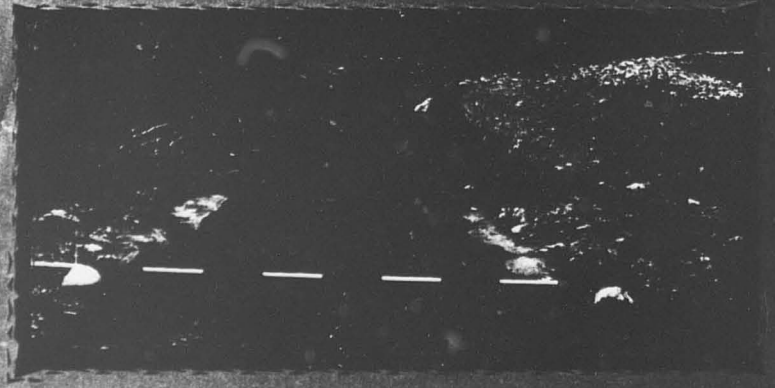
1998

Beaver Dam Wash Instream Flow Assessment

United States Bureau of Land Management

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

BEAVER DAM WASH
INSTREAM FLOW ASSESSMENT



MARCH 1998

BEAVER DAM WASH
INSTREAM FLOW ASSESSMENT

James L. Fogg
Hydrologist
National Applied Resource Sciences Center
Denver, CO

Daniel P. Muller
Supervisory Physical Scientist
National Applied Resource Sciences Center
Denver, CO

Paul L. Summers
Hydrogeologist
National Applied Resource Sciences Center
Denver, CO

Jeffrey R. Simms
Fishery Biologist
Arizona State Office
Phoenix, AZ

Stephanie J. Ellingham
Natural Resource Specialist
Arizona Strip Field Office
St. George, UT

James S. Renthal
Natural Resource Specialist
Arizona State Office
Phoenix, AZ

Phillip L. Dittberner
Botanist
National Applied Resource Sciences Center
Denver, CO

U.S. Department of the Interior
Bureau of Land Management

March 1998

BLM/RS/ST-98/002+7200

BLANK PAGE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BACKGROUND, PURPOSE, AND OBJECTIVES OF ASSESSMENT

This report documents findings from an instream flow assessment conducted by the U.S. Bureau of Land Management (BLM) on Beaver Dam Wash in Mohave County, Arizona. The assessment, which focused on resources located at the mouth of Beaver Dam Wash from 1991 through 1994, provides a scientific basis for relating flow-dependent resources to streamflow levels. Natural resource values, methods of data collection and analysis, and flow requirements are presented in this report.

Beaver Dam Wash originates in the Bull Valley mountains of southwestern Utah and flows west (through Nevada) and south (through Utah and Arizona) as it drains toward its confluence with the Virgin River (Figure 1). The stream flows through approximately 8.4 miles of northwestern Arizona, including about 1.25 miles of public land administered by BLM. Beaver Dam Wash is an interrupted stream, which means it has perennial, intermittent, and ephemeral reaches. Perennial flow occurs in southwestern Utah, southeastern Nevada, and above the confluence with the Virgin River near Beaver Dam, Arizona.

Public lands along Beaver Dam Wash are administered by BLM's Arizona Strip Field Office. Management direction for these lands was established in the Arizona Strip Resource Management Plan (ASRMP) (USDI-BLM 1992). The ASRMP established three special management designations that include Beaver Dam Wash: the Virgin River Corridor Area of Critical Environmental Concern (ACEC), the Virgin River Corridor Special Recreation Management Area (SRMA), and the Beaver Dam Confluence Riparian Demonstration Area. The mouth of Beaver Dam Wash also is located within the 1/4-mile corridor of the Virgin River, which has been recommended as eligible and suitable for designation as a recreational river area in the National Wild and Scenic Rivers System. Eighteen agencies, organizations, and individuals provided support for special management designations for Beaver Dam Wash and the Virgin River through comment on the draft ASRMP (USDI-BLM 1992). In addition, the ASRMP identified the need for an instream flow assessment to support water right applications and quantify resource needs.

On August 24, 1989, the Arizona Strip Field Office filed an instream flow water right application with the Arizona Department of Water Resources (ADWR) for a 1/4-mile segment of Beaver Dam Wash at its confluence with the Virgin River. Flows requested in the application ranged from 1 cubic foot per second (cfs) during the winter months to 2 cfs during the spring and summer months. Flows were requested in support of fisheries, wildlife, and recreational uses. Attachment B of the water right application (Appendix A) identified the

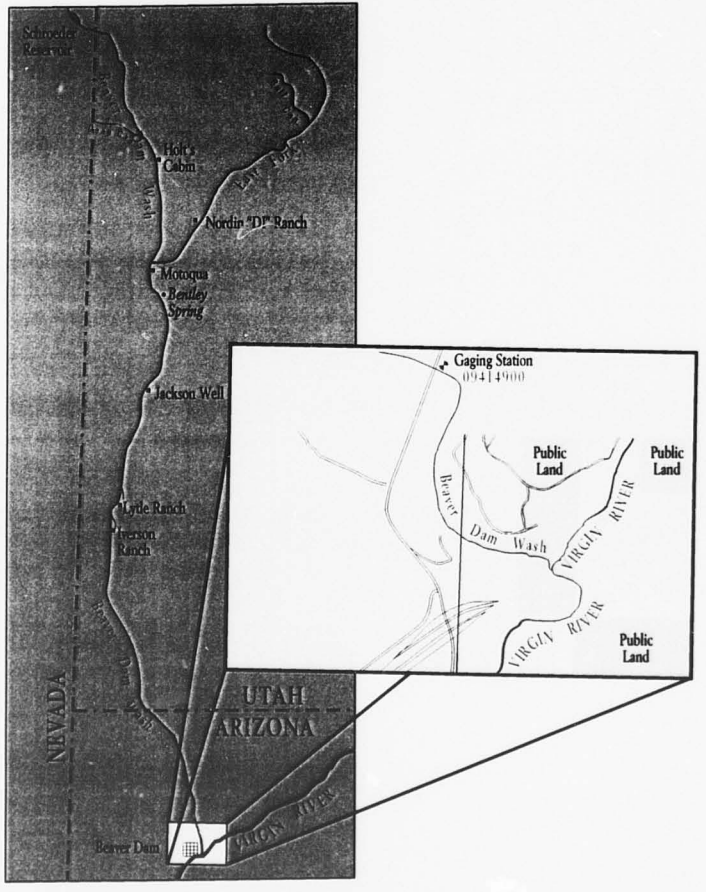


Figure 1. Map of Beaver Dam Wash/Virgin River area (1991).

preliminary nature of the amounts requested in the application, and indicated that amendments to the application might be filed if future studies provided more detailed and accurate information. This assessment provides the detailed information needed for complying with ADWR requirements.

In addition to obtaining an instream flow water right from ADWR, protection of identified resource values requires that BLM document the interrelationship between ground water in the recent alluvium of Beaver Dam Wash and surface streamflows through public land at the mouth of the Wash. Under Arizona water law, ground-water withdrawals are not regulated unless an "Active Management Area" (AMA) has been designated. To date, only five such AMA's have been designated in Arizona, all near the major drainages and urban areas in the southern part of the State. Unless an AMA is designated for Beaver Dam Wash (unlikely since such a designation was rejected by voters in 1991), ground-water withdrawals from Beaver Dam Wash alluvium will continue to threaten surface streamflows near the mouth of the Wash. However, under Arizona water law, ground water that is shown to be subflow to a surface stream is considered surface water for water rights purposes, and is managed in conjunction with granting of surface water rights. Thus, this assessment documents the relationships that exist between ground water in the youngest alluvium of Beaver Dam Wash and surface flow of the Wash as it crosses public land at its mouth.

The purpose of this assessment is to develop a clear understanding of water resource conditions required to support resource values and management objectives along Beaver Dam Wash, and to develop recommendations for protecting these resources. Specifically, this assessment will quantify instream flow needs in support of the water right claim to ADWR for the resource values described above. The specific objectives of the Beaver Dam Wash instream flow assessment are to:

- Understand the hydrology of Beaver Dam Wash, particularly the interaction of the surface- and ground-water systems.
- Develop relationships between streamflow and resource values, and evaluate flow requirements to maintain resource values.
- Determine the physical and legal availability of water for management purposes.
- Identify and evaluate flow protection strategies and related "protection realities" for management.

If feasible protection strategies cannot be identified, that information will be provided so that management objectives can be reevaluated.

Based on the original water right application, the resource assessment focused on the following specific values:

- Fisheries: The confluence of Beaver Dam Wash and the Virgin River is proposed as critical habitat for two endangered fish species: woundfin minnow and Virgin River roundtail chub. The occurrence of roundtail chub in Beaver Dam Wash has been documented in this assessment. Virgin River spinedace, which also inhabit Beaver Dam Wash, are precluded from listing as threatened as long as the tenets of a habitat conservation agreement are met.
- Recreation: The riparian area of Beaver Dam Wash on public lands near the Virgin River has been proposed as a cottonwood-wetland demonstration area and recreation site with interpretive trails for educational purposes. This segment is one of the few public access points for recreational floating, wading, bird watching, picnicking, and other greenbelt associated activities in an otherwise desert environment.
- Wildlife Habitat, Including Riparian Vegetation: Flows in Beaver Dam Wash support the best remaining riparian habitat in the lower Virgin River basin. The mature cottonwood-willow overstory and cattail-sedge understory riparian community provides important habitat for a variety of wildlife, including bats, leopard frogs, neotropical migratory birds, beavers, herons, and two State-candidate species: common black hawks and belted kingfishers. The nearest riparian habitats of equal quality are approximately 20 miles to the north on Beaver Dam Wash or 30 miles to the northeast on the Santa Clara River, both of which are located in Utah.

HYDROLOGIC SETTING

Hydrogeology

Geologic Setting

The study area is in the northern Mesquite Basin (Hintze 1986) and the Virgin River depression (Billingsly 1995). The basin is bounded on the east by the Beaver Dam Mountains, on the north by the Bull Valley Mountains in Utah, and on the south by the Virgin Mountains in Arizona (Figure 2). Structural lows are further refined and several faults are identified by gravity survey (Baer 1986). The depression is filled with sediments of the Muddy Creek Formation, which is a widespread deposit of lacustrine silts and clays and fluvial sands, silts, and clays having an average thickness of 2,900 feet (Billingsly 1995). Only the upper 200 feet are exposed in the study area; exposures are limited to the northern portion. West of Beaver Dam Wash, the formation is capped by a thin veneer of post-Tertiary gravel and eolian deposits. A layer of caliche caps the Muddy Creek Formation over a large area west of Beaver Dam Wash and has prevented erosion of the formation. East of Beaver Dam Wash, the formation is capped by a thicker sequence of post-Tertiary gravels than on the west side.

Widespread alluvial fans extend into the basin from mountain fronts, and have coalesced to form continuous deposits of alluvium. Alluvial fan deposits consist of unconsolidated to semiconsolidated interbedded sand, gravel, silt, and clay. Throughout most of the study area, the Muddy Creek Formation is overlain by terrace gravel and alluvial fan deposits of late Tertiary and Quaternary age. The channels of Beaver Dam Wash and its major tributaries are bounded on both sides by the Muddy Creek Formation or by the terrace gravels.

Streamflow in Beaver Dam Wash has incised into the Muddy Creek Formation for much of its length, forming a channel in which unconsolidated alluvial sand and gravel deposits have accumulated. The channel alluvium forms a distinct mappable unit of younger alluvium throughout the length of Beaver Dam Wash from near Motoqua, Utah, to the confluence of Beaver Dam Wash with the Virgin River in Arizona, a distance of about 36 miles. Figure 3 shows the mappable channel-fill on the Arizona side of the study area.

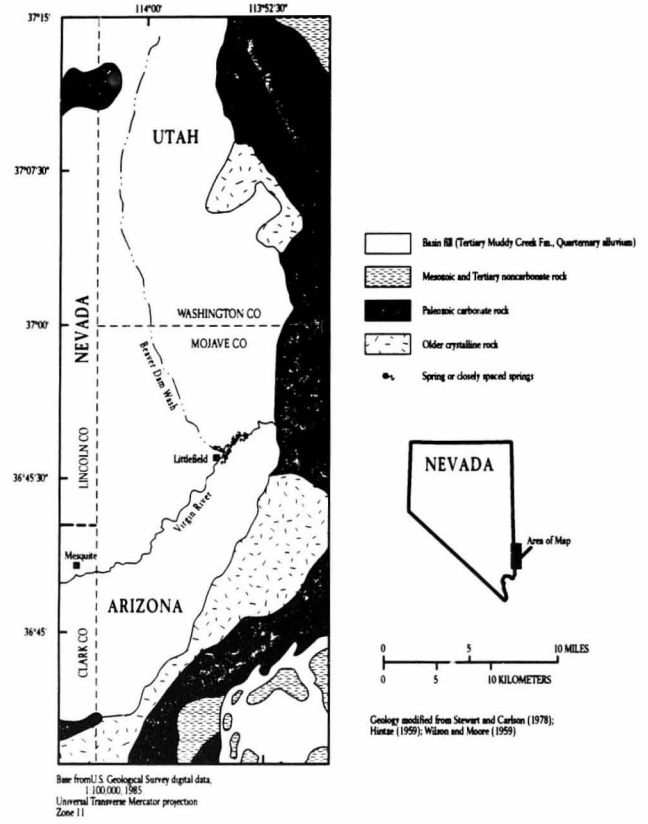


Figure 2. Location of Beaver Dam Wash and general geology of study area (after Holmes et al. 1997).

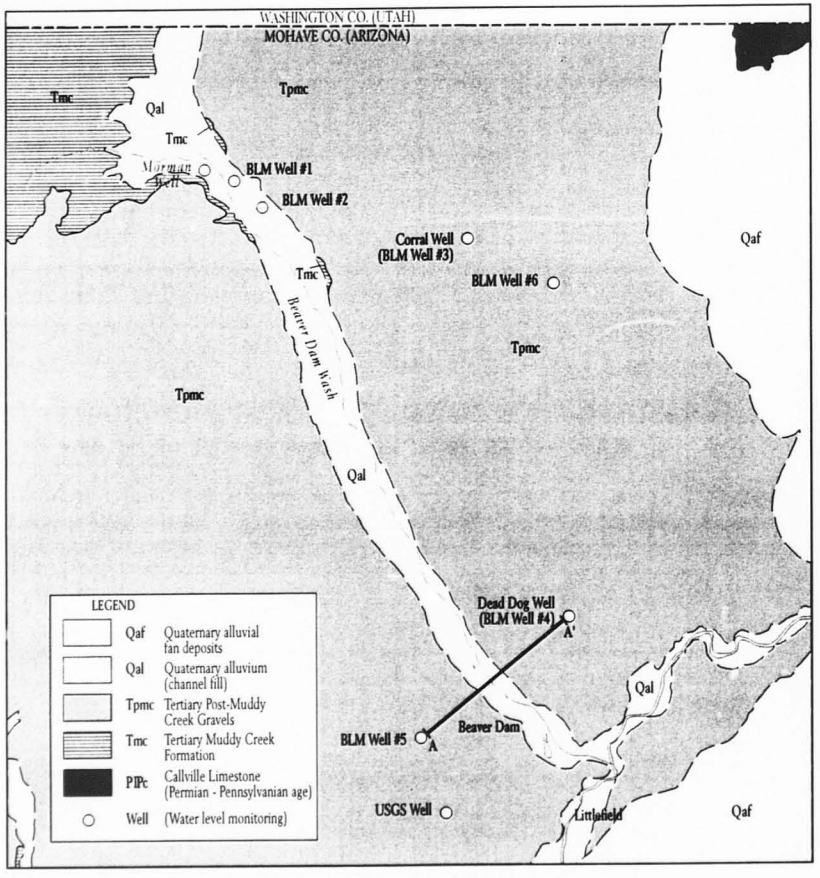


Figure 3. Geology of study area and location of observation holes (adapted from Moore 1972 and Holmes et al. 1997). A-A' is location of cross section in Figure 4.

Occurrence and Movement of Ground Water

Six observation wells were drilled in the study area by BLM during this study to determine ground-water levels, identify zones of permeability, and interpret ground-water flow patterns. Two wells were drilled in the channel fill to characterize ground-water flow in the channel, next to the flowing stream. Four wells were drilled into the Muddy Creek Formation on the terraces east and west of Beaver Dam Wash (three holes on the east side and one hole on the west side of the Wash). A summary of the wells is shown in Table 1.

Table 1. Summary of observation holes drilled by BLM during this study.

Name of Well	Legal Description	Depth of Well (feet)	Surface Elevation (feet)	Geologic Source[1]	Depth to Water Level [feet (date)]	Water Level Elevation (feet)	Producing Interval (feet below surface)	Comments
Beaver Dam Wash (Well #1)	T. 41 N., R. 16 W., sec. 1, NESWSW	76	2,110	Qal (channel fill)	21 (11-3-92)	2,089	21-76	Drilling terminated early due to caving and very high waterflow. Est. 230 gpm with air lift.
Beaver Dam Wash (Well #2)	T. 41 N., R. 16 W., sec. 1, SESESW	40	2,105	Qal (channel fill)	See comments	—	—	Drilling terminated at 40 ft. due to caving. No water level measured, but water probably at depth of caving.
Dead Dog (Well #3)	T. 41 N., R. 15 W., sec. 28, SENWNE	360	2,075	Tpmc, Tmc	203.4 (2-4-93)	1,871.76	300-360	Aquifer is series of thin sand/gravel layers. Yield estimated at 30 gpm with air lift.
Corral (Well #4)	T. 41 N., R. 15 W., sec. 8, NESENE	600	2,285	Tmc	381.25 (2-9-94)	1,903.75	460-480 (possible other aquifers at 500-520 and 540-550)	Mud used at 470 due to caving. Continued drilling to 600 ft. Aquifers below 470 are based on cuttings.
West Side (Well #5)	T. 41 N., R. 15 W., sec. 31, SENWNW	400	2,155	Tpmc, Tmc	Dry	—	—	Dry. No thick gravel layers encountered from 50 ft. down.
Well #6	T. 41 N., R. 15 W., sec. 9, SENESE	380	2,180	Tpmc	See comments	—	—	Drilling terminated at 380 due to caving. Water likely at 375-380.

[1] Qal = Quaternary alluvium; Tpmc = Tertiary post Muddy Creek gravels; Tmc = Tertiary Muddy Creek Formation.

Ground water occurs in four hydrostratigraphic units within the study area: 1) alluvial fans along the mountain fronts, 2) thin sand and gravel layers in the upper Muddy Creek Formation, 3) sand and gravel in the alluvium overlying the Muddy Creek Formation (i.e., post-Muddy Creek Tertiary gravels), and 4) Quaternary channel alluvium of Beaver Dam Wash (described as channel fill in this report). Of these deposits, the channel fill is the primary aquifer in the study area, accounting for almost 100 percent of the water withdrawn from wells in the study area (Holmes et al. 1997). Minor quantities of ground water occur in thin zones within the Muddy Creek Formation and in the post-Muddy Creek Tertiary gravels (Figure 4). Ground water in alluvial fans is limited to the area near the mountain front, and is primarily a source of recharge to the post-Muddy Creek Tertiary gravels and the Muddy Creek Formation. The unit is not considered a good source of water supply, and no water supply wells have been drilled into the unit.

Post-Muddy Creek Tertiary Gravels

Ground water in the post-Muddy Creek gravels occurs in sand and gravel deposits near the contact with the underlying Muddy Creek Formation at depths of less than 500 feet. However, due to the gradational contact between the two units, identification of the exact contact is sometimes difficult. The amount of water available to wells from this unit is believed to be small, and ground water may be limited to localized areas in the unit. A well drilled by the U.S. Geological Survey (USGS) about 1.5 miles north of the Arizona-Utah State line and about 3.5 miles east of Beaver Dam Wash did not penetrate any saturated zone in this unit (Holmes et al. 1997).

Muddy Creek Formation

The Muddy Creek Formation underlies gravel, sand, and silt deposits of Tertiary and Quaternary age on the terraces east and west of Beaver Dam Wash, and also underlies the channel-fill alluvium in Beaver Dam Wash. On the east side of Beaver Dam Wash, the top of the Muddy Creek Formation is interpreted to occur at a depth of about 200 feet below ground surface, underlying a sequence of mostly sand and gravel. On the west side of Beaver Dam Wash, the Muddy Creek Formation is interpreted to occur only about 50 feet below the surface, underlying thin terrace gravels, Eolian sand, and a caliche layer. The Muddy Creek Formation consists preponderantly of fine-grained silt, silty clay, and clay deposits; thus, it is generally of low hydraulic conductivity, and ground water occurs only in thin sand and gravel layers that may be localized due to facies changes in the formation.

Saturated layers in the Muddy Creek Formation are believed to occur below the Beaver Dam Wash channel fill, and there is likely no discharge of ground water from the Muddy Creek Formation into the channel alluvium except near the confluence of Beaver Dam Wash and the Virgin River. Some ground-water movement into the Muddy Creek Formation is believed to

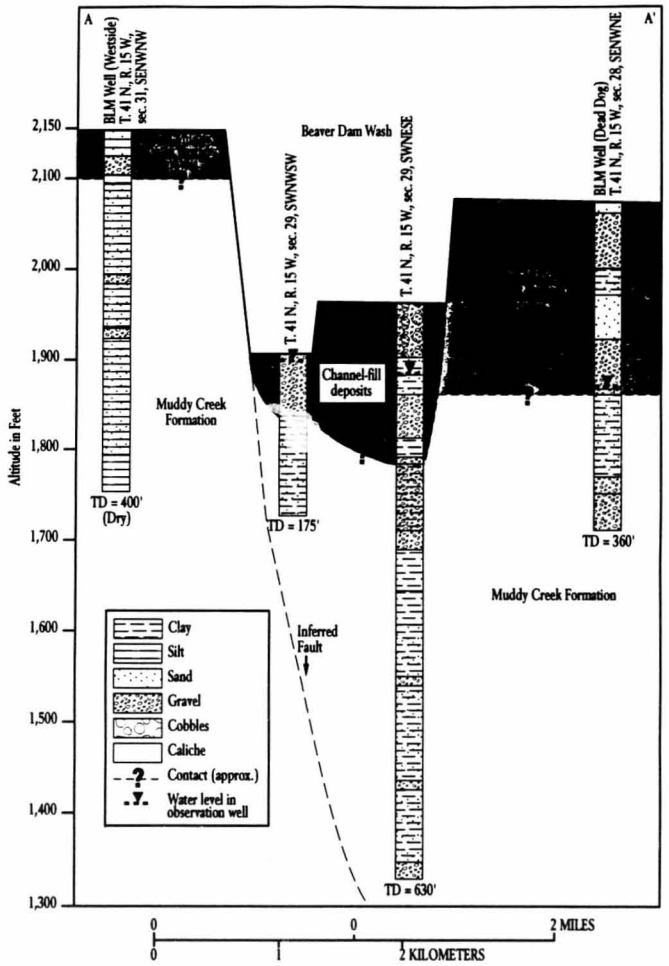


Figure 4. Cross section of Beaver Dam Wash, showing general relationship of geologic units in the Beaver Dam Wash area (location of cross section shown as A-A' in Figure 3); water levels are as of 2/8-9/94 (modified from Holmes et al. 1997).

occur as leakage from the channel fill. About 1 mile above the confluence with the Virgin River, saturated layers of the Muddy Creek Formation are in contact with the channel alluvium, and ground-water inflow from the Muddy Creek Formation discharges into the channel alluvium (Holmes et al. 1997).

Observation wells drilled for this study into the Muddy Creek Formation on the east side of Beaver Dam Wash indicate that ground water occurs under confined conditions in the uppermost portion of the formation or in the overlying post-Muddy Creek Tertiary gravels, at or near the contact with the Muddy Creek Formation. The exact depths of saturated intervals and flow patterns within the Muddy Creek Formation and the overlying gravels are not well-established due to a lack of sufficient drill holes in the formation. However, data from this study suggests that ground water in the Muddy Creek Formation has a flow path to the southwest at a depth below the level of the channel-fill aquifer.

Ground water in the Muddy Creek Formation was encountered under confined conditions at depths ranging from about 360 feet to about 500 feet in observation holes drilled east of Beaver Dam Wash. On the west side of the Wash, a 400-foot test well drilled by the BLM into the Muddy Creek Formation was dry, while a 599-foot observation well drilled by the USGS about 1-1/2 miles south (T. 41 N., R. 15 W., sec. 6 SESESW) encountered three confined aquifers at depths of 468-488, 508-518, and 588-598 feet. A comparison of aquifer depths in the USGS well on the west side of the Wash and the BLM well on the east side of the Wash (Dead Dog well) suggests that a fault may exist along Beaver Dam Wash that displaced Muddy Creek strata downward on the east side of the fault. The most likely fault placement is along the west side of the Wash, with downdropped Muddy Creek strata on the east side of the fault, along an arcuate fault plane as described by Baer (1986).

Channel Alluvium

Beaver Dam Wash is filled with sand and gravel deposits of alluvial origin derived from erosion of the Bull Valley Mountains to the north and the Beaver Dam Mountains to the east. These sand and gravel deposits comprise the Beaver Dam Wash channel-fill aquifer. Ground water occurs in the channel fill along the entire length of the Wash from near Motoqua, Utah, to the confluence with the Virgin River in Arizona. Ground water in the channel-fill alluvium flows to the southeast, in the same direction as surface flow in the channel. The channel-fill alluvium forms a separate aquifer that is generally less consolidated, and is estimated to have a higher hydraulic conductivity than gravel layers in either the Muddy Creek Formation or the post-Muddy Creek Tertiary gravels deposited on either side of Beaver Dam Wash.

Estimates of the average thickness of alluvial deposits comprising the channel-fill aquifer range from 62 feet (Leslie and Associates 1990) to about 100 feet (Holmes et al. 1997). However, logs of several wells drilled in the Wash suggest that, at least in places,

ground water within the channel alluvium occurs in two aquifers separated by several feet of clayey sediments (Leslie and Associates 1990). The upper aquifer is unconfined and the lower aquifer has slight confining conditions, but the hydraulic head of the lower confined aquifer is lower than the head in the unconfined aquifer. Logs of shallow wells drilled in the channel alluvium show perforated intervals generally ranging from about 20 to 70 feet deep, with some intervals beginning as shallow as 10 feet deep (Enright 1996).

Recharge to the channel-fill aquifer occurs from at least four sources: 1) infiltration of surface flow in the main channel of Beaver Dam Wash, 2) intermittent surface flow in drainages tributary to Beaver Dam Wash, 3) lateral inflow from post-Muddy Creek gravels, and 4) inflow from sand and gravel deposits in the upper part of the Muddy Creek Formation. Average annual recharge from stream infiltration (sources 1 and 2) has been estimated at about 15,600 acre-feet per year (about 21.5 cfs), and average annual inflow from the upper Muddy Creek and its overlying units (sources 3 and 4) has been placed at about 1,900 acre-feet per year (about 2.6 cfs) (Holmes et al. 1997). In the case of inflow from other formations (sources 3 and 4), almost all of the recharge to the channel alluvium is believed to occur in the last mile of Beaver Dam Wash (near the confluence) where Beaver Dam Wash is incised to at or near the level of the Muddy Creek Formation.

Discharge from the channel-fill aquifer also occurs through several pathways. Approximately 9,000 acre-feet per year (about 12.4 cfs) is believed to be subsurface discharge, with roughly half going to the Muddy Creek Formation and its overlying sediments, and the other half going to the alluvium of the Virgin River. Another 4,000 acre-feet (about 5.5 cfs) of channel-fill ground water is consumed each year through evapotranspiration and well withdrawals. And approximately 4,300 acre-feet per year (nearly 6 cfs) discharges to streamflow in the last few miles of Beaver Dam Wash above the confluence with the Virgin River.

Surface-Water/Ground-Water Interaction

Streamflow in Beaver Dam Wash occurs in perennial and intermittent reaches. In places, ground water in the channel-fill alluvium emerges to the surface, creating perennial reaches. In other places, subsurface water generally varies from a few inches to a few feet below the stream channel, depending on the quantity of flow in the stream. Intermittent streamflow is characterized by the existence of subflow beneath the intermittent reach.

Subsurface flow in the channel-fill alluvium provides water for streamflow along certain reaches. This is due to thinning of the alluvium, narrowing of the alluvium, or scour during high-intensity runoff events that incise the channel until it intersects the underlying subflow, creating a perennial reach. This occurred in the reach below the Arizona-Utah State line, where flood events in 1993 incised the channel down to the water table. As of October 1997, the reach remained perennial.

The most notable exception to relatively shallow ground water in the channel alluvium is in the reach from just below Snow Spring Wash in Utah (about 14.8 miles above the confluence of the Virgin River) to the Utah-Arizona State line (about 10.5 miles above the confluence of the Virgin River). In this reach, the alluvium is extraordinarily thick, and subsurface water is 84 feet below the stream as measured in 1958. A more recent water level on this well is not available. However, a short distance downstream, just south of the Utah-Arizona State line, the water level in the channel alluvium rises to within 25 feet of ground surface due to geologic control. During periods of high streamflow, ground water rises to within at least 3.5 feet of the surface, and likely is in direct hydraulic connection with the surface flow (Figure 5). This occurred during higher than average streamflows in 1993. Holmes et al. (1997) report that in the lowest 6 miles of Beaver Dam Wash, water levels in several wells along the bed of the Wash are near or at the level of the channel in the Wash. Hydraulic connection probably exists during times of high streamflow throughout the entire lower reach of Beaver Dam Wash.

Because of the free interaction between ground water in the alluvial channel fill and surface flow in Beaver Dam Wash,

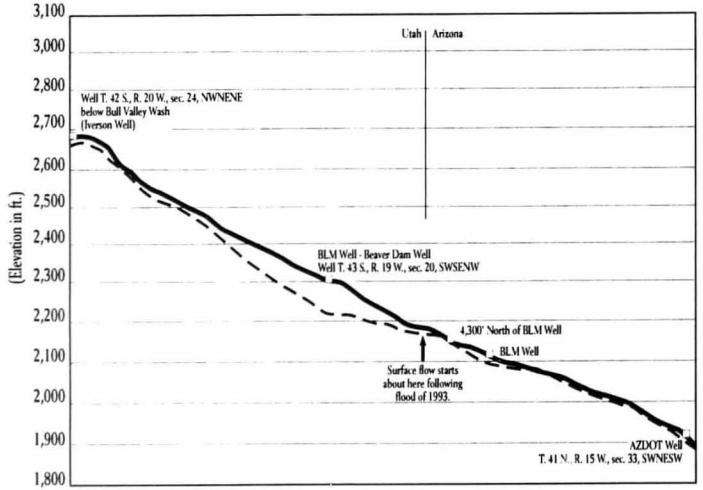


Figure 5. Longitudinal profile of Beaver Dam Wash showing gradient of ground water in channel-fill aquifer (horizontal distance not to scale).

water level changes in the channel fill are directly related to streamflow in the Wash (Holmes et al. 1997). Whereas the confined aquifers in the upper Muddy Creek Formation and overlying Tertiary gravels east of Beaver Dam Wash exhibit little, if any, variation in static water level (as measured at BLM test wells in the first year subsequent to drilling and in October 1997), water levels in the Beaver Dam Wash channel alluvium have shown pronounced changes during the same period, with rising water levels corresponding to times of increased streamflow (Holmes et al. 1997). For example, a well near the USGS streamgage at the Highway 91 bridge (T. 41 S., R. 15 W., sec. 33, NWNESW) shows increased water levels that generally correspond to a hydrograph of annual mean discharge at the USGS gaging station at Littlefield (Holmes et al. 1997). A substantial rise in water level was observed in this well during 1993 to 1994 when very high floodflows were recorded (Figure 6) (Enright 1996).

There are at least five other wells in the channel alluvium that show a similar rise in water levels during the same time period, all reflecting an increase in water level due to increased infiltration from high streamflow (Enright 1996).

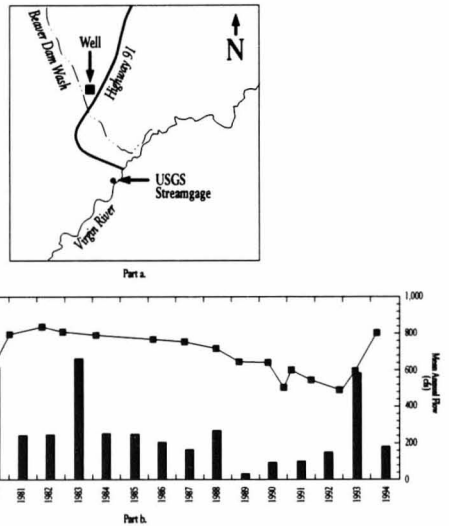


Figure 6. Relationship of water level fluctuations and streamflow near the confluence of Beaver Dam Wash and the Virgin River. Streamflow is measured at the gage on the Virgin River near the confluence. Water level measurements are at a well about the 3/4-mile up from the confluence (T. 41 S., R. 15 W., sec. 33, SWNESW).

These wells are distributed from near the Arizona-Utah border to about 1 mile above the Highway 91 bridge. Thus, the channel alluvium responds as a definable unconfined aquifer, with a changing level of saturation depending on the amount of available infiltration from streamflow. The leakage of streamflow into the channel fill during periods of high runoff likely produces mounding of ground water beneath the stream channel, and as the ground-water level continues to rise, creates a continuously saturated zone between the surface flow and subflow (Figure 7). During periods of high streamflow, the subflow likely rises to the level of the channel bed, and at times is higher than the bottom of the channel, contributing ground-water flow into the stream channel.

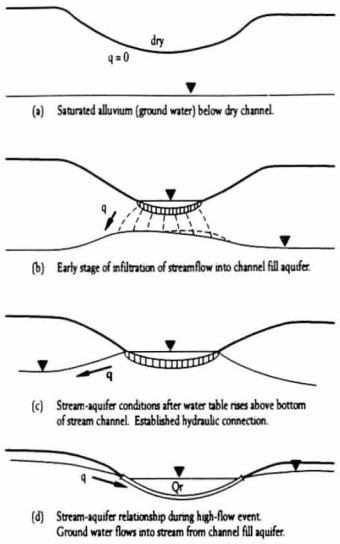


Figure 7. Stream-aquifer interface during high-flow conditions in Beaver Dam Wash.

The direction of subsurface flow in the alluvial fill is linked to surface water in the Wash. Water in the channel-fill alluvium generally flows southward, following the surface drainage toward the Virgin River. Subsurface flow and surface flow move under almost identical gradients toward the confluence with the Virgin River. The gradient of the two components of flow is very similar, whether measured over a long segment (e.g., from several miles above the State line to the confluence) or over a relatively short distance (e.g., the Arizona segment only) (Figure 8). The measured hydraulic gradient of subsurface flow in the channel fill from the Iverson well (about 9 miles above the Arizona-Utah line) to the Arizona Department of Transportation well (T. 41 N., R. 15 W., sec. 33, SWNESW) near the confluence is .0096. The gradient in the surface flow is .0091. Similarly, the surface-flow gradient near the State line flattens out slightly to .007, and the subflow gradient also flattens out slightly to .008.

Water Quality

Chemical quality of ground water in the channel alluvium and surface flow is consistently similar over the entire distance of Beaver Dam Wash, from high on the Utah side near Motoqua to near the confluence with the Virgin River. Water in the channel alluvium and the stream is of a calcium-bicar-

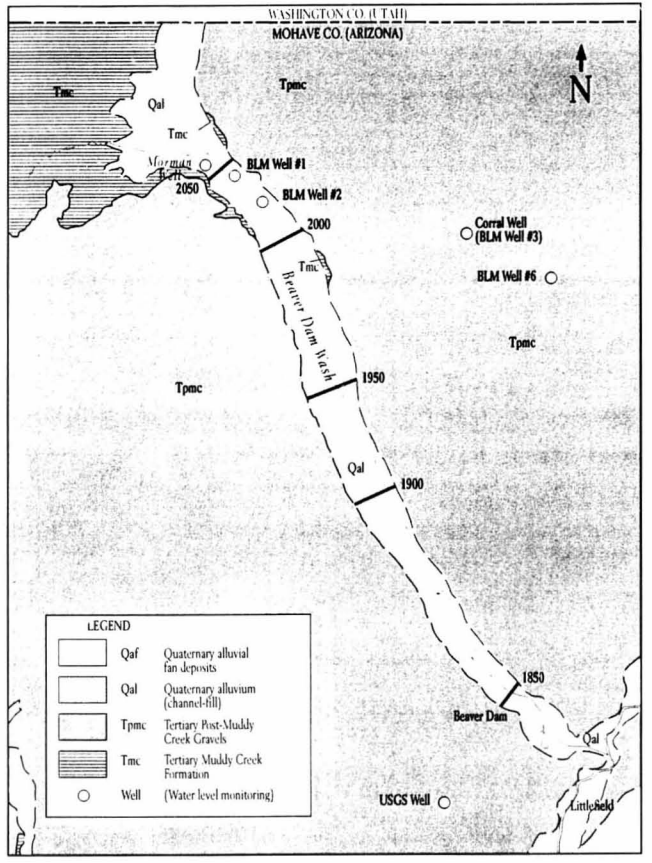


Figure 8. Geology of study area and water level elevations in channel-fill aquifer. Water level contours as of February 1991 in feet above mean sea level (after Black and Rascona 1991).

bonate type low in total dissolved solids (TDS) (less than 500 mg/L). Near the confluence, surface water and subsurface flow mix with water from the Muddy Creek Formation and overlying Tertiary gravels; i.e., water that in this area is influenced by local recharge of the Virgin River into these formations (Holmes et al. 1997). The Muddy Creek and overlying Tertiary gravels thus discharge a calcium-magnesium-sulfate-type water derived from the Virgin River near the confluence, which accounts for a higher concentration of dissolved solids in the subflow near the confluence (Enright 1996).

Streamflow

The streamflow that sustains resource values near the mouth of Beaver Dam Wash derives from two very different processes. The majority of the time, streamflow is sustained by discharge of ground water from the channel alluvium of the Wash. This streamflow is remarkably consistent in quantity and quality, varying little throughout the year. Superimposed on this groundwater discharge are infrequent runoff events that increase streamflow and sediment transport, occasionally in dramatic fashion. Duration of surface runoff is primarily influenced by type of precipitation event associated with the runoff. Summer thunderstorms provide high-intensity, short-duration rainfall that generates significant amounts of surface runoff; however, the short duration of these storms generally results in runoff lasting only a few hours. In contrast, winter frontal storms may produce moderate-intensity, long-duration rainfall that generates significant runoff lasting for several days. Flood events associated with these longer storms generally have pronounced effects on channel morphology.

Streamflow data for Beaver Dam Wash in Arizona is limited to about 1.5 years of systematic record from the USGS gaging station at the old Highway 91 bridge at Beaver Dam. The only complete year of record is water year 1994 (Table 2). Gage data has been supplemented with approximately 65 miscellaneous measurements of discharge at the mouth since 1990.

Data from the gage are not suitable as direct estimates of streamflow at the mouth because of substantial gains from ground water in the mile of stream between the gage and the confluence. However, gage data may be used to estimate monthly and annual means at the mouth using a procedure described by Riggs (1969). The procedure entails using an instantaneous discharge measurement at an ungaged point (at the mouth) near the middle of the month and the systematic record of a nearby gage (at Beaver Dam). The ratio of measured discharge at the ungaged site to daily mean flow at the gage is applied to the monthly mean flow at the gage to estimate monthly mean flow at the ungaged site. Using

Table 2. Streamflow in Beaver Dam Wash (in cubic feet per second) at Beaver Dam, Arizona — water year 1994.

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	3.1	2.4	2.5	3.7	2.8	2.3	2.9	2.2	2.6	2.6	2.0	2.0
2	2.8	2.8	2.3	3.4	2.7	2.4	2.9	2.2	2.6	2.5	1.8	2.0
3	3.0	3.0	2.2	3.5	2.7	2.7	2.9	2.2	2.8	2.5	1.7	2.0
4	2.5	2.9	2.4	3.6	2.9	2.7	3.1	2.3	2.5	2.4	1.7	2.1
5	2.3	2.7	2.2	3.0	2.9	2.5	3.1	2.5	1.9	2.3	1.7	2.1
6	2.2	2.8	2.1	2.9	3.1	2.9	3.2	2.6	1.9	2.2	1.7	2.2
7	3.4	2.7	2.3	3.6	3.3	3.2	3.3	2.7	2.1	2.3	1.8	1.9
8	3.0	2.7	2.4	3.2	3.3	3.0	3.5	2.6	2.1	2.4	1.9	1.9
9	2.8	2.8	2.6	3.3	3.5	2.5	3.2	2.5	1.9	2.3	2.0	1.9
10	2.8	2.8	2.4	3.2	2.7	2.1	3.2	2.5	1.4	2.2	1.9	2.0
11	2.9	3.1	2.7	2.6	2.7	1.7	3.2	2.5	1.8	2.3	2.0	2.1
12	3.0	2.8	2.7	2.5	2.7	2.0	3.2	2.6	1.9	2.4	1.9	2.2
13	3.0	2.7	2.5	2.5	2.8	2.2	3.3	2.7	1.7	2.4	1.9	2.2
14	2.6	2.7	2.8	2.7	2.9	2.2	3.3	2.7	1.5	2.3	1.9	2.3
15	2.7	2.5	3.0	2.8	2.9	2.4	3.2	2.5	1.7	2.4	1.9	2.1
16	3.0	2.5	2.7	2.8	3.0	2.3	3.0	2.4	1.6	2.3	1.8	2.0
17	3.2	2.6	2.9	2.8	3.3	2.3	3.0	2.5	1.7	2.3	1.8	2.1
18	3.2	2.7	2.9	2.9	11	2.6	3.0	2.5	1.9	2.5	1.9	2.1
19	3.1	2.7	3.0	2.8	3.2	2.7	2.8	2.4	2.2	2.5	2.5	1.9
20	3.0	2.8	3.1	2.8	2.9	2.8	2.1	2.1	2.1	2.4	2.4	2.1
21	3.0	2.8	3.4	2.8	2.8	2.7	2.3	2.4	2.2	2.2	2.3	2.1
22	2.9	2.8	3.5	2.8	2.7	2.8	2.1	2.4	2.0	2.1	2.2	2.1
23	3.0	2.8	3.5	2.8	2.2	2.8	2.1	2.7	1.8	2.2	2.3	2.3
24	3.0	2.9	3.7	2.7	2.1	3.1	2.1	2.6	1.8	2.1	2.2	2.2
25	3.0	2.8	4.0	2.4	2.1	3.2	2.2	2.0	2.0	1.9	2.3	2.2
26	2.9	2.9	3.7	2.4	2.1	2.6	2.2	2.3	2.0	2.0	2.2	2.3
27	2.9	2.9	3.7	2.7	2.1	2.6	2.3	2.4	2.2	1.9	2.3	2.2
28	3.1	2.8	3.7	2.7	2.4	2.7	2.3	2.4	2.4	1.9	2.2	2.2
29	2.8	2.5	3.7	2.8	---	2.7	2.4	2.6	2.4	1.9	2.3	2.4
30	2.6	2.7	3.8	2.8	---	2.8	2.3	2.7	2.5	1.9	2.1	2.5
31	2.4	---	3.7	2.8	---	2.8	---	2.4	---	2.0	2.0	---
Total	89.2	82.6	92.1	90.3	85.8	80.3	83.7	76.1	61.2	69.6	62.6	63.7
Mean	2.9	2.8	3.0	2.9	3.1	2.6	2.8	2.5	2.0	2.3	2.0	2.1
Max	3.4	3.1	4.0	3.7	11	3.2	3.5	2.7	2.8	2.6	2.5	2.5
Min	2.2	2.4	2.1	2.4	2.1	1.7	2.1	2.0	1.4	1.9	1.7	1.9
Ac-Ft	177	164	183	179	170	159	166	151	121	138	124	126

the 1994 water-year record and miscellaneous measurements at the mouth, estimates of monthly means and an annual mean flow for Beaver Dam Wash at the mouth are presented in Table 3.

Comparison of Table 3 with Table 2 reveals that estimated mean flows at the mouth are much greater than measured mean flows at the Beaver Dam gage. This is caused by substantial ground-water discharge between these two points on the stream. Paired measurements of streamflow at the gage and the mouth allow quantification of gains in flow between these two points (Table 4). (Some gage discharges are from actual flow measurements, while the remainder are daily means from the gage record.) Average flow increase between the gage and the mouth is about 5.9 cfs, with a standard deviation of 1.2 cfs. Thus, ground-water contributions to streamflow between the gage and the confluence are expected to range from about 4.7 to 7.1 cfs approximately 68 percent of the time, and from about 3.5 to 8.3 cfs approximately 95 percent of the time. The estimated average gain in streamflow of 5.9 cfs between the gage and the mouth agrees well with reported estimates of ground-water discharge (6.1 cfs) in this reach for the 1990-94 period (Holmes et al. 1997).

Daily values of streamflow for Beaver Dam Wash at the mouth are estimated for the 1994 water year (Table 5) using

Table 3. Estimated mean flows (in cubic feet per second) at the mouth of Beaver Dam Wash — water year 1994 (after Riggs 1969).

Date	Measured Flow at Mouth	Mean Daily Flow at Gage	Mean Monthly Flow at Gage	Mean Monthly Flow at Mouth
10/15/93	9.1	2.7	2.9	9.7
11/22/93	10.5	2.8	2.8	10.3
12/16/93	8.8	2.7	3.0	9.6
01/18/94	10.6	2.9	2.9	10.6
02/15/94	10.8	2.9	3.1	11.4
03/21/94	10.6	2.7	2.6	10.2
04/19/94	8.0	2.8	2.8	8.0
05/13/94	8.3	2.7	2.7	8.2
06/17/94	8.7	1.7	2.0	10.5
07/15/94	7.2	2.4	2.3	6.7
08/09/94	8.5	2.0	2.0	8.6
09/16/94	6.6	2.0	2.1	7.0
			Annual Mean =	9.2

Table 4. Streamflow gains between gage and mouth (in cubic feet per second).

Date	Flow at Mouth	Flow at Gage	Gain
04/20/93	9.1	3.5	5.6
04/28/93	9.4[1]	2.9[2]	6.5
05/17/93	8.6	3.2	5.4
06/01/93	7.7[1]	2.0[2]	5.7
06/21/93	6.8	2.6	4.2
07/15/93	8.4	2.0	6.4
08/02/93	6.4[1]	1.8[2]	4.6
08/19/93	8.1	2.2	5.9
09/14/93	7.4	0.9	6.4
10/15/93	9.1	2.7	6.4
11/22/93	10.5	2.8	7.7
12/16/93	8.8	2.7	6.0
01/05/94	8.9[1]	3.2[2]	5.8
01/18/94	10.6	2.9	7.7
02/15/94	10.8	2.9	7.9
02/22/94	10.5[1]	3.0[2]	7.5
03/21/94	10.6	2.7	7.9
04/19/94	8.6	3.0[2]	5.0
	7.4[1]		
05/13/94	8.3	2.7	5.6
05/19/94	7.5[1]	2.8[2]	4.8
06/13/94	8.7	1.7	7.0
06/28/94	7.3[1]	2.8	4.5
07/15/94	7.2	2.4	4.8
08/09/94	8.5[1]	2.2	6.3
08/24/94	6.2	2.2	4.0
09/16/94	6.6	2.0	4.6
		mean ΔQ=5.93 ~ 5.9 std dev ΔQ=1.18 ~ 1.2	

[1] Measured by U.S. Geological Survey.
[2] Measured streamflow.

Table 5. Estimated daily flow (in cubic feet per second) at the mouth of Beaver Dam Wash — water year 1994. *From average measured monthly gains between USGS station and mouth** (ADWR 1997).

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	*6.4	*7.7	*6.0	*6.7	*7.7	*7.9	*5.0	*5.2	*5.7	*4.8	*5.1	*4.6
1	9.5	10.1	8.5	10.4	10.5	10.2	7.9	7.4	8.3	7.4	7.1	6.6
2	9.2	10.5	8.3	10.1	10.4	10.3	7.9	7.4	8.3	7.3	6.9	6.6
3	9.4	10.7	8.2	10.2	10.4	10.6	7.9	7.4	8.5	7.3	6.8	6.6
4	8.9	10.6	8.4	10.3	10.6	10.6	8.1	7.5	8.2	7.2	6.8	6.7
5	8.7	10.4	8.2	9.7	10.6	10.4	8.1	7.7	7.6	7.1	6.8	6.7
6	8.6	10.5	8.1	9.6	10.8	10.8	8.2	7.8	7.6	7.0	6.8	6.8
7	9.8	10.4	8.3	10.3	11.0	11.1	8.3	7.9	7.8	7.1	6.9	6.5
8	9.4	10.4	8.4	9.9	11.0	10.9	8.5	7.8	7.8	7.2	7.0	6.5
9	9.2	10.5	8.6	10.0	11.2	10.4	8.2	7.7	7.6	7.1	7.1	6.5
10	9.2	10.5	8.4	9.9	10.4	10.0	8.2	7.7	7.1	7.0	7.0	6.6
11	9.3	10.8	8.7	9.3	10.4	9.6	8.2	7.7	7.5	7.1	7.1	6.7
12	9.4	10.5	8.7	9.2	10.4	9.9	8.2	7.8	7.6	7.2	7.0	6.8
13	9.4	10.4	8.5	9.2	10.5	10.1	8.3	7.9	7.4	7.2	7.0	6.8
14	9.0	10.4	8.8	9.4	10.6	10.1	8.3	7.9	7.2	7.1	7.0	6.9
15	9.1	10.2	9.0	9.5	10.6	10.3	8.2	7.7	7.4	7.2	7.0	6.7
16	9.4	10.2	8.7	9.5	10.7	10.2	8.0	7.6	7.3	7.1	6.9	6.6
17	9.6	10.3	8.9	9.5	11.0	10.2	8.0	7.7	7.4	7.1	6.9	6.7
18	9.6	10.4	8.9	9.6	18.7	10.5	8.0	7.7	7.6	7.3	7.0	6.7
19	9.5	10.4	9.0	9.5	10.9	10.6	7.8	7.6	7.9	7.3	7.6	6.5
20	9.4	10.5	9.1	9.5	10.6	10.7	7.1	7.3	7.8	7.2	7.5	6.7
21	9.4	10.5	9.4	9.5	10.5	10.6	7.3	7.6	7.9	7.0	7.4	6.7
22	9.3	10.5	9.5	9.5	10.4	10.7	7.1	7.6	7.7	6.9	7.3	6.7
23	9.4	10.5	9.5	9.5	9.9	10.7	7.1	7.9	7.5	7.0	7.4	6.9
24	9.4	10.6	9.7	9.4	9.8	11.0	7.1	7.8	7.5	6.9	7.3	6.8
25	9.4	10.5	10.0	9.1	9.8	11.1	7.2	7.2	7.7	6.7	7.4	6.8
26	9.3	10.6	9.7	9.1	9.8	10.5	7.2	7.5	7.7	6.8	7.3	6.9
27	9.3	10.6	9.7	9.4	9.8	10.5	7.3	7.6	7.9	6.7	7.4	6.8
28	9.5	10.5	9.7	9.4	10.1	10.6	7.3	7.6	8.1	6.7	7.3	6.8
29	9.2	10.2	9.7	9.5	---	10.6	7.4	7.8	8.1	6.7	7.4	7.0
30	9.0	10.4	9.8	9.5	---	10.7	7.3	7.9	8.2	6.7	7.2	7.1
31	8.8	---	9.7	9.5	---	10.7	---	7.6	---	6.8	7.1	
Mean	9.28	10.45	8.97	9.61	10.76	10.49	7.79	7.65	7.74	7.05	7.12	6.72
Median	9.40	10.50	8.90	9.50	10.50	10.60	7.95	7.70	7.70	7.10	7.10	6.70

the gage record described above and an average monthly ground-water discharge between the gage and the mouth. While estimates of flow at the mouth are not exact, maximum and minimum values provide an idea of the natural range of variability for base flow conditions. The 1994 water year provides a good period of record for base flow estimates because of the absence of large runoff events during the year.

The USGS estimate of average baseflow at the mouth for 1993-94 is 7.8 cfs (Holmes et al. 1997), which agrees well with the data in Table 5. Mean and median monthly flows for the 1994 water year are also shown in Table 5.

A complete record of miscellaneous discharge measurements near the mouth of Beaver Dam Wash is presented in Table 6. These measurements have been

Table 6. Streamflow measurements at the mouth of Beaver Dam Wash (in cubic feet per second).

Month	Calendar Year					Median
	90	91	92	93	94	
Oct	5.7 (22)	7.3 (16)	4.5 (15)	9.1 (15)	7.1 (13) ***6.6 (6)***	6.8
Nov	6.6 (22)	7.4 (15)	7.7 (24)	10.5 (22)	10.8 (21)	7.7
Dec		8.9 (16)	7.7 (15)	8.8 (16)	10.9 (15)	8.8
Jan		8.3 (24)	9.2 (16)	10.3 (14)	10.6 (18) ***9.0 (5)***	9.2
Feb		7.8 (21)	10.0 (14)	9.5 (9)	10.8 (15) ***10.5 (22)***	10.0
Mar	8.4 (30)	10.1 (25)	8.9 (13)	29.1 (16)	10.6 (21)	10.1
Apr	9.5 (26)		9.0 (15)	9.1 (20) ***9.4 (28)***	8.6 (19) ***7.4 (19)***	9.1
May	7.9 (16)	8.0 (14)	6.8 (15)	8.6 (17)	8.3 (13) ***7.5 (19)***	7.9
Jun	5.9 (25)	6.9 (14)	6.4 (17)	6.8 (21) ***7.7 (1)***	8.7 (13) ***7.3 (28)***	6.9
Jul	7.3 (31)	6.2 (15)	7.5 (15)	8.4 (15)	7.2 (15)	7.3
Aug	6.6 (29)	5.7 (15)	4.9 (17)	8.1 (19) ***6.4 (2)***	6.2 (24) ***8.5 (9)***	6.4
Sep	6.1 (17)	5.6 (12)	5.3 (25)	7.4 (14)	6.6 (16)	6.1
					Median of Medians	7.8

NOTE: Numbers appearing in parentheses denote the day measurement was taken. Numbers appearing in ***italics*** denote measurements taken by USGS.

made by the USGS and BLM over a period of about 5 years (1990-1994). Median streamflows are estimated from four to seven measurements available for each month. Monthly median flows range from about 6.1 cfs in September to a little more than 10 cfs in March. Thus, Beaver Dam Wash streamflow at the mouth is expected to equal or exceed these values about 50 percent of the time. An annual median derived from the 12 monthly values is about 7.8 cfs. Median flows at the mouth estimated from these instantaneous measurements (1990-1994) are compared to median flows previously estimated for the 1994 water year in Figure 9.

The long-term (1970-95) average streamflow of Beaver Dam Wash at the mouth has been estimated at 12.5 cfs. Of this, about 6 cfs (about 4,300 acre-feet per year) is attributed to spring discharge to the stream near the mouth (Holmes et al. 1997). The remaining 6.5 cfs is attributed to surface runoff in response to snowmelt in the upper watershed and precipitation throughout the basin.

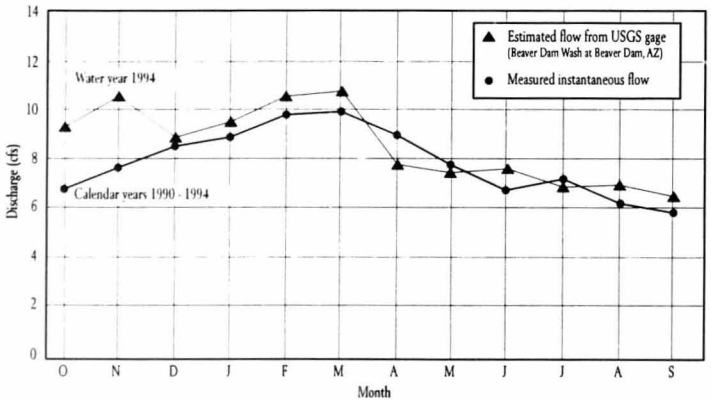


Figure 9. Comparison of monthly medians at the mouth of Beaver Dam Wash (ADWR 1997).

Channel Morphology

The public land surrounding the confluence of Beaver Dam Wash and the Virgin River is a very dynamic landscape influenced by extremely active channels of these two desert streams. Flood events in either of these two drainages have a pronounced effect on channel location and morphology for both streams. Channel evolution provides temporal changes in the quality of aquatic and riparian habitats associated with these systems. It is the dynamic nature of the processes active here, along with the dependable supply of relatively high-quality fresh water, that gives this area its high resource values.

The dynamic nature of the Virgin River channel is documented in a sequence of aerial photographs of the confluence area over the last 30 years (Figures 10 though 13). In the earliest photos (1966 and 1976), the Virgin River is actively eroding the outside of its meander bend on the western half of the public land. The mouth of Beaver Dam Wash is distributary, and a Virgin River overflow channel is present near the eastern border of the public land. In the later photos (1980 and 1991), the main channel of the Virgin River has occupied the position of the previous overflow channel near the eastern edge of the public parcel. The last photo (1991) reveals a single channel for Beaver Dam Wash and bank erosion along the southernmost edge of the Virgin River meander.

Extremely active channels, as evidenced in this area by the Virgin River, are common among desert streams. Storm-driven runoff and predominantly sandy bed material are generally responsible for this kind of channel behavior. The location of the Beaver Dam Wash confluence on the outside of a meander bend renders the processes particularly noticeable in this area. Constriction of the valley walls just downstream of the confluence under the interstate highway bridge also may enhance these processes by creating a backwater condition on the Virgin River during exceptionally large flood events (such as the flood from the Quail Creek dam break in 1989). The general character of desert streams and the specific characteristics of this site make it a classic location for investigation of geomorphic processes.

Superimposed on the geomorphic processes of the Virgin River are the large flood events experienced in the Beaver Dam Wash drainage. Floods in Beaver Dam Wash are commonly produced by summer thunderstorms and winter frontal rains; however, the longer duration of runoff associated with frontal systems generally causes much greater changes in channel morphology. Channel evolution during and after these flood events produces a wide variety of aquatic and riparian habitats, even over a relatively short period of time.

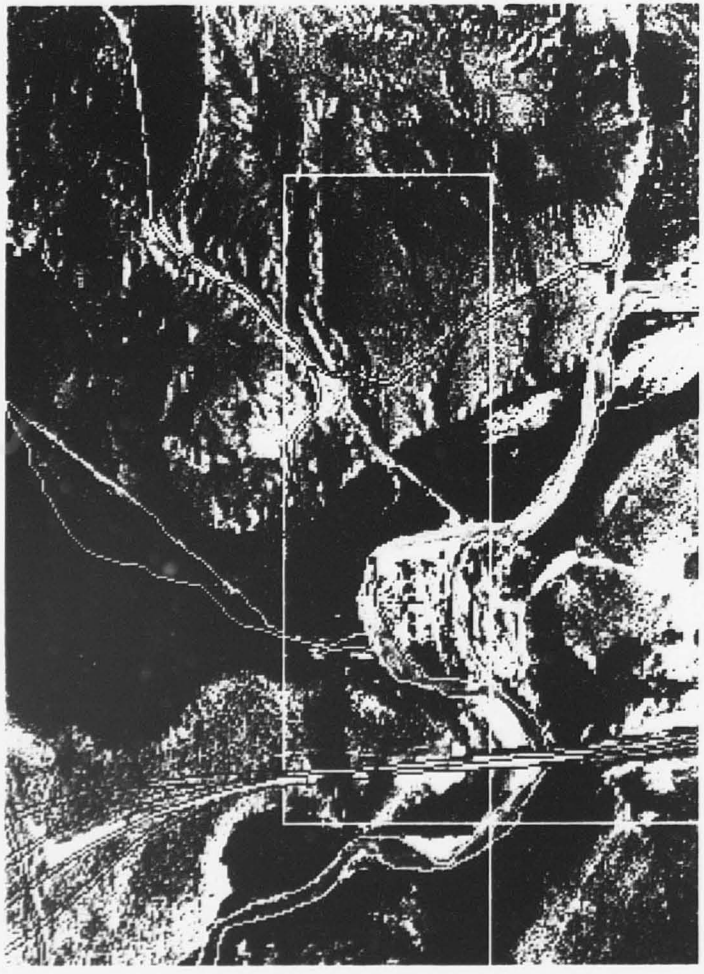


Figure 10. Aerial photograph, Beaver Dam Wash/Virgin River confluence, 1966. Areas within the yellow lines are public lands.

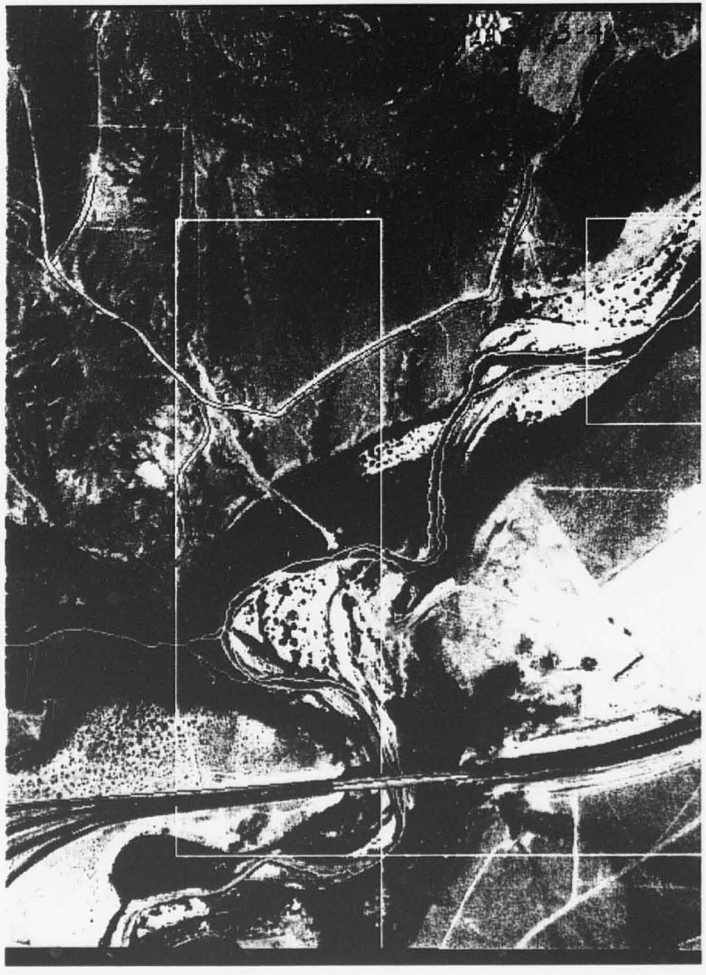


Figure 11. Aerial photograph, Beaver Dam Wash/Virgin River confluence, 1976.

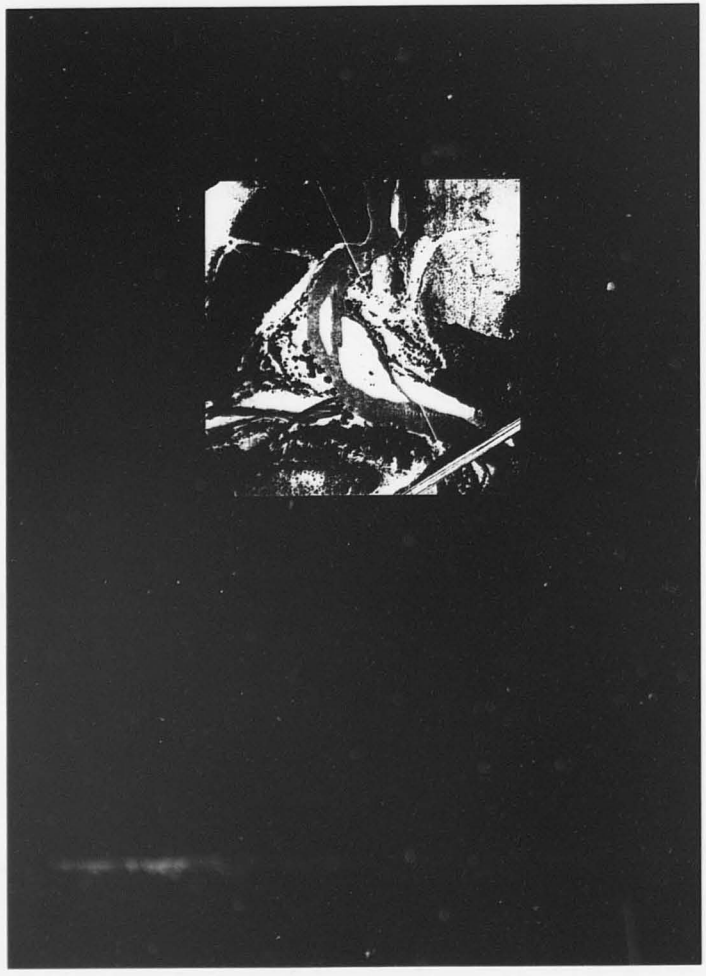


Figure 12. Aerial photograph, Beaver Dam Wash/Virgin River confluence, 1980.

Figure 13. Aerial photograph, Beaver Dam Wash/Virgin River confluence, 1991.

Figures 14 through 24 demonstrate dynamic channel evolution in Beaver Dam Wash over a period of about 5 years. The earliest photographs (Figures 14 and 15) were taken in the fall of 1991 and represent an advanced ecological condition for the channel and riparian area on public land. The channel was narrow, with well-vegetated banks and bed material armored with gravel and small cobble. Overhanging vegetation and woody material provided good aquatic habitat, and riparian vegetation showed diversity of composition and structure.

Figure 14. Advanced ecological condition (9/13/91).

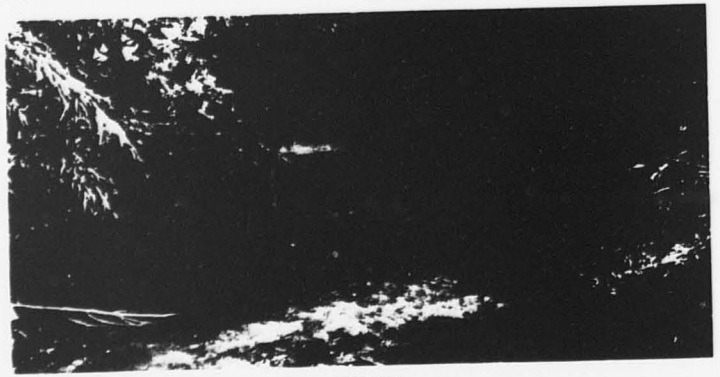


Figure 15. Advanced ecological condition (9/13/91).

Channel conditions changed dramatically following a moderately large flood in the spring of 1992 (Figures 16 and 17). Channel width increased substantially, resulting in a braided channel, and bed materials were poorly sorted. Succession of riparian vegetation was reset to an early seral condition, with willows and cottonwoods attempting to recolonize fresh sediment deposits. Cover and habitat diversity for aquatic species also was reduced substantially.

Figure 16. Effects of moderate flood during spring 1992 (8/17/92).

Figure 17. Effects of moderate flood during spring 1992 (10/15/92).

Changes in channel morphology and riparian condition were extreme following a major flood in the winter of 1993 (Figures 18 and 19). Estimated peak flows of approximately 6,000 cfs (USGS 1994) produced dramatic increases in channel width and new sites for riparian reproduction.

Diversity of aquatic habitat was greatly reduced, as channel units (e.g., pools and riffles) were obliterated and woody debris was removed from the system. The channel was in a very early ecological state, and processes of channel evolution and ecological succession were reset to initial conditions.

Figure 18. Effects of major flood during winter 1993 (9/8/93).

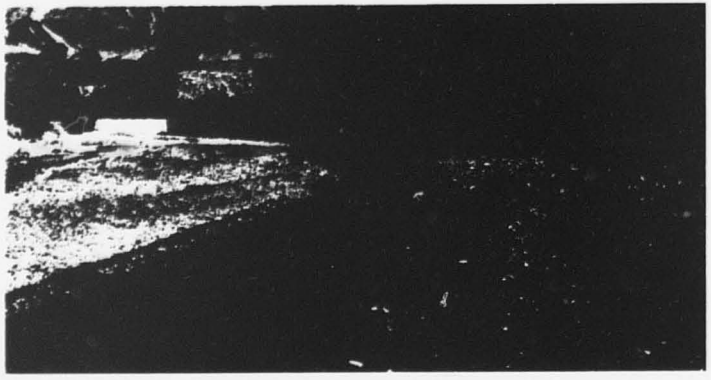


Figure 19. Effects of major flood during winter 1993 (9/8/93).

Conditions depicted in the six previous photographs were repeated in less than 2 years following the 1993 floods. Figures 20 and 21 reveal a moderately advanced ecological condition that had developed along the channel by the summer of 1994. Again the streambanks were well-vegetated, providing

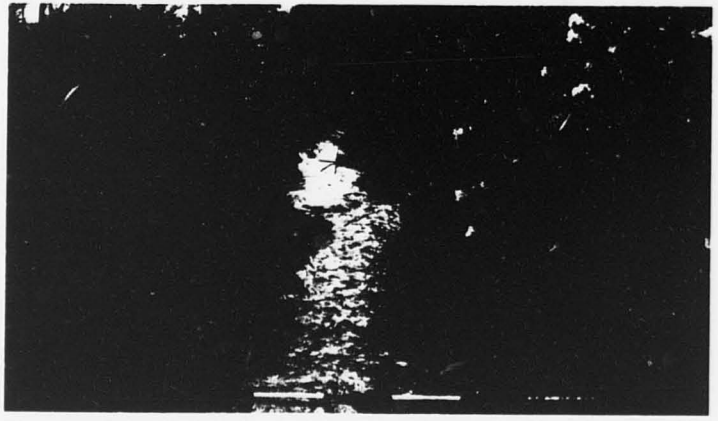


Figure 20. Moderately advanced ecological condition (8/24/94).

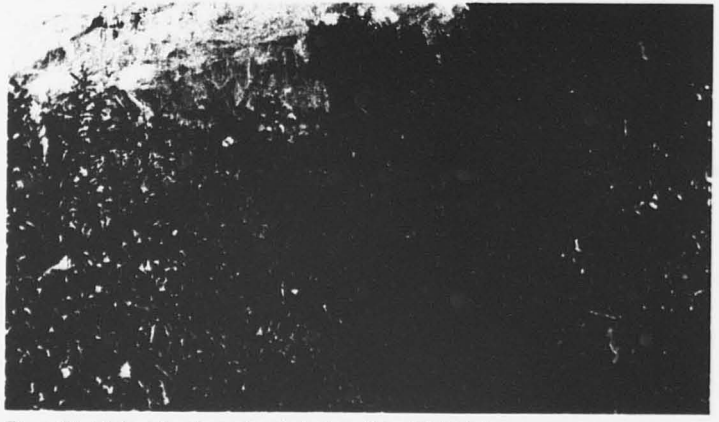


Figure 21. Moderately advanced ecological condition (10/13/94).

shade, cover, and introduced material to the channel. Figure 22 depicts conditions following a moderate flood, and Figures 23 and 24 depict conditions following a major flood of approximately 13,000 cfs (instantaneous flow), both during the winter of 1995. Resulting channel conditions are similar to those described above.

Flood sequences are the driving force for geomorphic change along Beaver Dam Wash and are partially responsible for the rich diversity of riparian communities that occur in the area. Geomorphic response to flood events produces a variety of microhabitats for riparian reproduction and establishment. The magnitude of floods required to produce these habitats depends on the antecedent conditions before each event. When prolonged periods of base flow have allowed establishment of riparian vegetation and development of a narrow primary channel, moderately large floods are sufficient to initiate channel widening, with sediment deposition during the recession producing sites for riparian regeneration. Following a moderate flood, a much larger flow is required to bring about similar processes on a wider channel. In general, larger flood events cause greater channel adjustments and create larger areas for regeneration and ecological succession after the event. Thus, there is no single flood magnitude that is associated with these processes.

Figure 22. Effects of moderate flood during winter 1995 (2/17/95).

However, it is possible to estimate a minimum flood magnitude required to initiate these processes. The minimum flood required to initiate channel adjustments is the flow that slightly exceeds bankfull discharge of the stream when it is in an advanced ecological condition. Although the channel is narrow and the banks are well-vegetated, the non-cohesive nature of the substrate results

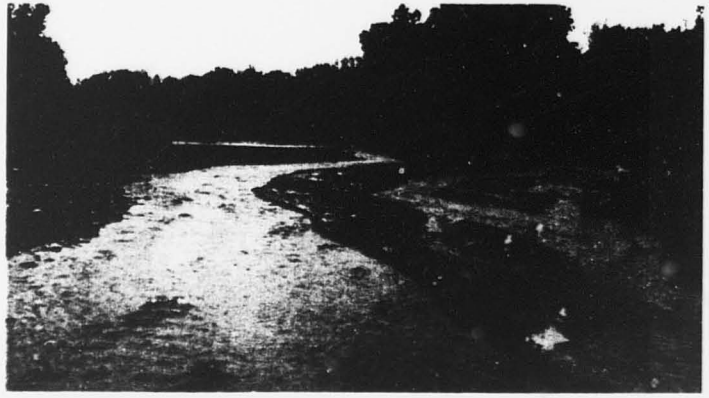


Figure 23. Effects of major flood during winter 1995 (3/20/95).

Figure 24. Effects of major flood during winter 1995 (3/20/95).

in channel widening and other adjustments when bankfull flow is exceeded for durations of a few hours or more. For this assessment, bankfull flow was estimated for cross sections surveyed when the channel was in such an advanced ecological condition.

Relationships between water level in the channel and stream discharge were obtained using normal depth calculations (Manning's equation) for both riffle and run cross sections (Figures 25 and 26). Roughness coefficients (n values) for the calculations were calibrated to field measurements for low-water stages and were estimated for high-water stages based on observed bedforms during flood events. (Standing waves indicative of antidune bedforms are common during flood events.)

Estimates of the flow required to exceed bankfull condition vary somewhat between the cross sections. The riffle cross section (Figure 25) had steep banks on both sides of the stream. The

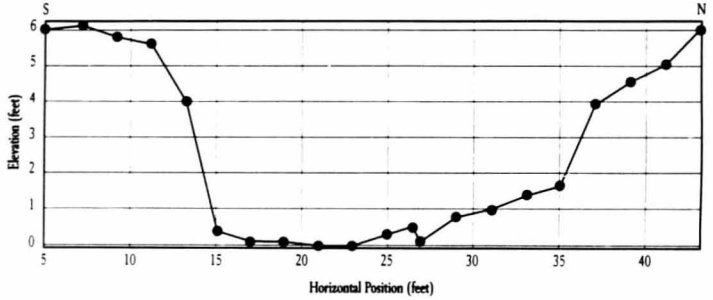


Figure 25. Riffle cross section on Beaver Dam Wash, 1991.

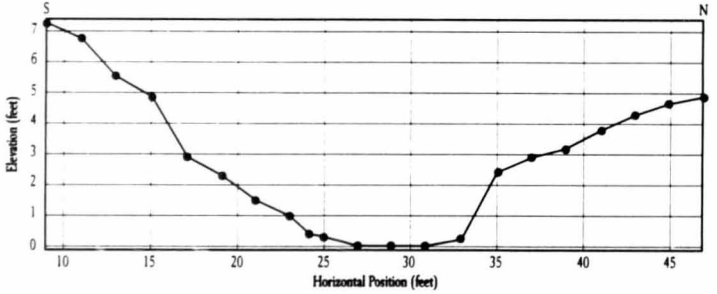


Figure 26. Shallow run cross section on Beaver Dam Wash, 1991.

stage-discharge relation for this section (Table 7) indicates that flows of about 1,000 cfs will begin to overtop the north bank of the stream, while flows in the range of 2,500 to 3,500 cfs are required to overtop the higher south bank of the stream. The run cross section (Figure 26) had a well-defined bank on the north side of the stream, which is overtopped at flows between 300 and 500 cfs (Table 8). The south bank of the stream is not well-defined, but it appears that flows in the range of 1,000 to 2,000 cfs would reach most of the bank.

Thus, it appears that channel adjustments will begin to occur with floods as small as a few hundred cfs, but that flows in the range of 1,000 to 3,500 cfs are required to access most of the streambank and initiate widespread channel adjustments. Peak flows of 5,940 and 13,000 cfs were recorded during the course of this study; thus, it appears the present magnitude and frequency of flooding in Beaver Dam Wash are adequate to maintain the riparian processes that are occurring.

The superposition of Beaver Dam Wash flood hydrology and geomorphic processes on geomorphic processes associated with Virgin River flooding have produced an incredibly dynamic and diverse landscape at the confluence of these two streams. This landscape provides aquatic, riparian, and terrestrial habitats supporting a wide assemblage of resource values, including a variety of human uses.

Table 7. Stage-discharge data for riffle cross section:
Cross-section number 1
Date of cross-section measurement: 910911
Channel slope range: 0.0093 to 0.0093
Velocity formula: user supplied Manning's n

Stage ft	Area ft²	Perim. ft	Width ft	R ft	DAvg ft	Slope	n	VAvg ft/s	Q cfs
0.50	4.4	13.5	13.2	0.3	0.3	0.0093	0.060	1.1	4.95
1.00	11.5	17.0	16.3	0.7	0.7	0.0093	0.056	2.0	22.99
1.50	20.4	20.3	19.3	1.0	1.1	0.0093	0.051	2.8	57.21
2.00	30.7	22.6	21.1	1.4	1.5	0.0093	0.047	3.7	114.54
2.50	41.4	23.9	21.9	1.7	1.9	0.0093	0.043	4.8	200.52
3.00	52.5	25.1	22.6	2.1	2.3	0.0093	0.039	6.1	319.85
3.50	64.0	26.3	23.3	2.4	2.7	0.0093	0.034	7.6	483.89
4.00	75.8	27.6	24.0	2.8	3.2	0.0093	0.030	9.4	710.82
4.50	88.4	30.1	26.3	2.9	3.4	0.0093	0.027	11.1	1041.33
5.00	102.2	32.9	28.8	3.1	3.5	0.0093	0.024	12.8	1528.14
5.50	117.1	35.0	30.7	3.3	3.8	0.0093	0.021	15.0	2287.07
6.00	133.4	39.6	35.1	3.4	3.8	0.0093	0.019	16.8	3630.68

Table 8. Stage-discharge data for riffle cross section:
Cross-section number 2
Date of cross-section measurement: 910911
Channel slope range: 0.0093 to 0.0093
Velocity formula: user supplied Manning's n

Stage ft	Area ft²	Perim. ft	Width ft	R ft	DAvg ft	Slope	n	VAvg ft/s	Q cfs
0.50	3.7	9.6	9.4	0.4	0.4	0.0093	0.057	1.3	4.92
1.00	8.7	11.3	10.7	0.8	0.8	0.0093	0.053	2.3	19.79
1.50	14.7	14.0	13.2	1.0	1.1	0.0093	0.049	3.0	44.08
2.00	21.7	16.0	14.9	1.4	1.5	0.0093	0.046	3.9	83.73
2.50	29.6	18.5	17.1	1.6	1.7	0.0093	0.042	4.7	139.44
3.00	39.0	22.3	20.8	1.7	1.9	0.0093	0.038	5.5	214.65
3.50	50.2	25.4	23.6	2.0	2.1	0.0093	0.034	6.6	333.08
4.00	62.6	28.0	25.9	2.2	2.4	0.0093	0.030	8.1	507.39
4.50	76.2	31.0	28.6	2.5	2.7	0.0093	0.026	9.9	753.37
5.00	91.4	35.0	32.3	2.6	2.8	0.0093	0.023	11.8	1145.10
5.50	107.9	37.0	33.7	2.9	3.2	0.0093	0.021	14.1	1777.09
6.00	125.0	38.6	34.7	3.2	3.6	0.0093	0.018	17.1	2780.92
6.50	142.5	40.0	35.5	3.6	4.0	0.0093	0.016	21.4	4533.15

RESOURCE ASSESSMENT

When the assessment began in August of 1991, the riparian plant community along Beaver Dam Wash had reached an advanced ecological condition near the confluence with the Virgin River (Figures 14 and 15). The reach above the confluence was characterized as a low-gradient (1.5 percent) perennial stream, 5-12 feet wide, with sand, gravel, and cobble substrate. The channel was narrow and deep, with diverse fish habitat comprised of pools, riffles, runs, and glides. Much of the stream had well-vegetated banks, which provided shade, overhanging cover, and bank stability, while other areas were barren with exposed, sandy banks. Woody debris and root wads enhanced pool development and fish cover. Filamentous algae (dominated by Cladophora) and rooted aquatic plants (e.g., watercress) grew in thick mats where coarse substrate and adequate sunlight existed.

Field work was carried out at two stages of ecological conditions: 1) late seral stages encountered during September 1991, and 2) early seral stages encountered during September 1993. The analysis focused on late seral stage (i.e., September 1991), which was believed to represent the best conditions for fish and wildlife habitat and for recreation. Thus, instream flow quantities identified in this report support the late successional situation. However, the dynamic flood-related processes described previously are important for maintaining the overall Beaver Dam Wash ecosystem, including resource values described in this report.

Fisheries

Resource Values

The Colorado River system, of which Beaver Dam Wash and the Virgin River are a part, harbors a largely native and unique ichthyofauna, which has been subject to introduction of predatory and competitor fishes from distant drainages. In addition, aquatic habitat throughout the Colorado drainage has been altered through damming and diversion of surface water, ground-water withdrawals, water pollution, channelization and floodplain alteration, grazing, logging, mining, and other land-disturbing activities (Miller 1961, Minckley and Deacon 1968, 1992).

The Virgin River and its tributaries have been subjected to many, if not all, of these potentially destructive activities (Cross 1975, Deacon 1988). Habitat in the greater Virgin River system has been characterized as moderately to severely damaged, with some habitat lost to large withdrawals of water (Minckley 1985). Habitat degradation, coupled with invasion of an abundance of exotic fishes, has led to Federal listing of two species as endangered in the Virgin River system. A third species is a candidate for Federal protection. Two other species once regarded as Category 2 candidates have been released from this status through a

recent administrative change in the definition of candidate species (U.S. Fish and Wildlife Service 1995).

The need to protect the integrity of the Virgin River and its tributaries is at a critical point, with five of its six native fish species requiring special attention and protection. The Virgin River, including the 100-year floodplain at the Beaver Dam confluence, has been proposed as critical habitat for Virgin River native fishes (U.S. Fish and Wildlife Service 1991). Three of the six native species (desert sucker, flannelmouth sucker, and speckled dace) have evolved distinctly different stocks: streamlined, large-finned stock adapted to the swift currents of the main stem Virgin River, and stubby-bodied, small-finned stock adapted to the slower, shallower flow of tributaries (Rinne and Turner 1992). In order to maintain the diversity of populations with distinct physical characteristics and other unique attributes, both main stem and tributary stocks of fish need to be conserved.

Tributaries, as well as upstream reaches on the main stem, play an important role in maintaining refugia from catastrophic events (e.g., Quail Creek Dam failure in 1989). Such catastrophic events have had a heavy impact on the native fishery of the Virgin River. Tributaries like Beaver Dam Wash provide an opportunity for recolonization of the Virgin River main stem after such events (DeMaris et al. 1993, Rinne and Turner 1992).

Eleven fish species were collected in Beaver Dam Wash (Table 9), of which five are native to the Colorado River system and six were introduced from other drainages.

Virgin Spinedace

The Virgin spinedace was previously proposed for addition to the Federal list of threatened and endangered wildlife (U.S. Fish and Wildlife Service 1994). This species' trend is "declining," meaning that either the species is decreasing in numbers and/or it is facing increasing threats (U.S. Fish and Wildlife Service 1991). Since completion of a conservation agreement, the status of the Virgin spinedace has been changed from proposed threatened to candidate species.

Spinedace occur in Beaver Dam Wash and in the Virgin River immediately downstream of the confluence (Cross 1975, Minckley 1973, Valdez et al. 1991), although the population in lower Beaver Dam Wash has been depleted by channelization (Minckley 1973). Records show that a substantial population inhabited the lowermost portion of the Wash (Deacon 1991). The 1993 distribution of spinedace in Beaver Dam Wash is presented in Figure 27. This species prefers cool, clear, flowing streams comprised of pools, runs, and riffles, although they can be found in the Virgin River near springs and the mouths of tributaries. Spinedace use pools and runs most often. Shear zones (the interface of a low-velocity water column and adjacent high velocity areas) associated with cover are an important habitat feature (Valdez et al. 1991).

Table 9. Numbers and relative abundance of fishes collected from Beaver Dam Wash: September 1991 and August 1993.

Species (Origin)	Number 1991	% Abundance	Number 1993	% Abundance	Legal Status
Red Shiner *Cyprinella lutrensis* (Introduced)	1,001	50.2	865	27.0	
Speckled Dace *Rhinichthys osculus* (Native)	743	37.3	2,022	63.1	
Desert Sucker *Catostomus clarki* (Native)	209	10.5	311	9.7	
Flannelmouth Sucker *Catostomus latipinnis* (Native)	–	–	8	<1	
Green Sunfish *Lepomis cyanellus* (Introduced)	21	1.1	–	–	
Virgin River Roundtail Chub *Gila robusta seminuda* (Native)	10	<1	–	–	FE; WSCA
Virgin Spinedace *Lepidomeda m. mollispinis* (Native)	4	<1	–	–	CA; WSCA
Black Bullhead *Ameiurus melas* (Introduced)	2	<1	–	–	
Yellow Bullhead *Ameiurus natalis* (Introduced)	1	<1	–	–	
Largemouth Bass *Micropterus salmoides* (Introduced)	1	<1	–	–	
Western Mosquitofish *Gambusia affinis* (Introduced)	1	<1	–	–	

Status Under the Endangered Species Act:
FE = Federally Endangered
WSCA = Wildlife of Special Concern in AZ
CA = Conservation Agreement in Lieu of Listing

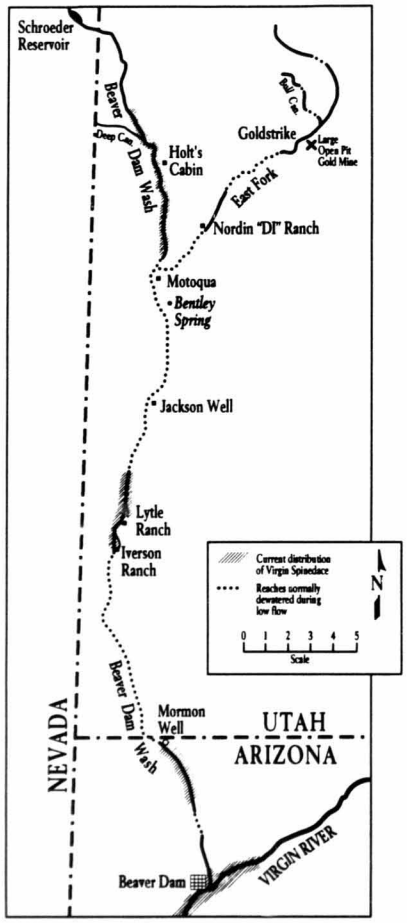


Figure 27. Distribution of Virgin spinedace in Beaver Dam Wash drainage, Arizona, Nevada, and Utah. Distribution based on data collected during 1990 in the Utah and Arizona portions only (adapted from Valdez et al. 1991)

Virgin River populations are thought to depend on tributaries or headwaters for completion of their life cycle. Cross (1975) noted that spinedace abundance in the Virgin River changed in the vicinity of Beaver Dam Wash throughout the year. For example, the highest concentrations of spinedace in the Virgin River at Littlefield were found in the fall and winter months. In contrast, spinedace were found in abundance in Beaver Dam Wash during April through July, and young of the year were abundant from May through August. Thus, seasonal use of spawning habitat in Beaver Dam Wash was strongly indicated (Cross 1975).

Floodwaters in Beaver Dam Wash provide the opportunity for fish isolated by an interrupted base flow to communicate by upstream or downstream migration. This was the case at Mormon Well located just inside Arizona near the Utah border. This site had no perennial water until the 1993 floods scoured out enough channel to intersect the water table. This reach now supports about a mile of aquatic habitat which was colonized by spinedace, presumably from an upstream population at Lytle Ranch. This same colonization process can be anticipated to occur elsewhere when conditions are conducive for migration and establishment.

Temperature is an important habitat parameter for Virgin spinedace. Deacon et al. (1987) reported an approximate temperature preference of 23.1 °C and a critical maximum temperature of about 37.0 °C. The spinedace can be considered a thermal specialist because its temperature preference is fairly narrow.

Temperature studies are supported by field observations of spinedace distribution favoring cooler water associated with tributaries and avoiding warmer temperatures found in the main stem Virgin River away from headwater or tributary influence (Deacon et al. 1987). Thus, for Virgin spinedace, Beaver Dam Wash is an important refugia of cool, high-quality water compared to the Virgin River with its naturally and culturally degraded water quality (Cross 1978, Heckmann et al. 1986, Deacon et al. 1987).

Beaver Dam Wash is important to the survival of Virgin spinedace because it provides: 1) refuge from and/or mitigation of extreme thermal conditions, 2) spawning habitat for adults, 3) high-quality water critical for survival in a river system with poor water quality, and 4) physical habitat with qualities that support occupancy.

Virgin River Roundtail Chub

The Virgin River roundtail chub is Federally listed as endangered (U.S. Fish and Wildlife Service 1993), meaning that it is in danger of extinction throughout all or a significant portion of its range. Chub have declined in the Virgin River in the vicinity of Beaver Dam Wash since 1979, but they are collected consistently in low numbers during annual monitoring (Hardy 1991). The Virgin River roundtail chub was once collected in abundance in the reach of the Virgin River that includes the mouth of Beaver Dam Wash.

Deacon and Minckley (1973) reported that the greatest numbers of Virgin River roundtail chub occurred between the springs at Littlefield and Beaver Dam Wash, Arizona, where they often comprised 60 percent of the fish population. They concluded that chub prefer deep pools or undercut banks with velocities less than 2.6 ft/sec. Cross (1975) attributed chub use of the area downstream of Beaver Dam Wash to permanence of surface water and greater habitat diversity (pools and runs) created by flood-deposited boulders. During this assessment, chub were found in several locations within Beaver Dam Wash in close proximity to spinedace. No reference to chub inhabiting Beaver Dam Wash could be located in the literature, yet its presence there is consistent with the findings of Deacon et al. (1987).

Thermal conditions may be an important limiting factor for chub in the Virgin River and may explain their presence in Beaver Dam Wash during this assessment. Deacon et al. (1987) reported an approximate temperature preference of 23.8 °C and a critical maximum temperature of 36.4 °C. Like spinedace, chub have a narrow temperature preference, making them thermal specialists. It has the lowest critical maximum temperature of native Virgin River fishes and a thermal selection curve very similar to that of Virgin spinedace. Deacon et al. (1987) suggested that summer water temperatures may have risen in the Virgin River over time, and Schumann (1978) suggested that chub populations appear to fare better during the hot summer months in areas where cool inflows moderate high water temperatures. At extreme low flows in the Virgin River, stream temperatures may approach or exceed the critical maximum for chub; thus, the mixing zone of Beaver Dam Wash and other spring-fed streams may provide critical habitat to the species at those times.

Many habitat relationships of this species remain poorly understood, but it appears that Beaver Dam Wash is valuable to Virgin River roundtail chub because it provides: 1) refuge from and/or mitigation of extreme thermal conditions, 2) a source of high-quality water in a system with poor water quality, 3) physical habitat with qualities that support occupancy, and 4) increased surface flow in the Virgin River.

Flannelmouth Sucker

The flannelmouth sucker was previously classified as a Category 2 candidate for threatened or endangered status (U.S. Fish and Wildlife Service 1991). The Category 2 candidate classification has been dropped recently by the U.S. Fish and Wildlife Service (1995).

Cross (1975) found that this species was commonly collected in both the lower reaches of tributaries and the main stem Virgin River, often on a year-round basis. Flannelmouth suckers have been collected in lower Beaver Dam Wash, as well as in the Virgin River at the confluence with Beaver Dam Wash. Sexually ripe individuals have been found in other small tributaries, such as

the Santa Clara River. Small (<100 millimeters total length) flannelmouth suckers were collected in Beaver Dam Wash during the 1993 sampling effort in this assessment.

Deacon et al. (1987) reported an approximate temperature preference and a critical maximum temperature of 25.9 °C and 37 °C, respectively, for flannelmouth. This sucker has the highest temperature preference of native Virgin River fishes and is widely distributed throughout the system. Apparently, it is not limited by the need for cool tributary or spring influences in the mid- and lower river, as are the speckled dace and spinedace. Nevertheless, Beaver Dam Wash is valuable to the flannelmouth sucker because it provides: 1) physical habitat with qualities that support occupancy by young of the year, and 2) increased surface flow in the Virgin River.

Desert Sucker

The desert sucker was added to the Federal list as a Category 2 candidate for threatened or endangered status (Stefferud 1994). The Category 2 candidate classification has been dropped recently by the U.S. Fish and Wildlife Service (1995).

This sucker was reported to have the widest distribution within the Virgin River system. It was collected in all of the tributary streams including Beaver Dam Wash (Cross 1975). Spawning activity was indicated through bright breeding coloration of desert suckers in collections made in May 1991. Desert sucker fry were collected at Beaver Dam Wash in mid-March 1975 (Cross 1975). In 1993, a wide variety of size classes of desert sucker, ranging from 40 to 165 mm total length, were collected in Beaver Dam Wash.

Deacon et al. (1987) found the approximate thermal preference and critical maximum temperature for this sucker to be 17.5 °C and 37.2 °C, respectively. This species is the most widely distributed in the Virgin River system. However, its abundance drops in the lower, warmer main stem and upper, colder tributaries. It is found in greatest abundance in the upper main stem and lower portions of tributaries.

Beaver Dam Wash is valuable to the desert sucker because it provides: 1) physical habitat with qualities that support a self-sustaining resident population with evidence of spawning and rearing habitat for young of the year, 2) refuge from and/or mitigation of extreme thermal conditions, and 3) increased surface flow in the Virgin River.

Woundfin Minnow

The woundfin minnow is Federally listed as an endangered species (U.S. Fish and Wildlife Service 1993). Woundfin were present in high numbers in the Virgin River at the mouth of Beaver Dam Wash before 1979, but have declined to the point where none have been found in sampling efforts since 1987 (Hardy 1991). The woundfin has been largely replaced by red shiner along this reach of the Virgin River.

Historically, the Virgin River adjacent to the mouth of Beaver Dam Wash was a highly productive area for woundfin, with flow from the Wash likely enhancing productivity of woundfin populations in the river at the confluence. Preserving the natural hydrology of one of the most productive woundfin locations may be important to woundfin management in the future.

Speckled Dace

Speckled dace carry no special legal status. Cross (1975) reported the species widely distributed in the main stem and tributary streams, including lower Beaver Dam Wash. The presence of small dace in collections made during this assessment and studies by Cross (1975) suggests that spawning occurs in Beaver Dam Wash. Deacon et al. (1987) reported an approximate temperature preference and critical maximum temperature of 15.8 °C and 36.8 °C, respectively, for speckled dace; thus, this dace has the lowest temperature preference of the Virgin River fishes. It is most abundant in the upper main stem and in tributaries of the mid- and lower Virgin River, and it is nearly always associated with cool, clear inflow from springs or tributaries in warmer segments of the river. Beaver Dam Wash is valuable to the speckled dace because it provides: 1) physical habitat with qualities that support a self-sustaining population, with evidence of spawning and rearing habitat for young of the year, and 2) a source of cool water.

Approach and Methods

The fisheries resources of Beaver Dam Wash were assessed through literature reviews, field reconnaissance, aquatic inventory, and habitat analysis. Literature pertaining to the Virgin River and its tributaries and their fishes was compiled. Literary data bases were searched at the Bureau of Land Management's Service Center Library and a list of citations assembled. A nearly complete assemblage of grey literature concerning the Virgin River watershed and its fishes was provided by Dr. Thomas B. Hardy (Utah State University). Dr. J.E. Deacon (University of Nevada, Las Vegas) and Dr. W.L. Minckley (Arizona Sate University) were contacted for their insight concerning the area's natural history.

A field reconnaissance was conducted on May 1, 1991, during which Beaver Dam Wash was investigated by observation and casual seining using a 10-foot x 4-foot x 1/8-inch seine. Fish were either photographed and released or preserved for later identification.

An aquatic inventory was conducted on September 12, 1991, and again in August 31, 1993. The investigations included both an inventory of the fish community and an inventory of fish habitat. Fish were collected using a Coffelt BP-4 electroshocking unit powered by a 12-volt battery. Fish were collected in an upstream manner by blocking the lower end of a short (approx. 10-yard) creek segment with a seine, as described above,

and shocking in a downstream manner until reaching the seine. Fish were captured using one dipnet with 1/8-inch mesh and with the block-net as they were entrained by the current. All habitats and all areas within the habitats were sampled, except for the shallowest margins, which did not allow for efficient shocking or dip-netting. All fish were counted, identified, and released downstream in order to reduce the probability of recapture. Shocking times for each effort were recorded. A representative sample of each species of fish was measured and the rest enumerated.

Aquatic habitat was inventoried and mapped for the entire BLM reach from the confluence with the Virgin River to the property line of the first private parcel. Channel configuration was surveyed using rod, level, and tape in 1991, and compass and hip chain in 1993. Creek habitats were inventoried using a classification system proposed by McCain et al. (1990). For each habitat recorded, mean habitat width and maximum depth were measured to the nearest 0.1 foot using a range pole, and mean length was measured to the nearest foot using a hip chain. Mean depth also was estimated to the nearest 0.1 foot. Three dominant substrate sizes were recorded in descending order of bottom covered.

Woody cover was measured and classified by size. The area of habitat with cover provided by woody material was measured to the nearest square foot. In a similar manner, the area of cover provided by submergent, emergent, floating, and overhanging (<3 ft. above the water surface) vegetation was recorded. The percent of overstory (overhanging vegetation >3 ft. above the water surface) was recorded using an ocular estimate. The running length of undercut bank, boulder edge, and bedrock ledge with characteristics suitable for fish cover also was recorded.

Instantaneous measurements of water temperature have been obtained for Beaver Dam Wash and the Virgin River monthly since 1990, along with instantaneous flow measurements. Water temperatures were recorded to the nearest 0.5 °F. All temperatures were converted to degrees Celsius and a comparison between the two waters was made for the warmest months (April through October) of 1990, 1991, 1992, and 1993.

For the habitat analysis, cross sections were established in representative habitat types for pool, riffle, and run. The cross sections were independent in the sense that no attempt was made to survey the hydraulic controls between transects for simulation of a continuous water-surface profile. Each cross section was established perpendicularly to the stream channel and marked with stakes. Cross sections were surveyed using standard rod and level survey procedures. Depths and velocities of the stream were measured using a wading rod and a standard pygmy meter. Techniques for obtaining velocities and determining streamflow followed those of Buchanan and Somers (1980). Substrate was classified and recorded at

each point where depth or elevation was measured. As described above, each macrohabitat was classified, and the proportion of pool, run, and riffle was determined by habitat length.

The effects of streamflow levels on physical habitat for native fishes were analyzed using the Physical Habitat Simulation Modeling System (PHABSIM) of the U.S. Fish and Wildlife Service (Milhous et al. 1989). Only one set of depth/velocity data was available for modeling the advanced ecological condition of Beaver Dam Wash. Thus, the independent nature of the habitat transects and the lack of multiple elevation-discharge data sets resulted in simulation of water-surface elevations for all cross sections using an approach based on Manning's equation.

The MANSQ computer program was used to model water surface elevations at the pool, riffle, and run habitat transects, using the field-measured discharge of 5.6 cfs to calibrate the roughness coefficient for Manning's equation. Since no data was available for varying roughness or water-surface slope for other discharges, only a small range of flows (0.5 to 20 cfs) was selected for simulation to minimize errors associated with variable roughness and water-surface slope. No attempt was made to model habitat associated with high flows.

The use of Manning's equation to estimate water surface elevations in pool habitats is a violation of the assumptions inherent in the equation (i.e., the assumption of uniform flow approaching normal depth). The nature of a pool is that it is a backwater condition caused by a downstream control. Because of this constraint, an option in the software was selected to minimize the effects of backwater on the computational procedures. This option seemed to generate a reasonable stage-discharge relationship for one of two pool transects originally modeled. The second pool transect was subsequently dropped from any additional analysis.

After acceptable water surface elevations were obtained for the range of simulated flows, cross-section velocity distributions were simulated using the IFG4 computer program. Velocities in the pool transect were modeled separately from the riffle and run transects. In both cases, cell-specific roughness coefficients (a velocity calibration parameter) were allowed to vary as a function of depth (i.e., the ratio of depth at the simulated flow to depth at the calibration flow in an exponential fashion). Several different exponents were tried in the function varying the roughness coefficient, with the final exponent chosen to provide the greatest range of flows with acceptable velocity adjustment factors (VAFs).

Cell-by-cell depths and velocities for each transect were then used in the HABTAE simulation model to estimate physical habitat for fisheries in Beaver Dam Wash. The HABTAE model uses the hydraulic information described above and habitat suitability index (SI) curves for each native species and life

stage to produce estimates of weighted usable area (WUA). Thus, WUA is an index of available fish habitat. Habitat SI curves for Virgin spinedace were provided by Deacon et al. (1991) based on data acquired from tributaries to the Virgin River, including Beaver Dam Wash. Habitat SI curves for all other species were provided by Dr. Thomas Hardy based on data obtained from the Virgin River Fishes Data Base (Utah State University, Logan).

Based on the SI curves, it was determined that the substrate was not an important habitat element for this analysis. Therefore, substrate was negated from the analysis by replacing the substrate value with 0 in the IFG4 files and running HABTAE with an option that ignores channel index values of 0 in the calculation of WUA. Since substrate was negated from the analysis, depth and velocity were the habitat parameters used to determine WUA. The option using the lowest limiting parameter was selected to calculate WUA. This implies a limiting factor concept where WUA is limited by the worst habitat component. In other words, it was assumed that the least suitable parameter (lowest SI value) for each cell determines or limits its use by fish.

From the habitat modeling, outputs were generated for pool, run, and riffle habitat. Estimates of weighted usable area for each habitat were weighted by the proportion of that habitat in the study reach to obtain a composite WUA. Outputs for each species and size class were compared, and flow recommendations were developed under the assumption that all outputs were valid.

Data for habitat modeling was collected in September 1991, when the stream was in the most advanced ecological condition of the assessment period. Data collected after the 1992 and 1993 floods was not modeled. The analysis was designed to provide an estimate of suitable fish habitat when conditions in Beaver Dam Wash are most favorable (i.e., when they provide the most habitat diversity), which is usually between major flood events.

Flow requirements for fisheries represent the range that would provide the most habitat (i.e., WUA) in the reach. Requirements were developed for an optimum flow and an acceptable range of flows for the species and size class most sensitive to reduced flows. Spinedace were determined to be the most sensitive species in this area, because they are dependent upon cool, clear water like that of Beaver Dam Wash. The optimum flow for each species was determined to be the flow that resulted in the most fish habitat for the reach. The acceptable range of flows was determined by comparing the rate of change in fish habitat with change in flow. If fish habitat decreased dramatically below a given flow, then that flow was selected for the minimum acceptable streamflow. If fish habitat decreased dramatically above a given flow, then that flow was selected as the maximum acceptable streamflow.

Analysis of Flow Requirements

The habitat inventory conducted in 1991 revealed a mosaic of habitat types, which included riffles, runs, glides, and pools (Figure 28). Bottom substrates varied widely from sand to rubble. The width:depth ratio was 13.6. Overstory canopy provided by trees ranged from 0 to 50 percent and averaged 17.5 percent per macrohabitat. Fish cover was abundant and varied widely, with the dominant type consisting of small and medium woody debris. Other cover types represented in significant amounts included overhanging vegetation, emergent vegetation, submergent vegetation, and undercut bank. The measured flow at the time of the inventory was 5.6 cfs. Figures 14 and 15 in the Channel Morphology section reveal the condition of the stream during this inventory.

In 1991, red shiners dominated the fish community and were found throughout the creek. These fish was found in nearly every habitat, but were noticeably absent from the swiftest currents. Speckled dace and desert sucker were abundant and widely distributed throughout the segment sampled. Mosquitofish were readily observed in shallow habitats lateral to flowing water, but were not very susceptible to capture with electrofishing gear. As a result of this bias, no conclusion can be made from the data presented in Table 9 concerning relative abundance of mosquitofish in Beaver Dam Wash. However, visual observations indicated mosquitofish were at least moderately abundant and well-distributed throughout the creek. Bullheads were restricted to a few isolated localities and were rarely encountered. Sunfish were present in low numbers, represented by subadults, and were widely distributed. The source of the nonnative fishes is unknown, but all can be found in the Virgin River.

Although no woundfin were encountered, two other special status species were collected in 1991: Virgin spinedace and Virgin River roundtail chub. Two voucher specimens of each species were deposited at the Zoology Museum at Arizona State University. The specimens were identified as Lepidomeda mollispinis and Gila seminuda. Spinedace were restricted to the midregion of the reach and were represented by adult-sized individuals (82-87 millimeters total length). Roundtail chub were widely distributed and represented by both adult and juvenile size classes (69-185 millimeters total length). The majority of chub were collected from those portions of pools and glides with woody debris, especially downed trees and debris jams.

The habitat inventory conducted in 1993 showed considerable change had occurred since 1991 (Figure 29). Habitats consisted of poorly defined run and riffle types. The width:depth ratio more than doubled to 32.5, indicating a wider, shallower channel. Bottom substrates were predominantly sand and gravel. Overstory canopy ranged from 0-10 percent and averaged less than 3 percent. Fish cover was scarce and consisted of small, woody debris and a minor amount of overhanging vegetation. Overall habitat

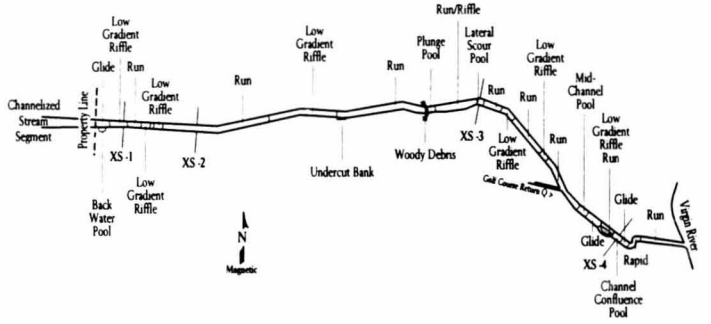


Figure 28. Beaver Dam Wash fish habitats (1991).

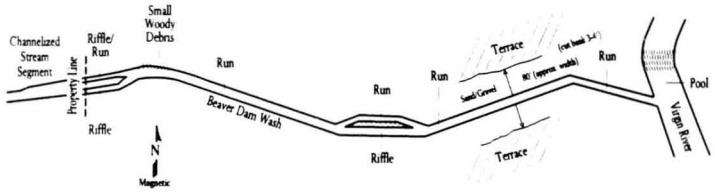


Figure 29. Beaver Dam Wash fish habitats (1993).

diversity (macrohabitat and microhabitat components) was very low. The measured flow at the time of the inventory was about 10.0 cfs.

The fish inventory in 1993 produced very different results as well. Speckled dace dominated the fish community (65 percent), followed by red shiner (27 percent). Both fishes were represented by all age classes. Desert suckers were common (10 percent) and were present as young or subadults. Eight flannelmouth suckers were collected; this species was not collected in previous surveys during this assessment. No other fishes were collected, and the western mosquitofish was not detected. Flooding had occurred for several days prior to the 1993 survey.

Outputs from PHABSIM included WUA's for five species and two to three life stages per species. In the case of

Virgin spinedace, two sets of SI curves were available. One set of SI curves was derived from habitat preference data collected in Beaver Dam Wash and other tributaries, and a second set of SI curves was derived from habitat preference data collected in the Virgin River. Only one set of SI curves were available for the other species.

Results for WUA's on spinedace show maximum habitat at 10 cfs for adult fish using SI curves for tributaries to the Virgin River. The optimal range of flows is between 6 and 20 cfs (Figure 30). WUA estimates produced using SI curves derived from Virgin River data were much lower, but showed the highest amounts of habitat at similar flows (Figure 31). This species was used to set required flow conditions, since it is clearly dependent on cool, clear tributary and spring flow, and is biologically imperiled in the lower half of the Virgin River.

Requirements for other species and life stages are provided in Table 10 and in Figures 32 through 35. Because the required flow range for spinedace overlaps the flow ranges for the other species, it is anticipated that flows that sustain the spinedace will sustain the other species using Beaver Dam Wash. An exception is adult Virgin River roundtail chub. The adult form of this fish shows increasing habitat with increased flow beyond the flows modeled. Because this fish requires large, slow, deep habitats, Beaver Dam Wash may never have enough flow to reach the point where habitat levels off or decreases with an incremental increase in flow. However, adult and juvenile chub have been collected in Beaver Dam Wash, which shows that it provides some habitat value to this species.

Warm-season water temperatures for Beaver Dam Wash and the Virgin River were compared from April 1990 to

Table 10. Required flows for the native fishes of Beaver Dam Wash, Mohave County, Arizona (in cfs).

Fish	Juvenile		Adult	
	Flow Max. WUA	Best Flow Range	Flow Max. WUA	Best Flow Range
Virgin spinedace tributary SI curves	N/A	N/A	10 cfs	6-20 cfs
Virgin spinedace Virgin River SI curves	N/A	N/A	20+ cfs	6-20 cfs
Virgin River roundtail chub	5 cfs	4-15 cfs	15+ cfs	7+ cfs
Speckled dace	4.5 cfs	3-12 cfs	4.5 cfs	3-10 cfs
Desert sucker	12 cfs	4-15 cfs	10 cfs	3-12 cfs
Flannelmouth sucker	12 cfs	4-15 cfs	12 cfs	5-15 cfs

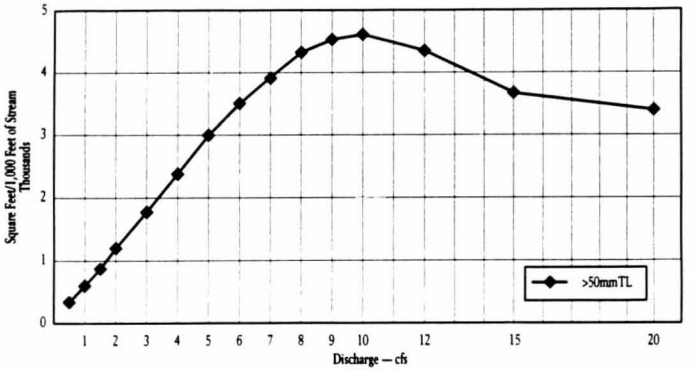


Figure 30. Beaver Dam Wash - weighted usable area: spinedace (tributary SI curves).

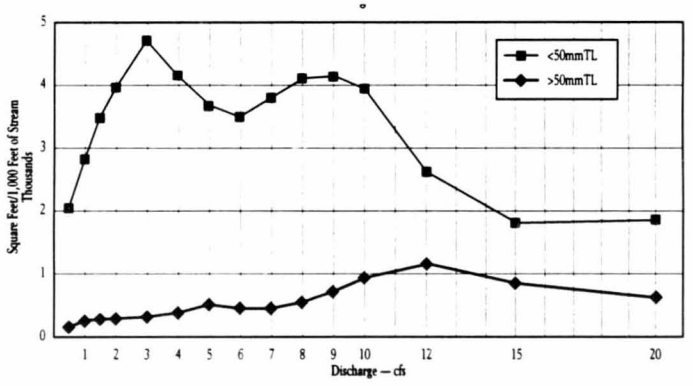


Figure 31. Beaver Dam Wash - weighted usable area: spinedace (Virgin River SI curves).

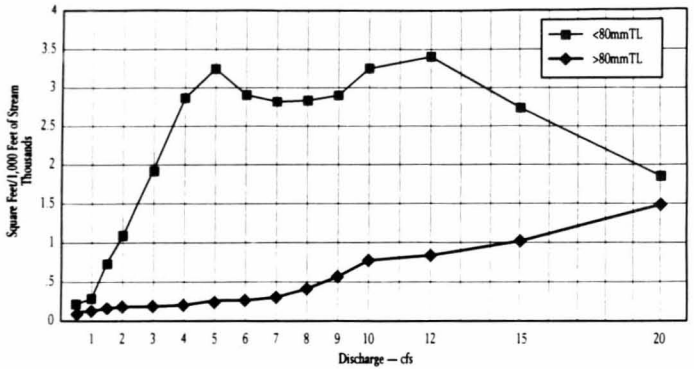


Figure 32. Beaver Dam Wash - weighted usable area: Virgin River roundtail chub.

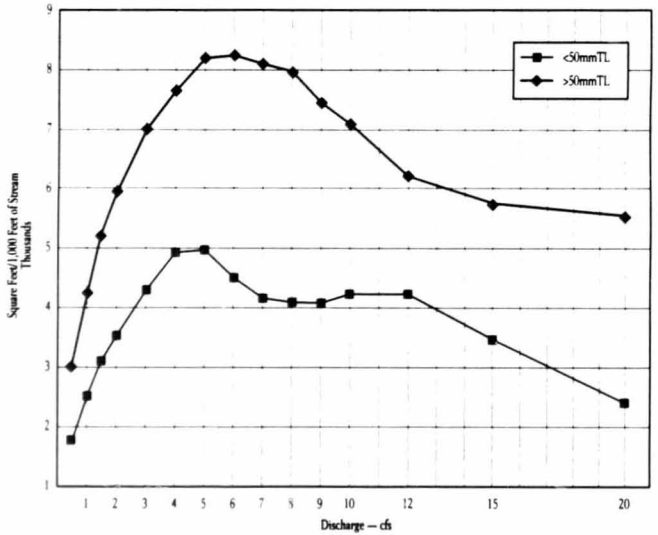


Figure 33. Beaver Dam Wash - weighted usable area: speckled dace.

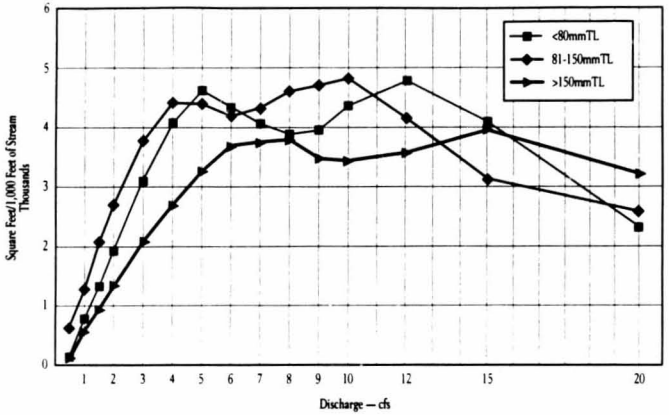


Figure 34. Beaver Dam Wash - weighted usable area: desert sucker.

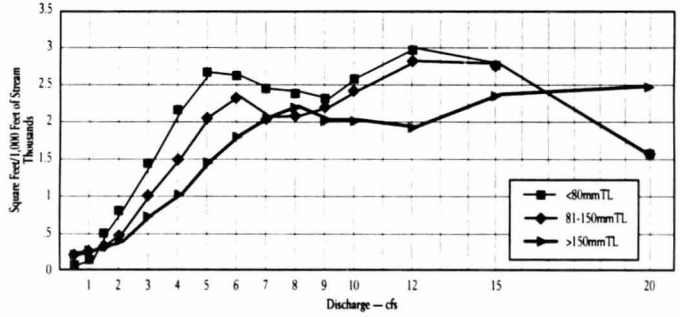


Figure 35. Beaver Dam Wash - weighted usable area: flannelmouth sucker.

October 1993 (Table 11). Prior to the large floods of 1992 and 1993, water temperatures in Beaver Dam Wash were consistently lower, averaging 3.9°C less than temperatures measured in the Virgin River. After the 1992 and 1993 floods, water temperatures often equaled or exceeded those of the Virgin River. The data collected indicates that the change in the temperature relationship between Beaver Dam Wash and the Virgin River is due largely to changes in channel morphology and vegetation shading after the 1992 and

Table 11. Water temperature data collected at Beaver Dam Wash and the adjacent portion of the Virgin River from April 1990 to October 1993.[1]

Date	Temperature Virgin River °C	Temperature Beaver Dam Wash °C	Temperature Difference °C
4-26-90	23.0	20.0	-3.0
5-16-90	25.0	20.5	-4.5
6-25-90	27.0	22.0	-5.0
7-31-90	26.5	21.0	-5.5
5-14-91	20.5	20.0	-0.5
7-15-91	27.0	18.5	-8.5
10-16-91	22.5	22.0	-0.5
4-15-92	18.9	24.4	+5.5
5-15-92	25.6	26.7	+1.1
6-17-92	24.4	25.6	+1.2
7-15-92	26.1	27.2	+1.1
8-17-92	27.2	26.1	-1.1
9-25-92	23.3	23.9	+0.6
10-15-92	22.8	23.9	+1.1
4-20-93	12.2	22.2	+10.0
5-1-93	18.3	25.6	+7.3
6-21-93	24.4	24.4	0.0
7-15-93	26.1	25.6	-0.5
8-31-93	27.0	26.0	-1.0
9-14-93	23.9	25.6	+1.7
10-15-93	18.9	22.2	+3.3

[1] A large flood occurred in March of 1992, resulting in loss of vegetation and alteration of channel morphology. Several larger floods occurred in January and February of 1993, resulting in even greater channel changes.

1993 floods. At no time during the 3 years in which temperature data was collected did any measured temperature approach the critical maximum temperature (Deacon et al. 1987) for any species of concern. However, without a continuous record of temperature, it is impossible to identify the frequency at which potentially lethal temperatures are approached or exceeded, since short-term events can influence water temperatures.

Fisheries Assessment

Beaver Dam Wash is a dynamic ecosystem subject to intense flooding from its own watershed and inundation from the Virgin River at flood stage. Periodically, large flood events will dramatically change the character of this stream segment, leaving the channel in a new position on the floodplain. As a result, the stream may become wide and shallow with a sand and gravel bottom. However, with time, the realigned channel will develop stable banks, vegetation, and increased fish-habitat diversity. The data collected shows that Beaver Dam Wash maintains a diverse, but temporally variable, fish community of both native and introduced species. The amount of water required for fisheries is for maintenance of physical habitat for native species in Beaver Dam Wash.

Beaver Dam Wash is valuable to the fishes of the Virgin River in several ways: 1) it supports five native fish species, 2) it likely supports stocks of these fishes that are tributary-adapted forms, 3) it provides refuge from catastrophic events that may affect the main stem of the Virgin River, 4) it provides thermal refuge for those species with lower heat tolerance, and 5) it provides a source of habitat with higher quality water than the Virgin River. The required flow of 6-20 cfs will support the Virgin spinedace with 3,500 to 4,500 square feet of habitat per 1,000 feet of stream. This volume of water is expected to support the other four species as well.

Providing water for an imperiled assemblage of native fishes is a fundamental step in maintaining viable populations of these sensitive species. Decreased discharge and poor water quality were suggested causes for the demise of a population of Virgin spinedace from a major portion of the Santa Clara River in Utah (Cross 1975). A decrease in existing streamflows in Beaver Dam Wash below those that occurred historically will increase variability in the system causing extremes in water quality (including temperature). These changes likely will decrease the suitability of this stream and the adjacent Virgin River for those fish species adapted to cooler, clearer waters. Thus, a significant reduction in flow from Beaver Dam Wash may decrease habitat potential for the local spinedace population. This would also have a negative impact on Virgin River roundtail chub and may reduce the potential for future reestablishment of woundfin.

Recreation

Resource Values

The perennial stream and outstanding riparian values associated with Beaver Dam Wash provide a number of recreational opportunities. However, current use of public lands surrounding the confluence with the Virgin River is limited by a number of factors. The user base is small, with less than 1,000 residents in the local communities of Beaver Dam, Littlefield, and Desert Springs in Arizona. Additional use occurs from residents in Mesquite, Nevada, and St. George, Utah, and occasionally from travelers along Interstate 15, although access is unmaintained and unsigned. Only 120 acres of public land surround the confluence, and the area is primitive and undeveloped. Thus, most recreational users are unaware of the opportunities that exist.

Statewide studies of recreation in Arizona rank riparian environments, such as the one associated with Beaver Dam Wash, as second only to developed sites for recreating within the state (Arizona State Parks Board and Arizona Outdoor Recreation Coordinating Commission 1992). Activities identified as most popular among state residents (hiking and picnicking) are readily available along Beaver Dam Wash, as are activities such as photography, which is popular along other desert streams (Moore et al. 1989). In addition, an estimated 50,000 to 100,000 visitors per year were projected for a proposed visitor center in the Virgin River Gorge about 7 miles from Beaver Dam Wash (Inside Outside Inc. 1992). Thus, recreational use of public lands along the Wash is expected to increase significantly as a result of public interest and management opportunities.

Public interest and special management designations for the Beaver Dam Wash confluence area are primarily related to the area's outstanding scenic values. Public land at the mouth of the Wash has recently been designated as a Riparian Demonstration and Recreation Area, with a need for interpretive trails for scientific and educational purposes (USDI-BLM 1992). Management goals identified for the confluence area include retaining scenic values, providing a variety of recreational opportunities, promoting public awareness of riverine ecosystem management, and managing recreational impacts (USDI-BLM 1992 and 1994). Site-specific plans for the area are in preliminary stages of development as a result of recent designation of the confluence as an ACEC.

Enjoyment of Nature

Recreational opportunities associated with the Wash are largely aesthetic in character. Normal streamflows do not support boating or recreational fishing, but instead provide a rare retreat for enjoyment of nature. Experiencing the elements through activities such as picnicking, hiking, photography, birdwatching, and wildlife observation is greatly enhanced by the stream and riparian environments. Riparian ecosystems like Beaver Dam Wash support a diversity of plant and animal communities that serve as a magnet for recreational use (Jackson et al. 1987).

Important aesthetic elements of the riparian environment include presence of shade; opportunity for solitude or feelings of remoteness; and perception of a natural ecosystem with diverse vegetation, wildlife, and geomorphic processes. Riparian vegetation provides shade for relief from extreme temperatures, an important consideration for recreation in the arid Southwest. On Beaver Dam Wash, where maximum daily temperatures meet or exceed 100 °F approximately 90 days per year, picnicking and day use are strongly dependent upon access to shade and the perennial stream. In addition, vegetation enhances opportunities for solitude and feelings of remoteness by screening adjacent developments and other recreational users. Riparian vegetation also influences structure and function of the stream ecosystem and is, in turn, influenced by the hydrologic and geomorphic processes of the stream.

Visitors to the area enjoy photography, birdwatching, and nature study in general. Because riparian communities support the greatest diversity of birds in the Southwest (Pase and Layser 1977), the area provides a rare opportunity for quality birdwatching. The riparian vegetation provides food, nesting, and cover to special status species, raptors, game, waterfowl, and nongame neotropical birds. Beaver Dam Wash also provides crucial habitat for many other wildlife species, including bats, beavers, bobcats, and fish. The value of this area to fish and wildlife is discussed at length in other sections of this report, but it is mentioned here because recreation opportunities such as wildlife observation and photography are activities enhanced by the aesthetics of this riparian environment.

The single most important feature contributing to the area's aesthetic beauty is likely the stream itself. The presence of a clear, babbling brook in the midst of this desert oasis completes the contrast and relief provided by the area from the stark, arid landscape surrounding it. Recreational users in desert canyons elsewhere in Arizona have ranked water as the most important element associated with the canyon settings (Moore et al. 1990). Indeed, the aesthetic value of moving water and its sounds are attributes common to all types of river recreation (Whittaker et al. 1993).

Not only does the presence of water affect aesthetic values associated with riparian environments, but quantity of flow also has been linked to public perceptions of scenic beauty. Brown and Daniel (1991) reported that flow levels alone accounted for 10 to 25 percent of the variability in perceptions of scenic beauty. In addition, recreationists in Aravaipa Canyon (southeast Arizona) were able to perceive very small changes in streamflow, with decreases as small as 1 cfs causing measurable decreases in user preference (Moore et al. 1989, Moore et al. 1990). Physical characteristics of low flows that diminish aesthetics of a stream include stagnant water; exposed rocky substrate and sandbars; decreased water quality; loss

of river features such as pools and riffles; and exposure of algae, scour lines, debris, or trash (Whittaker et al. 1993).

Several studies have been conducted to determine the relationship between aesthetic values and flow (Shelby et al. 1992, Fogg et al. 1992, Jackson et al. 1987). Generally, a parabolic relationship exists between flow quantity and recreation quality (Brown and Daniel 1991, Shelby et al. 1992), where low flows and high flows are unacceptable beyond certain points, detracting from scenic beauty or other recreational values. Brown and Daniel (1991) suggest recreational thresholds for low flows and high flows, with exposed riverbed decreasing scenic beauty and hazards associated with flooding detracting from user experiences. However, in Aravaipa Canyon, some users felt that flooding enhanced aesthetic values, as evidence of exciting natural processes (Moore et al. 1989).

Wading and Swimming

While riparian vegetation is important for recreation activities along Beaver Dam Wash, opportunities for direct interaction with water are important as well. There are paths and trails through the thick understory vegetation for exploring the area and accessing the streams. Hiking commonly occurs along these paths through "tunnels" in the vegetation, on floodplain terraces in the riparian zone, or within the stream channel on sand bars deposited by high flows. Stream depths are usually less than knee deep, causing little interference with travel. Crossing through the creek can be avoided, but most visitors eventually get wet. Thus, Beaver Dam Wash supports wading activities and is classified for full body contact under Arizona State water quality standards (ADEQ 1995). Occasionally, pools as deep as 4 feet may develop, allowing for full body immersion, but swimming per se is limited. However, smaller children have been observed laying, floating, and occasionally "swimming" in deeper waters and pools (Figure 36).

Several flow-related elements are important for the safety and pleasure of wading and swimming, but perhaps the most important criteria are stream

Figure 36. Recreational use of Beaver Dam Wash.

depth and velocity (Hyra 1978). Consequently, quantity of flow significantly affects quality of experience while wading or swimming. Sufficient stream depth is required for immersion and is created by physical relationships between quantity of streamflow and morphological features of the channel. Flow velocities are important elements for wading and swimming because the force of the water can exceed physical and safety limits of recreational users.

In addition, water quality may affect wading and swimming opportunities. Flow levels directly influence the water quality of a stream through simple dilution of contaminants. Generally, the more water present, the less potential there is for perceiving pollution (unless additional water supplies are also contaminated).

Potential for water quality degradation is high in the confluence area due to its location at the mouth of Beaver Dam Wash below all residential, commercial, and agricultural developments. The majority of developments are located within the floodplain of the Wash and have independent domestic wells and septic systems. An intensive survey of water quality in the Arizona portion of the Wash revealed increasing levels of dissolved solids, nitrite and nitrate, and chlorides between the Utah State line and the confluence. Although no water quality standards were violated, Cladophora glomerata, an algae which thrives in water with high levels of nitrogen, was much more prolific in reaches below areas of nutrient enrichment (ADEQ 1995). The stream is usually lined with algae, and occurrences of turbidity, oil, foul odors, and foam were observed during this assessment. Water quality degradation not only affects the perceptions of recreational users, but may have serious effects on wildlife and fish populations through increased levels of dissolved solids, nutrients, and algal growth.

Approach and Methods

The magnitude of recreational use on Beaver Dam Wash is limited. Historical user information is not available, and it is not currently practical to collect user information under existing management conditions. Traditional survey methods for evaluating user preferences were deemed impractical for the scope of this assessment. As a result, three approaches were used to assess aesthetics and recreation-related opportunities on Beaver Dam Wash: review of existing literature to determine recreation values and preferences that could be applied locally, determination of streamflow thresholds important to the maintenance of aesthetic values, and quantification of flow levels required for direct water-related activities, such as wading and swimming.

Methods used to quantify flow requirements associated with aesthetics and recreation opportunities were based on the premise that a parabolic relationship exists between streamflow and recreation value, where extreme high and low flows are unacceptable beyond a certain point because they diminish user satisfaction or enjoyment (Brown and Daniel 1991). This requires determination of specific water levels that provide an aesthetically pleasing

river channel, with flows adequate to: 1) cover the channel bed and substrate, 2) provide sufficient depth and velocity for the sight and sound of water, and 3) allow opportunities for direct interaction with the stream.

Aesthetic enjoyment of the Beaver Dam Wash confluence area is strongly linked to the condition of riparian resources along the stream. The rich diversity of aquatic and riparian species that are present during advanced stages of ecological succession greatly enhances the recreational experience. Thus, this analysis evaluates recreation attributes during advanced ecological conditions, when Beaver Dam Wash supports an incredibly dynamic and diverse ecology. Methods to determine flow requirements for fish and wildlife habitats generally support the evaluation of aesthetic qualities inasmuch as these resources contribute to the visitor's experience of the river.

Aesthetic experience of the river also is tied strongly to the sight and sound of streamflow in the channel. Because exposed streambed has been linked to decreasing scenic beauty in other desert streams of Arizona (Brown and Daniel 1991), a quantitative evaluation was developed to identify water levels that would provide a visually pleasing river scene without extensive areas of exposed streambed. The procedure utilized plots of submerged channel bottom versus discharge to identify flows that resulted in exposure of channel substrate.

Plots of submerged channel bottom (wetted perimeter) versus discharge were developed from field-surveyed cross sections and water surface slopes. Surveyed cross sections were plotted, and rating tables of water level (stage) versus discharge were developed as described previously (see Channel Morphology section). From the rating tables, plots of wetted perimeter versus discharge were used to determine the amount of submerged channel bottom at various flows. The plots provided a graphical indication of flows below which submerged bottom decreases and channel bed is exposed.

Quantification of flows related to wading and swimming involved more tangible types of attributes, such as depth and velocity requirements for enjoyment of the recreational opportunity. The literature review revealed a limited amount of information regarding depth and velocity preferences for wading and swimming; however, suitability criteria developed for small and medium streams by Hyra (1978) were deemed suitable for use on Beaver Dam Wash. Figure 37 provides an example of suitability criteria for swimming.

Hydraulic data from channel cross-section measurements and the stage-discharge rating tables described above were used to compare stream depths and velocities with the criteria developed by Hyra (1978). Plots of total and contiguous stream width with depths greater than some minimum value were particularly helpful for evaluating suitability of various flow levels for wading and swimming. Again the plots provided an indication of flows below which the stream becomes unacceptable for the activity.

Criteria

	Physical	Safety	Optimum
Depth			4 ft +
minimum	2.5 ft	3 ft	
maximum	NA	NA	
Velocity			0.25 - 0.75 fps
minimum	0 fps	0 fps	
maximum	3 fps	2 fps	

Comments: Water quality, temperature, slope of beach, visibility, and underwater slope are important considerations. Depth safety criteria does not permit diving.

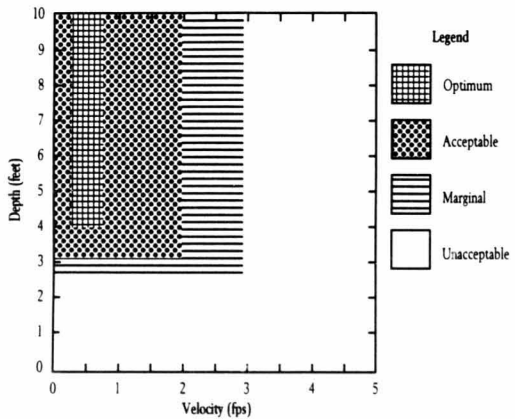


Figure 37. Water contact swimming criteria.

Analysis of Flow Requirements

Quantification of flows associated with recreation on Beaver Dam Wash includes evaluation of water needed to support both the aesthetics of the area and wading/swimming opportunities. As described previously, aesthetics of the area are influenced by both the general condition of riparian resources and the sight and sound of flowing water in this desert stream. The analysis of flows required to support aquatic species (fisheries) and terrestrial wildlife habitat (riparian vegetation) both support the recreational

assessment, because these resources are integral parts of the recreational setting.

In order to provide a visually pleasing river scene, extreme low flows exposing large areas of channel bottom should be avoided. To define the flow at which this begins to occur in Beaver Dam Wash, a plot of wetted perimeter (submerged bottom) versus discharge was constructed for reach-averaged hydraulic parameters. Reach-averaged hydraulic parameters (Table 12) were obtained by weighting individual cross-section hydraulics by the proportion of the total reach length occupied by that habitat type. The resulting plot of wetted perimeter versus discharge for the whole reach is shown in Figure 38.

Inspection of Figure 38 reveals that wetted perimeter changes very slowly with changes in flow at discharges greater than about 4 to 5 cfs. However, when discharge falls below 4 cfs, wetted perimeter begins to decrease more rapidly with each incremental loss of flow. Estimated stream widths at flows less than 1 cfs are reduced by more than 20 percent from widths associated with a 4-cfs flow. As flows fall below 4 cfs, edges of water begin to recede from channel banks, leaving an increasing percentage of the channel bottom

Table 12. Summary of average wetted perimeters for whole reach.

Discharge	Wetted Perimeter	Width	Width with Depth Greater Than:					Depth	C/S Area	Velocity
			0.25	0.50	1.00	1.50	2.00			
0.50	7.43	7.36	0.34	0.26	0.00	0.00	0.00	0.16	1.2	0.43
1.00	8.17	8.08	0.84	0.30	0.03	0.00	0.00	0.20	1.6	0.63
1.50	8.50	8.38	4.11	0.33	0.17	0.00	0.00	0.23	1.9	0.77
2.00	8.74	8.61	4.73	0.35	0.20	0.00	0.00	0.26	2.2	0.90
3.00	9.15	8.99	6.09	0.40	0.23	0.00	0.00	0.30	2.7	1.11
4.00	9.47	9.25	6.84	0.45	0.26	0.00	0.00	0.34	3.1	1.28
5.00	9.69	9.48	7.52	0.49	0.29	0.00	0.00	0.37	3.5	1.42
6.00	9.84	9.59	8.05	0.52	0.31	0.10	0.00	0.40	3.8	1.57
7.00	9.97	9.70	8.27	1.05	0.33	0.17	0.00	0.43	4.1	1.69
8.00	10.10	9.81	8.49	4.24	0.35	0.19	0.00	0.45	4.5	1.80
9.00	10.18	9.88	8.64	4.65	0.37	0.21	0.00	0.47	4.7	1.93
10.00	10.30	9.97	8.83	5.21	0.39	0.22	0.00	0.50	5.0	2.02
12.00	10.50	10.15	9.11	6.35	0.43	0.25	0.00	0.53	5.4	2.22
15.00	10.82	10.42	9.47	7.41	0.49	0.29	0.00	0.58	6.1	2.47
20.00	11.25	10.79	9.79	8.39	0.56	0.35	0.19	0.65	7.0	2.86

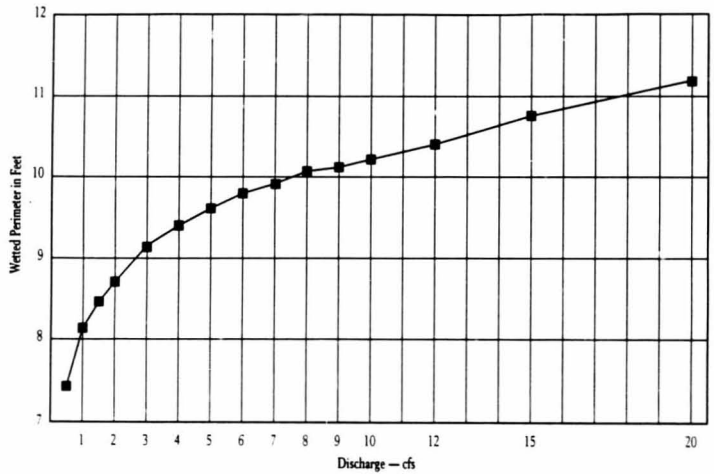


Figure 38. Beaver Dam Wash wetted perimeter versus discharge (summary of whole reach).

exposed. Because exposed channel bottom has been linked to decreasing scenic beauty in streams (Brown and Daniel 1991), required flows for maintaining the scenic beauty of Beaver Dam Wash are estimated at 4 cfs.

The aesthetic qualities of Beaver Dam Wash also are dependent upon periodic high flows to maintain the character of the stream. As described previously, flood flows are the driving force for natural morphological processes associated with aquatic and riparian ecosystems. Estimates of flood magnitudes required to maintain these processes were discussed in the Channel Morphology section.

In contrast with recreation opportunities associated with the area's scenic beauty (e.g., picnicking, photography, or birdwatching), wading in Beaver Dam Wash is a recreational activity that involves direct interaction with the stream. Quantification of flows required for wading was based on suitability criteria proposed by Hyra (1978) for small- and medium-sized streams. Figure 39 is a two-dimensional representation of depth-velocity combinations that are considered optimal, acceptable, marginal, and unacceptable for wading.

Figure 39 reveals that wading is an activity that requires a minimum depth of water. Minimum depths for wading proposed by Hyra (1978) are 0.25 feet for marginal conditions, 0.5 feet for acceptable conditions, and 0.75 feet for optimum conditions. Velocities don't start to affect wading opportunities until deeper flows are combined with fast water (2.5-3.0 fps). Table 12 shows maximum velocities of 2.5-3.0 fps are not a factor on Beaver Dam Wash until 15-20 cfs, which would represent an upper threshold for wading activities. Hyra also suggests a minimum velocity of .25 fps to provide optimum conditions for both wading and swimming activities.

Criteria

	Physical	Safety	Optimum
Depth			0.75 - 2.5 ft
minimum	0.25 ft	0.5 ft	
maximum	4 ft	3 ft	
Velocity			0.25 - 2.0 fps
minimum	0 fps	0 fps	
maximum	3 fps	2.5 fps	

Comments: Depth in feet multiplied by velocity in fps should equal 10 or less. Safety depends upon height and weight of individual as well as substrate type.

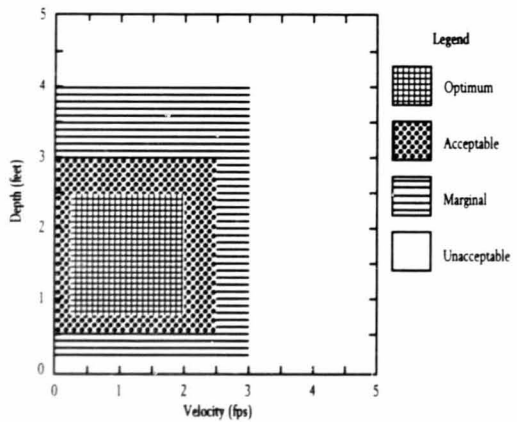


Figure 39. Water contact wading criteria.

Application of minimum wading depth criteria to modeled, reach-averaged hydraulic parameters for Beaver Dam Wash is shown in Figure 40. In this figure, the width of the stream is an indicator of the usable area available for wading opportunities. In addition to total stream width, Figure 40 depicts the width of stream with depth greater than the minimum criteria for marginal and acceptable wading conditions (>.25 and >.50 feet). For marginal conditions, width of stream suitable for wading starts decreasing as flows fall below about 6 cfs, with suitability for wading dropping steeply at flows below about 1.5 to 3 cfs. For acceptable conditions, width of stream suitable for wading drops steeply at flows below about 8 cfs. Thus, required flows for acceptable wading conditions are estimated at about 8 cfs, and required flows for marginal wading conditions are estimated at about 1.5 to 6 cfs.

Similar evaluations of depth and velocity versus suitability criteria could be used to analyze swimming opportunities on Beaver Dam Wash (see Figure 37). However, for swimming to occur, stream depth needs to be great enough to accommodate total body immersion. Suitability criteria from Hyra (1978) indicate minimum depths of 2.5 feet are necessary for swimming. Depth/discharge data (Table 12) for Beaver Dam Wash indicate such depths do not exist below 20 cfs, after which velocities become too extreme for normal swimming experiences. Obviously, the physical setting of Beaver Dam Wash has limitations that generally restrict

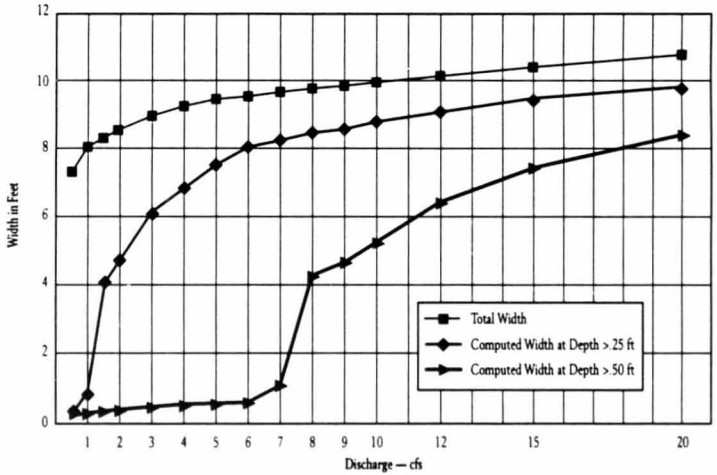


Figure 40. Beaver Dam Wash - total and computed widths for averaged reach.

true swimming opportunities, but flows between 9 and 20 cfs might provide some marginal conditions for swimming in small pools.

Recreation Assessment

The recreational value of Beaver Dam Wash relies on the aesthetics associated with a moving stream and its surrounding high-quality riparian and wildlife habitat, as well as direct contact with the stream itself. In Beaver Dam Wash, flows required to maintain a visually pleasing stream with little exposed substrate are estimated at 4 cfs. Stream conditions required to enjoy marginal wading opportunities exist between 1.5 and 6 cfs, with more acceptable conditions occurring at 8 cfs. Adequate depths necessary to participate in limited swimming opportunities exist between 9 and 20 cfs.

Wildlife Habitat (Riparian Resources)

Resource Values

Streamflows in Beaver Dam Wash provide drinking water and support crucial habitat for a variety of wildlife, including bats, leopard frogs, neotropical migratory birds, beavers, and herons, and many special status species, including common black hawks and belted kingfishers. Riparian resources in Beaver Dam Wash support 49 species of mammals and 44 species of reptiles and amphibians. Table 13 lists sensitive animal species that occur or may occur along Beaver Dam Wash and have received State and/or Federal designation as special status species. Management goals for this area include protection of existing wildlife resources and preservation of instream flows for flow-dependent values.

Wildlife Species and Habitat Requiremenis

Reptiles, amphibians, and mammals have specific habitat requirements associated with riparian and aquatic ecosystems. Riparian environments provide greater vegetative diversity and ecotonal benefits than surrounding upland areas, especially in the desert Southwest. Up to 60 percent of vertebrates in arid regions are found exclusively in riparian habitats (Ohmart and Anderson 1986). For example, beaver require abundant quantities of young cottonwood and willow and perennial flow with depths of 3 feet or more for food and dam/lodge construction (Ohmart and Anderson 1986). However, due to severity of hydrologic events in the region, beavers and muskrats commonly construct dams in side channels and tributaries with lower velocities and more stable channels, or excavate dens in streambanks under overhanging roots (Figure 41). Other species, such as fringe-tail and California leaf-nose bats, use mature riparian vegetation for roosting sites and require an abundant source of insect prey. Amphibious species, such as frogs, depend upon moist vegetation and standing water in ponds and wetlands for food and shelter. Habitat needs such as these are abundant in the riparian ecosystem associated with Beaver Dam Wash.

Table 13. State and/or Federally listed special status animal species that occur or may occur in Beaver Dam Wash.

Common Name	Scientific Name	Species Status*
	Birds	
Peregrine Falcon	*Falco peregrinus anatum*	FE - WSCA
Bald Eagle	*Haliaeetus leucocephalus*	FT - WSCA
Snowy Egret	*Egretta thula*	NL - WSCA
Willow Flycatcher	*Empidonax trailii extimus*	FE - WSCA
American Bittern	*Botaurus lentiginosus*	NL - WSCA
Yellow-Billed Cuckoo	*Coccyzus americanus*	NL - WSCA
Common Black Hawk	*Buteogallus anthracinus*	NL - WSCA
Belted Kingfisher	*Ceryle alcyon*	NL - WSCA
	Mammals	
Red Bat	*Lasiurus borealis*	NL - WSCA
	Amphibians	
Relict Leopard Frog	*Rana onca*	NL - WSCA
Northern Leopard Frog	*Rana pipiens*	NL - WSCA
	Reptiles	
Desert Tortoise	*Xerobates (=Gopherus) agassizii*	FT - WSCA
	Fish	
Woundfin Minnow	*Plagopterus argentissimus*	FE - WSCA
Virgin River Chub	*Gila seminuda*	FE - WSCA
Virgin River Spinedace	*Lepidomeda mollispinis mollispinis*	CA - WSCA
Flannelmouth Sucker	*Catostomus latipinnis*	NL - WSCA

* FE = Federal Endangered Species; FT = Federal Threatened Species; NL = Not Listed; WSCA = Wildlife of Special Concern in Arizona; CA = Conservation Agreement in Lieu of Listing

Figure 41. Exposed beaver dam in bank.

In addition, Beaver Dam Wash provides avian habitats that are unavailable elsewhere along the lower Virgin River, where only dense stands of tamarisk normally line the floodplain. Such tamarisk has been characterized as generally poor habitat for wildlife, particularly compared to other mixed-vegetation types (Kasprzyk and Bryant 1989), and Riffey (1979 and 1980) reported that tamarisk along the Virgin River was generally less productive for birds. There are 248 bird species that potentially occur along Beaver Dam Wash, including the common black hawk, Bell's vireo, belted kingfisher, killdeer, and ducks. Many of these species, such as the common black hawk, have specific habitat requirements with respect to cottonwood-willow ecosystems, and several species, such as the yellow-billed cuckoo and summer tanager, survive only in these forest types (Table 14). Cottonwood-willow ecosystems support the highest densities of breeding birds of any habitat type in Arizona, and studies show a direct linear relationship between number of nesting birds and number of mature cottonwood trees per acre (Johnson 1971, Carothers and Johnson 1971 and 1975, Johnson and Carothers 1982, Pase and Layser 1977). In addition, the complexity, diversity, and vertical structure of cottonwood-willow forests and their understory provide niche partitioning for many bird species (Stromberg 1993).

Thus, wildlife are critically dependent upon riparian resources for many life-supporting functions. The various components of riparian and aquatic communities provide wildlife with defense or escape cover; food, water, or prey sources; temperature regulation; and feeding, reproduction, nesting, and resting areas (AGFD 1993, Jones 1986). Maintenance of these riparian communities requires flow regimes that provide adequate supplies of water and conditions for regeneration of riparian plant communities. Although the

Table 14. Birds of Beaver Dam Wash and their habitat preferences.

Species	Habitat Preferences	Activities
Common Black Hawk	Mature Cottonwood Stands	Nesting
Phainopepla	Mesquite/mistletoe	Feeding
Verdin	Mesquite	Nesting
Yellow-Billed Cuckoo	Mature Cottonwoods, Dense Understory	Sightings
Bewicks Wren, Ash-Throated Flycatcher	Mature Cottonwood - Willow Cavities	Nesting
Bell's Vireo	Cottonwood - Marsh Ecotones	Nesting
Killdeer	Rocky Floodplains	"Nesting"
Ladder-Backed Woodpecker	Dead Snags	Nesting
Belted Kingfisher	Perennial Streams	Feeding
Abert's Towhee	Flood Debris and Understory Brush	Nesting
Spotted Sandpiper	Marshes and Lagoons	Feeding
Red-Winged Blackbird	Cattails	Nesting
Summer Tanager	Cottonwood-Willow Canopies	Feeding, Nesting

riparian area at the mouth of Beaver Dam Wash is relatively small in size (about 21.2 acres), it contains a very diverse mixture of these habitats, species, and communities.

Riparian Communities and Complexes

A 1993 field survey identified a mosaic of 24 riparian communities occurring near the confluence of Beaver Dam Wash and the Virgin River. Because of the great diversity of communities near the confluence, riparian vegetation was grouped into four community complexes. These complexes were primarily defined by vegetation, but included associated species of wildlife and other biotic life. The complexes identified were: 1) mature riparian woodland, 2) mixed shrub-tree and understory, 3) wetland, and 4) early successional communities. Table 15 lists the four complexes, with associated plant

Table 15. Beaver Dam Wash study area vegetation complexes and associated information.

Description of Complex	Communities	Area Acres (percent)	Dominant Vegetation Layers* (feet)
Mature riparian (late successional) woodland: high habitat diversity, including multilayering of short, medium, and tall vegetation for variety of cover and food.	1) Cottonwood 2) Willow 3) Mixed willow/cottonwood 4) Cottonwood/willow wetland understory	6.7 (31.6)	A 30-80 B 10-20 C 3-10 D 1-3
Mixed shrub-tree and understory: moderate habitat diversity, except for pure stands of tamarisk with little understory.	1) Cottonwood/arrowweed understory 2) Willow/tamarisk understory 3) Cottonwood/ Russian olive understory 4) Mixed cottonwood/tamarisk 5) Mixed tamarisk/willow 6) Mixed willow/arrowweed 7) Mixed cottonwood/willow/ arrowweed	9.1 (42.9)	B 10-20 A 10-20
Wetland: low habitat diversity, predominantly obligate wetland species.	1) Cattail 2) Wetland/cattail 3) Mesquite wetland	0.3 (1.4)	D <8 B 5-15
Early successional: moderate habitat diversity with combination of mixed shrub and invader species	1) Arrowweed 2) Tamarisk 3) Grass 4) Tamarisk/arroweed understory 5) Arrowweed/mixed shrub 6) Russian olive 7) Mesquite 8) Creosote/grass understory 9) Atriplex 10) Mixed arrowweed/mesquite	5.0 (23.6)	C 3-8 B 6-12

* Codes for vegetation layers: A-cottonwood and willow; B-tamarisk, mesquite, and Russian olive; C-seepwillow and arrowweed; D-cattail and sedges.

communities and other characteristics. In a general sense, the biodiversity and habitat value of these four vegetation/biotic complexes decrease from the higher successional types (mature riparian woodland) to the lower successional types (early successional).

Riparian Ecology

Riparian communities in all the complexes identified above require water sufficient to maintain growth and vigor of community vegetation. Extended base flows during the growing season interact with available ground water to sustain this riparian vegetation throughout the confluence area. Use of water varies considerably by plant species and conditions in which the plants are growing. Important controlling variables are temperature, humidity, and wind movement (climatic variables); density, life stage, and vigor of the plants (biological variables); and depth to water, water availability, and others (hydrologic variables). Table 16 lists estimates of annual water use for major vegetation communities occurring near the confluence. The wide range in water use estimates for some species results from the variety of environmental conditions controlling evapotranspiration and the difficulty of accurately measuring water use, even in controlled studies.

The true wetland communities identified in the field survey are generally found in two environments. Lentic wetland communities are associated with ponded water and generally occur where depressions in the land surface intersect a very shallow water table. Maintenance of these communities requires maintenance of the water table. Lotic wetland communities are associated with flowing water and generally occur along the bed and banks of Beaver Dam Wash. Maintenance of these communities requires flows sufficient to support rooted aquatic plants

Table 16. Approximate annual rates of water use (adapted from Muckel 1966, Horton and Campbell 1974, and Kasprzyk and Bryant 1989).

Species	Acre-Feet Per Acre	Locality and Source
Cottonwood	5.0-6.0	Safford Valley, AZ and San Luis Rey Valley, CA
	3.6	Cottonwood Wash (Northwest AZ)
Willows	4.5	Santa Ana, CA
Wet meadow grasses	1.5	Humboldt River, NV
Saltgrass	0.8-4.0	Depending on depth to water table and location
Tamarisk	7.0-9.2	Safford Valley, AZ
		Also noted a position correlation to water depth
	7.5-12.0	Lower Virgin
Mesquite-burrobrush	1.1	Sycamore Creek (Maricopa Co., AZ)
Mesquite	1.8	Agua Fria

(e.g., watercress) within the main channel and obligate wetland plants (e.g., cattails) along the channel margin.

Distribution of riparian complexes and communities is strongly controlled by depth to water and soil characteristics in the assessment area. The soils of Beaver Dam Wash have been identified and mapped as predominantly Black Butte silt loam and Vinton fine sandy loam (Bagley 1980). Both are well-drained soils found on floodplains and low terraces, with water tables 4 to 6 feet in depth near the confluence. The Black Butte silt loam contains inclusions of river wash and is a deep soil found on floodplains of mixed parent materials. It is moderately permeable and has a moderate water-holding capacity. It is rarely flooded, but has a 4- to 5-foot depth to water from March through September. The Vinton fine sandy loam is a deep, moderate- to well-drained soil on floodplains and low terraces. It is occasionally wet and slightly saline. Permeability is high, and water-holding capacity is low to moderate. Soil moisture availability to plant roots depends on soil texture, structure, and soil water tension. Silty and clayey soils have good water-holding capacity and greater capillarity compared to the coarser textured sands and gravel. Thus, cottonwood and other species located near the confluence of Beaver Dam Wash may survive temporary declines in the water table better than trees located in areas with coarser textured soils.

Table 17 relates riparian-community vegetation types to stand age (as reflected by diameter breast height), and root depth to water. Cottonwood and willows depend on continuously available shallow ground water and surface soil moisture for survival in their early life stages (Fenner et al. 1984, Johnson et al. 1976). As they get older, they may tolerate longer periods with less water, but still must have water available to root systems during much of the year. Heavy mortality of cotton-

Table 17. Species relationships to water sources (adapted from Jackson et al. 1987 and Horton and Campbell 1974).

Species	Diameter Breast High (inches)	Root Depth to Water (feet)
Cottonwood	1-3	1-7.5
	4-15	2.5-8
	16-24	6-13
	25-88	5-27
Willow	1-3	3-7.5
	10-18	7.5-9.5
Seepwillow	5.5	4-10
Mesquite		6-10, 0-20
Tamarisk		8-10

wood has been attributed to drought and extreme low flows elsewhere in Arizona (McNatt et al. 1980).

Tamarisk is more tolerant of drought conditions and may not become established where water is near the surface. If depth to water is less than about 5 feet, tamarisk does not develop dense stands, and intershrub spaces are usually dominated by saltgrass or bermudagrass. A lowering water table in such areas will allow the tamarisk to grow dramatically and replace the grasses (Horton 1977). Similarly, tamarisk does not develop dense stands where the water table is greater than about 15 to 20 feet below the surface. Hence, declining water tables in some areas have reduced viability of tamarisk stands, apparently because the ground water was beyond the reach of plant roots (Campbell and Dick-Peddie 1964).

Mesquite likely is the riparian species that is most tolerant of drought conditions. It occurs primarily on abandoned floodplains (stream terraces) elevated above the current water level and somewhat away from the channel. Mesquite has been reported to root to depths of 175 feet in extreme cases, but more commonly to depths of 25 feet or less (Laney and Hjalmarson 1977).

Distribution of riparian communities and complexes also may be influenced by chemical quality of the soil water. Cottonwoods have a relatively low salinity tolerance and do not survive well when salinity concentrations in available soil water are greater than about 2,000 milligrams per liter. Tamarisk is tolerant of much higher salinities (Krzysik 1990) and has a salt-concentrating mechanism called guttation that increases soil salinity in the vicinity of the roots. Thus, riparian complexes and communities along Beaver Dam Wash that lack a significant component of tamarisk are more dependent on good water quality for both seed germination (Table 18) and plant growth.

Table 18. Optimal conditions for germination of seeds of selected Southwest woody riparian species (adapted from Siegel and Brock 1990 and Fenner et al. 1984).

Species	Optimal Germination Response
Velvet mesquite	10° to 38°C 0 to -4 bars water stress 0 to >100 meq/l salinity pH 4 through 10 Many years seed viability
Gooding willow	21° to 27°C 0 to -2 bars water stress 0 to >100 meq/l salinity pH 6 to 7 10 week seed viability
Fremont cottonwood	16° to 21°C 0 to -4 bars water stress 0 to >50 meq/l salinity pH 5 to 7 20 week seed viability

Flood events on both the Virgin River and Beaver Dam Wash influence the regeneration of riparian communities near the confluence. Flooding creates conditions favorable for reproduction of certain riparian species, but successful regeneration depends upon a proper sequence of events (i.e., after flood deposits have created a suitable seed bed, there must be no additional catastrophic floods until stands are well-developed). An example of the development of riparian gallery forests has been described as beginning with fresh sediment deposits in overflow channels, abandoned meanders, and point bars that provide moist areas for seepwillow to pioneer. Seepwillow requires a sustained flow for germination and seedling establishment, and because of its shallow root system, is confined to sites with shallow ground water. As water levels drop, seepwillow is adversely affected, and deeper rooted species begin to dominate the site (Laney and Hjalmarson 1977). Sediment aggradation occurs as the seepwillow matures, providing a seed bed for cottonwood or the spreading of willow roots from adjacent areas (Brady et al. 1985). Thus, seed production and viability, root growth rates, distance from channel, and timing of flood events are important considerations in community development and successional processes.

Seed production of riparian species found along Beaver Dam Wash varies greatly by species and season. In southeast Arizona, Warren and Turner (1975) reported cottonwood seed production from mid-March to mid-April, and tamarisk and seepwillow seed production from early May to mid-October. On the Salt River near Tempe, Horton et al. (1960) reported cottonwood seed production only in April, tamarisk seed production from April to October, and seepwillow seed production in spring and fall, but not summer. Cottonwood seed production in the upper Gila River basin (Arizona and New Mexico) occurred slightly later (May and June), likely because these sites were much higher in elevation (Brock 1994). At Beaver Dam Wash, cottonwood seed production usually occurs in April and May, and tamarisk seed is generally available from late spring into early fall.

Physical requirements for germination of cottonwood are fairly restrictive. Cottonwood seeds must germinate within 1 to 5 weeks after dispersal or lose viability; thus, the seeds must encounter fresh deposits of moist sediment during the short period of seedfall in the spring. Establishment of cottonwood seedlings requires that roots reach a minimum depth of 500 mm (19.7 in.) during the first year (Pope 1984). Root growth rates of 6 to 7 millimeters per day are reported in the literature (Pope 1984, Fenner et al. 1984); thus, about 70 to 80 days are required for roots to attain sufficient depth to access adequate water supplies for future growth. During this period, roots must remain in contact with soil containing readily available moisture (Fenner et al. 1984). If soil drying is too rapid and root growth cannot keep pace with receding water levels, the seedlings will die.

A high rate of seed production and an effective means of dissemination help

explain the rapid spread of tamarisk and its domination of many riparian habitats (Warner and Turner 1975). Tamarisk seed often germinates while floating on the water, then roots and establishes with receding waters when it comes to rest upon moist substrate. Fresh seed germinates rapidly, generally in less than 24 hours. Seeds of tamarisk require prolonged moisture supply for germination and subsequent establishment, and retain their viability for only a few weeks (Horton et al. 1960). If short-lived seeds do not encounter a wet situation within this brief period, establishment fails. Survival is dependent upon saturated soils during the first 2 to 4 weeks of growth. Tamarisk seedlings tend to become established along channels during slowly receding spring runoff that coincides with periods of high seed production. Rapidly receding flows following late summer thunderstorms are less favorable for seedling establishment, especially during hot weather when the banks dry out quickly. Thus, the timing of seed and moisture availability is critical.

Approach and Methods

A reconnaissance survey of vegetation and biotic communities at the confluence of Beaver Dam Wash and the Virgin River was completed as a first step toward determining flow needs for wildlife riparian habitat. The reconnaissance was a combination of aerial photo interpretation and field survey of the site. The biotic communities, their extent, and conditions were noted. Age-class structure was not specifically noted, but some assumptions could be made based on size of trees and history of the site.

The reconnaissance survey was followed by an extensive literature search to document ecological requirements of species and communities occurring at the confluence. In particular, information was obtained concerning ecological requirements directly related to hydrology of the stream and associated ground water. Consumptive water use and depth-to-water relationships were especially useful for relating habitat needs to streamflows in Beaver Dam Wash. Depth of water for rooted aquatic macrophytes was important for assessment of low flows, and substrate requirements for successful reproduction of riparian species were a consideration for evaluation of high flows. Indications are that quality of soil water at a site also may influence distribution and health of riparian species.

Estimates of water consumed by vegetation at the confluence of Beaver Dam Wash and the Virgin River were deemed of high importance because of the valuable habitat provided for wildlife by this vegetation. Evapotranspiration rates obtained from the literature were used to estimate water use by the various communities comprising the riparian ecosystem. Annual water use for the entire area was estimated by summing water use attributed to each of the communities. Evapotranspiration by the riparian community represents a consumption of local ground water in direct connection with the stream.

Connection of the stream with the local water table required that estimated annual water use by evapotranspiration be converted to a rate of streamflow that would offset drafts on the ground water. Annual evapotranspiration estimated for the entire area was apportioned throughout the calendar year according to published records of measured evaporation rates near St. George, Utah, and Las Vegas, Nevada. Maximum streamflow requirements for Beaver Dam Wash were obtained by converting the highest monthly evapotranspiration rate from acre-feet per month to cubic feet per second.

The presence of rooted aquatic macrophytes in Beaver Dam Wash required an assessment of habitat availability versus streamflow for the lower end of the flow range. The analysis used plots of wetted perimeter (submerged channel width) versus discharge to identify flows below which submerged channel bottom decreased significantly. The analysis was essentially identical to the analysis of exposed channel bottom that was conducted for evaluating aesthetic impacts of very low flows. Details of the methodology are discussed in the Recreation section.

The physical link between ground-water levels in the alluvium and streamflow in Beaver Dam Wash also required documentation to establish the interconnectedness of the system. Thus, six well points were installed in 1990 to monitor depth to water in the alluvium throughout the natural range of streamflow. Depth to water was monitored monthly for the duration of the assessment in conjunction with monthly flow measurements at the mouth of the Wash. Plots of monthly flow and ground-water levels were then analyzed for similarities or differences. In addition, an attempt was made to relate distribution of riparian community types to water levels in the alluvium.

Chemical quality (especially salinity) of ground water may also affect distribution and viability of riparian communities near the confluence. Salinity of the Virgin River is much greater than that of Beaver Dam Wash, a phenomenon that is reflected in the chemical quality of ground water in the alluvium along these two streams. In addition to monitoring water levels in the area, electrical conductivity was monitored at the well points in an attempt to identify relationships between ground-water quality near the confluence, water levels in the alluvium, and streamflow in Beaver Dam Wash.

Several riparian species that provide valuable wildlife habitat are dependent on high flows to produce suitable sites and moisture regimes for successful regeneration. Physical processes of scour and fill that occur during flood events are important considerations for maintaining these communities. Thus, high flows were subjected to hydraulic analysis to determine minimum flows necessary to initiate channel scour and fill. Hydraulic analysis focused on identification of bankfull flows, which must be exceeded to initiate these processes. Details of the analysis were discussed in the Channel Morphology section.

Analysis of Flow Requirements

The reconnaissance survey of vegetation and biotic communities at Beaver Dam Wash identified four riparian-community complexes providing wildlife habitat values (Table 15). These communities were defined primarily on the basis of dominant plant species. The literature review provided a great deal of information regarding ecology of the dominant species, especially as it relates to the hydrology of the area. In particular, information on evapotranspiration rates, depth-to-water requirements, salinity tolerances, and substrate requirements was useful for relating habitat values to streamflows in Beaver Dam Wash.

Evapotranspiration rates were estimated for the four community complexes on the basis of published evapotranspiration data for the dominant species in each complex. Table 19 presents estimated annual water use by complex, as well as total evapotranspiration estimated for the entire area. Total annual water use is not evenly distributed throughout the year, but is greatest during the summer months when evapotranspiration is at a maximum during peak photosynthetic activity. Thus, annual water use was distributed throughout the year on the basis of monthly evaporation rates at the nearest recording locations. Data from St. George, Utah, and Las Vegas, Nevada, reveal that peak monthly evaporation rates during the summer account for roughly 15 to 19 percent of the total annual evaporation at those sites. Assuming a similar temporal distribution of evapotranspiration at the Beaver Dam Wash confluence, approximately 15.5 to 19.6 acre-feet of water are consumed by riparian habitats each month during the hottest part of the summer. Assuming temporarily that all water consumed by riparian habitats is contributed from Beaver Dam Wash streamflow, peak summer evapotranspiration converts to a flow rate of about 0.3 cfs, which would be the minimum flow needed to meet consumptive requirements of the riparian habitat.

Table 19. Evapotranspiration (ET) rates for lower Beaver Dam Wash riparian vegetation.

Complex	Area (acres)	ET (ft/yr)*	Species	ET (ac-ft/yr)
Mature riparian	6.7	4.5	Fremont's cottonwood	30.2
		(3.6-6.0)	Gooding willow	
			Sandbar willow	
Mixed shrub	9.1	5.0	Cottonwood	45.5
		(4.5-12.0)	Arrowweed	
			Willow	
			Tamarisk	
			Russian olive	
Wetland	0.3	NS	Cattail	NS
			Reed	
			Three-square bulrush	
			Tamarisk	
			Mesquite	
Early successional	5.0	5.5	Tamarisk	27.5
		(1.0-7.0)	Russian olive	
			Arrowweed	
			Mesquite	
			Seepwillow	
			Creosote	
			Atriplex	
			Grasses	
			TOTAL ET	103.2

* Values in parentheses are ranges of ET rates found in the literature.
NS Not significant.

Of the four riparian-community complexes described for this area, the wetland complex has the greatest dependence on flows in the Wash, especially in the lotic habitats along the channel bed and banks. Loss of streamflow in Beaver Dam Wash would have immediate and direct impacts on obligate wetland species in these locations. Because severity of low flows will determine degree of desiccation for many of these obligate species (e.g., watercress), the analysis attempted to identify flows at which the edge of water recedes from channel margins. The analysis is identical to that described in the Recreation section for assessing aesthetic impacts of low flows. From that analysis, it was determined that edge of water begins to recede from channel margins at flows less than about 4 cfs; thus, about 4 cfs is the minimum flow required to protect obligate wetland species occurring along the bed and banks of Beaver Dam Wash.

Other riparian community complexes also are dependent upon streamflow in Beaver Dam Wash, both because of physical and chemical connection of alluvial ground water with the stream, and because of dynamic channel-adjustment processes that provide a variety of microhabitats for riparian regeneration. Figure 42 depicts the location of well points installed to measure water levels and electrical conductivity of ground water during the course of the assessment. Well point #1 was located immediately adjacent to the original channel and was destroyed by floods in January 1993. The remaining well points documented the hydraulic connection between alluvial ground-water levels and surface flows in the Wash and provided interesting insights for interpretation of the site's hydrology.

The relationship between Beaver Dam Wash streamflows and water levels in the alluvium is illustrated in Figures 43 and 44. Figure 43 depicts discharge measurements made at the mouth of the Wash, and Figure 44 depicts depth to water at the well points on the same days as the discharge measurements. It is apparent from the plots that depth to water in the well points fluctuates annually in phase with streamflow in Beaver Dam Wash. Highest base flows in the Wash usually occur in spring

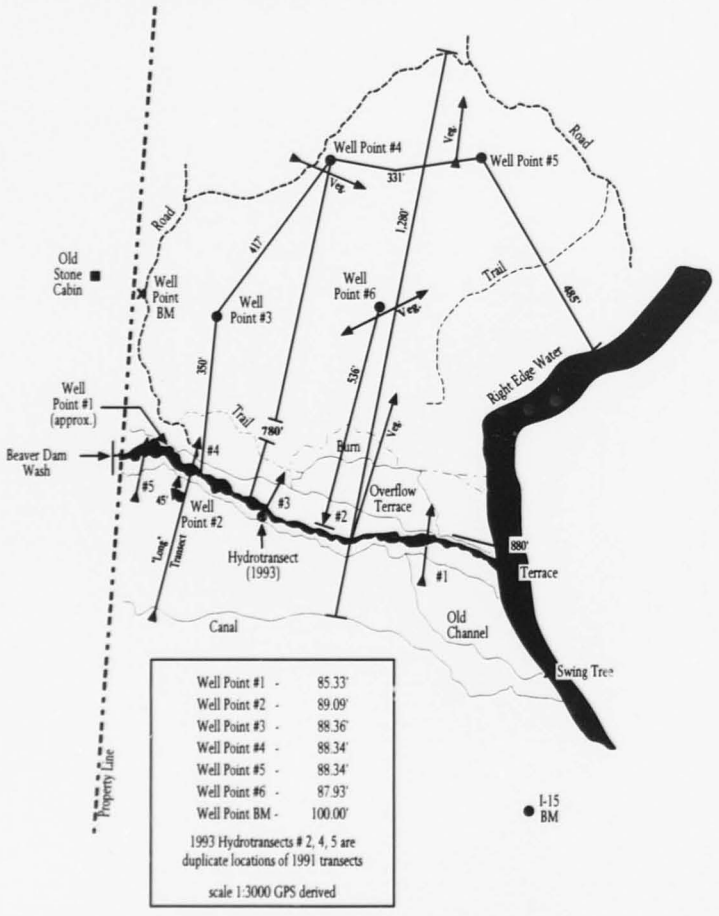


Figure 42. Vegetation transects map.

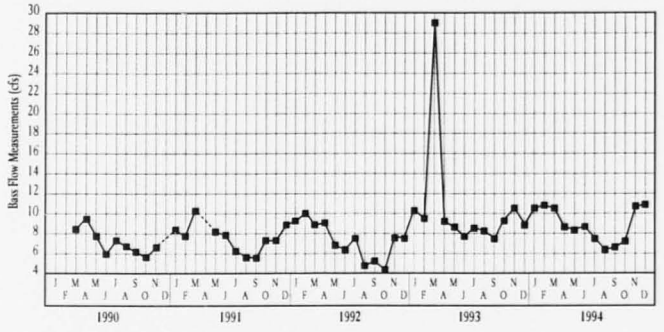


Figure 43. Beaver Dam Wash base flow measurements (cfs).

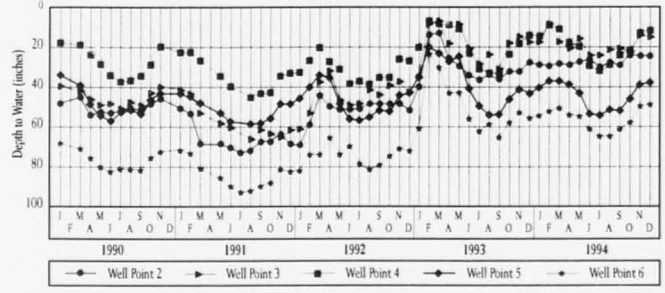


Figure 44. Well point depths to water (inches).

(February and March), which is also the period of highest water levels in the well points. Late summer low flows in the Wash are coincident with declining water tables in the alluvium.

The lowest flow measured at the mouth of the Wash (about 4.5 cfs) occurred in late summer of 1992, while the lowest water levels in the alluvium (i.e., greatest depths to water) occurred in late summer 1991. The lower ground-water levels in 1991 compared to 1992 likely resulted from absence of high flows in the spring of 1991—high flows that would have recharged the alluvium and raised the water table. A spring flood did occur in 1992 and kept alluvial water levels higher throughout the summer, even though late summer streamflows were lower than the previous year.

Water level declines in the alluvium (i.e., increasing depths to water) occasionally preceded declines in stream discharge by about 1 month. Declines in alluvial water levels likely indicate a decreasing pressure head on ground water discharging to the Wash upstream of public lands. Loss of such ground-water discharge not only jeopardizes surface flow through public lands, but also threatens ground-water levels supplying riparian communities near the confluence.

Whereas all well points showed annual cycles in the level of the water table, some well points also showed an upward trend over the assessment period that was not reflected in other well points. In particular, well points #2, 3, and 6 maintained much higher water levels after the large floods of 1993, while well point #5 showed no long-term effect from the floods. This suggests that the influence of Beaver Dam Wash floodflows on alluvial ground water is greatest for those riparian habitats closest to the Wash. Riparian habitats further removed from the channel likely are also influenced by flows in the Virgin River, as well as the general pressure head of water in the alluvium.

Depth to water at all the well points except one (#6) generally ranged from 1 to 6 feet below land surface throughout most of the assessment period. These ground-water levels favor development of cottonwood and willow stands important to Beaver Dam Wash and its associated wildlife. The inability of tamarisk to establish dense stands where depth to water is less than about 5 feet partially explains the great diversity of riparian habitats near the confluence of the Wash. However, significant lowering of the water table from ground-water withdrawals upgradient of this area would pose a serious threat to many of the riparian communities, as depths to water of 6 feet or more would favor invasion and establishment of tamarisk.

Physical connection of the stream with shallow ground water in the alluvium is not the only interaction occurring with consequences for wildlife habitat distribution. Chemical quality of ground water also is affected by surface water, not only along the channel of Beaver Dam Wash, but along the main stem Virgin River as well. Comparison of electrical conductivities (Figure 45) with the map of well points (Figure 42) shows that salinity of ground water is higher at well points closest to the Virgin River (e.g., well point #5) and lower at points closest to Beaver Dam Wash (e.g., well point #2). Well point #2 (located nearest to Beaver Dam Wash on the south side), showed a slight decrease in conductivity (Figure 45) during a significant rise in ground-water levels late in the measurement period (Figure 43). At the same time, well point #6 showed a substantial rise in conductivity during a similar rise in ground-water levels. Well point #6 likely has been influenced by Virgin River salinity, since the channel of the Virgin River shifted to the west (i.e., closer to well point #6) during the floods of 1993. In contrast, the slight decrease in conductivity at well point #2 suggests that proximity to Beaver Dam Wash appears to mitigate

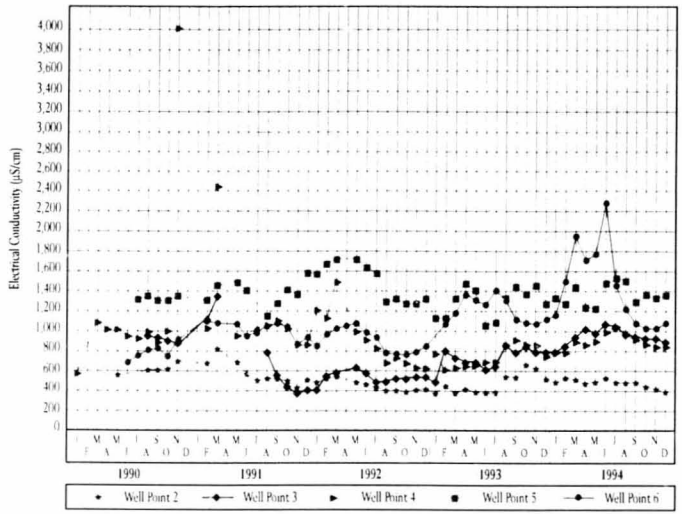


Figure 45. Well point electrical conductivity (µS/cm)

increasing salinities when water levels in the alluvium are rising.

It was not possible to relate spatial distribution of riparian communities to salinity of the ground water (as indicated by electrical conductivity). Conductivities were generally less than 2,000 µS/cm, indicating that soil-water salinities (total dissolved solids) generally were less than 1,500 milligrams per liter (mg/L). Thus, the salinity tolerance of cottonwoods (2,000 mg/L) is not being exceeded. However, the largest stands of tamarisk in the confluence area occur between the Virgin River and well point #5, the well point with the highest conductivities throughout most of the assessment period. Hence, it's likely that declining water levels in the alluvium accompanied by encroachment of saline water from the Virgin River also favor invasion and establishment of tamarisk.

Wildlife Habitat (Riparian Resources) Assessment

Evapotranspiration by riparian vegetation along Beaver Dam Wash is a consumptive use of ground water from streamflow in the Wash. Maximum evapotranspiration during the summer months was estimated to consume about 0.3 cfs. Without replenishment of this water from streamflow in the Wash, water table declines will favor

establishment of tamarisk over cottonwood and willow. In addition, streamflow levels less than about 4 cfs will result in lost habitat for rooted aquatic macrophytes along the edge of the Beaver Dam Wash channel.

Water level and conductivity information gained from the well points indicates that both physical and chemical connections exist between Beaver Dam Wash streamflows and ground water in the alluvium. Although ground-water levels and quality are presently adequate to maintain wildlife habitats near the confluence, the coincidence of maximum depths to water with minimum flows in the Wash raises concern that additional losses of surface flow would result in additional drops in the water table. Since lowering of the water table would favor tamarisk replacement of cottonwood/willow communities, flows less than 4 to 4.5 cfs measured in this assessment would likely result in loss of associated wildlife habitat.

In addition to maintenance of base flows for supporting riparian habitats, a natural flood regime is important for providing sites for regeneration. The hydraulic analysis described in the Channel Morphology section attempted to identify bankfull discharges that must be exceeded to initiate channel scour and fill, two important processes for creating regeneration sites. That analysis identified minimum floodflows of more than 300 to 500 cfs to initiate channel adjustments, and flows of 1,000 to 3,500 cfs to effect widespread morphological change. Such flows are effective for creating new point bars and other fresh sediment deposits that serve as nursery areas for cottonwood, willow, and seepwillow communities.

PROTECTION OF INSTREAM FLOW: LEGAL ANALYSIS

This legal analysis describes Arizona's process for acquiring instream flow water rights and evaluates legal availability of water on BLM-administered public lands at the mouth of Beaver Dam Wash. Alternatives for securing and protecting flows needed to support resource values identified in this assessment are also described. In addition, this analysis addresses threats to streamflows from nearby ground-water pumping and makes recommendations for protection of the ground-water system supporting surface flow in the Wash.

Arizona State Appropriative Water Rights

Acquisition of State appropriative water rights begins with application to ADWR, which has jurisdiction over surface water allocations and may approve or deny the application. The application describes the amount of water sought, intended beneficial use, and location of that use [see Ariz. Rev. Stat 45-152(B)]. The ADWR generally requires that at least 1 year of monthly streamflow data be submitted with the application, and 4 years of flow data be collected before a certificate of water right is granted.

The State of Arizona began development of an instream flow water right program in December 1986, and issued guidelines for filing instream flow applications in December 1991. Arizona guidelines define instream flow as the maintenance flow necessary to preserve instream values such as aquatic and riparian habitats, fish and wildlife, and water-based recreation in a particular stream or stream segment (ADWR 1991). Arizona has provided for the appropriation of water for fish and wildlife and recreation purposes [see Ariz. Rev. Stat. 45-151(A)]. The in situ use of such appropriated water was recognized by the Arizona Court of Appeals in the case of McClellan v. Jantzen, 547 Pl2d 494,496 (Az. Ct. Appl. 1976):

> "... in 1941 when 'wildlife, including fish' and in 1962 when 'recreation' were added to the purposes for appropriation, the concept of in situ appropriation of water was introduced — it appearing to us that these purposes could be enjoyed without a diversion. We find nothing, however, which would indicate that the legislature intended that such an in situ appropriation would not carry with it the exclusive vested rights to use the water for these purposes."

The beneficial uses for which instream flow rights may be granted are recreation and wildlife, including fish, as allowed by Arizona law. If ADWR determines that the amounts are reasonable and that the application does

not conflict with prior vested rights and is not adverse to the public interest or public safety, the application is granted through the issuance of a water use permit. After a permit is issued, the applicant must submit 4 years of data and associated analysis for review to ADWR. Also required are completed Proof of Appropriation and Affidavit of Appropriator forms. Once ADWR has determined that the appropriation has been perfected, a certificate is issued.

The application for an instream flow water right must also include a justification. Frequently, an applicant files an abbreviated initial application, which establishes a priority date, and completes the application at a later date with a detailed analysis and justification of the amount of water needed. The justification identifies the monthly flows needed to maintain the beneficial uses for which application was made.

Current Status of BLM Water Right Application

In 1989, BLM submitted an application for an instream flow water right, pursuant to Arizona law, for the reach of Beaver Dam Wash owned by the United States and managed by BLM. (A copy of the application is included in Appendix A.) The current BLM application of 1175.84 acre-feet per year (1-2 cfs) is based primarily on the needs of threatened and endangered fish. The application was protested by 12 different parties in late 1989. Two additional protests by irrigation companies are likely to be rejected, according to ADWR, since they are from outside of Arizona. Protests are often withdrawn after discussion and negotiation with the protestors. If protests are not withdrawn, ADWR may still grant a water use permit by finding the protest without merit or by rejecting the protest after a hearing.

Based on the findings of this assessment, the amount of instream flow originally applied for will need to be increased. The apparent options for BLM in changing its claims would be to either amend the current application or apply for additional amounts necessary to protect resource values. Guidance available from ADWR states that monthly streamflow rates originally claimed on an application to appropriate may be amended based on the results of a subsequent study. This is not considered a deficiency in the original application and can be accomplished without loss of the original priority date (ADWR 1991). Recent communications with ADWR, however, indicate that if more water than the original amount is claimed, then a new application must be filed for the additional amount. Thus, the additional amount claimed under the new application would have a new and more junior priority date.

Protection of an Instream Flow Water Right

An Arizona instream flow water right has certain shortcomings and does not provide complete security for continued flows (e.g., an appropriative water right is not protected from reduced water availability caused by unregulated ground-water pumping). It would be preferable, for example, to assert and obtain a Federal reserved water right that may provide additional protection for this stream segment, if it were possible. However, the BLM land adjacent to Beaver Dam Wash is not "reserved" land (e.g., wilderness or a military reservation), but is public domain land without special status. Thus, a Federal reservation does not presently exist. And while the adjacent reach of the Virgin River has been recommended as eligible and suitable for Wild and Scenic River status (a Congressional designation that would constitute a Federal reservation), the status of Beaver Dam Wash for inclusion in the reservation would need to be explicitly addressed by Congress in any such designation. Hence, in the present situation, BLM cannot assert a Federal reserved water right for this stream, nor rely on the unique protections that come with a Federal reserved right. Since there is no other kind of water right that can be advanced by BLM, the only option is to attempt to perfect a water right in accordance with Arizona law for the uses of recreation and wildlife, including fish.

In addition, there are presently a great number of problems, actions, and issues for the entire Virgin River Basin, many of which involve the Federal Government. This situation could give rise to an action in the U.S. Supreme Court for apportionment of the river among Utah, Nevada, and Arizona. However, even if such an action were initiated and the river's flow divided among the three states, Arizona's apportionment would still be administered by ADWR. If Beaver Dam Wash water was included in a Virgin River action, BLM would still be applying to ADWR for its water rights. Thus, the strategy most likely to result in legal protection continues to be perfection of a water right in accordance with Arizona law for the uses of recreation and wildlife, including fish.

Existing Water Uses

Most of the watershed runoff that sustains surface flow and recharges the channel alluvium of Beaver Dam Wash enters the Wash in Utah. The quantity of surface flow and subflow that then moves into Arizona from Utah is significant to Arizona's uses. Total estimated use of Beaver Dam Wash surface water in Utah is about 2,370 acre-feet per year (3.3 cfs), although the certificated amount for all Utah water rights on the Wash is higher (Bingham 1991). The withdrawals from the Wash within Utah today, while not negligible, are small compared to the flow into Arizona.

In Arizona, 10 permitted or certificated water rights on or adjacent to Beaver Dam Wash total 5,153 acre-feet per year (ADWR 1995). Eighty-one percent of that amount is in two claims: 3,620 acre-feet by Littlefield Irrigation Company, and 536 acre-feet by R. Frisby. (Both withdrawals occur between the USGS gage and the mouth.) Additional applications have been made for 9,957 acre-feet, but are not yet permitted (derived from data in Leslie & Associates 1990). This amount includes BLM's instream flow application for 1,176 acre-feet. An additional 3,000 acre-feet are withdrawn by 61 registered wells in and close to the Wash (Holmes et al. 1997). The current annual total of all Arizona Beaver Dam Wash uses, existing and applied for, is approximately 18,000 acre-feet.

Holmes et al. (1997) estimate total discharge of the Beaver Dam Wash system at about 22,000 acre-feet per year, including subsurface outflow to the Virgin River, and subsurface losses to surrounding formations (see Hydrogeology section). Flow appears to be sufficient to support present uses and applications, including the BLM instream flow application. While flows may also be sufficient to support some additional future uses, protection of instream flows for resource values along the Wash will be important in light of the rapid development occurring in this arid region.

Effects of Ground-Water Pumping Under Arizona Law

A major problem remains for the holder of an instream flow water right because Arizona has a bifurcated water management system in which surface water is managed separately from ground water. In Arizona, surface water may only be appropriated through a water right issued by ADWR, while ground water (outside of an Active Management Area or AMA) may be legally pumped by merely notifying ADWR of intent to do so. Thus, the holder of an instream flow water right is at risk from nearby ground-water development and associated pumping.

Outside of AMAs, ground-water pumping has little regulation in Arizona, and use of ground water outside these areas is not subject to the appropriation process. AMAs were created by Arizona's 1980 Groundwater Management Act. They are geographic areas, particularly around larger urban centers, where ground-water use requires special management. In these areas, permits for ground-water use are required, and ground-water use must be consistent with long-range planning. Eventually a goal of safe yield must be reached, where new uses must be balanced by new supplies.

The ADWR has the authority to establish an AMA, if officials determine it is needed, or an AMA can be established by popular vote of the community. An effort to create an AMA for Beaver Dam Wash near Littlefield, Arizona, failed by popular vote in 1992. No plans to renew the effort are presently being considered. However, if any

widespread support for an AMA developed, the issue could be reopened.

An exception to the bifurcated water management system occurs where ground water is determined to be subflow to a stream. In such cases, ground-water pumping may be managed under the surface water appropriation rules. Guidance in defining subflow was provided in a 1994 decision by the Gila River adjudication trial court. The court confirmed that there must be a hydraulic connection between the stream and the subflow zone. Beyond that, the court found that water pumped from the younger, floodplain alluvium was to be considered subflow and managed as surface water. Water pumped from the older alluvium of the regional basin-fill aquifer would be managed as ground water for which a water right would not be needed. The court recognized that additional criteria were necessary to distinguish subflow associated with the stream from underground tributary flow toward or away from the main channel. These criteria include:

1. Water-level elevation of the subflow must be relatively the same as the elevation of the stream.

2. Subflow water must be moving in the same general direction as the streamflow.

3. Gradient of the subflow must be comparable to the stream gradient.

4. There must be no significant difference between chemical composition of the subflow and streamflow.

5. Subflow must be adjacent to and beneath a perennial or intermittent stream. An ephemeral section of a perennial or intermittent stream may have subflow if the ephemeral section is caused by surface water diversion or ground-water pumping. There must, however, be a saturated zone beneath connected to similar zones beneath the upper and lower perennial or intermittent stream sections. (In re: General Adjudication...in the Gila River System and Source, June 30, 1994.)

This 1994 decision is currently the basis for appropriability determinations made by ADWR to identify subflow to surface water throughout the State of Arizona. The decision could still be changed by the Arizona Supreme Court or the State legislature.

Ground water beneath the entire length of Beaver Dam Wash seems to meet the court's criteria for subflow, with the possible exception of parts of the ephemeral stream definition, and the preponderance of evidence strongly supports a subflow determination. If ADWR determines that subflow exists, then a BLM instream flow water right, as well as other existing water rights on the Wash, will have a new measure of protection against pumping in and near the channel.

SUMMARY AND RECOMMENDATIONS

The Beaver Dam Wash assessment provides a scientific basis for relating flow-dependent resources to streamflow levels. The purpose of this section is to summarize the results of the assessment and recommend flows required to protect and maintain fish habitat, recreation, and riparian resource values in Beaver Dam Wash. Considerations for comprehensive instream flow management are also identified.

Flow Recommendations

During the period of study (i.e., 1991 to 1995), ecological conditions in lower Beaver Dam Wash varied due to extremely dynamic flood-related processes occurring naturally within the watershed. The Hydrologic Setting section of this report describes hydrologic, geomorphic, and ecological factors contributing to this dynamic condition. Recommended flows for specific resources in Beaver Dam Wash, which are listed in Table 20, are for ecological conditions reflecting a late successional status, as observed during the fall of 1991. Although this status represents the best conditions for fish, wildlife, and recreation, the dynamic nature of this system is an important influence on these resources and should be maintained.

Table 20. Recommended flows (cfs) for lower Beaver Dam Wash, near Virgin River confluence.

Resource Value	Flows (1/1 to 12/31)
Fish Habitat	6.0
Recreation	4.0
Wildlife Habitat	4.0

The Virgin River and its tributaries support a largely native and unique fish population and aquatic system. Five of eleven fish species found in Beaver Dam Wash during this assessment are native to the Colorado River system, including the Virgin River roundtail chub, which is Federally listed as endangered. Habitat was modeled for five species and two or three life stages per species. Flows required to sustain Virgin spinedace are also expected to sustain other species in Beaver Dam Wash. Habitat for adult Virgin River roundtail chub, however, increases with flows beyond those modeled. Recommended yearlong flows for Virgin spinedace should be in the range of 6 to 20 cfs, with a minimum flow requirement of 6 cfs.

The perennial stream and outstanding riparian values associated with Beaver Dam Wash provide recreational opportunities that are largely aesthetic in character. Recommended flows for recreation are based on evaluations of flows needed to support both enjoyment of nature and wading/swimming opportunities. Flows less than 4 cfs

cause significant portions of the channel bottom to be exposed, and thus decrease scenic beauty in the stream. Based on analysis of certain hydraulic parameters, flows ranging from 1.5 to 8 cfs are required for wading, and flows from 9 to 20 cfs are required for swimming. The recommended minimum flow for recreational opportunities, with an emphasis on aesthetics and wading, is 4 cfs throughout the year.

Streamflows in Beaver Dam Wash provide drinking water and support crucial riparian habitat for a variety of wildlife, including two bird species that are Federally listed as endangered. Factors contributing to this highly valuable riparian area include a reliable source of ground water and good water quality to sustain plant communities (i.e., lower salinity levels than in the Virgin River floodplain). Lowering the water table within the floodplain of Beaver Dam Wash at the Virgin River confluence may cause cottonwood and willow to be replaced by tamarisk, and thus make the riparian area less diverse. Recommended minimum flows for maintaining water levels sufficient to support the riparian area are 4 to 4.5 cfs.

Management Considerations

Under Arizona law, protection from ground-water pumping for an instream flow water right is uncertain. Consequently, the following actions are recommended to assist BLM in protecting Beaver Dam Wash riparian resources and other flow-dependent values.

1. Continue to pursue an appropriative instream flow water right from ADWR.

The BLM application for 1.5-2 cfs was filed in August 1989. ADWR has not acted on the application while waiting for complete justification. This report provides justification for flow requirements for resource values along Beaver Dam Wash. BLM should file a new application for the difference between the amount originally claimed and the new total amount as determined from this assessment. Continued pursuit of this water right is the most practical and effective means of protecting the perennial flow of Beaver Dam Wash. BLM also must be prepared to defend its application against existing and new protests. In addition, once an instream flow water right is granted, BLM may need to protest new applications that threaten the instream flows.

2. Monitor ground-water pumping.

It will be important for BLM to carefully monitor pumping activities in the Beaver Dam Wash area, particularly the potential impact of new wells on instream flows. (This will also require future monitoring of streamflow levels in the Wash.) The 1994 decision of the Gila River Adjudication Court has provided a basis for BLM objections to new wells that are pumping subflow. It is too early to tell how ADWR will approach this problem in the context of administering water rights applications, as opposed to the context of stream adjudications. However, by encouraging

ADWR to address the potential adverse impact of new wells, BLM will be creating a record to support administrative complaints if streamflow in the Wash diminishes.

3. Increase coordination with water resources management agencies in Arizona and throughout the Virgin River basin.

BLM should actively participate in any attempts to apportion Virgin River streamflows (including the waters of Beaver Dam Wash) and settle Virgin River issues. BLM should also coordinate with entities interested in addressing how ground water is managed in the State of Arizona.

Although not directly connected to the water right application for Beaver Dam Wash, an apportionment of the Virgin River among the states of Utah, Arizona, and Nevada may, nevertheless, be beneficial in this case. An apportionment would help by precisely defining the rights of the upstream states of Nevada and Utah. If a court decision or interstate compact was reached, each state would have its entitled quantity defined. Arizona would then be assured of a known quantity with which to work.

Comprehensive, broad-based settlement of issues could bring about concessions from parties in Arizona that are usually reticent about Federal instream flow water rights or the ground-water/surface-water connection. Such concessions could include: 1) resurrection of an AMA proposal for the Beaver Dam Wash area and a limit on new wells; 2) elimination of any protests pending against BLM's Beaver Dam Wash application; 3) possible agreement by ADWR that the application will be granted; 4) possible negotiation of criteria for determination of what will constitute "subflow" within the lower Beaver Dam Wash area; and 5) other similar concessions from Nevada and Utah.

BLM should also communicate and coordinate with other organizations and agencies that have an interest in changing how ground water is managed under Arizona law. In particular, the bifurcated management system that treats ground-water withdrawals independently of surface-water rights leaves Arizona's remaining riparian areas in a state of great uncertainty. While this may not be a high priority for the Arizona legislature, awareness of the importance of Arizona's remaining riparian areas is growing throughout the state. Arizona's riparian areas are increasingly recognized not only as extraordinary concentrations of natural resources, but as potential sources of tourism revenue. Other entities that may be interested in pursuing legislative action include the Salt River Project, the Arizona Nature Conservancy, the Arizona Game and Fish Department, the U.S. Forest Service, and possibly the State Land Department.

4. Maintain natural flood regime.

The public land surrounding the confluence of Beaver Dam Wash and the Virgin River is a very dynamic landscape influenced by the extremely active channels of these two desert

streams. Flood events in either of these two drainages have a pronounced effect on channel location and morphology for both streams. The dynamic nature of these processes is an important factor rendering this lower Beaver Dam Wash area high in resource values (e.g., extensive and diverse riparian vegetation).

The "advanced ecological condition" tends to create conditions optimal for native fishes as well as many introduced species, and is essential to maintaining the native biota. Equally essential are the early successional stages created by flooding. These conditions, while nearly catastrophic to native species, are even more likely to be catastrophic to introduced species. The cooler, more stable conditions during periods of stable flows are conducive to development of larger populations of native (and introduced) species. Floods tend to differentially select against introduced species. Native species may repopulate reaches from refugia elsewhere in the system—possibly because they are washed downstream by flooding. It is the interplay between preferred and non-preferred temperatures, floods and stable flows, and variability and stability that tends to maintain the biota.

It is estimated that necessary channel adjustments will begin to occur with floods as small as a few hundred cfs, but that flows in the range of 1,000 to 3,500 cfs are required to access most of the streambank and initiate widespread channel adjustments. During the course of this assessment, several events of this magnitude occurred, leading to the conclusion that the present magnitude and frequency of flooding in Beaver Dam Wash are adequate to maintain the riparian processes that are occurring. Future development (e.g., reservoirs, surface-water diversions) within the watershed that could affect floodflows should be closely monitored by BLM. Such developments should be evaluated for significance of impact to flows, and resulting concerns should be brought to the attention of permitting entities in Nevada, Utah, and/or Arizona.

LITERATURE CITED

Arizona Department of Environmental Quality (ADEQ). 1995. The Beaver Dam Wash intensive survey: An investigation to determine whether excessive nutrients are contributing to the surface water of the Beaver Dam Wash. Surface Water Monitorin Unit OFR 95-4, Hydrologic Support and Assessment Section, Phoenix, AZ. 22 pp.

Arizona Department of Water Resources (ADWR). 1991. A guide to filing applications for instream flow water rights in Arizona. Office of Water Management. Phoenix, AZ. 52 pp.

Arizona Department of Water Resources (ADWR). 1995. Personal communication. Phoenix Office.

Arizona Department of Water Resources (ADWR). 1997. Personal communication. Phoenix Office.

Arizona Game and Fish Department (AGFD). 1993. Arizona riparian inventory and mapping project. Phoenix, AZ. 138 pp.

Arizona State Parks Board and Arizona Outdoor Recreation Coordinating Commission. 1992. Arizona outdoor recreation needs assessment, executive summary. Phoenix, AZ. 9 pp.

Baer, J.L. 1986. Reconnaissance gravity and magnetic survey of the northern Mesquite Basin, Nevada-Utah. In: Griffen D.T. and W.R. Phillips (eds). Thrusting and extensional structures and mineralization in the Beaver Dam Mountains, southwestern Utah. Utah Geological Association, Publication 15.

Bagley, D.G. 1980. Soil survey of the Virgin River area, Nevada - Arizona: Parts of Clark and Lincoln Counties, Nevada and Part of Mohave County, Arizona. USDA, Soil Conservation Service. 147 pp.

Billingsly, G.H. 1995. Geologic map of the Littlefield quadrangle, northern Mohave County. Arizona. U.S. Geological Survey Open-File Report 95-559.

Bingham Engineering. 1991. Lytle Ranch and Beaver Dam Wash water rights and applications. Prepared for Brigham Young University and Clyde, Pratt and Snow. Salt Lake City, UT. 35 pp.

Black, K.R. and S.J. Rascona. 1991. Maps showing groundwater conditions in the Virgin River Basin, Mohave County, Arizona, Lincoln and Clark Counties, Nevada. State of Arizona, Department of Water Resources, Hydrologic Map Series Report 22.

Brady, W., D.R. Patton, and J. Paxson. 1985. The development of southwestern riparian gallery forests. In R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.). Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. pp 39-43.

Brock, J.H. 1994. Phenology and stand of woody riparian plants in the Southwestern United States. Desert Plants 11:23-31.

Brown, T.C. and T.C. Daniel. 1991. Landscape aesthetics of riparian environments: relationship of flow quantity to scenic quality along a wild and scenic river. Water Resources Research. 27(8): 1787-1795.

Buchanan, T.J. and W.P. Somers. 1980. Discharge measurements at gaging stations - book 3, ch. A8. Techniques of water-resources investigations of the United States Geological Survey. United States Government Printing Office, Washington DC:1969.

Campbell, C.J. and W.A. Dick-Peddie. 1964. Comparison of phreatophyte communities on the Rio Grande in New Mexico. Ecol. 45:492-502.

Carothers, S.W. and R.R. Johnson. 1971. A summary of the Verde Valley breeding bird survey. Proj. FW-16-10, Ariz. Game and Fish Dept. Land and Water Proj. Investigations, Phoenix. 20 pp.

Carothers, S.W. and R.R. Johnson. 1975. Water management practices and their effects on nongame birds in range habitats. In: Smith, D.R. (Tech. Coord.) Proc. Symp. on Manage of For. and Range Habitats for Nongame Birds. USDA For. Serv. Gen. Tech. Rep. WO-1. 343 pp.

Cross, J.N. 1975. Ecological distribution of the fishes of the Virgin River. Master's thesis, University of Nevada, Las Vegas. 187 pp.

Cross, J.N. 1978. Status and ecology of the Virgin River roundtail chub, Gila robusta seminuda (Osteichthyse: Cyprinidae). Southwest naturalist. 23(3):519-528.

Deacon, J.E. 1988. The endangered woundfin and water management in the Virgin River, Utah, Arizona, Nevada. Fisheries 13(1):18-24.

Deacon, J.E. 1991. Distinguished Professor, Department of Biological Sciences, University of Las Vegas, Nevada. June 12, 1991; Telephone conversation in which Beaver Dam Wash, Arizona was discussed. Field notes were provided of fish collections made in 1963, 1973, 1982, and 1984.

Deacon, J.E. and W.L. Minckley. 1973. A review of information on the woundfin Plagopterus argentissimus Cope (Pisces; cyprinidae). Progress Report to the Bureau of Sport Fisheries and Wildlife, Salt Lake City, Utah.

Deacon, J.E., A. Rebane and T.B. Hardy. 1991. Final report to National Park Service: a habitat preference analysis of the Virgin spinedace in Zion National Park, Utah. Order No. PX 1200-8-0078. pp. 29 + append.

Deacon J.E., P.B. Schumann, and E.L. Stuenkel. 1987. Thermal tolerances and preferences of fishes of the Virgin River System (Utah, Arizona, Nevada). Great Basin Naturalist. 47(4):538-546.

DeMaris, B.D., T.E. Dowling, and W.L. Minckley. 1993. Post-perturbation genetic changes in populations of endangered Virgin River chubs. Conservation Biology 7(2):334-341.

Enright, M. 1996. Selected hydrological data for Beaver Dam Wash and adjacent areas, Washington County, Utah, Lincoln County, Nevada and Mohave County, Arizona. U.S. Geological Survey Open-File Report 96-493.

Fenner, P., W.W. Brady, and D.R. Patton. 1984. Observations on seeds and seedlings of Fremont cottonwood. Desert Plants 6(1):55-58.

Fogg, J.L., B.L. Hanson, H.T. Mottl, D.P. Muller, R.C. Eaton, and S. Swanson. 1992. Rio Chama instream flow assessment. USDI Bureau of Land Management Service Center, Denver, CO. 133 pp.

Hardy, T.B. 1991. Status report on the fishes of the Virgin River. Department of Civil and Environmental Engineering, Utah State University, Logan, Utah.

Heckmann, R.A., J.E. Deacon, and P.D. Greger. 1986. Parasites of the woundfin minnow, Plagopterus argentissimus, and other endemic fishes from the Virgin River, Utah. Great Basin Nat. 46(4):662-676.

Hintze, L.F. 1986. Stratigraphy and structure of the Beaver Dam Mountains, southwestern Utah. In: Griffen D.T. and W.R. Phillips (eds). Thrusting and extensional structures and mineralization in the Beaver Dam Mountains, Southwestern Utah. Utah Geological Association, Publication 15.

Holmes, W.F., G.E. Pyper, J.S. Gates, M. Enright, D. Schefer, and K. Waddell. 1997. Geohydrology and water quality of the Beaver Dam Wash area, Washington County, Nevada, and Mohave County, Arizona. U.S. Geological Survey Water Resources Investigations Report 97-4193.

Horton, J.S. 1977. The development and perpetuation of the permanent tamarisk type in the phreatophyte zone of the southwest. In: Johnson, R.R. and D.A. Jones (Tech. Coord.). Symposium on the importance, preservation and management of the riparian habitat. USDA, For. Serv. Gen. Tech. Rep. RM-43. pp. 124-127.

Horton, J.S. and C.J. Campbell. 1974. Management of phreatophyte and riparian vegetation for maximum multiple use values. USDA, For. Serv. Research Paper RM-117. 23pp.

Horton, J.S., F.C. Mounts, and J.M. Kraft. 1960. Seed germination and seedling establishment of phreatophyte species. Rocky Mtn. For. Range Expt. Sta., Paper No. 48. 26pp.

Hyra, R. 1978. Methods of assessing instream flows for recreation. Instream Information Paper No. 6, Cooperative Instream Flow Service Group, USDI Fish and Wildlife Service, Fort Collins, CO. FWS/OBS-78/34. 43 pp.

Inside Outside Inc. 1992. The northern Arizona and southern Utah visitor information and interpretation assessment. Prepared for USDA Forest Service, Southwestern Region, Albuquerque, NM, and USDI Bureau of Land Management, Arizona State Office, Phoenix, AZ. 47 pp.

Jackson, W., T. Martinez, P. Cuplin, W.L. Minkley, B. Shelby, P. Summers, D. McGlothlin, and B. Van Haveren. 1987. Assessment of water conditions and management opportunities in support of riparian values: BLM San Pedro River properties. USDI Bureau of Land Management Service Center, Denver, CO. 180 pp.

Johnson, R.R. 1971. Tree removal along southwestern rivers and effects on associated organisms. Amer. Phil. Soc., Yearb. 1970. pp. 321-322.

Johnson, R.R. and S.W. Carothers. 1982. Riparian habitat and recreation: interrelationships and impacts in the Southwest and Rocky Mountain region. Eisenhower Consortium Bulletin 12, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 31 pp.

Johnson, W.E.C., R.L. Burgess, and W.R. Keammerer. 1976. Forest overstory vegetation and environment on the Missouri River floodplain in North Dakota. Ecol. Monogr. 46:59-84.

Jones, K.B. 1986. Deserts. In: Cooperrider, A.Y., R.J. Boyd, and H.R. Stuart, editors. Inventory and monitoring of wildlife habitat. USDI Bureau of Land Management Service Center, Denver, CO. pp. 123-145.

Kasprzyk, M.J. and G.L. Bryant. 1989. Results of biological investigations from the Lower Virgin River vegetation management study. USDI Bur. of Reclamation REC-ERC-89-2. 75pp.

Krzysik, A.J. 1990. Biodiversity in riparian communities and watershed management. In: Riggins, R.E., E.B. Jones, R. Singh, and P.A. Rechard. Watershed planning and analysis in action. Amer. Soc. Civil Engineers. NY. pp. 533-548.

Laney, R.L. and H.W. Hjalmarson. 1977. Effects of phreatophyte removal on water quality in the Gila River phreatophyte project area, Graham County, Arizona. U.S. Geological Survey Professional Paper 655-M. 23pp.

Leslie and Associates. 1990. Hydrological study of the Beaver Dam Wash Aquifer in Mohave County, Arizona. Part I, Report. Part II, Appendices.

McCain, M., D. Fuller, L. Decker, and K. Overton. 1990. Stream habitat classification and inventory procedures for Northern California. Fish Habitat Relationships Technical Bulletin No. 1. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Region.

McNatt, R.N., R.J. Hallock, and A.W. Anderson. 1980. Riparian habitat and instream flow studies. Lower Verde River: Fort McDowell Reservation, Arizona. Riparian Habitat Analysis Group, USDI Fish and Wildl. Serv., Region 2. Albuquerque, NM. 52pp.

Milhous, R.T., M.A. Updike, and D.M. Schneider. 1989. Computer reference manual for the Physical Habitat Simulation System (PHABSIM) - Version 2. USDI Fish and Wildlife Service, National Ecology Research Center, Fort Collins, CO. 519 pp.

Miller R.R. 1961. Man and the changing fish fauna of the American Southwest. Papers of the Michigan Academy of Science, Arts and Letters 46:365-404.

Minckley W.L. 1973. The fishes of Arizona. Arizona Game and Fish Department, Phoenix, Arizona.

Minckley, W.L. 1985. Native fishes and natural aquatic habitats in U.S. Fish and Wildlife Service Region II west of the Continental Divide. Report to the U.S. Fish and Wildlife Service, Albuquerque, New Mexico. Department of Zoology, Arizona State University, Tempe, Arizona. pp ix + 158.

Minckley, W.L. and J.E. Deacon. 1968. Southwest fishes and the enigma of "endangered species." Science 159:1424-1432.

Minckley W.L. and J.E. Deacon (eds.). 1992. Battle against extinction: native fish management in the American West. University of Arizona Press, Tucson. pp 291.

Moore, R.T. 1972. Geology of the Virgin and Beaverdam Mountains, Arizona. Arizona Bureau of Mines Bulletin 186.

Moore, S.D., M.E. Wilkosz, and S.K. Brickler. 1990. The recreational impact of reducing the "laughing waters" of Aravaipa Creek, Arizona. Rivers. 1(1):43-50.

Moore, S.D., S.K. Brickler, J.W. Shockey, and D.A. King. 1989. Sociological aspects of recreation at Aravaipa Canyon Wilderness, Arizona. USDI Bureau of Land Management, Safford District, Safford, AZ. 141 pp.

Muckel, D.C. 1966. Phreatophytes - water use and potential water savings. Journal Irrigation and Drainage Division, American Society of Civil Engineers. 92(4):27-34.

Ohmart, R.D. and B.W. Anderson. 1986. Riparian habitat. In: Cooperrider, A.Y., R.J. Boyd, and H.R. Stuart, editors. Inventory and monitoring of wildlife habitat. USDI Bureau of Land Management Service Center, Denver, CO. pp. 169-199.

Pase, C.P. and E.F. Layser. 1977. Classification of riparian habitat in the Southwest. In: Importance, preservation and management of riparian habitat: Symposium proceedings. USDA Forest Service General Technical Report RM-43, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. pp 5-9.

Pope, D.P. 1984. Methods of vegetative regeneration and moisture regime requirements of selected southwest riparian species. Unpubl. MS Thesis. Arizona State Univ., Tempe, AZ. 44pp.

Riffey, M.M. 1979. Virgin River transect studies. Report No. 5 for USDI Bureau of Land Management, Arizona Strip District, St. George, UT. 168 pp.

Riffey, M.M. 1980. Breeding bird avian utilization on nine study areas of the Arizona Strip. Report No. 6. USDI, Bureau of Land Management, Arizona Strip District, St. George, UT. 335 pp.

Riggs, H.C. 1969. Mean streamflow from discharge measurements. Bulletin of the International Association of Scientific Hydrology, XIV, 4.

Rinne J.N. and P.R. Turner. 1992. Reclamation and alteration as management techniques, and a review of methodology in stream renovation. In: Minckley, W.L. and J.E. Deacon, eds. Battle against extinction: native fish management in the American west. University of Arizona Press:1992. pp. 219-246.

Schumann, P.B. 1978. Response to temperature and dissolved oxygen in the roundtail chub, Gila robusta Baird & Girard. Unpublished thesis, University of Nevada, Las Vegas.

Shelby, B., T.C. Brown, and J.G. Taylor. 1992. Streamflow and recreation. USDA Forest Service General Technical Report RM-209, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 27 pp.

Siegel, R.S. and J.H. Brock. 1990. Germination requirements of key southwestern woody riparian species. Desert Plants 10(1):3-8.

Stefferud, S. Fish and Wildlife Biologist. U.S. Fish and Wildlife Service, Ecological Services, Phoenix, AZ. February 2, 1994. Phone conversation concerning new additions to Federal candidate list.

Stromberg, J.C. 1993. Fremont cottonwood-Gooding willow riparian forests: a review of their ecology, threats, and recovery potential. Journal of the Arizona-Nevada Academy of Science. (in press).

U.S. Department of the Interior, Bureau of Land Management (USDI-BLM). 1992. Arizona Strip District Resource Management Plan and Environmental Impact Statement. Arizona Strip, St. George, UT. 769 pp.

U.S. Department of the Interior, Bureau of Land Management (USDI-BLM). 1994. Draft. Virgin River Corridor Area of Critical Environmental Concern: Beaver Dam Wash confluence management goals. Arizona Strip District, St. George, UT.

U.S. Department of the Interior, Bureau of Land Management (USDI-BLM). Draft. Virgin River corridor area of critical environmental concern plan. Arizona Strip District, St. George, UT.

U.S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species. Federal Register, 50 CFR Part 17. 56(225):58814.

U.S. Fish and Wildlife Service. 1991. Endangered and threatened species of Arizona (with 1992 addendum). U.S. Fish and Wildlife Service, Phoenix, Arizona.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; endangered and threatened wildlife and plants. 50 CFR 17.11 & 17.12; August 23, 1993. U.S. Government Printing Office 1993:342-447/94033.

U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants; proposed rule to list the fish Virgin spinedace as a threatened species. Federal Register, 50 CRF Part 17. 59(95):25875-25880.

U.S. Fish and Wildlife Service. 1995. Memorandum (FWS/TE/95-01837). Policy on candidate assessment and petition management under the Endangered Species Act. From the Director to Regional Directors, Regions 1, 2, 3, 4, 5, 6, and 7.

U.S. Geological Survey (USGS). 1994. Water resources data, Utah, water year 1993. UT-93-1. 333 pp.

Valdez, R.A., W.J. Masslich, R. Radant, and D. Knight. 1991. Status of the Virgin spinedace (Lepidomeda mollispinis mollispinis) in the Virgin River Drainage, Utah. Project Report prepared for the Utah Division of Wildlife Resources, Salt Lake City, Utah. Contract No. 90-0633.

Warren, D.K. and R.M. Turner. 1975. Saltcedar (Tamarix chinensis) seed production, seedling establishment, and response to inundation. Jour. Ariz. Aca. Sci. 10:135-144.

Whittaker, D., B. Shelby, W. Jackson, and R. Beschta. 1993. Instream flows for recreation: a handbook on concepts and research methods. USDI National Park Service, Rivers and Trails Conservation Program, Alaska Region, Anchorage, AK. 104 pp.

APPENDIX A: BLM WATER RIGHT APPLICATION

ARIZONA DEPARTMENT OF WATER RESOURCES
99 East Virginia Avenue
Phoenix, Arizona 85004

APPLICATION FOR A PERMIT TO APPROPRIATE PUBLIC WATER OF THE STATE OF ARIZONA

NO._____

FILED_____

1. Name U.S. Bureau of Land Management Telephone 801-673-3545
   Address 390 N. 3050 E. St. George, UT 84770
2. Type of source and name, if any. Instream flow, Beaver Dam Wash
   a tributary of Virgin River on the _____ watershed.
   do not complete
3. Use of water
   A. Domestic
      1. No. of Persons_____ 2. No. Of Families_____
   B. Municipal
      1. Population to be served_____
      2. Estimate of future population and water requirements_____
   C. Irrigation
      1. Location of the irrigated acreage
      _____¼_____¼_____¼ ,Section _____, Township_____ N/S, Range_____E/W
      _____¼_____¼_____¼ ,Section _____, Township_____ N/S, Range_____E/W
      2. Number of acres to be irrigated_____
      3. Describe type of crop to be irrigated_____
   D. Stockwatering
      1. Kind of stock_____ 2. No. of stock_____
   E. Power - Describe the nature of the works by which power is to be developed, pressure head, points of release of water and the uses to which the power will be applied.
   F. Mining
      1. Kind of mining claims_____
      2. Methods of supplying and using water_____
   G. Recreation
      1. Character of area to be used Beaver Dam Aquatic Habitat Management Area, Cottonwood Wetlands Habitat. (See Attachment A for Recreation Summary)
   H. Wildlife
      1. Kinds of wildlife See Attachment A
      2. Character of area to be served Beaver Dam Aquatic Habitat Management Area, Cottonwood Wetlands Habitat
   I. Groundwater Recharge_____
   J. Storage & Recovery_____
4. Amount of water

Use	Amount	Measure	Months of use
Wildlife	see Attachment B		1/1 to 12/31
Fisheries	see Attachment B		1/1 to 12/31
Recreation	see Attachment B		1/1 to 12/31

Attachment A
U.S. Bureau of Land Management
Application for Permit to Appropriate Water

Background

The Beaver Dam Wash flows through about 8.4 miles of the extreme northwest corner of Arizona. Approximately 1.25 miles of that distance is across public lands. It originates in southwestern Utah and terminates at the Virgin River near Littlefield, Arizona. The upper portion of the wash is dry at the surface except during spring runoff and after convectional summer storms. Water flows downstream through coarse alluvium and perennial flow emerges on public and private lands near Beaver Dam, Arizona. This application is for instream flow on that portion of Beaver Dam Wash from where it exits private lands at Beaver Dam to its confluence with the Virgin River (See No. 6 on application form, Legal description of place of use, Attachment C and map - Attachment D).

Instream Flow Beneficial Uses

A. Fisheries

The confluence of Beaver Dam Wash and the Virgin River is habitat for one Federal and State listed endangered species, the woundfin minnow; a proposed Federal endangered and State listed endangered species, the Virgin River roundtail chub; and a candidate Federal Category II and State listed endangered species, the Virgin River spinedace. Studies by Cross, 1975, indicate that the confluence is the most productive location in Arizona for the woundfin minnow. It is also the primary habitat for the Virgin River spinedace which requires the good quality water provided by Beaver Dam Creek.

The U.S. Fish and Wildlife Service is responsible for endangered species protection, but the Bureau of Land Management has responsibility under the Endangered Species Act to maintain or enhance their habitats on public lands. Approximately 2.0 cfs is needed to maintain the fisheries habitat primarily throughout the spawning period during the warm spring and hot summer months.

B. Wildlife

Flows in the Beaver Dam Wash provide drinking water and critical habitat for a variety of wildlife including the spiny soft-shelled turtle, bull frogs, beavers, blue herons, the State candidates - common black hawk and the belted king fisher.

The habitat in the Beaver Dam Wash has been listed by the Nature Conservancy as a unique cottonwood wetlands community. Most of this habitat has been degraded or significantly impacted by the diversion of water and removed by development on the private lands adjacent to the area covered by this application. Sufficient water is needed to maintain the fresh water table on this strip of land in order to prevent salt-water encroachment from the Virgin River from killing off native non-salt tolerant species. Approximately 2.0 cfs is needed to maintain the wildlife habitat during the growing season and a minimum of 1.0 cfs is needed through the winter months to prevent salt water encroachment and build up of saline soils.

C. Recreation

The area covered by this application has been proposed as a cottonwood-wetlands demonstration and recreational area with interpretive tracts for educational purposes. The confluence is one of the only public access points for recreational floating, wading, bird watching, picnicking, and other greenbelt associated activities. The confluence is an exit point for people floating the river. There is use by people who wade across the Virgin River from popular nearby springs. Cfs needs, to maintain the area for recreation, are the same as for fisheries and wildlife.

ATTACHMENT B

U.S. BUREAU OF LAND MANAGEMENT APPLICATION FOR A PERMIT TO APPROPRIATE WATER

Amount of Water

This application requests an instream flow appropriation for a continuous stretch of the Beaver Dam Wash from the point at which it exits private land at Beaver Dam to its confluence with the Virgin River (See No. 6 on application form - legal description of place of use, Attachment C, and map - Attachment D).

The amount of water requested in this application represents an approximation of the instream flow requirements needed to sustain the natural values of Beaver Dam Wash as discussed in Attachment A. The amounts are based on information available to the applicant at the time of this filing. Amendments may be made to this application as future studies give more detailed and accurate information.

The requested quantities are listed in the following table. They are expressed as mean daily flows for each month. They are derived from recent flow estimates by BLM and measurements taken by U.S.G.S. for a water report on the Virgin River Valley in 1969.

Beaver Dam Wash Instream Flows

Month	Requested Flows, cfs
October	1.5
November	1.5
December	1.0
January	1.0
February	1.0
March	1.5
April	2.0
May	2.0
June	2.0
July	2.0
August	2.0
September	2.0

Attachment C

Legals Starting at Private - Public Land Boundary

Beginning Point: SE quarter of the NW quarter of Section 4, T40N, R15W, G & SRB & M. The beginning point of appropriation is the Beaver Dam Creek where it emerges from private land into public land. The affected stream segments thence flow downstream through the following (all locations are referenced to G & SRB & M):

SE quarter of the NW quarter of Section 4, T40N, R15W
NE quarter of the SW quarter of Section 4, T40N, R15W

Ending Point: Intersection of Beaver Dam Creek with the Virgin River on the NE quarter of the SW quarter of Section 4, T40N, R15W.

BIBLIOGRAPHY

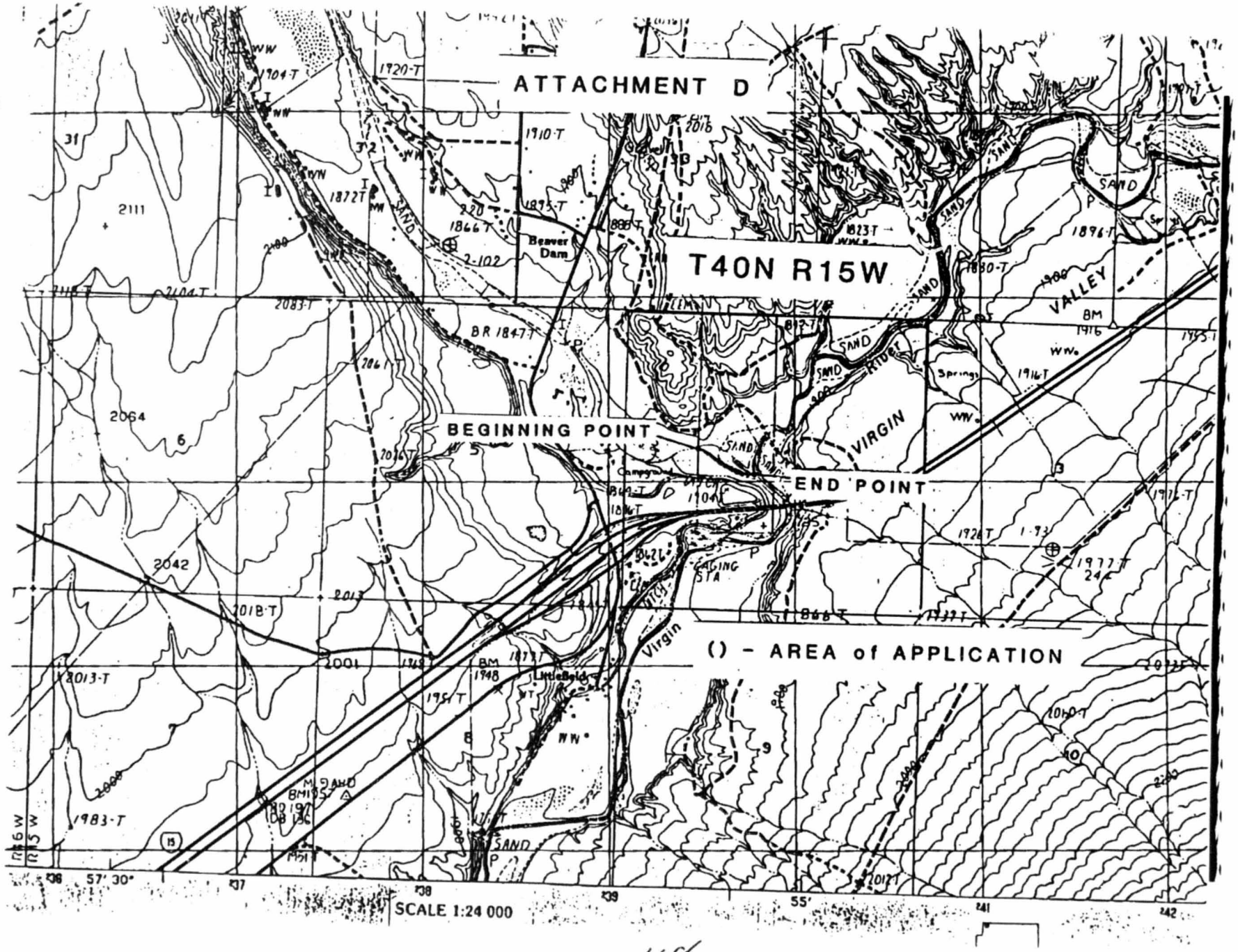
Cross, J.N. 1975. Ecological distribution of the fishes of the Virgin River (Utah, Arizona, Nevada). M.D. Thesis, Univ. Nevada, Las Vegas. pp. 187.

Deacon and T. M. Baugh. 1984. Fish population monitoring activities by the Woundfin Recovery Team, Virgin River, Utah, Arizona, Nevada, April 18, 1984. Environ. Cons., Inc., Las Vegas, Nevada.

Deacon and T. B. Hardy. 1982. Streamflow requirements of woundfin (Plagopterus argentissimus): Cyprinidae in the Virgin River, Utah, Arizona, Nevada. Festschrift for Walter W. Dalquest. Dept. Bio., Midwestern St. Univ. pp. 45-56.

Glancey, P. A. and A. S. Van Denburgh. 1969. Water resource appraisal of the lower Virgin River Valley area, Nevada, Arizona, and Utah. U.S.G.S., Wat. Res. Recon. Ser. Rept. 51.

Pregler, C. E. 1988. Shivwits Area Wildlife Management Situation Analysis, Arizona Strip District, Bureau of Land Management.


ATTACHMENT D
T40N R15W
BEGINNING POINT
END POINT
() - AREA of APPLICATION
Beaver Dam
VALLEY
VIRGIN
RIDGE
SAND
Virgin
Littlefield
SCALE 1:24 000

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1998	Final

4. TITLE AND SUBTITLE
Beaver Dam Wash Instream Flow Assessment

5. FUNDING NUMBERS

6. AUTHOR(S)
Jim Fogg, Dan Muller, Paul Summers, Jeff Simms, Stephanie Ellingham, Jim Renthal, Phil Dittberner

8. PERFORMING ORGANIZATION REPORT NUMBER
BLM/RS/ST-98/002+7200

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of the Interior
Bureau of Land Management
National Applied Resource Sciences Center
P.O. Box 25047
Denver, CO 80225-0047

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report documents findings from an instream flow assessment conducted by the U.S. Bureau of Land Management on Beaver Dam Wash in Mohave County, Arizona. The assessment, which focused on resources located at the mouth of Beaver Dam Wash from 1991 through 1994, provides a scientific basis for relating flow-dependent resources to streamflow levels. Natural resource values, methods of data collection and analysis, and flow requirements are presented in this report.

14. SUBJECT TERMS

- Instream flow
- Fisheries resources
- Recreation resources
- Water rights
- Wildlife habitat
- Riparian resources

15. NUMBER OF PAGES
122 including covers

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102