

AN INVENTORY AND CLASSIFICATION OF SURFACE WATER RESOURCES
IN GRAND CANYON NATIONAL PARK, ARIZONA

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AN INVENTORY AND CLASSIFICATION OF SURFACE WATER RESOURCES
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Data were gathered on the location, history, permanence, and quality of surface water resources within a 1,881 square mile area in northern Arizona. The availability of surface water was found to be primarily related to geologic structure, aquifer mechanics, and annual precipitation. The Muav Limestone is the major geologic formation in which perennial springs arise, while locally other formations may yield smaller quantities of water. Ephemeral and intermittent water sources predominate in the region, with the few perennial streams (excepting the Colorado River) being related to large perennial spring systems on both the north and south sides of the Colorado River. A classification system for surface waters in the southwestern United States is presented.

INTRODUCTION

The seasonality and limited availability of water in a primary region such as Grand Canyon National Park dictate the fact that water is a precious commodity, much in demand by man and the biota. A logical first step in the management of arid lands natural areas would be a comprehensive inventory of the surface water resources. Generalized water resource inventories covering large geographical areas exist (Caldwell 1968, Arenal 1969, Qureshi 1975, Qureshi 1978), although detailed inventories of arid lands natural areas are largely unavailable. This paper presents information on the methodology and results of an inventory of surface water resources in the Grand Canyon region of northern Arizona, with a classification system for surface waters applicable to the southwestern United States.

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Previous water resources research in the Grand Canyon region, while providing a wealth of information on various topics pertaining to the availability and location of local water sources, has not produced an organized system of information on regional hydrology. No scientific information on Grand Canyon was available until publication of "Report upon the Colorado River of the West" (Ives 1861), which contained some mention of local water sources and availability. Powell explored the length of the Grand Canyon in 1869 and noted the presence of water sources in his journal, "Exploration of the Colorado River of the West" (Powell 1875). The "Tertiary History of the Grand Canyon District" (Dutton 1882) was later published by the U.S. Geological Survey (USGS), outlining regional spring locations and other exact water resource information. The USGS gathered the majority of water resource information after 1882, including a synopsis of tributary flow into the Colorado River by LaRue (1925) and Johnson and Sanderson (1968). As the majority of the region is extremely arid, much work has been done to define the geologic occurrence of ground water supplies, in order to locate potentially productive drilling sites (Metzger 1961, Hantoon 1962). Recent research into regional hydrology includes karst hydrology (Hantoon 1968, 1974), hydro-mechanics of local ground-water systems (Hantoon 1970), and "The Relationship Between Tectonic Structure and Aquifer Mechanics in the Western Grand Canyon District, Arizona" (Hantoon 1977). A series of USGS maps showing local ground-water conditions is only partially published (Farrar 1979).

STUDY AREA

The study area encompasses 1,881 square miles within Coconino and Mohave counties between latitude 36°00' and 36°28' and between longitudes 111°45' and 112°45'. The Grand Canyon region is an area of high, semiarid plateaus dissected by deeply entrenched drainages formed by the Colorado River and its tributaries. Elevations in the region range from less than 300m to 2850m, creating a mosaic of primarily non-forested habitats. The entire region is characterized by a relative scarcity of open or flowing water sources and minimal precipitation (25-76 cm/yr) which may vary greatly from year to year.

METHODOLOGY

Data were gathered on the location, history, permanence, and quality of surface waters in the study area. Information was stored on inventory field cards developed specifically for that purpose. Site numbers were plotted on corresponding maps, and locations noted in mercator grid coordinates on field cards to aid in computer-location and mapping. Maps and field cards are on permanent file with the Division of Resource Management, Grand Canyon National Park.

A project priority was to compile a list of known perennial water sources within the study area. Sources were classified as perennial on the basis of detailed records indicating the source had not gone dry within historic times, or the presence of plants indicating perennial surface waters. Maidenhair fern (*Adiantum capillus-veneris*)

was used as an indicator of perennial surface waters in areas below the rim (approximately 2150m) of Grand Canyon. Three other hydrophytic species exist within the area whose presence requires moist mud or rich, moist soil, but whose relationship to perennial surface waters was not understood completely enough or early enough in the inventory to be useful. Columbine (*Aquilegia chrysantha*), crimson monkeyflower (*Mimulus cardinalis*), and helleborine orchid (*Epipactis gigantea*) all require moist mud or mesic habitats (Kearney and Peebles 1951). The above-mentioned species all have shallow root systems which would appear to be an adaptation to wetter conditions. No published research was found to justify the use of any of the four above plants as indicators of perennial surface water. Prominent phreatophyte species including cottonwood (*Populus fremontii*), willow (*Salix* spp.), mesquite (*Prosopis juliflora*), and the introduced salt cedar (*Quercus chinensis*) have not been found to indicate perennial surface water.

No appropriate classification scheme for the Southwest at the level of detail needed was available. Inventory sites were classified according to the system devised specifically for the project (Table 1). This system addresses biological concerns, endangered and threatened species, political concerns, limnological concerns, and public health and access. The classification is a hierarchical system (from general to specific) designed to emphasize the public health aspects of surface water for the park visitor, especially the backcountry user. To derive the classification and the code, numbers from each hierarchical level are combined in sequence to yield an 11-digit number. This numerical classification has the advantage of permitting the meaningful grouping of surface waters and a secondary advantage of permitting easy computer storage and mapping of data gathered. A zero can be inserted at any level where appropriate information is lacking. The terms acre-foot (ac/ft), cubic feet per second (cfs), and gallons per minute (gpm) are used throughout.

A Digitized Hierarchy for The Classification of Surface Water Resources

Where:

- 10,000 permanence
- 11,000 continuity in space
- 11,100 origin
- 11,110 volume and nature of source
- 11,111 nearest perennial source
- 11,111.1 legally threatened and endangered biota
- 11,111.11 primary value or use
- 11,111.111 secondary value or use
- 11,111.1111 water quality (w.q.)
- 11,111.11111 source of w.q. problem
- 11,111.111111 nature of w.q. problem

Definitions

Cistern is a large receptacle for storing water; especially, a tank, usually underground, in which rain water is collected for use. For this classification, the term cistern includes its intake (catchment) area.

Continuous stream is one that does not have interruptions in space. It does not have wet and dry stretches (Meinzer 1923).

Developed Spring is a spring that has been dug, piped, pumped, and/or completely contained in order to obtain maximum discharge for human use of some sort. The term "developed" does not include those springs of which a portion has been diverted (with pipes, ditches, or other method); a developed spring is one in which the entire discharge is being utilized.

Endangered species means any species which is in danger of extinction throughout all or a significant portion of its range (U.S. Fish and Wildlife Service 1978).

Ephemeral stream is one that flows only in direct response to precipitation. It receives no water from springs and no long-continued supply from melting snow or other surface source. Its stream channel is at all times above the water table. The term may be arbitrarily restricted to streams or stretches of streams that do not flow during periods of as much as one month (Meinzer 1923). *

Intermittent stream flows only at certain times when it receives water from springs or runoff. If it is spring fed, the intermittent character of the stream is generally due to fluctuations of the water table whereby the stream channels stand a part of the time below and a part of the time above the water tables. If fed by runoff, the surface source is generally the gradual or long-continued melting of snow in a mountainous or other cold tributary area. The term may be arbitrarily restricted to streams or stretches of streams that flow continuously during periods of at least one month (Meinzer 1923). *

Interrupted stream is one which is interrupted in space, containing (a) perennial stretches with intervening intermittent or ephemeral stretches or (b) intermittent stretches with intervening perennial stretches (Meinzer 1923).

Perennial stream is one which has not gone dry within historic times. Perennial streams are generally fed in part by springs, and their upper surfaces generally stand lower than the water table in the localities through which they flow (Meinzer 1923). *

Playa lake is a shallow, wind-scoured basin that may cover a large area. They are characteristic of deserts. At irregular intervals, desert basins become the seats of broad, shallow sheets of water which quickly gather and almost as quickly evaporate, leaving mud flats to mark their sites. They are essentially ephemeral freshwater lakes (Reeves 1970).

Pothole is a hole worn into the solid rock by wind, solution, or by sand, gravel, and water at falls and strong rapids. Includes the term "plunge pool."

Stocktank is an artificial reservoir for livestock water; it is a local term in the Southwest.

Storage tank is water artificially impounded in service or underground reservoirs for future use (Langbein and Iseri 1960).

Threatened species means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (U.S. Fish and Wildlife Service 1978).

Well is an artificial excavation that derives some fluid from the interstices of the rocks or soil which it penetrates. It is applied to excavations from which water can be drawn by siphons, or to artesian wells. A water well necessarily extends into the zone of saturation (Meinzer 1923).

* Pond/lake, pothole, and stocktank may be classified as perennial, intermittent and ephemeral.

RESULTS

A total of 537 surface water sources was identified within the study area. Perennial sources comprised 57 (11%) of these, with intermittent and ephemeral sources making up the remainder (89%). Total surface water sources included the following: 194 springs (including seeps), 143 streams, 85 lakes, 84 stocktanks, 15 potholes, nine wells, four storage tanks or groups of storage tanks, two developed springs, and one cistern. The majority of data gathered, including geologic formation, flow rates, substrate, and site vegetation will be analyzed by computer at a later date.

The 57 identified perennial sources in Table 1 comprise 21 perennial streams or stretches of streams and 36 perennial springs or seeps which may or may not feed into perennial streams. Of the 36 known perennial springs or seeps, 17 arise from the Muav Limestone; four from the Bright Angel Shale; three from the Tapeats Sandstone; two each from the Redwall Limestone, Coconino Sandstone, and Supai Formation; one each from the Esplanade Sandstone and Toroweap Formation; and the sources of four are unknown. Identified perennial sources occur at an average density of one in every 33 square miles.

DISCUSSION

The total number of identified surface water sources in the study area only approximates the total number of existing sources of all types. Source types which are documented in the literature, such as wells, are easily inventoried. The nine wells located within the study area represent virtually 100% of all existing wells. Other source types which are not well-documented and are inventoried primarily through field work, such as potholes, exist in numbers far greater than those indicated by this inventory.

TABLE 1. Classification System for Surface Water Resources,
Canyon National Park

10000	Perennial Water Source
20000	Intermittent Water Source
30000	Ephemeral Water Source
40000	Inactive Water Source (dry for the last 5 consecutive years)
1000	Continuous Water Supply/Single Source
2000	Continuous Water Supply/Multiple Source
3000	Interrupted Water Supply/Single Source
4000	Interrupted Water Supply/Multiple Source
5000	Not Applicable (i.e. standing water source)
100	Natural Water Source
10	Flowing Water (more than 50 cfs)
20	Flowing Water (10 to 50 cfs)
30	Flowing Water (1 to 10 cfs)
40	Flowing Water (.1 to 1 cfs)
50	Flowing Water (.01 to .1 cfs)
60	Flowing Water (less than .01 cfs or 4.488 gpm)
70	Pond/Lake (greater than or equal to .1 ac/ft)
80	Pothole (less than .1 ac/ft)
90	Playa Lake
200	Man-Altered/Artificial Water Source
10	Developed Spring
20	Ditch
30	Well
40	Storage Tank
50	Cistern
60	Stocktank
1	more than 8 mi. to Next Perennial Source
2	7 to 8 mi. to Next Perennial
3	6 to 7 mi. to Next Perennial
4	5 to 6 mi. to Next Perennial
5	4 to 5 mi. to Next Perennial
6	3 to 4 mi. to Next Perennial
7	2 to 3 mi. to Next Perennial
8	1 to 2 mi. to Next Perennial
9	less than 1 mi. to Next Perennial Source
.1	Endangered Plant Species
.2	Threatened Plant Species
.3	Endangered Animal Species
.4	Threatened Animal Species
.5	Does not Support Endangered or Threatened Species
.01	Ceremonial/Religious
.02	Domestic Use, Developed or Undeveloped
.03	Recreational Use, Swimming, Bathing and Drinking
.04	Agriculture and Livestock Use
.05	Fishing
.06	Aesthetics
.07	Outstanding Scientific Value
.08	Supports Riparian Vegetation
.09	Sediment Transport

Table 1. (continued)

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- .001 Ceremonial/Religious
 - .002 Domestic Use, Developed or Undeveloped
 - .003 Recreational Use, Swimming and Bathing
 - .004 Agriculture and Livestock Use
 - .005 Fishing
 - .006 Aesthetics
 - .007 Outstanding Scientific Value
 - .008 Supports Riparian Vegetation
 - .009 Only One Main Use
 - .0001 Water Quality Problem (public-health level)
 - .0002 Water Quality Problem (non-public health level)
 - .0003 No Water Quality Problem
 - .00001 Problem Source Outside Park
 - .00002 Problem Source Within Park
 - .00003 Problem Source Within and Outside Park
 - .000001 Biological Problem
 - .000002 Chemical Problem
 - .000003 Biological and Chemical Problem
 - .000004 Sedimentation Problem
 - .000005 Thermal Problem
 - .000006 Other Problem
-

Of the 36 identified perennial springs or seeps within the study area, the 17 which arise from the Muav Limestone indicate its importance as a local aquifer. The majority of springs and seeps (perennial and non-perennial) inventoried by Huntton (1977) in the Western Grand Canyon District, 35 of 87 total springs and seeps, was positioned stratigraphically in some member of the Muav Limestone. The Muav is highly fractured and channelized, is underlain by the impervious Bright Angel Shale, and has been referred to many times as a good aquifer (Metzger 1961, Twenter 1962). The Muav Limestone could be the source of many smaller perennial springs and seeps in the study area which were not identified by the present inventory.

Two locations within the study area are noticeably lacking in perennial water sources. The Coconino and Kaibab Plateaus are characterized by ephemeral and intermittent water sources, and are both largely underlain with highly permeable Kaibab Limestone. Twenter (1962) noted that no large springs issue from the Kaibab Limestone, indicating that ground water probably drains from the formation into the underlying rocks. This, in addition to the fact that the Kaibab Limestone occupies such a large outcrop area on the relatively level Kaibab and Coconino Plateaus, should account for the lack of perennial water in those locations.

Table 2. Known perennial¹ water sources within Grand Canyon National Park.

Site No. ²	Name	Location	Geologic Source
BA-1	Boucher Creek ³	NE of Eremita Mesa	-----
BA-79	Bright Angel Creek	River Mile 87.6 (right)	-----
BA-57	Angel Spring		Muav Limestone
BA-56	Emmert Spring		Muav Limestone
BA-59	Ribbon Spring		Muav Limestone
BA-13	Roaring Springs		Muav Limestone
BA-58	Transept Spring		Muav Limestone
S-17	Buckhorn Creek	River Mile 41 (right)	-----
BA-24	Barro Spring	Pipe Creek	Bright Angel Shale
VT-5	Cliff Spring	Cape Royal	Toroweap Formation
BA-78	Colorado River	USGS Gaging Station	-----
BP-78	Copper Creek	River Mile 110.2 (left)	-----
BA-76	Crystal Creek	River Mile 98.2 (right)	-----
BA-49	Crystal Spring		Tapeats Sandstone
KP-26	Deer Creek	River Mile 136.2 (right)	-----
KP-11	Deer Spring		Muav Limestone
KP-42	Unnamed Spring		?
BA-68	Garden Creek	River Mile 89 (left)	-----
BA-26	East and West Springs		Muav Limestone
VT-9	Grandview Spring	Hance Canyon	Muav Limestone
VT-8	JT Spring	Hance Canyon	Muav Limestone
KP-28	Havasupai Creek	River Mile 156.7 (left)	-----
S-2	Havasupai Springs		Supai Group
KP-14	Unnamed Spring		Redwall Limestone
S-6	Unnamed Springs		Supai Group
BA-74	Hermit Creek	River Mile 94.9 (right)	-----
BA-30	Dripping Springs		Coconino Sandstone
BA-10	Santamaria Spring		Esplanade Sandstone
BA-6a	Unnamed Spring		Tapeats Sandstone
BA-104	Unnamed Spring		Coconino Sandstone
BP-83	Hundred and Twenty Mile Creek	Blacktail Canyon	-----
KP-34	Hundred and Fifty Mile Creek	River Mile 149.7 (right)	-----
KP-27	Kanab Creek	River Mile 143.5 (right)	-----
VT-23	Little Colorado River	River Mile 61.4 (left)	-----
N-8	Nankoweap Creek	River Mile 52.5 (right)	-----
N-10	At Last Spring		Muav Limestone
BP-31	Ole Creek	River Mile 145.5 (left)	-----
BA-105	Phantom Creek	West side of Bright Angel Canyon	-----
BA-61	Haunted Spring		Muav Limestone

Table 2. (continued)

Site No.	Name	Location	Geologic Source
BA-60	Phantom Spring		Muav Limestone
HP-68	Royal Arch Creek	River Mile 116.4 (left)	-----
HP-67	Shinumo Creek	River Mile 108.6 (right)	-----
PP-47	Shinumo Spring		Muav Limestone
PP-35	Tapeats Creek	River Mile 133.7 (left)	-----
PP-1	Tapeats Spring		Muav Limestone
PP-11	Thunder River	Tributary of Tapeats Creek	-----
PP-7	Thunder Spring		Muav Limestone
N-14	Vasey's Paradise	River Mile 31.9 (right)	Redwall Limestone
HP-22d	Unnamed Seep	Turquoise Canyon	Bright Angel Shale
HP-27c	Unnamed Seep	Slate Canyon	Muav Limestone
KP-43	Unnamed Seep	River Mile 148.2 (right)	?
KP-44	Unnamed Spring	River Mile 155 (right)	?
KP-45	Unnamed Seep	River Mile 138 (right)	Tapeats Sandstone
KP-47	Unnamed Seep	River Mile 152.7 (right)	Muav Limestone
KP-51	Unnamed Seep	140-Mile Canyon	Bright Angel Shale
N-18	Unnamed Seep	River Mile 35.5 (left)	?
S-46e	Unnamed Seep	Forster Canyon	Bright Angel Shale

¹ Sources are classified as perennial on the basis of detailed field records indicating the source has not gone dry within historic times, or on the presence of maidenhair fern (*Adiantum capillus-veneris*). Further research will no doubt identify other perennial sources within the study area. Sources which may possibly be perennial, and have never been known to go dry, but lacking sufficient field or historic records include: Bedrock Canyon Creek (PP-40), Galloway Canyon Creek (PP-41), Grapevine Canyon Creek (BA-80), Matkatamiba Canyon Creek (KP-35), Monument Canyon Creek (BA-46), Noble Spring (PP-25), Pipe Spring (BA-25), Slate Creek (BA-75), South Big Spring (PP-28), Stone Creek (PP-42), and White Creek (PP-36). Clear Creek Spring (VT-44) and a portion of Clear Creek (BA-82) were identified as perennial on the basis of the presence of maidenhair fern after this manuscript was typed.

² Site numbers correspond to USGS topographic maps deposited with the Division of Resource Management, Grand Canyon National Park.

³ A stream classified as perennial may be perennial for part or all of its length. Sources of streams, when springs which feed them are not listed, are unclear or unknown.

Intermittent and ephemeral sources predominate in the region. While intermittent sources receive water from springs or long-term runoff and ephemeral sources contain water only in direct response to runoff, there is some degree of difficulty in separating the two if historical information is lacking. The appearance of intermittent sources may be deceptive as well, as some go dry for only several seasons a decade. While it is difficult to quantitatively relate precipitation and runoff to the occurrence of local surface water resources, some inferences may be made. Little precipitation fell during the years of 1976 and 1977 and many water sources were dry for the first time on record, as indicated by historic information gathered. However, the winter of 1978-1979 was very wet, causing many intermittent streams to flow throughout the summer of 1979, when they no doubt had previously been dry by June. Since several of these sites had not been inventoried prior to the spring and summer of 1979, their volume and apparent summer-constant flow were deceptive when viewed from the perspective of one year's data.

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LITERATURE CITED

- Arenal, R.C. del. 1969. Water resources of Mexico. Water Res. Bull. 5(1):19-38.
- Caldwell, L.T. 1968. A study of water resources in the Canberra area and the Queanbeyan River watershed (Googong Dam catchment). Water Res. Bull. 4(4):15:27.
- Dutton, C.E. 1882. Tertiary history of the Grand Canyon District. U.S. Geol. Survey Monog. No. 2, Wash., D.C. 264p.
- Farrar, C.D. 1979. Map showing ground-water conditions in the Kaibito and Tuba City areas, Coconino and Navajo Counties, Arizona--1978. U.S. Geol. Survey Water Res. Investigations 79-58, Open-file Rpt., Tucson, Ariz. 1 map.
- Hantoon, P.W. 1968. Hydrogeology of the Tapeats Amphitheater and Deer Basin, Grand Canyon, Arizona: a study in karst hydrology. M.S. Thesis, Univ. Ariz., Tucson. 105p.
- _____. 1970. The hydro-mechanics of the ground water system in the southern portion of the Kaibab Plateau, Arizona. Ph.D. Thesis, Univ. Ariz., Tucson. 381p.
- _____. 1974. The karstic ground water basins of the Kaibab Plateau, Arizona. Water Res. Research 10(3):579-590.
- _____. 1977. Relationship of tectonic structure to aquifer mechanics in the Western Grand Canyon District, Arizona. Univ. Wyoming Water Res. Series No. 66. 51p.
- Ives, J.C. 1861. Report upon the Colorado River of the West. U.S. Govt. Print. Off., Wash., D.C. 131p.

- Johnson, P.W., and R.B. Sanderson. 1968. Spring flow into the Colorado River - Lees Ferry to Lake Mead, Arizona. Water Res. Rpt. No. 34, Ariz. State Land Dept., Phoenix. 25p.
- Kearney, T.H., and R.H. Peebles. 1951. Arizona flora. Univ. of Cal. Press, Berkeley. 1085p.
- Langbein, W.B., and K.T. Iseri. 1960. General introduction and hydrologic definitions -- manual of hydrology: part 1, general surface-water techniques. U.S. Geol. Survey Water-Supply Paper 1541-A, Govt. Print. Off., Wash., D.C. 29p.
- LaRue, E.C. 1925. Water power and flood control of the Colorado River below Green River, Utah. U.S. Geol. Survey Water-Supply Paper 556, Wash., D.C.
- Meinzer, O.E. 1923. Outline of ground-water hydrology with definitions. U.S. Geol. Survey Water-Supply Paper 494, Govt. Print. Off., Wash., D.C. 71p.
- Metzger, D.G. 1961. Geology in relation to availability of water along the South Rim, Grand Canyon National Park, Arizona. U.S. Geol. Survey Water-Supply Paper 1475-C, Govt. Print. Off., Wash., D.C. 38p.
- Powell, J.W. 1875. Exploration of the Colorado River of the West and its tributaries. U.S. Govt. Print. Off., Wash., D.C. 291p.
- Qureshi, Z. 1975. Surface water resources of St. Johns River, Florida. Water Res. Bull. 11(3):568-574.
- _____. 1978. Surface water resources of northwest Florida. Water Res. Bull. 14(3):710-718.
- Reeves, C.C., Jr., ed. 1970. Playa lake symposium. Int. Center for Arid and Semi-Arid Land Studies and Dept. of Geosciences Publ. No. 4, Texas Tech Univ., Lubbock. 334p.
- Twenter, F.R. 1962. Geology and promising areas for ground-water development in the Hualapai Indian Reservation, Arizona. U.S. Geol. Survey Water-Supply Paper 1576-A, Govt. Print. Off., Wash., D.C. 38p.
- U.S. Fish and Wildlife Service. 1978. The Endangered Species Act of 1973 (including amendments). U.S. Dept. Interior, Fish and Wildl. Service. 43p.