ARIZONA DEPARTMENT OF WATER RESOURCES
FLOOD MITIGATION SECTION

REQUIREMENT FOR

FLOODPLAIN AND FLOODWAY DELINEATION

IN RIVERINE ENVIRONMENTS

The Director of the Arizona Department of Water Resources under the authority outlined in ARS 48-3605(A) establishes the following standard for delineation of floodplains and floodways in riverine environments, and for use in floodplain management in Arizona:

Flood discharge rates, water surface elevations, and floodway limits determined for use in fulfilling the requirements of approved local community and county flood damage prevention ordinances will be determined by applying the alternative procedures outlined in State Standard Attachment 2-96 entitled "Delineation of Riverine Floodplains and Floodways in Arizona" (SSA 2-96) or by an alternative procedure reviewed and accepted by the Director.

For the purpose of application of these procedures, floodplains will include all watercourses officially identified by the Federal Emergency Management Agency as part of the National Flood Insurance Program; all watercourses which have been identified by a local floodplain administrator as having significant potential flood hazards; or all watercourses with drainage areas more than 1/4 of a square mile or a 100-year estimated flow rate of more than 500 cubic feet per second. Application of administrative floodway procedures will be only for streams that do not currently have a floodway identified by the Federal Emergency Management Agency as part of the National Flood Insurance Program. Application of the procedures outlined in SSA 2-96 will not be necessary if the local community or county has in effect a drainage, grading or stormwater ordinance which, in the opinion of the Director, results in the same or a more stringent level of flood protection than application of the procedure would ensure.

This requirement is effective July 1, 1996. State Standard 2-96 and State Standard Attachment 2-96 replace State Standard 2-92 and State Standard Attachment 2-92, adopted in September, 1992, and State Standard 2-92 (Supplement 1) and State Standard Attachment 2-92 (Supplement 1), adopted in November, 1994. Please discard all copies of the superseded standards and attachments.

Copies of this State Standard and State Standard Attachment can be obtained by contacting the Department's Flood Warning and Dam Safety Section at (602) 417-2445.

NOTICE

This document is available in alternative formats. Contact the Department of Water Resources, Flood Mitigation Section at (602) 417-2445 or (602) 417-2455 (TDD).

ARIZONA DEPARTMENT OF WATER RESOURCES
FLOOD MITIGATION SECTION

Delineation of Riverine Floodplains and Floodways in Arizona

500 North Third Street
Phoenix, Arizona 85004

(602) 417-2445

STATE STANDARD ATTACHMENT **JULY, 1996**

SSA 2-96

DISCLAIMER OF LIABILITY

The methods contained in this publication are intended to be a reasonable way of setting minimum floodplain management requirements where better data or methods do not exist. As in all technical methods, engineering judgment and good common sense must be applied and the methods rejected where they do not offer a reasonable solution.

It must be recognized that while enforcement of the criteria established herein will generally reduce flood damages to new and existing development, there will continue to be flood damages in Arizona. Where future-condition hydrology (which considers the cumulative effects of development) is not used, future development will probably increase downstream peak discharge rates which may result in flooding. Unlikely or unpredictable events such as dam failures may also cause extreme flooding.

The Arizona Department of Water Resources is not responsible for the application of the methods outlined in this publication and accepts no liability for their use. Sound engineering judgment is recommended in all cases.

The Arizona Department of Water Resources reserves the right to modify, update, or otherwise revise this document and its methodologies. Questions regarding information or methodologies contained in this document and/or floodplain management should be directed to the local floodplain administrator or the office below:

Flood Mitigation Section
Arizona Department of Water Resources
500 North Third Street
Phoenix, Arizona 85004

Phone: 602-417-2445
FAX: 602-417-2423

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INTRODUCTION

Purpose

State Standard 2-96. The intent of this document is to provide methodologies for estimating 100-year peak discharges, delineating 100-year floodplain limits, and determining administrative floodway boundaries for riverine floodplains in Arizona. Methodologies for non-riverine floodplain areas, such as alluvial fans, are not addressed. The purpose of estimating 100-year peak discharges is for use in delineating 100-year floodplain and floodway limits and estimating hydraulic conditions associated with 100-year flooding, and for use in other water resource management purposes. The purpose of delineating 100-year floodplain limits is to prevent or reduce flood risk for activities in flood-prone areas. The purpose of determining an administrative floodway is to provide a zone of acceptable encroachment which will allow for development while reducing or eliminating damage to property and preventing hazards to life and health. An administrative floodway is defined as a zone of conveyance which will safely pass floodwaters.

Alternative Methodologies. The purposes of the floodplain management methodologies recommended in this document are to reduce or eliminate flood damage to property, to prevent the disruption of normal activities by flooding, to prevent hazards to life and health from flooding, and to regulate the use of flood-prone lands. It is necessary to adopt uniform floodplain management criteria that provide the desired degree of protection throughout Arizona. However, these criteria must be flexible enough to allow communities to use approved alternative methodologies which may not be described in this document. To be approved, an alternative methodology must be reviewed and approved in writing by appropriate Arizona Department of Water Resources (ADWR) staff, as well as by the floodplain administrator for the community in which it will be applied. Application of the methodologies outlined in this document is not mandated if the local community or county has in effect a drainage, grading or stormwater ordinance which, in the opinion of the ADWR Director, results in the same or a more stringent level of flood protection than application of the methodologies described in this document.

Floodplain Management. To provide a context for the recommended floodplain management methodologies, a brief discussion of the National Flood Insurance Program (NFIP), the role of the Arizona Department of Water Resources, and floodplain and floodway standards are provided in Appendices A, B, and C, respectively.[1]

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[1] Many floodplain activities require permits from or review by other local, state, or federal agencies (e.g., Army Corps of Engineers Section 404 permit (placement of fill), or Environmental Protection Agency NPDES stormwater permit). Individuals should check with the appropriate agencies to determine specific needs.

General Information

Although the data needed for floodplain management and flood hazard identification are generally straightforward, the procedures for obtaining these data are widely varied. In general, four types of information are required:

- Discharge Rate
- Floodplain Limits/Water Surface Elevation
- Floodway Boundaries
- Documentation

Discharge Rate. The 100-year peak discharge rate is used for all floodplain management methodologies described in this document. The 100-year flood, or one percent flood, is the highest rate of flow expected during the 100-year flood event and is commonly measured in the U.S. in cubic feet per second (cfs). Appendix C presents a discussion of the 100-year flood as the nationwide floodplain management standard.

Floodplain Limits/Water Surface Elevation. The 100-year floodplain limits are the area of inundation resulting from the 100-year peak discharge. The area of flood inundation may be estimated by predicting the width of flooding over a floodplain, or by comparing the estimated 100-year water surface elevation to known ground elevations. It is also possible to estimate the flow velocity, depth, scour potential, and other flood characteristics for a particular location when estimating the floodplain limits and water surface elevation.

Floodway Boundaries. The floodway is the area along a watercourse which must be reserved for the conveyance of flood waters. The floodway width is estimated using the 100-year peak discharge and appropriate local encroachment criteria. Encroachment means placing fill, structures, developments, or other material within the floodplain limits. This document describes specific procedures for estimating *administrative* floodway boundaries. An administrative floodway is a floodway delineated by the procedures described in this document, as opposed to floodway delineation procedures mandated by the NFIP.

Documentation. Documentation of the procedures used to estimate peak discharge, floodplain limits, water surface elevation or other hydraulic characteristics, and floodway boundaries must be maintained by each individual NFIP participating community for all development within the regulatory floodplain. State Standard 1-97 describes documentation requirements for floodplain studies in Arizona.

Three-Level Approach

Procedures for estimating the first three types of floodplain management information listed above are described below. Three levels of analysis are presented for each type of information. *Level 1* procedures are the minimum level of regulation acceptable, and are intended for use where only limited site and flood data are available, and where site improvements are minimal. *Level 2* procedures require a basic understanding of hydrologic principles and mathematics, and are appropriate for single lot developments where some site and flood data are available. *Level 3* involves detailed engineering analysis, and is intended for use on larger developments or where regional floodplain management issues are impacted.

Throughout this document Level 1, Level 2, and Level 3 refer to increasing levels of effort in analysis. **It should be understood that the lowest level of effort generally produces the most conservative results.** Level 1 will generally produce more conservative results than Level 2. Likewise, Level 2 will generally produce more conservative results than Level 3. It is the responsibility of each community and the individuals proposing floodplain improvements to determine the appropriate level of analysis. Communities and/or property owners are encouraged, and in some cases will be required to spend the necessary time and money to perform a Level 2 or Level 3 engineering analysis in order to comply with local, state, or federal regulations, and to ensure that all new construction in Arizona is protected against flood damages.

Wherever appropriate, existing detailed engineering or hydrologic information should be used, instead of the results of Level 1, 2 or 3 methodologies. For example, where a detailed hydrologic model for a watershed has already been developed or USGS gage information is available for a watercourse, the existing flow rate estimates should be used to determine floodplain limits or floodway boundaries. Similarly, where a detailed HEC-2 model has been developed for a stream reach for other purposes, the results of that model should generally be used to delineate the floodplain and floodway, rather than the Level 1 or Level 2 methodologies described in this document. In general, for any given site, the same Level methodology should be used for hydrology, floodplain delineation and floodway boundary determination. For example, if a Level 2 floodway is being delineated, the Level 2 (or lower) hydrology methodology should be used to estimate the 100-year discharge.

FEMA Floodplain Zones

This document presents floodplain hazard identification procedures which are acceptable for use in Arizona. However, a driving force in floodplain management and implementation of the NFIP in the United States is Federal Emergency Management Agency (FEMA), which has prepared the majority of floodplain delineations in Arizona. Because it is vital for all Arizona communities to remain eligible for the NFIP, any existing study which has been adopted by FEMA shall be considered the minimum base for floodplain management for the specific study area or flooding source. That is, the rate of flow, water surface elevations, floodplain limits, and floodway boundaries as accepted by FEMA are the minimum values to be used. Therefore, the first step by a community, before performing any of the analyses described in this document, should be to determine if there is an existing FEMA study which has been performed for the subject area.

ADWR will assist any community that requires help locating existing FEMA studies. If the subject area is located within an existing FEMA flood hazard zone delineated by detailed methods, a Level 3 analysis will be required if any changes are proposed. In cases where a community feels strongly that a FEMA study is incorrect, ADWR will assist the community in appealing to FEMA to correct the study's deficiencies.

Guidance for managing development in FEMA flood zones is provided in:

1. FEMA, National Flood Insurance Program & Related Regulations, 44CFR, Chap. 1.

2. FEMA, 1995, Guidelines: Specifications for Study Contractors - FEMA 37.

3. FEMA, 1995, Managing Floodplain Development in Approximate Zone A Areas - A Guide for Obtaining and Developing Base Flood (100-year) Flood Elevations - FEMA 265.

PROCEDURES

Overview

This section briefly describes the recommended methodologies for estimating the 100-year discharge, floodplain limits or water surface elevation, and floodway boundaries at any riverine site in Arizona. More detailed information and example applications for Level 1 and Level 2 methodologies are provided in Appendices D - I. Detailed descriptions of Level 3 methodologies are beyond the scope of this document, but should be readily available from an Arizona-registered professional engineer.

Level 1 Procedures

The purpose of Level 1 analysis is to provide floodplain management procedures that are simple to use and that require data which are readily available. Level 1 procedures estimate flood depth and floodway width independent of detailed site topography, hydraulic equations, or hydrologic models. Level 1 methodologies will provide conservative values for peak discharge, flood depths, and floodway widths, so that finished floor elevations and floodway setbacks can be estimated for a proposed project with very little data and engineering expertise. However, it is necessary to be able to delineate and measure the watershed area to apply Level 1 procedures. Watershed area can be delineated on readily-available U.S. Geological Survey (USGS) topographic quadrangle maps.

Table 1. Level 1 Methodology Summary

Data Type	Variable Obtained	Data Required	Methodology	Example
Discharge	100-Year Discharge	Watershed Area	USGS Data Envelope Curve	Appendix D
Floodplain	Flow Depth	Watershed Area	FEMA Data Regression Equation	Appendix E
Floodway	Floodway Width	Watershed Area	FEMA Data Regression Equation	Appendix F

Discharge. The Level 1 discharge methodology was derived from a recently published comprehensive analysis of stream gage records in the Southwest (Thomas et. al., 1994). The methodology consists of an envelope curve constructed using the maximum discharges from Arizona and the Southwest gaged by the USGS. Because the methodology is based on an envelope curve, the peak discharge estimates tend to be conservative. An example application of the Level 1 discharge methodology is provided in Appendix D.

Floodplain/Floodway. Equations for the Level 1 floodplain and floodway methodologies were derived using depth, floodway width and drainage area from FEMA flood insurance studies in Arizona. Regression analyses were performed using these data for various regions in Arizona. Estimation of a 100-year discharge rate is not required to estimate floodplain depths or floodway widths using the Level 1 procedures. Detailed information on the development of the regression equations used in this report is available from the Flood Warning and Dam Safety Section of ADWR. Level 1 floodplain and floodway examples are provided in Appendices E and F, respectively.

Within the Level 1 floodway fringe, the regulatory elevation shall be a minimum of 1 foot above the highest adjacent existing ground elevation, or one foot above the estimated floodplain elevation, whichever is higher. If a drainage structure such as a combination culvert/roadway dip-section, bridge, or embankment of any kind is to be placed across a watercourse, a Level 2 or Level 3 analysis is required.

Level 2 Procedures

Level 2 requires the estimation of the 100-year peak discharge (hydrology) and the 100-year floodplain (hydraulics) using simplified engineering procedures. If a drainage structure such as a combination culvert/roadway dip-section, bridge, or embankment of any kind is to be placed across a watercourse that will create a significant backwater effect or hydraulic obstruction, a Level 3 analysis may be required. The Level 2 procedures are:

Table 2. Level 2 Methodology Summary

Data Type	Variables Obtained	Data Required	Methodology	Example
Discharge	100-Year Discharge	Watershed Area Mean Elevation Mean Annual Evaporation Mean Annual Precipitation	USGS Regression Equations	Appendix G
Floodplain	Water Surface Elevation Channel Velocity Channel Depth	Channel Cross Sections Roughness Value 100-Year Discharge Rate Channel Slope	Manning's Rating	Appendix H
Floodway	Floodway Width Floodway Elevation	Channel Cross Sections Roughness Value 100-Year Discharge Rate Channel Slope	Administrative Floodway	Appendix I

Discharge. Equations for estimating peak discharges for ungaged watersheds in Arizona and the Southwest were developed by the U.S. Geological Survey using stream gage records, regression analyses and newly developed statistical procedure for arid regions. Unique equations were developed for each of seven regions within Arizona, including a region for watersheds at high elevation (> 7,500 feet). Required information includes the watershed area, and may include one of the following: (1) mean annual precipitation, (2) mean elevation, or (3) mean annual evaporation. Figures showing the required precipitation and evaporation data for the entire State of Arizona, and sample applications are provided in Appendix G. Mean elevation may be determined from USGS topographic maps, as described in Appendix G.

The Level 2 discharge methodology illustrated in Appendix G is generally not recommended for certain types of watersheds, including the following:

- Urban watersheds
- Alluvial fan and distributary flow area watersheds
- Watersheds with significant areas of flood irrigation agricultural fields
- Watersheds with highly permeable soils (e.g., fractured limestone, volcanic cinders)
- Watersheds with significant flood control reservoirs or diversions

For the types of watersheds listed above Level 1 or Level 3 discharge methodologies generally should be used. Other Level 2 application guidelines are provided in Appendix G.

Floodplain Limits/ Water Surface Elevation. Floodplain limits can be delineated by using Manning's equation to estimate water surface elevation (normal depth) for channel cross sections located at the proposed development. The developer should provide normal depth calculations at several representative cross-section locations adjacent to the proposed improvement/development. Cross-sections should also be located both upstream and downstream of the proposed improvement/development. Cross sections should be spaced at 300 to 500 feet intervals with a minimum of three cross sections required along short reaches. Calculations must include pre- and post-development conditions. Manning's equation, applied by using manual calculations or computer software, is recommended to compute normal depth. Floodplains will be delineated using normal depth or critical depth, whichever is greater. Where critical or supercritical flow exists, the finished floor elevation should established using the energy grade line as the base flood elevation, as illustrated in Appendix H.

It is recommended that structures not be placed in the 100-year floodplain without some type of floodway analysis. At minimum, an assessment of flood depth and velocity should be performed and structures[2] should not be placed within the area where the following criteria are exceeded:

- Houses built on foundations: Depth x Velocity > 10 and Depth > 2.5 ft.
- Mobile homes: Depth x Velocity > 6 and Depth > 1.5 ft.

A Level 2 floodplain delineation example is provided in Appendix H.

Administrative Floodway Boundaries. The administrative floodway is an area reserved for the conveyance of flood flows. Figure 1 illustrates a typical riverine 100-year floodplain, administrative floodway, and floodway fringe. The area between the edge of the 100-year floodplain and the administrative floodway is commonly referred to as the floodway fringe. Encroachment into the floodway fringe area shall be allowed for development as long as the structure(s) is protected from the 100-year flood. No encroachment of any kind shall be allowed within the area determined as an administrative floodway using a Level 2 procedure.

The administrative floodway procedures may be used if all of the following criteria are met:

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[2] These criteria do not apply to structures constructed on engineered fill material elevated above the regulatory water surface elevation.

- A detailed FEMA Flood Insurance Study does not exist for the watercourse.
- The local floodplain administrator has approved the use of the Level 2 floodway procedure.
- The procedure is being used for a single lot residential or single lot commercial development.
- The watercourse consists of an identified flooding area which may or may not have overbank flooding and has a subcritical flow regime.
- The flood conveyance area of the watercourse is generally uniform, without significant changes in cross-sectional geometry or longitudinal slope.

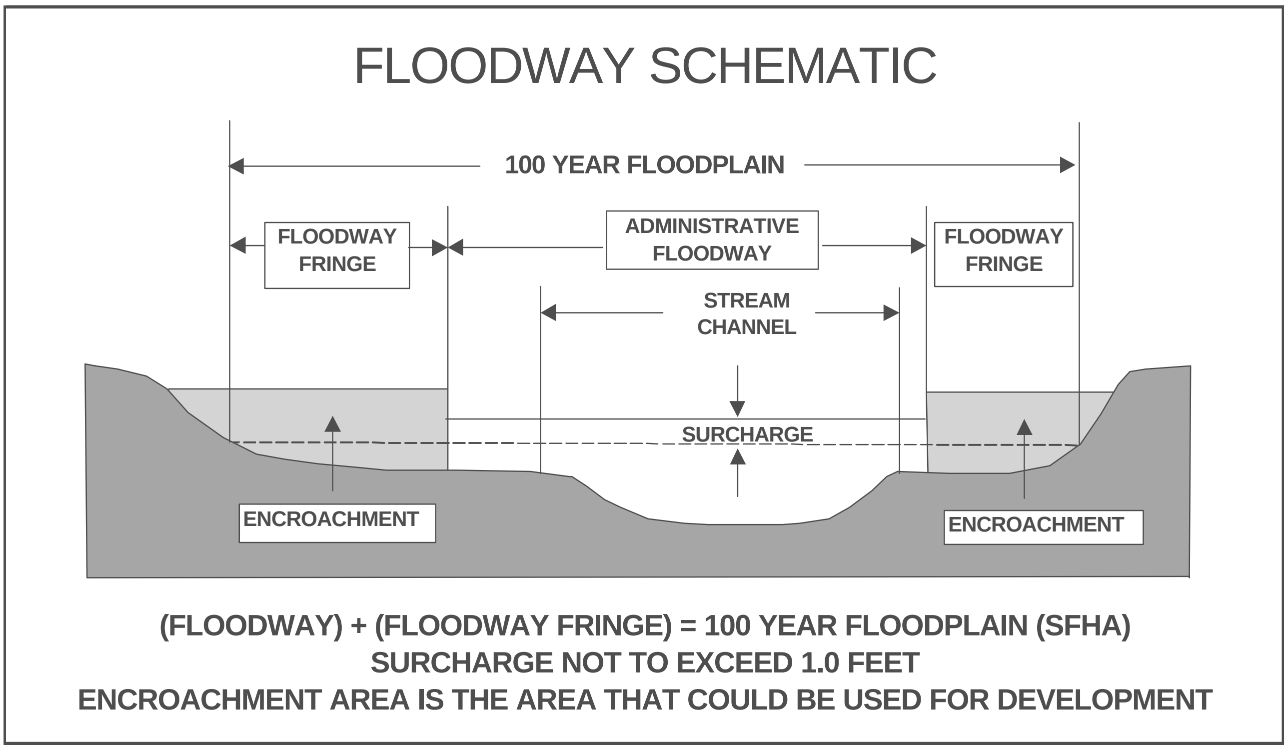
The procedure is not intended for use if a detailed FEMA Flood Insurance Study exists or for the following conditions:

- I Multi-lot development.
- II Alluvial fan, distributary, or bifurcated flood hazard areas.
- III Watercourses having a supercritical flow regime.
- IV Watercourses which have large changes in cross-sectional geometry or longitudinal slope within close proximity of the study area.
- V Watercourses where significant hydraulic structures are present that would create backwater effects, such as large roadway crossings with culverts or bridges, dams, and detention/retention structures.

Level 3 floodway delineation procedures are required for the situation listed above. Administrative floodway procedures are described in Appendix I.

Figure 1

FLOODPLAIN - FLOODWAY - FLOODWAY FRINGE ILLUSTRATION



Administrative Floodway Fringe Encroachment Standards. Encroachment into the floodway fringe area is typically accomplished using various methods including pilings, piers, columns, and/or engineered fill material. Finished pad elevations for structures shall be constructed 1 foot above the encroached 100-year water surface elevation[3], regardless of the method of encroachment used. For pilings, piers, columns, and similar methods, scour and lateral force analysis shall be performed and incorporated into the design.

For engineered fill, the following criteria shall be met:

- Fill material will be placed to raise the ground surface uniformly 1 foot above the encroached 100-year water surface elevation.
- Fill must be compacted. The typical compaction standard is 95% of the maximum density obtainable with the Standard Proctor Test method issued by the American Society for Testing and Materials (ASTM Standard D-698). This requirement applies to fill pads prepared for residential or commercial structure foundations. This requirement does not apply to filled areas intended for other uses.
- The toe of the proposed fill material shall intercept the natural ground surface at the floodway boundary location established by the encroachment analysis.
- Fill slopes for granular materials shall not be steeper than three horizontal on one vertical (3:1) unless substantiating data (e.g., a geotechnical report) justifying steeper slopes is submitted.
- Adequate protection shall be provided for fill slopes exposed to 100-year peak discharges with velocities of five feet per second or less by covering them entirely with grass, vines, or similar vegetative growth.
- Adequate protection shall be provided for fill slopes exposed to 100-year peak discharges with velocities greater than five feet per second by armoring them entirely with stone or rock slope protection or some other acceptable method.
- Fill areas or building pads should extend beyond the outside perimeter of a structure. A minimum of twenty-five (25) feet in all directions is recommended.

Note that a Level 2 approach may not be applicable to all cases. The local floodplain administrator may request that a more detailed Level 3 procedure be used.

[3] One foot above the 100-year Energy Grade Line if flow is critical or supercritical.

Level 3 Procedures

Level 3 procedures require the estimation of the 100-year discharge (hydrology), and the 100-year floodplain and floodway (hydraulics) using more sophisticated engineering procedures than in Level 1 or Level 2. The Level 3 analyses will generally be more expensive, though an overall cost savings may be realized in drainage structure and/or flood-proofing construction costs. Level 3 documentation will comply with those defined in SSA 1-90 (Instructions for Organizing and Submitting Technical Documentation for Flood Studies) by the Arizona Department of Water Resources.

Methods approved for use in hydrologic analyses include frequency/peak discharge estimation using the computer programs HEC-1 by the Corps of Engineers and TR-55 and TR-20 by the Soil Conservation Service for synthetic peak discharge estimation. Where possible, any synthetic peak discharge estimation techniques should be calibrated to locally observed hydrologic conditions. Where stream gage records are available, flood frequency estimates can be made using statistical analysis. Floodplain and floodway analyses will be conducted using step-backwater methodology. The computer models HEC-2 or HEC-RAS by the Corps of Engineers are preferred. A Level 3 example is not provided in this document.

Table 3. Level 3 Methodology Summary

Information Type	Variable Obtained	Data Required	Acceptable Methodologies
Discharge	100-Year Discharge Flood Hydrograph	Detailed Information Watershed Data Precipitation Data	Computer Models: HEC-1, TR-20, TR-55, others Approved Local Methodologies Flood Frequency from Gage Data
Floodplain	Water Surface Profile Channel Hydraulics	Surveyed Cross Sections Hydraulic Data	Computer Models: HEC-2, others
Floodway	Floodway Width Channel Hydraulics	Surveyed Cross Sections Hydraulic Data	Computer Models: HEC-2, others

References

Arizona Department of Water Resources, Flood Warning and Dam Safety Section "Requirement for Floodplain Delineation in Riverine Environments - State Standard 2-92 (and Attachment)," September 1992.

Arizona Department of Water Resources, Flood Warning and Dam Safety Section "Requirement for Floodplain and Floodway Delineation in Riverine Floodplains - State Standard Attachment SSA 2-92," January 1996.

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Henderson, F.M., "Open Channel Flow," Macmillan Publishing Co., Inc., New York, 1966.

Thomas, B.E., Hjalmarson, H.W., Waltemeyer, S.D., “Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States,” USGS Open File Report 93-419, 1994.

Thomsen, B.W., and Hjalmarson, H.W., 1991, U.S. Geological Survey, Water Resources Division, “Estimated Manning’s Roughness Coefficients for Stream Channels and Floodplains in Maricopa County, Arizona,” Prepared for the Flood Control District of Maricopa County, April.

APPENDICES

Appendix A: National Flood Insurance Program

The United States Congress passed the National Flood Insurance Act of 1968 as a first attempt to provide relief for individuals with property in flood-prone areas, and to begin to develop uniform standards for floodplain management. Since 1968, the Act has been amended several times. This Appendix contains passages from the Act wherein the definition of community includes the state.

The National Flood Insurance Act of 1968 was enacted by Title XIII of the Housing and Urban Development Act of 1968 (L. 90-448, August 1, 1968) to provide previously unavailable flood insurance protection to property owners in flood-prone areas. Mudslide protection was added to the Program by the Housing and Urban Development Act of 1969. Flood-related erosion protection was added to the Program by the Flood Disaster Protection Act of 1973 (L. 93-234, December 31, 1973). The Flood Disaster Protection Act of 1973 requires the purchase of flood insurance on and after March 2, 1974, as a condition of receiving any form of Federal or federally-related financial assistance for acquisition or construction purposes with respect to insurable buildings and mobile homes within an identified special flood, mudslide, or flood-related erosion hazard area that is located within any community participating in the Program. The Act also requires that on and after July 1, 1976, or one year after a community has been formally notified by the Administrator of its identification as a community containing one or more special flood, mudslide, or flood-related erosion hazard areas, no such Federal financial assistance, shall be provided within such an area unless the community in which the area is located is then participating in the Program, subject to certain exceptions.

To qualify for the sale of federally-subsidized flood insurance a community must adopt and submit to the Administrator as part of its application, floodplain management regulations, satisfying at a minimum the criteria designed to reduce or avoid future flood, mudslide (i.e., mudflow) or flood-related erosion damages. These regulations must include effective enforcement provisions.

The NFIP has been successful in requiring new buildings to be protected from damage by the 100-year flood. However, the program had few incentives for communities to do more than enforce the minimum regulatory standards. Flood insurance rates had been the same in all participating communities, even though some do much more than regulate construction of new buildings to the national standards.

Until 1990 the program did little to recognize or encourage community activities to reduce flood damages to existing buildings, to manage development in areas not mapped by the NFIP, to protect new buildings beyond the minimum NFIP protection level, to help insurance agents obtain flood data, or to help people obtain flood insurance. Because these activities can have a great impact on the insurance premium base, flood damages, flood insurance claims, and federal disaster assistance payments, the Federal Insurance Administration (FIA) has implemented the Community Rating System (CRS). The deadline for the first applications to participate in the CRS program were due to FEMA Region IX offices by December 5, 1990.

Flood insurance premium credits are available in communities based on their CRS classification. There are ten classes with Class 1 having the greatest premium credit and Class 10 having no premium credit. A community's CRS class is based on the number of credit points calculated for the activities that are undertaken to reduce flood losses, facilitate accurate insurance rating, and promote the awareness of flood insurance. A community is automatically in Class 10 unless it applies for CRS classification and it shows that the activities it is implementing warrant a better class. The amount of premium credit for each class is published annually by the Flood Insurance Administration. The CRS rewards those communities that are doing more than the minimum NFIP requirements which encourage their residents to prevent or reduce flood losses. The system also provides an incentive for communities to initiate new flood protection activities.

Appendix B: Arizona Department of Water Resources

In 1973, the Arizona Legislature required the Arizona Water Commission (now the Arizona Department of Water Resources) to develop and adopt criteria for the 50- and 100-year floods for use by the Arizona communities for the purpose of floodplain management. In response, the Water Commission published Floodplain Delineation Criteria and Procedures, Report Number Four in October 1973.

In 1979, the Governor designated the Arizona Water Commission as the State Coordinating Agency for the National Flood Insurance Program (NFIP). In 1980, the Legislature created the Arizona Department of Water Resources (ADWR). The State NFIP responsibility was then shifted to the ADWR. The State Statutes do not spell out any specific duties for the coordinating agency, although the Water Commission/ADWR has had certain responsibilities for floodplain management since 1973.

The Arizona Legislature added a specific requirement for ADWR to develop and adopt criteria for floodplain delineation throughout the state under ARS Titles 45 and 48, in 1984. This requirement has led the Department to review, revise and supplement the criteria established in 1973. The National Flood Insurance Act as amended in 1986 lists 12 duties and responsibilities for the state:

1. Enact enabling legislation in floodplain management. The Legislature adopted such legislation in 1973 and has amended it as needed.

2. Encourage and assist communities in qualifying for participation in the NFIP. <u>All Arizona communities with flood prone areas are participating in the NFIP</u>.

3. Assist communities in the adoption of ordinances. The ADWR staff works continually with communities to keep their ordinances up-to-date with the NFIP and the State Statutes.

4. Provide communities and the public with information on floodplain management. ADWR staff works with the public and communities on an ongoing basis. A Community Assistance Handbook and a quarterly newsletter are two of the methods used. ADWR staff also meet with community officials and speak at public meetings.

5. Assist communities in disseminating elevation requirements for flood-prone areas. Due to limited staff, ADWR refers most public requests for information to the communities. ADWR staff assists communities in obtaining information and understanding it so that they may respond effectively to public requests.

6. Assist in the delineation of flood-prone areas. ADWR has delineated floodplains and contributed financially to such delineations. Staff reviews delineations performed by others.

7. Recommend priorities for Federal floodplain management activities within the state. ADWR has worked with a number of Federal agencies on priorities.

8. Notify FIA of community failures in floodplain management. ADWR works with communities to correct deficiencies in their programs. In extreme cases, staff will notify FIA of problems.

9. Establish state floodplain management standards. Current State Statutory requirements equal or exceed the minimum FIA requirements.

10. Assure coordination and consistency of floodplain management activities with other agencies. ADWR meets with other agencies as necessary to coordinate activities.

11. Assist in the identification and implementation of flood hazard mitigation recommendations. ADWR has several mitigation functions and works with other agencies as necessary to optimize mitigation opportunities.

12. Participate in floodplain management training activities. ADWR staff support quarterly workshops for community staff and others on floodplain management and assist in training when opportunities arise.

Appendix C: 100-Year Floodplain and Floodway Standards

The 100-Year Floodplain

Throughout the United States the standard for floodplain management is the 100-year flood or peak discharge. The 100-year flood is a flood with a one percent chance of being equaled or exceeded in any given year. Since there is seldom enough data to exactly define the 100-year flood at a particular location, the value is estimated from existing records using statistical and/or empirical hydrologic engineering methods. Inherent in the estimating procedure is the risk that as additional data becomes available previous estimates may require revision. Also, peak discharge estimates often assume that weather characteristics remain constant and that the watershed and channel characteristics remain the same during the entire period of record.

The FIA and FEMA have adopted the 100-year flood as the national standard for floodplain management and floodplain study purposes. The 100-year flood is also referred to as the regulatory flood or base flood. In addition to floodplain studies, the 100-year flood also has been used as the level of protection for the design of many drainage structures. Primary considerations in determining the level of flood protection necessary are health and safety, acceptable risk, and cost. Flood control projects such as dams and emergency spillways which provide protection to critical downstream or adjacent developments, are sometimes designed to a much higher standard (i.e., the 250-year, 1,000-year, or Probable Maximum Flood). Storm drains for street drainage may be designed to a much lower standard for cost saving reasons, and when the capacity of the storm drain is exceeded the excess storm water may cause flooding.

While the mandated standard of the 100-year flood for floodplain management can be debated, the concept is sound and a uniform standard must be used. The Federal Office of Management and Budget re-evaluated the 100-year flood standard for the National Flood Insurance Program in the early 1980's and found no reason to change. It is anticipated that none of the criteria presently used by Federal Emergency Management Agency will change in the near future.

FEMA criteria and the Arizona Revised Statutes require that all residences and occupied structures must be constructed so that their lowest floor is a minimum of one-foot above the 100-year water surface elevation of the 100-year flood. Local floodplain regulation standards must meet the minimum federal and state standards. However, a community may adopt stricter local floodplain regulations if they wish. Several communities in Arizona have adopted more stringent floodplain regulations.

The 100-Year Floodway

The FEMA floodway standard is essential for the success of floodplain management. Any development in a floodplain which obstructs the flow of water generally causes the water surface elevation to be higher across the rest of the floodplain. Limitations on floodplain encroachment are necessary to help reduce adverse impacts from new development in floodways on existing structures. Under the Arizona Revised Statutes and the National Flood Insurance Program, floodplain encroachment is allowed only to the extent that it causes no more than a one foot rise in the 100-year water surface elevation when considered across the entire floodplain. The remaining unencroached area is reserved for conveyance of the 100-year flood and is referred to as the regulatory floodway. Once a regulatory floodway is established, no further development is allowed within this special conveyance area without approval of the local community and FEMA. Technical data which supports the floodway revision must be provided. A community may adopt stricter floodway regulations if they wish. Several communities throughout Arizona and the U.S. have adopted regulations which require that floodway encroachments raise the natural water surface elevation less than the one foot FEMA criteria (e.g., one-tenth foot, one-half foot).

Appendix D: Level 1 Peak Discharge Estimate - Example

100-Year Discharge Estimate

Level 1 discharge estimates may be obtained from the envelope curve shown in Figure D-1. The envelope curve is drawn above the largest discharges in Arizona and the Southwest gaged by the U.S. Geological Survey. To estimate the 100-year discharge at proposed development, measure the watershed area on a USGS topographic quadrangle map in square miles. Plot the measured watershed area on the curve and read the corresponding peak discharge estimate.

Discharge Example #D1: Estimate the 100-year peak discharge for a proposed development in Cochise County on Double Dry Creek.

STEP 1: Measure the watershed area. The watershed area at the site is measured on a USGS topographic quadrangle map at 17 square miles.

STEP 2: Compute the 100-year peak discharge using Figure D-1. A = 17 sq. mi.

Q100 = 31,000 cfs

Results: The Level 1 methodology indicates that the 100-year peak discharge is 31,000 cfs for the example site[1]. In all cases, the floodplain administrator should review the discharge estimate to determine if the Level 1 estimate is appropriate, and if a Level 2 or Level 3 analysis is warranted.

[1] Note that application of Level 2 procedures for this example would indicate a 100-year discharge estimate of about 6,200 cfs.

Figure D-1 **LEVEL 1 ENVELOPE CURVE**

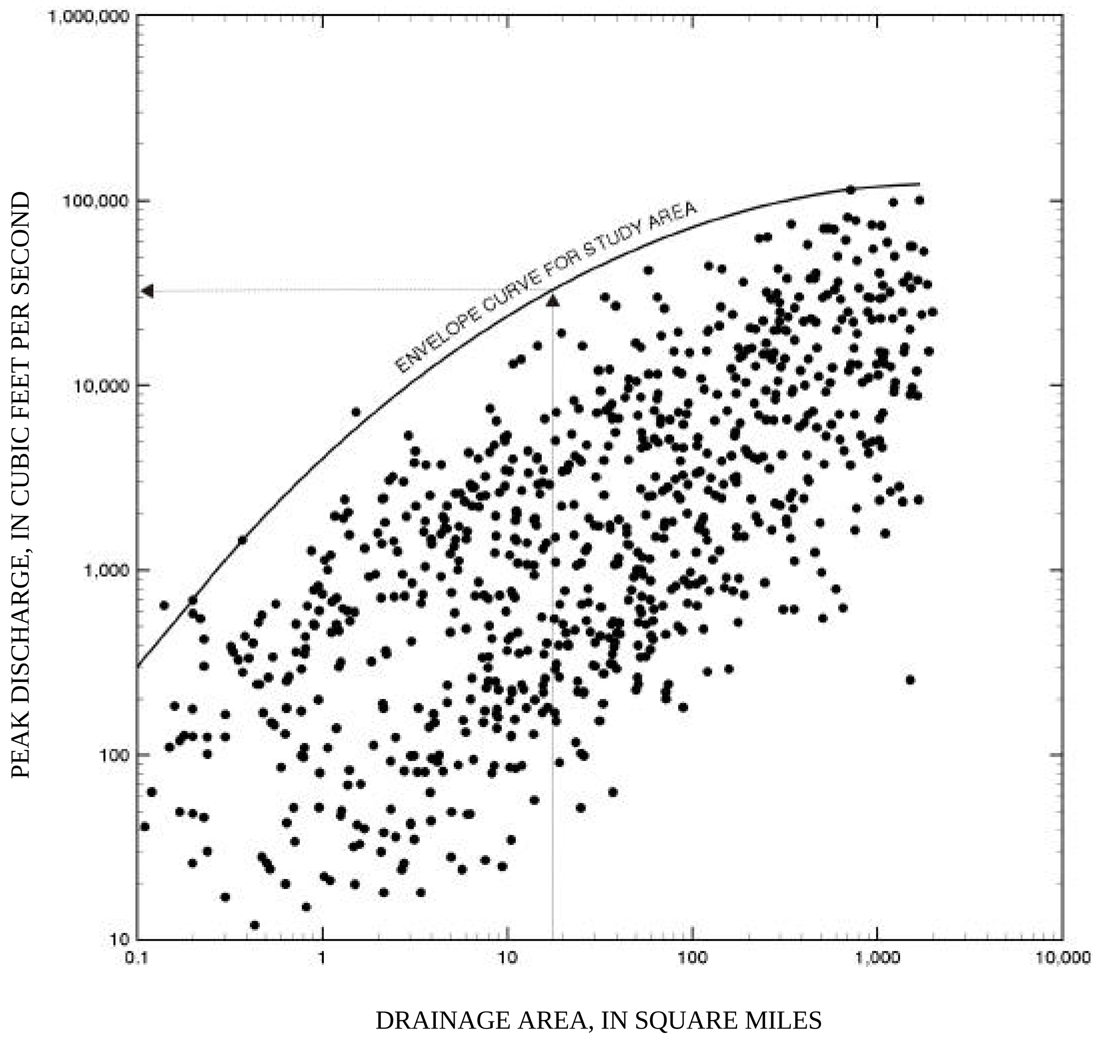


Figure modified from Thomas, B.E. and others, 1994, Methods for Estimating Magnitude & Frequency of Floods in the Southwestern United States. USGS Open File Report 93-419. Figure #17.

Appendix E: Level 1 Floodplain Limits - Equations and Example

Floodplain Depth Estimation

Three depth equation regions are presented for use in Figure E-1. Flood depth estimating equations are presented below for each region shown on Figure E-1. For areas not included in one of the regions described below and shown in Figure E-1, contact the Arizona Department of Water Resources for guidance.

Flood depth = Y (ft.)
Drainage Area = A (sq. mi.)

Region I-D. Encompasses the area north of the Mogollon Rim, including the upper Verde River Basin, excluding the Little Colorado River at and below Woodruff.

$$Y = 5.47 \times A^{0.213}$$

Region II-D. Encompasses the area within Apache, Cochise, Coconino, Gila, Graham, Greenlee, Maricopa, Mohave and Yavapai Counties, except above the Mogollon Rim.

$$Y = 9.89 \times A^{0.132}$$

Region III-D. Encompasses the area within LaPaz, Pima, Pinal, Santa Cruz and Yuma Counties, except the Colorado River.

$$Y = 7.62 \times A^{0.118}$$

Floodway Width Example #E1: Estimate the floodplain elevation for a proposed development in Cochise County on Double Dry Creek. The drainage area at the site is measured from a USGS topographic quadrangle map at 17 square miles.

STEP 1: Determine Flood Depth Region on Figure E-1.Cochise County is in Region II-D.

STEP 2: Compute flood depth (y) from equation II-D. A = 17 sq. mi.

$$Y = 9.89 \times (17)^{0.132} = 14 \text{ feet}$$

STEP 3: Estimate Base Flood Elevation (BFE) at Y + 1 ft. = 15 feet.

Results: The Level 1 methodology indicates that the lowest finished floor of the proposed development should be at least 15 feet above the bottom of the adjacent wash as illustrated in Figure E-2. The floodplain administrator should review the floodplain depth estimate to determine if a Level 2 or Level 3 analysis is warranted.

Figure E-1

MAP OF REGIONS FOR FLOOD DEPTH FORMULAE

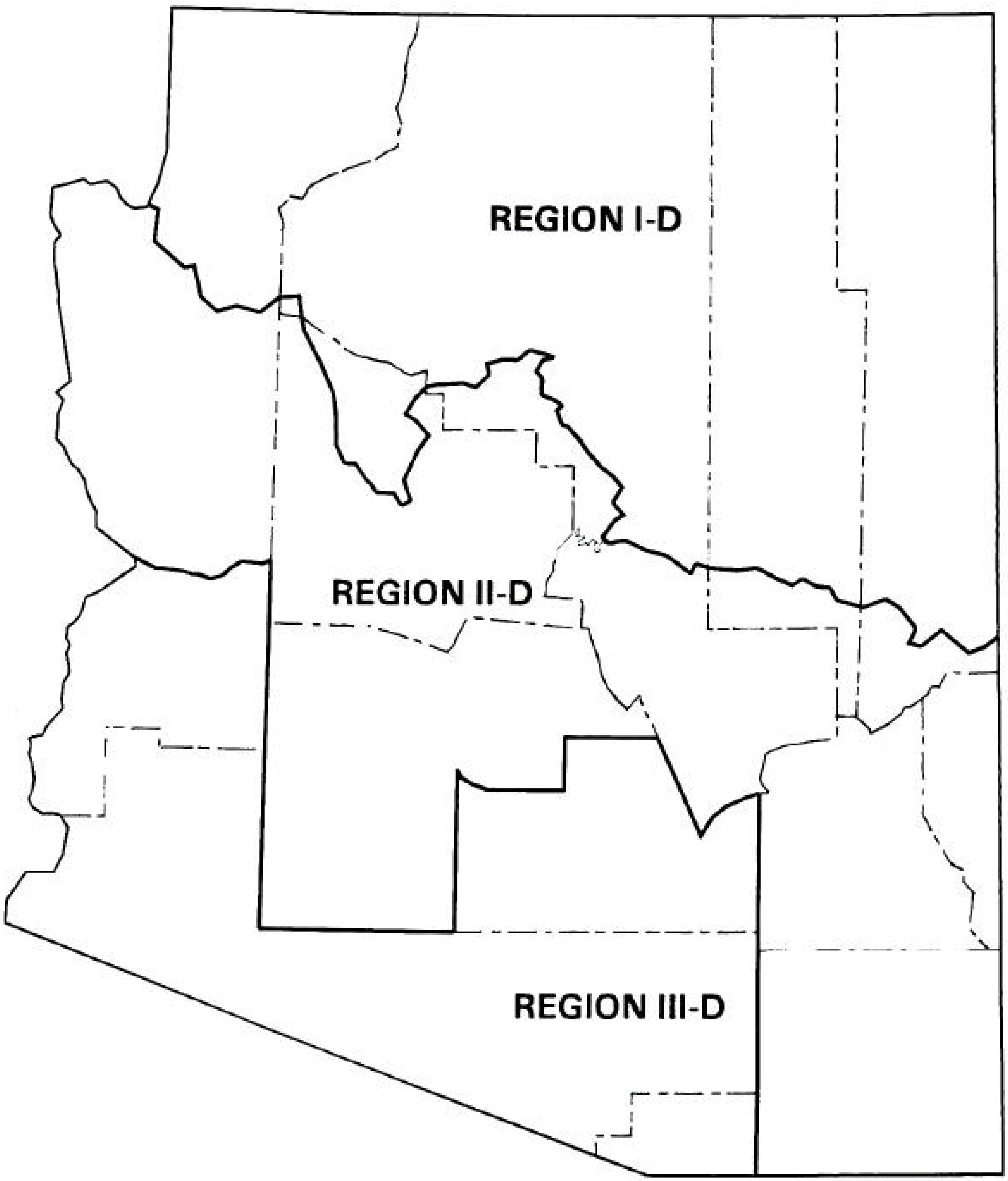
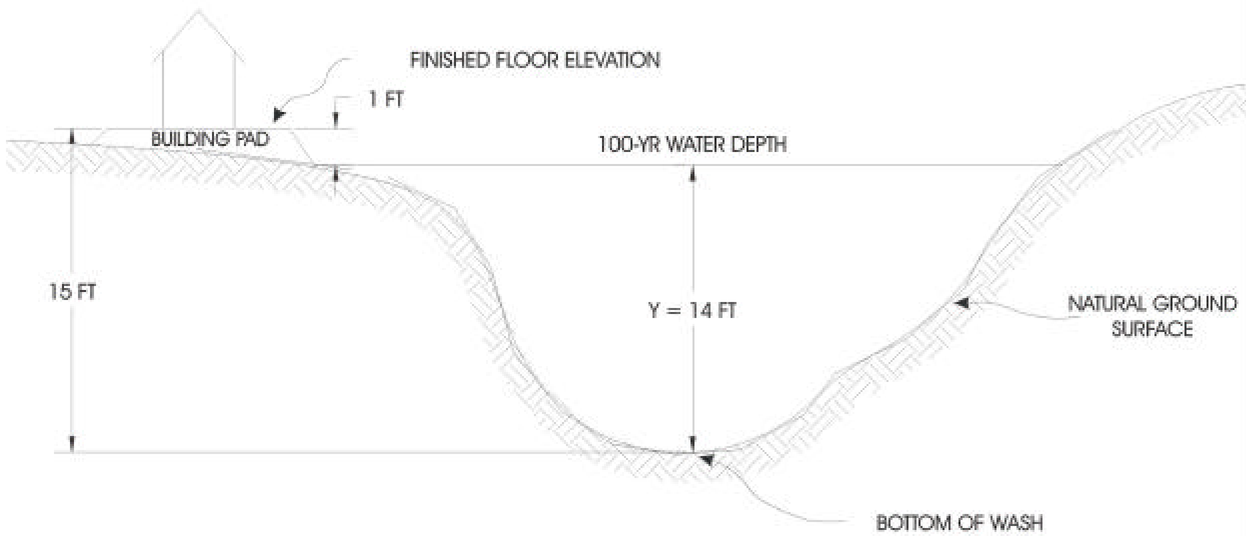


FIGURE E-2 FLOOD DEPTH EXAMPLE #E1 (N.T.S.)



CROSS-SECTIONAL VIEW OF SITE #E1

Appendix F: Level 1 Floodway Width - Equations and Examples

Four floodway-width equation regions are presented for use in Figure F-1. Floodway width estimating equations are presented below for each region shown on Figure F-1. For areas not included in one the regions described below and shown in Figure F-1, contact the Arizona Department of Water Resources for guidance.

Floodway Width = FW (ft.)
Drainage Area = A (sq. mi.)

Region I-W. Encompasses the area north of the Mogollon Rim, including the Arizona Strip north of the Grand Canyon, and the Verde River watershed upstream of Sycamore Creek near Perkinsville:

$$FW = 105 \text{ x } A^{0.449}$$

Region II-W. Encompasses the area within Apache, Gila, Graham, Greenlee, LaPaz, Mohave and Yuma Counties below the Mogollon Rim.

$$FW = 157 \text{ x } A^{0.407}$$

Region III-W. Encompasses the area within portions of Cochise, Coconino, Santa Cruz Counties and Yavapai County below the Mogollon Rim and in the Verde River Basin below Sycamore Creek near Perkinsville.

$$FW = 218 \text{ x } A^{0.261}$$

Region IV-W. Encompasses the area within Maricopa, Pima and Pinal Counties.

$$FW = 377 \text{ x } A^{0.289}$$

Floodway Width Example #F1: Estimate the floodway set-back requirement for a proposed single lot development in Cochise County on Double Dry Creek. The drainage area at the site is measured from a USGS topographic quadrangle map at 17 square miles.

STEP 1: Determine Floodway Region on Figure F-1. Cochise County is in Region III-W.

STEP 2: Compute flood depth (y) from equation III-W. A = 17 sq. mi.

$$FW = 218 \text{ X } (17)^{0.261} = 457 \text{ ft.}$$

STEP 3: Estimate floodway setback at ½ the estimated floodway width = 228.5 ft.

Results: The Level 1 methodology indicates that the structure should be located a minimum of 457 feet/2, or 228.5 feet, from the center of the wash, as illustrated in Figure F-2. The setback is equal to half the floodway width since the floodway extends on both sides of the wash. The local floodplain administrator should review the floodway width estimate to determine if the Level 1 estimate is appropriate, or if a Level 2 or Level 3 analysis is warranted.

Figure F-1

MAP OF REGIONS FOR FLOODWAY WIDTH FORMULAE

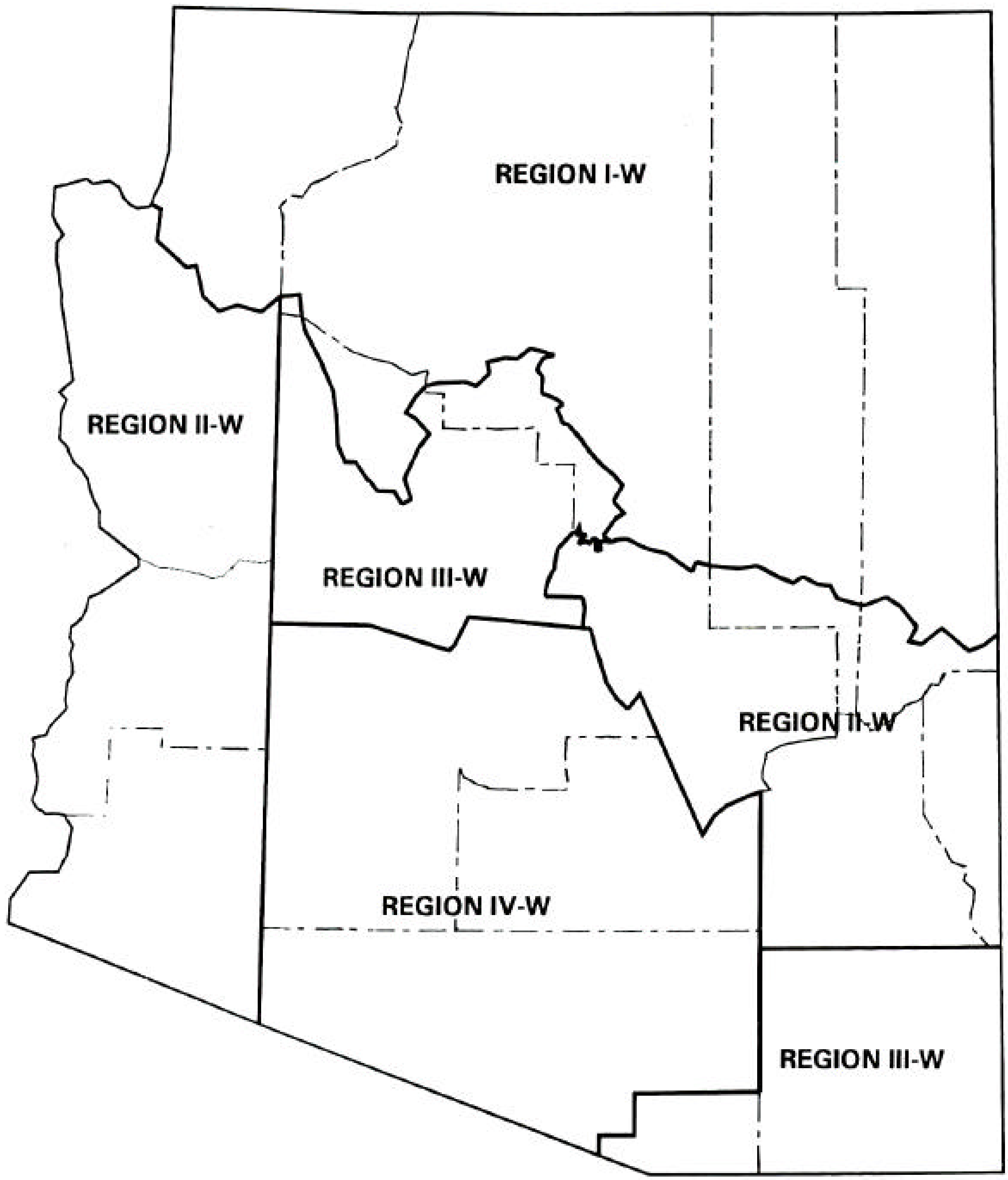
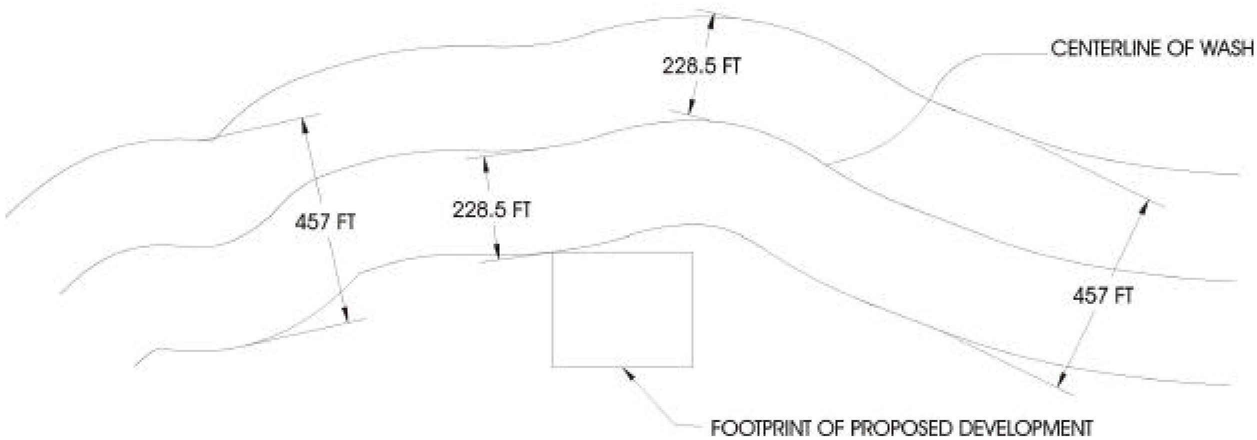


FIGURE F-2 FLOODWAY WIDTH EXAMPLE #F1 (N.T.S.)



FLOODWAY WIDTH = 457 FT
SETBACK FROM CENTERLINE OF WASH = 228.5 FT

Appendix G. Level 2 - Estimating Peak Discharges on Ungaged Rural Watersheds

Overview of Methodology

Equations for estimating peak discharges for ungaged watersheds in Arizona and the Southwest were developed by the US Geological Survey using stream gage records and regression analyses and a newly developed statistical procedure for arid regions, the hybrid method. Unique equations were developed for each of seven regions within Arizona, including a region for watersheds at high elevation (> 7,500 feet). Required information includes the watershed area and up to one of the following: (1) mean annual precipitation, (2) mean elevation, or (3) mean annual evaporation. Figures G-2 to G-3 show some of these required data for the entire State of Arizona. A detailed description of the procedures and numerous examples are provided by the USGS in Thomas et. al., 1994.

Step-by-Step Procedures

Step 1 Locate watershed on region map (Figure G-1)

Step 2 Select appropriate regional equations (Tables G-1 to G-7)

Step 3 Determine required input parameters for region (Tables G-1 to G-7)

a. Determine watershed area (A, square miles)
b. Estimate mean annual precipitation (P, inches) Region 1, Figure G-2
c. Estimate mean annual evaporation (EV, inches) Region 11, Figure G-3
d. Estimate mean elevation of watershed (EL, feet) Regions 8,14,12,

Step 4 Check if watershed is within "Cloud of Common Values[1]" (Figures G-4 to G-8)

Step 5 Apply equations to obtain discharge estimates

a. Watershed in one region (See Example #G1)
b. Watershed elevation above 6,750 feet? (See Example #G2)
c. Watershed located within two adjacent regions? (See Example #G3)

Limitations:

1. Methodology generates discharge *estimates*, NOTE error range given (Tables G1-G7).

2. Watersheds characteristics analyzed should fall within the range of data used to develop the equations. Watersheds with values outside these data ranges may have higher standard

[1] There is no cloud of common values for Regions 10 and 13 because only drainage area is required for the recommended procedure.

error than indicated in Tables G-1 to G-7.

3. The equations may not be appropriate for the following watershed types:

- Urban Areas[2]
- Alluvial Fan/Distributary Flow/Sheet Flow Areas[3]
- Agricultural Areas with flood irrigation structures[3]
- Areas with highly permeable bedrock or cinders[3]
- Areas with large dams or diversions[3]

For the watershed types above use the Level 1 or 3 discharge methodology.

Table G-1. Region 1 Equations

Recurrence Interval	Equation	Average Standard Error (%)
2	$Q = 0.124\ A^{0.845}\ P^{1.44}$	59
5	$Q = 0.629\ A^{0.807}\ P^{1.12}$	52
10	$Q = 1.43\ A^{0.786}\ P^{0.958}$	48
25	$Q = 3.08\ A^{0.768}\ P^{0.811}$	46
50	$Q = 4.75\ A^{0.758}\ P^{0.732}$	46
100	$Q = 6.78\ A^{0.750}\ P^{0.668}$	46

Q = discharge, cfs
A = drainage area, sq. miles
P = mean annual precipitation, inches

Table G-2. Region 8 Equations

Recurrence Interval	Equation	Average Standard Error (%)
2	$Q = 598\ A^{0.501}\ EL^{-1.02}$	72
5	$Q = 2620\ A^{0.449}\ EL^{-1.28}$	62
10	$Q = 5310\ A^{0.425}\ EL^{-1.40}$	57
25	$Q = 10500\ A^{0.403}\ EL^{-1.49}$	54
50	$Q = 16000\ A^{0.390}\ EL^{-1.54}$	53
100	$Q = 23300\ A^{0.377}\ EL^{-1.59}$	53

NOTE: EL = mean elevation in watershed/1000. See Thomas et. al., 1994 for procedure for estimating elevation.

[2] The recommended equations will tend to *underestimate* peak discharges.
[3] The recommended equations will tend to *overestimate* peak discharges.

Table G-3. Region 10 Equations		
Recurrence Interval	**Equation**	**Average Standard Error (log units)**
2	$Q = 12\ A^{0.58}$	1.14
5	$Q = 85\ A^{0.59}$	0.602
10	$Q = 200\ A^{0.62}$	0.675
25	$Q = 400\ A^{0.65}$	0.949
50	$Q = 590\ A^{0.67}$	0.928
100	$Q = 850\ A^{0.69}$	1.23`
Q = discharge, cfs A = drainage area, sq. miles		

Table G-4. Region 11 Equations		
Recurrence Interval	**Equation**	**Average Standard Error (log units)**
2	$Q = 26\ A^{0.62}$	0.609
5	$Q = 130\ A^{0.56}$	0.309
10	$Q = 0.10\ A^{0.52}\ EV^{2.0}$	0.296
25	$Q = 0.17\ A^{0.52}\ EV^{2.0}$	0.191
50	$Q = 0.24\ A^{0.54}\ EV^{2.0}$	0.294
100	$Q = 0.27\ A^{0.58}\ EV^{2.0}$	0.863
Q = discharge, cfs A = drainage area, sq. miles EV = mean annual evaporation, inches		

Table G-5. Region 12 Equations		
Recurrence Interval	**Equation**	**Average Standard Error (%)**
2	$Q = 41.1\ A^{0.629}$	105
5	$Q = 238\ A^{0.687}\ EL^{-0.358}$	68
10	$Q = 479\ A^{0.661}\ EL^{-0.398}$	52
25	$Q = 942\ A^{0.630}\ EL^{-0.383}$	40
50	$Q = 10^{(7.36-4.17\ A\text{^}(-0.08))}\ (EL)^{-0.440}$	37
100	$Q = 10^{(6.55-3.17\ A\text{^}(-0.11))}\ (EL)^{-0.454}$	39
Q = discharge, cfs A = drainage area, sq. miles NOTE: EL = mean elevation in watershed/1000. See Thomas et. al., 1994 for procedure for estimating elevation.		

Table G-6. Region 13 Equations		
Recurrence Interval	**Equation**	**Average Standard Error (%)**
2	$Q = 10^{(6.38-4.29\ A\text{^}(-0.06))}$	57
5	$Q = 10^{(5.78-3.31\ A\text{^}(-0.08))}$	40
10	$Q = 10^{(5.68-3.02\ A\text{^}(-0.09))}$	37
25	$Q = 10^{(5.64-2.78\ A\text{^}(-0.10))}$	39
50	$Q = 10^{(5.57-2.59\ A\text{^}(-0.11))}$	43
100	$Q = 10^{(5.52-2.42\ A\text{^}(-0.12))}$	48
Q = discharge, cfs A = drainage area, sq. miles		

Table G-7. Region 14 Equations		
Recurrence Interval	**Equation**	**Average Standard Error (%)**
2	$Q = 583\ A^{0.588}\ EL^{-1.3}$	74
5	$Q = 618\ A^{0.524}\ EL^{-0.70}$	63
10	$Q = 361\ A^{0.464}$	65
25	$Q = 581\ A^{0.462}$	63
50	$Q = 779\ A^{0.462}$	64
100	$Q = 1010\ A^{0.463}$	66
Q = discharge, cfs A = drainage area, sq. miles NOTE: EL = mean elevation in watershed/1000. See Thomas et. al., 1994 for procedure for estimating elevation.		

Figure G-1 **FLOOD REGIONS IN ARIZONA**

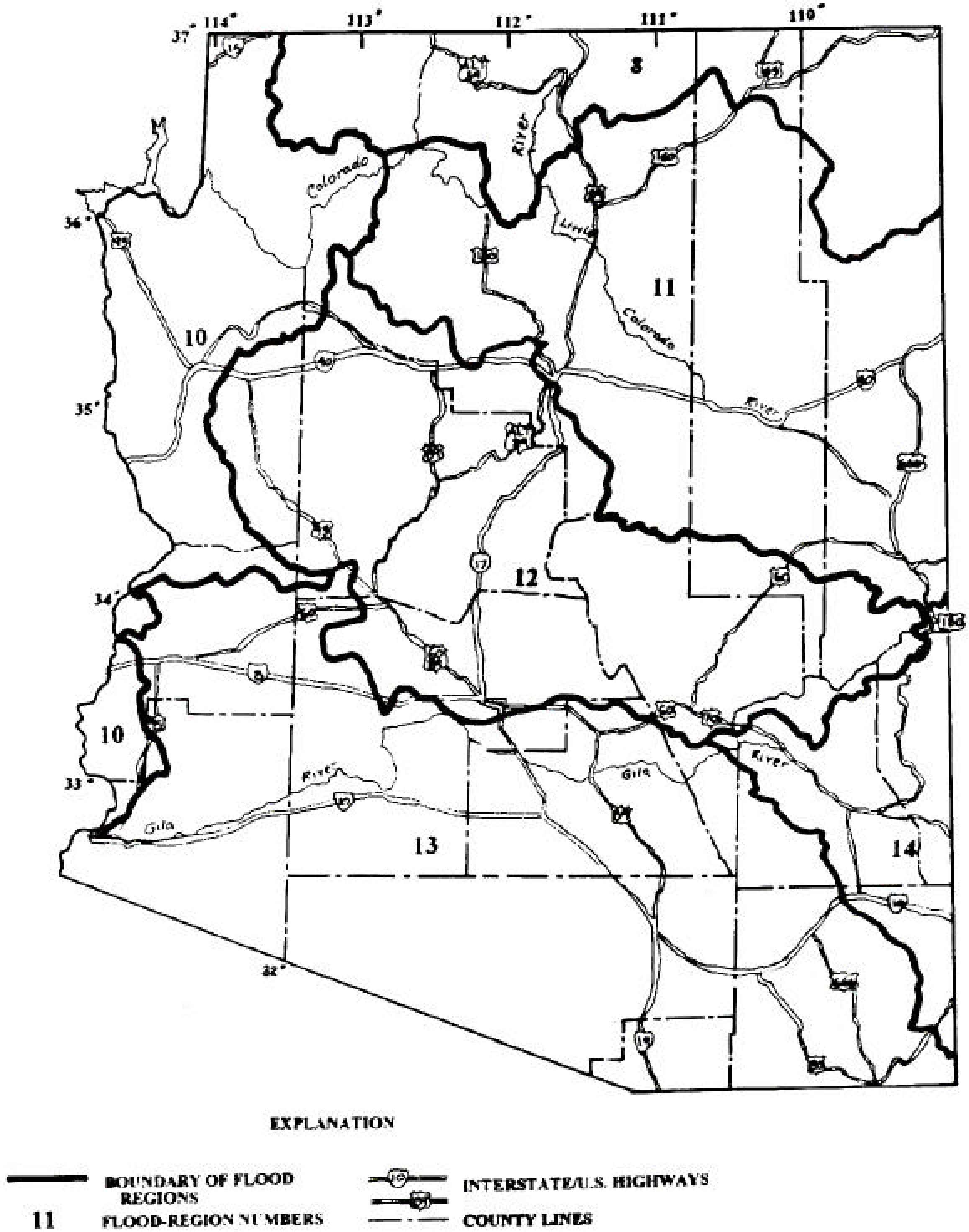
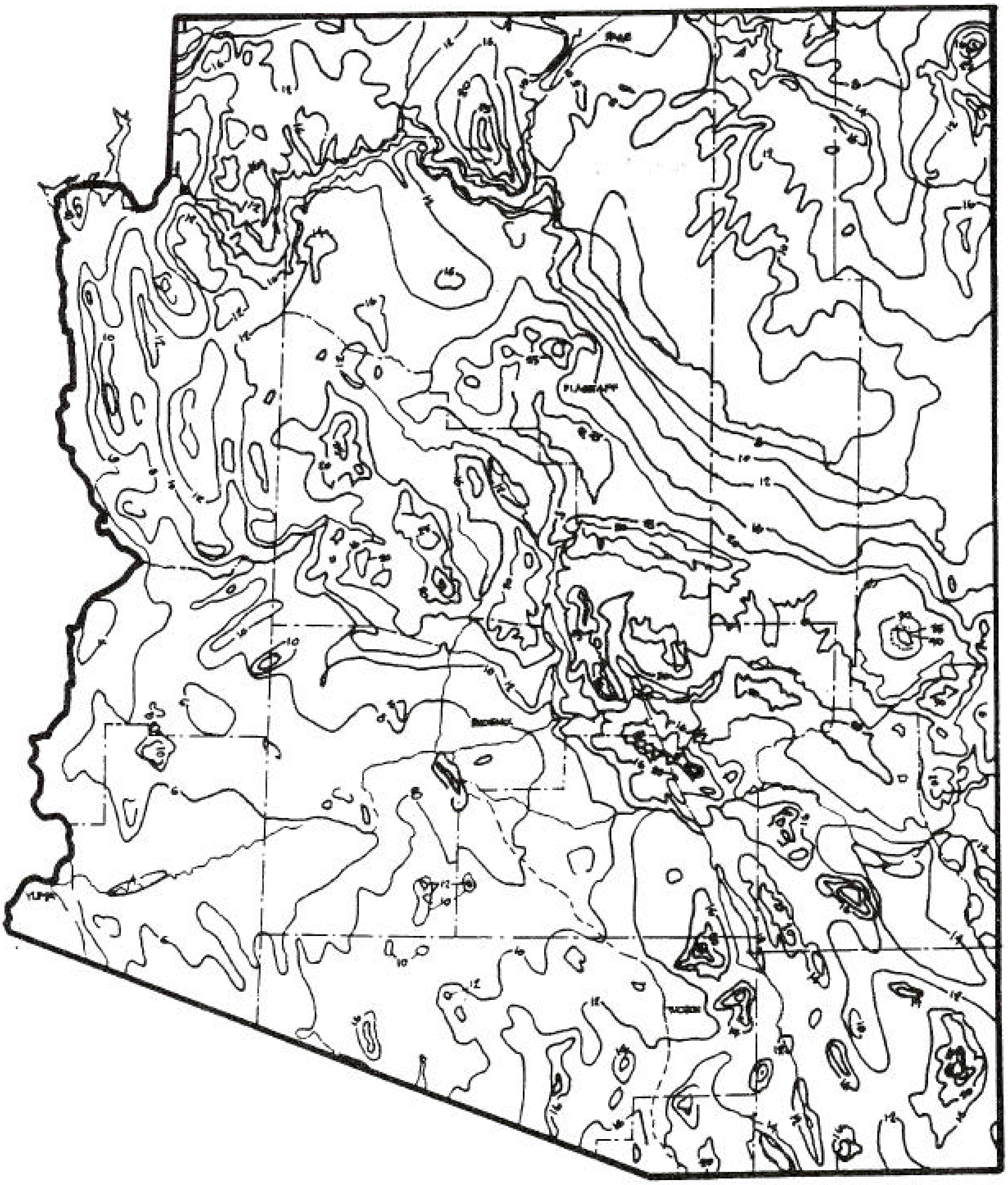


Figure modified from Thomas, B.E. and others, 1994, Methods for Estimating Magnitude & Frequency of Floods in the Southwestern United States, USGS Open File Report 93-419. Figure # 7.

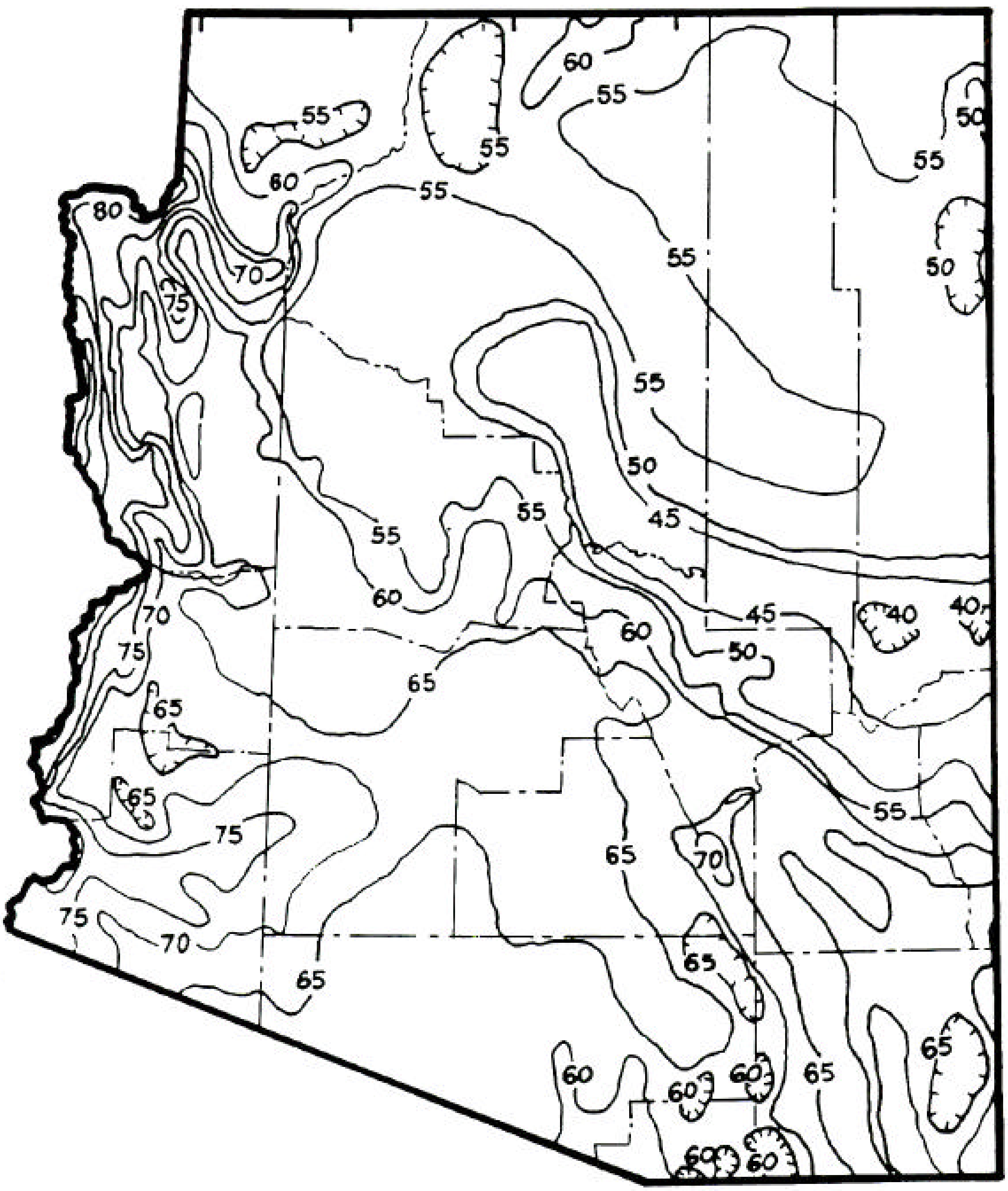
Figure G-2 **MEAN ANNUAL PRECIPITATION (PREC.), 1931-1960**



— 65 — **Mean Annual Precipitation, in inches**

Figure modified from ADOT, 1993, Highway Drainage Design Manual--Hydrology. Figure #10-10.

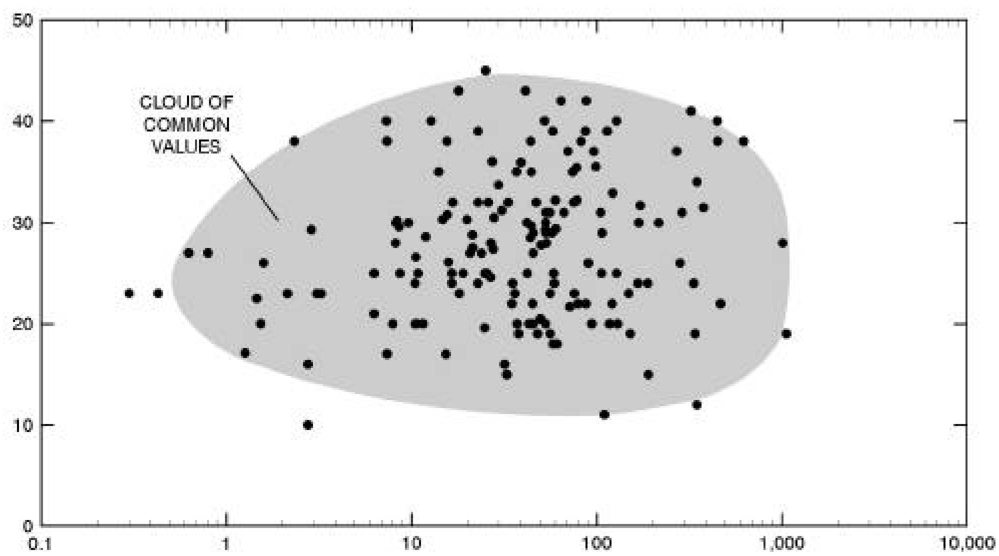
Figure G-3 **MEAN ANNUAL EVAPORATION (EVAP)**



— 65 — **Mean Annual Evaporation, in inches**

Figure modified from ADOT, 1993, Highway Drainage Design Manual--Hydrology. Figure #10-11.

Figure G-4 **Joint distribution of mean annual precipitation and drainage area for gaged sites in the High-Elevation Region 1.**

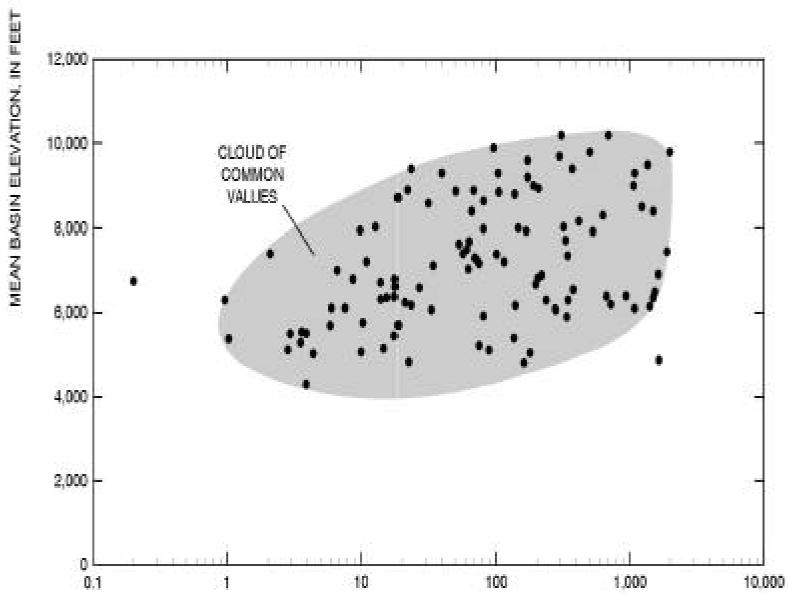


DRAINAGE AREA, IN SQUARE MILES

Figure modified from Thomas, B.E. and others, 1994, Methods for Estimating Magnitude & Frequency of Floods in the Southwestern United States. USGS Open File Report 93-419. Figure # 18.

Figure G-5 **Joint distribution of mean basin elevation and drainage area for gaged sites in the Four Corners Region 8.**

MEAN BASIN ELEVATION, IN FEET



DRAINAGE AREA, IN SQUARE MILES

Figure modified from Thomas, B.E. and others, 1994, Methods for Estimating Magnitude & Frequency of Floods in the Southwestern United States. USGS Open File Report 93-419. Figure # 33.

Figure G-6 **Joint distribution of mean annual evaporation and drainage area for gaged sites in the Northeastern Arizona Region 11.**

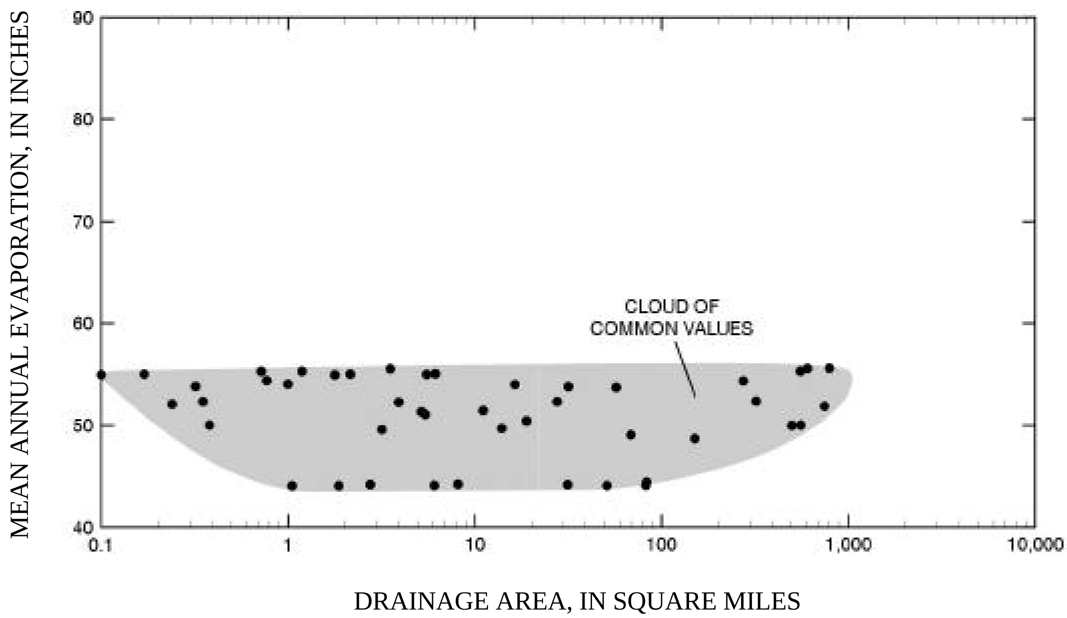
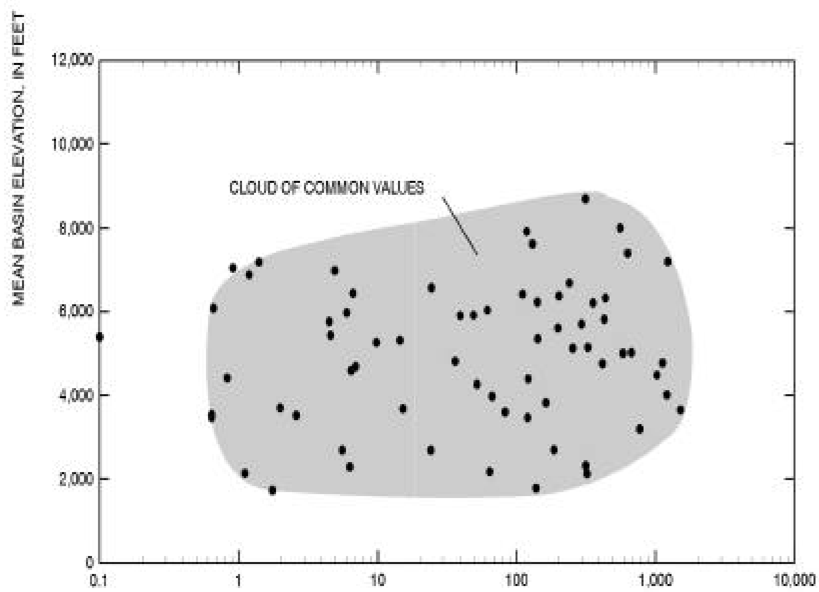


Figure modified from Thomas, B.E. and others, 1994, Methods for Estimating Magnitude & Frequency of Floods in the Southwestern United States. USGS Open File Report 93-419. Figure # 36.

Figure G-7 **Joint distribution of mean basin elevation and drainage area for gaged sites in the Central Arizona Region 12.**

MEAN BASIN ELEVATION, IN FEET



DRAINAGE AREA, IN SQUARE MILES

Figure modified from Thomas, B.E. and others, 1994, Methods for Estimating Magnitude & Frequency of Floods in the Southwestern United States. USGS Open File Report 93-419. Figure # 40.

Figure G-8 **Joint distribution of mean basin elevation and drainage area for gaged sites in the Upper Gila Basin Region 14.**

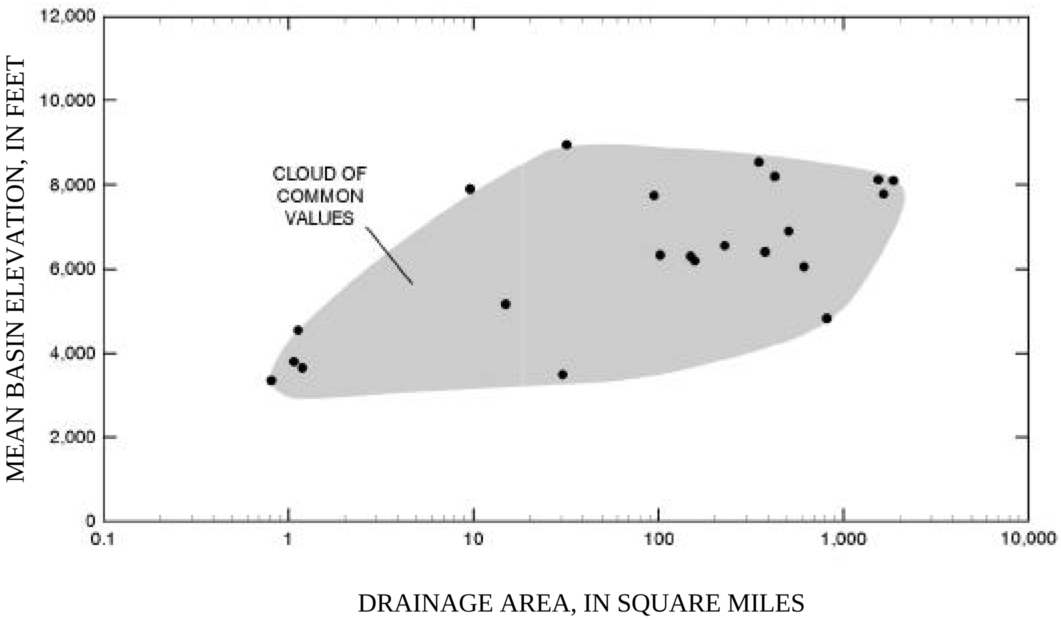


Figure modified from Thomas, B.E. and others, 1994, Methods for Estimating Magnitude & Frequency of Floods in the Southwestern United States. USGS Open File Report 93-419. Figure # 43.

Example #G1. Rural Watershed Within One Flood Region.

Estimate peak discharges for recurrence intervals of 50 and 100 years (Q_{50} and Q_{100}) for an ungaged site in Central Arizona Region 12 (Figures G-1 and G-7, Table G-5). The required basin characteristics are drainage area (A), in square miles, and mean basin elevation (EL), in feet. The drainage area was planimetered from a USGS topographic map, and measures 110 mi^2, and the mean basin elevation is 5,900 ft. The drainage area and mean elevation are within the cloud of common values for the region (Figure G-7).

The characteristics are inserted into the appropriate equations as follows:

$$Q_{50} = 10^{(7.36-4.17\ A\text{^}(-0.08))}\ (EL)^{-0.440}$$

$$Q_{50} = 10^{(7.36-4.17\ (110)\text{^}(-0.08))}\ (5.90)^{-0.440}$$

$$Q_{50} = 14{,}381 \text{ cfs} = 14{,}400 \text{ cfs}$$

and

$$Q_{100} = 10^{(6.55-3.17\ A\text{^}(-0.11))}\ (EL)^{-0.454}$$

$$Q_{100} = 10^{(6.55-3.17\ (110)\text{^}(-0.11))}\ (5.90)^{-0.454}$$

$$Q_{100} = 20{,}410 \text{ cfs} = 20{,}400 \text{ cfs}$$

Example #G2. Rural Watershed Within Two Flood Regions.

For watersheds that lie within two or more regions, an averaging procedure based on the percentage of area in each region may be used to determine a peak discharge estimate. The peak discharges are estimated for each region as if the drainage area is entirely in one region. Then, a weighted peak discharge is estimated using the procedures illustrated below.

A hypothetical study site has a drainage area that lies within Southern Great Basin Region 10 and Southern Arizona Region 13 (Figure G-1). Estimate the peak discharge for recurrence intervals of 10 and 100 years. The only required basin characteristic is drainage area (A), in square miles, measured at 57 mi^2 by planimetering from high altitude aerial photographs of known scale. The drainage area falls within the range of data for Regions 10 and 13[4]. The watershed is divided so that 36 mi^2 falls within Region 10, and 21 mi^2 is located within Region 13.

For Region 10:

$$Q_{10} = 200\ A^{0.62}$$
$$Q_{10} = 200\ (57)^{0.62} = 2{,}453 \text{ cfs}$$
$$Q_{10} = 2{,}450 \text{ cfs}$$

$$Q_{100} = 850\ A^{0.69}$$
$$Q_{100} = 850\ (57)^{0.69} = 13{,}835 \text{ cfs}$$
$$Q_{100} = 13{,}800 \text{ cfs}$$

For Region 13:

$$Q_{10} = 10^{(5.68-3.02\ A\wedge(-0.09))}$$
$$Q_{10} = 10^{(5.68-3.02\ (57)\wedge(-0.09))} = 3{,}812 \text{ cfs}$$
$$Q_{10} = 3{,}810 \text{ cfs}$$

$$Q_{100} = 10^{(5.52-2.42\ A\wedge(-0.12))}$$
$$Q_{100} = 10^{(5.52-2.42\ (57)\wedge(-0.12))} = 10{,}722 \text{ cfs}$$
$$Q_{100} = 10{,}700 \text{ cfs}$$

Weighted Discharges are:

$$Q_{10(weighted)} = \frac{(2{,}450 \times 36) + (3{,}810 \times 21)}{57} = 2{,}950 \text{ cfs}$$

$$Q_{100(weighted)} = \frac{(13{,}800 \times 36) + (10{,}700 \times 21)}{57} = 12{,}700 \text{ cfs}$$

---

[4] No cloud of common values available for these regions since area is the only independent variable.

Example G3. Rural Watershed Partially Within High-Elevation Region

A hypothetical study site, at the concentration point, is in a low- to middle-elevation flood region (Regions 8-14), but is within 700 feet of the high elevation region (Region 1) boundary. Discharge estimates for watersheds within 700 feet of the high elevation boundary should be weighted using the Region 1 equations, Therefore, an averaging procedure based on the relation between the elevation of the study site and the 700-foot transition zone should be used. The peak discharges are estimated for each region as if the drainage area is entirely located in one region. Then, a weighted discharge is estimated using the procedures illustrated below.

Estimate the peak discharges for recurrence intervals of 2 and 50 years for an ungaged site in Northeastern Arizona Region 11 with site elevation of 7,100 feet. The site is within 700 feet of the boundary of High Elevation Region 1, which is 7,500 feet in Arizona. The required basin and climatic characteristics are drainage area (A) in square miles, mean annual evaporation (E) in inches, and mean annual precipitation (P) in inches. The drainage area was measured on USGS topographic maps at 45 mi2, the mean annual evaporation was determined to be 55 inches using Figure G-3, and the mean annual precipitation was determined to be 12 inches using Figure G-2. The drainage area, mean annual evaporation, and mean annual precipitation fall within the cloud of common values shown in Figures G-4 and G-7.

For Region 11:

$$Q_2 = 26\ A^{0.62}$$
$$Q_2 = 26\ (45)^{0.62}$$
$$Q_2 = 275\ \text{cfs}$$

$$Q_{50} = 0.24\ A^{0.54}\ E^{2.0}$$
$$Q_{50} = 0.24\ (45)^{0.54}\ (55)^{2.0} = 5{,}671\ \text{cfs}$$
$$Q_{50} = 5{,}670\ \text{cfs}$$

For High-Elevation Region 1:

$$Q_2 = 0.124\ A^{0.845}\ P^{1.44}$$
$$Q_2 = 0.124\ (45)^{0.845}\ (12)^{1.44}$$
$$Q_2 = 111\ \text{cfs}$$

$$Q_{50} = 4.75\ A^{0.758}\ P^{0.732}$$
$$Q_{50} = 4.75\ (45)^{0.758}\ (12)^{0.732}$$
$$Q_{50} = 525\ \text{cfs}$$

Weighted Discharges are:

$$Q_{2(\text{weighted})} = (275 \times (7{,}500\text{-}7{,}100)/700) + (111 \times (1 - (7{,}500\text{-}7{,}100)/700))$$
$$Q_{2(\text{weighted})} = 205\ \text{cfs}$$

$$Q_{50(\text{weighted})} = (5{,}670 \times (7{,}500\text{-}7{,}100)/700) + (525 \times (1\text{-} (7{,}500\text{-}7{,}100)/700))$$
$$Q_{50(\text{weighted})} = 3{,}470\ \text{cfs}$$

For Additional Information and Examples[5]:

Thomas, B.E., Hjalmarson, H.W., Waltemeyer, S.D., 1994, *Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States*. USGS Open File Report 93-419.

See Also:

"A Study to Evaluate Existing Methods for Determining Peak Discharges for Ungaged Watersheds in Arizona, Phase II & III Report, Report prepared for the State Standards Work Group, May 1995. Prepared by Benchmark Consulting Services, Ltd.

Notice: *A spreadsheet software program described in Appendix J is available from ADWR. This program is set up to perform the Level 2 discharge calculations for Arizona. Contact ADWR for more information.*

5 The procedures and examples described above are based on, or taken directly from the references cited. These references should be consulted in the event of errors, omissions or other discrepancies.

Appendix H: Level 2 Floodplain Limits/Water Surface Elevation Example

Manning's Equation: Manning's equation is an empirical formula that can be used to estimate flow velocity, depth, and/or discharge. Detailed background information and example applications can be found in any standard civil engineering or hydraulics manual. In addition, there are numerous computer software applications that use Manning's equation to estimate water surface elevation, velocity, depth, width, or other hydraulic variables. The U.S. Forest Service distributes a Manning's rating program "XSPRO, which can be obtained through the National Technical Information Service, or from the ADWR Flood Warning and Dam Safety Section.

Procedures for hand calculation of the normal depth for a channel with simple geometry is illustrated below. Manning's Equation for velocity of flow in an open channel is:

$$V = [1.49\ R^{2/3}\ S^{1/2}]\ /n$$

where: V = Mean velocity, feet per second (fps)
n = Manning coefficient of channel roughness, dimensionless
S = Channel slope, feet per feet
R = Hydraulic radius, feet; R = A/WP
and A = Cross-sectional area of the flowing water, square feet
WP = Wetted perimeter, feet

Velocity, V, can be related to discharge, Q (cfs), by the continuity equation (Q = AV). For wide rectangular channels where flow width is more than ten times the depth, hydraulic radius is approximately equal to the average depth (R = Y). Using these relationships, the following form of Manning's equation can be written:

$$Q = [1.49\ A\ Y^{2/3}\ S^{1/2}]\ /n$$

Various hydraulic textbooks and handbooks provide tables of "n" values for various types of channels. A conservative estimate of "n" is recommended for this level of study. When channel cross-section consists of different roughness, the cross-section should be subdivided and different roughness should be used for main channel and overbanks.

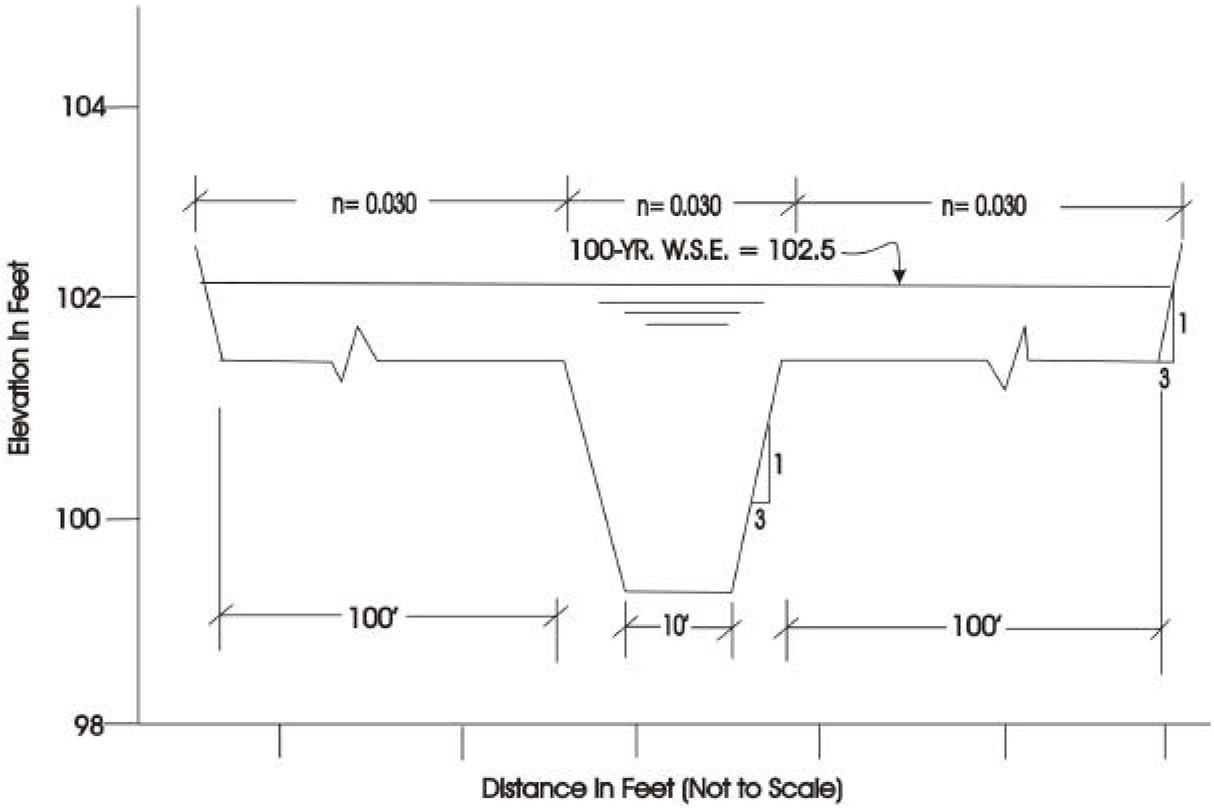
Critical depth may also be computed using the hydraulic data obtained by applying Manning's equation, using the following relationships.

- If $Q^2/g > A^3/T$ then the flow is supercritical
- If $Q^2/g = A^3/T$ then the flow is at critical depth
- If $Q^2/g < A^3/T$ the flow is subcritical

where: Q = Peak Discharge (cfs); A = Conveyance Area (ft^2)
$g = 32.2\ ft/sec^2$ T = Top Width (ft)

Figure H-1

NORMAL DEPTH EXAMPLE CROSS SECTION



Example #H1: Find the 100-year flow depth and velocity for the channel illustrated in Figure H-1. The 100-year discharge has been estimated at 375 cfs (Q100 = 375 cfs), the channel roughness (n) is 0.030, and the channel slope measured from a USGS topographic map is 0.005 ft/ft.

STEP 1: Find the Normal Depth, Y_n and velocity, V, by trial and error.

Try Elev. 102 ft. Where: $Y_n = 2$ ft

Areas = $[(22 + 10)/2] \times 2 = 32 \text{ ft}^2$
WP = $10 + 2 \times 6.3 = 22.6$ ft
R = $32/22.6 = 1.4$ ft
V = $[1.49\ (1.41)^{2/3}\ (0.005)^{1/2}]/0.030 = 4.4$ fps
Q = $32 \times 4.4 = 142$ cfs
142 cfs < 375 cfs (not deep enough)

Try elev. = 102.5, Where: $Y_n = 2.5$ ft.

A = $[(225 + 222)/2] \times 0.5 + 32 = 143.75 \text{ ft}^2$
A = $(0.5 \text{ X } 22) + 32 = 43 \text{ ft}^2$
WP = 225.81 ft
R = $143.75/225.81 = 0.64$ ft
V = $[1.49\ (0.64)^{2/3}\ (0.005)^{1/2}]/0.030 = 2.61$ fps
Q = $143.75(2.61) = 375$ cfs

Therefore: $Y_n = 2.5$ ft, and
V = 2.61 fps

STEP 2: Add the depth to the channel elevation to obtain the 100-yr. water surface elevation.

100 ft. + 2.5 ft. = 102.5 ft

STEP 3: Check the flow regime using the equations provide above.

$Q^2/g > A^3/T$
$(375 \text{ cfs})^2/32.2 \text{ ft/sec}^2 < (143.75 \text{ ft.}^2)^3/225 \text{ ft.}$
4,367 < 13,202 (ft^5). Therefore, flow is subcritical.

Results. The water surface elevation solution of 102.5 feet ($Y_n = 2.5$ ft) should be used. If the flow regime is critical or supercritical then additional analysis should be made and the energy gradeline[1] rather than the normal depth should be used. This process is repeated at several cross-sections and the respective water surface elevations are estimated. Water surface elevations between two cross-sections may be interpolated and an approximate floodplain plotted. The finished floor elevation of a structure must be a minimum of 1 foot above the highest water surface elevation adjacent to the structure.

[1] The energy grade line elevation is estimated as the water surface elevation plus the velocity head. The velocity head is computed as $V^2/2g$.

Alternatively, the channel geometry and hydraulic information can be entered into a computer program, such as XSPRO[2] or another commercial application, and the water surface elevation, velocity, depth, energy grade line, and flow regime computed automatically. Additional descriptive information on application of Manning's equation is provided in Appendix I.

Example #H2. Find the 100-year flow depth and velocity for the channel shown in Figure H-2 and determine the required finished floor elevation. The 100-year discharge was estimated at 11,000 cfs using a Level 2 analysis. Channel slope is 1.2 percent (0.012 ft./ft.). A constant, composite Manning's n value of 0.045 is estimated for the channel and floodplain.

<u>STEP 1</u>: Since the channel has irregular geometry, the XSPRO computer program (See Appendix J) was used to perform a channel rating. XSPRO Output is shown in Table H-2.1.

Table H-2.1. XSPRO Manning's Rating Output

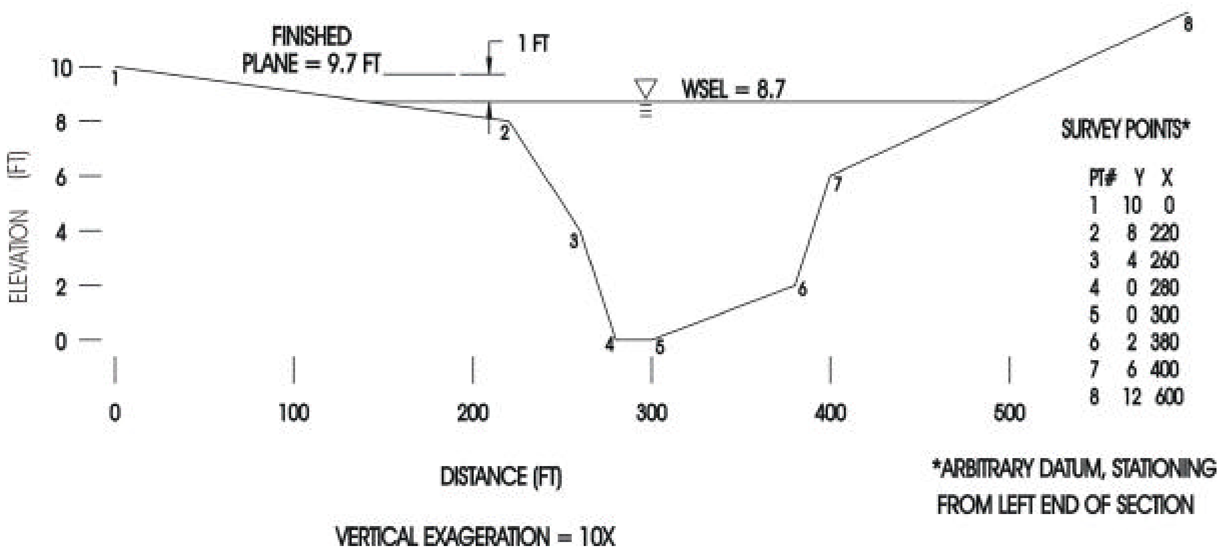
Stage (ft)	Average Depth (ft)	Average Velocity (ft/s)	Discharge (cfs)	Width (ft)	Froude Number
8.6	3.7	8.7	10,796	332	0.80
8.7	37	8.6	10,981	347	0.79
8.8	3.6	8.5	11,189	361	0.79

<u>STEP 2</u>: Match 100-year discharge estimate of 11,000 cfs to XSPRO profiles, and determine 100-year water surface elevation (depth) and finished floor elevation.

Depth of 100-year event:	8.7 feet
Width of 100-year event:	347 feet
Required finished floor elevation:	9.7 feet.

[2] XSPRO is a Manning's equation program distributed by the U.S. Forest Service. Numerous other private, for-profit vendors of Manning's equation software exist.

FIGURE H-2 LEVEL 2 FLOODPLAIN EXAMPLE



Appendix I. Level 2 Administrative Floodway Boundary Methodology

Methodology Overview

Three steps that are generally required to delineate an administrative floodway:

STEP 1. Estimate the 100-year peak discharge.
STEP 2. Determine the 100-year floodplain limits or water surface elevation.
STEP 3. Determine the administrative floodway width.

Administrative Floodway Determination

The procedures for estimating the administrative floodway boundaries using manual calculation procedures are:

STEP 1. Estimate the 100-year peak discharge for the watercourse using the Level 2 discharge methodology described in Appendix G. For drainage areas that do not meet the criteria for a Level 2 methodology, use the Level 1 or 3 methodology.

STEP 2. Provide normal depth calculations, using the procedures outlined in Appendix H, at several representative cross section locations adjacent to the proposed improvement/ development for existing conditions. Cross sections should be located both upstream and downstream of the proposed improvement, as well as adjacent to the proposed improvement. Cross sections should be spaced at 300 to 500 feet intervals, with a minimum of three cross sections required along short reaches. A sufficient number of cross section points should be obtained to describe the channel and overbank geometry. Manning's roughness coefficients can be estimated using the references provided earlier or other similar publications.

STEP 3. Cross sections should be plotted on engineering type 10 x 10 grid line paper (i.e., ten lines to the inch in both the vertical and horizontal direction). Cross sections should be plotted at a scale that will make it easy to perform the floodway encroachment computations explained below. A vertical scale of 1 or 2 feet per inch and a horizontal scale of 100 or 200 feet per inch works well with wide watercourses. The horizontal scale may be adjusted to 10 feet per inch on narrow watercourses.

Provide normal depth calculations, using the same cross sections as in Item 2 above, to determine the administrative floodway area. This is accomplished using a trial and error procedure by encroaching from <u>both</u> edges of the 100-year floodplain equally <u>so as not to increase the existing condition water surface elevation more than one foot</u>. The encroachment shall be by equal conveyance of flood flow area and not necessarily by equal overbank encroachment lengths. *Encroachment beyond the channel bank and into the main channel area is not permitted. Encroachments must stop at the channel bank*. Channel banks can typically be identified by a distinct grade break between the bank slope and the overbank floodplain, a change in vegetative density between the channel bed and overbank floodplain or geomorphic characteristics of the stream. Where the bank is not visually identifiable, the Corps of Engineers definition of the overbank area beginning where depth of flow is less than 3 feet and velocities less than 3 feet per second may be used.

Begin the floodway encroachment procedure by drawing a vertical line (wall) set within the floodplain from the left edge of the floodplain limit. The distance from the left floodplain limit to the vertical line should be about 25% (¼) of the total floodplain width (i.e., if the floodplain has a 400 foot top width, then the first left vertical wall should be set 100 feet into the floodplain from the left edge of the floodplain limit). The next step is to count the number of squares on the 10 x 10 grid paper that contain flood flow area between the left edge of the floodplain limit and the left vertical wall. Next, set the right vertical wall by simply starting at the right floodplain limit, moving to the left and counting the number of squares that contain flood flow until there are the same number of squares as contained in the left floodway fringe, and then set the right vertical wall. At this point there will be a cross section showing the 100-year water surface, the 100-year floodplain, and two vertical walls set in from the left and right edges of the floodplain limits. Remember that the vertical walls are set in from the floodplain limits using the same total squares (area) and not the same distance.

Next, re-compute the 100-year water surface elevation using Manning's equation and the left and right vertical walls as the new left and right top of bank. Set the left and right bank elevations 2 feet above the unencroached 100-year water surface elevation. Repeat this procedure by moving the left and right vertical walls an equal number of squares each trial until you have obtained a 1 foot rise in the 100-year water surface elevation from the unencroached condition. Usually 3 to 5 trial computations are necessary. This procedure is repeated at each cross section.

Once the administrative floodway limits have been established at each cross section the location can be plotted on the site plan of the property as shown in Example #I1 and Example #I2.

Notice: *A computer program developed by the U.S. Army Corps of Engineers "Simplified Floodway Determination (SFD) Computer Program User's Manual is available from ADWR and may used in place of the procedures described is this Appendix. See Appendix J for more information.*

Example #I1. A land owner owns 5 acres of land in Santa Cruz County, adjacent to a large wash (Figure I-1). Determining how much of his property is located in the 100-year floodplain and administrative floodway and how much land may be claimed for future land planning purposes.

STEP 1. Measure the drainage area using a USGS topographic quadrangle map and estimate the 100-year peak discharge rate. For a drainage area of 85.2 square miles, using the Level 2 discharge methodology shown in Appendix G, the 100-year peak discharge is estimated at 12,600 cfs.

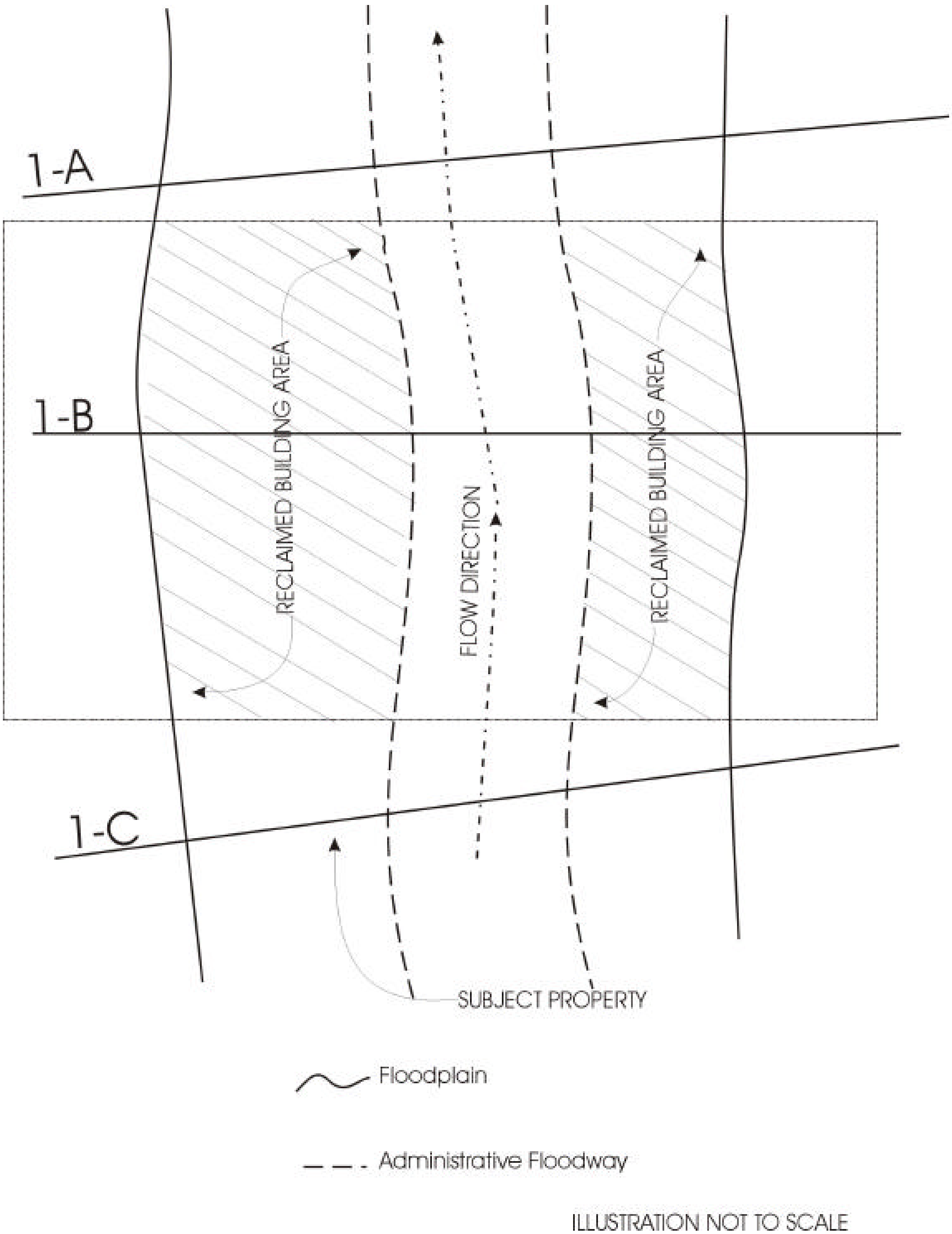
STEP 2. Using three field-surveyed cross sections, determine the 100-year normal depth and floodplain limits using the Level 2 methodology described in Appendix H. The locations of the cross-sections are shown on a property map of the parcel (Figure I-1). Figure I-2, I-3, and I-3 show the plotted cross-sections and normal depth calculations. The estimated 100-year water surface at each cross-section is plotted on Figure I-1 to delineate the 100-year floodplain.

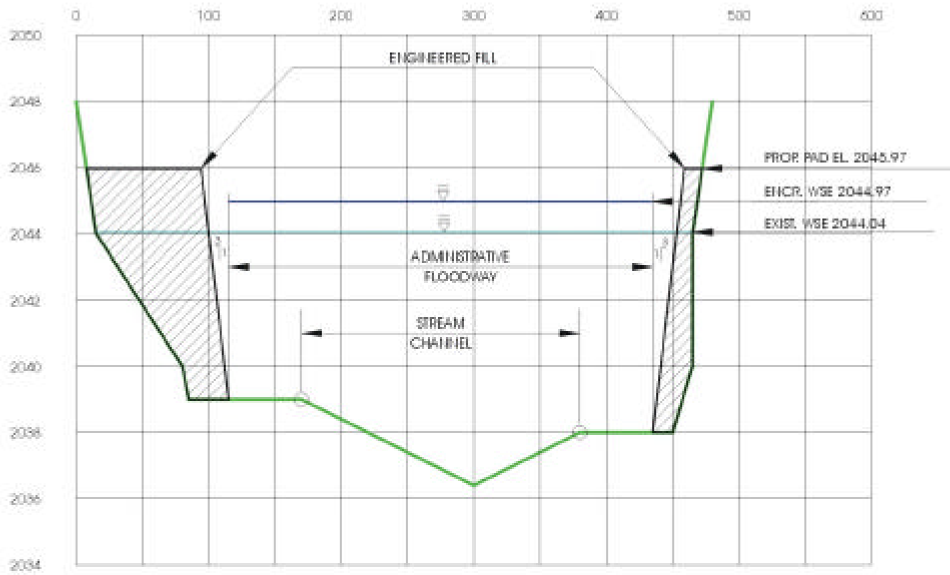
STEP 3. Establishes the administrative floodway by equal encroachment into the 100-year floodplain using cross-sections in Figures I-2, I-3, and I-4. This is accomplished by trial and error procedures using vertical walls (representing equal conveyance areas being moved from the floodplain) and recalculating a new normal depth until the water surface elevation is raised not greater than 1 foot. The resultant information from each cross-section is plotted on Figure I-1.

STEP 4. The available development area, amount of reclaimed land, and fill requirements can be estimated from this information. Fill requirements should be based on the highest water surface elevation adjacent to the proposed structure(s) by interpolation from the encroached cross-sections.

STEP 5. The hydraulic calculations indicate velocities exceeding 5 feet per second. The fill material which is exposed to the stream's flow will require erosion protection.

Figure I-1


1-A
1-B
1-C
RECLAIMED BUILDING AREA
FLOW DIRECTION
RECLAIMED BUILDING AREA
SUBJECT PROPERTY
Floodplain
Administrative Floodway
ILLUSTRATION NOT TO SCALE



SECTION 1-A

GIVEN: Q = 12,600 CFS S = 0.8% N = 0.048

○ = CHANNEL BANK

EXISTING CONDITION:

WSE = 2044.04 FT.

DEPTH = 6.04 FT.

VELOCITY = 6.49 FPS

AREA = 1942.42 S.F.

PERIMETER = 541.54 FT.

TOP WIDTH = 541 FT.

FLOW REGIME IS SUBCRITICAL

ENCROACHED CONDITION:

WSE = 2044.97 FT.

DEPTH = 6.97 FT.

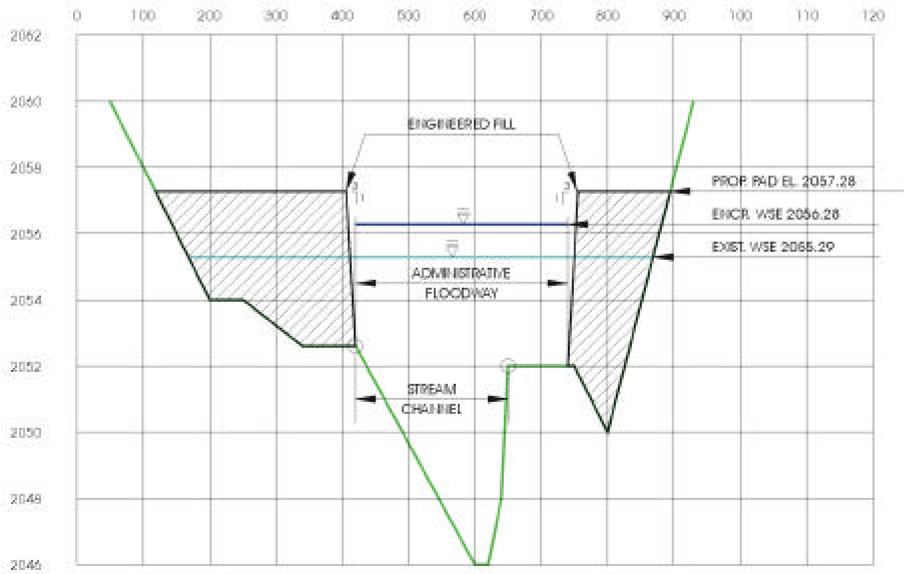
VELOCITY = 7.88 FPS

AREA = 1599.18 S.F.

PERIMETER = 333.13 FT.

TOP WIDTH = 320 FT.

FLOW REGIME IS SUBCRITICAL



SECTION 1-B

GIVEN: Q = 12,600 CFS S = 0.8% N = 0.048

○ = CHANNEL BANK

EXISTING CONDITION:

WSE = 2055.29 FT.

DEPTH = 9.29 FT.

VELOCITY = 5.82 FPS

AREA = 2167.07 S.F.

PERIMETER = 711.83 FT.

TOP WIDTH = 710 FT.

FLOW REGIME IS SUBCRITICAL

ENCROACHED CONDITION:

WSE = 2056.28 FT.

DEPTH = 20.28 FT.

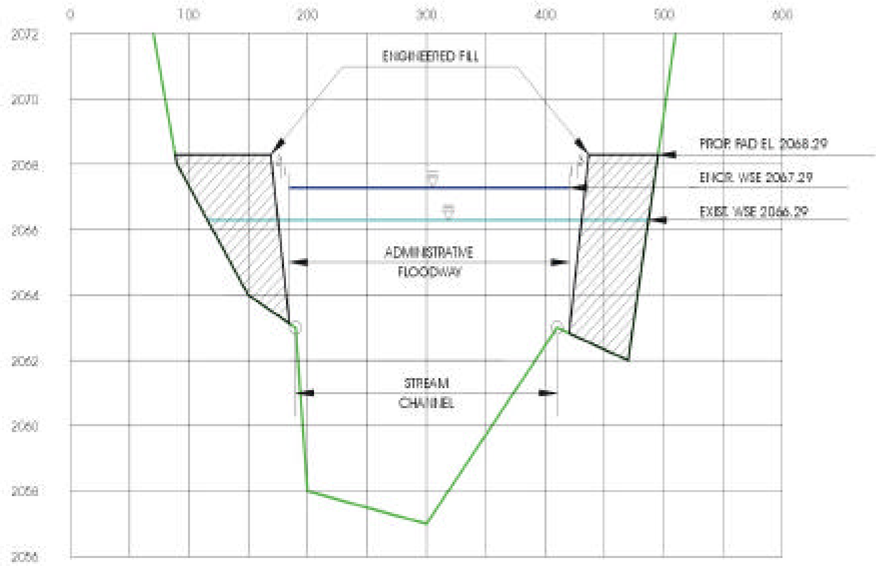
VELOCITY = 8.17 FPS

AREA = 1542.04 S.F.

PERIMETER = 304.09 FT.

TOP WIDTH = 295 FT.

FLOW REGIME IS SUBCRITICAL



SECTION 1-C

GIVEN: Q = 12,600 CFS S = 0.8% N = 0.048

○ = CHANNEL BANK

EXISTING CONDITION:

WSE = 2066.29 FT.

DEPTH = 8.29 FT.

VELOCITY = 7.58 FPS

AREA = 1663.74 S.F.

PERIMETER = 367.68 FT.

TOP WIDTH = 366 FT.

FLOW REGIME IS SUBCRITICAL

ENCROACHED CONDITION:

WSE = 2067.29 FT.

DEPTH = 9.29 FT.

VELOCITY = 8.93 FPS

AREA = 1411.51 S.F.

PERIMETER = 243.77 FT.

TOP WIDTH = 230 FT.

FLOW REGIME IS SUBCRITICAL

Example #I2. A land owner has 10 acres located in a moderately urbanized sheet flow area within unincorporated Maricopa County at an elevation of 1,200 ft. above sea level (Figure I-5). The land owner would like to construct a new home on fill within an area which has historically experienced flooding and has been told by the local floodplain administrator to use a Level 2 methodology to conduct a drainage study of the area.

STEP 1. Estimate the 100-year peak discharge. Using a USGS Topographic Quadrangle Map, it is determined that the drainage area is approximately 0.8 square miles. Because the watershed is located in an urban watershed on an alluvial fan, and because the watershed elevation is outside the “cloud of common values for Region 12 shown in Appendix G, the Level 2 discharge methodology may not be used. Therefore, the Level 1 discharge methodology will be used. Using the envelope curve provided in Appendix D, the 100-year peak discharge is estimated at 3,090 cfs.

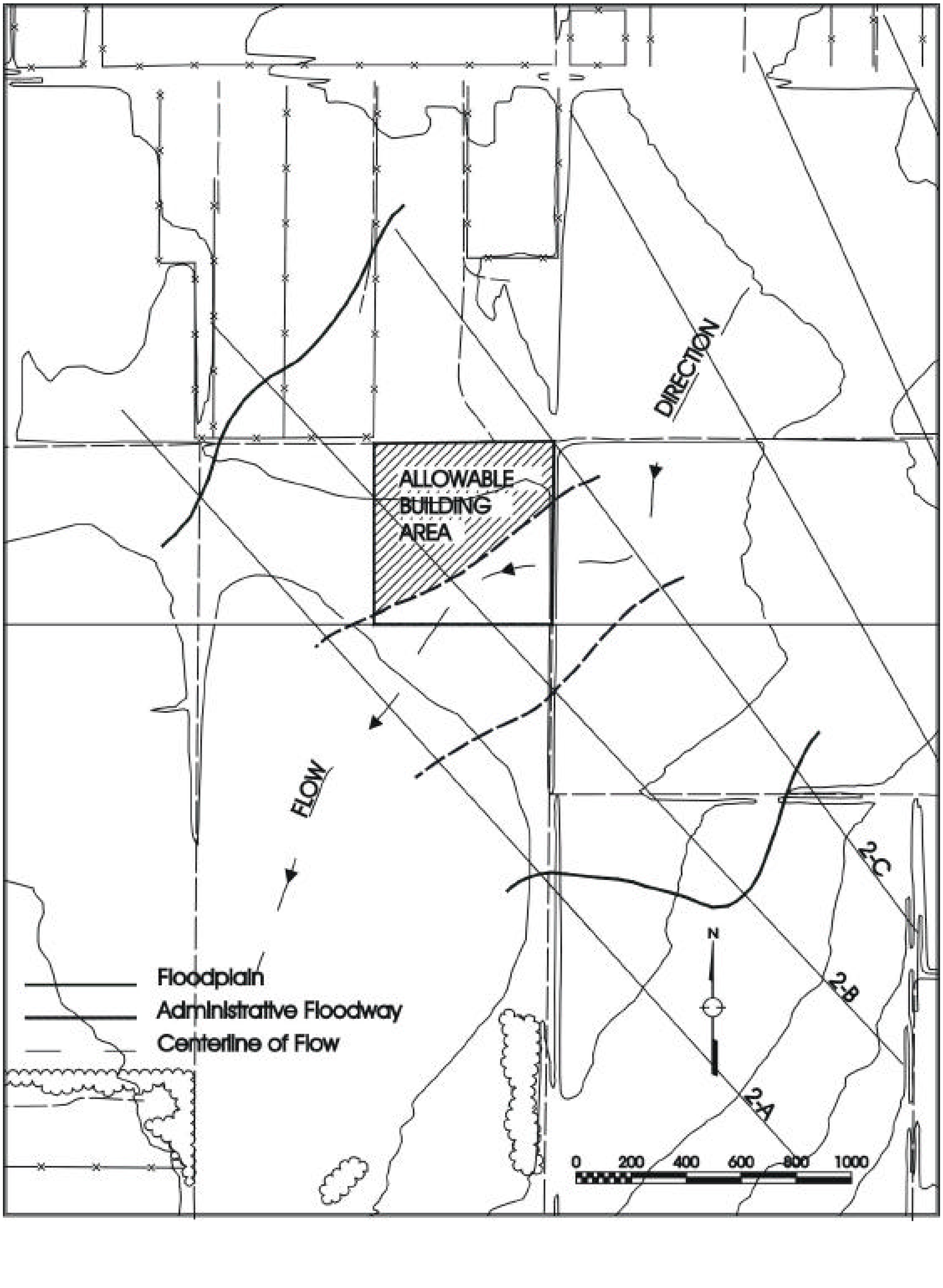
STEP 2. Estimate the floodplain limits using Manning’s ratings of cross sections at the site. Cross sections of the site were acquired from recent aerial mapping of the area and were used to obtain three cross-sections. The locations of the cross-sections are shown on Figure I-5. Figures I-6, I-7, and I-8 show the plotted cross-sections and normal depth calculations. The resultant 100-year water surface at each cross-section is plotted on Figure I-5 to delineate the 100-year floodplain.

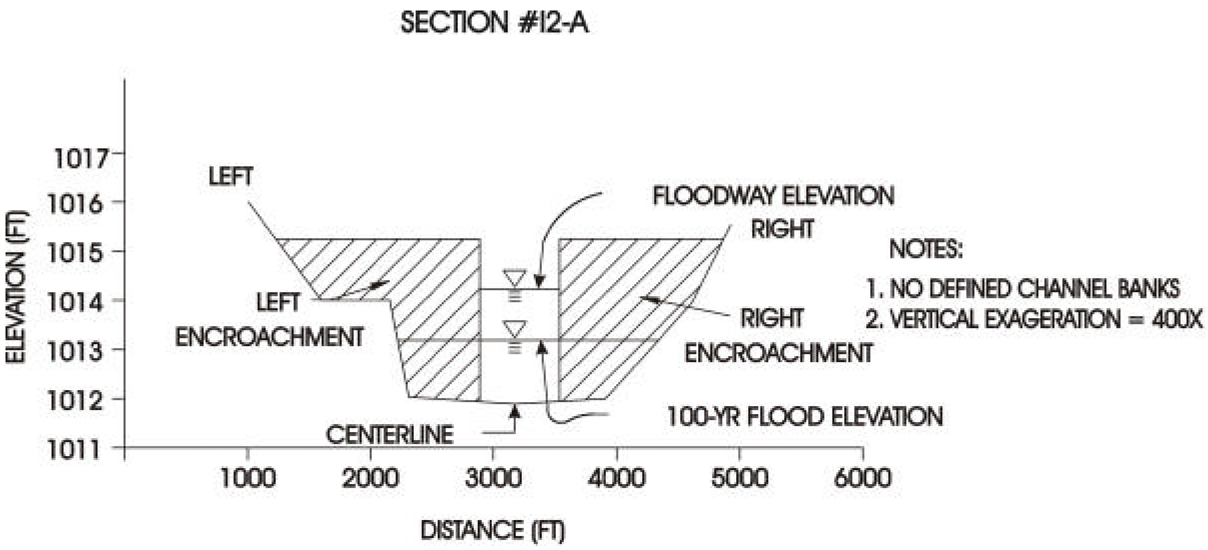
STEP 3. Determine the administrative floodway limits using equal encroachment into the 100-year floodplain and the cross-sections from Figures I-6, I-7, and I-8. This is accomplished by a trial and error procedure where vertical walls (representing equal conveyance areas being removed from the floodplain) are placed within the cross-section and a new normal depth calculation is performed. This is repeated until a maximum increase of 1 foot above the existing condition water surface elevation is obtained.

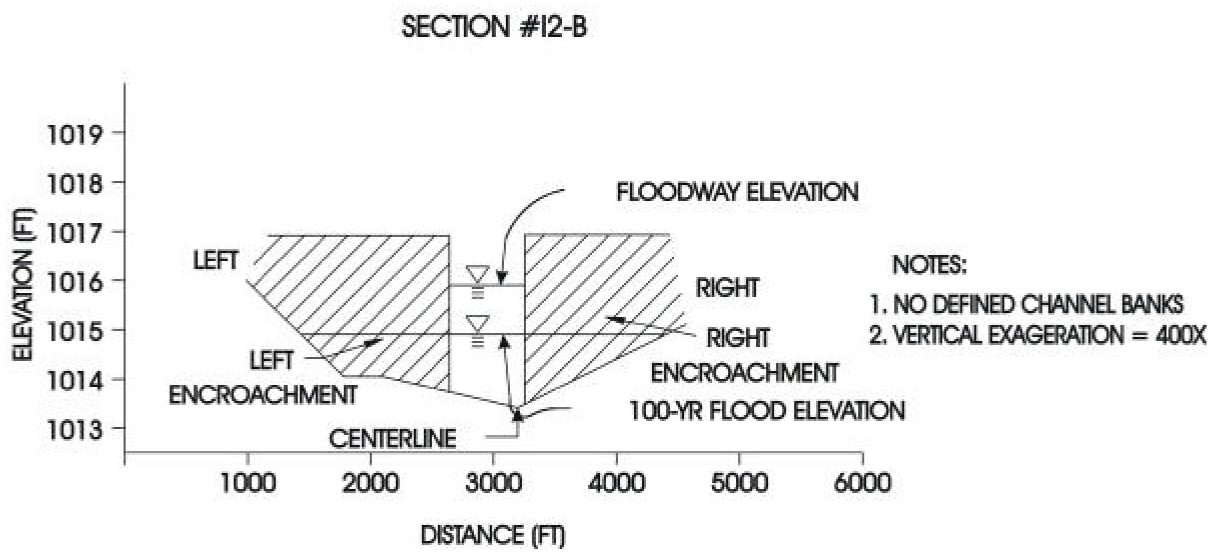
STEP 4. The finished building pad will be constructed of engineered fill material placed at an elevation one foot above the encroached 100-year water surface elevation. The highest encroached water surface elevation adjacent to the structure (typically upstream) is used to determine the building pad elevation.

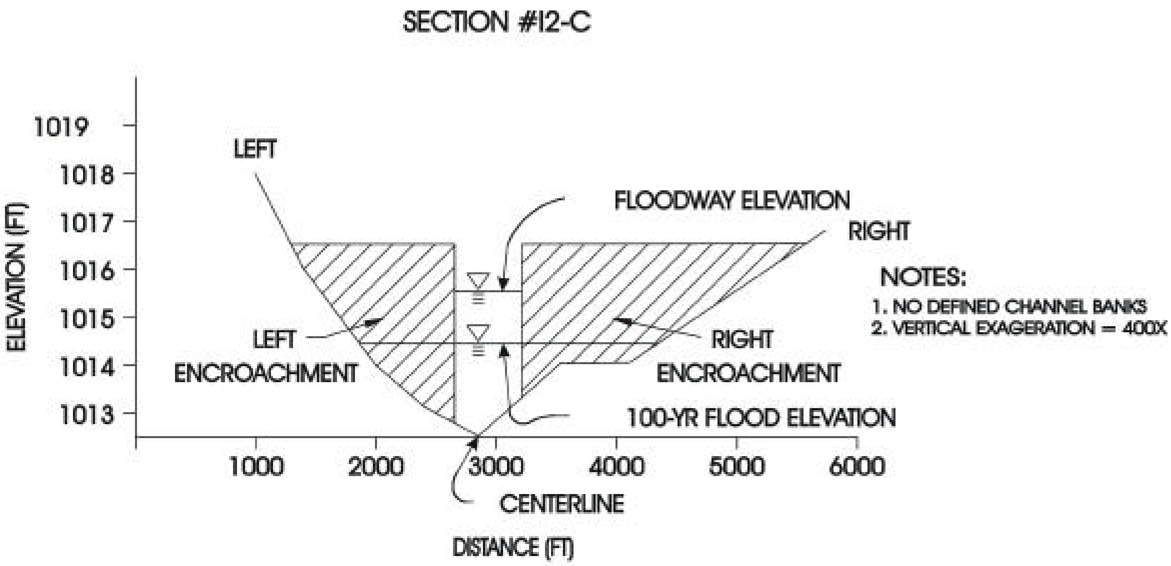
STEP 5. The hydraulic calculations indicate velocities less than 5 feet per second. The fill material exposed to the watercourse's flow require vegetative erosion protection as approved by the local floodplain administrator.

Figure I-5


DIRECTION
ALLOWABLE
BUILDING
AREA
FLOW
2-C
2-B
2-A
N
Floodplain
Administrative Floodway
Centerline of Flow
0
200
400
600
800
1000


SECTION #12-A
1017
1016
1015
1014
1013
1012
1011
ELEVATION (FT)
LEFT
LEFT
ENCROACHMENT
FLOODWAY ELEVATION
RIGHT
RIGHT
ENCROACHMENT
CENTERLINE
100-YR FLOOD ELEVATION
NOTES:
1. NO DEFINED CHANNEL BANKS
2. VERTICAL EXAGERATION = 400X
1000
2000
3000
4000
5000
6000
DISTANCE (FT)


SECTION #12-B
1019
1018
1017
1016
1015
1014
1013
ELEVATION (FT)
FLOODWAY ELEVATION
LEFT
LEFT
ENCROACHMENT
RIGHT
RIGHT
ENCROACHMENT
100-YR FLOOD ELEVATION
CENTERLINE
NOTES:
1. NO DEFINED CHANNEL BANKS
2. VERTICAL EXAGERATION = 400X
1000
2000
3000
4000
5000
6000
DISTANCE (FT)



HYDRAULIC DATA SUMMARY	SECTION #A F/P	SECTION #A F/W	SECTION #B F/P	SECTION #B F/W	SECTION #C F/P	SECTION #C F/W
WSEL	1013.21	1014.21	1014.85	1015.85	1014.39	1015.39
DEPTH (MAXIMUM)	1.31	2.31	1.45	2.45	1.89	2.89
VELOCITY	1.49	2.18	1.64	2.33	1.83	2.44
TOPWIDTH	2114	650	2896	630	2452	528
FLOW REGIME	SUBCRITICAL		SUBCRITICAL		SUBCRITICAL	
SLOPE	0.0016		0.0017		0.0020	
N	0.0480		0.0480		0.0550	
Q100	3200		3200		3200	

Appendix J: Application Software

Computer software is available from ADWR to assist in the application of the methodologies described in this document. Software includes the following:

Discharge Methodology

A spreadsheet program, originally developed in QuattroPro, was developed to assist in computation of the USGS regression equations (Level 2 Hydrology, as described in this report). The spreadsheet was set up to compute regression equations for a single or for multiple regions.

Floodplain Methodology

The U.S. Forest Service computer program, XSPRO, a Manning's rating software application, was used in the development of the examples shown in this document. XSPRO is available from the U.S. Forest Service, from the National Technical Information Service, or from government document repositories as follows:

- XSPRO: A Channel Cross-Section Analyzer. Technical Note 387. August 1992. U.S. Dept. Of The Interior - Bureau of Land Management and U.S. Dept. Of Agriculture - Forest Service.

It is noted that numerous other Manning's equation computer programs, software packages, and publications are available from commercial vendors or public agencies that would meet the objectives of the state standard.

Floodway Determination

The U.S. Army Corps of Engineers has developed a computer program called Simplified Floodway Determination (SFD). This program is described in a publication entitled:

- Simplified Floodway Determination (SFD) Computer Program User's Manual, The Hydrologic Engineering Center, U.S. Army Corps of Engineers. May 1989.

Availability of Software

The software described above is available from the Department of Water Resources Flood Warning and Dam Safety Section.