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August 10, 2009

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

BELL BEND NUCLEAR POWER PLANT
RESPONSE TO RAI SET NO. 19
QUESTION 2 AND REQUEST FOR
EXTENSION FOR QUESTION 1
BNP-2009-214 Docket No. 52-039

References: 1) M. Canova (NRC) to R. Sgarro (PPL Bell Bend, LLC), Bell Bend COLA – Request for Information No. 19 (RAI No. 19) – RHEB -2845, e-mail dated July 10, 2009

The purpose of this letter is to respond to the request for additional information (RAI) identified in the referenced NRC correspondence to PPL Bell Bend, LLC (PPL). This RAI addresses Probable Maximum Flood on Streams and Rivers, as discussed in Chapter 2 of the Final Safety Analysis Report (FSAR) and submitted in Part 2 of the Bell Bend Nuclear Power Plant Combined License Application (COLA).

The enclosure provides our response to RAI No. 19, Question 02.04.03-2. This response includes COLA text changes which will be incorporated into a future revision of the COLA.

RAI No. 19 Question 02.04.03-1 requests additional information regarding flooding associated with Walker Run and Unnamed Tributary #1. In order to provide this information, additional refined conceptual design is required to provide inputs for potential flooding analysis for the BBNPP site.

PPL, working with UniStar, has recently decided to move forward with an alternative stormwater management (SWM) design in response to feedback from the staff, Army Corps of Engineers, and PA Department of Environmental Protection. The revised design will enhance SWM while reducing both construction and permanent impacts to wetlands. As a result, Walker Run will no longer be relocated as currently described in the BBNPP COLA. PPL and UniStar are currently working on the implementation schedule for these changes, and PPL will provide firm schedules for responses to these RAIs by August 24, 2009.

The future COLA update represents a new regulatory commitment.

If you have any questions, please contact the undersigned at 570.802.8102.

D079
NRO

I declare under penalty of perjury that the foregoing is true and correct.

Executed on August 10, 2009

Respectfully,

Rocco R. Sgarro

Rocco R. Sgarro

RRS/kw

Enclosure: As stated

cc: (w/o Enclosures)

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Enclosure 1

Response to NRC Request for Additional Information Set No. 19, Question 2
Bell Bend Nuclear Power Plant

Question 02.04.03-2

Staff review indicates that a quantitative estimate of the maximum discharge and water surface elevation associated with the Probable Maximum Flood (PMF) for the North Branch Susquehanna River (NBSR) was not provided in Section 2.4.3 of the FSAR. The PMF computed for the neighboring Susquehanna Steam Electric Station (SSES) was referenced, however details were not provided. In accordance with the requirements of 10 CFR 100.20(c), 10 CFR 52.79(a)(1)(iii), and General Design Criterion 2, the applicant is requested to provide a full evaluation of the PMF for the NBSR as it applies to the Bell Bend site. The FSAR shall also be updated to include this analysis.

Response

The PMF computed for the neighboring Susquehanna Steam Electric Station (SSES) was originally referenced in Section 2.4.3 of the Final Safety Analysis Report (FSAR), which was calculated to be 548 feet (ft) mean sea level (msl). A simplified analysis was performed to estimate the maximum discharge and water surface elevation associated with the Probable Maximum Flood (PMF) for the Susquehanna River near the BBNPP site, in order to determine whether the referenced PMF is valid for the current BBNPP site.

Using MS Excel 2003, a stage-discharge curve for the Susquehanna River near the BBNPP site was developed using historic USGS annual peak flow and stage elevation data recorded at the Wilkes-Barre and Danville gauge stations. Using the Region 4 envelope curve provided in USGS Water-Supply Paper 1887, which considers the peak discharges that were generated on the Susquehanna River by the Hurricane Agnes flood event of 1972, two maximum "credible" peak discharges were estimated for the Susquehanna River near the BBNPP site: (1) the maximum "credible" peak discharge corresponding to a drainage area of 10,000 square miles, which is the approximate size of the BBNPP site drainage area and can be read directly from the envelope curve; and (2) the discharge corresponding to a drainage area of 10,200 square miles, which is equal to the size of the BBNPP site drainage area and can be extrapolated after digitizing the envelope curve in MS Excel 2003. The water surface elevation (WSE) corresponding to each estimated peak discharge was then determined using the equation representing the interpolated stage-discharge curve developed previously.

Based on the simplified analysis performed, the water surface elevations in the Susquehanna River near the BBNPP site corresponding to the maximum "credible" peak discharge estimated for site drainage areas of 10,000 and 10,200 square miles were calculated to be 527.70 ft msl (500,000 cfs) and 533.09 ft msl (612,591 cfs), respectively. Assuming that the BBNPP site drainage area is 10,200 square miles, the PMF elevation is best estimated as 533.09 ft msl based on the simplified analysis. This estimate is conservative since the effective drainage area at the BBNPP site is less than 10,200 square miles due to the presence of upstream flood control storage projects.

It can be concluded that the PMF elevation of 548 ft msl for the neighboring SSES Units 1 & 2 is also valid for the BBNPP site since it provides a more conservative definition of the PMF elevation when compared to the result obtained from the simplified analysis. The BBNPP site plant grade elevation is 674 ft msl, which is 126 ft above the PMF elevation of 548 ft (Reference 2 of Attachment 1). Furthermore, the BBNPP site is approximately 140.91 ft above the estimated PMF elevation of 533.09 ft msl.

Calculations to support the PMF results can be found in RIZZO (2009) "Simplified Probable Maximum Flood (PMF) Analysis (Response to RAI 02.04.03-2)", which can be found in Attachment 1.

COLA Impact

Markups of the relevant FSAR sections are provided below.

2.4.3 PROBABLE MAXIMUM FLOOD (PMF) ON STREAMS AND RIVERS

The U.S. EPR FSAR includes the following COL Item in Section 2.4.3:

A COL applicant that references the U.S. EPR design certification will provide site-specific information to describe the probable maximum flood of streams and rivers and the effect of flooding on the design.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

The proposed Bell Bend Nuclear Power Plant (BBNPP) site is located in Salem Township, Luzerne County, Pennsylvania on the west side of the North Branch of Susquehanna River as shown on Figure 2.4-23. The source of potential flooding at the proposed site is local intense precipitation directly over the site. This section discusses the Probable Maximum Flood (PMF) on streams and rivers as a result of the Probable Maximum Precipitation (PMP) over the watershed. All runoff from the BBNPP site enters the North Branch Susquehanna River at the mouth of Walker Run. The BBNPP site sits on a relatively flat upland area about 174 ft (53 m) elevation above the nominal Susquehanna River level. The site is 22 mi (35 km) downstream of Wilkes- Barre, PA and 5 mi (8 km) upstream of Berwick, PA. The BBNPP site is situated in the Walker Run watershed, which is within the Middle Susquehanna River Sub-basin and has a drainage area of 4.10 mi2 (10.6 km2). Walker Run Stream flows along the western side of the BBNPP site. An Unnamed Tributary to Walker Run flows along the south/southeast boundary of the site.

The 1972 flood that occurred throughout the Mid-Atlantic United States as a result of Hurricane Agnes is the most significant flood event on record. The critical factor affecting the record flooding was the near continuous nature of rainfall during Hurricane Agnes. From June 20 through June 25, an average of 6-10 in (15-25 cm) of rain fell over the Mid-Atlantic region (NOAA, 2008). These high rainfalls produced record flooding on the Susquehanna River, equaling or exceeding flood recurrence intervals of 100 years along portions of the Susquehanna River (NOAA, 2008).

The 1972 flood generated peak stream flows of 345,000 cfs (9,769 m^3/s) at Wilkes-Barre on June 24th and 363,000 cfs (10,279 m^3/s) at Danville on June 25th (USGS, 2008a)(USGS,2008b). On June 25, 1972 a river crest of 517.36 ft (157.7 m) msl and mean daily flow of 329,837 cfs (9,340 m^3/s) was recorded near the Susquehanna Steam Electric Station (SSES) intake structure (Ecology III, 1986).

The PMF evaluation for SSES Units 1 & 2 showed the PMF elevation on the Susquehanna River would not reach an elevation of 548 ft (167 m) msl (PPL, 1999). A simplified analysis was performed to determine whether this PMF elevation is valid for the adjacent BBNPP site. A stage-discharge curve for the Susquehanna River near the BBNPP site was developed through interpolation using data from the Wilkes-Barre (USGS 01536500) and Danville (USGS 01540500) gauge stations (immediately upstream and downstream from the BBNPP site, respectively). The peak discharges in the Susquehanna River near the BBNPP site were interpolated on a drainage area basis using the upstream and downstream gauge drainage areas as established by the USGS (DA_{ug} = 9,960 square miles (USGS, 2008b) and DA_{dg} = 11,220 square miles (USGS, 2008a), respectively) and an impact point drainage area (DA_{ip}) of 10,200 square miles (PPL, 1993). The formula used to conduct the interpolation of peak discharges in the Susquehanna River near the BBNPP site is as follows (NHDES, 2003):

$$\boxed{X_{ip} := \left[\left(1-\frac{DA_{ip}-DA_{ug}}{DA_{dg}-DA_{ug}}\right)\cdot\frac{X_{ug}}{DA_{ug}}+\left(1-\frac{DA_{dg}-DA_{ip}}{DA_{dg}-DA_{ug}}\right)\cdot\frac{X_{dg}}{DA_{dg}}\right]\cdot DA_{ip}}$$

DA = Drainage Area.
X = Peak Discharge.
ug = upstream gage (Wilkes-Barre).
dg = downstream gage (Danville).
ip = impact point (BBNPP site location).

The corresponding stage elevations (or water surface elevations) near the BBNPP site were calculated through linear interpolation between the upstream and downstream gauges. The upstream gauge, downstream gauge and the BBNPP site (or the BBNPP river intake structure) are located at approximately river mile 189.5, 136.9 and 167.8, respectively.

Using the Region 4 envelope curve provided in USGS Water-Supply Paper 1887 (Crippen and Bue, 1977), which considers the peak discharges that were generated on the Susquehanna River by the Hurricane Agnes flood event of 1972, two (2) maximum "credible" peak discharges were estimated for the Susquehanna River near the BBNPP site: (1) the maximum "credible" peak discharge corresponding to a drainage area of 10,000 square miles, which is the approximate size of the BBNPP site drainage area and can be read directly from the envelope curve (Crippen and Bue, 1977); and (2) the discharge corresponding to a drainage area of 10,200 square miles, which is equal to the size of the BBNPP site drainage area (PPL, 1993) and can be extrapolated after digitizing the envelope curve in MS Excel 2003. The water surface elevation (WSE) corresponding to each estimated peak discharge was determined using the interpolated stage-discharge curve developed previously. The maximum "credible" peak discharge and the corresponding water surface elevation in the Susquehanna River near the BBNPP site estimated for site drainage areas of 10,000 and 10,200 square miles were calculated to be 500,000 cfs (14,158 m^3/s) (527.70 ft (160.84 m) msl) and 612,591 cfs (17,347 m^3/s) (533.09 ft (162.49 m) msl), respectively. Assuming that the BBNPP site drainage area is 10,200 square miles (PPL, 1993), the PMF elevation is best estimated as 533.09 ft (162.49 m) msl based on the simplified analysis performed. Therefore, it can be concluded that the PMF elevation of 548 ft (167 m) msl for the neighboring SSES Units 1 & 2 is also valid for the BBNPP site since it provides a more conservative definition of the PMF elevation when compared to the result obtained from the simplified analysis (PPL, 1999). The BBNPP site plant grade elevation is 674 ft (205 m) msl, which is 126 ft (38 m) above the PMF elevation of 548 ft (167 m) (PPL, 1999). Furthermore, the BBNPP site is approximately 140.91 ft (42.95 m) above the estimated PMF elevation of 533.09 ft (162.49 m) msl.

Walker Run was analyzed for the Probable Maximum Flood (PMF) due to its proximity to the fact that the site lies within Walker Run Watershed. The analysis was based on the reroute of Walker Run to reflect the post-construction site layout as displayed in Figure 2.4-5. Walker Run flows towards the south until it converges with the Susquehanna River at approximately river mile 164 (km 264). Walker Run collects runoff from the area surrounding the plant site and also areas northwest, west, and southwest of the plant site. The total collection area for the Walker Run watershed is approximately 4.10 mi^2 (10.61 km^2). Walker Run has a difference in elevation of approximately 290 ft (88 m) over its entire length with an overall slope of 1.5 percent. ~~The PMC evaluation for SSES Units 1 & 2 showed the PMC elevation on the Susquehanna River would not reach an elecation of 548 feet. The Site elevation for SSES Units 1 & 2 is 670 ft (204 m) msl. There is a 122 foot difference in elecation for the existing PMF evaluation and the site grade. BBNPP site elevation is 674 feet~~

~~and after assessing the PMF evaluation, it is not possible for the PMF to increase to 126 feet to cause any flooding at the proposed BBNPP site (PPL, 1999).~~ The Unnamed Tributary adjacent to the project site was modeled as a flow change location within the Hydrologic Engineering Center's River Analysis System Version 3.1.3 (HECRAS 3.1.3) at the corresponding cross section location 11,594. The Unnamed Tributary channel will be removed and the flow will be diverted to ESWEMS Retention Pond. All safety-related structures, systems, and components for BBNPP are located at approximately el. 674 ft (205.4 m) msl.

~~The 1972 flood that occurred throughout the Mid-Atlantic United States as a result of Hurricane Agnes is the most significant flood event on record. The critical factor affecting the record flooding was the near continuous nature of rainfall during Hurricane Agnes. From June 20 through June 25, an average of 6-10 in(15-25 cm) of rain fell over the Mid Atlantic region (NOAA, 2008). These high rainfalls produced record flooding on the Susquehanna River, equaling or exceeding flood recurrence intervals of 100 years along portions of Susquehanna River (NOAA, 2008).~~

~~The 1972 flood generated peak stream flows of 345,000 cfs (9,769 m^3/s) at Wilkes-Barre on June 24th and 363,000 cfs (10,279 m^3/s) at Danville on June 25th (USGS, 2008a)(USGS, 2008b). On June 25, 1972 a river crest of 517.36 ft (157.7 m) msl and mean daily flow of 329,837 cfs (9,340 m^3/s) was recorded near the SSES intake structure (Ecology III, 1986).~~

The results of the PMF analysis indicate a maximum PMF water surface elevation of 670.96 ft (204.51 m) msl at Walker Run. The grade elevation for the proposed BBNPP is set to 674 ft (205.4 m) msl, which provides an elevation difference of approximately 3.0 ft (0.9 m) between the BBNPP safety related structures, systems, and components and estimated PMF water level at Walker Run.

2.4.3.7 References

Clark, 1945. Storage and the Unit Hydrograph, Transactions: American Society of Civil Engineers, Volume 110, p. 1419-1488, C.O Clark, 1945

Crippen and Bue, 1977. "Maximum Floodflows in the Conterminous United States," Water Supply Paper 1887, U.S. Geological Survey (USGS), Washington, DC, 1977.

Ecology III, 1986. Pre-Operational Studies of the Susquehanna River in the Vicinity of the Susquehanna Steam Electric Station, 1971-1982. Ecology III, Inc. December 1986.

Miller, 1975. Simplified Equations of Unsteady Flow, K. Mahmood and V. Yevjevich, eds., Unsteady Flow in Open Channels, Volume I, Water Resources Publications, Ft. Collins, Co., W.A. Miller and J.A Cunge,1975

NHDES, 2003. New Hampshire Department of Environmental Services, II Methods, 2003, Website: http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/documents/2003methods.pdf, Date Accessed: March 20, 2008.

NOAA, 1978. Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, Hydrometeorological Report No. 51, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, June 1978.

NOAA, 1982. Application of Probable Maximum Precipitation Estimates - United States East of the 105th Meridian, Hydrometeorological Report No. 52, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, August 1982

NOAA, 2008. National Weather Service Middle Atlantic River Forecast Center, National Oceanic and Atmospheric Administration, Website: http://ahps.erh.noaa.gov/marfc/Flood/agnes.html, Date accessed: February 7, 2008.

PPL, 1993. Susquehanna Steam Electric Station (SSES) Units 1 & 2 Final Safety Analysis Report (FSAR), Section 2.4 Hydrologic Engineering, Revision 46, Pennsylvania Power and Light (PPL), Figure 2.4-6, June 1993.

Response to NRC Request for Additional Information Set No. 19 (RAI Set No. 19
Question #2)
Rev. 0
Bell Bend Nuclear Power Plant
Berwick, Pennsylvania

Attachment 1 – RIZZO 2009 calculation package "Simplified Probable Maximum Flood
(PMF) Analysis (Response to RAI 02.04.03-2)"

PAUL C. RIZZO ASSOCIATES, INC.
CONSULTANTS

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. 1 of 6
Chkd.By PJM Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

DW = David Wallner David Wallner
PM = Paul Martinchich

Purpose:

Provide a simplified analysis to estimate the maximum discharge and water surface elevation associated with the Probable Maximum Flood (PMF) for the Susquehanna River near the BBNPP site. The PMF computed for the neighboring Susquehanna Steam Electric Station (SSES) was originally referenced in Section 2.4.3 of the Final Safety Analysis Report (FSAR), which was calculated to be 548 ft mean sea level (msl) (see ***Reference 2***). Therefore, from this simplified analysis a conclusion must be made as to whether the referenced PMF is valid for the current BBNPP site.

Assumptions:

1. When interpolating between the upstream and downstream gauge stations to develop the stage-discharge curve for the Susquehanna River near the BBNPP site, it is assumed that the USGS annual peak flows and stage elevations recorded at each station occur on the same day and at the same time.

2. A stage-discharge curve for the BBNPP site was developed through interpolation using data from the Wilkes-Barre (USGS 01536500) and Danville (USGS 01540500) gauge stations (immediately upstream and downstream from the BBNPP site, respectively). The peak discharges in the Susquehanna River near the BBNPP site were interpolated on a drainage area basis using the upstream and downstream gauge drainage areas as established by the USGS (DA_{ug} = 9,960 square miles and DA_{dg} = 11,220 square miles, respectively; see ***Attachment A***) and an impact point drainage area (DA_{ip}) of 10,200 square miles (***Reference 1***). The corresponding stage elevations (or water surface elevations) near the BBNPP site were calculated through linear interpolation between the upstream and downstream gauges. The upstream gauge, downstream gauge and the BBNPP site (or the BBNPP river intake structure) are located at approximately river mile 189.5, 136.9, and 167.8, respectively (see ***Attachment E***).

3. As suggested in Chapter 11 of the U.S. Army Corps of Engineers (USACE) Flood-Runoff Analysis Engineering Manual (see ***Reference 3***) and discussed further in USGS Water-Supply Paper 1887 (see ***Reference 4***), the maximum "credible" peak discharge for the Susquehanna River near the BBNPP site will be estimated using the envelope curve that represents the region of interest. Based on Figure 1 in USGS Water-Supply Paper 1887, the envelope curve for Region 4 will be used to estimate the maximum "credible" peak discharge (see ***Reference 4***).

4. The impact point drainage area (or the drainage area of the ungauged BBNPP site) is 10,200 square miles (***Reference 1***), which will be used to interpolate peak discharges in

the Susquehanna River near the BBNPP site and estimate the maximum "credible" peak discharge from the Region 4 envelope curve.

5. The envelope curves provided in USGS Water-Supply Paper 1887 were developed based on data from sites with drainage areas of less than 10,000 square miles (see ***Reference 4***). Since the impact point drainage area (or the drainage area of the ungauged BBNPP site) exceeds this limit by 200 square miles, two (2) maximum "credible" peak discharges were estimated for the Susquehanna River near the BBNPP site using the Region 4 envelope curve: (1) the discharge corresponding to a drainage area of 10,000 square miles, which is the approximate size of the BBNPP site drainage area and can be read directly from the envelope curve (see ***Reference 4***); and (2) the discharge corresponding to a drainage area of 10,200 square miles, which is equal to the size of the BBNPP site drainage area and can be extrapolated after digitizing the envelope curve using MS Excel 2003.

Methodology:

Using MS Excel 2003, a stage-discharge curve for the Susquehanna River near the BBNPP site was developed using historic USGS annual peak flow and stage elevation data recorded at Wilkes-Barre and Danville gauge stations. Using the Region 4 envelope curve provided in USGS Water-Supply Paper 1887, which considers the peak discharges that were generated on the Susquehanna River by the Hurricane Agnes flood event of 1972 (see ***Reference 4***), two (2) maximum "credible" peak discharges were estimated for the Susquehanna River near the BBNPP site: (1) the maximum "credible" peak discharge corresponding to a drainage area of 10,000 square miles, which is the approximate size of the BBNPP site drainage area and can be read directly from the envelope curve (see ***Reference 4***); and (2) the discharge corresponding to a drainage area of 10,200 square miles, which is equal to the size of the BBNPP site drainage area and can be extrapolated after digitizing the envelope curve in MS Excel 2003. The water surface elevation (WSE) corresponding to each estimated peak discharge was then determined using the equation representing the interpolated stage-discharge curve developed previously.

Input:

USGS peak streamflow and stage elevation data for Wilkes-Barre (USGS 01536500) and Danville (USGS 01540500) gauge stations.

References:

USGS, 2008a. Peak Streamflow for Pennsylvania USGS 01540500 Susquehanna River at Danville, PA. Website: http://nwis.waterdata.usgs.gov/pa/nwis/peak?site_no=01540500&agency_cd=USGS&format=html, Date accessed: January 25, 2008. (See "***Attachment A***")

USGS, 2008b. Peak Streamflow for Pennsylvania USGS 01536500 Susquehanna River at Wilkes-Barre, PA. Website: http://nwis.waterdata.usgs.gov/pa/nwis/peak?site_no=01536500&agency_cd=USGS&format=html, Date accessed: January 25, 2008. (See "*Attachment A*")

PPL, 1993. Susquehanna Steam Electric Station (SSES) Units 1 & 2 Final Safety Analysis Report (FSAR), Figure 2.4-6 Revision 46, Figure 2.4-6, Pennsylvania Power and Light (PPL), June 1993. (Attached as "*Reference 1*")

PPL, 1999. Susquehanna Steam Electric Station (SSES) Units 1 & 2 Final Safety Analysis Report (FSAR), Section 2.4 Hydrologic Engineering, Revision 62, Pensylvania Power and Light (PPL), October 1999. (Attached as "*Reference 2*")

USACE, 1994. U.S. Army Corps of Engineers (USACE), "Flood-Runoff Analysis" Engineering Manual (EM 1110-2-1417), 31 August 1994. (Attached as "*Reference 3*")

Crippen and Bue, 1977. "Maximum Floodflows in the Conterminous United States," Water Supply Paper 1887, U.S. Geological Survey (USGS), Washington, DC, 1977. (Attached as "*Reference 4*")

NHDES, 2003. New Hampshire Department of Environmental Services (NHDES), II Methods, 2003, Website: http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/documents/2003methods.pdf, Date Accessed: March 20, 2008. (Attached as "*Reference 5*")

FEMA, 2008. Flood Insurance Map, Luzerne County, Federal Emergency Management Agency (FEMA).
Website: http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1, Date Accessed: March 27, 2008. (Attached as "*Reference 6*")

Calculations

G:\DJW\Berwick NPP (07-3891)\Water Resource Work\FSAR 2.4.3, RAI 02.04.03-2\Stage-Discharge Interpolation.xls

G:\DJW\Berwick NPP (07-3891)\Water Resource Work\FSAR 2.4.3, RAI 02.04.03-2\Envelope Curve for Region 4.xls

Peak flow stage-discharge curves were generated at the Wilkes-Barre (USGS 01536500) and Danville (USGS 01540500) gauge stations on the Susquehanna River using the USGS data provided in ***Attachment A***. A stage-discharge curve for the BBNPP site was developed through interpolation using data from the Wilkes-Barre and Danville gauge stations (immediately upstream and downstream from the BBNPP site, respectively). The peak discharges in the Susquehanna River near the BBNPP site were interpolated on a drainage area basis using the upstream and downstream gauge drainage areas as established by the USGS (DA_{ug} = 9,960 square miles and DA_{dg} = 11,220 square miles, respectively; see ***Attachment A***) and an impact point drainage area (DA_{ip}) of 10,200 square miles (***Reference 1***). The formula used to conduct the interpolation (see ***Reference 5*** attached) is displayed below.

$$X_{ip} := \left[\left(1 - \frac{DA_{ip} - DA_{ug}}{DA_{dg} - DA_{ug}}\right) \cdot \frac{X_{ug}}{DA_{ug}} + \left(1 - \frac{DA_{dg} - DA_{ip}}{DA_{dg} - DA_{ug}}\right) \cdot \frac{X_{dg}}{DA_{dg}}\right] \cdot DA_{ip}$$

DA = Drainage Area.
X = Peak Discharge.
ug = upstream gage (Wilkes-Barre).
dg = downstream gage (Danville).
ip = impact point (site location).

The corresponding stage elevations (or water surface elevations) near the BBNPP site were calculated through linear interpolation between the upstream and downstream gauges. The upstream gauge, downstream gauge and the BBNPP site (or the BBNPP river intake structure) are located at approximately river mile 189.5, 136.9, and 167.8, respectively (see ***Attachment E***). All stage-discharge curves and calculations can be found in ***Attachment B***.

Using the Region 4 envelope curve provided in USGS Water-Supply Paper 1887, which considers the peak discharges that were generated on the Susquehanna River by the Hurricane Agnes flood event of 1972 (see ***Reference 4***), two (2) maximum "credible" peak discharges were estimated for the Susquehanna River near the BBNPP site: (1) the maximum "credible" peak discharge corresponding to a drainage area of 10,000 square miles, which is the approximate size of the BBNPP site drainage area and can be read directly from the envelope curve (see ***Reference 4***); and (2) the discharge corresponding to a drainage area of 10,200 square miles, which is equal to the size of the BBNPP site drainage area and can be extrapolated after digitizing the envelope curve in MS Excel 2003. The extrapolated Region 4 envelope curve and the calculated maximum "credible" peak discharge corresponding to a drainage area of 10,200 square miles can be found in ***Attachment C.***

The water surface elevation (WSE) corresponding to each estimated maximum "credible" peak discharge was determined using the equation representing the interpolated stage-discharge curve; these calculations can be found in ***Attachment D.***

Results:

All stage-discharge curves and calculations can be found in ***Attachment B***. Keep in mind that the calculation is being made under the assumption that the USGS annual peak flows and stage elevations recorded at each gauge station occur on the same day and at the same time.

Using the Region 4 envelope curve provided in USGS Water-Supply Paper 1887, the maximum "credible" peak discharge corresponding to a drainage area of 10,000 square miles is approximately 500,000 cfs (***Reference 4***). To determine the maximum "credible" peak discharge corresponding to the actual BBNPP site drainage area of 10,200 square miles, the Region 4 envelope curve was digitized and extrapolated. Using the equation representing the line of best fit ($y = 6{,}947 * x^{0.4853}$, where "y" is discharge in cfs and "x" is drainage area in square miles), the maximum "credible" peak discharge corresponding to a drainage area of 10,200 square miles was calculated to be 612,591 cfs (see ***Attachment C***).

The WSE corresponding to each estimated maximum "credible" peak discharge was determined using the equation representing the interpolated stage-discharge curve ($y = [-6E\text{-}5 * x^2] + [0.1146 * x] + 485.4$, where "y" is elevation in feet and "x" is discharge in 1,000 cfs). The water surface elevations in the Susquehanna River near the BBNPP site corresponding to the maximum "credible" peak discharge estimated for site drainage areas of 10,000 and 10,200 square miles were calculated to be 527.70 ft msl (500,000 cfs) and 533.09 ft msl (612,591 cfs), respectively. All calculations that were performed to determine the WSE near the BBNPP site can be found in ***Attachment D***.

The discharge and water surface elevation (WSE) corresponding to other flood events near the BBNPP site are provided in **Table 1** below. The flow rate near the BBNPP site generated by the Hurricane Agnes flood event of 1972 was interpolated on a drainage area basis using the upstream (Wilkes-Barre) and downstream (Danville) gauge station data as discussed previously. The flood event identified as the "Estimated PMF" (or the maximum "credible" discharge and WSE) corresponds to the complete analysis that was discussed previously for a site drainage area of 10,200 square miles (***Reference 1***). The "Estimated PMF" was also factored to account for the fact that the simplified analysis discussed previously was based on an older study.

Table 1: BBNPP Site Flood Event Results

Flood Event	Q (cfs)	WSE (ft msl)
FEMA 100-yr*	266,049	514.00
Flood of Record (Hurricane Agnes, 1972)**	348,873	518.08
Estimated PMF**	612,591	533.09
Factored Estimated PMF (x 1.3)**	796,368	538.61

*See ***Reference 6*** attached.
**WSE estimated using the interpolated stage-discharge curve: $y = [-6E-5*x^2] + [0.1146*x] + 485.4$.

Conclusions:

The PMF computed for the neighboring Susquehanna Steam Electric Station (SSES) was originally referenced in Section 2.4.3 of the FSAR, which was calculated to be 548 ft mean sea level (msl) (see ***Reference 2***). Based on the simplified analysis performed, the water surface elevations in the Susquehanna River near the BBNPP site corresponding to the maximum "credible" peak discharge estimated for site drainage areas of 10,000 and 10,200 square miles were calculated to be 527.70 ft msl (500,000 cfs) and 533.09 ft msl (612,591 cfs), respectively. Assuming that the BBNPP site drainage area is 10,200 square miles (***Reference 1***), the PMF elevation is best estimated as 533.09 ft msl based on the simplified analysis. This estimate is conservative since the effective drainage area at the BBNPP site is less than 10,200 square miles due to the presence of upstream flood control storage projects.

It can be concluded that the PMF elevation of 548 ft msl for the neighboring SSES Units 1 & 2 is also valid for the BBNPP site since it provides a more conservative definition of the PMF elevation when compared to the result obtained from the simplified analysis. The BBNPP site plant grade elevation is 674 ft msl, which is 126 ft above the PMF elevation of 548 ft (***Reference 2***). Furthermore, the BBNPP site is approximately 140.91 ft above the estimated PMF elevation of 533.09 ft msl.

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Analysis (Response to RAI 02.04.03-2) Sheet No. A1 of A9
Chkd.By TSM Date 7/17/09 Project No. 07-3891

Attachment A

USGS Gage Station Data: Wilkes-Barre and Danville

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. A2 of A9
Chkd.By ZSM Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

USGS 01536500 Susquehanna River at Wilkes-Barre, PA

Luzerne County, Pennsylvania
Hydrologic Unit Code 02050107
Latitude 41°15'03", Longitude 75°52'52" NAD27
Drainage area 9,960 square miles
Gage datum 510.86 feet above sea level NAVD88

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
1787	Oct. 05, 1786	Not Available	189,000
1807	Apr. 1807	Not Available	202,000
1809	Jul. 1809	Not Available	95,200
1833	May 14, 1833	Not Available	176,000
1865	Mar. 18, 1865	33.10	232,000
1891	Jan. 24, 1891	26.80	164,000
1892	Apr. 04, 1892	21.60	112,000
1893	May 05, 1893	22.02	115,000
1894	May 21, 1894	20.00	97,100
1895	Apr. 10, 1895	21.82	113,000
1896	Apr. 01, 1896	24.00	135,000
1897	Oct. 15, 1896	19.00	88,600
1898	Apr. 26, 1898	17.82	78,900
1899	Mar. 06, 1899	18.22	82,100
1900	Mar. 02, 1900	19.70	94,500
1901	Nov. 28, 1900	22.00	115,000
1902	Mar. 02, 1902	31.40	213,000
1903	Mar. 25, 1903	22.40	119,000
1904	Mar. 09, 1904	30.60	204,000
1905	Mar. 26, 1905	23.40	129,000
1906	Apr. 01, 1906	18.10	81,300
1907	Mar. 16, 1907	16.00	65,500
1908	Feb. 17, 1908	23.50	130,000
1909	May 02, 1909	23.00	125,000
1910	Mar. 03, 1910	26.10	157,000
1911	Mar. 29, 1911	19.70	94,500
1912	Apr. 03, 1912	23.20	127,000
1913	Mar. 28, 1913	28.50	184,000
1914	Mar. 29, 1914	28.30	182,000
1915	Feb. 26, 1915	23.30	127,000
1916	Apr. 02, 1916	26.50	160,000
1917	Mar. 28, 1917	17.70	75,700
1918	Mar. 15, 1918	23.00	124,000
1919	May 24, 1919	16.60	66,900
1920	Mar. 13, 1920	26.00	155,000

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. A3 of A9
Chkd.By Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

USGS 01536500 Susquehanna River at Wilkes-Barre, PA

Luzerne County, Pennsylvania
Hydrologic Unit Code 02050107
Latitude 41°15'03", Longitude 75°52'52" NAD27
Drainage area 9,960 square miles
Gage datum 510.86 feet above sea level NAVD88

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
1921	Mar. 10, 1921	19.00	86,600
1922	Nov. 29, 1921	22.30	117,000
1923	Mar. 05, 1923	19.60	91,800
1924	Apr. 08, 1924	23.50	129,000
1925	Feb. 13, 1925	25.10	145,000
1926	Mar. 26, 1926	19.40	90,100
1927	Nov. 17, 1926	22.70	121,000
1928	Oct. 20, 1927	24.70	141,000
1929	Apr. 22, 1929	26.40	159,000
1930	Mar. 09, 1930	16.70	67,600
1931	Mar. 30, 1931	17.60	74,700
1932	Apr. 02, 1932	20.50	107,000
1933	Aug. 25, 1933	19.72	99,800
1934	Mar. 06, 1934	18.00	85,500
1935	Jul. 10, 1935	25.39	151,000
1936	Mar. 20, 1936	33.07	232,000
1937	Jan. 23, 1937	17.15	77,300
1938	Sep. 24, 1938	14.70	64,900
1939	Feb. 22, 1939	23.80	137,000
1940	Apr. 01, 1940	31.53	212,000
1941	Apr. 07, 1941	23.50	138,000
1942	Mar. 11, 1942	20.62	111,000
1943	Jan. 01, 1943	29.37	191,000
1944	May 09, 1944	18.50	90,000
1945	Mar. 05, 1945	21.80	119,000
1946	May 29, 1946	32.01	210,000
1947	Apr. 07, 1947	24.88	151,000
1948	Mar. 23, 1948	28.76	193,000
1949	Dec. 31, 1948	17.39	82,700
1950	Mar. 30, 1950	27.04	172,000
1951	Apr. 01, 1951	22.72	128,000
1952	Mar. 13, 1952	22.39	124,000
1953	Dec. 12, 1952	19.43	98,000
1954	May 05, 1954	16.85	78,900
1955	Mar. 03, 1955	17.80	85,900

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Analysis (Response to RAI 02.04.03-2) Sheet No. A4 of A9
Chkd.By RSM Date 7/17/09 Project No. 07-3891

USGS 01536500 Susquehanna River at Wilkes-Barre, PA

Luzerne County, Pennsylvania
Hydrologic Unit Code 02050107
Latitude 41°15'03", Longitude 75°52'52" NAD27
Drainage area 9,960 square miles
Gage datum 510.86 feet above sea level NAVD88

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
1956	Mar. 09, 1956	28.17	186,000
1957	Apr. 07, 1957	20.48	107,000
1958	Apr. 08, 1958	26.80	170,000
1959	Jan. 23, 1959	21.14	113,000
1960	Apr. 02, 1960	29.60	184,000
1961	Feb. 27, 1961	26.20	163,000
1962	Apr. 02, 1962	22.84	128,000
1963	Mar. 28, 1963	22.26	131,000
1964	Mar. 10, 1964	Not Available	188,000
1965	Feb. 14, 1965	11.10	44,600
1966	Feb. 15, 1966	18.25	93,500
1967	Mar. 29, 1967	17.16	84,800
1968	Mar. 24, 1968	19.19	101,000
1969	Apr. 07, 1969	16.57	80,500
1970	Apr. 04, 1970	20.92	115,000
1971	Mar. 17, 1971	20.28	110,000
1972	Jun. 24, 1972	40.91	345,000
1973	Apr. 06, 1973	18.04	91,800
1974	Dec. 28, 1973	18.24	93,400
1975	Sep. 27, 1975	35.06	228,000
1976	Feb. 19, 1976	21.34	118,000
1977	Sep. 26, 1977	21.62	121,000
1978	Jan. 27, 1978	21.08	116,000
1979	Mar. 07, 1979	31.02	192,000
1980	Mar. 23, 1980	19.50	104,000
1981	Feb. 22, 1981	19.57	104,000
1982	Oct. 29, 1981	17.24	86,400
1983	Apr. 16, 1983	23.86	138,000
1984	Dec. 14, 1983	29.76	192,000
1985	Mar. 14, 1985	13.04	55,800
1986	Mar. 16, 1986	27.36	172,000
1987	Apr. 05, 1987	19.22	98,500
1988	May 21, 1988	16.88	82,200
1989	May 12, 1989	21.12	117,000
1990	Feb. 18, 1990	15.75	74,900

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. A5 of A9
Chkd.By TSM Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

USGS 01536500 Susquehanna River at Wilkes-Barre, PA

Luzerne County, Pennsylvania
Hydrologic Unit Code 02050107
Latitude 41°15'03", Longitude 75°52'52" NAD27
Drainage area 9,960 square miles
Gage datum 510.86 feet above sea level NAVD88

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
1991	Oct. 25, 1990	22.69	134,000
1992	Mar. 28, 1992	18.46	92,000
1993	Apr. 02, 1993	29.87	185,000
1994	Mar. 26, 1994	24.16	148,000
1995	Jan. 22, 1995	15.76	72,100
1996	Jan. 20, 1996	34.45	221,000
1997	Nov. 10, 1996	23.57	128,000
1998	Jan. 09, 1998	24.79	138,000
1999	Jan. 25, 1999	21.59	112,000
2000	Feb. 29, 2000	23.66	129,000
2001	Apr. 11, 2001	19.49	96,800
2002	Mar. 28, 2002	17.02	78,900
2003	Mar. 22, 2003	22.84	122,000
2004	Sep. 19, 2004	34.96	227,000
2005	Apr. 04, 2005	30.88	189,000
2006	Jun. 28, 2006	34.14	218,000

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. A6 of A9
Chkd.By TSM Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

USGS 01540500 Susquehanna River at Danville, PA

Montour County, Pennsylvania
Hydrologic Unit Code 02050107
Latitude 40°57'29", Longitude 76°37'10" NAD27
Drainage area 11,220 square miles
Gage datum 431.29 feet above sea level NGVD29

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
1865	Mar. 18, 1865	28.00	Not Available
1900	Mar. 02, 1900	15.90	105,000
1901	Nov. 28, 1900	18.50	135,000
1902	Mar. 03, 1902	26.90	243,000
1903	Mar. 25, 1903	18.20	132,000
1904	Mar. 27, 1904	19.62	148,000
1905	Mar. 26, 1905	18.62	136,000
1906	Apr. 01, 1906	15.40	99,500
1907	Mar. 17, 1907	13.00	73,400
1908	Feb. 17, 1908	17.40	122,000
1909	May 02, 1909	18.40	134,000
1910	Mar. 03, 1910	21.00	165,000
1911	Mar. 29, 1911	15.20	97,300
1912	Apr. 03, 1912	17.91	129,000
1913	Mar. 28, 1913	23.11	192,000
1914	Mar. 29, 1914	22.60	186,000
1915	Feb. 26, 1915	19.00	141,000
1916	Apr. 02, 1916	21.80	175,000
1917	Mar. 29, 1917	14.80	92,900
1918	Mar. 16, 1918	18.60	139,000
1919	May 24, 1919	13.70	80,800
1920	Mar. 14, 1920	20.90	170,000
1921	Mar. 10, 1921	15.50	101,000
1922	Nov. 30, 1921	18.10	133,000
1923	Mar. 05, 1923	15.80	105,000
1924	Apr. 08, 1924	18.80	142,000
1925	Feb. 13, 1925	20.30	162,000
1926	Mar. 27, 1926	15.50	101,000
1927	Nov. 17, 1926	18.80	142,000
1928	Oct. 21, 1927	19.90	156,000
1929	Apr. 23, 1929	20.35	163,000
1930	Mar. 09, 1930	13.50	78,700
1931	Mar. 30, 1931	14.35	88,500
1932	Apr. 02, 1932	17.05	119,000
1933	Aug. 25, 1933	17.04	119,000

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. A7 of A9
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USGS 01540500 Susquehanna River at Danville, PA

Montour County, Pennsylvania
Hydrologic Unit Code 02050107
Latitude 40°57'29", Longitude 76°37'10" NAD27
Drainage area 11,220 square miles
Gage datum 431.29 feet above sea level NGVD29

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
1934	Mar. 06, 1934	14.50	98,600
1935	Jul. 11, 1935	20.00	153,000
1936	Mar. 20, 1936	27.42	250,000
1937	Jan. 23, 1937	15.20	93,400
1938	Oct. 24, 1937	13.80	79,400
1939	Feb. 22, 1939	19.20	139,000
1940	Apr. 02, 1940	25.25	222,000
1941	Apr. 07, 1941	19.45	142,000
1942	Mar. 11, 1942	17.08	116,000
1943	Jan. 01, 1943	24.00	204,000
1944	May 09, 1944	15.48	97,600
1945	Mar. 05, 1945	17.55	121,000
1946	May 29, 1946	25.98	234,000
1947	Apr. 07, 1947	19.95	150,000
1948	Mar. 24, 1948	22.63	184,000
1949	Jan. 01, 1949	15.16	89,600
1950	Mar. 30, 1950	21.81	168,000
1951	Dec. 05, 1950	19.02	131,000
1952	Mar. 13, 1952	18.84	127,000
1953	Dec. 13, 1952	16.80	103,000
1954	May 05, 1954	14.71	82,100
1955	Mar. 03, 1955	15.09	85,900
1956	Mar. 09, 1956	22.47	175,000
1957	Apr. 08, 1957	17.78	114,000
1958	Apr. 08, 1958	21.87	169,000
1959	Jan. 24, 1959	17.45	112,000
1960	Apr. 02, 1960	23.92	198,000
1961	Feb. 28, 1961	21.72	167,000
1962	Apr. 02, 1962	19.38	136,000
1963	Mar. 29, 1963	18.89	130,000
1964	Mar. 11, 1964	25.13	261,000
1965	Feb. 14, 1965	Not Available	44,900
1966	Feb. 15, 1966	16.26	98,900
1967	Mar. 30, 1967	15.23	87,500
1968	Mar. 24, 1968	16.75	104,000

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Analysis (Response to RAI 02.04.03-2) Sheet No. A8 of A9
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USGS 01540500 Susquehanna River at Danville, PA

Montour County, Pennsylvania
Hydrologic Unit Code 02050107
Latitude 40°57'29", Longitude 76°37'10" NAD27
Drainage area 11,220 square miles
Gage datum 431.29 feet above sea level NGVD29

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
1969	Apr. 07, 1969	14.67	81,700
1970	Apr. 04, 1970	18.24	122,000
1971	Mar. 17, 1971	17.34	111,000
1972	Jun. 25, 1972	32.16	363,000
1973	Dec. 08, 1972	15.96	99,600
1974	Dec. 29, 1973	16.39	103,000
1975	Sep. 28, 1975	27.52	257,000
1976	Feb. 19, 1976	18.13	120,000
1977	Sep. 27, 1977	18.04	122,000
1978	Mar. 23, 1978	17.98	116,000
1979	Mar. 07, 1979	23.93	188,000
1980	Mar. 23, 1980	16.65	104,000
1981	Feb. 22, 1981	16.95	105,000
1982	Oct. 30, 1981	14.61	83,300
1983	Apr. 17, 1983	20.53	149,000
1984	Apr. 07, 1984	24.14	194,000
1985	Mar. 14, 1985	11.77	55,300
1986	Mar. 16, 1986	22.68	173,000
1987	Apr. 06, 1987	16.74	104,000
1988	May 21, 1988	14.81	83,500
1989	May 15, 1989	17.70	116,000
1990	Feb. 18, 1990	13.51	70,900
1991	Oct. 25, 1990	18.51	124,000
1992	Mar. 29, 1992	15.37	89,200
1993	Apr. 03, 1993	23.97	187,000
1994	Mar. 26, 1994	20.15	139,000
1995	Jan. 22, 1995	13.81	73,700
1996	Jan. 21, 1996	25.96	209,000
1997	Dec. 03, 1996	19.06	130,000
1998	Jan. 10, 1998	20.43	143,000
1999	Jan. 25, 1999	17.81	116,000
2000	Feb. 29, 2000	19.24	132,000
2001	Apr. 11, 2001	15.95	97,800
2002	May 15, 2002	14.84	84,700
2003	Mar. 22, 2003	18.81	130,000

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. A9 of A9
Chkd.By RSN Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

USGS 01540500 Susquehanna River at Danville, PA

Montour County, Pennsylvania
Hydrologic Unit Code 02050107
Latitude 40°57'29", Longitude 76°37'10" NAD27
Drainage area 11,220 square miles
Gage datum 431.29 feet above sea level NGVD29

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
2004	Sep. 19, 2004	26.22	220,000
2005	Apr. 04, 2005	24.28	202,000
2006	Jun. 28, 2006	28.19	260,000

http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01536500&agency_cd=USGS&format=html (Wilkes-Barre)
http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01540500&agency_cd=USGS&format=html (Danville)

Attachment B

Peak Flow Stage-Discharge Curves

G:\DJW\Berwick NPP (07-3891)\Water Resource Work\FSAR 2.4.3, RAI 02.04.03-2\Stage-Discharge Interpolation.xls

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. B2 of B9
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Peak Discharge Interpolation Formula

$$X_{ip} := \left[\left(1 - \frac{DA_{ip} - DA_{ug}}{DA_{dg} - DA_{ug}}\right) \cdot \frac{X_{ug}}{DA_{ug}} + \left(1 - \frac{DA_{dg} - DA_{ip}}{DA_{dg} - DA_{ug}}\right) \cdot \frac{X_{dg}}{DA_{dg}}\right] \cdot DA_{ip}$$

DA = Drainage Area.
X = Peak Discharge.
ug = upstream gage (Wilkes-Barre).
dg = downstream gage (Danville).
ip = impact point (site location).

Stage Elevation Interpolation Formula

$$SE_{ip} := SE_{ug} - \left[\frac{RM_{ug} - RM_{ip}}{RM_{ug} - RM_{dg}} \cdot \left(SE_{ug} - SE_{dg}\right)\right]$$

RM = River Mile.
SE = Stage Elevation.
ug = upstream gage (Wilkes-Barre).
dg = downstream gage (Danville).
ip = impact point (site location).

*Site peak discharge interpolated based on drainage area.
*Site Drainage Area = 10,200 square miles (***Reference 1***).
*Drainage areas for upstream and downstream gauges are included in ***Attachment A***.

*Site stage elevation calculated using linear interpolation between the upstream and downstream gauges (refer to figure in ***Attachment E***). Note that the coordinates (Latitude, Longitude) of the upstream and downstream gauges are provided in ***Attachment A***, and the BBNPP site location on the Susquehanna River is taken as the proposed intake structure location. The river mile distance corresponding to each of these locations was determined using ArcGIS Version 9.2.

DA_{dg} = 11,220 square miles, RM_{dg} = 136.9
DA_{ug} = 9,960 square miles, RM_{ug} = 189.5
DA_{ip} = 10,200 square miles, RM_{ip} = 167.8

	Stage-Discharge at Danville			Stage-Discharge at Wilkes-Barre			Interpolated Stage-Discharge	
Water Year	Peak Streamflow (cfs)	Peak Streamflow (1000 cfs)	Stage Elevation MSL (ft)	Peak Streamflow (cfs)	Peak Streamflow (1000 cfs)	Stage Elevation MSL (ft)	Interpolated Peak Streamflow (1000 cfs)	Interpolated Stage Elevation MSL (ft)
1900	105,000	105	447.19	94,500	95	530.56	97	496
1901	135,000	135	449.79	115,000	115	532.86	119	499
1902	243,000	243	458.19	213,000	213	542.26	219	508
1903	132,000	132	449.49	119,000	119	533.26	122	499
1904	148,000	148	450.91	204,000	204	541.46	195	504
1905	136,000	136	449.91	129,000	129	534.26	130	499
1906	99,500	100	446.69	81,300	81	528.96	85	495
1907	73,400	73	444.29	65,500	66	526.86	67	493
1908	122,000	122	448.69	130,000	130	534.36	129	499
1909	134,000	134	449.69	125,000	125	533.86	127	499
1910	165,000	165	452.29	157,000	157	536.96	159	502
1911	97,300	97	446.49	94,500	95	530.56	95	496
1912	129,000	129	449.20	127,000	127	534.06	128	499
1913	192,000	192	454.40	184,000	184	539.36	186	504
1914	186,000	186	453.89	182,000	182	539.16	183	504
1915	141,000	141	450.29	127,000	127	534.16	130	500
1916	175,000	175	453.09	160,000	160	537.36	163	503
1917	92,900	93	446.09	75,700	76	528.56	79	495
1918	139,000	139	449.89	124,000	124	533.86	127	499
1919	80,800	81	444.99	66,900	67	527.46	69	493
1920	170,000	170	452.19	155,000	155	536.86	158	502
1921	101,000	101	446.79	86,600	87	529.86	89	496
1922	133,000	133	449.39	117,000	117	533.16	120	499
1923	105,000	105	447.09	91,800	92	530.46	94	496

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Chkd.By _BSM_ Date _7/17/09_ Analysis (Response to RAI 02.04.03-2) Project No. _07-3891_

	Stage-Discharge at Danville			Stage-Discharge at Wilkes-Barre			Interpolated Stage-Discharge	
Water Year	Peak Streamflow (cfs)	Peak Streamflow (1000 cfs)	Stage Elevation MSL (ft)	Peak Streamflow (cfs)	Peak Streamflow (1000 cfs)	Stage Elevation MSL (ft)	Interpolated Peak Streamflow (1000 cfs)	Interpolated Stage Elevation MSL (ft)
1924	142,000	142	450.09	129,000	129	534.36	132	500
1925	162,000	162	451.59	145,000	145	535.96	148	501
1926	101,000	101	446.79	90,100	90	530.26	92	496
1927	142,000	142	450.09	121,000	121	533.56	125	499
1928	156,000	156	451.19	141,000	141	535.56	144	501
1929	163,000	163	451.64	159,000	159	537.26	160	502
1930	78,700	79	444.79	67,600	68	527.56	70	493
1931	88,500	89	445.64	74,700	75	528.46	77	494
1932	119,000	119	448.34	107,000	107	531.36	109	497
1933	119,000	119	448.33	99,800	100	530.58	103	497
1934	98,600	99	445.79	85,500	86	528.86	88	495
1935	153,000	153	451.29	151,000	151	536.25	152	501
1936	250,000	250	458.71	232,000	232	543.93	236	509
1937	93,400	93	446.49	77,300	77	528.01	80	494
1938	79,400	79	445.09	64,900	65	525.56	68	492
1939	139,000	139	450.49	137,000	137	534.66	138	500
1940	222,000	222	456.54	212,000	212	542.39	214	507
1941	142,000	142	450.74	138,000	138	534.36	139	500
1942	116,000	116	448.37	111,000	111	531.48	112	497
1943	204,000	204	455.29	191,000	191	540.23	194	505
1944	97,600	98	446.77	90,000	90	529.36	92	495
1945	121,000	121	448.84	119,000	119	532.66	120	498
1946	234,000	234	457.27	210,000	210	542.87	215	508
1947	150,000	150	451.24	151,000	151	535.74	151	501
1948	184,000	184	453.92	193,000	193	539.62	192	504
1949	89,600	90	446.45	82,700	83	528.25	84	495
1950	168,000	168	453.10	172,000	172	537.90	172	503
1951	131,000	131	450.31	128,000	128	533.58	129	499
1952	127,000	127	450.13	124,000	124	533.25	125	499
1953	103,000	103	448.09	98,000	98	530.29	99	496
1954	82,100	82	446.00	78,900	79	527.71	80	494
1955	85,900	86	446.38	85,900	86	528.66	86	495
1956	175,000	175	453.76	186,000	186	539.03	185	504
1957	114,000	114	449.07	107,000	107	531.34	108	497
1958	169,000	169	453.16	170,000	170	537.66	170	503
1959	112,000	112	448.74	113,000	113	532.00	113	498
1960	198,000	198	455.21	184,000	184	540.46	187	505
1961	167,000	167	453.01	163,000	163	537.06	164	502
1962	136,000	136	450.67	128,000	128	533.70	130	499
1963	130,000	130	450.18	131,000	131	533.12	131	499

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By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. B5 of B9
Chkd.By TSA Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

	Stage-Discharge at Danville			Stage-Discharge at Wilkes-Barre			Interpolated Stage-Discharge	
Water Year	**Peak Streamflow (cfs)**	**Peak Streamflow (1000 cfs)**	**Stage Elevation MSL (ft)**	**Peak Streamflow (cfs)**	**Peak Streamflow (1000 cfs)**	**Stage Elevation MSL (ft)**	**Interpolated Peak Streamflow (1000 cfs)**	**Interpolated Stage Elevation MSL (ft)**
1966	98,900	99	447.55	93,500	94	529.11	95	495
1967	87,500	88	446.52	84,800	85	528.02	85	494
1968	104,000	104	448.04	101,000	101	530.05	102	496
1969	81,700	82	445.96	80,500	81	527.43	81	494
1970	122,000	122	449.53	115,000	115	531.78	116	498
1971	111,000	111	448.63	110,000	110	531.14	110	497
1972	363,000	363	463.45	345,000	345	551.77	349	515
1973	99,600	100	447.25	91,800	92	528.90	93	495
1974	103,000	103	447.68	93,400	93	529.10	95	496
1975	257,000	257	458.81	228,000	228	545.92	234	510
1976	120,000	120	449.42	118,000	118	532.20	119	498
1977	122,000	122	449.33	121,000	121	532.48	121	498
1978	116,000	116	449.27	116,000	116	531.94	116	498
1979	188,000	188	455.22	192,000	192	541.88	192	506
1980	104,000	104	447.94	104,000	104	530.36	104	496
1981	105,000	105	448.24	104,000	104	530.43	104	497
1982	83,300	83	445.90	86,400	86	528.10	86	494
1983	149,000	149	451.82	138,000	138	534.72	140	501
1984	194,000	194	455.43	192,000	192	540.62	193	505
1985	55,300	55	443.06	55,800	56	523.90	56	491
1986	173,000	173	453.97	172,000	172	538.22	173	503
1987	104,000	104	448.03	98,500	99	530.08	100	496
1988	83,500	84	446.10	82,200	82	527.74	83	494
1989	116,000	116	448.99	117,000	117	531.98	117	498
1990	70,900	71	444.80	74,900	75	526.61	74	493
1991	124,000	124	449.80	134,000	134	533.55	133	499
1992	89,200	89	446.66	92,000	92	529.32	92	495
1993	187,000	187	455.26	185,000	185	540.73	186	505
1994	139,000	139	451.44	148,000	148	535.02	147	501
1995	73,700	74	445.10	72,100	72	526.62	73	493
1996	209,000	209	457.25	221,000	221	545.31	219	509
1997	130,000	130	450.35	128,000	128	534.43	129	500
1998	143,000	143	451.72	138,000	138	535.65	139	501
1999	116,000	116	449.10	112,000	112	532.45	113	498
2000	132,000	132	450.53	129,000	129	534.52	130	500
2001	97,800	98	447.24	96,800	97	530.35	97	496
2002	84,700	85	446.13	78,900	79	527.88	80	494
2003	130,000	130	450.10	122,000	122	533.70	124	499
2004	220,000	220	457.51	227,000	227	545.82	226	509
2005	202,000	202	455.57	189,000	189	541.74	192	506

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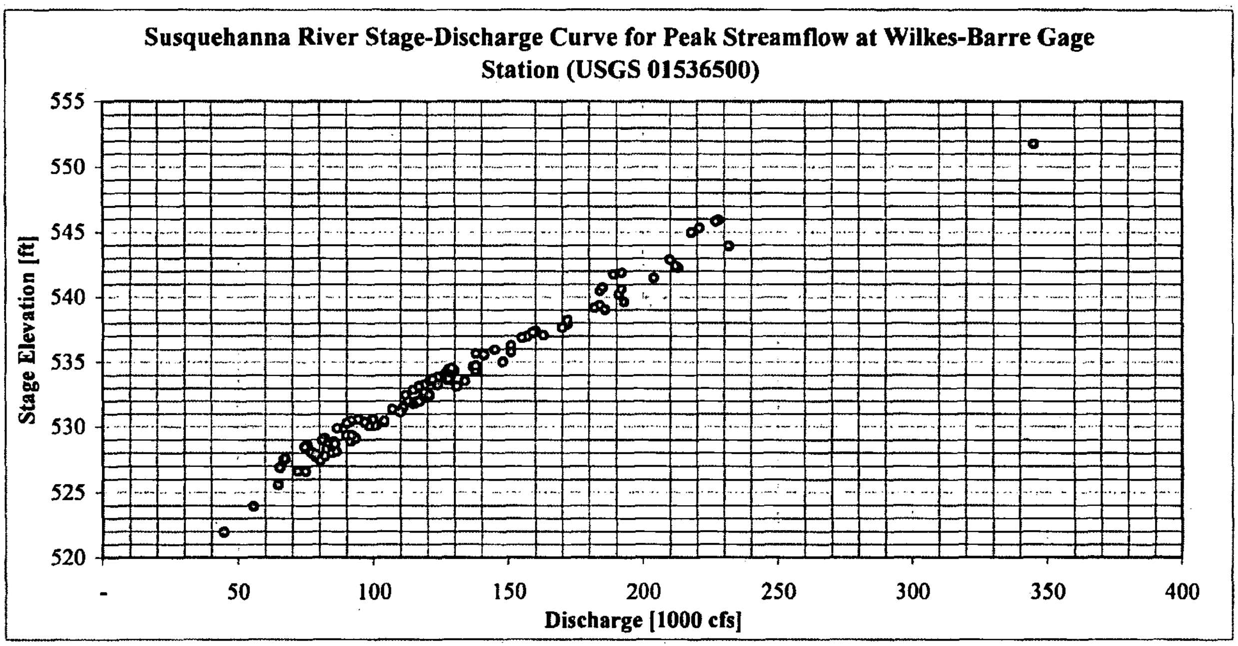
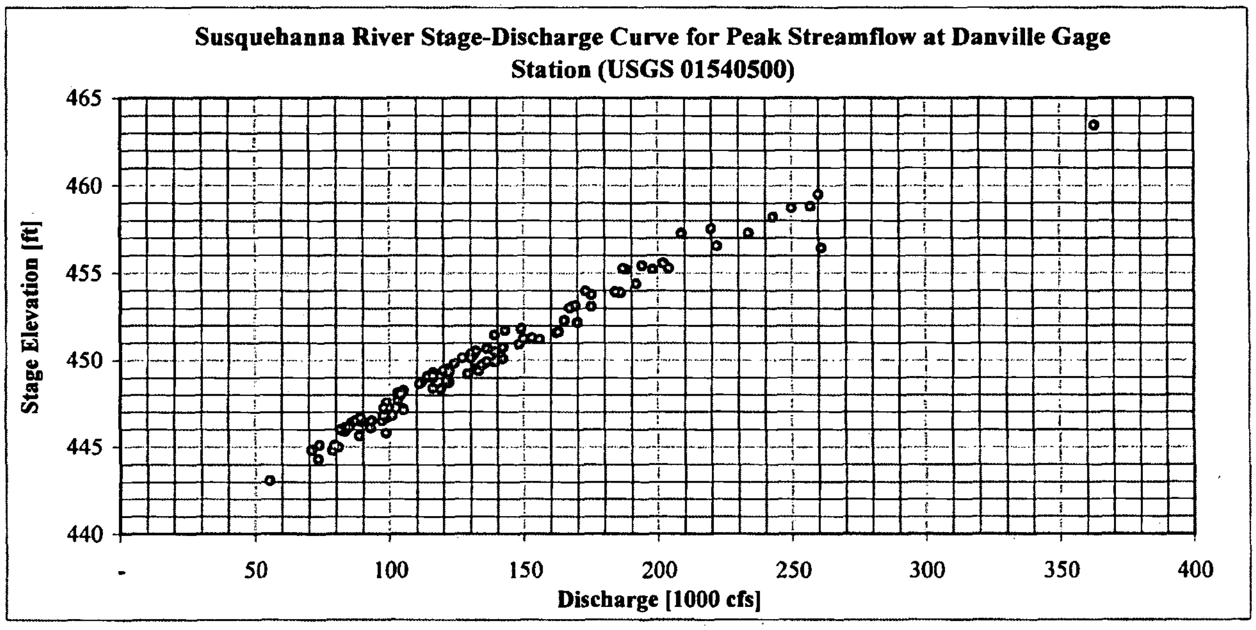
Chkd.By RJM Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

	Stage-Discharge at Danville			Stage-Discharge at Wilkes-Barre			Interpolated Stage-Discharge	
Water Year	Peak Streamflow (cfs)	Peak Streamflow (1000 cfs)	Stage Elevation MSL (ft)	Peak Streamflow (cfs)	Peak Streamflow (1000 cfs)	Stage Elevation MSL (ft)	Interpolated Peak Streamflow (1000 cfs)	Interpolated Stage Elevation MSL (ft)
2006	260,000	260	459.48	218,000	218	545.00	226	510

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. B7 of B9
Chkd.By Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891



Wilkes-Barre Gage Station (USGS 01536500) Drainage Area= 9,960 Square Miles



Danville Gage Station (USGS 01540500) Drainage Area= 11,220 Square Miles

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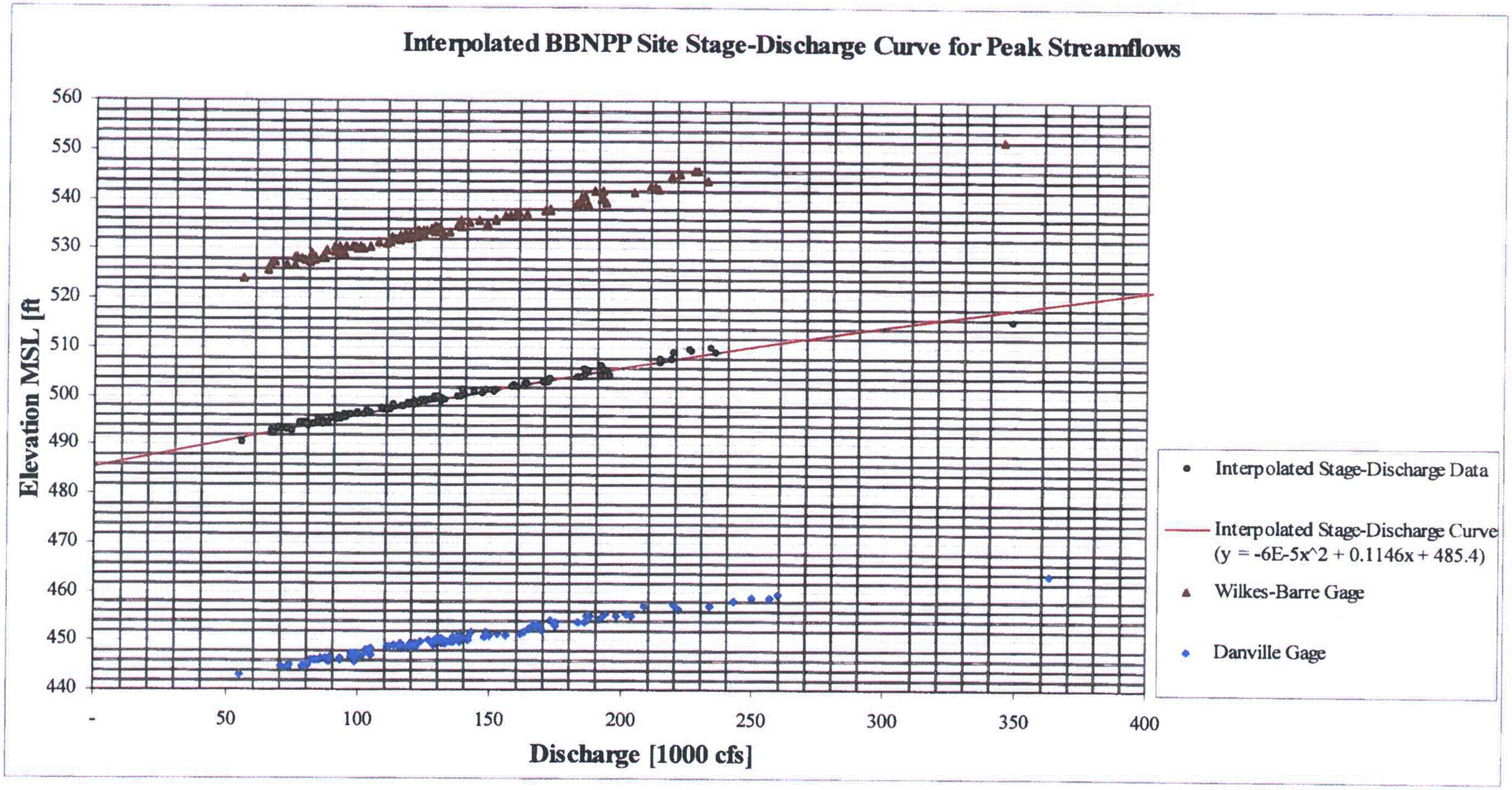
Chkd.By TSM Date 7/17/09 Project No. 07-3891



Interpolated BBNPP Site Stage-Discharge Curve for Peak Streamflows

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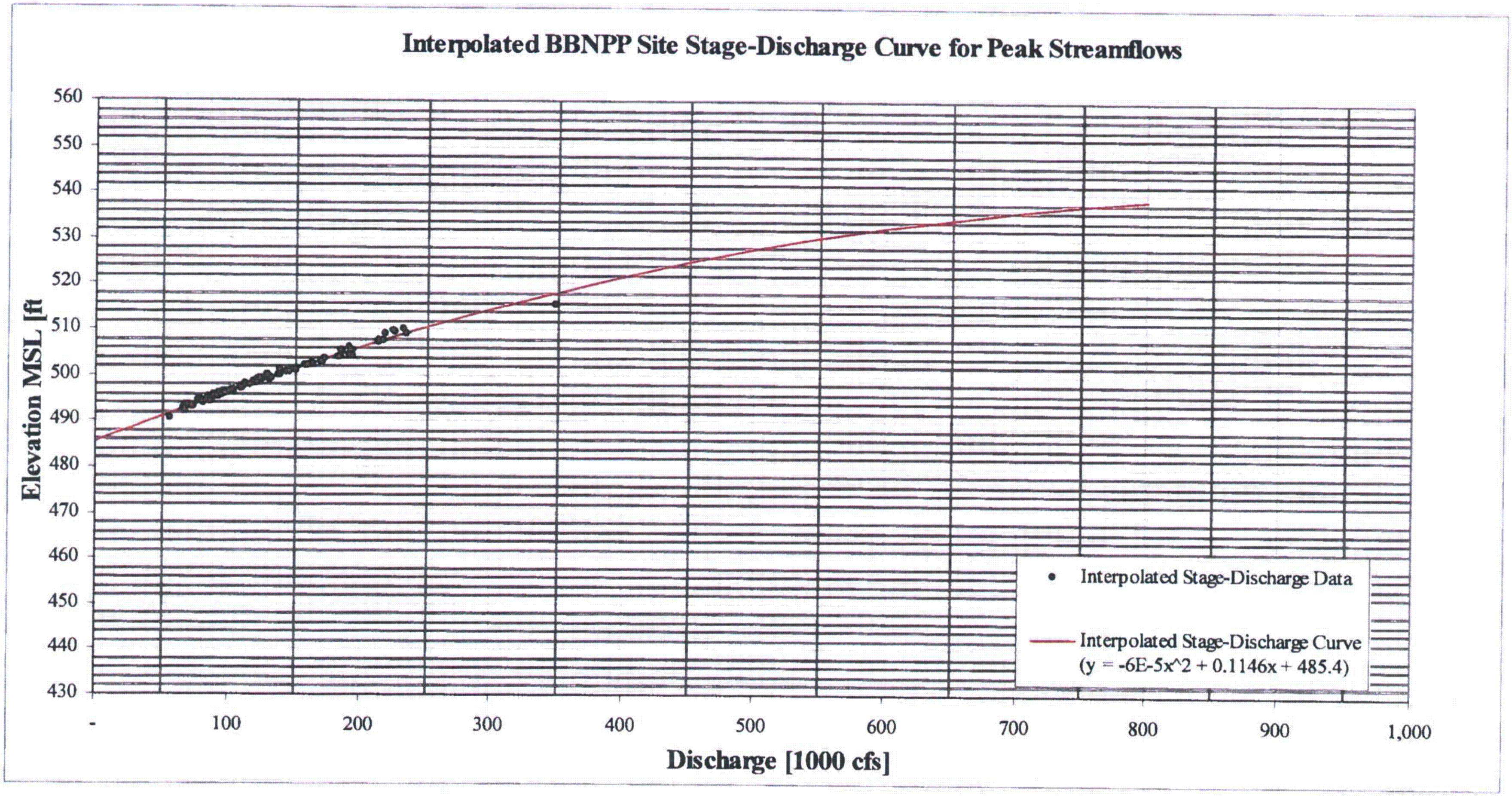
Chkd.By Date 7/17/09 Project No. 07-3891



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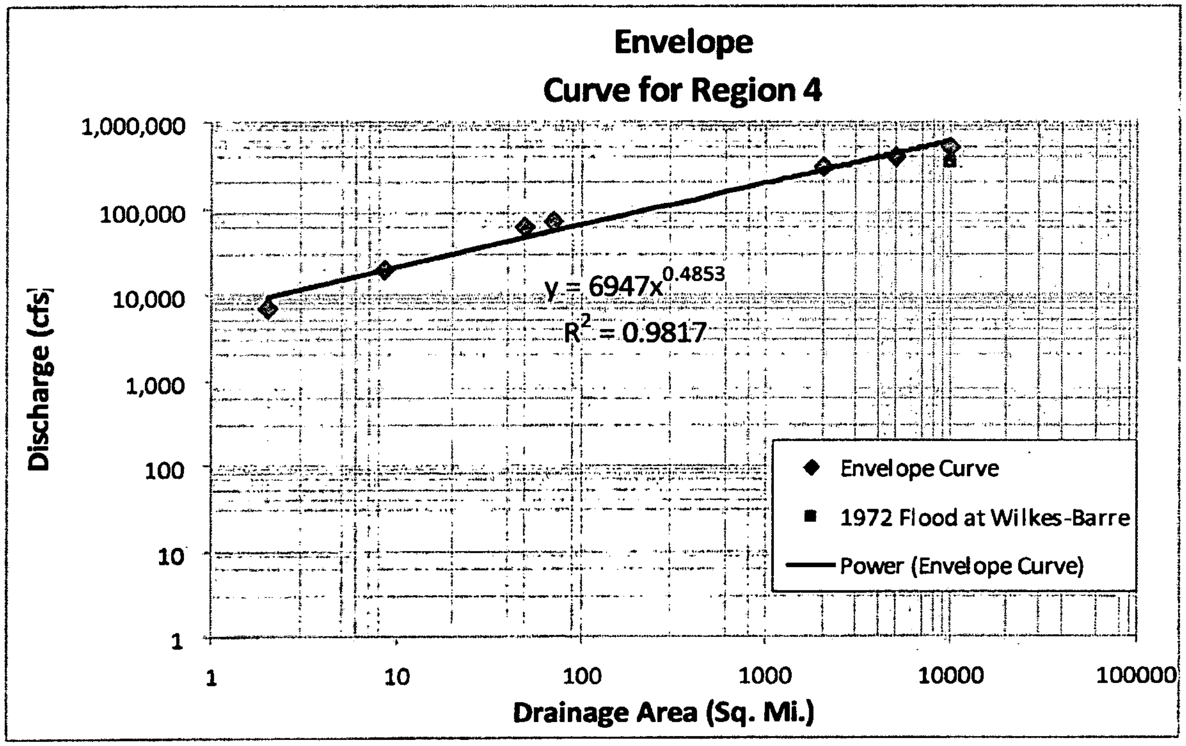
Attachment C

Digitized and Extrapolated Region 4 Envelope Curve

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. C2 of C3
Chkd.By Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891



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By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. C3 of C3
Chkd.By Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

$$y = 6947\,x^{0.4853}$$

y = discharge [cfs]
x = drainage area [square miles]

$\therefore$ when $x = 10,200$:

$$y = 6947\,(10\,200)^{0.4853}$$
$$= 612,591$$

so the maximum "credible" peak discharge is 612,591 cfs

Attachment D

WSE Calculations

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. D2 of D3
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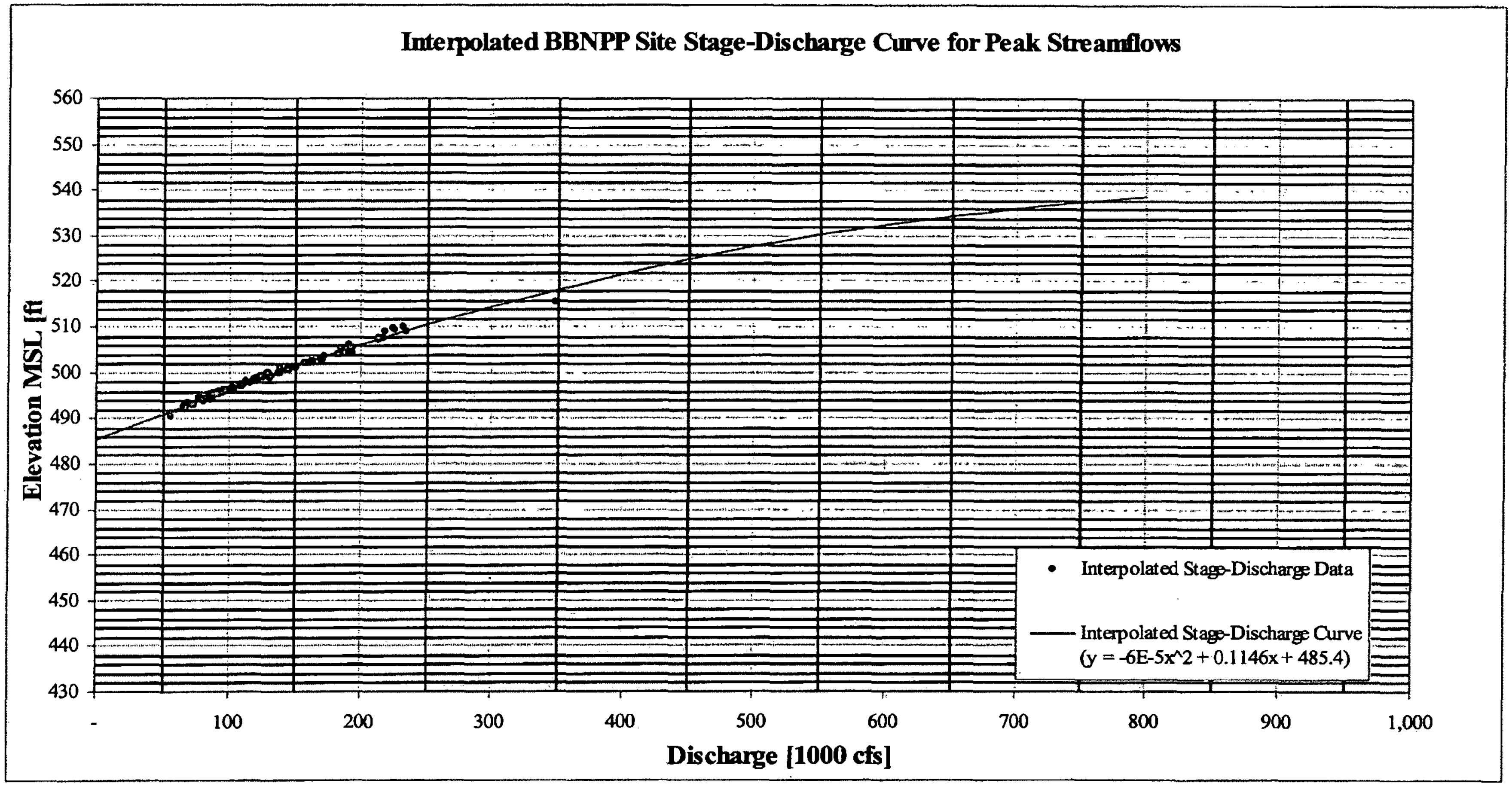

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By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. D3 of D3
Chkd.By Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

$$y = -6E\text{-}5\,x^2 + 0.1146x + 485.4$$

y = elevation [ft]
x = discharge [1000 cfs]

∴ for a maximum "credible" peak discharge of 500,000 cfs (determined using the Region 4 envelope curve for a drainage area of 10,000 square miles; see Reference 4):

$$y = -6E\text{-}5\,(500)^2 + 0.1146(500) + 485.4$$

$$\boxed{y = 527.70 \text{ ft msl}}$$

for a maximum "credible" peak discharge of 612,591 cfs (determined by digitizing and extrapolating the Region 4 envelope curve; see Attachment C):

$$y = -6E\text{-}5\,(612.591)^2 + 0.1146(612.591) + 485.4$$

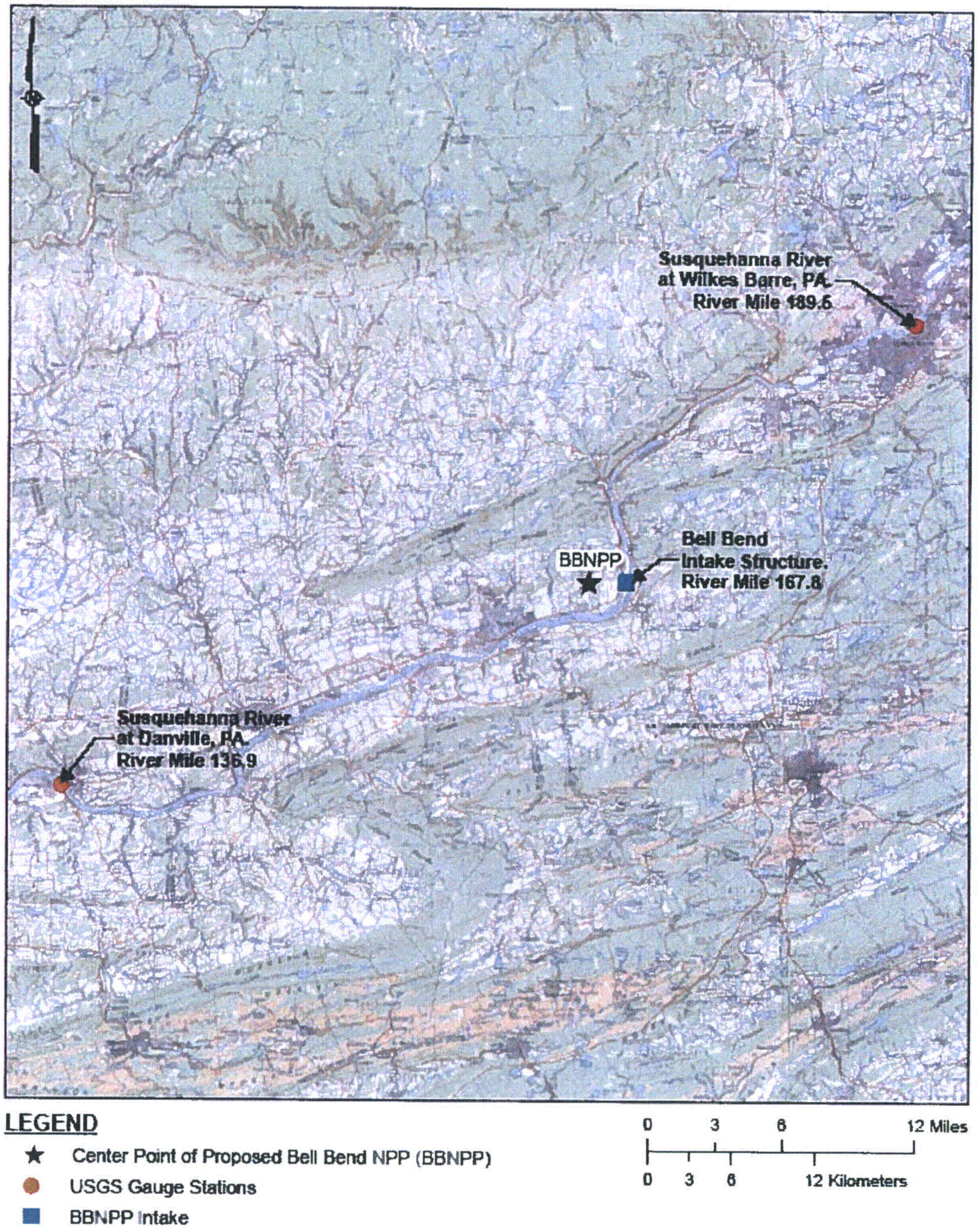
$$\boxed{y = 533.09 \text{ ft msl}}$$

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. E1 of E2
Chkd.By BM Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

Attachment E

Figure Showing the River Mile Locations of the Wilkes-Barre and Danville Gauge Stations and the BBNPP River Intake Structure

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Analysis (Response to RAI 02.04.03-2) Sheet No. E2 of E2
Chkd.By JSM Date 7/17/09 Project No. 07-3891



REFERENCES:
- Sargent & Lundy, 12156-004-CSK-001.
- Susquehanna River FEMA Data.
- USGS 100K Quadrangles: Allentown (1984), Scranton (1986), Sunbury (1984), & Williamsport East (1984).

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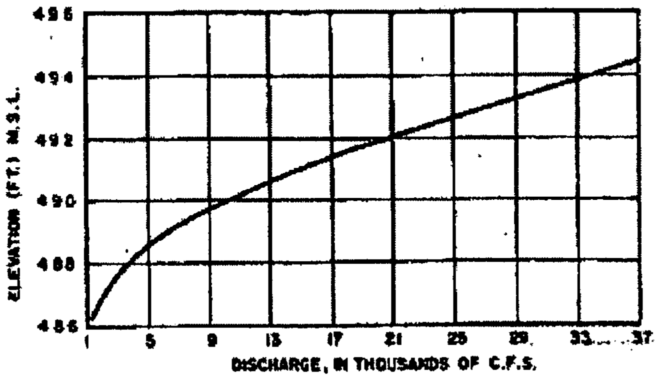
By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. Refl 1 of Refl 2
Chkd.By TSM Date 7/17/09 Analysis (Response to RAI 02.04.03-2) Project No. 07-3891

Reference 1

Impact Point Drainage Area (DA_{ip})



NOTES: ELEVATIONS MEASURED BY GAGE AT SUSQUEHANNA SITE

FLOWS MEASURED AT WILKES-BARRE AND DANVILLE. FLOW AT SITE OBTAINED BY INTERPOLATION ON BASIS OF DRAINAGE AREA.

DRAINAGE AREAS :

WILKES-BARRE 9960 SQ MILES (25795 SQ KM)
SUSQUEHANNA SITE 10200 SQ MI (26416 SQ KM)
DANVILLE 11220 SQ MI (29058 SQ KM)

FSAR REV. 46, 06/93

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 AND 2
FINAL SAFETY ANALYSIS REPORT

STAGE DISCHARGE CURVE,
DISCHARGE RANGE
1000 - 37000 CFS

FSAR FIGURE 2.4-6

PP&L DRAWING

Reference 2

Maximum PMF Water Elevation on the Susquehanna River Near the BBNPP Site

By DW Date 7/17/2009 Subject Simplified Probable Maximum Flood (PMF) Sheet No. Ref2 2 of Ref2 2
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C is the discharge coefficient conservatively assumed to be 0.45 because of the limited submergence conditions encountered

A is the cross-sectional area of the scupper inlet in square feet

g is the gravitational acceleration equal to 32.2 ft/sec/sec

h is the upstream head in feet of water measured to the centerline of the flow through the scupper

Ice accumulation could affect the site drainage by blocking drains and culverts. This effect has been considered in the overall evaluation of the effect of the local PMP described in the section.

2.4.3 PROBABLE MAXIMUM FLOOD (PMF) ON STREAMS AND RIVERS

The conditions producing the PMF are defined by the Corps of Engineers as the "hypothetical flood characteristics (peak discharge, volume, and hydrograph shape) that are considered to be the most severe reasonably possible at a particular location, based on a relatively comprehensive hydrometeorological analysis of critical runoff-producing precipitation (and snowmelt, if pertinent) and hydrologic factors favorable for maximum flood runoff" (Ref. 2.4-25). The PMF for the Susquehanna SES was derived for the only water system, except local runoff that could affect site flooding, the Susquehanna River. A maximum PMF water elevation on the Susquehanna River with coincident wind-generated waves of 548.0 ft msl was calculated in the site vicinity, which is over 120 feet below site grade elevation of 670 ft msl. There are no other adjacent streams that would have an impact on plant flooding.

The guidelines provided in Appendix A of Regulatory Guide 1.59 were followed throughout the analyses. Because the Susquehanna SES is a flood-dry site, conservative assumptions and baseline conditions were adopted to maximize the PMF water elevations.

2.4.3.1 Probable Maximum Precipitation

To determine the PMF for this study, the Probable Maximum Precipitation (PMP) storm location, magnitude and temporal distribution were taken directly from Corps data (Ref. 2.4-26).

The Corps had previously computed the Standard Project Flood (SPF) at Wilkes-Barre (Ref. 2.4-27). Both the storm pattern used on the basin (Ref. 2.4-26) and the magnitude and distribution of precipitation (Ref. 2.4-28) were derived by the Corps. The storm pattern thus obtained was laid over a map of the basin, the sub-basin outlines were drawn on the map and, by inspection, an average value of total rainfall on each sub-basin was estimated from the storm pattern isohyets. This is shown on Figure 2.4-14. The 12 six-hour time segments into which the 72-hour PMP storm was divided (Ref. 2.4-26) were converted into 18 four-hour time segments. This division allowed direct use of the available unit hydrographs previously derived by the Corps of Engineers (Ref. 2.4-29) as discussed in Subsection 2.4.3.3.

Reference 3

USACE "Flood-Runoff Analysis" Engineering Manual (EM 1110-2-1417)

EM 1110-2-1417
31 August 1994

US Army Corps
of Engineers

ENGINEERING AND DESIGN

Flood-Runoff Analysis

ENGINEER MANUAL

Chapter 11
Simplified Techniques

11-1. Introduction

a. Simplified techniques include numerous approaches for determining the approximate magnitude of the peak flow expected for events of varying frequency. These approaches are useful for an approximate answer with a minimum of effort. They are often used in ungauged drainage areas.

b. This chapter describes the role of simplified techniques for flood-runoff analysis. Various methods for estimating the peak flow associated with varying frequencies will be discussed including the rational method, regression techniques, SCS methods, and maximum expected envelop curves.

11-2. Rational Method

a. The so-called rational method is a popular, easy-to-use technique for estimating peak flow in any small drainage basin having mixed land use. It generally should not be used in basins larger than 1 square mile. The peak flow can be calculated by the following equation:

$$Q = CIA \qquad (11\text{-}1)$$

where:

Q = peak flow, in cubic feet per second

C = runoff coefficient

I = rainfall intensity, in inches per hour

A = drainage area, in acres

b. The coefficient is the proportion of rainfall that contributes to runoff. Table 11-1 is an example of the relationship between this coefficient and land use. In basins having a significant nonhomogeneity of land use, an average coefficient can easily be determined by multiplying the percentage of each land use in the basin by its appropriate coefficient from Table 11-1.

c. The rainfall intensity is specifically defined for an event or the frequency of interest and for a duration equal to or greater than the time of concentration of the watershed. Time of concentration (T_c) is defined as the time for runoff to travel from the most distant point of the watershed to the watershed outlet. T_c influences the shape and peak of the runoff hydrograph and is a parameter used in many simplified techniques. Numerous methods exist in the literature for estimating T_c. The SCS has developed a method that takes a physically based approach to calculating T_c, which can be found in Chapter 2 of SCS (1986).

d. Use of the rational method for large drainage areas should be discouraged because of the greater complexity of land use and drainage pattern and the unlikelihood of having uniform rainfall intensity for a duration equal to the time of concentration. The method assumes that the peak flow occurs from uniform rainfall intensity over the entire area once every portion of the basin is contributing to runoff at the outlet.

11-3. Regional Frequency Analysis

a. Regional frequency analysis usually involves regression analysis of gauged watersheds within the general region. Through this very powerful technique, sufficiently reliable equations can often be derived for peak flow of varying frequency given quantifiable physical basin characteristics and rainfall intensity for a specific duration. Once these equations are developed, they can then be applied to ungauged basins within the same region.

b. A regional analysis usually consists of the following steps:

(1) Select components of interest, such as mean and peak discharge.

(2) Select definable basin characteristics of gauged watershed: drainage area, slope, etc.

(3) Derive prediction equations with single- or multiple-linear regression analysis.

(4) Map and explain the residuals (differences between computed and observed values) that constitute "unexplained variances" in the statistical analysis on a regional basis.

c. This procedure for development of the regression equation from gauged basin data is illustrated in Figure 11-1. The equation can then be used in ungauged areas within the same region and for data of similar magnitude to that used in the development process. Much

Table 11-1
Typical C Coefficients (for 5- to 10-year Frequency Design)

DESCRIPTION OF AREA	RUNOFF COEFFICIENT
Business	
Downtown areas	0.70 - 0.95
Neighborhood area	0.50 - 0.70
Residential	
Single-family areas	0.30 - 0.50
Multiunits, detached	0.40 - 0.60
Multiunits, attached	0.60 - 0.75
Residential (suburban)	0.25 - 0.40
Apartment dwelling areas	0.50 - 0.70
Industrial	
Light areas	0.50 - 0.80
Heavy areas	0.60 - 0.90
Parks, cemeteries	0.10 - 0.25
Playgrounds	0.20 - 0.35
Railroad yard areas	0.20 - 0.40
Unimproved areas	0.10 - 0.30
Streets	
Asphaltic	0.70 - 0.95
Concrete	0.80 - 0.95
Brick	0.70 - 0.85
Drives and walks	0.75 - 0.85
Roofs	0.75 - 0.95
Lawns, Sandy soil	
Flat, 2%	0.05 - 0.10
Average, 2-7%	0.10 - 0.15
Steep, 7%	0.15 - 0.20
Lawns, Heavy soil	
Flat, 2%	0.13 - 0.17
Average, 2-7%	0.18 - 0.22
Steep, 7%	0.25 - 0.35

(from Viessman et al. 1977)

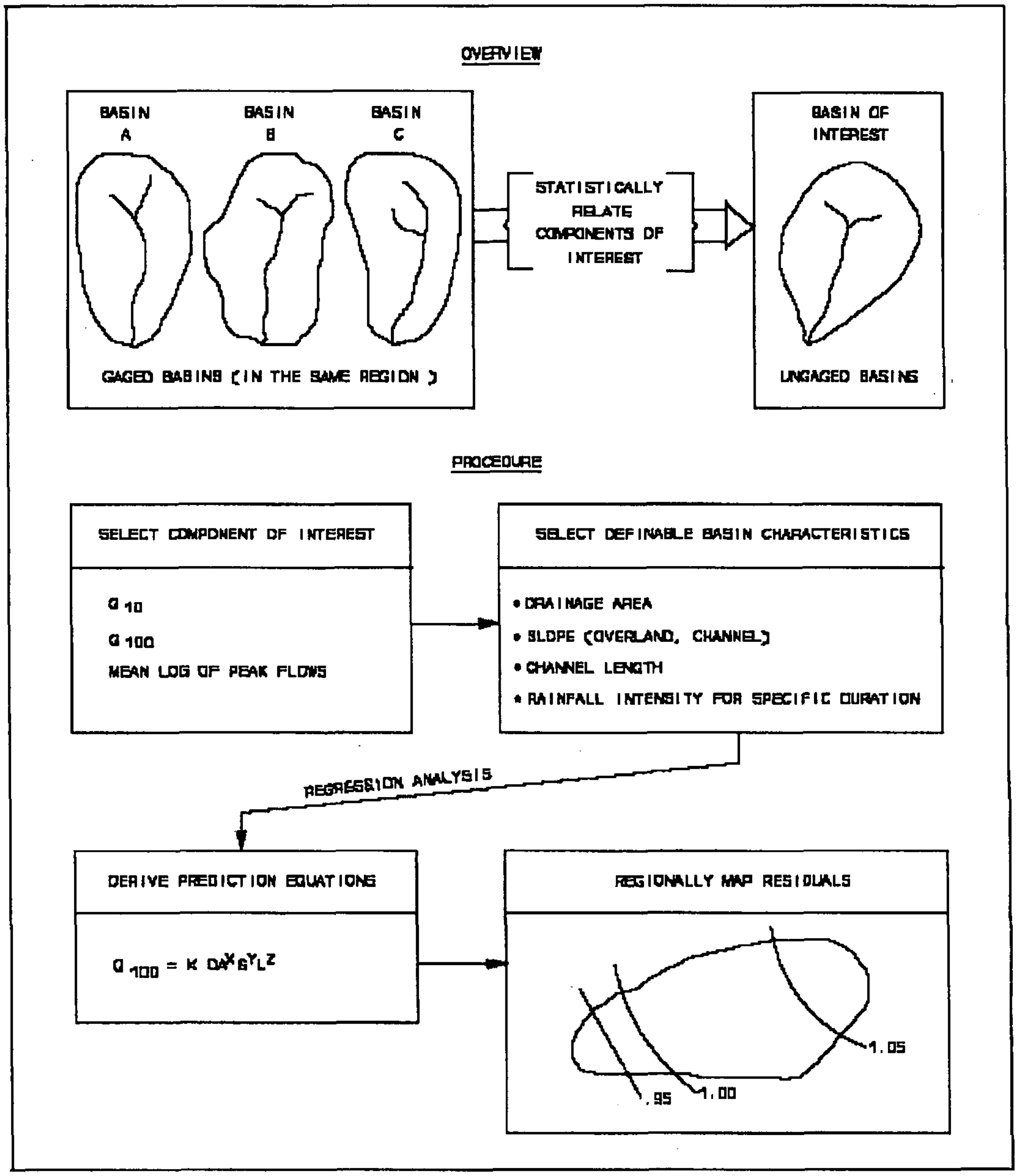


Figure 11-1. Regional analysis

more detail on regression and regional frequency analysis is available in EM 1110-2-1415, Hydrologic Frequency Analysis.

d. Regional equations have already been developed by the U.S. Geological Survey (USGS) and published for the various areas of the United States. An example of this type of equation is the following:

$$Q_{100} = 19.7\, A^{0.88}\, P^{0.84}\, H^{-0.33} \qquad (11\text{-}2)$$

where

Q_{100} = the 1 percent chance flood peak, in cubic feet per second

A = drainage area, in square miles

P = mean annual precipitation, in inches

H = average main channel elevation at 10 and 85 percent points along the main channel length, in 1,000 ft

e. Table 11-2 illustrates various examples of regional equations for the entire state of California. These equations make no assumptions regarding statistical distribution or skew. Both characteristics are inherent in the data used to develop the regression equations. These predeveloped USGS regional equations may or may not be as good as ones developed specifically for the region of interest; but they are already available, and development of regional equations is an expensive approach.

f. In contrast to the USGS regional equations shown above, the USACE usually develops regional frequency equations as documented in EM 1110-2-1415. The USACE type equations are of the following form:

$$Q = \bar{X} + kS \qquad (11\text{-}3)$$

$$\bar{X} = aA^{b}L^{c}(1+I)^{d} \qquad (11\text{-}4)$$

$$S = eA^{f}G^{g}L^{h} \qquad (11\text{-}5)$$

where

Q = flood peak for varying frequency, in cubic feet per second

$\bar{X}$ = mean of the logarithms of annual series peak flood events, in cubic feet per second

k = log Pearson type II deviates

S = standard deviation of the logarithms annual series peak flood events, in cubic feet per second

$A,L,I\&G$ = various (some are logarithmic) quantifiable physical basin characteristics

$a\&e$ = represent regression constants

$b,c,d,f,g\&h$ = represent regression coefficients

g. The USACE methods assume a log Pearson type III distribution for "k" values and a weighted skew coefficient for peak flood events. The equation provides a peak flow for various frequency levels associated with the value of "k." Values of "k" are found in various USACE literature such as the EM 1110-2-1415.

h. Other governmental agencies (i.e., city and county) have developed regional frequency equations, but they may be difficult to locate.

i. Regardless of the source of the equations, the user must identify the standard error of estimate (SE) associated with the equation. The SE of estimate defines the possible range of error in the value of flow predicted by the regression equation. Assuming the error is log normally distributed, there is a 68 percent chance that the "true value" of flow is within ± 1 SE and a 95 percent chance that it is within ± 2 SE.

j. For the example of the USGS equation for Q_{100} (the Central Coast region of California), the standard error is 0.41 log units. The true value of Q_{100} is within ± antilog of (0.41 + log Q_{100}). It can then be stated with 68 percent confidence that for the example above where the equation predicted the Q_{100} to be 1,000 cfs, the true value is between 2,570 and 389 cfs. Since the calculated flows (Q_{100}) for this data set vary from 159 cfs to 30,682 cfs, the example of Q_{100} at 1,000 cfs is not an unlikely case. This large range in confidence limits is not unusual for a regression approach. Often this approach is the best available technique to estimate the flow frequency at ungauged locations.

k. Again, it bears repeating that when using regression equations from any source, make sure the equations were developed within the region of interest, the basin characteristics for the watershed of interest are within the range of those used to derive the equations, and the

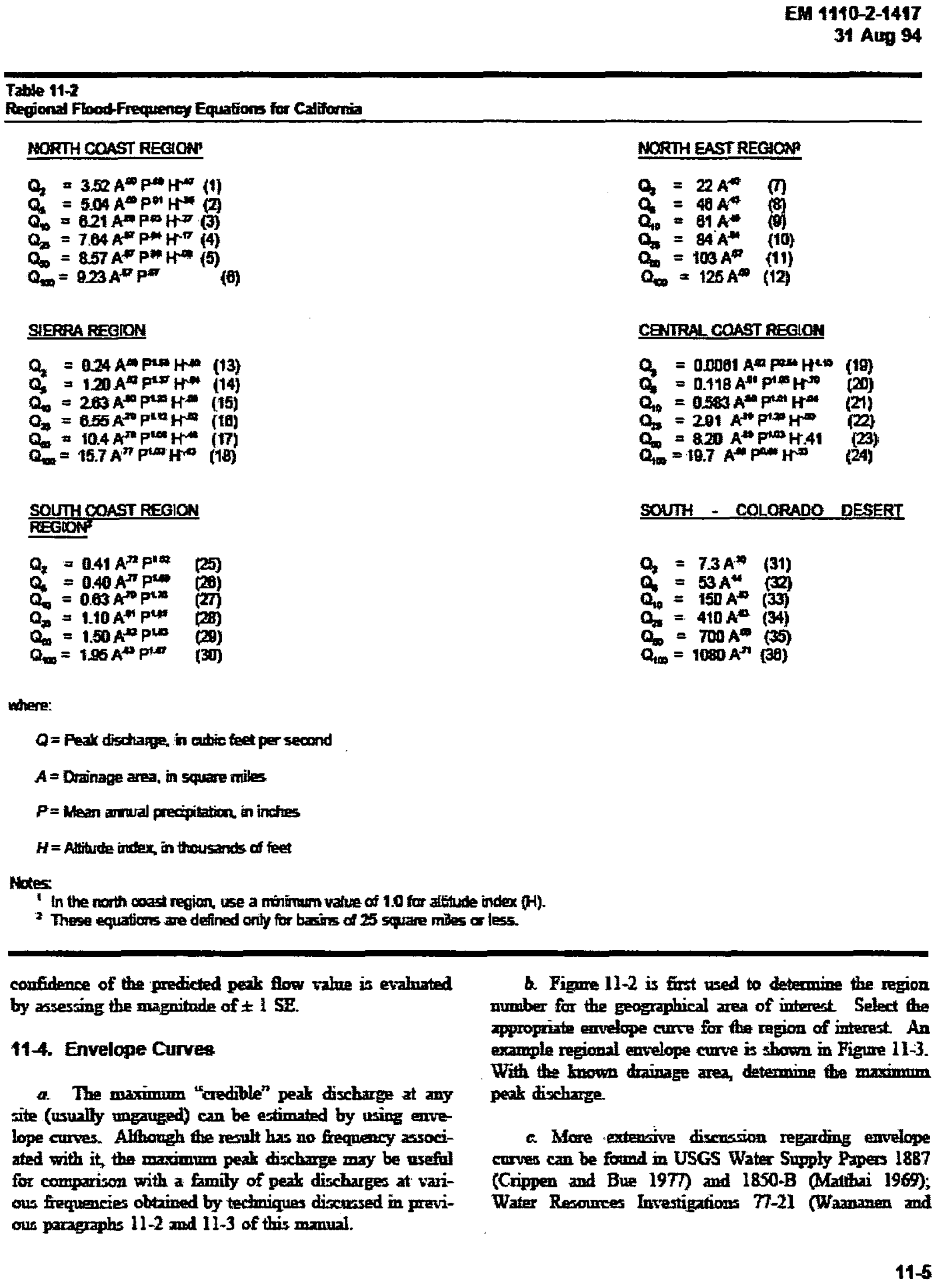


Table 11-2
Regional Flood-Frequency Equations for California

NORTH COAST REGION[1]

$Q_2 = 3.52\ A^{.90} P^{.89} H^{-.47}$ (1)
$Q_5 = 5.04\ A^{.89} P^{.91} H^{-.35}$ (2)
$Q_{10} = 6.21\ A^{.88} P^{.93} H^{-.27}$ (3)
$Q_{25} = 7.64\ A^{.87} P^{.94} H^{-.17}$ (4)
$Q_{50} = 8.57\ A^{.87} P^{.96} H^{-.08}$ (5)
$Q_{100} = 9.23\ A^{.87} P^{.97}$ (6)

NORTH EAST REGION[2]

$Q_2 = 22\ A^{.40}$ (7)
$Q_5 = 46\ A^{.45}$ (8)
$Q_{10} = 61\ A^{.49}$ (9)
$Q_{25} = 84\ A^{.54}$ (10)
$Q_{50} = 103\ A^{.57}$ (11)
$Q_{100} = 125\ A^{.59}$ (12)

SIERRA REGION

$Q_2 = 0.24\ A^{.88} P^{1.58} H^{-.80}$ (13)
$Q_5 = 1.20\ A^{.82} P^{1.37} H^{-.64}$ (14)
$Q_{10} = 2.63\ A^{.80} P^{1.25} H^{-.58}$ (15)
$Q_{25} = 6.55\ A^{.79} P^{1.12} H^{-.52}$ (16)
$Q_{50} = 10.4\ A^{.78} P^{1.06} H^{-.48}$ (17)
$Q_{100} = 15.7\ A^{.77} P^{1.02} H^{-.43}$ (18)

CENTRAL COAST REGION

$Q_2 = 0.0061\ A^{.92} P^{2.54} H^{-1.10}$ (19)
$Q_5 = 0.118\ A^{.91} P^{1.95} H^{-.79}$ (20)
$Q_{10} = 0.583\ A^{.90} P^{1.61} H^{-.64}$ (21)
$Q_{25} = 2.91\ A^{.89} P^{1.26} H^{-.50}$ (22)
$Q_{50} = 8.20\ A^{.89} P^{1.03} H .41$ (23)
$Q_{100} = 19.7\ A^{.88} P^{0.84} H^{-.33}$ (24)

SOUTH COAST REGION
REGION[2]

$Q_2 = 0.41\ A^{.72} P^{1.62}$ (25)
$Q_5 = 0.40\ A^{.77} P^{1.69}$ (26)
$Q_{10} = 0.63\ A^{.79} P^{1.75}$ (27)
$Q_{25} = 1.10\ A^{.81} P^{1.81}$ (28)
$Q_{50} = 1.50\ A^{.82} P^{1.85}$ (29)
$Q_{100} = 1.95\ A^{.83} P^{1.87}$ (30)

SOUTH - COLORADO DESERT

$Q_2 = 7.3\ A^{.30}$ (31)
$Q_5 = 53\ A^{.44}$ (32)
$Q_{10} = 150\ A^{.53}$ (33)
$Q_{25} = 410\ A^{.63}$ (34)
$Q_{50} = 700\ A^{.68}$ (35)
$Q_{100} = 1080\ A^{.71}$ (36)

where:

Q = Peak discharge, in cubic feet per second

A = Drainage area, in square miles

P = Mean annual precipitation, in inches

H = Altitude index, in thousands of feet

Notes:
[1] In the north coast region, use a minimum value of 1.0 for altitude index (H).
[2] These equations are defined only for basins of 25 square miles or less.

confidence of the predicted peak flow value is evaluated by assessing the magnitude of ± 1 SE.

11-4. Envelope Curves

a. The maximum "credible" peak discharge at any site (usually ungauged) can be estimated by using envelope curves. Although the result has no frequency associated with it, the maximum peak discharge may be useful for comparison with a family of peak discharges at various frequencies obtained by techniques discussed in previous paragraphs 11-2 and 11-3 of this manual.

b. Figure 11-2 is first used to determine the region number for the geographical area of interest. Select the appropriate envelope curve for the region of interest. An example regional envelope curve is shown in Figure 11-3. With the known drainage area, determine the maximum peak discharge.

c. More extensive discussion regarding envelope curves can be found in USGS Water Supply Papers 1887 (Crippen and Bue 1977) and 1850-B (Matthai 1969); Water Resources Investigations 77-21 (Waananen and

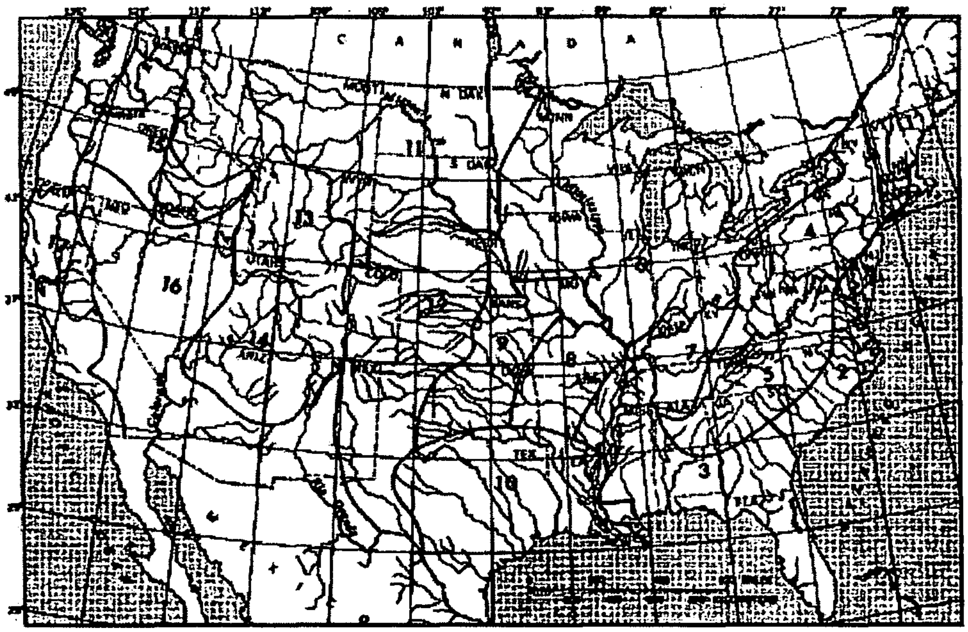


Figure 11-2. Map of the conterminous United States showing flood-region boundaries

Crippen 1977); and the American Society of Civil Engineers, *Hydraulic Journal* (Crippen 1982).

11-5. Rainfall Data Sources

This section lists the most current 24-hour rainfall data published by the National Weather Service (NWS) for various parts of the country. For the area generally west of the 105th meridian, TP-40 has been superseded by the (NOAA) Atlas 2, "Precipitation-Frequency Atlas of the Western United States," published by the NOAA.

a. East of 105th Meridian (Hershfield 1961). "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," U.S. Department of Commerce, Weather Bureau, Technical Paper No. 40, Washington, DC. For durations of 1 hour and less, TP40 has been superseded by Hydrometeorological Report No. 35, U.S. Department of Commerce, National Weather Service, Silver Springs, MD.

b. West of 105th Meridian (Miller, Frederick, and Tracey 1973). "Precipitation-Frequency Atlas of the Western United States, Volume I, Montana; Volume II, Wyoming; Volume III, Colorado; Volume IV, New Mexico; Volume V, Idaho; Volume VI, Utah; Volume VII, Nevada; Volume VIII, Arizona; Volume IX, Washington; Volume X, Oregon; Volume XI, California," U.S. Department of Commerce, National Weather Service, NOAA Atlas 2, Silver Springs, MD.

c. Alaska (Miller 1963). "Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska for Areas to 400 Square Miles, Durations to 24 Hours and Return Periods From 1 to 100 Years," U.S. Department of Commerce, Weather Bureau, Technical Paper No. 47, Washington, DC.

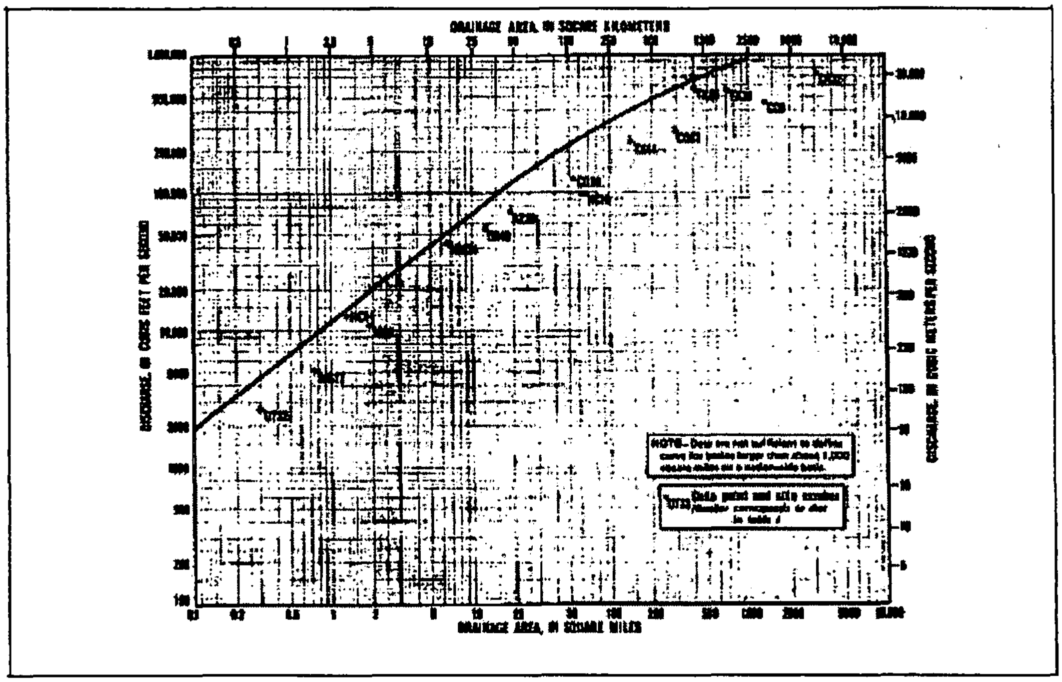


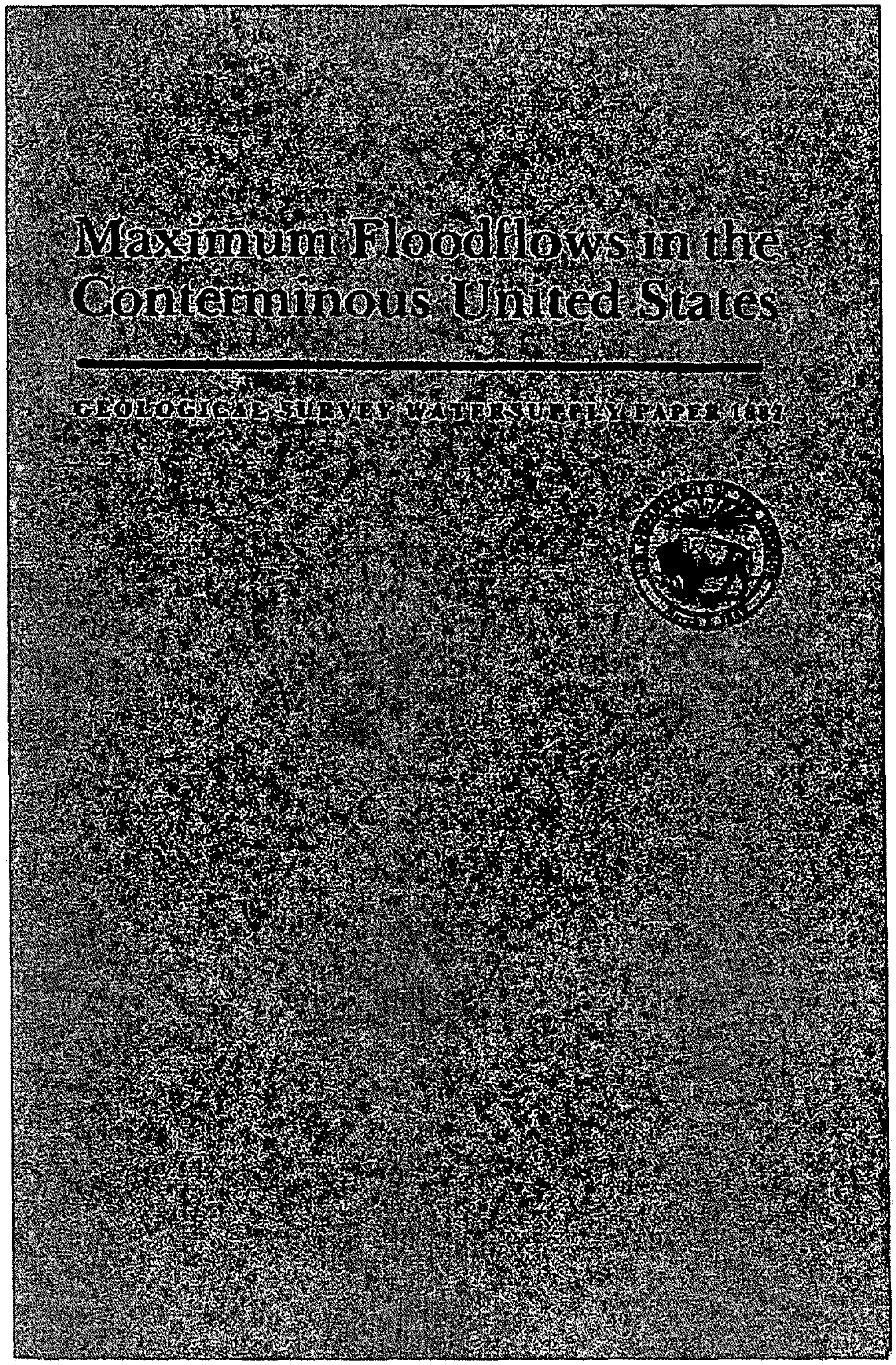
Figure 11-3. Peak discharge versus drainage area, and envelope curve for Region 1

d. Hawaii (U.S. Department of Commerce 1962). "Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Duration to 24 Hours and Return Periods From 1 to 100 Years," U.S. Department of Commerce, Weather Bureau, Technical Paper No. 43, Washington, DC.

e. Puerto Rico and Virgin Islands (U.S. Department of Commerce 1961). "Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and Virgin Islands for Areas to 400 Square Miles, Durations to 24 Hours, and Return Periods From 1 to 100 years," U.S. Department of Commerce, Weather Bureau, Technical Paper No. 42, Washington, DC.

Reference 4

USGS Water-Supply Paper 1887



Maximum Floodflows in the Conterminous United States

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1887

MAXIMUM FLOODFLOWS IN THE CONTERMINOUS UNITED STATES

By J. R. CRIPPEN and CONRAD D. BUE

ABSTRACT

Peak floodflows from thousands of observation sites within the conterminous United States were studied to provide a guide for estimating potential maximum floodflows. Data were selected from 883 sites with drainage areas of less than 10,000 square miles (25,900 square kilometers) and were grouped into regional sets. Outstanding floods for each region were plotted on graphs, and envelope curves were computed that offer reasonable limits for estimates of maximum floods. The curves indicate that floods may occur that are two to three times greater than those known for most streams.

INTRODUCTION

Throughout history the borderlands of streams and lakes have been the pivotal regions about which human activities have centered. From earliest times our sustenance, work, and transport have required that we be close to the watercourse, the lake, or the sea.

Most of the time the river serves us well, but occasionally its flow becomes unmanageable and can suddenly become a threat. Today floods pose a greater menace to our welfare than ever before because we live in larger numbers beside water and have developed such a complex reliance upon it. We must therefore know as much as possible about the size of floods, especially major ones.

In this report the meaning of flood is limited to the quantity of flow (discharge) rather than stage (the height to which the water rises). Generally, at times of great floods, maximum discharge occurs when stage is highest; however, other factors such as ice jams may change this.

An extreme flood is usually caused by heavy rainfall at a time when conditions allow the highest possible rates of runoff. The size of the largest probable flood cannot be defined; however, a range of conditions may be established in which high floods may occur, based on past floods of streams having similar flood potential. In other words, what has happened in the past furnishes the best estimate of what may happen in the future.

Maximum floodflows from small basins are generally caused by intense, often short, storms over a small area. Maximum floodflows from large basins, on the other hand, are generally caused by storms of several days' duration over large areas. Whatever the amount of rainfall that has caused the highest known flow of a stream, someday a greater rainfall may cause an even greater flow.

Although an unusual flood is generally associated with the particular set of meteorological circumstances that caused it, sometimes situations arise in which extreme floods occur without extreme storms. Careful study often reveals a simple explanation for them, however. For example, the sudden release of ponded water by the breakup of an ice jam or the failure of a dam may cause a rise in flow out of proportion to the current rainfall. Because of their unique nature, such floods are unlikely to be repeated. Data known to relate to such unusual conditions have not been included in this study.

MAXIMUM-FLOOD EXPERIENCE

This study is limited to the consideration of extreme floods without reference to their frequency. It is intended to serve as a guide for making rule-of-thumb estimates of the magnitude of high flood discharges that may be expected at a given site on a stream. No complex analytical procedures are given. The study presents a compilation of selected maximum observed flood peaks, and it shows by maps and graphs how such floods vary with geographical location and with size of drainage basin. As mentioned earlier, the study is concerned with floods as expressed in terms of discharge. Random conditions of time and location that are involved in determining the height to which streams may rise, as distinct from their discharge, are too complex for analysis in this study.

The floods discussed here have been observed through September 1974 at sites having drainage areas of less than 10,000 mi^2 (25,900 km^2). This study does not consider floods from larger basins because they are likely to be affected by many more complex factors than floods in smaller basins.

Data used in this report consist of peak discharges known to have occurred at 883 observation sites throughout the conterminous United States. Table 1 summarizes pertinent information on each site's peak flow and the basin from which it came. Most of the entries are data from conventional stream-gaging stations that have been operated for varying lengths of time. Some entries, however, are from crest-stage stations where only data of high flood peaks have been obtained, usually for fewer than 10 years. A few entries show data from sites where only the single peak flow that is listed is known, or perhaps one or two more peaks. These floods may be of special interest because they were high enough to attract attention and be measured even though they did not occur at a regular data-collection site.

The station numbers shown in table 1 have been assigned to identify the sites according to a standard U.S. Geological Survey system. Flood information from a site to which no station number has been assigned is listed as being from a miscellaneous site. The site numbers that are shown in the first column of table 1 are used only for identification in this report.

The daily discharge shown in table 1 is the mean discharge for the day in which the peak flood discharge occurred, or for the day before or after if that day had a higher discharge. Comparison of the peak discharge and the daily discharge with which it is associated may be an indication of the flashiness of the stream. Peak flows from large basins are generally more sustained than peak flows from small basins.

Peak flows from basins smaller than about 0.2 mi^2 (0.5 km^2) are not listed because in basins of this size the flow pattern can be easily dominated by unique conditions that are not likely to occur or be recognized if they do occur in larger basins. Another drawback to using extremely small basins is that an error in defining the area (in terms of percentage of the stated area) can be very large.

Since the date of the peak flows noted here, reservoirs and other facilities have been constructed on some of the streams. These changes make it unlikely that peak flows as large as those observed under natural conditions will recur. At a few of the sites listed in table 1 there have been peak flows resulting from once-only events, such as the failure of a dam, that were greater than the listed peak. Peaks of that kind have been omitted.

After the summary was compiled, an attempt was made to group the data from table 1 by regions using physiographic type (Fenneman, 1931, 1938) and variations in rainfall intensity (U.S. Weather Bureau, 1961) as the initial bases for subdivision. The experience of hydrologists who had worked with flood data throughout the Nation was then sought as a guide to make further breakdowns, thus combining the data as regional sets.

Some of these regional sets demonstrated that further separations were required. The boundaries in figure 1, therefore, represent a compromise among the several sources of information. Clear-cut hydrologic differences, where they exist, provided primary criteria for separation, followed by experience and judgment. Finally, arbitrary decisions were made, considering convenience to the user.

Floods that are outstanding in terms of discharge per unit of area are shown in figures 2 through 19. Data from extreme floods throughout the Nation have been abstracted from table 1 and are plotted in figure 2. The sizes of the basins represented in figure 2 range from 0.3 mi² (0.78 km²) to 7,088 mi² (18,358 km²). The envelope curves show the limits of the greatest floods known to have occurred in the Nation (fig. 2) or in the region in question (figs. 3-19). The curves do not indicate any physical limitations, but floods that exceed them will probably be extremely rare.

ESTIMATING POTENTIAL FLOOD PEAKS

The data, maps, and graphs in this report are intended to guide the user in making reasonable estimates of the maximum potential floodflows in the region of his interest. Depending upon the user's needs, htere are various ways of making estimates. One way is simply to inspect table 1 and compare with the site of interest. Another is to base the estimate upon the area of the basin in question and upon the curve shown on the appropriate graph of regional floods.

As time passes, floods may occur that lie outside the curves used in this report. If more extreme floods occur, they should be plotted on the appropriate regional graph, and, if necessary, a new curve should be drawn to supersede the old one.

Inspection of the graphs for the various regions (figs. 3-19) shows that the envelope curves indicate the possibility of discharges two or three times as great as the largest that have been experienced in most streams in the regions. Thus, on most streams floods may occur that are considerably greater than those known.

SUMMARY

Flood-discharge records ranging from a few years to many years in length are available for many basins. Among these records are a few floods that are unusually high for the particular climate, topography, and geology involved. By inspecting the records of 883 of the most extreme floods listed in table 1 and illustrated in figures 2-19, a reasonable estimate of extreme-flood potential can be made. No probability or frequency can be given to the floods that are estimated by using the techniques of this study.

SELECTED REFERENCES

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., Inc., 534 p.

——1938, Physiography of eastern United States: New York, McGraw-Hill Book Co., Inc., 714 p.

Hoyt, W. G., and Langbein, W. B., 1955, Floods: Princeton, N.J., Princeton Univ. Press, 469 p.

U.S. Weather Bureau, 1961, Rainfall frequency atlas of the United States: Tech. Paper 40, 115 p.

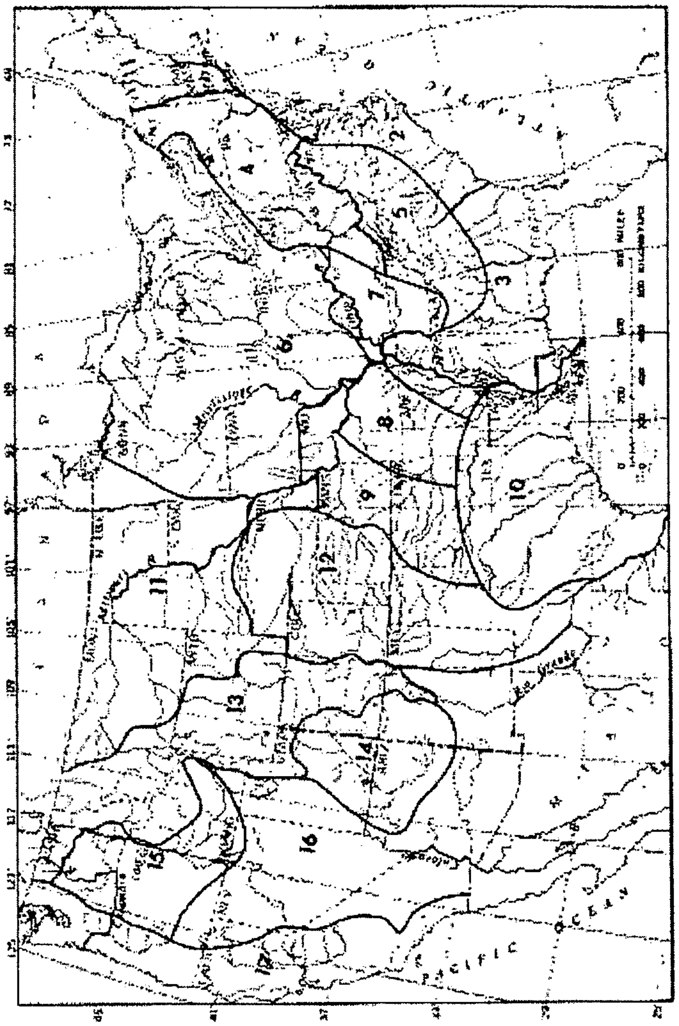


FIGURE 1.—Map of the conterminous United States showing flood-region boundaries.

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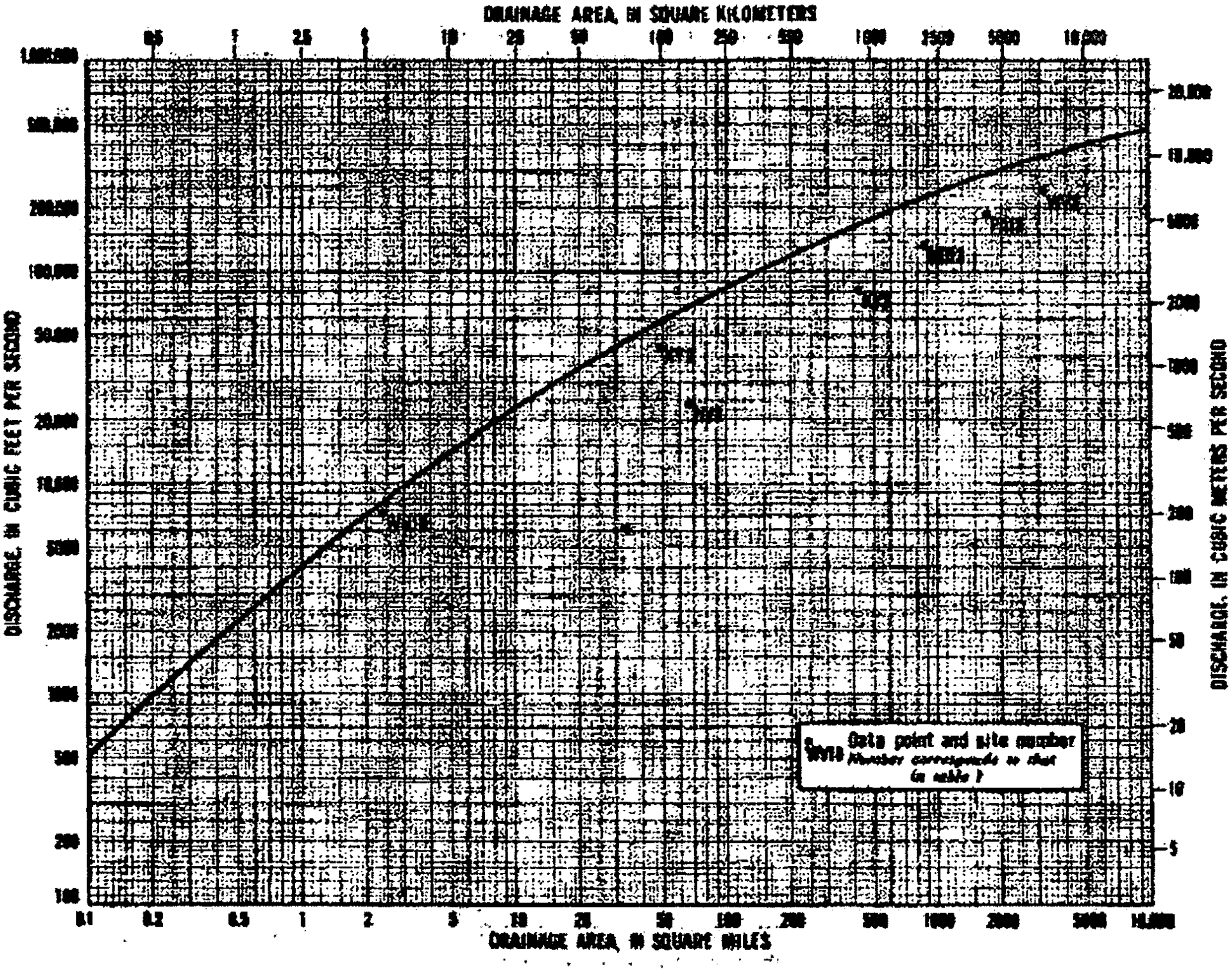

FIGURE 6.—Peak discharge versus drainage area, and envelope curve for region 4.

TABLE 1.—*Extreme floods at selected sites*—Continued

Site number	Station number and site name	Drainage area (mi²)	Length of flood record	Flood peak data				Region
				Date	Discharge (ft³/s)			
					Peak	Unit	Daily	
	OREGON--CONTINUED							
OR30	14321000 UMPQUA R NR ELKTON	3683	A	12-23-64	265000	72	260000	17
OR31	14322000 ELK CR NR DRAIN	104	C	2-10-61	15000	144	11200	17
OR32	14323100 SMITH R NR GARDINER	206	C	2-10-61	[1]42000	204		17
OR33	14325000 SF COQUILLE R AT POWERS	169	B	12-22-64	48900	289	34900	17
OR34	14361500 ROGUE R AT GRANTS PASS	2459	B	12-23-64	[1]152000	62	124000	17
OR35	14366000 APPLEGATE R NR APPLEGATE	483	B	12-22-64	45700	95	30600	17
OR36	14371500 GRAVE CR AT PEASE BRIDGE, NR PLACER	22.1	B	12-22-64	6240	282	4020	17
OR37	14375500 WF ILLINOIS R NR O'BRIEN	42.4	B	12-22-64	16100	380	13200	17
OR38	14378000 ILLINOIS R NR SELMA	665	C	12-22-64	160000	241	125000	17
OR39	MISC. 1 BUTTER CR TRIB NR ECHO	1.4	D	6- 9-48	5220	3730		15
OR40	MISC. 2 MEYERS CANYON NR MITCHELL	12.7	D	7-13-56	54500	4290		15
OR41	MISC. 3 LANE CANYON NR ECHO	5.04	D	7-26-65	28500	5650		15
	PENNSYLVANIA							
PA 1	01431500 LACKAWAXEN R AT HAWLEY	290	B	8-19-55	51900	179	26800	4
PA 2	01442500 BRODHEAD CR AT MINISINK HILLS	259	C	8-19-55	68800	266	30500	4
PA 3	01472174 PICKERING CR NR CHESTER SPRINGS	5.98	C	6-22-72	2410	403	450	4
PA 4	01447500 LEHIGH R AT STODDARTSVILLE	91.7	B	8-19-55	31900	348	18900	4
PA 5	01481000 BRANDYWINE CR AT CHADDS FORD	287	A	6-22-72	23800	83	9260	4
PA 6	01536500 SUSQUEHANNA R AT WILKES-BARRE	9960	A	6-24-72	345000	35	329000	4
PA 7	01544000 FIRST F SINNEMAHONING CR	245	B	7-18-42	80000	327		4
PA 8	01545500 WBR SUSQUEHANNA R AT RENOVO	2975	A	3-18-36	236000	79	201000	4
PA 9	01567000 JUNIATA R AT NEWPORT	3354	A	6- 1-89	209000	62		4
PA10	01567500 BIXLER RUN NR LOYSVILLE	15.0	C	11- 1-56	8780	585	799	4

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TABLE 1

PENNSYLVANIA--CONTINUED

PA11	01573000	SWATARA CR AT HARPER TAVERN	337	A	6- 1-89	88050	261		4
PA12	03047500	KISKIMINETAS R AT AVONMORE	1723	B	3-18-36	185000	107	135000	4
PA13	03048500	KISKIMINETAS R AT VANDERGRIFT	1825	B	3-18-36	185000	101		4
PA14	MISC. 1	BRODHEAD CR AT ANALOMINK	124	D	8-18-55	72200	582		4
PA15	MISC. 2	LILLIBRIDGE CR NR PORT ALLEGANY	6.73	D	7-18-42	16000	2380		4
PA16	MISC. 3	ALLEGHENY R AT PORT ALLEGANY	249	D	7-18-42	77000	309		4
PA17	MISC. 4	WALLENPAUPACK CR AT SOUTH STERLING	14.3	D	8-19-55	22200	1550		4
PA18	MISC. 5	FREEMAN RUN AB AUSTIN	14.6	D	7-18-42	19000	1300		4
PA19	MISC. 6	CASTILE RUN AT RIGGLE FARM	4.25	D	6-45-41	10000	2350		4
PA20	MISC. 7	ANNIN CR NR TURTLEPOINT	11.4	D	7-18-42	24000	2110		4
PA21	MISC. 8	MILL CR AT ERIE	12.9	D	8- 3-15	13000	1010		4

RHODE ISLAND

RI 1	01106000	ADAMSVILLE BROOK AT ADAMSVILLE	7.91	B	12-27-69	316	40	279	2
RI 2	01111500	BRANCH R AT FORESTDALE	91.2	A	3-19-36	5800	64		2
RI 3	01112500	BLACKSTONE R AT WOONSOCKET	416	B	8-19-55	32900	79	25900	2
RI 4	01114500	WOONASQUATUCKET R AT CENTERDALE	38.3	B	3-18-68	1440	38	1250	2
RI 5	01116000	SBR PAWTUXET R AT WASHINGTON	63.8	B	3-18-68	1860	29	1650	2
RI 6	01118500	PAWCATUCK R AT WESTERLY	295	B	11- -27	7000	24		2

SOUTH CAROLINA

SC 1	02131000	PEE DEE R AT PEEDEE	8830	B	9-22-45	220000	25	217000	5
SC 2	02131500	LYNCHES R NR BISHOPVILLE	675	B	9-19-45	29400	44	27300	2
SC 3	02136000	BLACK R AT KINGSTREE	1260	B	6-14-73	58000	46	52800	2
SC 4	02146000	CATABA R NR ROCK HILL	3050	B	5-23-01	151000	50		5
SC 5	02147500	ROCKY CR AT GREAT FALLS		C	8-23-67	31300	161	21100	5

See footnotes at end of table.

Reference 5

Formula Used to Interpolate the Peak Discharge Near the BBNPP Site

Stream flow at each impact point is determined by areal transposition methods. Monthly average stream flows in cubic feet per second at a gage were converted to cfsm by dividing the monthly stream flow by the gage's drainage area in square miles. The drainage areas of each impact point can then be multiplied by this flow value to yield the average monthly stream flow at each location. Between two gages, where more than a single gage might apply to an impact point, interpolation of the stream flow at each gage is used. The watershed area between the two gages is measured and the ratio of that area above and below the impact point is used as the ratio of the monthly stream flow used from each gage.

$$AMS_{(ip)} = \left\{ \left(\left[1 - \left([DA_{(ip)} - DA_{(ug)}] / [DA_{(dg)} - DA_{(ug)}] \right) \right] * AMS_{(ug)} \right) + \left(\left[1 - \left([DA(dg) - DA(ip)] / [DA(dg) - DA_{(ug)}] \right) \right] * AMS_{(dg)} \right) \right\} * DA_{(ip)}$$

Where:
$AMS_{(ip)}$ = average monthly stream flow at an impact point between gages
$DA_{(ip)}$ = drainage area of the impact point in square miles
$DA_{(ug)}$ = drainage area of the upstream gage in square miles
$DA_{(dg)}$ = drainage area of the downstream gage in square miles
$AMS_{(ug)}$ = average monthly streamflow of the upstream gage in cfsm;
$AMS_{(dg)}$ = average monthly streamflow of the downstream gage in cfsm

C. General Standard Determination

The General Standard is a quantitative way to evaluate water use among streams of different sizes and characteristics. When the rivers have protected flows established for them, water use will be assessed based on the the protected flows instead of the General Standard. The General Standard is not a Protected Instream Flow, but instead is a set of criteria for evaluating water use in watersheds where a protected flow has not yet been established. Water use is compared to the General Standard, which is derived from monthly stream flow per unit area. When stream flow is higher, the General Standard for water use is higher. When aggregate water use exceeds the General Standard, the stream segment is not in compliance with the General Standard. The General Standard acts as a means of assessing water use versus stream flow that is comparable on all the Designated Rivers. Rivers that are not in compliance are the highest priorities for developing protected instream flows.

The four water use criteria in the General Standard are expressed as values in cfsm making these values drainage basin-size dependent. To calculate the General Standard for the impact points in the watershed, the monthly streamflow at a gage location is converted to cfsm by dividing the flow by the gage's drainage area. Streamflow in cfsm for each impact point is then compared to the four tiers of the General Standard as described in Env-Ws 1903.02 (c) of the Instream Flow Rules, which are listed above.

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Reference 6

FEMA Flood Insurance Map

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