Wyoming Water Resources Center
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FY 2001

Introduction

The NIWR/State of Wyoming Water Research Program (WRP), placed at the University of Wyoming, oversees the coordination of Wyomings participation in the NIWR program. The primary purposes of the program are to support and coordinate research relative to important water resources problems of the State and Region, support the training of scientists in relevant water resource fields, and promote the dissemination and application of the results of water-related research.

State support for the research program includes direct funding through the Wyoming Water Development Commission and active State participation in identifying research needs and project selection and oversight. Primary participants in the WRP are the USGS, the Wyoming Water Development Commission, and the University of Wyoming. A Priority and Selection Committee (P&S Committee)--consisting of representatives from agencies involved in water related activities in the State--solicits and identifies research needs, selects projects, and reviews and monitors progress. The Director serves as a point of coordination for all activities and serves to encourage research by the University of Wyoming addressing the needs identified by the P&S Committee. The State also provides direct funding for the administration of the WRP.

The WRP supports faculty and students in University of Wyoming academic departments. Faculty acquire funding through competitive, peer reviewed proposals. Since its inception in the year 2000, the WRP has funded researchers in six academic departments and has supported a total of nine research projects. Each project represents the education of one or more students. The WRP provides interaction from all the groups involved rather than being solely a University of Wyoming research program. Results of research are encouraged to be presented in peer-reviewed publications, project report and thesis format, and user oriented bulletins. Results are also available through the Wyoming Water Resources Data Systems library.

Research Program

Hydrologic Impacts of Improved Irrigation Efficiencies and Land Use Changes

Basic Information

Title:	Hydrologic Impacts of Improved Irrigation Efficiencies and Land Use Changes
Project Number:	2001WY1741B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	
Focus Category:	Hydrology, Surface Water, Irrigation
Descriptors:	Hydrograph analysis,Return flow
Principal Investigators:	Drew Johnson , Larry Pochop , Bruce Brinkman , John Barnes

Publication

1. Venn, B. J. (2002). Hydrologic Impacts Due to Conversion from Flood to Sprinkler Irrigation Practices. MS Thesis. Department of Civil and Architectural Engineering. Laramie, WY, University of Wyoming.
2. Venn, B. J., D. W. Johnson, et al. (2002). "Hydrologic Impacts Due to Conversion from Flood to Sprinkler Irrigation Practices." Journal of Irrigation and Drainage Engineering submitted for publication, June 2002.

Problem and research objectives:

The conversion from flood irrigation to sprinkler irrigation provides many benefits to farming communities including savings in water, energy, and labor, which are supplemented with the farmer's ability to produce increased crop yields (Guitjens and Goodrich 1994). With the conversion to sprinkler irrigation, farmers can place more acreage into production, and adjust harvest dates to best fit market conditions. Perhaps the greatest benefit to farmers resulting from changing irrigation practices is the increase in total irrigation efficiency. Irrigation efficiency is defined as the ratio of net volume of water beneficially used by the crops to the volume of water applied to the crops (Burt, Clemmons et al. 1997). Delivery systems and many climatic and geologic factors, such as wind, soil type, solar influences and precipitation influence irrigation efficiencies. Irrigation efficiencies reported for flood irrigation systems range from 45% to 60%, while sprinkler irrigation efficiencies range from 60% to 80% (Wolter and Bersisavlijevic 1991; Zalidis, Dimitriadis et al. 1997). In most case studies, average irrigation efficiencies increase from approximately 50% to 70% after converting from flood to sprinkler irrigation.

While improvements in irrigation efficiency are well documented when changing from flood to sprinkler irrigation, impacts to the watershed are not well known. The resulting impacts to a river basin hydrology are the focus of this study.

Objectives of this study are to quantify the potential hydrologic impacts to a watershed when irrigation systems are converted from flood to sprinklers and to relate these impacts to the various hydrologic components through which they occur. Specific objectives include the determination of changes in: (1) return flow timing, (2) irrigation efficiencies, (3) total annual river flow, (4) land use; including agricultural production, (5) surface water and groundwater quality, and (6) groundwater levels in the unconfined aquifer impacting river recharge.

Methodology:

Because of its physical characteristics, the Star Valley presents a unique opportunity to study the hydrologic impacts of irrigation changes and differences in irrigation efficiencies. The Salt River and many of its tributaries flowing through the Star Valley provide as much as 95% of the water used for irrigation. The Greys River flows through a narrow drainage basin of approximately 1160 km^2 (448 mi^2) on the other side of the Salt River Mountain Range adjacent to the Salt River. The Greys River is in close proximity to the Salt River and it contains nearly the same flow as the Salt River. However, unlike the Salt River, the Greys River has not been significantly impacted by changes in irrigation practices since the river only provides water to about 200 ha (500 acres) of irrigated agriculture. As such, a comparison of flows in the two rivers before and after the application of sprinkler systems provides an excellent method to investigate impacts associated with the change from flood irrigation to sprinkler irrigation.

Double mass balance plots were created for analyzing the flow consistency of the Salt River, utilizing the Greys River as a control. The period of record analyzed was from 1954 through 2000. United States Geological Survey (USGS) stream gages were used as the primary data resources. USGS station 13027500 located near Etna, Wyoming above the Palisades Reservoir (latitude 43 – 04', longitude 111 – 02') was used to represent the Salt River flows. USGS station 13023000 located near Alpine, Wyoming above the Palisades Reservoir (latitude 43 – 08', longitude 110 – 58') was used to represent the Greys River flows. The slopes of the double mass balance plots represent ratios of cumulative monthly flow in the Greys River to cumulative monthly flow in the Salt River. This ratio for each month was calculated for flows prior to the change to sprinkler irrigation and another ratio was calculated for flows after sprinkler irrigation. The difference in ratios between the pre-sprinkler and post-sprinkler periods for a month multiplied by the average monthly flow in the Salt River for that month represents the change of average stream flow in the Salt River for that month. Annual conservation of water was calculated by summing the average monthly values of the months considered to be statistically significant. Annual conservation of water and an assumed prior flood irrigation efficiency were used to estimate changes in irrigation efficiencies.

Conservation of water resulting from different irrigation practices is associated with changes in hydrologic mechanisms acting in the drainage basin. One mechanism affecting the river basin hydrology is canal evaporation. Canal evaporation losses during conveyance that occurred with the flood irrigation systems are eliminated with sprinkler systems. Based upon monthly evaporation losses for reservoirs and estimates of surface area of water in the canals, evaporation loss calculations for the open canals were made for two of the larger irrigation districts, the Cottonwood Irrigation District and the Dry Creek Irrigation District. These calculations were then extrapolated to estimate the canal evaporation for the entire drainage basin.

The groundwater hydrology is also impacted by changes in irrigation practices. Direct impacts to groundwater hydrology, such as changes in groundwater elevation, aquifer capacity, and the hydrologic cycle occur due to changes in seepage and deep percolation. Well logs obtained from the Groundwater Division at the Wyoming State Engineer's Office for every well installed in the Star Valley area were analyzed to try to determine any impacts to the groundwater elevation. The well logs contained information on the owner of the well, the type of water use, initial static level of the groundwater, initial groundwater depth, the depth of the well, the main water bearing zone, the approximate location of the well, the geology of the soils enclosing the well, and the drilling date of the well.

The changes in irrigation practices may also have impacts upon the water quality within the watershed. The Star Valley contains large saline deposits (Walker 1965), and the leaching of salts during irrigation may cause water quality concerns with respect to domestic and agricultural use. The gaging station, USGS stream gage #13027500, utilized for stream flow analysis on the Salt River contained data on water quality, including salinity, total dissolved solids, and conductance for the period of 1965-1975. Fortunately, the period of record contains data years before and after the change in irrigation techniques

Principal findings and significance

Objectives of this study were to quantify the potential hydrologic impacts to a watershed when irrigation systems are converted from flood to sprinklers and to relate these impacts to the various hydrologic components through which they occur. Specific objectives included the determination of changes in: (1) return flow timing, (2) irrigation efficiencies, (3) total annual river flow, (4) land use; including agricultural production, (5) surface water and groundwater quality, and (6) groundwater levels in the unconfined aquifers impacting river recharge.

Return flow timing was impacted by the conversion to sprinkler irrigation. Stream flows increased 34% in May and 50% in June, while decreasing 14% and 15% for August and September. These changes are related to how on-field application efficiency of irrigation water increases with sprinkler irrigation. Because conveyance for sprinkler irrigation now occurs in a pipe network, deep percolation, seepage, and groundwater recharge related to the former flood irrigation practices are eliminated. The change in timing of return flows has the potential to hamper irrigators in the lower end of the valley, because the river flow has decreased during the time of the irrigation season when the irrigation water is under its greatest demand. Practical solutions for reducing the impacts of the return flow timing include installation of catchments. The early spring runoff could be stored and utilized more beneficially to alleviate the 15% decrease in available in-stream flow at the end of the irrigation season.

The overall irrigation efficiency in the study area increased from an assumed value of 50% for flood irrigation to 70% for sprinkler irrigation. The 20% increase in irrigation efficiency resulted in major hydrologic impacts to the Salt River basin, including an increase in average annual flow of 65.62 MCM (53,200 acre-ft). The average annual Salt River Flow is approximately 722 MCM (575,000 acre-ft), and the 65.62 MCM of excess flow represents 9% of the average annual Salt River flow. The increased flow is substantial as it represents approximately 55% of the average annual consumptive use requirement in the study area.

The excess flow occurred even with an increase in crop yields. After the conversion from flood irrigation to sprinklers, average crop yields increased from 1.6 ton/acre to 2.1 ton/acre. Crop yields increased because farmers can now more evenly distribute irrigation water to their fields and irrigate higher reaches of their fields. Since 1990, population increased in the area by about 17%. This increase in population has yet to show any significant impact upon river basin hydrology.

The surface water quality appears unaffected by the conversion in irrigation practices. Dissolved solids concentrations within the Salt River for the sprinkler period maintained quantities within 10% of the concentrations measured for the pre-sprinkler period. The results of the limited groundwater quality data indicate that TDS values are lower in sprinkler irrigated areas.

The observed impacts to the river basin hydrology are mainly due to canal evaporation, ET, phreatophytic consumption, unlined canal seepage, and changes to the aquifer system. Unlined canal evaporation estimates account for approximately 1.25 MCM/year (1,500 acre-ft/year) of the increased annual flow. Unlined canal seepage losses were estimated to be 50 MCM/year (40,000 acre-ft/year). The volume of water conserved through reduction in seepage can account for 80% of the increased flow in the Salt River. However, this estimate cannot be directly applied as true savings, because it is assumed that a large fraction but not all of the seepage water eventually returned to the Salt River later in the year. The water table appears to have decreased in sprinkler irrigated areas since 1971. Unlined canal evaporation and irrecoverable groundwater losses account for 2% and 65% respectively of the increased stream flow in the Salt River. Approximately 32% of the observed increased stream flow remains unaccounted for in this study. The unaccounted for water in the water balance may be due to conservative estimates and/or other mechanisms not quantified in this study including phreatophytic vegetation consumption, ET, and additional evaporation from soil surfaces.

Conclusions of this study are based on limited groundwater information. In the future, a more in depth study of the changes in groundwater hydrology is necessary. Lysimeters in the study area have been installed in the last five years, which should provide additional information on the impacts to the groundwater hydrology.

Water in the semi-arid western U.S. is a vital resource. In an attempt to conserve this valuable commodity, irrigation practices in the Star Valley in western Wyoming were converted from flood to sprinkler irrigation to improve application and conveyance efficiencies. The conversion from flood to sprinkler irrigation increased overall irrigation efficiencies and agricultural production, but other impacts to the river basin hydrology also occurred, including changes in groundwater storage, groundwater quality, and return flow timing.

Erosion Potential Model Development and Channel Monitoring

Basic Information

Title:	Erosion Potential Model Development and Channel Monitoring
Project Number:	2001WY1781B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	
Focus Category:	Geomorpological and Geochemical Processes, Water Quantity, Management and Planning
Descriptors:	GIS, Coal bed methane,Channel erosion
Principal Investigators:	Gregory Vincent Wilkerson

Publication

1. Baxter, Jeffrey, 2002, The Channel Geometry Of Dead Horse Creek, Powder River Basin, Wyoming, MS Dissertation, Department of Geography and Recreation, University of Wyoming, Laramie, WY, pp. 88.

Problem and Research Objectives:

Coal bed methane (CBM) development in the Powder River (structural) Basin (PRB), located in northeast Wyoming, has been occurring at an increasing rate since about 1990 (WOGCC, 2000). As of March 2001 about 4,900 coalbed methane gas wells were in production, about 9,600 wells have been drilled and 600 of those have been plugged, and about 10 wells are drilled every day of the week (Bleizeffer, 2001).

The process of extracting coal bed methane involves drilling a well into a coal seam and then pumping water out of the well that is mixed with the methane in the coal seam. The gas and water separate in the well and the gas is sent to a pipeline. On average, water from CBM wells is produced at a rate of 12 gpm per well (BLM, 1999).

In June 2000 the U.S. Bureau of Land Management (BLM) held public scooping meetings to facilitate development of a new resource management plan for oil and gas development in all of Johnson, Campbell, and Sheridan counties as well as a significant portion of Converse County (Figure 1; Tollefson, 2001). At that time the BLM was looking at analyzing the impacts of having up to 35,000 wells developed in a 10-year period (although as many as 70,000 wells may be constructed over the lifetime of the development). Assuming that 33% of the 35,000 anticipated CBM wells are producing 12 gpm of water at a given time, surface water would be produced at an average rate of 140,000 gpm (312 cfs or 225,000 ac-ft/yr). For comparison, note that the storage capacities of Keyhole Reservoir and Lake de Smet Reservoir, in northeast Wyoming, are 340,000 acre-ft and 239,000 acre-ft, respectively.

Legally, CBM product water can be discharged on the surface only at National Pollution Discharge Elimination System (NPDES) permitted points (BLM, 1999). It is expected that much of the water will be discharged from pipelines into existing surface drainages. It is impossible to know with certainty how much CBM produced water will be discharged into surface drainages since, in some areas, water storage systems are being constructed to contain water and because there is the possibility that some of the water will be reinjected. Conversely, the estimated discharge rate for individual wells that was presented above (12 gpm) is variable—discharge rates as high as 60 gpm have been reported (PRB, 2000) and the estimated productive life of a CBM well is 10 to 20 years (BLM, 1999a). Over this time, there is great potential for CBM produced water to cause sedimentation and erosion in affected stream channels and tributaries.

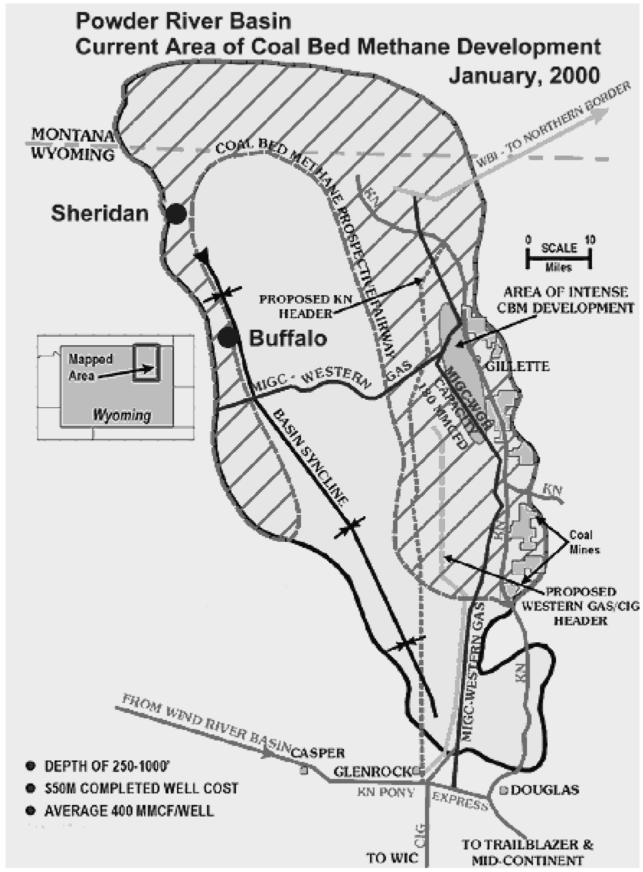

Figure 1 – Powder River Basin. Current area of coal bed methane development (PRB, 2000).

The State of Wyoming, Department of Environmental Quality (DEQ) regulates sedimentation, erosion, and other issues affecting the quality of water in Wyoming (BLM, 1999). The DEQ is also responsible for granting NPDES permits to discharge produced water. Recognizing the need to manage CBM product water, the DEQ has asked the University of Wyoming to evaluate the erosion vulnerability of drainages in the PRB. **The primary objective of this study is to develop a computer program that will help DEQ policy managers formulate appropriate management decisions associated with the NPDES permitting process. This study has three components: (1) development of an analytical model for predicting the erosion potential of a channels in the PRB, (2) channel monitoring, and (3) model verification.** The computer program and all data derived from this effort will be made available to the public so that others responsible for or concerned about watersheds affected by CBM development will be able to use it to evaluate alternative CBM product water management development scenarios.

Methodology:

Model development and implementation

An analysis of data published by the U.S. Geological Survey (Lowham, 1988) is being performed and the results are being used to develop an analytical model that yields an erosion potential index for channels in the PRB.

The analytical model will be implemented in a computer program called Erosion Potential (EP) Modeler, which will execute in ArcView, a geographical information system (GIS). A GIS environment facilitates evaluation of the input variables for the model. Input variables for the model are:

1. The point in the channel at which erosion potential is to be assessed. Identification of the point of interest is facilitated by the use of readily available U.S. Geological Survey (USGS) digital raster graphics.
2. The drainage area for the point in the channel. The computer program computes the drainage area using USGS digital elevation models (DEMs).
3. The two-year peak discharge for the drainage area, if known
4. The geographic factor for the drainage area (accounts for geographic and orographic effects on peak flows; Lowham, 1988). The program uses a digital raster map to compute geographic factors.
5. The anticipated CBM product water discharge for the drainage area

Output from the program includes the pre- and post-CBM development equilibrium channel width and the percent change in the equilibrium channel width. The percent change in the equilibrium width is the erosion potential index. Figure 2 shows a screen capture from an EP Modeler demonstration and illustrates results obtained from the program.

Channel monitoring effort

The second component of this project consists of monitoring erosion in two channels within the Powder River Basin: Deadhorse Creek and Burger Draw. Six reaches along Deadhorse Creek and its tributaries, and two reaches along Burger Draw have been established. A survey of each reach was performed in either March or August 2000 and again in August 2001 using a Sokkia SET 3110 total station. Established reach lengths range from 500 ft to 1,200 ft. Within each reach, four to eight cross-sections were established and surveyed**.** A survey of the channel centerline was also performed. Thus far, the channel monitoring effort has thus far provided baseline data that will be compared with data to be collected in the future.

Model verification and calibration

To achieve the third objective of this study, data from the channel monitoring effort will be used to verify the reasonableness of pre- and post-CBM development equilibrium channel widths predicted using EP Modeler and to calibrate EP Modeler.

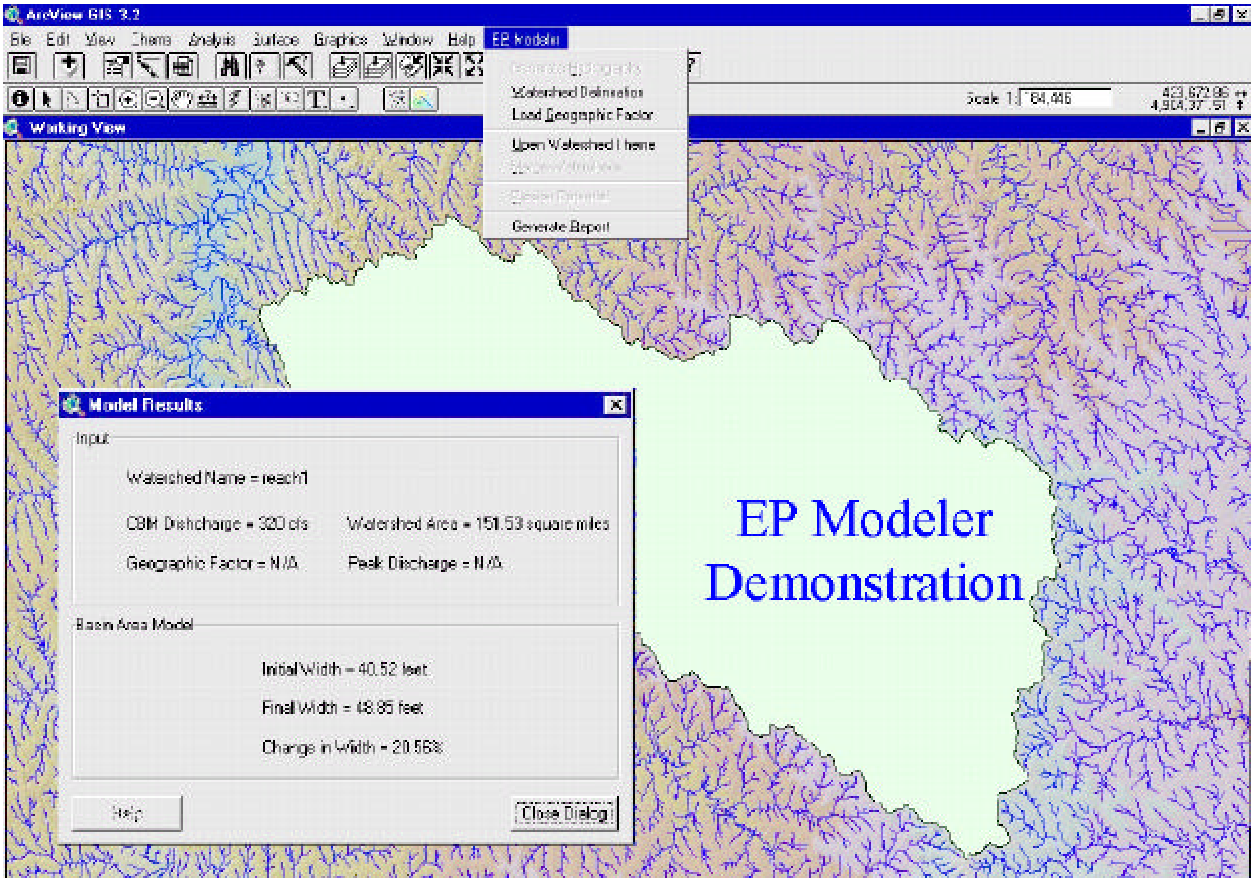

Figure 2 – Screen capture from a demonstration of EP Modeler.

Principal Findings and Significance:

Principal findings to date indicate that the data in Lowham (1988) can be used to estimate equilibrium widths for channels in the PRB. The model developed for predicting equilibrium channel widths has a standard error of 0.55 ft in log units. The computer program being developed for this study, EP Modeler, is in the final stages of completion. The program, a user's manual, and technical report describing the program will be completed by the end of July 2002 and will be made available via the world wide web.

Data from field surveys performed in the year 2000 has been evaluated. Data from the 2001 and 2002 surveys will be processed and documented by the end of February 2003. Validation and calibration of EP Modeler will be performed on an ongoing basis as new survey data is processed.

The model and data derived from this study are significant because it will help DEQ policy managers formulate appropriate management decisions associated with the NPDES permitting process particularly in regards to managing CBM product water. Also, since the computer program and all data derived from this effort will be made available to the public, others responsible for or concerned about watersheds affected by CBM development will be able to use it to evaluate alternative CBM product water management development scenarios.

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

Basic Information

Title:	Testing of Hydrologic Models for Estimating Streamflow in Mountainous Areas of Wyoming
Project Number:	2001WY1901B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	
Focus Category:	Hydrology, Models, Water Quantity
Descriptors:	Model studies, Hydrologic models, Surface drainage, Base flow, Instream flow,Mountain streams
Principal Investigators:	Bruce Brinkman , Hugh Lowham , Larry Pochop , Lawrence Ostresh

Publication

1. Brinkman, Bruce; Hugh Lowham, Winter 2001, Winter Flow Modeling for the Mountainous Areas of Wyoming, Wyoming Water Flow, Volume LXIV, Issue 1, Pages 13-14.

Introduction

When data are needed for small streams in mountainous areas, there often is a shortage of streamflow records available. The ideal situation for planning of a water-related project is to have a long period of streamflow record available for the site. 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 study site, it may be necessary to make estimates of streamflow.

This project is a research study to test and refine models for estimating streamflows during the low-flow period of the water year. Funding is provided by the Wyoming Water Development Commission, University of Wyoming, and U.S. Geological Survey. The project officially began July 1, 2000, and currently is in the second year of a three-year study.

Objectives

The objectives of the project are:

1. To test the accuracy of various current techniques for estimating streamflows at ungaged sites in mountainous areas, especially during the low-flow period of winter months,
2. To investigate methods for improving the accuracy of current estimating techniques, and
3. To provide research and technical experience for a University of Wyoming student.

The study is constrained by having limited funds for travel and per diem. A study area close to Cheyenne and Laramie (home bases for the principal investigators and a University of Wyoming student) was considered desirable in order to minimize travel costs.

Approach

The study plan was coordinated with staff from the Wyoming State Engineer's Office, U.S. Forest Service, and U.S. Geological Survey (USGS). Field visits and sharing of resources and data were coordinated with USGS staff.

Descriptions of the planning and review meetings are summarized in Appendix A, and descriptions of the field visits are summarized in Appendix B, at the back of the report.

During the first year of the study, sites in the Medicine Bow Mountains, mainly on Brush Creek, were selected for study and measurement (maps 1 and 2, Appendix C). A review of the Brush Creek data showed that additional drainages, with a greater diversity of basin characteristics, were needed in order to accomplish the project objectives. For the second year of the study, additional sites were selected in three new areas:

1. Sierra Madre on the Encampment River drainage,
2. Medicine Bow Mountains on the Rock Creek and Little Laramie drainages, and
3. Medicine Bow Mountains on the Douglas Creek drainage.

Map 1 (Appendix C) shows locations of the drainage basins selected for the project study. Table 1 (Appendix D) summarizes the measurement sites.

Existing Data

Previous studies for estimating flows of mountainous streams include Lowham (1988) and Misalis, Wesche, and Lowham (1999). These studies used streamflow data from gaged sites having essentially natural flows, measurements of basin characteristics from topographic maps, and measurements of channel dimensions from field observations. In general, drainage area, basin elevation, and mean annual precipitation are the basin characteristics that have been found to be significant in determining the magnitude of annual and monthly runoff. This study includes these same data, but also uses streamflow data from monthly measurements on numerous small streams, and additional basin characteristics identified from emerging technologies, such as remote sensing products.

Streamflow data are available for the USGS streamflow stations, and include:
- Average annual flow (Q_a)
- Mean Monthly flow
- Minimum Monthly flow
- Monthly (Q10, Q50, Q90) exceedence values

The following basin data are available:
- Basin characteristics and channel measurements for streamflow stations
- Digital topographic coverage
- Snow measurement stations
- Digital files of primary vegetation
- Digital files of surface soils
- Digital files of bedrock geology
- Digital files of surface geology
- Digital files of land ownership (primarily federal)

Collection of Streamflow Data

Monthly measurements of streamflow were collected near mid-month during October through March or April at each of the selected ungaged sites (figures 1 and 2). Concurrent measurements were obtained at nearby gaged sites.

Initial visits were made to each of the sites during the summer or fall to observe basin conditions, and to select measurement locations. Measurements of discharge are made using standard procedures (Rantz, 1982). The sites are accessed during the winter using snowmobiles and snowshoes. Prior to making the measurement, a snow shovel and ice bar are necessary to clear the measurement section. Snow cover often reaches depths of up to 5 feet (Brinkman and Lowham, 2001). When culverts are available, a volumetric measurement is made with a bucket and stopwatch. Buckets of 6 to 12 gallons are used, with the size depending on the clearance between the streambed and the invert of the culvert. When suitable culvert sites are not available, the measurements are made with a current meter. Table 2 (Appendix D) is a summary of the streamflow data collected for the four study areas

Figure 1.--Selection of streamflow site, RL-8 North Fork Little Laramie River, October 18, 2001

Figure 2.—Winter measurement, Brush Creek area

Basin and Channel Characteristics

Measurements of basin characteristics, such as drainage area, basin elevation, mean annual precipitation, and basin slope, are being determined from maps for each of the sub-basins. Field measurements of channel width are being obtained for each stream site.

Aerial photographs and/or imagery are being examined to determine unique characteristics of the sub-basins that may have an influence on the magnitude of monthly runoff. For example, thermal imagery may highlight areas of significant ground-water inflows. Parameters that depict areas of large ground-water inflow could quantify basins that have relatively large yields during the base-flow period. Measurements of man-made influences, such as areas of forest harvest, could quantify associated changes to natural runoff.

Test of Current Estimating Techniques

Monthly discharge measurements were collected at ungaged sites in four separate areas. These data are being compared with estimates of long-term monthly streamflow using the following techniques:

- Relation to concurrent daily mean discharges at nearby streamflow-gaging station to determine long-term monthly mean flow (Riggs, 1969; Parrett and Cartier, 1990, and Lowham, 1988, p. 35)
- Equations developed by Misalis, Wesche, and Lowham (1999)
- Equation developed by Lowham (1988) for mean annual flow, with monthly flows estimated on the basis of relative proportion of monthly flow for the nearby streamflow-gaging station

The <u>concurrent-measurement method</u> estimates streamflow at ungaged sites by correlating with concurrent discharges at a nearby gaged site. The gaged and ungaged sites should be in the same general area and have drainage basins that are hydrologically similar. Measurements of streamflow are made near mid-month at each selected ungaged site and are correlated with concurrent streamflows at the nearby gaged site. The relation between the streamflows at the two sites is then used to transfer the long-term monthly streamflow characteristic at the gaged site to the ungaged site. For example, table 3 is a summary of the October 2000 data for sites in the Brush Creek area.

Mean monthly discharges fluctuate from year-to-year, depending on the weather. Monthly discharge measurements at the ungaged sites therefore need to be adjusted to account for dry or wet years. For example, the mean-daily flow for October 23, 2000 at the gaged site BC-1, was 9.6 cfs. The long-term mean monthly discharge at the gage for water years 1961-2001 is 14.0 cfs, which is 1.46 times greater than 9.6 cfs. The measured discharge at each of the ungaged sites was subsequently multiplied by 1.46 to determine the adjusted long-term mean monthly discharge for October.

Similar adjustment coefficients were determined for each month as shown in the following table.

Month	a Long-term mean for water years 1961-2001 (cfs)	b Mean daily flow for measurement day (cfs)	a/b = c Coefficient for determining adjusted long-term mean-monthly flow (cfs)
Oct	14.0	9.6	1.46
Nov	11.5	8.6	1.34
Dec	10.0	9.0	1.11
Jan	9.27	8.4	1.10
Feb	9.24	7.6	1.22
Mar	10.5	7.7	1.36
Apr	23.6	27	0.87
May	169		
June	258		
July	56.3		
Aug	13.8		
Sept	12.6		
Annual	49.9		

The concurrent-measurement method uses field visits and discharge measurements to determine estimates of monthly flow, and it is considered to be relatively accurate in comparison to office techniques that use measurements of basin features. For this study, the concurrent-measurement method is used as the base to which the other estimating techniques would be compared to determine their relative accuracy.

Relations developed by Misalis, Wesche, and Lowham (1999) use basin characteristics and channel width to estimate streamflow values. One set of estimating equations (Misalis, Wesche, and Lowham (1999, p. 109) was developed using data for 24 gaged streams in the Medicine Bow Mountains. The equation for estimating October mean-monthly flow is:

$Q = 0.77446\ DA^{.729}$, where

Q= mean monthly flow, in cfs, and
DA = contributing drainage area, in mi^2.

A second set of estimating equations (Miselis, Wesche, and Lowham, 1999, p. 85) was developed using data for 140 gaged streams in mountainous regions throughout Wyoming. The equation for estimating October mean-monthly flow is:

$Q = 0.40148\ DA^{.907}$.

Example estimates of mean monthly flows using the above equations for sites in the Brush Creek area are shown in table 3 for October 2000.

Relations developed by Lowham (1988, p. 28), used data for 140 gaged streams, for estimating mean annual flow in the Mountainous Regions of Wyoming. The equation using drainage area and mean annual precipitation for the basin, is:

$Q_a = 0.013\, A^{0.93} PR^{1.43}$, where

Q_a = mean annual flow, in cfs,
A = contributing drainage area, in mi^2, and
PR = average annual precipitation, in inches.

Using the procedure described by Lowham (1988, p. 40, 41), the October mean monthly flow at site BC-1 (gaging station 06622700) is 14 cfs, which is 2.33 percent of the mean annual flow. Using the equation above, the estimated mean annual flow at ungaged site BC-4 is 3.35 cfs. Mean monthly flows for the ungaged site BC-4 are then computed using respective percentages for each month as shown below:

Month	a Long-term mean at gaged site BC-1 (station 06622700) for water years 1961-2001 (cfs)	b Monthly flow/ annual runoff/ months a/49.9/12(100) (percentage)	Mean monthly flow at ungaged site b X 3.35 X 12 (cfs)
Oct	14.0	2.338009	0.94
Nov	11.5	1.920508	0.77
Dec	10.0	1.670007	0.67
Jan	9.27	1.548096	0.62
Feb	9.24	1.543086	0.62
Mar	10.5	1.753507	0.70
Apr	23.6	3.941216	1.58
May	169	28.223113	11.3
June	258	43.086172	17.3
July	56.3	9.402138	3.78
Aug	13.8	2.304609	0.92
Sept	12.6	2.104208	0.84
Annual	49.9	100	3.35

The studies by Miselis, Wesche, and Lowham (1999) and Lowham (1988) also present equations using channel width to estimate streamflow. These equations are not examined as part of this progress report, but they will be included in the final report.

Refinement of Estimating Techniques

An analysis is being made of the selected basins, especially of features that could be used as parameters to improve the estimating equations. The first step is to determine features of mountainous basins that could be identified and defined from current data. Elevation, elevation change (slope), basin orientation and percent of basin exposure to direct sunlight, vegetation type and percent of cover, and surface soil types, are features that are relatively easy to identify from existing maps. The next step is to look at precipitation and geology maps, and remote-sensing products to determine additional features that could be related to the magnitude of low flows.

For example, figure 3 is a graph that shows results of streamflow measurements that were obtained in the Brush Creek area on October 23, 2000. The best-fit relation shows that discharge increases with drainage area. Some sites have relatively high yields, and thus plot above the best-fit line. Other sites have relatively low yields, and plot below the line. Parameters in addition to drainage area are being investigated to determine why a stream such as site BC-5, Fish Creek tributary, would have a relatively high yield, while site BC-9, Harden Creek, would have a relatively low yield.

Student Training

During the first year of the study, technical experience was provided to Justin Montgomery, an undergraduate student who assisted with the project. Justin was an active participant in both data collection and analysis. He participated in the August 14, 2000 field site visit, and compiled digital map files of the project area. Maps 4-9 are example maps produced by Justin using Geographic Information System coverage available at the University of Wyoming.

For the second year of the study, graduate student James Riley was assigned to the project. James attended an orientation meeting on April 19, 2001, and participated in a field visit on April 20, 2001. During the summer months, he worked with Dr. Larry Ostresh to compile a digital data base of the project map areas. Beginning with the fall semester, he assisted in the development of an analysis to determine the effect of clear-cut areas on base flows. This work continued through the spring semester.

Mr. Riley is pursuing a Masters Degree from the Department of Geography and Recreation at the University of Wyoming under the direction of Dr. Ostresh. His thesis topic stems directly from work he has performed on this grant: The relationship of winter base streamflows to clear-cut and other tree-less areas. His committee has been formed and has approved his Thesis Proposal; he expects to graduate in December, 2002. It is anticipated that Mr. Riley will present at least two papers related to this grant and his thesis at professional meetings within the next year.

The Department of Geography and Recreation was established in 1985 when the Department of Geography (founded 1966) combined with the Department of Recreation and Park Administration (founded 1975). Geography coursework at UW extends back to a first course in physical geography taught by Aven Nelson in 1890. From 1910 to 1955, geography was taught in the College of Education, while the Geology Department provided courses in physical geography through the 1950s. Geography was fully brought into the College of Arts and Sciences in 1960.

The department offers a diverse set of programs in geography, planning, and natural resources management. It is well located for the geographical study of human and biophysical phenomena of the Rocky Mountain/Great Plains region. Curricula focus on the nature, origin, and behavior of the natural environment and how humans spatially interact among themselves and their surroundings.

Department faculty have expertise in such areas as physical geography, biogeography, natural resource management, cultural geography, historical geography, economic geography, planning, cartography, and geographic information science (GIS).

The department has a lead role in GIS education at UW. It offers a core sequence of two courses taught each fall and spring that provide students with an introduction to GIS concepts and methods. Lectures are supplemented with hands-on training in a recently renovated lab that has 16 PCs and associated digitizers, plotters, printers, scanners, etc. The major software is ArcView and Arc/Info, although Idrisi, Trimble Pathfinder, and several other products are also available. Additionally, the department offers an Advanced GIS class once each year; other GIS related courses include GPS, remote sensing, computer cartography, and quantitative methods.

The department maintains close ties with the Wyoming Geographic Information Sciences Center (WyGISC) -- indeed, the assistant director and several of the current staff are graduates of the department's Bachelor or Masters programs.

Summary

The nine selected sites on the Brush Creek area have relatively uniform basin characteristics and streamflow yields. An additional site on the east side of the Medicine Bow Mountains was added in order to gain more variability in basin characteristics. The site is located at a station formerly operated by the University of Wyoming.

During the first year of the study, technical experience was provided to Justin Montgomery, an undergraduate student who assisted with the project. Justin was an active participant in both data collection and analysis. He participated in the August 14, 2000 field site visit, and compiled digital map files of the project area.

For the second year of the study, an intensive effort was made to collect data from additional basins with a greater variety of basin features. A new student assistant, James Riley was assigned to the study.

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Rantz, S.E., 1982, Measurement and computation of streamflow: v. 1, Measurement of stage and discharge; v. 2, Computation of discharge: U.S. Geological Survey Water-Supply Paper 2175, 631 p.

Riggs, 1969, Mean streamflow from discharge measurements: International Association of Scientific Hydrology Bulletin XIV, no. 4, p. 95-110.

Appendix A -- Summary of Meetings and Project Reviews

Bruce Brinkman and Hugh Lowham (principal investigators) met on May 30, 2000, and reviewed the available streamflow data and the project approach.

Bruce Brinkman, Hugh Lowham, Larry Pochop (Director, Water Research Program, University of Wyoming), and Justin Montgomery (undergraduate student, University of Wyoming) met at the WWDC Office on July 31, 2000, and discussed the project approach and possible study areas. Justin presented Arc View maps of the Brush Creek area in the Medicine Bow Mountains. Excellent digital coverage of vegetation, geology, and other basin features is available for this area. Based on the available digital coverage and potential low travel costs, the Medicine Bow Mountains appear to be the best choice for the project study.

On November 14, 2000, following a field trip to the Medicine Bow Mountains, Bruce Brinkman and Hugh Lowham met with Larry Pochop and Dennis Feeney in Laramie and discussed the project.

On November 27, 2000, Bruce Brinkman and Hugh Lowham met in Cheyenne to develop the progress report.

On November 28, 2000, Bruce Brinkman, Hugh Lowham, and Larry Pochop presented progress to the Priority and Selection Committee.

A telephone conference was held on February 23, 2001, between Bruce Brinkman, Hugh Lowham, Larry Pochop, and Larry Ostrech to discuss a replacement for Justin Montgomery, who had accepted work on another project.

Bruce Brinkman and Hugh Lowham met with Larry Ostresh, Larry Pochop, and student James Riley in Laramie on April 19 to discuss the project and to plan for the next field trip.

Ken Lindskov was contracted by Hugh Lowham to meet with staff from the EROS Data Center. Mr. Lindskov, a hydrologist and retired USGS employee, lives in Rapid City, South Dakota, and was able to make a one-day trip to the Center. He met with the Chief of the Center, and the Chief of the Scientific Application Branch, and discussed the availability of digital-map files that would depict ground-water storage. Remote-sensing data such as thermal or radar imagery collected during September or October might depict significant ground-water reservoirs that contribute to low flows. A summary report (April 30, 2001) by Mr. Lindskov showed that no such existing data were available for the project area.

John Newton was contracted to compute watershed characteristics for project basins in the Medicine Bow area using 1:24,000 digital elevation models at 30-meter pixel resolution. Mr. Newton is a hydrologist and former USFS employee, familiar with GIS data for the Medicine Bow Mountains. He computed basin area, relief, drainage density, source density, and a shape factor for the sites, and applied regression techniques to relate the measured low flows to the basin characteristics. A summary report (May 18, 2001) showed drainage area to be highly correlated with the low flows; however, none of the other basin characteristics were found to be significant.

On September 17, 2001, Hugh Lowham and Bruce Brinkman met to discuss preparation of the progress report and to plan the October field visit.

On October 17, 2001, Hugh Lowham met with Larry Ostresh and James Riley to discuss progress on preparation of maps and compilation of basin data. Hugh Lowham also met with Mike Winters of the USFS, Laramie Ranger District, to determine what procedures were necessary in order to install weirs for measuring discharge in stream channels within the National Forest. It was determined that a letter request, complete with map and sketch plan, would be sufficient application for such installations, and that the fee would be waived for such scientific research.

On November 28, 2001, Bruce Brinkman presented progress to the Priority and Selection Committee. The Committee had two comments: 1) Question on how data collection in the project relates to a state-wide effort, and 2) suggestion to pay close attention to error estimates associated with current meter measurements. These comments were addressed by Hugh Lowham on December 31, 2001.

A progress meeting was conducted on December 14, 2001, in Laramie. A discussion was held on the effects of clear cutting on winter flows.

A progress meeting was conducted on February 11, 2002, in Laramie. Discussion was held on developing the data set and applying multiple regression techniques to obtain an improved set of estimating relations. It is planned that Jimmy Riles will participate in the March streamflow measurement trip.

Hugh Lowham met with Jimmy Riles on March 12, 2002, to discuss channel-geometry measurements and multiple regression techniques that will be used in the study project.

On April 12, 2002, a progress meeting was held in Laramie. An annotated outline was developed for the progress report. Task assignments were made for completing the project study. A progress report will be assembled by June 5, 2002, for submittal to the USGS-WWDC supported Water Research Program. The summary report for the project study has target dates of October 1 (draft) and December 1, 2002 (final).

Appendix B – Summary of Field Data Collection

Bruce Brinkman, Hugh Lowham, and Justin Montgomery made a field visit to the Medicine Bow Mountains on August 14, 2000, and met with Water Hydrographer-Commissioner Jack Gibson at the North Brush Creek gaging station. Streamflow-gaging station 06622700, North Brush Creek near Saratoga, has a drainage area of 37.4 square miles, and 41-year period of record (May 1960 to current year). Eight ungaged sites were selected in the North Brush drainage basin. (See figures 1and 2, and table 1). An additional site was selected on Mill Creek, which is a tributary of South Brush Creek. The selected sites are accessible by snowmobile during winter months.

Bruce Brinkman and Hugh Lowham made a field visit by vehicle to the North Brush Creek area on October 23, 2000, and collected discharge measurements at each of the nine sites. A preliminary summary of the October data is shown in table 2 and figure 2. Following a review of the data, it was determined that additional basins, with a greater diversity of basin characteristics, could help with the analysis. The nine existing sites have relatively similar basin characteristics and water yields.

Bruce Brinkman and Hugh Lowham made a field visit by snow machines on November 13 and 14, 2000. Discharge measurements were made at eight of the sites in the North Brush Creek area. Site 4 was not measured due to shortage of time and poor access conditions. A review of the US Forest Service and Colorado State University research site on air quality was made on November 14, with Allen Elsworth and other staff. Although some streamflow data are being collected as part of the research study, none was applicable to this study. Sites on Nash Fork were investigated for possible addition to the streamflow sites. A measurement was made at the discontinued University of Wyoming streamflow site, Nash Fork Creek above Brooklyn Lodge (site BC-11).

Bruce Brinkman and Hugh Lowham made a field visit by snow machines on December 14, 2000. All sites except for BC-10 and BC-11 were measured. New powder snow about 3 feet deep made access to the sites difficult. Very little ice was encountered beneath the deep snowpack. Anchor ice was attached to the culverts, and it was cleared before the bucket measurements were made.

Bruce Brinkman and Hugh Lowham made a field visit by snow machines on January 16, 2001. All sites except for S-10 were measured. The North Brush Creek drainage had about two feet of new powder snow. It was noted in the gage house that USGS/WSE personnel had measured the streamflow at site BC-1 on December 15, the day after Brinkman and Lowham measured.

Bruce Brinkman and Hugh Lowham made a field visit by snow machines on February 20,2001. All sites except for BC-10 were measured. The weather was partly cloudy and warm. The snow was very sugary, not set up.

An attempt was made to make a field visit on March 14, 2001; however, the trip was cancelled due to heavy snow conditions. A field visit was made on March 16, and all sites were measured except for BC-10. Very little ice has formed at the measuring sites since the last visit. The weather was partly cloudy with light snow in the afternoon.

On April 20, Bruce, Hugh, Larry Ostrech, and James made a field visit by snow machines. The group met with USGS hydrologist Wilford Sadler, and made concurrent measurements at the Brush Creek gage site. Concurrent discharge measurements were conducted in order to test the accuracy of the pygmy versus electromagnetic meters.

On August 1, 2001, Bruce Brinkman, Hugh Lowham, Larry Ostresh, and James Riley made a site visit to the Rock Creek area and selected potential new sites to be added to the project data-collection effort.

A site visit was made on October 15, 2001, to the Rock Creek sites by Bruce Brinkman and Hugh Lowham. Heavy snow had occurred the previous day, with about 18-inches of accumulation. On October 16, sites near Foxpark on Lake Creek, Lincoln Creek, and Pelton Creek were selected for addition to the study, and discharge was measured at each site. The sites near Foxpark have basins with significant sagebrush cover, and thus offer a variety of land cover.

On October 18, 2001, Hugh Lowham conducted a site visit on Illinois Creek and Park Run near Foxpark, and selected three sites for addition to the project. These sites will require a weir for discharge measurement. Weirs will be installed following approval by the USFS.

The November measurements were made during November 12-14, 2001. Very little snow was present, and snow machines were not necessary. Streams in the Foxpark area were measured on November 12, streams in the Medicine Bow area were measured on November 13, and streams in Sierra Madre on Encampment River tributaries were measured on November 14. Measurements were made by Hugh Lowham, with assistance from Mike Lowham. On November 14, Mike Lowham assisted Wil Sadler of the USGS to measure the site at streamflow gaging station 06623800 Encampment River above Hog Park Creek, near Encampment. Two weirs were constructed by for assistance in measuring the small flows on Illinois Creek. However, the installation cut across the channel was rocky, and difficulty was experienced in achieving a suitable seal. Bentonite chips could be added to help provide a seal at future installations.

The December measurements were made during December 17-20, and Dec 24, 2001, by Hugh Lowham and Mike Lowham. Streams in the Medicine Bow area were measured on December 18. The weather was cold and windy. Bare spots were encountered on the road, making snowmobiling difficult. GPS location were checked on all sites. The Sierra Madre sites were measured on December 19. There was light snow on the north side of the project area, but moderate snow cover on the south end. Streams in the Foxpark area were measured on December 24.

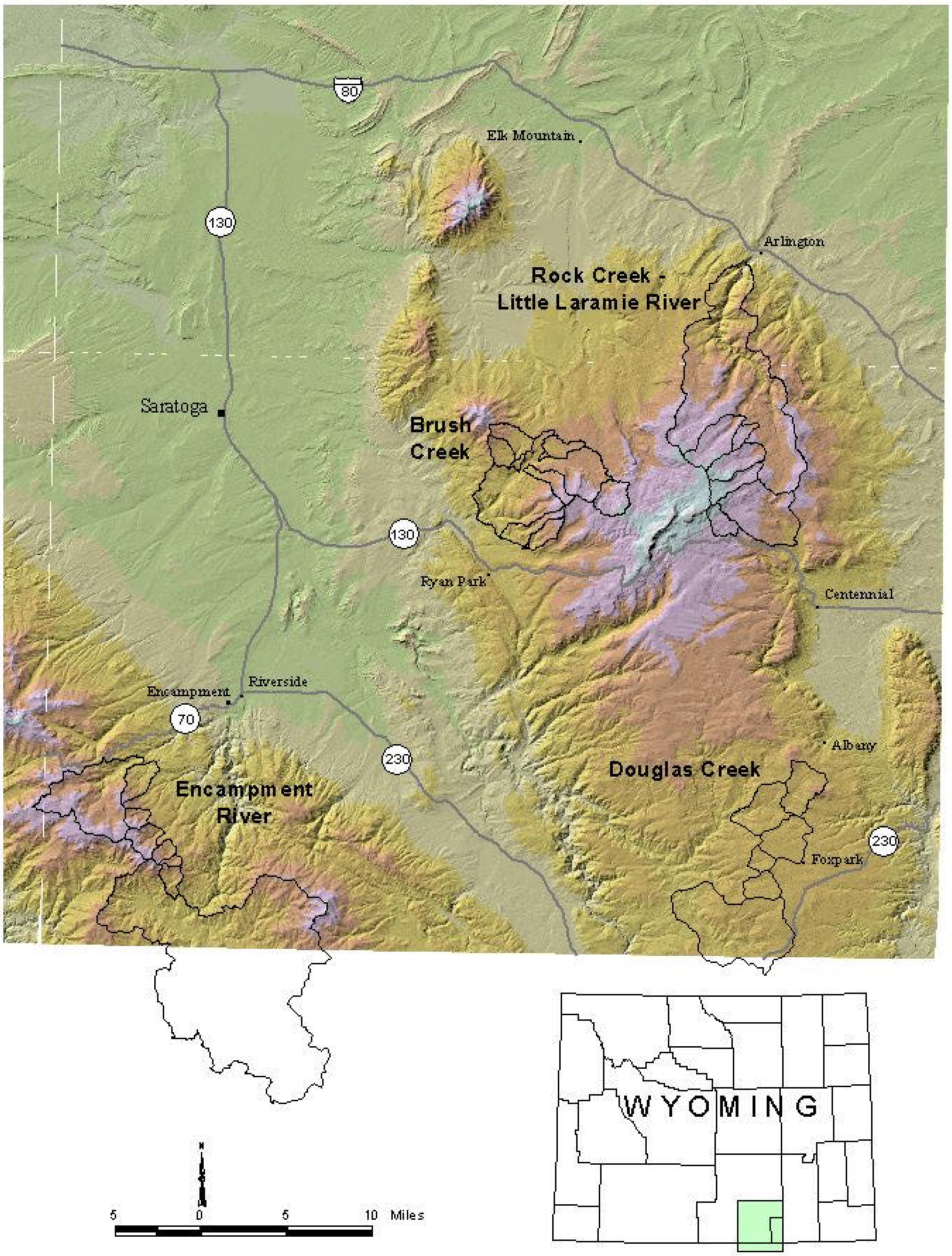
The January 2002 measurements were made during January 15-20. Mike Lowham assisted Wil Sadler in measuring the Rock Creek and North Brush Creek sites on January 15. Bruce Brinkman and Hugh Lowham measured the Sierra Madre project sites on

January 16, while Mike Lowham assisted Wil Sadler in streamgaging for Encampment River. The Rock Creek sites were measured by Hugh Lowham and Mike Lowham on January 17. Very cold and windy conditions were encountered at the Foxpark sites, which were measured by Hugh Lowham and Mike Lowham on January 19 and 20. Heavy ice was encountered on sites DC-1 to DC-3. It is likely that freezeup is occurring resulting in erratic flows.

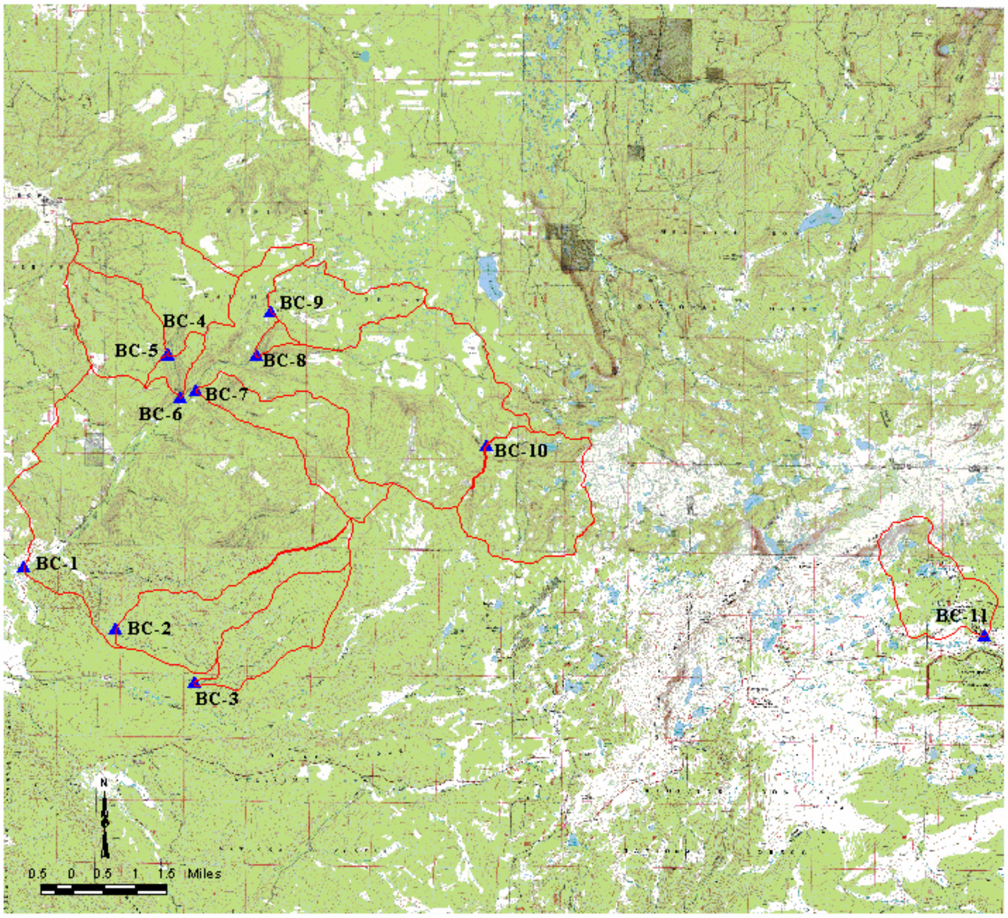
The February 2002 measurements were made during February 12-14 by Hugh Lowham and Mike Lowham. Photographs were obtained for each site, and GPS locations were checked and found to be the same as previously noted. Only light snow had occurred since last month. The snowpack was greatly below normal. The Sierra Madre sites were measured on February 12, and the snowpack increased from north to south. The Rock Creek sites were measured on February 13, and significant reaches of bare road were encountered, making snowmobiling difficult. Foxpark sites were measured on February 14, with heavy ice conditions encountered at DC-1 and DC-2, due to light snow and cold temperatures.

Heavy snow occurred just prior to the March 2002 measurements. The measurements were made during March 13-15 by Hugh Lowham and Mike Lowham. The Sierra Madre sites were measured on March 13, with very heavy snow accumulation since the last visit. The Foxpark sites were measured on March 14, with heavy new snow. The Rock Creek sites were measured on March 15, with heavy new snow, and 5 to 6 feet of snow depth at most of the measurement sites.

Appendix C – Maps



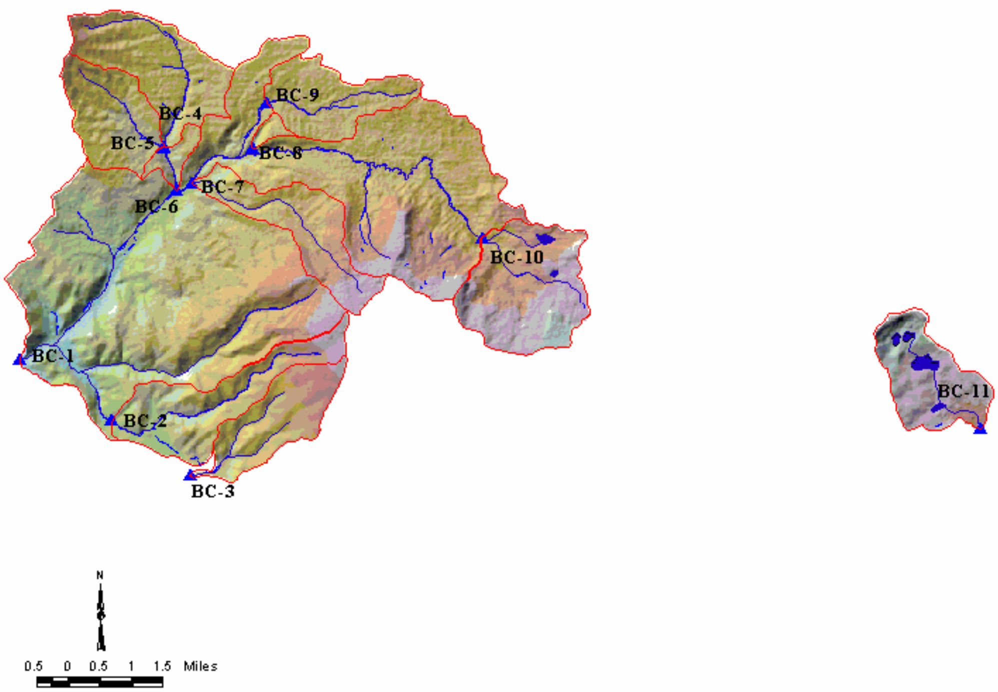
Map 1. -- Location of drainage basins selected for the project study.



Brush Creek
Streamflow Measurement Sites

BC-1 North Brush Creek Gage, 06622700
BC-2 Lincoln Creek
BC-3 Mill Creek
BC-4 Fish Creek, Upper Site
BC-5 Unnamed Tributary to Fish Creek
BC-6 Fish Creek, Lower Site
BC-7 Cassidy Creek
BC-8 Unnamed Tributary
BC-9 Harden Creek
BC-10 North Brush Creek, Upper Site
BC-11 Nash Fork Creek

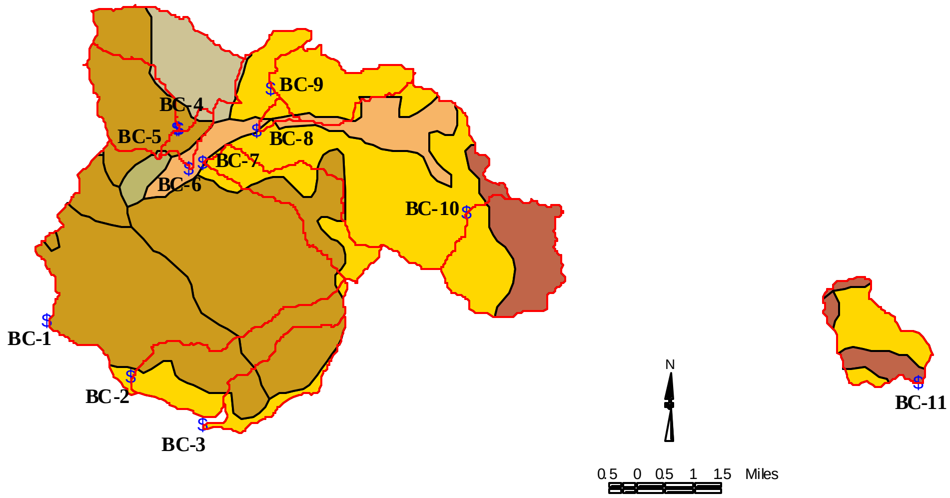
Map 2.--Location of drainage basins in Brush Creek area, with topographic map background



Brush Creek
Streamflow Measurement Sites

BC-1	North Brush Creek Gage, 06622700
BC-2	Lincoln Creek
BC-3	Mill Creek
BC-4	Fish Creek, Upper Site
BC-5	Unnamed Tributary to Fish Creek
BC-6	Fish Creek, Lower Site
BC-7	Cassidy Creek
BC-8	Unnamed Tributary
BC-9	Harden Creek
BC-10	North Brush Creek, Upper Site
BC-11	Nash Fork Creek

Map 3.--Location of drainage basins in Brush Creek area, with digital elevation model background



EXPLANATION

$ **BC-1** Streamflow measurement site and number

Surface Geology -- From James C. Case, Christopher S. Arneson, and Laura L. Hallbe, 1998, Wyoming Surficial Geology: Spatial Data and Visualization Center, Laramie, Wyoming. http://www.sdvc.uwyo.edu/24k/surfgeol.html

Ri - Bedrock and glaciated bedrock including hot spring deposits and volcanic necks; mixed with scattered shallow deposits of eolian, grus, slopewash, colluvium, residuum, glacial, and alluvium

gi - Glacial deposits mixed with scattered deposits of slopewash, residuum, grus, alluvium, colluvium, landslide, and/or bedrock outcrops

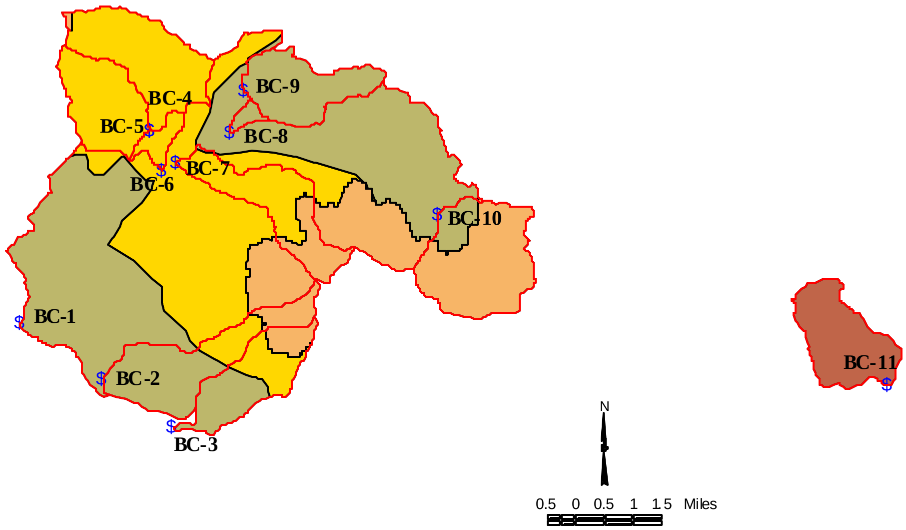
li - Landslide mixed with scattered deposits of slopewash, residuum, Tertiary landslides, and bedrock outcrops; landslides too small and numerous to show separately

oai - Glacial outwash and alluvium mixed with scattered deposits of glacial, terrace, hot spring, bedrock outcrops, residuum, slopewash, and grus

ri - Residuum mixed with alluvium, eolian, slopewash, grus, and/or bedrock outcrops

sci - Slopewash and colluvium mixed with scattered deposits of slopewash, residuum, grus, glacial, periglacial, alluvium, eolian, and/or bedrock outcrops

Map 4. -- Location of drainage basins in Brush Creek area, with surface geology background.



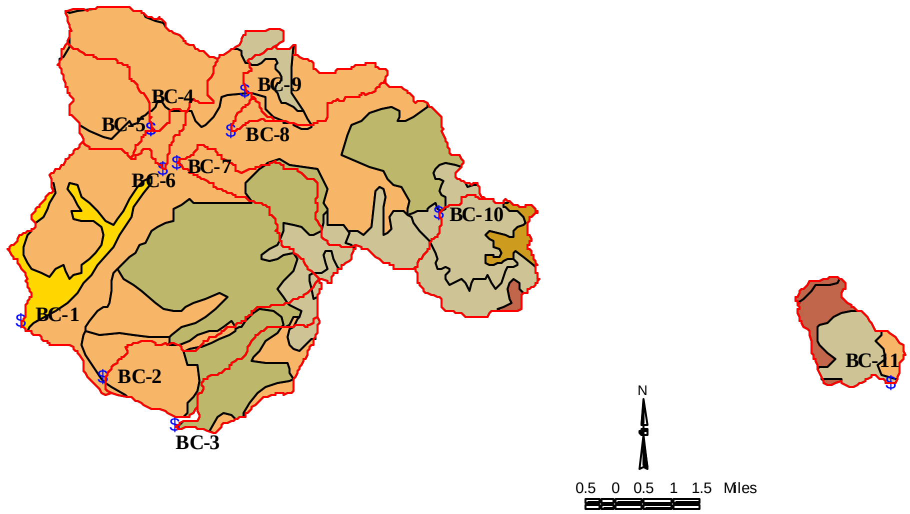
EXPLANATION

$ **BC-1** Streamflow measurement site and number

Soils -- From Larry C. Munn and Christopher S. Arneson, 1999, Draft 1:100,000-Scale Digital Soils Map of Carbon County: University of Wyoming Agricultural Experiment Station. http://www.sdvc.uwyo.edu/100k/soil100.html

- Typic Dystrocryepts, loamy-skeletal, mixed; Humic Dystrocryepts, loamy-skeletal, mixed; Rock Outcrop; Histic Cryaquepts, fine-loamy over sandy or sandy-skeletal, mixed
- Pachic Argicryolls, fine-loamy, mixed, Typic Argicryolls, fine, smectitic - Lithic Haplocryolls, loamy-skeletal, mixed
- Typic Haplocryalfs, loamy-skeletal, mixed - Typic Dystrocryepts, loamy-skeletal, mixed-Lithic Cryorthents, sandy-skeletal, mixed
- Typic Dystrocryepts, loamy-skeletal, mixed - Humic Dystrocryepts, loamy-skeletal, mixed Histic Cryaquepts, fine-loamy over sandy or sandy-skeletal - Rock Outcrop

Map 5. -- Location of drainage basins in Brush Creek area, with soils background.



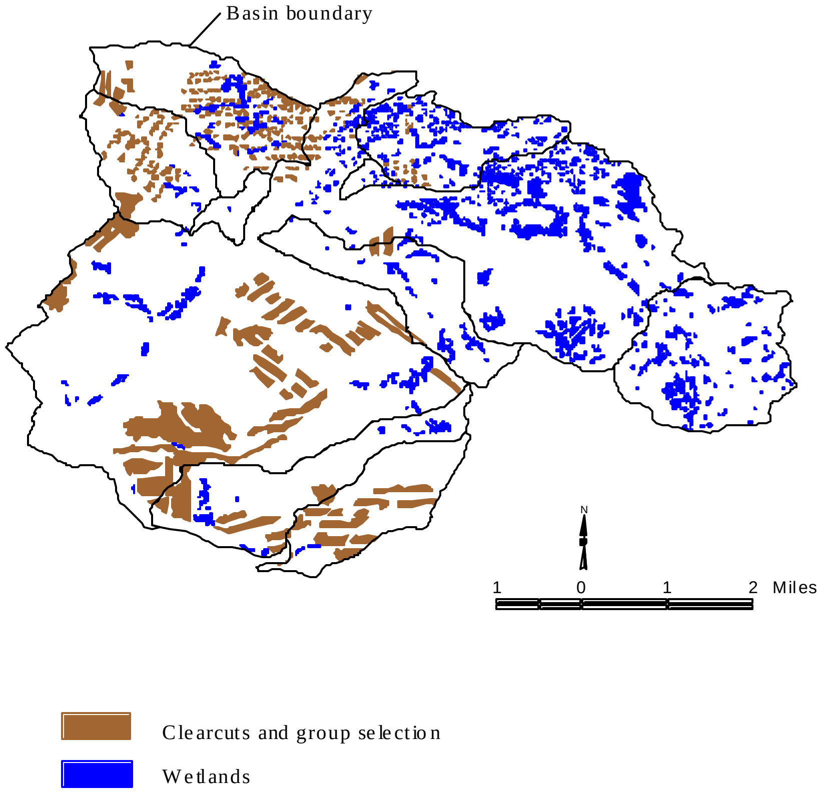
EXPLANATION

$ **BC-1** Streamflow measurement site and number

Land Cover -- From Analysis, Wyoming Gap, 19961201, Land Cover for Wyoming: University of Wyoming, Spatial Data and Visualization Center, Laramie, Wyoming. http://www.sdvc.uwyo.edu/24k/landcov.html

- Alpine Exposed Rock / Soil
- Aspen Forest
- Clearcut Conifer
- Lodgepole Pine
- Spruce - Fir
- Subalpine Meadow

Map 6. -- Location of drainage basins in Brush Creek area, with land cover background.



Map 7. -- Drainage basins in Brush Creek area,
with clearcuts, group selection, and wetlands.

Appendix D – Tables and Graph

Table 1.--Summary of streamflow sites and basin characteristics (May 30, 2002)

Site	Flow Measuring Site	Latitude (deg min sec)	Longitude (deg min sec)	Basin Area (square miles)	Perimeter (miles)	Elevation Top (feet)	Elevation Middle (feet)	Elevation Bottom (feet)	Elevation Mean (feet)	Elevation Range (feet)	Elevation Standard Deviation (feet)
BC-1	North Brush Creek Gage, 06622700	41 22 09	106 31 22	37.77	32.21	10837	9393	8015	9414	2822	573.2
BC-2	Lincoln Creek	41 21 20	106 29 41	2.71	10.21	10597	9183	8425	9282	2172	549.9
BC-3	Mill Creek	41 20 37	106 28 15	2.01	7.35	10456	9639	8760	9633	1696	372.7
BC-4	Fish Creek, Upper Site	41 25 04	106 28 49	2.77	8.26	10305	9331	8835	9413	1470	231.2
BC-5	Unnamed Tributary to Fish Creek	42 25 05	106 28 51	1.97	5.95	10052	9255	8871	9281	1181	215.9
BC-6	Fish Creek, Lower Site	41 24 29	106 28 35	5.13	9.82	10305	9301	8638	9335	1667	245.9
BC-7	Cassidy Creek	41 24 35	106 28 19	2.24	9.01	10607	9757	8727	9789	1880	447.5
BC-8	Unnamed Tributary	41 25 05	106 27 14	0.17	2.04	9491	9380	9039	9331	453	124.3
BC-9	Harden Creek	41 25 42	106 26 58	1.96	6.89	9636	9396	9229	9414	407	83.7
BC-10	North Brush Creek, Upper Site	41 23 54	106 23 03	3.31	7.46	10837	10305	9665	10291	1171	247.8
BC-11	Nash Fork Creek, Above Brooklyn Lake Lodge	41 21 25	106 13 57	2.14	6.48	11417	10525	10128	10562	1289	236.2
RL-1	Rock Creek Gage, 06632400	41 35 09	106 13 17	62.88	44.79	11237	9885	7789	9800	3448	610.3
RL-3	North Fork Rock Creek	41 27 33	106 13 45	5.56	11.19	10945	10446	9705	10406	1240	232.2
RL-4	Middle Fork Rock Creek	41 27 05	106 12 30	1.19	5.21	10587	10190	9774	10210	814	197.5
RL-5	Park Trail Creek	41 25 53	106 12 03	4.26	9.27	11115	10463	9757	10428	1358	313.1
RL-6	South Fork Rock Creek	41 25 03	106 12 07	2.86	9.52	11237	10663	10020	10635	1217	268.8
RL-8	North Fork Little Laramie River	41 21 03	106 09 47	11.68	15.31	11188	10066	9049	10026	2139	417.8
DC-1	Lake Creek at Lincoln Creek	41 07 29	106 10 22	5.02	10.14	9774	9177	8786	9176	988	160.2
DC-2	Lincoln Creek at Lake Creek	41 07 14	106 10 03	5.24	10.32	9272	9075	8819	9069	453	76.9
DC-3	Lake Creek at Douglas Creek	41 07 00	106 14 02	18.04	21.24	9774	9068	8553	9055	1220	161.6
DC-4	Illinois Creek	41 04 36	106 12 45	1.54	5.64	9423	9144	8976	9154	446	60.1
DC-6	Park Run Creek	41 03 55	106 13 38	4.42	10.39	9426	9114	8835	9113	591	75.7
DC-7	Pelton Creek	41 03 23	106 17 27	23.06	24.02	9288	8822	8340	8841	948	208.5
ER-2	North Fork Encampment River	41 09 35	106 53 25	16.24	22.77	10564	9882	8189	9746	2375	501.5
ER-3	Willow Creek	41 09 23	106 53 06	3.08	8.09	10325	8799	8333	8953	1991	496.6
ER-4	Miner Creek	41 06 56	106 52 53	1.44	4.92	10410	9760	9134	9774	1276	319.3
ER-5	South Fork Miner Creek	41 05 59	106 51 57	2.71	7.46	10453	9987	8999	9907	1453	360.8
ER-6	North Soldier Creek	41 05 27	106 51 21	1.25	4.51	10413	9570	9239	9628	1175	310.7
ER-7	South Soldier Creek	41 04 41	106 50 50	0.59	3.75	10167	9570	9255	9568	912	189.2
ER-8	Unnamed Creek	41 02 31	106 51 07	1.76	6.28	10079	9311	8491	9317	1588	309.2
ER-9	Hog Park Creek Gage, 06623800	41 01 50	106 49 29	100.46	65.88	11401	9337	8215	9394	3186	645.5

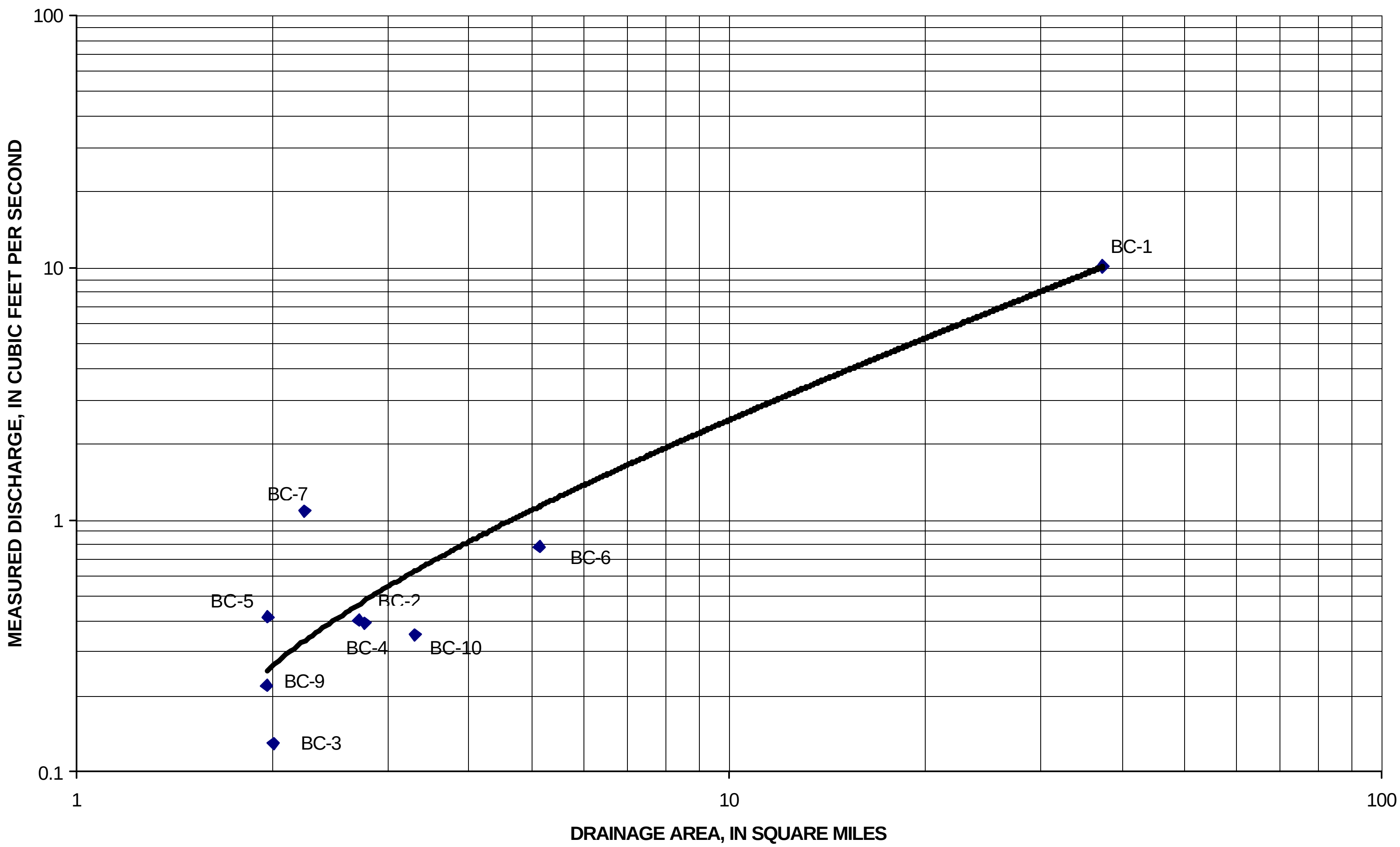
Table 1 continued.--Summary of streamflow sites and basin characteristics (May 30, 2002)

Site	Flow Measuring Site	Slope Maximum (feet/mile)	Slope Minimum (feet/mile)	Slope Range (feet/mile)	Slope Mean (feet/mile)	Slope Standard Deviation (feet/mile)	Aspect degrees (direction)
BC-1	North Brush Creek Gage, 06622700	4,235	0	4,235	963	558	289.30 (W)
BC-2	Lincoln Creek	2,825	0	2,825	1,050	515	244.61 (SW)
BC-3	Mill Creek	2,718	31	2,687	829	379	236.43 (SW)
BC-4	Fish Creek, Upper Site	2,658	0	2,658	743	442	125.23 (SE)
BC-5	Unnamed Tributary to Fish Creek	2,952	0	2,952	928	435	121.27 (SE)
BC-6	Fish Creek, Lower Site	2,952	0	2,952	835	460	125.96 (SE)
BC-7	Cassidy Creek	2,988	0	2,988	895	423	303.42 (NW)
BC-8	Unnamed Tributary	3,449	31	3,418	1,099	824	290.68 (W)
BC-9	Harden Creek	1,611	0	1,611	460	251	254.49 (W)
BC-10	North Brush Creek, Upper Site	4,235	0	4,235	856	461	331.96 (NW)
BC-11	Nash Fork Creek, Above Brooklyn Lake Lodge	4,870	0	4,870	773	565	144.20 (SE)
RL-1	Rock Creek Gage, 06632400	13,080	0	13,080	1,003	740	23.03 (NE)
RL-3	North Fork Rock Creek	3,581	0	3,581	646	425	36.21 (NE)
RL-4	Middle Fork Rock Creek	1,894	0	1,894	578	286	40.78 (NE)
RL-5	Park Trail Creek	2,616	0	2,616	698	349	56.14 (NE)
RL-6	South Fork Rock Creek	3,968	0	3,968	668	443	56.83 (NE)
RL-8	North Fork Little Laramie River	3,305	0	3,305	768	457	119.93 (SE)
DC-1	Lake Creek at Lincoln Creek	2,304	0	2,304	609	354	173.10 (S)
DC-2	Lincoln Creek at Lake Creek	2,391	0	2,391	412	289	64.47 (NE)
DC-3	Lake Creek at Douglas Creek	2,815	0	2,815	591	378	27.00 (NE)
DC-4	Illinois Creek	1,822	0	1,822	482	294	154.32 (SE)
DC-6	Park Run Creek	2,046	0	2,046	453	290	325.46 (NW)
DC-7	Pelton Creek	4,968	0	4,968	657	403	216.32 (SW)
ER-2	North Fork Encampment River	6,342	0	6,342	1,053	623	29.58 (NE)
ER-3	Willow Creek	2,825	0	2,825	1,005	461	38.40 (NE)
ER-4	Miner Creek	3,608	44	3,564	1,201	549	48.76 (NE)
ER-5	South Fork Miner Creek	3,374	31	3,343	1,158	519	63.36 (NE)
ER-6	North Soldier Creek	4,500	0	4,500	979	566	59.38 (NE)
ER-7	South Soldier Creek	2,583	0	2,583	963	426	43.48 (NE)
ER-8	Unnamed Creek	3,080	0	3,080	1,053	445	184.97 (S)
ER-9	Hog Park Creek Gage, 06623800	5,937	0	5,937	1,174	644	280.27 (W)

Site	Flow Measuring Site	10/2000 (cfs)	11/2000 (cfs)	12/2000 (cfs)	01/2001 (cfs)	02/2001 (cfs)	03/2001 (cfs)	04/2001 (cfs)	10/2001 (cfs)	11/2001 (cfs)	12/2001 (cfs)	01/2002 (cfs)	02/2002 (cfs)	03/2002 (cfs)
BC-1	North Brush Creek Gage, 06622700	10.10	-	9.08	9.00	8.00	7.78	27.39						
BC-2	Lincoln Creek	0.40	0.47	0.49	0.44	0.48	0.46	1.42						
BC-3	Mill Creek	0.14	0.19	0.20	0.19	0.18	0.18	-						
BC-4	Fish Creek, Upper Site	0.39	0.71	0.64	0.55	0.62	0.56	3.21						
BC-5	Unnamed Tributary to Fish Creek	0.41	0.39	0.56	0.27	0.37	0.38	1.13						
BC-6	Fish Creek, Lower Site	0.78	1.03	-	0.96	0.67	0.90	-						
BC-7	Cassidy Creek	1.08	0.88	0.82	0.25	0.80	0.76	1.49						
BC-8	Unnamed Tributary	0.00	0.00	-	-	-	-	0.00						
BC-9	Harden Creek	0.22	0.20	0.31	0.12	0.46	0.34	0.79						
BC-10	North Brush Creek, Upper Site	0.35	-	-	-	-	-	-						
BC-11	Nash Fork Creek, Above Brooklyn Lake Lodge	-	0.58	-	0.13	0.38	0.52	0.99						
RL-1	Rock Creek Gage, 06632400								-	-	-	-	-	-
RL-3	North Fork Rock Creek								0.67	0.65	0.39	0.13	0.35	0.32
RL-4	Middle Fork Rock Creek								0.07	0.10	0.07	0.07	0.07	0.06
RL-4a	Middle Fork Rock Creek (a)								-	0.07	0.05	0.05	0.05	0.04
RL-5	Park Trail Creek								0.75	0.76	0.39	0.32	0.24	0.24
RL-6	South Fork Rock Creek								0.20	0.26	0.09	0.04	0.08	0.08
RL-8	North Fork Little Laramie River								2.63	2.36	1.82	1.53	1.49	1.60
DC-1	Lake Creek at Lincoln Creek								0.68	0.34	0.28	0.29	0.42	0.34
DC-2	Lincoln Creek at Lake Creek								0.22	0.27	0.19	0.24	0.25	0.32
DC-3	Lake Creek at Douglas Creek								0.85	1.19	1.49	0.71	1.15	1.80
DC-4	Illinois Creek								0.03	0.03	0.04	0.04	0.03	0.03
DC-6	Park Run Creek								-	0.08	0.06	0.07	0.07	0.12
DC-7	Pelton Creek								0.87	0.97	0.77	1.09	0.85	0.83
ER-2	North Fork Encampment River									1.96	1.69	2.11	1.48	1.42
ER-3	Willow Creek									0.57	0.37	0.72	0.50	0.31
ER-4	Miner Creek									0.26	0.24	0.23	0.20	0.21
ER-5	South Fork Miner Creek									0.45	0.47	0.35	0.36	0.29
ER-5a	South Fork Miner Creek (a)									0.04	-	-	0.03	0.04
ER-6	North Soldier Creek									0.30	0.32	0.28	0.19	0.18
ER-7	South Soldier Creek									0.12	0.12	0.10	0.08	0.08
ER-8	Unnamed Creek									0.38	0.34	0.30	0.30	0.35
ER-9	Hog Park Creek Gage, 06623800									-	-	-	-	-

Table 3.--Summary of October data for Brush Creek area

Site	Basin area (sq mi)	Measured discharge (10/23/00) (cfs)	Adj long-term-mean monthly (cfs)	Miselis (1999) p 109 equation (cfs)	Miselis (1999) p 85 equation (cfs)	Lowham (1988) monthly (cfs)	Mean annual precipitation (inches)
BC-1	37.8	10.1	14.00	10.94	16.71	12.56	28
BC-2	2.71	0.4	0.58	1.60	1.78	1.19	30
BC-3	2.01	0.14	0.20	1.29	1.02	0.70	25
BC-4	2.77	0.39	0.57	1.63	1.36	0.94	25
BC-5	1.97	0.41	0.60	1.27	1.01	0.68	25
BC-6	5.13	0.78	1.14	2.55	2.36	1.67	25
BC-7	2.24	1.08	1.58	1.39	1.35	0.91	28
BC-8	0.17	0	0.00	0.21	0.15	0.09	30
BC-9	1.96	0.22	0.32	1.26	1.33	0.88	30
BC-10	3.31	0.35	0.51	1.85	2.71	1.79	35
BC-11	2.14	-	-	1.35	1.08	0.74	25



Graph 4.--October measured discharge versus drainage area for Brush Creek sites

Field Evaluation of the Fate of Wastewater Components from Septic Systems

Basic Information

Title:	Field Evaluation of the Fate of Wastewater Components from Septic Systems
Project Number:	2001WY2021B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	
Focus Category:	Nitrate Contamination, Waste Water, None
Descriptors:	Wastewater treatment, Nitrogen,Groundwater quality
Principal Investigators:	Marjorie Bedessem , Thomas Edgar

Publication

Problem and research objectives:
Community subdivisions and rural areas are often characterized by a single community well or individual water wells and individual septic sanitary systems. The proximity of the water supply to the community's septic tank leach fields creates a concern that contaminants may be transported from the waste disposal system to the water supply aquifer. Of particular concern is the fate of nitrogen compounds, such as ammonia and nitrates, and the fate of microorganisms, particularly pathogens.

In recent years, septic system modifications have been proposed to include reactive zones to minimize nitrate contamination of ground waters. The study is expected to furnish an evaluation of the effectiveness of septic system reactive zones in controlling bacterial and nutrient contamination (nitrogen compounds) from leach fields. This study is already being supported through federal 319 funds, and this project only provides supplemental funding to address development of an additional monitored field site representative of the rural ranchette area in the vicinity of either Cheyenne or Laramie, Wyoming.

Methodology:
A modified leach field design utilizing a reactive barrier will be installed in Cheyenne or Laramie at a new homesite in addition to the approved standard leach field design. The well sampling system will be designed to permit vadose zone as well as saturated zone sampling and allow comparison of the treatment efficiency of side by side systems. Three boreholes will be drilled at each site to install the access tubes. The boreholes will be located in the drainfield or just surrounding the drainfield. At least three depths will be monitored using a nested sample probe. Wastewater flowrates will be measured and samples will be analyzed for DO, pH, nitrite and nitrate, ammonia, TKN, BOD_5 and fecal coliforms.

Principal findings and significance:
The modified leach field design based on local soils is being developed from column studies conducted through a federal 319 grant which is currently underway. The installation has been delayed until the summer of 2002 based on the results of the column studies. Site design may also be revised in response to the results of a Nebraska reactive barrier field study due out in July 2002. Homeowners who are in areas considered to be at risk and representative of existing rural ranchette development in Wyoming have been identified. Homeowner incentives for participation in the program and legal implications of those incentives are currently being considered in coordination with the Wyoming Department of Environmental Quality.

Combining Modern and Paleo-Climate Data to Enhance Drought Prediction and Response

Basic Information

Title:	Combining Modern and Paleo-Climate Data to Enhance Drought Prediction and Response
Project Number:	2001WY2081B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	
Focus Category:	Drought, None, None
Descriptors:	Climate,Drought
Principal Investigators:	Stephen Jackson , Stephen Gray , Kenneth Gerow , Christopher L Fastie

Publication

1. Gray, S.T. C.L. Fastie, S.T. Jackson, J.L. Betancourt and K. Taylor. 2001. 1000 year drought records from tree-rings in the Bighorn Basin, Wyoming. Proceedings of the 2001 Annual Meeting of the Ecological Society of America, Madison, Wisconsin http://abstracts.allenpress.com/esa-cgi/document.cgi?YEAR=2001&ID=28695

Problem and Research Objectives:
The State of Wyoming spent more time during the 20th Century under severe drought conditions (Palmer Drought Severity Index <-3) than any other state except Colorado (McKee et al. 1993; NOAA 1990). In fact, half of Wyoming's major river basins experienced severe drought conditions for more than 15% of the time from 1895-1995 (WGA 1996; NDMC 2000), accounting for millions of dollars in damage to crops, livestock, and wildlife along with diminished tourism and wildfires (WGA 1996).
A clear need exists for assessing potential drought impacts, developing contingency plans, and identifying inception of meteorological droughts. However, the drought record of the past 100-130 years is inadequate for implementation of these tasks. A more complete and realistic appraisal of Wyoming drought requires assessment over a much longer period, spanning several centuries. Sole dependence on the past century's record in assessing drought susceptibility and impact is analogous to a physician's relying only on the past five years of a patient's medical history, which may not include earlier events diagnostic of susceptibility to disease, allergy, or infection. In the case of drought, symptoms of susceptibility to severe and prolonged events, possibly far worse than those experienced during the past century, can only be observed by examining the records of previous centuries. Those records are available in tree-ring archives for many regions of Wyoming. Tree-rings are an excellent source of drought proxy data because of their long duration (centuries to millennia) and high (at least annual) temporal resolution (Fritts 1976). Furthermore, tree-rings have been used with great success in documenting droughts throughout North America (Cook et al. 1995) and to reconstruct the relationship between droughts and circulation indices (Stahle et al. 1998). By developing a network of tree-ring records from western Wyoming, we are providing a detailed reconstruction of drought events spanning the last 500 to 1000 years that can be used to enhance our understanding of extreme climate events in this state and the Rocky Mountain West as a whole.

Methodology:
This project centers on the development of a network of tree-ring sites selected to provide 500-1,000+ year reconstructions of regional droughts in western Wyoming, and the use of those records to improve methods of drought prediction.

Study Area: This study focuses on western Wyoming, specifically the Clark's Fork, Shoshone, Bighorn, Wind, and Green River drainages. Tree-ring sites along the edges of the Bighorn Basin and in the Flaming Gorge area of SW Wyoming and NE Utah form the core of our network.

Field Techniques: Tree-rings are useful for drought reconstructions when water availability becomes critically limiting and persists for long enough that the growth of many trees over a wide area is affected (Fritts 1976). At lower elevations, growth is most often limited by precipitation. Therefore, we have selected a network of sites at lower tree line for drought reconstructions. Our work shows that limber pine (*Pinus flexilis*), Douglas-fir (*Psuedotsuga menziesii*), ponderosa pine (*Pinus ponderosa*) and, at Flaming Gorge, pinyon pine (*Pinus edulis*) are the most appropriate species for drought reconstructions in the study region. These species are found on dry sites throughout the area and reach sufficient age to produce 500-1,000+ year climate reconstructions. To date we have sampled over 400 trees, including dead snags and sub-fossil wood, at 7 sites throughout the study area.

Dating and Measurement of Cores: In the laboratory, we dry, mount, and progressively sand all cores to at least 400 grit (Cook and Kairiukstis 1990, Grissino-Meyer 1996), and assign exact dates to each ring using standard crossdating methods (Stokes and Smiley 1968, Swetnam et al. 1985). We then measure all rings from the dated series to the nearest 0.001 mm using a computer-based optical measuring device.

Reconstructing Droughts from Tree Growth: We use correlation analysis to compare modern meteorological records with tree-ring widths produced during the same time period (Fritts 1976). Monthly or seasonal climate variables with the highest correlation coefficients are then chosen for reconstruction. Response functions, a type of statistical equation describing the relationship between climate and growth, are then developed (Fritts 1991). After using subsets of the data to verify the climate/growth relationship, a new transfer function is developed which provides reconstructed climate values by substituting ring widths in the equation.

Investigating the relationship between drought and large-scale circulation patterns: We are using methods developed by Hirschboeck et al. (1996), Woodhouse (1997), and Cayan et al. (1999) to determine the relationship between circulation indices (CI) and drought in western Wyoming. Briefly, we are comparing the occurrence of both modern and paleo droughts with independent CI records using a combination of regression-based and event-based techniques. First, using the regression-based approach, we look for correlations between droughts recorded in the instrumental record and CIs for the same time period. We then use event-based analysis, a technique that looks for coincidence between unusual climatic events, to determine if extreme CI values correspond with regional droughts. Since the instrumental record has several important limitations, we repeat these analyses using data from our tree-ring sites. Products will include maps showing the relative influence of individual CIs on western Wyoming.

Principal Findings and Significance:

During the first year of this project, we completed sampling and analysis of the Bighorn Basin portion of the study area and a significant portion of the southern study area. In total, we have sampled trees at 13 sites. Seven sites are in the Bighorn Basin portion of the study area, making this one of the densest climate reconstruction networks in the Rocky Mountain region. To date, key findings from the project include:

1. Drought events in our long-term tree ring records are often longer and more severe than any droughts observed in the instrumental record of the past 120 years. Therefore, modern droughts do not represent the scope of events we should expect and plan for.
2. The spatial extent of droughts varies widely between events. While some droughts are seen throughout the study area (and even the entire Rocky Mountain West), others occur at only one or two sites or in clusters around a geographic location. In fact, the spatial distribution of droughts varies so widely that drought indices or response plans based on predetermined geographic regions or zones may be inadequate.

3. Statistical analyses of our long-term drought records show that dry events often occur at more-or-less regular intervals. In particular, droughts often return at both 30 and 50-year cycles throughout much of the study area. However, these oscillations are not stable through the entire proxy record, and should not be over emphasized in predictive models of drought.
4. Drought conditions in western Wyoming are often highly persistent. In the Southwestern U.S., 2-3 years of drought are often followed by several years of normal to wet conditions. In Wyoming, however, dry years are much more likely to be followed by additional dry years, with drought cycles often extending over 10 or more years. The 20^{th} Century has been somewhat unusual in that this persistence has been dampened. A return to the high-persistence mode of the previous several centuries would lead to droughts of far greater duration than those experienced in recent decades.
5. Droughts in western Wyoming show a strong link to circulation patterns in the northern and tropical Pacific. In addition, circulation anomalies in the Gulf of Mexico and Northern Atlantic may lead to rare but severe and long-duration events that affect the entire Rocky Mountain Region from Montana to the Mexican Border. This knowledge will be invaluable for improving our ability to predict the occurrence of future droughts.

We are concluding the sampling and analysis of all our sites in the early portion of project-year two. Our focus will then shift to 1) Analyses of large-scale patterns of drought, 2) Investigations related to the application of drought indices for prediction and response and 3) A detailed exploration of the relationship between dry events and large-scale circulation. Based on our results to date, we are confident that this project will provide important contributions concerning the nature and prediction of droughts in Wyoming and the Rocky Mountain West.

Information Transfer Program

Basic Information

Title:	Product Accessibility and Dissemination for the Water Reserach Program at the University of Wyoming
Start Date:	3/1/2001
End Date:	2/28/2002
Descriptors:	water library, worldwide web, water resources data,Data dissemination
Principal Investigators:	Dennis Feeney, Larry Pochop

Publication

Problem and Research Objectives:

In the west, water is critical to survival. Data and information concerning this resource are very valuable. However, unless information developed from research is easily obtained, all of the effort and expense of collecting, analyzing, and reporting the information is of little use. Therefore, the objective of this project is to establish an efficient and effective way to disseminate the data and information developed by the Water Resources Program.

Methodology:

This is an ongoing project. To continue to meet our objective, the following tasks were successfully completed:

- **Development of the Water Resources Program Web Site**

We developed and maintain a web site for the Water Resources Program. You can view this web site at the following URL:

http://www.wrds.uwyo.edu/wwrp/

We use this site to disseminate information about the Water Resources Program, and eventually to host the reports and products developed by the Program's researchers. To date, we have used the site to post the Program's Request for Proposals, contact information, useful links, and announcements, such as the Announcement/Request for Proposals for the Fiscal Year 2001 National Competitive Grant Program authorized by section 104(g) of the Water Resources Research Act of 1984, as amended.

- **Report given to Program's Priority and Selection Committee**

All proposals for the Water Resources Program are reviewed by a Priority and Selection Committee. This is a group of federal and state representatives that give initial approval as to which proposals qualify for funding. Earlier this year, we made a presentation to the Priority and Selection Committee emphasizing the importance of proper data dissemination to the overall Water Resources Program. The Committee agreed and funded our project for another year.

- **Distribution of Information through Water Library**

The Water Resources Data System's Water Library collects and maintains publications on water, particularly Wyoming water issues. The Library provides physical and bibliographic access to various publications that have been produced by federal and state government agencies, student research and other sources. The Water Library exists to provide current and historical information on regional water issues, maintain and expand the Wyoming Water Bibliography on the Internet (a search-based catalog of the locations and holdings of regional water publications) and provide access to these publications. Our patrons include students, faculty members, government employees and the public.

The Water Library began as a small collection of materials that was used by the Wyoming Water Resources Center. Today, thanks in large part to funding by the US Geological Survey, this comprehensive collection of more than 18,000 documents is an exceptional resource for individuals desiring more in-depth information on the state's water resources. The Water Library web page is now online. We have added a link to the new web page from the WRDS homepage:

http://www.wrds.uwyo.edu

Click on the first link under Online Data Products and Services. We are working at making more and more of the collection available online.

We will house in the Library all of the data and information developed under the Water Resources Program which will further increase the viability of the collection. Researchers with the Water Resources Program use the Water Library for their secondary data collection. Additionally, the Water Library continues to employ one University of Wyoming student who works approximately 10 to 15 hours per week during the fall and spring semesters, and approximately 25 hours per week during the summer.

The Water Resources Data System (which includes the Water Library) is the single largest repository of water and climate data and information in the State of Wyoming. Our database and library collection will continue to grow thanks again in large part to the US Geological Survey's Water Resources Program.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	7	0	0	0	7
Masters	3	0	0	0	3
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

Publications from Prior Projects

None