ACCESSING WATERSHED-RELATED DATA SETS THROUGH THE WORLD WIDE WEB

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There is a continuing need to increase people's awareness of the contributions of watershed management to conservation, sustainable development, and appropriate use of natural resources. Computer technologies are highly effective in storing, retrieving, and summarizing watershed-based data sets on the World Wide Web. Such information is valuable to managers when planning and implementing watershed management practices, to researchers when testing and validating predictive models, and to educators when learning and teaching about hydrologic processes. Information from the Beaver Creek watershed in north-central Arizona was incorporated into a Web site to illustrate the accessibility of such data. These data represent natural resource responses to watershed management practices in ponderosa pine (*Pinus ponderosa*) forest and pinyon-juniper (*P. edulis-Juniperus* sp.) woodland types in the Southwest. A system is also included for documenting and retrieving images, publications, and reports produced during the Beaver Creek project using various parameters such as keywords, dates, and locations. This paper describes procedures used to store, retrieve, and summarize Beaver Creek watershed-based data on the World Wide Web.

Beaver Creek Watershed

The Beaver Creek watershed is in north-central Arizona (see descriptions at http://www.rmrs.nau.edu/ wsmgt/ beavercr/, http:// ag.arizona.edu/OALS/watershed/, and http://www.verde.org/). The center of the watershed is about 50 km south of Flagstaff. The watershed, encompassing 111,300 ha upstream from the junction of Beaver Creek and the Verde River, is part of the Salt and Verde River basins, which are major river drainages in central Arizona (Baker 1999). The Salt and Verde rivers provide much of the surface water for Phoenix and other communities in the heavily populated Salt River Valley. The Beaver Creek watershed was selected for study because it represents extensive areas of ponderosa pine forests and pinyon-juniper woodlands in the Southwest.

Annual precipitation varies from year to year, which is characteristic of the climate in the Southwest (Baker 1999). On average, the ponderosa pine forests receive 500 to 635 mm of water and the pinyon-juniper woodlands receive 460 to 500 mm annually from rain and snow. Most of the annual runoff (95% in the ponderosa pine and 85% in the pinyon-juniper woodlands) is from the melting snowpack in March and April.

In descending order with respect to elevation, the three vegetation types on the watershed are ponderosa pine, pinyon-juniper (including alligator juniper [*Juniperus deppeana*] and Utah juniper [*J. osteosperma*] subtypes), and semi-desert shrubs. Ponderosa pine, characteristic of 4.5 million ha in the Southwest, dominates the hillsides and plateau above 2,000 m. Scattered throughout these forests are clumps of Gambel oak (*Quercus gambelii*), the predominant deciduous tree. Woodlands of intermingled pinyon, Utah juniper, and alligator juniper grow between 1,370 and 2,000 m elevation, as they do on some 20.6 million ha in the Southwest.

Methods of Data Collection

A system of paired watersheds, established within a given vegetation type, was used to evaluate treatment responses. Initial comparisons of the water yield and other products from small, natural watersheds were completed before any treatments were applied. After the pretreatment evaluation, one of the watersheds of each pair was altered by vegetative manipulations and the other was used as a control. Twenty pilot watersheds within the Beaver Creek area (Baker 1999; Baker and Ffolliott

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2000) were established between 1957 and 1962 to test treatment effects. Of these, 18 watersheds were from 27 to 824 ha in size. The other two basins, encompassing 4,900 and 6,680 ha, were created to demonstrate the effects of management practices on areas similar in size to those common to land managers. In the early 1970s, 24 smaller subwatersheds with uniform soil, plant life, and topography were delineated in areas with diverse ecological characteristics. Seventeen subwatersheds were on volcanic-derived soils and seven were on sedimentary-derived soils (three at Rattle Burn and four at the Heber site) to document the differences in resource responses from different parent materials. Information from these smaller, homogeneous subwatersheds helped refine and verify findings from studies on the 20 pilot watersheds, and promoted their application to a wide range of conditions.

Studies in ponderosa pine forests and pinyon-juniper woodlands have evolved from an emphasis on evaluation of changes in water yield to include evaluation of changes in livestock forage, timber production, wildlife habitats, recreational values, and soil movement. A wide range of management treatments were tested on Beaver Creek (Baker 1999; Baker and Ffolliott 2000). Treatments included conversion of vegetation type in the pinyon-juniper woodlands and silvicultural practices, such as clearcutting, thinning, and strip cutting, to increase water yields; patch cutting to favor wildlife; and shelterwood cutting to promote maximum sustained timber production in the ponderosa pine forest. Hydrologic response, timber and forage yields, soil erosion, sediment production, water quality, scenic beauty, and the dynamics of insect, bird, small animal, and big game populations were measured posttreatment. Early research was summarized in state-of-the-art publications (Brown et al. 1974; Clary et al. 1974).

Organization of the Web Site

Data sets from Beaver Creek are organized to reflect the components of a water budget; that is, precipitation inputs (quantity and quality) minus streamflow outputs (quantity and quality) equals evapotranspiration (as modified by geology, soil, elevation, and vegetation). Data are expressed in English units of measure as used in original data collections; computers allow rapid conversion to metric units of measure. The Beaver Creek Evaluation Project Web site contains these data sets as well as links to the following categories (http://www.rmrs.nau.edu/wsmgt/beavercr/):

- *Overview.* Provides a site description, a site history, and a description of research, and highlights research findings. Most sections include a list of selected references pertaining to the topic addressed. Maps are available showing the stream system, both ephemeral and perennial, vegetation types, soils, geology, town and road systems, locations of stream gages, and meteorologic instrumentation.
- *Watershed Descriptions.* Includes watershed area, slope, aspect, elevation, gage locations, vegetation type, parent material type, stream gage type, period of record, treatment information, results, comments, and references, where appropriate. Descriptive photos are available. Each watershed page has a map that enables a user to navigate to another watershed. Some of the pilot watersheds also contained smaller subbasins, and these pages include similar descriptive data as outlined above.
- *Publications.* Links to the project's searchable publication database, which contains nearly 700 annotated citations for publications and reports that were developed from the Beaver Creek project (Baker and Ffolliott 1998; Baker et al. 2000a). Publications are divided into 24 subject areas and can be searched by category, keywords, date, author, or any combination of these.
- *Management Implications.* Provides key findings for water, sediment production, timber and forage production, and other results from the research on the ponderosa pine and pinyon-juniper vegetation types. A list of references for additional information is included.
- *Data.* Contains an overview and description of precipitation, weather, streamflow, vegetation, soil, and animal data. Pertinent references are included. A brief description and the file format are available for each data type. Most data were collected from 1957 through 1983.

Precipitation. Includes precipitation depth by gage and watershed and precipitation chemistry.

Weather. Contains data on air temperature and humidity, wind speed and direction, snow, and solar radiation.

Stream. Consists of instantaneous and daily streamflow information by watershed and streamflow chemistry.

Vegetation. Includes timber and range data by inventory dates for the various watersheds. Scientific and common names of plant species are available for the major vegetation types (ponderosa pine, pinyon-juniper, and desert shrub).

Soil. Contains soil descriptions, type, texture, and depth by watershed.

Animal. Includes data for the various animal inventories by date and watershed. Scientific and common names of animal species for the major vegetation types are available.

- *Images.* Links to a searchable image database with more than 2,000 images that were collected during the Beaver Creek project (Baker et al. 2000b). Several options, both simple and complex, are available for searching the image collection using keywords, site names, and comments. Hints, examples, and drop-down lists are provided to assist users in making searches.
- *Personnel.* Lists names of personnel associated with the project from 1957 through 1983.
- *Related Links.* Includes links to other Web sites of potential interest to users of the Beaver Creek site.
- *Current Events.* Links to topics of current interest.

Background on Data Collection

The following information should help users understand the data sets in the Beaver Creek project Web site and permit more efficient interrogation and interpretation. The instrumentation and measurement procedures used in data collection are described.

Precipitation Data

All hydrology-related data were collected on a water year basis from October 1, Julian Day (JD) 274 through September 30, JD 273. Precipitation falling on the watershed from 1957 through 1982 was measured with a network of about 60 gages. Four types of rain gages were used in collecting the measurements: recording rain gages (0100 series), standard (20.3 cm [8 inch]) non-recording rain gages located next to recording gages (0200 series), remote (not adjacent to a recording gage) standard non-recording gages (0300 series), and Sacramento storage gages (0400 series). One recording rain gage, the 0100 series, and its companion standard gage, the 0200 series, were generally located on each watershed. Additional standard rain gages (the number depended on the size of the watershed and accessibility), the 0300 series, were located on each watershed and were visited weekly. The Sacramento storage gages, the 0400 series, are large gages capable of storing up to 1,000 mm of precipitation. These gages were located at remote locations that were difficult to reach and were serviced twice a year. Gage locations were selected on the basis of access and assurance of adequate coverage on each watershed. Precipitation measured in the standard 20.3 cm rain gage was used to designate the true amount at each site. The nearest recording gage was used to prorate the amounts measured in all non-recording gages. All watersheds contained two to six precipitation gages. Average watershed precipitation inputs were subsequently determined using the Theissen Method of averaging for the allotted number of precipitation gages. The Theissen Method permits arbitrary weighing of each gage catch by the area nearest to it. This is accomplished by connecting all gages, as plotted on a map, by a straight line. Perpendicular bisectors of each connecting line are drawn, forming polygons around each fractional area of the watershed lying within that polygon.

Air Temperature and Relative Humidity

A weather station was located in the Utah juniper vegetation type on watershed 3 (WS3; 0001) and in the alligator juniper type on WS4 (0009). Three weather stations were located in the ponderosa pine type on WS8 (0020), WS17 (0035), and WS20 (0038). Analog hygrothermographs were used to record air temperature and relative humidity with a weekly chart. The period of record is usually from water year 1957 through 1982. These data can be used to characterize additional meteorological conditions on the watersheds.

Streamflow Data

Streamflow was measured using the Beaver Creek supercritical, trapezoidal flume on the 18 pilot watersheds (Baker 1986). Larger control sections, developed to measure flow in excess of 28.3 m^3/sec but with sufficient precision for long-term hydrologic investigations, were located on Woods Canyon (WS19) and Bar M Canyon (WS 20), the two largest watersheds (Brown 1969). Streamflow from the 24 subwatersheds, established in the early 1970s, was measured in 0.6 m H flumes with a maximum capacity of 0.3 m^3/sec. Daily streamflow data include total flow in cubic meters and in area millimeters, peak discharge in cubic meters per second, and time of occurrence. Monthly flow is included for all water years of record.

Management Implications

The information and data sets at this Web site can be used in many ways by land managers, researchers, educators, policy makers, and the interested public. These and similar data sets provide a basis that can help watershed managers resolve future land stewardship issues. Although these databases

in their original form are in the public domain, they were only minimally useful because knowledge of their existence was limited and accessibility was difficult. Accessing these databases via the Web allows people to download them into software packages and models that did not exist when the data were being collected. Research results from the Beaver Creek watershed project are applicable in many arid and semi-arid regions of the world, and they provide long-term resource data for new analysis techniques and model applications. There have been more than 70 technical publications based on this project since it was terminated in 1983 (Baker and Ffolliott 1998).

As useful as the Beaver Creek Evaluation Project Web site presently is, plans are to continue adding data and information to further improve the site. Among these additional data sets are sedimentation concentrations and streamflow chemistry; snowpack accumulation and melt patterns; forest overstory growth, yield, and quality; forage production and use; and wildlife habitat use. Aerial photos, inventory plot maps, and other information can also be added as additional GIS layers.

The Beaver Creek Evaluation Project Web site is technical in nature. To increase educational outreach to more people, a related project, Watershed Management in the Southwest (http://ag.arizona.edu/OALS/watershed/), was developed to provide additional background material about watershed management and, specifically, the Beaver Creek Experimental Watershed.

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