Flood Map Revision Workshop

HYDROLOGY

Prepared for:
Flood Control District of
Maricopa County

Prepared By:

PBS&J
Phoenix, Arizona

Visit www.pbsj.com

June 23, 2003

PBSJ

Entellus

Flood Control District of Maracopa County

FLOOD MAP REVISION WORKSHOP
HYDROLOGY

June 23, 2003
Phoenix, Arizona

APPENDIX

A:

- **Data Request**
- **Flood Map – Related Fees**
- **FEMA Forms MT – 2**

B: **Recognizing Effective Data**

C: **Flood Frequency Analysis**

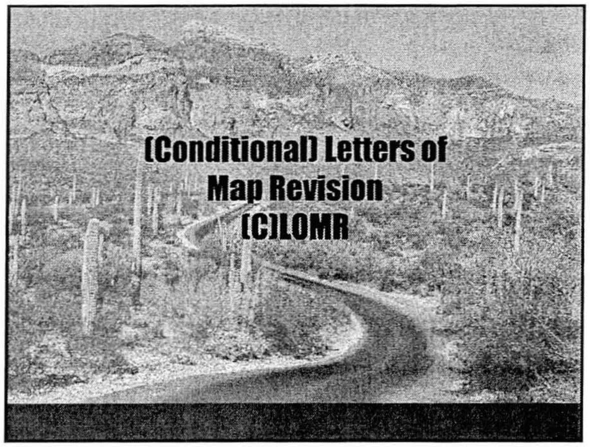
D: **USGS Regional Regression Equations**

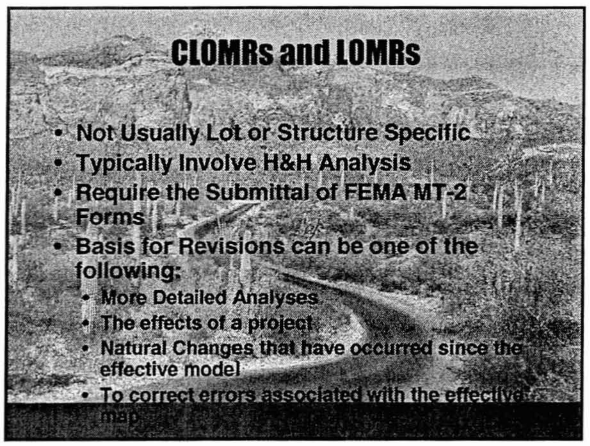
- **Methods for Estimating Flood Magnitude and Frequency in Rural Areas of Arizona**
- **Nationwide Urban Equations**
- **Flood Frequency Program, Version 3**

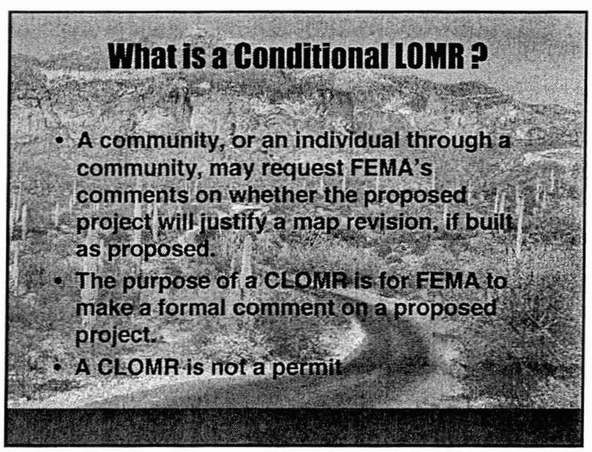
E: **Confidence Limits**

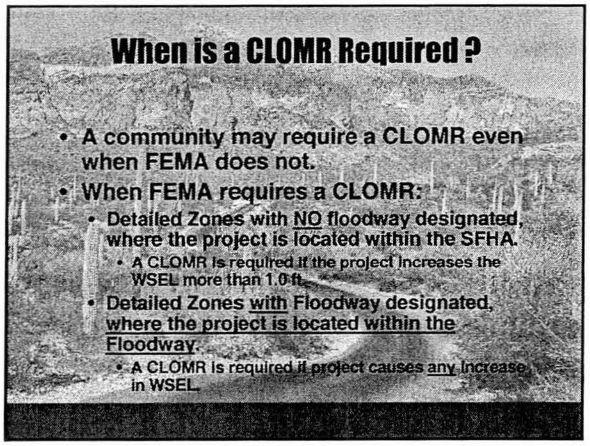
F: **Short Duration Rainfall for the Western United States**

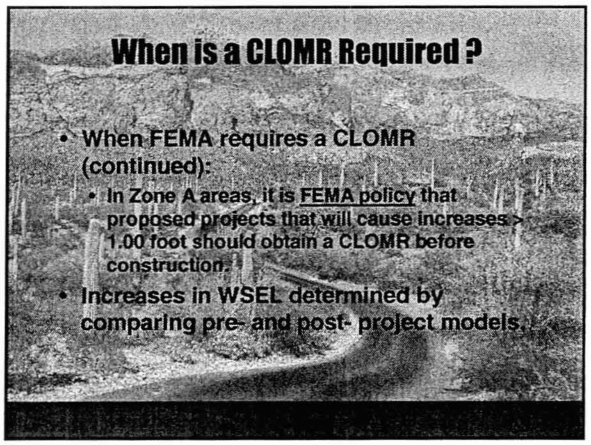
G: **Hydrology Review**

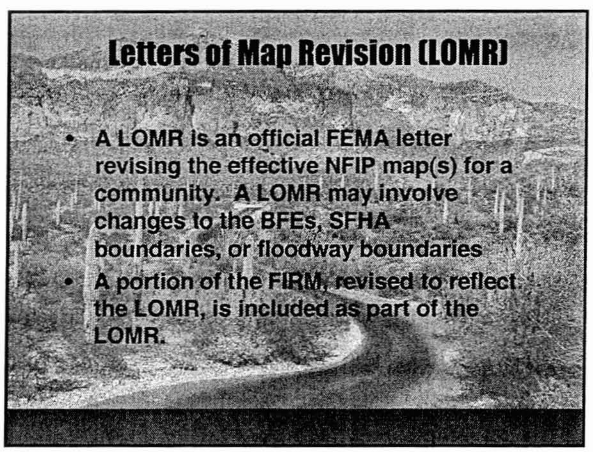

(Conditional) Letters of
Map Revision
(C)LOMR

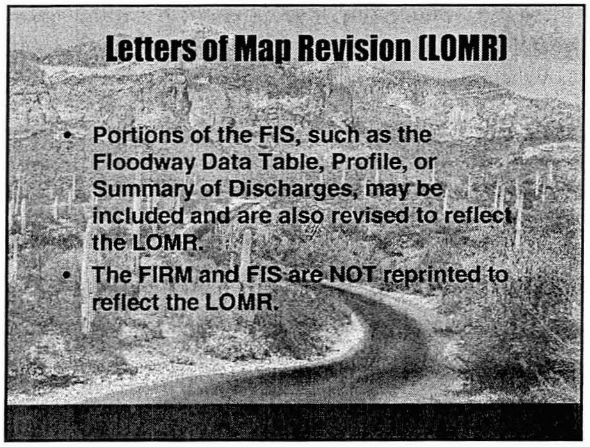

CLOMRs and LOMRs
• Not Usually Lot or Structure Specific
• Typically Involve H&H Analysis
• Require the Submittal of FEMA MT-2 Forms
• Basis for Revisions can be one of the following:
• More Detailed Analyses
• The effects of a project
• Natural Changes that have occurred since the effective model
• To correct errors associated with the effective map

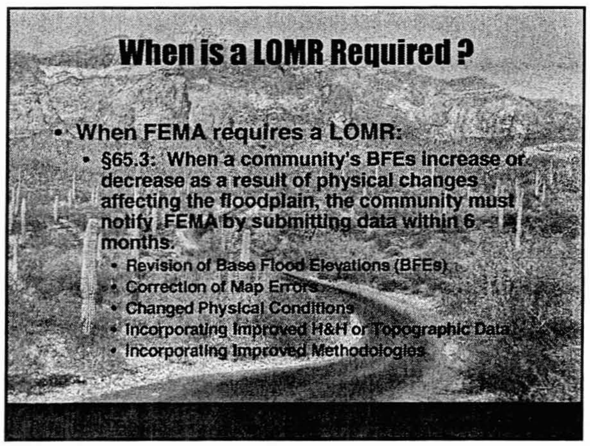

What is a Conditional LOMR ?
• A community, or an individual through a community, may request FEMA's comments on whether the proposed project will justify a map revision, if built as proposed.
• The purpose of a CLOMR is for FEMA to make a formal comment on a proposed project.
• A CLOMR is not a permit

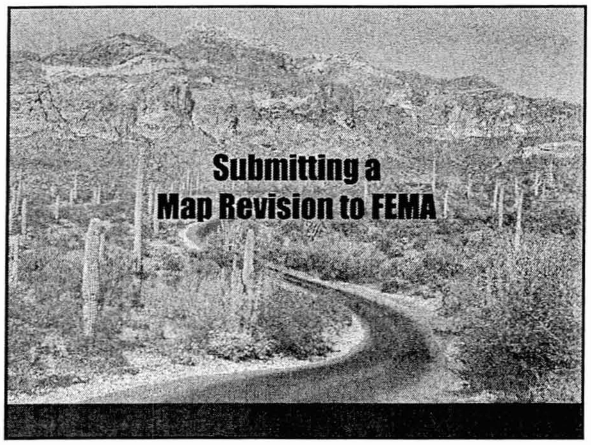

When is a CLOMR Required ?
• A community may require a CLOMR even when FEMA does not.
• When FEMA requires a CLOMR:
• Detailed Zones with NO floodway designated, where the project is located within the SFHA.
• A CLOMR is required if the project increases the WSEL more than 1.0 ft.
• Detailed Zones with Floodway designated, where the project is located within the Floodway.
• A CLOMR is required if project causes any increase in WSEL.


When is a CLOMR Required ?
• When FEMA requires a CLOMR (continued):
• In Zone A areas, it is FEMA policy that proposed projects that will cause increases > 1.00 foot should obtain a CLOMR before construction.
• Increases in WSEL determined by comparing pre- and post- project models.

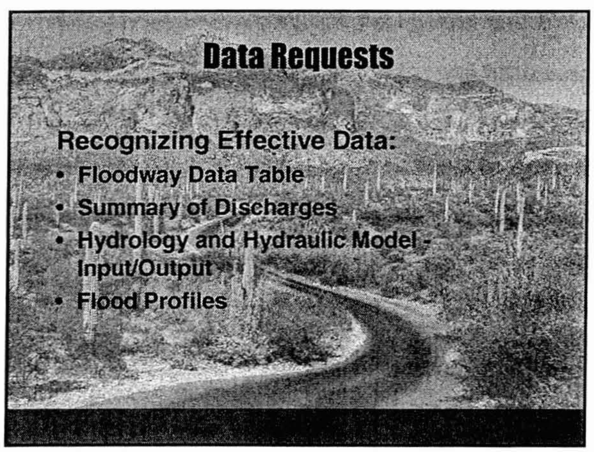

Letters of Map Revision (LOMR)
• A LOMR is an official FEMA letter revising the effective NFIP map(s) for a community. A LOMR may involve changes to the BFEs, SFHA boundaries, or floodway boundaries
• A portion of the FIRM, revised to reflect the LOMR, is included as part of the LOMR.

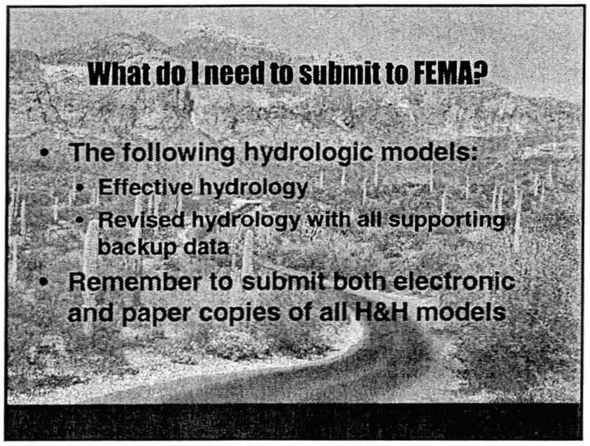

Letters of Map Revision (LOMR)
• Portions of the FIS, such as the Floodway Data Table, Profile, or Summary of Discharges, may be included and are also revised to reflect the LOMR.
• The FIRM and FIS are NOT reprinted to reflect the LOMR.


When is a LOMR Required ?
• When FEMA requires a LOMR:
• §65.3: When a community's BFEs increase or decrease as a result of physical changes affecting the floodplain, the community must notify FEMA by submitting data within 6 months.
• Revision of Base Flood Elevations (BFEs)
• Correction of Map Errors
• Changed Physical Conditions
• Incorporating Improved H&H or Topographic Data
• Incorporating Improved Methodologies


Submitting a
Map Revision to FEMA


Data Requests
How to order FIS Data
http://www.fema.gov/mit/tsd/st_order.htm


Data Requests
Recognizing Effective Data:
• Floodway Data Table
• Summary of Discharges
• Hydrology and Hydraulic Model - Input/Output
• Flood Profiles


What do I need to submit to FEMA?
• The following hydrologic models:
• Effective hydrology
• Revised hydrology with all supporting backup data
• Remember to submit both electronic and paper copies of all H&H models

FEMA's Response

Processing

- For CLOMR and LOMR:
  - FEMA will notify requester and community within 60 days if more data required
  - FEMA provides requester and community, within 90 days of receipt of adequate information and fee, a LOMR or CLOMR or other written determination.
  - This is 90 days from the last piece of information received
- Legal requirements associated with public notice may lengthen the process in certain cases

Processing (continued)

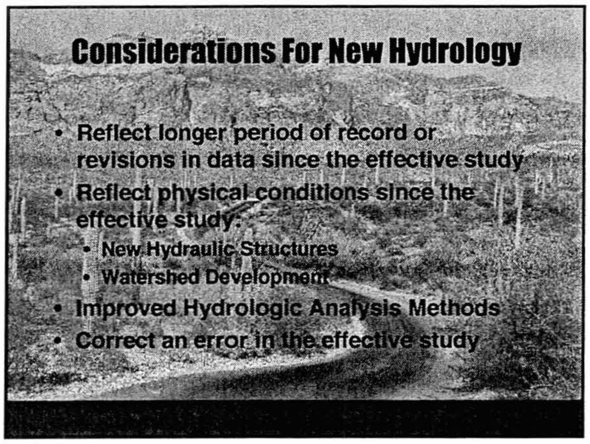
- Cases submitted to FEMA are processed on a "first submitted, first submission with all data, first completed" schedule.
- Plan for a minimum of 90 days, and more likely several months processing time, as FEMA reviews hundreds of components in your submission. Expect data requests from FEMA and the associated time to respond to such requests.
- Respond promptly to data requests, otherwise you lose time and money.
- The best way to speed up your processing time is to submit the case early and 100% complete and correct.

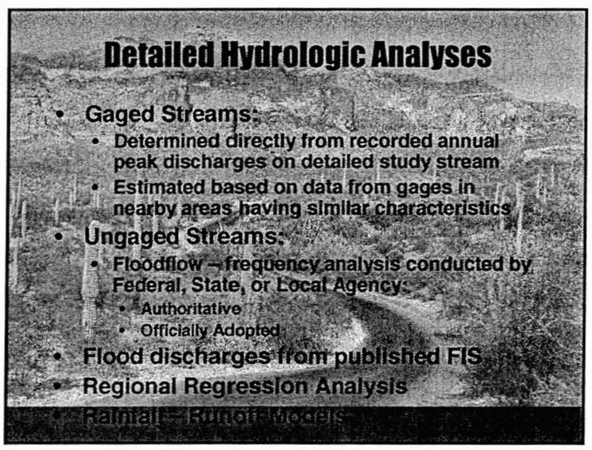

Application/Certification Forms
FEMA Forms MT-2
http://www.fema.gov/mit/tsd/dl_mt-2.htm

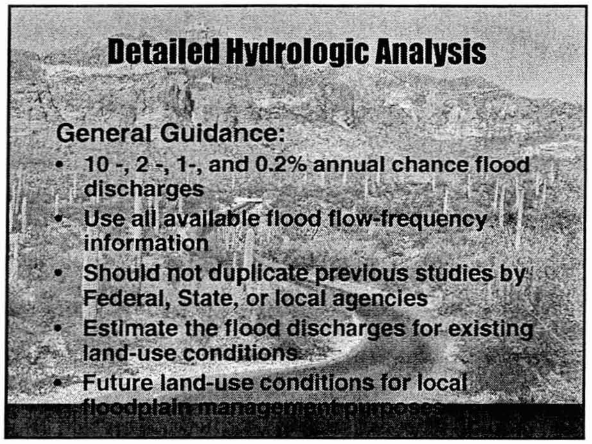

Application/Certification Forms (MT-2)
• Form #2 – Riverine Hydrology & Hydraulics
• Section A – Hydrology:
• Use this form if discharges are different than those used in the effective FIS.
• Reason for new hydrologic analysis:
• Alternative Methodolies
• Improved Data
• Explain why results are better than FIS

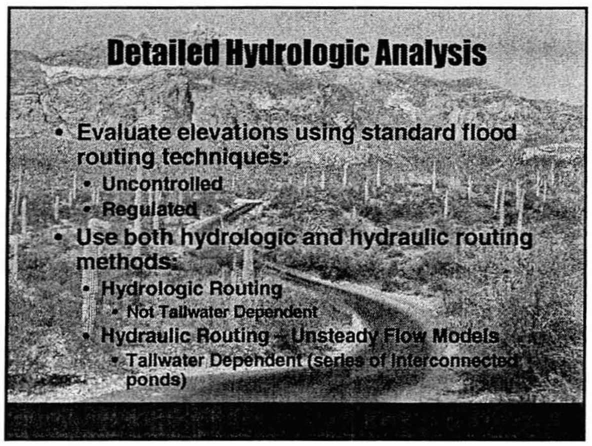

Application/Certification Forms (MT-2) (continued)
• Compare the effective 1% annual chance discharge to revised 1% annual chance discharge.
• 3 Representative locations
• Transition to unrevised portion of stream

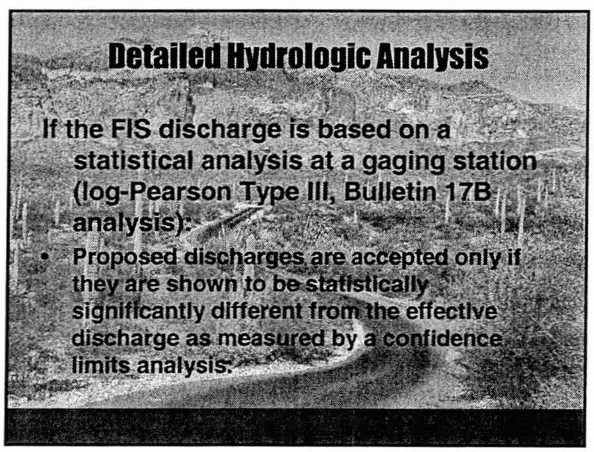

Application/Certification Forms (MT-2) (continued)
• Specify method of new analysis:
• Submit supporting data
• Submit data in digital and paper formats.
• Approval of new hydrology by local, state or Federal agencies (if required).
• Sediment Transport:
• Yes – Form 3 – Section F
• No – Explain why sediment transport not considered.


Considerations For New Hydrology
• Reflect longer period of record or revisions in data since the effective study
• Reflect physical conditions since the effective study:
• New Hydraulic Structures
• Watershed Development
• Improved Hydrologic Analysis Methods
• Correct an error in the effective study


Detailed Hydrologic Analyses
• Gaged Streams:
• Determined directly from recorded annual peak discharges on detailed study stream
• Estimated based on data from gages in nearby areas having similar characteristics
• Ungaged Streams:
• Floodflow – frequency analysis conducted by Federal, State, or Local Agency:
• Authoritative
• Officially Adopted
• Flood discharges from published FIS
• Regional Regression Analysis
• Rainfall – Runoff Models


Detailed Hydrologic Analysis
General Guidance:
• 10 -, 2 -, 1-, and 0.2% annual chance flood discharges
• Use all available flood flow-frequency information
• Should not duplicate previous studies by Federal, State, or local agencies
• Estimate the flood discharges for existing land-use conditions
• Future land-use conditions for local floodplain management purposes


Detailed Hydrologic Analysis
• Evaluate elevations using standard flood routing techniques:
• Uncontrolled
• Regulated
• Use both hydrologic and hydraulic routing methods:
• Hydrologic Routing
• Not Tailwater Dependent
• Hydraulic Routing – Unsteady Flow Models
• Tailwater Dependent (series of interconnected ponds)


Detailed Hydrologic Analysis
If the FIS discharge is based on a statistical analysis at a gaging station (log-Pearson Type III, Bulletin 17B analysis):
• Proposed discharges are accepted only if they are shown to be statistically significantly different from the effective discharge as measured by a confidence limits analysis.

Detailed Hydrologic Analysis

For gaged streams – confidence limits are computed for the updated frequency curve:

- Proposed discharge used if effective discharge is outside the 90-percent confidence interval
- Effective discharge is used if within the 50-percent confidence interval
- If effective discharge falls between 50- and 90-percent intervals, consult the Regional PO for a case-by-case analysis

Detailed Hydrologic Analysis

Confidence limits can be computed for frequency curves from:

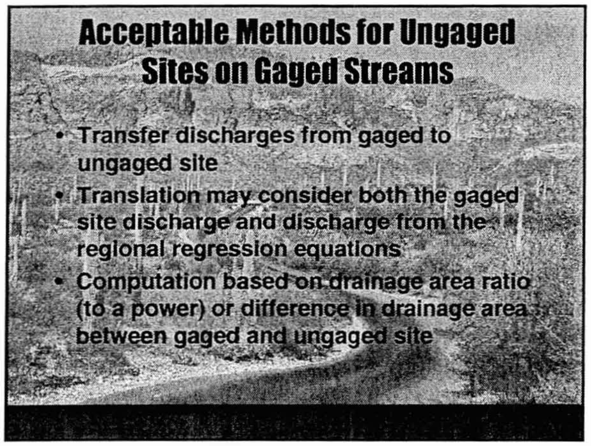
- Rainfall-runoff models (USACE EM 1110-2-1619, dated August 1, 1996)

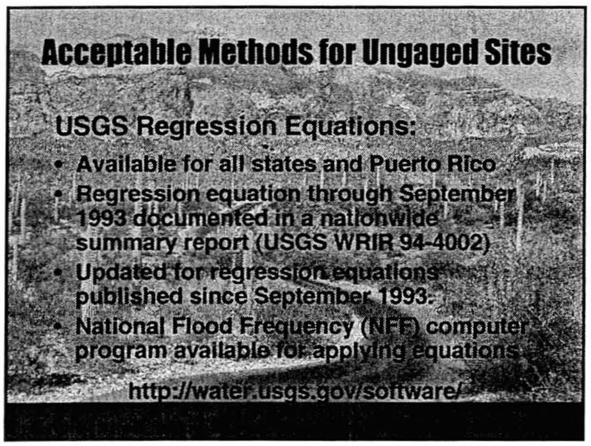
  (http://www.usace.army.mil/publications/eng-manuals/em1110-2-1619)
- Regression equations

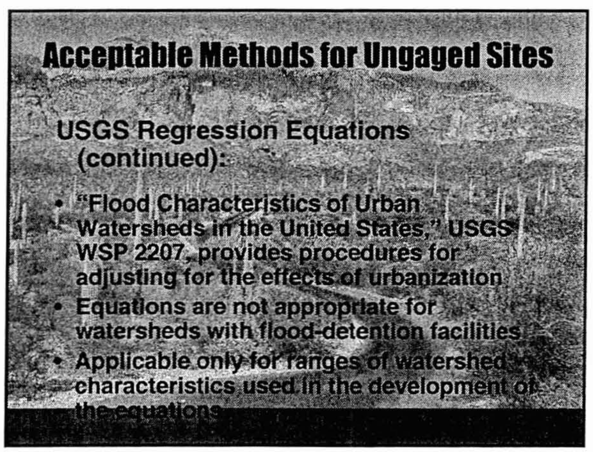
Acceptable Methods for Determining FIS Discharges

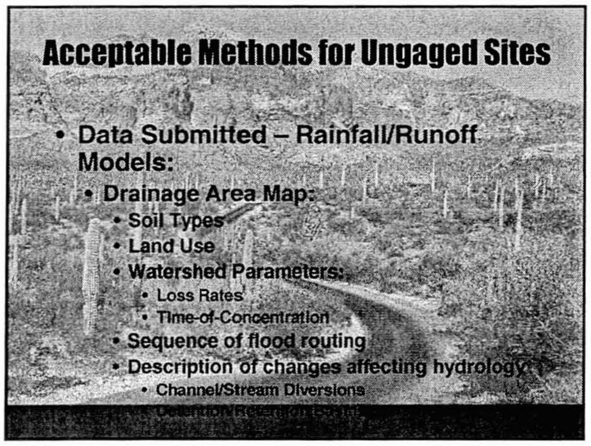
Statistical analysis of flood data at a gaging station (log-Pearson Type III, Bulletin 17B):

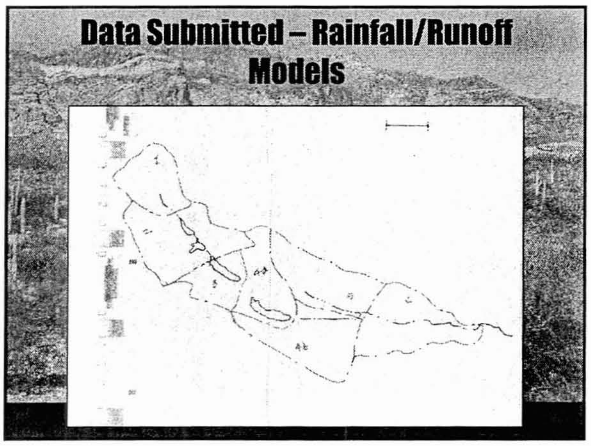
- Results more reliable as record length increases (utilize confidence limits analysis)
- Comparison with nearby hydrologically similar watersheds may aid analysis, particularly for gaging stations with few years of record

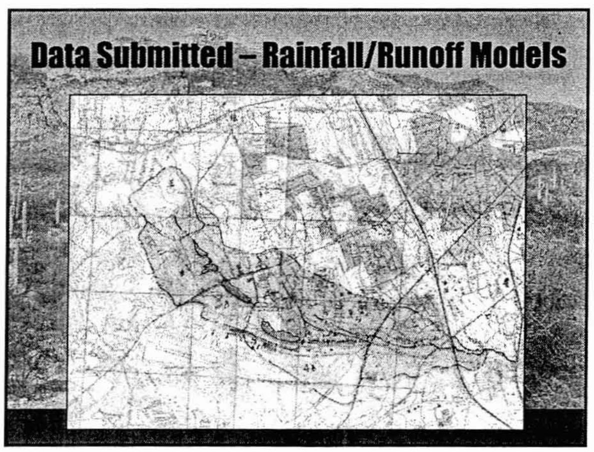

Acceptable Methods for Ungaged Sites on Gaged Streams
• Transfer discharges from gaged to ungaged site
• Translation may consider both the gaged site discharge and discharge from the regional regression equations
• Computation based on drainage area ratio (to a power) or difference in drainage area between gaged and ungaged site


Acceptable Methods for Ungaged Sites
USGS Regression Equations:
• Available for all states and Puerto Rico
• Regression equation through September 1993 documented in a nationwide summary report (USGS WRIR 94-4002)
• Updated for regression equations published since September 1993.
• National Flood Frequency (NFF) computer program available for applying equations
http://water.usgs.gov/software/

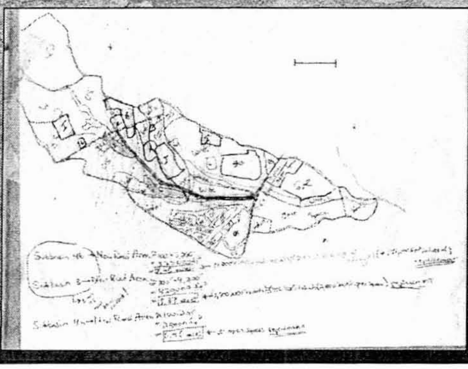

Acceptable Methods for Ungaged Sites
USGS Regression Equations (continued):
• "Flood Characteristics of Urban Watersheds in the United States," USGS WSP 2207, provides procedures for adjusting for the effects of urbanization
• Equations are not appropriate for watersheds with flood-detention facilities
• Applicable only for ranges of watershed characteristics used in the development of the equations


Acceptable Methods for Ungaged Sites
• Data Submitted – Rainfall/Runoff Models:
• Drainage Area Map:
• Soil Types
• Land Use
• Watershed Parameters:
• Loss Rates
• Time-of-Concentration
• Sequence of flood routing
• Description of changes affecting hydrology
• Channel/Stream Diversions


Data Submitted – Rainfall/Runoff Models

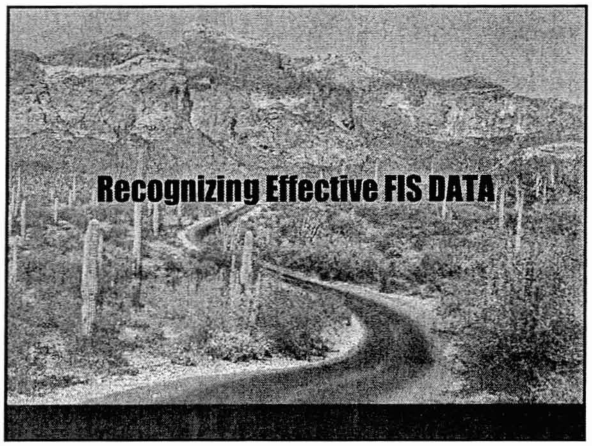

Data Submitted – Rainfall/Runoff Models

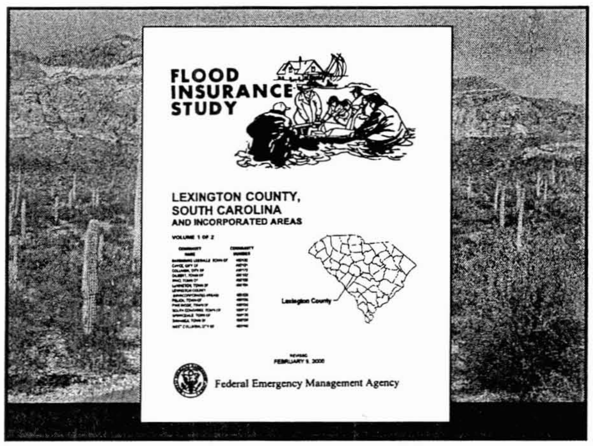
Data Submitted – Rainfall/Runoff Models

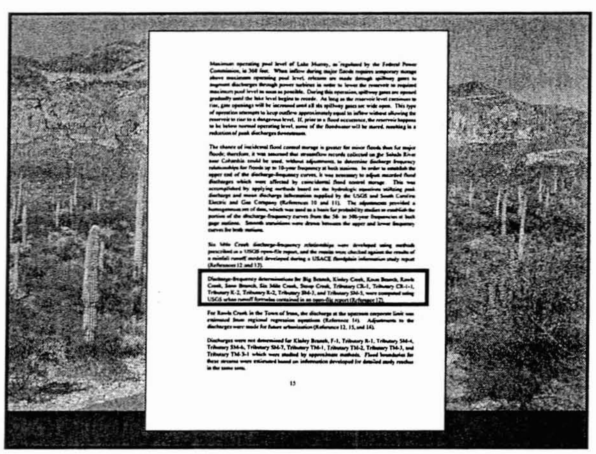


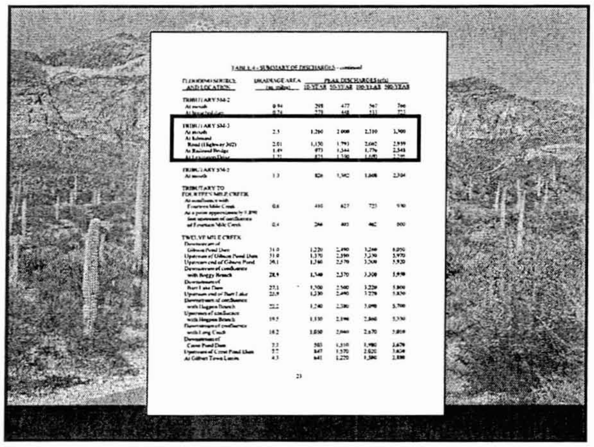
MT-2 Forms Common Problems

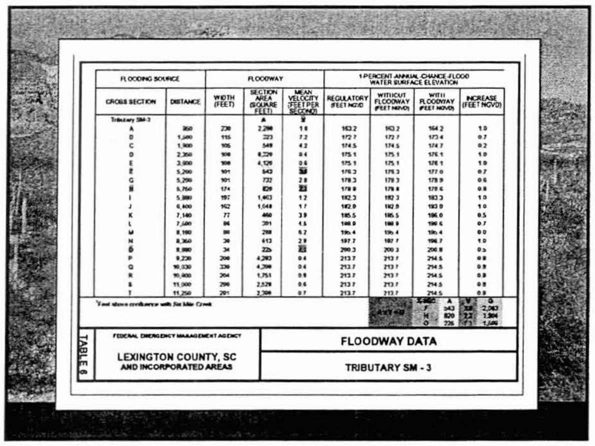
- Form 2: Hydrology:
  - Explanation for new hydrologic method not submitted
  - Computer model not approved by FEMA
  - Alternate method submitted, but no improvement from old method (no significant difference)
  - Wrong regression equations used or regression equations used when not appropriate
  - Model not calibrated where calibration required
  - All FIS recurrence intervals not analyzed


Recognizing Effective FIS DATA


FLOOD INSURANCE STUDY
LEXINGTON COUNTY, SOUTH CAROLINA
AND INCORPORATED AREAS
Lexington County
Federal Emergency Management Agency







FLOODING SOURCE		FLOODWAY			1-PERCENT ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NGVD)	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE (FEET NGVD)
Tributary SM-3			A	V				
A	360	230	2,280	1.0	163.2	163.2	164.2	1.0
B	1,600	115	323	7.2	172.7	172.7	173.4	0.7
C	1,900	105	549	4.2	174.5	174.5	174.7	0.2
D	2,350	900	8,229	0.4	175.1	175.1	176.1	1.0
E	3,900	900	4,120	0.6	175.1	175.1	176.1	1.0
F	5,200	101	543	3.8	176.3	176.3	177.0	0.7
G	5,290	101	732	2.8	178.3	178.3	178.9	0.6
H	5,750	174	820	2.2	178.8	178.8	178.6	0.8
I	5,980	197	1,463	1.2	182.3	182.3	183.3	1.0
J	6,400	162	1,048	1.7	182.0	182.0	183.0	1.0
K	7,140	77	460	3.9	185.5	185.5	186.0	0.5
L	7,600	86	391	4.6	188.9	188.9	189.6	0.7
M	8,180	80	288	6.2	196.4	196.4	196.4	0.0
N	8,360	30	613	2.9	197.7	197.7	198.7	1.0
O	8,880	34	225	7.1	200.3	200.3	200.8	0.5
P	9,230	200	4,283	0.4	213.7	213.7	214.5	0.8
Q	10,330	330	4,290	0.4	213.7	213.7	214.5	0.8
R	10,900	204	1,751	0.9	213.7	213.7	214.5	0.8
S	11,000	290	2,529	0.6	213.7	213.7	214.5	0.8
T	11,250	201	2,300	0.7	213.7	213.7	214.5	0.8

[1] Feet above confluence with Six Mile Creek

X-SEC	A	V	Q
F	543	3.8	2,063
H	820	2.2	1,804
O	225	7.1	1,598

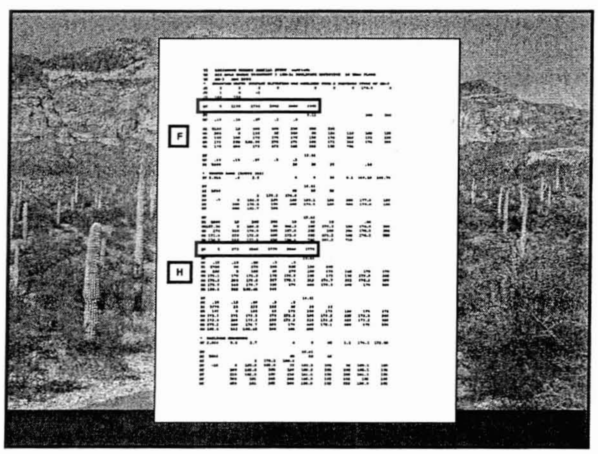
TABLE 6

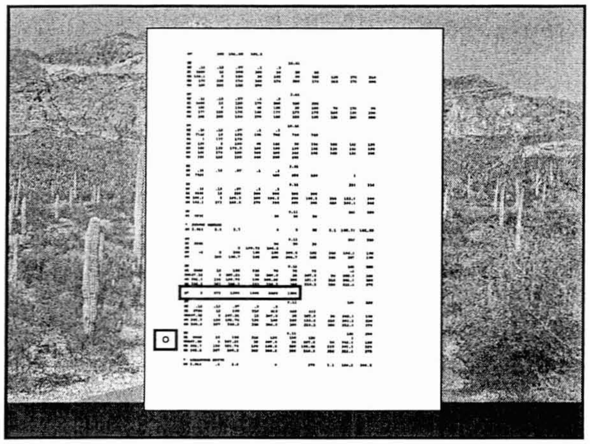
FEDERAL EMERGENCY MANAGEMENT AGENCY

LEXINGTON COUNTY, SC
AND INCORPORATED AREAS

FLOODWAY DATA

TRIBUTARY SM - 3





Flood Frequency Analysis

Statistical Analysis

- A *population* is the totality of the measurements or counts obtainable from all objects possessing some common specified characteristics.
- A *sample* is a set of measurements which constitut part or all of the population.
- A *random sample* is a sample in which any one individual measurement in the population is as likely to be included as another.
- A biased sample is a sample in which certain individual measurements have a greater chance to be included than others.

Source: Introduction to Probability [illegible] Freeman and Company [illegible]

Statistical Analysis

Gaged Streams:

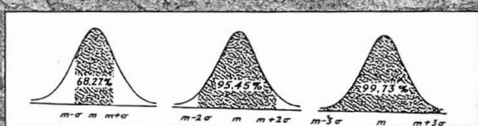
- Guidelines for determining floodflow frequency
  - Bulletin 17B
- Annual maximum peak flows
  - http://water.usgs.gov/nwis/gov
- Computer software
  - USACE, *HEC-FFA, Frequency Analysis*
  - USGS, *Peak FQ, Annual Flood Frequency Analysis* using *Bulletin 17B Guidelines*

Statistical Analysis

Confidence Limits:

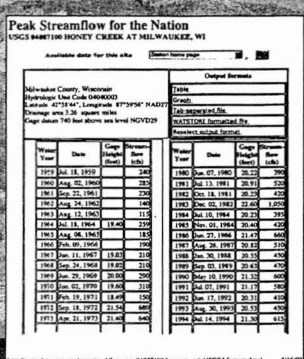
- The limits which will contain a parameter with a probability of some given percent (e.g. 95%, 84%, 75%) are called confidence limits of the parameters.
- The interval between the confidence limits is called the confidence interval (e.g. 90%, 68%, and 50%).

Statistical Analysis



Special areas under the normal curve.

Statistical Analysis



Peak Streamflow for the Nation

USGS 04087100 HONEY CREEK AT MILWAUKEE, WI

Available data for this site: Station home page

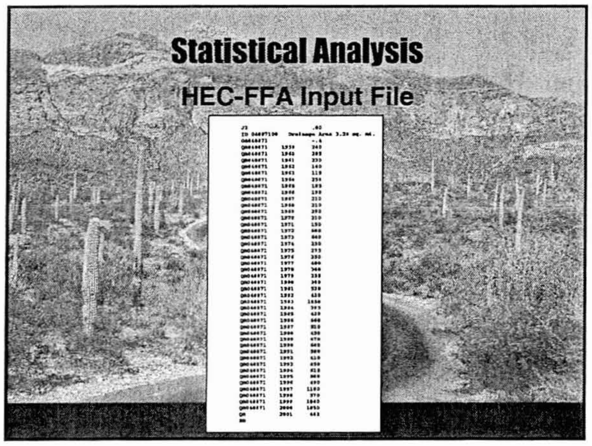
Milwaukee County, Wisconsin
Hydrologic Unit Code 04040003
Latitude 42°58'44", Longitude 87°59'56" NAD27
Drainage area 3.26 square miles
Gage datum 740 feet above sea level NGVD29

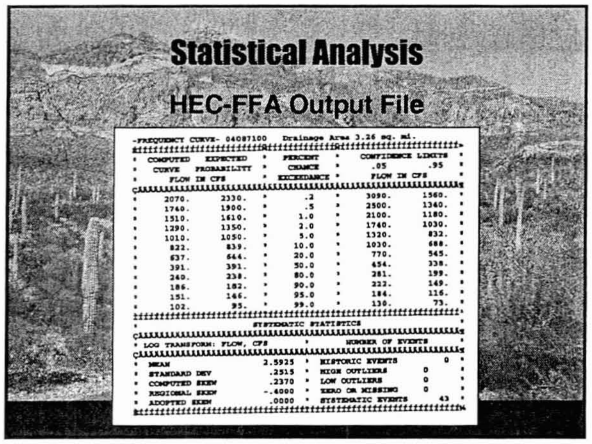
Output formats: Table, Graph, Tab-seperated file, WATSTORE formatted file, Reselect output format

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1959	Jul. 18, 1959		240
1960	Aug. 02, 1960		285
1961	Sep. 22, 1961		230
1962	Aug. 24, 1962		140
1963	Aug. 12, 1963		115
1964	Jul. 18, 1964	19.40	259
1965	Aug. 08, 1965		185
1966	Feb. 09, 1966		190
1967	Jun. 11, 1967	19.03	210
1968	Sep. 24, 1968	19.02	210
1969	Jun. 29, 1969	20.00	290
1970	Jun. 02, 1970	19.60	310
1971	Feb. 19, 1971	18.49	150
1972	Sep. 18, 1972	21.54	680
1973	Apr. 21, 1973	21.40	640

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1980	Jun. 07, 1980	20.22	390
1981	Jul. 13, 1981	20.91	520
1982	Oct. 18, 1981	20.23	420
1983	Dec. 02, 1982	22.60	1,050
1984	Jul. 10, 1984	20.23	395
1985	Nov. 01, 1984	20.40	420
1986	Jun. 27, 1986	21.47	660
1987	Aug. 26, 1987	20.82	510
1988	Jan. 30, 1988	20.55	450
1989	Sep. 03, 1989	20.63	470
1990	May 10, 1990	21.32	600
1991	Jul. 07, 1991	21.17	580
1992	Jun. 17, 1992	20.31	410
1993	Aug. 30, 1993	20.53	450
1994	Jul. 14, 1994	21.30	615

http://waterdata.usgs.gov/nwis/peak?site_no=04087100&agency_cd=USGS&format=html 5/16/03



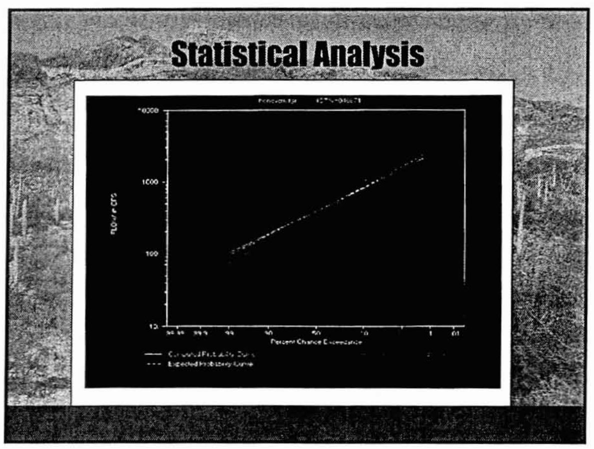


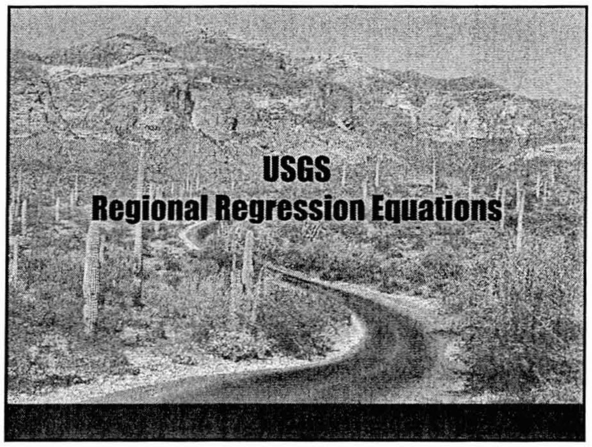
-FREQUENCY CURVE- 04087100 Drainage Area 3.26 sq. mi.

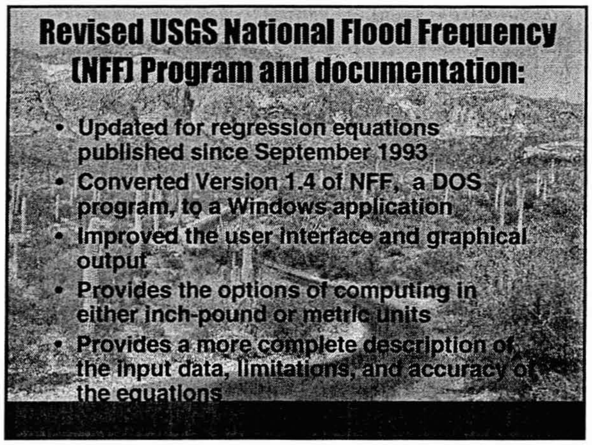
COMPUTED CURVE FLOW IN CFS	EXPECTED PROBABILITY FLOW IN CFS	PERCENT CHANCE EXCEEDANCE	CONFIDENCE LIMITS .05 FLOW IN CFS	CONFIDENCE LIMITS .95 FLOW IN CFS
2070.	2330.	.2	3090.	1560.
1760.	1900.	.5	2500.	1340.
1510.	1610.	1.0	2100.	1180.
1290.	1350.	2.0	1740.	1030.
1010.	1050.	5.0	1320.	832.
822.	839.	10.0	1030.	688.
637.	644.	20.0	770.	545.
391.	391.	50.0	454.	338.
240.	238.	80.0	281.	199.
186.	182.	90.0	222.	149.
151.	146.	95.0	184.	116.
102.	95.	99.0	130.	73.

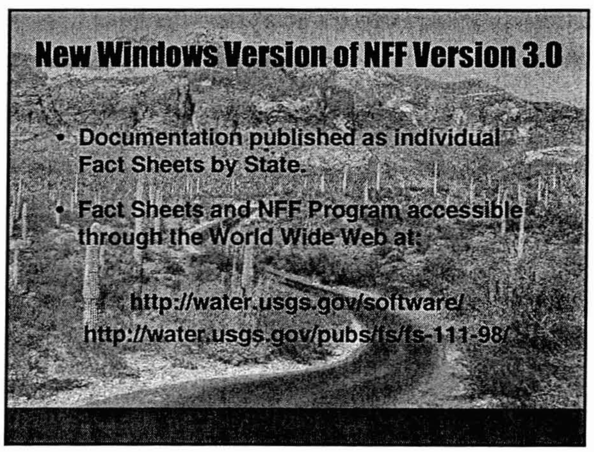
SYSTEMATIC STATISTICS

LOG TRANSFORM: FLOW, CFS		NUMBER OF EVENTS	
MEAN	2.5925	HISTORIC EVENTS	0
STANDARD DEV	.2515	HIGH OUTLIERS	0
COMPUTED SKEW	.2370	LOW OUTLIERS	0
REGIONAL SKEW	-.4000	ZERO OR MISSING	0
ADOPTED SKEW	.0000	SYSTEMATIC EVENTS	43

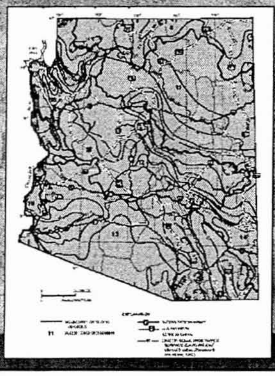



USGS
Regional Regression Equations


Revised USGS National Flood Frequency (NFF) Program and documentation:
• Updated for regression equations published since September 1993
• Converted Version 1.4 of NFF, a DOS program, to a Windows application
• Improved the user interface and graphical output
• Provides the options of computing in either inch-pound or metric units
• Provides a more complete description of the input data, limitations, and accuracy of the equations


New Windows Version of NFF Version 3.0
• Documentation published as individual Fact Sheets by State.
• Fact Sheets and NFF Program accessible through the World Wide Web at:
http://water.usgs.gov/software/
http://water.usgs.gov/pubs/fs/fs-111-98/

USGS Regional Regression Equations



USGS Regional Regression Equations

Flood-peak discharge regression equations and associated statistics for regions 12 and 13 in Arizona (modified from Thomas and others, 1997)

[Q_T peak discharge, in cubic feet per second for recurrence interval T, 2 to 100 years; AREA, drainage area in square miles; ELEV, mean basin elevation, in feet above sea level (NGVD of 1929)]

Regression equation	Average standard error of prediction, in percent	Equivalent years of record
Region 12 – 68 stations		
$Q_2 = 41.1AREA^{0.629}$	105	0.23
$Q_5 = 238AREA^{0.687}(ELEV/1,000)^{-0.358}$	68	1.90
$Q_{10} = 479AREA^{0.661}(ELEV/1,000)^{-0.398}$	52	6.24
$Q_{25} = 942AREA^{0.630}(ELEV/1,000)^{-0.383}$	40	17.80
$Q_{50} = 10^{(7.36 - 4.17AREA^{-0.08})}(ELEV/1,000)^{-0.440}$	37	27.5
$Q_{100} = 10^{(8.56 - 3.17AREA^{-0.11})}(ELEV/1,000)^{-0.454}$	39	32.1
Region 13 – 73 stations		
$Q_2 = 10^{(6.35 - 4.29AREA^{-0.06})}$	57	2.0
$Q_5 = 10^{(5.78 - 3.31AREA^{-0.08})}$	40	6.25
$Q_{10} = 10^{(5.86 - 3.02AREA^{-0.09})}$	37	11.1
$Q_{25} = 10^{(5.94 - 2.78AREA^{-0.10})}$	39	15.0
$Q_{50} = 10^{(6.57 - 2.60AREA^{-0.11})}$	43	15.9
$Q_{100} = 10^{(6.62 - 2.42AREA^{-0.12})}$	48	16.1

Source: USGS, 1999. The National Flood-Frequency Program-Methods for Estimating Flood Magnitude and Frequency in Rural Areas in Arizona. USGS Fact Sheet 111-98, January 1999.

Detailed Hydrologic Analysis

Range of explanatory variables for which regression equations are applicable

Hydrologic Study region	Drainage area in square miles[1]	Mean annual evaporation, in inches	Mean basin elevation in feet above[2]	Mean annual precipitation, in inches
Region 1	0.6 – 1,061	–	–	11 – 43
Region 8	1.0– 1,990	–	4,300 – 10,200	–
Region 10	0.1 – 1,000	–	–	–
Region 11	0.2 – 980	44.1 – 55.7	–	–
Region 12	0.6 – 1,520	–	1,730 – 8,700	–
Region 13	0.1 – 1,780	–	–	–
Region 14	0.8 – 1,860	–	3,350 – 8,950	–

[1]For best results, applications should be limited to basins of less than 200 square miles.

[2]NGVD of 1929.

Source: The National Flood-Frequency Program – Methods For Estimating Flood Magnitude and Frequency in Arizona. USGS Fact Sheet 111-98, January 1999.

Regional Regression Equations

- Improving estimates with gaged data.

$$\log Q_t(W) = \frac{N \bullet \log Q_t(G) + EQ \bullet \log Q_T(R)}{N + EQ}$$

- Site near gaged sites on the same stream (50-50 percent of drainage area of gaged site.

$$\log Q_T(u) = Q_T(W)\left(\frac{Area\ ungaged}{Area\ gaged}\right)^b$$

- Sites in Transition Zones:
  - Compute weighted estimate by multiplying each region estimate by the fraction of the drainage are in that region – sum the products

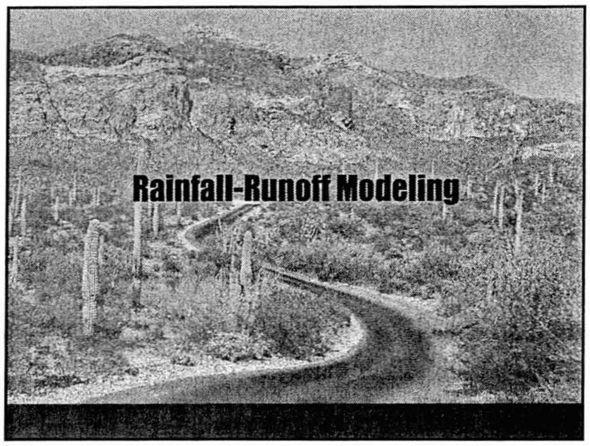
Nationwide Urban Equations

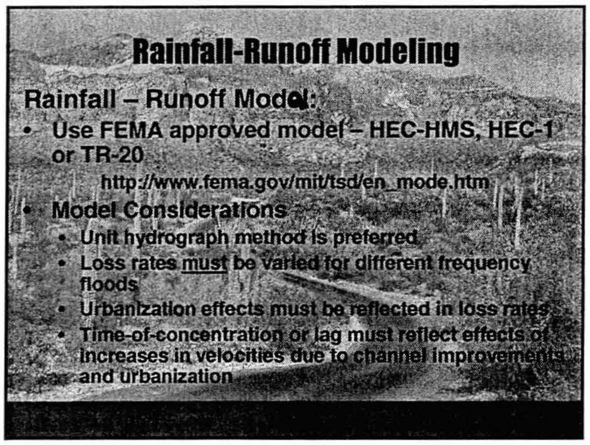
- Seven parameter equations available in NFF
- Basin development factors, BDF, is the most important factor
- Equations are not geographically biased.
- Standard error of estimate varies from ±38 percent (50-percent-annual-chance flood) to ±49 percent (0.2-percent- annual-chance flood).

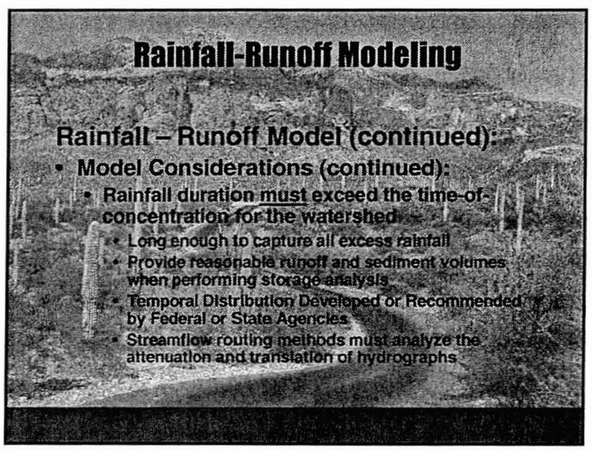
Motivation for using regression equations

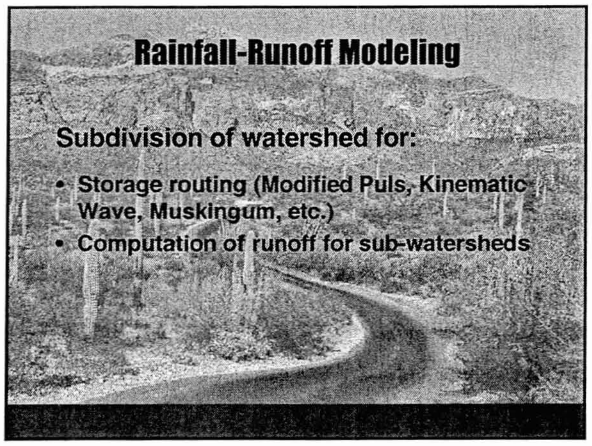
A 1981 U.S. Water Resources Council report confirmed the applicability of regression equations for estimating flood discharges at ungaged rural sites.

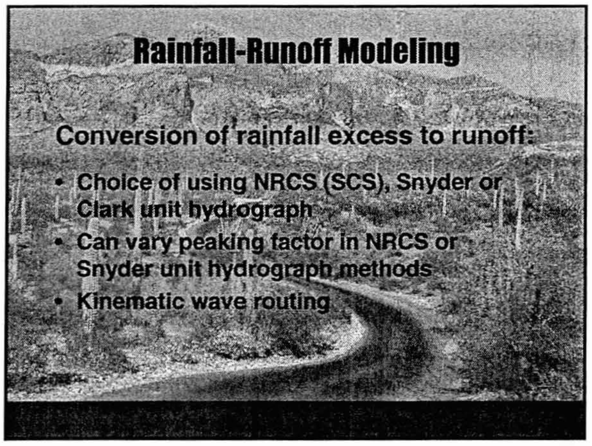
The findings indicated that regression equations provide more unbiased, reproducible estimates in a shorted period of time than any of the rainfall-runoff models or other procedures that were evaluated.

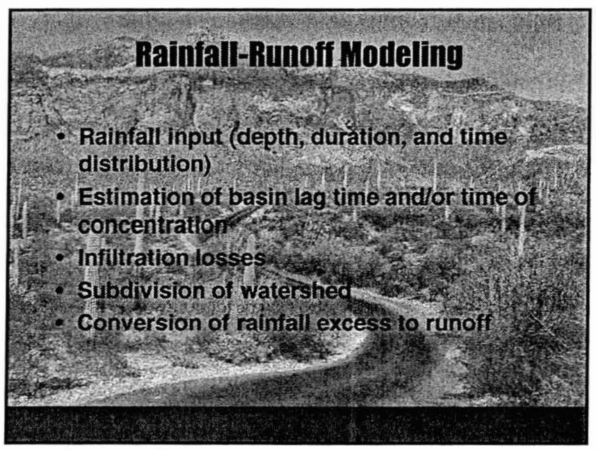

Rainfall-Runoff Modeling

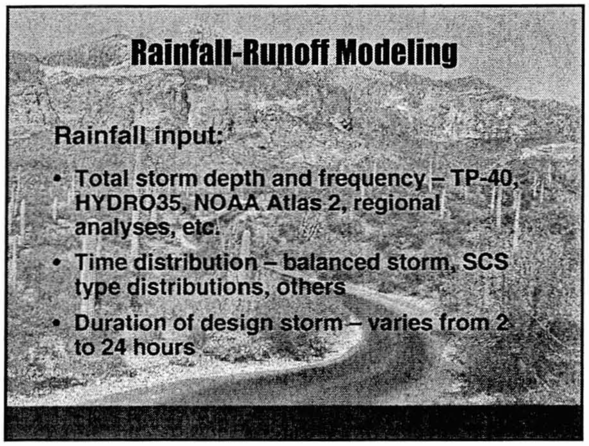

Rainfall-Runoff Modeling
Rainfall – Runoff Model:
• Use FEMA approved model – HEC-HMS, HEC-1 or TR-20
http://www.fema.gov/mit/tsd/en_mode.htm
• Model Considerations
• Unit hydrograph method is preferred
• Loss rates must be varied for different frequency floods
• Urbanization effects must be reflected in loss rates
• Time-of-concentration or lag must reflect effects of increases in velocities due to channel improvements and urbanization

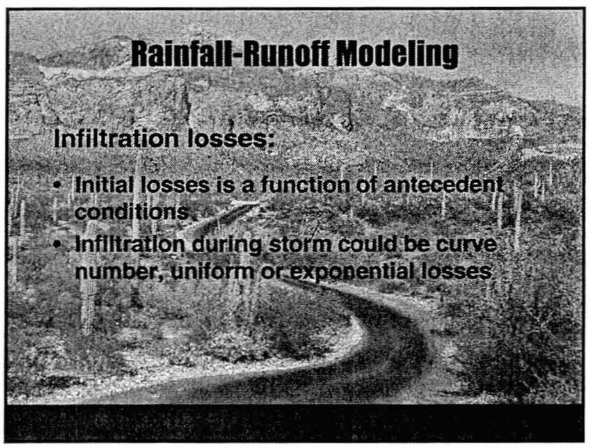

Rainfall-Runoff Modeling
Rainfall – Runoff Model (continued):
• Model Considerations (continued):
• Rainfall duration must exceed the time-of-concentration for the watershed
• Long enough to capture all excess rainfall
• Provide reasonable runoff and sediment volumes when performing storage analysis
• Temporal Distribution Developed or Recommended by Federal or State Agencies
• Streamflow routing methods must analyze the attenuation and translation of hydrographs

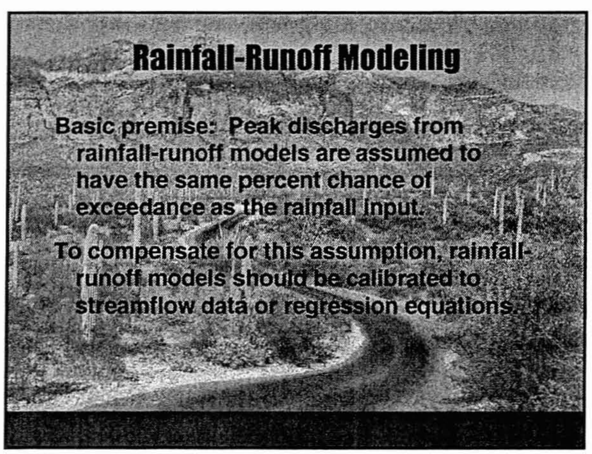

Rainfall-Runoff Modeling
Subdivision of watershed for:
• Storage routing (Modified Puls, Kinematic Wave, Muskingum, etc.)
• Computation of runoff for sub-watersheds

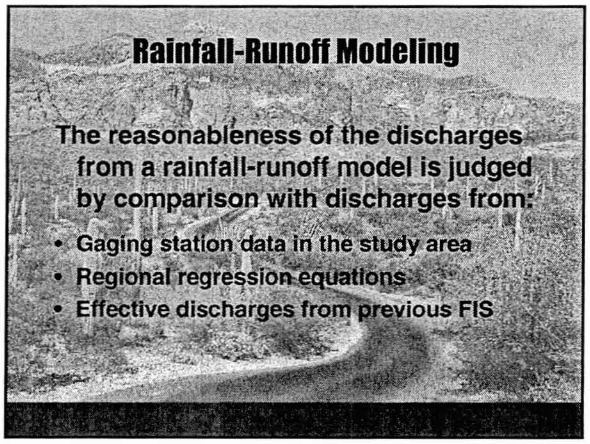

Rainfall-Runoff Modeling
Conversion of rainfall excess to runoff:
• Choice of using NRCS (SCS), Snyder or Clark unit hydrograph
• Can vary peaking factor in NRCS or Snyder unit hydrograph methods
• Kinematic wave routing

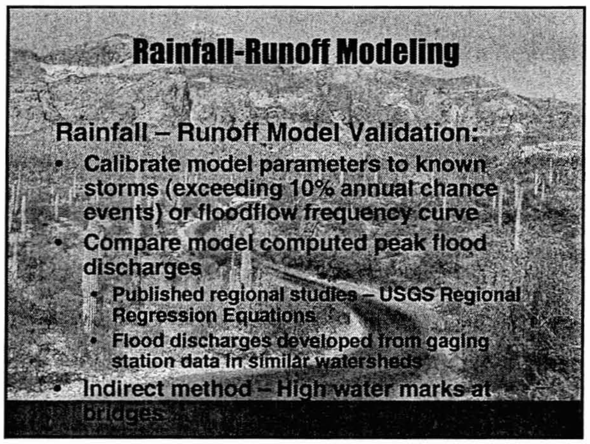

Rainfall-Runoff Modeling
• Rainfall input (depth, duration, and time distribution)
• Estimation of basin lag time and/or time of concentration
• Infiltration losses
• Subdivision of watershed
• Conversion of rainfall excess to runoff

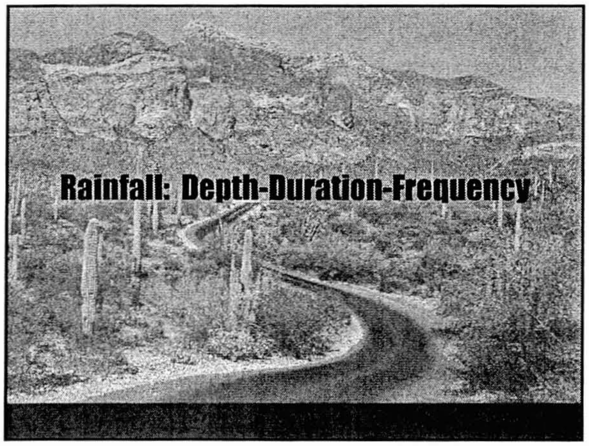

Rainfall-Runoff Modeling
Rainfall input:
• Total storm depth and frequency – TP-40, HYDRO35, NOAA Atlas 2, regional analyses, etc.
• Time distribution – balanced storm, SCS type distributions, others
• Duration of design storm – varies from 2 to 24 hours


Rainfall-Runoff Modeling
Infiltration losses:
• Initial losses is a function of antecedent conditions
• Infiltration during storm could be curve number, uniform or exponential losses


Rainfall-Runoff Modeling
Basic premise: Peak discharges from rainfall-runoff models are assumed to have the same percent chance of exceedance as the rainfall input.
To compensate for this assumption, rainfall-runoff models should be calibrated to streamflow data or regression equations.


Rainfall-Runoff Modeling
The reasonableness of the discharges from a rainfall-runoff model is judged by comparison with discharges from:
• Gaging station data in the study area
• Regional regression equations
• Effective discharges from previous FIS


Rainfall-Runoff Modeling
Rainfall – Runoff Model Validation:
• Calibrate model parameters to known storms (exceeding 10% annual chance events) or floodflow frequency curve
• Compare model computed peak flood discharges
• Published regional studies – USGS Regional Regression Equations
• Flood discharges developed from gaging station data in similar watersheds
• Indirect method – High water marks at bridges



Current Valid Precipitation Frequency References

CURRENT VALID PRECIPITATION FREQUENCY REFERENCES

	5 min – 60 min	1 hr – 24 hr	2 day – 10 day
Western US	Arkell & Richards (1986) Frederick & Miller (1979)	NOAA Atlas 2 (1973)	Tech. Paper 49 (1964)
Eastern US	Tech. Memo 35 (1977)	Tech. Paper 40 (1961)	Tech. Paper 49 (1964)
Hawaii	Tech. Paper 43 (1962)	Tech. Paper 43 (1962)	Tech. Paper 43 (1962)
Alaska	Tech. Paper 47 (1963)	Tech. Paper 52 (1965)	Tech. Paper 52 (1965)
Puerto Rico	Tech. Paper 42 (1961)	Tech. Paper 42 (1961)	Tech. Paper 53 (1965)

SOURCE: NOAA – National Weather Service
Hydrometeorological Design Studies Center Website

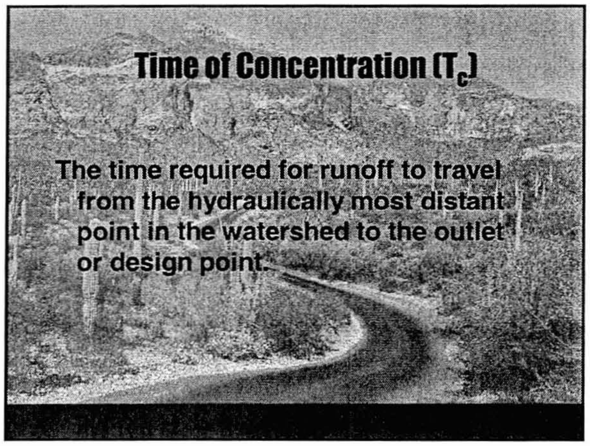
Rainfall Distribution

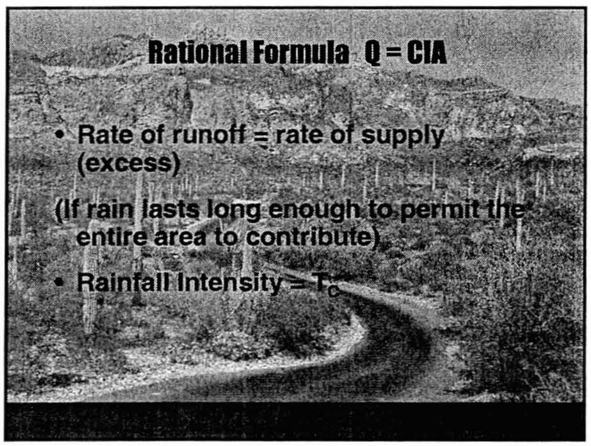
Rainfall Distribution

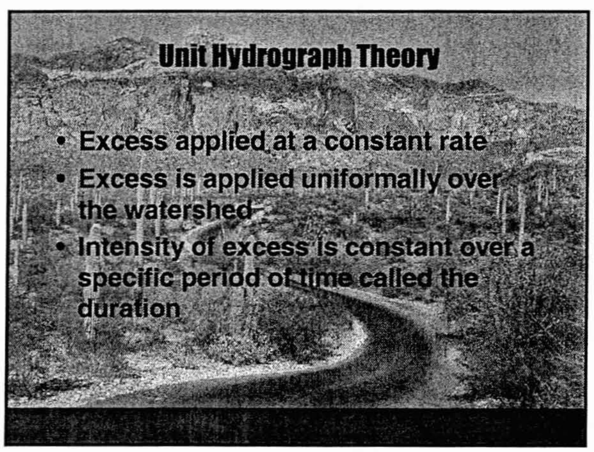
Ratios to obtain n-minute estimates from 1-hour values

	Ratio to 1-hour			
Duration (minutes)	Arkell & Richards[1] (1986)		NOAA Atlas 2	NWS Technical Paper No. 24
	2-year	100-year		
5	0.34	0.30	0.29	0.32
10	0.51	0.46	0.45	0.49
15	0.62	0.59	0.57	0.59
30	0.82	0.80	0.74	0.78

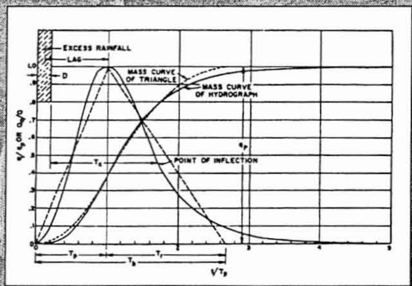
[1] Region 8 – Southwest Deserts


Time of Concentration (T_c)
The time required for runoff to travel from the hydraulically most distant point in the watershed to the outlet or design point.


Rational Formula Q = CIA
• Rate of runoff = rate of supply (excess)
(If rain lasts long enough to permit the entire area to contribute)
• Rainfall Intensity = T_C

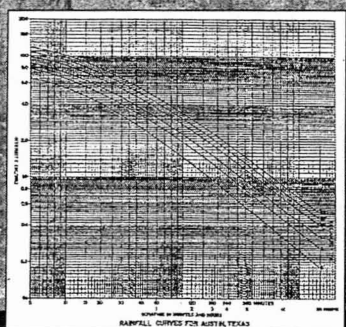

Unit Hydrograph Theory
• Excess applied at a constant rate
• Excess is applied uniformally over the watershed
• Intensity of excess is constant over a specific period of time called the duration

NRCS DIMENSIONLESS UNIT HYDROGRAPH



T_c determines the shape of the runoff hydrograph

Intensity-Duration-Frequency (IDF) for Austin, Texas



Precipitation Intensity is an essential determinant in the hydrologic response of a watershed

Intensity (in./hr.)	Duration (hrs.)	Volume (in.)
24	0.25	6
12	0.50	6
6	1.00	6
3	2.00	6
2	3.00	6
1	6.00	6

Precipitation events with similar intensities may have significantly different volumes and durations when there is a difference in frequency

Frequency (yr.)	Duration (mins.)	Volume (in.)	Intensity (in./hr.)
10	15	1.54	6.2
5	10	1.05	6.3
2	5	0.54	6.5

"Nested" Rainfall Intensity

The inclusion of short duration rainfall intensities within longer duration storms.

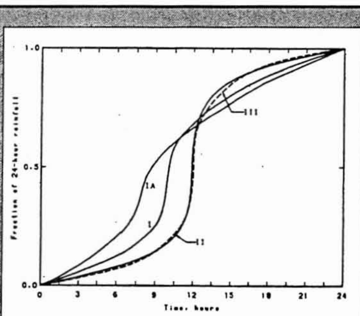


Figure B-1.—SCS 24-hour rainfall distributions.

NRCS 24-hour rainfall distributions

Rainfall Depth-Duration (1% annual chance precipitation)

	Precipitation Depth (Inch)			
Time	NWS TP-40/Hydro-35	NRCS 24-Hour, Type II	Austin, TX IDF (3-hour)	USGS WRIR 98-4044
5 min.	0.88	0.63	0.99	—
10 min.	1.48	1.26	1.71	—
15 min.	1.91	1.89	2.26	2.33
30 min.	3.03	3.80	3.38	2.89
60 min.	4.20	—	—	3.97
1 hr.	4.25	4.52	4.67	4.34
2 hr.	4.75	5.37	4.75	5.54
3 hr.	5.95	5.95	6.87	6.06
6 hr.	7.25	7.07	—	6.79
12 hr.	8.75	8.41	—	8.27
24 hr.	10.00	10.00	—	9.22

Rainfall-Runoff Modeling HEC-1 Input

PH RECORD – HYPOTHETICAL STORMS (NWS, 24-HOUR)

			PHNR							
ID	PFREQ	TRSBA	5-min.	15-min.	60-min.	2-hr.	3-hr.	6-hr.	12-hr.	24-hr.
PH	–	–	0.88	1.91	4.20	4.75	5.96	7.25	8.75	10.00

PC RECORD – CUMULATIVE PRECIPITATION TIME SERIES (NRCS TYPE II, 24-HOUR)

3.80

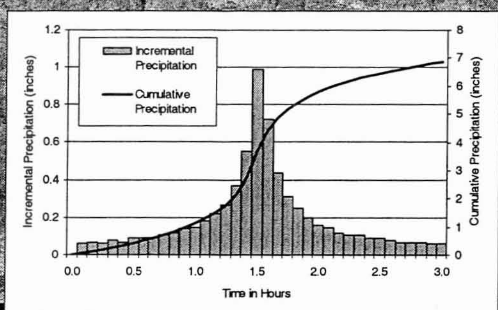
ID	PRCPS(1)		PRCPR(n)							
PC	0	0.06	0.11	0.16	0.22	0.28	0.36	0.41	0.48	0.56
PC	0.63	0.71	0.80	0.89	0.98	1.09	1.20	1.33	1.47	1.63
PC	1.81	2.04	2.35	2.83	6.83	7.35	7.72	7.49	8.20	8.38
PC	8.54	8.68	8.80	8.91	9.02	9.12	9.21	9.29	9.37	9.45
PC	9.52	9.59	9.65	9.72	9.78	9.84	9.89	9.95	10.00	

PI PI RECORD-INCREMENTAL PRECIPITATION TIME SERIES (NRCS TYPE II, 24-HOUR)

3.80

ID	STORM									
ID	PRCPR(1)		PRCPR(n)							
PB	10									
PI	0	0.053	0.055	0.056	0.059	0.061	0.063	0.067	0.069	0.072
PI	0.183	0.234	0.309	0.3482	3.779	0.719	0.373	0.266	0.208	0.183
PI	0.477	0.080	0.085	0.090	0.097	0.105	0.114	0.126	0.139	0.158
PI	0.158	0.138	0.125	0.113	0.105	0.096	0.91	0.086	0.080	0.075
PI	0.073	0.069	0.066	0.064	0.060	0.059	0.066	0.066	0.063	

Incremental and Cumulative Precipitation Time Series



Application Case Study

- Upper Walnut Creek
- Austin, Texas
- 0.5-square mile watershed
- 3-watershed subareas
- Detention Pond
  - Excavated volume 22-acre feet
  - Outlet-pipe culvert at Road Crossing
  - Minimum pond elevation 838.05 feet, NGVD
  - Top of embankment 850.50 feet, NGVD

Peak Discharge Comparison (cfs)

HEC-1 Model Operation	NWS		NCRS		IDF Austin, TX
	3-hr	24-hr	3-hr	24-hr	3-hr
Runoff	194	217	207	231	230
Combine	458	529	477	583	537
Pond Route	301	344	311	362	348
Channel Route	279	325	290	343	330
Combine	1,058	1,243	1,140	1,343	1,249
Maximum Pond Elevation*	847.1	848.6	847.4	849.3	848.76

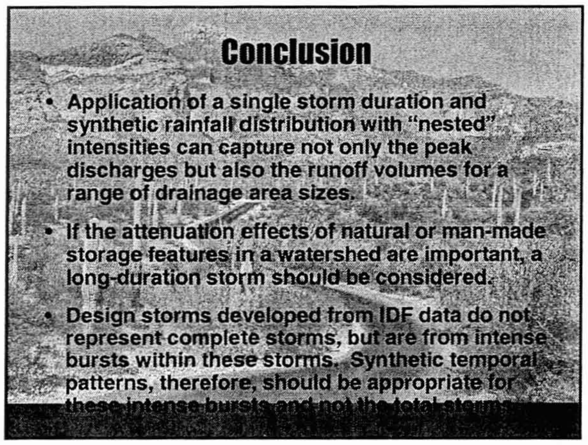
Detention pond top of embankment elevation 850.50 feet, NGVD

Water Surface Elevation Comparison (feet, NGVD)

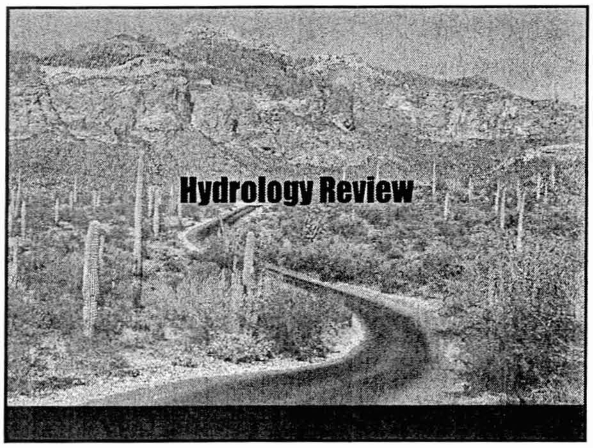
	Balanced Storm NWS			NRCS Type II			Austin, TX IDF	Diff. NRCS
	3-hr.	24-hr.	Diff.	3-hr.	24-hr.	Diff.	3-hr.	24-hr.
	821.25	821.54	0.29	821.38	821.70	0.31	821.56	0.14
	823.14	823.68	0.54	823.38	823.70	0.32	823.69	0.01
	822.82	823.22	0.40	822.95	823.26	0.31	823.24	0.02
	825.83	826.15	0.32	825.99	826.37	0.38	826.16	0.21
	828.43	828.80	0.37	828.60	828.94	0.34	828.81	0.13
	833.56	833.91	0.35	833.73	834.09	0.36	833.92	0.17
	837.93	838.29	0.36	838.09	838.46	0.37	838.30	0.16
	840.99	841.40	0.41	841.18	841.60	0.42	841.41	0.19
	842.35	842.79	0.44	842.55	843.02	0.47	842.81	0.21
Detention Pond	847.10*	848.61*	1.51	847.10*	849.30*	2.20	848.76*	0.54
Detention Pond	847.10*	848.61*	1.51	847.41*	849.30*	1.89	848.76*	0.54
	852.52	857.65	0.13	852.59	852.72	0.13	852.72	0
	857.23	857.36	0.13	857.30	857.44	0.14	857.43	0.01
	859.69	859.83	0.14	859.77	859.90	0.13	859.90	0

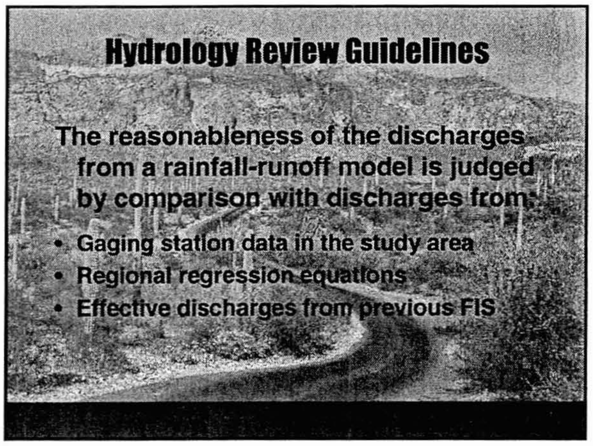
* Hydrograph Routing Results from HEC-1

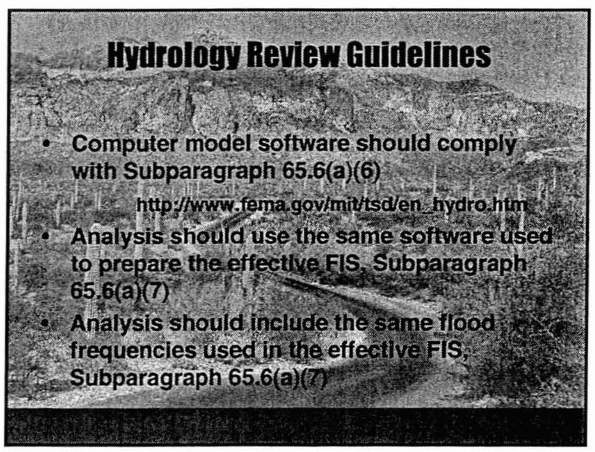
Detention Pond top of embankment elevation 850.50 feet, NGVD


Conclusion
• Application of a single storm duration and synthetic rainfall distribution with "nested" intensities can capture not only the peak discharges but also the runoff volumes for a range of drainage area sizes.
• If the attenuation effects of natural or man-made storage features in a watershed are important, a long-duration storm should be considered.
• Design storms developed from IDF data do not represent complete storms, but are from intense bursts within these storms. Synthetic temporal patterns, therefore, should be appropriate for

CTP


Hydrology Review


Hydrology Review Guidelines
The reasonableness of the discharges from a rainfall-runoff model is judged by comparison with discharges from:
• Gaging station data in the study area
• Regional regression equations
• Effective discharges from previous FIS


Hydrology Review Guidelines
• Computer model software should comply with Subparagraph 65.6(a)(6)
http://www.fema.gov/mit/tsd/en_hydro.htm
• Analysis should use the same software used to prepare the effective FIS, Subparagraph 65.6(a)(7)
• Analysis should include the same flood frequencies used in the effective FIS, Subparagraph 65.6(a)(7)

Hydrology Review Guidelines (cont.)

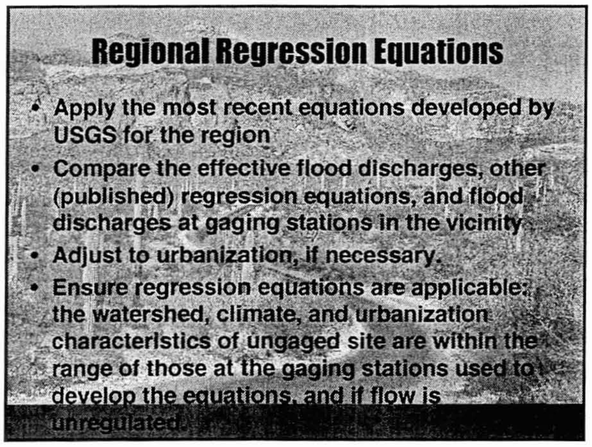
- Proposed hydrology from Rainfall/Runoff models should be compared with the effective hydrology and regional regression equations or streamflow recorded on similar watersheds
- Proposed hydrology should be significantly different as measured by confidence limits (statistically) than the effective hydrology; Subparagraph 65.6(a)(5)

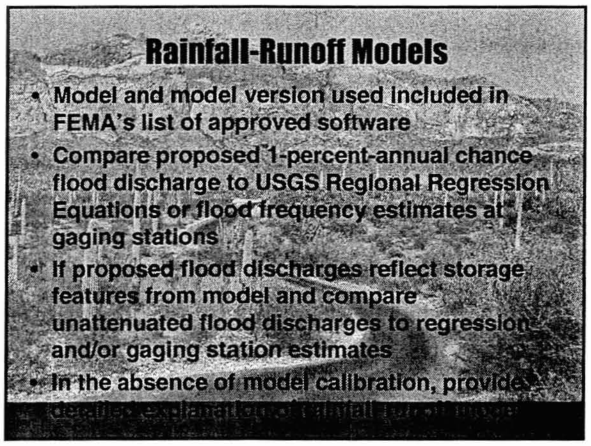
Review of Proposed Discharges

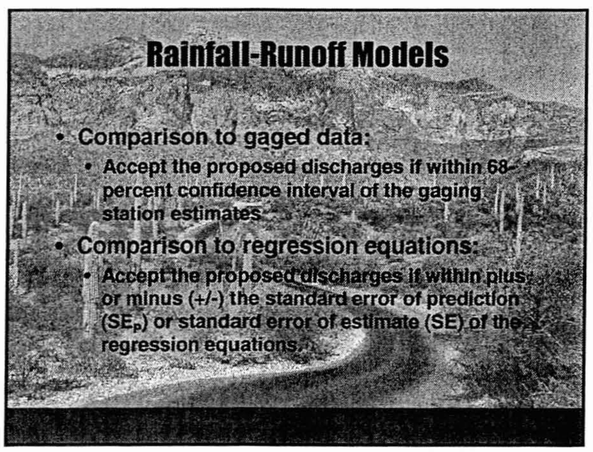
- Assessment of "Reasonableness"
- Comparison to Regression Equations
- Review of Applied Methodology
- Also, consider effect of Proposed Discharge on 1-percent-annual-chance Water Surface Elevations (BFE's)

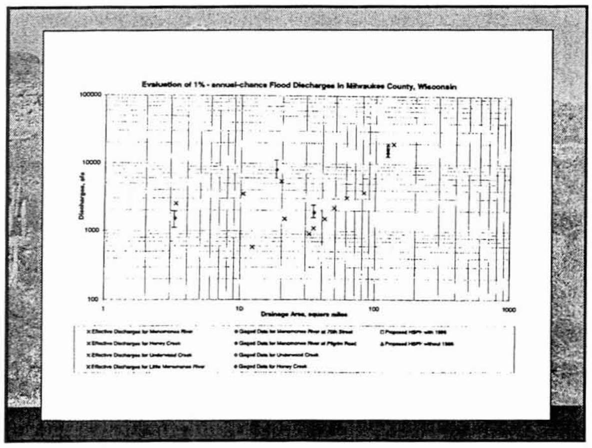
Gaging Station Data

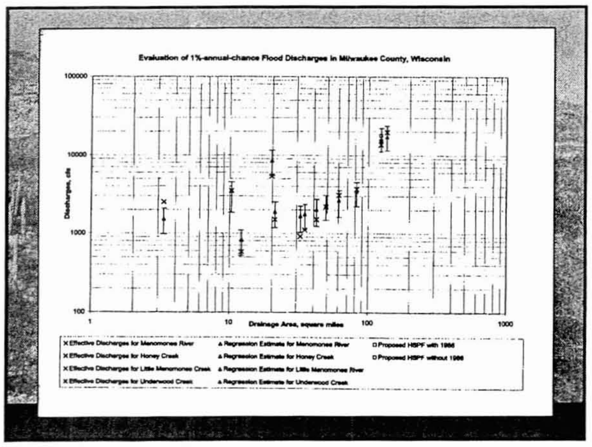
- Conforms to Bulletin 17B guidelines
- At least 10-years of record to define the 1-percent-annual-chance flood
- At least 10-years of non-zero record in arid regions
- Less than 10-year of record
  - Compare to precipitation data
  - Regional estimates for similar watershed

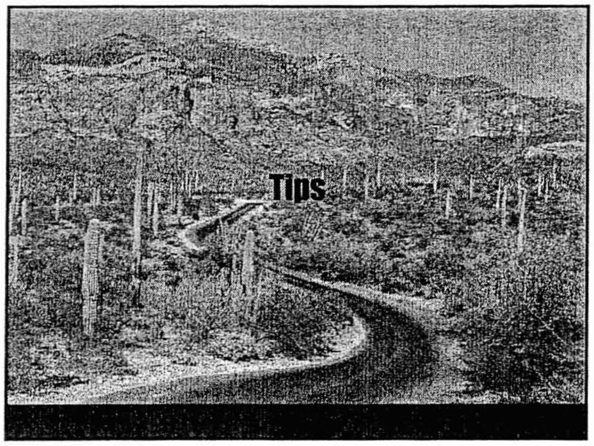

Regional Regression Equations
• Apply the most recent equations developed by USGS for the region
• Compare the effective flood discharges, other (published) regression equations, and flood discharges at gaging stations in the vicinity
• Adjust to urbanization, if necessary.
• Ensure regression equations are applicable: the watershed, climate, and urbanization characteristics of ungaged site are within the range of those at the gaging stations used to develop the equations, and if flow is unregulated.

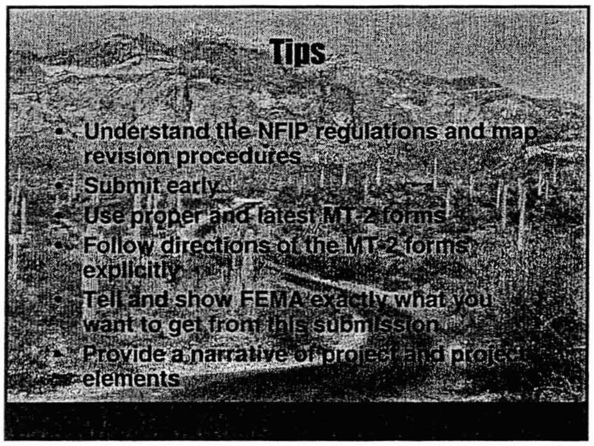

Rainfall-Runoff Models
• Model and model version used included in FEMA's list of approved software
• Compare proposed 1-percent-annual chance flood discharge to USGS Regional Regression Equations or flood frequency estimates at gaging stations
• If proposed flood discharges reflect storage features from model and compare unattenuated flood discharges to regression and/or gaging station estimates
• In the absence of model calibration, provide

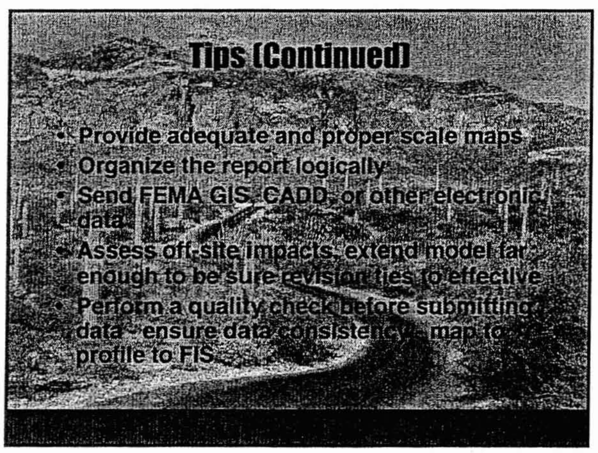

Rainfall-Runoff Models
• Comparison to gaged data:
• Accept the proposed discharges if within 68-percent confidence interval of the gaging station estimates
• Comparison to regression equations:
• Accept the proposed discharges if within plus or minus (+/-) the standard error of prediction (SEp) or standard error of estimate (SE) of the regression equations.


Evaluation of 1% - annual-chance Flood Discharges in Milwaukee County, Wisconsin
Discharges, cfs
100000
10000
1000
100
1
10
100
1000
Drainage Area, square miles


Evaluation of 1%-annual-chance Flood Discharges in Milwaukee County, Wisconsin
Discharges, cfs
100000
10000
1000
100
1
10
100
1000
Drainage Area, square miles
Effective Discharges for Menomonee River
Effective Discharges for Honey Creek
Effective Discharges for Little Menomonee Creek
Effective Discharges for Underwood Creek
Regression Estimate for Menomonee River
Regression Estimate for Honey Creek
Regression Estimate for Little Menomonee River
Regression Estimate for Underwood Creek
Proposed HSPF with 1986
Proposed HSPF without 1986


Tips


Tips
• Understand the NFIP regulations and map revision procedures
• Submit early
• Use proper and latest MT-2 forms
• Follow directions of the MT-2 forms explicitly
• Tell and show FEMA exactly what you want to get from this submission
• Provide a narrative of project and project elements


Tips (Continued)
• Provide adequate and proper scale maps
• Organize the report logically
• Send FEMA GIS, CADD, or other electronic data
• Assess off-site impacts, extend model far enough to be sure revision ties to effective
• Perform a quality check before submitting data - ensure data consistency - map to profile to FIS

Tips (Continued)

- Respond to additional data requests from FEMA in a timely manner
- Coordinate with community PRIOR to submitting to FEMA
- Use CHECK-2 and CHECK-RAS programs from FEMA web site

Additional Information

- Questions: 1-877-FEMA-MAP (Toll Free)
- Map Service Center: 1-800-358-9616
- Useful Web Pages
  - FEMA Engineers and Surveyors Web Pages (Forms)
    - http://www.fema.gov/mit/tsd/en_main.htm
  - FEMA Guidelines and Specs for Study Contractors
    - http://www.fema.gov/mit/tsd/DL_[illegible].htm
  - How to Order FIS Data
    - http://www.fema.gov/[illegible]/ST_order.htm

Additional Information (cont.)

- Useful Web Pages (continued)
  - Title 44 of the CFR (FEMA)
    - http://www.access.gpo.gov/nara/cfr/waisidx_99/44cfrv1_99.html
  - NFIP Information for State and Local Officials
    - http://www.fema.gov/nfip/g_info.htm
  - FEMA FAQ for Floodplain Managers
    - http://www.fema.gov/mit/tsd/FQ_genFP.htm

APPENDIX A

- **Data Request**

- **Flood Map – Related Fees**

- **FEMA Forms MT - 2**

Flood Insurance Study (FIS) Data Requests

The Federal Emergency Management Agency (FEMA) has identified seven categories into which requests for FIS data are separated. se categories are:

Category 1 - Paper copies, diskettes, or microfiche of hydrologic and hydraulic backup data for current or historical FISs
Category 2 - Paper or Mylar copies of topographic mapping developed during the FIS process
Category 3 - Paper copies or microfiche of survey notes developed during FIS process
Category 4 - Paper copies of individual Letters of Map Change
Category 5 - Paper copies of preliminary map panels
Category 6 - Computer tapes or CD-ROMs of Digital Line Graph or Digital Flood Insurance Rate Map files
Category 7 - Computer diskette and user manuals for FEMA models (e.g., wave height, wave run up, alluvial fan)

A non-refundable fee of $120 will be required to initiate requests for data from categories 1, 2, and 3. This fee will cover the preliminary costs of research and retrieval. The costs of processing requests in categories 1, 2, and 3 will vary based on the complexity of the research involved in retrieving the data and the volume and medium of the data to be reproduced and distributed. The initial fee will be applied against the total costs to process the data request, and the requester will be invoiced for the remainder of the fee. No data will be provided to a requester until the entire fee has been paid.

The final fees for processing FIS data requests for Categories 1, 2, and 3 are calculated by adding labor charges (actual hours times $33 per hour); reproduction costs of materials used; and a standard charge to cover the costs related to library maintenance.

No initial fee will be required to initiate requests for data from categories 4 through 7. Each requester will be contacted regarding the availability of the materials and the fee associated with obtaining the requested materials. No data will be provided to a requester until the fee has been paid.

The costs of processing requests under categories 4 through 7 will not vary. Therefore, FEMA has established the flat user fees shown below for these categories of requests.

Category 4 - $40 for first letter; $10 for each additional letter
Category 5 - $35 for first panel; $2 for each additional panel
ıtegory 6 - $150 for first county; $100 for each additional county in the same request
ategory 7 - $25 per copy

The following information should be included in your written request:

- Complete community name (including county and state)
- Community identification number, if known
- Name(s) of flooding source(s) and specific location(s) for which data are needed
- Specific data needed (see list of available products above)
- Effective date of FIRM/FBFM for which data are requested (enclose an annotated copy of FIRM/FBFM, if available, identifying area of interest)
- Contact person's name, address, and telephone number
- File format of digital mapping, if desired in a format other than Micro Station (DGN)
- Projection and horizontal datum of digital mapping, if desired in a format other than UTM and NAD27

Federal Emergency Management Agency

Washington, D.C. 20472

The average request takes 2 to 3 weeks to fill.

You will be contacted after we have determined whether the requested data are available and the final fee is assessed.

Checks or money orders should be made payable to the NATIONAL FLOOD INSURANCE PROGRAM. Please include your check, if applicable, with your written request and mail to:

Requests for data for states in FEMA Regions I through IV (Alabama, Connecticut, Delaware, D.C., Florida, Georgia, Kentucky, Maine, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Puerto Rico, Rhode Island, South Carolina, Tennessee, Vermont, Virginia, Virgin Islands, and West Virginia) should be sent to:

Dewberry & Davis LLC
2977 Prosperity Avenue
Fairfax, Virginia 22031
Tel (703) 876-0148
Fax (703) 876-0073

Requests for data for states in FEMA Regions V through VII (Arkansas, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Minnesota, Missouri, Nebraska, New Mexico, Ohio, Oklahoma, Texas, and Wisconsin) should be sent to:

PBS&J
12101 Indian Creek Court
Beltsville, Maryland 20705
Tel (301) 210-6800
Fax (301) 210-5435

Requests for data for states in FEMA Regions VIII through X (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming) should be sent to:

Michael Baker Jr., Inc.
3601 Eisenhower Avenue
Suite 600
Alexandria, Virginia 22304
Tel (703) 960-8800
Fax (703) 329-3023

If paying by credit card, please complete the Credit Card Information Form and mail it or send a facsimile of it with your request.

Data will be released upon receipt of final payment.

FEDERAL EMERGENCY MANAGEMENT AGENCY **CREDIT CARD INFORMATION**	**FEMA USE ONLY**	*O.M.B. No. 3067-0147* *Expires April 30, 2001*

PAPERWORK REDUCTION ACT

Public reporting burden for this form is estimated to average 6 minutes per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing and reviewing the form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, S.W., Washington, DC 20472, Paperwork Reduction Project (3067-0147). You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Please do not send your completed form to the above address.

If paying by credit card, this form must be completed. **THIS FORM MUST BE MAILED OR FAXED TO:**

Federal Emergency Management Agency
Revisions Fee-Collection System Administrator
P.O. Box 398
Merrifield, Virginia 22116-3173
Fax: (703) 849-0282

Request # ____________________ (if known)   Amount: $______________

☐ INITIAL FEE   ☐ FINAL FEE   ☐ MASTERCARD   ☐ VISA

CARD NUMBER

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

EXP. DATE

☐☐ - ☐☐
Month   Year

____________________   ____________________
Date   Signature

NAME (AS IT APPEARS ON CARD): ____________________

ADDRESS: ____________________

____

DAYTIME PHONE: ____________________

Flood Insurance Study (FIS) Data Request Form

se provide the following information as applicable for the area where you require data:

- Complete community name (including county and state) ______________________________

- Community identification number, if known ______________________________

- Name(s) of flooding source(s) and specific location(s) for which data are needed ______________________________
  (Attach FIRM panel showing subject area if available)
  ____
  ____

- Specific data needed (see list of available products on previous page) ______________________________
  ____

- Effective date of FIRM for which data are requested (enclose an annotated copy of FIRM/FBFM, if available, identifying area of interest) ______________________________

- File format of digital mapping (choose one):
  - MicroStation DGN ☐
  - ArcView SHP ☐
  - ArcInfo E00 ☐

  Projection of digital mapping:
  UTM ☐ State Plane ☐ Other ☐ Specify ________

  Horizontal Datum:
  NAD27 ☐ NAD83 ☐ Other ☐ Specify ________

  Units:
  Feet ☐ Meters ☐

- Contact person and Firm/Agency name ______________________________
- Email Address ______________________________
- Daytime Phone/fax number: ph ______________ fax ______________
- Mailing Address ______________________________
  ____
  ____

- I am employed by (choose one):

☐ Private Firm ☐ State Agency ☐ Federal Agency ☐ Local Gov't ☐ FEMA Study Contractor* ☐ Other

* Please provide contract number ______________

Federal Emergency Management Agency
Washington, D.C. 20472

Flood Hazard Mapping

Flood Hazard

Flood Map-Related Fees

This page outlines the revised fee schedule for processing certain types of requests for changes to National Flood Insurance Program (NFIP) maps. The change in the fee schedule will allow FEMA to further reduce the expenses to the NFIP by more fully recovering the costs associated with processing conditional and final map change requests. The revised fee schedule for map changes is effective for all requests dated **September 1, 2002**, or later and supersedes the current fee schedule, which was established on June 1, 2000.

Current requirements are summarized below and available for download. The revised fees include those associated with single-lot/single-structure Conditional Letters of Map Amendment (CLOMAs), Conditional Letters of Map Revision - based on Fill (CLOMR-Fs), and Letters of Map Revision - based on Fill (LOMR-Fs) requests, and certain Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) requests.

For information on Map and Insurance products, please see the Map Service Center web site.

The files are available for download in WinZip and Adobe PDF format. The PDF file(s) may not display correctly with older versions of Adobe Reader. For best results it is recommended that the latest version of the Adobe Reader that is available for your Operating System be used to view the file(s). Click on the "More Info" icon if you need additional information about how to obtain and use the free Adobe Reader or WinZip.

Download Notices in Adobe PDF Format

Federal Register notice announcing revised fees, effective as of September 1, 2002. (85 KB PDF file)

More Information about Adobe® Reader®

Get help with acronyms used on this page.

CURRENT FEE SCHEDULE FOR MITIGATION PRODUCTS AND SERVICES (effective as of September 1, 2002).

Requests for Single Lot, Single Structure Map Change	Fee	Comment
Single lot, single structure LOMA	Free	N/A
Single lot, single structure CLOMA and CLOMR-F	$500	Flat Fee
Single lot, single structure LOMR-F	$425	Flat Fee
Single lot, single structure LOMR-F based on as-built information (CLOMR-F previously issued by FEMA)	$325	Flat Fee

Requests for Multiple Lot, Multiple Structure Map Change	Fee	Comment
Multi-lot, multi-structure LOMA	Free	N/A
CLOMA	$700	Flat Fee
CLOMR-F and LOMR-F	$800	Flat Fee
LOMR-F based on as-built information (CLOMR-F previously issued by FEMA)	$700	Flat Fee

Requests for Map Change Requiring Special Technical Review	Fee	Comment
CLOMR based on new hydrology, bridge, culvert, channel or combination thereof	$4,000	Flat Fee
CLOMR based on levee, berm, or other structural measures	$4,500	Flat Fee
LOMR/PMR based on bridge, culvert, channel or combination	$4,200	Flat Fee
LOMR/PMR based on levee, berm, or other structural measures	$6,000	Flat Fee
LOMR based on as-built information (CLOMR previously issued by FEMA)	$3,800	Flat Fee
LOMR/PMR based solely on submission of more detailed data	Free	N/A
LOMR/CLOMR based on structural measures on alluvial fans	$5,000	Initial fee plus $50 per hour. Requester will be invoiced for remaining balance

Payment must be received before services will be rendered. Check, money orders, and credit cards are accepted.

Exemptions to the above Map Change Fees:

- Map changes based on mapping or study analysis errors;
- Map changes based on the effects of natural changes within the SFHA;
- Requests for LOMAs;
- Federally sponsored flood-control projects where 50 percent or more of the project's costs are federally funded;
- Map changes based on detailed hydrologic and hydraulic studies conducted by Federal, State, or local agencies to replace approximate studies conducted by FEMA and shown on the effective FIRM; and
- Map changes based on flood hazard information meant to improve upon that shown on the flood map or within the flood study. *NOTE: Improvements to flood maps or studies that partially or wholly incorporate man-made modifications within the SFHA will not be exempt from fees.*

Requests for Flood Insurance Back-up Data	Fee
1. Paper copies, diskettes or microfiche of hydrologic and hydraulic back-up data	$120 initial fee. Final fee based on $33/hour research plus expenses
2. Paper or mylar copies of topographic mapping	$120 initial fee. Final fee based on $33/hour research plus expenses
3. Paper copies or microfiche of survey notes	$120 initial fee. Final fee based on $33/hour research plus expenses
4. Paper copies of individual Letters of Map Change	$40 for first letter. Additional letters are $10 each
5. Paper copies of Preliminary Flood Insurance Rate Maps	$35 for first panel of the community. Additional panels $2 each. Additional communities $24 first panel, $2 additional panels
6. Computer tapes and CD-ROMs of Digital Line Graphs or DFIRMs	$150 for first community, $100 each additional community
7. Computer diskettes and user manuals for FEMA computer programs	$25 per copy

Categories 1, 2, and 3 require payment before materials are provided. For Categories 4 through 7, we will phone you about the availability of materials and provide an estimate of fees before payment is due.

Fee exemptions for Flood Insurance Study Back-up Data:

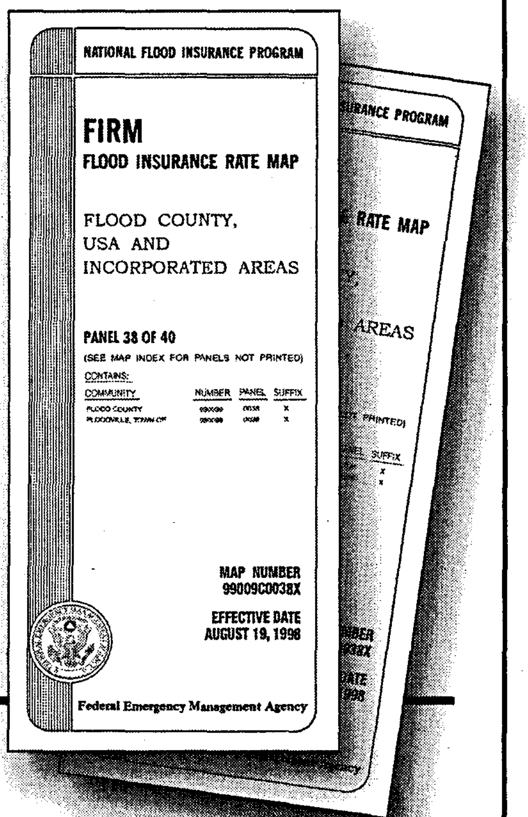
- Private architectural-engineering firms under contract to us to perform or evaluate studies and restudies
- Federal agencies that perform or contract for studies and restudies for us (i.e., U.S. Army Corps of Engineers, U.S. Geological Survey, Natural Resources Conservation Service, and Tennessee Valley Authority)
- Communities that supply digital community GIS data to us and request the Digital Line Graph data or DFIRM files (Category 6)
- Communities that request data during the statutory 90-day appeal period for an initial or revised FIS for that community
- Mapped participating communities that request data at any time other than during the statutory 90-day appeal period, provided that the

MT-2

FEDERAL INSURANCE AND MITIGATION ADMINISTRATION
HAZARD MAPPING DIVISION

REVISIONS TO NATIONAL FLOOD INSURANCE PROGRAM MAPS

APPLICATION FORMS AND INSTRUCTIONS FOR CONDITIONAL LETTERS OF MAP REVISION AND LETTERS OF MAP REVISION



MT-2
FEMA FORM 81-89 SERIES
SEPT 02

FEMA

Federal Emergency Management Agency

INSTRUCTIONS FOR COMPLETING THE APPLICATION FORMS FOR CONDITIONAL LETTERS OF MAP REVISION AND LETTERS OF MAP REVISION

GENERAL

In 1968, the U.S. Congress passed the National Flood Insurance Act, which created the National Flood Insurance Program (NFIP). The NFIP was designed to reduce future flood losses through local floodplain management and to provide protection for property owners against potential losses through flood insurance.

As part of the agreement for making flood insurance available in a community, the NFIP requires the participating community to adopt floodplain management ordinances containing certain minimum requirements intended to reduce future flood losses. The NFIP regulations for floodplain management are the minimum criteria a community must adopt for participation in the NFIP. The community is responsible for approving all proposed floodplain development and for ensuring that permits required by Federal or State law have been received. State and community officials, based on knowledge of local conditions and in the interest of safety, may set higher standards for construction or may limit development in floodplain areas. If the State or Community has adopted more restrictive or comprehensive floodplain management criteria, those criteria take precedence over the minimum NFIP requirements.

The community is also responsible for submitting data to the Federal Emergency Management Agency (FEMA) reflecting revised flood hazard information so that NFIP maps can be revised as appropriate. This will allow risk premium rates and floodplain management requirements to be based on current data.

Submissions to FEMA for revisions to effective Flood Insurance Studies (FISs), Flood Insurance Rate Maps (FIRMs), or Flood Boundary Floodway Maps (FBFMs) by individual and community requesters will require the signing of application forms. These forms will provide FEMA with assurance that all pertinent data relating to the revision are included in the submittal. They will also ensure that: (a) the data and methodology are based on current conditions; (b) qualified professionals have assembled data and performed all necessary computations; and (c) all individuals and organizations affected by proposed changes are aware of the changes and will have an opportunity to comment on them.

If the submission involves revisions to multiple flooding sources, then separate forms should be completed for each flooding source.

NFIP regulations can be accessed at http://www.access.gpo.gov/nara/cfr/waisidx_00/44cfrv1_00.html or can be obtained by calling FEMA's Map Assistance Center at 1-877-FEMA MAP (1-877-336-2627). FEMA's Internet site at http://www.fema.gov/mit/tsd/frm_form.htm provides access to the forms and latest fees and revision procedures. FEMA is preparing online tutorials to assist users of the NFIP maps. The tutorials for revisions to the NFIP maps are currently being prepared and will be available soon. Other online tutorials are available at http://www.fema.gov/mit/tsd/ot_main.htm.

WHEN TO USE THESE FORMS

This package is applicable for requests of the following:

Conditional Letter of Map Revision (CLOMR)	A letter from FEMA commenting on whether a proposed project, if built as proposed, would meet minimum NFIP standards or proposed hydrology changes [see 44 Code of Federal Regulations (CFR) Ch. 1, Parts 60, 65, and 72].
Letter of Map Revision (LOMR)	A letter from FEMA officially revising the current NFIP map to show changes to floodplains, floodways, or flood elevations (see 44 CFR Ch. 1, Parts 60, 65, and 72).

WHEN NOT TO USE THESE FORMS

This package is not applicable for requests of the following:

Letter of Map Amendment (LOMA)	A letter from FEMA stating that an **existing** structure or parcel of land that has not been elevated by fill (**natural ground**) would not be inundated by the base flood.
Conditional Letter of Map Amendment (CLOMA)	A letter from FEMA stating that a **proposed** structure that is not to be elevated by fill (**natural ground**) would not be inundated by the base flood if built as proposed.
Letter of Map Revision Based on Fill (LOMR-F)	A letter from FEMA stating that an **existing** structure or parcel of land that has been **elevated by fill** would not be inundated by the base flood.
Conditional Letter of Map Revision Based on Fill (CLOMR-F)	A letter from FEMA stating that a parcel of land or **proposed** structure that will be **elevated by fill** would not be inundated by the base flood if fill is placed on the parcel as proposed or the structure is built as proposed.

For these requests, either the MT-EZ form package titled *Amendments to National Flood Insurance Program Maps, Application Form for Single Residential Lot or Structures,* or the MT-1 form package titled *Amendments and Revisions to National Flood Insurance Program Maps, Application Forms and Instructions for Letters of Map Amendment, Conditional Letters of Map Amendment, Letters of Map Revision Based on Fill, and Conditional Letters of Map Revision Based on Fill* are appropriate. The MT-EZ forms are used for single structure or lot requests that do not involve the placement of fill. The MT-1 forms are used for requests involving multiple structures or lots. The MT-EZ form package may be downloaded from FEMA's Internet site at http://www.fema.gov/mit/tsd/dl_mt-ez.htm, and the MT-1 form package may be downloaded from FEMA's Internet site at http://www.fema.gov/mit/tsd/dl_mt-1.htm. Either form package may also be obtained by calling FEMA's Map Assistance Center at 1-877-FEMA MAP (1-877-336-2627).

SUMMARY OF FORMS

Application forms for requesting a revision from FEMA are included in the back of this package. There are six forms plus a payment form in this package, which cover various situations for revisions. When submitting a request only the forms applicable to the request need to be submitted. The following is a list of the forms and a brief summary of when each is applicable.

Form 1 - Overview & Concurrence Form provides the basic information regarding the revision request and requires the signatures of the requester, community official, and engineer. This form is required for all revision requests.

Form 2 - Riverine Hydrology & Hydraulics Form provides the basic information on the scope and methodology of hydrologic and/or hydraulic analyses that are prepared in support of the revision request. This form should be used for revision requests that involve new or revised hydrologic and/or hydraulic analyses of rivers, streams, ponds, or small lakes.

Form 3 - Riverine Structures Form provides the basic information regarding hydraulic structures constructed in the stream channel or floodplain. This form should be used for revision requests that involve new or proposed channelization, bridges/culverts, dams, and/or levees/floodwalls.

Form 4 - Coastal Analysis Form provides the basic information on the scope and methodology of coastal analyses that are prepared in support of the revision request. This form should be used for any revision requests that involve new or revised coastal analyses.

Form 5 - Coastal Structures Form provides the basic information regarding hydraulic structures constructed along the coast. This form should be used for revision requests that involve new or proposed levees/dikes, breakwaters, bulkheads, seawalls, and/or revetments located along the coast.

Form 6 - Alluvial Fan Flooding Form provides the basic information for analyses of alluvial fans. This form should be used for revision requests involving alluvial fans.

Payment Information Form - Provides the basic information regarding any fees paid for a CLOMR, LOMR, or External Data Request.

FEES

FEMA has implemented a procedure to recover costs associated with reviewing and processing requests for modifications to published flood information and maps. The current fees for review and processing of CLOMR and LOMR requests may be obtained from FEMA's Internet site at http://www.fema.gov/mit/tsd/frm_fees.htm or by calling FEMA's Map Assistance Center at 1-877-FEMA MAP (1-877-336-2627).

Some requests for revisions may be exempt from the fees. NFIP Regulation, 44 CFR Ch. 1, Section 72.5, describes the circumstances for requests to be exempt from paying the fees. The exemptions are also described on FEMA's Internet site at http://www.fema.gov/mit/tsd/frm_fees.htm.

Payment must be made by credit card, check or money order. Checks and money orders should be made payable in U.S. funds to the National Flood Insurance Program. Please forward payment along with a completed Payment Information Form to the following address:

Using U.S. Postal Service:
Federal Emergency Management Agency
Revisions Fee-Collection System Administrator
P.O. Box 3173
Merrifield, VA 22116-3173

Using Overnight Service:
Revisions Fee-Collection System Administrator
c/o Dewberry & Davis, LLC METS Division
8401 Arlington Boulevard, Stop 19A
Fairfax, VA 22031

Please note, that the fee is to be sent to a different address than the request package. See page 4 for where to submit the request package.

WHAT TO SUBMIT

A CLOMR or LOMR request should include the application forms along with the appropriate supporting information. A notebook-style format is preferred. The submittal should include the following:

1. Completed application forms.
2. Narrative on project and submittal (optional but very helpful). Knowing the project and purpose of the request better ensures the needs of the requester are met.
3. Hydrologic Computations (if applicable) along with digital files of computer models used.
4. Hydraulic Computations (if applicable) along with digital files of computer models used.
5. Certified topographic map with floodplain and floodway (if applicable) delineations.
6. Annotated FEMA FIRM and/or FBFM to reflect changes due to project (FIRMs and /or FBFMs can be ordered on-line at http://msc.fema.gov/stores/MSC).
7. Items required to satisfy any FEMA NFIP regulatory requirements.

Before FEMA will replace the effective FIS information with the revised, the requester must: (a) provide all of the data used in determining the revised floodplain boundaries, flood profiles, floodway boundaries, etc.; (b) provide all data necessary to demonstrate that the physical modifications to the floodplain meet NFIP regulations, have been adequately designed to withstand the impacts of the 1% annual chance flood event, and will be adequately maintained; and (c) demonstrate that the revised information (e.g., hydrologic and hydraulic analyses and the resulting floodplain and floodway boundaries) is consistent with the effective FIS information.

Where to Submit

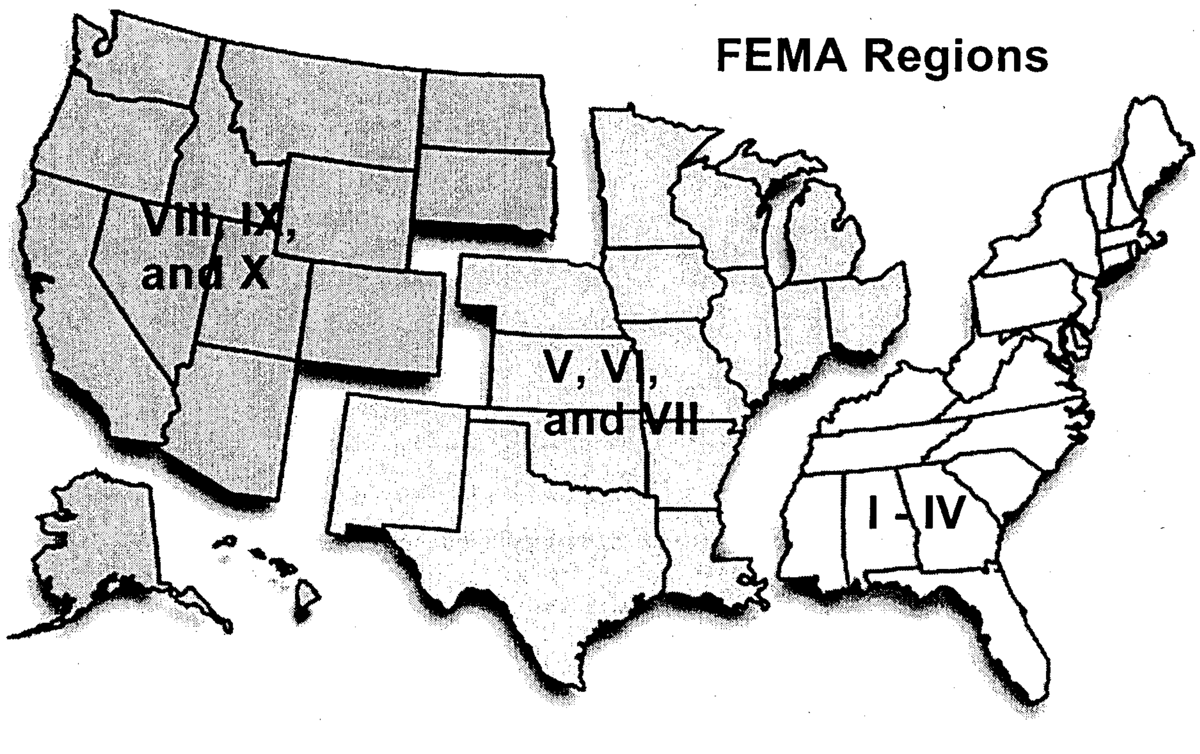
The completed package should be submitted to the appropriate address indicated in the following table. Note, fees are submitted to a separate address (see "Fees," page 3).

If your request includes property in...

Regions VIII, IX, and X	Regions V, VI, and VII	Regions I - IV
Alaska, American Samoa, Arizona, California, Colorado, Guam, Hawaii, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, U.S. Trust Territory of the Pacific Islands, Utah, Washington, and Wyoming	Arkansas, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Minnesota, Missouri, Nebraska, New Mexico, Ohio, Oklahoma, Texas, and Wisconsin	Alabama, Connecticut, Delaware, District of Columbia, Florida, Georgia, Kentucky, Maine, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Puerto Rico, Rhode Island, South Carolina, Tennessee, U.S. Virgin Islands, Vermont, Virginia, and West Virginia

Mail your request to...

FEMA Map Coordination Contractor 3601 Eisenhower Avenue, Suite 600 Alexandria, VA 22304-6425	FEMA Map Coordination Contractor 12101 Indian Creek Court Beltsville, MD 20705	FEMA Map Coordination Contractor P.O. Box 2210 Merrifield, VA 22116-2210



INSTRUCTIONS FOR COMPLETING THE OVERVIEW & CONCURRENCE FORM (FORM 1)

This form provides the basic information regarding revision requests and must be submitted with each request. It contains much of the material needed for the Federal Emergency Management Agency (FEMA) to assess the nature and complexity of the proposed revision. It will identify: (a) the type of response expected from FEMA; (b) those elements that will require supporting data and analyses; and (c) items needing concurrence of others. This form will also ensure that the community is aware of the impacts of the request and has notified affected property owners, if required. All items must be completed accurately. If the revision request is being submitted by an individual, firm, or other non-community official, contact should be made with appropriate community officials. National Flood Insurance Program (NFIP) regulation Title 44 CFR Ch. 1, Section 65.4, requires that revisions based on new technical data be submitted through the Chief Executive Officer (CEO) of the community or a designated official. Should the CEO refuse to submit such a request on behalf of another party, FEMA will agree to review it only if written evidence is provided indicating that the CEO or designee has been requested to do so.

Section A: Requested Response from FEMA

Indicate the type of response being requested. Brief descriptions of possible responses are provided in the introduction; more detail regarding these responses and the data required to obtain each response are provided in the NFIP regulations, Title 44 CFR Ch. 1.

Section B: Overview

1. The Community Number, Community Name, State, Map Number, Panel Number, and Effective Date can be obtained from the Flood Insurance Rate Map (FIRM) title block. The sample FIRM panels (Figures 1 and 2) provide a convenient example of information to complete item 1.

2. Flooding source refers to a specific lake, stream, ocean, etc. This should match the flooding source name shown on the FIRM, if it has been labeled. (Examples: Lake Michigan, Duck Pond, or Big Hollow Creek).

3. Project Name/Identifier can be the name of a flood control project or other pertinent structure having an impact on the effective FIS, the name of a subdivision or area, or some other identifying phrase.

4. The zone designations affected can be obtained from the FIRM.

5. a. Indicate the basis for the revision request.
    - Physical Changes include watershed development, flood control structures, etc. Note that fees will be assessed for FEMA's review of proposed and "as-built" projects, as outlined in NFIP regulations 44 CFR Ch. 1, Part 72.
    - Improved Methodology/Data may be a different technique (model) or adjustments to models used in the effective FIS.
    - Regulatory Floodway Revisions involve any shift in the FEMA-designated floodway boundaries, regardless of whether the shift is mappable.
    - Other involves any basis for the request not including the above items.

    b. Indicate the types of flooding and structure(s) associated with the revision request.

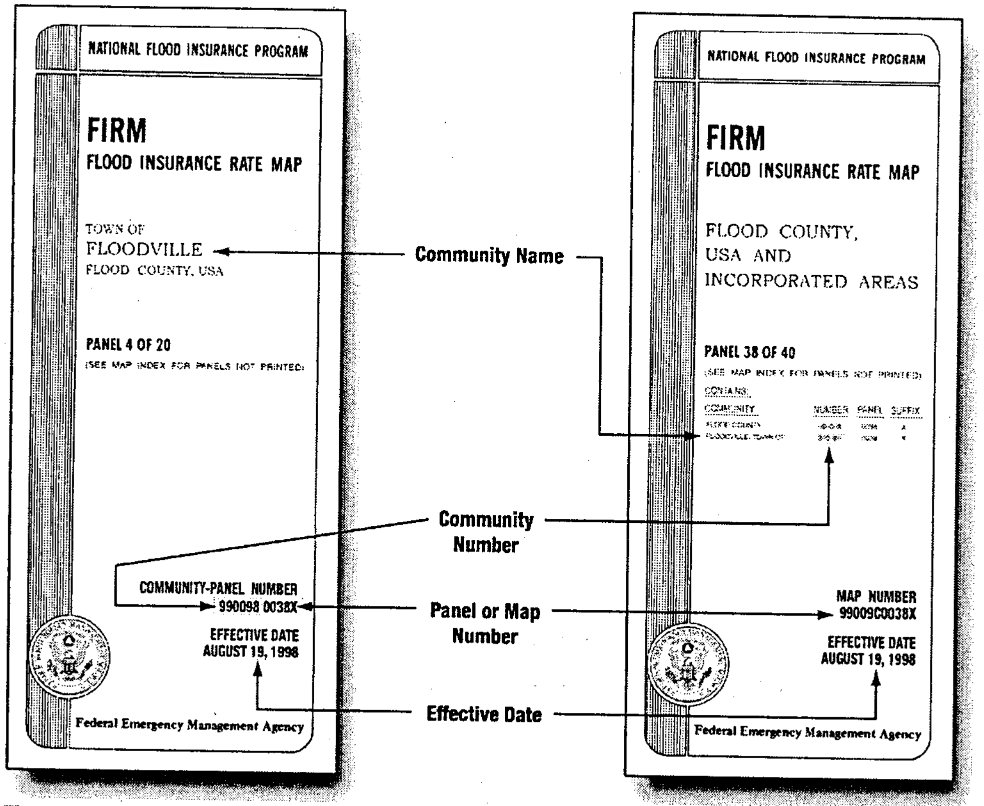


Figure 1. Sample FIRM Panel (Single Community)

Figure 2. Sample FIRM Panel (Countywide)

Section C: Review Fee

Enter the fee amount associated with the request, or attach an explanation as to why the revision meets the requirements for a fee exemption. The current fees for review and processing of Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) requests may be obtained from FEMA's Internet site at http://www.fema.gov/mit/tsd/frm_fees.htm.

Section D: Signature

Signature and Title of Revision Requester

The person signing this certification should own the property involved in the request or have legal authority to represent a group/firm/organization or other entity in legal actions pertaining to the NFIP.

The requester is responsible for obtaining all necessary Federal, State, and local permits as a condition of obtaining a LOMR or CLOMR. The community is required to make sure that all necessary permits have been obtained prior to issuing a floodplain development permit. The most commonly required Federal permits are wetlands permits under Section 404 of the Clean Water Act of 1972 and incidental take permits under Section 10 of the Endangered Species Act of 1972. Necessary State permits vary depending on the State. If the requester needs a wetlands permit or is not sure if one is required, he should contact the U.S. Army Corps of Engineers District Office. If the requester's proposed development impacts threatened or endangered species or if he is unsure if it does, he should consult with the nearest U.S. Fish and Wildlife Service field office.

Signature and Title of Community Official

The person signing this certification should be the CEO for the community involved in this revision request or an official legally designated by the CEO. If more than one community is affected by the change, the community official from the community that is most affected should sign the form, and letters from the other affected communities should be enclosed. If the community or communities disagree with the proposed revision, a signed statement should be attached to the request explaining the reasons or basis for disagreement.

Under 44 CFR 60.3(a)(2), the community is required to ensure, prior to issuing a floodplain development permit that an applicant has obtained all necessary Federal and State permits related to development. The most commonly required Federal permits are wetlands permits under Section 404 of the Clean Water Act of 1972 and incidental take permits under Section 10 of the Endangered Species Act of 1972. Necessary State permits vary depending on the State. If the community is not sure if a wetlands permit is required, refer the applicant to the U.S. Army Corps of Engineers District Office. If the proposed development impacts on threatened or endangered species or the community is unsure if it does, have the applicant consult with the nearest U.S. Fish and Wildlife Service field office.

Certification by Registered Professional Engineer and/or Land Surveyor

The person certifying this submittal must provide a valid license number and expiration date for their license. If this information is provided, affixing a seal is optional. If a seal is available, however, it may be affixed in the seal box provided on this form. The licensed professional engineer and/or land surveyor should have a current license in the State where the affected communities are located. While the individual signing this form is not required to have obtained the supporting data or performed the analyses, he or she must have supervised and reviewed the work.

A certification by a registered professional engineer or other party does not constitute a warranty or guarantee of performance, expressed or implied. Certification of data is a statement that the data is accurate to the best of the certifier's knowledge. Certification of analyses is a statement that the analyses have been performed correctly and in accordance with sound engineering practices. Certification of structural works is a statement that the works are designed in accordance with sound engineering practices to provide protection from the 1% annual chance flood. Certification of "as-built" conditions is a statement that the structure(s) has been built according to the plans being certified, is in place, and is fully functioning.

If the requester is a Federal agency who is responsible for the design and construction of flood control facilities, a letter stating that, "the analyses submitted have been performed correctly and in accordance with sound engineering practices" may be submitted in lieu of certification by a registered professional engineer. Regarding the certification of completion of flood control facilities, a letter from the Federal agency certifying its completion and the flood frequency event to which the project protects may be submitted in lieu of this form.

Forms Submitted

Indicate which forms are submitted with the revision request.

INSTRUCTIONS FOR COMPLETING THE RIVERINE HYDROLOGY & HYDRAULICS FORM (FORM 2)

This form should be used for revision requests that involve new or revised hydrologic and/or hydraulic analyses of rivers, streams, ponds, or small lakes. A separate form should be used for each flooding source.

Section A: Hydrology

This section is to be completed when discharges other than those used in the effective Flood Insurance Study (FIS) are proposed.

1. Indicate the reason for the new or revised hydrologic analysis. For revisions based on alternative methodologies or improved data, an explanation as to why the alternative methodology or improved data provides better results over the FIS must be presented and supported throughout the form.

2. Compare the effective 1% annual chance (100-year) discharges to the revised 1% annual chance discharges at three representative locations.

   In accordance with National Flood Insurance Program (NFIP) regulations, if only a portion of a detailed study stream is revised, transition to the unrevised portion must be ensured to maintain the continuity of the study. Attach an explanation of how the proposed discharge in the revised portion of the stream transitions to the effective discharge in the unrevised portion of the stream, and vice versa.

3. Specify the method used for the new analysis. Attach any additional backup computations and supporting data such as a drainage area map, soils map, soil group names, time of concentration computations, curve numbers, etc. Disks with the digital models should also be included. Models submitted in support of a revision request must meet the requirements of Subparagraph 65.6(a)(6) of the NFIP regulations. A list of accepted FEMA hydrologic models can be found at http://www.fema.gov/mit/tsd/en_hydro.htm.

4. If approval of the new hydrologic analysis is required by a local, State, or Federal agency, indicate if the analysis and resulting peak discharge value(s), have been approved by the appropriate local, State, or Federal agency and attach evidence of the approval.

5. In locations where sediment transport affects hydrology, the effects of sediment transport should be considered in the hydrology and Section F of Form 3 should be submitted.

Section B: Hydraulics

This section is to be completed when the request involves a hydraulic analysis for riverine flooding that differs from that used to develop the Flood Insurance Rate Map (FIRM).

1. Indicate the reach of stream to be revised. The area of the revision is defined by an effective tie-in at the upstream and downstream limits. For streams that have a detailed study, an effective tie-in is obtained when the revised base flood and floodway elevations are within 0.5 feet of the effective elevations, and the revised floodway encroachment stations match the effective floodway stations at both the upstream and downstream limits. For streams that do not have a detailed study, an effective tie-in is obtained when the revised base flood elevations are within 0.5 feet of the pre-project conditions model at both the upstream and downstream limits. Please note that the area of revision and the project area are not necessarily the same. If the revised model does not tie-in to the effective study at the project limits, the model must be extended upstream and downstream until it ties-in to the effective study.

2. Indicate the Hydraulic Method used for the revision. A list of Hydraulic models accepted by FEMA can be found at http://www.fema.gov/mit/tsd/en_hydra.htm. If using a hydraulic model that does not appear on the list of accepted models, please provide documentation showing that the model meets the requirements of NFIP regulation 65.6(a)(6).

3. Indicate if the CHECK-2 or CHECK-RAS programs were used to verify that the hydraulic estimates and assumptions in the model are comparable to the assumptions and limitations of HEC-2 or HEC-RAS. CHECK-2 and CHECK-RAS are review tools that identify areas of potential error or concern. These tools do not replace engineering judgment. CHECK-2 and CHECK-RAS can be downloaded from FEMA's Internet site at http://www.fema.gov/mit/tsd/frm_soft.htm. We recommend that you review your HEC-2 and HEC-RAS models with CHECK-2 and CHECK-RAS. If you disagree with the comment messages, please attach an explanation of why the messages are not valid in each case. To reduce processing time, review your hydraulic model and resolve valid modeling discrepancies, before submitting it for review.

4. Indicate the hydraulic models submitted.

Submittal requirements for areas that have detailed flooding: Printouts of input and output listings along with files on diskette or CD for each of the models and supporting data (e.g., description of vegetation and land use map) for the source of input parameters used in the models listed below must be provided. The summary must include a description of any changes made from model to model (e.g., Duplicate Effective Model to Corrected Effective Model). At a minimum, the Duplicate Effective Model and the Revised or Post-Project Conditions Model must be submitted. The hydraulic analyses shall be performed for all flood frequencies and the floodway published in the effective FIS.

Submittal requirements for areas that do not have detailed flooding: Only the 1% annual chance (Base) flood computations are required. A hydraulic model is not required for areas that do not have detailed flooding; however, Base Flood Elevations (BFEs) may not be added to the revised FIRM. If a hydraulic model is developed for the area, the Existing or Pre-project Model and the Revised or Post-Project Conditions Model, if applicable, described below must be submitted.

Duplicate Effective Model

The duplicate effective model is a copy of the hydraulic analysis used in the effective FIS, referred to as the effective model. The effective model should be obtained and then reproduced on the requester's equipment to produce the duplicate effective model. This is required to ensure that the effective model's input data has been transferred correctly to the requester's equipment and to ensure that the revised data will be integrated into the effective data to provide a continuous FIS model upstream and downstream of the revised reach.

For information on how to obtain copies of the effective FIS models, see FEMA's Internet site at http://www.fema.gov/mit/tsd/st_order.htm. If data from the effective model is available and the same modeling program is being used, the requester must generate models that duplicate the FIS profiles and the elevations shown in the Floodway Data Table in the FIS report to within 0.1 foot. The appropriate FEMA Regional Office should be contacted if this model cannot be produced. See Appendix C for the addresses and telephone numbers of FEMA's Regional Offices. If the effective model is not available, the new model must be calibrated to reproduce the FIS profiles within 0.5 foot. If an alternative hydraulic model is used, it must be shown that the use of the original model is inappropriate and the new model must be calibrated to reproduce the FIS profiles within 0.5 foot.

Corrected Effective Model

The Corrected Effective Model is the model that corrects any errors that occur in the Duplicate Effective Model, adds any additional cross sections to the Duplicate Effective Model, or incorporates more detailed topographic information than that used in the current effective model. The Corrected Effective Model must not reflect any man-made physical changes since the date of the effective model. An error could be a technical error in the modeling procedures, or any construction in the floodplain that occurred prior to the date of the effective model but was not incorporated into the effective model.

Existing or Pre-Project Conditions Model

The Duplicate Effective Model or Corrected Effective Model is modified to produce the Existing or Pre-Project Conditions Model to reflect any modifications that have occurred within the floodplain since the date of the Effective model but prior to the construction of the project for which the revision is being requested. If no modification has occurred since the date of the effective model, then this model would be identical to the Corrected Effective Model or Duplicate Effective Model. The existing or pre-project model may be required to support conclusions about the actual impacts of the project associated with the revised or post-project model or to establish more up-to-date models on which to base the revised or post-project conditions model.

Revised or Post-Project Conditions Model

The Existing or Pre-Project Conditions Model (or Duplicate Effective Model or Corrected Effective Model, as appropriate) is modified to reflect revised or post-project conditions. This model must incorporate any physical changes to the floodplain since the effective model was produced as well as the effects of the project. When the request is for a proposed project, this model must reflect proposed conditions.

The information requested on the Riverine Hydrology & Hydraulics Form is intended to document the steps taken by the requester in the process of preparing the revised or post-project conditions hydraulic model and the resulting revised FIS information. The following guidelines should be followed when completing the form:

- All changes to the duplicate and subsequent models must be supported by certified topographic information, bridge plans, construction plans, survey notes, etc.

- Changes to the hydraulic models should be limited to the stream reach for which the revision is being requested. Cross sections upstream and downstream of the revised reach should be identical to those in the effective model. If this is done, water surface elevations and topwidths computed by the revised models should match those in the effective models upstream and downstream of the revised reach as required.

- There must be consistency between the revised hydraulic models, the revised floodplain and floodway delineations, the revised flood profiles, topographic work map, annotated FIRMs and/or Flood Boundary Floodway Maps (FBFMs), construction plans, bridge plans, etc.

Section C: Mapping Requirements

A certified topographic map of suitable scale, contour interval, and planimetric definition must be submitted showing the applicable items indicated on the form. If a digital version of the map is available, it may be submitted so that the FIRM may be more easily revised.

Attach an annotated FIRM panel showing the revised 1% and 0.2% annual chance floodplains and floodway boundaries. The revised boundaries must tie into the effective boundaries. The annotated FIRM ensures that FEMA is aware of how the requester anticipates the FIRM will be revised.

Section D: Common Regulatory Requirements

1. Indicate "yes" for the following situations:
    - Projects that will have construction within the floodway, which cause the BFEs to increase (more than 0.00 feet), or
    - Projects that will have construction within the floodplain of streams that have a detailed effective study, but for which a floodway has not been established, which cause the BFEs to increase more than 1.0 foot (or any other more stringent requirement set by the community or State).

    If either of the two situations occurs, then the conditions in NFIP Regulation 44 CFR Ch. 1, Section 65.12 must be met. The conditions of NFIP Regulation 44 CFR Ch. 1, Section 65.12 include:

- An evaluation of alternatives, which would not result in a BFE increase above that permitted demonstrating why these alternatives are not feasible;
- Documentation of individual legal notice to all affected property owners within and outside of the community, explaining the impact of the proposed action on their property;
- Concurrence of the Chief Executive Officer (CEO) and any other communities affected by the proposed actions; and
- Certification that no structures are located in areas that would be impacted by the increased base flood elevation.

2. Indicate if the placement of fill is involved with the revision request. Fill is defined as material from any source placed to raise the ground to or above the BFE. If fill has been placed to remove an area or structure from the Special Flood Hazard Area (SFHA), the community must sign the appropriate section of Form 1 certifying that the area to be removed from the special flood hazard area, to include any structures or proposed structures, (will) meets all of the standards of the local floodplain ordinances, and is reasonably safe from flooding in accordance with NFIP Regulation 44 CFR 65.2(c). "Reasonably safe from flooding" means that the base flood waters will not inundate the land or damage the structures to be removed from the SFHA and that any subsurface waters related to the base flood will not damage existing or proposed buildings. Information on ensuring that structures built on fill in or near the SFHA are reasonably safe from flooding may be obtained from FEMA's Technical Bulletin 10-01, "Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe from Flooding," which is available on FEMA's Internet site at http://www.fema.gov/pdf/fima/tb1001.pdf.

3. Indicate if the request involves a floodway revision. If the floodway is being revised, the requirements of NFIP Regulation 44 CFR Ch. 1, Section 65.7 must be met. These requirements include submitting a copy of a public notice distributed by the community stating the community's intent to revise the floodway or a statement by the community that it has notified all affected property owners and affected adjacent jurisdictions. Samples of a public notice and of an individual notification for a floodway revision are shown in Figures 3 and 4, respectively.

4. Indicate if property owner notification and acceptance (if available) are required because the revision request involves increases in flood hazards from those shown on the FIRM. FEMA must provide a statutory 90-day appeal period for all map revisions entailing Base (1% annual chance [100-year]) Flood Elevation (BFE) changes. LOMRs with decreasing flood hazards (1% annual chance water-surface elevations, floodplains, or floodways) typically are effective the day of issuance, with any necessary appeal period provided afterwards. LOMRs with increasing flood hazards typically are not effective until after any required appeal period has expired and any necessary ordinance changes have been made by the community (3 to 6 months). However, a LOMR that reflects increasing flood hazards may be effective on the day of issuance if all property owners affected by these increases are notified and approve of the increases, and the community concurs with the revision. Samples of individual notifications for various increases in the SFHAs, BFEs, and floodways are shown on Figures 4 through 8.

The {insert community name} {insert appropriate community department for floodplain management}, in accordance with National Flood Insurance Program regulation 65.7(b)(1), hereby gives notice of the {insert community designation Township's / Village's/ Borough's / County's} intent to revise the floodway, generally located between {insert general location of floodway revision}. Specifically, the floodway shall be revised from a point {describe downstream limit of floodway revision} to a point {describe upstream limit of floodway revision}. As a result of the floodway revision, the floodway shall {widen and/or narrow} with a maximum widening of {insert maximum widening} feet at a point approximately {insert location of widening} and/or a maximum narrowing of {insert maximum narrowing} feet at a point approximately {insert location of narrowing}.

Maps and detailed analysis of the floodway revision can be reviewed at the {insert location} at {insert location address}. Interested persons may call {insert community contact name or position} at {insert contact phone number} for additional information from ... to ... {insert dates during which community contact person can be contacted}.

Figure 3.
SAMPLE NOTIFICATION FOR LOMR FLOODWAY REVISION
(to be used by community when placing a notice in a newspaper)

{Date}

{Affected property owner name}
{Affected property owner mailing address}

Re: Notification of Floodway Revision for {flooding source}

Dear Mr./Ms./Mr. & Mrs. {Affected property owner}

The Flood Insurance Rate Map (FIRM) for a community depicts the floodplain, the area which has been determined to be subject to a 1% (100-year) or greater chance of flooding in any given year. The floodway is the portion of the floodplain that includes the channel of a river or other watercourse and the adjacent land area that must be reserved in order to discharge the base flood without cumulatively increasing the water-surface elevation by more than a designated height.

The {insert community name} {insert appropriate community department for floodplain management}, in accordance with National Flood Insurance Program regulation 65.7(b)(1), hereby gives notice of the {insert community designation Township's / Village's/ Borough's / County's} intent to revise the 1% annual chance (100-year) floodway, generally located between {insert general location of floodway revision}. Specifically, the floodway shall be revised from a point {describe downstream limit of floodway revision} to a point {describe upstream limit of floodway revision}. As a result of the floodway revision the floodway shall {widen and/or narrow} with a maximum widening of {insert maximum widening} feet at a point approximately {insert location of widening} and a maximum narrowing of {insert maximum narrowing} feet at a point approximately {insert location of narrowing}.

Maps and detailed analysis of the floodway revision can be reviewed at the {insert location} at {insert location address}. If you have any questions or concerns about the proposed project or its affect on your property, you may contact {name of appropriate community official} of {name of community} at {community official contact information} from ... to ... {insert dates during which community contact person can be contacted}.

Sincerely,

{Community official name}
{Community official position}
{Community official contact information}

Figure 4.
SAMPLE LETTER FOR LOMR FLOODWAY REVISION NOTIFICATION
(to be used by community if notifying property owners individually by letter)

{Date}

{Affected property owner name}
{Affected property owner mailing address}

Re: Notification of increases in 1% (100-year) annual chance water-surface elevations

Dear Mr./Ms./Mr. & Mrs. {Affected property owner}

The Flood Insurance Rate Map (FIRM) for a community depicts land which has been determined to be subject to a 1% (100-year) or greater chance of flooding in any given year. The FIRM is used to determine flood insurance rates and to help the community with floodplain management.

{Revision Requester} is applying for a Conditional Letter of Map Revision from the Federal Emergency Management Agency (FEMA) on behalf of {Revision requester's client} to revise FIRM {insert FIRM #, panel #, and suffix} for {insert community name, state} along {insert name of flooding source}. {Revision requester's client} is proposing {describe project} as part of {explain project purpose}.

The proposed project will result in increases {and decreases} in the 1% annual chance water-surface elevations for {insert flooding source} with a maximum increase of {enter maximum increase} feet at a point approximately (location of maximum increase} and a maximum decrease in the 1% annual chance water-surface elevation of {enter maximum decrease} feet at a point approximately {location of maximum decrease}.

This letter is to inform you of the proposed increases in the 1% annual chance water-surface elevations on your property at {insert physical address}.

If you have any questions or concerns about the proposed project or its affect on your property, you may contact {name of appropriate community official} of {name of community} at {community official contact information} from ... to ... {insert dates during which community contact person would like to be contacted}.

Sincerely,

{Revision requester name}

Figure 5.
SAMPLE LETTER FOR CLOMR NOTIFICATION OF INCREASES IN BFEs

{Date}

{Affected property owner name}
{Affected property owner mailing address}

Re: Notification of {widening and/or narrowing} of 1% (100-year) annual chance floodplain

Dear Mr./Ms./Mr. & Mrs. {Affected property owner}

The Flood Insurance Rate Map (FIRM) for a community depicts land which has been determined to be subject to a 1% (100-year) or greater chance of flooding in any given year. The FIRM is used to determine flood insurance rates and to help the community with floodplain management.

{Revision Requester} is applying for a Letter of Map Revision (LOMR) from the Federal Emergency Management Agency (FEMA) on behalf of {Revision requester's client} to revise FIRM {insert FIRM #, panel #, suffix} for {insert community name, state} along {insert name of flooding source}. {Revision requester} is proposing to revise the FIRM to reflect {describe project}.

The revision to the FIRM will result in widening {and narrowing} of the 1% annual chance (Zone A) floodplain for {insert name of flooding source}. The maximum widening of {enter maximum increase} feet occurs at a point approximately {location of maximum widening} while the maximum narrowing of {enter maximum narrowing} feet occurs at a point approximately {location of maximum narrowing}.

{Choose one of the following two paragraphs}

This letter is to inform you of the revision of the 1% annual chance (Zone A) floodplain on your property at {insert physical address}.

{or}

We would like to obtain your acceptance of revision of the 1% annual chance (Zone A) floodplain on your property at {insert physical address}. Please sign and date the provided copy of this letter to signify your acceptance and return it to {Revision Requester's address} by {insert date to return acceptance by}.

If you have any questions or concerns about the proposed changes to the FIRM or its effects on your property, you may contact me at {Revision requester contact phone number}.

Sincerely,

{Revision requester name}

{Insert the following if asking for property owner acceptance}
I, {insert property owner name}, accept the redelineation of the 1% annual chance floodplain as described above.

______________________________ {insert property owner name}   ______________ Date

Figure 6.
SAMPLE LETTER FOR LOMR NOTIFICATION & ACCEPTANCE IN ZONE A THAT WILL WIDEN AND NARROW THE FLOODPLAIN BUT NOT ESTABLISH BFEs

{Date}

{Affected property owner name}
{Affected property owner mailing address}

Re: Notification of {widening and/narrowing} of 1% (100-year) annual chance floodplain and establishment of Base Flood Elevations

Dear Mr./Ms./Mr. & Mrs. {Affected property owner}

The Flood Insurance Rate Map (FIRM) for a community depicts land which has been determined to be subject to a 1% (100-year) or greater chance of flooding in any given year. The FIRM is used to determine flood insurance rates and to help the community with floodplain management.

{Revision Requester} is applying for a Letter of Map Revision (LOMR) from the Federal Emergency Management Agency (FEMA) on behalf of {Revision requester's client} to revise FIRM {insert FIRM #, panel #, suffix} for {insert community name, state} along {insert name of flooding source}. {Revision requester} is proposing to revise the FIRM to reflect {describe project}.

The Letter of Map Revision will result in:

1. Establishment of Base (1% annual chance) Flood Elevations (BFEs). Currently, the flooding along {flooding source} is based on an approximate study.

2. Widening {and narrowing} of the 1% annual chance floodplain with the maximum widening of {enter maximum increase} feet at a point approximately {location of maximum widening} and the maximum narrowing of {enter maximum narrowing} feet at a point approximately {location of maximum narrowing}.

{Please choose one of the following two paragraphs}

This letter is to inform you of the establishment of Base Flood Elevations and revision of the 1% annual chance floodplain on your property at {insert physical address}.

{or}

We would like to obtain your acceptance of the establishment of Base Flood Elevations and revision of the 1% annual chance floodplain on your property at {insert physical address}. Please sign and date the provided copy of this letter and return it to {Revision Requester's address} by {insert date to return acceptance by}.

If you have any questions or concerns about the proposed changes to the FIRM or its effect on your property, you may contact me at {Revision requester contact phone number}.

Sincerely,

{Revision requester name}

{Insert the following if asking for property owner acceptance}
I, {insert property owner name}, accept establishment of Base Flood Elevation on {insert flooding source name} and redelineation of the 1% annual chance floodplain as described above.

______________________________ _______________

{insert property owner name} Date

Figure 7.
SAMPLE LETTER FOR LOMR NOTIFICATION & ACCEPTANCE IN ZONE A THAT WILL ESTABLISH BFEs & WIDEN AND NARROW THE FLOODPLAIN

{Date}

{Affected property owner name and address}

Re: Notification of 1% (100-year) annual chance water-surface elevation increases {and widening of the 1% annual chance floodplain}

Dear Mr./Ms./Mr. & Mrs. {Affected property owner}

The Flood Insurance Rate Map (FIRM) for a community depicts land which has been determined to be subject to a 1% (100-year) or greater annual chance of flooding in any given year. The FIRM is used to determine flood insurance rates and to help the community with floodplain management.

{Revision Requester} is applying for a Letter of Map Revision (LOMR) from the Federal Emergency Management Agency (FEMA) on behalf of {Revision requester's client} to revise FIRM {insert FIRM #, panel #, suffix} for {insert community name, state} along {insert name of flooding source}. {Revision requester's client} is proposing {describe project} as part of {explain project purpose}.

The Letter of Map Revision will result in:

1. Increases {and decreases} in the 1% annual chance water-surface elevations with a maximum increase of {enter maximum increase} feet at a point approximately {location of maximum increase} and a maximum decrease in the 1% annual chance water-surface elevation of {enter maximum decrease} feet at a point approximately {location of maximum decrease}.

2. Widening {and narrowing} of the 1% annual chance floodplain with the maximum widening of {enter maximum increase} feet at a point approximately {location of maximum widening} and the maximum narrowing of {enter maximum narrowing} feet at a point approximately {location of maximum narrowing}.

{Choose one of the following two paragraphs}

This letter is to inform you of revision of the 1% annual chance water-surface elevation and 1% annual chance floodplain on your property at {insert physical address}.

{or}

We would like to obtain your acceptance of revision of the 1% annual chance water-surface elevation and 1% annual chance floodplain on your property at {insert physical address}. Please sign and date the provided copy of this letter to signify your acceptance and return it to {Revision Requester's address} by {insert date to return acceptance by}.

If you have any questions or concerns about the proposed changes to the FIRM or its effect on your property, you may contact me at {Revision requester contact phone number}.

Sincerely,

{Revision requester name}

{Insert the following if asking for property owner acceptance}
I, {insert property owner name}, accept increases in the 1% annual chance water-surface elevations and redelineation of the 1% annual chance floodplain as described above.

______________________________ ________________
{insert property owner name} Date

Figure 8.
SAMPLE LETTER FOR LOMR NOTIFICATION & ACCEPTANCE THAT WILL RESULT IN INCREASES IN ZONE AE OF BFEs & WIDENING OF THE FLOODPLAIN

INSTRUCTIONS FOR COMPLETING THE RIVERINE STRUCTURES FORM (FORM 3)

This form should be used for revision requests that involve new or proposed channelization, bridges/culverts, dams, and/or levees/floodwalls. Only complete the sections of this form that are applicable to the revision request. A separate form should be used for each flooding source that has structures involved in the revision request.

Section A: General

Provide the name of the structure (e.g., Main Street Bridge or Flood Creek channelization), the type of structure, the location of the structure (e.g., 1000 feet upstream of Main Street or River Mile 10.4), and the appropriate cross-section labels for the structures that are part of the revision request. Attach additional pages if the revision request involves more than 3 structures. This form is not required for existing structures that are included in the hydraulic model for the effective Flood Insurance Rate Map (FIRM).

Section B: Channelization

This section is to be completed when any portion of the stream channel is altered or relocated. The purpose of the Channelization section and the information to be submitted, is to ensure that the channel will function properly as designed and pass the 1% annual chance flood as determined by the hydraulic analysis. When the Channelization section is submitted, a Riverine Hydrologic & Hydraulic Form (Form 2) must also be submitted.

1. Indicate all accessory structures included with the channelization. The accessory structures should be shown on the submitted plans.

2. Attach engineering drawings of the channelization certified by a registered professional engineer. The drawings should include a plan view of the channelization that shows pre-construction topography and post-construction grading, channel cross section, channel lining, channel inlet and outlet, and details for any accessory structures included with the channelization.

   Typically, channelization increases the channel velocity above the natural channel velocity. Provide information that supports the conclusion that the channel lining will withstand the velocities associated with the 1% annual chance flood. The type of channel lining should be indicated on the plans.

3. Indicate the channel design criteria (i.e., capacity and type of flow) and if there is a potential for a hydraulic jump.

4. In locations where sediment transport will affect the Base Flood Elevations (BFEs), the effects of sediment transport should be considered in the channelization analysis and Section F of Form 3 should be submitted.

Section C: Bridge/Culvert

This section is to be completed when the request involves a new bridge or culvert or a new or revised analysis of an existing bridge or culvert.

1. Indicate the reason for the new or revised bridge/culvert modeling.

2. Indicate the model used to analyze the hydraulics at the bridge/culvert. If this model is different than the model used to analyze the flooding on the stream, then include an explanation of why a different model was used to analyze the bridge/culvert.

3. Attach plans of the structure certified by a registered professional engineer. The bridge/culvert plans should include the information listed on the form. Indicate the items included on the plans, and attach an explanation of why any information is not included.

4. In locations where sediment transport will affect the BFEs, the effects of sediment transport should be considered in the bridge/culvert analysis and Section F of Form 3 should be submitted.

Section D: Dam

This section is to be filled out when there is an existing, proposed, or modified dam along a stream studied in detail. Provide a complete engineering analysis and engineering drawings of the dam. The drawings should indicate the dam dimensions (height, top width, side slopes), the crest elevation of the top of the dam, the type of spillway, the spillway dimensions, the crest elevation of the spillway, the type of outlet, the outlet dimensions, and the invert elevation of the outlet.

1. Indicate the reason for the revision request involving a dam.

2. Indicate the agency or organization that designed the dam.

3. Indicate if the hydrologic analysis is revised as a result of the dam. Any storage upstream of the dam, considered in the hydrologic analysis to reduce the peak base flood discharge, should be totally dedicated to flood control. If the outflow of the dam is regulated, submit an explanation of the flow regulation plan. Complete Form 2, Riverine Hydrology & Hydraulics Form, if the hydrology changes.

4. In locations where sediment transport will affect the BFEs, the effects of sediment transport should be considered in the dam analysis and Section F of Form 3 should be submitted.

5. Indicate if the Base Flood Elevations change as a result of the dam. If impacted, list the elevations. Indicate the stillwater elevations behind the dam.

6. Attach a copy of the Operation and Maintenance Plan for the dam with the revision request.

Section E: Levee/Floodwall

This section is to be completed when the revision request involves a new or modified levee and/or floodwall system. A levee is a man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding. The purpose of this section is to ensure that the levee or floodwall is designed and/or constructed to provide protection from the 1% annual chance flood, in full compliance with National Flood Insurance Program (NFIP) Regulation 44 CFR Ch. 1, Section 65.10, before reflecting its effects on an NFIP map.

In addition, a vicinity map along with a complete set of flood profile sheets, plan sheets, and layout detail sheets must be submitted. These sheets must be numbered, and an index must be provided that clearly identifies those sheets specifically relating to the levee or floodwall in question.

1. Indicate all the applicable levee/floodwall system elements, including their locations and types, and provide engineering drawings certified by a registered professional engineer. The drawings should show the items indicated.

2. Indicate the amount of freeboard that the levee has above the base flood elevation. Riverine levees must provide a minimum freeboard of three feet above the BFE. An additional one-half foot above the minimum must be provided at the upstream end of the levee, tapering to not less than the minimum at the downstream end of the levee. An additional one-foot above the minimum freeboard is required on both sides of the river or stream for a distance of 100 feet upstream of structures (such as bridges) riverward of the levee or wherever the flow is constricted. If exceptions to the minimum freeboard requirements are requested, attach documentation addressing NFIP Regulation 44 CFR Ch. 1, Subparagraph 65.10(b)(1)(ii).

   Ice-jams can increase the flood elevations on a stream. Indicate if the stream has a history of ice-jams, and, if so, provide evidence that the minimum freeboard still exists with the ice-jam effects.

3. List the closure devices for all openings through the levee system. All openings must be provided with closure devices that are structural parts of the system during operation and design.

4. Complete the information to show where embankment protection is required, and submit supporting embankment protection analysis. The embankment protection analysis must demonstrate that no appreciable erosion of the levee embankment can be expected during the 1% annual chance flood, as a result of either current or waves, and that anticipated erosion will not result in failure of the levee embankment or foundation directly or indirectly through reduction of the seepage path and subsequent instability. Factors to be addressed include, but are not limited to: expected flow velocities, expected wind and wave action, ice loading, impact of debris, slope protection techniques, duration of flooding at various stages and velocities, embankment and foundation materials, levee alignment, bends, transitions, and levee side slopes. The table provide in the form is for riprap protection. If another method of embankment protection is used, then a table with similar information should be prepared and submitted with the forms.

5. Complete the information to summarize the analysis of the levee and foundation. This analysis must evaluate both stability and seepage during the loading conditions associated with the base flood. The seepage analysis shall demonstrate that seepage into or through the levee embankment and foundation will not result in seepage and piping that will jeopardize the embankment and foundation stability. The slope stability analysis shall demonstrate that the levee cross section is stable under all loading and unloading conditions for the base flood. The analysis should include the river or channel slopes. Guidance on seepage and stability analyses is outlined in the U.S. Army Corps of Engineers (USACE) manual "Design and Construction of Levees," EM 1110-2-1913. This manual may be obtained at http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1913/toc.htm. Additional information on acceptable factors of safety for underseepage is in USACE technical letter "Design Guidance for Levees," ETL 1110-2-555. This technical letter may be obtained from the USACE Internet site at http://www.usace.army.mil/inet/usace-docs/eng-tech-ltrs/etl1110-2-555/toc.html. The factors that must be addressed in these analyses include: depth of flooding, duration of flooding, foundation conditions at the site, embankment and cut slope geometry and length of seepage path at the critical locations, internal drainage in the levee, seepage and/or stability berms and management of trees and vegetation. All backup material for these analyses should be submitted.

6. See above embankment and foundation stability discussion. In addition, waterstops and joint materials should be incorporated into the floodwall design as outlined in USACE manual "Waterstops and Other Preformed Joint Materials for Civil Works Structures," EM 1110-2-2102 to prevent passage of water through the wall. This manual may be obtained at http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-2102/toc.htm.

7. Complete the information to summarize the results from an analysis of potential settling of the levee. The settlement analysis must assess the potential and magnitude of future losses of freeboard and must demonstrate that the minimum freeboard requirements will be maintained. The analysis must address embankment loads, compressibility of embankment soils, compressibility of foundation soils, age of the levee system, and construction compaction methods. In addition, a detailed settlement analysis and determination of the appropriate amount of overbuild using procedures such as those described in USACE manuals "Settlement Analysis," EM 1110-2-1904 and "Design and Construction of Levees," EM 1110-2-1913, Chapter 6, must be submitted. Submit all backup information used in the analysis.

8. Complete the information to summarize an analysis of potential flooding from interior drainage. In accordance with NFIP Regulation 44 CFR Ch. 1, Subparagraph 65.10(b)(6), the interior drainage analysis must be based on the joint probability of interior and exterior flooding and the capacity of facilities for evacuating interior floodwaters. The analysis must identify the extent of the flooded area, and the water-surface elevation(s) of the 1% annual chance flood if the average depth is greater than one foot. This information is to show on a certified topographic work map. Submit the calculation and back-up information for the analysis of flooding potential from interior drainage.

9. Complete the information and attach any supporting documentation regarding the design criteria indicated.

10. Complete the information to summarize the operational plan and criteria. For a levee system to be recognized by the Federal Emergency Management Agency (FEMA), the operational criteria must be as described in NFIP Regulation 44 CFR Ch. 1, Subparagraph 65.10(c).

11. Indicate if the maintenance plan for the levee is in compliance with NFIP Regulation 44 CFR Ch. 1, Subparagraph 65.10(d).

12. Submit a copy of the Operation and Maintenance Plan with the revision request. This plan should address maintenance standards, intervals and procedures. It should also include requirements for management of vegetation similar to what is outlined in USACE manual "Landscape Planting and Vegetation Management for Floodwalls, Levees and Embankment Dams," EM 1110-2-301. This manual can be obtained from the USACE Internet site at http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-301/toc.htm. This plan should also include the design and construction requirements and inspection procedures for future utility crossings. The Operation and Maintenance Plan may not have to be submitted when requesting a Conditional Letter of Map Revision (CLOMR) for a proposed levee. However, it will be required after the levee is constructed and a revision to the FIRM is requested.

Section F: Sediment Transport

Complete the information to summarize an analysis of sediment transport (including scour and deposition) if there is any indication from historical records that sediment transport can affect the BFE, or if based on the stream morphology, vegetative cover, development of the watershed and bank conditions, there is a potential for debris and sediment transport to affect the BFE or a structure. If sediment transport will not affect the BFE or a structure, then indicate that this section is not applicable and include an explanation as to why a sediment analysis was not performed. Please note that bulked flows are used to evaluate the performance of a structure during the base flood, but FEMA does not map BFEs based on bulked flows.

INSTRUCTIONS FOR COMPLETING THE COASTAL ANALYSIS FORM (FORM 4)

The information requested on the Coastal Analysis Form is intended to document the steps taken by the requester in the process of preparing the revised models or analyses and the resulting revised Flood Insurance Study (FIS) information. Refer to the *Consolidated Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D: Guidance for Coastal Flooding Analyses and Mapping,* which can be obtained from the Federal Emergency Management Agency's (FEMA's) Internet site at http://www.fema.gov/mit/tsd/dl_cgs.htm, for the wave height analyses and mapping procedures used by FEMA for coastal areas. Wave height, wave run-up, and storm induced erosion may be analyzed using the program, CHAMP 1.1, which was developed for FEMA. CHAMP 1.1 may be obtained from FEMA's Internet site at http://www.fema.gov/mit/tsd/frm_soft.htm. A list of accepted FEMA coastal models can be found on FEMA's Internet site at http://www.fema.gov/mit/tsd/en_coast.htm. The following guidelines should be followed when completing the form:

Section A: Coastline to be Revised

Describe the limits of the restudied area. Road names and/or landmarks in the vicinity of the restudied area or transects used in the effective FIS may be used as reference points.

Section B: Effective FIS

The type of analyses (approximate or detailed wave parameter computations) used for the effective FIS for the community being restudied must be provided. This information is available in the hydrologic and hydraulic sections of the FIS report.

Section C: Revised Analysis

All changes to effective models must be supported by certified topographic information, structure plans, survey notes, storm surge data, meteorological data, etc. All equations or models used must be referenced. Descriptions and/or sketches of transect profiles should be attached for revised erosion, wave height, wave runup, and wave overtopping analyses. Wave runup and wave overtopping should be considered when the wave heights approach the crest of the shore protection structure or natural land forms. If FEMA procedures are not used in the revised analyses, provide an explanation.

Section D: Results

Information must be provided to determine the impact of the analysis on the mapping of the coastal high hazard areas, including the location of the coastal high hazard area boundaries, maximum wave height elevation, and the maximum wave runup elevation. Mapping resulting from the re-analysis of the effective study must tie-in with areas not re-studied. The mapped inland limit of the coastal high hazard areas (V Zones) as a result of the re-analysis must be in compliance with National Flood Insurance Program (NFIP) Regulation 44 CFR Ch. 1, Section 65.11 in areas where primary frontal dunes are present.

Section E: Mapping Requirements

With the revision request, submit a certified topographic map showing the information indicated in the Mapping Requirements Section of the Coastal Analysis Form. Also submit a copy of the current FIRM annotated to show the revised 1% annual chance floodplain boundaries.

INSTRUCTIONS FOR COMPLETING THE COASTAL STRUCTURES FORM (FORM 5)

The Coastal Structures Form is to be completed when a revision to coastal flood hazard elevations and/or areas is requested based on coastal structures being credited as providing protection from the base flood. The purpose of the Coastal Structures Form is to ensure that the structure is designed and constructed to provide protection from the base flood without failing or causing an increase in flood hazards to adjacent areas. Refer to the *Consolidated Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D: Guidance for Coastal Flooding Analyses and Mapping* which can be obtained from the Federal Emergency Management Agency's (FEMA's) Internet site at http://www.fema.gov/mit/tsd/dl_cgs.htm, for the criteria for evaluating flood protection structures.

If the coastal structure is a levee/floodwall, complete the Levee/Floodwall System section of the Riverine Structure Form (Form 3), in addition to this form. When the Coastal Structures Form is submitted, the Coastal Analysis Form (Form 4) should also be submitted.

Section A: Background

Information about the type of structure, the location, the material being used, and the age of the structure must be provided. Certified "as built" plans must also be provided. If these plans are not available, an explanation must be given with sketches of the general structure dimensions as described. If the structure design has been certified by a Federal agency to provide flood protection and withstand forces from the 1% annual chance (base) flood, the dates of the project completion and certification of the structure should be provided, and the remainder of the form does not need to be completed.

Section B: Design Criteria

Documentation must be provided that ensures a coastal structure is designed and constructed to withstand the wind and wave forces associated with the base flood. The minimum freeboard of the structure must be in compliance with National Flood Insurance Program (NFIP) Regulation 44 CFR Ch. 1, Section 65.10. Additional concerns include the impact to areas directly landward of the structure that may be subjected to overtopping and erosion along with possible failure of the structure due to undermining from the backside and the possible increase in erosion to unprotected properties at the ends of the structure. The evaluation of protection provided by sand dunes must follow the criteria outlined in NFIP Regulation 44 CFR Ch. 1, Section 65.11.

Section C: Adverse Impact Evaluation

If the structure is new, proposed, or modified, and will impact flooding and erosion for the areas adjacent to the structure, provide an explanation and documentation to support your conclusions.

Section D: Community and/or State Review

Provide documentation of Community and/or State review of the revision.

Section E: Certification

The licensed professional engineer and/or land surveyor should have a current license in the State where the affected communities are located. While the individual signing this form is not required to have obtained the supporting data or performed the analyses, he or she must have supervised and reviewed the work.

If the requester is a Federal agency who is responsible for the design and construction of flood control facilities, a letter stating that "the analyses submitted have been performed correctly and in accordance with sound engineering practices" may be submitted in lieu of certification by a registered professional engineer. Regarding the certification of completion of flood control facilities, a letter from the Federal agency certifying its completion and the flood frequency event to which the project protects may be submitted in lieu of this form.

INSTRUCTIONS FOR COMPLETING THE ALLUVIAL FAN FLOODING FORM (FORM 6)

This form should be used for revision requests involving alluvial fans. The purpose of this form is to ensure that a structural flood control measure in areas subject to alluvial fan flooding is designed and/or constructed to provide protection from the 1% annual chance flood, in compliance with National Flood Insurance Program (NFIP) Regulation 44 CFR Ch. 1, Section 65.13, before it is recognized on an NFIP map. Elevating a parcel of land or a structure by fill or other means will not serve as a basis for removing areas subject to alluvial fan flooding from an area of special flood hazards. See NFIP Regulation 44 CFR Ch. 1, Section 65.13. Complete engineering analyses must be submitted in support of each section of this form. In addition, it may be necessary to complete other forms relating to specific flood control measures, such as levees/floodwalls, channelization, or dams.

Section A: Three-Stage Analysis

The three-stage analysis of alluvial fans is described in the Federal Emergency Management Agency's (FEMA's) *Consolidated Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping,* which can be obtained from the Federal Emergency Management Agency's (FEMA's) Internet site at http://www.fema.gov/mit/tsd/dl_cgs.htm.

1. Complete the information regarding the characterization of the alluvial fan landform.

2. Complete the information regarding the definition of active and inactive areas.

3. Complete the information regarding the determination of the 100-year floodplain boundaries.

Section B: Structural Flood Control Measures

Complete the information regarding any flood control structures. Submit Form 3, Riverine Structure Form, and an Operation and Maintenance Plan with the revision request. The Operation and Maintenance Plan may be submitted when requesting a Conditional Letter of Map Revision (CLOMR), but is not required. However, it will be required after construction is complete and a revision to the Flood Insurance rate Map (FIRM) is requested.

Section C: Mapping Requirements

With the revision request, submit a certified topographic map showing the information indicated in the Mapping Requirements section of the Alluvial Fan Flooding Form. Also submit a copy of the current FIRM annotated to show the revised 1% annual chance floodplain boundaries.

INSTRUCTIONS FOR COMPLETING THE PAYMENT INFORMATION FORM

The Payment Information Form must be completed for all requests requiring a fee. The current fee schedule for the reviewing and processing of Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) requests may be obtained from the Federal Emergency Management Agency's (FEMA's) Internet site at http://www.fema.gov/mit/tsd/frm_fees.htm or by calling FEMA's Map Assistance Center at 1-877-FEMA MAP (1-877-336-2627).

Indicate the name of the community and a project identifier (e.g., Floodville Estates Subdivision or Small Creek Channel Improvements). The fees are sent to a different location from the revision request package. It is important to have the name of the community and a project identifier on the fee form, so that fees can be matched to the revision requests.

Indicate whether the fee is being submitted for an MT-1 application, an MT-2 application, or an External Data Request. This form is used for several types of requests. The type of request should be indicated so that the fees can be matched to the revision requests.

The request or case number should be indicated if it is known. Generally, this number is not known when a revision is initially requested. However, the case number should be indicated in any subsequent correspondence with FEMA.

Indicate the amount and method of payment being used to pay the fee.

APPENDIX A - COMMONLY USED ACRONYMS

BFE	Base (1% annual chance) Flood Elevation. It is the height of the base flood, usually in feet, in relation to the datum used, or the depth of the base flood usually in feet, above the ground surface. The base flood is the flood that has a 1% probability of being equaled or exceeded in any given year (also referred to as the 100-year flood or the 1% annual chance flood).
CFR	Code of Federal Regulations.
CHHA	Coastal High Hazard Area. An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms or seismic sources. CHHAs are indicated as V or VE Zones on the Flood Insurance Rate Maps.
CLOMR	Conditional Letter of Map Revision. A letter from FEMA commenting on whether a proposed project, if built as proposed, would meet the minimum standards of the National Flood Insurance Program.
FBFM	The Flood Boundary and Floodway Map. The floodplain management map issued by FEMA that depicts, on the basis of detailed analyses, the boundaries of the 100- and 500-year floodplain and the regulatory floodway.
FEMA	Federal Emergency Management Agency.
FHBM	The Flood Hazard Boundary Map. The initial flood insurance map issued by FEMA that identified on the basis of approximate analyses, the areas of 100-year flood hazard in a community.
FIRM	Flood Insurance Rate Map. An official map of a community, on which the Administrator has delineated both the special hazard areas and the risk premium zones applicable to the community.
FIS	Flood Insurance Study. An engineering study performed under contract to FEMA to identify flood-prone areas and to determine BFEs, flood insurance rate zones, and other flood risk data for a community.
LOMR	Letter of Map Revision. A letter from FEMA officially revising the current NFIP map to show changes to floodplains, floodways, or flood elevations.
NFIP	National Flood Insurance Program.
PMR	Physical Map Revision. A reprinted NFIP map incorporating changes to floodplains, floodways, or flood elevations. Because of the time and cost involved to change, reprint, and redistribute an NFIP map, a PMR is usually processed when a revision reflects large scope changes.
SFHA	Special Flood Hazard Area. Areas inundated by a flood having a 1% probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).
USACE	U.S. Army Corps of Engineers.
WSEL	Water Surface Elevation.

APPENDIX B - USEFUL INTERNET SITES

Public Information:

http://www.fema.gov - FEMA's Internet site.

http://www.fema.gov/mit/tsd/en_main.htm - FEMA's Internet site for engineers and surveyors.

http://www.fema.gov/mit/tsd/ot_main.htm - FEMA's Internet site for online tutorials.

http://www.fema.gov/fema/csb.htm - National Flood Insurance Program Community Status Book.

http://msc.fema.gov/stores/MSC - Internet site for ordering NFIP maps.

http://www.access.gpo.gov/nara/cfr/waisidx_00/44cfrv1_00.html - NFIP regulations.

Amendment/Revision Forms and Information:

http://www.fema.gov/mit/tsd/dl_mt-ez.htm - MT-EZ form package, *Amendments to National Flood Insurance Program Maps, Application Form for Single Residential Lot or Structure.*

http://www.fema.gov/mit/tsd/dl_mt-1.htm - MT-1 form package, *Revisions to National Flood Insurance Program Maps, Application Forms for Conditional and Final Letters of Map Amendment and Letters of Map Revision Based on Fill.*

http://www.fema.gov/mit/tsd/dl_mt-2.htm - MT-2 form package, *Revisions to National Flood Insurance Program Maps, Application Forms and Instructions for Conditional Letters of Map Revision and Letters of Map Revision.*

http://www.fema.gov/mit/tsd/frm_fees.htm - Fee schedule for review and processing of CLOMR and LOMR requests.

http://www.fema.gov/mit/tsd/st_order.htm - Internet site for ordering backup information for an existing Flood Insurance Study.

Documents, Guidelines and Manuals:

http://www.fema.gov/pdf/fima/tb1001.pdf - FEMA's Technical Bulletin 10-01, "Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe from Flooding."

http://www.fema.gov/mit/tsd/dl_zonea.htm - FEMA's manual, "Managing Floodplain Development in Approximate Zone A Areas, A Guide for obtaining and developing Base (100-year) Flood Elevations."

http://www.fema.gov/mit/tsd/dl_cgs.htm - FEMA's *Consolidated Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping.*

http://www.fema.gov/mit/tsd/dl_cgs.htm - FEMA's *Consolidated Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D: Guidance for Coastal Flooding Analyses and Mapping.*

http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1913/toc.htm - USACE manual "Design and Construction of Levees," EM 1110-2-1913.

http://www.usace.army.mil/inet/usace-docs/eng-tech-ltrs/etl1110-2-555/toc.html - USACE technical letter "Design Guidance for Levees," ETL 1110-2-555.

http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-2102/toc.htm - USACE manual "Waterstops and Other Preformed Joint Materials for Civil Works Structures," EM 1110-2-2102.

http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-301/toc.htm - USACE manual "Landscape Planting and Vegetation Management for Floodwalls, Levees and Embankment Dams," EM 1110-2-301.

Software:

http://www.fema.gov/mit/tsd/en_modl.htm - List of numerical models accepted by FEMA for the NFIP usage.

http://www.fema.gov/mit/tsd/frm_soft.htm - Engineering software developed by FEMA. The site also includes additional information, such as tutorials, user's manuals and guidance documentation for certain programs.

Federal Agencies:

http://www.epa.gov/ - Environmental Protection Agency

http://www.nasa.gov/ - National Aeronautics and Space Administration (NASA)

http://www.noaa.gov/ - National Oceanic and Atmospheric Administration (NOAA)

http://www.nws.noaa.gov/ - National Weather Service (NWS)

http://www.nrcs.usda.gov/ - Natural Resources Conservation Service (NRCS)

http://www.usace.army.mil/ - U.S. Army Corps of Engineers (USACE)

http://www.hec.usace.army.mil/ - USACE Hydrologic Engineering Center (HEC)

http://www.usda.gov/ - U.S. Department of Agriculture (USDA)

http://www.fws.gov/index.html - U.S. Fish & Wildlife Service

APPENDIX C - FEMA OFFICES

REGION I

(Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont)

FEMA, Federal Insurance and Mitigation Division
J. W. McCormack Post Office and
Courthouse Building, Room 442
Boston, Massachusetts 02109-4595
(617) 223-9540

REGION II

(New York, Puerto Rico, New Jersey)

FEMA, Federal Insurance and Mitigation Division
26 Federal Plaza, Room 1351
New York, New York 10278-0001
(212) 667-8900

REGION III

(Delaware, D.C., Maryland, Pennsylvania, Virginia, West Virginia)

FEMA, Federal Insurance and Mitigation Division
One Independence Mall, Sixth Floor
615 Chestnut Street
Philadelphia, Pennsylvania 19106-4404
(215) 931-5506

REGION IV

(Alabama, Florida, Georgia, Kentucky, Mississippi, N. Carolina, S. Carolina, Tenn.)

FEMA, Federal Insurance and Mitigation Division
Koger Center - Rutgers Building
3003 Chamblee Tucker Road
Atlanta, Georgia 30341-4112
(770) 220-5400

REGION V

(Illinois, Indiana, Michigan Minnesota, Ohio, Wisconsin)

FEMA, Federal Insurance and Mitigation Division
536 South Clark Street, Sixth Floor
Chicago, Illinois 60605-1509
(312) 408-5548

REGION VI

(Arkansas, Louisiana, New Mexico, Oklahoma, Texas)

FEMA, Federal Insurance and Mitigation Division
Federal Regional Center
800 North Loop 288
Denton, Texas 76209-3606
(940) 898-5165

REGION VII

(Iowa, Kansas, Missouri, Nebraska)

FEMA, Federal Insurance and Mitigation Division
2323 Grand Boulevard, Suite 900
Kansas City, Missouri 64108-2670
(816) 283-7062

REGION VIII

(Colorado, Montana, N. Dakota, S. Dakota, Utah, Wyoming)

FEMA, Federal Insurance and Mitigation Division
Denver Federal Center
Building 710, Box 25267
Denver, Colorado 80225-0267
(303) 235-4800

REGION IX

(Arizona, California, Hawaii, Nevada)

FEMA, Federal Insurance and Mitigation Division
1111 Broadway, Suite 1200
Oakland, California 94607-4036
(510) 627-7100

REGION X

(Alaska, Idaho, Oregon, Washington)

FEMA, Federal Insurance and Mitigation Division
Federal Regional Center
130 228th Street, S.W.
Bothell, Washington, 98021-9796
(206) 487-4600

HEADQUARTERS

Federal Emergency Management Agency
Federal Insurance and Mitigation Administration
Hazards Studies Branch
500 C Street, SW
Washington, DC 20472
1-877-FEMA MAP (1-877-336-2627)

FEDERAL EMERGENCY MANAGEMENT AGENCY
OVERVIEW & CONCURRENCE FORM

O.M.B. No. 3067-0148
Expires September 30, 2005

PAPERWORK BURDEN DISCLOSURE NOTICE

ɔlic reporting burden for this form is estimated to average 1 hour per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, SW, Washington, DC 20472, Paperwork Reduction Project (3067-0148). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

A. REQUESTED RESPONSE FROM FEMA

This request is for a (check one)

❑ CLOMR: A letter from FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision, or proposed hydrology changes (See 44 CFR Ch. 1, Parts 60, 65 & 72).

❑ LOMR: A letter from FEMA officially revising the current NFIP map to show the changes to floodplains, regulatory floodway, or flood elevations. (See Parts 60 & 65 of the NFIP Regulations).

B. OVERVIEW

1. The NFIP map panel(s) affected for all impacted communities is (are):

Community No.	Community Name	State	Map No.	Panel No.	Effective Date
Ex: 480301 480287	Katy, City Harris County	TX TX	480301 48201C	0005D 0220G	02/08/83 09/28/90

2. Flooding Source: ______________________________

3. Project Name/Identifier: ______________________________

4. FEMA zone designations affected: ______________ (choices A, AH, AO, A1-A30, A99, AE, AR, V, V1-V30, VE, B ,C, D, X)

5. Basis for Request and Type of Revision:

   a. The basis for this revision request is (check all that apply)

   ❑ Physical Change ❑ Improved Methodology/Data

   ❑ Regulatory Floodway Revision ❑ Other (Attach Description)

   Note: A photograph and narrative description of the area of concern is not required, but is very helpful during review.

   b. The area of revision encompasses the following types of flooding and structures (check all that apply).

   Types of Flooding: ❑ Riverine ❑ Coastal ❑ Shallow Flooding (e.g., Zones AO and AH)

   ❑ Alluvial fan ❑ Lakes ❑ Other (Attach Description)

   Structures: ❑ Channelization ❑ Levee/Floodwall ❑ Bridge/Culvert

   ❑ Dam ❑ Fill ❑ Other, Attach Description

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☐ Yes Fee amount: $ ________

☐ No, Attach Explanation

Please see FEMA website at http://www.fema.gov/mit/tsd/frm_fees.htm **for Fee Amounts and Exemptions.**

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name:	Company:	
Mailing Address:	Daytime Telephone No.:	Fax No.:
	E-Mail Address:	
Signature of Requester (required):		Date:

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the the community floodplain management requirements, including the requirement that no fill be placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title:		Telephone No.:
Community Name:	Community Official's Signature: (required)	Date:

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name:	License No.:	Expiration Date:
Company Name:	Telephone No.:	Fax No.:
Signature:		Date:

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if...
☐ Riverine Hydrology & Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☐ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

Seal (optional)

FEDERAL EMERGENCY MANAGEMENT AGENCY

RIVERINE HYDROLOGY & HYDRAULICS FORM

O.M.B. No. 3067-0148
Expires September 30, 2005

PAPERWORK BURDEN DISCLOSURE NOTICE

Flooding Source: ______________________________

Note: Fill out one form for each flooding source studied.

A. HYDROLOGY

1. Reason for New Hydrologic Analysis (check all that apply)

- ☐ Not revised (skip to section 2)
- ☐ Alternative methodology
- ☐ No existing analysis
- ☐ Proposed Conditions (CLOMR)
- ☐ Improved data
- ☐ Changed physical condition of watershed

2. Comparision of Representative 1%-Annual-Chance Discharges

Location	Drainage Area (Sq. Mi.)	FIS (cfs)	Revised (cfs)

3. Methodology for New Hydrologic Analysis (check all that apply)

- ☐ Statistical Analysis of Gage Records
- ☐ Regional Regression Equations
- ☐ Precipitation/Runoff Model ______________________ [TR-20, HEC-1, HEC-HMS, etc.]
- ☐ Other (please attach description)

Please enclose all relevant models in digital format, maps, computations (including computation of parameters), and documentation to support the new analysis. The document, "Numerical Models Accepted by FEMA for NFIP Usage" lists the models accepted by FEMA. This document can be found at: http://www.fema.gov/mit/tsd/en_modl.htm.

4. Review/Approval of Analysis

If your community requires a regional, state, or federal agency to review the hydrologic analysis, please attach evidence of approval/review.

5. Impacts of Sediment Transport on Hydrology

Was sediment transport considered? ☐Yes ☐No If Yes, then fill out Section F (Sediment Transport) of Form 3. If No, then attach your explanation for why sediment transport was not considered.

B. HYDRAULICS

1. Reach to be Revised

	Description	Cross Section	Water-Surface Elevations (ft.) Effective	Proposed/Revised
Downstream Limit				
Upstream Limit				

2. Hydraulic Method Used

Hydraulic Analysis ______________________ [HEC-2, HEC-RAS, Other (Attach description)]

B. HYDRAULICS (CONTINUED)

3. Pre -Submittal Review of Hydraulic Models

FEMA has developed two review programs, CHECK-2 and CHECK-RAS to aid in the review of HEC-2 and HEC-RAS hydraulic models respectively. These review programs verify that the hydraulic estimates and assumptions in the model data are in accordance with NFIP requirements, and that the data are comparable with the assumptions and limitations of HEC-2/HEC-RAS. CHECK-2 and CHECK-RAS identify areas of potential error or concern. These tools do not replace engineering judgment. CHECK-2 and CHECK-RAS can be downloaded from http://www.fema.gov/mit/tsd/frm_soft.htm. We recommend that you review your HEC-2 and HEC-RAS models with CHECK-2 and CHECK-RAS. If you disagree with a message, please attach an explanation of why the message is not valid in this case. Review of your submittal and resolution of valid modeling discrepancies will result in reduced review time.

HEC-2/HEC-RAS models reviewed with CHECK-2/CHECK-RAS? ☐ Yes ☐ No

4. Models Submitted

Duplicate Effective Model*	Natural File Name	________	Floodway File Name	________
Corrected Effective Model*	Natural File Name	________	Floodway File Name	________
Existing or Pre-Project Conditions Model	Natural File Name	________	Floodway File Name	________
Revised or Post-Project Conditions Model	Natural File Name	________	Floodway File Name	________
Other - (attach description)	Natural File Name	________	Floodway File Name	________

*Not required for revisions to approximate 1%-annual-chance floodplains (Zone A) - for details, refer to the corresponding section of the instructions.

The document "Numerical Models Accepted by FEMA for NFIP Usage" list the models accepted by FEMA. This document can be found at: http://www.fema.gov/mit/tsd/en_modl.htm.

C. MAPPING REQUIREMENTS

A certified topographic map must be submitted showing the following information (where applicable): the boundaries of the effective, existing, and proposed conditions 1%-annual-chance floodplain (for approximate Zone A revisions) or the boundaries of the 1%- and 0.2%-annual-chance floodplains and regulatory floodway (for detailed Zone AE, AO, and AH revisions); location and alignment of all cross sections with stationing control indicated; stream, road, and other alignments (e.g., dams, levees, etc.); current community easements and boundaries; boundaries of the requester's property; certification of a registered professional engineer registered in the subject State; location and description of reference marks; and the referenced vertical datum (NGVD, NAVD, etc.).

Note that the boundaries of the existing or proposed conditions floodplains and regulatory floodway to be shown on the revised FIRM and/or FBFM must tie-in with the effective floodplain and regulatory floodway boundaries. Please attach **a copy of the effective FIRM and/or FBFM**, annotated to show the boundaries of the revised 1%- and 0.2%-annual-chance floodplains and regulatory floodway that tie-in with the boundaries of the effective 1%- and 0.2% -annual-chance floodplain and regulatory floodway at the upstream and downstream limits of the area of revision.

D. COMMON REGULATORY REQUIREMENTS

1. For CLOMR requests, do Base Flood Elevations (BFEs) Increase? ☐ Yes ☐ No

   For CLOMR requests, if either of the following is true, please submit evidence of compliance with Section 65.12 of the NFIP regulations:

   - The proposed project encroaches upon a regulatory floodway and would result in increases above 0.00 foot.
   - The proposed project encroaches upon a SFHA with BFEs established and would result in increases above 1.00 foot.

2. Does the request involve the placement or proposed placement of fill? ☐ Yes ☐ No

   If Yes, the community must acknowledge that the area to be removed from the special flood hazard area, to include any structures or proposed structures, meets (will meet) all of the standards of the the local floodplain ordinances, and is (will be) reasonably safe from flooding in accordance with NFIP regulation 44 CFR 65.2(c). Please see the MT-2 Instructions for more information.

3. For LOMR requests, is the regulatory floodway being revised? ☐ Yes ☐ No

   If Yes, attach evidence of regulatory floodway revision notification. As per Paragraph 65.7(b)(1) of the NFIP regulations, notification is required for requests involving revisions to the regulatory floodway. (Not required for revisions to approximate 1%-annual-chance floodplains [studied Zone A designation] unless a regulatory floodway is being added. Elements and examples of regulatory floodway revision notification can be found in the MT-2 Form 2 Instructions.)

4. For LOMR requests, does this request require property owner notification and acceptance of BFE increases? ☐ Yes ☐ No

   If Yes, please attach proof of property owner notification and acceptance (if available). Elements of and examples of property owner notification can be found in the MT-2 Form 2 Instructions.

FEDERAL EMERGENCY MANAGEMENT AGENCY
RIVERINE STRUCTURES FORM

O.M.B. No. 3067-0148
Expires September 30, 2005

PAPERWORK BURDEN DISCLOSURE NOTICE

Flooding Source: ______________________________

Note: Fill out one form for each flooding source studied.

A. GENERAL

Complete the appropriate section(s) for each Structure listed below:

Channelization................. complete Section B
Bridge/Culvert................ complete Section C
Dam............................... complete Section D
Levee/Floodwall............... complete Section E
Sediment Transport......... complete Section F (if required)

Description Of Structure

1. **Name of Structure:** ______________________________

   Type (check one): ☐ Channelization ☐ Bridge/Culvert ☐ Levee/Floodwall ☐ Dam

   Location of Structure: ______________________________

   Downstream Limit/Cross Section: ______________________________

   Upstream Limit/Cross Section: ______________________________

2. **Name of Structure:** ______________________________

   Type (check one): ☐ Channelization ☐ Bridge/Culvert ☐ Levee/Floodwall ☐ Dam

   Location of Structure: ______________________________

   Downstream Limit/Cross Section: ______________________________

   Upstream Limit/Cross Section: ______________________________

3. **Name of Structure:** ______________________________

   Type (check one): ☐ Channelization ☐ Bridge/Culvert ☐ Levee/Floodwall ☐ Dam

   Location of Structure: ______________________________

   Downstream Limit/Cross Section: ______________________________

   Upstream Limit/Cross Section: ______________________________

Note: For more structures, attach additional pages as needed.

B. CHANNELIZATION

Flooding Source: ____________________

Name of Structure: ____________________

1. Accessory Structures

The channelization includes (check one):

- ❑ Levees (Attach Levee/Floodwall System Analysis Form - Section E)
- ❑ Superelevated sections
- ❑ Debris basin/detention basin
- ❑ Other (Describe):
- ❑ Drop structures
- ❑ Transitions in cross sectional geometry
- ❑ Energy dissipator

2. Drawing Checklist

Attach the plans of the channelization certified by a registered professional engineer, as described in the instructions.

3. Hydraulic Considerations

The channel was designed to carry ____ (cfs) and/or the ________ -year flood.

The design elevation in the channel is based on (check one):

❑ Subcritical flow ❑ Critical flow ❑ Supercritical flow ❑ Energy grade line

If there is the potential for a hydraulic jump at the following locations, check all that apply and attach an explanation of how the hydraulic jump is controlled without affecting the stability of the channel.

❑ Inlet to channel ❑ Outlet of channel ❑ At Drop Structures ❑ At Transitions
❑ Other locations (specify): ____________________

4. Sediment Transport Considerations

Was sediment transport considered? ❑ Yes ❑ No If Yes, then fill out Section F (Sediment Transport).
If No, then attach your explanation for why sediment transport was not considered.

C. BRIDGE/CULVERT

Flooding Source: ____________________

Name of structure: ____________________

1. This revision reflects (check one):

- ❑ New bridge/culvert not modeled in the FIS
- ❑ Modified bridge/culvert previously modeled in the FIS
- ❑ New analysis of bridge/culvert previously modeled in the FIS

2. Hydraulic model used to analyze the structure (e.g., HEC-2 with special bridge routine, WSPRO, HY8): ____________________
If different than hydraulic analysis for the flooding source, justify why the hydraulic analysis used for the flooding source could not analyze the structures. Attach justification.

3. Attach plans of the structures certified by a registered professional engineer. The plan detail and information should include the following (check the information that has been provided):

- ❑ Dimensions (height, width, span, radius, length)
- ❑ Shape (culverts only)
- ❑ Material
- ❑ Beveling or Rounding
- ❑ Wing Wall Angle
- ❑ Skew Angle
- ❑ Distances Between Cross Sections
- ❑ Erosion Protection
- ❑ Low Chord Elevations - Upstream and Downstream
- ❑ Top of Road Elevations - Upstream and Downstream
- ❑ Structure Invert Elevations - Upstream and Downstream
- ❑ Stream Invert Elevations - Upstream and Downstream
- ❑ Cross-Section Locations

4. Sediment Transport Considerations

Was sediment transport considered? ❑ Yes ❑ No If Yes, then fill out Section F (Sediment Transport).
If No, then attach your explanation for why transport was not considered.

D. DAM

Flooding Source: ______________________________

ne of Structure: ______________________________

1. This request is for (check one): ❑ Existing dam ❑ New dam ❑ Modification of existing dam

2. The dam was designed by (check one): ❑ Federal agency ❑ State agency ❑ Local government agency

   ❑ Private organization Name of the agency or organization: ______________________________

3. Does the project involve revised hydrology? ❑ Yes ❑ No

   If Yes, complete the Riverine Hydrology & Hydraulics Form (Form 2)

4. Does the submittal include debris/sediment yield analysis? ❑ Yes ❑ No

   If Yes,then fill out Section F (Sediment Transport).
   If No, then attach your explanation for why debris/sediment analysis was not considered.

5. Does the Base Flood Elevation behind the dam or downstream of the dam change?

   ❑ Yes ❑ No If Yes, complete the Riverine Hydrology & Hydraulics Form (Form 2) and complete the table below.

Stillwater Elevation Behind the Dam

FREQUENCY (% annual chance)	FIS	REVISED
10-year (10%)	________	________
50-year (2%)	________	________
100-year (1%)	________	________
500-year (0.2%)	________	________
Normal Pool Elevation	________	________

lease attach a copy of the formal Operation and Maintenance Plan.

E. LEVEE/FLOODWALL

1. System Elements

a. This Levee/Floodwall analysis is based on (check one):

- ☐ upgrading of an existing levee/floodwall system
- ☐ a newly constructed levee/floodwall system
- ☐ reanalysis of an existing levee/floodwall system

b. Levee elements and locations are (check one):

- ☐ earthen embankment, dike, berm, etc. Station ________to _____
- ☐ structural floodwall Station ________to _____
- ☐ Other (describe): ______________________________ Station ________to _____

c. Structural Type (check one):

- ☐ monolithic cast-in place reinforced concrete
- ☐ reinforced concrete masonry block
- ☐ sheet piling
- ☐ Other (describe):

d. Has this levee/floodwall system been certified by a Federal agency to provide protection from the base flood?

☐ Yes ☐ No

If Yes, by which agency? ______________________________

e. Attach certified drawings containing the following information (indicate drawing sheet numbers):

1. Plan of the levee embankment and floodwall structures Sheet Numbers: ________
2. A profile of the levee/floodwall system showing the Base Flood Elevation (BFE), levee and/or wall crest and foundation, and closure locations for the total levee system. Sheet Numbers: ________
3. A profile of the BFE, closure opening outlet and inlet invert elevations, type and size of opening, and kind of closure Sheet Numbers: ________
4. A layout detail for the embankment protection measures. Sheet Numbers: ________
5. Location, layout, and size and shape of the levee embankment features, foundation treatment, floodwall structure, closure structures, and pump stations. Sheet Numbers: ________

2. Freeboard

a. The minimum freeboard provided the BFE is:

Riverine

3.0 feet or more at the downstream end and throughout	☐ Yes	☐ No
3.5 feet or more at the upstream end	☐ Yes	☐ No
4.0 feet within 100 feet upstream of all structures and/or constrictions	☐ Yes	☐ No

Coastal

1.0 foot above the height of the one percent wave associated with the 1%-annual-chance stillwater surge elevation or maximum wave runup (whichever is greater)	☐ Yes	☐ No
2.0 feet above the 1%-annual-chance stillwater surge elevation	☐ Yes	☐ No

2. Freeboard (continued)

Please note, occasionally exceptions are made to the minimum freeboard requirement. If an exception is requested, attach documentation addressing Paragraph 65.10(b)(1)(ii) of the NFIP regulations.

If No is answered to any of the above, please attach an explanation.

b. Is there an indication from historical records that ice-jamming can affect the BFE? ☐ Yes ☐ No

If Yes, provide ice-jam analysis profile and evidence that the minimum freeboard discussed above still exists.

3. Closures

a. Opening through the levee system (check one): ☐ exists ☐ does not exist

If opening exists, list all closures:

Channel Station	Left or Right Bank	Opening Type	Highest Elevation for Opening Invert	Type of Closure Device

(Extend table on an added sheet as needed and reference)

Note: Geotechnical and geologic data
In addition to the required detailed analysis reports, data obtained during field and laboratory investigations and used in the design analysis for the following system features should be submitted in a tabulated summary form. (Reference U.S. Army Corps of Engineers [USACE] EM-1110-2-1906 Form 2086.)

.. Embankment Protection

a. The maximum levee slope landside is: __________

b. The maximum levee slope floodside is: __________

c. The range of velocities along the levee during the base flood is: ________ (min.) to ________ (max.)

d. Embankment material is protected by (describe what kind): ____________________

e. Riprap Design Parameters (check one): ☐ Velocity ☐ Tractive stress
Attach references

Reach	Sideslope	Flow Depth	Velocity	Curve or Straight	Stone Riprap			Depth of Toedown
					D_{100}	D_{50}	Thickness	
Sta _____ to _____								
Sta _____ to _____								
Sta _____ to _____								
Sta _____ to _____								
Sta _____ to _____								
Sta _____ to _____								

(Extend table on an added sheet as needed and reference each entry)

4. Embankment Protection (continued)

f. Is a bedding/filter analysis and design attached? ☐ Yes ☐ No

g. Describe the analysis used for other kinds of protection used (include copies of the design analysis):

Attach engineering analysis to support construction plans.

5. Embankment and Foundation Stability

a. Identify locations and describe the basis for selection of critical location for analysis:

____

☐ Overall height: Sta. __________ , height _______ ft.

☐ Limiting foundation soil strength:

Sta. __________ , depth _______ to

strength ϕ = ________ degrees, c = _________ psf

slope: SS = ________ (h) to ________ (v)

(Repeat as needed on an added sheet for additional locations)

b. Specify the embankment stability analysis methodology used (e.g., circular arc, sliding block, infinite slope, etc.):

____

c. Summary of stability analysis results:

Case	Loading Conditions	Critical Safety Factor	Critical (Min.)
I	End of construction		1.3
II	Sudden drawdown		1.0
III	Critical flood stage		1.4
IV	Steady seepage at flood stage		1.4
VI	Earthquake (Case I)		1.0

(Reference: USACE EM-1110-2-1913 Table 6-1)

d. Was a seepage analysis for the embankment performed? ☐ Yes ☐ No

If Yes, describe methodology used: ______________________________

e. Was a seepage analysis for the foundation performed? ☐ Yes ☐ No

f. Were uplift pressures at the embankment landside toe checked? ☐ Yes ☐ No

g. Were seepage exit gradients checked for piping potential? ☐ Yes ☐ No

h. The duration of the base flood hydrograph against the embankment is _________ hours.

Attach engineering analysis to support construction plans.

6. Floodwall and Foundation Stability

a. Describe analysis submittal based on Code (check one):

☐ UBC (1988) or ☐ Other (specify): ______________________

b. Stability analysis submitted provides for:

☐ Overturning ☐ Sliding If not, explain: ____________

c. Loading included in the analyses were:

☐ Lateral earth @ P_A = ______ psf; P_p = _____ psf

☐ Surchage-Slope @ _______ , ☐ surface _____ psf

☐ Wind @ P_w = _____ psf

☐ Seepage (Uplift); ____________ ☐ Earthquake @ P_{eq} = _______ %g

☐ 1%-annual-chance significant wave height _____ft.

☐ 1%-annual-chance significant wave period: _____sec.

d. Summary of Stability Analysis Results: Factors of Safety.

Itemize for each range in site lay out dimension and loading condition limitation for each respective reach.

Loading Condition	Criteria (Min)		Sta	To	Sta	To
	Overturn	Sliding	Overturn	Sliding	Overturn	Sliding
Dead & Wind	1.5	1.5				
Dead & Soil	1.5	1.5				
Dead, Soil, Flood, & Impact	1.5	1.5				
Dead, Soil, & Seismic	1.3	1.3				

(Ref: FEMA 114 Sept 1986; USACE EM 1110-2-2502)

(Note: Extend table on an added sheet as needed and reference)

e. Foundation bearing strength for each soil type:

Bearing Pressure	Sustained Load (psf)	Short Term Load (psf)
Computed design maximum		
Maximum allowable		

f. Foundation scour protection ☐ is, ☐ is not provided. If provided, attach explanation and supporting documentation.

Attach engineering analysis to support construction plans.

7. Settlement

a. Has anticipated potential settlement been determined and incorporated into the specific construction elevations to maintain the established freeboard margin? ☐ Yes ☐ No

b. The computed range of settlement is ______ ft. to _________ ft.

c. Settlement of the levee crest is determined to be primarily from:

☐ Foundation consolidation
☐ Embankment compression
☐ Other (Describe):

d. Differential settlement of floodwalls ☐ has ☐ has not been accommodated in the structural design and construction.

Attach engineering analysis to support construction plans.

8. Interior Drainage

a. Specify size of each interior watershed:

Draining to pressure conduit: ______ acres
Draining to ponding area: _________ acres

b. Relationships Established

Ponding elevation vs. storage	☐ Yes ☐ No
Ponding elevation vs. gravity flow	☐ Yes ☐ No
Differential head vs. gravity flow	☐ Yes ☐ No

c. The river flow duration curve is enclosed: ☐ Yes ☐ No

d. Specify the discharge capacity of the head pressure conduit: _________ cfs

e. Which flooding conditions were analyzed?

• Gravity flow (Interior Watershed)	☐ Yes ☐ No
• Common storm (River Watershed)	☐ Yes ☐ No
• Historical ponding probability	☐ Yes ☐ No
• Coastal wave overtopping	☐ Yes ☐ No

If No for any of the above, attach explanation.

f. Interior drainage has been analyzed based on joint probability of interior and exterior flooding and the capacities of pumping and outlet facilities to provide the established level of flood protection. ☐ Yes ☐ No

If No, attach explanation.

g. The rate of seepage through the levee system for the base flood is __________ cfs.

h. The length of levee system used to drive this seepage rate in item g: _________ ft.

8. Interior Drainage (continued)

i. Will pumping plants be used for interior drainage? ❑ Yes ❑ No

If Yes, include the number of pumping plants:
For each pumping plant, list:

	Plant #1	Plant #2
The number of pumps		
The ponding storage capacity		
The maximum pumping rate		
The maximum pumping head		
The pumping starting elevation		
The pumping stopping elevation		
Is the discharge facility protected?		
Is there a flood warning plan?		
How much time is available between warning and flooding?		

Will the operation be automatic? ❑ Yes ❑ No

If the pumps are electronic, are there backup power sources? ❑ Yes ❑ No

(Reference: USACE EM-1110-2-3101, 3102, 3103, 3104, and 3105)

Include a copy of supporting documentation of data and analysis. Provide a map showing the flooded area and maximum ponding elevations for all interior watersheds that result in flooding.

9. Other Design Criteria

a. The following items have been addressed as stated:

Liquefaction ❑ is ❑ is not a problem
Hydrocompaction ❑ is ❑ is not a problem
Heave differential movement due to soils of high shrink/swell ❑ is ❑ is not a problem

b. For each of these problems, state the basic facts and corrective action taken:

Attach supporting documentation.

c. If the levee/floodwall is new or enlarged, will the structure adversely impact flood levels and/or flow velocities floodside of the structure? ❑ Yes ❑ No

Attach supporting documentation.

d. Sediment Transport Considerations:

Was sediment transport considered? ❑ Yes ❑ No If Yes, then fill out Section F (Sediment Transport).
If No, then attach your explanation for why sediment transport was not considered.

E. LEVEE/FLOODWALL (CONTINUED)

10. Operational Plan and Criteria

a. Are the planned/installed works in full compliance with Part 65.10 of the NFIP regulations? ☐ Yes ☐ No

b. Does the operation plan incorporate all the provisions for closure devices as required in Paragraph 65.10(c)(1) of the NFIP regulations? ☐ Yes ☐ No

c. Does the operation plan incorporate all the provisions for interior drainage as required in Paragraph 65.10(c)(2) of the NFIP regulations? ☐ Yes ☐ No

If the answer is No to any of the above, please attach supporting documentation.

11. Maintenance Plan

a. Are the planned/installed works in full compliance with Part 65.10 of the NFIP regulations? ☐ Yes ☐ No
If No, please attach supporting documentation.

12. Operations and Maintenance Plan

Please attach a copy of the formal Operations and Maintenance Plan for the levee/floodwall.

F. SEDIMENT TRANSPORT

Flooding Source: ______________________________

Name of Structure: ______________________________

If there is any indication from historical records that sediment transport (including scour and deposition) can affect the Base Flood Elevation (BFE); and/or based on the stream morphology, vegetative cover, development of the watershed and bank conditions, there is a potential for debris and sediment transport (including scour and deposition) to affect the BFEs, then provide the following information along with the supporting documentation:

Sediment load associated with the base flood discharge: Volume ______ acre-feet

Debris load associated with the base flood discharge: Volume ______ acre-feet

Sediment transport rate ______ (percent concentration by volume)

Method used to estimate sediment transport: ______________________________

Most sediment transport formulas are intended for a range of hydraulic conditions and sediment sizes; attach a detailed explanation for using the selected method.

Method used to estimate scour and/or deposition: ______________________________

Method used to revise hydraulic or hydrologic analysis (model) to account for sediment transport:
Please note that bulked flows are used to evaluate the performance of a structure during the base flood; however, FEMA does not map BFEs based on bulked flows.

____

If a sediment analysis has not been performed, an explanation as to why sediment transport (including scour and deposition) will not affect the BFEs or structures must be provided.

FEDERAL EMERGENCY MANAGEMENT AGENCY

COASTAL ANALYSIS FORM

O.M.B. No. 3067-0148
Expires September 30, 2005

PAPERWORK BURDEN DISCLOSURE NOTICE

blic reporting burden for this form is estimated to average 1 hour per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, SW, Washington, DC 20472, Paperwork Reduction Project (3067-0148). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

Flooding Source: ______________________________

Note: Fill out one form for each flooding source studied.

A. COASTLINE TO BE REVISED

Describe limits of study area: ______________________________

B. EFFECTIVE FIS

The area being revised in the effective FIS was studied by detailed methods using (check all that apply):

- ☐ Storm surge modeling
- ☐ Wave height computations
- ☐ Wave overtopping computations
- ☐ Primary Frontal Dune Assessment
- ☐ Wave setup computations
- ☐ Wave runup computations
- ☐ Dune erosion computations
- ☐ N/A (area not studied by detailed methods)

C. REVISED ANALYSIS

1. Number of transects in revised analyses: ____________

2. Information used to prepare the revision (check all that apply):

- ☐ Wave setup analyses (complete Items 3, 4, and 5 below)
- ☐ Stillwater elevation determinations (complete Item 3)
- ☐ Erosion considerations (complete Item 4)
- ☐ Wave runup analysis (complete Items 4 and 5)
- ☐ Wave height analysis (complete Items 4 and 5)
- ☐ Wave overtopping assessment (complete Items 4 and 5)
- ☐ More detailed topographic information (complete Section E)
- ☐ Shore protection structures (attach completed Coastal Structures Form - Form 5)
- ☐ Primary frontal dune assessment (complete Item 5)
- ☐ Other, attach basis of revision request with an explanation

3. Stillwater Elevation Determination
   a. How were Stillwater elevations determined?
      - ☐ Gage analysis (If revised gage analysis was used, provide copies of gage data and revised analysis.)
      - ☐ Storm surge analysis
      - ☐ Other (Describe): ______________________________
   b. Specify what datum was used in the calculations: ______________________________

      If not the FIS datum, have the calculations been adjusted to the FIS datum? ☐ Yes ☐ No Conversion factor: ____________

   If revised storm surge analysis, was FEMA's storm surge model utilized? ☐ Yes ☐ No
   . If FEMA's storm surge model was used, attach a detailed description of the differences between the current and the revised analyses, and why the revised analysis should replace the the current analysis.
   e. If wave setup was computed, attach a description of methodology used.
      Amount of wave setup added to stillwater elevation: ________ feet.

C. REVISED ANALYSIS (continued)

4. Revised Analysis (i.e., erosion, wave height, wave runup, primary frontal dune, and wave overtopping)

If FEMA procedures were utilized to perform the revision, attach a detailed description of differences between the current and the revised analyses, and why the revised analysis should replace the current analysis.

If FEMA procedures were not utilized to perform the revision, provide full documentation on methodology and/or models used; including operational program, and detailed differences between methodology and/or models utilized and FEMA's methodology and/or models. Also, attach an explanation of why new methodology and/or models should replace current methodology and/or models.

If revision reflects more detailed topographic information and fill has been/will be placed in a V Zone, and is not protected from erosion by a shore protection structure, provide a detailed description of how the fill has been treated in the revised analysis.

5. Wave Runup, Wave Height, and Wave Overtopping Analysis

Wave height analyses along a transect are greatly affected by starting wave conditions that propagate inland. Wave runup and overtopping analyses are typically considered when wave heights and/or wave runup are close to or greater than the crest of shore protection structures or natural land forms.

a. Was an analysis performed to determine starting wave height and period for input into WHAFIS?
☐ Yes ☐ No
If Yes, attach an explanation of the method utilized. If No, explain why these analyses were not performed.

b. Was wave setup included in wave height analysis and removed for erosion and wave runup analyses?
☐ Yes ☐ No

c. Was an overtopping analysis performed for any coastal shore protection structures or natural land forms that may be overtopped? ☐ Yes ☐ No

If Yes, attach an explanation of the methodology utilized and describe in detail the results of the analysis.

If overtopping was not analyzed, attach an explanation for why these analyses were not performed.

D. RESULTS

1. Stillwater storm surge elevation: ______ feet ______ Datum
2. Wave setup: ________ feet
3. Starting deep-water significant wave condition:
   height: ________ period: ____________
4. Maximum wave height elevation: ______ feet
5. Maximum wave runup elevation: ______ feet
6. Estimated amount of maximum overtopping: ______ cfs/feet
7. The areas designated as coastal high hazard areas (V Zones) have:
   ☐ increased ☐ decreased ☐ both

Attach a description where they have increased and/or decreased.

8. As a result of the revised analyses, the V Zone location has shifted a maximum of _______ feet seaward and ______ feet landward of its existing position.
9. The Base Flood Elevations have:
   ☐ increased ☐ decreased
   a. What was the greatest increase? _________ feet
   b. What was the greatest decrease? _________ feet
10. The special flood hazard area has:
   ☐ increased ☐ decreased ☐ both

Attach a description where it has increased or decreased.

E. MAPPING REQUIREMENTS

A certified topographic map must be submitted showing the following information (where applicable): effective, existing conditions, and proposed conditions 1%-annual-chance floodplain boundaries, revised shoreline due to either erosion or accretion, location and alignment of all transects, correct location and alignment of any structures, current community easements and boundaries, boundary of the requester's property, certification of a professional engineer registered in the subject State, location and description of reference marks and the referenced vertical datum (NGVD, NAVD, etc.).

Note that the existing or proposed conditions floodplain boundaries to be shown on the revised FIRM must tie-in with the effective floodplain boundaries. Please attach a copy of the current FIRM annotated to show the revised 1%-annual-chance floodplain boundaries that tie-in with effective 1%-annual-chance floodplain boundaries along the entire extent of the area of revision.

FEDERAL EMERGENCY MANAGEMENT AGENCY

COASTAL STRUCTURES FORM

O.M.B. No. 3067-0148
Expires September 30, 2005

PAPERWORK BURDEN DISCLOSURE NOTICE

Public reporting burden for this form is estimated to average 1 hour per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, SW, Washington, DC 20472, Paperwork Reduction Project (3067-0148). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

Flooding Source: ____________________

Note: Fill out one form for each flooding source studied.

A. BACKGROUND

1. Name of structure (if applicable): ____________________

2. Structure location: ____________________

3. Type of structure:

   ☐ Levee/Floodwall* ☐ Anchored Bulkhead ☐ Revetment ☐ Gravity Seawall

   ☐ Breakwater ☐ Pile supported seawall ☐ Other ____________________

   ***Note:** If the coastal structure is a levee/floodwall, complete section E of Form 3 (Riverine Structures Form). The remainder of this form does not need to be completed.

4. Material structure is composed of (check all that apply):

   ☐ Stone ☐ Earthen fill ☐ Concrete ☐ Steel ☐ Sand

   ☐ Other ____________________

5. The structure is (check one):

   ☐ New or proposed ☐ Existing ☐ Modification of existing structure

   ☐ Replacement structure of the same size and design as what was previously at the site

   Describe in detail the existing structure and/or modifications being made to the structure and the purpose of the modifications:

   If existing, please include date of construction: ____________________

6. Copies of certified "as-built" plans ☐ are ☐ are not attached. Attach all design analyses that apply.

   If "as-built" plans are not available for submittal, please explain why and submit a sketch with general structure dimensions including: face slope, height, length, depth, and toe elevation referenced to the appropriate datum (e.g., NGVD 1929, NAVD 1988, etc.)

7. Has a Federal agency with responsibility for the design of coastal flood protection structures designed or certified that the structures have been adequately designed and constructed to provide protection against the 1%-annual-chance event?

   ☐ Yes ☐ No

   If Yes, specify the name of the agency and dates of the project completion and certification.

   ____

   If Yes, then no other sections of this form need to be completed.

B. DESIGN CRITERIA

1. Design Parameters

   a. Were physical parameters representing the 1%-annual-chance event or greater used to design the coastal flood protection structure?
   ☐ Yes ☐ No

   b. The number of design water levels that were evaluated ________ (number) range from the mean low water elevation of _______ feet to the 1%-annual-chance stillwater surge elevation of _____________ feet. The critical water level is_____ feet. The datum that these elevations are referenced to is __________ (e.g., NGVD 1929, NAVD 1988, etc.).

   Attach an explanation specifying which water levels and associated wave heights and periods were analyzed.

   c. Were breaking wave forces used to design the structure? ☐ Yes ☐ No

   If No, attach an explanation why they were not used for design.

2. Settlement

   a. What is the expected settlement rate at the site of the structure? __________________

   Please attach a settlement analysis.

3. Freeboard

   a. Does this structure have 1 foot of freeboard above the height of the 1%-annual-chance wave-height elevation or maximum wave runup (whichever is greater)?
   ☐ Yes ☐ No

   b. Does the structure have freeboard of at least 2 feet above the 1%-annual-chance stillwater surge elevation?
   ☐ Yes ☐ No

4. Toe Protection

   Specify the type of toe protection: ____________________________________

   If no toe protection is provided, provide analysis of scour potential and attach an elevation of structural stability performed with potential scour at the toe.

5. Backfill Protection

   Will the structure be overtopped during the 1%-annual-chance event?
   ☐ Yes ☐ No

   If the structure will be overtopped, attach an explanation of what measures are used to prevent the loss of backfill from rundown over the structure, drainage landward, under or laterally around the ends of the structure, or through seams and drainage openings in the structure.

6. Structural Stability - Minimum Water Level

   a. For coastal revetments, was a geotechinical analysis of potential failure in the landward direction by rotational gravity slip performed for maximum loads associated with minimum seaward water level, no wave action, saturated soil conditions behind the structure, and maximum toe scour?
   ☐ Yes ☐ No

   b. For gravity and pile-supported seawalls, were engineering analyses of landward sliding, landward overturning, and of foundation adequacy using maximum pressures developed in the sliding and overturning calculations performed?
   ☐ Yes ☐ No

   c. For anchored bulkheads, were engineering analyses performed for shear failure, moment failure, and adequacy of tiebacks and deadmen to resist loading under low-water conditions?
   ☐ Yes ☐ No

7. Structural Stability - Critical Water Level (Note: All structures must be designed to resist the maximum loads associated with the critical water level to be credited as providing protection from the 1%-annual-chance event.)

a. For coastal revetments, were geotechnical analyses performed investigating the potential failure in the seaward direction by rotational gravity slip or foundation failure due to inadequate bearing strength?
☐ Yes ☐ No

b. For revetments, were engineering analyses of rock, riprap, or armor block's stability under wave action or uplift forces on the rock, riprap, or armor blocks performed?
☐ Yes ☐ No

c. Are the rocks graded?
☐ Yes ☐ No

d. Are soil or geotextile filters being used in the design?
☐ Yes ☐ No

e. For gravity and pile supported seawalls, were engineering analyses of landward sliding, landward overturning, and foundation adequacy performed?
☐ Yes ☐ No

f. For anchored bulkheads, were engineering analyses of shear and moment failure performed using "shock" pressures?
☐ Yes ☐ No

For all analyses marked "No" above for the appropriate type of structure, please attach an explanation for why the analyses were not performed.

8. Material Adequacy

The design life of the structure given the existing conditions at the structure site is _____years.

.ce and Impact Alignment

a. Will the structure be subject to ice forces?
☐ Yes ☐No

If Yes, attach impact analysis and design for details for such forces.

b. Will the structure be subjected to impact forces from boats, ships, or large debris?
☐ Yes ☐No

If Yes, attach impact analysis.

10. Structure Plan Alignment

The structure is (check one):

☐ Isolated ☐ Part of a continuous structure with redundant return walls at frequent intervals.

Please provide a map showing the location of the structure and any natural land features that shelter the structure from wave actions.

C. ADVERSE IMPACT EVALUATION

1. If the structure is new, proposed, or modified, will the structure impact flooding and erosion for areas adjacent to the structure?
   ☐ Yes ☐ No
   If Yes, attach an explanation.

D. COMMUNITY AND/OR STATE REVIEW

1. Has the design, maintenance, and impact of the structure been reviewed and approved by the community, and any Federal, State, or local agencies having jurisdiction over flood control and coastal construction activities in the area the structure impacts?
   ☐ Yes ☐ No

   If Yes, attach a list of agencies who have reviewed and approved the project.

   If No, attach an explanation why review and approval by the appropriate community or agency has not been obtained.

E. CERTIFICATION

As a Professional Engineer, I certify that the above structures will withstand all hydraulic and wave forces associated with the 1%-annual-chance flood without significant structural degradation. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: ______________________

License No.: ______________ Exp. Date: ______________

Company Name: ______________________

Telephone No.: ______________ Fax. No.: ______________

Signature: ______________________ Date: ______________

Seal (optional)

FEDERAL EMERGENCY MANAGEMENT AGENCY

ALLUVIAL FAN FLOODING FORM

O.M.B.No. 3067-0148
Expires September 30, 2005

PAPERWORK BURDEN DISCLOSURE NOTICE

Flooding Source: ____

Note: Fill out one form for each flooding source studied.

A. THREE-STAGE ANALYSIS (Based on FEMA Guidelines dated February 23, 2000)

1. Stage 1 Analysis

   a. The landform is composed of (check one): ☐ alluvial ☐ debris flow deposits.
   b. Source of data used to determine composition, morphology, and location of the landform:

   ____

   c. Is there an NRCS soils survey and soil survey map available? ☐ Yes ☐ No
   If Yes, please include a copy of the map and any pertinent sections of the soil survey

2. Stage 2 Analysis

   a. The alluvial fan exhibits ☐ active ☐ inactive ☐ a combination of active and inactive alluvial fan flooding.
   b. Approximate age of inactive fan surfaces (thousands of years): __________ yrs.
   c. Is there an opportunity for avulsions that could lead channels or sheetfloods across the older fan surfaces?
   ☐ Yes ☐ No
   d. Is there evidence of headcutting that could lead to stream piracy? ☐ Yes ☐ No
   e. Is there geomorphic evidence of past avulsions during the Holocene epoch? ☐ Yes ☐ No
   f. The fan exhibits the following types of flooding (check one):

   ☐ Flooding along stable channels
   ☐ Sheetflow
   ☐ Debris flow
   ☐ Unstable flow path flooding

3. Stage 3 Analysis

The boundaries of the 1%-annual-chance floodplain have been determined using (check one):

☐ Risk-Based Analysis
☐ FEMA FAN Program (if discharge at the apex is different than that given in the effective FIS, then attach MT-2, Form 2 along with a plot of the flood freqency curve on long-normal probability paper and include the drainage area above the hydrographic apex, and the mean, standard deviation, and skew coefficient of the curve)
☐ Sheetflow Methods
☐ Hydraulic Analytical Methods
☐ Geomorphic Data, Post-Flood Hazard Verification, and Historical Information
☐ Composite Methods

B. STRUCTURAL FLOOD CONTROL MEASURES

1. The following structural flood control measures are proposed or built (check one):

   ☐ Channelization ☐ Levee/Floodwall ☐ Dam ☐ Sedimentation

2. Do the constructed or proposed structural measures affect flood hazards (including velocity, scour, and sediment deposition), on other areas of the fan? ☐ Yes ☐ No

3. Attach completed Form 3 (Riverine Structures Form).

4. Sediment Transport Considerations:
   Was sediment transport considered? ☐ Yes ☐ No If Yes, then fill out Form 3, Section F (Sediment Transport).
   If No, then attach your explanation for why sediment transport was not considered.

5. Please attach a copy of the formal Operations and Maintenance Plan.

C. MAPPING REQUIREMENTS

Attach a certified topographic work map showing the following:

-The boundaries of the alluvial fan including: toe, topographic and hydrologic apexes, and lateral boundaries

-The delineation of the active and inactive portions of the fan as determined by the Stage 2 Analysis

-The revised 1%-annual-chance floodplain boundaries, as determined by the Stage 3 Analysis, that tie into the effective floodplain boundaries

-The correct alignment of all structural features

-The map scale

FEDERAL EMERGENCY MANAGEMENT AGENCY

PAYMENT INFORMATION FORM

Community Name: ______________________________

ject Identifier: ______________________________

THIS FORM MUST BE MAILED, ALONG WITH THE APPROPRIATE FEE, TO ONE OF TWO POST OFFICE BOXES (SEE BELOW) OR FAXED TO THE FAX NUMBER BELOW.

Type of request:

MT-1 application fee
MT-2 application fee } (Insert **3173** as the P.O. Box number in the address below)

External Data Requests (EDRs) (Insert **398** as the P.O. Box number in the address below)

Federal Emergency Management Agency
Revisions Fee-Collection System Administrator
P. O. Box _______
Merrifield, Virginia 22116
Fax: (703) 849-0282
Phone: (703) 849-0432

Request # ______________________________ (if known) Amount: ______________

☐ INITIAL FEE * ☐ FINAL FEE ☐ FEE BALANCE ** ☐ MASTER CARD ☐ VISA ☐ CHECK ☐ MONEY ORDER

ote: Applicable only for EDR and/or Alluvial Fan requirements (as appropriate)
ote: Applicable only if submitting a corrected fee for an ongoing request.

COMPLETE THIS SECTION ONLY IF PAYING BY CREDIT CARD

☐☐☐☐ – ☐☐☐☐ – ☐☐☐☐ – ☐☐☐☐
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
CARD NUMBER

EXP. DATE
☐☐ – ☐☐
Month Year

_____________________ Date

_____________________ Signature

NAME (AS IT APPEARS ON CARD): ______________________________
(please print or type)

ADDRESS:
(for your Credit card receipt-please print or type) ______________________________

____

DAYTIME PHONE: ______________

APPENDIX B

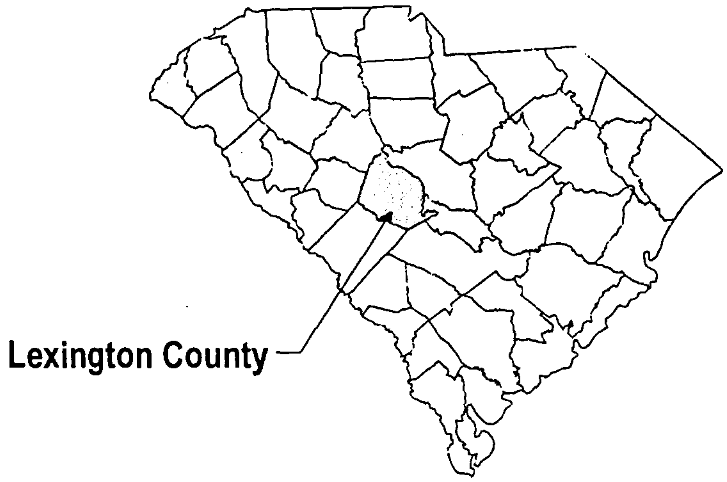
- **Recognizing Effective Data**

FLOOD INSURANCE STUDY

LEXINGTON COUNTY, SOUTH CAROLINA
AND INCORPORATED AREAS

VOLUME 1 OF 2

COMMUNITY NAME	COMMUNITY NUMBER
BATESBURG LEESVILLE, TOWN OF	450130
CAYCE, CITY OF	450131
COLUMBIA, CITY OF	450172
GILBERT, TOWN OF	450132
IRMO, TOWN OF	450133
LEXINGTON, TOWN OF	450134
LEXINGTON COUNTY (UNINCORPORATED AREAS)	450129
PELION, TOWN OF	450135
PINE RIDGE, TOWN OF	450136
SOUTH CONGAREE, TOWN OF	450137
SPRINGDALE, TOWN OF	450138
SWANSEA, TOWN OF	450139
WEST COLUMBIA, CITY OF	450140



REVISED:
FEBRUARY 9, 2000

Federal Emergency Management Agency

Maximum operating pool level of Lake Murray, as 'regulated by the Federal Power Commission, is 360 feet. When inflow during major floods requires temporary storage above maximum operating pool level, releases are made through spillway gates to augment discharges through power turbines in order to lower the reservoir to required maximum pool level as soon as possible. During this operation, spillway gates are opened gradually until the lake level begins to recede. As long as the reservoir level continues to rise, gate openings will be increased until all six spillway gates are wide open. This type of operation attempts to keep outflow approximately equal to inflow without allowing the reservoir to rise to a dangerous level. If, prior to a flood occurrence, the reservoir happens to be below normal operating level, some of the floodwater will be stored, resulting in a reduction of peak discharges downstream.

The chance of incidental flood control storage is greater for minor floods than for major floods; therefore, it was assumed that streamflow records collected on the Saluda River near Columbia could be used, without adjustments, to determine discharge frequency relationships for floods up to 10-year frequency at both stations. In order to establish the upper end of the discharge-frequency curves, it was necessary to adjust recorded flood discharges which were affected by coincidental flood control storage. This was accomplished by applying methods based on the hydrologic equations utilizing peak discharge and mean discharge information supplied by the USGS and South Carolina Electric and Gas Company (References 10 and 11). The adjustments provided a homogeneous set of data, which was used as a basis for probability studies to establish the portion of the discharge-frequency curves from the 50- to 500-year frequencies at both gage stations. Smooth transitions were drawn between the upper and lower frequency curves for both stations.

Six Mile Creek discharge-frequency relationships were developed using methods prescribed in a USGS open-file report, and the results were checked against the results of a rainfall runoff model developed during a USACE floodplain information study report (References 12 and 13).

Discharge-frequency determinations for Big Branch, Kinley Creek, Koon Branch, Rawls Creek, Senn Branch, Six Mile Creek, Stoop Creek, Tributary CR-I, Tributary CR-1-1, Tributary K-2, Tributary R-2, Tributary SM-3, and Tributary SM-5, were computed using USGS urban runoff formulas contained in an open-file report (Reference 12).

For Rawls Creek in the Town of Irmo, the discharge at the upstream corporate limit was estimated from regional regression equations (Reference 14). Adjustments to the discharges were made for future urbanization (Reference 12, 15, and 16).

Discharges were not determined for Kinley Branch, F-1, Tributary R-1, Tributary SM-4, Tributary SM-6, Tributary SM-7, Tributary TM-1, Tributary TM-2, Tributary TM-3, and Tributary TM-3-1 which were studied by approximate methods. Flood boundaries for these streams were estimated based on information developed for detailed study reaches in the same area.

TABLE 4 - SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-YEAR	50-YEAR	100-YEAR	500-YEAR
TRIBUTARY SM-2					
At mouth	0.94	298	477	567	766
At breached dam	0.74	279	448	533	723
TRIBUTARY SM-3					
At mouth	2.5	1,260	2,000	2,310	3,300
At Edmund Road (Highway 302)	2.01	1,130	1,793	2,062	2,959
At Railroad Bridge	1.49	973	1,544	1,776	2,548
At Lexington Drive	1.21	875	1,390	1,600	2,295
TRIBUTARY SM-5					
At mouth	1.3	826	1,362	1,608	2,304
TRIBUTARY TO FOURTEEN MILE CREEK					
At confluence with Fourteen Mile Creek	0.6	410	627	723	930
At a point approximately 1,890 feet upstream of confluence of Fourteen Mile Creek	0.4	266	403	462	600
TWELVE MILE CREEK					
Downstream of Gibson Pond Dam	31.0	1,220	2,490	3,260	6,050
Upstream of Gibson Pond Dam	31.0	1,370	2,590	3,330	5,970
Upstream end of Gibson Pond	30.1	1,360	2,570	3,300	5,920
Downstream of confluence with Boggy Branch	28.9	1,340	2,570	3,300	5,950
Downstream of Barr Lake Dam	27.1	1,300	2,500	3,220	5,800
Upstream end of Barr Lake	25.9	1,330	2,490	3,220	5,830
Downstream of confluence with Hogpen Branch	22.2	1,240	2,380	3,090	5,700
Upstream of confluence with Hogpen Branch	19.5	1,130	2,190	2,860	5,330
Downstream of confluence with Long Creek	16.2	1,050	2,040	2,670	5,010
Downstream of Crout Pond Dam	7.7	503	1,510	1,980	3,670
Upstream of Crout Pond Dam	7.7	847	1,570	2,020	3,630
At Gilbert Town Limits	4.3	641	1,220	1,580	2,880

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE-FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NGVD	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE (FEET NGVD)
Tributary SM-3			A	V				
A	950	230	2,280	1.0	163.2	163.2	164.2	1.0
B	1,500	115	323	7.2	172.7	172.7	173.4	0.7
C	1,900	105	549	4.2	174.5	174.5	174.7	0.2
D	2,350	100	6,320	0.4	175.1	175.1	176.1	1.0
E	3,600	100	4,120	0.6	175.1	175.1	176.1	1.0
F	5,200	101	543	3.8	176.3	176.3	177.0	0.7
G	5,290	101	732	2.8	178.3	178.3	178.9	0.6
H	5,750	174	820	2.2	178.8	178.8	179.6	0.8
I	5,880	197	1,463	1.2	182.3	182.3	183.3	1.0
J	6,400	162	1,048	1.7	182.9	182.9	183.9	1.0
K	7,140	77	460	3.9	185.5	185.5	186.0	0.5
L	7,590	86	391	4.5	188.9	188.9	189.6	0.7
M	8,180	80	288	6.2	195.4	195.4	195.4	0.0
N	8,350	30	613	2.9	197.7	197.7	198.7	1.0
O	8,880	34	225	7.1	200.3	200.3	200.8	0.5
P	9,230	200	4,283	0.4	213.7	213.7	214.5	0.8
Q	10,030	330	4,390	0.4	213.7	213.7	214.5	0.8
R	10,600	204	1,751	0.9	213.7	213.7	214.5	0.8
S	11,000	290	2,528	0.6	213.7	213.7	214.5	0.8
T	11,250	291	2,390	0.7	213.7	213.7	214.5	0.8

[1]Feet above confluence with Six Mile Creek

A x V = Q

X-SEC	A	V	Q
F	543	3.8	2,063
H	820	2.2	1,804
O	225	7.1	1,598

TABLE 6

FEDERAL EMERGENCY MANAGEMENT AGENCY

LEXINGTON COUNTY, SC
AND INCORPORATED AREAS

FLOODWAY DATA

TRIBUTARY SM - 3

```
T1    LEXINGTON COUNTY SPECIAL STUDY  sm3fisfb
T2    SIX MILE CREEK TRIBUTARY 3 (SM-3) DUPLICATE EFFECTIVE  10 YEAR FLOOD
T3    SM-3    AUG 1993
*    STARTING WATER SURFACE ELEVATION WAS OBTAINED FROM A PREVIOUS STUDY OF SM-3
J1      0        2        0        0                 0        0        0    174.2        0
J2      1        0       -1
J3    100      150

QT      5     1130     1793     2062     2959     2062
ET                                                9.11                       260      340
NC    .15      .15      .07       .1       .3

F
X1   5180       19      260      280      230      230      230
GR    200        0      188       30      186       60      184      110      182      125
GR    180      150      178      170      176      190      174      210      172      230
GR    171      260   168.66      270      171      280      172      310      174      390
GR    176      450      178      475      180      520      182      740

ET                                               12.41
NC    .15      .15      .07       .3       .5
X1   5200                                   20       20       20               .14

*  EDMUND ROAD (ROUTE 302)
SC 2.014        .4      2.6                  6        8       80      8.1   169.19   168.78

ET                                               10.41
X1   5290                                   90       90       90
X2                        2    175.2    176.6
BT     -7        0    184.4      160      100    180.1      160      200    177.8      160
BT             300    176.6      160      400    176.9      160      500    179.0      160
BT             600    181.7      160

ET                                               15.41
X1   5300       19      280      306       10       10       10               .41
GR187.34         0    184.9       50    181.3      100    179.3      150    176.6      200
GR    174      250    170.6      280    167.8      282      168      304    170.5      306
GR  171.4      350    172.8      400    173.4      450    175.2      500    176.2      550
GR  176.9      600    177.5      650    180.4      700    181.2      718

QT      5      973     1544     1776     2548     1776
ET                                               15.41
NC    .15      .15      .09       .3       .5
X1   5750       22      170      180      830      120      450
H
GR    182        0      180       40      178      100      176      140      175      170
GR  171.1      172    171.3      178    174.9      180      175      190    173.9      240
GR  175.3      250    175.8      317    175.1      319    174.7      323    176.1      325
GR  175.9      340    174.7      390      176      440    179.1      490      178      526
GR  180.4      532   180.45      540

ET                                               14.41
NC    .15      .15      .09       .3       .5
X1   5770       23      235      255       20       20       20
GR    182        0      180       40      178      100      176      140      175      170
GR  173.2      172    173.2      178    173.2      180    173.2      235    172.5      240
GR  172.5      250    173.2      255    173.2      319    173.2      323    173.2      325
GR  173.2      340    174.7      390      176      440    179.1      490      178      526
GR  180.4      532   180.45      540      181      600

*  RAILROAD CROSSING
SC 2.014       0.4      2.7                  4        0       60      1.1    174.1   172.98

ET                                               10.41
X1   5830                                   60       60       60
X2                        2    178.1    180.8
BT    -16        0    183.9    182.0       25    183.5      165       50    183.1      165
BT             100    182.6      165      150    182.5      165      200    182.1      165
BT             218    182.0      165      250    181.4      165      300    181.1      165
BT             350      181      165      388    180.9      165      400      181      165
BT             450      181      165      500    180.9      165      550    180.8      165
```

```
ET                                              9.11                    503     703
NC     .06     .06     .03      .3      .5
X1    9160      16     503     703     280     280     280
X2                       2   193.5   212.4
BT     -15       0   214.0   185.0      60   213.5   185.0     200   213.5   185.0
BT             260   213.0   185.0     320   213.0   185.0     380   212.5   185.0
BT             400   212.5   185.0     450   212.5   185.0     490   212.4   185.0
BT             520   212.4   185.0     570   212.5   185.0     620   212.5   185.0
BT             690   213.9   185.0     750   214.0   185.0     810   214.1   185.0
GR     218       0     216      25     214      75     212     135     210     285
GR     210     425     210     480     213     490     212     500   210.6     503
GR     190     533     190     673   210.6     703     212     706     214     873
GR     216    1000

ET                                             10.41
NC     .06     .06     .03      .1      .3
X1    9230      16     503     703      70      70      70
GR     218       0     216      25     214      75     212     135     210     285
GR     210     425     210     480     213     490     212     500   210.6     503
GR     190     533     190     673   210.6     703     212     706     214     873
GR     216    1000

X1    9270      16     468     705      40      40      40
GR     218       0     216      30     214      75     212     135     210     285
GR     210     375     212     435     213     455     212     465   210.6     468
GR     192     498     192     675   210.6     705     212     708     214     875
GR     216     935

X1   10030      15     214     544     760     760     760
GR     220       0     218      90     216     140     214     175     212     210
GR   210.6     214     200     245     200     430     200     500   210.6     544
GR     212     550     214     560     216     575     218     585     220     650
NC     .08     .08     .03      .1      .3

X1   10600      19     298     502     570     570     570
GR     224       0     222      60     220     100     218     180     216     260
GR     214     280     212     290   210.6     298     207     320     205     335
GR     205     470   210.6     502     212     510     214     525     216     540
GR     218     560     220     610     222     635     224     670

X1   11000      19     225     515     310     490     400
GR     224       0     222      75     220     115     218     140     216     160
GR     214     190     212     220   210.6     225     206     240     205     400
GR     206     500   210.6     515     212     520     214     530     216     540
GR     218     550     220     560     222     570     224     640

X1   11250      17  224.67  515.33     110     290     250              .5
X4       2   210.6  224.67   210.6  515.33
GR     224       0     222      75     220     115     218     140     216     160
GR     214     190     212     220     206     240     205     400     206     500
GR     212     520     214     530     216     540     218     550     220     560
GR     222     570     224     640

EJ
T1  LEXINGTON COUNTY   sm3fisfb
T2  TRIBUTARY SM-3 DUPLICATE EFFECTIVE  50 YEAR FLOOD
T3  SM-3 TRIBUTARY TO SIX MILE CREEK
J1               3                                                      175.4
J2       2       0      -1
T1 LEXINGTON COUNTY   sm3fisfb
T2  TRIBUTARY SM-3 DUPLICATE EFFECTIVE 100 YEAR FLOOD
T3  SM-3 TRIBUTARY TO SIX MILE CREEK
J1               4                                                      176.2
J2       3       0      -1
T1  LEXINGTON COUNTY   sm3fisfb
T2  TRIBUTARY SM-3  DUPICATE EFFECTIVE 500 YEAR FLOOD
T3  SM-3 TRIBUTARY TO SIX MILE CREEK
J1               5                                                      179.7
J2      15       0      -1
ER
```

BT		600	181.45	181.0						

ET						15.41				
NC	.15	.15	.07	.1	.3					
X1	5880	12	360	380	50	50	50			
GR	184.1	0	184	30	182	80	180	125	178	210
GR	176	330	174	360	174	380	176	410	178	450
GR	180	520	182	570						

ET						3.41				
NC	.15	.15	.07	.1	.3					
X1	6400	15	155	175	520	520	520			
GR	185	0	184	40	182	55	180	70	178	95
GR	177	155	176	165	177	175	178	240	180	250
GR	182	260	184	270	186	320	188	335	200	350

ET						10.41				
NC	.15	.15	.07	.1	.3					
X1	7140	18	165	195	740	740	740			
X4	1	177	175							
GR	190	0	188	65	186	80	184	100	182	120
GR	180	165	179.5	180	180	195	182	230	184	250
GR	186	270	188	300	190	340	192	365	194	395
GR	196	420	198	440	200	455				

ET						3.41				
NC	.15	.15	.07	.1	.3					
X1	7590				450	450	450		5	

ET						9.11			230	310
NC	.15	.15	.07	.3	.5					
X1	8180	10	255	300	590	590	590			
GR	200.8	0	196.3	100	196.5	200	195.5	255	183.9	269
GR	183.2	273	183.8	278	198	300	205	400	206.6	500

ET						9.11			225	325
X1	8230				50	50	50			

* BILOXI SQUARE										
SC	2.014	0.4	2.7		8	8	40	8.1	185.73	185.68

ET						9.11			210	335
X1	8280				50	50	50			
X2			2	193.73	196.2					
BT	-6	0	200	160	100	196.6	160	200	196.2	160
BT		300	198.7	160	400	204.7	160	500	207	160

ET						9.11			165	225
X1	8350	15	190	210	70	70	70		-5	
GR	207.33	0	207.21	15	207.9	35	207.8	50	203.9	100
GR	201.7	150	190.74	190	190.95	200	191.6	210	201.2	229
GR	205.8	267	208.3	283	208.5	300	210.3	350	211.4	375
QT	5	875	1390	1600	2295	1600				
ET						9.11			185	220
NC	.15	.15	.07	.3	.5					
X1	8760	15	190	210	410	410	410			
GR	207.33	0	207.21	15	207.9	35	207.8	50	203.9	100
GR	201.7	150	192.74	190	188	200	193.6	210	201.2	229
GR	205.8	267	208.3	283	208.5	300	210.3	350	211.4	375

O

ET						9.11			185	220
X1	8880	15	190	215	120	120	120		3	
GR	207.33	0	207.21	15	207.9	35	207.8	50	203.9	100
GR	201.7	150	191.74	190	185.5	200	196.62	215	201.2	229
GR	205.8	267	208.3	283	208.5	300	210.3	350	211.4	375

* LEXINGTON DRIVE										
SC	2.014	.4	2.6		4		275	1.1	189.5	188.5

APPENDIX C

- Flood Frequency Analysis

The waterdata.usgs.gov server is expected to be unavailable on Sunday May 18 from 10am - 2pm due to facilities maintenance. It is hoped that this outage will last 1 hour or less, but may be longer.
Please check state Web servers for data during this time period (xx.waterdata.usgs.gov - where **xx** is the state code). Thank You.

Peak Streamflow for the Nation

USGS 04087100 HONEY CREEK AT MILWAUKEE, WI

Milwaukee County, Wisconsin
Hydrologic Unit Code 04040003
Latitude 42°58'44", Longitude 87°59'56" NAD27
Drainage area 3.26 square miles
Gage datum 740 feet above sea level NGVD29

Output formats

- Table
- Graph
- Tab-separated file
- WATSTORE formatted file
- Reselect output format

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1959	Jul. 18, 1959		240
1960	Aug. 02, 1960		285
1961	Sep. 22, 1961		230
1962	Aug. 24, 1962		140
1963	Aug. 12, 1963		115
1964	Jul. 18, 1964	19.40	259
1965	Aug. 08, 1965		185
1966	Feb. 09, 1966		190
1967	Jun. 11, 1967	19.03	210
1968	Sep. 24, 1968	19.02	210
1969	Jun. 29, 1969	20.00	290
1970	Jun. 02, 1970	19.60	310
1971	Feb. 19, 1971	18.49	150
1972	Sep. 18, 1972	21.54	680
1973	Apr. 21, 1973	21.40	640

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1980	Jun. 07, 1980	20.22	390
1981	Jul. 13, 1981	20.91	520
1982	Oct. 18, 1981	20.23	420
1983	Dec. 02, 1982	22.60	1,050
1984	Jul. 10, 1984	20.23	395
1985	Nov. 01, 1984	20.40	420
1986	Jun. 27, 1986	21.47	660
1987	Aug. 26, 1987	20.82	510
1988	Jan. 30, 1988	20.55	450
1989	Sep. 03, 1989	20.63	470
1990	May 10, 1990	21.32	600
1991	Jul. 07, 1991	21.17	580
1992	Jun. 17, 1992	20.31	410
1993	Aug. 30, 1993	20.53	450
1994	Jul. 14, 1994	21.30	615

1974	Jun. 09, 1974	19.33	250
1975	Mar. 22, 1975	19.41	275
1976	Mar. 04, 1976	19.97	350
1977	Jul. 18, 1977	20.30	400
1978	Sep. 13, 1978	20.04	360
1979	Mar. 30, 1979	19.35	255

1995	Aug. 16, 1995	20.79	500
1996	Jun. 17, 1996	20.74	490
1997	Jun. 21, 1997	22.70	1,100
1998	Aug. 05, 1998	2.13	570
1999	Jun. 13, 1999	22.54	1,040
2000	Jul. 02, 2000		1,850
2001	Jul. 22, 2001		462[2]

Peak Streamflow Qualification Codes.

- 2 -- Discharge is an Estimate

```
TT FLOOD FLOW FREQUENCY ANALYSIS
TT USGS 04087100 Honey Creek at Milwaukee, WI
J2                   .00
ID 04087100   Drainage Area 3.26 sq. mi.
GS040871             -.4
QR040871    1959     240
QR040871    1960     285
QR040871    1961     230
QR040871    1962     140
QR040871    1963     115
QR040871    1964     259
QR040871    1965     185
QR040871    1966     190
QR040871    1967     210
QR040871    1968     210
QR040871    1969     290
QR040871    1970     310
QR040871    1971     150
QR040871    1972     680
QR040871    1973     640
QR040871    1974     250
QR040871    1975     275
QR040871    1976     350
QR040871    1977     400
QR040871    1978     360
QR040871    1979     255
QR040871    1980     390
QR040871    1981     520
QR040871    1982     420
QR040871    1983    1050
QR040871    1984     395
QR040871    1985     420
QR040871    1986     660
QR040871    1987     510
QR040871    1988     450
QR040871    1989     470
QR040871    1990     600
QR040871    1991     580
QR040871    1992     410
QR040871    1993     450
QR040871    1994     615
QR040871    1995     500
QR040871    1996     490
QR040871    1997    1100
QR040871    1998     570
QR040871    1999    1040
QR040871    2000    1850
QR          2001     462
ED
```

```
*************************************    ************************************
*               FFA                 *    *                                  *
*     FLOOD FREQUENCY ANALYSIS      *    *  U.S. ARMY CORPS OF ENGINEERS    *
*     PROGRAM DATE:  FEB 1995       *    * THE HYDROLOGIC ENGINEERING CENTER *
*          VERSION:  3.1            *    *        609 SECOND STREET         *
*     RUN  DATE   AND   TIME:       *    *     DAVIS, CALIFORNIA 95616      *
*        04 JUN 03    12:47:14      *    *         (916) 756-1104           *
*                                   *    *                                  *
*************************************    ************************************
```

INPUT FILE NAME: Honeycrk.txt
OUTPUT FILE NAME: Honeycrk.out

```
**TITLE RECORD(S)**
TT   FLOOD FLOW FREQUENCY ANALYSIS
TT   USGS 04087100 Honey Creek at Milwaukee, WI

**JOB RECORD**
        A        B  CLIMIT  NDSSCV     IEXT
J2    .00      .00     .00       0        0

**STATION IDENTIFICATION**
ID    04087100    Drainage Area 3.26 sq. mi.

**GENERALIZED SKEW**
     ISTN   GGMSE     SKEW
GS 040871    .000     -.40

**SYSTEMATIC EVENTS**
     43 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ FINAL RESULTS ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ

-PLOTTING POSITIONS- 04087100 Drainage Area 3.26 sq. mi.

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	WEIBULL PLOT POS
0	0	1959	240.	1	2000	1850.	2.27
0	0	1960	285.	2	1997	1100.	4.55
0	0	1961	230.	3	1983	1050.	6.82
0	0	1962	140.	4	1999	1040.	9.09
0	0	1963	115.	5	1972	680.	11.36
0	0	1964	259.	6	1986	660.	13.64
0	0	1965	185.	7	1973	640.	15.91
0	0	1966	190.	8	1994	615.	18.18
0	0	1967	210.	9	1990	600.	20.45
0	0	1968	210.	10	1991	580.	22.73
0	0	1969	290.	11	1998	570.	25.00
0	0	1970	310.	12	1981	520.	27.27
0	0	1971	150.	13	1987	510.	29.55
0	0	1972	680.	14	1995	500.	31.82
0	0	1973	640.	15	1996	490.	34.09
0	0	1974	250.	16	1989	470.	36.36
0	0	1975	275.	17	2001	462.	38.64
0	0	1976	350.	18	1988	450.	40.91
0	0	1977	400.	19	1993	450.	43.18
0	0	1978	360.	20	1982	420.	45.45
0	0	1979	255.	21	1985	420.	47.73
0	0	1980	390.	22	1992	410.	50.00
0	0	1981	520.	23	1977	400.	52.27
0	0	1982	420.	24	1984	395.	54.55
0	0	1983	1050.	25	1980	390.	56.82
0	0	1984	395.	26	1978	360.	59.09
0	0	1985	420.	27	1976	350.	61.36
0	0	1986	660.	28	1970	310.	63.64
0	0	1987	510.	29	1969	290.	65.91
0	0	1988	450.	30	1960	285.	68.18
0	0	1989	470.	31	1975	275.	70.45
0	0	1990	600.	32	1964	259.	72.73
0	0	1991	580.	33	1979	255.	75.00
0	0	1992	410.	34	1974	250.	77.27
0	0	1993	450.	35	1959	240.	79.55
0	0	1994	615.	36	1961	230.	81.82
0	0	1995	500.	37	1968	210.	84.09
0	0	1996	490.	38	1967	210.	86.36
0	0	1997	1100.	39	1966	190.	88.64
0	0	1998	570.	40	1965	185.	90.91
0	0	1999	1040.	41	1971	150.	93.18
0	0	2000	1850.	42	1962	140.	95.45
0	0	2001	462.	43	1963	115.	97.73

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 43 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.710

0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 81.4

HIGH OUTLIER TEST

BASED ON 43 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.710

0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 1880.

-SKEW WEIGHTING -

BASED ON 43 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = .136
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = .302

FINAL RESULTS

-FREQUENCY CURVE- 04087100 Drainage Area 3.26 sq. mi.

COMPUTED CURVE	EXPECTED PROBABILITY	PERCENT CHANCE	CONFIDENCE LIMITS .05	.95
FLOW IN CFS		EXCEEDANCE	FLOW IN CFS	
2070.	2330.	.2	3090.	1560.
1740.	1900.	.5	2500.	1340.
1510.	1610.	1.0	2100.	1180.
1290.	1350.	2.0	1740.	1030.
1010.	1050.	5.0	1320.	832.
822.	839.	10.0	1030.	688.
637.	644.	20.0	770.	545.
391.	391.	50.0	454.	338.
240.	238.	80.0	281.	199.
186.	182.	90.0	222.	149.
151.	146.	95.0	184.	116.
102.	95.	99.0	130.	73.

SYSTEMATIC STATISTICS

LOG TRANSFORM: FLOW, CFS		NUMBER OF EVENTS	
MEAN	2.5925	HISTORIC EVENTS	0
STANDARD DEV	.2515	HIGH OUTLIERS	0
COMPUTED SKEW	.2370	LOW OUTLIERS	0
REGIONAL SKEW	-.4000	ZERO OR MISSING	0
ADOPTED SKEW	.0000	SYSTEMATIC EVENTS	43

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+++++++++++++++++++++++++
+ END OF RUN            +
+ NORMAL STOP IN FFA    +
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APPENDIX D

- USGS REGIONAL REGRESSION EQUATIONS

> **Methods for Estimating Flood Magnitude & Frequency in Rural Areas in Arizona**

> **Nationwide Urban Equations**

> **Flood Frequency Program, Version 3**

science for a changing world

The National Flood-Frequency Program—Methods for Estimating Flood Magnitude and Frequency in Rural Areas in Arizona

Introduction

Estimates of the magnitude and frequency of flood-peak discharges and flood hydrographs are used for a variety of purposes, such as for the design of bridges, culverts, and flood-control structures; and for the management and regulation of flood plains. To provide simple methods of estimating flood-peak discharges, the U.S. Geological Survey (USGS) has developed and published equations for every State, the Commonwealth of Puerto Rico, and a number of metropolitan areas in the United States. In 1993, the USGS, in cooperation with the Federal Emergency Management Agency and the Federal Highway Administration, compiled all current USGS statewide and metropolitan area equations into a computer program, titled "The National Flood-Frequency (NFF) Program" (Jennings and others, 1994).

Since 1993, new or updated equations have been developed by the USGS for various areas of the Nation. These new equations have been incorporated into an updated version of the NFF Program.

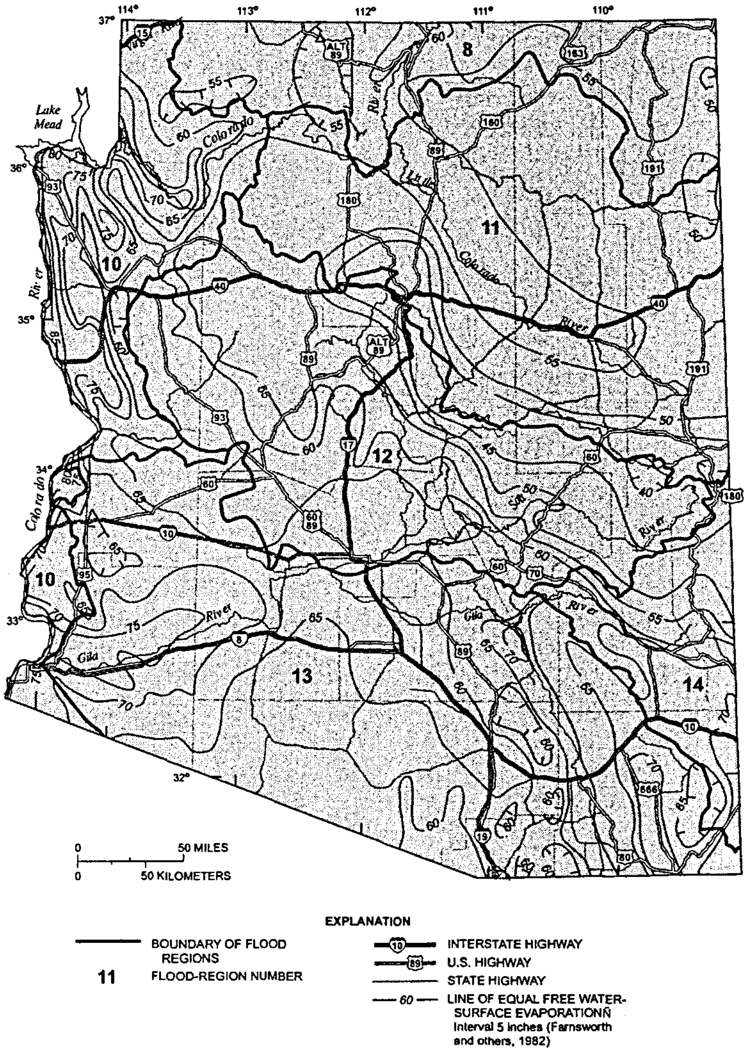
Fact sheets that describe application of the updated NFF Program to various areas of the Nation are available. This fact sheet describes the application of the updated NFF Program to streams that drain rural areas in Arizona.

Overview

The State of Arizona is wholly located within a regional flood study area that encompasses the arid lands of the southwestern United States (Thomas and others, 1997). The study area is divided into 16 hydrologic flood regions, of which 7 include portions of Arizona (fig. 1). These regions were delineated on the basis of regional flood sources (snowmelt, summer thunderstorms, or cyclonic rainfall), elevation, and analysis of flood yields and residuals of preliminary regional flood-frequency relations. Within Arizona, sites greater in elevation than 7,500 feet above sea level [National Geodetic Vertical Datum of 1929 (NGVD of 1929)] are considered to be in region 1. Sites located at elevations of 7,500 feet or less may belong to regions 8, 10, 11, 12, 13, or 14 on the basis of geographic location (fig. 1).

Thomas and others (1997) developed regression equations for estimating peak discharges (Q_T), in cubic feet per second, that have recurrence intervals that range from 2 to 100 years for ungaged, unregulated rural streams. The NFF Program provides estimates of the 500-year discharge on the basis of extrapolation. Although some sites with drainages greater than 200 square miles were used to develop the equations, applications are best limited to 200 square miles or less.

Figure 1. Hydrologic flood regions for Arizona.



Procedure

The equations are based on the inch-pound system of units, but the NFF Program will accept and report either the inch-pound or metric system of units. The explanatory watershed variables used in the regression equations are as follows:

Drainage area (AREA), in square miles, is the total area that contributes runoff upstream of the location of the stream site of interest.

Mean annual precipitation (PREC), in inches, is the average mean annual precipitation for the basin as determined from isohyetal maps developed by the U.S. Weather Bureau (1963). The average is best determined by use of grid sampling techniques. Lines of equal precipitation from the Weather Bureau map are intersected with (drawn on to) a map of the drainage basin, a grid with equal-size cells is overlaid on the map, the mean annual precipitation is determined at each grid intersection, and the values are averaged.

Mean basin elevation (ELEV), in feet above sea level, is also determined by grid sampling techniques. The elevations of a minimum of 20 equally spaced points are determined, and the average of the points is taken. As many as 100 points may be needed for large basins.

Mean annual evaporation (EVAP), in inches, is the mean annual free water-surface evaporation at the study site. This variable should be estimated for the stream site of interest by linear interpolation between the lines of free surface-water evaporation shown in figure 1.

The regression equations, the average standard errors of prediction, and the equivalent years of record for regions 1, 8, 12, 13, and 14 are given in table 1. The average standard errors of prediction are an average measure of the accuracy of the regression equations when estimating peak-discharge values for ungaged watersheds similar to those that were used to derive the regression equations. The equivalent years of record is the number of years of streamflow record needed to achieve the same accuracy as the regression equation.

Table 1. Flood-peak discharge regression equations and associated statistics for regions 1, 8, 12, 13, and 14 in Arizona (modified from Thomas and others, 1997)

[Q_T, peak discharge, in cubic feet per second for recurrence interval *T*, 2 to 100 years; AREA, drainage area, in square miles; PREC, precipitation, in inches; ELEV, mean basin elevation, in feet above sea level (NGVD of 1929)]

Regression equation	Average standard error of prediction, in percent	Equivalent years of record
Region 1 (For sites located at elevations greater than 7,500 feet above sea level[1]) -165 stations		
$Q_2 = 0.124AREA^{0.845}PREC^{1.44}$	59	0.16
$Q_5 = 0.629AREA^{0.807}PREC^{1.12}$	52	.62
$Q_{10} = 1.43AREA^{0.786}PREC^{0.958}$	48	1.34
$Q_{25} = 3.08AREA^{0.768}PREC^{0.811}$	46	2.50
$Q_{50} = 4.75AREA^{0.758}PREC^{0.732}$	46	3.37
$Q_{100} = 6.78AREA^{0.750}PREC^{0.668}$	46	4.19
Region 8 -108 stations		
$Q_2 = 598AREA^{0.501}(ELEV/1{,}000)^{-1.02}$	72	0.37
$Q_5 = 2{,}620AREA^{0.449}(ELEV/1{,}000)^{-1.28}$	62	1.35
$Q_{10} = 5{,}310AREA^{0.425}(ELEV/1{,}000)^{-1.40}$	57	2.88
$Q_{25} = 10{,}500AREA^{0.403}(ELEV/1{,}000)^{-1.49}$	54	5.45
$Q_{50} = 16{,}000AREA^{0.390}(ELEV/1{,}000)^{-1.54}$	53	7.45
$Q_{100} = 23{,}300AREA^{0.377}(ELEV/1{,}000)^{-1.59}$	53	9.28
Region 12 -68 stations		
$Q_2 = 41.1AREA^{0.629}$	105	0.23
$Q_5 = 238AREA^{0.687}(ELEV/1{,}000)^{-0.358}$	68	1.90
$Q_{10} = 479AREA^{0.661}(ELEV/1{,}000)^{-0.398}$	52	6.24
$Q_{25} = 942AREA^{0.630}(ELEV/1{,}000)^{-0.383}$	40	17.8
$Q_{50} = 10^{(7.36 - 4.17AREA^{-0.08})}(ELEV/1{,}000)^{-0.440}$	37	27.5
$Q_{100} = 10^{(6.55 - 3.17AREA^{-0.11})}(ELEV/1{,}000)^{-0.454}$	39	32.1
Region 13 - 73 stations		
$Q_2 = 10^{(6.38 - 4.29AREA^{-0.06})}$	57	2.0
$Q_5 = 10^{(5.78 - 3.31AREA^{-0.08})}$	40	6.25
$Q_{10} = 10^{(5.68 - 3.02AREA^{-0.09})}$	37	11.1
$Q_{25} = 10^{(5.64 - 2.78AREA^{-0.10})}$	39	15.0
$Q_{50} = 10^{(5.57 - 2.59AREA^{-0.11})}$	43	15.9
$Q_{100} = 10^{(5.52 - 2.42AREA^{-0.12})}$	48	16.1
Region 14- 22 stations		
$Q_2 = 583AREA^{0.588}(ELEV/1{,}000)^{-1.3}$	74	1.69
$Q_5 = 618AREA^{0.524}(ELEV/1{,}000)^{-0.70}$	63	3.54
$Q_{10} = 361AREA^{0.464}$	65	4.95
$Q_{25} = 581AREA^{0.462}$	63	7.75
$Q_{50} = 779AREA^{0.462}$	64	9.65
$Q_{100} = 1{,}010AREA^{0.463}$	66	11.2

[1]NGVD of 1929

The regression equations for regions 10 and 11 were developed using an iterative regression method (Hjalmarson and Thomas, 1992) and a modified form of the station year statistical analysis method (Fuller, 1914). The regression equations, the estimated average standard errors of regression, and the equivalent years of record for regions 10 and 11 are given in table 2. The average standard error of regression is an estimate of the predictive accuracy of these regression equations and is determined by a direct sampling method.

The approximate ranges of the explanatory watershed variables over which the equations are applicable are shown in table 3. Thomas and others (1997) presented the actual ranges of applicability as two-dimensional clusters or clouds of explanatory variables plotted against one another. The ranges shown in table 3 define a rectangular space that brackets the clouds and, therefore, include airs of values of the explanatory variables near the corners of the rectangle that are outside of the clouds. Application of the equations for values of the variables near the extremes of a range should be done cautiously. The standard errors increase appreciably when any explanatory watershed variable is near or outside the quoted range.

Improving Estimates with Gaged Data

The U.S. Water Resources Council (1981, appendix 8) described weighting techniques to improve estimates of peak discharge at gaged locations by combining the estimates derived from analysis of gage records with estimates derived from other means including regression equations.

The weights for these two estimates are based on the length of the gage record (in years) and the equivalent years of record of the applicable regression equation. The weighted estimate of peak discharge is computed as:

$$\log Q_T(W) = \frac{N \cdot \log Q_T(G) + EQ \cdot \log Q_T(R)}{N + EQ}$$

where

$Q_T(W)$ is the weighted estimate for recurrence interval T at the gaged site,

$Q_T(G)$ is the estimate of Q_T derived from analysis of the gage records,

$Q_T(R)$ is the estimate of Q_T derived from application of the regression equation,

N is the number of years of gage record, and

EQ is the equivalent years of record (table 1 and 2).

The accuracy of the weighted discharge estimate, in equivalent years of record, is equal to $N + EQ$. The NFF Program contains the appropriate algorithms for this computation, which differs slightly from that described by Thomas and others (1997).

Table 2. Flood-peak discharge equations and associated statistics for regions 10 and 11 in Arizona (modified from Thomas and others, 1997)

[Q_T, peak discharge for recurrence interval T, 2 to 100 years, in cubic feet per second; AREA, drainage area, in square miles; EVAP, mean annual evaporation, in inches]

Estimated average standard error of regression for these equations includes much of the within-station residual variance and therefore is not comparable to standard error of estimate from an ordinary-least-squares regression.

Regression equation	Estimated average standard error of regression, in log units	Equivalent years of record
Region 10 -104 stations		
$Q_2 = 12\ AREA^{0.58}$	1.14	0.618
$Q_5 = 85\ AREA^{0.59}$	.602	3.13
$Q_{10} = 200\ AREA^{0.62}$	.675	3.45
$Q_{25} = 400\ AREA^{0.65}$	.949	2.49
$Q_{50} = 590\ AREA^{0.67}$	.928	3.22
$Q_{100} = 850\ AREA^{0.69}$	1.23	2.22
Region 11 -46 stations		
$Q_2 = 26\ AREA^{0.62}$	0.609	0.428
$Q_5 = 130\ AREA^{0.56}$	.309	2.79
$Q_{10} = 0.10\ AREA^{0.52}EVAP^{2.0}$	.296	4.63
$Q_{25} = 0.17\ AREA^{0.52}EVAP^{2.0}$	.191	17.1
$Q_{50} = 0.24\ AREA^{0.54}EVAP^{2.0}$	.294	9.20
$Q_{100} = 0.27\ AREA^{0.58}EVAP^{2.0}$	.863	1.32

Sites Near Gaged Sites on the Same Stream

Thomas and others (1997) showed how the weighted estimate of peak discharge at a gaged site can be used to estimate the peak discharge of an ungaged site on the same stream that has a drainage area that is between 50 and 150 percent of the drainage area of the gaged site. The weighted estimate is computed as:

$$Q_T(u) = Q_T(W) \cdot \left(\frac{Area_{ungaged}}{Area_{gaged}}\right)^b ,$$

where

$Q_T(u)$ is the weighted peak-discharge estimate for the recurrence interval T at the ungaged site,

$Q_T(W)$ is the weighted estimate of peak discharge at the gaged site,

$AREA_{ungaged}$ and $AREA_{gaged}$ are the drainage areas of the ungaged and gaged sites, respectively, and

b is an exponent for each region as follows:

Region	Exponent
1	0.8
8	.4
10	.6
11	.6
12	.6
13	.5
14	.5

The adjustment to the weighted estimate of peak discharge at the gaged site can be used when the drainage area at the ungaged site is within 50 to 150 percent of the drainage area of the gaged site. Otherwise, the estimate at the ungaged site should be based on the appropriate regression equation only.

Sites in Transition Zones

When the drainage area of the site of interest is in more than one of the regions 8, or 10-14, a weighted estimate of the peak discharge should be computed. The equations for the appropriate regions should be applied independently by using basinwide estimates of the required explanatory variables. The weighted estimate is then computed by multiplying each regional estimate against the fraction of the drainage area in that region and summing the products. The NFF Program provides an algorithm for this computation.

When the elevation of the stream site of interest is between 6,800 and 7,500 feet, a weighted estimate of the peak discharge should be computed by using the equations for region 1 and the other regions in which the basin is located. The applicable equations are each applied by using basinwide estimates of the required explanatory variables, and the region estimates are weighted as a function of elevation as follows:

$$Q_T(W) = Q_T(u) \cdot \frac{7,500 - E}{700} + Q_T)(Region 1) \cdot \left(1 - \left(\frac{7,500 - E}{700}\right)\right)$$

$Q_T(W)$ is the weighted peak-discharge estimate for the recurrence interval T at the site of interest,

$Q_T(u)$ is the estimate of peak discharge using the equations for regions 8, or 10-14 as appropriate,

$Q_T(Region\ 1)$ is the estimate of the peak discharge using the equations for region 1, and

E is the elevation of the stream site of interest.

The NFF Program does not provide an algorithm for this weighting computation.

Thomas and others (1997) summarized the basin characteristics, the estimates of peak discharge, and the weighted estimates of peak discharge for most of the 1,323 sites used in the study, including 259 sites in Arizona.

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Table 3. Range of explanatory variables for which regression equations are applicable

[--, not applicable.]

Hydrologic study region	Drainage area, in square miles[1]	Mean annual evaporation, in inches	Mean basin elevation, in feet above sea level[2]	Mean annual precipitation, in inches
Region 1	0.6–1,061	--	--	11–43
Region 8	1.0–1,990	--	4,300–10,200	--
Region 10	0.1–1,000	--	--	--
Region 11	0.2–890	44.1–55.7	--	--
Region 12	0.6–1,520	--	1,730–8,700	--
Region 13	0.1–1,780	--	--	--
Region 14	0.8–1,860	--	3,350–8,950	--

[1]For best results, applications should be limited to basins of less than 200 square miles.
[2]NGVD of 1929.

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USGS hydrologic analysis software is available for electronic retrieval through the World Wide Web (WWW) at http://water.usgs.gov/software/ and through anonymous File Transfer Protocol (FTP) from water.usgs.gov (directory: /pub/software). The WWW page and anonymous FTP directory from which the National Flood-Frequency software and user documentation can be retrieved are http://water.usgs.gov/software/nff.html and /pub/software/surface_water/nff, respectively.

Additional earth science information is available from the USGS through the WWW at http://www.usgs.gov/ or by calling 1-800-426-9000.

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The National Flood Frequency Program, Version 3:

A Computer Program for Estimating Magnitude and Frequency of Floods for Ungaged Sites

Water-Resources Investigations Report 02-4168

U.S. Department of the Interior
U.S. Geological Survey

URBAN FLOOD-FREQUENCY ESTIMATING TECHNIQUES

By V.B. Sauer

INTRODUCTION

The National Flood Frequency (NFF) Program provides equations for estimating the magnitude and recurrence intervals for floods in urbanized areas throughout the conterminous United States and Hawaii. The seven-parameter nationwide equations described in USGS Water-Supply Paper (WSP) 2207, by Sauer and others (1983), are based on urban runoff data from 199 basins in 56 cities and 31 States. These equations have been thoroughly tested and proven to give reasonable estimates for floods having recurrence intervals between 2 and 500 years. A later study by Sauer (1985) of urban data at 78 additional sites in the southeastern United States verified the seven-parameter equations as unbiased and having standard errors equal to or better than those reported in WSP 2207.

Additional equations for urban areas in some States have been included in the NFF program as optional methods to estimate and compare urban flood frequency. These equations were developed for local use within their designated urban area and should not be used for other urban areas.

NATIONWIDE URBAN EQUATIONS

The following seven-parameter equations and definitions are excerpted from Sauer and others (1983). The equations are based on multiple regression analysis of urban flood-frequency data from 199 urbanized basins,

$$UQ2 = 2.35\, A^{.41}\, SL^{.17}\, (RI2+3)^{2.04}\, (ST+8)^{-.65}\, (13\text{-}BDF)^{-.32}\, IA^{.15}\, RQ2^{.47}$$
standard error of estimate is 38 percent

$$UQ5 = 2.70\, A^{.35}\, SL^{.16}\, (RI2+3)^{1.86}\, (ST+8)^{-.59}\, (13\text{-}BDF)^{-.31}\, IA^{.11}\, RQ5^{.54}$$
standard error of estimate is 37 percent

$$UQ10 = 2.99\, A^{.32}\, SL^{.15}\, (RI2+3)^{1.75}\, (ST+8)^{-.57}\, (13\text{-}BDF)^{-.30}\, IA^{.09}\, RQ10^{.58}$$
standard error of estimate is 38 percent

$$UQ25 = 2.78\, A^{.31}\, SL^{.15}\, (RI2+3)^{1.76}\, (ST+8)^{-.55}\, (13\text{-}BDF)^{-.29}\, IA^{.07}\, RQ25^{.60}$$
standard error of estimate is 40 percent

$$UQ50 = 2.67\, A^{.29}\, SL^{.15}\, (RI2+3)^{1.74}\, (ST+8)^{-.53}\, (13\text{-}BDF)^{-.28}\, IA^{.06}\, RQ50^{.62}$$
standard error of estimate is 42 percent

$$UQ100 = 2.50\, A^{.29}\, SL^{.15}\, (RI2+3)^{1.76}\, (ST+8)^{-.52}\, (13\text{-}BDF)^{-.28}\, IA^{.06}\, RQ100^{.63}$$
standard error of estimate is 44 percent

$$UQ500 = 2.27\, A^{.29}\, SL^{.16}\, (RI2+3)^{1.86}\, (ST+8)^{-.54}\, (13\text{-}BDF)^{-.27}\, IA^{.05}\, RQ500^{.63}$$
standard error of estimate is 49 percent

where

UQ2, UQ5,... UQ500 are the urban peak discharges, in cubic feet per second (ft^3/s), for the 2-, 5-, ... 500-year recurrence intervals;

A is the contributing drainage area, in square miles, as determined from the best available topographic maps; in urban areas, drainage systems sometimes cross topographic divides. Such drainage changes should be accounted for when computing A;

SL is the main channel slope, in feet per mile (ft/mi), measured between points that are 10 percent and 85 percent of the main channel length upstream from the study site (for sites where SL is greater than 70 ft/mi, 70 ft/mi is used in the equations);

RI2 is the rainfall, in inches (in) for the 2-hour, 2-year recurrence interval, determined from U.S. Weather Bureau (USWB) Technical Paper 40 (1961) (eastern USA), or from NOAA Atlas 2 (Miller and others, 1973) (western USA);

ST is basin storage, the percentage of the drainage basin occupied by lakes, reservoirs, swamps, and wetlands; in-channel storage of a temporary nature, resulting from detention ponds or roadway embankments, should not be included in the computation of ST;

BDF is the basin development factor, an index of the prevalence of the urban drainage improvements;

IA is the percentage of the drainage basin occupied by impervious surfaces, such as houses, buildings, streets, and parking lots; and

RQT, are the peak discharges, in cubic feet per second, for an equivalent rural drainage basin in the same hydrologic area as the urban basin, for a recurrence interval of T years; equivalent rural peak discharges are computed from the rural equations for the appropriate State, in the NFF program, and are automatically transferred to the urban computations.

The basin development factor (**BDF**) is a highly significant variable in the equations, and provides a measure of the efficiency of the drainage basin. It can easily be determined from drainage maps and field inspections of the drainage basin. The basin is first divided into upper, middle, and lower thirds on a drainage map, as shown in figure 1A-C. Each third should contain about one-third of the contributing drainage area, and stream lengths of two or more streams should be approximately the same in each third. However, stream lengths of different thirds can be different. For instance, in figure 1C, the stream distances of the lower third are all about equal, but are longer than those in the middle third. Precise definition of the basin thirds is not considered necessary because it will not have much effect on the final value of BDF. Therefore, the boundaries between basin thirds can be drawn by eye without precise measurements.

Within each third of the basin, four characteristics of the drainage system must be evaluated and assigned a code of 0 or 1. Summation of the 12 codes (four codes in each third of the basin) yields the BDF. The following guidelines should not be considered as requiring precise measurements. A certain amount of subjectivity will necessarily be involved, and field checking should be performed to obtain the best estimates.

1. Channel improvements.—If channel improvements such as straightening, enlarging, deepening, and clearing are prevalent for the main drainage channels and principal tributaries (those that drain directly into the main channel), then a code of 1 is assigned. To be considered prevalent, at least 50 percent of the main drainage channels and principal tributaries must be improved to some degree over natural conditions. If channel improvements are not prevalent, then a code of 0 is assigned.
2. Channel linings.—If more than 50 percent of the length of the main channels and principal tributaries has been lined with an impervious surface, such as concrete, then a code of 1 is assigned to this characteristic; otherwise, a code of 0 is assigned. The presence of channel linings would obviously indicate the presence of channel improvements as well. Therefore, this is an added factor and indicates a more highly developed drainage system.
3. Storm drains or storm sewers.—Storm drains are defined as those enclosed drainage structures (usually pipes), commonly used on the secondary tributaries where the drainage is received directly from streets or parking lots. Many of these drains empty into open channels; however, in some basins they empty into channels enclosed as box and pipe culverts. Where more than 50 percent of the secondary tributaries within a subarea (third) consists of storm drains, then a code of 1 is assigned to this aspect; otherwise, a code of 0 is assigned.
4. Curb-and-gutter streets.—If more than 50 percent of the subarea (third) is urbanized (covered with residential, commercial, and/or industrial development), and if more than 50 percent of the streets and highways in the subarea are constructed with curbs and gutters, then a code of 1 is be assigned to this aspect; otherwise, a code of 0 is assigned. Drainage from curb- and-gutter streets commonly empties into storm drains.

Estimates of urban flood-frequency values should not be made using the seven-parameter equations under certain conditions. For instance, the equations should not be used for basins where flow is controlled by reservoirs, or where detention storage is used to reduce flood peaks. The equations also should not be used if the rural equations for the region of interest contain independent variables, such as basin development factor, percentage of impervious area, percentage of urban development, or an urbanization index. Though classified in

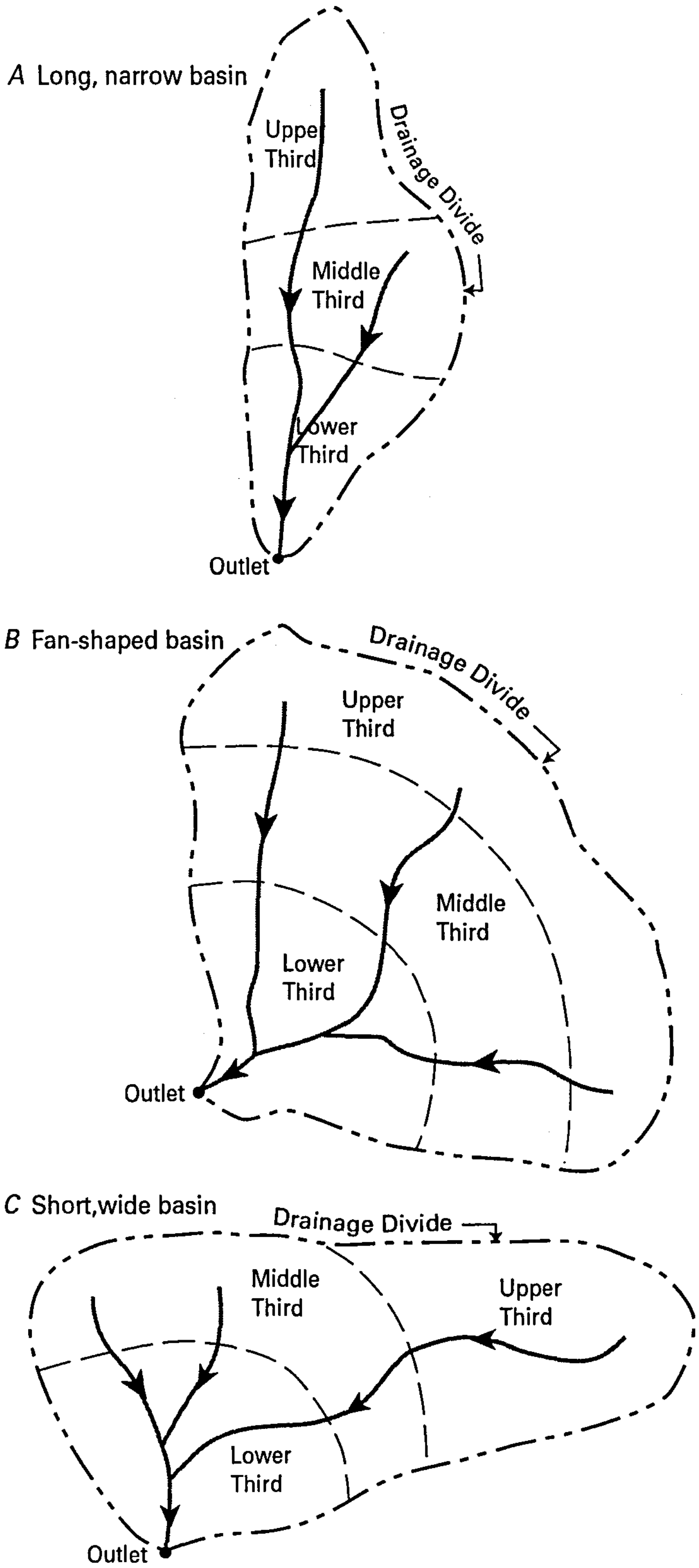

Figure 1. Schematic of typical drainage basin shapes and subdivision into basin thirds. Note that stream-channel distances within any given third of a basin in the examples are approximately equal, but between basin thirds the distances are not equal, to compensate for relative basin width of the thirds (from Jennings and others, 1994).

NFF as rural equations, estimates obtained from equations that contain these types of variables already reflect the effects of urbanization.

The urban equations should not be used if any of the values of the seven parameters are outside the range of values used in the original regression study (except for SL, which is limited to 70 ft/mi). These ranges are provided in the NFF Program, and the user is warned by the program anytime a variable value exceeds the range. The program will compute urban estimates even though a parameter may be outside the range; however, the standard error of estimate may be greater than the value given for each equation.

LOCAL URBAN EQUATIONS

The NFF Program includes additional equations for some cities and metropolitan areas that were developed for local use in those designated areas only. These local urban equations can be used in lieu of the nationwide urban equations, or they can be used for comparative purposes. It would be highly coincidental for the local equations and the nationwide equations to give identical results. Therefore, the user should compare results of the two (or more) sets of urban equations, and compare the urban results to the equivalent rural results. Ultimately, it is the user's decision as to which urban results to use.

The local urban equations are described in this report in the individual summaries of State flood-frequency techniques for States that use the same equations as those that appeared in the previous version of NFF. The local urban equations are described in fact sheets for States that have updated either their rural or urban equations since the previous version of NFF was released (Jennings and others, 1994). In addition, some of the rural reports contain estimation techniques for urban watersheds. Several of the rural reports suggest the use of the nationwide equations given by Sauer and others (1983) and described above.

USING THE NATIONAL FLOOD FREQUENCY PROGRAM, VERSION 3: A COMPUTER PROGRAM FOR ESTIMATING MAGNITUDE AND FREQUENCY OF FLOODS FOR UNGAGED SITES

U.S. Geological Survey Fact Sheet 084-02

The text and graphics are presented here in pdf format (print quality) 2.9MB.

Estimates of the magnitude and frequency of flood-peak discharges and flood hydrographs are used for a variety of purposes, such as the design of bridges and culverts, flood-control structures, and flood-plain management. These estimates are often needed at ungaged sites where no observed flood data are available for frequency analysis. Regression equations are commonly used to estimate the magnitude and frequency of flood-peak discharges and flood hydrographs at ungaged sites. These equations are developed by statistically relating the flood characteristics to the physical and climatic characteristics of the watersheds for a group of streamgaging stations within a region that have virtually natural streamflow conditions. Regression equations enable the transfer of flood characteristics from gaged sites to ungaged sites simply by determining the needed watershed and climatic characteristics for the ungaged site.

In 1994, the U.S. Geological Survey (USGS), in cooperation with the Federal Highway Administration and the Federal Emergency Management Agency, released version 1 of the National Flood Frequency (NFF) Program (Jennings and others, 1994). This Microsoft DOS[1] program provided engineers and hydrologists a practical tool for computing estimates of flood-peak discharges having recurrence intervals of 2 to 500 years for user-selected sites on rural and urban streams. The 2-year flood occurs, on average, once in 2 years and has a 50 percent chance of occurring in any single year, whereas the 500-year flood occurs, on average, once in 500 years and has a 0.2 percent chance of occurring in any single year.

Version 1 of NFF contained all USGS-developed regional regression equations that were available as of September 1993 for estimating unregulated flood frequencies. NFF also provided the ability to generate flood-frequency plots and plots of typical flood hydrographs corresponding to a given rural and/or urban peak discharge. Since the release of NFF version 1, new or updated equations have been developed by the USGS for most of the Nation. Longer periods of record, and improved methods for measuring basin characteristics and developing regression analyses, have generally led to improved precision of the updated equations over those that they have replaced. The new and updated equations have been compiled and incorporated into a new, easier-to-use, Microsoft Windows[1] version of the NFF Program (Ries and Crouse, 2002). Version 3 of the NFF software compiles more than 2,000 flood-flow equations developed by the USGS for 289 regions of the Nation, the Commonwealth of Puerto Rico, and the island of Tutuilla, American Samoa, into a single, user-friendly package. The flood-frequency equations contained in NFF were taken from statewide flood-frequency reports that were prepared generally in cooperation with individual State Departments of Transportation, and/or other government agencies, and were published either by the USGS or the State Departments of Transportation.

NFF Program Capabilities

Version 3 of NFF can be used to:

- Obtain estimates of flood frequencies for sites in rural (unregulated) ungaged basins.
- Obtain estimates of flood frequencies for sites in urbanized basins.
- Estimate maximum floods based on envelope curves developed by Crippen and Bue (1977).
- Create hydrographs of estimated floods for sites in rural or urban basins and manipulate the appearance of the graphs.
- Create flood-frequency curves for sites in rural or urban basins and manipulate the appearance of the curves.
- Obtain improved flood-frequency estimates for gaging stations by weighting estimates obtained from the systematic flood records for the stations with estimates obtained from regression equations.
- Obtain improved flood-frequency estimates for ungaged sites by weighting estimates obtained from the regression equations with estimates obtained by applying the flow per unit area for an upstream or downstream gaging station to the drainage area for the ungaged site.
- Save output from the program in text and graphic files.
- Obtain documentation and instruction for use of the program from help files.

Obtaining And Installing NFF Software

NFF can be downloaded from the Internet at the Web address listed at the end of this report. NFF has two components: NFFv3.exe, which is the computer program, and NFFv3.mdb, which is the database. Download each file to the local hard drive by double-clicking on the file names or icons shown in the Web browser window. Next, go to the location of NFFv3.exe on the local hard drive using Windows Explorer or My Computer. Double-click on the file name (NFFv3.exe) to start the NFF Setup Wizard. The Setup Wizard will prompt for a directory name in which to install NFF (typically, C:\Program Files\NFF\), will allow selection of the Start Menu folder in which to place the program's shortcut, and ask whether or not to create a desktop icon for the program. After all of the selections are completed, click on the Install button to complete the installation. The NFFv3.mdb file must then be copied to the NFF directory when the installation is complete.

Using The NFF Software

NFF can be started by double-clicking on the NFF icon on the desktop or by clicking on the NFF menu item under Programs in the **Start** menu. A small window will open that allows entry of the user's name, specification of the NFF work file to which data will be stored, and choice of English or metric units for computation.

The main NFF user interface window is shown in figure 1. Three pull-down menus at the top of the user interface allow users to (1) open and save work, and create reports for printing, (2) create hydrographs and frequency plots, and (3) access the help file, the NFF Web site, and version information for the program. Just below the pull-down menus are a pair of boxes that allow selection of the State (required) in which the site of interest is located, and naming of the site (optional).

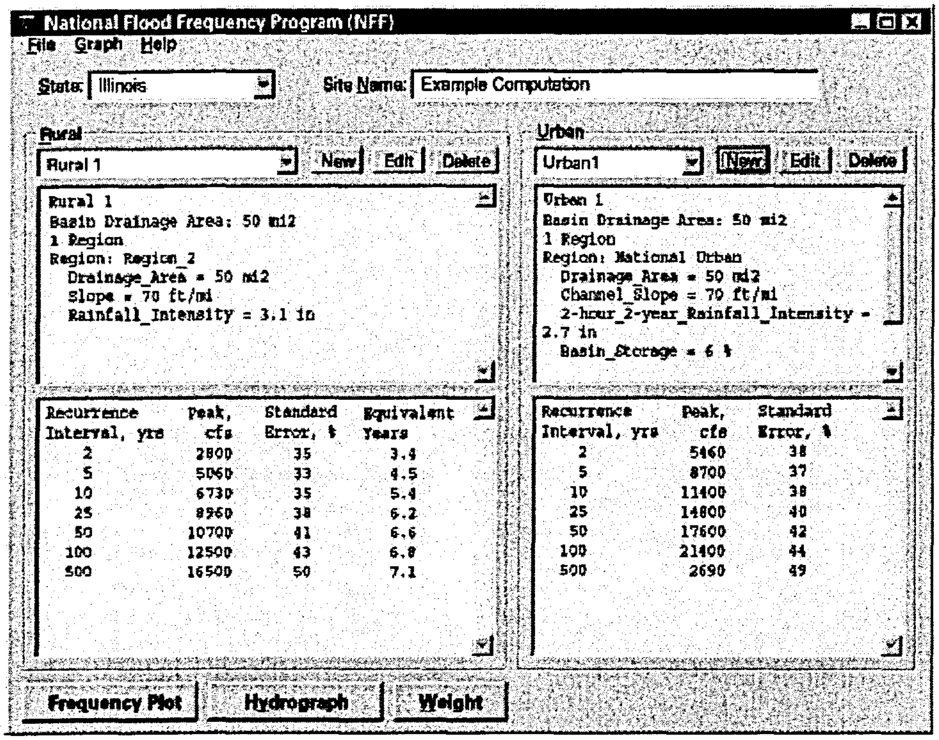

Figure 1. View of the main window of NFF.

Two large frames — one for rural estimates and the other for urban estimates — fill the center of the main window. A box at the top left of each frame shows the name of the current scenario (a set of estimates for a site). To the right of each box are three buttons, allowing users to (1) create a new scenario, (2) edit the current scenario, or (3) delete the current scenario. Below these buttons are two text boxes. The top box shows input parameters used to evaluate the regression equations for the selected scenario. The bottom box shows the output, including the recurrence intervals, the estimated peak flows, the standard errors of estimate or prediction, and the equivalent years of record for the estimates. The standard errors and the equivalent years of record provide indications of the reliability of the estimates.

Clicking on either of the **New** buttons opens the **Edit Scenario** window (figure 2), which allows users to select the hydrologic region of interest and enter the basin and climatic characteristics needed to evaluate the equations for that region. The scenario name can be specified by typing it into the box at the top of the window, or the program will automatically name the scenario based on the type of scenario (rural or urban) and the number of scenarios that have previously been run. When a region is selected, the names of the basin and climatic characteristics needed to solve the equations for that region are shown in the window. The values are entered in the boxes next to the basin and climatic characteristic names. Placing the cursor over one of these boxes or clicking in a box causes the minimum and maximum values of the basin and climatic characteristics, which were used to develop the equations, to appear in a pop-up text box and in a text line below the list of basin and climatic characteristics. Values outside the ranges shown can be entered, but the resulting peak-flow estimates will be extrapolations with unknown errors.

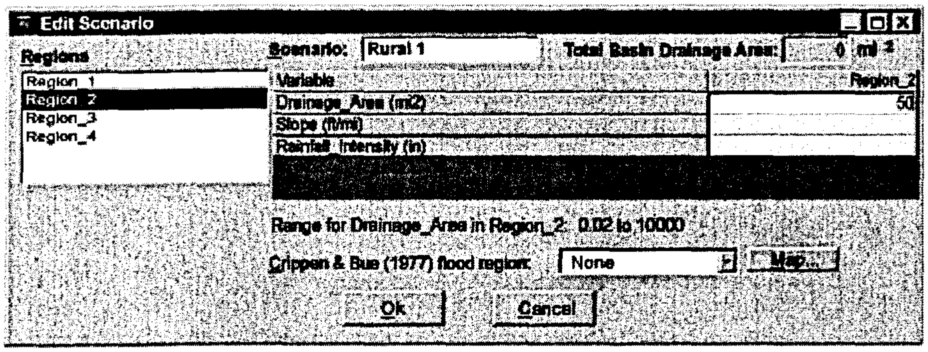

Figure 2. View of the Edit Scenario Window.

Sauer and others (1983) developed regression equations for estimating flood frequencies for urban ungaged sites throughout the United States that are included in NFF. Additional urban equations are available in NFF for several states and municipalities. The urban equations typically use rural estimates for the same site as predictor variables in the urban equations. NFF generates a warning when urban estimates are requested for a site and the rural estimates for the site have not yet been determined.

Three buttons at the bottom of the main window access the **Frequency Plot**, **Hydrograph**, and **Weight** options. Clicking on any of these buttons after a rural scenario is created causes another window to open. The **Frequency Plot** window, allows selection of the plotting scenario. Clicking the plot button causes the selected plotting scenario to be generated in the Frequency Plot window, as shown in figure 3. Pull-down menus allow printing and saving of the plots, modifying of the axes, titles, line styles and legends, listing of the data used to create the plot, and closing of the plot window.

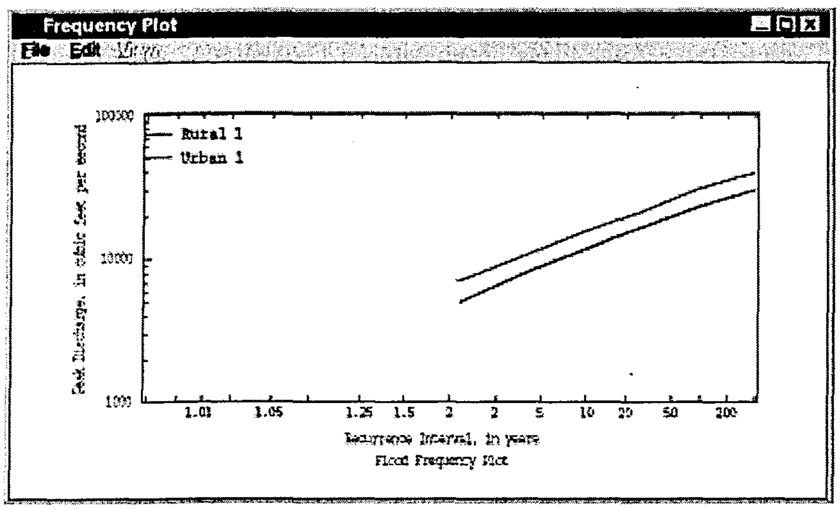

Figure 3. View of the Frequency Plot Window.

The **Hydrograph** window allows selection of the scenario and the recurrence interval to be plotted, as well as a lag time. If the scenario is based on the national urban equations (Sauer and others, 1983), the lag time can be estimated by specifying the basin length, in miles. Clicking the **Plot** button causes a window to open containing the hydrograph plot (figure 4). The pull-down menus provide capabilities including printing, saving, and modifying the axes, titles, line styles and legend of the plot, as well as listing the data used to create the plot, and closing the plot window.

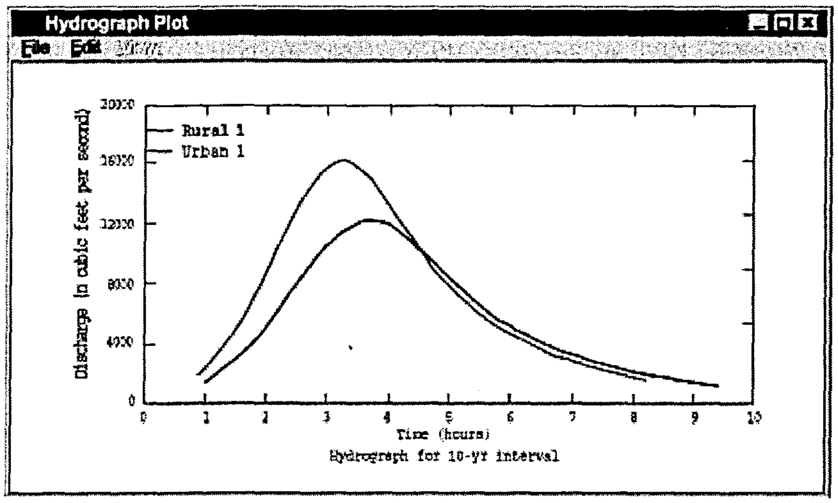

Figure 4. View of the Hydrograph Plot Window.

The **Weight** window can compute weighted estimates for both gaging stations and ungaged sites. A rural scenario of regression estimates must first be obtained for the gaging station before weighted estimates can be obtained. When the **Weight** window is opened, a button at the top of the window is initially set to calculate weighted estimates for a gaging station. Entering the years of actual record for the gaging station and the peak-flow estimates determined from observed data will cause weighted estimates to be calculated for the gaging station based on the length of years of observed data and the equivalent years of record for the estimates. Clicking on the **Apply** button saves the weighted estimates as a weighted scenario and places them in the output box of the rural frame in the main NFF window.

To obtain weighted estimates for an ungaged site, first create weighted estimates for the gaging station to be used for estimating peak flows for the ungaged site, then create a rural scenario for the ungaged site. The gaging station must be on the same stream as the ungaged site, and the drainage area for the ungaged site must be within 0.5 and 1.5 times the drainage area for the gaging station for the weighting to be applied. The weighting feature for ungaged sites requires weighted estimates for the nearest gaging station to be used in estimating peak flows, and requires that a scenario for the ungaged site also be created. Then, a rural scenario for the ungaged site must also be created. When the **Weight** window is open, click on the button at the top right of the window that allows weighting for an ungaged site using weighted gaged values. Select the rural weighted scenario for the gaging station from the pull-down list that will appear in the window, then click on **Apply** to compute the weighted estimates for the ungaged site and make them appear in the output box of the rural frame in the main NFF window. These weighted estimates for the ungaged site combine the weighted estimates for the gaging station with the regression equation estimates for the ungaged site on the basis of the drainage areas at the gaged and ungaged sites.

Documentation Of Equations And Parameters

The Help file can be accessed through the Help menu at the top of the NFF main window. It provides complete documentation of the technical methods used to estimate peak flows in the software.

The NFF Web site provides links to online reports, fact sheets, and state summaries that document the software and the equations in NFF. Full documentation of the equations and information necessary to solve them is provided in the individual reports for each state. Many of the state reports published since the release of NFF version 1 are available for download from the Web. In addition, fact sheets are available that summarize the reports for 20 states with new or corrected equations developed since the release of NFF version 1. Summaries from the original NFF report (Jennings and others, 1994) are available online for the states that have not developed new equations since the previous software release.

The NFF Web and site and links will be updated as new equations become available. It is recommended that users check these sites periodically to determine whether changes in the software have been made or new equations have been developed for areas of interest that will require obtaining an updated version of the database and new documentation.

Prepared by Craig D. Perl and Kernell G. Ries III

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USGS hydrologic analysis software is available for electronic retrieval through the World Wide Web (WWW) at http://water.usgs.gov/software/, and through anonymous File Transfer Protocol (FTP) from water.usgs.gov (directory: /pub/software). The WWW page and anonymous FTP directory from which the National Flood-Frequency software and user documentation can be retrieved at http://water.usgs.gov/software/nff.html and /pub/software/surface_water/nff, respectively. NFF software version 3 requires Windows 98/NT Version 4.0 or higher with service pack 5 or higher. For optimal performance, a processor running at 400 megahertz or faster with at least 64 megabytes of memory is recommended. A VGA or better color monitor is also recommended.

Additional earth science information is available from the USGS at http://water.usgs.gov/ or by calling 1-888-ASK-USGS.

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APPENDIX E

- **Confidence Limits**

- **Estimating Discharge – Probability Function without recorded events**

CECW-EH-Y

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

EM 1110-2-1619

Manual
No. 1110-2-1619

1 August 1996

Engineering and Design
RISK-BASED ANALYSIS FOR FLOOD DAMAGE REDUCTION STUDIES

1. Purpose. This manual describes and provides procedures for risk and uncertainty for Corps of Engineers flood damage reduction studies.

2. Applicability. The guidance presented and procedures described in this manual apply to all HQUSACE elements, major subordinate commands, districts, laboratories, and separate field operating activities having civil works responsibilities.

3. General. The procedures described herein lead to estimation of expected benefits of proposed flood damage reduction plans using risk and uncertainty analysis. Quantitative and qualitative methods of representing the likelihood and consequences of exceedance of the capacity of selected measures are also included. The procedures are generally an extension and expansion of the traditional plan formulation and evaluation regulations described in other Corps of Engineers guidance materials, in particular ER 1105-2-101 and ER 1105-2-100, and thus do not supersede guidance presented therein.

FOR THE COMMANDER:

ROBERT H. GRIFFIN
Colonel, Corps of Engineers
Chief of Staff

Chapter 1
Introduction

1-1. Purpose of Document

a. Risk involves exposure to a chance of injury or loss. The fact that risk inherently involves chance leads directly to a need to describe and to deal with uncertainty. Corps policy has long been (1) to acknowledge risk and the uncertainty in predicting floods and flood impacts, and (2) to plan accordingly. Historically, that planning relied on analysis of the expected long-term performance of flood-damage-reduction measures, on application of safety factors and freeboard, on designing for worst-case scenarios, and on other indirect solutions to compensate for uncertainty. These indirect approaches were necessary because of the lack of technical knowledge of the complex interaction of uncertainties in predicting hydrologic, hydraulic, and economic functions and because of the complexities of the mathematics required to do otherwise.

b. With advances in statistical hydrology and the widespread availability of high-speed computerized analysis tools, it is possible now to describe the uncertainty in choice of the hyrologic, hydraulic, and economic functions, to describe the uncertainty in the parameters of the functions, and to describe explicitly the uncertainty in results when the functions are used. Through this risk and uncertainty analysis (also known as *uncertainty propagation*), and with careful communication of the results, the public can be informed better about what to expect from flood-damage-reduction projects and thus can make better-informed decisions.

c. This document describes and provides procedures for risk and uncertainty analysis for Corps flood-damage reduction studies. It presents templates for display of results. Finally, this document suggests how risk and uncertainty can be taken into account in plan selection.

1-2. Applicability

The guidance presented and procedures described in this manual apply to all Headquarters, U.S. Army Corps of Engineers (HQUSACE) elements, major subordinate commands, laboratories, and separate field operating activities having civil works responsibilities.

1-3. Summary of Procedures

a. The procedures described in this document lead to:

(1) Estimation of expected benefits and costs of proposed flood-damage-reduction plans.

(2) Description of the uncertainty in those estimates.

(3) Quantitative and qualitative representation of the likelihood and consequences of exceedance of the capacity of selected measures.

The procedures generally are an extension and expansion of the traditional plan formulation and evaluation procedures described in Engineer Regulations (ER) 1105-2-100 and ER 1105-2-101 and thus do not supersede guidance contained there.

b. The analyses proposed herein depend on:

(1) Quantitative description of errors or uncertainty in selecting the proper hydrologic, hydraulic, and economic functions to use when evaluating economic and engineering performance of flood-damage-reduction measures.

(2) Quantitative description of errors or uncertainty in selecting the parameters of those functions.

(3) Computational techniques that determine the combined impact on plan evaluation of errors in the functions and their parameters.

The results of plan evaluation following these guidelines are not the traditional statements of economic benefit and probability of exceedance of an alternative. Instead the results are descriptions of the likelihood that an alternative will deliver various magnitudes of economic benefit and the expected probability of exceedance, considering the uncertainty in all that goes into computation of that probability.

1-4. Definition of Terms

To describe effectively the concepts of flood risks and uncertainty, this document uses the terminology shown in Table 1-1.

Table 1-1
Terminology Used in this Manual

Term	Definition
Function uncertainty (also referred to as distribution uncertainty and model uncertainty)	Lack of complete knowledge regarding the form of a hydrologic, hydraulic, or economic function to use in a particular application. This uncertainty arises from incomplete scientific or technical understanding of the hydrologic, hydraulic, or economic process.
Parameter	A quantity in a function that determines the specific form of the relationship of known input and unknown output. An example is Manning's roughness coefficient in energy loss calculations. The value of this parameter determines the relationship between a specified discharge rate and the unknown energy loss in a specific channel reach.
Parameter uncertainty	Uncertainty in a parameter due to limited understanding of the relationship or due to lack of accuracy with which parameters can be estimated for a selected hydrologic, hydraulic, or economic function.
Sensitivity analysis	Computation of the effect on the output of changes in input values or assumption.
Exceedance probability	The probability that a specified magnitude will be exceeded. Unless otherwise noted, this term is used herein to denote annual exceedance probability: the likelihood of exceedance in any year.
Median exceedance probability	In a sample of estimates of exceedance probability of a specified magnitude, this is the value that is exceeded by 50 percent of the estimates.
Capacity exceedance	Capacity exceedance implies exceedance of the capacity of a water conveyance, storage facility, or damage-reduction measure. This includes levee or reservoir capacity exceeded before overtopping, channel capacity exceedance, or rise of water above the level of raised structures.
Conditional probability	The probability of capacity exceedance, given the occurrence of a specified event.
Long-term risk	The probability of capacity exceedance during a specified period. For example, 30-year risk refers to the probability of one or more exceedances of the capacity of a measure during a 30-year period.

1-5. Organization of Document

This document includes the following topics:

For	See
A summary of procedures presented in this document	Chapter 1
Brief definition of terms used	Chapter 1
An overview of Corps' plan formulation and economic evaluation procedures	Chapter 2
An overview of procedures for uncertainty analysis	Chapter 2
Procedures for evaluating engineering performance of damage-reduction measures	Chapter 3
Guidance on describing uncertainty of discharge and stage frequency functions	Chapter 4
Guidance on describing uncertainty of stage-discharge functions	Chapter 5
Guidance on describing uncertainty of stage-damage functions	Chapter 6
Templates for displaying uncertainty analysis results	Chapter 7
References, including Corps publications that are pertinent to uncertainty analysis and other references that may be useful	Chapter 8
An example of plan formulation and evaluation in which uncertainty is considered	Chapter 9

Chapter 4
Uncertainty of Discharge-Probability Function

4-1. Function Development

a. A discharge or stage-probability function is critical to evaluation of flood damage reduction plans. The median function is used for the analytical method. The manner in which the function is defined depends on the nature of the available data. A direct analytical approach is used when a sample (such as stream gauge records of maximum annual discharges) is available and it fits a known statistical distribution such as log Pearson III. Other approaches are required if recorded data are not available or if the recorded data do not fit a known distribution. These approaches include using the analytical method after defining parameters of an adopted discharge-probability function generated by various means and the graphical or "eye fit" approach for fitting the function through plotting position points. The synthetic statistics approach is applied when the statistics for an adopted discharge-probability function are consistent with hydrologically and meteorologically similar basins in the region. The adopted function may be determined using one or more of the methods presented in Table 4-1. The graphical approach is commonly used for regulated and stage-probability functions whether or not they are based on stream gauge records or computed and stage-probability functions whether or not they are based on stream gauge records or computed from simulation analysis.

b. The without-project conditions discharge-probability functions for the base years are derived initially for most studies and become the basis of the analysis for alternative plans and future years. These functions may be the same as the without-project base year conditions or altered by flood damage reduction measures and future development assumptions. The uncertainty associated with these functions may be significantly different, in most instances greater.

c. Flood damage reduction measures that directly affect the discharge or stage-probability function include reservoirs, detention storage, and diversions. Other measures, if implemented on a large scale, may also affect the functions. Examples are channels (enhanced conveyance), levees (reduction in natural storage and enhanced conveyance), and relocation (enhanced conveyance).

4-2. Direct Analytical Approach

a. General. The direct analytical approach is used when a sample of stream gauge annual peak discharge values are available and the data can be fit with a statistical distribution. The median function is used in the risk-based analysis. The derived function may then be used to predict specified exceedance probabilities. The approach used for Corps studies follows the U.S. Water Resources Council's recommendations for Federal planning involving water resources presented in publication Bulletin 17B (Interagency Advisory Committee on Water Data 1982) and in EM 1110-2-1415 and ER 1110-2-1450.

Table 4-1
Procedures for Estimating Discharge-Probability Function Without Recorded Events (adapted from USWRC (1981))

Method	Summary of Procedure
Transfer	Discharge-probability function is derived from discharge sample at nearby stream. Each quantile (discharge value for specified probability) is extrapolated or interpolated for the location of interest.
Regional estimation of individual quantiles or of function parameters	Discharge-probability functions are derived from discharge samples at nearby gauged locations. Then the function parameters or individual quantiles are related to measurable catchment, channel, or climatic characteristics via regression analysis. The resulting predictive equations are used to estimate function parameters or quantiles for the location of interest.
Empirical equations	Quantile (flow or stage) is computed from precipitation with a simple empirical equation. Typically, the probability of discharge and precipitation are assumed equal.
Hypothetical frequency events	Unique discharge hydrographs due to storms of specified probabilities and temporal and areal distributions are computed with a rainfall-runoff model. Results are calibrated to observed events or discharge-probability relations at gauged locations so that probability of peak hydrograph equals storm probability.
Continuous simulation	Continuous record of discharge is computed from continuous record of precipitation with rainfall-runoff model, and annual discharge peaks are identified. The function is fitted to series of annual hydrograph peaks, using statistical analysis procedures.

b. Uncertainty of distribution parameters due to sampling error.

(1) Parameter uncertainty can be described probabilistically. Uncertainty in the predictions is attributed to lack of perfect knowledge regarding the distribution and parameters of the distribution. For example, the log Pearson type III distribution has three parameters: a location, a scale, and a shape parameter. According to the Bulletin 17B guidance, these are estimated with statistical moments (mean, standard deviation, and coefficient of skewness) of a sample. The assumption of this so-called method-of-moments parameter-estimation procedure is that the sample moments are good estimates of the moments of the population of all possible annual maximum discharge values. As time passes, new observations will be added to the sample, and with these new observations the estimates of the moments, and hence the distribution parameters, will change. But by analyzing statistically the sample moments, it is possible to draw conclusions regarding the likelihood of the true magnitude of the population moments. For example, the analysis might permit one to conclude that the probability is 0.90 that the parent population mean is between 10,000 m^3/s and 20,000 m^3/s. As the discharge-probability function parameters are a mathematical function of the moments, one can then draw conclusions about the parameters through mathematical manipulation. For example, one might conclude that the probability is 0.90 that the location parameter of the log Pearson type III model is between a specified lower limit and a specified upper limit. Carrying this one step further to include all three parameters permits development of a description of uncertainty in the frequency function itself. And from this, one might conclude that the probability is 0.90 that the 0.01-probability discharge is between 5,000 m^3/s and 5,600 m^3/s. With such a description, the sampling described in Chapter 2 can be conducted to describe the uncertainty in estimates of expected annual damage and annual exceedance probability.

(2) Appendix 9 of Bulletin 17B presents a procedure for approximately describing, with a statistical distribution, the uncertainty with a log-Pearson type III distribution with parameters estimated according to the Bulletin 17B guidelines. This procedure is summarized in Table 4-2; an example application is included in Tables 4-3 and 4-4.

(3) The sampling methods described in Chapter 2 require a complete description of error or uncertainty about the median frequency function. To develop such a description, the procedure shown in Table 4-2 can be repeated for various values of *C*, the confidence level. Table 4-3, for example, is a tabulation of the statistical model that describes uncertainty of the 0.01-probability quantile for Chester Creek, PA.

c. Display of uncertainty. The probabilistic description of discharge-probability function uncertainty can be displayed with confidence limits on a plotted function, as shown in Figure 4-1. These limits are curves that interconnect discharge or stage values computed for each exceedance probability using the procedure shown in Table 4-2, with specified values of *C* in the equations. For example, to define a so-called *95-percent-confidence limit*, the equations in Table 4-2 are solved for values of *P* with *C* constant and equal to 0.95. The resulting discharge values are plotted and interconnected. Although such a plot is not required for the computations proposed herein, it does illustrate the uncertainty in estimates of quantiles.

4-3. Analytical Approach

The analytical approach for adopted discharge-probability functions, also referred to as the synthetic approach, is described in Bulletin 17B (Interagency Advisory Committee 1982). It is used for ungauged basins when the function is derived using the transfer, regression, empirical equations, and modeling simulation approaches presented in Table 4-1 and when it is not influenced by regulation, development, or other factors. The discharge-probability function used is the median function and is assumed to fit a log Pearson Type II distribution by deriving the mean, standard deviation, and generalized skew from the adopted function defined by the estimated 0.50-, 0.10-, and 0.01-exceedance probability events. Assurance that the adopted function is valid and is properly fitted by the statistics is required. If not, the graphical approach presented in the next section should be applied. The value of the function is expressed as the equivalent record length which may be equal to or less than the record of stream gauges used in the deviation of the function. Table 4-5 provides guidance for estimating equivalent record lengths. The estimated statistics and equivalent record length are used to calculate the confidence limits for the uncertainty analysis in a manner previously described under the analytical approach.

4-4. Graphical Functions

a. Overview. A graphical approach is used when the sample of stream gauge records is small, incomplete,

Table 4-2
Procedure for Confidence Limit Definition (from Appendix 9, Bulletin 17B)

The general form of the confidence limits is specified as:

$$U_{P,C}(X) = \bar{X} + S\,(K^{U}_{P,C})$$

$$L_{P,C}(X) = \bar{X} + S\,(K^{L}_{P,C})$$

in which X and S and are the logarithmic mean and standard deviation of the final estimated log Pearson Type III discharge-probability function, and $K^{U}_{P,C}$ and $K^{L}_{P,C}$ are upper and lower confidence coefficients. [Note: P is the exceedance probability of X, and C is the probability that $U_{P,C} > X$ and that $L_{P,C} < X$.]
"The confidence coefficients approximate the non-central t-distribution. The non-central-t variate can be obtained in tables (41,42), although the process is cumbersome when G_W is non-zero. More convenient is the use of the following approximate formulas (32, pp. 2-15) based on a large sample approximation to the non-central t-distribution (42).

$$K^{U}_{P,C} = \frac{K_{G_w,P} + \sqrt{K^2{}_{G_w,P} - ab}}{a}$$

$$K^{L}_{P,C} = \frac{K_{G_w,P} + \sqrt{K^2{}_{G_w,P} - ab}}{a}$$

in which:

$$a = 1 - \frac{Z_C^2}{2\,(N-1)}$$

$$b = K^2_{G_w,P} - \frac{Z_C^2}{N}$$

and Z_C is the standard normal deviate (zero-skew Pearson Type III deviate with cumulative probability, C (exceedance probability 1-C). The systematic record length N is deemed to control the statistical reliability of the estimated function and is to be used for calculating confidence limits even when historic information has been used to estimate the discharge-probability function.

Examples are regulated flows, mixed populations such as generalized rainfall and hurricane events, partial duration data, development impacts, and stage exceedance probability. The graphical method does not yield an analytical representation of the function, so the procedures described in Bulletin 17B cannot be applied to describe the uncertainty. The graphical approach uses plotting positions to define the relationship with the actual function fitted by "eye" through the plotting position points. The uncertainty relationships are derived using an approach referred to as order statistics (Morgan and Henrion 1990). The uncertainty probability function distributions are assumed normal, thus requiring the use of the Wiebull's plotting positions, representing the expected value definition of the function, in this instance.

b. Description with order statistics. The order statistics method is used for describing the uncertainty for frequency functions derived for the graphical approach. The method is limited to describing uncertainty in the estimated function for the range of any observed data, or if none were used, to a period of record that is equivalent in information content to the simulation method used to derive the frequency function. Beyond this period of record, the method extrapolates the uncertainty description using asymptotic approximations of error distributions. The procedure also uses the equivalent record length concepts described in Section 4-3 and presented in Table 4-5.

Table 4-3
Example of Confidence Limit Computation (from Appendix 9, Bulletin 17B)

The 0.01 exceedance probability discharge for Chester Creek at Dutton Mill gauge is 18,990 cfs. The discharge-probability curve there is based on a 65-year record length (N = 65), with mean of logs of annual peaks (X) equal to 3.507, standard deviation of logs (S) equal to 0.295, and adopted skew (G_w) equal to 0.4. Compute the 95-percent confidence limits for the 0.01 exceedance probability event.

Procedure: From a table of standard normal deviates, Z_C for the 95-percent confidence limit (C = 0.95) is found to be 1.645. For the 0.01 probability event with G_w = 0.4, the Pearson deviate, $K_{Gw,P} = K_{0.4,0.01}$ is found to be 2.6154. Thus a and b are computed as

$$a = 1 - \frac{(1.645)^2}{2\,(65 - 1)} = 0.9789$$

$$b = (2.6154)^2 - \frac{(1.645)^2}{65} = 6.7987$$

The Pearson deviate of the upper confidence limit for the 0.01-probability event is

$$K^U_{0.01,0.95} = \frac{2.6154 + \sqrt{(2.164)^2 - (6.7987)\,(0.9789)}}{0.9789} = 3.1112$$

and the Pearson deviate of the lower confidence limit for the 0.01-probability event is

$$K^L_{0.01,0.95} = \frac{2.6154 - \sqrt{(2.164)^2 - (6.7987)\,(0.9789)}}{0.9789} = 2.2323$$

Thus the upper confidence-limit quantile is

$$U_{0.01,0.95}\,(X) = 3.507 + 0.295\,(3.1112) = 4.4248$$

and the lower quantile is

$$L_{0.01,0.95}\,(X) = 3.507 + 0.295\,(2.2323) = 4.1655$$

The corresponding quantiles in natural units are 26,600 cfs and 14,650 cfs, respectively.

Table 4-4
Distribution of Estimates of Chester Creek 0.01-Probability Quantile

Exceedance Probability	Discharge, cms
0.9999	320
0.9900	382
0.9500	415
0.9000	437
0.7000	491
0.5000	538
0.3000	592
0.1000	694
0.0500	753
0.0100	895
0.0001	1,390

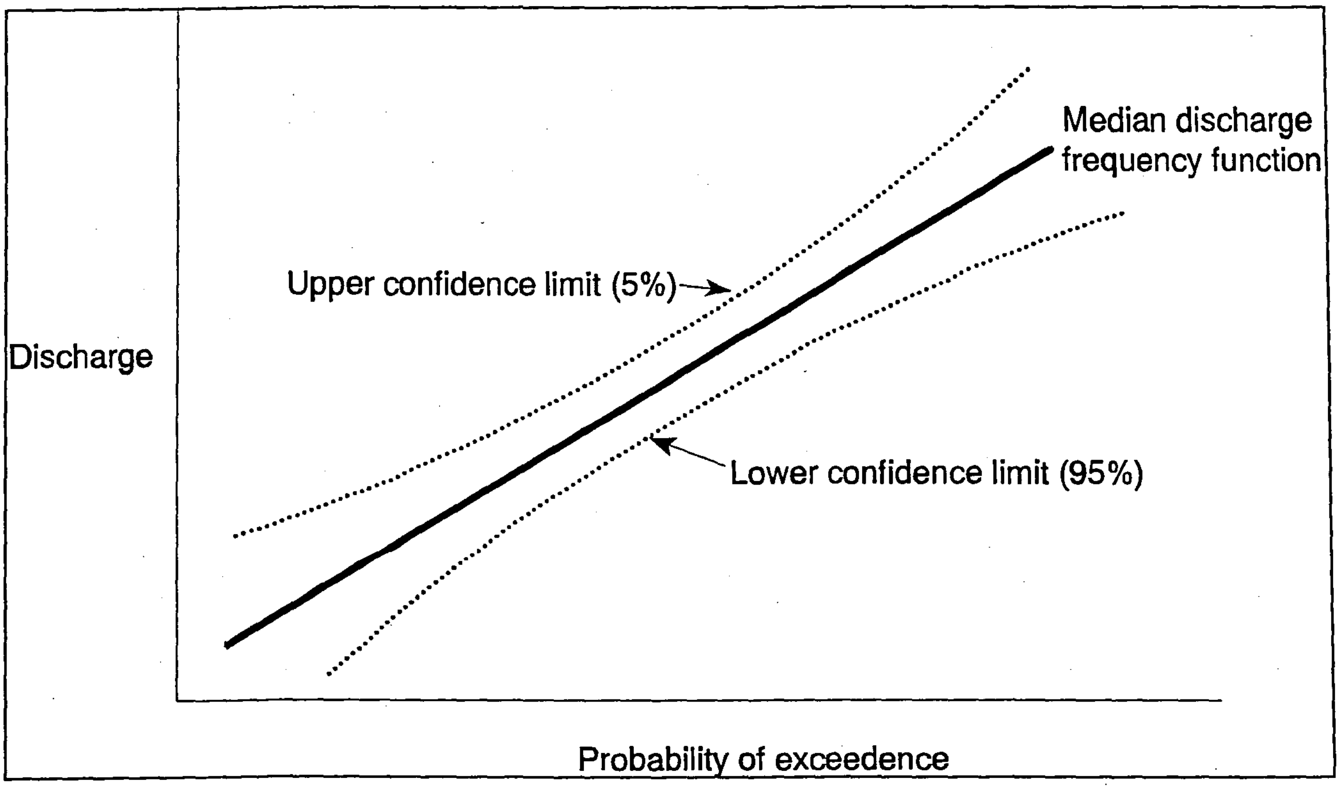
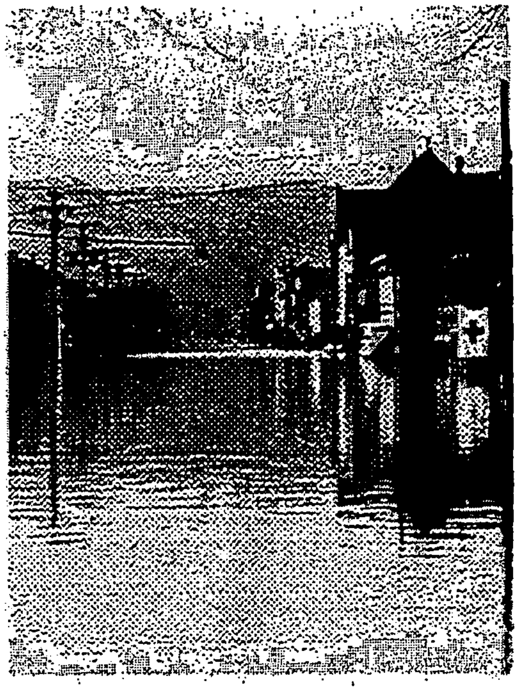


Figure 4-1. Confidence limits

Table 4-5
Equivalent Record Length Guidelines

Method of Frequency Function Estimation	Equivalent Record Length[1]
Analytical distribution fitted with long-period gauged record available at site	Systematic record length
Estimated from analytical distribution fitted for long-period gauge on the same stream, with upstream drainage area within 20% of that of point of interest	90% to 100% of record length of gauged location
Estimated from analytical distribution fitted for long-period gauge within same watershed	50% to 90% of record length
Estimated with regional discharge-probability function parameters	Average length of record used in regional study
Estimated with rainfall-runoff-routing model calibrated to several events recorded at short-interval event gauge in watershed	20 to 30 years
Estimated with rainfall-runoff-routing model with regional model parameters (no rainfall-runoff-routing model calibration)	10 to 30 years
Estimated with rainfall-runoff-routing model with handbook or textbook model parameters	10 to 15 years

[1] Based on judgment to account for the quality of any data used in the analysis, for the degree of confidence in models, and for previous experience with similar studies.



Guidelines For Determining

Flood Flow Frequency

Bulletin # 17B
of the
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INTERAGENCY ADVISORY COMMITTEE
ON WATER DATA

U.S. Department of the Interior
Geological Survey
Office of Water Data Coordination
Reston, Virginia 22092

Appendix 3

TABLES OF K VALUES

The following table[1] contains K values for use in equation (1), for skew coefficients, G, from 0 to 9.0 and 0 to -9.0 and exceedance probabilities, P, from 0.9999 to 0.0001.

Approximate values of K can be obtained from the following transformation (26) when skew coefficients are between 1.0 and -1.0:

$$K = \frac{2}{G} \left[\left[\left(K_n - \frac{G}{6} \right) \frac{G}{6} + 1 \right]^3 - 1 \right] \qquad (3\text{-}1)$$

where K_n is the standard normal deviate and G is the skew coefficient. Because of the limitations (27) involved in use of this and other transforms, use of the table is preferred.

---

[1] This table was computed by Dr. H. Leon Harter and published in _Technometrics_, Vol. 11, No. 1, Feb. 1969, pp. 177-187, and Vol. 13, No. 1, Feb. 1971, pp. 203-204, "A New Table of Percentage Points of the Pearson Type III Distribution" and "More Percentage Points of the Pearson Distribution," respectively. These publications describe values only for positive coefficient of skew. Values for negative coefficient of skew were obtained by inverting the positive table and changing signs. The latter work was performed by the Central Technical Unit, SCS, Hyattsville, Md.

*

$$\tilde{P} = \frac{H-WL}{H} \quad (5\text{-}1b)$$

where H is the historic record length, L the number of peaks truncated and W the systematic record weight as computed in Appendix 6, equation 6-1.

2. Recompute the exceedance probabilities, P, for selected points, P_d, on the frequency curve using equation 5-2:

$$P = \tilde{P} \times P_d \quad (5\text{-}2)$$

This accounts for the omission of peaks below the truncation level.

3. The exceedance probabilities, P, computed by equation 5-2 are usually not those needed to compute the synthetic sample statistics. Therefore, it is necessary to interpolate either graphically or mathematically to obtain log discharge values for the 0.01, 0.10, and 0.50 exceedance probabilities.

4. Since the conditional probability adjusted frequency curve does not have known statistics, synthetic ones will be computed. These synthetic statistics will be determined based on the values for the three exceedance probabilities determined in step 3, using the following equations.

$$G_s = -2.50 + 3.12 \frac{\text{Log}(Q_{.01}/Q_{.10})}{\text{Log}(Q_{.10}/Q_{.50})} \quad (5\text{-}3)$$

$$S_s = \frac{\text{Log}\ (Q_{.01}/Q_{.50})}{K_{.01} - K_{.50}} \quad (5\text{-}4)$$

$$\overline{X}_s = \text{Log}(Q_{.50}) - K_{.50}(S_s) \quad (5\text{-}5)$$

where G_s, S_s, and $\overline{X}_s$ are the synthetic logarithmic skew coefficient, standard deviation, and mean, respectively; $Q_{.01}$, $Q_{.10}$, and $Q_{.50}$ are discharges *with 0.01, and 0.10, and 0.50 exceedance probabilities respectively; and $K_{.01}$ and $K_{.50}$ are Pearson Type III deviates for exceedance probabilities of 0.01 and 0.50 respectively, and skew coefficient G_s. Equation 5-3 is an approximation appropriate for use between skew values of +2.5 and -2.0.

5. The frequency curve developed from the synthetic statistics should be compared with the observed annual peak discharges. The plotting position should be based upon the total number of years record, n or H, as appropriate.

The minimum additional requirement to arrive at a final frequency curve is the determination of the weighted skew. Examples 3 and 4 of Appendix 12 illustrate the basic steps in computing a frequency curve using the conditional probability adjustment. Other considerations in a complete analysis might include two-station comparison, use of rainfall data, or other techniques described in this report. *

NOTATION

G_s	= synthetic logarithmic skew coefficient
H	= historic record length
$K_{.01}$, $K_{.50}$	= Pearson type III deviate from Appendix 3 for exceedance probabilities of 0.01 and 0.50 respectively, and skew coefficient G_s.
L	= number of peaks truncated
N	= number of peaks above the truncation level
n	= total number of years of record
P	= exceedance probabilities
$\tilde{P}$	= estimated probability that an annual peak will exceed the truncation level.
P_d	= selected points on the frequency curve
$Q_{.01}$, $Q_{.10}$, $Q_{.50}$	= discharges with exceedance probabilities of 0.01, 0.10, and 0.50, respectively
S_s	= synthetic logarithmic standard deviation
W	= systematic record weight from Appendix 6
$\overline{X}_s$	= synthetic logarithmic mean

*

CONFIDENCE LIMITS

The record of annual peak flows at a site is a random sample of the underlying population of annual peaks and can be used to estimate the frequency curve of that population. If the same size random sample could be selected from a different period of time, a different estimate of the underlying population frequency curve probably would result. Thus, an estimated flood frequency curve can be only an approximation to the true frequency curve of the underlying population of annual flood peaks. To gauge the accuracy of this approximation, one may construct an interval or range of hypothetical frequency curves that, with a high degree of confidence, contains the population frequency curve. Such intervals are called confidence intervals and their end points are called confidence limits.

This appendix explains how to construct confidence intervals for flood discharges that have specified exceedance probabilities. To this end, let X_P^* denote the true or population logarithmic discharge that has exceedance probability P. Upper and lower confidence limits for X_P^*, with confidence level c, are defined to be numbers $U_{P,c}(X)$ and $L_{P,c}(X)$, based on the observed flood records, X, such that the upper confidence limit $U_{P,c}(X)$ lies above X_P^* with probability c and the lower limit $L_{P,c}(X)$ lies below X_P^* with probability c. That is, the confidence limits have the property that

$$\text{Probability} \quad \{U_{P,c}(X) \geq X_P^*\} = c \qquad \text{(9-1a)}$$

$$\text{Probability} \quad \{L_{P,c}(X) \leq X_P^*\} = c \qquad \text{(9-1b)}$$

*

*Explicit formulas for computing the confidence limits are given below; the above formulas simply explain the statistical meaning of the confidence limits.

The confidence limits defined above are called <u>one-sided</u> confidence limits because each of them describes a bound or limit on just one side of the population p-probability discharge. A two-sided confidence interval can be formed from the overlap or union of the two one-sided intervals, as follows:

$$\text{Probability} \left\{ L_{P,c}(X) \leq X_P^* \leq U_{P,c}(X) \right\} = 2c-1 \tag{9-2}$$

Thus, the union of two one-sided 95-percent confidence intervals is a two-sided 90-percent interval. It should be noted that the two-sided interval so formed may not be the narrowest possible interval with that confidence level; nevertheless, it is considered satisfactory for use with these guidelines.

It may be noted in the above equations that $U_{P,c}(X)$ can lie above X_P^* if and only if $U_{P,c}(X)$ lies above a fraction (1-P) of all possible floods in the population. In quality control terminology, $U_{P,c}(X)$ would be called an upper <u>tolerance limit</u>, at confidence level c, for the proportion (1-P) of the population. Similarly, $L_{P,c}(X)$ would be a lower tolerance limit for the proportion (P). Because the tolerance limit terminology refers to proportions of the population, whereas the confidence-limit terminology refers directly to the discharge of interest, the confidence-limit terminology is adopted in these guidelines.

Explicit formulas for the confidence limits are derived by specifying the general form of the limits and making additional simplifying assumptions to analyze the relationships between sample statistics and population statistics. The general form of the confidence limits is specified as:

$$U_{P,c}(X) = \overline{X} + S\left(K^U_{P,c}\right) \tag{9-3a}$$

$$L_{P,c}(X) = \overline{X} + S\left(K^L_{P,c}\right) \tag{9-3b}$$

*

* in which $\overline{X}$ and S are the logarithmic mean and standard deviation of the final estimated log Pearson Type III frequency curve and $K^U_{P,c}$ and $K^L_{P,c}$ are upper and lower confidence coefficients.

The confidence coefficients approximate the non-central t-distribution. The non-central t-variate can be obtained in tables (41, 32), although the process is cumbersome when G_W is non-zero. More convenient is the use of the following approximate formulas (32, pp. 2-15), based on a large sample approximation to the non-central t-distribution (42):

$$K^U_{P,c} = \frac{K_{G_W,P} + \sqrt{K^2_{G_W,P} - ab}}{a} \quad (9\text{-}4a)$$

$$K^L_{P,c} = \frac{K_{G_W,P} - \sqrt{K^2_{G_W,P} - ab}}{a} \quad (9\text{-}4b)$$

in which

$$a = 1 - \frac{z_c^2}{2(N-1)} \quad (9\text{-}5)$$

$$b = K^2_{G_W,P} - \frac{z_c^2}{N} \quad (9\text{-}6)$$

and z_c is the standard normal deviate (zero-skew Pearson Type III deviate) with cumulative probability c (exceedance probability 1-c). The systematic record length N is deemed to control the statistical reliability of the estimated frequency curve and is to be used for calculating confidence limits even when historic information has been used to estimate the frequency curve.

The use of equations 9-3 through 9-6 is illustrated by calculating 95-percent confidence limits for $X^*_{0.01}$, the 0.01 exceedance probability flood, when the estimated frequency curve has logarithmic mean, standard deviation, and skewness of 3.00, 0.25, and 0.20, respectively based on 50 years of systematic record.

*

*

$z_c = 1.645$ $K_{G_W,P} = 2.4723$

$$a = 1 - \frac{(1.645)^2}{98} = 0.9724$$

$$b = (2.4723)^2 - \frac{(1.645)^2}{50} = 6.058$$

$$K^u_{0.01,\,0.95} = \frac{2.4723 + \sqrt{(2.4723)^2 - (0.9724)(6.058)}}{0.9724}$$

$$= 3.026$$

$$K^L_{0.01,\,0.95} = \frac{2.4723 - \sqrt{(2.4723)^2 - (0.9724)(6.058)}}{0.9724}$$

$$= 2.059$$

$$U_{0.01,\,0.95}(X) = 3.00 + (0.25)(3.026) = 3.756$$

$$L_{0.01,\,0.95}(X) = 3.00 + (0.25)(2.059) = 3.515$$

The corresponding limits in natural units (cubic feet per second) are 3270 and 5700; the estimated 0.01 exceedance probability flood is 4150 cubic feet per second.

Table 9-1 is a portion of the non-central t tables (43) for a skew of zero and can be used to compute $K^U_{P,c}$ and $K^L_{P,c}$ for selected values of P and c when the distribution of logarithms of the annual peaks is normal (i.e., G_W=0).

An example of using table 9-1 to compute confidence limits is as follows: Assume the 95-percent confidence limits are desired for $X^*_{0.01}$, the 0.01 exceedance probability flood for a frequency curve with logarithmic mean, standard deviation and skewness of 3.00, 0.25 and 0.00, respectively, based on 50 years of systematic record.

*

* $K^{U}_{0.01,\ 0.95} = 2.862$ Found by entering table 9-1 with confidence level 0.05, systematic record length 50 and exceedance probability 0.01.

$K^{L}_{0.01,\ 0.95} = 1.936$ Found by entering table 9-1 with confidence level 0.95, systematic record length 50 and exceedance probability 0.01.

$U_{0.01,\ 0.95}(X) = 3.00 + 0.25(2.862) = 3.715$

$L_{0.01,\ 0.95}(X) = 3.00 + 0.25(1.936) = 3.484$

The corresponding limits in natural units (cubic feet per second) are 3050 and 5190; the estimated 0.01 exceedance probability flood is 3820 cubic feet per second. *

*

Appendix 9 Notation

$U_{P,c}(X)$ = upper confidence limit in log units

$L_{P,c}(X)$ = lower confidence limit in log units

P = exceedance probability

c = confidence level

X_P^* = population logarithmic discharge for exceedance probability P

$\overline{X}$ = mean logarithm of peak flows

S = standard deviation of logarithms of annual peak discharges

$K_{G_W,P}$ = Pearson Type III coordinate expressed in number of standard deviations from the mean for weighted skew (G_W) and exceedance probability (P).

G_W = weighted skew coefficient

$K_{P,c}^U$ = upper confidence coefficient

$K_{P,c}^L$ = lower confidence coefficient

N = systematic record length

z_c = is the standard normal deviate *

*

TABLE 9-1
CONFIDENCE LIMIT DEVIATE VALUES FOR NORMAL DISTRIBUTION

Confidence Level	Systematic Record Length N	EXCEEDANCE PROBABILITY .002	.005	.010	.020	.040	.100	.200	.500	.800	.900	.950	.990
.01	10	6.178	5.572	5.074	4.535	3.942	3.048	2.243	.892	-.107	-.508	-.804	-1.314
	15	5.147	4.639	4.222	3.770	3.274	2.521	1.841	.678	-.236	-.629	-.929	-1.458
	20	4.675	4.212	3.832	3.419	2.965	2.276	1.651	.568	-.313	-.705	-1.008	-1.550
	25	4.398	3.960	3.601	3.211	2.782	2.129	1.536	.498	-.364	-.757	-1.064	-1.616
	30	4.212	3.792	3.447	3.071	2.658	2.030	1.457	.450	-.403	-.797	-1.107	-1.667
	40	3.975	3.577	3.249	2.893	2.500	1.902	1.355	.384	-.457	-.854	-1.169	-1.741
	50	3.826	3.442	3.125	2.781	2.401	1.821	1.290	.340	-.496	-.894	-1.212	-1.793
	60	3.723	3.347	3.038	2.702	2.331	1.764	1.244	.309	-.524	-.924	-1.245	-1.833
	70	3.647	3.278	2.974	2.644	2.280	1.722	1.210	.285	-.545	-.948	-1.272	-1.865
	80	3.587	3.223	2.924	2.599	2.239	1.688	1.183	.265	-.563	-.968	-1.293	-1.891
	90	3.538	3.179	2.883	2.561	2.206	1.661	1.160	.250	-.578	-.984	-1.311	-1.913
	100	3.498	3.143	2.850	2.531	2.179	1.639	1.142	.236	-.591	-.998	-1.326	-1.932
.05	10	4.862	4.379	3.981	3.549	3.075	2.355	1.702	.580	-.317	-.712	-1.017	-1.563
	15	4.304	3.874	3.520	3.136	2.713	2.068	1.482	.455	-.406	-.802	-1.114	-1.677
	20	4.033	3.628	3.295	2.934	2.534	1.926	1.370	.387	-.460	-.858	-1.175	-1.749
	25	3.868	3.478	3.158	2.809	2.425	1.838	1.301	.342	-.497	-.898	-1.217	-1.801
	30	3.755	3.376	3.064	2.724	2.350	1.777	1.252	.310	-.525	-.928	-1.250	-1.840
	40	3.608	3.242	2.941	2.613	2.251	1.697	1.188	.266	-.565	-.970	-1.297	-1.896
	50	3.515	3.157	2.862	2.542	2.188	1.646	1.146	.237	-.592	-1.000	-1.329	-1.936
	60	3.448	3.096	2.807	2.492	2.143	1.609	1.116	.216	-.612	-1.022	-1.354	-1.966
	70	3.399	3.051	2.765	2.454	2.110	1.581	1.093	.199	-.629	-1.040	-1.374	-1.990
	80	3.360	3.016	2.733	2.425	2.083	1.559	1.076	.186	-.642	-1.054	-1.390	-2.010
	90	3.328	2.987	2.706	2.400	2.062	1.542	1.061	.175	-.652	-1.066	-1.403	-2.026
	100	3.301	2.963	2.684	2.380	2.044	1.527	1.049	.166	-.662	-1.077	-1.414	-2.040

*

*

TABLE 9-1 (CONTINUED)
CONFIDENCE LIMIT DEVIATE VALUES FOR NORMAL DISTRIBUTION

EXCEEDANCE PROBABILITY

Confidence Level	Systematic Record Length N	.002	.005	.010	.020	.040	.100	.200	.500	.800	.900	.950	.990
.10	10	4.324	3.889	3.532	3.144	2.716	2.066	1.474	.437	-.429	-.828	-1.144	-1.715
	15	3.936	3.539	3.212	2.857	2.465	1.867	1.320	.347	-.499	-.901	-1.222	-1.808
	20	3.743	3.364	3.052	2.712	2.338	1.765	1.240	.297	-.541	-.946	-1.271	-1.867
	25	3.623	3.255	2.952	2.623	2.258	1.702	1.190	.264	-.570	-.978	-1.306	-1.908
	30	3.541	3.181	2.884	2.561	2.204	1.657	1.154	.239	-.593	-1.002	-1.332	-1.940
	40	3.433	3.082	2.793	2.479	2.131	1.598	1.106	.206	-.624	-1.036	-1.369	-1.986
	50	3.363	3.019	2.735	2.426	2.084	1.559	1.075	.184	-.645	-1.059	-1.396	-2.018
	60	3.313	2.974	2.694	2.389	2.051	1.532	1.052	.167	-.662	-1.077	-1.415	-2.042
	70	3.276	2.940	2.662	2.360	2.025	1.511	1.035	.155	-.674	-1.091	-1.431	-2.061
	80	3.247	2.913	2.638	2.338	2.006	1.495	1.021	.144	-.684	-1.103	-1.444	-2.077
	90	3.223	2.891	2.618	2.319	1.989	1.481	1.010	.136	-.693	-1.112	-1.454	-2.090
	100	3.203	2.873	2.601	2.305	1.976	1.470	1.001	.129	-.701	-1.120	-1.463	-2.101
.25	10	3.599	3.231	2.927	2.596	2.231	1.671	1.155	.222	-.625	-1.043	-1.382	-2.008
	15	3.415	3.064	2.775	2.460	2.112	1.577	1.083	.179	-.661	-1.081	-1.422	-2.055
	20	3.320	2.978	2.697	2.390	2.050	1.528	1.045	.154	-.683	-1.104	-1.448	-2.085
	25	3.261	2.925	2.648	2.346	2.011	1.497	1.020	.137	-.699	-1.121	-1.466	-2.106
	30	3.220	2.888	2.614	2.315	1.984	1.475	1.002	.125	-.710	-1.133	-1.479	-2.123
	40	3.165	2.838	2.568	2.274	1.948	1.445	.978	.108	-.726	-1.151	-1.499	-2.147
	50	3.129	2.805	2.538	2.247	1.924	1.425	.962	.096	-.738	-1.164	-1.513	-2.163
	60	3.105	2.783	2.517	2.227	1.907	1.411	.950	.088	-.747	-1.173	-1.523	-2.176
	70	3.085	2.765	2.501	2.213	1.893	1.401	.942	.081	-.753	-1.181	-1.532	-2.186
	80	3.070	2.752	2.489	2.202	1.883	1.392	.935	.076	-.759	-1.187	-1.538	-2.194
	90	3.058	2.740	2.478	2.192	1.875	1.386	.929	.071	-.763	-1.192	-1.544	-2.201
	100	3.048	2.731	2.470	2.184	1.868	1.380	.925	.068	-.767	-1.196	-1.549	-2.207

*

TABLE 9-1 (CONTINUED)
CONFIDENCE LIMIT DEVIATE VALUES FOR NORMAL DISTRIBUTION

*

Confidence Level	Systematic Record Length N	EXCEEDANCE PROBABILITY .002	.005	.010	.020	.040	.100	.200	.500	.800	.900	.950	.990
.75	10	2.508	2.235	2.008	1.759	1.480	1.043	.625	-.222	-1.155	-1.671	-2.104	-2.927
	15	2.562	2.284	2.055	1.803	1.521	1.081	.661	-.179	-1.083	-1.577	-1.991	-2.775
	20	2.597	2.317	2.085	1.831	1.547	1.104	.683	-.154	-1.045	-1.528	-1.932	-2.697
	25	2.621	2.339	2.106	1.851	1.566	1.121	.699	-.137	-1.020	-1.497	-1.895	-2.648
	30	2.641	2.357	2.123	1.867	1.580	1.133	.710	-.125	-1.002	-1.475	-1.869	-2.614
	40	2.668	2.383	2.147	1.888	1.600	1.151	.726	-.108	-.978	-1.445	-1.834	-2.568
	50	2.688	2.400	2.163	1.903	1.614	1.164	.738	-.096	-.962	-1.425	-1.811	-2.538
	60	2.702	2.414	2.176	1.916	1.625	1.173	.747	-.088	-.950	-1.411	-1.795	-2.517
	70	2.714	2.425	2.186	1.925	1.634	1.181	.753	-.081	-.942	-1.401	-1.782	-2.501
	80	2.724	2.434	2.194	1.932	1.640	1.187	.759	-.076	-.935	-1.392	-1.772	-2.489
	90	2.731	2.441	2.201	1.938	1.646	1.192	.763	-.071	-.929	-1.386	-1.764	-2.478
	100	2.739	2.447	2.207	1.944	1.652	1.196	.767	-.068	-.925	-1.380	-1.758	-2.470
.90	10	2.165	1.919	1.715	1.489	1.234	.828	.429	-.437	-1.474	-2.066	-2.568	-3.532
	15	2.273	2.019	1.808	1.576	1.314	.901	.499	-.347	-1.320	-1.867	-2.329	-3.212
	20	2.342	2.082	1.867	1.630	1.364	.946	.541	-.297	-1.240	-1.765	-2.208	-3.052
	25	2.390	2.126	1.908	1.669	1.400	.978	.570	-.264	-1.190	-1.702	-2.132	-2.952
	30	2.426	2.160	1.940	1.698	1.427	1.002	.593	-.239	-1.154	-1.657	-2.080	-2.884
	40	2.479	2.209	1.986	1.740	1.465	1.036	.624	-.206	-1.106	-1.598	-2.010	-2.793
	50	2.517	2.244	2.018	1.770	1.493	1.059	.645	-.184	-1.075	-1.559	-1.965	-2.735
	60	2.544	2.269	2.042	1.792	1.513	1.077	.662	-.167	-1.052	-1.532	-1.933	-2.694
	70	2.567	2.290	2.061	1.810	1.529	1.091	.674	-.155	-1.035	-1.511	-1.909	-2.662
	80	2.585	2.307	2.077	1.824	1.543	1.103	.684	-.144	-1.021	-1.495	-1.890	-2.638
	90	2.600	2.321	2.090	1.836	1.553	1.112	.693	-.136	-1.010	-1.481	-1.874	-2.618
	100	2.613	2.333	2.101	1.847	1.563	1.120	.701	-.129	-1.001	-1.470	-1.861	-2.601

*

TABLE 9-1 (CONTINUED)
CONFIDENCE LIMIT DEVIATE VALUES FOR NORMAL DISTRIBUTION

* Confidence Level	Systematic Record Length N	EXCEEDANCE PROBABILITY .002	.005	.010	.020	.040	.100	.200	.500	.800	.900	.950	.990
.95	10	1.989	1.757	1.563	1.348	1.104	.712	.317	-.580	-1.702	-2.355	-2.911	-3.981
	15	2.121	1.878	1.677	1.454	1.203	.802	.406	-.455	-1.482	-2.068	-2.566	-3.520
	20	2.204	1.955	1.749	1.522	1.266	.858	.460	-.387	-1.370	-1.926	-2.396	-3.295
	25	2.264	2.011	1.801	1.569	1.309	.898	.497	-.342	-1.301	-1.838	-2.292	-3.158
	30	2.310	2.053	1.840	1.605	1.342	.928	.525	-.310	-1.252	-1.777	-2.220	-3.064
	40	2.375	2.113	1.896	1.657	1.391	.970	.565	-.266	-1.188	-1.697	-2.125	-2.941
	50	2.421	2.156	1.936	1.694	1.424	1.000	.592	-.237	-1.146	-1.646	-2.065	-2.862
	60	2.456	2.188	1.966	1.722	1.450	1.022	.612	-.216	-1.116	-1.609	-2.022	-2.807
	70	2.484	2.214	1.990	1.745	1.470	1.040	.629	-.199	-1.093	-1.581	-1.990	-2.765
	80	2.507	2.235	2.010	1.762	1.487	1.054	.642	-.186	-1.076	-1.559	-1.964	-2.733
	90	2.526	2.252	2.026	1.778	1.500	1.066	.652	-.175	-1.061	-1.542	-1.944	-2.706
	100	2.542	2.267	2.040	1.791	1.512	1.077	.662	-.166	-1.049	-1.527	-1.927	-2.684
.99	10	1.704	1.492	1.314	1.115	.886	.508	.107	-.892	-2.243	-3.048	-3.738	-5.074
	15	1.868	1.645	1.458	1.251	1.014	.629	.236	-.678	-1.841	-2.521	-3.102	-4.222
	20	1.974	1.743	1.550	1.336	1.094	.705	.313	-.568	-1.651	-2.276	-2.808	-3.832
	25	2.050	1.813	1.616	1.399	1.152	.757	.364	-.498	-1.536	-2.129	-2.633	-3.601
	30	2.109	1.867	1.667	1.446	1.196	.797	.403	-.450	-1.457	-2.030	-2.515	-3.447
	40	2.194	1.946	1.741	1.515	1.259	.854	.457	-.384	-1.355	-1.902	-2.364	-3.249
	50	2.255	2.002	1.793	1.563	1.304	.894	.496	-.340	-1.290	-1.821	-2.269	-3.125
	60	2.301	2.045	1.833	1.600	1.337	.924	.524	-.309	-1.244	-1.764	-2.202	-3.038
	70	2.338	2.079	1.865	1.630	1.365	.948	.545	-.285	-1.210	-1.722	-2.153	-2.974
	80	2.368	2.107	1.891	1.653	1.387	.968	.563	-.265	-1.183	-1.688	-2.114	-2.924
	90	2.394	2.131	1.913	1.674	1.405	.984	.578	-.250	-1.160	-1.661	-2.082	-2.883
	100	2.416	2.151	1.932	1.691	1.421	.998	.591	-.236	-1.142	-1.639	-2.056	-2.850

*

APPENDIX F

- Short Duration Rainfall for the Western United States

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SHORT DURATION RAINFALL RELATIONS FOR THE WESTERN UNITED STATES

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1. INTRODUCTION

Long records of short-duration (less than 1 hr) precipitation observations necessary to estimate precipitation-frequency amounts are only available for a relatively small number of stations. This dearth of data has made the development of generalized short-duration estimates difficult, especially in the western United States where station density is particularly low and where significant meteorological variation can occur over short distances. The first short duration precipitation-frequency estimates for the western United States were based on very limited data (U.S. Weather Bureau 1953, 1954). Later, Hershfield (1961) developed precipitation-frequency maps for the entire continental United States and used uniform ratios to relate the shorter-duration amounts to longer-duration amounts. By relating the shorter durations to a longer duration that had significantly greater station density, the detailed depiction of the spatial variation of the longer duration could effectively be incorporated into the shorter duration estimates. This approach was based on the assumption that the variation of the ratio fields was smoother than was the variation of the absolute values themselves.

Miller et al. (1973), hereafter referred to as NOAA Atlas 2, developed a technique to treat spatial variations in mountainous areas and applied it in the western United States. Miller et al. chose to adopt Hershfield's nationally averaged ratios for short durations. Frederick et al. (1977) developed isoheytal maps of short-duration precipitation-frequency amounts instead of ratios for the eastern and central United States. They limited their study to the largely nonorographic portions of the United States where meteorological variation was modest and where data density was generally highest. Finally, Frederick and Miller (1979) studied short-duration precipitation-frequency amounts in the state of California. In spite of the relatively high station density, they decided to develop regional ratios rather than maps depicting the spatial variation of the short-duration estimates because of the large meteorological variability within the state.

The present study develops short duration precipitation-frequency ratios for the 10 western states not included in either Frederick et al. (1977) or Frederick and Miller (1979): Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming. The ratios relate 5-, 10-, 15-, and 30-minute precipitation-frequency amounts to 1-hour amounts from NOAA Atlas 2. We addressed a number of problems in developing these ratios. First, the station density was lower (17,000 mi^2/station) compared to the eastern and central United States (12,000 mi^2/station) and California (600 mi^2/station). Second, the rugged topography, ranging from sea level to over 14,000 ft, imposed limitations on the data's applicability, especially since most stations tended to represent lower elevations. Third, there are wide variations in climatology within the study area.

2. THE DATA

The data used in this study are the largest annual precipitation amounts for 5-, 10-, 15-, 30- and 60-minute durations. The amounts for each duration for a given year were not necessarily from the same storm, but rather were the largest amounts for that year, regardless of date of occurrence.

The locations of the 61 stations included in this study are shown in figure 1. Of these, 55 had at least 15 years of data at all durations. Six stations had less than 15 years and were used only on a limited basis; three stations were significantly above the surrounding terrain and were used only for comparative purposes. The earliest data records go back to 1896 and the most recent data were through 1984. The average number of years with data for stations with 15 years or more of data was approximately 45 years at all durations.

Each station record was examined to see if significant changes in location and elevation occurred. Fifteen stations moved during their periods of record by more than the nominal distance and elevation cutoffs of 5 miles and 200 feet. These 15 moves were further examined with

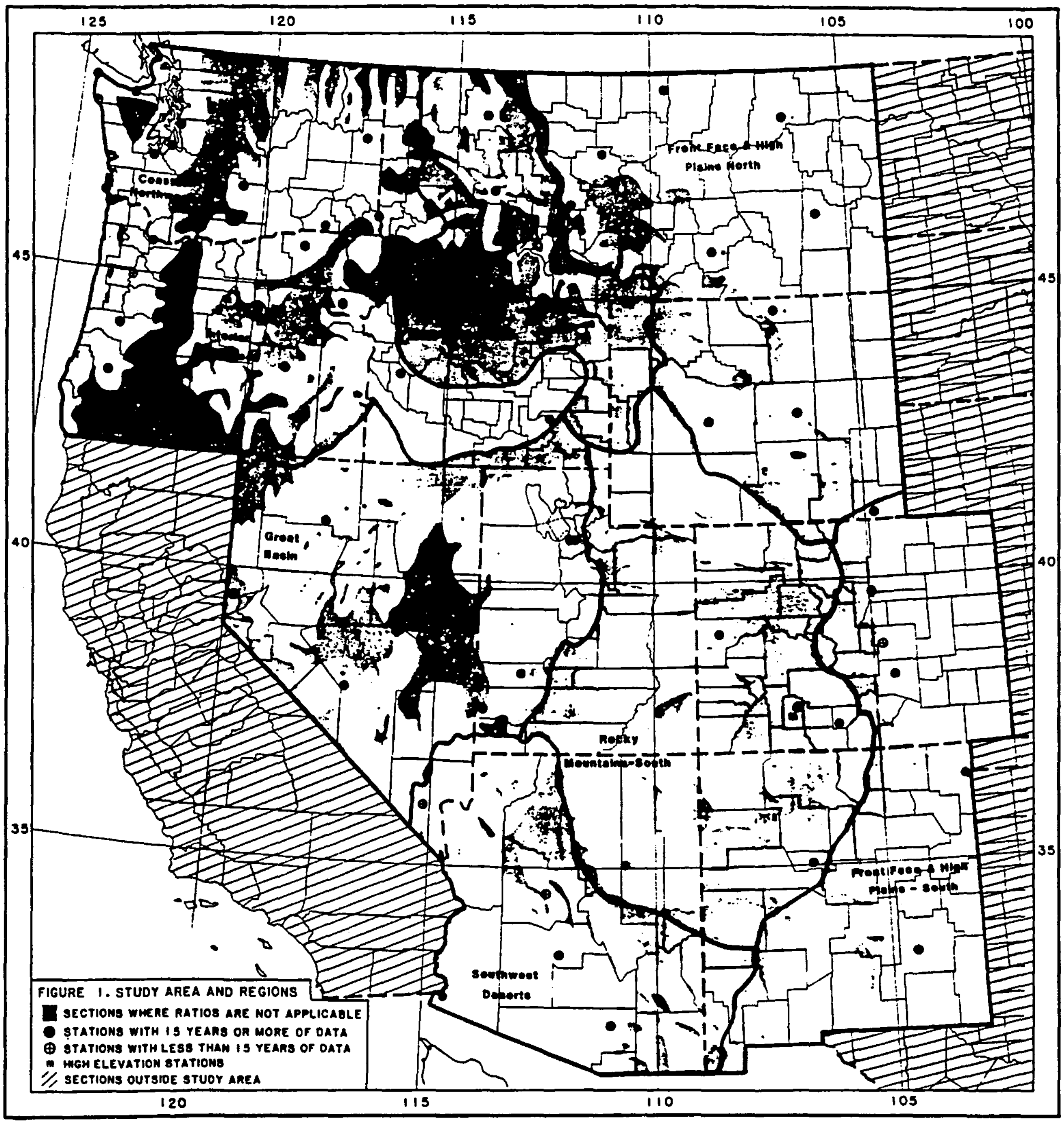

FIGURE 1. STUDY AREA AND REGIONS

respect to changes in terrain, local climatology, and urban/rural character. If, for example, a station moved 8 miles, but that move was on flat terrain with no adjacent mountains, then the relocation was probably not of climatological significance. On this basis, 7 stations made significant moves.

A detailed examination of these 7 stations revealed no consistent biases attributable to the station moves. Any possible biases were apparently smaller than the natural variability of the data themselves. Maximum short-duration amounts tended to vary more from one year to the next at most locations than did the longer duration amounts, such as 24-hour observations. In addition, no discernable biases were found that could be attributed to urban influences.

We also considered the possibility of secular trends. For example, we examined the question of whether the data from one station for the period 1900 to 1940 could be compared to the data for a second station which covered the period 1940 to 1980. Significant long-term secular trends were not evident and it was concluded that non-overlapping records were comparable.

3. PRECIPITATION-FREQUENCY STATISTICS

Frequency values were determined for all durations by fitting the data to the Fisher-Tippett Type I distribution using the Gumbel fitting technique (Gumbel 1958). Additional statistics, including skew and standard deviation, were computed for all stations. These statistics were useful as guides to understand similarities and differences in the precipitation frequencies of different stations and different regions. For example, standard deviations were larger in the southwest deserts than in the coastal northwest due to the difference between the sporadic summertime convective character of the first region and the more regular wintertime stratiform character of the second.

Ratios of 5-, 10-, 15- and 30-minute amounts to 1-hour amounts were computed for all 61 stations for the 2- and 100-year return periods. Due to the use of ratios, no correction was necessary to convert from annual to partial duration series. The next step was to average these ratios over geographic regions.

4. DETERMINATION OF REGIONS

The study area was divided into the 8 regions shown in figure 1 and listed in table 1. The determination of the number of regions involved a balance between two opposing factors. First, the regions had to be large enough to include an adequate number of stations within each to provide statistically stable results by virtue of large sample size. Second, the regions had to be small enough so that each region adequately represented a climatologically homogeneous area. The discussion below outlines how the regional boundaries were determined.

The ratios for each duration were plotted on maps for both the 2- and 100-year return periods. By plotting the ratios and finding the similarities and differences between adjoining stations, a first pass was made at determining the regions. Regional breakdowns of the western states based on climatological factors considered in previous studies were also examined. In addition, several other factors were considered. One such factor was the seasonal distribution of rainfall, ranging from the winter maximum/summer minimum in the Pacific Northwest, to the spring-summer maximum/winter minimum of the High Plains, to the less varied distribution in sections of the Intermountain Region. A second climatological factor was the seasonal distribution of thunderstorm activity, a prime producer of large short duration values. A third factor was the 6 hour and derived 1 hour patterns from NOAA Atlas 2. Other aspects of a more general nature included maximum rainfall patterns and principal paths of moisture inflow for storms producing large precipitation amounts.

We also examined the regional frequency of occurrence by month of annual maximum 1-hour amounts. For example, the maximum 3 consecutive months for 1-hour events in the Coastal Northwest is October through December, while in the Interior Northwest it is from June through August despite the fact that July and August are generally the months of lowest total rainfall. For both these regions, the proportion of the total number of annual events occurring in the most active 3-month period is lower than for other regions, being only 55 and 60 percent, respectively. This contrasts with the Rocky Mountains-South and the Southwest Deserts where upwards to 90 percent of the largest 1-hour amounts occurred during the most active 3 consecutive months, July through September.

The last significant factor in determining the regions was topography. In the general sense, topography is well correlated with the climatology discussed above and thus is not a separate factor. However, on a more detailed scale, the topography helps delineate the regional boundaries. For example, the crest of the Cascades separates the Coastal Northwest from the Interior Northwest in a well-defined fashion. Other geographic boundaries are not as well defined. There is no sharp discontinuity delineating the boundary between the northern and southern sections of the Front Face and High Plains. However, the northern boundary of the South Platte River Basin was chosen because this represents an approximate east-west division between where the Front Face of the Rocky Mountains changes from a north-south orientation in New Mexico and Colorado to a northwest-southeast orientation in Wyoming and Montana. This change in orientation influences the availability of moisture inflow to the two regions. The Front Face and High Plains could have been divided into three or more regions since the ratios gradually changed from south to north. However, the necessity of having enough stations per region to obtain stable ratios argued against this decision.

In some cases it was difficult to choose exact boundaries because a given station had statistical, climatological, and topographic similarities to two adjoining regions. Such was the case for Flagstaff, Arizona, which sits on top of a rim that separates the Southwest Deserts from the Rocky Mountains-South. Due to the greater similarity in the frequency statistics to the Southwest Deserts, it was included in that region, and the region boundary was drawn just to the north of Flagstaff.

5. REGIONAL RATIOS

Ratios were averaged over each region by weighting the individual stations by their length of record. The 2-year values were analyzed first because they were less susceptible than the 100-year values to sampling fluctuations resulting from the relatively short record lengths. The trends between regions, between durations, and between return periods were of primary interest. We attempted to minimize sampling variability by maintaining continuity and consistency in these trends.

Another consideration was comparisons with previous studies. U.S. Weather Bureau (1953, 1954) presents short-duration estimates for the western states for 3 regions: West of the Coastal Ranges, east of the Coastal Ranges and west of 115°W, and between 105° and 115°W. In both Hershfield (1961) and NOAA Atlas 2, short-duration ratios do not vary by region, but rather are based on national averages.

Table 1.—Five, 10-, 15- and 30-minute ratios for 2- and 100-year return periods

Region No.	Region	2-Year Return Period 5 minutes	10	15	30	100-Year Return Period 5 minutes	10	15	30
1	Coastal Northwest	.30	.45	.56	.73	.36	.53	.64	.82
2	Interior Northwest	.35	.53	.64	.81	.37	.56	.67	.85
3	Rocky Mountains-North	.38	.57	.68	.84	.35	.55	.67	.84
4	Front Face and High Plains-North	.39	.58	.69	.85	.37	.56	.69	.87
5	Great Basin	.34	.51	.61	.81	.34	.52	.63	.84
6	Rocky Mountains-South	.35	.54	.65	.83	.32	.50	.62	.81
7	Front Face and High Plains-South	.33	.51	.62	.83	.29	.46	.59	.81
8	Southwest Deserts	.34	.51	.62	.82	.30	.46	.59	.80

Ratios to 1 Hour

The final consideration was comparability to information for locations adjacent to the study area. Taking such information into account accomplished two goals. First, it contributed to the degree of consistency and continuity between this study and other reports. Second, it provided additional insight into the variation of the ratios in this report, providing anchors, so to speak, at the study area boundaries. For areas east of the study region, we compared our results to Frederick et al. (1977) and for California we related our results to Frederick and Miller (1979). In addition, we developed frequency estimates for several stations with short-duration data in surrounding states. Fourteen stations were analyzed for this purpose, 10 in the Plains States and 4 in California. Most of these stations were close enough to be directly comparable to adjacent stations within the study area, while a few were chosen at greater distances from the boundaries to provide some idea of the trend in ratios leading up to the study area.

It was concluded that the ratios in this report were consistent with previous studies. The final ratios are listed in Table 1. A comparison between these ratios and those from NOAA Atlas 2 and Weather Bureau (1953, 1954) is shown in Table 2.

6. APPLICATION OF RATIOS

The ratios derived in the above analysis are based on stations whose elevations tended to be in the lower sections of each region. To extrapolate these statistics to much higher elevations would be a questionable undertaking, because of the complex effects of slope, funneling, and rain shadows that often occur in these areas. As such, the ratios are not applicable to all elevations within each region, but rather to a general range of elevations. The ranges of applicable elevation, approximately 3,000 to 3,500 ft in most areas, are summarized in table 3. In a few cases, areas are excluded that contain stations included in the analysis. The regional ratios were reviewed in light of this fact, and it was determined that no adjustments were necessary.

Areas of non-applicability, based on elevation and location considerations, are shown in figure 1 as shaded areas. These areas are based primarily on smoothed contour maps of the western states. Due to the generalized nature of the contours, there are isolated sections, primarily at the edge of shaded areas, where the ratios might be applicable. Conversely, there are isolated peaks and high elevations which are not shown as part of any shaded areas, but which may, in fact, be non-applicable areas.

Table 2.—Ratios compared to other reports

Dur. (min)	This Report*	NOAA Atlas 2	Weather Bur. (1953, 1954)*
5	.34	.29	.32
10	.52	.45	.49
15	.64	.57	.59
30	.82	.79	.78

Ratio to 1 Hour

*Averaged over all regions and for all return periods

Note: Comparisons are for illustrative purposes only. Each report covers a different geographic area, and averaging is done without regard to size of region or specific return periods involved.

Table 3.—Applicable elevations within regions

Region No.	Generally Applicable elevations (ft)
1	0-2500
2	50-3000 Columbia Basin to 2500-5500 SE
3	2000-5000 N to 4000-7000 S
4	2000-5000 N to 4000-7000 S
5	3500-7000
6	4500-8000 N to 3500-7000 S
7	4000-7500 N to 3500-7000 S
8	3000-6500 mountains to 100-3500 deserts

As discussed in section 5, ratios do not necessarily change abruptly at all regional boundaries, such as is the case along the crest of the Cascades. Probably the most gradual change is between the two halves of the Front Face and High Plains. Most other regional boundaries are better defined by local topography and climatology. Ratios for locations close to most boundaries are probably best estimated by taking into account neighboring ratios to some extent.

In many cases, it might be desirable to find values for a return periods between 2 and 100 years, or for durations different than those given in this report. To do this it is first necessary to compute the absolute values for the standard durations and return periods for the location in question. This can be done using the ratios in this report and 1-hour values determined from NOAA Atlas 2 in conjunction with the two graphs shown in figures 2 and 3. Figure 2, a probability grid based on the Fisher-Tippett distribution, is used to interpolate return periods. Figure 3, a standard semi-log scale, is used to interpolate durations.

Three examples are given below to illustrate the interpolation procedures. The first is for return period, the second for duration, and the third for both return period and duration. The location chosen is Twin Falls, Idaho, and the source used to determine the 1-hour values is NOAA Atlas 2 (the 1-hour values were derived from the 6-hour maps using the appropriate regression equations). The 2- and 100-year 1-hour values are 0.33 and 0.92 inches. Using the ratios in this report from the Interior Northwest, the 2-year return period values for 5, 10, 15 and 30 minutes are 0.12, 0.17, 0.21. and 0.27 inches, and the 100-year return period values are 0.34, 0.52, 0.62 and 0.78 inches.

In the first example, the 10-year return period is found for the 15-minute duration. The 2- and 100-year return period values of 0.21 and 0.62 inches are plotted in figure 2 (line C), and the 10-year value of 0.38 is read off the Y-axis. In the second example, the 20-minute duration is found for the 2-year return period. The 5-, 10-, 15- and 30-minute, and 1-hour values of 0.12, 0.17, 0.21, 0.27 and 0.33 inches are plotted in figure 3 (line A) and a best fit curve, which can usually be approximated with a straight line, is drawn through these points. The 20-minute value of 0.24 inches is then read off the Y-axis. In the third example, the 20-minute duration is found for the 10-year return period. First, the 10-year values for the standard durations are found in figure 2 (lines A through E), the results being 0.21, 0.31, 0.38, 0.48 and 0.57 inches. These five durations are then plotted figure 3 (line B), to obtain a 20-minute value of 0.42 inches.

7. DISCUSSION OF RESULTS

The relatively high ratios encountered throughout the 10 states examined in this study, as compared to the remainder of the country, result from differences in the precipitation climatology. In all regions except the Coastal Northwest, the continental regime, including the lack of available moisture in the lee of mountain barriers, is a significant factor. The result is high short duration rainfall rates which are difficult to maintain for periods as long as 1 hour, thus causing relatively high ratios. Almost all of these events occur in late spring and summer thunderstorms that are not associated with the larger storm systems more typical of winter. Within a given region, all durations between 5 minutes and 1 hour display approximately the same seasonality.

Even the Coastal Northwest has relatively high ratios when compared to coastal California, although the mechanisms here are different. The northern coast receives considerably more rain on an annual basis than does the southern coast. Much of this rain is of a non-convective nature with steady rain over periods of several hours, as opposed to convective events on the on the order of an hour, somewhat more typical of the southern coast. Therefore, 1-hour amounts tend to be slightly lower in the north. On the other hand, maximum short-duration rates for 5- to

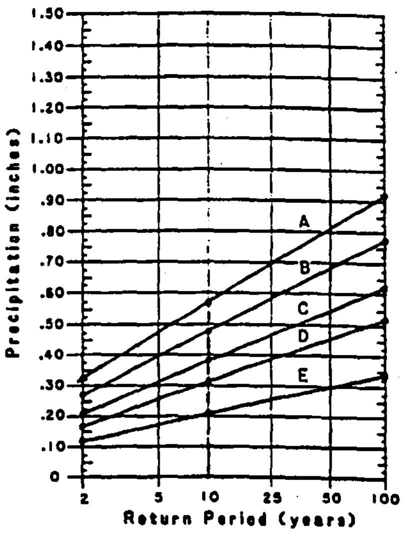

Figure 2.—Example of return period interpolation.

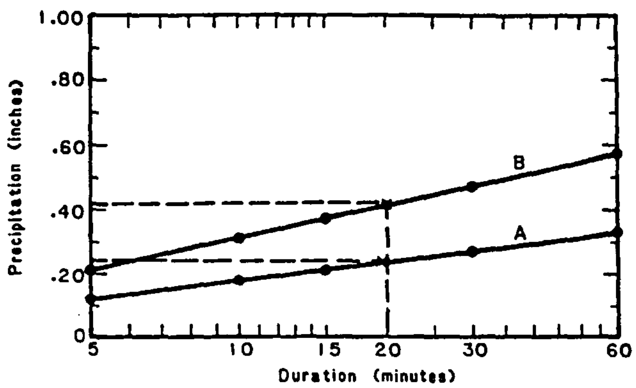

Figure 3.—Example of duration interpolation.

30-minute periods show less variation from north to south. The combination of comparable 5- to 30-minute rates with generally lower hourly rates produces somewhat higher ratios in the north. Maximum short-duration values along the northern coast occur most often in the fall and early winter at all durations, and often result from convective shower and thunderstorm activity embedded in or associated with synoptic scale storm systems. However, isolated summer thunderstorms occasionally produce significant events.

The climate of the western states is controlled primarily by two features, and these in turn affect the climatology of short-duration events. First is the semi-permanent high pressure system that sits off the California Coast, moving south in winter and north in summer. This system affects the westernmost part of the study area most directly, producing a pattern of wet winters and dry summers. This is true both to the west and east of the Cascades, although annual rainfall is considerably less to the east due to the sheltering effect of the mountains. The second feature, dominating the eastern part of the study area, is moisture from the Gulf of Mexico, which produces an almost opposite seasonal trend of wet springs and summers and relatively drier winters. In the spring, the Atlantic sub-tropical high pressure system extends westward into the Gulf and sets up a southerly flow of moist air into the high plains and eastern Rockies which is generally maintained through the summer. The climate of the southwest deserts is affected to some degree by both of these features. The Gulf of Mexico influence contributes to a summer maximum in precipitation and the Pacific influence causes a secondary winter maximum.

The eastern half of the study area tends to have the largest short-duration amounts in terms of absolute values. This is due to the inflow of Gulf moisture occurring during the warm season, which is the time of maximum convective potential, combined with the continental regime which favors short-duration convection.

Ratios in the study area tend to increase from west to east in the north, from the Coastal Northwest to the Front Face and High Plains-North. They increase from south to north in the two Front Face and High Plains regions. They also tend to increase in a southeast to northwest direction from the Front Face and High Plains-South to the Interior Northwest and Rocky Mountains-North. Looking outside the study area, ratios increase from California northward into the Coastal Northwest, and increase westward from the plains into the two Front Face and High Plains Regions. Climatically, the trends reflect the increasingly continental regime and decreasing availability of moisture moving east away from the Pacific Ocean and north and west away from the Gulf of Mexico. As a result of these trends, the highest ratios are generally found in the Front Face and High Plains-North and the lowest ratios in the Coastal Northwest and also the Front Face and High Plains-South and Southwest Deserts.

8. SUMMARY

A series of 64 ratios were developed for ten western states to be used in conjunction with 1-hour values from NOAA Atlas 2. With these ratios, precipitation-frequency estimates can be determined for 5-, 10-, 15-, and 30-minute durations for return periods of 2 and 100 years in each of eight regions. Some areas within each region were excluded due to elevation and exposure considerations.

The results show ratios that are generally higher than in most other sections of the country. These differences are well explained by climatological factors. Although these results appear meteorologically consistent, caution must be exercised when using them because of the small size of the data sample and the meteorological complexity of the study area.

9. ACKNOWLEDGEMENTS

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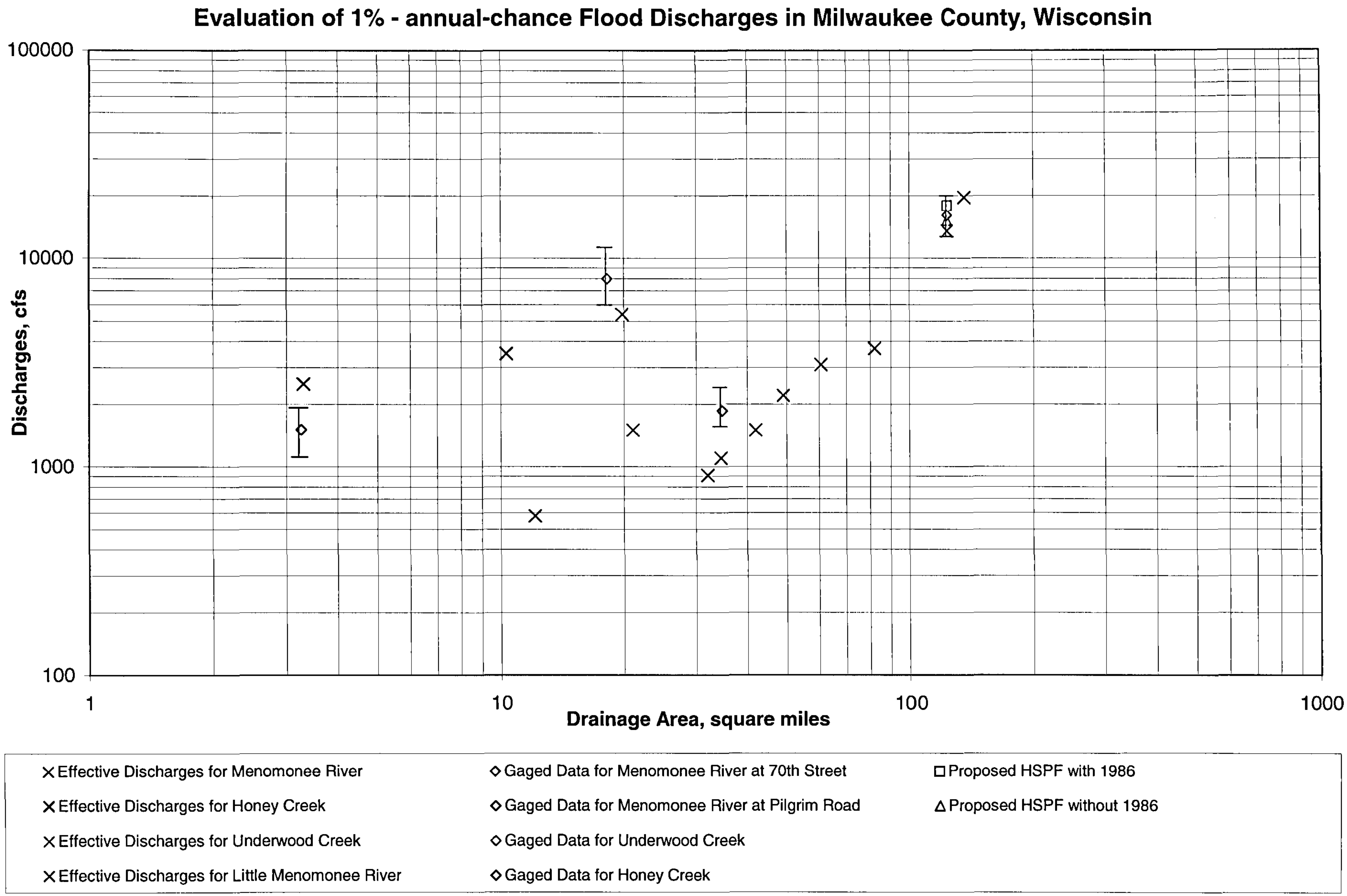
APPENDIX G

- HYDROLOGY REVIEW



Evaluation of 1% - annual-chance Flood Discharges in Milwaukee County, Wisconsin
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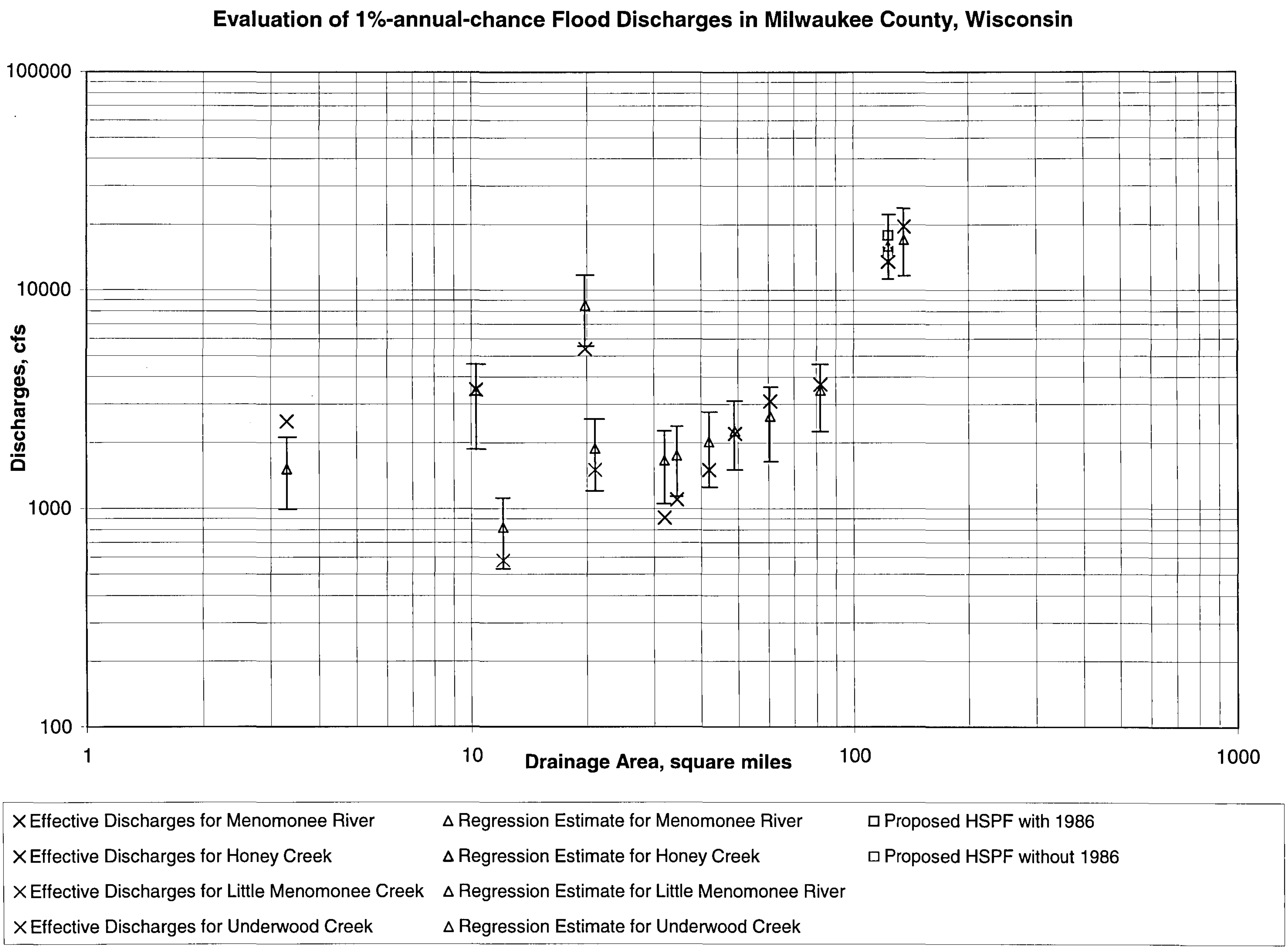
Drainage Area, square miles
Effective Discharges for Menomonee River
Effective Discharges for Honey Creek
Effective Discharges for Underwood Creek
Effective Discharges for Little Menomonee River
Gaged Data for Menomonee River at 70th Street
Gaged Data for Menomonee River at Pilgrim Road
Gaged Data for Underwood Creek
Gaged Data for Honey Creek
Proposed HSPF with 1986
Proposed HSPF without 1986


Evaluation of 1%-annual-chance Flood Discharges in Milwaukee County, Wisconsin
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Discharges, cfs
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Drainage Area, square miles
Effective Discharges for Menomonee River
Effective Discharges for Honey Creek
Effective Discharges for Little Menomonee Creek
Effective Discharges for Underwood Creek
Regression Estimate for Menomonee River
Regression Estimate for Honey Creek
Regression Estimate for Little Menomonee River
Regression Estimate for Underwood Creek
Proposed HSPF with 1986
Proposed HSPF without 1986

Map MODERNIZATION

Federal Emergency Management Agency

FEMA's Flood Hazard Mapping Program

Guidelines and Specifications for Flood Hazard Mapping Partners

Appendices A-M/Glossary/Acronyms

FEDERAL EMERGENCY MANAGEMENT AGENCY

www.fema.gov/mit/tsd/dl_cgs.htm

FINAL

February 2002

APPENDIX C

GUIDANCE FOR RIVERINE FLOODING ANALYSES AND MAPPING

This Appendix documents the study methods and review procedures that assigned Mapping Partners shall use in conducting detailed and approximate hydrologic and hydraulic analyses for riverine flooding sources, preparing floodplain mapping to reflect the results of those analyses, and conducting hydrologic analyses of closed-basin lakes.

C.1 Detailed Hydrologic Analyses

As part of the initial scope of work defined by the Federal Emergency Management Agency (FEMA) Regional Project Officer (RPO) and other members of the Flood Map Project Management Team (detailed in Volume I, Section 1.3 of these Guidelines), the flooding sources for which detailed hydrologic analyses must be conducted will be identified. This section addresses methods and assumptions to be used in conducting detailed hydrologic analyses for riverine flooding sources.

C.1.1 General Guidance

For detailed hydrologic analyses, the exceedance probability of flood events to be studied must be determined. At a minimum, the Mapping Partner that is performing the hydrologic analysis shall analyze the 1-percent-annual-chance event; however, determinations of the 10-, 2-, and 0.2-percent-annual-chance flood discharges will often be requested as well. Where appropriate, the Mapping Partner that is performing the hydrologic analysis shall use all available flood flow-frequency information and shall not duplicate previous work by Federal, State, or local agencies, or work performed as part of a new or revised Flood Insurance Study (FIS) for FEMA. Where such data are not available, where conditions have changed invalidating the published information, or where the methodologies or data used in the previous FIS(s) are not appropriate, a new hydrologic analysis will be required.

The Mapping Partner shall estimate the flood discharges for existing land-use conditions. However, FEMA and the Mapping Partner may also consult with community officials to determine whether they want to consider developing hydrology based on future land-use conditions for local floodplain management purposes as described in the Final Rule dated (this date not set yet). If the community decides to include future-conditions hydrology within the scope of work for the Flood Map Project, the technical information will be developed by the community and provided to FEMA and the Mapping Partner. Additionally, the community will need to adopt and/or revise the local floodplain management ordinances and regulations to support any future-conditions flood hazards they request to be shown on the Flood Insurance Rate Map (FIRM) and in the FIS Report.

The Mapping Partner should consider gaged versus ungaged streams and the appropriateness of developing a rainfall-runoff model. Each of these approaches is briefly discussed later in this section. When an expected probability adjustment (Interagency Advisory Committee on Water Data, 1982) has been included in published flood discharge determinations, the Mapping Partner shall contact the RPO for approval before proceeding.

Prior to conducting a hydrologic analysis, the Mapping Partner must work with the RPO to identify which, if any, of the hydraulic structures are to be included in the analysis (such as a large impoundment) and to identify appropriate methodologies for analyzing their impacts on peak flows and volumes. If effective FIS flood discharge data are to be used, the Mapping Partner shall verify that the data are current before proceeding.

C.1.1.1 Floodplain Storage Considerations

Large storage areas that exist in a floodplain will significantly attenuate flooding within a community. The Mapping Partner shall evaluate attenuation using a standard flood routing technique. Storage in the floodplain may be uncontrolled, such as in detention ponds, isolated small natural depressions, and in wide floodplains of large rivers, or controlled with reservoirs. The requirements for performing hydrologic analyses of uncontrolled flood storage and controlled flood storage are presented below.

C.1.1.1.1 Uncontrolled Flood Storage

Uncontrolled detention ponds and natural depressions both provide uncontrolled flood storage. Detention ponds typically are used in developed areas for onsite storage, and these ponds limit post-development peak flow rates from a design storm to those of the pre-development stage. The ponds also are used for regional detention based on a master plan for the watershed area of interest. Depending on climate characteristics and local design standards that vary across the nation, detention ponds may be able to attenuate peak flow rates for a 1-percent-annual-chance storm for arid areas; however, in more humid areas, most ponds are designed for storms with 20- to 50-percent-annual-chance storms.

Usually, an ungated spillway and a low-level, ungated conduit comprise the detention pond outflow structure. The effectiveness of a detention pond in attenuating peak flow rates in the downstream reach depends on the pond's location in the watershed and its storage and release characteristics. While an onsite detention pond may be effective for a single development site, it may not be as effective for a large urban watershed that has many onsite detention facilities that are not located and designed systematically (Maidment, 1993). The Mapping Partner shall analyze floodplain storage in small isolated natural depressions, where outflow is only through overflow, as uncontrolled detention ponds with appropriate outflow characteristics.

The Mapping Partner may use both hydrologic and hydraulic routing methods to route the flow through ponds. Hydrologic routing methods are to be used when the outflow from the pond is not dependent on tailwater. Most of the single-event hydrologic models (e.g., HEC-HMS, HEC-1, TR-20) use hydrologic routing methods. The Mapping Partner must use hydraulic routing methods when outflow from the pond is dependent on tailwater conditions. For example, tailwater condition is a control factor where a series of interconnected detention ponds are used for flood attenuation in a relatively flat watershed. The hydraulic routing for ponds is often performed with an unsteady-flow model. A list of models accepted by FEMA for this purpose may be found on FEMA's Flood Hazard Mapping website at http://www.fema.gov/mit/tsd/en_modl.htm.

Wide floodplains with significant storage areas often exist along large rivers in relatively flat watersheds. The Mapping Partner may use the unsteady-flow models, both one-dimensional models with quasi-two-dimensional capabilities and two-dimensional models, that appear on FEMA's accepted models list to simulate flood attenuation due to this type of storage.

C.1.1.1.2 Controlled Flood Storage

Most large reservoirs on large river systems are operated with outflow controls. In these reservoirs, gates are used for regulating flow through outlet structures. The gates are operated according to established rules that determine the relationship between inflow, outflow, storage, and water demand.

The Mapping Partner normally shall not consider storage capability below the Normal Pool Elevation of reservoirs operated primarily for purposes other than flood control because the availability of such storage is uncertain. The exception is when all of the following conditions have been met:

- Operation of the project in accordance with its documented water control plan could affect the 1-percent-annual-chance flood elevations in a community by 1 foot or more.

- The storage capability to be considered is totally dedicated to flood control. Where different amounts of storage can be totally dedicated during different parts of the year, the Mapping Partner shall obtain flood discharges from the joint probability combination of frequency curves established for each part of the year that the different storage levels are dedicated. Joint use storage based on forecasted inflow is not acceptable for NFIP purposes.

- A project water control plan providing explicit details of operation during flooding conditions is in effect and has been reviewed and approved by FEMA or another Federal agency responsible for Federal flood-control activities. The Mapping Partner that is performing the hydrologic analysis shall contact the RPO to discuss the review and approval process.

- A written commitment to dedication of the flood-storage capacity and to the approved reservoir operation plan is assured through a mandatory condition of Federal or State licensing or through a direct agreement between the project operator and FEMA for non-Federal projects.

C.1.1.2 Gaged Streams

Flood discharges may be determined directly from gage data in areas where river gages are located, or may be estimated based on data from gages in nearby areas having similar characteristics.

C.1.1.2.1 At a Gaging Station

The Mapping Partner shall perform floodflow-frequency analyses in accordance with the guidelines for determining floodflow frequency presented in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) and subsequent modifications. To use analysis techniques other than those outlined in Bulletin 17B, the Mapping Partner shall obtain approval by the RPO and provide written justification for their use. The basic floodflow-frequency curve for gaged sites on unregulated streams may be obtained from the U.S. Geological Survey (USGS), Water Resources Division; from published reports of the USGS; or derived using methods described in Bulletin 17B. The annual maximum peak flows used in floodflow-frequency analyses are available on the USGS web page at http://water.usgs.gov/nwis/sw. Computer programs for performing Bulletin 17B analyses are available from the U.S. Army Corps of Engineers (USACE) (U.S. Department of the Army, 1992) and the USGS (U.S. Department of the Interior, 1998).

The Mapping Partner shall use the floodflow-frequency curve and adjust it, if necessary, to provide reliable flood discharge estimates for the site under consideration. The Mapping Partner also may use the methodologies outlined in the USACE Engineering Manual No. 1110-2-1415 (U.S. Department of the Army, 1993) to develop frequency curves for gaged streams. The Mapping Partner shall document reasons for the modification and procedures that were used to modify the published USGS floodflow-frequency curves. When modeling mixed populations of hydrologic events, the Mapping Partner shall refer to Engineering Manual No. 1110-2-1415 or Appendix F of these Guidelines.

C.1.1.2.2 Near a Gaging Station

Generally, for peak flood discharges for ungaged sites on a gaged stream, both the gaged site information and information from an appropriate regional estimate, where available, are to be considered. The Mapping Partner shall select an appropriate transfer technique for establishing flood discharges at the ungaged location. The selected transfer technique must consider the difference in the drainage areas at the gaged and ungaged sites. The procedures prescribed in most regional floodflow-frequency reports published by the USGS are recommended for this purpose. These transfer procedures usually use information from the gaged site and the regional estimate when the ungaged site is within 50 to 200 percent of the drainage area at the gaging station. In cases where a more specialized local study of a watershed may be more appropriate than one prepared by the USGS, the Mapping Partner shall consult with the RPO before proceeding.

For gaged streams with regulated flows, peak flood discharges may be obtained from the agency responsible for the regulation. If the effects of regulation on floodflow frequency have not been established, the Mapping Partner shall determine the most appropriate analysis technique and obtain approval from the RPO before proceeding. Guidance on regulated frequency analysis can be found in USACE EM 1110-2-1415 (U.S. Department of the Army, 1993)

C.1.1.3 Ungaged Streams

Acceptable hydrologic analysis methods for ungaged streams include regional regression analyses and the rainfall-runoff model.

C.1.1.3.1 Regional Regression Analysis

The Mapping Partner shall make use of any valid existing floodflow-frequency analysis conducted by a Federal, State, or local agency that have authoritatively established and officially adopted the flood discharges for the ungaged stream under consideration, or the Mapping Partner shall make use of flood discharges from published FISs. In the absence of such an analysis or in cases in which the analysis is outdated, the Mapping Partner shall use, where appropriate, the most recently published USGS report for estimating flood magnitude and frequency that is applicable to the Flood Map Project area. Such reports are generally available on a statewide basis. The Mapping Partner shall exercise caution to ensure that these reports are used only for conditions and locations for which they are recommended.

The USGS has published regression equations for estimating flood discharges for urban watersheds in several states including Alabama, Florida, Georgia, Missouri, North Carolina, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Virginia, Washington, and Wisconsin. Where the statewide reports do not contain procedures to account for urbanized conditions, or the statewide equations do not apply to the watershed conditions, the Mapping Partner that is performing the analysis shall adjust the flood discharges determined for the rural condition using techniques described in *Flood Characteristics of Urban Watersheds in the United States* (U.S. Department of the Interior, 1983). The Mapping Partner may use the USGS "National Flood Frequency" program (U.S. Department of the Interior, 1994) to determine flood discharges of different frequencies for the continental United States, Alaska, Hawaii, and Puerto Rico for both rural and urbanized conditions. When a regression equation other than those published by the USGS is proposed, the Mapping Partner shall obtain the approval of the RPO and shall justify the use of this equation.

USGS also has developed the region-of-influence method to estimate flood discharges, and computer programs have been published for Arkansas, Louisiana, and North Carolina. In the region-of-influence method, regression equations are computed for an ungaged site by selecting from a statewide database of gaging stations a predetermined number of stations having characteristics similar to the ungaged site. This method does not involve published regression equations. The Mapping Partner may use the region-of-influence method. The Mapping Partner shall obtain the approval of the RPO and shall justify the use of this method.

C.1.1.3.2 Rainfall-Runoff Model

Where USGS regional regression equations are not applicable due to flow regulation, storage, watershed development, or other unique basin characteristics, the Mapping Partner may obtain RPO approval to develop a rainfall-runoff model using a computer program such as HEC-HMS, HEC-1 or TR-20. A list of models accepted by FEMA for this purpose may be found on FEMA's Flood Hazard Mapping website at http://www.fema.gov/mit/tsd/en_modl.htm. A wide variety of automation tools have been developed to facilitate hydrologic modeling. These products range from simple graphical user interfaces that help input model parameters to highly advanced GIS-based tools that contain state-of-the-art software and modeling approaches with fully integrated data processing, graphics, and visualization capabilities. The tools have been organized into three categories based on their relationship to accepted FEMA models. The following is the policy for their acceptance for use in FEMA's flood hazard mapping program.

- Category 1: These simple tools can be either pre-processing or post-processing independent modules. They function in conjunction with, but separately from, the executable file of a computer model that is on FEMA's accepted models list. These tools are considered acceptable for use in the flood hazard mapping program because they are not computer models themselves.

- Category 2: These software tools are computer models that perform modeling routines that emulate a model on FEMA's accepted model list; however, their source code has been rewritten to perform these tasks, instead of using the accepted model's source code. Category 2 software tools must be reviewed and placed on the list of accepted models.

- Category 3: These software tools use new hydrologic modeling methods and/or models not currently on the FEMA-accepted models list. They may add pre- or post-processing functions similar to the other categories of tools as well. Because these are new computer models, Category 3 software tools must be reviewed and placed on the list of accepted models.

In developing a rainfall-runoff model, the Mapping Partner shall consider the following factors:

- The unit hydrograph method is preferred when developing hydrographs. However, subwatershed drainage areas shall be appropriately defined within the limit that the unit hydrograph is able to reflect watershed response to changing conditions.

- Loss rates must be varied when computing different frequency floods. Urbanization effects must be reflected in the loss rates.

- Time of concentration or lag computations must reflect effects of increases in velocities due to channel modifications and urbanization.

- Rainfall duration, at a minimum, must exceed the time of concentration for the watershed and must be large enough to capture all excess rainfall as well as provide reasonable runoff and sediment volumes when performing storage analyses. The Mapping Partner may use the critical storm concept to determine the storm duration, or use the duration specified in guidelines developed by state agencies responsible for flood control or floodplain regulation. The critical storm is a design storm (total amount, duration, temporal distribution) which provides the highest flood discharge/water-surface elevation for the flooding source. The Mapping Partner should determine the critical storm through a sensitivity analysis of various storm durations to determine which storm duration produces the highest flood discharge/water-surface elevation (e.g., 6-hour vs. 24-hour). Note that for communities that only get short duration storms, the storm durations to be evaluated must be longer than the time of concentration of the watershed, and not the duration of the rainfall.

- Temporal distributions developed or recommended by Federal or State agencies responsible for flood control or regulating floodplains must be used.

- Streamflow routing methods must be able to analyze the attenuation and translation of hydrographs.

The Mapping Partner shall calibrate the parameters in the models against known storms in the study area and, when available data permits, against a floodflow-frequency curve before the model is used to estimate flood discharges. The Mapping Partner shall compare computed peak flood discharges from the hydrologic model to flood discharges from published regional studies (e.g., USGS regression equations) when they are applicable, or to flood discharges developed from gaging station data in watersheds with similar characteristics. If the discharge values are not comparable, the Mapping Partner shall submit a Special Problem Report to the RPO to explain the differences before beginning the hydraulic analysis.

C.1.2 Considerations for Restudies

In general, a restudy of hydrologic analyses could be initiated for any of four reasons:

1. To reflect longer periods of record or revisions in data;

2. To reflect changed physical conditions;

3. To take advantage of improved hydrologic analysis methods; or

4. To correct an error in the hydrologic analysis for the effective FIS.

Examples of changed physical conditions include the addition of a hydraulic structure or other watershed development that has affected the effective analyses. Regardless of the reason for the restudy, the Mapping Partner must provide detailed documentation of the changes that have been addressed in the restudy and why flood discharges developed for the restudy are more accurate than those developed for the effective FIS. If the reason for the restudy is an improved method, the Mapping Partner must provide documentation as to why the alternative method is superior and must obtain RPO approval to use the improved method.

A study of a community's flood hazards may include a flooding source for which FEMA has not established BFEs. In these cases, the Mapping Partner shall consult Subsection C.1.2.1 for necessary guidance on establishing flood discharges.

C.1.2.1 Preliminary Hydrologic Analysis

The Mapping Partner shall compare the proposed flood discharges to all available floodflow-frequency data that exist for the study area to ensure compatibility. The Mapping Partner also must inform the RPO, as well as Federal, State, and local agencies involved in water resources programs in the area, of the proposed flood discharges. Any discrepancies between available information and the flood discharges proposed for the FIS must be resolved by the Mapping Partner. Such discrepancies shall be brought immediately to the attention of the RPO in a Special Problem Report, as flood discharge discrepancies shall not be the cause for delay in the study. In addition, the Mapping Partner shall keep the RPO informed of progress made in resolving such discrepancies.

C.1.2.1.1 Comparing Proposed and Effective Flood Discharges

In determining whether to grant a revision request, or to fund a detailed restudy of a community's flood hazards, revisions shall be considered only when a more recent floodflow-frequency analysis yields flood discharge values that are statistically significant from the effective flood discharges, or when flood discharges yield significant differences in base (1-percent-annual-chance) flood elevations (BFEs).

Determining Statistical Significance

The Mapping Partner shall base the test for significance on the confidence limits of the more recent analysis. The new flood discharges shall be adopted if the previous flood discharges do not fall within the 95 and 5-percent confidence limits (90-percent confidence interval) of the recent estimates; the previous flood discharges shall be adopted if they fall within the 75 and 25-percent confidence limits (50-percent confidence interval) of the recent estimates. The Mapping Partner shall consult Bulletin 17B for procedures on computing confidence limits for gaged streams. The computation of confidence and prediction limits for regression estimates is documented in statistical textbooks (Montgomery & Peck, 1982).

Significant Changes in Base Flood Elevations

When the effective flood discharges fall between the 50 and 90-percent confidence limits, the Mapping Partner may use the effective FIS step-backwater computation to evaluate the effect of the new flood discharges on effective BFEs. If the new flood discharges yield BFEs that differ from the effective BFE obtained from the effective water-surface profile by more than 0.5 foot, a detailed hydrologic analysis would then be conducted. Otherwise, the selected stream should not be restudied at this time, unless other substantial changes in hydraulic conditions exist, such as channelization and construction of flood-control structures; or unless there are errors in the effective study.

Where significantly different flood discharges are proposed for use, the RPO shall be contacted immediately for approval. Where confidence limit tests are not applicable, the Mapping Partner shall bring unresolved discrepancies to the attention of the RPO. The determining factor then becomes the affect on the BFE as described above.

C.1.2.1.2 Choice of Methodology

The hydrologic methodology shall be determined during the scoping process for the study and include input from FEMA and the Mapping Partner(s). The complexity of the study and the effective models and methodology must be considered in making this choice.

The Mapping Partner shall apply frequency analysis of flow data at gaging stations, using procedures provided in Bulletin 17B (Interagency Committee on Water Data, 1982) wherever possible. When the systematic record at a gaging station is less than 50 years, the Mapping Partner shall weight the results with estimates from other methods, such as USGS regression equations. The Mapping Partner may use the method developed by Hardison, published in USGS Professional Paper 750-C, to estimate the equivalent years of record for regression equations that are needed in the weighting process (U.S. Department of the Interior, 1971). Guidance on weighting two estimates of flood discharges is also given in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982), and USGS regression equation reports.

USGS regression equations, adjusted for urbanization if appropriate, are recommended for estimating the existing-conditions base flood discharges for restudied streams if a flood hydrograph is not required and if the regression equations are applicable to the restudied streams. The regression equations are to be applied only to streams having characteristic parameter values that are within the range of values of the gages used to develop the regression equations.

For watersheds with existing hydrologic models, the Mapping Partner may use an existing model in lieu of USGS regression equations if the model was calibrated. Such models must, however, be updated to account for any development that has occurred in the watershed since the existing model was created. The Mapping Partner must exercise caution when selecting a methodology for watersheds that are undergoing or are projected to undergo development. In such cases, the Mapping Partner shall consider developing a rainfall-runoff model in lieu of a gaged analysis with non-homogeneous data or the use of regression equations.

The Mapping Partner shall calibrate the parameters in rainfall-runoff models against major known storms that exceed 10-percent-annual-chance events for single-event analysis if the data are available. The data to calibrate the model are to include the following:

- Peak flood discharges developed at gaging stations, computed by indirect methods (e.g., computations at bridge cross sections based on high water marks), or flood discharge hydrographs from responsible agencies;
- Rainfall distribution, reported at a minimum of hourly intervals, at rain gages within the storm area and within or near the watershed being studied;
- Total rainfall values at rain gages within the storm area or isohyetal map of the storm, indicating the duration of the storm;
- Rainfall and soil moisture conditions before the storm for single-event analysis.

Observed high water marks may also be of value when calibrating both hydrologic and hydraulic models against historical events.

The Mapping Partner may calibrate the rainfall-runoff model against the various flood discharges of a frequency analysis. Regardless of whether models have been calibrated against historical events, further calibration may be required to produce floodflows from the 10-percent, 2-percent, 1-percent, and 0.2-percent-annual-chance rainfall that are comparable to the floodflows from the frequency analysis, if records are available. If reasonable matches cannot be reached by maintaining calibration parameters within acceptable ranges, then a review of the model methodology and its application to the watershed is warranted.

Where models are calibrated against historical events and are applied properly, and where the modeled floodflows and frequency floodflows do not agree, the Mapping Partner shall consider adjusting the design rainfall's volume and distribution. The design rainfall distribution is typically selected from traditional distributions prepared by the Natural Resources Conservation Service (NRCS) and the USACE, but recommendations from State agencies responsible for flood control or floodplain management regarding state or regional distributions also may be accepted. Where feasible, in coordination with Federal and State agencies, the Mapping Partner shall select a reasonable rainfall distribution for the model to best simulate floodflows corresponding to a frequency analysis in accordance with the guidance of Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). For flooding sources where the volume of flood discharge is the major concern, such as ponds in a closed basin, the Mapping Partner may determine the rainfall duration by comparing the calculated lake stages with the stage-frequency curve.

C.1.2.2 Preliminary Hydrologic Analysis Submittal Requirements

The Mapping Partner shall submit the preliminary results of the analysis to the FEMA RPO or identified FEMA regional engineer for review prior to completing and submitting the hydraulic analysis. The FEMA RPO or regional engineer will forward the analysis to the appropriate Project Officer at FEMA Headquarters for subsequent review by a Mapping Partner selected by FEMA to review the hydrologic analysis.

To avoid internal discontinuities in the restudy data, proposed flood discharge values must be compatible with those in the effective analyses at the limits of detailed study.

Should significant discontinuities exist between the updated flood discharges and those used in the effective FIS, the Mapping Partner shall consult with the RPO and complete a Special Problem Report.

C.2 Hydrologic Review

A Mapping Partner selected by FEMA, identified during the initial Scoping Meeting (see Volume I, Section 1.3 of these Guidelines), shall review the proposed flood discharges prior to their being used in hydraulic analyses. The intent is to agree on the 1-percent-annual-chance flood discharges before the hydraulic analyses are conducted, and to avoid hydraulic and mapping analysis revisions necessitated by subsequent flood discharge revisions. Therefore, the Mapping Partner performing the analysis shall work with FEMA to ensure that hydrology issues are identified as early as possible. This early review could reduce the level of effort during both the study and the production of the FIS Report and FIRM.

The goal of the hydrologic review is to provide an assessment of the "reasonableness" of the proposed 1-percent-annual-chance flood discharges and, if necessary, to suggest alternative methods that may provide more reasonable flood discharges. The reasonableness of a flood discharge depends on the requirements of the study and its selected methodologies. The Mapping Partner that is reviewing the hydrologic analysis shall check all methods for the reasonableness of their specific application and the sources of the data. A comparison of proposed flood discharges against criteria related to the regression equations is a good first screening tool; however, it does not replace the need to review the applied methodology.

In addition to comparing proposed flood discharges to those derived from gaged data and regression equations, the reviewing Mapping Partner shall compare the proposed flood discharges to the effective flood discharges, noting any significant discrepancies and possible reasons for those discrepancies. Also, the reviewing Mapping Partner shall consider the effect on BFEs as a result of different flood discharges (not just changes in flood discharges) as a check on reasonableness.

The procedures detailed below are recommended for preliminary hydrologic reviews of analyses submitted in support of studies and restudies, map revisions, and appeals. They are applicable to hydrologic analyses conducted using gaging station data, regional regression equations, and rainfall-runoff models.

C.2.1 Hydrologic Analysis Based on Gaging Station Data

Proposed 1-percent-annual-chance flood discharges based on gaging station data are generally reviewed for conformance to the guidelines in Bulletin 17B (Interagency Committee on Water Data, 1982). If procedures other than those outlined in Bulletin 17B were applied, then the reviewing Mapping Partner shall determine whether these procedures are reasonable. At least 10 years of record are needed to define the 1-percent-annual-chance flood discharge; however, estimates based on shorter periods of record must be compared to flood estimates based on precipitation data and to regional estimates for similar watersheds as described in Bulletin 17B. In more arid regions, there are often many years when the annual peak flow is zero. For these conditions, at least 10 years of nonzero flow are recommended for defining the 1-percent-annual-chance flood discharge.

Floodflow-frequency curves for gaging stations are routinely published by the USGS as part of regional floodflow-frequency studies. The reviewing Mapping Partner can compare these published flood discharges to the proposed flood discharges to judge their reasonableness. The Mapping Partner shall compare the effective flood discharges to the confidence limits of the proposed flood discharges to determine which flood discharges are more appropriate.

For regulated watersheds, floodflow-frequency curves are often developed for unregulated conditions and then converted to regulated conditions by utilizing the current reservoir operation criteria. The designated Mapping Partner shall review the regulated floodflow-frequency curve to determine whether acceptable procedures were used to convert to regulated conditions. Guidance on regulated frequency analysis can be found in USACE Engineering Manual No. 1110-2-1415 (U.S. Department of the Army, 1993).

C.2.2 Hydrologic Analysis Based on Regional Regression Equations

The reviewing Mapping Partner shall compare the proposed 1-percent-annual-chance flood discharges computed from regional regression equations to the effective flood discharge, to flood discharges from other (published) regression equations that are applicable to the region, and to flood discharges at gaging stations in the vicinity. In general, proposed regional regression equations should be the most recent published equations developed by the USGS for the region unless justification is provided for the use of earlier equations.

The reviewing Mapping Partner shall assume the proposed regression equations are applicable if the watershed, climatic, and urbanization characteristics of the ungaged sites are within the range of those at the gaging stations used to develop the equations, and if flow is not regulated. If appropriate, the regional regression equations may be adjusted for urbanization using procedures in *Flood Characteristics of Urban Watersheds in the United States* (U.S. Department of the Interior, 1983) or, if available, urban regression equations for the applicable state or metropolitan area.

The reviewing Mapping Partner shall compare the proposed regression estimates to gaging station estimates in nearby watersheds having similar characteristics to those of the studied streams. The Mapping Partner may obtain estimates of 1-percent-annual-chance flood discharges at nearby gaging stations from published USGS regional flood reports if the frequency curves were published in the last 10 years and if no major floods have occurred in the intervening time. Otherwise, floodflow-frequency estimates for the gaging stations are to be updated in accordance with Bulletin 17B (Interagency Advisory Committee on Water Data, 1982).

The reviewing Mapping Partner shall plot the 1-percent-annual-chance flood discharge estimates from these sources against drainage area on logarithmic paper to determine whether the proposed flood discharges are reasonable. Confidence intervals of the gaging station estimates may be estimated using Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) or procedures given in *Frequency and Risk Analysis* (Kite, 1999) or in *Handbook of Hydrology* (Maidment, 1993). The Mapping Partner may use the 68-percent confidence interval, which is analogous to plus or minus one standard error for a normal distribution, to judge the reasonableness of flood discharges derived from regression equations. If the proposed flood discharges generally lie within the 68-percent confidence interval of the gaged data, then these flood discharges are accepted as reasonable for the hydraulic analysis. If not, then options for obtaining more reasonable flood discharges shall be provided.

The reviewing Mapping Partner shall use caution in reviewing 1-percent-annual-chance flood discharges derived from regression equations that are significantly different from those derived from gage data. When the regression estimates differ significantly from data from long-term gaging stations and the elevation difference is significant, the regression estimate may be adjusted based on the gaging station data.

C.2.3 Hydrologic Analysis Based on a Rainfall-Runoff Model

The reviewing Mapping Partner shall first verify that the rainfall-runoff model is included on FEMA's Acceptable Models List, which is posted on the FEMA website (http://www.fema.gov/mit/tsd/en_modl.htm). The Mapping Partner shall compare the proposed 1-percent-annual-chance flood discharges from the rainfall-runoff model to the flood discharges from USGS regional regression equations (if they are applicable) and to flood discharges at gaging stations in the vicinity. Procedures for developing estimates from gaging station data and regression equations are discussed in Subsections C.2.1 and C.2.2.

The reviewing Mapping Partner shall plot the flood discharge estimates from these sources against drainage area on logarithmic paper to determine if the proposed flood discharges are reasonable. Plus or minus one standard error bars (68-percent confidence intervals) should be shown about the regression and gaging station estimates. The USGS regional flood reports typically provide the standard error of prediction or estimate. The Mapping Partner shall use the standard error of prediction, if available, because this is more indicative of the predictive accuracy of the equations. The proposed flood discharges from the rainfall-runoff model are considered reasonable if they are generally within one standard error of the regression and gaging station estimates. If not, the Mapping Partner must review the rainfall-runoff model in greater detail to determine why there are significant differences. Some unique characteristics of the watershed may explain these differences and justify the use of the proposed rainfall-runoff model estimates, and the Mapping Partner that performed the hydrologic analysis must provide detailed information to explain these unique characteristics.

Even if the criteria for flood discharge reasonableness are satisfied, a review of the rainfall-runoff model is advisable to determine that the model was applied appropriately.

Recommendations to use a reasonable flood discharge in the hydraulic model cannot be made if the calculation of the flood discharges was incorrect and yielded reasonable flood discharges only by chance. Such a study is subject to appeal or protest on the basis of being scientifically or technically incorrect.

In watersheds with significant storage, hydrologic routing may be needed in estimating the flood discharges. Some hydrologic routing methods require a relationship between the water-surface elevation and the cross-sectional area, or the floodplain storage area between cross sections. For those methods, a hydraulic model is required as part of the hydrologic analysis, and the hydraulic model used to generate rating curves shall be provided for review with the hydrologic model.

The reviewing Mapping Partner shall ensure that the rainfall-runoff model has been calibrated against available data as described in Subsection C.1.1.3.2. Where reliable gaging station data are available, the rainfall-runoff model must be calibrated against them. In ungaged watersheds where high-water marks from major flood events are available, the Mapping Partner shall ensure that the rainfall-runoff model and the hydraulic model have been calibrated against the high-water marks. If no high-water marks from major events exist, and regression equations are determined not to be applicable, the Mapping Partner that performed the hydrologic analysis shall provide a detailed explanation of the rainfall-runoff model, and the designated Mapping Partner shall review the model in detail to determine flood discharge reasonableness.

C.2.4 Hydrologic Review Documentation

The reviewing Mapping Partner shall document the results of the review in a memorandum or letter that will be sent to the RPO and to the Mapping Partner that performed the hydrologic analysis. The documentation shall describe the review approach and conclusions (whether flood discharges are reasonable or unreasonable) and shall provide options for resolving any concerns. If the proposed flood discharges are determined to be unreasonable, the options may include, but are not limited to:

- Requesting further justification or documentation that the proposed 1-percent-annual-chance flood discharges should be used;
- Suggesting an alternative study method; or
- Revising the analysis to obtain more reasonable results.

C.3 Detailed Hydraulic Analyses

During the initial Scoping Meeting (Volume I, Section 1.3 of these Guidelines), the RPO and other members of the Flood Map Project Management Team will decide which flooding sources within the community will be studies using detailed hydraulic analyses. Guidance for performing these analyses is provided in the subsections that follow.