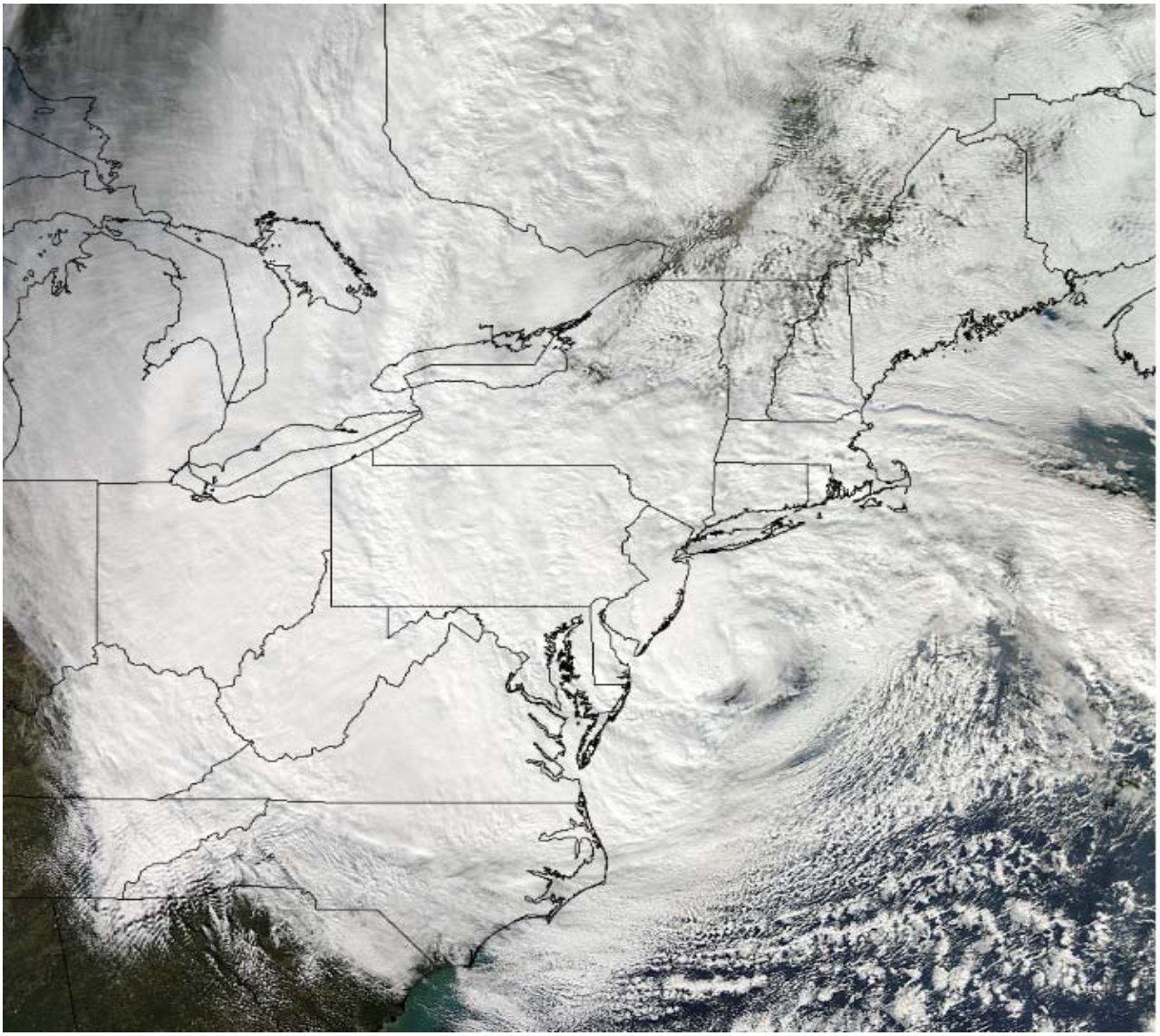
2012

Hydrologic Conditions in the Delaware River Basin



SUPERSTORM SANDY- Sandy engulfs the Delaware River Basin and surrounding states on October 29, 2012, 2:20 p.m. EDT.

Credit: NASA/Goddard MODIS Rapid Response Team

Prepared by DRBC Water Resources Management Branch, Operations Section

September 2013

Delaware River Basin Commission
DELAWARE · NEW JERSEY
PENNSYLVANIA · NEW YORK
UNITED STATES OF AMERICA

Hydrologic Conditions in the Delaware River Basin
Annual Report 2012

Hydrologic Highlights of 2012

A Dry Start to the Year

Much of the Delaware River Basin (DRB) experienced below-normal precipitation and snowpack during the early months of 2012. The lack of significant snowpack was of particular concern because the water it stores is vital for recharging the DRB's rivers, lakes, reservoirs, and groundwater. A February 1, 2012 snow survey conducted by the New York City Department of Environmental Protection (NYCDEP) indicated water storage totaling less than one billion gallons (BG) above the Cannonsville, Pepacton, and Neversink reservoirs[1]. The historical average for the Delaware system for that date is 27 BG. Total snowpack water storage increased to 13 BG by the March 1 NYCDEP survey, but it was still 68 percent below the historical average[2] of 41 BG for that time of the year.

The dry conditions were not severe enough to require the Delaware River Basin Commission (DRBC) or any of the basin states to implement drought declarations, but streamflow and groundwater were impacted. Many streams and rivers were flowing at 50 percent or less of normal by March and April. By mid-spring, U.S. Geological Survey (USGS) groundwater monitoring wells in Monroe, Schuylkill, and Carbon counties in Pennsylvania recorded water levels below the drought emergency level (0- to-5 percentile depth). Several other groundwater monitoring wells in the Pennsylvania portion of the basin also reported below-normal water levels in the drought watch (10- to 25-percentile depth) to drought warning (5- to 10- percentile depth) range[3].

In its April 17 report, the U.S. Drought Monitor represented portions of the upper DRB as "D0-Moderately Dry," but the majority of the DRB was depicted as "D1-Moderate Drought." Drought conditions in the state of Delaware were more acute and were represented as "D2- Drought-Severe." Although the DRB's hydrologic conditions improved with the return of above-normal rainfall in late May, the U.S. Drought Monitor depicted portions of the DRB as abnormally dry to severe drought (the latter in the state of Delaware) until the arrival of Hurricane Sandy in late October.

Tropical Storm Isaac

Remnants of Tropical Storm Isaac impacted the DRB during the first week of September. Flooding did not occur at any of the Middle Atlantic River Forecast Center's (MARFC) river forecast points, but the storm produced flash flooding on smaller streams and localized street flooding. The basin generally received between one and two inches of rain from this system. Locally higher rainfall amounts of three to seven inches occurred in northern Delaware, northeastern and southeastern Pennsylvania, and northern New Jersey.

Superstorm Sandy

Hurricane Sandy passed over portions of the DRB in late October 2012. Sandy was the 18th named storm of the 2012 Hurricane Season and the second-most costly hurricane in U.S. history, second only to Hurricane Katrina in 2005. The storm made landfall as a post-tropical cyclone just south of Atlantic City, N.J. at 8 pm on October 29. Sandy produced a major – and in some locations a record – storm surge along the New Jersey coast. This extreme surge was due to the fact that Sandy arrived during the astronomical high tide period. As Sandy pushed

[1] Snow Survey #2, New York City Department of Environmental Protection, 2/1/2012
[2] Snow Survey #3, New York City Department of Environmental Protection, 3/1/2012
[3] USGS, 30-day duration observation well graphs, http://pa.water.usgs.gov/infodata/well_duration.php.

west into Pennsylvania, the tidal sections along the Delaware River at and near Philadelphia also experienced record water levels.

Heavy rain and high winds began from southeast to northwest as Sandy skimmed Delaware and approached New Jersey's shores. Five inches to as much as a foot of rain fell in South Jersey and Delaware. To the north of the hardest hit areas, one to three inches of rain was reported and flooding was minimal.

Very high wind gusts accompanied Sandy, bringing down trees and utility lines and causing long-term power outages. The highest gusts were to the north and east of the storm's center and Sandy provided many areas of the mid-Atlantic region with some of the highest wind gusts since Hurricane Hazel in October 1954. Gusts in Ocean County, N.J. reached near 90 mph and many areas in the basin experienced gusts of more than 50 mph[4].

Precipitation

Twenty-nine of the 38 reported counties[5] within the DRB ended the year with below-normal precipitation. Annual precipitation totals ranged from 36.8 inches in Philadelphia County, Pa. to 51.9 inches in Ocean County, N.J. Annual precipitation departures from normal ranged from 7.2 inches below normal in Philadelphia Co. to 6.3 inches above normal in Ocean Co.

The following amounts were recorded during 2012 at select stations throughout the DRB[6]: observed precipitation above Montague, N.J. was 44.17 inches (or 0.91 inches above normal), observed precipitation above Trenton, N.J. was 44.10 inches (or 0.79 inches below normal), and observed precipitation at Wilmington, Del. was 36.31 inches (or 6.50 inches below normal).

Figure 1 presents the annual precipitation by county in the Delaware River Basin and Table 1 presents normal and observed monthly precipitation totals at select stations in the DRB for 2012.

Streamflow

Observed monthly mean streamflow at select stations along the Lehigh River, the Schuylkill River, and the main stem of the Delaware River were below normal during February through April 2012. This was due to the previously mentioned dry winter with below-normal snowpack that limited recharge to streams and rivers.

The lowest monthly mean streamflow occurred during April 2012. Along the main stem Delaware River at Montague, N.J. and Trenton, N.J., the streamflow averaged 30 percent and 33 percent-of-normal, respectively. During April 7-22, new daily low flow records were set on those days for the Delaware River at Trenton. Streamflow observations along the Delaware's largest tributaries were also very low, averaging 35 percent of normal flow on the Lehigh River at Bethlehem and 46 percent of the normal flow on the Schuylkill River at Philadelphia. Streamflow at these select stations improved during May-June and were below normal to normal during July-August.

[4] Superstorm Sandy information was sourced from the *Superstorm Sandy Storm Summary*, National Weather Service, Philadelphia/Mount Holly Office.

[5] This information is based on precipitation data from the National Weather Service Middle Atlantic River Forecast Center (NWS MARFC) 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. The NWS uses several precipitation stations to calculate an average precipitation total for each county. Annual precipitation departures are calculated by DRBC staff using the NWS MARFC data.

[6] Select station precipitation data were provided by the NWS and the Delaware River Master's Office. Annual precipitation departures are calculated by DRBC staff using the provided data.

Above-normal rainfall during October produced the highest monthly mean streamflow of the year at many locations in the DRB. During the month, streamflow along the main stem Delaware River at Montague and Trenton averaged more than double the normal flow. Many locations along the Lehigh and Schuylkill rivers averaged two to three times their normal October streamflow. Streamflow observations at the select stations remained above normal for the remainder of 2012. Table 2 presents observed monthly mean streamflow at select stations for 2012. Figure 2 and Figure 3 present annual hydrographs for 2012 at Montague and Trenton, respectively.

Reservoir Storage

Lower Basin

Both Beltzville Reservoir (located on the Pohopoco Creek, a tributary of the Lehigh River) and Blue Marsh Reservoir (located on the Tulpehocken Creek, a tributary of the Schuylkill River) maintained storage in the normal range during 2012. Consequently, the DRBC's lower basin drought operating plan was not implemented.

The commission directed releases from Beltzville Reservoir during a brief period in late summer 2012 to maintain the streamflow objective of 3,000 cubic feet per second (cfs) on the Delaware River at Trenton, N.J. DRBC-directed releases totaling 0.73 BG began on August 28 and ended on September 4 in anticipation of rainfall from the remnants of Tropical Storm Isaac.

Figure 4 and Figure 5 present 2012 reservoir elevations for Beltzville and Blue Marsh, respectively. Please note in Figure 5 that the Blue Marsh reservoir elevation was briefly lowered to the Drought Warning level (elevation 283 feet) in anticipation of Hurricane Sandy in late October 2012. Storage returned to the normal winter pool level (elevation 285 feet) soon after the storm event.

No releases were made from Merrill Creek Reservoir during 2012. Storage in this reservoir, located near Phillipsburg N.J., is used to replace evaporative losses caused by power generation when the basin is under DRBC-declared drought operations and the equivalent average daily flow target on the Delaware River at Trenton is below 3,000 cfs.

Upper Basin

The three New York City (NYC) Delaware reservoirs – Cannonsville, Pepacton, and Neversink – are located in the upper DRB and are operated under the Flexible Flow Management Program (FFMP)[7]. Combined storage did not go below the drought watch level during 2012; consequently, DRBC's basinwide drought operating plan was not implemented.

On January 1, 2012, combined storage in Cannonsville, Pepacton, and Neversink reservoirs was 263 BG, which is 97 percent usable capacity and 73 BG above the long-term median usable storage for the date. However, without the normal amount of snowpack to recharge the water supply during the spring melt, reservoir storage declined to below the median by mid-April. Conditions improved during May with the return of normal to above-normal rainfall in the upper basin. The NYC reservoirs refilled by late May, several weeks after the normal refill date of May 1. Soon after refilling, storage rapidly declined and dipped below the median on June 1, but increased to above the median by early autumn. On December 31, 2012, combined storage in the three reservoirs was 223 BG, which is 82 percent usable capacity and 34 BG above the long-term median usable storage for the date. Figure 6 presents NYC reservoir storage levels for 2012.

[7] The NYC reservoirs were operated in accordance with the FFMP, a temporary operations plan which addresses fisheries releases and discharge mitigation. The FFMP was unanimously approved by the parties to the 1954 U.S. Supreme Court Decree (four basin states and NYC).

Releases totaling approximately 22.3 BG were directed by the Delaware River Master from the NYC reservoirs during April, July, August, and September 2012. These releases are required to meet the normal flow target of 1,750 cfs on the Delaware River at Montague, N.J. By comparison, directed releases totaled 0.85 BG in 2011 and 101 BG during the drought year 2001.

Groundwater

The groundwater level in the New Castle County, Del. coastal plain well began the year above the normal range (>75-percentile)[8]. Storage declined throughout the spring and early summer, but remained within the lower half (25-to 50-percentile) of the normal range. By July, the groundwater level was below the normal range (<25-percentile), where it would remain until the end of 2012.

The groundwater level in the Cumberland County, N.J. coastal plain well began the year above the normal range (>75-percentile). It experienced a slow decline from January through October, but remained within the normal range (25- to 75-percentile) for much of 2012. October rainfall increased the water level to above the normal range by November, where it remained through the end of the year. Figure 7 and Figure 8 present graphics of groundwater levels throughout the year for the Delaware Geological Survey (DGS) well in New Castle Co. and the U.S. Geological Survey (USGS) well in Cumberland Co., respectively.

Salt Front

The salt front is defined as the 250 parts-per-million (PPM) isochlor. The seven-day average location of the salt front is used by DRBC as an indicator of salinity intrusion in the Delaware Estuary. The salt front's location fluctuates 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 (0.5 miles below Pea Patch Island, Del.) to river mile 81 in mid-October (Marcus Hook, Pa.).

The farthest recorded upstream location of the salt front, river mile 102, was measured during the 1960's drought of record. The farthest upstream location of the salt front in 2012 was river mile 77 during late July and early August. This location is one mile downstream of the Delaware-Pennsylvania state line. Figure 9 presents the seven-day average location of the 250-PPM isochlor during 2012.

[8] USGS water level ranges are defined as: Above Normal (>75-percentile); Normal (25- to 75- percentile flows); Below Normal (<25-percentile).

Figure 1: 2012 Annual Precipitation in the Delaware River Basin

Total Precipitation (top) and Total Departure from Normal (bottom) in Inches

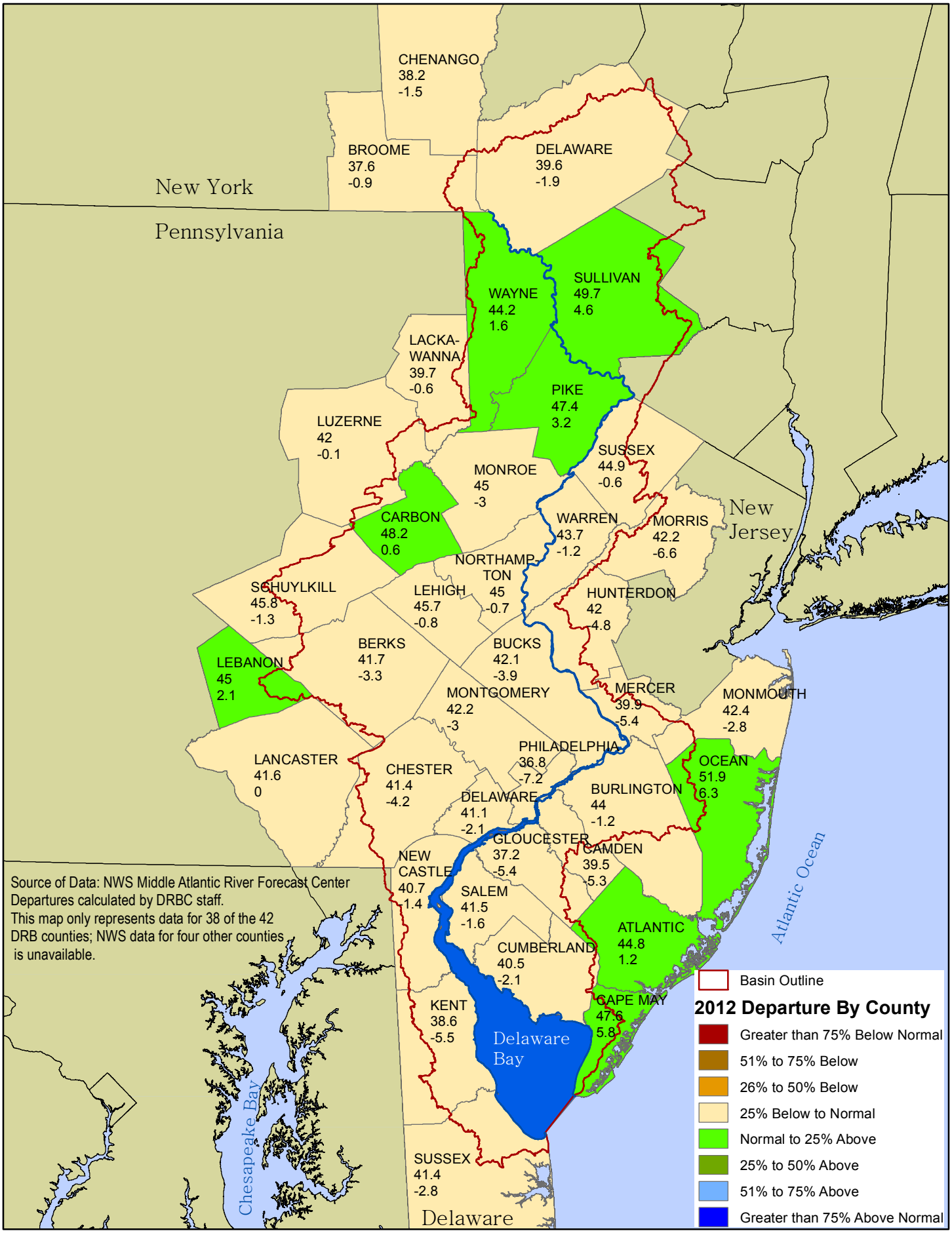


TABLE 1: 2012 PRECIPITATION AT SELECTED STATIONS IN THE DELAWARE RIVER BASIN (INCHES)

	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
JANUARY	3.02	2.88	3.50	2.96	3.15	3.00	3.72	2.38	3.52	2.59	3.43	2.55
FEBRUARY	2.65	1.09	2.75	1.11	2.96	0.90	2.77	1.54	2.74	1.84	2.81	2.09
MARCH	3.33	2.04	3.56	1.00	3.52	1.30	3.60	0.80	3.81	0.79	3.97	0.92
APRIL	3.77	2.59	3.49	2.92	4.02	2.70	3.68	1.94	3.49	2.55	3.39	2.56
MAY	4.21	5.58	4.47	5.63	4.04	6.00	4.52	4.70	3.89	3.35	4.15	2.25
JUNE	3.96	3.18	3.99	4.43	3.89	3.30	4.36	3.76	3.29	2.94	3.59	3.64
JULY	4.09	5.55	4.27	4.02	4.21	4.70	4.07	2.72	4.39	1.48	4.28	3.05
AUGUST	3.85	3.37	4.35	3.75	4.15	3.50	3.61	4.05	3.82	5.37	3.51	2.81
SEPTEMBER	3.83	6.62	4.37	4.76	3.93	6.70	4.36	4.90	3.88	5.48	4.01	5.29
OCTOBER	3.38	5.18	3.33	5.13	3.41	5.80	3.28	8.23	2.75	4.08	3.08	6.25
NOVEMBER	3.83	1.05	3.70	1.00	3.99	1.10	3.54	0.90	3.16	1.05	3.19	0.98
DECEMBER	3.34	5.04	3.39	4.31	3.62	5.10	3.31	2.99	3.31	4.42	3.40	3.92
TOTAL 2012	**43.26**	**44.17**	**45.17**	**41.02**	**44.89**	**44.10**	**44.82**	**38.91**	**42.05**	**35.94**	**42.81**	**36.31**
DIFF 2012		**0.91**		**-4.15**		**-0.79**		**-5.91**		**-6.11**		**-6.50**

NOTES:

1. Average Above Montague, NJ is based on weighted average of 10 stations.

2. Average Above Trenton, NJ is based on the weighted average of 99 stations.

PERIOD OF RECORD FOR NORMAL DATA/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

NORM = Normal
OBS = Observed

TABLE 2: 2012 STREAMFLOW (IN CFS) IN THE DELAWARE RIVER BASIN

OBSERVED MONTHLY MEAN FLOW VERSUS NORMAL[1] MONTHLY FLOW

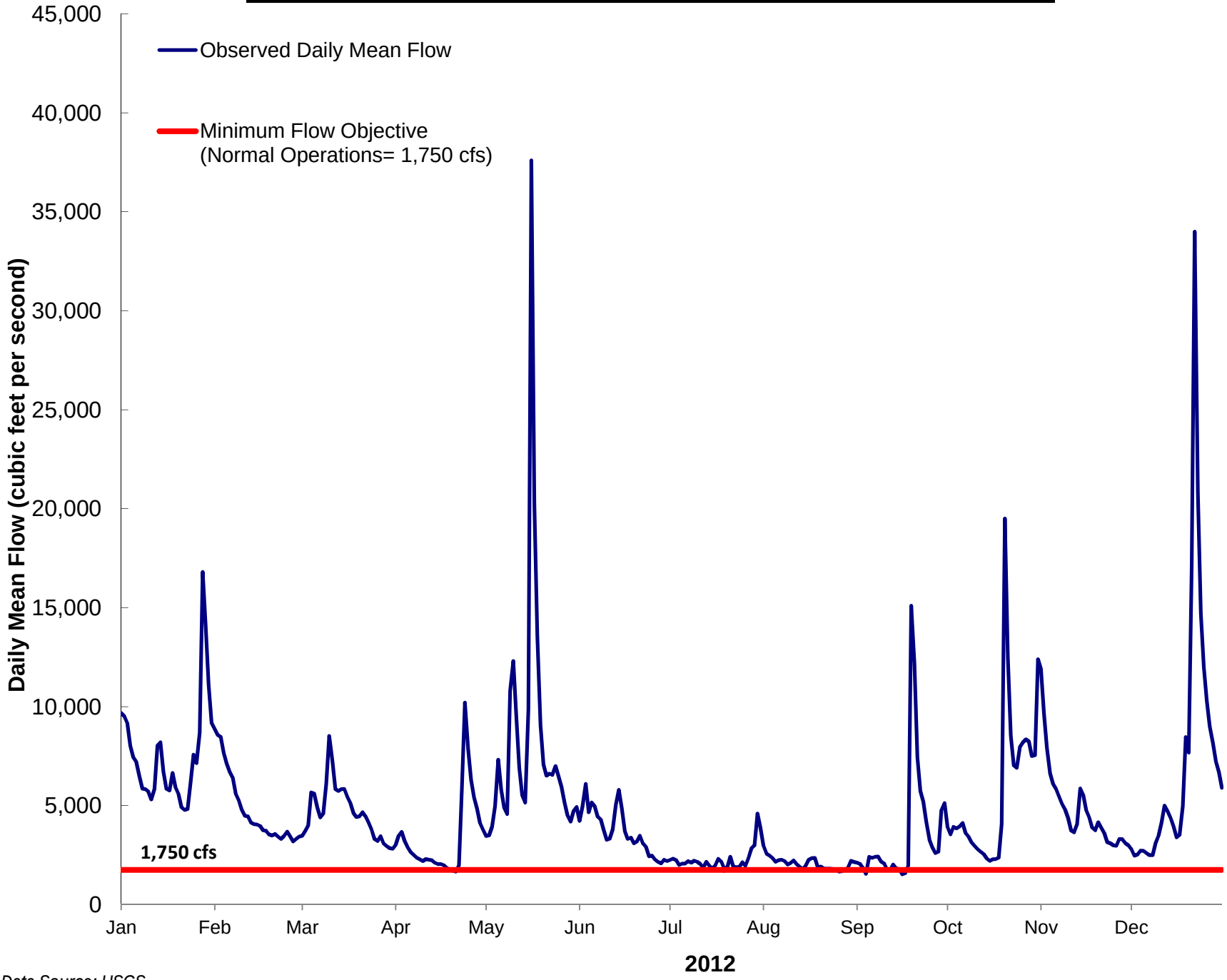
		Delaware River @ Montague	Lehigh River @ Lehighton	Lehigh River @ Bethlehem	Delaware River @ Trenton	Schuylkill River @ Philadelphia	Schuylkill River @ Pottstown
Jan	OBS	7,550	1,450	3,340	16,865	4,283	2,785
	% NORM	151.8%	132.1%	128.9%	131.1%	153.3%	139.1%
Feb	OBS	4,681	1,013	2,236	10,724	2,583	1,794
	% NORM	82.0%	76.8%	74.5%	77.5%	64.1%	65.5%
Mar	OBS	4,655	769	1,583	8,761	2,080	1,331
	% NORM	52.8%	43.5%	41.3%	48.1%	45.3%	44.8%
Apr	OBS	3,356	532	1,272	6,634	1,629	974
	% NORM	29.5%	30.3%	34.9%	33.0%	45.5%	36.3%
May	OBS	8,024	1,503	3,386	14,630	3,171	2,129
	% NORM	116.9%	95.2%	122.7%	107.2%	114.0%	102.7%
Jun	OBS	3,692	1,120	3,152	9,511	2,815	2,173
	% NORM	109.7%	116.2%	158.6%	116.1%	154.2%	154.8%
Jul	OBS	2,274	526	1,149	4,121	861	728
	% NORM	88.3%	72.2%	80.2%	67.0%	62.1%	68.8%
Aug	OBS	2,086	515	1,144	4,193	1,158	869
	% NORM	98.0%	113.1%	105.1%	82.7%	100.4%	105.5%
Sep	OBS	3,562	960	2,123	7,700	1,793	1,264
	% NORM	164.5%	220.3%	183.9%	154.0%	162.7%	136.1%
Oct	OBS	5,635	1,367	2,695	11,438	3,789	2,695
	% NORM	235.7%	196.1%	181.4%	215.0%	304.6%	286.7%
Nov	OBS	4,800	1,709	2,708	11,151	2,836	1,732
	% NORM	110.7%	133.3%	117.7%	106.8%	120.0%	99.3%
Dec	OBS	7,209	1,699	2,908	14,897	3,671	2,101
	% NORM	146.6%	125.8%	105.5%	131.7%	118.8%	98.5%

[1]Median of monthly mean values for 1971-2000 period were used to calculate the normal monthly flow, 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.

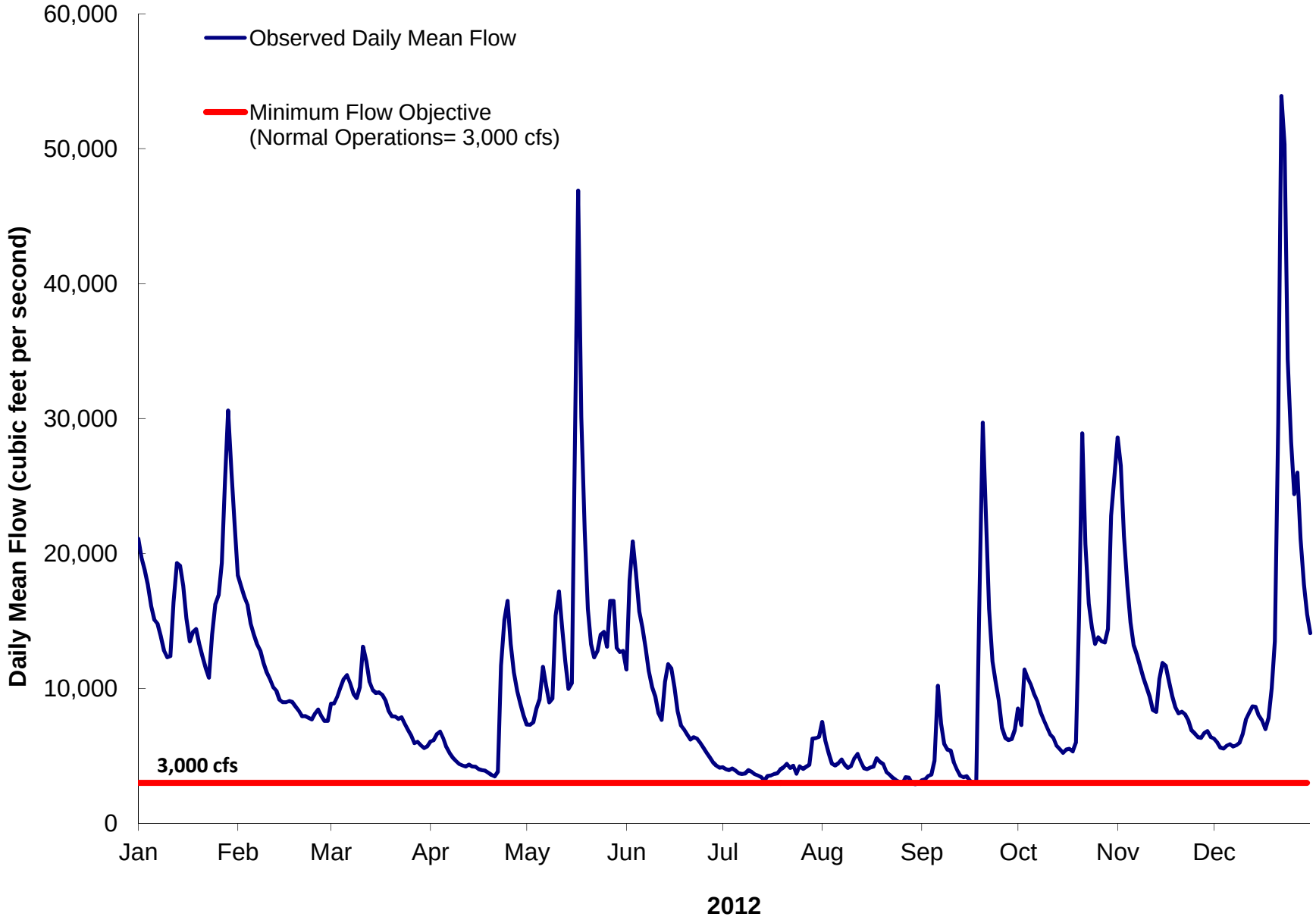
cfs = cubic feet per second

FIGURE 2: DELAWARE RIVER AT MONTAGUE, NJ



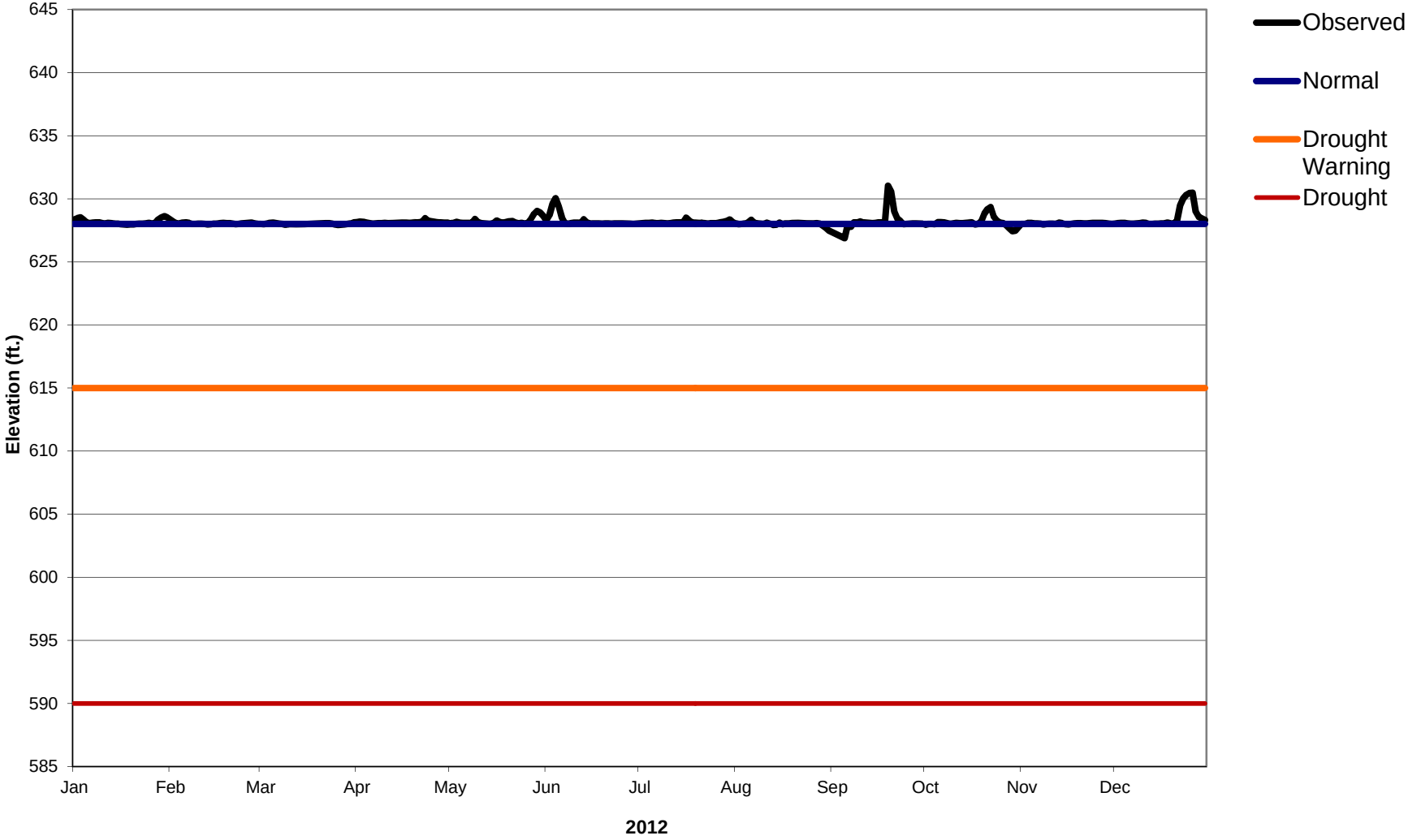
Data Source: USGS
Graph generated by DRBC staff.

FIGURE 3: DELAWARE RIVER AT TRENTON, NJ



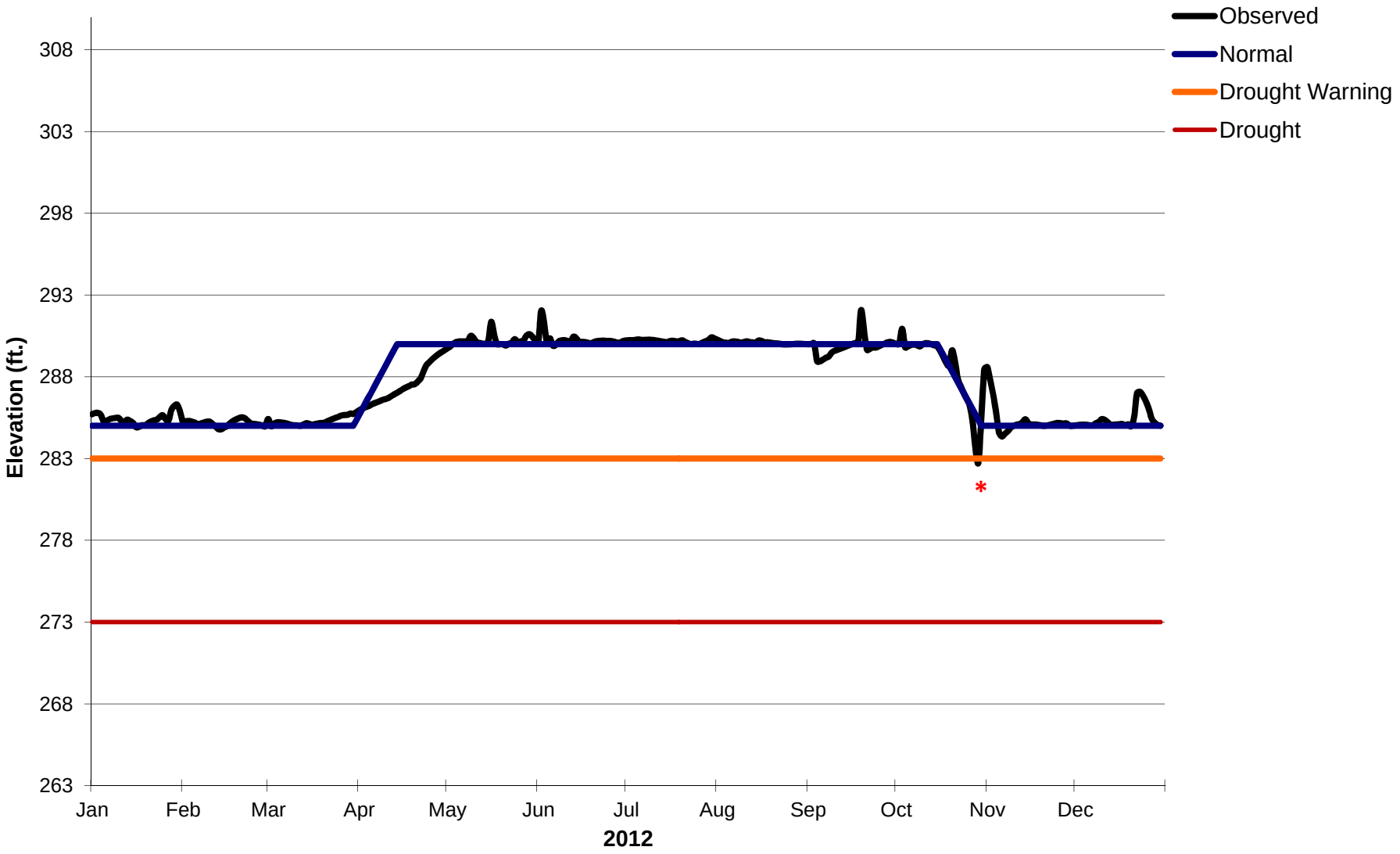
Data Source: USGS
Graph generated by DRBC staff.

FIGURE 4: BELTZVILLE RESERVOIR ELEVATION



Notes:
1. The normal pool elevation is 628 feet.
2. Data was provided by the Army Corps of Engineers (morning values). Graph generated by DRBC staff.

FIGURE 5: BLUE MARSH RESERVOIR ELEVATION



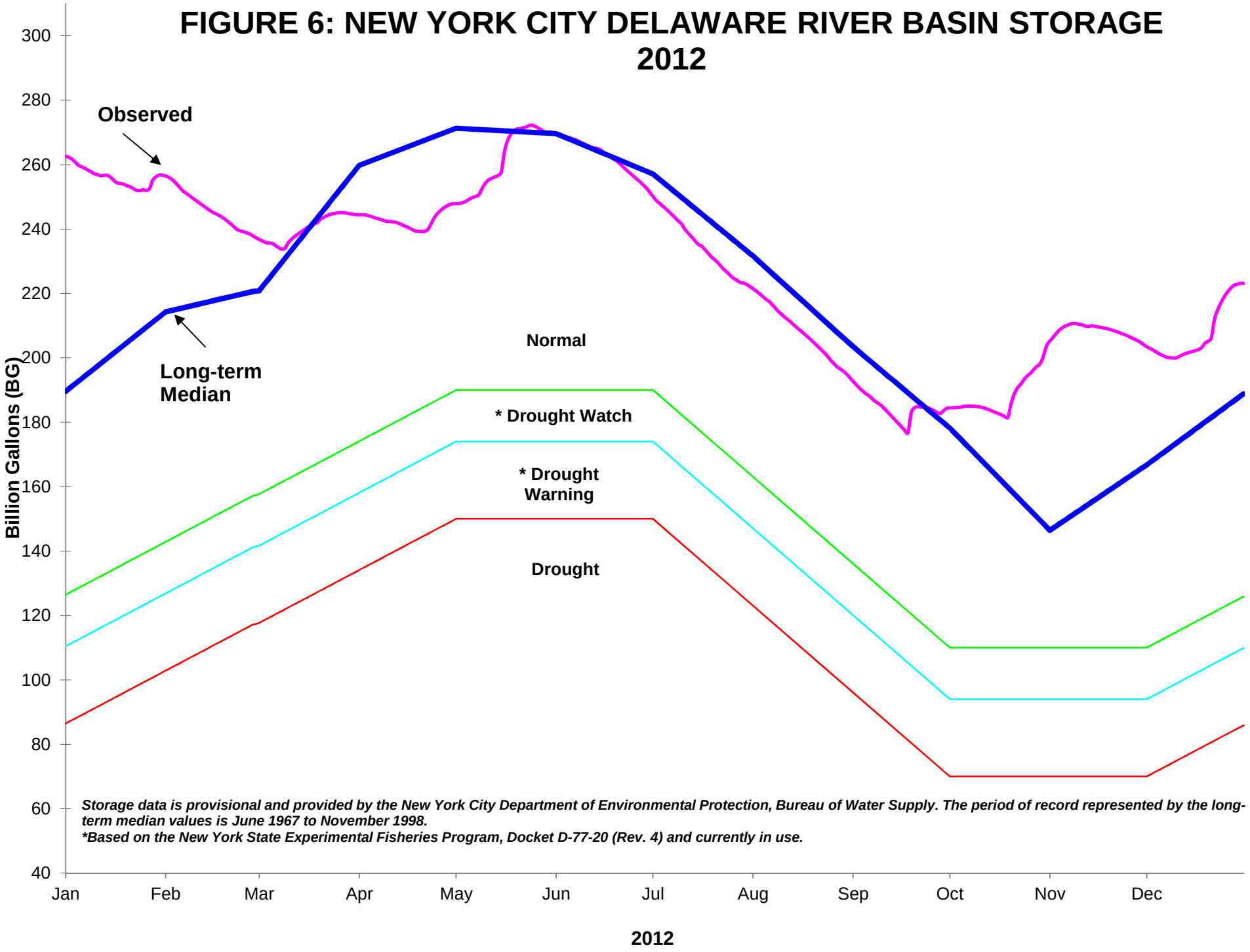
Notes:

1. Winter Pool=285 feet (October-March)/Summer Pool= 290 feet (April-September).

2. Data was provided by the Army Corps of Engineers (morning values). Graph generated by DRBC staff.

***Pre-emptive release made by the Army Corps of Engineers in anticipation of Hurricane Sandy.**

FIGURE 6: NEW YORK CITY DELAWARE RIVER BASIN STORAGE 2012



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) and currently in use.

FIGURE 7: DGS WELL-NEW CASTLE CO., DELAWARE
Average Depth to Water and 2012 Observations of Depth to Water

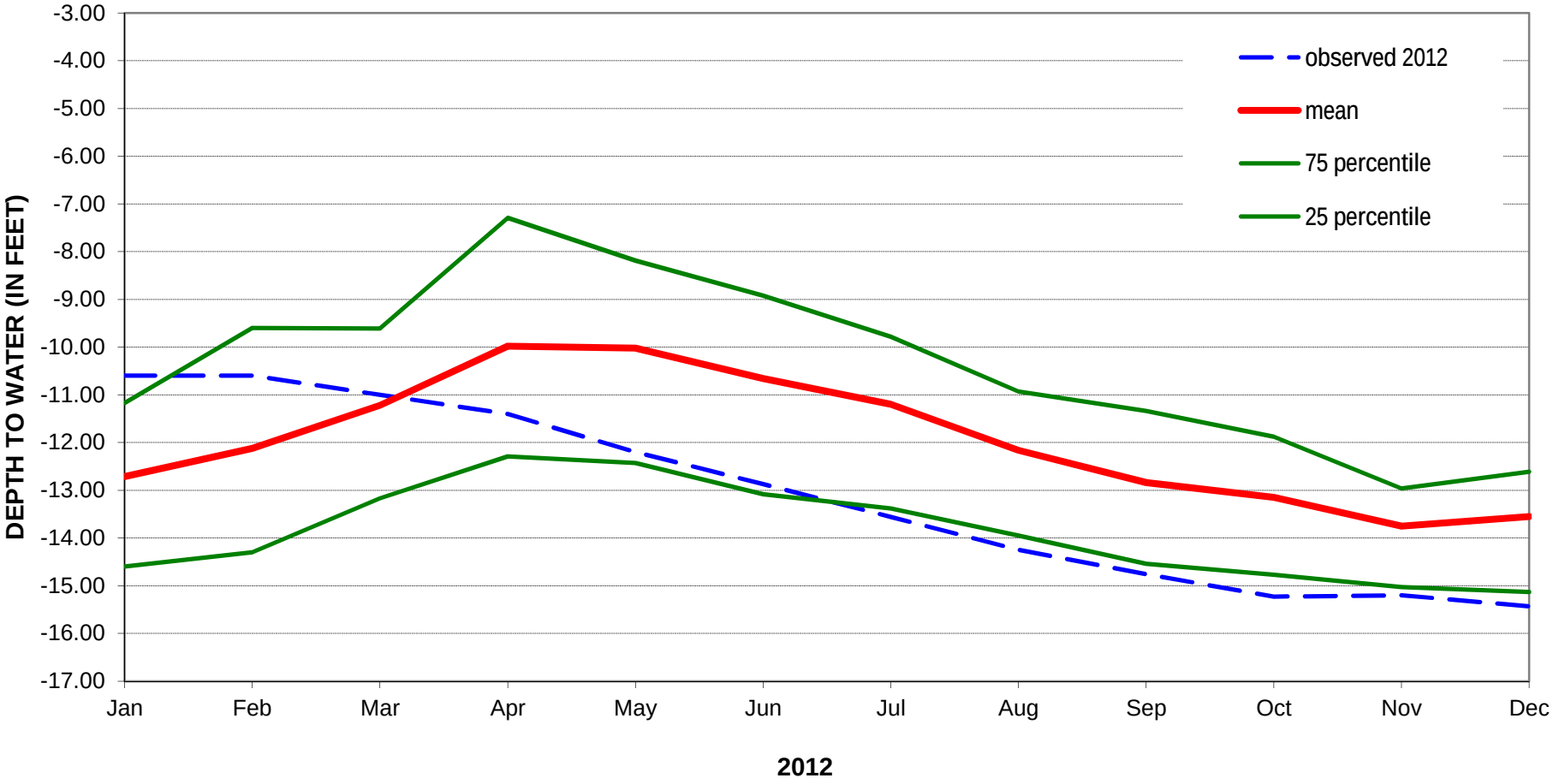


FIGURE 8: USGS WELL-CUMBERLAND CO., NEW JERSEY
Average Depth to Water and 2012 Observations of Depth to Water

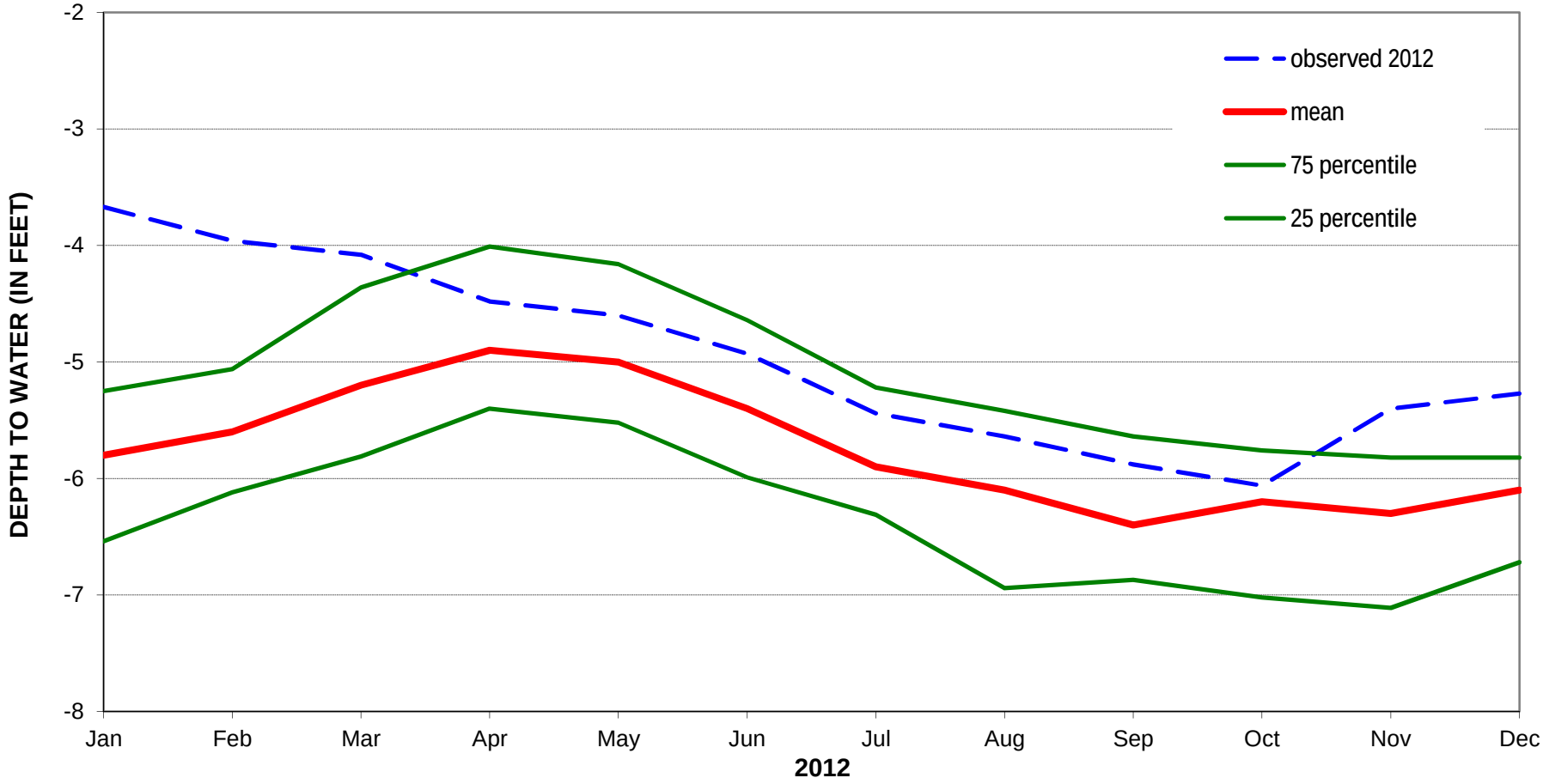
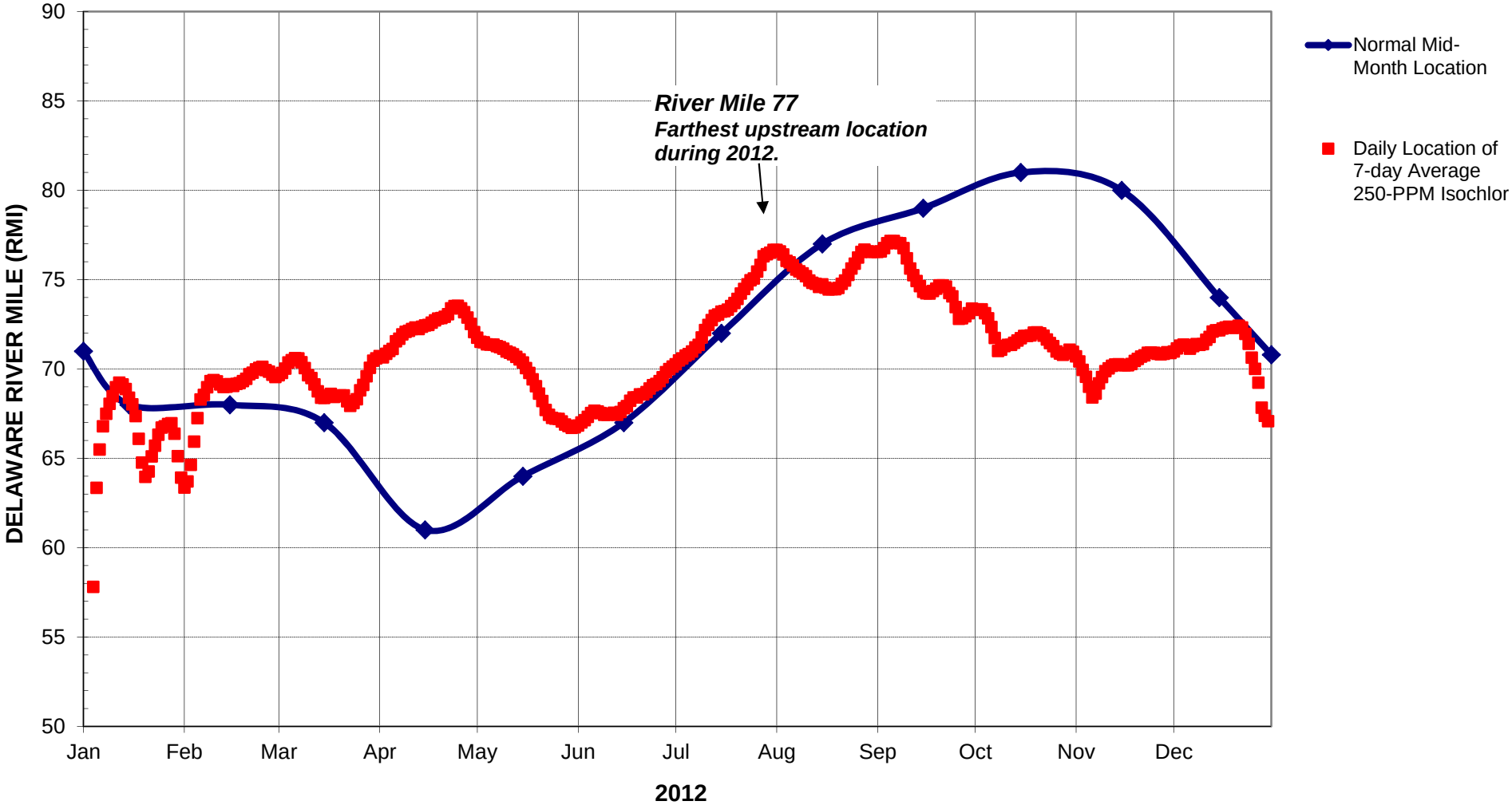


FIGURE 9: 7-DAY AVERAGE LOCATION OF THE 250-PPM ISOCHLOR



NOTE: DRBC does not estimate locations below river mile 54.
PPM = parts per million