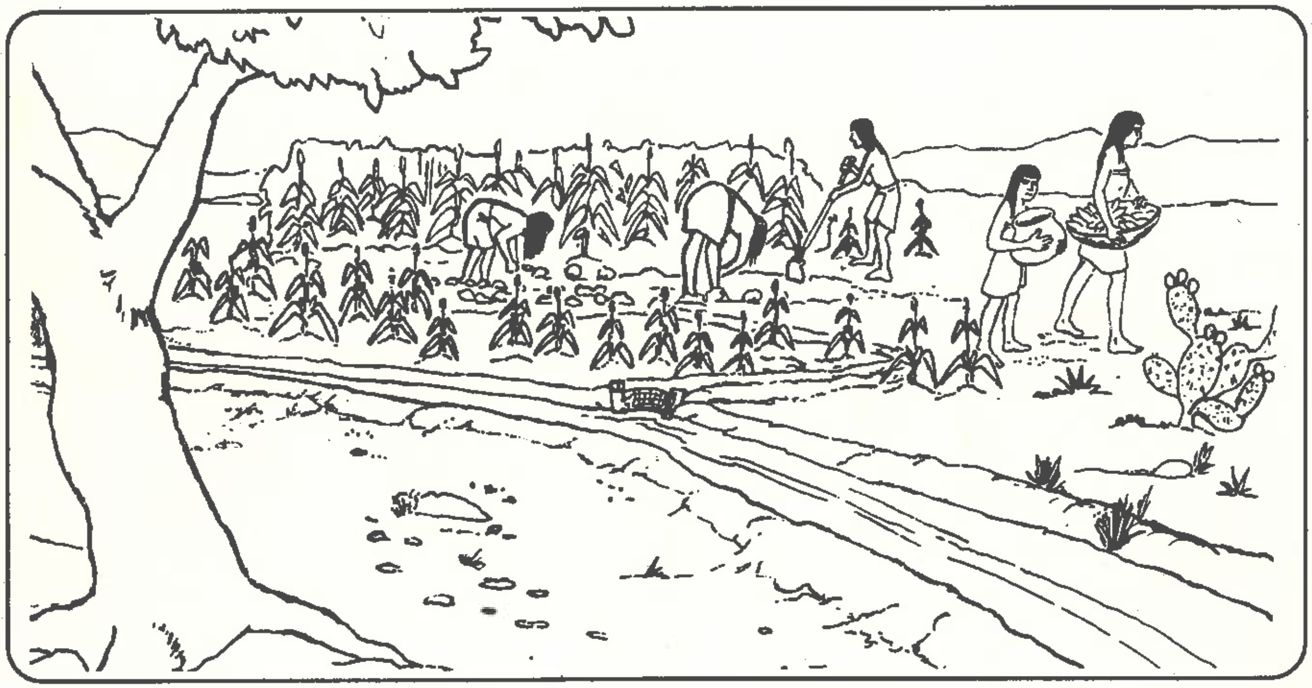
PREHISTORIC IRRIGATION IN ARIZONA



A Component of the Arizona Historic Preservation Plan

Prepared for:
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Notes regarding this version of *Prehistoric Irrigation in Arizona: A Context for Canals and Related Cultural Resources*:

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Allen Dart
February 15, 2018

FINAL

PREHISTORIC IRRIGATION IN ARIZONA:

A CONTEXT FOR CANALS AND RELATED CULTURAL RESOURCES

Prepared by

Allen Dart
Center for Desert Archaeology
Technical Report 89-7

1989

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ACKNOWLEDGEMENTS

In a symphonic production, the piano soloist's work can be fully appreciated only when the piano technicians and other persons--those who do not share the spotlights' gleam--have nonetheless contributed a little something of themselves in preparing the instruments and music hall for the performance. Likewise, in producing this work on prehistoric irrigation there were many kind people behind the curtain whose knowledge and expertise the author relied upon; I hope they see a little of themselves in the good parts of this production, and that they will blame me, the performer, for any errors that are my fault alone.

Funding and primary review for this project were through the Arizona State Historic Preservation Office; the efforts of Pat Stein, Teresa Hoffman, Sherry Lerner, and Donna Gaines of that office were invaluable. Particularly helpful reviews were also provided by Jerry Howard (Soil Systems, Inc., Phoenix); William E. Doolittle (Department of Geography, Univeristy of Texas at Austin); Mary Bernard-Shaw, Bill Doelle, Mark Elson, Jim Heidke, and Henry Wallace (Institute for American Research, now Desert Archaeology, Tucson); Kathy Pedrick (U.S. Bureau of Reclamation), James Schoenwetter (Arizona State University), Gary Stumpf (U.S. Bureau of Land Management), and J. Scott Wood (Archeologist, Tonto National Forest).

Much of the "sheet music" used in this production included unpublished papers, manuscripts, maps, and verbal information. Material for significant parts of the work were provided by Cory Breternitz and Jerry Howard, who provided several papers, drawings, and maps produced by Soil Systems, Inc.; Michael Barton and the Department of Anthropology, Arizona State University, who allowed me to copy many pages and photos from the University's Frank Midvale archival collection; Sharon Urban, who helped me access the Arizona State Museum (University of Arizona) archaeological site survey files; Dave Wilcox and Dawn Greenwald, who provided copies of the Museum of Northern Arizona's archaeological site records; and Jane Pike and Bill Gibson for providing records of archaeological sites recorded by the Bureau of Land Management. Additional information was provided courtesy of the following people and institutions: J. Scott Wood (Tonto National Forest); Paul R. Fish; Peter J. Pilles, Jr.; Adrienne Rankin and Margie Green of Archaeological Consulting Services, Inc. (Tempe); Dave Gregory; Don Dove; Bill Doelle; and Lyle Stone.

Figures 2, 4, 8, and 9 were drafted by Becky Quayle Craig; Becky was remarkably patient with me whenever I came to her with new material to draft onto her 'already completed' editions. Those who furnished other illustrations are acknowedged in the figure captions. Finally, my thanks to Ted Feragne for providing editing services intended to make the report more comprehensible to readers who are not professional archaeologists.

Finally, this report would not have been possible without the contributions of Omar Turney and Frank Midvale. Any serious student of prehistoric irrigation in Arizona owes a great deal to these two men who pioneered our study of ancient irrigation works in the state.

Allen Dart
June 5, 1989

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SURVIVAL IN THE SUN

Beads of muddy sweat trickled down the old fellow's bronzed brow as he trudged alongside the ditch in the early morning light. Pausing, he laid down the heavy, crook-ended stick that he'd fashioned from the root and trunk of a small, dead mesquite tree, then bent over, reaching down to the ditch's water level to pull up a large stone slab that was standing erect at the top of the ditch bank. Shading his eyes against the glare of the morning sun that was reflecting off the water's surface, he could see that removing the slab had allowed some of the water to seep, then gush, out through the new gap in the top of the bank, into a furrow that was formed between two built-up dirt ridges. This furrow would carry some of the scummy water toward the field he'd be watering this morning. Wiping off some of the sweat and dirt from his face, then retrieving his stick, he lumbered a little way out along this little ditch and maneuvered the crooked end of the stick to scrape away part of the built-up ridge of earth that enclosed the furrow, opening up a runnel that flowed through the ridge into a little patch of green. After the earth had been soaked for a few minutes he pushed some of the hot, moist dirt back up onto the ridge with his foot, a motion that cooled his burning feet at the same time as it stopped the little gush of water that had been nourishing this part of his field. Moving down a little farther, he went through the motions again--opening a hole in the ditch side and allowing water to flow out, closing the hole after a while, moving farther down to open up a new flow into a different part of the corn field. He would toil until noon, carefully manipulating the ditch water, occasionally chasing out ground squirrels or picking off some of the worms that were sneaking bites of his produce, wiping off the rivulets of perspiration, pulling a weed here, there.

By the time the sun had just passed its zenith, it would be so hot that to escape the blistering heat he'd have to stop and rest in a shaded area where the temperature had only gotten up to 110 degrees. About the only thing he could do for the next few hours would be to drink some of the water that was cooling in a pottery jar under a ramada next to the house, eat a little, and maybe take a long nap, as it was too sweltering to think of anything else. By midafternoon his toil would begin again, continuing a couple more hours until the clouds would finally darken the ground and, with abrupt, deafening thunderclaps, explode their lifegiving rain onto the desert floor with a fury that would drown lizards, flood the corn-thieving squirrels out of their burrows, wash out a handful of young corn plants, and drive the man under a nearby mesquite tree or into his earth-covered lodge. Not an easy life. But irrigating this desert would allow him and his family to produce enough food for fairly steady eating through the rest of this summer and the months beyond. Just before the coming of the more gentle, steady rainstorms of winter, they'd start anew, cleaning out the ditches and rebuilding the wood-and-brush dams that diverted the river into their canals, getting everything ready to plant and irrigate another crop the coming spring.

Farmers over a thousand years ago probably lived like this in what is now the Phoenix area of south-central Arizona. Even though they were living in what could be called a Stone Age, Arizona's prehistoric farmers had developed sophisticated knowledge about how to irrigate the torrid desert lowlands, and thereby had caused to flourish grains and squashes, beans, an array of herbs and condiments, even cotton to weave into clothing. Their many techniques for control of water and thus for survival in the sun were born of necessity in a hot, arid land; their water control methods varied with the different landscapes and with the different cultures themselves. One water control method, *canal irrigation--the construction of artificial canals or channels to carry water via gravity flow from a source to fields that otherwise would be dry*--is a hallmark of the ancient Indians who inhabited the lowland desert areas of the south-central part of Arizona between 500 and 1500 years ago. The sophistication and extent of the irrigation works during this early era of Arizona's occupation rightfully excite the interest of our modern age (Judd 1931). Ever since the 1690s, when Spanish missionaries and soldiers first began reconnoitering southern Arizona for the establishment of missions, secular settlements, and forts, newcomers to the region have marveled at the water works that were left as reminders of the only true irrigation culture in the prehistoric United States (Burrus 1971; Mange 1954; Halseth 1932). In 1887, over 150 years after the first Spanish settlements were founded and after the territory had been ceded to the United States by Mexico, the earthen embankments along some of the ancient canals in the Phoenix area were still so big and troublesome that farmers had to reduce the resale price of their land to offset the cost of leveling new fields (Turney 1929:53). The allure of these magnificent ruins to scientists and historians led to detailed investigations of the prehistoric irrigation systems of the Phoenix area beginning in 1887 and 1888 (Figure 1; Haury 1945:39-42), and archaeologists during the hundred years since the first investigations have remained keenly interested in these systems.

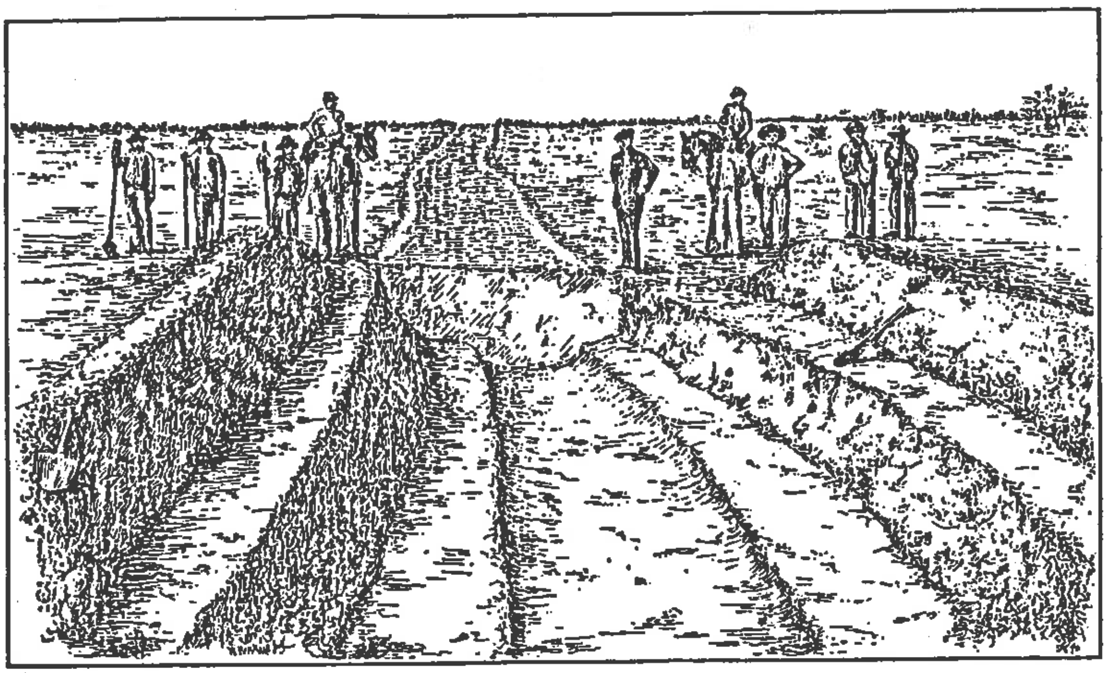

Figure 1. A sketch showing a small secondary ditch within the major canal as revealed by excavations at Los Muertos, a ruined Hohokam village (Haury 1945:41).

A century of archaeological studies has revealed a wealth of information about these water systems. The general public should know about the fascinating history of these structures. The annals of this area reveal how widespread are the irrigation works once built along streams in Arizona. Along with these canal structures, other buildings were erected by the tribes. Sad to say, few people nowadays realize these structures existed, and still fewer appreciate their significance. Moreover, our current appraisal of their purpose, methods of construction, and so on, is by no means final. But what is beyond dispute is that these unique artifacts of early Arizona should be protected and preserved. Luckily, it can be done.

THE SETTINGS OF IRRIGATION IN ANCIENT ARIZONA

CULTURAL AND TEMPORAL SETTINGS

The earliest known, and eventually the most extensive prehistoric irrigation systems in North America were engineered and constructed by people who once inhabited the valleys of the lower Salt and Gila rivers (Figure 2). These systems were so remarkable that in 1870, over four centuries after their abandonment, the early historic period settlers chose the name "Phoenix" for what would eventually become Arizona's capital city. Noting the venerable remnants of the long-abandoned Indian canals and villages round about them, they chose this name anticipating that the new city would rise upon the vestiges of the old just as the legendary Phoenix bird, consumed by fire, was reborn from its own ashes (Halseth 1932; Granger 1983).

Though other names have been applied to them, the canal builders of antiquity in the Phoenix area are now known as the *Hohokam*, a name given to them by the Pima Indians (Turney 1929:53; Haury 1976:5). The Hohokam culture extended approximately from the San Pedro River valley on the east to a point slightly beyond the great bend of the Gila River on the west, and from somewhere near Arizona's boundary with Mexico northward into Arizona's rugged mountains below the Mogollon Rim (Figure 2). Although the Indians of Arizona began farming on a limited scale nearly 3000 years ago (Huckell 1988), construction of the Hohokam irrigation systems probably did not begin until a few centuries after Christ. It is still unknown whether the first use of canals by native Arizonans was the result of a local invention or an idea introduced to them from cultures in Mexico who already had thousands of years of experience in creating an agricultural technology. Regardless of who originated the idea of irrigation in Arizona, by the time the European Renaissance was getting under way during the 14th century the Hohokam had far surpassed all other North American cultures in canal-building; by that time the Hohokam had constructed well over 350 miles of main canals in the Salt River Valley alone (Nicholas 1981), and many more miles of canals in the rest of Arizona.

The Hohokam were sedentary villagers who made much if not all of their living by farming. Besides canals, they are known for cremating their dead and for making distinctive artifacts including tan or buff pottery with red painted designs, jewelry carved from sea shells, and items of stone (Figure 3). They dwelt mainly in pit-houses--lodges partly dug into the ground, with walls and roofs built of tree limbs and brush covered over with earth. Characteristic of many of the larger Hohokam villages occupied prior to A.D. 1100 are great, oval, earthen structures known as "ball courts" because they are believed to have been used to play a ritual ball game. Some time after 1100, changes occurred in Hohokam society. Many of the ball courts fell out of use; burials became more common than cremations; and pit-house villages were abandoned as new, large settlements consisting of above-ground adobe structures were erected. Several of these later Hohokam villages included ample adobe architecture atop monumental mounds amid massive mud walls several feet thick (Turney 1929). New kinds of pottery were added--some decorated in black, white, and red, others just solid red. By A.D. 1300, the cultural change was so pronounced that some researchers have referred to this later version of Hohokam society as the "Salado culture."

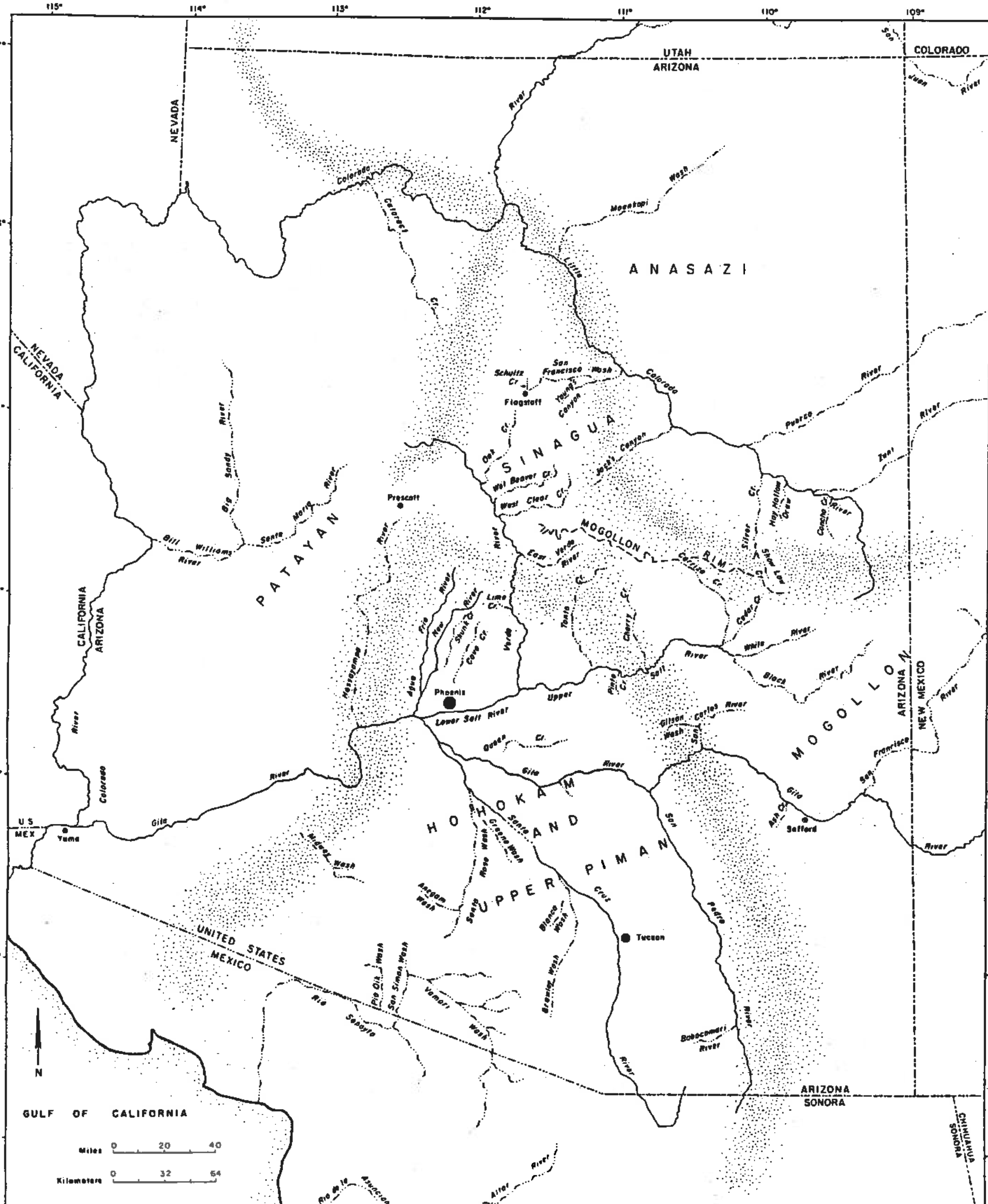

Figure 2. Map showing the prehistoric culture areas of Arizona.

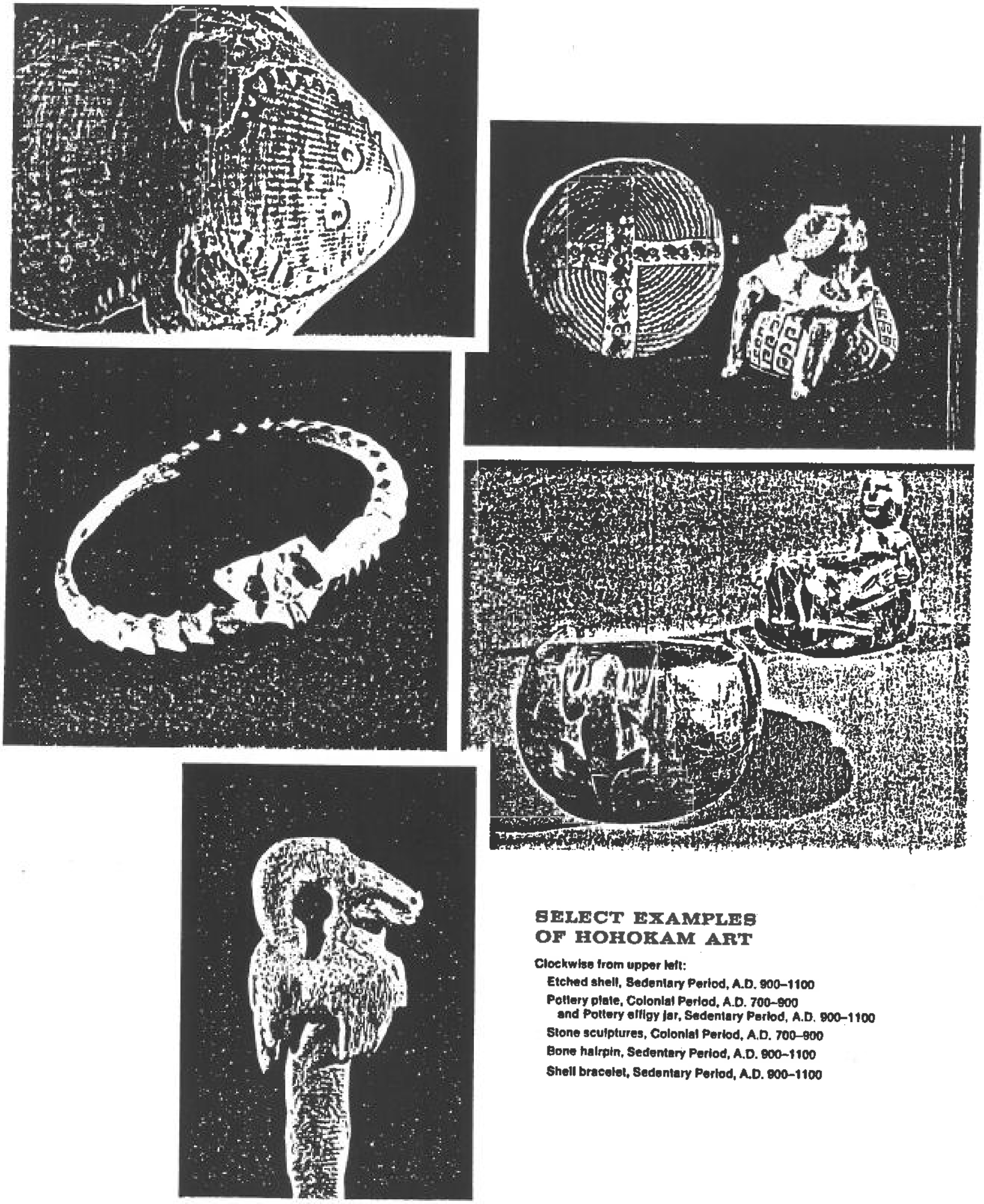

Figure 3. Select examples of Hohokam art (Haury 1976:ii).

For reasons still unknown, around A.D. 1450 the cultural tradition declined drastically, and the Hohokam villages and magnificent canal systems were given up to the mercy of the elements. Failure of their canal systems may have been at least partly to blame for this cultural decline, because canal use seems to have been either quite limited or entirely absent among the Hohokam people's successors, the Pima Indians, who lived along the Gila River when the first Spanish settlers arrived in the late 17th century (Doelle 1981; cf. Manje 1954:118-121; for opposing views see Russell [1975]; Castetter and Bell [1942]; Ezell [1961, 1963]). On the other hand, in the extreme southern and southeastern part of the former Hohokam domain, among other *Upper Pima* Indians who spoke languages related to the tongue of the Gila Pima, irrigation appears to have sprung up anew as a major means of food production some time just before the Europeans arrived. Irrigated fields of the Upper Pima were observed by Spanish missionary parties in the late 17th century in the Santa Cruz Valley, from the vicinity of what is now Tucson southward to Mission Tumacacori; in the San Pedro Valley between the Mexican boundary and this river's confluence with the Gila River; just south of the Mexican border along the Sonoyta River (Manje 1954:77-83,92-94,110,158; Smith 1966:21; Doelle 1984:205); and 30 to 50 miles south of the border at villages along the Cocóspera, Altar, and San Miguel rivers (Bolton 1936:251,253,273).

Arizona's prehistoric peoples who lived outside of the Hohokam-Pima culture area also constructed irrigation systems, but neither theirs nor those of the Upper Pima cultures who succeeded them were built to nearly so grand a scale as the Hohokam systems. Immediately north of the Hohokam, in the region that stretches from the rugged mountains above Phoenix northward to the high Colorado Plateau, a society known as the *Sinagua* came to prominence in the 11th century and survived until after A.D. 1400. The constellation of traits identifying the Sinagua was at times distinctive, including certain kinds of plain brown pottery, burials in which the bodies were laid out straight, and masonry-lined pithouses. At other times, however, the Sinagua tradition appears to have incorporated traits more typical of the cultures in neighboring regions; these include Hohokam-like ball courts, red-on-buff pottery, and canals. The Sinagua people's black and white pottery and fine rock-masonry architecture, by contrast, suggest an influence from the *Mogollon* and *Anasazi* peoples who lived farther to the north and east. The Mogollon and the Anasazi, who built most of the large pueblos and cliff-dwellings in east-central and northeastern Arizona, also practiced irrigation, albeit on a limited scale, between A.D. 950 and 1400. And it is possible that prehistoric canal systems were also built by people of southwestern Arizona's *Patayan* culture who left archaeological remnants not too different from those of the Hohokam; Patayan archaeological materials date from approximately A.D. 800 until the early 1900s and are common in the valleys of the lower Colorado River and the Gila River west of the Gila's great bend (Figure 2).

LOCATIONS OF PREHISTORIC IRRIGATION WORKS IN ARIZONA

Exactly where stream-fed canals were built in Arizona prehistorically appears to have depended on both environmental and human factors. Obviously the foremost environmental condition necessary was the presence of an above-ground stream. The stream had to meet certain conditions, though. First, because pumping devices were unknown before the arrival of Europeans, it had to be possible to divert the water into a canal by means of gravity-flow alone, that is, without the use of any sort of a pump or lift. Therefore, it was not practical to irrigate from streams whose banks were composed of rock or from streams whose channels were so deeply incised that massive effort would have been required to dig through their high banks. Furthermore, the stream had to flow during the portion of the year when frost was not a hindrance to the growth of crop plants and, finally, the stream had to provide enough water (in addition to rainwater) for a crop to become established and to mature. As long as a stream met all of these environmental conditions, it was apt to become an irrigation source.

Some areas along Arizona's rivers meet all of these conditions, yet were not used as irrigation sources. Why? At least two cultural explanations are possible. One is that irrigation is hard work and will not be used unless necessary; small groups with an abundance of either wild food or rain-fed crops would not need to irrigate. Another explanation may be that peoples who lived along the untapped stretches of suitable rivers in the forgotten times of Arizona were so strongly partial to the way of life in which they had grown up that they resisted introduction of a strange new food production technology. This is known to have happened among other Indian peoples, for example, when the United States attempted to persuade Plains Indian tribes to take up farming. Any of these factors, alone or in combination, could explain why irrigation was never used to any significant degree among, for example, the Patayan peoples who inhabited the lower Colorado River valley.

The streams that were used for prehistoric irrigation are located in a number of major natural watersheds, including those drained by the Salt, Verde, Gila, Agua Fria, New, San Pedro, Santa Cruz, and Little Colorado rivers (Figure 4). Streams that only flowed short distances before they disappeared into southern Arizona's desert sands were also utilized.[1]

The Salt-Verde Watershed

Lower Salt River Valley

The most extensive and complex prehistoric canal systems in the state had their genesis along the lower Salt River in what is now the metropolitan area of Phoenix (Figures 5, 6). At least 16 Hohokam canal systems originated along the last 40 miles of the Salt River, below its confluence with the Verde. Figure 5 shows 10 canal intakes along the north side of the river and forming 8 major irrigation systems--and 6 intakes on the south side. At least seven of these prehistoric systems were eventually reused by the first Anglo-American settlers in the lower Salt Valley in the 19th century (Turney 1929:51-52). More than 350 miles of major Hohokam canals have been identified in these systems, not counting the smaller distribution and lateral canals that delivered water directly to the fields.[2] Because many archaeological studies have been done as part of the planning for recent urban development in the Phoenix metropolitan area, the canals of the lower Salt have been more intensively studied than any other prehistoric irrigation systems in the United States. Most conclusions about prehistoric irrigation in the southwestern U.S. therefore derive from data on prehistoric irrigation works in that area.

Elsewhere within the lower Salt Valley, Hohokam canals have been identified along Cave Creek, an ephemeral stream that terminates in a delta just north of the Salt River. Frank Midvale identified one ancient canal emanating from the east bank of the creek about 12 miles north of the center of Phoenix and three more canals approximately 5 to 6 miles farther north.[3] More recently, prehistoric canals have been found to extend along Cave Creek as far as 20 miles north of central Phoenix.[4]

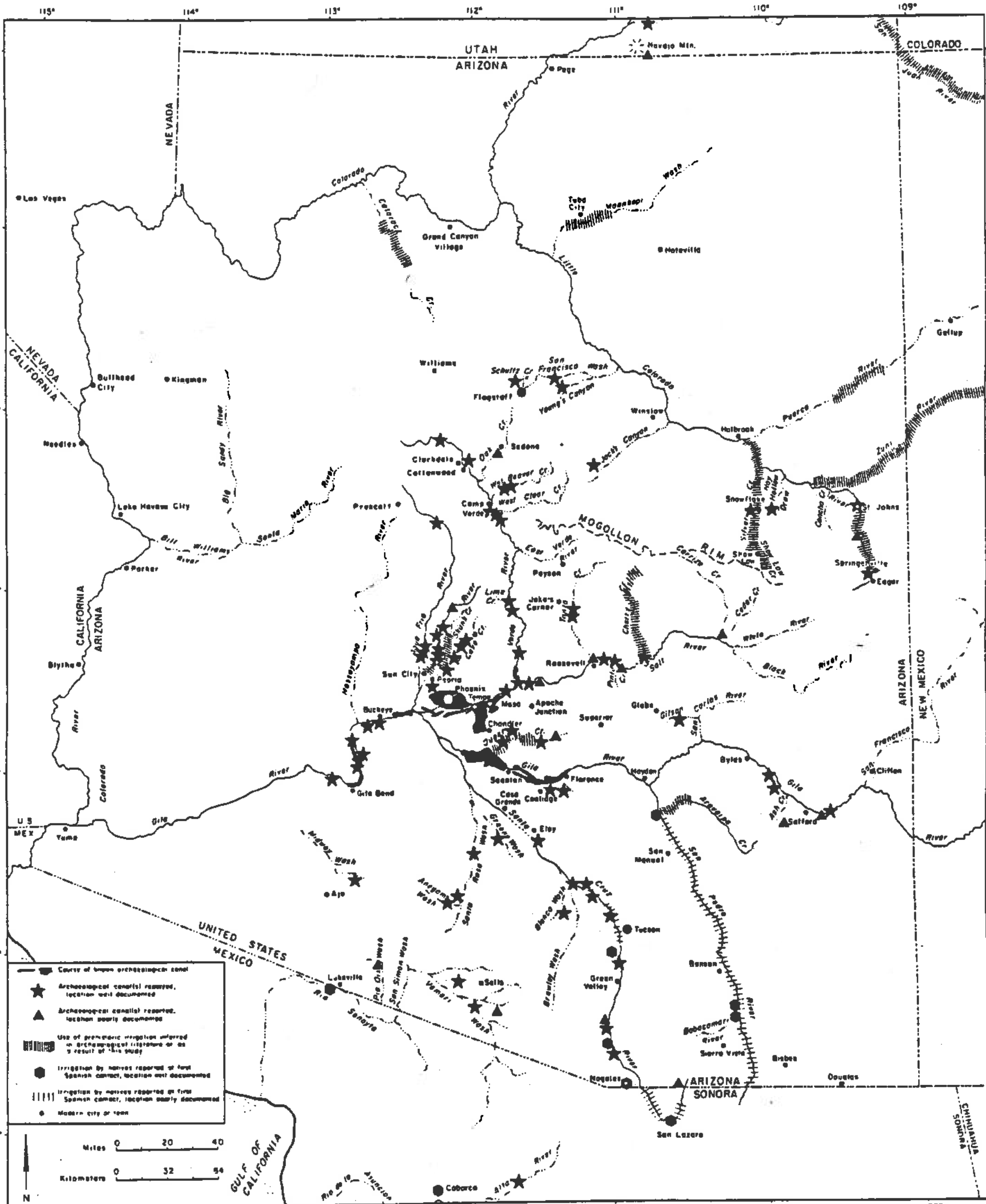

Figure 4. Locations of prehistoric irrigation works that have been reported or suggested in Arizona.

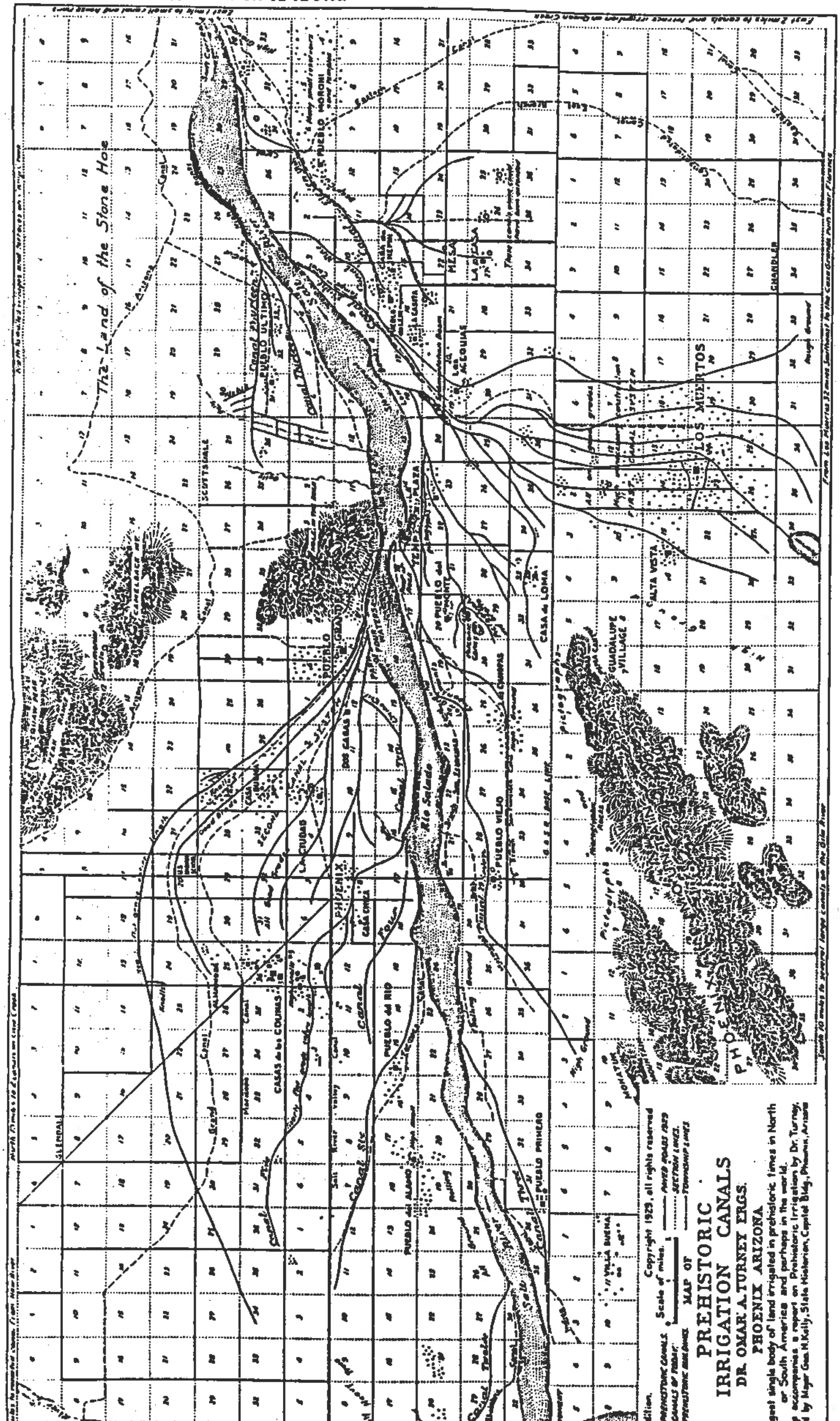

Figure 5. Omar A. Turney's map of prehistoric canals in the Salt River Valley (Turney 1929).

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Soil Systems, Inc., Phoenix

Figure 6. Jerry B. Howard's map of prehistoric canals in the Salt River Valley (Courtesy of Soil Systems, Inc., Phoenix).

Upper Salt River and Tributaries

Irrigation was employed as early as A.D. 750 along the upper Salt River east of its confluence with the Verde, but on a limited scale compared with the lower Salt. Possible prehistoric canals were reported at two sites 1 to 5 miles above the Verde confluence.[5] Nine miles above the Verde confluence, a possible canal was identified in the southeastern one-third of the area now under Saguaro Lake, in a year when the lake had been drained down lower than normal. The researcher who found this feature noted, "Prehistoric canals buried under water. Nearly every large artificial lake in Arizona (if not all of them) has remains of Indian ruins buried and lost under its waters" (Midvale 1971:Book XXXI).

Farther east, ancient canals were found in the Tonto Basin (where Lake Roosevelt is now located) on the north side of the Salt River between the Arroyo Pinal and Tonto Creek, and irrigation ditches are said to have once existed for 13 miles along the south side of the upper Salt at the edge of Roosevelt Lake.[6] A visible, possibly prehistoric canal was observed on the south side of Roosevelt Lake about a half-mile east of Pinto Creek.[7] All ancient canals of the upper Salt River that are now listed in the cultural resources inventory of the Tonto National Forest are east of Pinto Creek, near the mouth of Campaign Creek.[8]

Prehistoric canals have also been identified along the tributaries of the Salt River north and east of Roosevelt Lake. Along Tonto Creek, one canal was identified just south of Jake's Corner where Highway 188 drops into the valley and begins to run parallel to the creek; another was found 3 miles farther south along the west side of the creek.[9] Along Carrizo Creek near its confluence with Cedar Creek an ancient canal was reported at a pueblo ruin.[10] Near the mouth of Pinto Creek a double row of stones 300 feet long was tentatively interpreted as an ancient canal.[11] And along Cherry Creek, at least one prehistoric canal has been reported and some historic canals have been interpreted as reused prehistoric ones because they were found in association with prehistoric sites.[12]

Verde River and Tributaries

Many prehistoric irrigation works have been reported along the lower 100 miles of the Verde River and its tributaries West Clear Creek, Wet Beaver Creek, Lime Creek, Oak Creek, and Dragoon Creek. Along the Verde just north of its confluence with the Salt, archaeologists identified prehistoric canals at several Hohokam habitation sites that were occupied between A.D. 500 and 1450.[13] Farther north, a well preserved canal remnant about 2 miles below the mouth of Lime Creek, on the east side of the Verde, was photographed in the late 19th century and was later called the "Big Horseshoe Canal".[14] About 30 miles upstream from the Salt River confluence in the area now submerged by Horseshoe Reservoir, the "Limestone" canal originated opposite Lime Creek and flowed south along the east side of the Verde; another canal originated on the west side of the Verde, and a single canal emanated from Lime Creek immediately west of its juncture with the river.[15] One other site about 1 mile south of Horseshoe Dam reportedly contains two more prehistoric canals.[16]

In the upper Verde Valley, researchers in the 1890s reported two prehistoric canals near a point known as Spanish Wash about 3.5 miles below Camp Verde and "many evidences of irrigating ditches" about 8 miles south of Camp Verde.[17] Near the Tuzigoot ruin 18 miles upriver from Camp Verde and 13 miles below Perkinsville, prehistoric canals were reportedly visible in the 1880s, and in 1973 test excavations revealed two buried canals that may be prehistoric.[18] The northernmost prehistoric canal known along the Verde River was reported in the vicinity of Perkinsville.[19]

In the valley of Wet Beaver Creek a prehistoric canal is still visible at Montezuma Well (Figure 7). It did not tap a stream, though; instead, it flowed from a sink-hole lake.[20] However, canals that did draw their water from Wet Beaver Creek between A.D. 900 and 1350 have been reported about 1 to 5 miles upstream from Montezuma Well.[21] Prehistoric canals have also been observed near the mouth of West Clear Creek and near Courthouse Butte along Oak Creek.[22]

An early researcher presumed that "small ditches" had been present along "Dragoon Creek"; his mention of Dragoon Creek in the same sentence as Clear Creek, Beaver Creek, and the upper Verde suggests that Dragoon Creek was another tributary of the Verde River.[23] However, its location is uncertain; the name does not occur on any of the current USGS topographic maps covering the Verde watershed, and the only stream called "Dragoon" listed in *Arizona's Names* is located in the southeastern part of the state (Granger 1983:214-215,717).

Figure 7. A segment of the prehistoric canal that emanated from Montezuma Well (Midvale 1971:Book XVII).

The Gila River Watershed (Exclusive of Salt River Watershed)

The Gila River and Its Minor Tributaries

Irrigation appears to have been employed between A.D. 750 and 1450 in the broader parts of the Gila River Valley from above Safford on the east to the Gila Bend area on the west. Irrigation features were reported at two sites 9 and 10 miles east of Safford: at one--the Chichilticale pueblo site--a canal was confidently identified as prehistoric, whereas the antiquity of a canal at the nearby site was less certain.[24] Five miles east of Safford near Solomonville (now Solomon [Granger 1983:574]), one researcher noted "reservoirs on the mesa from which terraced gardens below were irrigated," and another heard of, but did not confirm, prehistoric canals along Ash Creek, 7 or more miles south of Pima in the Mount Graham foothills.[25] Distinct remains of irrigation canals associated with ancient villages were found about 8 miles east of old Fort Thomas--near what is now called Indian Hot Springs--and at least four others were reported in that vicinity and near old Fort Goodwin (the present Fort Thomas [Granger 1983:266,610-611]).[26] Another canal was found about 12 miles east of Globe along Gilson Wash, a tributary of the Gila (via the San Carlos River).[27] Many of the canals in the upper Gila watershed drew their water from tributaries that headed in the foothills rather than from the Gila River (Bandelier 1892:410-411; Gila Pueblo 1929-1930).

In the vicinity of the San Pedro confluence, the Gila enters a canyon where archaeological surveys of the bottomlands report no irrigation features, although dry farming features are abundant; this non-irrigated segment of the river extends westward to the Buttes region 12 miles east of Florence.[28] From the latter point westward to the

Gila's confluence with the Salt River existed the largest proportion of the Gila's prehistoric irrigation systems.[29] At least one of the central Gila Basin canals emanated from an apparently unnamed tributary of the Gila about 5 miles southeast of Florence.[30] Several additional prehistoric canal systems have been identified along the lower Gila River, west of the Salt River confluence beginning near the town of Avondale and extending through the Gila's great bend almost to the Painted Rock Mountains west of the town of Gila Bend.[31]

Although the precise dates of the Gila River canals have yet to be determined, all are presumed to predate the late 17th century occupation of the Gila Valley by the Piman and Yuman Indians. Irrigation is not mentioned in the early Spanish accounts of that region (Bolton 1936; Doelle 1981), and the canals are associated with sites occupied by the prehistoric Hohokam.

The Agua Fria and New Rivers

At least five ancient canals have been identified along the Agua Fria River, which joins the Gila River about 6 miles downstream from the Gila's confluence with the Salt. Three miles above the Gila a prehistoric canal emanated from the Agua Fria and carried water to fields on the flood plain of the Gila River[32] (Figure 4). Prior to 1930 there was evidence of an irrigation canal along the Agua Fria 21 miles north of the Gila, and another canal thought to be of Hohokam origin was found about 2 miles east of the Agua Fria, 23 miles above the Gila.[33] A canal 27 miles above the Gila was found to date to ca. A.D. 1400.[34] Finally, a Hohokam canal was reported approximately 17 miles southeast of Prescott, but this canal was spring-fed and may have been used only for filling a reservoir rather than for farming.[35]

The New River is the largest tributary of the Agua Fria. Four main canals fed by the New River were located between 13 and 18 miles above the Agua Fria confluence, and several others existed between 5 and 8 miles farther north. All these canals appear to predate A.D. 1100.[36] Another ancient New River canal with associated "terraced lands" was reportedly 43 miles northwest of Phoenix.[37] It is difficult to determine where the latter might actually be located because the distance and bearing do not place it along the New River. It may be suggested, though, that it was no more than 27 miles above the Agua Fria confluence because the New River Valley becomes very rugged northward beyond that distance.

Along Skunk Creek, a tributary of the New River, what may once have been a prehistoric canal was recorded, but subsequent testing suggested that this feature was not an ancient canal.[38] There is still no evidence that prehistoric irrigation was employed along Skunk Creek, but a specialist in ancient stream flow patterns suggests that at the time of Hohokam occupations Skunk Creek could have supported limited stream irrigation.[39]

Queen Creek

Midway between the Salt and Gila rivers is Queen Creek, a major desert wash. It flows to the west, eventually forming a delta within the Gila Valley. As early as the 1920s, ancient canals were suggested to extend all the way from the Queen Creek delta up to the point where the creek first emerges from the Superstition Mountains; specifically noted were two canals--one 6 miles long where the creek emerges from the mountains, and another farther west that "branched and branched and rebranched again until it resembled the veins of a leaf; with each last branch a tiny rivulet. The whole ground was thus fed, the service lines being but a few yards apart."[40] Later researchers identified five floodwater irrigation systems emanating from Queen Creek between Apache Junction and

Florence (near where the Salt-Gila Aqueduct now runs) and two other canals in the Queen Creek delta region.[41] Comparison of soil maps and known canal courses along both Queen Creek and the Salt River suggests a strong correlation of certain soil phases with prehistoric canals (Dart 1986). These comparative data suggest locations for additional Queen Creek canals west of the Salt-Gila Aqueduct, mapped for the first time in this study (Figures 4, 8).

San Pedro River

In his account of the early Spanish expedition into southern Arizona in 1697, Padre Kino's party noted good agricultural lands along the San Pedro River, and that ditches for irrigation were already present. A military officer accompanying Kino specifically mentioned irrigation canals at three Upper Pima villages along this river, from the northernmost a few miles above the river's confluence with the Gila to the most southerly, close to the Mexican boundary.[42]

In stark contrast to the reports of Upper Pima irrigation systems, virtually no evidence of Hohokam irrigation systems has been found along the San Pedro, even though large Hohokam villages existed in the San Pedro Valley prior to the Upper Piman occupation. It has been suggested that the Hohokam of the San Pedro relied entirely on direct rainfall and floodwater runoff for crop-raising and that, if Hohokam irrigation systems did exist there, they would have been confined to the river flood plain (which is relatively narrow and circumscribed by high terraces).[43] However, the absence of evidence for Hohokam irrigation in this valley could be attributed to the relative scarcity of archaeological excavations along this river specifically designed to discover irrigation features, and to the likelihood that modern irrigation canals in the valley follow the same courses as prehistoric ones. It would not be surprising to find either Hohokam or Upper Pima canals along much of the San Pedro and along the lower stretches of its larger tributaries such as Aravaipa Creek and the Babocomari River.[44]

Santa Cruz River

Prehistoric canals of both the Hohokam and Upper Pima have been observed along the Santa Cruz River from its headwaters as far north as Picacho (Figure 4). Despite extensive archaeological surveys along stretches of the Santa Cruz, hardly any of the prehistoric canals reported along this river occur on the river's terraces; instead, most appear to have been confined to flood plain locations.

Several Hohokam canals have been reported in the Santa Cruz Valley, but few of these reports have been substantiated by archaeological excavation. The northernmost Santa Cruz Valley Hohokam site yet reported to contain a Hohokam canal is 2 miles south of Picacho.[45] Hohokam canals have been documented through excavation at the Los Morteros site near Marana[46] and other possible canals have been reported in the same vicinity.[47] Just downriver from Tucson, near the confluence of Rillito Creek, features tentatively interpreted as Hohokam canals were recorded during archaeological excavations.[48] South of Tucson, a possible canal was identified on the San Xavier Indian Reservation[49], but this report has since been seriously questioned (see below). Other possible Hohokam canals have been reported in the upper Santa Cruz Valley between Canoa and Otero, Arizona; along the portion of the river that swings through Mexico; and also about 5 miles east of Lochiel, Arizona.[50] And a few miles west of Tucson along Blanco Wash, a tributary of the Santa Cruz River, a linear feature that could have been an ancient canal has also been recorded (Figure 4).[51]

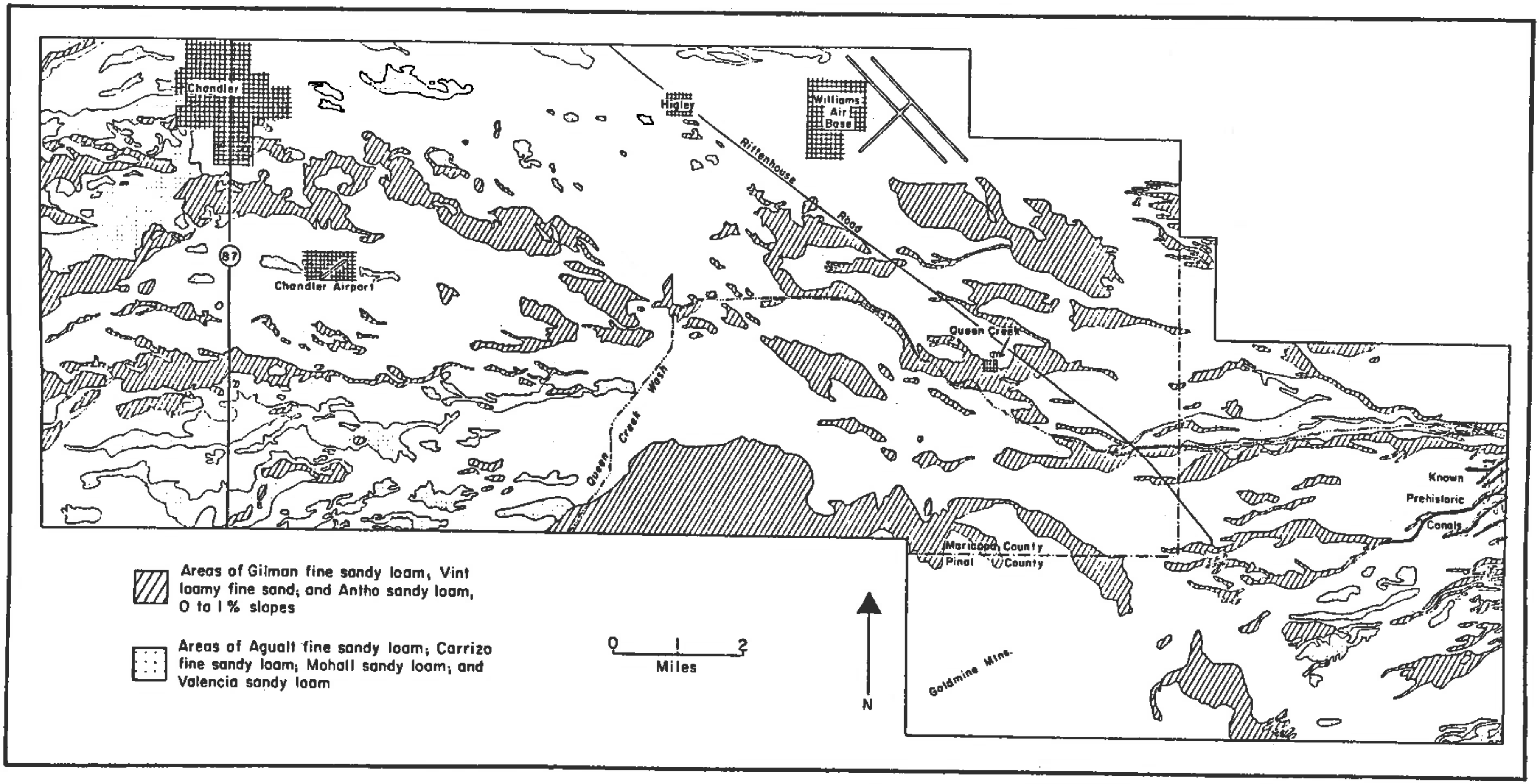

Figure 8. Map showing correlation of prehistoric canals and soils along Queen Creek, plus distribution of sandy loam soils that may indicate other prehistoric canals.

Upper Piman canals were reported along the Santa Cruz in the early Spanish accounts of expeditions into southern Arizona (Manje 1954:92-94; Bolton 1936:363,367). One was at San Agustin de Oiaur (or Oiaut), a village in the northern part of the Tucson Basin. Also, lands around the Upper Pima communities of San Xavier del Bac, San Cayetano del Tumacacori (both eventually were to become the locations of Spanish missions), and San Luis de Bacoancos (probably where Nogales is now located) were found to be fertile and irrigated.[52] Irrigation systems tentatively identified as Upper Piman have been found by archaeologists along the upper Santa Cruz. One consisted of two abandoned, overlapping canal channels found during excavations 4 miles upstream from Tumacacori at the Paloparado ruin, a village that contained evidence of both Hohokam and Upper Piman occupations; the excavator interpreted Paloparado as the ruined village of San Cayetano and believed that the canals he found there were Upper Piman features that dated from Hohokam times.[53] However, the published data on this excavation do not rule out the possibility that these ditches could have originated long after the Upper Piman occupation of the site. Another possibly Upper Piman canal was found about 3 miles north of Tubac. Called the "Tubac Canal," it was a series of canal segments extending about a half-mile along the first terrace west of the river. As is typical at Upper Piman sites, only plainware pottery was associated with the Tubac canal.[54] One other abandoned Santa Cruz River canal known to predate 1875, but whose actual age and cultural affiliation are unknown, was found near Amado.[55]

Before one jumps to conclusions about the existence or authenticity of these structures, it is well to bear in mind that the best-documented examples of prehistoric canals along the Santa Cruz River are those known from detailed archaeological excavation studies that include both trenching and areal stripping[56]. Other excavations of features originally judged (through surface evidence alone or through archaeological test trenches) to be prehistoric canals have invalidated, or at least, failed to support original interpretations of those features and caused doubts about many other reports of prehistoric irrigation features identified only on the basis of surface inspections. For example, at the Valencia archaeological site in Tucson, a linear depression that was at first thought to be a canal was later tested by archaeologists, who then conkcluded that it was in fact only an eroded dirt road.[57] The identification of the possible canal along Blanco Wash[51] can therefore be questioned because the feature described along that wash sounds much like the feature that tested at the Valencia site. Another supposed canal found in a series of archaeological test trenches at the Valencia site was clearly a buried channel. Its shape, size, orientation, fill (which contained Hohokam artifacts), and proximity to a major Hohokam site all suggested it was a prehistoric canal; nonetheless, after extensive excavation it proved to be of natural origin.[58] The latter finding caused one archaeologist to reject his own previous identification of a surface feature south of Tucson as a Hohokam canal.[59] These examples provide a "cautionary tale" regarding the need for detailed archaeological testing of possible canal features, particularly in areas outside the Phoenix Basin.

Other Tributaries of the Colorado River

The San Juan Valley

The San Juan River drains directly into the Colorado River just north of the Arizona boundary, in Utah. Although the San Juan does not enter Arizona, its valley and tributaries extend into the northeasternmost part of the state. Farming in most of this region is impossible because of advanced erosion that exposes the bedrock. However, situated on alluvial deposits in the depths of longer canyons and along the San Juan River were sites that were irrigated by the prehistoric Anasazi people. Canals that date to

Pueblo III times (A.D. 1150-1300) have been found along the Arizona boundary south of Navajo Mountain, and along the San Juan River just 11 to 15 miles north of the state boundary.[60] Although the only archaeogically excavated examples of canals were fed by either slope run-off or springs, the fact that canal technology was used makes it plausible that other canals emanated from the San Juan or its larger tributaries.

The Little Colorado Watershed

Prehistoric canals in the Little Colorado watershed area are described in early Mormon accounts of their first colonization of east-central Arizona, and were later documented along the Little Colorado River and its tributaries.[61] An early researcher of the ancient canals in Arizona recounted hearing stories of single canals on mountain streams, including one canal somewhere north of Springerville that was 20 miles long.[62] Other anthropologists cited reports of ancient irrigation canals in the vicinity of Round Valley and Springerville, and described a canal 2 miles north of Springerville that dated to the Pueblo IV period (A.D. 1300 to 1600).[63] At least some of the canals in this region, for example, canals at St. Johns, Springerville, and Tule Spring (near Lyman Lake) were dependent on springs rather than streams.[64]

Towards the towns of Show Low and Snowflake, canals along Show Low Creek, Silver Creek, Hay Hollow Draw, and at Concho Flats are associated with pueblo ruins dated between A.D. 950 and 1400.[65] Farther northwestward, prehistoric canals have been reported at the Nuvakwewtaqa (Chavez Pass) ruin[66] near Chavez Draw, which drains into the Little Colorado via Jack's Canyon; and nearby at the Pershing site,[67] which is along a stream in Anderson Canyon. Along the San Francisco Wash about 14 miles northeast of Flagstaff a prehistoric, "clay-lined" irrigation canal was found to have been used during the Pueblo I period prior to A.D. 900,[68] and another Pueblo I irrigation canal was reported just north of Flagstaff along Schultz Creek, a tributary of San Francisco Wash.[69] Prehistoric irrigation has also been inferred at the Ridge Ruin site that was occupied between A.D. 1070 and 1200 in Young's Canyon,[70] another tributary of the San Francisco Wash.

It is possible that ancient irrigation was in use along the Puerco and Zuni Rivers, and on Moenkopi Wash. An old earthen dam across an arroyo that flows into the Puerco River near Sanders formed a reservoir at a village of the Pueblo III period (A.D. 1100-1300); this dam was reportedly similar to dams at other sites in east-central Arizona and in the Quemado area of New Mexico.[71] It has also been reported that reservoirs constructed by damming arroyos were integral parts of irrigation systems elsewhere in the areas drained by the Little Colorado.[72] That irrigation was in use along the lower Zuni River it reasfonable to suggest because irrigation apparently was practiced in the Zuni Pueblo area along the upper Zuni River in New Mexico prior to A.D. 1375.[73] Canals existed at Moenkopi during the late 19th and early 20th centuries[74]; while it is possible the Hopis learned this practice from early Spanish missionaries, it is also plausible that the canals there were used prehistorically, because the prehistoric ancestors of the Hopi were in contact with the people of Zuni.

The Colorado River's Tributaries Below Grand Canyon

Just downstream from the Grand Canyon, Cataract Creek flows into Havasu Creek before reaching the Colorado River. It has been assumed that the relatively large increase in the number of archaeological sites along Cataract Creek Canyon after A.D. 900 was made possible by the use of irrigation.[75] However, no physical evidence of any archaeological canals has been reported in this area.

Except for the Gila River, the Colorado's tributaries below Cataract Creek rarely carry enough water to make irrigation possible. No archaeological reports or early historical accounts mention irrigation along any of these other tributaries; in fact some indicate that irrigation was not practiced in these areas.[76]

The Colorado River

There is little evidence that early irrigation was practiced along the Colorado River. Indeed, irrigation was probably impossible along the part of this river above the Grand Canyon, because the flow was too fast to control and the river was too far below the level of the surrounding plains for water to have been diverted. Below the Grand Canyon most of the river's wide flood plain is so deeply inundated by flooding every year that Indians could have raised a crop using only the water retained in the ground after floods; this would have made irrigation unnecessary along the lower Colorado. However, Indian tribes living along the lower Colorado during the historic period protected their fields from floods by building dams, levees, and ditches (Castetter and Bell 1951). At least one of the lower Colorado River tribes--the Cocopa of Mexico--had words in their native language for each of these structures, which suggests that this flood control technology had been in use a long time, possibly even back into prehistory; in more recent times, the Cocopa are also known to have used canals to irrigate small patches of land that otherwise would have been left dry by the river's floods (Kelly 1977:27-28).

The Papagueria

The Papagueria is the homeland of the Tohono O'odham Indians, an Upper Piman group known historically as the Papago. The Papagueria extends from the Gila River southward about 200 miles to the Altar River (Figure 4) and from the Baboquivari Mountains southwest of Tucson about 90 miles westward slightly beyond Ajo (Lumholtz 1975:16). Most of the streams in this region flow only briefly, after rainstorms, eventually disappearing into the desert sands before reaching any permanent stream.

Relatively little is known of the archaeology of the Papagueria, but some prehistoric irrigation works have been identified. At the time of the earliest European contact, canals were in use among the Upper Pima along the Sonoyta River immediately south of the U.S. border. The Rio Sonoyta (Figure 4) is a small stream with a permanent flow in the area immediately south of Lukeville, Arizona. Eventually, however, the water sinks into the sands of the Sonoran desert. The canals in the Sonoyta Valley, which were in use by the Upper Pima in the 1690s when the Spanish first arrived, were apparently rather small channels fed by the Sonoyta River where it flowed permanently.[77] It is possible that some of the canals extended from the river onto the Arizona side of the international border.

All the other known prehistoric Papaguerian canals apparently predate the Rio Sonoyta canals and were constructed by the Hohokam (or a society whose archaeological remnants are similar to those of the Hohokam). These earlier canals all emanated from washes that probably carried water sporadically, only after heavy or prolonged rain storms. In the Baboquivari Valley, a prehistoric canal reportedly extended 17 miles from Baboquivari Peak to the village of Vamori.[78] Others have been reported near Vamori and Fresnal washes north of the Valshni village site[79]; along Sells Wash[80]; along Anegam Wash[81]; along an unnamed tributary of Midway Wash, 12 miles northeast of Ajo[82]; and along Greene Wash, 11 miles south of the city of Casa Grande.[83] Also, canals probably fed prehistoric Hohokam reservoirs between Gu Achi and Anegam washes[84]; along the Santa Rosa Wash; and in the vicinity of Pia Oik Wash.[84]

A channel-like feature evident along Vekol Wash north of Interstate Highway 8 was long believed by some local residents to be an ancient canal. However, an archaeologist who was considered an expert on prehistoric canals examined this feature in detail and concluded that it was not a prehistoric canal.[85]

REMNANTS OF ANCIENT IRRIGATION WORKS AND RELATED CULTURAL RESOURCES

In addition to structures known to have been used directly for irrigation, other cultural features and human activity sites, as well as certain natural phenomena, are often found in association with Arizona's prehistoric irrigation works. These are some of the most common ones:

IRRIGATION STRUCTURES

Actual irrigation structures can be divided into two basic categories: those that capture and divert stream flow, and those that transport water to places where it can be used. Recognizable remnants of prehistoric water-capturing structures at the initial canal intake (head) areas are scant, probably because those that did exist were only made of earth and brush, and so were easily wiped out by floods. Even in the last two centuries, the Gila River Pima Indians and other Arizona irrigators who did not have the advantage of concrete diversion dams were not able to maintain their stream-diversion structures for more than a year at a time (Lindauer 1984). Because actual diversion structures of the ancient irrigators are so ephemeral, archaeologists studying Arizona irrigation generally have assumed that in prehistoric times the streams were diverted into canals by one of two simple means. First, in cases where the stream's banks were no more than a few feet higher than the surface of the water it may have been possible to simply dig a canal deeper than the water level of the stream so that the water would flow into the new channel by natural gravity action alone (e.g., see Rodgers 1977:25-53; Crown 1984b:251). In order to make the water flow more directly into such a canal, a weir of upright poles interwoven with bundles of brush could be constructed (Castetter and Bell 1942:159). An irrigation engineer offered his opinion that true dams would not have been necessary for any of the prehistoric canals that he had seen in Arizona, and that the Hohokam canals were so aligned as to become natural drainage ways from the creeks and rivers (Turney 1929:162-163).

Besides this method, forcible water diversion may have been necessary in some situations. For example, in situations where stream banks were so high that it was impossible to practice simple diversion, it would have been necessary to build a fairly substantial dam or other diversion structure out into the stream bed in order to raise the water level high enough to flow into a canal (Figure 9). Recent observations of peoples such as the Gila River Pima and Maricopa Indians who used canals, but did not build concrete dams (e.g., Haury 1976:148 & Figure 8.47; Bryan 1929:445-448), suggest that ancient diversion structures in Arizona would have been simple levees or weirs constructed of earth, rock, poles, and brush. These earthen structures may have withstood enough stream pressure to raise the water level as much as five feet (Turney 1929:150) but they still would have to be rebuilt regularly, at least once a year.

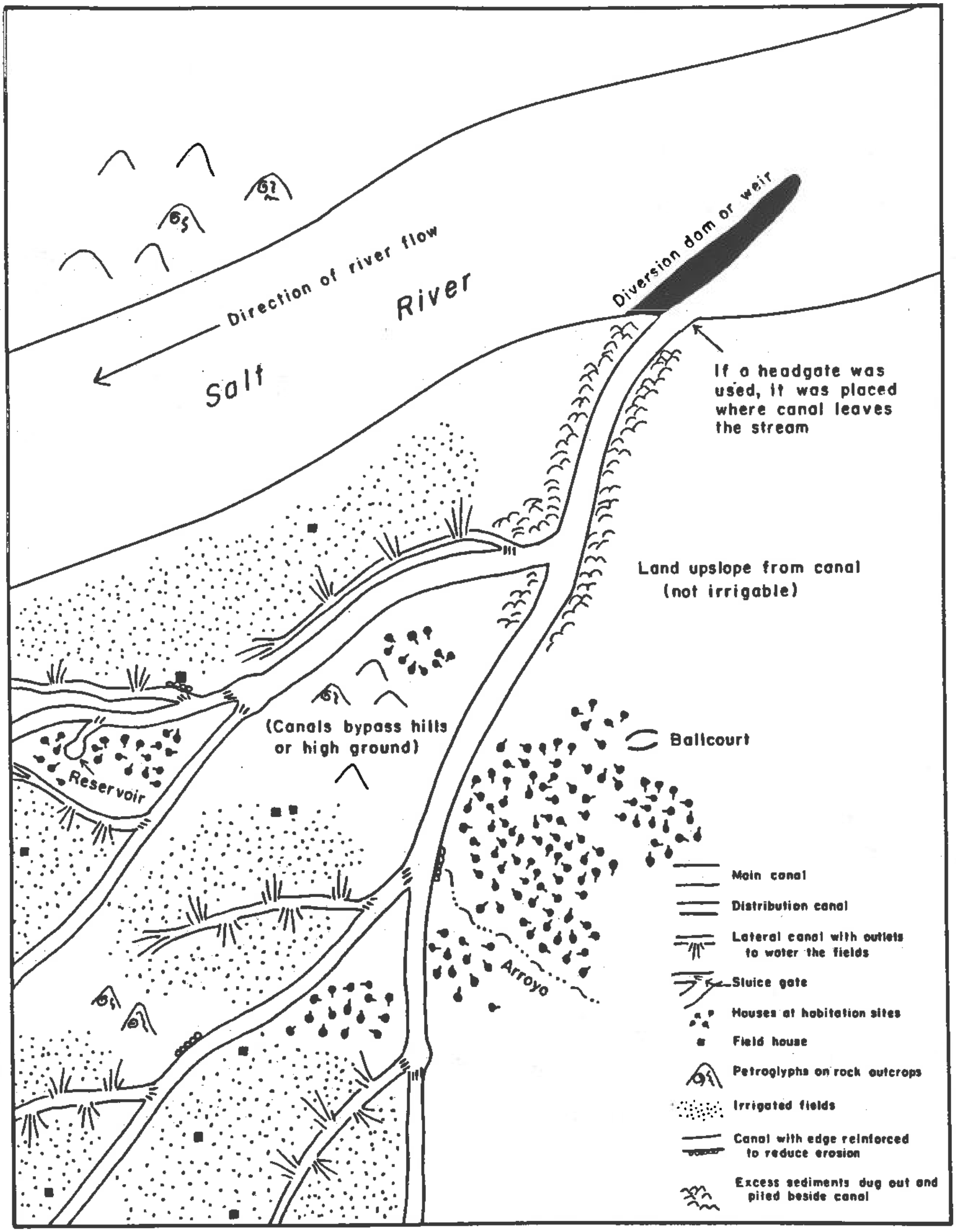

Figure 9. Schematic plan of a typical Hohokam canal system in the Salt River Valley.

Two rock configurations found in the past century may have been the only actual historical remnants of features used for stream diversion prehistorically in Arizona. One of these was a line of "rocks the size of a stage coach" according to an early Anglo-American settler of the Salt River Valley. This line of rocks extended out into the Salt River at the intake of the Hohokam canal known as the Canal Mesa (Midvale 1968) or Canal Eleven (Turney 1929). It cannot be proven that the rocks were placed intentionally by the Hohokam, however, and all trace of them is now gone (Nials and Gregory 1986:44). The other possible diversion dam remnant was a group of large boulders found at an ancient canal head along Cave Creek (Midvale 1971:Book XIIIb).

Most prehistoric canals simply diverted streams in only one place--the canal head or intake. However, at least some canals were evidently designed to also divert water from one or more secondary streams that the canals had to cross. For instance, the edges of two Hohokam canals along the New River and Cave Creek were reinforced with substantial, wall-like linings of rock much like modern riprap channel linings where the canals crossed impermanent washes. These linings apparently functioned to divert runoff waters of those drainages into the canals (Henderson and Rodgers 1979; Doyel 1985:304-308). In the Buckeye area near the lower Gila River, a single Hohokam canal diverted water from several individual, intermittent drainages; it is not known whether diversion structures along this canal were built at each drainage or whether the water was diverted into the canals by simple gravity (Rodgers 1976:66).

Structures that were used for transporting irrigation water include various kinds and sizes of canals as well as accessory features built along the canals to help direct and regulate the flow of water. Several recent archaeological studies in Arizona distinguish three different kinds of prehistoric canals: main, distribution, and lateral canals (Figure 9). Main canals are generally viewed as conduits that convey large amounts of water directly from the water source over fairly long distances (Masse 1976:41; Doolittle 1989). Distribution canals are often found within field areas and serve to route water directly from the main canal to the lateral canals, which in turn empty their water directly onto the fields (Masse 1976:41; Doolittle 1989). However, it is usually "quite difficult to differentiate the specific functional components, especially in view of the fact that system components and features are usually encountered piecemeal" during archaeological studies and those components that are found may have been used during several different periods of time (Masse 1987:17-18). Further, not all prehistoric irrigation systems were large enough to incorporate such diversity in canal types (e.g., Breternitz 1957a, 1957b).

The largest prehistoric canals known in Arizona--those along the Central Gila River and the lower Salt--can certainly be considered main canals. Many of these main canals have been traced over 10 miles from their heads along the rivers. Two of the longest canals, the Casa Grande canal along the Gila and the Grande canal along the lower Salt, each extended over 15 miles from its point of origin and up to 6 miles away from the river channel (Midvale 1965, 1968); other canals in the valley of the Salt are 9 to 10 miles away from the river (Figures 5, 6). The actual cross-sectional dimension of one of the Hohokam main canals in the Park of Four Waters, near the Pueblo Grande ruins in Phoenix, is 36 feet wide and 10 feet deep; the crests of the earthen banks piled up alongside this canal are still 10 feet high and the distance between the crests of the banks is 85 feet (Masse 1981:408). Because they transported water over areas not being utilized for farming, the water level in primary distribution canals could be and often was lower than the land surfaces next to those canals. A lateral canal, in contrast, must be elevated slightly above the level of the field, so that its water can pour out onto the field (Figure 10). Therefore, it is rare to discover prehistoric lateral canals because so many of them have been graded away during the course of subsequent land use (Cummings 1926:9-10). However, archaeological studies of the few laterals that have been identified suggest that these canals were rarely more than 6 feet wide and 1 or 2 feet deep (Haury 1976; 128-129; Ackerly et al. 1987; Masse 1987).

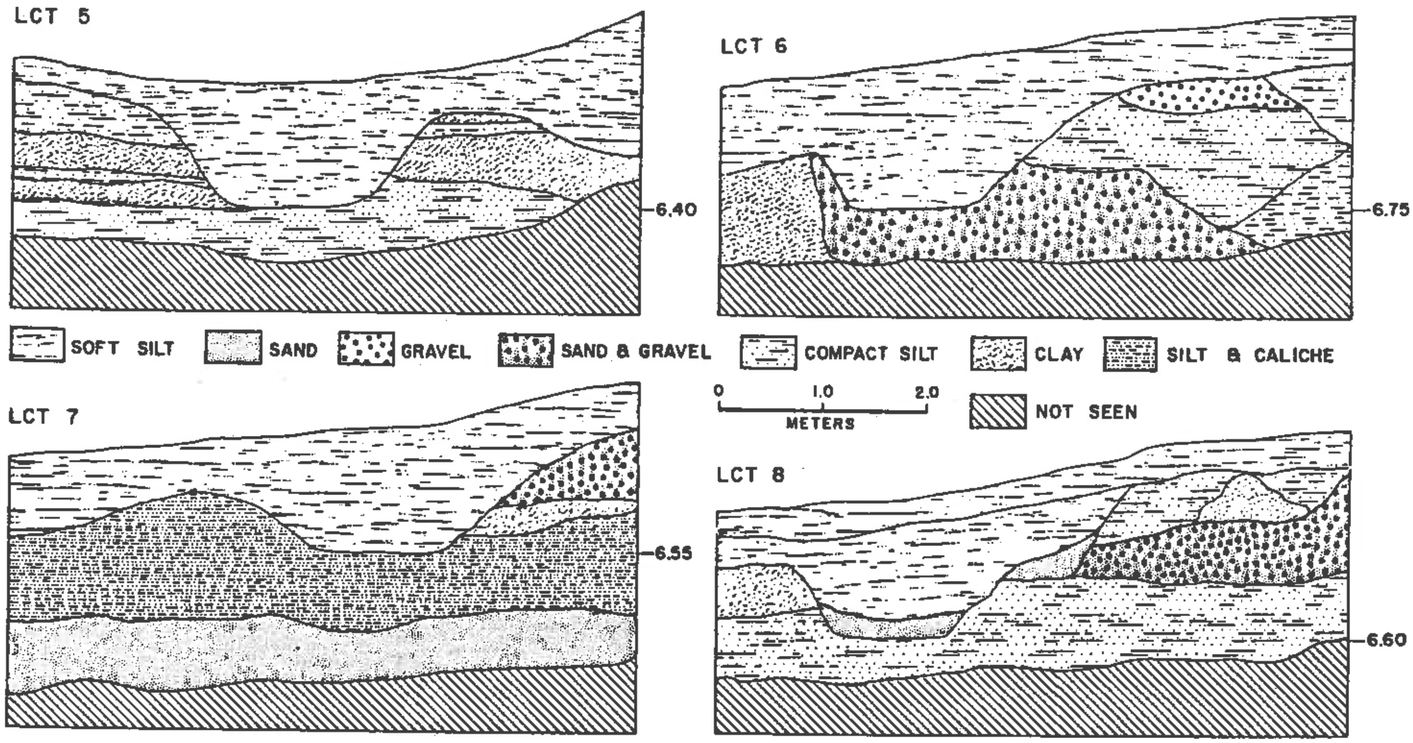

Figure 10. Profiles of four cross-sections of the Hohokam lateral canal at the Snaketown ruins (Haury 1976:129).

How might one recognize a prehistoric canal? There are at least nine possible indicators of an ancient canal's course over an undisturbed surface (Midvale 1968:29-30):

1. a canal segment that retains nearly the original contour (rarely seen) (Figure 11);
2. a partly eroded remnant of the canal, with the area between the banks partly filled (Figure 12);
3. a heavily eroded remnant of the canal, with the area between banks nearly filled (Figure 13);
4. a long mound [or a low ridge, see Dart (1986)] marking the canal course, with the actual canal still buried in the approximate center of the mound (Figure 14);
5. two parallel zones of rock on the surface [sometimes associated with particular arrays of vegetation, see Dart 1983a:366,387,525,526; Rankin 1989] (Figure 15);
6. a wide path of ancient artifacts and debris across the desert;
7. rock-walled or slab-retained canals, usually small in size (Figure 16);
8. a single dike or rubble wall opposing an even hillslope (the dike/wall marks the downhill bank of the canal [Figure 17]);
9. a canal segment marked by a natural cement [caliche] lining caused by lime left behind when the water evaporated; examples of this type occur at Montezuma Well National Monument (Figure 7) and in the Little Colorado River drainage (Bandelier 1892; Danson 1957:63; Midvale 1968; 1971).

Prehistoric canal courses may once have run in some cases where historic or modern canals now exist, because some more recent canals are known to have followed prehistoric canal courses (Turney 1929; Midvale 1968, 1970, 1971).

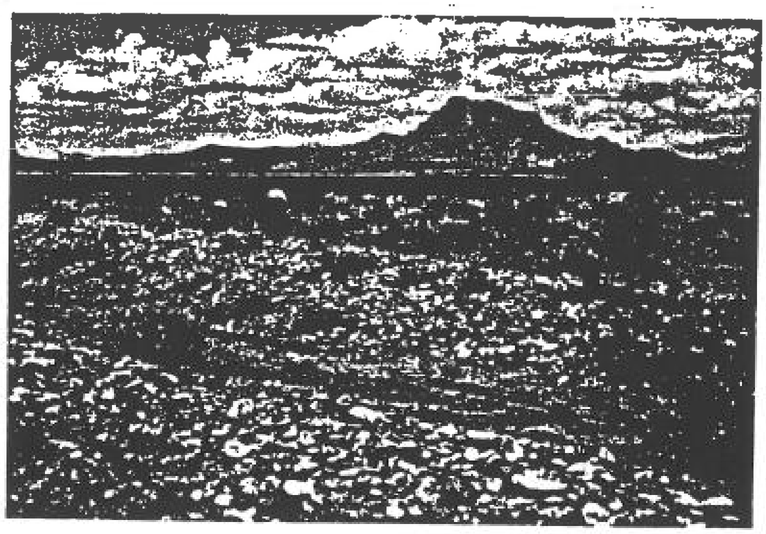

Figure 11. Cross view of a Hohokam canal where it starts cutting through a rocky ridge (Midvale 1971:Book VIII, p. 20).

Figure 12. Segment of a partly filled-in Hohokam canal, showing canal intersection area (Midvale 1971:Book VIII, p. 21).

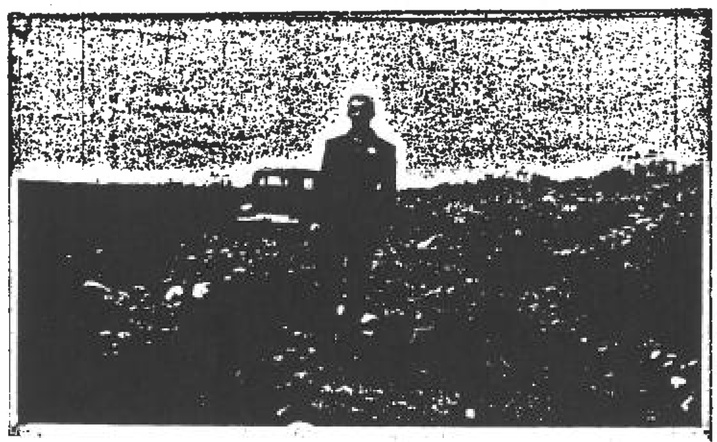

Figure 13. 1945 view of Frank Midvale in center of a Hohokam canal nearly filled to the banks with sand (Midvale 1971:Book VIII, p. 17).

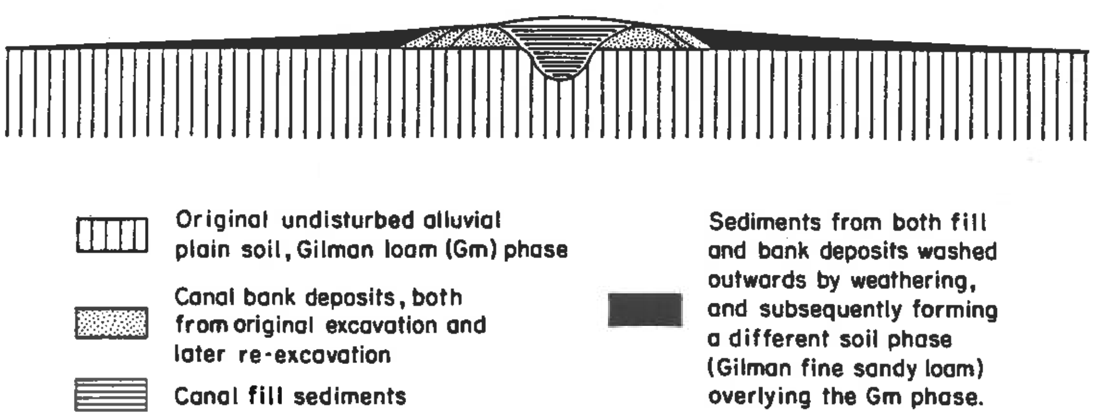

Figure 14. Idealized cross-section of a Hohokam canal buried within a low ridge (Dart 1986).

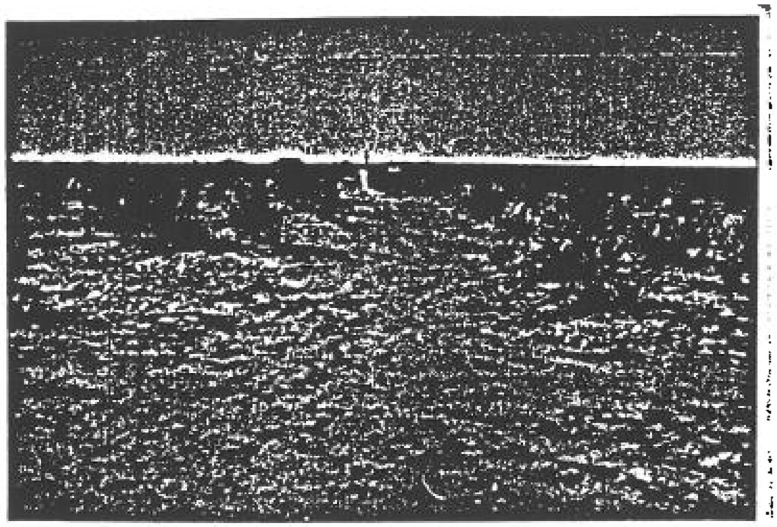

Figure 15. Hohokam canal indicated by two parallel zones of rock on the surface (Midvale 1971:Book VIII, p. 6)

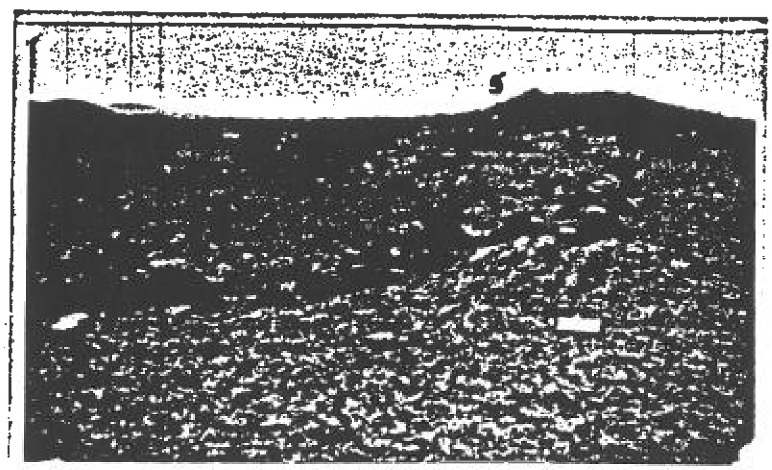

Figure 16. Stone outline of a Hohokam canal branch or diversion works (Midvale 1971:Book XIIIb, p. 15).

Figure 17. Hohokam canal along the base of a hill slope, with a dike or wall of rocks marking the downhill bank of the canal (Midvale 1971:Book XIIIb, p. 14)

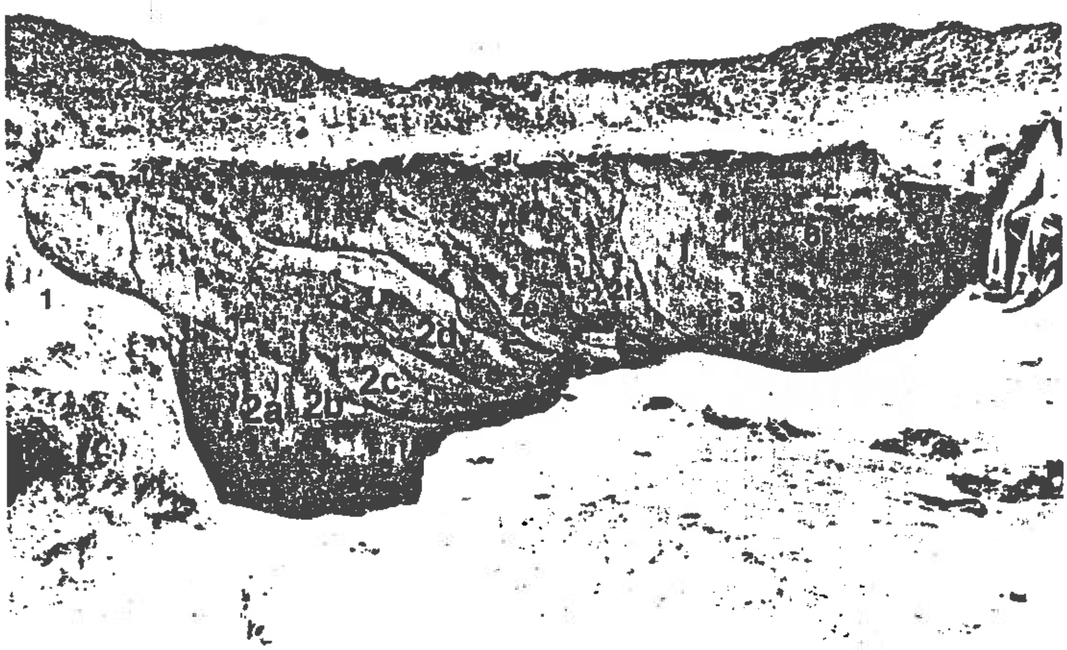

Figure 18. Sequent channels of Hohokam Canals 2, 3, and 6 at Snaketown (Haury 1976:139).

What do the buried parts of prehistoric canals look like? The main characteristic that indicates a canal is the presence of a linear depression filled with a layer or successive layers of fine-grained sediments--sands, silts, or clays (Figures 10, 18). The particles of each sediment layer may vary, but the fill layer(s) have usually been deposited by alluvial action, that is, in flowing water. In cross section, prehistoric canals usually are either U-shaped or V-shaped (Figure 18; Haury 1976:120-151; Masse 1976, 1987; Herskovitz 1981; Dart 1983a:374,377; Ackerly et al. 1987; Huckleberry 1988b). However, some had flat bottoms and sloping or vertical sides (Antieau 1981), and the interiors of others were quite irregular or contained multiple channels of different shapes (Figure 18; Haury 1976:139; Cable et al. 1982:67). In cases where the modern ground surface has not been severely disturbed, earthen embankments alongside the channel of the canal can often be seen; these embankments may include many cobbles, even boulders (Breternitz 1957a; Doyel 1985), that were removed as the canal was dug through underlying rocky soils. And if the canal was used for a relatively long time, it is common to find later channels superimposed over earlier ones; in these cases the layering in the canal-fill sediments may be extremely complex (Figure 18; Haury 1976:120-151; Masse 1976; 1987).

Arizona's prehistoric canals differ from historical and modern irrigation systems in several ways. For example, except where they traversed large expanses of flat, unbroken land the prehistoric canals were rarely straight; rather, each one tended to meander, following the contours of the land (Figures 6, 9) in order to maintain a consistent drop in elevation over a given distance of ground (Nials and Gregory 1986). Instead of branching at right-angles as do most modern canals, prehistoric main canals tended to branch at 45-degree angles, forming a pattern like the veins of a leaf (Figures 9, 19; Turney 1929:145; Masse 1981; Nials and Gregory 1986). Clay or other mineral residues often settled out of the water and accumulated in the ancient canal bottoms, forming a layer of fine sediment that when dry resembles a plastered lining (Bandelier 1892:388-389; Schroeder 1958:30; Haury 1976:128,132). In reality, if a prehistoric canal was plastered at all, it usually was only with a coating of mud plaster applied to repair relatively short segments that had been breached (Nials and Gregory 1986; cf. Breternitz 1957a:50; Haury 1976:128). Never were Arizona's ancient canals intentionally lined with any kind of plaster that approached the hardness of concrete. And, whereas later canals were trapezoidal and wider than they were deep, prehistoric ones were generally parabolic and relatively narrow (Nials and Gregory 1986; Huckleberry 1988b:167).

Besides the banks of spoil dirt that accumulated alongside the canals as they were originally constructed and later cleaned out, other human-fabricated features used to aid in the operation of prehistoric canals in Arizona included gates to control the water flow at canal heads and intersections; erosion control features; aqueducts; deepened sections that may have served to conserve water, regulate flow, or trap waterborne sediments; and other internal features constructed of rocks. A large variety of prehistoric artifacts and cultural features not used in canal operation, as well as sediments and other natural materials, are also found in direct association with the ancient water conduits.

"Head gates" and "sluice gates" (the latter also called gate structures or diversion gates [Nials and Gregory 1986]) are devices that can be adjusted to regulate the flow of water passing through a canal (Doolittle 1989). Remains of prehistoric head gates--the gates at canal intakes along the streams--have not been found because, if they even existed, they would have been integral parts of the stream diversion structures that have been destroyed by centuries of floods. There is abundant evidence though, that prehistoric canals branched off from one another (Figures 5, 6, 12, 16; Turney 1929:21; Halseth 1932; Midvale 1971; Dart 1983a:375-376,525-526) and that sluice gates were used at these canal intersections to channel water into one canal branch or the other (Figure 9). Excavations of some canal intersections have revealed series of post holes or rocks, suggesting that

Figure 19. Aerial photograph showing remnants of prehistoric irrigation canals (faint dark lines) in fallow fields at Tempe (Arizona Department of Transportation).

some sluice gates were built of upright poles interwoven with brush or mats (Hodge 1893:325; Haury 1976:125-128; Cable et al. 1982:67), while others were temporary dams made of rock and earth (Herskovitz 1981:21-24; Fish and Fish 1984:155), and still others were combinations involving posts, rocks, earth, and brush or mats (Figure 20; Nials and Gregory 1986; Ackerly et al. 1987:95-97; Greenwald and Ciolek-Torello 1988). At places where canals branched into the narrower laterals or where the laterals were to empty into the fields, sluice gates may have consisted simply of large boulders (Masse 1987:70) or intentionally modified slabs (Turney 1929:56; Halseth 1932). At some canal intersections rock piles or single boulders have been reported, but it is not known whether these are remains of sluice gates; some of them may have functioned as ownership or boundary markers (Rodgers 1985:283-284; Masse 1987:70; Rankin 1989:619). No evidence has been found that pipes or siphons were used as components of prehistoric irrigation systems in Arizona to draw the water out of laterals onto the fields as modern farmers do.

Erosion was apparently a major problem in some canals (e.g., Greenwald and Ciolek-Torrello 1988). Sometimes walls or wall-like structures of rock and soil (Figure 17) were built to reinforce canal edges that had either ruptured, or were subject to water erosion at canal bends and branches, opposite hill slopes, or where canals crossed arroyos (Figure 9; Rodgers 1977, 1978; Henderson and Rodgers 1979; Dart 1983a; Doyel 1985:304-309; Rankin 1989). Rock alignments may also have been constructed across canal courses to serve as check-dams to reduce erosion by slowing the water flow (Rodgers 1977). In other cases erosion was limited by dumping concentrations of rocks, earth, and artifacts into eroded areas of the canals, much like the modern "riprap" construction technique (Haury 1976:126-127), and perhaps also by placing single boulders at weak spots (Masse 1987:70). Pool-like bulges at canal intersections (Figure 9) may have been constructed to slow the water flow and thus retard erosion (Ackerly et al. 1987; 84-86; Huckleberry 1987:143; Masse 1987:191). Some of the more formal masonry structures used to direct water and control erosion could be termed aqueducts (Doolittle 1989), since they are elevated structures obviously built to maintain canal gradients over washes or low areas (Midvale 1971:Book XIX; Rodgers 1977, 1978; Doyel 1985:304-309). If the prehistoric irrigators of Arizona had learned the use of "drop structures" they could have made their canals "step down" over fairly steep-graded slopes to alleviate major erosion; but unless simple check-dams across canal courses (Rodgers 1977) functioned as drop structures, the latter kind of feature was unknown in prehistoric North America (Nials and Gregory 1986; Doolittle, personal communication 1989).

Besides erosion, another major problem was that sediments--both those borne in the water and those that washed in from the canal banks--tended to clog the canals, which thus had to be cleaned out repeatedly (Turney 1929; Dart 1986; Huckleberry 1987). Some prehistoric canal systems were dug through low that contained ponds; where the canals entered the ponds, the canal-borne sediments were precipitated out of the water as the flow lost speed (Turney 1929:88; Huckleberry 1987:153-156; Masse and Layhe 1987:108-111). In other cases canal sections were apparently dug either deeper or wider than average; whether or not these changes in shape were actually intended to slow the water and sort out the sediments so that they could be removed, such sorting was apparently at least one result (Withers 1973:84-86; Haury 1976:142; Gardiner et al. 1987:31; Greenwald and Ciolek-Torrello 1988). Intentional deepening of certain portions of canals was apparently also used for other purposes, though. Canal segments intentionally dug deeper by the Hohokam may have been intended to conserve water in "dipping pools" after the canal flow had dwindled (Haury 1976:135-136). Other Hohokam canals exhibit a "canal within a canal" appearance (Figure 1), which was perhaps a conservation measure during times of low water (Haury 1945:41, 1976:148; Busch et al. 1976; Nials and Gregory 1986).

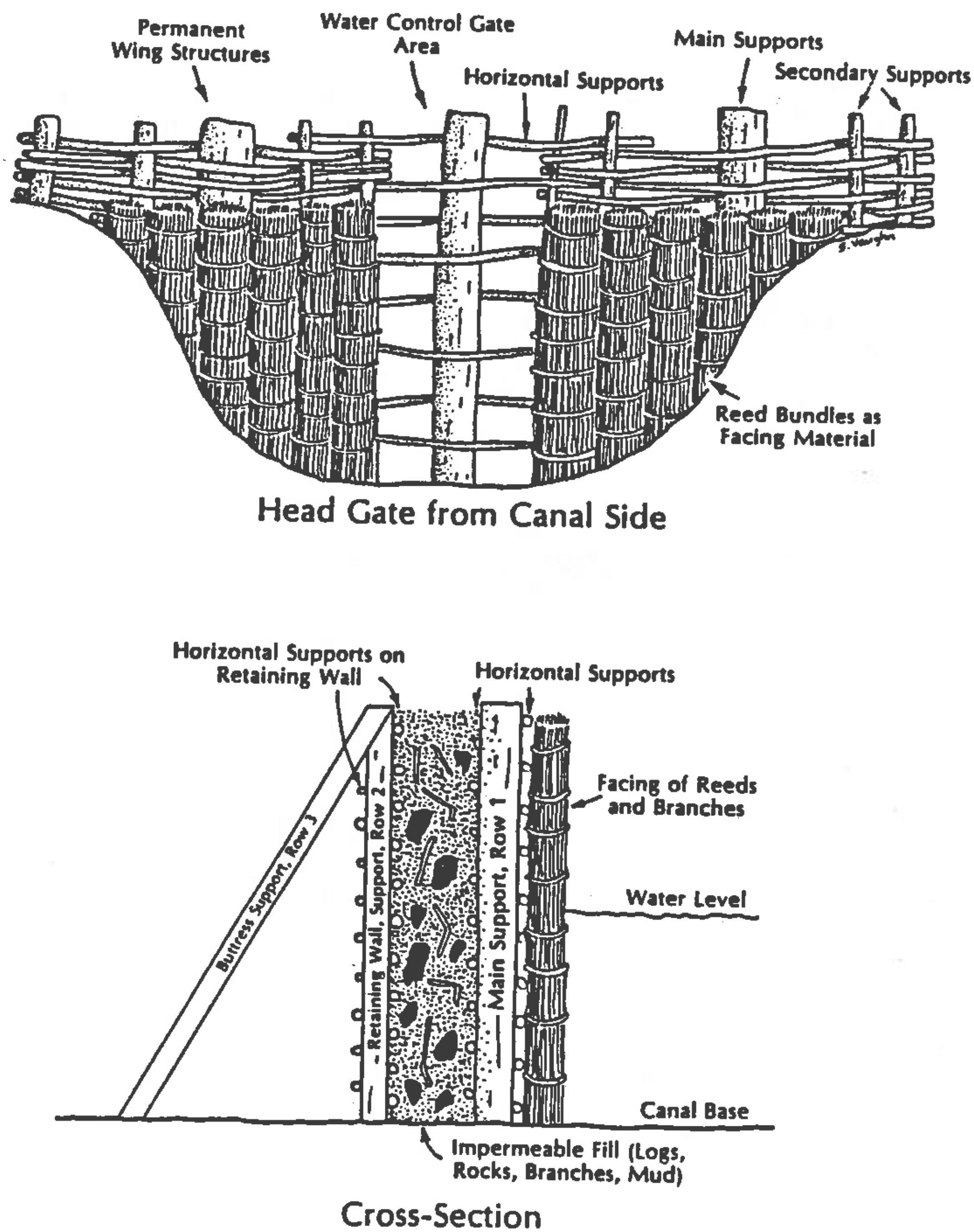

Figure 20. Suggested configuration of a Hohokam canal head gate (Ackerly 1987:96).

Certain manmade features not used for canal operation or maintenance have also been found near canals, including various pits, hearths and ovens, living structures, and even human graves. These features not directly related to canal function usually are only coincidentally associated with the canals, having been built either prior to canal construction or after canal abandonment.

The most frequent artifacts found in and alongside Arizona's prehistoric Indian canals are sherds of pottery, but other artifacts commonly found associated with canals include just about all types of things that could also be expected at prehistoric Indian habitation sites in Arizona: flaked stone tools and debris, hammerstones, grinding stones, pieces of shell jewelry, and miscellaneous rocks (both broken and unbroken) used by the Indians for various purposes. In addition, other materials that accumulated in the earth that filled and covered these old canals, either when they were in use or afterward, are often recovered in archaeological studies of canals. These materials include charcoal and other plant residues, such as pollen, shells of freshwater mollusks, micro-organisms, oxidized zones indicating burning of vegetation within the canals, and deposits of chemical compounds and minerals (Haury 1976:120-151; Masse 1976, 1987; Herskovitz 1981:19-34; Huckleberry 1988b; Palacios-Fest and Cohen 1988). Most of these items were left when the Indians worked the canals or when they cleaned them of debris and sediment, or when eroded or washed-out segments were repaired (Woodbury 1960; Nials and Gregory 1986; Dart 1986). For example, in one apparent washout of a Hohokam canal, abundant stones and more than 500 pounds of pottery sherds were dumped to stop erosion of a break in the canal bank (Haury 1976:125-126).

HOW WAS THE WATER USED?

Fields and Gardens

Undoubtedly, most of the water in prehistoric irrigation systems was used in fields to produce crops. Canal-irrigated fields of antiquity along the Agua Fria, New, Verde, and upper Salt rivers, and along Beaver and Cave creeks, are easily identifiable because in these fields the farmers rearranged stones into recognizable patterns to control the flow and distribution of water (Mindeleff 1896:244; Fewkes 1898:549-550; Fish and Fish 1984). In at least some of these areas the canals run from the streams into shallow basins or slightly concave areas of deep, loamy soil ranging from 50 to over 600 feet wide and over one-half mile long, and that slope downward at grades of less than 1 percent (Doyel 1985:297-313; Rodgers 1985:265-283). Specific prehistoric fields within these basins are identified most easily by the alignments of rocks that usually run perpendicular to the direction of slope and that range from a few feet long up to 200 feet long. These rock alignments appear to have been used, in conjunction with piled brush, to direct the flow of water across fields. Other rock lines form grid patterns, suggesting that they marked individual garden plots or windrows. The larger lines of rock tend to be at the upslope ends of the fields, where the maximum control of the water would have been necessary as it entered the field. Cobble piles have often been found in the fields, and may have been dumped there during field clearing or as ground cover to retain moisture in the soil. Thus, crops planted in and next to these piles would be better protected against the loss of moisture through evaporation. Single boulders in prehistoric fields could be simply misplaced from other alignments, or might have held down poles or brush piles used to direct water flow, or may have been used to mark garden plots of certain individual farmers (Castetter and Bell 1942:131; Mindeleff 1896:244; Canouts 1975; Dart 1983a:405-410; Rodgers 1985:265-283). Also located in these ancient, rocky field areas were locations where other activities took place, now indicated only by small to large scatters of prehistoric artifacts--predominantly chipped stone tools and debris--usually located on less-arable areas, such as where geologically ancient streams had deposited lots of gravel (Schroeder 1960; Doyel 1984, 1985:297-313). At the edges of some fields are substantial alignments of rock that may represent rock that was cleared out of the fields (Castetter and Bell 1942:125) or were constructed to prevent irrigation water escaping the field (Rodgers 1985:265-283). To confirm that these areas associated with both canals and rock features were used as fields, soil samples from them have been analyzed for the presence of pollen and burned plant parts and seeds. Several domestic plants including corn, squash, and cotton, and even many weedy plants usually found in agricultural areas, have been identified in these analyses (Fish 1983; Miksicek 1983; Gish 1985).

In areas where prehistoric fields are not marked by rock features like those of the northern Hohokam-southern Sinagua range, other means can be used to identify fields. For example, patterns of topography and modern vegetation in suspected fields can be compared to the patterns normally associated with historic agricultural fields to see if the patterns are similar. Also, analyses of the soil from suspected fields for pollen, other plant residues, and chemical composition may indicate that these areas were indeed used for farming (Berlin et al. 1977; Masse 1981:411; Dart 1983a:527-547, 623-624). Where prehistoric canal networks divide the land surface into spiderweb-like patterns (Figure 19), it can be assumed that most or all of the trapezoidal areas bounded on all sides by canals were probably irrigated plots unless those areas are higher than the level of the surrounding canals (Figure 9). Fields in normally rocky or gravelly regions may be indicated by the presence of large areas that appear to have been intentionally cleared of rocks, especially areas strategically located to maximize catchment of runoff, for example, at bottoms of drainages where soils are deep and high in organic material (Lightfoot and Plog 1984). Prehistoric fields can also be identified by seeing what kinds of locations were used for fields by later peoples, those who used relatively simple irrigation technologies, then examining suspected prehistoric field areas to see if artifacts or other cultural features typical of the historical field situations are present (Withers 1973:84-86; Lindauer 1984). Once a field has been identified, one may assume it was irrigated if it is at a lower elevation than the level of the water in the canal (Figure 9; Turney 1929:142; Breternitz 1957a:30; Crown 1984b:242,246-247; Nicholas and Neitzel 1984).

Water for Living

Besides being used for agriculture, canal water in prehistoric Arizona was also routed into people's living areas. Canals that ended in (or flowed through) prehistoric habitation sites almost certainly would have been used to provide the inhabitants with drinking water (Haury 1976:135). It is possible that the water in these canals was also used for washing, swimming, bathing, frolicking, and even trash and sewage disposal (Haury 1976:136; Fink 1988). There is no evidence, however, that the canals were navigated by boats or rafts (Haury 1976:149).

Prehistoric canals sometimes were routed to large pits that evidently served as reservoirs (Figure 9). Some of these may have been constructed to hold drinking water alone, but the water in others may also have been used for other nonagricultural purposes, such as dredging and mixing adobe clay (for constructing buildings) or for making pottery (Haury 1945; Raab 1975; Masse 1980a; Dart 1983a; Ackerly et al. 1987:80,99-110).

WHAT WAS IN THE WATER?

The water in streams is full of suspended sediments and aquatic life (fishes, mollusks, plants, micro-organisms). Stream water also contains chemicals and minerals, and often organic material derived from decaying plants and animals. All of these materials would have been swept into the prehistoric canals that tapped Arizona's streams. Many of them must have entered the Indians' villages; some sediments settled out into the slow-flowing portions of the canals, others were eventually deposited onto the fields. Deposition of sediments in some areas irrigated from streams fed by runoff water (rather than by springs) may have built up the land surface as much as 30 inches or more, forming distinctive new types of soil (Dart 1983a:534-537, 1986:77; Fish 1983:592,595-597), but such large deposits would appear to have been an exception (Jerry Howard, personal communication 1989). However, even relatively small deposits of new sediments and organic materials by the canals would have continually replenished the nutrients necessary for plant growth (Bryan 1929; Hackenberg 1974:48). However, areas that were heavily and continuously irrigated may have experienced soil water-logging and salinization as a result of the long-term build-up of salts carried in the water (Nials and Gregory 1986). Also, sediment build-up in fields may have raised the field surfaces closer to the level of the canal water, making it more difficult for the water to simply flow out of the canal onto the field when desired. Finally, it would have been necessary to periodically dig out the sediments that accumulated in the canals (Figure 9) in order to keep the canals from becoming clogged with mud.

OTHER CULTURAL SITES AND FEATURES ASSOCIATED WITH PREHISTORIC IRRIGATION

Certain other kinds of home sites, work sites, and cultural features are often associated with prehistoric irrigation systems in Arizona. The relationships of these sites and features to the canals may not be so obvious as that between canals and the structures and materials that were directly tied to the irrigation systems' form and function.

Some of the most prominent archaeological sites associated with prehistoric canal systems are ruins of home sites. These may exhibit quite a range in size (Figure 9) and construction types. For example, small habitation sites may include only one or a few pit-houses; sites of this kind are best interpreted as field houses (Figure 9) or small farmstead settlements (Mindeleff 1896:246-247; Breternitz 1957b:50-52, 1960:9; Rodgers 1978; Henderson and Rodgers 1979; Herskovitz 1981; Dart 1983a:366-392; Doyel 1984; Fish and Fish 1984). Larger ruins that encompass many houses or many-roomed pueblos are generally regarded as village sites (Figures 5, 6; Brooks and Vivian 1978; Ackerly et al. 1987; Antieau 1981:138-142; Bernard-Shaw 1988; DiPeso 1956:4; Fish et al. 1980; Haury 1976; Howard 1988b; Lightfoot and Plog 1984; Masse 1987; Midvale 1965, 1968).

Other archaeological sites sometimes associated with prehistoric canals appear to have been used not as dwellings, but were used rather for limited or special activities. For example, petroglyphs found close to canals may have been used to identify individual families' field areas or water rights (Figure 9; Midvale 1971:Book VIII; Doyel 1984). Some of the glyphs have been found together with rock circles less than 10 feet in diameter but with few artifacts that would give clues to these features' uses or ages (Doyel 1984). One site that was found in association with a major canal along the New River included petroglyphs and two opposing, crescent-shaped rock alignments that were interpreted as boundaries of a Hohokam ball court or some other form of ceremonial structure; also found were several small rock shelters, trail systems, and what look like terraced fields (Doyel 1984; Mark D. Elson, personal communication 1988). Granaries, pit-ovens, and various artifacts have also been found in association with prehistoric canals (Rodgers 1977:25-53).

THE CANALS WERE PART OF A WHOLE CULTURE

Irrigation structures, features that received canal water, irrigation by-products, and the other cultural sites and features were used together as integrated systems. Just as the canal systems of Arizona's different regions differed from one another, so did the physical lay-out of the different settlement systems. For example, there appear to have been well developed hierarchies of primary and secondary villages, hamlets, and field house sites along several of the complex canal systems of the lower Salt Valley (Figure 9). In contrast, people were far less concentrated along some of the less complex irrigation systems, such as those generated by the Hohokam along the New River and by the Sinagua in the upper Verde River region (compare Figure 6).

INVESTIGATING PREHISTORIC IRRIGATION WORKS

Other than stumbling across a feature that fits one of the canal descriptions above, how can prehistoric irrigation works be discovered, investigated, and interpreted? To obtain the most reliable information one should look not only to the modern users of irrigation, but also to other people familiar with both ancient and modern irrigation works: archaeologists, irrigation engineers, geologists, hydrologists, anthropologists, and other specialists familiar with the peculiar conditions of archaeology, biology, earth sciences, hydraulics, and cultural practices associated with irrigation systems.

IDENTIFYING PREHISTORIC IRRIGATION SYSTEMS AND RELATED CULTURAL PROPERTIES

In areas that have been largely undisturbed by modern civilization, the most efficient method of identifying archaeological sites in general, and irrigation features specifically, is to conduct an archaeological survey, that is, to search on top of the ground for evidence of prehistoric (or later) use. The ground-surface evidence might include items as large as the ruins of great structures (including irrigation works) and as small as single artifacts, such as pieces of pottery or stone tools. Any evidence of early occupation found during an archaeological survey may then be interpreted to determine who lived there, when they were there, what they were doing, and why and how they were doing it. Archaeological surveys and the interpretations associated with them have been the main source of our information about the locations of prehistoric irrigation systems in Arizona. Surveys that identified prehistoric irrigation works in Arizona were formally begun in the 1880s by an early anthropologist, Adolph F. Bandelier (1892), and they have continued through the 20th century, resulting in increasingly detailed maps of prehistoric irrigation systems in the state (Figures 5, 6).

Prehistoric irrigation works can also be discovered below the ground by excavating in areas likely to contain such features (see "Common Denominators of Canal Locations," above). Several major archaeological studies of prehistoric canals were done in the 1980s as part of the planning processes for building new freeways, reservoirs, and other land improvement projects. These inquiries produced valuable insights even in areas that had been drasticallly changed by recent construction. They have allowed scientists to focus on several of the prehistoric canal systems, providing much of the information currently known about prehistoric irrigation in Arizona. Studies have shown that archaeological interpretation can distinguish buried canals from natural stream courses (Howard and Huckleberry 1988). The depth, width, and extent of particular canals and associated structures can be determined, and associated irrigation structures, sediments, and artifacts found in association with them can be investigated. Excavations in areas thought to contain canals, even if the excavations are not part of a formal archaeological excavation project (for instance, trenches excavated during road construction and buried utility emplacement) can still be examined by archaeologists to obtain information useful for archaeological interpretation of prehistoric canals.

MAKING SENSE OF PREHISTORIC IRRIGATION SYSTEMS: EVALUATION CRITERIA

Besides the information presented earlier regarding how prehistoric canal systems operated, the criteria for evaluating their significance--in essence, their importance for furthering our understanding of them--are based mainly on the systems' distribution over the land and the changes that occurred in them through time (Howard 1988a). By combining information from all kinds of archaeological investigations, irrigation systems can be identified and studied in detail so that we can make sense of them. A prehistoric canal is important if it can help answer any of the following questions regarding size, use, efficiency, age, origin, and role in the progression of human society:

How Big Were the Canal Systems?

Evaluation of the overall size of a prehistoric, stream-fed irrigation system may be made through an archaeological survey, if any of the irrigation-related features are visible on the ground and if the surveyors are trained to recognize prehistoric canal segments. Even where the actual structures are no longer visible, the courses of ancient canals may sometimes be traced using aerial photographs; radar and other equipment that allows interpretation of subsurface phenomena; and detailed maps of soil, vegetation, and topography. However, excavations in Arizona have shown repeatedly that most prehistoric canals are not entirely mappable from the surface, suggesting that previous estimates of total canal length in prehistoric Arizona are much too low (Masse 1976, 1987; Huckleberry 1988b:167). Therefore, even if archaeological surveys have already identified the approximate layout of a canal system, archaeological excavations can provide still more detailed information about the system's size and capacity. For example, a canal's length and its widths and depths at various places, can be assessed relatively quickly by digging trenches along the canal's predicted course, examining trench cross-sections in detail, and hand-excavating short canal segments to determine their horizontal shape.

How Well Did These Canals Work?

Several techniques of archaeological excavation allow scientific specialists to evaluate the history and efficiency of prehistoric canal systems. Cross-sections of the sediments contained in a canal are extremely important, for they can answer many questions about both their use and efficiency. For example, if a canal was used for a long time, a cross-section will usually show that the canal was filled with several sequential layers of sediment (Figure 18). The presence of relatively more earth piled along the sides of the canal than could have accumulated during its original construction indicates that sediments that tended to clog the canal had to be removed occasionally in order to keep the canal functioning.

The efficiency of prehistoric canals can be evaluated by comparing them to more modern canals. Examination of the various sluice gates, erosion control devices, linings, and other corollary features--or the lack thereof--helps scientists determine how canals were used and how efficient they were (Nials and Gregory 1986). For instance, an analysis of the physical components and structure of Hohokam canal systems has led to the conclusion that, compared to modern irrigation systems, Hohokam systems were technologically simple and relatively inefficient in their use of water (Nials and Gregory 1986). The Hohokam probably lacked the ability to construct permanent intake facilities, and their intake structures and head gates, like those of the early historic irrigators, were probably regularly damaged or destroyed. The technology of drop structures (stair-like drops in elevation that tend to slow water velocity where it runs over relatively steep slopes, instead of allowing faster flows that lead to canal erosion) was unknown, and the great majority of Hohokam canals were unlined. Thus, despite the truly impressive character of prehistoric Hohokam canal systems, their technology limited the potential efficiency of the systems and made them particularly vulnerable to the vagaries of flow in the Salt River (Nials and Gregory 1986:71). This probably holds true for all the other prehistoric canal systems of Arizona, whether of the Hohokam or other cultures.

By assuming that certain stream-flow conditions were in effect at the time of canal use, then using fluid-engineering criteria applied to equations for computing volume and speed of water flowing in open channels, the velocity and discharge for individual prehistoric canals can be estimated (Huckleberry 1988a). The area available for irrigation can be estimated by adding up the topographically suitable land area beneath particular canal segments and measuring how much of this land could be served, given estimated velocity and discharge figures. These estimates must be tempered, though, by determining how much of the irrigation system being studied was in use at any one time, and then estimating velocity, discharge, and acreage for the period(s) of time when certain parts of the system are known to have been in use (Schroeder 1960; Nicholas 1981:19; Huckleberry 1988a).

How Old Are These Canals?

Several methods have been devised for determining when these canals were built and used (see separate description entitled "Methods of Dating Prehistoric Canals). The known dates indicate that Arizona's Hohokam canal systems are the earliest ones in the southwestern United States, so it is quite possible that canal irrigation spread from the Hohokam to other prehistoric peoples of Arizona (Breternitz 1957b; Fish et al. 1980), New Mexico (Dozier 1970:31-34,38-42), and northwestern Mexico (Doolittle 1988). However, no one is yet certain whether the Hohokam invented irrigation or whether they learned about canals from a more complex society far to the south, in central or southern Mexico (Haury 1976:150). If this question is ever settled it may eventually be possible to find out when and why people began using irrigation in the Americas.

If we can determine when a canal was built and used, we may then also be able to determine which houses were used at the same time. In addition to determining approximate ages of canals, it now appears possible in many cases to learn during which part of the year a prehistoric canal was used and when it was dry.

How Did Irrigation Systems Change Over the Years?

Machinery and metal tools did not exist at the time Arizona's prehistoric canals were built, and there is no evidence to suggest that hordes of laborers were organized at one time to construct an entire canal system. It is possible that most or all of the state's canal systems of old were dug from the streams outward toward the fields, so that the water could be used to soften the ground for digging as the work progressed. Studies seem to show that several of the Hohokam irrigation systems, on the Salt River at least, were constructed beginning at the river and progressing outward, because main canals closest to the river appear to date five centuries or more earlier than the main canal segments farthest from the river (Turney 1929; Nicholas 1981; Nicholas and Neitzel 1984). This is only one of the indications that the irrigation systems changed through time. The Hohokam living in the Salt River Valley in A.D. 1400 would have been looking at much different canal configurations than their forebears who had begun using irrigation hundreds of years earlier. However, the systems that existed in 1400 were not simply expanded versions of canals used earlier; complex sequences of rebuilding and remodeling occurred through time, and many parts of some systems were abandoned as other parts were being built (Howard 1988a).

Detailed archaeological studies show that even the courses of certain canals changed remarkably over time. Younger canals are often built on top of older ones running along the same course, and sometimes they are slightly offset (Figure Y). This is not unexpected, because the ancient canals almost never had hard linings that would have kept them in one position, and they also were continually being filled with silt that had to be cleaned out time and again. Probably because of problems with silt accumulation, or because of occasional destruction of the few riverbank areas suitable for locations of diversion dams, major canal segments along some irrigation systems may have become unusable decades or centuries after they were originally built (Turney 1929; Dart 1986). Unusable canals could sometimes be bypassed by digging cross-cut canals between different systems, as indicated by maps of the Salt River canals (Figures F*-H*). This was probably not possible in all cases, though, and may be one of the reasons why so many different Hohokam irrigation systems were brought about in the Salt River Valley. Though as many as 16 canal systems were eventually used by the Hohokam along the lower Salt River in the thousand years preceding A.D. 1500, all of these systems were probably not in use at the same time. This was also the situation in more recent times: many separate irrigation systems were built shortly after the American occupation of the Salt River Valley in the latter part of the 19th century, but eventually most of those systems were abandoned in favor of consolidating the irrigation effort and concentrating on two or three large systems efficient enough to divert the entire flow of the river.

WHY SHOULD WE BE CONCERNED ABOUT PREHISTORIC IRRIGATION FEATURES?

PREHISTORIC IRRIGATION WORKS ARE IMPORTANT

Archaeological sites, including prehistoric irrigation works, can make important contributions to our knowledge of mankind's past. Because archaeological sites are covered by historic preservation laws, their importance is often measured within a legal framework. For legal purposes, archaeological site significance is evaluated using criteria set forth in the legislation that established the National Register of Historic Places. An archaeological site is considered significant (and thus eligible for inclusion in the National Register) if it may contribute scientific, prehistoric, historic, or archaeological information about the nation's cultural heritage (King et al. 1977:95-100; see separate section entitled "Historic Properties Eligible for Nomination to the National Register of Historic Places, and Legal Provisions Concerning Those Properties"). Other factors that can be considered in determining an archaeological site's importance are its value for education, recreation, and economic development.

Importance for Research

As a result of their discoveries in a rather brief archaeological study of ancient canals in Tempe, Bruce Masse and Susan Brew observed, "We have again seen that Hohokam irrigation systems are by no means simple and easily interpretable; there is still much to be gained by the future study of additional canals and systems, data that ultimately will be critically important for our understanding of Hohokam cultural evolution" (Masse 1987:ix). Indeed, there is still much to learn. In order to define a prehistoric irrigation system's value for research, one must be aware of the issues to which remnants of such a system can contribute. These issues include basic questions about the canals themselves as well as issues of broader anthropological and agricultural interest.

The basic elements of research on prehistoric canal systems include continued documentation of the systems' locations and sizes, their operational characteristics and limitations, and their evolution, decline, and even abandonment through time. Recognition of what the prehistoric environment was like is also critical if we are to understand these elemental research issues. For example, was the average amount of water flowing down the state's rivers during prehistoric times comparable to the amount of water the rivers carry today? How many of the Hohokam canals along the Salt River were operated at the same time, and did those being operated at the same time use all of the river's water?

The data from this research not only in Arizona, but throughout the world, are the building blocks needed to address larger research issues. Several issues concern the kinds of interaction that occurred within and between irrigation communities. Did the prehistoric peoples of Arizona ever institute means of managing the distribution of water to different locations along the various canal systems, or to determine how much water individual canal users were entitled to? Were certain individuals in charge of recruiting and managing the laborers to build and maintain the canals, or was there simply a loose organization managed by consensus, in which all able-bodied members of the irrigation society simply agreed to come together when needed to maintain the systems? How was the irrigation water allocated to the various communities along each irrigation system? If irrigation allowed food surpluses to accumulate, were these surpluses considered the property of the individual farmers, or of the entire society, and if the latter, who was in charge of managing them? If one canal system failed by silting up or other adverse factors, were the people who relied on that system taken care of by those along other systems that remained operable? Or did they have to fend for themselves by trying to rebuild their canal system or by usurping the farmlands of other groups?

The study of irrigation features can help us understand the basic characteristics of prehistoric human populations--their size, growth, density, and distribution. One can ask how and why irrigation influenced these characteristics of human communities. The fact that it did so is demonstrated by the relatively large size and density of many of the villages along the major irrigation systems of Arizona and other parts of the world (Hole et al. 1969:342-371; Adams 1971), and the distribution of ancient villages, towns, and cities dependent on those systems. Irrigation obviously would have allowed increases in size, growth, and density of prehistoric populations by making intensive crop production possible. However, irrigation may also have had negative effects on the same populations. For example, if they had been used for disposal of sewage and other wastes, it is possible that ancient canals were unsanitary and carried organisms that caused a number of infectious diseases (Fink 1988). Or, if disputes arose over how water was to be allocated, feuds may have erupted among the communities that used a single canal system.

The adoption of irrigation technology apparently had little overall effect on long-term agricultural production in some areas of Arizona (e.g., Breternitz 1957a, 1957b). However, in other areas, for example along the lower Salt River and parts of the Gila Valley, it is plain to see that irrigation was once the key to human subsistence and that just about every place where it was possible to irrigate, given the prehistoric technology, was eventually irrigated. Could the adoption of irrigation in the lower Salt and Gila basins eventually have initiated a vicious circle, in which increased production led to increased population, which in turn required further increases in production? If so, what happened when there was no more land to irrigate and these people's numbers were limited by their inability to expand into non-irrigable areas? This phenomenon of population circumscription relative to the available resources may have been one of the main factors that started human society on the road toward complex social organization and, eventually, true states (Carneiro 1970; Dickson 1987; Cable and Mitchell 1988).

Taking these issues to their logical conclusion, studies of prehistoric irrigation systems figure quite prominently in attempts to understand how complex societies--that is, urban civilizations--have progressed since the earliest beginnings of humankind. The phenomenon of civilization and its principal characteristic, urbanism, are understood to be founded on agriculture, and this usually means a type of agriculture made possible by a complex food production technology such as irrigation. It is possible that under some circumstances irrigation leads to a social organization characterized by elites and pyramidally arranged power (Wittfogel 1957). Because the first true cities of the world were all founded on agriculture supported by complex irrigation practices, agriculture, irrigation, autocracy, and cities might be linked. Moreover, as technology, such as irrigation, appears and becomes more complex, it is generally accompanied by or makes possible new social, economic, and religious forms (Leone 1972:355; Bellah 1970:20-50).

Just how important was irrigation in bringing about the world's complex societies? We know it must have played a role in both social and political advance because nearly all the early civilizations in the world--from the Fertile Crescent of the Old World to Mexico and Peru in the New--had invented complex irrigation systems. And yet, if irrigation was such a major factor in the elaboration of those early civilizations, why did Arizona's prehistoric societies, with their irrigation systems rivaling the best in the ancient world, never become as complex socially as the major early civilizations elsewhere in the world?

Regardless of whether it is a canal or one of many other kinds of irrigation-related features, if an individual irrigation-related property might contribute information relevant to research issues such as these, then that cultural property is significant according to National Register criteria. This assumes, of course, that the surviving parts of that property still retain some of the original characteristics of location, design, setting, materials, workmanship, feeling, and association, as stated in federal law (36 CFR 60.6).

Importance for Education and Recreation

Archaeological findings from canal studies might be of great value not only to the aboriginal segment of our society, but to the society at large. Because prehistoric canals and other irrigation-related features are often dated repositories of many sorts of ancient biological and geological materials, they are valuable educational resources for scientific studies. Archaeological data derived from them may tell us a lot about past climates and the evolution of cultivated plants; at least some of these kinds of information may contribute to long-term planning in agriculturally marginal areas (Lipe 1974:218).

Regarding education in history and social studies, archaeology can be important in establishing group identity and a pride in past accomplishments among emerging national or newly self-conscious ethnic groups (Fowler 1987; Arden 1989). The fact that Arizona contains some of the most extensive and complex prehistoric irrigation works in the world should be taught in the state's primary and secondary schools and should be included in educational materials for teaching social studies, geography, agriculture, and alternative technologies. Although Arizona's prehistoric irrigation works were developed exclusively by indigenous peoples, these features are nevertheless valuable resources for educating people of other cultures as well as people of aboriginal American ancestry. There is a great demand for education in anthropology and archaeology as attested by persisting enrollments in formal college courses as well as continuing education classes in these subjects. As is true for all historic properties, including archaeological sites, prehistoric irrigation works have educational value because the information that they contain can give us all a sense of our cultural heritage. They allow us a glimpse into a particular portion of the history of a nation that is composed of diverse human groups and individuals. By piecing together the tangible evidence of the prehistoric sites and structures (such as canals and related features) with written and oral histories, we gain more appreciation and understanding of the growth and forward movement of different societies through the ages and about how all those societies have come together to form today's world.

The recreational value of prehistoric irrigation sites and features is indicated by Arizona's many recreational facilities and annual events catering to a vibrant public interest in archaeology. Archaeological sites or museums have been developed for public display in at least 10 national parks and monuments, six state parks, and several cities and towns in the state. And at least 45 communities, public parks, and monuments in Arizona (and one in Utah!) have scheduled events and special programs during recent celebrations of "Arizona Archaeology Week," an annual program.

The establishment of two local parks that focus primarily on prehistoric irrigation themes shows that prehistoric irrigation systems have recreational potential. The Park of Four Waters in Phoenix was set aside specifically to protect some of the best remaining examples of prehistoric Hohokam canals along the lower Salt River. And in 1975 a property containing several well preserved Hohokam Indian ruins and canals, as well as some historical canals, was donated to the City of Mesa for improvement as an archaeological and historical park highlighting the history of irrigation; this property was subsequently listed in the National Register of Historic Places and designated the "Park of the Canals" (Howard 1988c).

Importance for Economic Development

The study of prehistoric irrigation systems has implications for worldwide economic progress. For example, determining the reasons why the ancient canals of the Phoenix Basin failed may be extremely important to assure successful agricultural practices in arid lands today. What can be learned of the Hohokam mistakes in reclamation through irrigation? And how can this knowledge be put to use so that today's agriculturalists do not have to repeat those mistakes and may irrigate indefinitely?

Arizona's archaeological irrigation works are also of value on the local level, as demonstrated by taking count of those who visit archaeological parks, monuments, excavations, museums, and Arizona Archaeology Week activities. Obviously, such visitation promotes commerce. It is rare to find a community that is not willing to have a national monument or a state park established in its vicinity because these facilities benefit local communities by promoting tourism. Increased visitation in turn leads to commercial betterment and community growth.

Archaeology can also be used effectively for advertising and public relations, because many people are eager to visit sites where archaeological excavations are in progress. The Salt River Project and several land modernization companies in Arizona have already realized that there are considerable public relations opportunities available to companies that sponsor archaeological studies on their properties in the early stages of a land modification project.

PREHISTORIC IRRIGATION WORKS ARE THREATENED

There are several ways in which Arizona's remaining prehistoric irrigation works are threatened with destruction. First, the detrimental processes of nature such as erosion, animal burrowing, tree-root intrusion, and perhaps earthquakes (see Holmlund 1986) have affected prehistoric canals in the centuries since they were abandoned. These natural processes have destroyed virtually all diversion structures along the streams, and probably have effaced many portions of the canals. However, destruction through natural means has been minimal in comparison with mankind's effect on these ancient irrigation works.

Human activities, especially those of the last century, have been especially devastating to archaeological sites. Beginning in the last half of the nineteenth century there was an influx of U.S. citizens into the Arizona Territory. Many of these newcomers soon realized the great agricultural potential of the areas along Arizona's streams, and in their efforts to build irrigation systems and open up farmland they destroyed many of the ancient Indian villages and irrigation works that had occupied the river bottomlands and adjacent irrigable terraces (Turney 1929). As commerce increased with Arizona's rapid population growth during the twentieth century, more and more land was plowed, more was disturbed by building new settlements. As growth has picked up speed in the past few years, the prehistoric cultural resources of Arizona have been obliterated at an alarming rate that shows no sign of abating. Modern agricultural destruction has continued but it was long ago superseded by construction of new housing and commercial developments, highways, water projects, and utilities; in fact, installation of utility lines within existing streets in the Phoenix metropolitan area is one of the worst threats to the ancient canal systems of the Salt River valley.

Pot-hunting and wanton vandalism of ancient ruins is an added problem that is curbing the longevity of our archaeological sites in Arizona, but certainly most of the recent destruction of our archaeological heritage has been unintentional. For example, unless they are adept at recognizing archaeological material, heavy equipment operators do not even know when their graders, backhoes, or bulldozers have damaged an archaeological feature. And even if a machine operator does recognize archaeological material as it is being unearthed, it is usually not the operator's decision to stop work so that the material can be adequately studied; destruction in such a case is the unintentional result of a long chain of decisions by engineers, developers, and others who planned and sponsored the land modification in the first place.

SAVING PREHISTORIC IRRIGATION WORKS FOR EVERYONE

Prehistoric irrigation canals and related archaeological features that are found to be important should be considered resources that can be used to advantage. How may the potential of these resources be realized?

Both archaeological surveys and excavation studies must be done, especially in areas outside the Salt and Gila river valleys, because current techniques and knowledge are not sufficient if we want to know all we can about important prehistoric irrigation canals and related archaeological features. Researchers should be encouraged to use every means to date prehistoric canal features that are under study, to determine the systems' operational characteristics, and to launch and perfect new methods of both dating and discovering how they operated. Also, interpretive studies to unravel mysteries of prehistoric irrigation systems with respect to community interaction, demographic change, agricultural intensification, and changing social and political organization and development must be stimulated further in future work.

There are many ways in which the remaining examples of prehistoric irrigation works can be protected and publicized. Archaeological parks can be established and improved. Museums can be encouraged to display materials illustrating particular aspects of archaeology, including prehistoric irrigation features. It should also be possible to exhibit prehistoric irrigation works and other ancient features in settings less formal than parks, preserves, and museums, and to make people aware of them by posting signs and by indicating their locations in official city and state maps, bus schedules, convention brochures, and other promotional materials. Tours of irrigation features can be given during the annual Arizona Archaeology Week and when archaeological excavations first uncover some of these features. Preservation of the features can be stimulated by nominating them to the National Register of Historic Places or by encouraging protective societies, such as the Archaeological Conservancy, to buy the properties that contain the features.

Finally, formal education campaigns can make the general public more aware of Arizona's unique heritage of more than a millennium of ancient irrigation works. Information on them can be supplied to national publishers of school textbooks in history and social studies. Producers of public television programs such as *Nova* and *Odyssey* can be encouraged to do video features or series on prehistoric irrigation in the Americas, including Arizona. Educational packets can be distributed to the state's school systems so that information on prehistoric canals can be added to school archaeology programs. More efforts can be made to include irrigation features in future Arizona Archaeology Week activities and to invite schools and other specific groups (retirement communities, churches, etc.) to attend these events. And finally, a state-wide educational campaign using television, radio, newspaper, and bumper stickers can be undertaken to increase awareness of prehistoric canals and other archaeological features. The possibilities are probably endless.

SUGGESTIONS FOR FURTHER READING

Ackerly, Neal W., Jerry B. Howard, and Randall H. McGuire
1987 *La Ciudad Canals: A Study of Hohokam Irrigation Systems at the Community Level.* Anthropological Field Studies No. 17. Arizona State University, Tempe.

This study describes and interprets the irrigation systems that were investigated prior to construction of a freeway through the archaeological site of La Ciudad, an ancient Hohokam village along the Salt River in Phoenix. The volume includes a critical review of several archaeological studies of Hohokam irrigation systems.

Castetter, Edward F., and Willis H. Bell
1942 *Pima and Papago Indian Agriculture.* University of New Mexico Press, Albuquerque.

Castetter and Bell provided excellent descriptions of the agricultural practices (including irrigation) used historically by the Pima and Tohono O'odham (formerly called Papago) Indians of southern Arizona. Because the Pima and Tohono O'odham lived in virtually identical natural surroundings as their Hohokam predecessors, and exhibited similar settlement patterns, *Pima and Papago Indian Agriculture* has long been used by archaeologists to interpret the agricultural practices of the prehistoric Hohokam. (Available only in libraries and private collections.)

Doyel, David E., and Mark D. Elson
1985 *Hohokam Settlement and Economic Systems in the Central New River Drainage, Arizona.* Publications in Archaeology No. 4. Soil Systems, Phoenix.

This study is especially useful for its descriptions of the kinds of rock features found associated with prehistoric fields and canals in the areas peripheral to the Phoenix Basin.

Haury, Emil W.
1976 *The Hohokam: Desert Farmers and Craftsmen. Excavations at Snaketown, 1964-1965.* University of Arizona Press, Tucson.

Archaeological excavations at the village of Snaketown, Arizona, are described in this important contribution to archaeological studies of the ancient Hohokam. Pages 120-151 examine many of the different kinds of cultural features that may be found in Hohokam irrigation systems, and discuss how archaeologists study and interpret these features.

Masse, W. Bruce
1981 Prehistoric Irrigation Systems in the Salt River Valley, Arizona. *Science* 214:408-415.

This article provides a good, quick, general overview of the ancient irrigation systems in the Phoenix metropolitan area.

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NOTES ON CANAL LOCATIONS

1. The prehistoric irrigation works identified in this study were located by reviewing archaeological publications and archival material dealing with the subject. These sources include Frank Midvale's papers and maps at Arizona State University (Midvale 1971); Gila Pueblo's records of sites located in regions that include major streams; and the Arizona State Museum (ASM) computerized archaeological site data inventory known as AZSITE. AZSITE (1989) was queried for a list of all archaeological sites where either canals or dams had been recorded, then the original records of all archaeological sites on the output list were reviewed; all sites at which the canals or dams appear to be prehistoric irrigation features are mapped and referenced in this report. Except where indicated after the site number, site designations mentioned below were assigned by ASM; any other institution or agency that assigned an archaeological site designation is indicated in parentheses after each designation, using the following initials: Arizona State University (ASU), Bureau of Land Management (BLM), Gila Pueblo (GP), and Museum of Northern Arizona (MNA). The "AZ" prefix that is part of most site designations used by various institutions in Arizona has been dropped for convenience below; other site number prefixes ("NA" for Museum of Northern Arizona, "SN" for Sonora) are retained. The locations of prehistoric irrigation works that have been reported thus far in Arizona are indicated in Table 1 and Figure 4.
2. Turney (1922, 1929); Midvale (1968, 1971); Nicholas (1981); Howard (1989 [map in preparation]).
3. Midvale (1971:Book XIIIb).
4. Holiday (1974); Rodgers (1977); Smith (1977); Henderson and Rodgers (1979); site T:4:28 (AZSITE 1989).
5. U:6:37 and U:6:46 (AZSITE 1989).
6. Bandelier (1892:421-424); archaeological site records for Roosevelt:9:4 and Roosevelt:9:13 (Gila Pueblo 1929-1930).
7. Fuller et al. (1976:59,74).
8. J. Scott Wood, personal communication to author, 1989.
9. J. Scott Wood, personal communication to author, 1989.
10. Bandelier (1892:398-400).
11. Site Roosevelt:9:4 (Gila Pueblo 1929-1930).
12. Site V:5:67 (ASU) (Wells 1971:8); J. Scott Wood, personal communication to author, 1989.
13. Hagenstad (1969:27); Midvale (1971:Book XX); Canouts (1975:84,275,283).
14. Mindeleff (1896); Midvale (1971:Book XIX).
15. Midvale (1971:Book XIX).
16. Site U:2:20 (ASU) (AZSITE 1989).
17. Mindeleff (1896:238-243); Fewkes (1898:537-538).
18. Schroeder (1960:35); Hartman (1976:26).
19. Midvale (1971:Book XVIII).
20. Schroeder (1958:26-27); Midvale (1971:Book XVII).
21. Schroeder (1960:22,27,35); Fish and Fish (1984).
22. Mindeleff (1896:243-244); Breternitz (1960:9); Fewkes (1898:550).
23. Turney (1929:155).
24. Site CC:2:3 is identified as Chichilticale pueblo (Haury 1984); the nearby site is CC:2:31 (AZSITE 1989).
25. Solomon canals were noted by Turney (1929:157); Ash Creek canals were reported above sites L:1:10 - L:1:13 (GP) (Gila Pueblo 1929-1930).

26. Bandelier (1892:410-411).
27. Bandelier (1892:413-414).
28. Bandelier (1892:413-414); Debowski et al. (1976:2,90).
29. Cummings (1926); Turney (1929:149); Judd (1931); Midvale (1965; 1971:Map 91); Haury (1976:120-151); Brooks and Vivian (1978:18-19); Crown (1984a).
30. Site AA:3:112 (AZSITE 1989).
31. Turney (1929:69-70); Wasley and Johnson (1965:24-25); Midvale (1970, 1971, 1974); Rodgers (1976:65-66,72-73); Antieau (1981:138-142,259); AZSITE (1989).
32. Midvale (1971:Book XV).
33. Site A:7:5 (GP), later designated T:7:11 by ASM (Gila Pueblo 1929-1930); site T:7:14 (AZSITE 1989).
34. Dove (1977:18). This canal, which may also have been noted by Turney (1929:142), was later named the "Dove Canal" by Frank Midvale (1971:Book XXV) (Dove, personal communication 1989).
35. Weed and Ward (1970:7).
36. Midvale (1971:Book XIV); Doyel (1984); Doyel and Elson (1985); Rankin (1988).
37. Turney (1929:157).
38. Bruder (1983:77-78).
39. Earl (1983).
40. Turney (1929:145).
41. Dart (1983a:363-392); Brooks and Vivian (1978).
42. Manje (1954:77-83).
43. Masse (1980b:209-210,217,220).
44. Bolton (1936:367).
45. Site AA:6:2 (AZSITE 1989).
46. Site AA:12:57 (Bernard-Shaw 1988, 1989).
47. Sites AA:12:118 and AA:12:231 (AZSITE 1989; Fish et al. 1989).
48. Site AA:12:90 (Kinkade and Fritz 1975:29-31).
49. Site BB:13:221 (AZSITE 1989; Doelle and Wallace 1986:100).
50. Sites DD:8:42, EE:10:29 (in Sonora, Mexico), and EE:10:6 (AZSITE 1989).
51. Site AA:11:5 (BLM) (AZSITE 1989).
52. Manje (1954:92-94); Kessell (1966:71); Smith (1966:12 [Note 36]).
53. DiPeso (1956:4,202-203,443).
54. Site DD:8:126 (AZSITE 1989).
55. Frick (1954:49).
56. Bernard-Shaw (1988:158; 1989).
57. Doelle (1985:35).
58. Dart (1985).
59. The canal in question, located on the San Xavier Reservation at site BB:13:221, is now believed by Doelle to have been a natural feature (William H. Doelle, personal communication to author, 1989).
60. Cummings (1910:32); Lindsay (1961:178,182-184; 1969:Figure 2,199-211); Sharrock et al. (1961); Jennings (1966:43-46).
61. Lightfoot and Plog (1984).
62. Turney (1929:157).
63. Bandelier (1892:390); Danson (1957:63).
64. Bandelier (1892:386-390); Danson (1957:63).
65. Lightfoot and Plog (1984:184-185).
66. Lightfoot and Plog (1984:183).
67. Site NA 7207 (Fish et al. 1980; McGregor 1958).
68. Breternitz (1957b:50-53); Pilles (1979:463).
69. Site NA 5907 (Breternitz 1957a:28-30).
70. Site NA 1785 (Fish et al. 1980).

71. Arizona State Museum records compare a dam at site K:15:2, near Sanders, to dams at Danson's (1957) site 617 in east-central Arizona and at the Green site near Quemado.
72. Lightfoot and Plog (1984:183).
73. Kintigh (1984).
74. Hack (1942:34-36).
75. Schwartz (1956:80).
76. For example, Stone (1986, 1987).
77. Manje (1954:110,158); Smith (1966:21).
78. Castetter and Bell (1942:36-37).
79. Withers (1973:84-86).
80. Site SN C:4:10 (AZSITE 1989).
81. Site Z:12:16 (Dart 1983b; AZSITE 1989).
82. Site Z:10:1 (BLM) (AZSITE 1989).
83. Sites AA:6:9 and AA:6:10 (AZSITE 1989).
84. Sites Z:12:13, Locus A (Masse 1980a:68,74-75), AA:5:43 (Raab 1975:300-302,305); and Sonora C:2:2 (Gila Pueblo 1929-1930).
85. Midvale (1971:Book XXIX).

Table 1. Arizona streams along which prehistoric irrigation systems have been reported or inferred (organized alphabetically).

Stream Name	Watershed	Stream Name	Watershed
Agua Fria River	GR	Pinto Creek	SV
Anegam Wash	PA	Puerco River*	CO
Aravaipa Creek*	GR	Queen Creek	GR
Ash Creek*	GR	Salt River	SV
Babocomari River*	GR	San Francisco Wash	CO
Baboquivari Wash	PA	San Juan River***	CO
Blanco Wash**	GR	San Pedro River	GR
Carrizo Creek	SV	Santa Cruz River	GR
Cataract Creek*	CO	Santa Rosa Wash	PA
Cave Creek	SV	Schultz Creek	CO
Cedar Creek	SV	Sells Wash	PA
Chavez Wash	CO	Show Low Creek	CO
Cherry Creek*	SV	Silver Creek	CO
Colorado River*	--	Skunk Creek*	GR
Dragoon Creek*	SV	Sonoyta River***	PA
Gila River	GR	Tonto Creek	SV
Gilson Wash	GR	Unnamed wash (SE of Florence)	GR
Greene Wash	PA	Midway Wash***	PA
Gu Achi Wash*	PA	Vamori or Fresnal Wash	PA
Hay Hollow Draw	CO	Verde River	SV
Lime Creek	SV	West Clear Creek	SV
Little Colorado River	CO	Wet Beaver Creek	SV
Moenkopi Wash*	CO	Young's Canyon	CO
New River	GR	Zuni River*	CO
Oak Creek	SV		

Key to watersheds (see text):
- SV Salt-Verde
- GR Gila River (exclusive of Salt-Verde)
- CO Other Tributaries of the Colorado River
- PA Papagueria
- -- Colorado River is discussed alone in text

Notes:
- * Irrigation suggested; there are no actual reports of prehistoric irrigation works
- ** Questionable report of prehistoric irrigation
- *** Possible irrigation on Arizona tributaries of this stream

APPENDIX: GOALS, STRATEGIES, AND PRIORITIES FOR FUTURE RESOURCE PLANNING

The following goals and strategies are suggested for future planning by the Arizona State Historic Preservation Office (SHPO). An outline of suggested planning priorities is included at the end of this appendix.

PROTECT THE RESOURCES AND REMEDY DEFICIENCIES IN OUR KNOWLEDGE OF THEM

Goal A: Protect the Resources

Many planners of modern development projects take care to make an inventory of all archaeological material that is likely to be affected when their projects proceed. When they find that their project threatens an archaeological site, one method of dealing with that site, currently popular and perfectly legal, is to implement a mitigation program to recover scientific data from the property, then to allow what is left of the archaeological site(s) to be destroyed as land modification proceeds. Certainly, when it is recognized that some prehistoric irrigation-related features will have to be destroyed in order to make way for modern land uses, efforts should at least be made to retrieve as much information as possible from these features before they are effaced. Special efforts should be made to persuade local governments of the Phoenix metropolitan area (Maricopa County and the City of Phoenix, City of Mesa, etc.) to allow at least voluntary archaeological monitoring and data recording whenever a trench is dug to install new utility service.

Although the data recovery method of historic preservation provides records of our cultural heritage, the acceptance of mitigation programs tacitly condones the eventual complete demise of the physical reminders of that heritage. Shouldn't proper stewardship of the resources that tell us about our past also consider methods that provide future generations with a chance to examine these prehistoric properties for themselves? To provide them with such opportunities, archaeological site management today must implement methods to protect irrigation-related properties in order to make it possible that the full potential of these resources may eventually be realized. Following are some recommendations for implementing protection.

Encourage National Register Nominations

The SHPO should encourage the nomination of prehistoric irrigation-related properties to the National Register of Historic Places, especially the nomination of properties on state and federal land. Listing of these properties should at least provide some incentive to preserve them even if it doesn't provide guarantees. National Register nominations can be encouraged by emphasizing their importance in requests for proposals for survey and planning grants; by requesting nominations during contract and other archaeological surveys where historic properties do not face immediate destruction; and by contacting private owners of historic properties to inform them of tax and other incentives for having their properties included in the National Register. Multiple Property nominations would be especially appropriate for documenting irrigation features, especially those along a single river drainage.

Encourage Land Exchanges

Many irrigation-related properties are located on Arizona trust land, which by law must be managed for the maximum possible income to the state. Because land uses such as commercial development can provide the state with more income than could be obtained by preserving archaeological resources, those resources often are included in mitigation programs, then destroyed as development proceeds. In order to stem this trend and supplant it with an in-place preservation tendency, the SHPO can encourage land exchanges in which State trust properties containing significant irrigation-related resources--especially prehistoric National Register sites and districts--would be transferred to the ownership of either the federal government or Arizona State Parks. Such an exchange was proposed recently by the Bureau of Land Management for the Los Robles and McClellan Wash Archaeological Districts, two National Register districts in the Tucson area, so that the resources in those districts could be protected in the BLM's Phoenix Resource Area. Exchanges of federal or state land for private properties that contain significant irrigation-related resources could also be encouraged.

One area to consider for such a land exchange is along the Central Arizona Project's Salt-Gila Aqueduct about 7 to 10 miles east of the town of Queen Creek. Exchange of some of this area would help to conserve and protect intact remains of prehistoric canals in one of the few broad expanses of Arizona state land where both prehistoric canals and reservoirs have been documented and investigated (Dart 1983a; Crown 1984a, 1984b). It would also help to protect any endangered or rare plant or animal species that might inhabit the area, e.g., Gila monsters were seen there during the Arizona State Museum's archaeological studies of 1980. Lands suggested for possible exchange to federal or State Parks ownership include Sections 23, 24, 25, 26, 35, and 36 in T2S, R8E, and Sections 19, 30, and 31 in T2S, R9E.

Encourage Irrigation-Related Park Management

Probably most of the benefits that prehistoric irrigation works have to offer can be realized by establishing and improving formal archaeological-theme parks and preserves that focus attention on ancient canals and their associated archaeological sites and features. The SHPO can award matching grants to local entities to plan the development of local parks or preserves containing irrigation resources.

An excellent example of how a park focusing on ancient canals might be developed has been presented by Howard (1988c) for the Park of the Canals in Mesa. The following recommendations have been devised using Howard's (1988c) report as a starting point.

Several existing or proposed parks in Arizona are suitable for instituting displays depicting prehistoric irrigation features. These include the City of Mesa's Park of the Canals (Howard 1988c); the Park of Four Waters in Phoenix (Masse 1976, 1981); the Gatlin site in Gila Bend (Weaver 1984); the proposed Hohokam-Pima National Monument (Wilcox et al. 1981); and the Gila River Indian Community's Cultural Center. All of these park properties encompass either actual remnants of Hohokam canals or reconstructed versions of them, in addition to canal related cultural features. Grants and any other incentives that can be provided should be offered toward developing and maintaining these parks.

Step-by-step procedures for establishing and improving parks that contain prehistoric canal features can be suggested. The first and most important step would be to devise a responsible overall park management plan that recognizes the needs of historic preservation along with other needs such as education, recreation, and management of natural resources. Perhaps at least partly because responsible management plans have not been brought to pass, the Park of the Canals and Park of Four Waters are currently in a crisis situation. The current "master plan" for Park of the Canals ignores the needs of historic preservation entirely, and this has already resulted in partial destruction of the historic properties there by new construction (Jerry Howard, personal communication 1989). Park of Four Waters is currently a hang-out for transients, closed to the public, that is repidly being destroyed by off-road vehicles. Action needs to be taken soon to care for both parks under the auspices of responsible management that recognizes the extremely delicate balance between bringing along an educational and recreational resource on the one hand while on the other preserving historical and archaeological remains and natural resources. It should be stressed that archaeological remains are fragile things, and that every disturbance of them results in a loss of their integrity. Planners should consider them when deciding where to place major facilities such as buildings and parking lots, but placement of even seemingly minor items like new drainageways is quite important, too.

The second step (already completed at Park of the Canals, the Gatlin site, and presumably at Park of Four Waters) is to determine where the boundaries of the park will be and to immediately conduct a complete inventory survey of all archaeological features within the proposed park area. Once the distribution of archaeological material is known, the portions of each park that would focus on prehistoric irrigation features could be designed to include areas for long-term preservation, for archaeological excavation, stabilization, and reconstruction, for public facilities, and for adjunct features.

A formal preserve area or areas might be established where disturbance of prehistoric archaeological features has been minimal. Areas in which no archaeological excavations have been done and where other disturbances have not occurred (or have been slight) would be ideal to show visitors what an ancient canal remnant looks like today after centuries of exposure to natural forces. A preserve area should be kept virtually free of all vehicle and pedestrian traffic in order to enhance preservation; public observation points should be limited to specified areas overlooking it. If the park has a full time staff the preserve area should require relatively little direct supervision, and volunteer docents could be recruited to provide guided tours and public interpretation and to discourage public entry into the preserve area.

Next, it might be appropriate to set aside an area or areas where archaeological excavations are in progress, or where canals and related features have been previously exposed by archaeological excavation and subsequently stabilized. This excavation area could demonstrate how the irrigation features looked when they were in use as compared to how they look today in the preserve area. An ongoing archaeological excavation area should be considered only a temporary aspect of the park, because archaeological excavation is itself destructive. At least part of this excavation aspect could be scheduled for the early stages of park development, and could be limited to areas scheduled for subsequent construction of any necessary park facilities. Areas of the park where archaeological features never existed or have since been disturbed would be the best place to build parking areas, shade and picnic ramadas, public restrooms, or interpretive facilities such as a museum. Some disturbed areas could also be left in their present state to point out the contrast with undisturbed or archaeologically studied areas and to increase public awareness of the plight faced by archaeological sites in the face of modern activities including land development and vandalism.

In order to take the fullest advantage of such a park and to attract as wide an audience as possible, a "multiple use" philosophy could be recommended provided that other uses do not impact archaeological features and are compatible with a theme of prehistoric irrigation. For example, Howard (1988c) suggests that an area of the Park of the Canals could be set aside as a botanical garden provided that the garden focus on the kinds of plants cultivated prehistorically, irrigation techniques and their effects on the cultigens, and plants gathered by prehistoric and early historic period Native American groups as well as the kinds of "useful weeds" that were encouraged, consciously or unconsciously, to grow along prehistoric canals. A noncompatible development, he suggests, would be construction of a playground.

At the archaeological parks that are already in existence or that have been proposed, the SHPO should provide incentives for erecting displays depicting prehistoric irrigation features in the following sequence: the Park of the Canals in Mesa; the Park of Four Waters in Phoenix; the Gatlin site (Gila Bend); the Gila River Indian Community Cultural Center; and finally, the proposed Hohokam-Pima National Monument if that monument is likely to become a reality.

Encourage Protective Acquisition of Irrigation-Related Properties

The SHPO can encourage protective entities such as the Archaeological Conservancy to acquire archaeological districts, sites, and features by informing the managers of these entities about properties that contain significant irrigation works, and by working with the entities to seek public and private grants for acquisition. Should acquisition money become available to the SHPO, some of this money can be used for grants of this kind. Any public monies used for this purpose should be awarded only with the stipulation that ownership will revert to the granting agency if the foundation's archaeological resource management policy changes. In Arizona, the Arizona Preservation Foundation accepts conservation easements, and the Archaeological Conservancy may also seek them. Therefore, private land owners can be encouraged to donate conservation easements of land containing irrigation resources.

Seek Establishment of a New State Land Category

It may eventually be feasible to establish a new category of state land to be administered by the State Parks Department: <u>state resource preserves</u>. As a division of Arizona State Parks the SHPO is a logical agency to determine whether real estate (including state trust land) could be purchased by Arizona State Parks for the explicit purpose of conserving, protecting, and promoting study of natural and cultural resources therein and, where possible, promoting increase in those resources. State resource preserves could be established by acts of the legislature just as the Homolovi, Cerro Prieto, Quiburi, and Empire Ranch state parks were founded recently.

Goal B: Remedy Deficiencies in Knowledge of the Resources

In order to remedy deficiencies in basic research needs for understanding prehistoric irrigation works, both archaeological surveys and excavation studies are necessary. Future archaeological surveys in the state, especially those within 10 miles of major streams, should include methods designed to identify any irrigation-related archaeological features using the indicators delineated by Midvale (1968; see above). Further, surveys in disturbed or nonriverine areas should attempt to discover remnants of irrigation features by studying soil and vegetation patterns and geomorphic conditions of the survey area.

Because our knowledge of prehistoric irrigation in river valleys outside of the lower Salt and Gila River valleys is relatively scant, the SHPO and other cultural resource management agencies could provide incentives to search for and document more canal systems in these "outlying" areas. For example, survey and planning grants could be offered by the SHPO for survey projects that would specifically search for prehistoric irrigation features along streams outside of the Hohokam culture area. In their requests for proposals to conduct surveys on government property, the agencies charged with management of cultural resources on those properties could specify that archaeological survey would specifically search for evidence of prehistoric irrigation.

More work is also needed to remedy deficiencies in our understanding of the kinds of prehistoric irrigation features currently known. It is of fundamental importance that agencies who set policy and sponsor archaeology encourage researchers to employ all known means to date prehistoric canal features that are under study, to determine the systems' operational characteristics, and to create new methods of both dating and discovering the operational parameters. Also, interpretive studies to unravel mysteries of prehistoric irrigation systems with respect to community interaction, demographic change, agricultural intensification, and changing social and political organization and development must be stimulated further in future work.

EDUCATE AND PUBLICIZE

The other two goals for future resource planning related to the context of prehistoric irrigation in Arizona are to promote the resources to practitioners of formal education as and to the general public. A logical first step for doing this would be to publish the text of this historic context in a popular format that would be usable by school systems and the general public alike.

Goal C: Promote the Resources to the Educational System

One of the easiest ways to promote information about prehistoric irrigation in Arizona would be to schedule school-group tours of irrigation features during future Arizona Archaeology Week activities.

To make Arizona's education professionals more aware of prehistoric irrigation features in Arizona a popular-format version of this historic contexts study should be distributed and advertised among formal educators, perhaps through the state department of education or the county school superintendents. The SHPO could also distribute other educational material to the state's school systems, and could encourage this material to be added to school archaeology programs such as the Tucson Unified School District's "Camp Cooper."

Education can also be promoted at the national level. The SHPO can contact national publishers to seek their input on how information on prehistoric irrigation resources can be used in school textbooks (especially in history, social studies, and American Indian studies), then fund an effort to provide the targeted information to national publishers of school textbooks in history and social studies.

Goal D: Make Information More Accessible to the Public

Several actions can be taken to make information on ancient irrigation-related feature more readily available to the general public. As is suggested above for school groups, tours of prehistoric canal sites could be encouraged during Arizona Archaeology Week. This would be especially appropriate in the Park of Four Waters and Park of the Canals because it would generate public interest in preserving and developing these parks. The potential public relations benefits of conducting archaeological data recovery programs should be pointed out--via publication of the historic contexts report in a popular format--to developers, construction contractors, large corporations that operate farms in Arizona, land managers, and others involved in land modification activities. Then, these groups should be encouraged to implement mitigation procedures even where these actions are not legally required. In order to provide background for archaeological consulting firms that might be hired to conduct these mitigation programs, either the original version or the popular version of the contexts report should also be distributed to the consulting firms as well as to other individuals and agencies likely to come in contact with prehistoric irrigation works, such as federal, state, and local government land managers.

More effort can be made to exhibit prehistoric irrigation works and other ancient features in settings less formal than parks and museums. In Mexico City, for example, people are most aware of their past because artifacts and ruins not only are everywhere, but they have been incorporated into subway stations, city parks, and other public facilities. The SHPO could encourage state and local governments to incorporate irrigation-related ruins into public life here in similar ways. Relatively inexpensively, for example, and perhaps with matching grants, local governments could erect signs to point out the locations of prehistoric canals, and the locations could also be sketched onto official city and state maps, bus schedules, convention brochures, and other promotional materials.

Attempts could be made to objectively determine in sociological, economic, or other terms, the type of person who visits archaeological museums, parks, or monuments, who gets involved in amateur societies, or who enrolls in college classes in anthropology and archaeology. Staff members and volunteers in national and state park systems could gather much information of these sorts, and museums could be encouraged to expand their efforts (Lipe 1974:217). Once gathered, this information could then be used to establish target audiences for mailings and other advertisements encouraging various irrigation-related activities, including promoting visitation at archaeology-theme parks, taking stewardship of archaeological sites, and participating in docent programs, literature searches, and (under qualified archaeologists' supervision) field research involving prehistoric irrigation features. The poll information could also be used in a cooperative program with the Arizona Commission of Agriculture and Horticulture to develop a media campaign (TV, radio, newspapers, bumper stickers) to increase public awareness of prehistoric irrigation. For example, the state of Texas recently took a "macho" phrase--*Don't Mess With Texas*--and twisted it so effectively into the public awareness of littering that highway littering was cut by as much as 80 percent; many non-Texans probably do not realize when they see the bumper sticker that this campaign was developed by the state highway department (William E. Doolittle, personal communication 1989). The Arizona SHPO could work with the State Commission of Agriculture and Horticulture (and agricultural businesses) to sponsor a mass-media (especially bumper-sticker) campaign using catchy slogans such as:

Arizona: Twelve Centuries of Irrigation
Arizona: Longest History of Irrigation in the U.S.
Arizona Canals: Our Second Millenium
Arizona Had 'Gators 1000 Years Ago (Irrigators, That Is!)

Producers of public television programs such as "Nova" and "Odyssey" could be encouraged by the SHPO to do a feature or even a series on prehistoric irrigation in the Americas; this would certainly put Arizona's irrigation features in the national public limelight.

Museums are important outlets for realizing the potential of irrigation-related archaeological sites. The SHPO could examine the possibilities of working with the National Park Service and the Bureau of Reclamation to open an exhibit hall at the Central Arizona Project Repository, which now curates material from several archaeological projects in which prehistoric irrigation features were investigated. Also, the SHPO could work together with national organizations such as the National Endowment for the Humanities to encourage museum facilities to display materials having to do with particular aspects of archaeology including prehistoric irrigation features.

Finally, although it would be costly, governments and civic groups could be encouraged to build viewing ramps over some of the larger examples of prehistoric canals in the Phoenix metropolitan area, and to build a display facility showing an archaeological cross-section of one or more canals, much like the glassed-in cross-section of the presidio excavation at Tubac State Park.

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AN OUTLINE OF SUGGESTED PRIORITIES FOR SHPO ACTION ON THE CONTEXT "PREHISTORIC IRRIGATION IN ARIZONA"

I. HIGHER GENERAL PRIORITY: PROTECT THE RESOURCES AND REMEDY DEFICIENCIES IN OUR KNOWLEDGE OF THEM

Goal A. Protect the resources.

Strategies:
1. Continue to enforce implementation of mitigation procedures where legally required.
2. Continue to promote in-place preservation wherever feasible, in the following sequence of priority:
   a. Encourage National Register nominations of irrigation-related historic properties
      (1) In RFPs for survey and planning grants
      (2) During other survey projects that will not result in immediate destruction of historic properties
      (3) By private land owners
   b. Encourage land exchanges to get State Trust properties that contain prehistoric National Register sites/districts into either Federal ownership (e.g., the Phoenix Resource Area BLM proposal for Los Robles, McClellan Wash, and Quiburi) or State Parks ownership [This option was not cited in draft report].
   c. Offer incentives (such as Survey and planning grants) for managing irrigation-related parks in a manner that best suits preservation of the cultural resources. Management should include:
      (1) Award matching grants to local entities to plan the development of local parks or preserves containing irrigation resources.
      (2) Develop step-by-step procedures for establishing and developing parks and preserves that contain prehistoric canal features. Priorities as follows:
         (a) Park management plan
         (b) Site Inventory survey
         (c) Design park to include areas for long-term preservation, for archaeological excavation, stabilization, and reconstruction, for public facilities, and for adjunct features.
      (3) At existing parks, develop displays depicting prehistoric irrigation features in the following sequence:
         (a) Park of the Canals (Mesa)
         (b) Park of Four Waters (Phoenix)
         (c) Gatlin site (Gila Bend)
         (d) Gila River Indian Community Cultural Center
         (e) Hohokam-Pima National Monument
   d. Encourage protective entities such as the Archaeological Conservancy to seek public and private grants for acquisition of archaeological districts, sites, and features. Should acquisition money become available to the SHPO, some of this money can be used for grants of this kind.
   e. Encourage private land owners to donate conservation easements of land containing irrigation resources.
   f. Look into possibility of creating "State Resource Preserves."

Goal B. Remedy deficiencies in knowledge of the resources.

Strategies (In Order of Priority):

1. Encourage archaeological research and contract firms/institutions/agencies to integrate methods designed specifically to identify irrigation-related features into their survey and excavation methods. E.g., ask them to look for indicators delineated by Midvale (1968) in their surveys.
2. Offer survey and planning grants (and any other incentives) for research into canal systems located outside the Salt and Gila valleys.
3. Work with contract sponsoring agencies to effect the following:
   a. Specify that archaeological surveys for each agency must specifically search for evidence of prehistoric irrigation.
   b. Encourage researchers to employ all known means to date prehistoric canal features that are under study, to determine the systems' operational characteristics, and to develop new methods of both dating and discovering the operational parameters.
   c. Stimulate interpretive studies of prehistoric irrigation systems: investigate community interaction, demographic change, agricultural intensification, and changing social and political organization and development.

II. SECONDARY PRIORITY: EDUCATE AND PUBLICIZE

Goal C. Promote the Resources to the Educational System.

Strategies (In Order of Priority):

1. Invite school groups to tour irrigation features during Arizona Archaeology Week.
2. Publish the historic context report in popular format.
3. Distribute and advertise availability of the historic context report statewide for general education and for implementing priorities below.
4. Through State Department of Education, distribute educational packets to the state's school systems to make Arizona education professionals more aware of prehistoric irrigation features in Arizona.
5. Contact school administrators directly and encourage them to establish or upgrade school archaeology programs (e.g., Tucson Unified School District's "Camp Cooper" program) and to include new material.
6. Contact national publishers to seek their input on how information on prehistoric irrigation resources could be used in school textbooks (especially in history, social studies, and American Indian studies).
7. Provide information on prehistoric irrigation to schoolbook publishers for inclusion in new books.

Goal D. Make Information More Accessible to the Public

Strategies: (In Order of Priority):

1. Set up public and special-group Archaeology Week tours of prehistoric canal sites
2. Distribute published historic context report to developers, construction contractors, large corporations that operate farms in Arizona, land managers, and others involved in land modification activities to heighten their awareness of public relations benefits of conducting archaeological data recovery programs.

3. Encourage developers, construction contractors, large corporations that operate farms in Arizona, land managers, and others involved in land modification activities to implement mitigation procedures where not legally required.
4. Offer matching grants or other incentives to develop educational materials for exhibition of information on prehistoric irrigation works and other ancient features in settings less formal than parks, preserves, and museums:
   - bus stations
   - city parks
   - other public facilities
5. Offer matching grants or other incentives to erect signs to show locations of prehistoric canals
6. Offer matching grants or other incentives to indicate canal locations in official city and state maps, bus schedules, convention brochures, other promotional materials.
7. Poll to objectively determine the type of person who visits archaeological museums, parks, or monuments, who gets involved in amateur societies, or who enrolls in college classes in anthropology and archaeology.
8. With Arizona Commission of Agriculture and Horticulture, develop cooperative media campaign (TV, radio, newspapers, bumper stickers) to increase public awareness of prehistoric irrigation.
9. Encourage producers of public television programs (e.g., "Nova" and "Odyssey") to do features or series on prehistoric irrigation in the Americas.
10. Prod USBR and NPS to open exhibit hall at the Central Arizona Project Repository.
11. Work together with NEH & other granting agencies to encourage museum display of materials having to do with particular aspects of archaeology including prehistoric irrigation features.
12. In cooperation with city governments, offer contracts to build viewing ramps over existing & larger examples of prehistoric canals in the Phoenix metropolitan area.

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METHODS OF DATING PREHISTORIC CANALS

There are several ways in which the age of a prehistoric canal system can be determined. A rough idea of the system's age can be based on the ages of archaeological habitation sites that are nearest it. Assuming that the occupation dates of some of the nearby sites are known, it may be assumed that the canal system was used when those sites were occupied. This method of dating is not foolproof because some archaeological sites near canal systems could have been abandoned long before the canals were built, or vice versa.

A slightly more accurate way of determining the age of a prehistoric canal system from associated surface information is to see whether artifacts of known ages occur in direct association with the canals of the system. This dating principle is based on knowledge from previous archaeological studies showing that certain artifact styles are characteristic of specific periods of time and that styles of certain kinds of artifacts changed through time. A modern example of this principle is American automobiles: it is easy to distinguish a car made during the 1920s from one made in the 1950s or the 1980s. From the styles of certain prehistoric artifacts present in an archaeological setting, approximate dates of human activity in that setting can be determined. In Arizona, certain kinds of pottery have been accurately attributed to certain periods and are the best kinds of artifacts available for determining the age of things found near them. Depending on the pottery types found near them, stylistic-artifact dating of canals may be accurate to within one or two centuries. In the layers of the earth that lie buried, such as the sediment layers within prehistoric canals, it can usually be assumed that the layers containing dated artifacts are no older than those artifacts.

Sometimes two or more layers of sediment are visible in a canal. The ages of these layers can be determined based on the principle of superposition: younger geologic layers generally lie above older ones. Combining this relative dating method with the more absolute artifact-style dating method, it is possible to date multiple canal-fill layers even if only one layer contains datable artifacts. For example if a layer of earth is found above an artifact deposited in A.D. 1220, then we know that this upper layer dates to A.D. 1220 and later; likewise, layers below this artifact would be assumed to date to 1220 or earlier.

There are also some fairly technical scientific analyses that can be done to date archaeological canals. Carbon-14, or radiocarbon analysis, is used to date organic (carbon-containing) materials such as charcoal, plant residues, and animal remains. This would seem a promising method of determining the ages of canals that contain organic materials. However, samples of wood charcoal or other datable carbon have generally not been collected from canal settings. Even when it is collected, it is not known how old the charcoal might have been before it got into the canal, so the relationship between its age and the use-date of the canal cannot always be accurately assessed. Recently, efforts have been made to carbon-date canal sediments that contain microscopic, organic residues in some abundance. These sediments have produced dates, but the dates as yet do not agree with dates obtained by using pottery associations, stratigraphy (study of layers), or other generally accepted methods (Waters et al. 1988). The other fairly technical method, archaeomagnetic dating, is based on the knowledge that the earth's magnetic field constantly shifts in intensity and direction and that when clay is heated beyond 200° Centigrade, the magnetic fields of iron particles within the clay take on the magnetic orientation of the earth's magnetic field. Prehistoric fire-pits and other structures that were plastered with clay and then burned therefore can indicate the orientation of the earth's magnetic field when the clay was last fired. Using maps of the past positions of the earth's magnetic field, the magnetic orientation in a burned clay sample can be used to determine the approximate date when the clay was last fired. Archaeomagnetic dating has been tried on unburned sediments deposited within ancient canals, with varying degrees of success.

HISTORIC PROPERTIES ELIGIBLE FOR NOMINATION TO THE NATIONAL REGISTER OF HISTORIC PLACES, AND LEGAL PROVISIONS CONCERNING THOSE PROPERTIES

National Register criteria for evaluation of historic properties read as follows:

> The quality of significance in American history, architecture, archeology, and culture is present in districts, sites, buildings, structures, and objects of State and local importance that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and
> (a) That are associated with events that have made a significant contribution to the broad patterns of our history; or
> (b) That are associated with the lives of persons significant in our past; or
> (c) That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
> (d) That have yielded, or may be likely to yield, information important in prehistory or history [36 CFR 60.4 & 800.10].

The significance of an archaeological site generally is determined with reference to Criterion (d), by assessing whether the site can contribute information relevant to particular anthropological research issues.

Any project having federal or state involvement (on federal or state land or involving federal or state money, permitting, or licensing) must be reviewed for its effects on cultural resources, which include prehistoric features such as canals. To determine whether an archaeological site or feature is significant, subsurface testing must be done in many instances. If it is decided that a project is likely to have an adverse effect on significant resources, mitigation measures--such as avoiding the resource or recovering data from it--must be developed (sometimes enough data can be obtained during a preliminary testing program to recommend clearance for the project to proceed). Maricopa and Pima counties now often require developers to survey for cultural resources prior to approval of zoning changes, and similar cooperative agreements are now being developed between the State Historic Preservation Office and other county and city governments.

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