USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Testing of Hydrologic Models for Estimating Streamflow in Mountainous Areas of Wyoming

Focus Category: HYDROL, MOD, WQN

Keywords: Instream flow, Streamflow estimating

Duration: March/2000 – Feb/2001 (With extension to be requested for two to three additional years)

FY 2000 Federal Funds: $12,520

FY 2000 Non-Federal Funds: $37,530

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Congressional District: 1

Statement of critical regional or State water problems

Approximately 70% of the surface water originating in Wyoming comes in the form of snow (Jacobs and Brosz, 1993) with snowfall amounts varying radically from year to year. In order for a water right to be properly allocated, some assurance is needed that the natural flows are available for the intended purpose. Management policies must account for the yearly, and sometimes large, variations in supply.

The ideal situation for planning and engineering involving streamflow is to have long-term data available for the site from a gaging station. However, economic constraints prevent the installation and operation of gages at every site where streamflow information may be needed. If a gaging station has not been operated at or near a site where a development or water right is being considered, then estimates of streamflow are useful.

Statement of results or benefits

Applications for accurate streamflow estimates are numerous. The process for instream flow applications in Wyoming calls for a recommendation for a instream flow right from the Wyoming Game and Fish Department (WGFD) followed by an evaluation of streamflow availability by the Wyoming Water Development Commission (WWDC). WWDC uses hydrologic models for evaluating the hydrologic feasibility of instream flow recommendations in mountainous areas where streamflow gaging records do not exist. The Wyoming Department of Environmental Quality (WDEQ) also needs hydrologic data, especially for low flow periods, for mountainous areas to assess watersheds for

Total Maximum Daily Loads. Other potential users of streamflow estimates are the Wyoming Department of Transporation for defining flood flow levels and probabilities and the USDA Forest Service for habitat evaluations and other watershed-based analyses.

Nature, scope, and objectives

This study is a continuation of a previous project for estimating monthly streamflow in the mountainous areas of Wyoming (Misalis, Wesche, and Lowham, 1999). The primary purpose of this phase of the study is to determine and document the accuracy of the available methods for estimating monthly streamflow. The secondary purpose is to review the possibilities of using emerging technologies, such as analyses using Geographic Information Systems (GIS) of color or infrared photography, that may help to describe differences in low flows.

Several methods are available for estimating streamflow; a particularly useful technique is to develop equations that relate streamflow characteristics to measurable features of the drainage basin. The equations are developed through a regression analysis. Data from gaged streams are used in the analysis. The resulting equations use features such as drainage area and elevation to estimate streamflow characteristics such as monthly flows.

Methods, procedures, and facilities

Accuracy of Estimates: The approach for determining the accuracy of available techniques would be to select five ungaged sites where applications for instream flow water rights are pending. Estimates of mean monthly streamflow would be made for the months of October through March, using the following techniques:

· Equations of monthly streamflow versus drainage-basin characteristics and channel width for the mountainous areas of Wyoming (Misalis, Wesche, and Lowham, 1999).

· Equations of mean-annual streamflow versus drainage-basin characteristics (Lowham, 1988), with monthly streamflows then determined by using data from nearby gaged streams. The relative distribution of flow for each month is transferred from the gaged site to the ungaged site. The monthly percentages of flow for the gaged site are applied to the estimate of mean-annual flow at the ungaged site to estimate the monthly flows at the ungaged site.

· Equations of mean-annual flow versus channel width (Lowham, 1988). The monthly streamflows are then determined using the distribution of flow recorded at nearby gaged sites as described above.

Data would then be collected at the five ungaged sites and compared with the estimates. Streamflow measurements would be made near mid-month for October through March. These months typically have the lowest flows for undeveloped mountain streams, which is the critical period for instream flows.

The monthly discharges are related to concurrent daily mean discharges at one or more nearby streamflow-gaging stations using a separate relation of 45-degree slope for each month. The monthly mean flow at the gaged site is then transferred though the appropriate relation to obtain an estimate of the monthly mean at the ungaged site (Riggs, 1969).

Five sites that have applications pending for instream flow water rights would be selected by the project investigator and staff of the Wyoming Water Development Commission (WWDC). The sites would be selected on the basis of:

· Economic considerations assuming travel from Cheyenne, and using opportunities for field assistance from the staffs of the WWDC and the Wyoming State Engineer's Office (WSE). Efforts would be made to minimize overnight travel, to use available private residences, or cabins that may be available from sources such as the U.S. Forest Service.

· Differences between the sites that provide ranges in drainage area, elevation, basin slope and aspect, and other pertinent basin features.

· Location with respect to existing or discontinued streamflow gages that have suitable long-term periods of record.

A monthly field trip would be made, with the principal investigator or one of his staff, and a staff member from the WWDC or WSE. Discharge measurements would be made at each ungaged site. If the selected gaged sites are operating, discharge records would be obtained from the operating agency. If the selected gaged sites are discontinued and not operating, then a discharge measurement would also need to be made at the gaged sites in addition to the ungaged sites.

The mountain sites generally would be accessed using snowmobiles or snowshoes, and winter safety procedures would be followed. This would include using detailed itineraries and reporting at the end of each day, traveling in a group of at least two persons, first-aid and CPR training by participants, and the use of good equipment including a cellular phone. Discharge measurements would be made using accepted standard procedures for winter and ice conditions.

Selection of a study area for ungaged sites in the Medicine Bow Mountains would have advantages: 1) Relatively short traveltime from Cheyenne, and 2) abundance of gaged sites available for comparison.

Evaluation of Emerging Technologies: The approach for determining the usefulness of emerging technologies such as analysis of color or infrared photos using GIS will be to review basins for the selected sites, and compare relative differences in streamflows with differences in patterns or color on aerial or satellite photos that depict basin features.

Aerial or satellite photographs and/or imagery will be obtained for the area of the selected sites. Streamflow characteristics for the gaged and ungaged sites will be summarized and unitized by dividing the flow by the drainage area and channel width. Comparisons of runoff per square mile and runoff per foot of channel width will then be made with the respective basin boundaries on the photographs. If a particular color or feature appears related to the magnitude of the flow, then measurements of the characteristic within the drainage area will be related to the flow characteristic.

General: It is suggested that the project be conducted for two years, so that at least two discharge measurements can be made for each month at each site. It is possible that field work during the second year could be reduced to 3 trips (December, January, and February) to reduce costs of the field work and make more funds available for data analysis.

Related Research

A study recently was completed that provides updated methods for estimating monthly streamflows in the mountainous areas of Wyoming (Misalis, Wesche, and Lowham, 1999). The report provides separate sets of regression relations for estimating mean monthly streamflow and other flow characteristics for each of the major mountain ranges. The study used streamflow data available as of 1998, and channel width measurements for additional stations to update a method developed by Lowham (1988).

The above-described methods for estimating streamflow use statistical analyses to determine the best-fit equations. The accuracy of the estimates is estimated using statistical methods that are part of the regression analysis, and from comparison of how the resulting model compares against station data that are withdrawn from the analysis. For areas where station data are short, withdrawal of stations from the baseline analysis can result in a less-accurate regression, even though a comparison can be achieved of how well the regression fits with the withdrawn data set.

Given the relatively small numbers of stations available for several of the mountain ranges, desirable ranges of independent variables (drainage area, elevation, slope, etc) were not available for the analyses after a test group of stations was withdrawn.

Additional methods of estimating streamflow, other than regression analysis with features of the drainage basin, are available. For example, the concurrent-measurement method (Parrett and Cartier, 1990, and Lowham, 1986, p. 35) estimates streamflow at ungaged sites by correlating with concurrent discharges at some nearby, hydrologically similar, gaged site. Periodic measurements of streamflow are made at a selected ungaged site. The measured streamflows at the ungaged site are correlated with concurrent streamflows at the selected gaged site. The relation between the streamflows at the two sites is used to determine the long-term monthly streamflow characteristic at the gaged site to the ungaged site. This method requires field data collection for the months of interest.