United States Department of the Interior

U. S. GEOLOGICAL SURVEY

James Leenhouts

Arizona Water Science Center
520 North Park Avenue
Tucson, Arizona 85719

520-670-6671 ext. 278
leenhout@usgs.gov

December 14, 2009

Jim Eychaner, Acting Western Region Science Coordinator for Water
Modoc Hall, USGS
3020 State University Drive East
Sacramento, CA 95819

Dear Jim,

Attached is a proposal to publish a report describing methods for estimating magnitude and frequency of floods at gaged and ungaged sites in Arizona. This project is linked to USGS StreamStats application and our findings will be integrated into the National StreamStats package.

This project has a complicated history in that we have started some work for Maricopa County Flood Control District, but are building a cooperator base to take the work statewide. We've been waiting for the outcome of that effort in order to send the correct proposal for review. It appears at this point that we will have the necessary cooperators and resources to proceed. Please contact me with any questions or concerns. Thank you.

Sincerely,

James Leenhouts
Associate Director, USGS Arizona Water Science Center

U.S. Geological Survey, Arizona Water Science Center

Rev 5 (12/17/99)

PROJECT PROPOSAL COVER SHEET

WRD REGION: Western

PROPOSAL NUMBER AZ10B (Revised)

DISTRICT OR PROJECT OFFICE: Arizona

DATE (Initial) Oct 1, 2009

PROJECT TITLE: Methods for Estimating Magnitude and Frequency of Floods in Arizona

DATE (Revised)

PROJECT NUMBER 9671DRG

BEGIN DATE (mo/yr) Oct 1, 2009

SHORT TITLE: Arizona StreamStats

END DATE (mo/yr) 09/2012

RESEARCH RESOURCE APPRAISAL X

PROJECT CHIEF: Nick Paretti

DISCIPLINE: groundwater %, surface-water 100%, ground-water quality %, surface-water quality %; or (exclusively) administration % (See instructions on back of page: A project is either *technical* or *administration*, it cannot be a mix of both. *Technical* percentages, *if used*, must total 100%. *Administration*, if used, must be 0 or 100%.

ESTIMATED PROJECT FUNDING

firm

CUSTOMER NAMES(S)/NUMBER(S): The Flood Control Districts of the Counties of: Maricopa, Cochise, Pinal, Greenlee, Navajo, Pima, and Yavapai plus the Bureau of Reclamation and Salt River Project

FISCAL YEAR:	2009	2010	2011	2012	
OFA/FEDERAL:	$	$?	$?	$	$
COOP REPAY:	$	$ 31,000	$ 25,000	$ 10,000	$
COOP DIRECT:	$	$ 31,000	$ 25,000	$ 10,000	$
COOP UNMATCHED:	$ 103,077	$ 305,354	$ 76,000	$ 22,799	$
COOP TOTAL:	$	$ 336,354	$ 101,00	$ 32,799	$
DOI COST SHARE	$	$	$	$	$
TOTAL FOR FISCAL YEAR:	$103,077	$336,354	$ 146,159	$32,799	$

REMARKS:

AUTHOR: Nick Paretti xx, 2009

DISTRICT ENDORSEMENT: John Hoffmann xx, 2009

DISTRICT ADMINISTRATIVE OFFICER: Margie Gilliland ________, 2009

REGIONAL ENDORSEMENT: ____________ ________, 20____

APPROVED BY: ____________ ________, 20____

Methods for Estimating Magnitude and Frequency of Floods in Arizona

Proposal Summary

Problem

Water managers at many agencies in Arizona are required to determine flood hazards for their jurisdictions. The first task of determining flood hazards is to estimate magnitude and frequency of floods in the area of concern. These flood estimates are then used with hydraulic models to estimate the areal extent and height of floods for the design of bridges, culverts, dams, embankments, and stormwater drainage facilities. Regional regression equations for estimating floods are an important tool in this process. These equations are outdated and need to be improved with (1) new peak-flow data, (2) new information on factors that affect flood flows (basin and climatic characteristics), and (3) new technology that facilitates regression analysis and application of regression equations. The new regression equations and new basin characteristic data will be integrated into a national automated program (StreamStats; U.S. Geological Survey (2008b)).

Objectives

The principal goal of the proposed project is to provide statistical streamflow information for gaged and ungaged sites via web-based tools to those tasked with the management, protection, and development of water resources in Arizona. Specific objectives of the study are to:

1) Determine basin and climatic characteristics for gaged streamflow sites and regionalize those sites based on climatic and physiographic attributes
2) Evaluate and identify trends or shifts in annual peak flows at gaged sites (non-stationarity).
3) Compute flood-frequency relations at gaged sites in Arizona.
4) Develop regional regression equations for estimating flood-frequency relations at ungaged sites (rural and urban)
5) Integrate the regression equations and basin characteristic information into the automated program, StreamStats.

Relevance and Benefits

The proposed work is consistent with the strategies listed in “Facing Tomorrow’s Challenges-U.S. Geological Survey Science in the Decade 2007-2017.” Specifically this work will address the strategic action, “A National Hazards, Risk, and Resilience Assessment Program” and provide readily accessible flood-frequency information that is needed in Arizona for the cost-effective and safe design of bridges, culverts, dams, stormwater-drainage facilities, embankments, and for the management of floodplains. The work will also address aspects of strategic action “Climate Variability and Change,” by analyzing long-term flood records to identify trends and seasonal shifts in the historic flood record. Flood control mangers as well as the general public will greatly benefit from the web-based user interface StreamStats program. It will decrease number information requests to USGS and reduce user error by standardizing information retrievals

Approach

Regional areas will be delineated based upon basin, climatic, and physiographic characteristics. Flood-frequency relations at gaged sites will be computed on sites meeting the criteria: 10 or more years of record and drainage area of less than about 4,000 square miles. The selected sites will be classified into three categories based on rural and urban attributes. Estimating flood-frequency relations at ungaged sites will be developed by using the regional-regression approach. With this approach, the regression models are developed using flood-frequency relations at gaged sites as the response variables and basin and climatic characteristics at gaged sites as the explanatory variables. Regression equations for urban areas will be developed separately by using the rural equations as baseline relations and adjusting the relations for the degree of urbanization. Regional regression equations and GIS basin characteristic data will be incorporated into the Arizona StreamStats database.

Product

The product of this project will be a USGS Series report, published in electronic format only, in FY2012. Authorship will include Nick Paretti from the USGS. The report is expected to include about 20 pages of text, 10 figures, 20 tables.

Schedule

The work elements will be carried out in FY2009 and FY2010, with a draft report to be completed by March 1, 20011. Final editing, USGS approval, and publication will follow, with a publication date anticipated to be no later than September 30, 2011.

METHODS FOR ESTIMATING MAGNITUDE AND FREQUENCY OF FLOODS IN ARIZONA

Introduction

Flood frequency information is needed in Arizona for the cost-effective design of bridges, culverts, dams, stormwater-drainage facilities, embankments, and for the management of floodplains. Federal, State, and local agencies use flood information to (1) manage water resources, (2) provide for public safety, (3) manage and plan infrastructure, and (4) manage, plan, and regulate land use. Engineers, consultants, utilities, and industries also use flood information for their activities and to comply with flood-hazard regulations. The first task of determining flood hazards in Arizona is to estimate magnitude and frequency of floods at gaged streamflow sites throughout the State. This information is only applicable at the location of the gaged sites, so regional methods are needed to estimate flood hazards at ungaged sites throughout the State. Regional regression equations are a commonly used method for ungaged sites, and regression equations are one of the approved methods of the Federal Emergency Management Agency (FEMA) (Federal Emergency Management Agency, 2008). This proposed study will develop regional regression equations for Arizona (fig. 1).

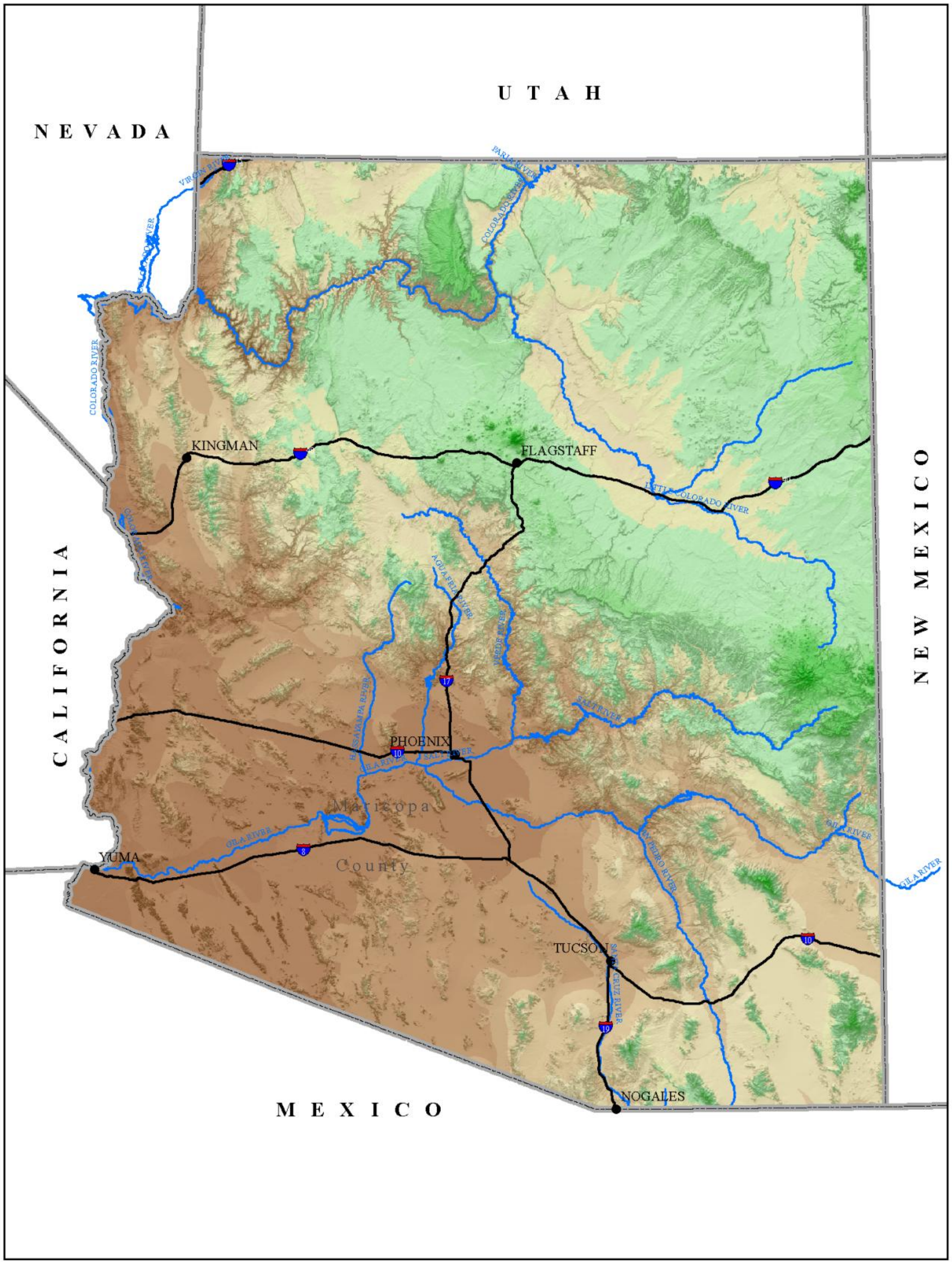


Figure 1. Map of Arizona.

Existing regional regression equations for Arizona were developed using peak-flow data through 1986 (Thomas and others, 1997). These equations can be updated and improved with (1) new peak-flow data, (2) new information on factors that affect flood flows (basin and climatic characteristics), and (3) new technology that facilitates regression analysis and application of regression equations.

Estimates of the response variables in the regression equations (flood-frequency relations at gaged sites) can be improved with 21 additional years of peak-flow data. Estimates of the explanatory variables in the regression equations can be improved by using new information on basin and climatic characteristics and new technology. Examples of new basin and climatic characteristics are new precipitation-frequency relations (NOAA Atlas 14; National Weather Service (2003)) and new climatic information (PRISM; Spatial Climate Analysis Service (2003)). Geographic-information system (GIS) technology can improve the accuracy of existing basin and climatic characteristics and can facilitate the development of new characteristics. New regression equations can be integrated into a national automated program (StreamStats; U.S. Geological Survey (2008b)). In the StreamStats program, a user accesses a web site and enters the location of the flood site; the program automatically performs all the computations to estimate a flood-frequency relation. This tool is easy to use, provides consistent results, and can apply complex regression equations.

Objectives

The general objective of this proposed study is to develop methods for estimating magnitude and frequency of floods in Arizona.

Specific objectives of the study are to:

1) Determine basin and climatic characteristics for gaged streamflow sites
2) Evaluate and identify trends or shifts in annual peak flows at gaged sites (non-stationarity). Evaluate the relations between peak flows and periods of climatic fluctuations such as

Atlantic Multidecadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), and El Nino—Southern Oscillation (ENSO)

3) Determine flood-frequency relations at gaged sites
4) Develop methods for estimating flood-frequency relations at ungaged sites for:
   a) Rural natural-flow areas, and
   b) Urban areas
5) Develop an automated program (StreamStats) to apply the methods for estimating flood-frequency relations at ungaged sites.

The analysis of trends in peak flows and relations between peak flows and climatic fluctuations (objective 2) is intended to identify if there is some non-stationarity in peak flows. If possible, identified non-stationarity will be evaluated to determine if it was caused by climatic fluctuations or by changes in watershed conditions. Peak-flow records with non-stationarity from climatic fluctuations will likely be included in the regional regression analysis. Peak-flow records with non-stationarity from changes in watershed conditions, such as urbanization, will be evaluated and possibly included in urban regional regression relations. The criteria for inclusion in urban regional relations are explained in task 4 in the approach section.

No attempts will be made to adjust or modify flood-frequency relations to account for non-stationarity that resulted from climatic fluctuations; there is no commonly accepted method for a non-stationarity adjustment and there is considerable uncertainty about how future climate change will affect the magnitude and frequency of floods.

Approach

Methods for estimating magnitude and frequency of floods in Arizona will be developed by using the regional regression approach. In this approach, flood information at gaged sites is transferred to ungaged sites by developing regression equations between flood frequency and basin characteristics.

U.S. Geological Survey, Arizona Water Science Center

Gaged sites in Arizona and some gaged sites in nearby parts of adjacent States will be selected for the study. The criteria for site selection are: (1) 10 or more years of record, and (2) a drainage area of less than about 4,000 square miles. The selected sites will be classified into three categories:

1) Rural areas with natural flow and runoff,
2) Urban areas with runoff that is affected by impervious areas and not appreciably affected by regulation or stream-channel alterations, and
3) Urban areas with runoff that is substantially affected by regulation or stream-channel alterations.

In addition to U.S. Geological Survey (USGS) gaged sites in Arizona and nearby States, records at about 80 gages operated by the Flood Control District of Maricopa County (FCDMC) will be screened and appropriate gages will be included in this study. An initial screening resulted in about 480 total gages for the study.

1) Basin and climatic characteristics will be determined for gaged sites by using geographic information system (GIS) technology and digital information on characteristics that affect flood flows. The first step will be to process ten-meter digital elevation models (DEMs) into a GIS coverage that is designed for hydrologic applications; drainage areas can be delineated more efficiently and more accurately in this way than on standard DEMs. In addition, the processed DEMs can be used to determine potentially important topographic characteristics such as mean basin elevation, basin shape, basin relief, channel slopes, and drainage density. GIS technology will also be used to determine other basin and climatic characteristics such as magnitude and frequency of precipitation, mean annual precipitation, seasonal precipitation, vegetation, soils, geology, population density, and extent of impervious areas.

2) Possible non-stationarity in annual peak flows at gaged sites will be determined by using the appropriate statistical tests for trends or shifts over time. Such tests could include linear regression, non-parametric trend tests, and tests for shifts in mean flows or variance of flows. The peak flows will also be separated into climatic time periods such as AMO, PDO, and ENSO, and analyzed for significant differences in peak flows among the time periods. The watersheds

of gages that are identified as having non-stationarity will be evaluated in an attempt to determine if the non-stationarity was a result of climatic fluctuations or changes in watershed conditions.

3) Flood-frequency relations at gaged sites will be estimated by using streamflow records through water year 2008. Flood-frequency relations will be calculated following Bulletin 17B guidelines (Interagency Advisory Committee on Water Data, 1982). The Hydrologic Frequency Analysis Workgroup (2008) is currently reviewing and evaluating Bulletin 17B, and any recommended changes to Bulletin 17B will be used in this study. The fit between flood-frequency relations and peak-flow data will be evaluated by using plotting positions, low-outlier threshold adjustments (Thomas and others, 1997), and goodness-of-fit tests (Hosking, 1990; Chowdhury and others, 1991; and Vogel and McMartin, 1991).

4) Methods for estimating flood-frequency relations at ungaged sites will be developed by using the regional-regression approach. Flood-frequency relations at gaged sites are the response variables and basin and climatic characteristics at gaged sites are the explanatory variables. The regression analysis will include investigation of: (1) different regression methods, (2) different forms of regression models, (3) geographic variation of flood characteristics, and (4) stratification by selected explanatory variables. The goal will be to develop accurate, logical, and practical regression equations.

Separate regression equations will developed for rural areas and urban areas. Regression equations for rural areas will be developed by using flood-frequency relations and basin characteristics for all gaged sites in rural areas. The equations for rural areas will be applicable in areas with runoff that are largely unaffected by human structures and activities.

Regression equations for urban areas will be developed by using the rural equations as baseline relations and adjusting the relations for the degree of urbanization. Explanatory variables that represent the density of impervious areas are added to the rural equations (Sauer and others, 1983; Moglen and Shivers, 2006). The effects of urbanization and other human activities will be carefully evaluated. Gaged sites and urban areas with runoff that is primarily affected by impervious areas will be included in the urban regression analysis. Gaged sites and urban areas that have stormwater-management facilities or stream-channel alterations that primarily decrease flood runoff will be evaluated on an individual basis. If the effects of those facilities or alterations are minor, those areas and gages will likely be included in the urban regression equations, but if the effects are substantial, those areas and gages will be classified as having undefined regional flood-frequency relations.

5) An automated program to apply the regional flood-frequency methods will be developed by entering results of this study into a USGS national automated program (StreamStats; U.S. Geological Survey (2008)). The user accesses the program at a web site and enters the location of the streamflow site; the program then makes all the necessary calculations to determine the flood-frequency relation at that site.

Additional objectives if funding is available

1) Determine flood-frequency relations at gaged sites for summer-thunderstorm runoff, late-summer/fall tropical-storm runoff, and winter frontal-storm runoff;
2) Determine flood-volume frequency relations at gaged sites;
3) Develop methods for estimating flood-frequency relations at ungaged sites for:
    a) Summer-thunderstorm runoff,
    b) Late-summer/fall tropical storm runoff,
    c) Winter frontal-storm runoff, and
    d) Flood volumes.
4) Evaluate relations between flood frequency and climatic fluctuations (AMO, PDO, and ENSO).

Approach for additional objectives

1) Flood-frequency relations for summer-thunderstorm runoff, late-summer/fall tropical-storm runoff, and winter-storm runoff at about 240 continuous-record gaged sites will be determined in two steps:

a) Analyze daily and instantaneous streamflow records and determine annual peaks that result from summer thunderstorms, late-summer/fall tropical storms, and winter frontal storms.

b) Develop flood-frequency relations for each runoff population by using Bulletin 17B guidelines (Interagency Advisory Committee on Water Data, 1982). Composite flood-frequency relations will also be developed by using various combinations of the three sets of frequency relations.

2) Flood-volume frequency relations at about 240 continuous-record gaged sites will be developed by calculating annual maximum flood volumes for selected durations such as 1, 3, 7, 15, and 30 days; and developing flood-volume frequency relations for each duration. The log-Pearson III probability distribution will be used with appropriate adjustments for outliers, zero flows, and regional skew.

3) Regional regression relations for (1) summer-thunderstorm runoff, (2) late-summer/fall tropical storm runoff, (3) winter-storm runoff, and (4) flood volumes will be developed by using the same procedures that are described in task 4 of the main approach section.

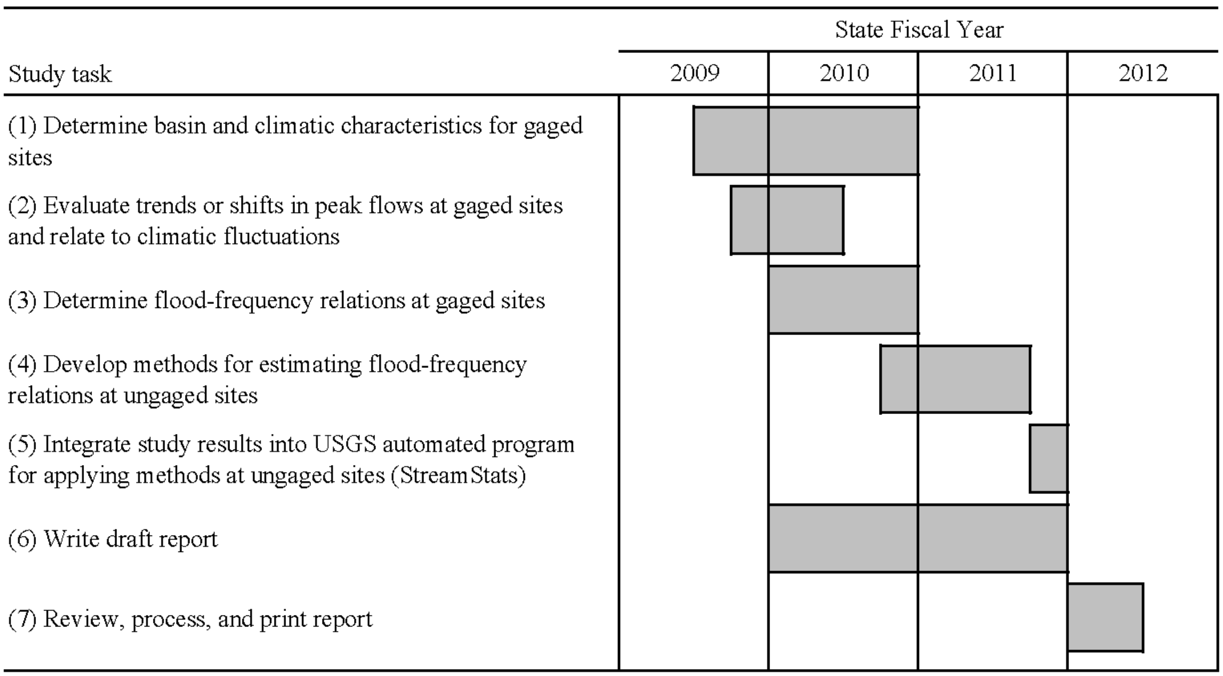
4) Relations between flood frequency and climatic fluctuations will be determined by grouping the annual peak flows into two climatic periods and calculating flood-frequency relations for each period. AMO, PDO, and ENSO have two distinct periods or phases; AMO shifts between warm and cool sea-surface temperatures (SST), PDO shifts between an index that represents SSTs and air pressures, and ENSO shifts between warm SSTs during El Niño conditions and cool SSTs during La Niña conditions.

Project duration and report

The project will require 3 years to complete. A project workplan (table 1) shows the timing and duration of project tasks. The workplan is in State Fiscal years (FY 2009 is July 1, 2008 to June

30, 2009). A draft report will be completed after 2.5 years (June 30, 2011) and the report will be printed at the end of 3 years (December 31, 2011). The report will be published as a USGS Scientific Investigations Report.

Table 1. Project workplan.



Project budget

Budget tables for labor (table 2), other expenses (table 3), fiscal year (table 4), and project tasks (table 5) are included in this document. Total cost is $618,390; costs by fiscal year are $103,077 for 2009, $336,355 for 2010, $146,159 for 2011, and $32,799 for 2012. Some optional or additional objectives and tasks were developed for this proposal and are described in the sections entitled “Additional objectives if funding is available” and “Approach for additional objectives”. Additional time and costs for these optional tasks are 4 months and $70,000 for annual flood-volume frequency, 5 months and $105,000 for seasonal peak-flow frequency relations, and 1 month and $20,000 for relation between peak-flow frequency relations and climatic fluctuations (table 6).

Table 2. Personnel detailed by area of expertise and tabulated by annual labor hours and State fiscal year costs.

	FY 2009		FY 2010		FY 2011		FY 2012		
Personnel	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Total cost
Project Chief	312	$24,929	1,840	$154,367	1,128	$99,365	160	$14,799	$293,460
Hydrologist (GIS)	608	$53,747	1,912	$177,472	0	$0	0	$0	$231,219
Hydrologic Technician	304	$16,538	0	$0	704	$42,223	0	$0	$58,761
Total	1,224	$95,214	3,752	$331,839	1,832	$141,588	160	$14,799	$583,440

Table 3. Other expense categories tabulated by State fiscal year.

Other expenses	FY 2009	FY 2010	FY 2011	FY 2012	Total
Travel (per diem)	$1,063	$1,116	$1,171	$0	$3,350
Training	$3,400	$3,400	$3,400	$0	$10,200
Software	$3,400	$0	$0	$0	$3,400
Publishing and printing	$0	$0	$0	$18,000	$18,000
Total	$7,863	$4,516	$4,571	$18,000	$34,950

Table 4. Total project costs by State fiscal year.

	FY 2009	FY 2010	FY 2011	FY 2012	Total
Fiscal year total budget	$103,077	$336,355	$146,159	$32,799	$618,390

Table 5. Project budget by task and State fiscal year.

Project task	FY 2009	FY 2010	FY 2011	FY 2012	Total
(1) Determine basin and climatic characteristics for gaged sites (includes compilation and processing of flow data, DEMs, and other GIS data)	$88,375	$180,417	$0	$0	$268,792
(2) Evaluate trends in peak flows at gaged sites	$14,702	$25,504	$0	$0	$40,206
(3) Determine flood-frequency relations at gaged sites	$0	$108,956	$0	$0	$108,956
(4) Develop methods for estimating flood-frequency relations at ungaged sites	$0	$5,369	$51,082	$0	$56,451
(5) Integrate study results into USGS automated system for applying methods at ungaged sites (StreamStats)	$0	$0	$49,975	$0	$49,975
(6) Report	$0	$16,108	$45,102	$32,799	$94,099
Fiscal year totals	$103,077	$336,354	$146,159	$32,799	$618,390

Table 6. Additional project time and costs for optional tasks described in sections entitled "Additional objectives if funding is available" and "Approach for additional objectives".

Additional project task	Additional project time (months)	Additional cost per task
(1) Determine flood-volume frequency relations for gaged sites and develop methods for estimating flood volumes at ungaged sites	4	$70,000
(2) Determine seasonal peak-flow frequency relations at gaged sites and develop methods for estimating seasonal peak-flow frequency relations at ungaged sites (runoff from summer thunderstorms, late-summer/fall tropical storms, and winter frontal storms)	5	$105,000
(3) Determine relation between peak-flow frequency relations and climatic fluctuations such as Atlantic multidecadal oscillation (AMO), Pacific Decadal Oscillation (PDO), and El Nino Southern Oscillation (ENSO)	1	$20,000

Selected References

Baldys, Stanley III, and Bayles, J.A., 1990, Flow characteristics of streams that drain the Fort Apache and San Carlos Indian Reservations, east-central Arizona, 1930-86: U.S. Geological Survey Water-Resources Investigations Report 90-4053, 59 p.

Boughton, W.C., and Renard, K.G., 1984, Flood-frequency characteristics of some Arizona watersheds: American Water Resources Association, Water Resources Bulletin, v. 20, no. 5, p. 761-769.

Butler, E., Reid, J.K., and Berwick, V.K., 1966, Magnitude and frequency of floods in the United States—Part 10. The Great Basin: U.S. Geological Survey Water-Supply Paper 1684, 256 p.

Burkham, D.E., 1976, Flow from small watersheds adjacent to the study reach of the Gila River Phreatophyte Project, Arizona: U.S. Geological Survey Professional Paper 655-I, 19 p.

Chowdhury, J.U., Stedinger, J.R., and Lu, L-H, 1991, Goodness-of-fit tests for regional GEV flood distributions: Water Resources Research, v. 72, no. 7, p. 1765-1776.

Eychaner, J.H., 1984, Estimation of magnitude and frequency of floods in Pima County, Arizona, with comparisons of alternative methods: U.S. Geological Survey Water-Resources Investigations Report 84-4142, 69 p.

Federal Emergency Management Agency, 2008, Guidelines and specifications for flood hazard mapping partners: Federal Emergency Management Agency accessed August 26, 2008 at URL http://www.fema.gov/plan/prevent/fhm/gs_main.shtm

Hedman, E.R., and Osterkamp, W.R., 1982, Streamflow characteristics related to channel geometry of streams in Western United States: U.S. Geological Survey Water-Supply Paper 2193, 17 p.

Hjalmarson, H.W., and Kemma, S.P., 1991, Flood hazards of distributary-flow areas in southwestern Arizona: U.S. Geological Survey Water-Resources Investigations Report 91-4171, 58 p.

Hjalmarson, H.W., and Thomas, B.E., 1992, A new look at regional flood-frequency relations for arid lands: American Society of Civil Engineers, Journal of Hydraulic Engineering, v. 118, no. 6, p. 868-886.

Hosking, J.R.M., 1990, L-Moments: analysis and estimation of distributions using linear combinations of order statistics: Journal of Royal Statistical Society, B, v. 52, no. 2, p. 105-124.

Hydrologic Frequency Analysis Workgroup, 2008, History of the hydrologic frequency analysis workgroup and previous flood frequency workgroups: Hydrologic Frequency Analysis Workgroup accessed November 17, 2008 at URL http://acwi.gov/hydrology/Frequency/History_HFAWG.pdf

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency, Bulletin 17B of the Hydrology Subcommittee: Reston, Virginia, U.S. Geological Survey, Office of Water Data Coordination, [183 p.]. [Available from National Technical Information Service, Springfield, VA 22161, as report no. PB 86 15 7278.]

Jennings, M.E., Thomas, W.O. Jr., and Riggs, H.C., 1994, Nationwide summary of U.S. Geological Survey regional regression equations for estimating magnitude and frequency of floods for ungaged sites, 1993: U.S. Geological Survey Water-Resources Investigations Report 94-4002, 196 p.

Kenny, T.A., Wilkowske, C.D., and Wright, S.J., 2007, Methods for estimating magnitude and frequency of peak flows for natural streams in Utah: U.S. Geological Survey Scientific Investigations Report 2007-5158, 28 p.

Linsley, R.K., 1986, Flood estimates: how good are they?: American Geophysical Union, Water Resources Research, v. 22, no. 9, p. 159-164.

Maricopa County Flood Control District, 2008a, Drainage design manual, hydraulics (July 2008 draft): Maricopa County Flood Control District, Phoenix, Arizona, 592 p.

Maricopa County Flood Control District, 2008b, Drainage design manual, hydrology (July 2008 draft): Maricopa County Flood Control District, Phoenix, Arizona, 376 p.

Moglen, G.E., and Shivers, D.E., 2006, Methods for adjusting U.S. Geological Survey rural regression peak discharges in an urban setting: U.S. Geological Survey Scientific Investigations Report 2006-5270, 55 p. http://water.usgs.gov/osw/pubs/sir2006_5270/

Moosburner, Otto, 1970, A proposed streamflow-data program for Arizona: Tucson, Arizona, U.S. Geological Survey open-file report, 56 p.

National Weather Service, 2003: NOAA Atlas 14, precipitation frequency estimates for the semiarid southwest United States, accessed September 5, 2008 at URL http://www.nws.noaa.gov/ohd/hdsc/

Newton, D.W., and Herrin, J.C., 1982, Assessment of commonly used methods of estimating flood frequency: Transportation Research Board 896, National Research Council, Washington D.C., p. 10-30.

Nigam, Sument, Barlow, Mathew, and Berbery, Ernesto, 1999, Analysis links Pacific decadal variability to drought and streamflow in United States: American Geophysical Union, EOS, v. 80, no. 61.

Patterson, J.L., and Somers, W.P., 1966, Magnitude and frequency of floods in the United States—Part 9. Colorado River basin: U.S. Geological Survey Water-Supply Paper 1683, 475 p.

Pope, G.L., Rigas, P.D., and Smith, C.F., 1998, Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996: U.S. Geological Survey Water-Resources Investigations Report 98-4225, 907 p.

Reich, B.M., and Renard, K.G., 1981, Application of advances in flood frequency analysis: Water Resources Bulletin, v. 17, no. 1, p. 67-74.

Reich, B.M., 1988, Flood frequency methods for Arizona streams: Arizona Department of Transportation Report FHWA-AZ88-801, 56 p.

Reynolds, S.J., 1989, Geologic map of Arizona, 1988 (scale 1:1,000,000): *in* Jenny, J.P., and Reynolds, S.J., (*eds*.) 1989, Geologic evolution of Arizona: Arizona Geological Society Digest 17, Tucson, Arizona, 866 p.

Roeske, R.H., 1978, Methods for estimating the magnitude and frequency of floods in Arizona: Arizona Department of Transportation Report ADOT-RS-15-121, 82 p.

Sauer, V.B., Thomas, W.O. Jr., Stricker, V.A., and Wilson, K.V., 1983, Flood characteristics of urban watersheds in the United States: U.S. Geological Survey Water-Supply Paper 2207, 63 p.

Spatial Climate Analysis Service, 2003, PRISM products: Corvallis, Oregon, Oregon State

University, accessed September 5, 2008 at URL http://www.ocs.orst.edu/prism/.

Stedinger, J.R., and Tasker, G.D., 1985, Regional hydrologic analysis 1. Ordinary, weighted, and generalized least-squares compared: American Geophysical Union, Water Resources Research, v. 21, no.9, p. 1421-1432.

Stiehr, P.L., 1981, Preliminary analysis of Arizona streamflow-data network for regional information: U.S. Geological Survey Open-File Report 81-920, 25 p.

Tasker, G.D., 1980, Hydrologic regression with weighted least squares: Water Resources Research, vol. 16, no. 6, p. 1107-1113.

Tasker, G.D., and Stedinger, J.R., 1989, An operational GLS model for hydrologic regression: Journal of Hydrology 111, p. 361-375.

Tasker, G.D., Hodge, S.A., and Barks, C.S., 1996, Region of influence regression for estimating the 50-year flood at ungaged sites: Water Resources Bulletin, vol. 32, no. 1, p. 163-170.

Thomas, B.E., Hjalmarson, H.W., and Waltemeyer, S.D., 1997, Methods for estimating magnitude and frequency of floods in the southwestern United States: U.S. Geological Survey Water-Supply Paper 2433, 195 p.

Thomas, B.E., 2007, Climatic fluctuations and forecasting of streamflow in the Lower Colorado River Basin: Journal of the American Water Resources Association, v. 43, no. 6, p. 1550-1569.

Thomas, W.O. Jr., 1985, A uniform technique for flood frequency analysis: American Society of Civil Engineers, Journal of Water Resources Planning and Management, v. 111, no. 3, p. 321-337.

Thomas, W.O., Grimm, M.M., and McCuen, R.H., 2003, Evaluation of flood frequency estimates for ungaged watersheds: Reston, Virginia, Advisory Committee on Water Information, accessed September 5, 2008 at URL http://water.usgs.gov/wicp/acwi/hydrology/Frequency/index.html.

Torre, Alberto Condes de la, 1970, Streamflow in the upper Santa Cruz River basin, Santa Cruz and Pima Counties, Arizona: U.S. Geological Survey Water-Supply Paper 1939-A, 26 p.

U.S. Geological Survey, 2008a, Global change hydrology program: Reston, Virginia, U.S. Geological Survey, Water Resources Discipline, Office of Surface Water, accessed September 5, 2008 at URL http://water.usgs.gov/osw/programs/globalchange.html.

U.S. Geological Survey, 2008b, StreamStats program: Reston, Virginia, U.S. Geological Survey, Water Resources Discipline, Office of Surface Water, accessed August 25, 2008 at URL http://water.usgs.gov/osw/streamstats/index.html.

U.S. Water Resources Council, 1981, Guidelines for determining flood flow frequency: Bulletin 17B of the Hydrology Committee, Water Resources Council, Washington D.C.

Vogel, R.M., and McMartin, D.E., 1991, Probability plot goodness-of-fit and skewness estimation procedures for the Pearson type 3 distribution: Water Resources Research, v. 27, no. 12, p. 3149-3158.

Vogelmann, J.E., Sohl, T.L., Campbell, P.V., and Shaw, D.M., 1998, Regional land cover characterization using Landsat Thematic Mapper data and ancillary data sources: Environmental Monitoring and Assessment, v. 51, p. 415-428 (http://edcwww.cr.usgs.gov/programs/lccp/)

Waltemeyer, S.D., 2006, Analysis of the magnitude and frequency of peak discharges for the Navajo Nation in Arizona, Utah, Colorado, and New Mexico: U.S. Geological Survey Scientific Investigations Report 2006-5306, 42 p.

Webb, R.H., and Betancourt, J.L., 1992, Climatic variability and flood frequency of the Santa

U.S. Geological Survey, Arizona Water Science Center

Cruz River, Pima County, Arizona: U.S. Geological Survey Water-Supply Paper 2379, 40 p.

Zeller, M.E., 1979, Hydrology manual for engineering design and flood plain management within Pima County, Arizona: Tucson, Arizona, Pima County Department of Transportation and Flood Control District, 147 p.

U.S. Geological Survey, Arizona Water Science Center

JOB HAZARD ANALYSIS

JOB SERIES:	JOB Description: Documentation of capture analysis, Lower Colorado River
EMPLOYEE NAME (Please Print): Nick Paretti	OFFICE SYMBOL:
EMPLOYEE SIGNATURE: /s/Nick Paretti	DATE: 5/14/09
ANALYZED BY (Immediate Supervisor): James Leenhouts	DATE: 5/14/09
REVIEWED BY (Safety Office): Fletcher Brinkerhoff/acting	DATE: 5/14/09

	YES	NO
Is employee in the Medical Surveillance Program?		X
Is employee required to wear personal protective equipment (i.e., safety boots or glasses, respirators, hearing protection, etc.)?	X	
Does employee require safety training (i.e., HTRW, confined space, HAZCOM, respirator, electrical, hearing)?		X

ACTIVITY	LOCATION	HAZARD	CONTROLS
Office Work		Eye strain	Ensure proper lighting. Ensure computer monitor and document copy stand are at approximately the same height and distance. Reduce computer screen glare by installing anti-glare/anti-static screens.
		Wrist strain	Ensure computer keyboards are adjusted so that the elbows are at a 90-degree angle and arms and hands are parallel to the floor. Use wrist rests or other supports so that wrists are maintained in a neutral position.
		Neck/shoulder fatigue	Ensure video display terminals are properly adjusted so that the top of the screen is slightly below eye level and the screen is between 18 and 28 inches away. Document or copy holders should be at the same height and distance and the screen.
		Slips/trips/falls	Use good housekeeping practices. Secure tripping hazards (cords) to floor. Do not leave file drawers open when unattended.
		Lifting	Use proper lifting techniques. Get assistance when necessary. When lifting, keep the load close to the body and lift with the legs.
		Electrical shock	Do not reconfigure wiring in systems furniture panels. Ensure equipment is properly maintained and grounded. Protect electrical cords from damage by using cord covers. Do not overload outlets.
		Walking	Be alert of walking surface, wear flat shoes with a non-skid sole.
		Falling off of furniture	Use a step stool. Do not use climb on furniture.
		Cutting tools	Cut in the direction away from hands and body.
		File cabinets/shelves	To avoid tipping, fill the bottom file first. Do not open more than one drawer at a time. Place heavy objects in the bottom shelves/drawers.
Travel	City, Highway and Secondary roads	Motor vehicle accidents	Obey traffic laws. Adjust vehicle operation to road and weather conditions. Employ defensive driving techniques. Complete defensive driver training once every 4 years.
		Uneven surfaces	Reduce speed appropriately.
		Deer and other wildlife	Stay alert, use caution, and drive defensively.
		Dust	Drive with windows closed.
		Reduced visibility	Ensure windows/mirrors are free from snow and ice. Drive with headlights on. Reduce speed appropriately.
		Slick, snowy, or icy roads	Use studded or chained tires, reduce speed, and increase following distances.