Hydrologic Conditions in the Delaware River Basin

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April 2005: Flooding in Lambertville, New Jersey

Annual Report 2005

Prepared by Operations Staff
June 2006

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Hydrologic Highlights of 2005- A Year of Flood and Drought

April Flooding

Two early spring rainstorms -- the first on March 28-29 and a second on April 2-3 -- combined with snowmelt to cause major flooding in the Delaware River Basin. The first of these two storms brought more than two inches of rain to the western and northern portions of the basin. Warm temperatures accompanied the rain and melted roughly half of the three inches of water equivalent that existed at the time in the northern watersheds of the basin. Less than a week after the first storm, a second rain event dropped an additional two inches of rain over the Delaware River's headwaters in the Catskill Mountains, melting nearly all of the remaining snowpack. Three to five inches of rain also soaked the middle portion of the basin.

Significant flooding began after the second storm. Along the main stem of the Delaware River, the flood crests exceeded those reached in Tropical Storm Ivan only six-and-a-half months earlier. Once again, the basin endured evacuations, bridge and road closures, and extensive damage. On April 3, the Delaware River at Montague, New Jersey crested at 31.69 feet (ft) or 206,000 cubic feet per second (cfs), the third highest crest on record. On April 4, the Delaware River at Trenton, New Jersey crested at 25.33 ft or 242, 000 cfs, the fourth highest crest on record[1].

Late Summer Drought

August and September 2005 were very dry months for the Delaware River Basin. Mounting precipitation deficits took their toll on the basin's hydrology as ground water levels declined and releases were required from both the New York City Delaware and lower basin reservoirs to augment Delaware River flows. In response to the dry conditions, New Jersey issued a statewide Drought Watch on September 13, 2005, urging residents to voluntarily conserve water.

Relief came in early October with the arrival of remnants of Tropical Storm Tammy. During October 7-8, Tammy produced rainfall in the four to eight inch range for much of the basin, with locally higher amounts of eight to twelve inches[2]. By month's end, streamflows and ground water levels had dramatically improved.

Precipitation

Despite very dry periods during 2005, the majority of counties[3] within the Delaware River Basin reported normal to above-normal annual precipitation. Annual departures ranged from 1.50 inches below normal in Cape May County, New Jersey to 9.40 inches above normal in Sussex County, New Jersey. Year-end precipitation totals ranged from 40.20 inches (Cape May Co., New Jersey) to as much as 55.00 inches (Sussex Co., New Jersey). See the attached map, *Figure 1: 2005 Annual Precipitation in the Delaware River Basin* for a depiction of precipitation totals and departures by county.

Regarding precipitation at selected stations around the basin, the observed precipitation above Montague, New Jersey for 2005 was 48.34 inches, or 5.08 inches above normal. Annual observed precipitation above Trenton, New Jersey was 51.12 inches, or 6.23 inches above normal. Finally, annual observed precipitation at Wilmington, Delaware was 40.30 inches, or 2.51 inches below normal. See the attached *Table 1: 2005 Precipitation at Selected Stations in the Delaware River Basin* for additional precipitation data.

Streamflow

During the early months of 2005, most streams in the basin were flowing at normal to above-normal levels. By late March and early April, two back-to-back rain events and subsequent flooding produced some of the highest average monthly streamflows of 2005. During April 2005, the average monthly streamflow at Montague was recorded as 23,956 cubic feet per second (cfs), which is 210 percent of normal for the month. Similarly,

streamflow at Trenton averaged 45,437 cfs (226 percent of normal). At the Lehigh River at Bethlehem, average monthly streamflow during April was 7,851 cfs (215 percent of normal) and at the Schuylkill River at Philadelphia, the average streamflow for the month was 8,403 cfs (234 percent of normal).

The basin experienced a drier than normal May and as a result, streamflows declined to below-normal levels at many stations in the basin. Many stations continued to experience below-normal streamflows into early fall, finally improving in October when heavy rains associated with Tropical Storm Tammy revived streamflows throughout the basin. Along the main stem, October's streamflow averages at Montague and at Trenton were 10,059 cfs (421 percent above normal) and 23,481 cfs (441 percent above normal), respectively. Streamflows remained near or above-normal levels for the remainder of the year.

Please refer to the attached *Table 2: 2005 Streamflow in the Delaware River Basin* for additional information about average monthly streamflow at selected stations. Refer to *Figure 2: Delaware River at Montague, NJ* and *Figure 3: Delaware River at Trenton, NJ* for annual hydrographs of these two Delaware River stations.

Reservoir Storage

Lower Basin

In order to meet the Delaware River flow objective of 3,000 cfs at Trenton, New Jersey, DRBC directed releases from the lower basin reservoirs in late summer. A total of 2,300 cfs were released over 21 days between August 5 and September 20, with more than 75 percent of the releases coming from Blue Marsh Reservoir.

The combined effects of directed releases and reduced inflows caused storage in Blue Marsh reservoir (located on the Tulpehocken Creek, a tributary of the Schuylkill River) to drop into the drought warning zone by late September. Fortunately, ample rainfall in early October caused storage to rebound into the normal range by the middle of the month. Beltzville Reservoir (located on the Pohopoco Creek, a tributary of the Lehigh River) experienced a sharp decline in storage during August and September, but remained in normal range throughout the year.

No releases were required from Merrill Creek Reservoir during 2005. Merrill Creek Reservoir, located in Phillipsburg, New Jersey, replaces evaporative losses caused by power generation and provides storage for augmenting flows at Trenton, New Jersey when the basin is under drought operations.

Please refer to *Figure 4: 2005 Directed Releases from Lower Basin Reservoirs* for a pie chart of individual reservoir releases from Blue Marsh and Beltzville reservoirs. Also, please refer to *Figure 5: Blue Marsh Reservoir Elevation* and *Figure 6: Beltzville Reservoir Elevation* for 2005 elevations.

Upper Basin

For the third year in a row, the New York City (NYC) reservoirs in the upper Delaware River Basin began the year with storage above the long-term median. As of January 1, the Cannonsville, Pepacton, and Neversink reservoirs had a combined storage of 270.990 billion gallons (bg), which is 100.1 percent of usable capacity and 81.427 bg above the median storage for the date.

Storage gradually declined through late March, but remained well above the long-term median storage. Two flood-producing rain events in late March and early April combined with snowmelt to boost storage to an annual recorded high of 288.588 bg on April 3, 2006. The reservoirs remained above capacity on May 1, the median date for refill.

After peaking from the heavy inflows of early April, reservoir storage began to decline. By mid-May, NYC Delaware storage had dropped below the long-term median. Late spring and summer rainfall deficits caused

storage to drop sharply away from the median. From May 23 through October 9, the Delaware River Master directed releases from the three reservoirs totaling approximately 70 bg. These releases were made to augment declining streamflow at Montague, New Jersey.

A precipitous decline continued until early October when much above normal rainfall increased inflows to the reservoir system. By the end of October, storage in the NYC Delaware reservoirs was back above the long-term median. Storage continued to increase and remained above the median during the normal recharge period of fall and early winter.

As of December 31, total usable storage in the three NYC Delaware reservoirs was 245.012 bg (90.5 percent of usable storage) which is 56.184 bg above the long-term median storage for the date. For a graphical presentation of NYC Delaware reservoir storage levels for 2005, please refer to *Figure 7: New York City Delaware River Basin Storage 2005.*

Ground Water

The average observed ground water levels in eight reported USGS observation wells in the Pennsylvania portion of the basin remained above the long-term average through May. By June, ground water levels declined to below the long-term average, marking the start of a seasonal downward trend which would continue throughout the summer. August and September proved to be the most severe months of 2005 as dry conditions caused the water levels to drop sharply away from the long-term average. Heavy rains in early October arrived in time to recharge the observation wells to above the long-term average. Ground water levels remained above average for the remainder of 2005.

Monthly measurements of ground water within two coastal plain wells (New Castle Co., Delaware and Cumberland Co., New Jersey) recorded levels within the normal (25- to 75-percentile) to above-normal (greater than 75-percentile) range for all of 2005. Monthly measurements for the Kent Co. well recorded levels below the normal range (less than 25-percentile) for months January through March. Monthly measurements from April through September fell within the normal range (25- to 75-percentile). Kent County well measurements were discontinued in September 2005.

Please refer to the attached *Figure 8: USGS Network Wells-Pennsylvania, Figure 9: DGS Well-New Castle Co., Delaware*, *Figure 10: USGS Well- Cumberland Co., New Jersey*, and *Figure 11: USGS Well-Kent Co., Delaware* for graphical presentations of ground water levels throughout 2005.

Salt Line

The *salt line* is defined as the 7-day average of the 250 parts-per-million isochlor. The salt line's location does fluctuate along the main stem Delaware River as streamflow increases or decreases in response to changing inflows, diluting or concentrating chlorides in the river. Long-term average mid-month locations range from river mile 61 in mid-April (.5 miles below Pea Patch Island, Delaware) to river mile 81 in mid-October (Marcus Hook, Pennsylvania).

During 2005, the salt line location ranged from as far downstream as below river mile 54 to as far upstream as river mile 90 (just two miles below the mouth of the Schuylkill River). See the attached *Figure 12: Location of the 7-Day Average of the 250-PPM Isochlor* for an overview of salt line locations along the Delaware River during 2005.

Notes:

[1]During the 1955 flood of record, the Delaware River at Montague, NJ and Trenton, NJ crested at 35.15 ft and 28.6 ft, respectively.
[2]Based on *Dopplar Radar Estimated Precipitation* maps from Intellicast.com web site.

[3]This information was based on precipitation data from the National Weather Service Middle Atlantic River Forecast Center for 38 of the 42 counties located either partially or completely in the Delaware River Basin. Data for the remaining four counties is not available. Departures from normal were calculated by DRBC staff.

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Annual Report 2005

Figures and Tables

FIGURE 1: 2005 ANNUAL PRECIPITATION IN THE DELAWARE RIVER BASIN

Total Precipitation (Top) and Departure from Normal (Bottom) In Inches

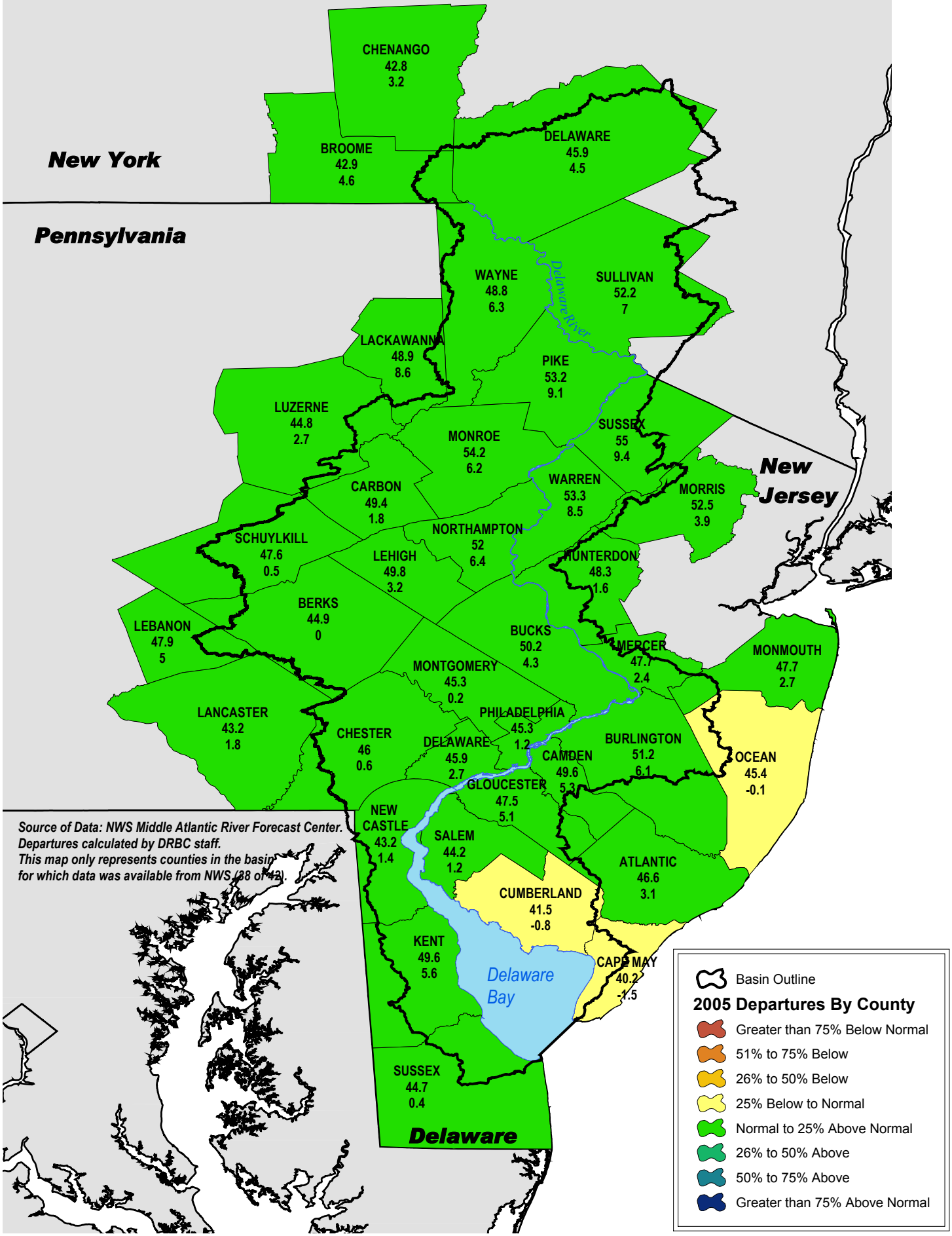


FIGURE 2: DELAWARE RIVER AT MONTAGUE, NJ

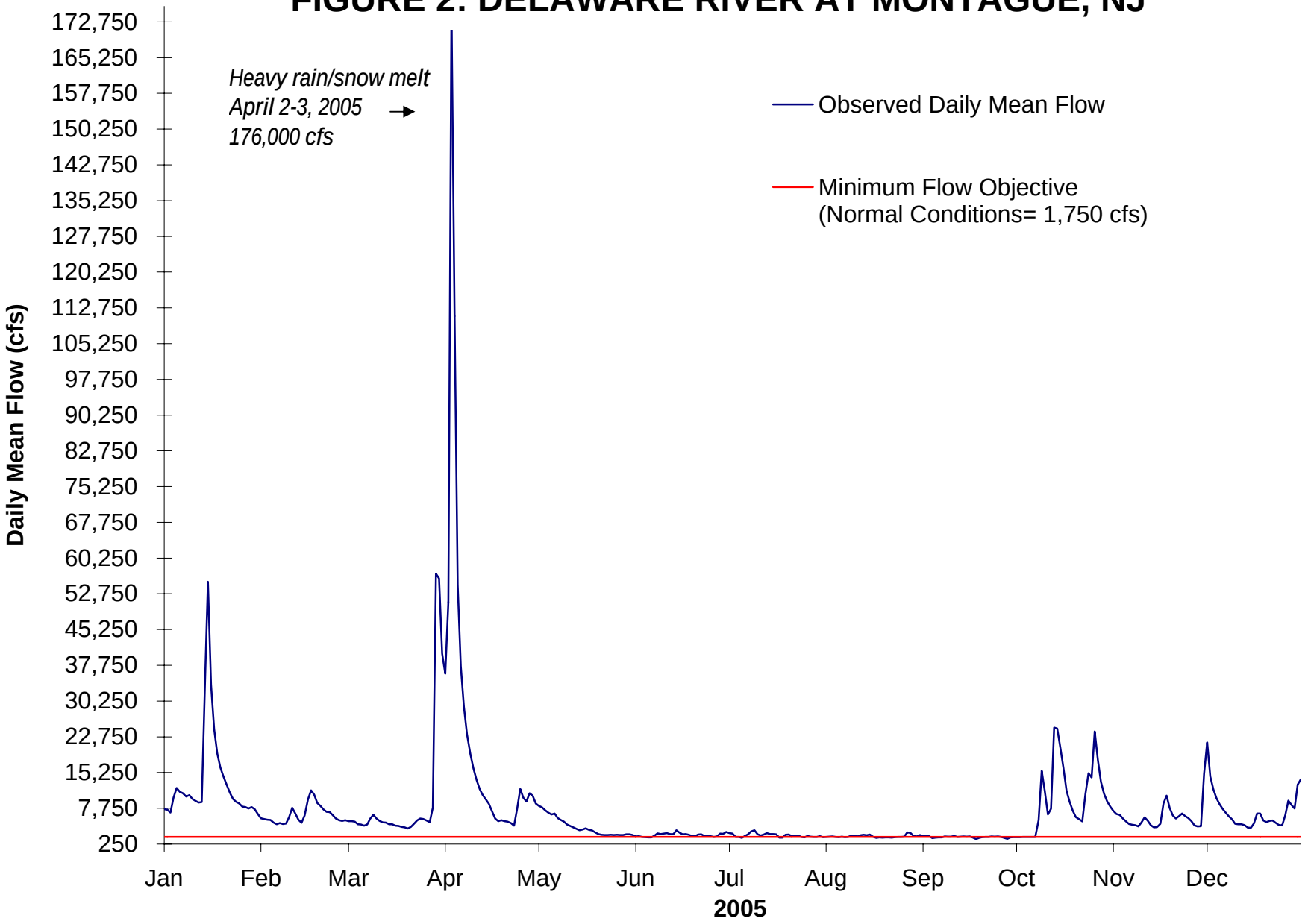


FIGURE 3: DELAWARE RIVER AT TRENTON, NJ

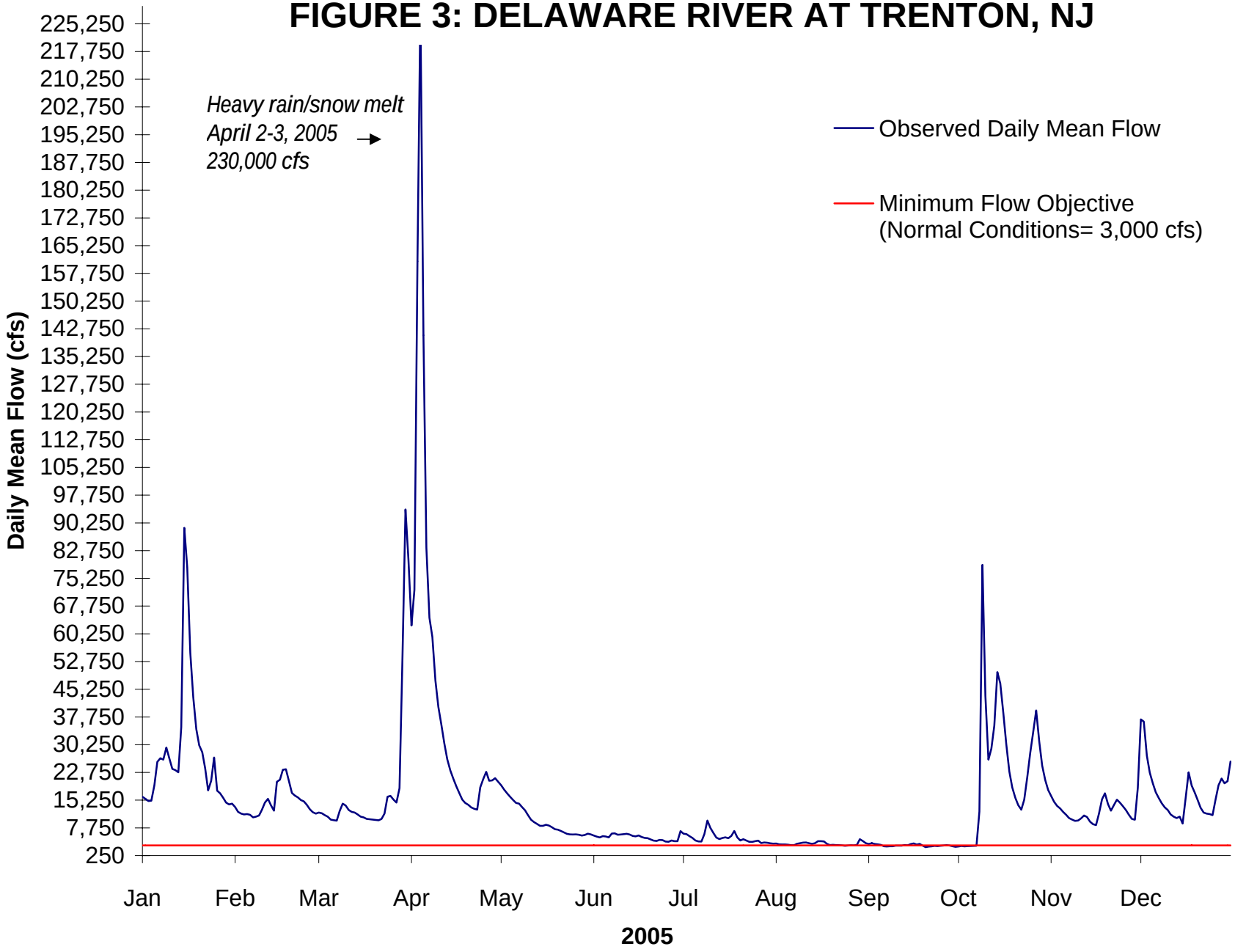
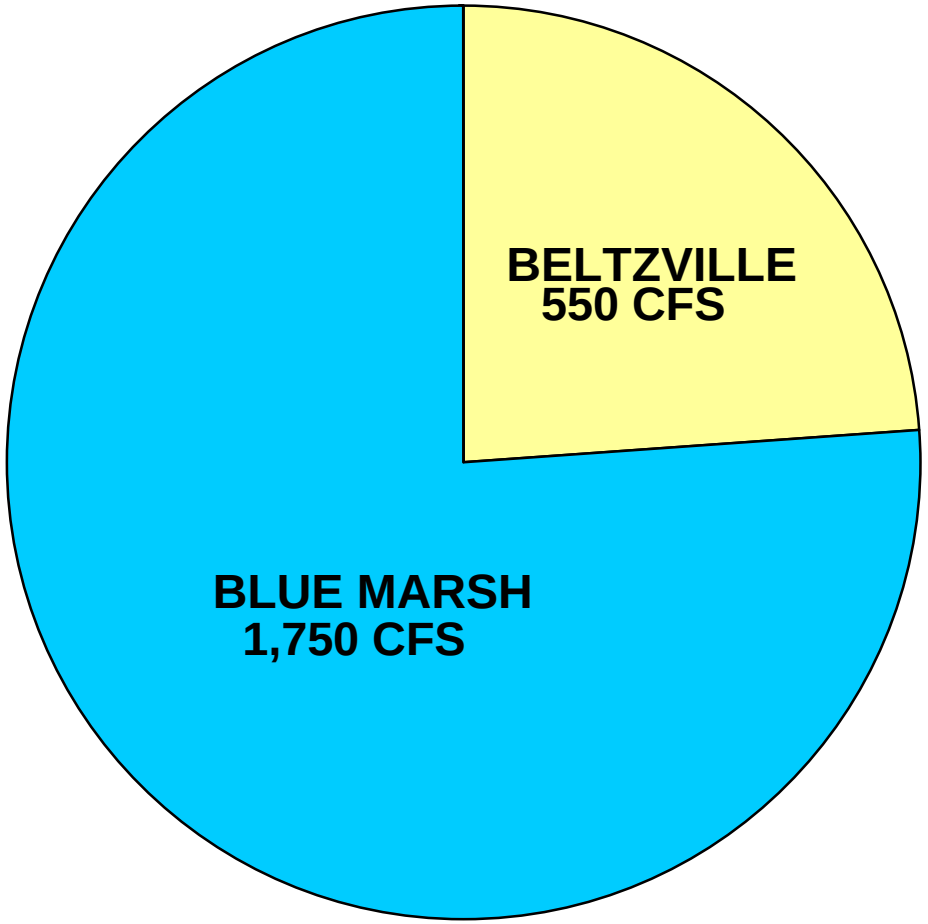


FIGURE 4: 2005 DIRECTED RELEASES FROM LOWER BASIN RESERVOIRS

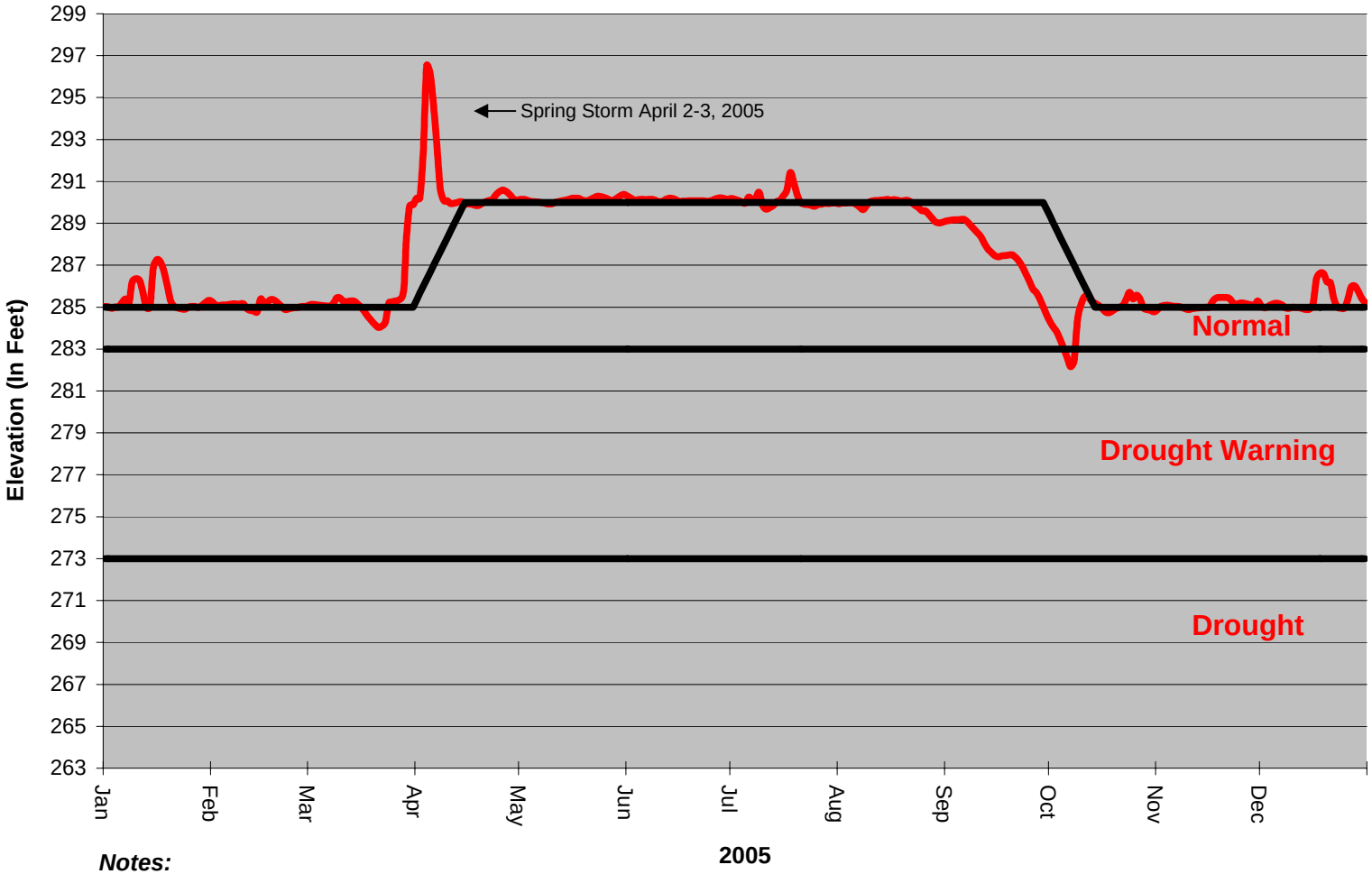
Released August-September



ANNUAL TOTAL=2,300 CFS-DAYS

Note: DRBC did not request flow augmentation releases from F.E. Walter Reservoir during 2005.

FIGURE 5: BLUE MARSH RESERVOIR ELEVATION

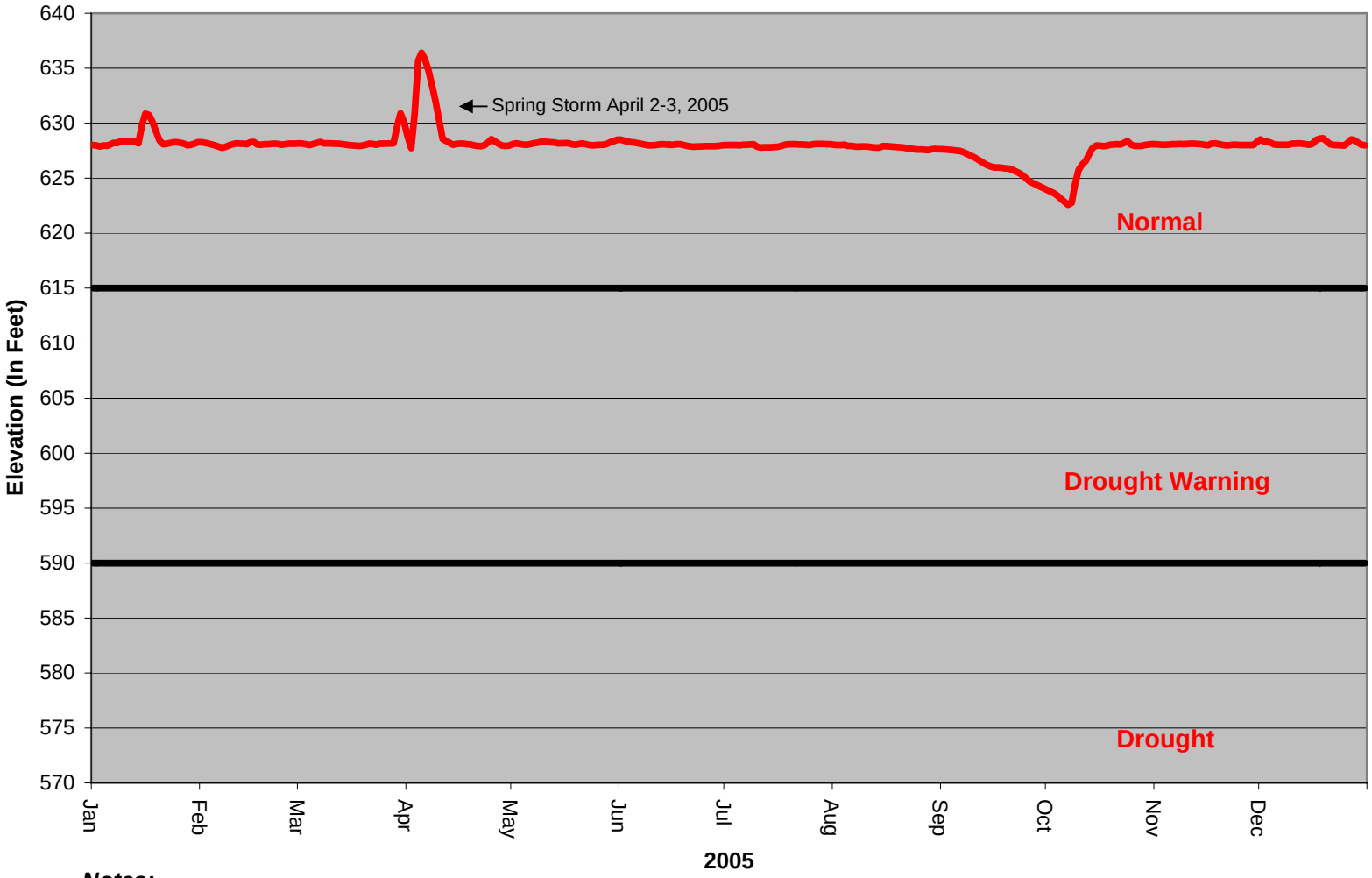


Notes:

1. Winter Pool=285 FT/ Summer Pool= 290 FT

2. Graph represents the daily 7 am elevations.

FIGURE 6: BELTZVILLE RESERVOIR ELEVATION

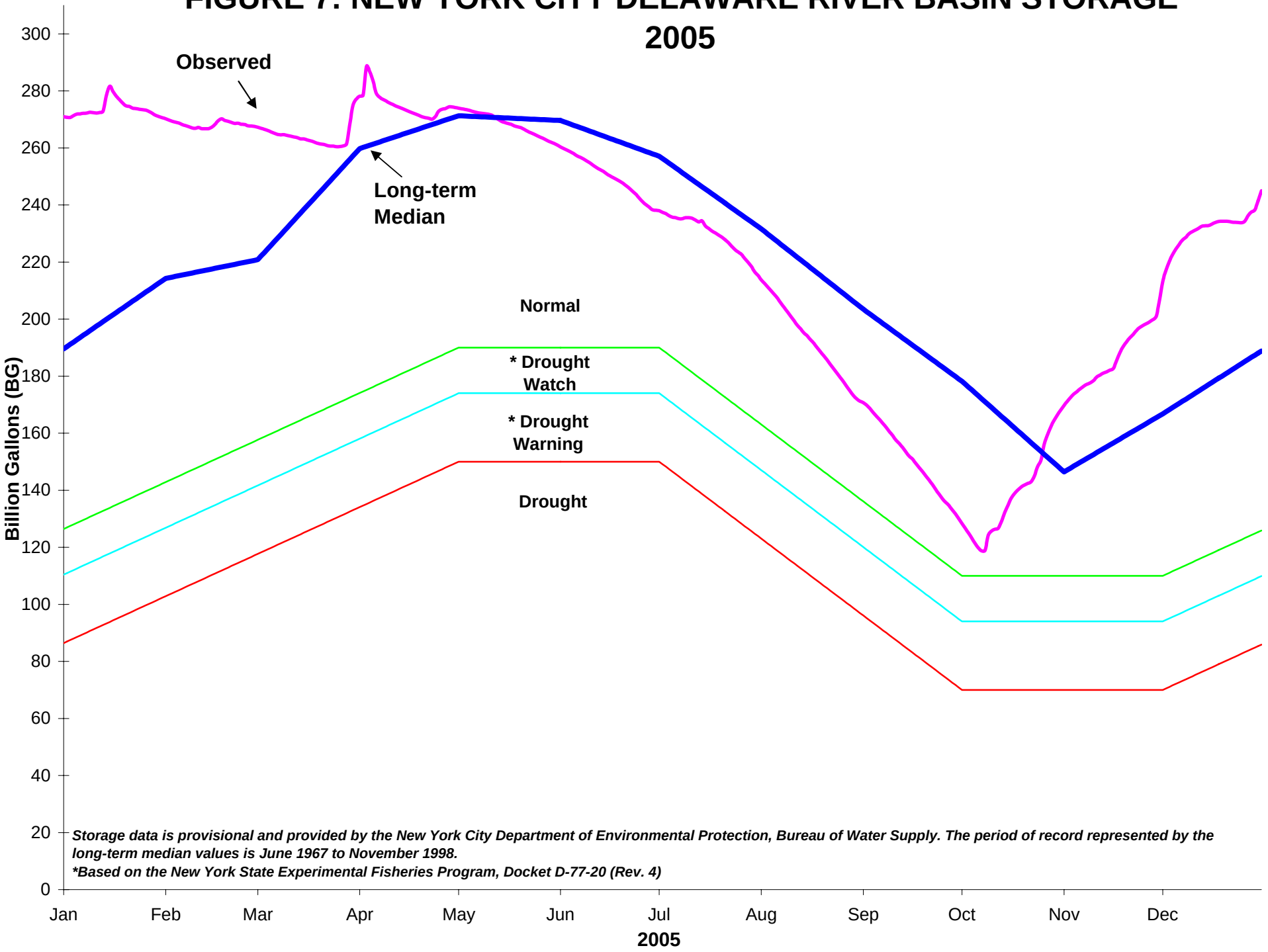


Notes:

1. Normal Pool Elevation 628 FT.

2. Graph represents the daily 7 am elevations.

FIGURE 7: NEW YORK CITY DELAWARE RIVER BASIN STORAGE
2005



Storage data is provisional and provided by the New York City Department of Environmental Protection, Bureau of Water Supply. The period of record represented by the long-term median values is June 1967 to November 1998.

Based on the New York State Experimental Fisheries Program, Docket D-77-20 (Rev. 4)

FIGURE 8: USGS NETWORK WELLS-PENNSYLVANIA
Average Vs. Actual 2005

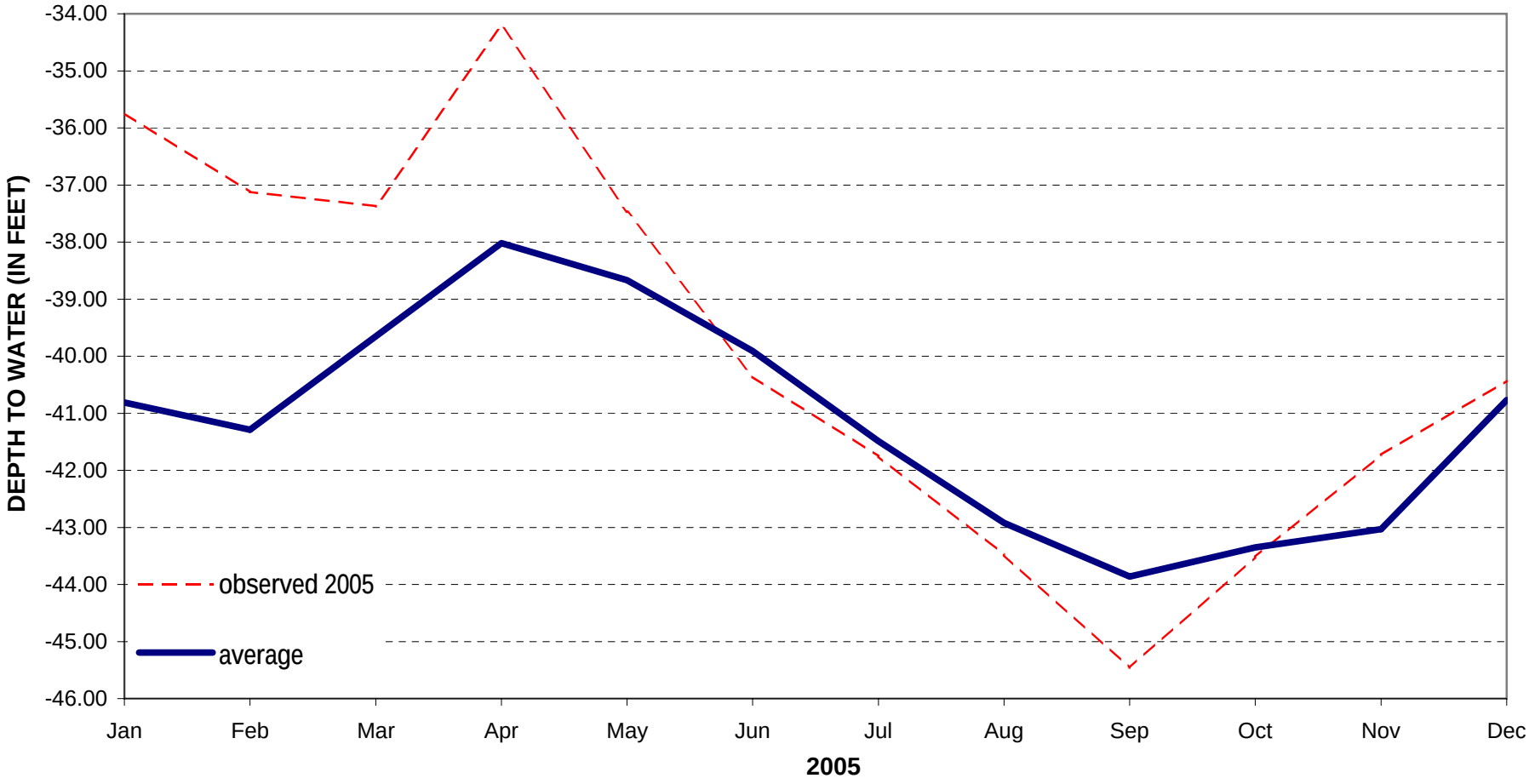


FIGURE 9: DGS WELL-NEW CASTLE CO., DELAWARE
Average Vs. Actual 2005

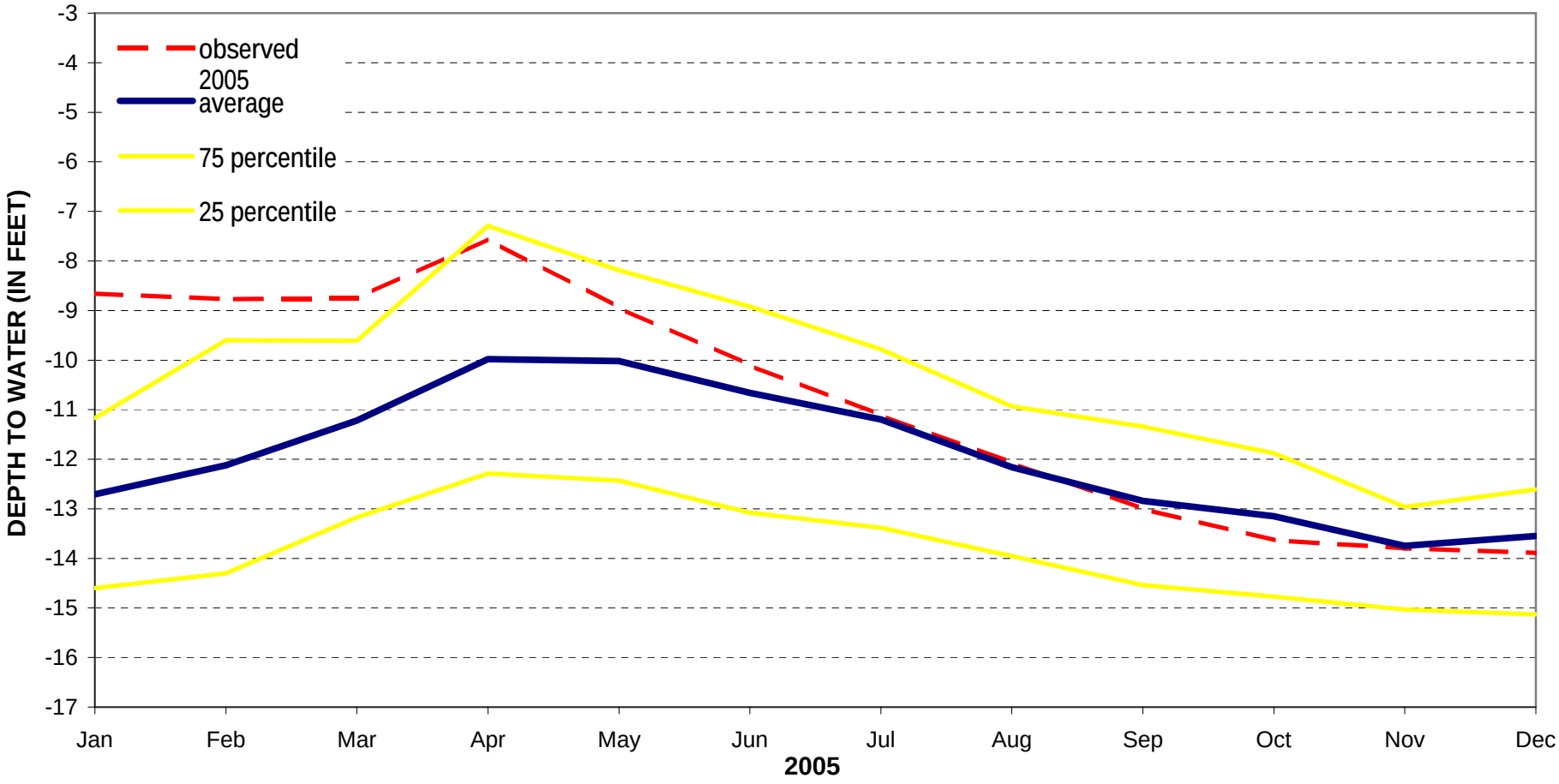


FIGURE 10: USGS WELL-CUMBERLAND CO., NEW JERSEY
Average Vs. Actual 2005

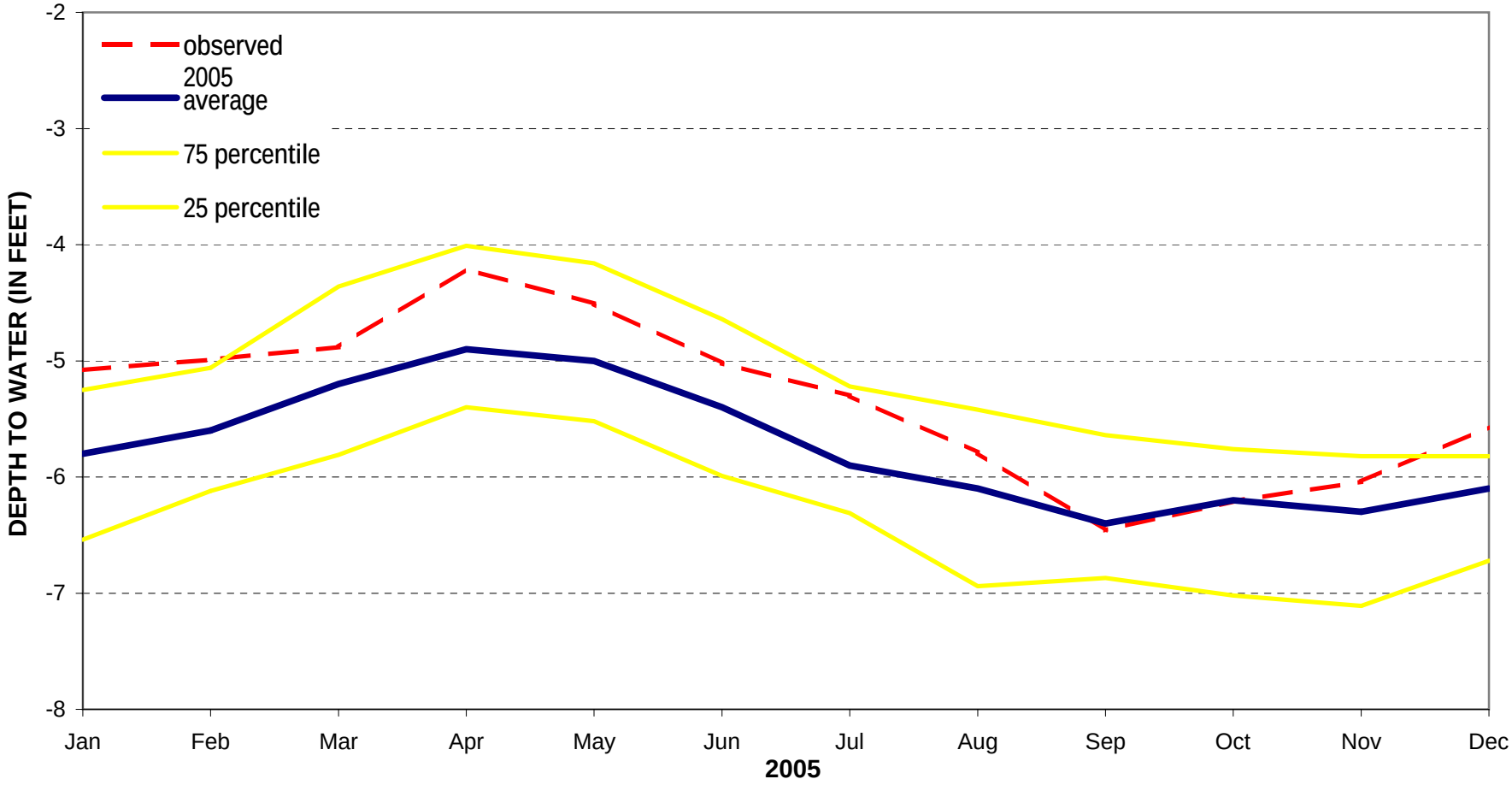
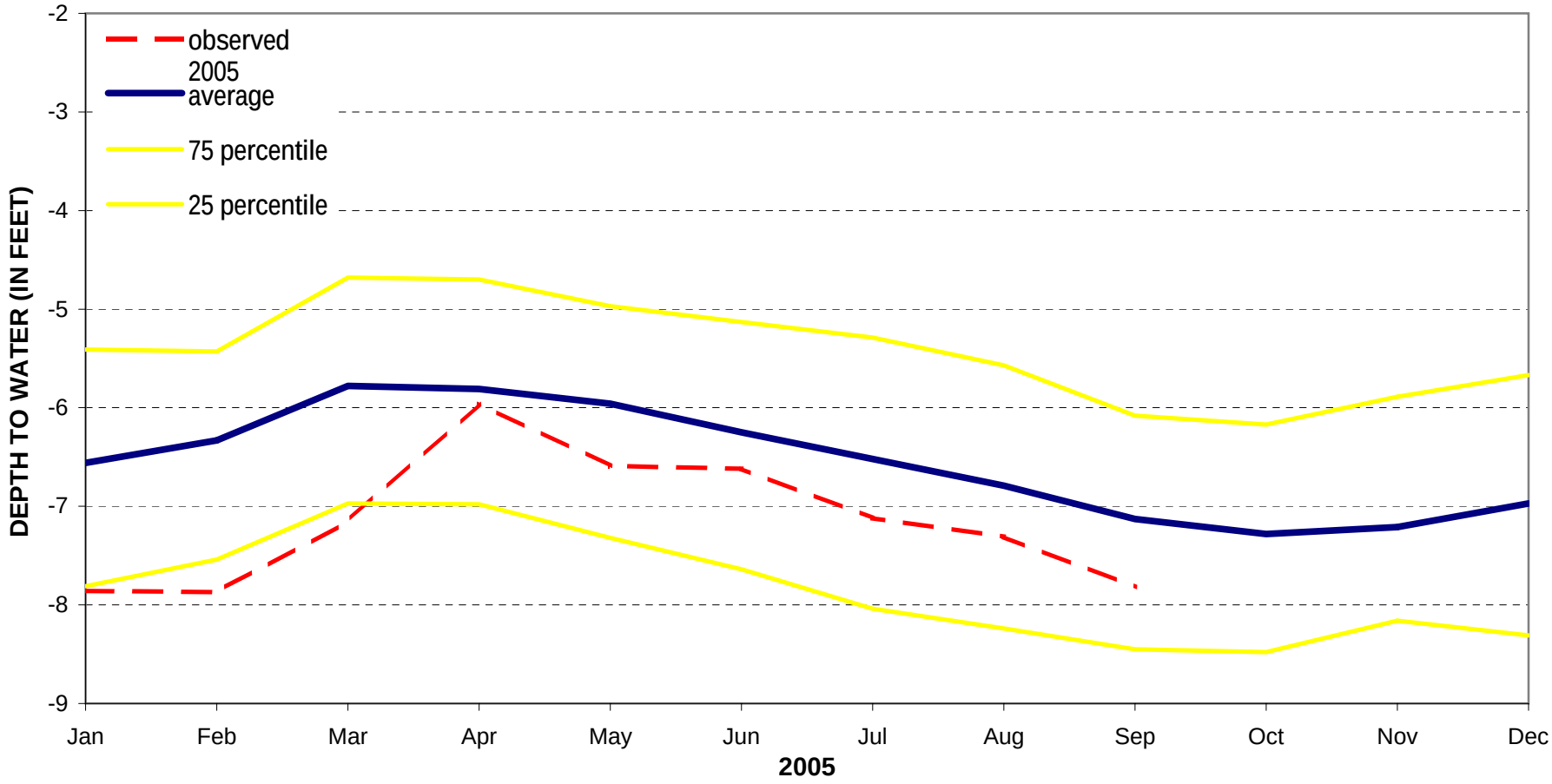
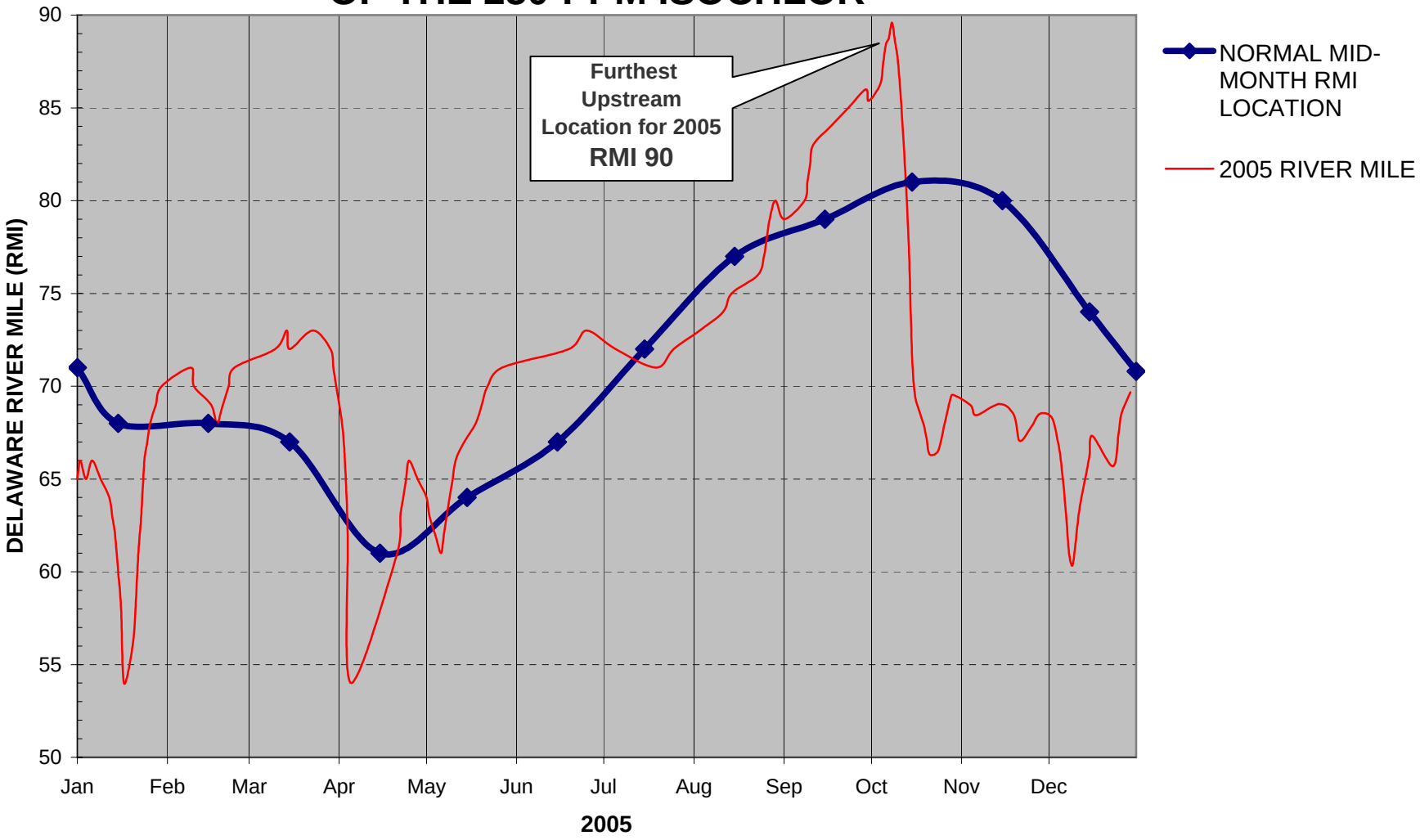


FIGURE 11: USGS WELL-KENT CO., DELAWARE
Average Vs. Actual 2005



Note: Kent County well measurements were discontinued in September 2005.

FIGURE 12: LOCATION OF THE 7-DAY AVERAGE OF THE 250-PPM ISOCHLOR



Note: DRBC does not estimate locations below river mile 54.

TABLE 1: 2005 PRECIPITATION AT SELECTED STATIONS IN THE DELAWARE RIVER BASIN (INCHES)

	AVG ABOVE MONTAGUE, NJ		ALLENTOWN, PA		AVG ABOVE TRENTON, NJ		READING, PA		PHILADELPHIA, PA		WILMINGTON, DE	
	NORM	OBS	NORM	OBS	NORM	OBS	NORM	OBS	NORM	OBS	NORM	OBS
JAN	3.02	5.67	3.50	5.38	3.15	5.63	3.72	4.14	3.52	4.45	3.43	3.84
FEB	2.65	1.86	2.75	2.72	2.96	2.62	2.77	2.03	2.74	2.61	2.81	2.65
MAR	3.33	4.23	3.56	3.75	3.52	4.45	3.60	3.83	3.81	3.66	3.97	4.10
APR	3.77	5.26	3.49	6.56	4.02	5.93	3.68	5.02	3.49	5.32	3.39	5.12
MAY	4.21	1.31	4.47	1.23	4.04	1.40	4.52	1.02	3.89	1.27	4.15	2.26
JUNE	3.96	3.40	3.99	4.27	3.89	3.03	4.36	1.43	3.29	3.31	3.59	2.25
JULY	4.09	2.92	4.27	4.23	4.21	3.60	4.07	8.17	4.39	4.31	4.28	4.83
AUG	3.85	3.59	4.35	2.14	4.15	3.14	3.61	1.70	3.82	2.57	3.51	1.35
SEPT	3.83	1.72	4.37	0.76	3.93	1.49	4.36	0.56	3.88	0.21	4.01	0.44
OCT	3.38	11.83	3.33	13.16	3.41	11.97	3.28	11.66	2.75	8.68	3.08	7.79
NOV	3.83	3.91	3.70	3.58	3.99	4.21	3.54	3.11	3.16	2.86	3.19	2.41
DEC	3.34	2.64	3.39	3.58	3.62	3.65	3.31	3.90	3.31	2.97	3.40	3.26
TOT 2005	***43.26***	***48.34***	***45.17***	***51.36***	***44.89***	***51.12***	***44.82***	***46.57***	***42.05***	***42.22***	***42.81***	***40.30***
DIFF 2005		**5.08**		**6.19**		**6.23**		**1.75**		**0.17**		**-2.51**

Period of Record and Data Sources:

Average above Montague, NJ --- 1941 to 2000, Delaware River Master
Allentown, PA --- 1971 to 2000, National Weather Service
Average above Trenton, NJ--- 1971-2000, National Weather Service
Reading, PA--- 1971 to 2000, National Weather Service
Philadelphia, PA--- 1971 to 2000, National Weather Service
Wilmington, DE--- 1971 to 2000, National Weather Service

TABLE 2: 2005 STREAMFLOW (IN CFS) IN THE DELAWARE RIVER BASIN

OBSERVED MONTHLY MEAN FLOW VERSUS [1]NORMAL MONTHLY FLOW

		Delaware River @ Montague	Lehigh River @ Lehighton	Lehigh River @ Bethlehem	Delaware River @ Trenton	Schuylkill River @ Philadelphia	Schuylkill River @ Pottstown
Jan	OBS	13,458	3,015	5,340	27,794	6,499	4,290
	% NORM	270.6%	274.6%	206.1%	216.0%	232.6%	214.3%
Feb	OBS	6,399	1,379	2,672	14,711	3,961	2,399
	% NORM	112.2%	104.6%	89.0%	106.3%	98.2%	87.6%
Mar	OBS	9,311	1,791	3,904	18,246	5,271	3,315
	% NORM	163.2%	135.9%	130.1%	131.8%	130.7%	121.0%
Apr	OBS	23,956	3,762	7,851	45,437	8,403	5,068
	% NORM	210.4%	214.6%	215.2%	226.0%	234.5%	189.1%
May	OBS	3,898	825	1,919	9,787	1,958	1,359
	% NORM	56.8%	52.3%	69.5%	71.7%	70.4%	65.6%
Jun	OBS	2,173	490	1,308	5,221	1,181	863
	% NORM	64.6%	50.8%	65.8%	63.7%	64.7%	61.5%
Jul	OBS	2,080	474	999	5,031	1,899	1,157
	% NORM	80.7%	65.2%	69.7%	81.8%	136.8%	109.3%
Aug	OBS	1,884	245	597	3,448	846	591
	% NORM	88.5%	54.0%	54.8%	68.0%	73.3%	71.8%
Sep	OBS	1,724	188	515	3,017	657	487
	% NORM	79.6%	43.2%	44.7%	60.4%	59.6%	52.4%
Oct	OBS	10,059	1,525	3,801	23,481	4,968	2,619
	% NORM	420.7%	218.8%	255.8%	441.4%	399.3%	278.6%
Nov	OBS	5,848	1,125	2,200	12,360	2,265	1,422
	% NORM	134.9%	87.7%	95.6%	118.4%	95.9%	81.5%
Dec	OBS	7,307	1,983	3,795	17,427	4,377	2,756
	% NORM	148.6%	146.8%	137.7%	154.1%	141.6%	129.2%

[1]Median of monthly mean values for 1971-2000 period were used, except for the Lehigh River at Lehighton. For Lehighton, normal flow values represent the median of monthly means for 1983-2000 (the entire period of record for the station).

Source: United States Geological Survey streamgage measurements. Based on provisional data and subject to change.