County. The Tonto Creek basin can be separated into two parts, the upper and lower basin. The upper basin is within the Study Area. The watershed area of the upper portion of the Tonto Creek basin is 675 square miles. The average annual flow from the upper basin is 80,000 acre-feet. (2)

The basin is drained by Tonto Creek, which flows southward and discharges into Roosevelt Lake. The mountains that border the basin are composed chiefly of igneous and metamorphic rocks, and the basin is underlain by more than 2,000 feet of unconsolidated to semiconsolidated sedimentary deposits.

The tributaries to Tonto Creek flow only for short periods mainly in response to runoff from precipitation.

AA. Fossil Springs/Creek

Fossil Springs/Creek (Creek) is located just below the edge of the Mogollon Rim, in the Mazatal Mountains of central Arizona, at the southern margin of the Colorado Plateau, in Fossil Creek Canyon. Fossil Creek forms the boundary between Yavapai and Gila counties, as well as Tonto and Coconino National Forests over most its course. The headwaters of the Creek and its extension to just south of Irving consist entirely of National Forest System lands, and include the northern portion of the Mazatzal Wilderness. No State, tribal, or other lands are included in this segment of the Creek.

Fossil Creek is one of Arizona's rare warm water perennial streams, flowing from a complex of springs, known as Fossil Springs, 14.3 miles through rugged and isolated terrain before entering the Verde River. Fossil Springs produces a constant water temperature of approximately 70 degrees Fahrenheit and a flow of 43 cfs (slightly more than 320 gallons per second), most of which is captured by Arizona Public Service (APS) at the 25-feet high Fossil Springs diversion dam located 0.3 mile downstream of the springs. Base flow below the diversion dam varies between 2 and 5 cfs, although episodic flows of much higher magnitude are possible from rainfall and snowmelt. At this flow rate, Fossil Springs produces approximately 31,000 acre-feet of water each year and represents a significant component of the base flow of the lower Verde River, particularly during the low flow season.

Fossil Creek is a major perennial tributary to the Verde River, draining southwest off the Mogollon Rim between the major sub-basins of East Verde River to the south and West Clear Creek to the north. Elevations in the watershed range from 7,260 feet along the Rim to 2,550 feet at the Verde River confluence. Rainfall and snowmelt contribute to intermittent stream flow between the upper basin and Fossil Springs. Perennial flow arises from Fossil Springs at an elevation of 4,280 feet, approximately 14.3 miles upstream from the Verde River. Virtually the entire Fossil Creek drainage area is on land administered by the U.S. Forest Service.

The water quality of Fossil Springs has a high calcium carbonate concentration. It has been estimated that approximately 12 metric tons per day of calcium carbonate is precipitated from full base flows in the 6.7 km stretch below Fossil Springs.

APS owns and operates the Childs and Irving hydroelectric facilities on Fossil Creek. Built in the early 1900s, these facilities utilize stream flow diverted from Fossil Creek to generate hydroelectric power.

In December 1992, APS filed an application with the Federal Energy Regulatory Commission (FERC) to relicense` the Childs-Irving Hydroelectric Project for 30 years. On August 14, 1997, FERC issued a draft Environmental Assessment (EA) on the relicensing proposal and invited public comment. After a period of negotiation with a coalition of groups including American Rivers, The Nature Conservancy, the Yavapai-Apache Tribe, the Northern Arizona Audubon Society, the Sierra Club, and the Center for Biological Diversity, APS signed an Agreement in Principle in 1999 to decommission the facilities and return full flows to Fossil Creek. FERC is currently analyzing the effects related to decommissioning and facility removal in the stream corridor and watershed. If decommissioning occurs according to the terms of the Agreement in Principle, APS will return base flows of approximately 43 cfs to Fossil Creek no later than December 31, 2004.

When the FERC decision is issued, APS has until 2009 to dismantle and remove most of their facilities and restore the sites. Some of the facilities will be retained for interpretive purposes, but all facilities at Irving (hydropower plant), Stehr Lake and the flumes, siphons and penstocks will be removed.

BB. Wilderness and Scenic Rivers—Fossil Creek

In 1993, the Forest Service conducted a preliminary analysis of Fossil Creek (Grant Loomis, Hydrologist, Tonto National Forest, personal communication). The study was for the purpose of determining if Fossil Creek could be considered for eligibility of its inclusion in the nation's Wild and Scenic Rivers system. The study was performed at the request of the state's congressional delegation. The study concluded that Fossil Creek was potentially eligible for inclusion because it was considered to be free flowing and possessed one or more "outstandingly remarkable" values (ORV). The segment of Fossil Creek between the Fossil Springs diversion dam and the Mazatzal Wilderness Boundary received a preliminary classification of "recreational," and the segment from the Mazatzal Wilderness boundary to the Verde Wild and Scenic River boundary was classified as "wild". Outstandingly remarkable values were listed as: Geologic, Fish, wildlife, Historic, and Riparian/Ecological. Free-flowing is defined in the Wild and Scenic Rivers Act , in part, as "…existing or flowing in natural condition without impoundment, diversion, straightening, rip-rapping, or other modification of the waterway."

In an associated study by the Forest Service, their policy requires that the Forest Service manage eligible river segments in a manner that does not impair their eligibility. The Forest Service has determined that a diversion from Fossil Creek is the type of activity that could impair eligibility for further consideration of Fossil Creek being established as a wild and scenic river.

CC. U.S. Fish and Wildlife Service/Arizona Game and Fish

Threatened and Endanger Species in Gila County.

County Species Lists – Gila County: Threatened and Endanger Species—2004 (26)

Common Name	Scientific Name	Status
Apache (Arizona) trout	*Oncorhynchus apache*	Threatened
Arizona agave	*Agave arizonica*	Endangered
Arizona hedgehog	*Echinocereus triglochidiatus var. arizonicus*	Endangered
Bald eagle	*Haliaeetus leucocephalus*	Threatened
Cactus ferruginous pygmy-owl	*Glaucidium brasilianum cactorum*	Endangered
California Brown pelican	*Plecanus occidentalis californicus*	Endangered
Chiricahua leopard frog	*Rana chiricahuensis*	Threatened
Colorado white salmon (pikeminnow)	*Ptychocheilus lucius*	Endangered
Gila topminnow	*Poeciliopsis occidentalis*	Endangered
Gila trout	*Oncorhynchus gilae*	Endangered
Lesser long-nosed bat	*Leptonycteris curasoae yerbabuenae*	Endangered
Loach minnow	*Tiaroga cobitis*	Threatened
Mexican spotted owl	*Stix occidentalis lucida*	Threatened
Razorback sucker	*Xyrauchen texanus*	Endangered
Southwestern willow flycatcher	*Empidonax traillii extimus*	Endangered
Spikedace	*Meda fulgida*	Threatened
Yuma clapper rail	*Rallus longirostris yumanensis*	Endangered
Proposed		
Gila chub	*Gil intermedia*	Proposed Endangered
Candidate		
Yellow-billed cuckoo	*Coccyzus americanus*	Candidate
Conservation Agreement		
Arizona bugbane	*Cimicifuga arizonica*	Conservation Agreement

DD. Effluent

One of the potential sources for additional water supply in the study area is effluent. At the time of the preparation of this Report (2004) most if not all of the wastewater generated by the Town of Payson was being treated into an effluent. All of that water was under contract for either irrigation purposes or aquifer recharge. It is expected that over the years of projected water demand, up to 2040, that there will be an increase in the available effluent available for supporting specific areas of reuse, e.g. public irrigation and recharge projects.

EE. North Gila County Sanitation District

The Northern Gila County Sanitary District (District) is the agency responsible for providing wastewater treatment for the Town of Payson service area. Wastewater collected within the District's boundaries is transported to the American Gulch Water Reclamation Facility (WRF). The reclamation facility is a biological nutrient removal process, which utilizes the following components: Primary Treatment, Bardenpho Process, Clarification, Tertiary Treatment, Disinfection, and Final Effluent Distribution and Disposal.

Reclaimed water is distributed to six customers (2003) for irrigation, dust control, construction activities and reused at the WRF. In addition to effluent distributed for reuse purposes, it is assumed that approximately 250,000 gallons per day (gpd) infiltrates through the bottoms of the lakes. Based on limited historical data, Table EE.1 American Gulch Water Reclamation Facility Effluent Water balance, presents a current water balance for reclaimed water produced at the WRF.

Table EE.1 American Gulch Water Reclamation Facility Water Balance

Month	Total Amount of Effluent Available (mgpm)[1]	Total Amount of Effluent Distributed to Reuse Customers (mgpm)	Assume Lake Infiltration (gpd)[2]	Excess Effluent Available for Recharge
Jul – 01	36.62	23.25	250,000	181,000
Aug – 01	39.56	31.78	250,000	1,000
Sept – 01	34.39	21.79	250,000	470,000
Oct – 01	33.55	25.93	250,000	0
Nov – 01	39.26	31.78	250,000	85,000
Dec – 01	37.00	14.29	250,000	483,000
Jan – 02	35.51	3.38	250,000	786,000
Feb – 02	32.14	16.10	250,000	323,000
Mar – 02	35.08	18.69	250,000	279,000
Apr – 02	34.23	24.38	250,000	78,000
May – 02	35.03	21.35	250,000	191,000
Jun—02	33.52	21.99	250,000	134,000

Notes:
(1) Million gallons per month
(2) Gallons per day

The excess effluent available for aquifer recharge varies from zero to over 700,000 gpd. The average annual volume of effluent available for recharge is 251,000 gpd, or nearly 280 acre-feet per year. The effluent from the WRF currently (2003) meets Class A+ reclaimed water standards.

FF. Non-Municipal Water Providers

Listed in Table FF.1 are the non-municipal water service providers for the study area. The water providers may be segregated into the groupings: Domestic Water Improvement Districts that have been established by Gila County, Private Water Companies who are licensed by the Arizona Corporation Commission, those water suppliers who do not qualify as a public water system but who have recognized as a water supplier to a limited service area (see definitions for "community"; "non-transient, non-community"; and "transient, non-community" water systems); and unregulated private wells. More details are given in the text presented below.

Table FF.1. Water Service Providers – Mogollon Rim Water Supply Study

Water Service Provider	Name	Public Water System Type
Public – Domestic Water Improvement Districts	Pine: Solitude Trails	Community
"	Pine: Strawberry Hollow	Transient/Non-Community
"	Pine: Pine Water Association	Community
"	Pine: Pine Creek Canyon/Portals IV	Community
"	Rim Trail (Washington Park/Shadow Rim	Community
Private – Unregulated (Cooperatives/Homeowner Associations, and Others)	Bear Flat	
"	Beaver Valley	Community
"	Bonita Creek	Transient/Non-Community
"	Christopher Creek/Hunter Creek/Zane Grey/Brooks	Community
"	Collins Ranch	Non-Transient/Non-Community
"	Diamond Point Recreation	Semipublic (non-regulated)
"	Diamond Point Shadows	Community
"	Ellison Creek Estates	Semipublic (non-regulated)
"	Ellison Creek Recreation	Semipublic (non-regulated)
"	Kohl's Ranch	Non-Transient/Non-Community
"	Oxbow Estates	Semipublic (non-regulated)
"	Pine Meadows	Semipublic (non-regulated)
"	Round Valley	Semipublic (non-regulated)
"	Summit Springs	Semipublic (non-regulated)
"	Thompson I & II	Semipublic (non-regulated)
"	Tonto Creek Estates	Community
"	Tonto Village	Community
"	Verde Glen/Cowan Ranch	Non-Transient/Non-Community
"	Wonder Valley/Freedom Acres	Transient/Non-Community

Private – Regulated Utility Firms	**Brooke Utilities**	
"	East Verde Park	Community
"	Flowing Springs	Community
"	Geronimo Estates	Community
"	Mead Ranch	Community
"	Mesa Del Caballo	Community
"	Pine	Community
"	Star Valley A & B	Community
"	Strawberry	Community
"	Whispering Pines	Community
"	Strawberry – Lufkin Hunt	Community

The following definitions are those of the Arizona Department Environmental Quality regarding safe drinking water system.

A "community water system" is one that serves 15 or more service connections used by year-round residents or that serves 25 or more year-round residents who use water for drinking, cooking, bathing, and cleaning. Community water systems may also serve all the businesses and other water users within their boundaries.

A "non-transient, non-community water system" is one that serves 15 or more service connections that are used by the same persons for at least six months per year, or serves the same 25 or more persons for at least six months per year. These water systems supply businesses where people may spend a large percentage of time, but these typically aren't a consumer's primary water source.

A "transient, non-community water system" is one that serves 15 or more service connections, but does not serve 15 or more service connections that are used that are used by the same persons for more than six months per year; or one that serves an average of at least 25 persons per day for at least 60 days per year, but does not serve the same 25 persons for more than six months per year.

The following Arizona Department of Water Resources definition for an exempt well is as follows: A well with a maximum pumping capacity of not more than 35 gallons per minute, which is used to withdraw groundwater for non-irrigation purposes.

GG. Domestic Water Improvement Districts -- Gila County

There are five public domestic water improvement districts (DWID) located within the study area boundaries: Solitude Trails, Strawberry Hollow, Pine Water Association, Pine Creek Canyon Portals IV and Rim Trail. All of the established DWIDs are located within the Pine community. In Arizona, a domestic water improvement district is a county improvement district which is either formed for the purpose of constructing or improving a domestic water delivery system or purchasing an existing domestic water delivery system and, if necessary, improvements to the system or a district that is converted from a county improvement district to a domestic water improvement district.

HH. Gila County Unregulated Cooperatives and Homeowners Associations

There are 18 unregulated cooperatives and homeowner associations providing water service within the study area.

II. Multijurisdictional Water Facilities Districts

During the late 1990s, Arizona Revised Statutes: Title 48, Chapter 34 was passed into law, Multijurisdictional Water Facilities Districts. The purpose of the law was to allow two or more municipal water systems to consider the formation of a multijurisdictional water facilities district for the purpose of mutual benefit in the construction, operation and maintenance of water related facilities. A Municipal water provider is defined as a city, town, domestic water improvement district, private water company or irrigation districts that supplies water for nonirrigation use. If there were a desire for some or all study parties to enter into a multijurisdictional water facilities district, State law would allow for the establishment of such an institutional arrangement.

JJ. Indian Water Rights/Settlements

Currently (2004) there are several Indian water settlements, associated with Tribe in Arizona, that are in some state of the settlement process. The Arizona Water Rights Settlement--Gila River Indian Community is awaiting Congressional approval of its settlement agreement. Water Settlement negotiations are still underway for the Indian communities of the Little Colorado River Basin. The tribes and nation that are included in the Little Colorado River Basin Water Settlement include the Navajo Nation, Hopi Tribe, Zuni Pueblo, and the San Juan Piaute Tribe.

The waters collected and stored in Blue Ridge Reservoir have been part of the water budget discussions for water settlements associated with the Navajo Nation, Hopi Tribe, and the Gila River Indian Community. December 10, 2004, President Bush signed the Arizona Water Settlement Act thus enacting an Indian community water settlement that had been decades in negotiations. This settlement act resolves long-held issues held by the federal government, the states of Arizona and New Mexico, local governments, the Gila River Indian Community, the Tohono O’odham Nation and other Native American communities in the region. The Navajo Nation and the Hopi Tribe’s water settlement issues were not resolved by the Arizona Settlement Act.

The Settlement Agreement is entered into among: the United States of America; the Gila River Indian Community; the State of Arizona; the Salt River Project Agricultural Improvement and Power District; the Salt River Valley Water Users’ Association; Phelps Dodge Corporation and several other settling parties.

Offered immediately below are pertinent sections of the Arizona Settle Act (P.L. 108-451) that are expected to impact the water supplies being consider in the Mogollon Rim Water Supply Study:

Sec. 213 – Miscellaneous Provisions -- Arizona Water Settlement Act ratifies the agreement between the United States and the Salt River Valley Water Users' Association dated September 6, 1917, and the rights of the Salt River Project to store water from the Salt River and Verde River at specified locations and to deliver the stored water to shareholders of the Project and others for recognized purposes, subject to specified requirements. Directs the United States, acting through the Secretary, to accept from the Salt River Project Agricultural Improvement and Power District the transfer of title to the Blue Ridge Project in Arizona.

BLUE RIDGE PROJECT TRANSFER AUTHORIZATION-

(1) DEFINITIONS- In this subsection:

(A) BLUE RIDGE PROJECT- The term `Blue Ridge Project' means the water storage reservoir known as `Blue Ridge Reservoir' situated in Coconino and Gila Counties, Arizona, consisting generally of--

(i) Blue Ridge Dam and all pipelines, tunnels, buildings, hydroelectric generating facilities, and other structures of every kind, transmission, telephone and fiber optic lines, pumps, machinery, tools, and appliances; and

(ii) all real or personal property, appurtenant to or used, or constructed or otherwise acquired to be used, in connection with Blue Ridge Reservoir.

(B) SALT RIVER PROJECT AGRICULTURAL IMPROVEMENT AND POWER DISTRICT- The term `Salt River Project Agricultural Improvement and Power District' means the Salt River Project Agricultural Improvement and Power District, a political subdivision of the State of Arizona.

(2) TRANSFER OF TITLE- The United States, acting through the Secretary of the Interior, shall accept from the Salt River Project Agricultural Improvement and Power District the transfer of title to the Blue Ridge Project. The transfer of title to the Blue Ridge Project from the Salt River Project Agricultural Improvement and Power District to the United States shall be without cost to the United States. The transfer, change of use or change of place of use of any water rights associated with the Blue Ridge Project shall be made in accordance with Arizona law.

(3) USE AND BENEFIT OF SALT RIVER FEDERAL RECLAMATION PROJECT-

(A) IN GENERAL- Subject to subparagraph (B), the United States shall hold title to the Blue Ridge Project for the exclusive use and benefit of the Salt River Federal Reclamation Project.

(B) AVAILABILITY OF WATER- Up to 3,500 acre-feet of water per year may be made available from Blue Ridge Reservoir for municipal and domestic uses in Northern Gila County, Arizona, without cost to the Salt River Federal Reclamation Project.

(4) CARE, OPERATION, AND MAINTENANCE- Upon the transfer of title of the Blue Ridge Project to the United States under paragraph (2), the Salt River Valley Water Users' Association and the Salt River Project Agricultural Improvement and Power District shall be responsible for the care, operation, and maintenance of the project pursuant to the contract between the United States and the Salt River Valley Water Users' Association, dated September 6, 1917, as amended.

(5) C.C. CRAGIN DAM & RESERVOIR- Upon the transfer of title of the Blue Ridge Project to the United States under paragraph (2), Blue Ridge Dam and Reservoir shall thereafter be known as the `C.C. Cragin Dam and Reservoir'.

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