Delaware River Basin Flooding
June 27-29, 2006

* Flood Crests
* Reservoirs
* Discussion


* Third Major Flood along Main Stem
Delaware River in Less than Two Years
* Also Flash Flood and Tributary Flooding

April 2005 Flood

1,938 Closed Claims; $69 Million in Losses*

Counties with Highest Number of Claims:

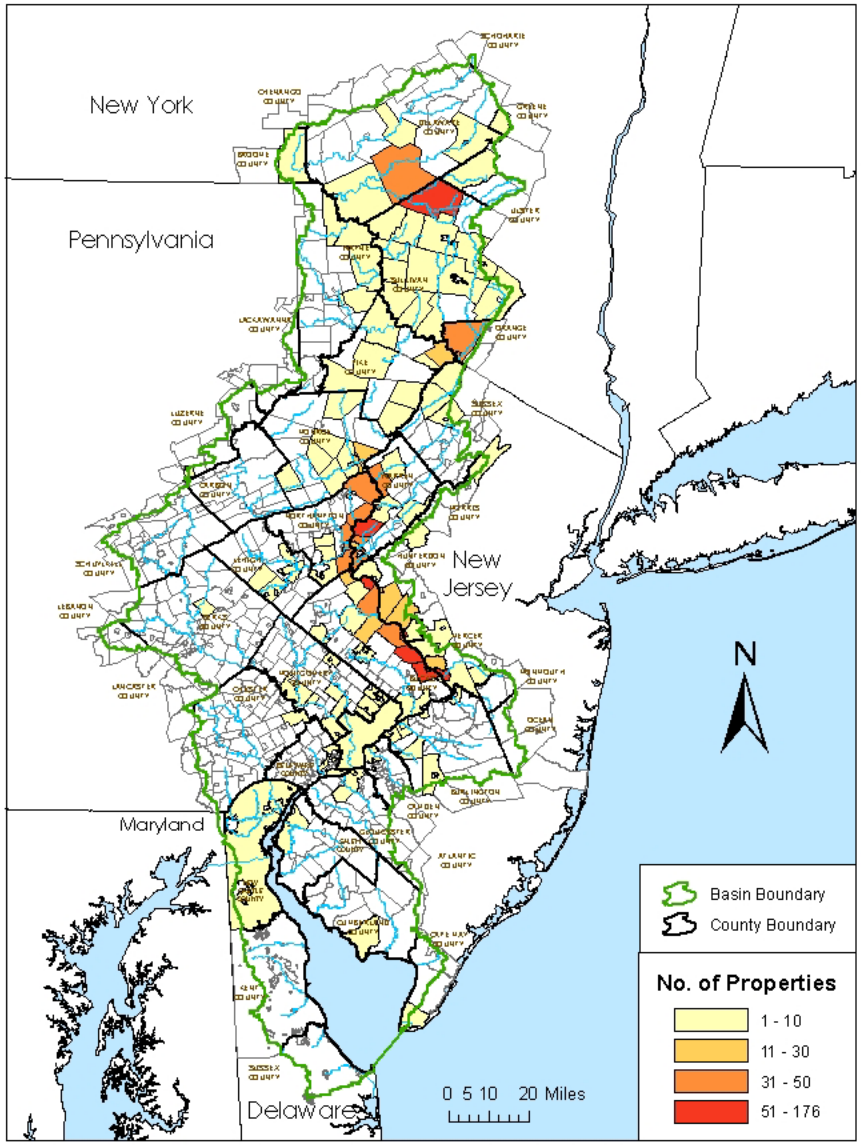
Bucks, PA	641
Warren, NJ	236
Northampton, PA	225
Hunterdon, NJ	208
Mercer, NJ	186
Sullivan, NY	96
Orange, NY	81
Delaware, NY	58
Monroe, PA	48
Pike, PA	37

Municipalities with Highest Number of Claims:

Yardley, PA	176
Trenton, NJ	164
Lambertville, NJ	83
New Hope, PA	81
Bridgeton, PA	66
Upper Makefield, PA	62
Rockland, NY	59
Harmony, NJ	53
Lower Makefield, PA	53
Riegelsville, PA	52

* Numbers do not represent uninsured flood damage.

National Flood Insurance Claims in the Delaware River Basin (by Municipality) April 2005 Event



Source: Federal Emergency Management Agency (FEMA). Claims represented include all National Flood Insurance Program (NFIP) closed claims as of 12/31/05 for dates of loss listed 4/2/05 - 4/5/05.

Prepared by Delaware River Basin Comission Staff, June 14, 2006

Preliminary June 2006 Flood Crests at Select U. S. Geological Survey (USGS) Gaging Stations

Station	Crest Time/Date	Crest Stage (ft)	Flood Stage (ft)	Crest Discharge (cfs)	Historical Daily Median Discharge [1] (cfs)
West Br. Del. R. @ Hale Eddy	1300 6/28	19.10	11	40,100	481
East Br. Del. R. @ Harvard	1645 6/28	16.62	N/A	22,100	137
Beaverkill @ Cooks Falls	0900 6/28 [2]	20.54	10	62,400	178
East Br. Del. R. @ Fishs Eddy	1045 6/28	21.45	13	78,600	395
Del. R. @ Callicoon	1715 6/28	20.37	12	141,000	1,100
Lackawaxen R. @ Hawley	1300 6/28	18.14	11	27,800	136
Del. R. @ Port Jervis	1815 6/28	21.47	18	180,000	1,980
Del. R. @ Montague	2215 6/28	32.16	25	212,000	2,350
Brodhead Cr.@ Minisink Hills	1930 6/27 [3]	9.25 [3]	10	11,400 [3]	203
Del. R. @ Belvidere	1130 6/29	27.16	22	225,000	3,580
Lehigh R. @ Bethlehem	1100 6/28	17.74	16	49,000	1,270
Del. R.@ Trenton	2045 6/29	25.09	20	237,000	5,320
Schuylkill R. @ Reading	1430 6/28	23.60	13	54,500	909

[1] Historical median of daily mean values for the crest date.

cfs = cubic feet per second

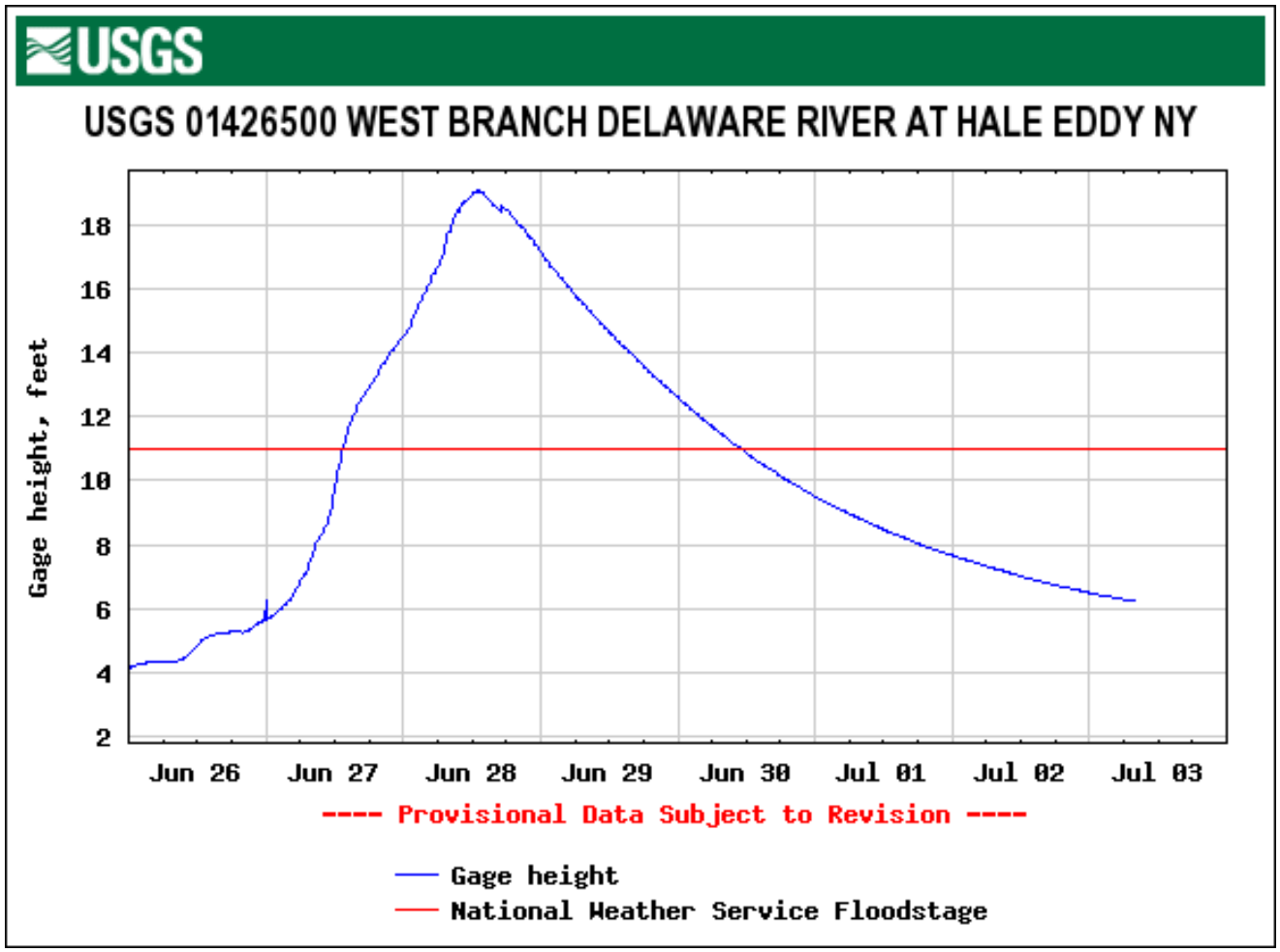
[2] DRBC estimate from USGS hydrograph.

[3] USGS reported peak prior to backwater flooding from the Delaware River.

All data is provisional and subject to revision.

Hale Eddy – Crest of 19.1 ft. is the 2nd highest on record

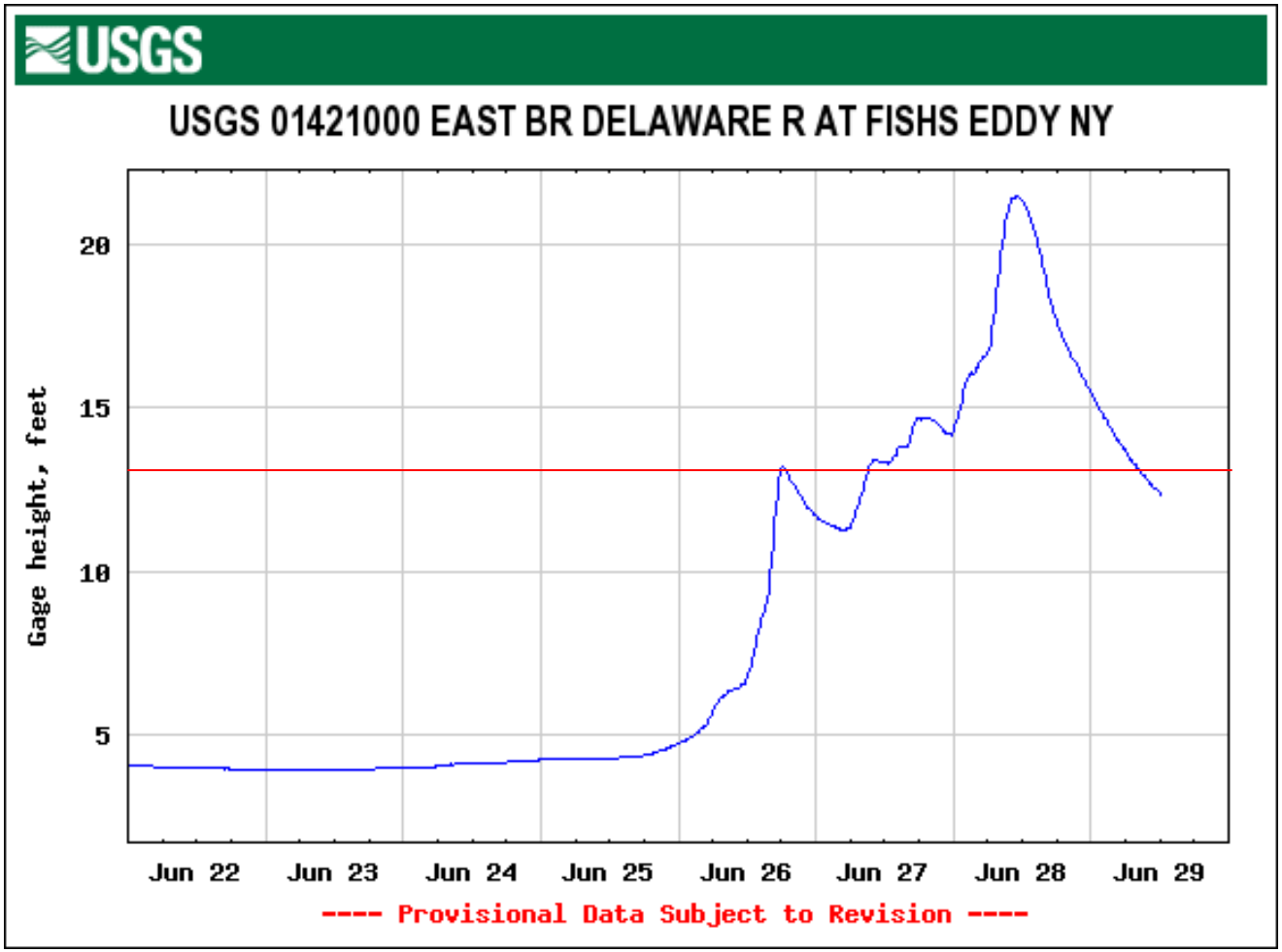
Historical Crests
(1) 20.30 ft on 1903/10/10
(2) 15.80 ft on 1924/09/30
(3) 15.70 ft on 1948/03/22
(4) 15.60 ft on 1938/09/22
(5) 15.30 ft on 1913/03/27



June 2006

Fishs Eddy – Crest of 21.45 ft. is the 4th highest on record

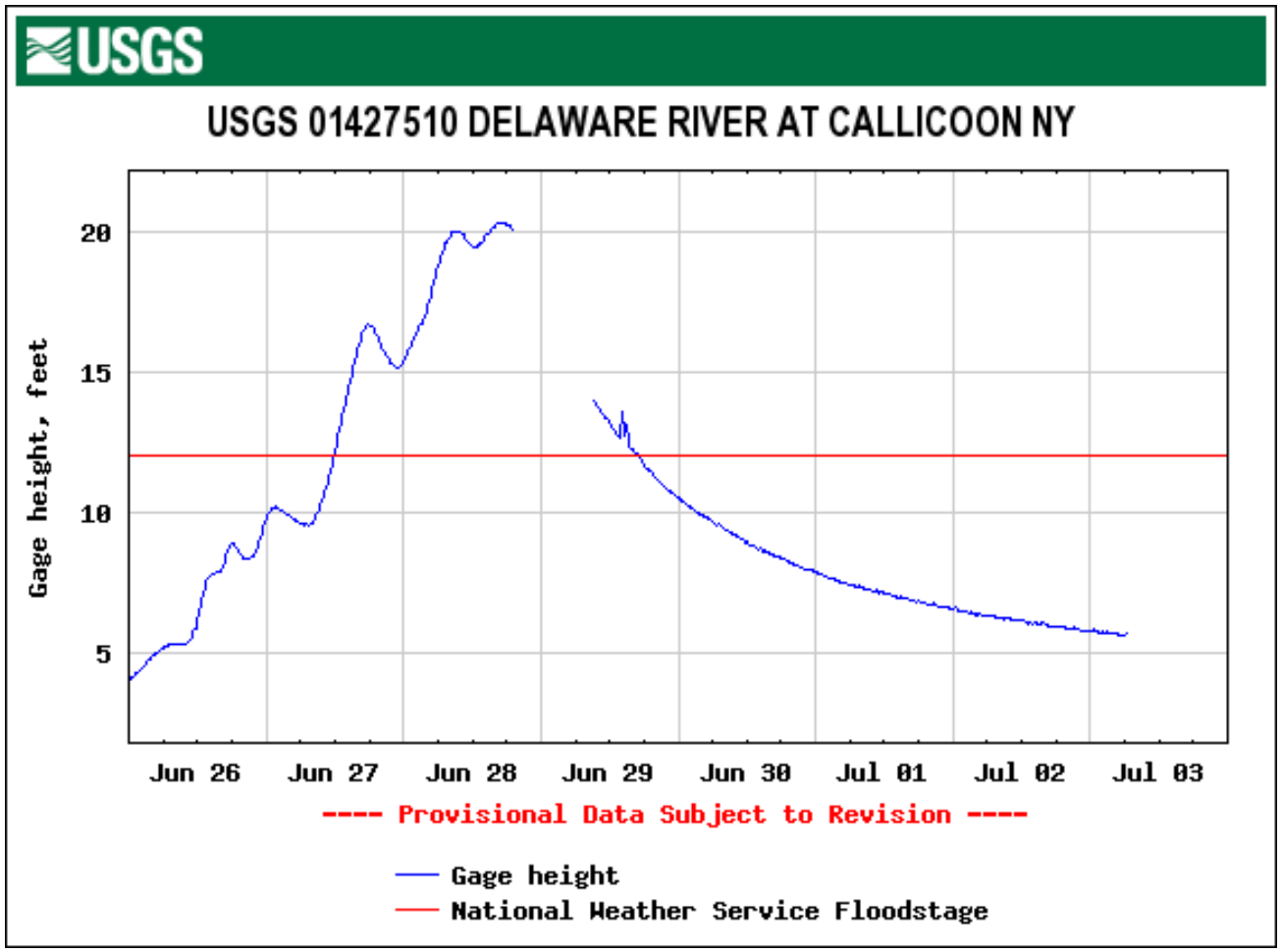
Historical Crests
(1) 23.60 ft on 1903/10/9
(2) 22.49 ft on 2005/04/3
(3) 21.40 ft on 2004/09/18
(4) 20.60 ft on 1933/08/24
(5) 19.20 ft on 1936/03/18



June 2006

Callicoon – Crest of 20.37 ft. is a new record

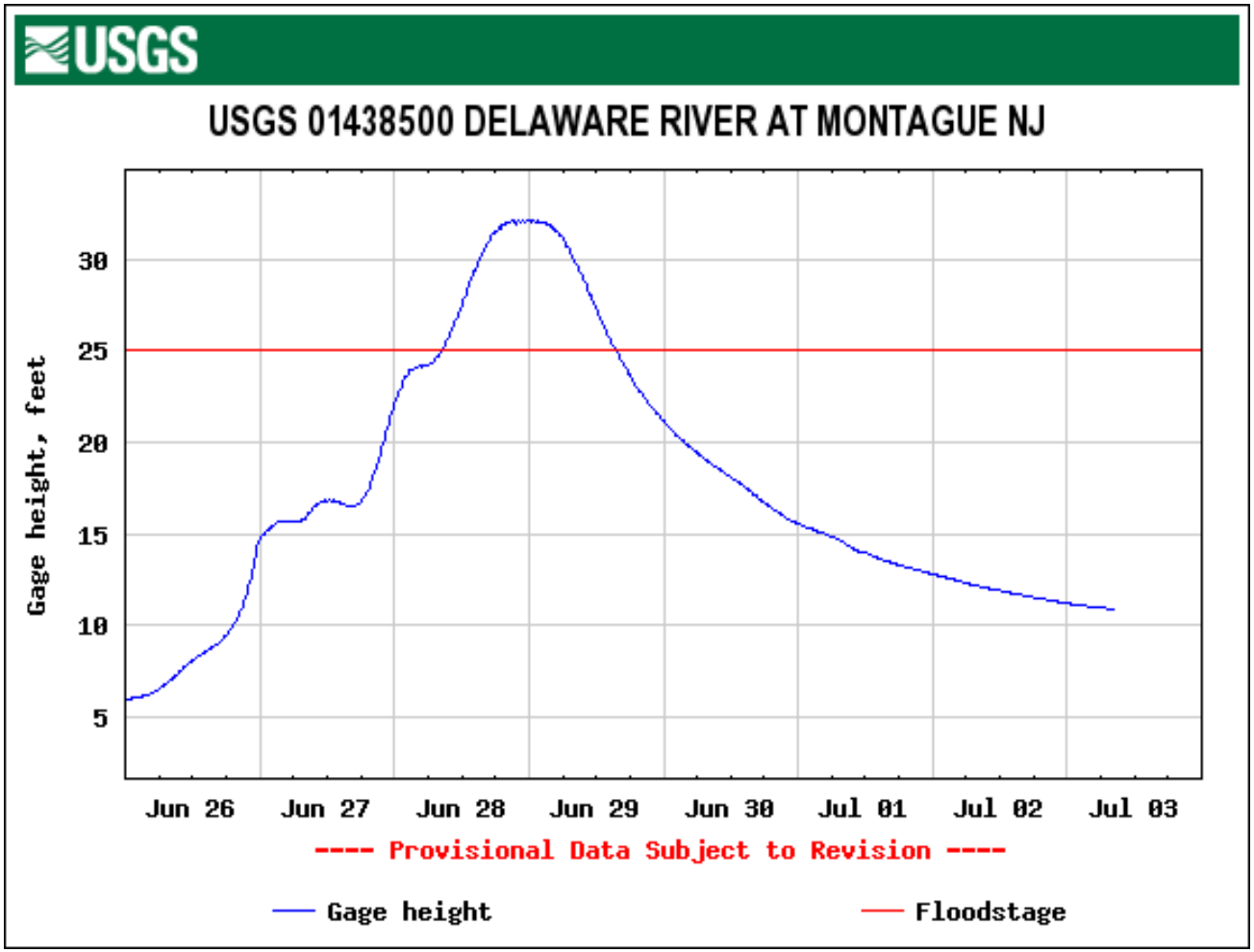
Historical Crests
(1) 17.80 ft on 2005/04/3
(2) 17.33 ft on 2004/09/18
(3) 16.31 ft on 1996/01/19
(4) 14.83 ft on 1979/01/9
(5) 13.42 ft on 1986/03/15



June 2006

Montague – Crest of 32.16 ft. is the 3rd highest on record

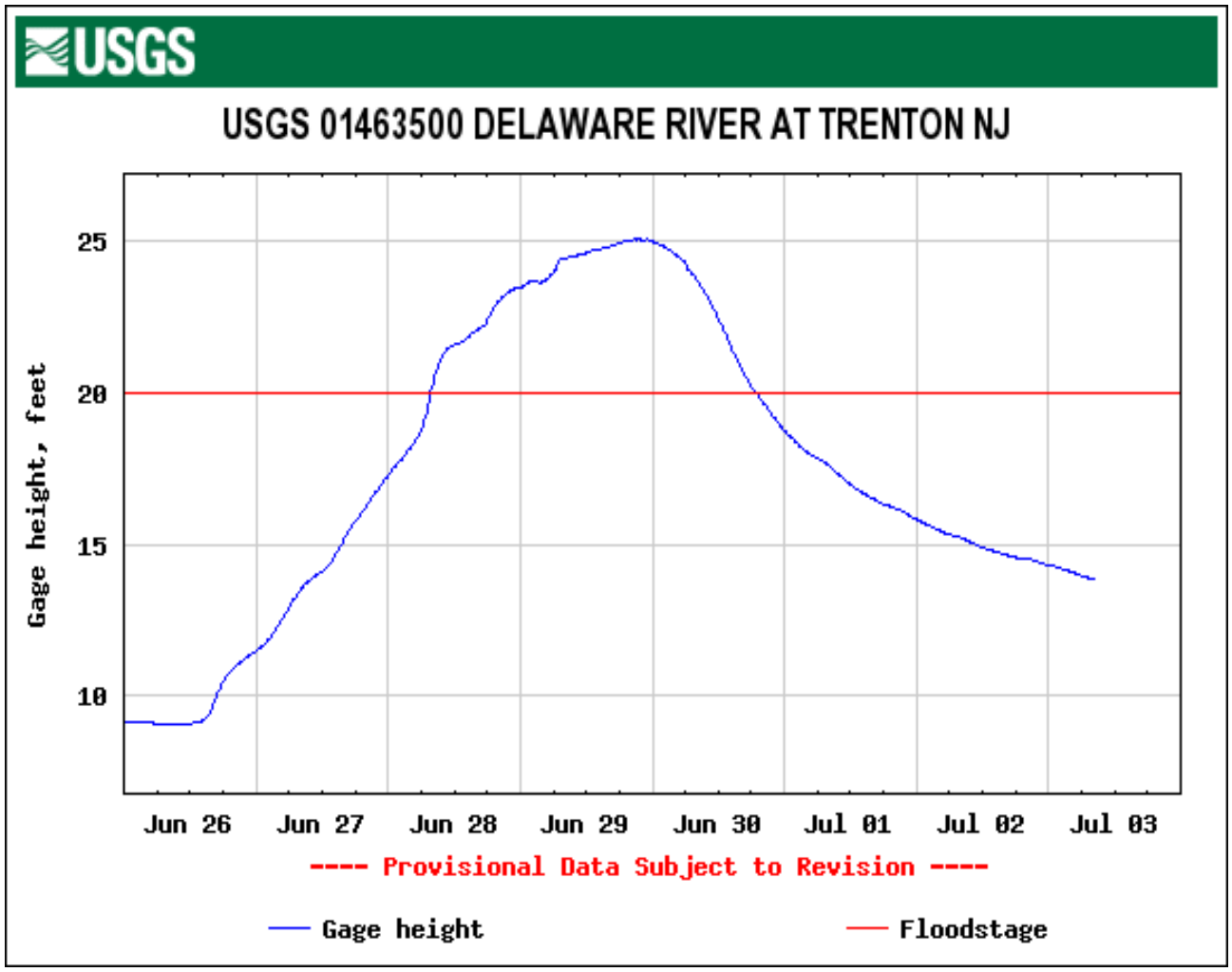
Historical Crests
(1) 35.50 ft on 1903/10/10
(2) 35.15 ft on 1955/08/19
(3) 31.69 ft on 2005/04/3
(4) 26.61 ft on 1996/01/20
(5) 25.70 ft on 1942/05/23



June 2006

Trenton – Crest of 25.09 ft. is the 5th highest on record

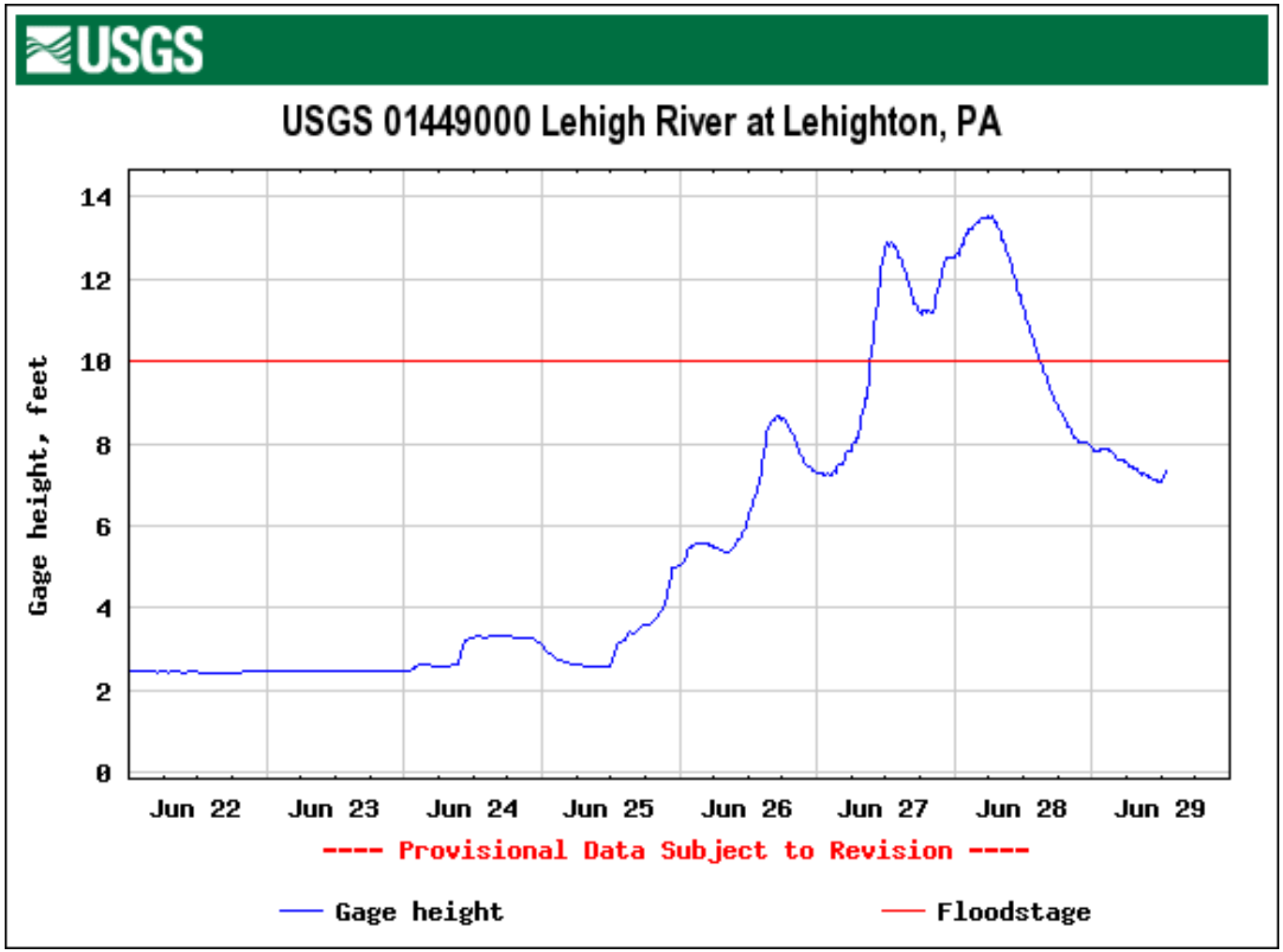
Historical Crests
(1) 30.60 ft on 1904/03/8
(2) 28.60 ft on 1955/08/20
(3) 28.50 ft on 1903/10/11
(4) 25.33 ft on 2005/04/4
(5) 24.43 ft on 1936/03/19



June 2006

Lehigh River at Lehighton – Crest of 13.51 ft.

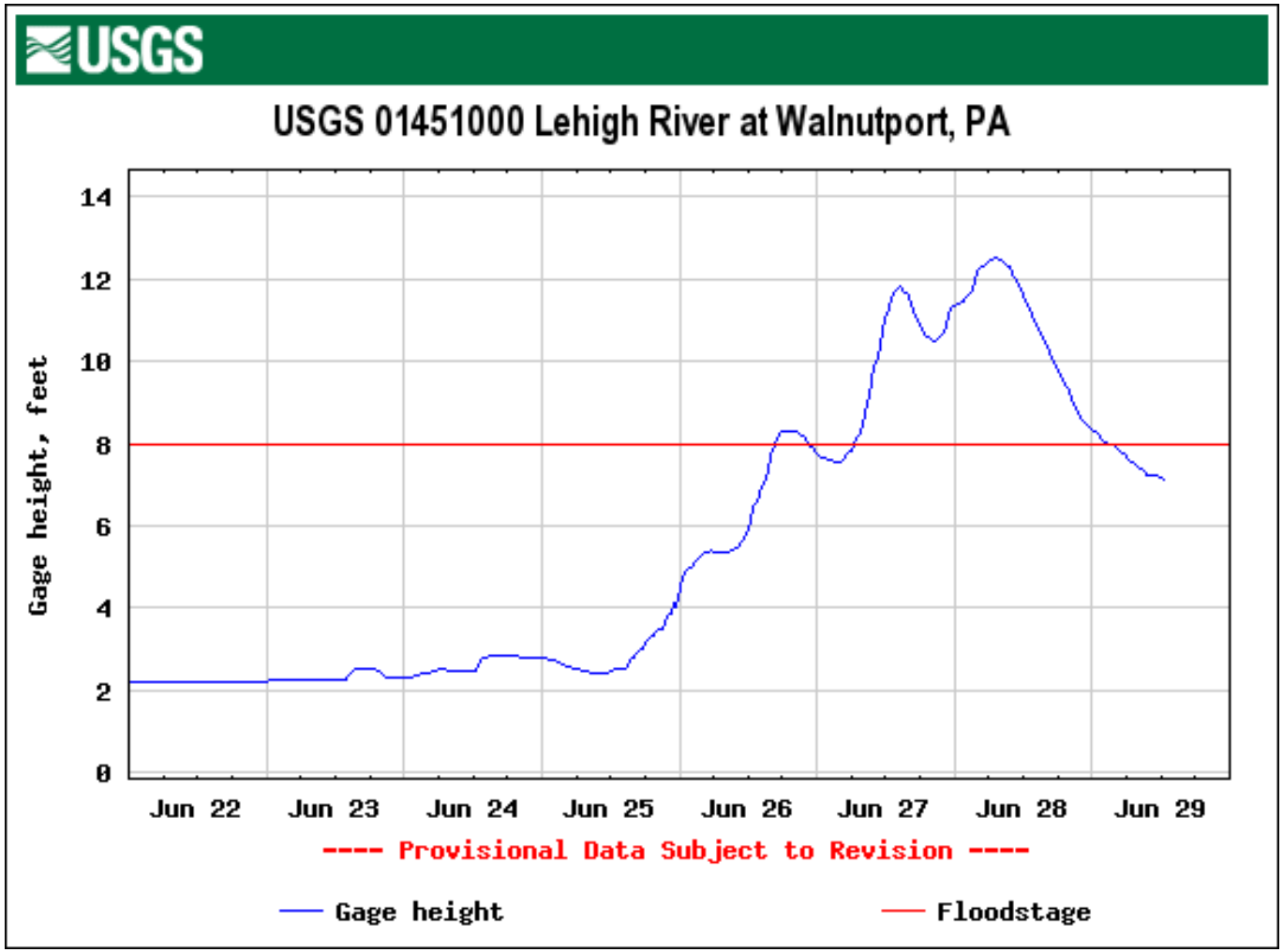
Historical Crests
(1) 20.80 ft on 1902/02/28
(2) 20.70 ft on 1942/05/23
(3) 20.30 ft on 1955/08/19
(4) 18.22 ft on 1985/09/27
(5) 15.90 ft on 1935/07/10



June 2006

Walnutport – Crest of 12.49 ft. is the 4th highest on record

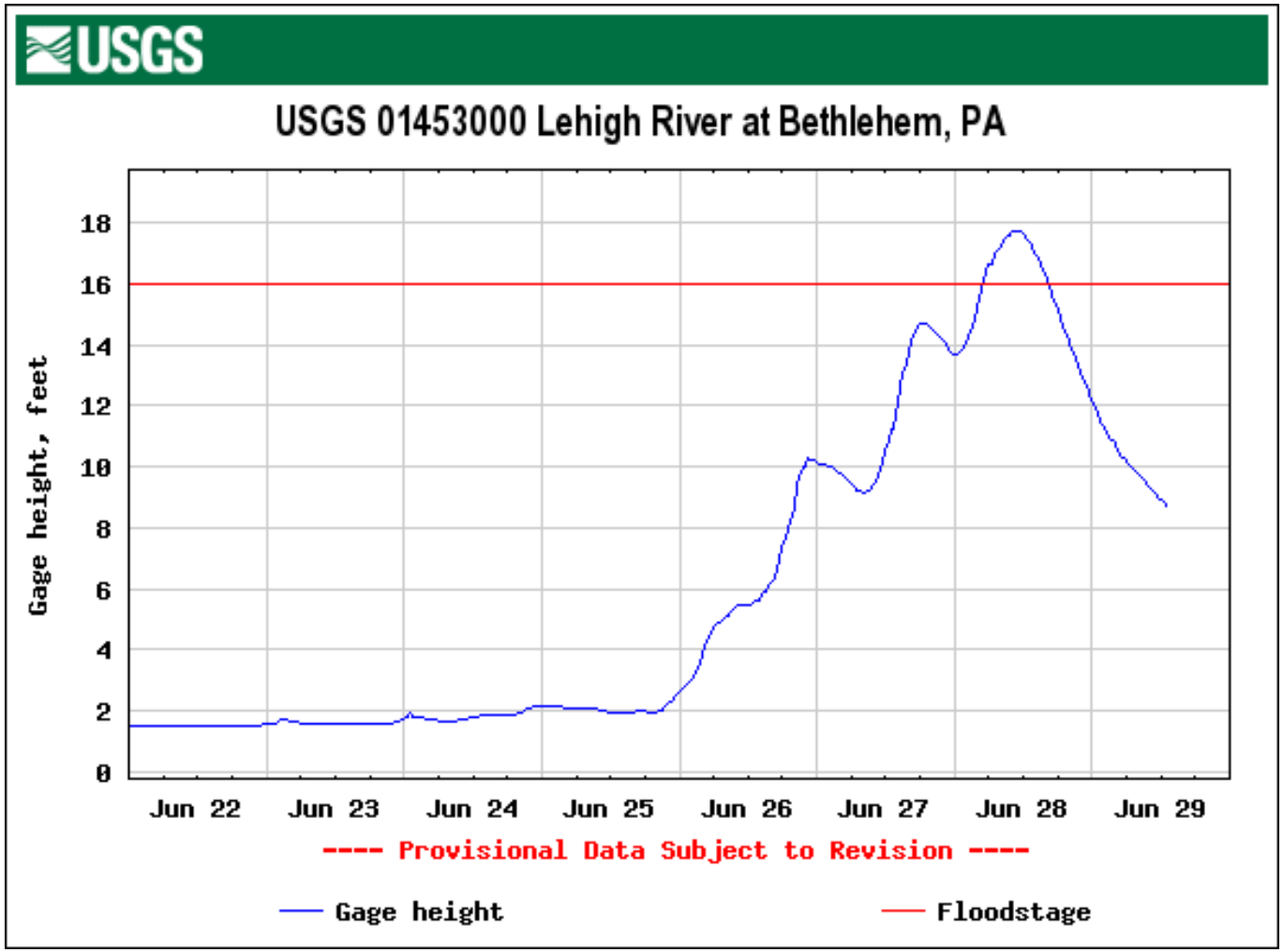
Historical Crests
(1) 20.60 ft on 1942/05/23
(2) 17.68 ft on 1955/08/19
(3) 12.66 ft on 1950/12/4
(4) 12.32 ft on 1996/01/19
(5) 12.29 ft on 2004/09/18



June 2006

Lehigh River at Bethlehem – Crest of 17.74 ft.

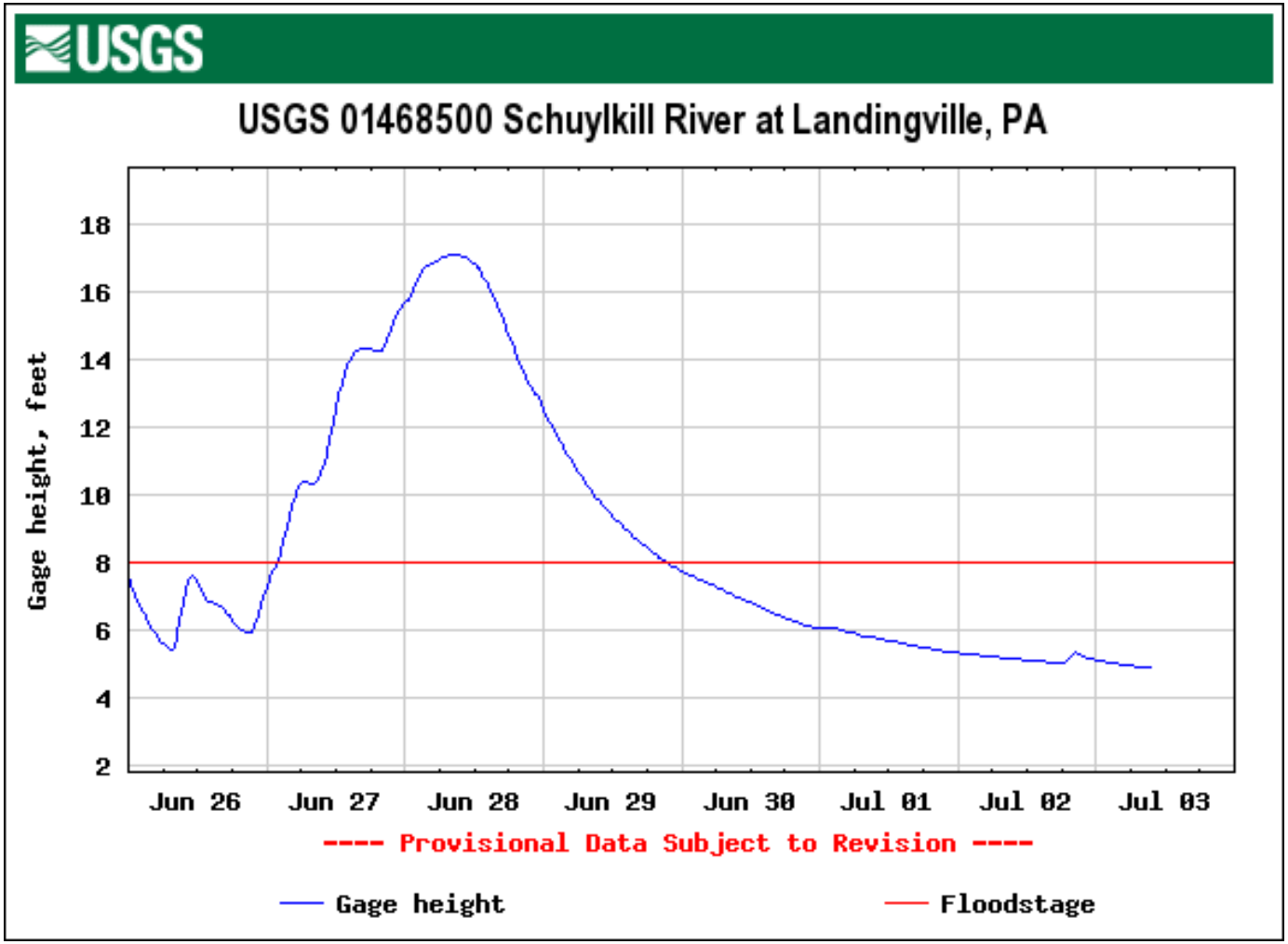
Historical Crests
(1) 25.90 ft on 1942/05/23
(2) 24.90 ft on 1902/02/28
(3) 23.38 ft on 1955/08/19
(4) 20.02 ft on 1972/06/23
(5) 18.79 ft on 2004/09/18



June 2006

Landingville – Crest of 17.11 ft. is the 2nd highest on record

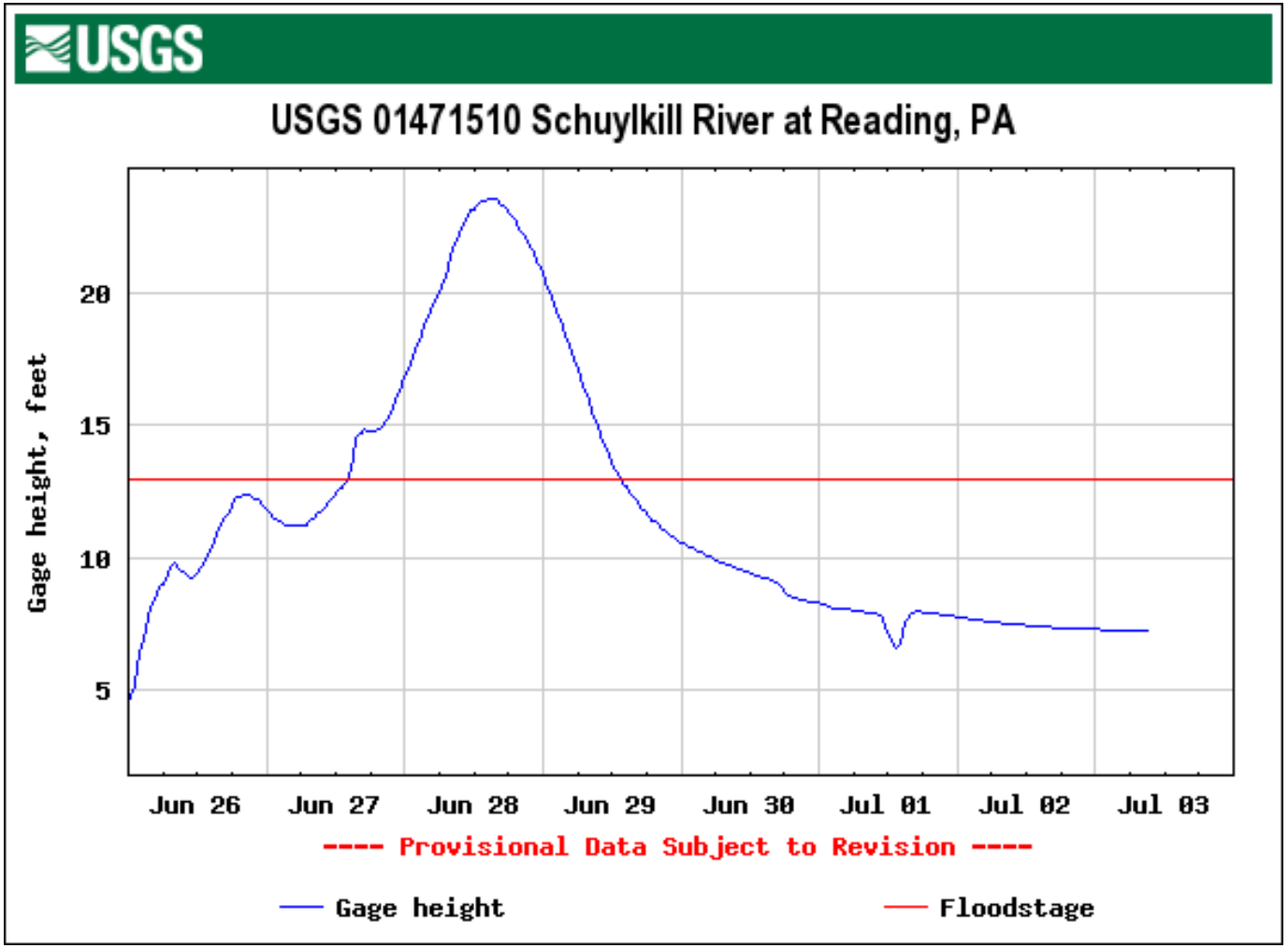
Historical Crests
(1) 17.36 ft on 1972/06/22
(2) 13.60 ft on 1983/04/16
(3) 13.36 ft on 1993/11/28
(4) 13.29 ft on 1983/11/25
(5) 12.90 ft on 1996/01/27



June 2006

Reading – Crest of 23.60 ft. is the 2nd highest on record

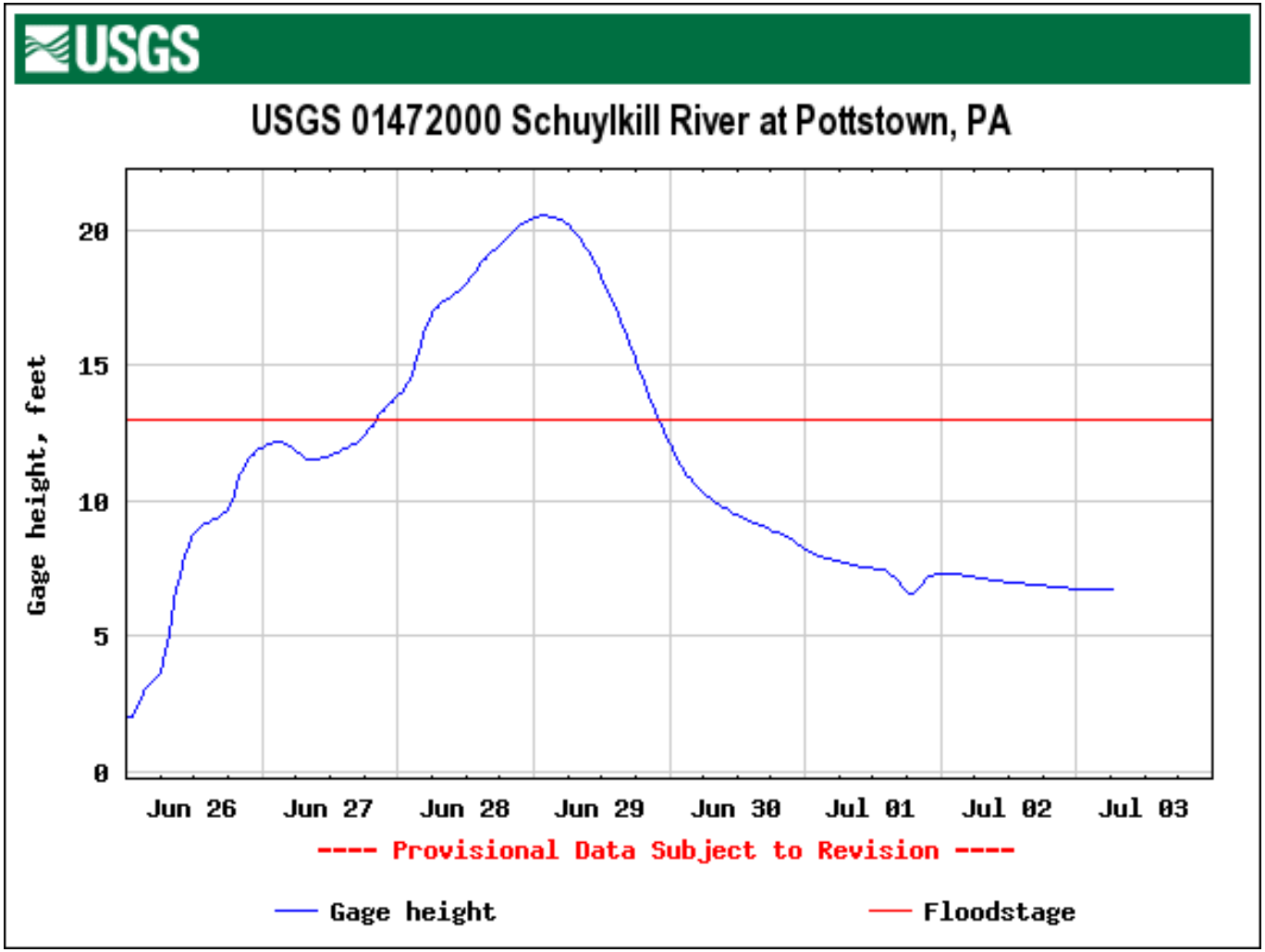
Historical Crests
(1) 31.30 ft on 1972/06/22
(2) 17.50 ft on 1983/04/16
(3) 17.36 ft on 1979/01/25
(4) 16.13 ft on 2004/09/18
(5) 16.09 ft on 1983/12/14



June 2006

Pottstown – Crest of 20.53 ft. is the 3rd highest on record

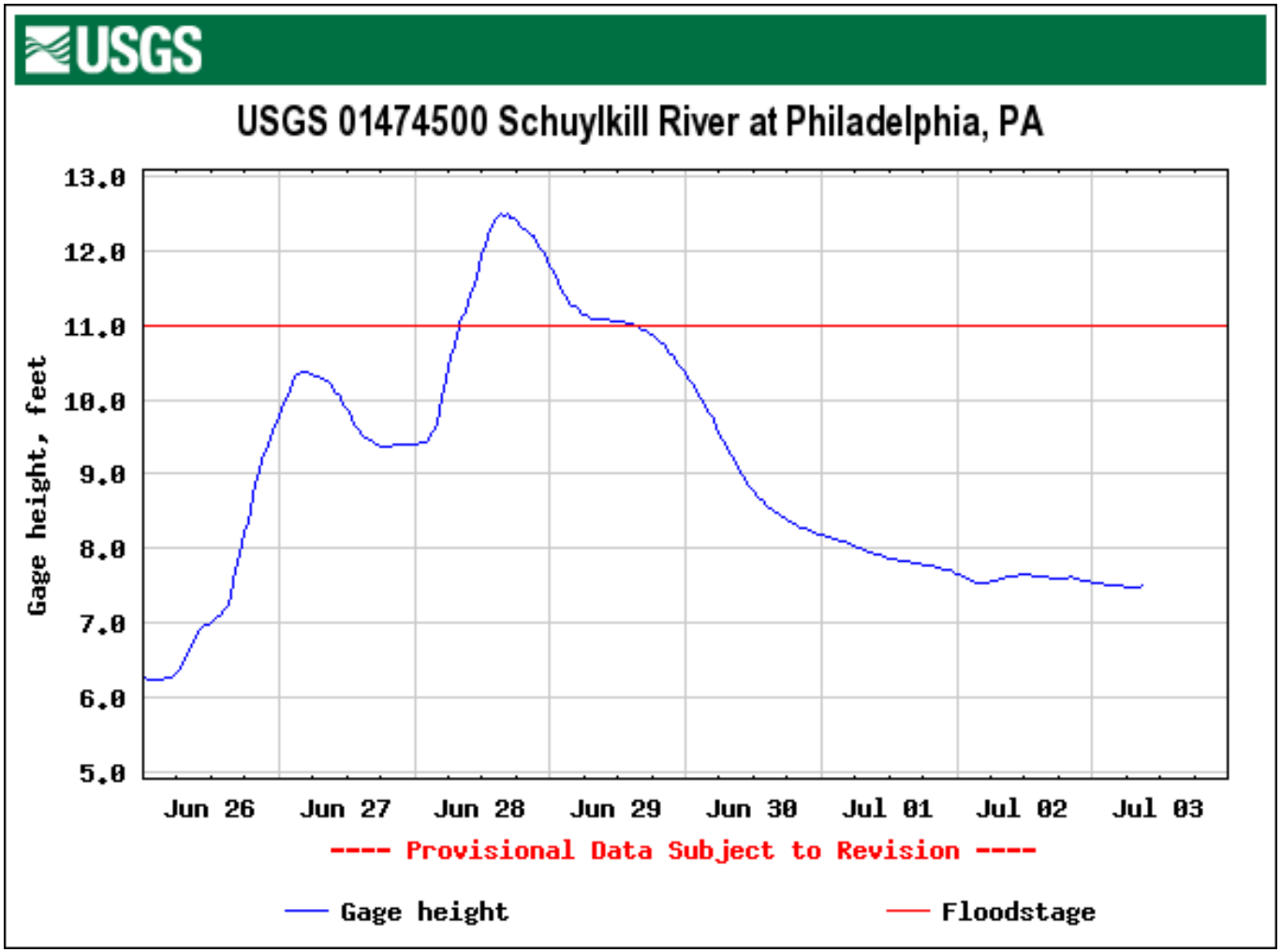
Historical Crests
(1) 29.97 ft on 1972/06/23
(2) 21.00 ft on 1902/02/28
(3) 20.15 ft on 1942/05/23
(4) 19.20 ft on 1933/08/24
(5) 18.21 ft on 1979/01/25



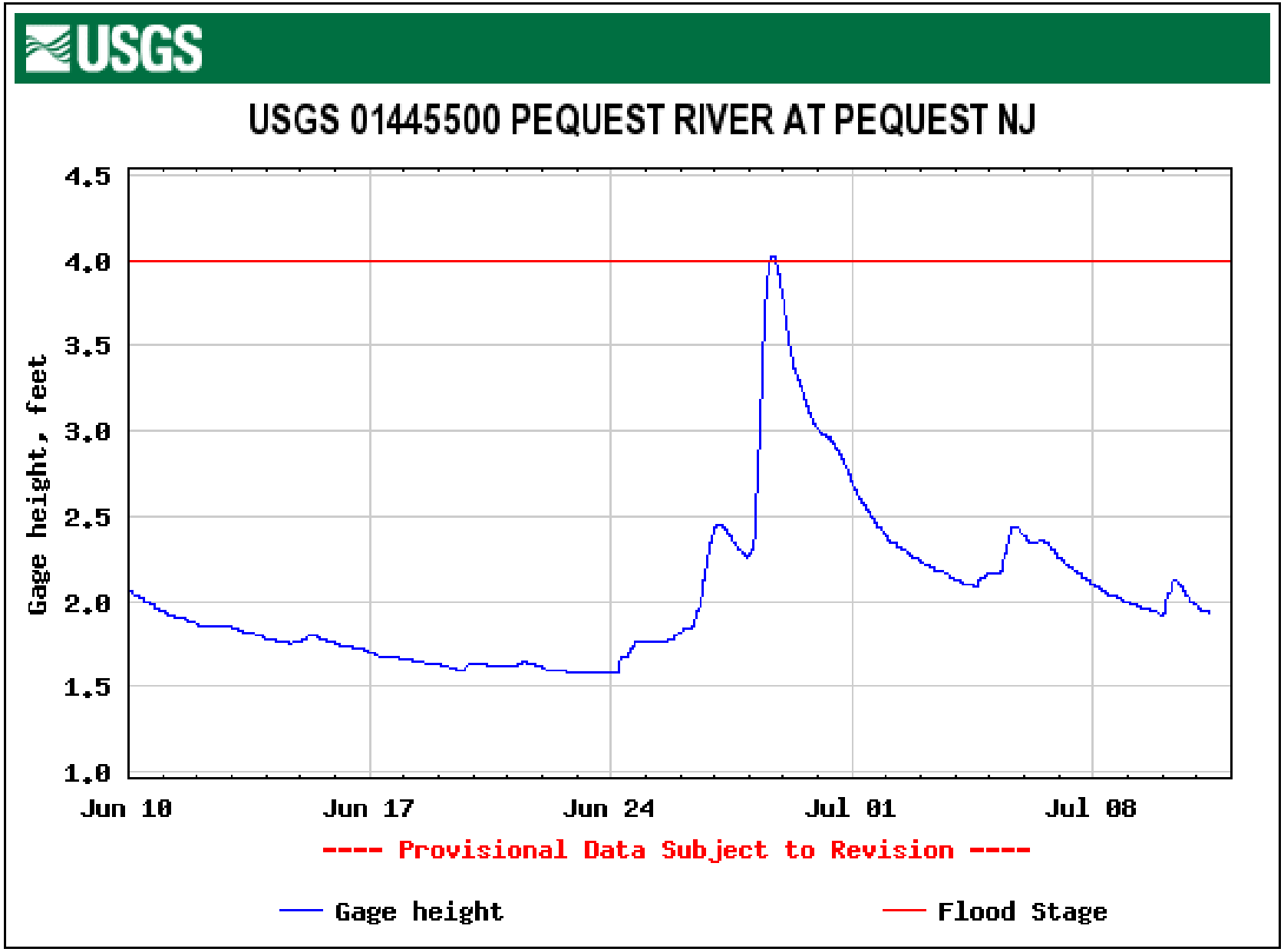
June 2006

Schuylkill River at Philadelphia – Crest of 12.49 ft.

Historical Crests
(1) 17.00 ft on 1869/10/4
(2) 14.80 ft on 1902/03/1
(3) 14.70 ft on 1933/08/24
(4) 14.65 ft on 1972/06/23
(5) 14.57 ft on 1946/06/2

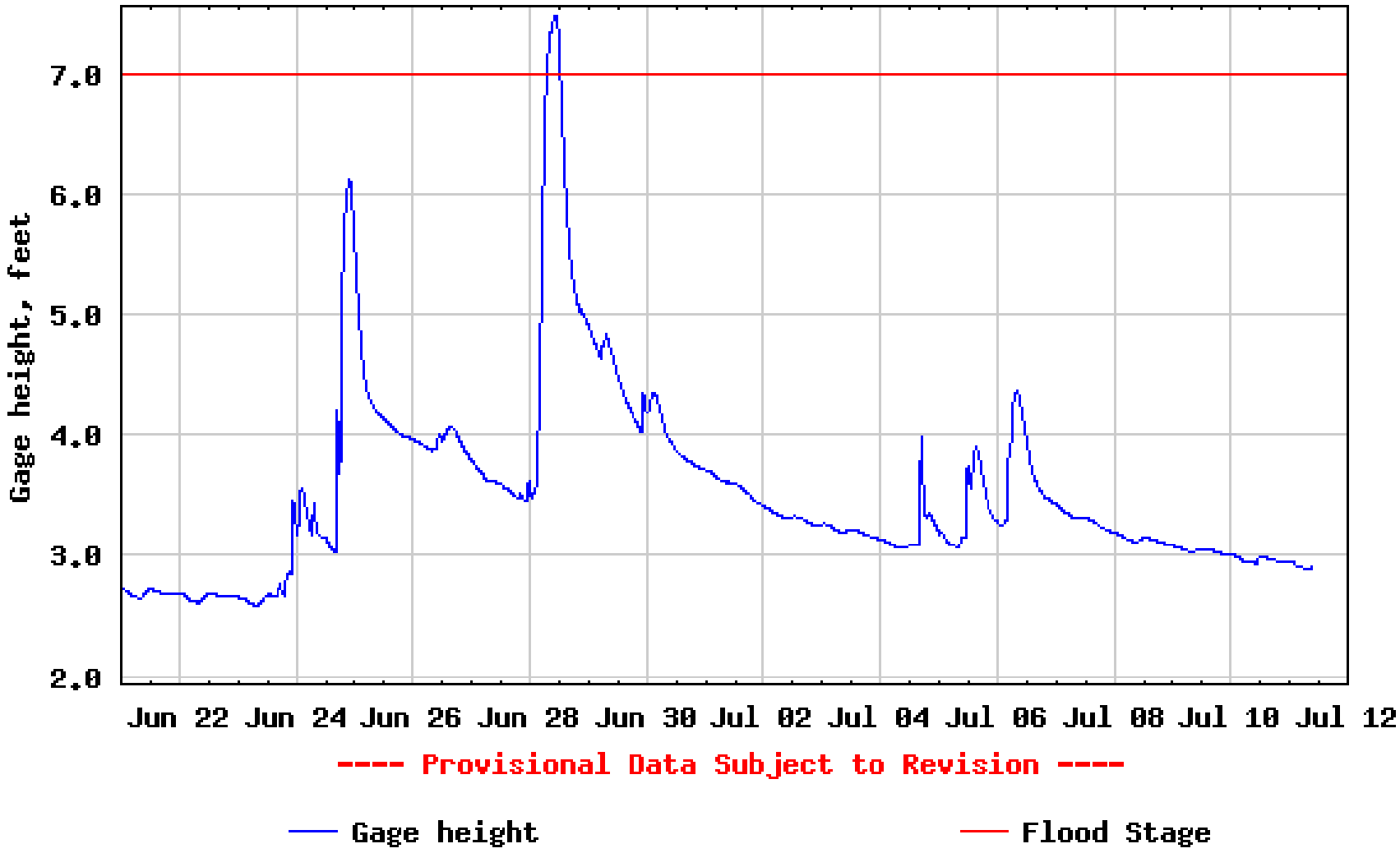


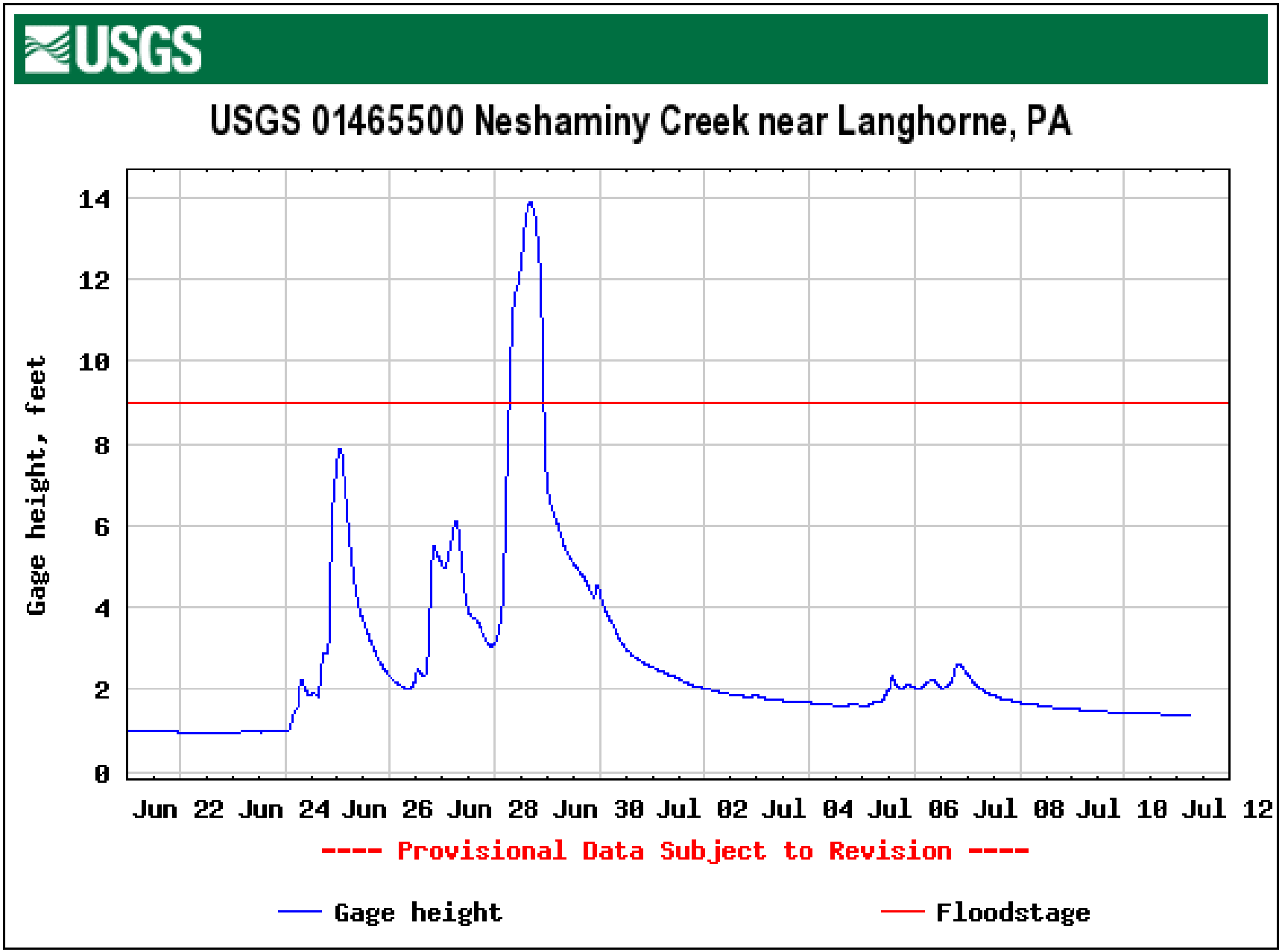
June 2006

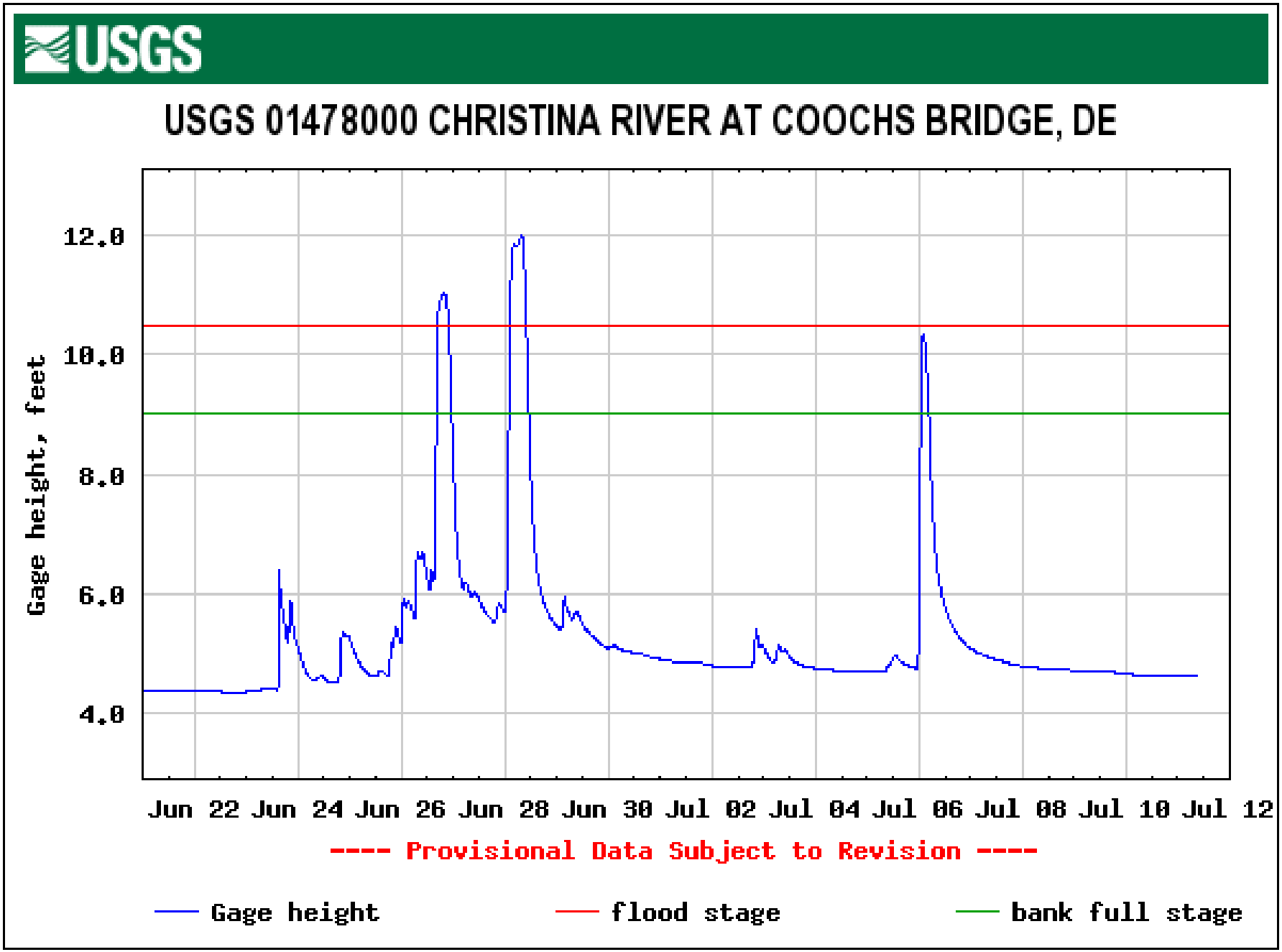

USGS
USGS 01445500 PEQUEST RIVER AT PEQUEST NJ
Gage height, feet
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Jun 10
Jun 17
Jun 24
Jul 01
Jul 08
---- Provisional Data Subject to Revision ----
Gage height
Flood Stage

USGS

USGS 01464000 ASSUNPINK CREEK AT TRENTON NJ

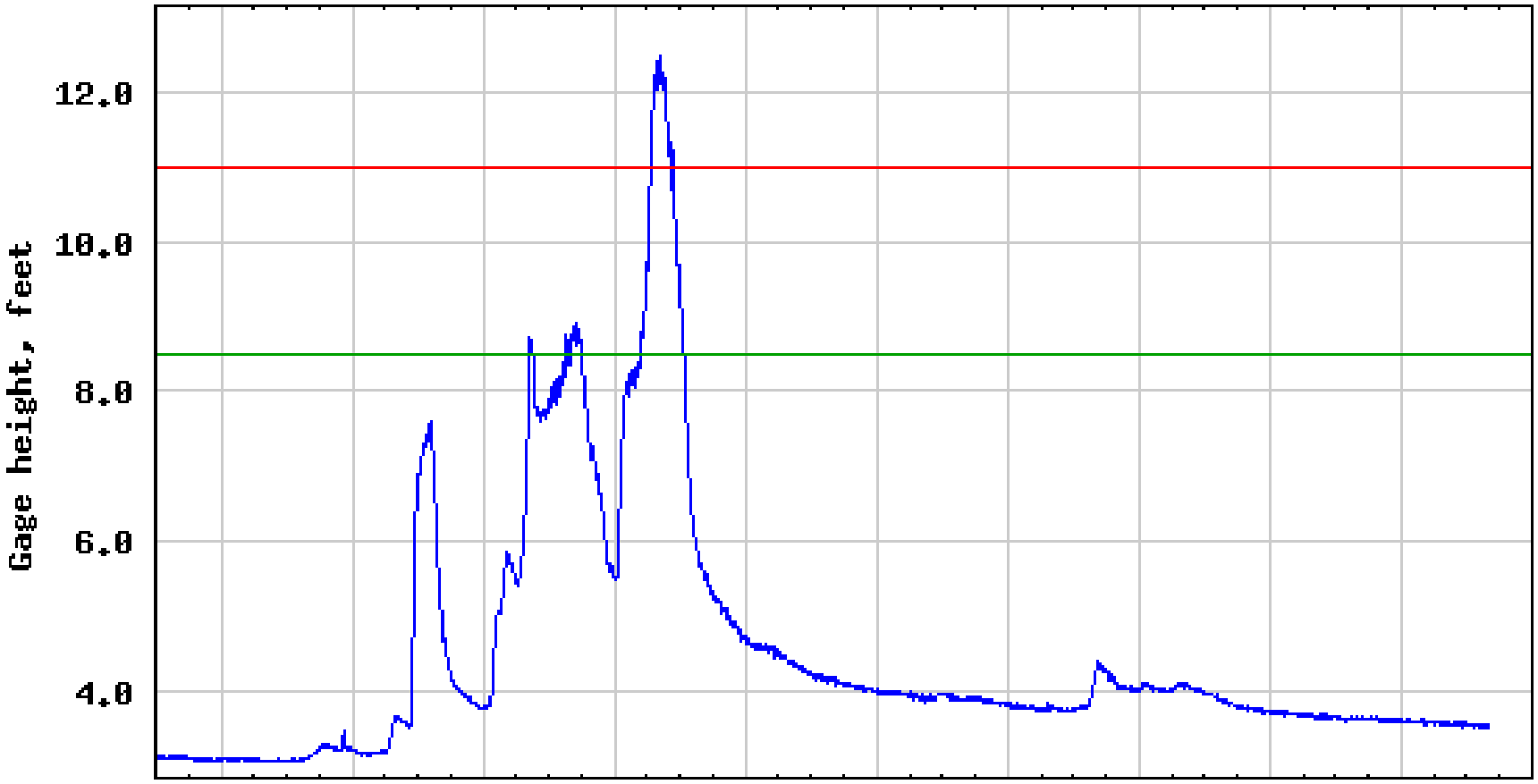



USGS
USGS 01465500 Neshaminy Creek near Langhorne, PA
Gage height, feet
14
12
10
8
6
4
2
0
Jun 22
Jun 24
Jun 26
Jun 28
Jun 30
Jul 02
Jul 04
Jul 06
Jul 08
Jul 10
Jul 12
---- Provisional Data Subject to Revision ----
Gage height
Floodstage


USGS
USGS 01478000 CHRISTINA RIVER AT COOCHS BRIDGE, DE
Gage height, feet
12.0
10.0
8.0
6.0
4.0
Jun 22 Jun 24 Jun 26 Jun 28 Jun 30 Jul 02 Jul 04 Jul 06 Jul 08 Jul 10 Jul 12
---- Provisional Data Subject to Revision ----
Gage height
flood stage
bank full stage

USGS

USGS 01481500 BRANDYWINE CREEK AT WILMINGTON, DE

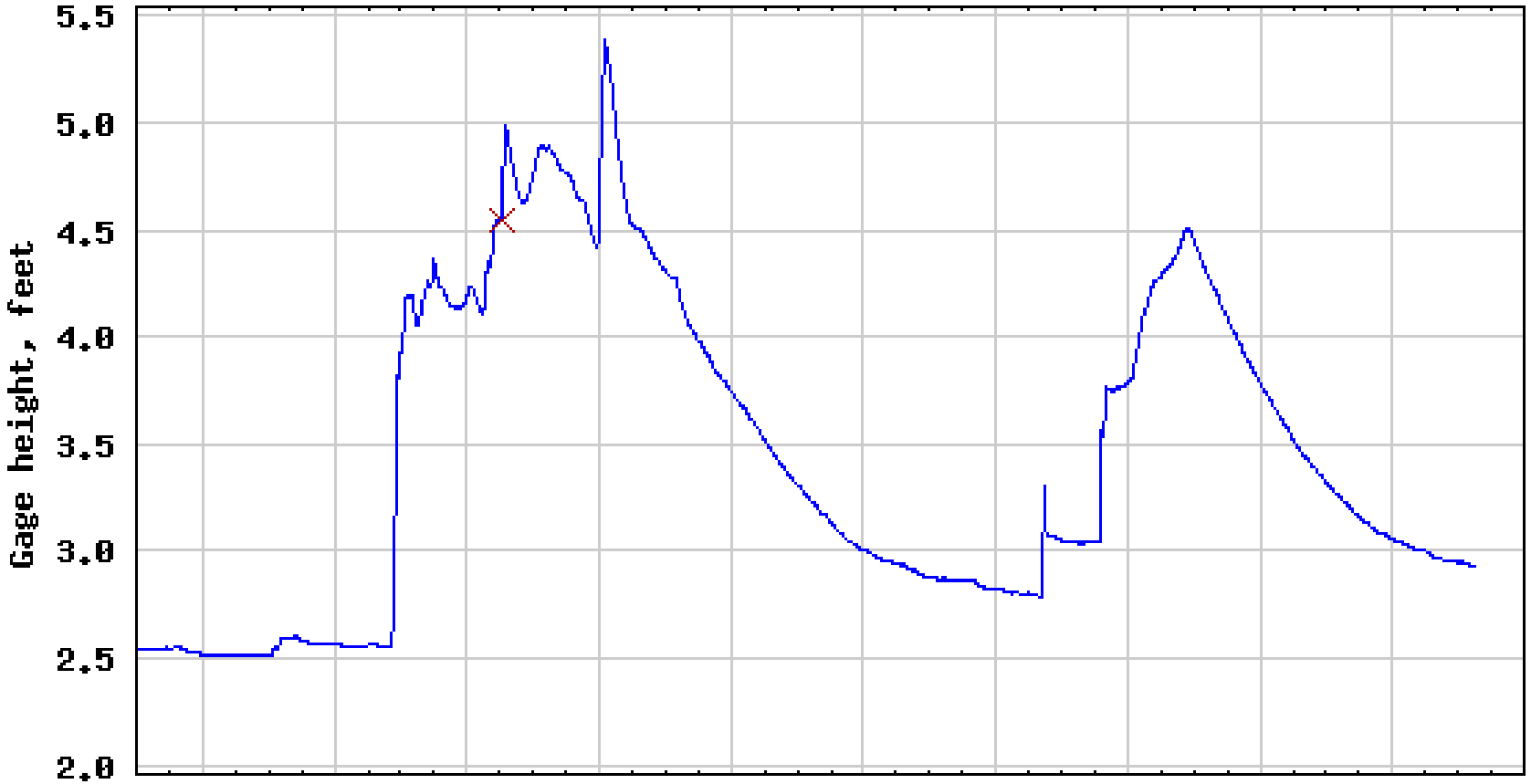


---- Provisional Data Subject to Revision ----

Gage height — flood stage — bank full stage

USGS

USGS 01483700 ST JONES RIVER AT DOVER, DE

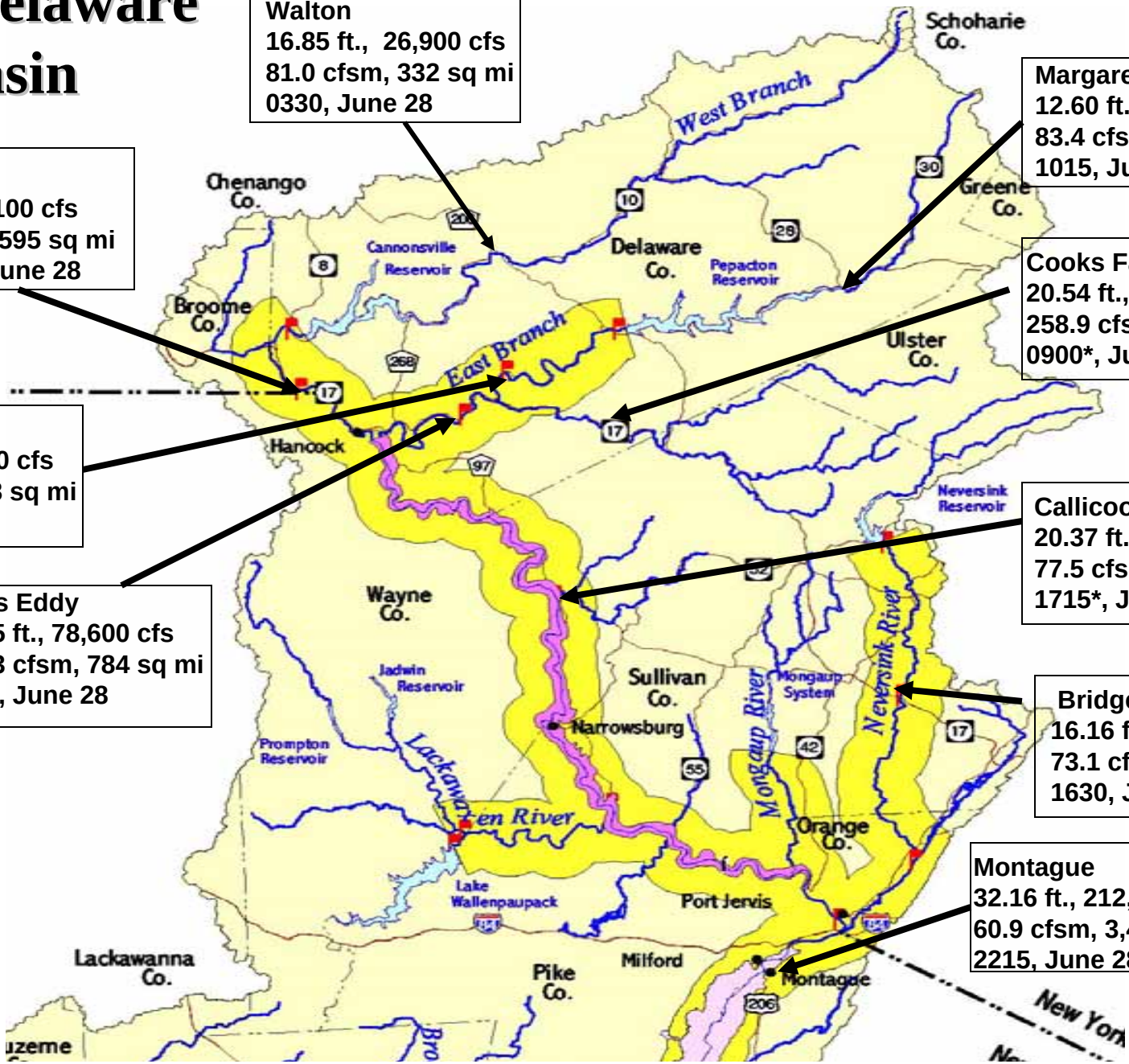


---- Provisional Data Subject to Revision ----

Gage height

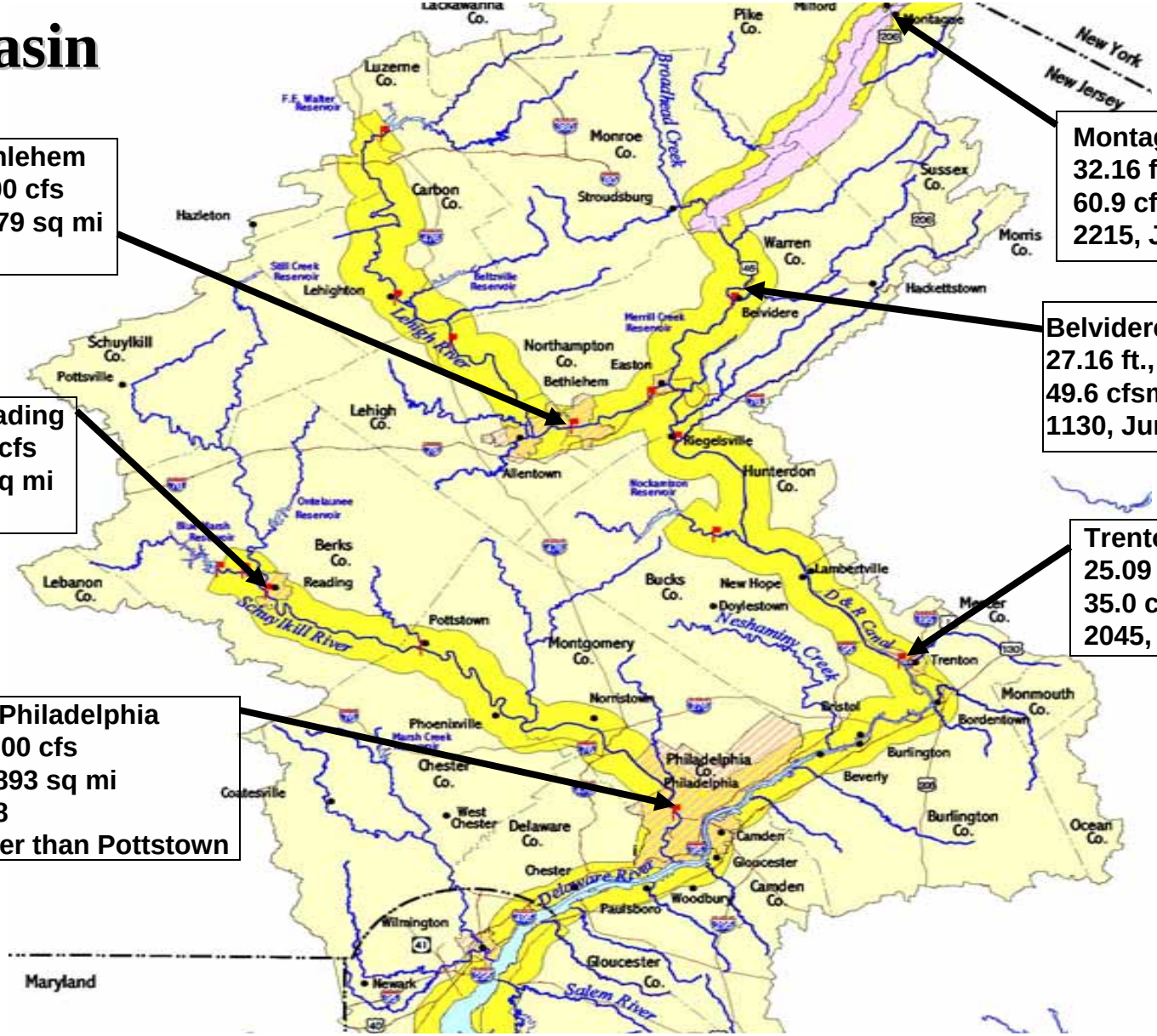
Measured gage height

Upper Delaware River Basin



Data Source:
U.S. Geological Survey cfsm=cubic feet per second per square mile cfs=cubic feet per second *=estimated

Middle Delaware River Basin



Lehigh at Bethlehem
17.74 ft., 49,000 cfs
38.3 cfsm, 1,279 sq mi
1100, June 28

Montague
32.16 ft., 212,000 cfs
60.9 cfsm, 3,480 sq mi
2215, June 28

Belvidere
27.16 ft., 225,000 cfs
49.6 cfsm, 4,535 sq mi
1130, June 29

Schuylkill at Reading
23.63 ft., 54,000 cfs
61.3 cfsm, 880 sq mi
1400, June 28

Trenton
25.09 ft., 237,000 cfs
35.0 cfsm, 6,780 sq mi
2045, June 29

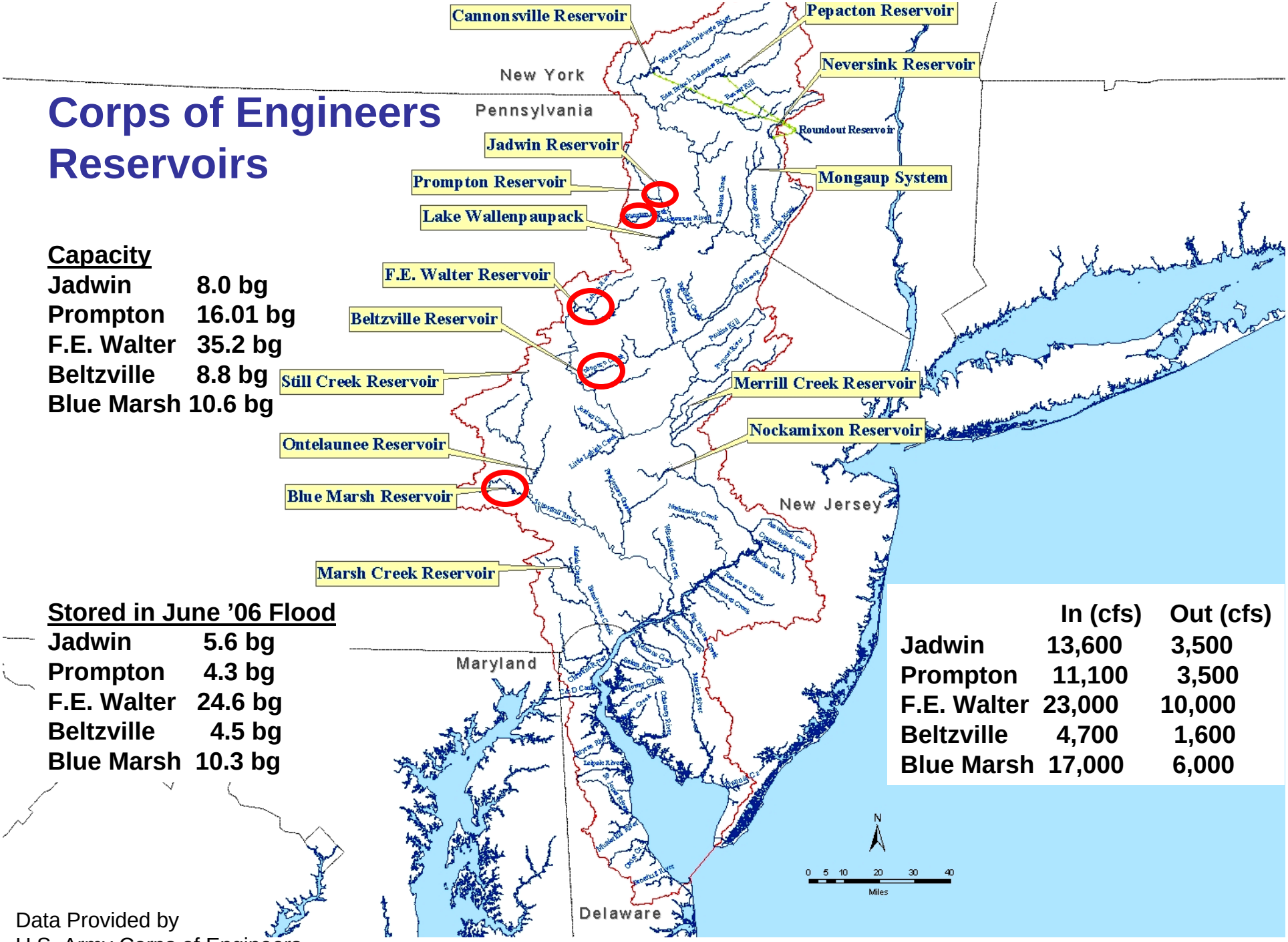
Schuylkill at Philadelphia
12.49 ft., 67,000 cfs
35.4 cfsm, 1,893 sq mi
1600, June 28
Crested Earlier than Pottstown

Data Source:
U.S. Geological Survey cfsm=cubic feet per second per square mile cfs=cubic feet per second

Photograph provided by U.S. Army Corps of Engineers

Effects of Reservoirs

Corps of Engineers Reservoirs



Capacity

Jadwin	8.0 bg
Prompton	16.01 bg
F.E. Walter	35.2 bg
Beltzville	8.8 bg
Blue Marsh	10.6 bg

Stored in June '06 Flood

Jadwin	5.6 bg
Prompton	4.3 bg
F.E. Walter	24.6 bg
Beltzville	4.5 bg
Blue Marsh	10.3 bg

	In (cfs)	Out (cfs)
Jadwin	13,600	3,500
Prompton	11,100	3,500
F.E. Walter	23,000	10,000
Beltzville	4,700	1,600
Blue Marsh	17,000	6,000

Data Provided by
U.S. Army Corps of Engineers

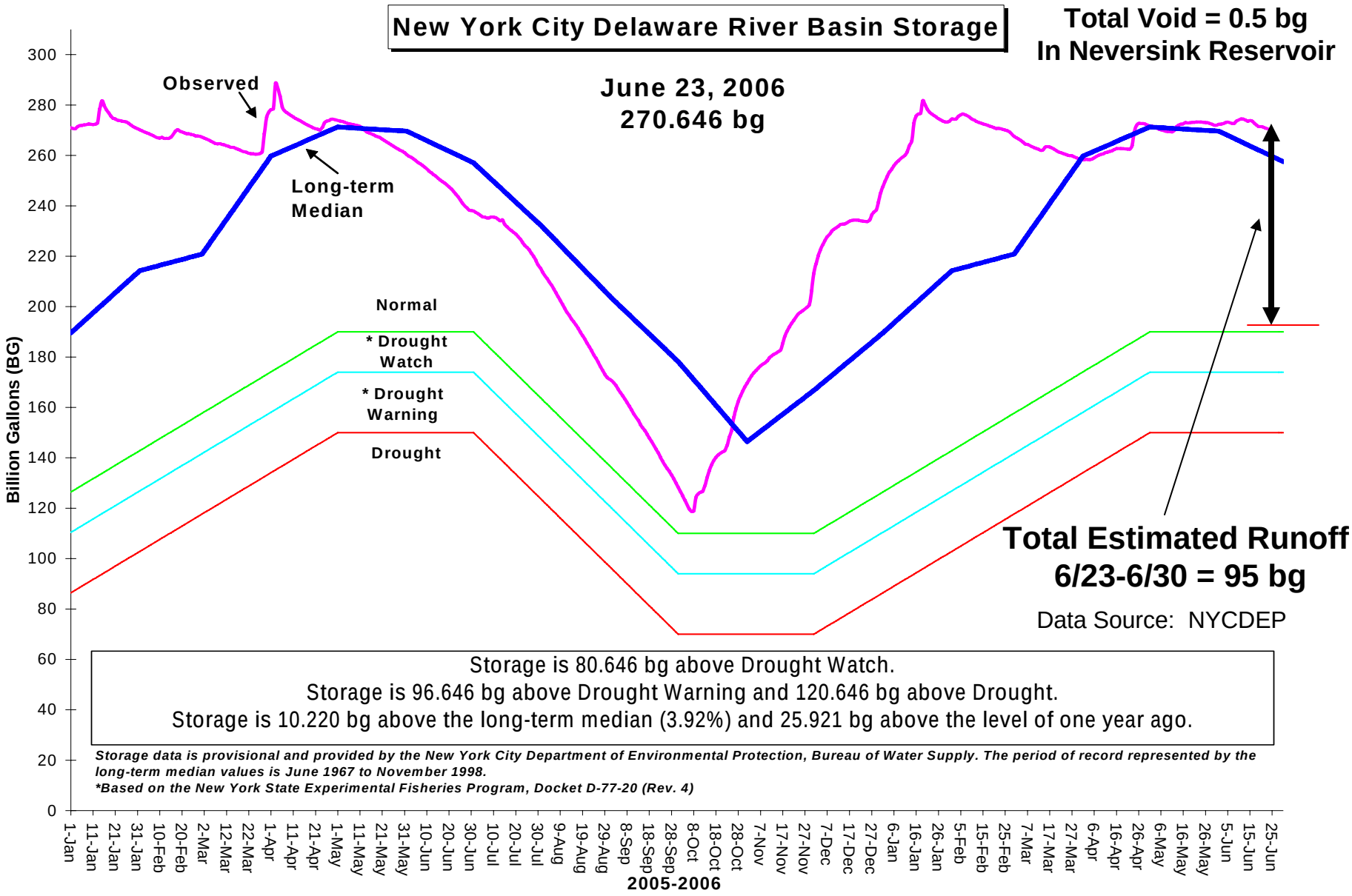
Stage Reductions by Corps Reservoirs

Gage	Flood Stage(ft)	Actual Stage (ft)	W/O Reservoirs(ft)
Lackawaxen River (Prompton,Jadwin)			
Honesdale	10.5	11.8	19.0 (-7.2)
Hawley	11.0	18.1	22.7 (-4.6)
Lehigh River (F.E. Walter, Beltzville)			
Lehighton	10.7	13.5	18 (-4.5)
Walnutport	8.0	12.5	16.2 (-3.7)
Allentown	40.0	49.0	53.0 (-4.0)
Bethlehem	14.2	17.7	22.2 (-4.5)
Schuylkill River (Blue Marsh)			
Reading	13	23.6	26.1 (-2.5)
Pottstown	13	20.5	22.6 (-2.1)

Note:
An emergency release of 5,400 cfs was made from Blue Marsh Reservoir beginning at about 4:00 am on June 28, in order to control the lake level and delay the reservoir from spilling.

Data Provided by
U.S. Army Corps of Engineers

New York City Water Supply Reservoirs



NYC Reservoir Maximum Possible Release Rates With Full Reservoirs

Cannonsville	**1.40 bgd**	**2,165 cfs**
Pepacton	**0.45 bgd**	**696 cfs**
Neversink	**0.205 bgd**	**317 cfs**

Maximum possible drawdown rate is 2.05 billion gallons per day (bgd) minus inflow plus the diversion rate. Release rates may be limited by downstream conditions.

Data Provided by New York City DEP

New York City Reservoirs
Maximum Inflow vs. Spill

Reservoir	Maximum Inflow (cfs)	Maximum Spill Rate (cfs)	%
Cannonsville	36,800 (0330, 6/28)	33,100 (1200, 6/28)	10
Pepacton	30,300 (0900, 6/28)	19,700 (1700, 6/28)	35
Neversink	15,000 (0900, 6/28)	9,000 (1140, 6/28)	40

Accumulated storage above the spillway crests totaled 25 bg for the three reservoirs.

Data Provided by New York City DEP

Lake Wallenpaupack Hydro-Power Reservoir

Approximately 11.5 bg of flood storage provided prior to opening gates.

Discharge through power plant conduit was 1700 cfs to delay opening gates.

Opened flood gates at 3:30 am on June 28th due to reservoir elevation reaching threshold of 1190 ft.

Maximum outflow rate was 8,000 cfs through gates plus 1700 through conduit or total of 9,700 cfs.

Maximum estimated inflow rate was 19,500 cfs.

Lackawaxen flow at Hawley would have peaked 11,000 cfs higher without dam in place.

Data Provided by PPL, LLC

Effects of Reservoirs on Main Stem Crests

A more explicit model is needed to account for hydrograph timing and routing in evaluating the main stem, and to serve as a basis for potential void programs

The National Weather Service forecasting model was used to estimate crest reductions for the April 2005 flood due to the New York City reservoirs and Lake Wallenpaupack.

Lower Basin	**0.5 to 1.5 ft.**
Upper Basin	**1.0 to 2.5 ft.**

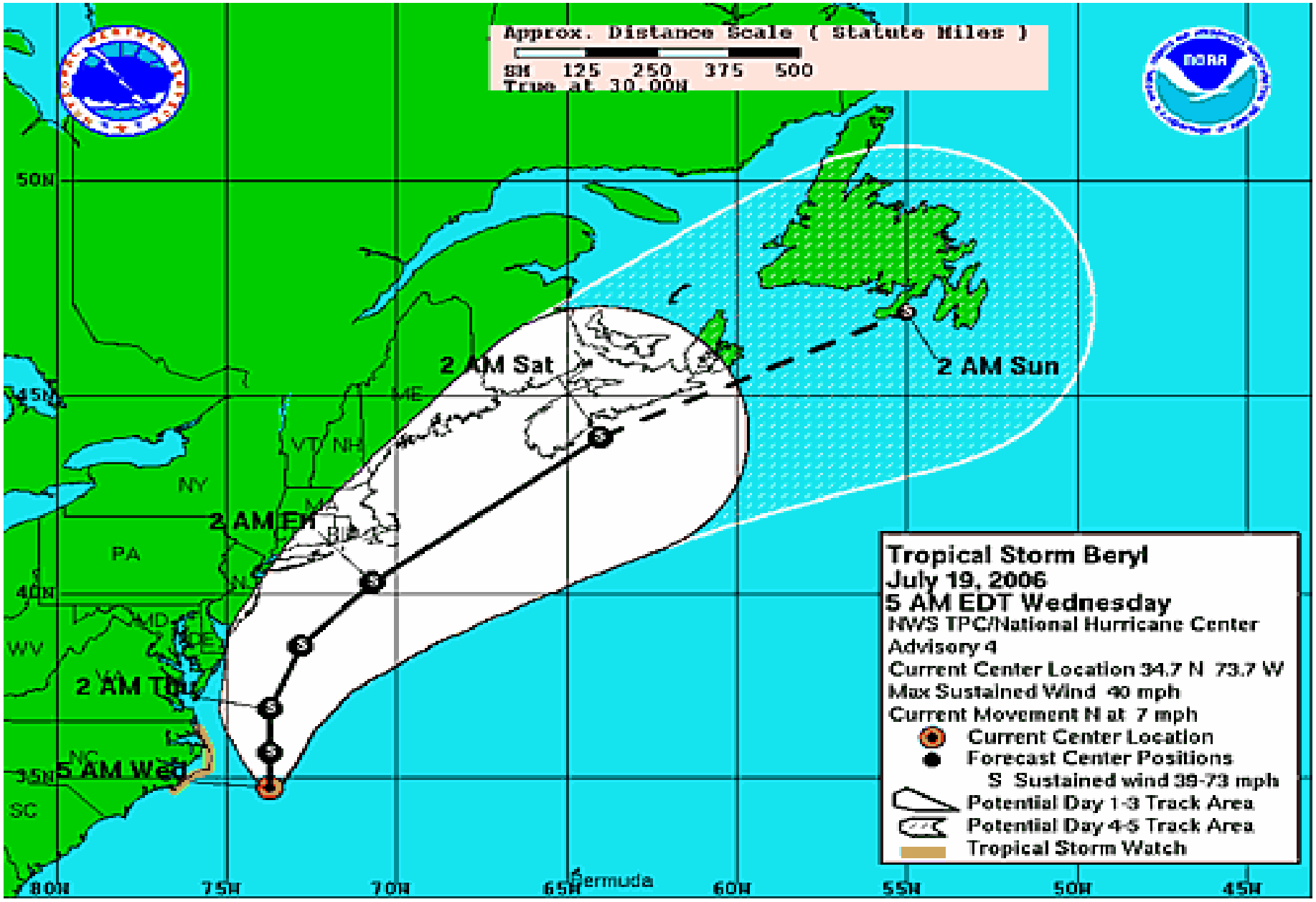
NYC Reservoirs control 14 percent of the drainage Area above Trenton, 26 percent above Montague, and 45 percent above Callicoon.

Effects of Reservoirs on Main Stem Crests

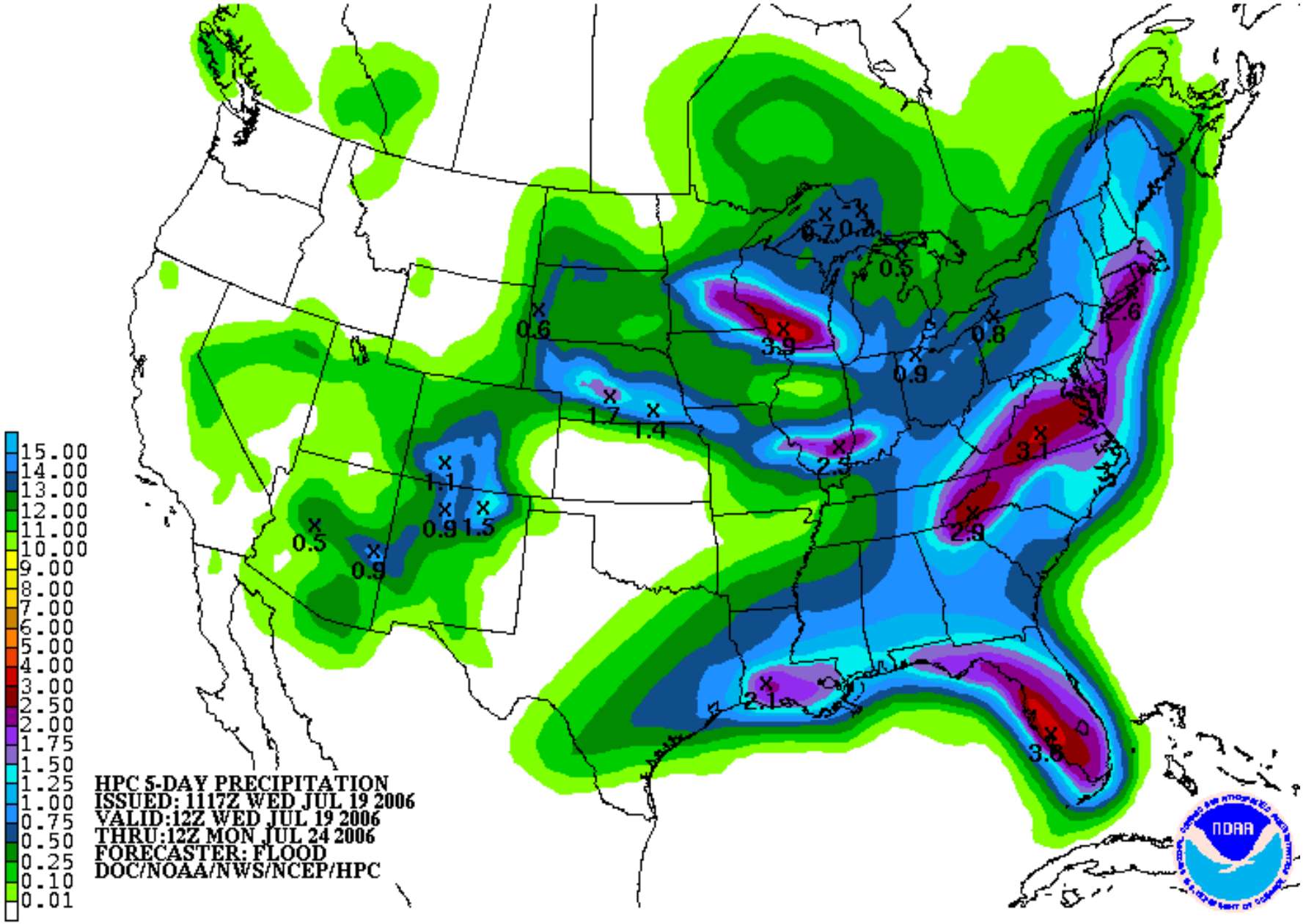
Analysis done for the 1981 Level B study showed that reservoirs now in place would lower the flood stage by 1.3 ft. at Trenton during repetition of the 1955 flood event.

Void programs must be unanimously approved by NYC and the four basin states. They cannot be ordered by the DRBC staff without agreements.

Tropical Storm Beryl



Provided by National Weather Service

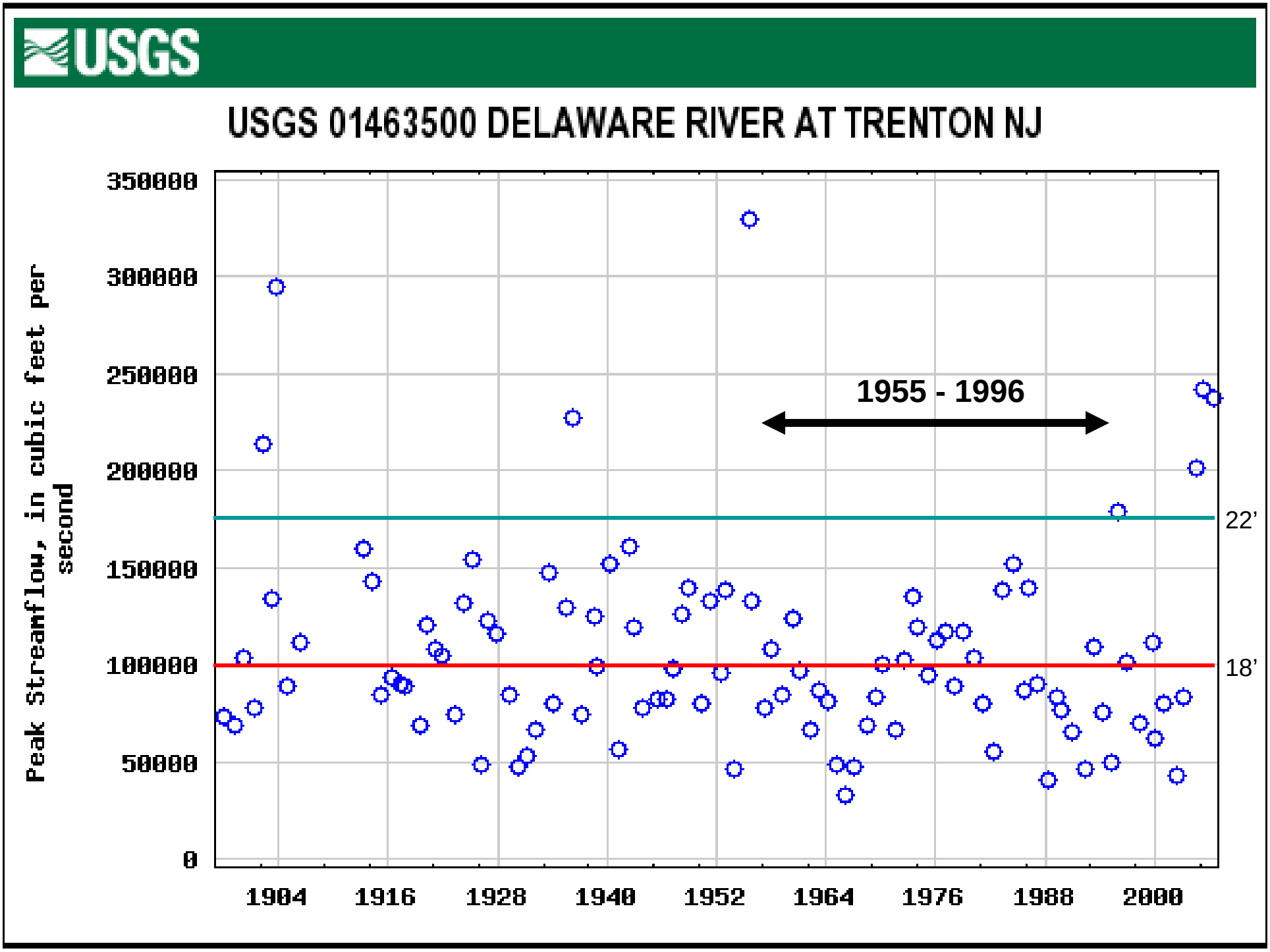


Provided by NOAA - National Weather Service.

Flood of 1955

Increased Federal Involvement in the Delaware River Basin:

- **Corps of Engineers Comprehensive Study of 1956-1960.**
- **Tock's Island Proposed.**


USGS
USGS 01463500 DELAWARE RIVER AT TRENTON NJ
Peak Streamflow, in cubic feet per second
350000
300000
250000
200000
150000
100000
50000
0
1904
1916
1928
1940
1952
1964
1976
1988
2000
1955 - 1996
22'
18'

Three Main Stem Floods in Less Than Two Years

Discussion of Solutions

Partial List of Recommendations Received by DRBC

Three Categories:

1) Lowering Current Flood Levels
2) Reducing Damage from Current Flooding
3) Preventing Flooding from Getting Worse

Lowering Current Flood Levels

- Main Stem Dam
- Tributary Dams
- Dedicated Voids in Water Supply Reservoirs
- Removal of Floodplain Structures
- Channel Modifications
- Stormwater Retrofitting
- Centralization of Flood Control Responsibilities

Reducing Damage from Current Flood Levels

- Removal of Floodplain Structures (Neshaminy)
- Elevation of Floodplain Structures (Neshaminy)
- Levees
- Stormwater Retrofitting
- Flood Warning Improvements
- Flood Stage Forecast Mapping
- Maintain and Improve Dam Safety Programs
- Dambreak Inundation Mapping
- Flood Insurance Map Modernization & Updating
- Local Floodproofing

Preventing Flood Levels from Getting Worse

- No New Construction in 100 yr Floodplains
- Stormwater BMP's for New Construction
- Debris Clearing and Channel Maintenance
- Re-evaluate Floodplains Using Maximum Build-out Assumptions
- Consider Changes in Extreme Precipitation Events due to Climate Change