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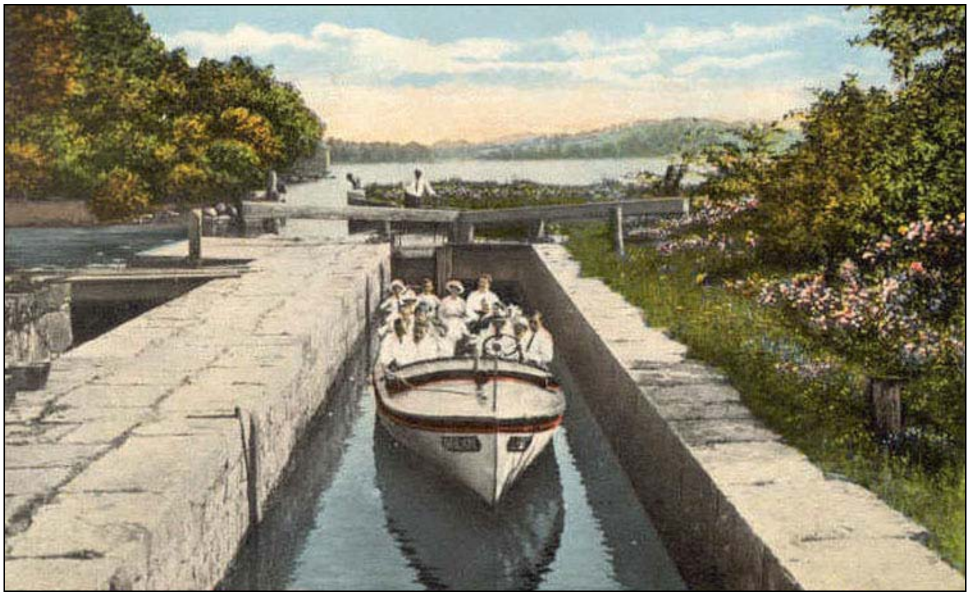
Reconstructed Streamflow in the Musconetcong River at Lake Hopatcong



January 2010

STATE OF NEW JERSEY
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Department of Environmental Protection
Bob Martin, *Acting Commissioner*

Land Use Management
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Karl Muessig, *State Geologist*

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NEW JERSEY GEOLOGICAL SURVEY

The mission of the New Jersey Geological Survey is to map, research, interpret and provide scientific information regarding the state's geology and groundwater resources. This information supports the regulatory and planning functions of DEP and other governmental agencies and provides the business community and public with information necessary to address environmental concerns and make economic decisions.

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On the cover:

The canal boat Dream on the feeder canal from Lake Hopatcong to the Morris Canal, ca. 1914. Rube Messinger, locktender, standing at rear. The Dream, owned by Charles Summers and operated out of Castle Edward Hotel on Lake Hopatcong, took guests on canal excursions. (Information from Marty Kane of the Canal Society of New Jersey. Image from the Society's web page: http://canalsocietynj.org)

Epigram:

> The ability to manage riverine ecosystems wisely comes from reliable data on current and past conditions, a fundamental and integrated understanding of riverine, institutional, and economic processes, the ability to forecast the responses of rivers and aquatic communities to environmental change or human actions, and effective communication of this information to resource-managers, policy-makers, and the public.
>
> Bencala, Hamilton and Petersen, 2006.

Reconstructed Streamflow in the Musconetcong River at Lake Hopatcong

by

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2010

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Reconstructed Streamflow in the
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Summary

Streamflow in the Musconetcong River at the outlet of Lake Hopatcong is heavily influenced by the lake. This report provides an estimate of 'natural' streamflows in the Musconetcong River; what flows might be if the lake were not there. This process is called streamflow reconstruction.

The reconstructed streamflow in the Musconetcong River is based on observed flow in the neighboring Rockaway River watershed. The stream gage on the Rockaway River at Berkshire Valley has a watershed nearly identical to that of the Musconetcong River's, and is an immediate neighbor. However it has a limited record, 1984-1996. This record is expanded by correlating it to the longer record of the stream gage on the Rockaway River above the Boonton Reservoir, 1937-2009. An area-weighted modification then provides reconstructed streamflow in the Musconetcong River at the outlet of Lake Hopatcong.

This reconstruction provides some insight into how the lake affects river flows. The passing flow required by the lake's operation plan (12 cfs) results in higher streamflows during dry periods than would otherwise occur. After a sustained dry period, when lake levels are lower than normal, filling the lake results in lower streamflows than would occur if the lake were not there. Thus the schedule of releases from the lake has implications both on lake levels and downstream flows. A frequency analysis of monthly low flows shows that the current passing flow is a reasonable estimate of the monthly median low flows in the summer.

Table 1. Abbreviations and Acronyms

Abbreviation/Acronym	Meaning
cfs	cubic feet per second
mg	million gallons
mgd	million gallons per day
mgm	million gallons per month
mgy	million gallons per year
NJDEP	New Jersey Department of Environmental Protection
NJGS	New Jersey Geological Survey, NJDEP
USGS	United States Geological Survey

Location and History

Lake Hopatcong is located on the Musconetcong River in northern New Jersey. By the early 1800's the river had been dammed to provide water power to a forge (National Reporter System, 1908). In the early-1800's the dam was raised and the lake (then also known as Brooklyn Pond or Great Pond) enlarged to provide water for the Morris Canal (fig. 1). Lake Hopatcong was the high point on the canal and water could flow both east and west through the canal. Water was retained in the lake during wet periods and fed into the canal during dry times. As a result, lake levels would fall by five to eight feet by autumn of a normal year (National Reporter System, 1908).

The Morris Canal's operators were required to release water from Lake Hopatcong to supply downstream users (Hoffman and Domber, in press). Mandated releases are called passing flows in New Jersey. Elsewhere they are called in-stream flows or pass-by flows. The Morris Canal ceased operations in the early 20th century and passed into state ownership. However the passing flow, 7.5 million gallons per day (12 cubic feet per second), continued and is now incorporated in to the Lake Hopatcong management plan.[1] The current releases from the dam are intended to maintain aquatic habitat and meet other downstream water needs.

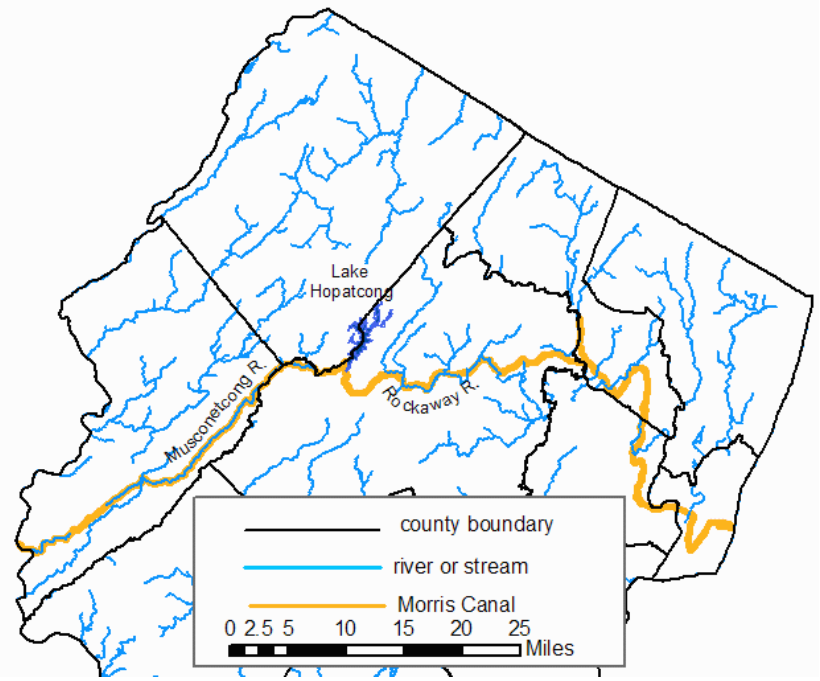

Figure 1. Lake Hopatcong in northern New Jersey.

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[1] "Lake Hopatcong Water Level Management Plan," unpublished manuscript on file with the New Jersey DEP, Division of Parks and Forestry, State Park Service, 16 p, ca 2001.

Available Streamflow Data

The U.S. Geological Survey (USGS) maintains a continuous streamflow gage on the Musconetcong River at the outlet of Lake Hopatcong (table 2, fig. 2). This represents the headwaters of the Musconetcong River. This gage was in operation from July 1928 through September 1975, and also April 2002 to the present (fig. 3). However, as the lake greatly moderates flow, this gage provides no insight into what flows would be in the Musconetcong if the lake were not present.

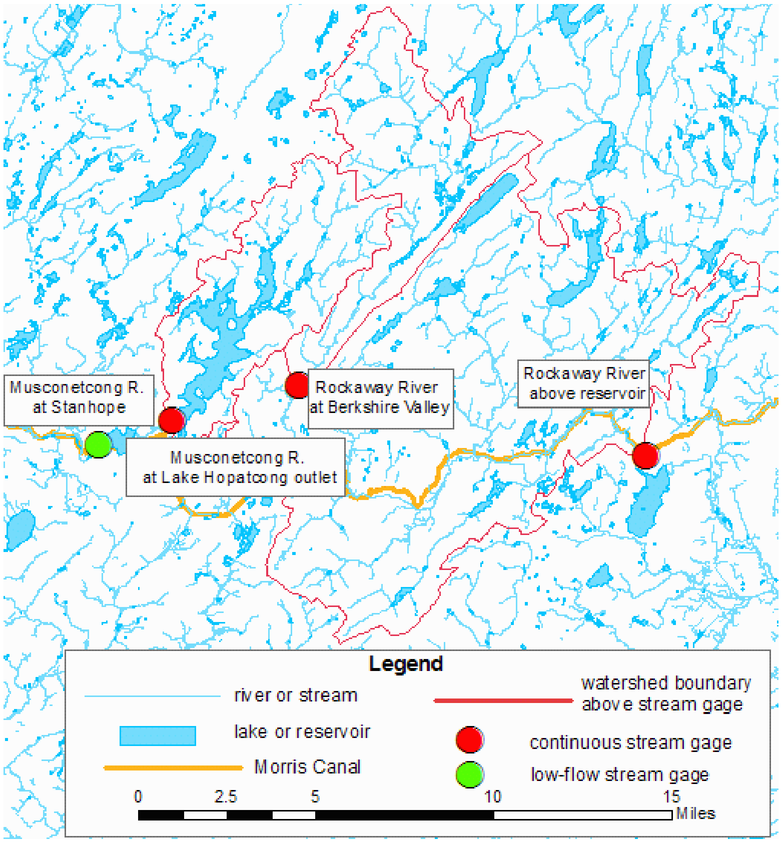


Figure 2. Selected stream gages with watershed boundaries.

The Rockaway River watershed is adjacent to the Musconetcong River watershed (fig. 2). The USGS operated a continuous streamflow gage on the Rockaway at Berkshire Valley from October 1984 to July 1996 (fig. 4). The watershed above this gage is the headwaters of the Rockaway River.

The USGS also maintains a continuous streamflow gage on the Rockaway River just upstream of the Boonton Reservoir (fig. 2). Data from this gage are available for the period October 1937 to the present (fig. 5).

The USGS also manually measures flow during dry periods at low-flow sites. One such site is on the Musconetcong River at the outlet of Lake Musconetcong in Stanhope (fig. 2). The data reported from this site are in table 3, along with average daily flow reported from the upstream gage at the outlet of Lake Hopatcong. It is difficult to draw any conclusion between these numbers because change of storage in Lake Musconetcong will affect the flows at the low-flow site.

Table 2. Streamflow gages

Gage #	Gage name	Type of gage	Watershed, square miles	Period of record for this analysis
01379700	Rockaway River at Berkshire Valley	continuous	24.4	10/16/1984 -07/21/1996
01380500	Rockaway River above reservoir	continuous	116.	10/1/1937 - 10/20/2009
01455500	Musconetcong River at outlet of Lake Hopatcong	continuous	25.3	7/19/1928 - 9/30/1975; 4/1/2002 - 10/20/2009
01455550	Musconetcong River at Stanhope	low flow	29.7	1973-1976, 1980

Table 3. Low flows in Musconetcong River

Date	Streamflow (cfs)	
	at outlet of Lake Hopatcong[1]	at Stanhope[2]
6/5/1973	71.	81.2
7/19/1973	16.	15
9/28/1973	26.	19.2
4/18/1974	83.	88.3
9/19/1974	53.	58.1
9/10/1975	117.	115
5/12/1976	-	16.9
10/31/1980	-	6.32

1. continuous gage 01455500, average daily flow
2. low-flow gage 01455550, instantaneous measurement

Table 4. Organizations and web sites

Organization	Web site
New Jersey Department of Environmental Protection	http://www.state.nj.us/dep/
New Jersey Geological Survey	http://njgeology.org
United States Geological Survey, NJ office	http://nj.usgs.gov/
New Jersey State Climatologist	http://climate.rutgers.edu/stateclim/
Lake Hopatcong Commission	http://www.lakehopatcong.org/

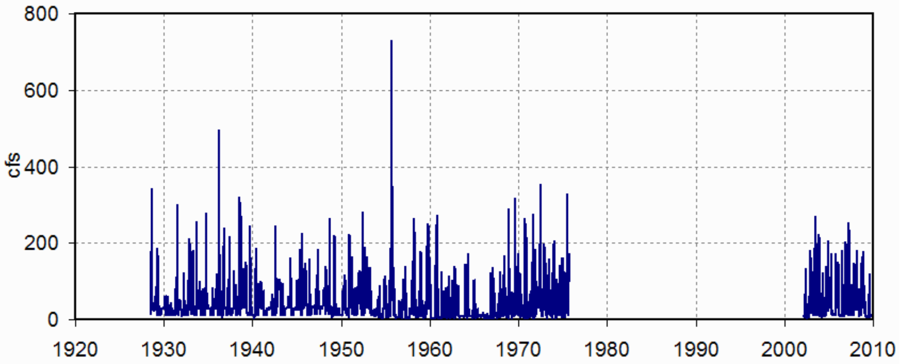


Figure 3. Observed streamflow, Musconetcong River at outlet of Lake Hopatcong.

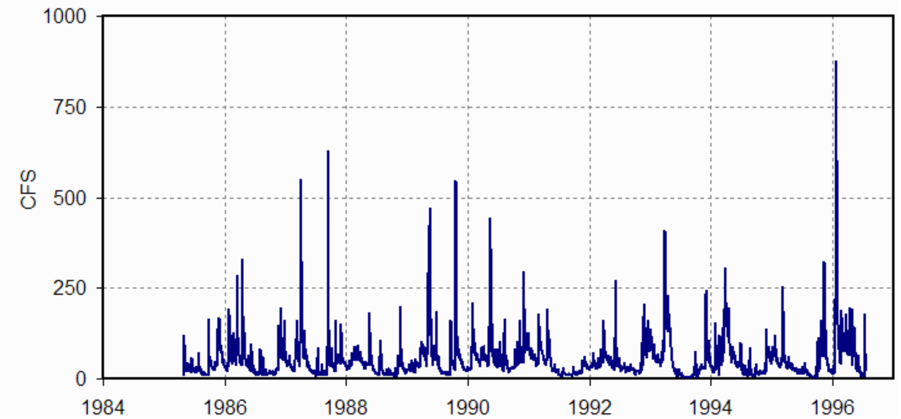


Figure 4. Observed streamflow, Rockaway River at Berkshire Valley.

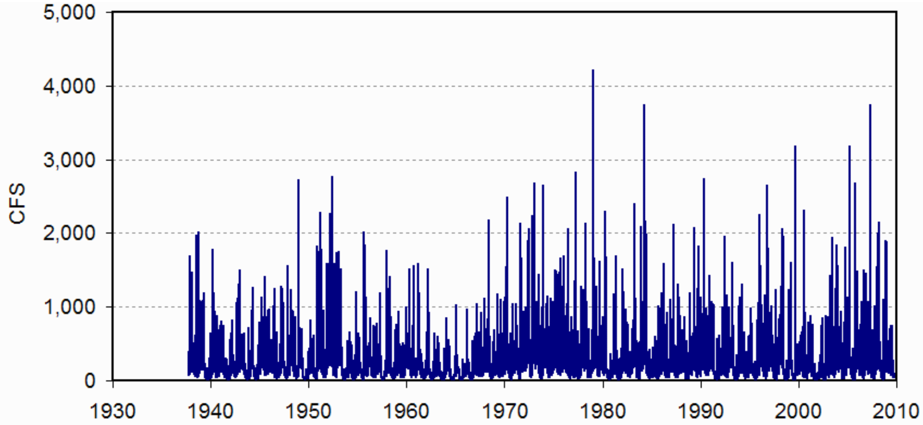


Figure 5. Observed streamflow, Rockaway River above the Boonton Reservoir.

Watershed Characteristics

The upper Musconetcong watershed (above the gage at the outlet of Lake Hopatcong) and the upper Rockaway watershed (above the gage at Berkshire Valley) are very similar.

Bedrock in each watershed is similar (fig. 6, table 5). The upper Musconetcong watershed consists entirely of igneous and metamorphic (fig. 8) rock. These are very poor aquifers. Bedrock in the upper Rockaway is 53% igneous and metamorphic. The remainder is sedimentary rock. These sedimentary units can contain more water than the igneous gneiss and granite. However, all of the bedrock units in both watersheds have been classified as aquifers of class D, with a median yield of 25 to 100 gallons per minute (Herman and others, 1998). Hydrogeologically, the bedrock units are very similar.

Limestone is not a significant component of either watershed. Watersheds in northwestern New Jersey with significant areas of limestone bedrock have significantly different low flows. It would be less accurate to attempt to correlate flows between stream gages if one watershed contains a significant amount of limestone bedrock and the other doesn't.

Both watersheds contain some thicker unconsolidated sediments in the bedrock valleys (fig. 7). In general, these units will sustain baseflows better than the bedrock units in the area. Since the upper Rockaway watershed contains more of these unconsolidated units this watershed may have greater low flows, on a per square mile basis, than the upper Musconetcong might have if Lake Hopatcong were not there. But this difference probably will not be a significant factor in this analysis.

The land use of both watersheds is also very similar (fig. 9, table 6). If surface water is removed from the comparison, then the two watersheds are nearly identical (fig. 10).

Since the two watersheds are adjacent, and not very large, they will experience similar weather conditions. This will result in similar patterns of streamflow in the two watersheds.

The geology, land use and weather of these two watersheds are very similar. If Lake Hopatcong were not influencing flows in the Musconetcong River, streamflow out of the watersheds would be highly correlated. Thus, streamflows in the Rockaway River at Berkshire Valley will be extremely useful in predicting what flows in the Musconetcong River would be without the effects of Lake Hopatcong.

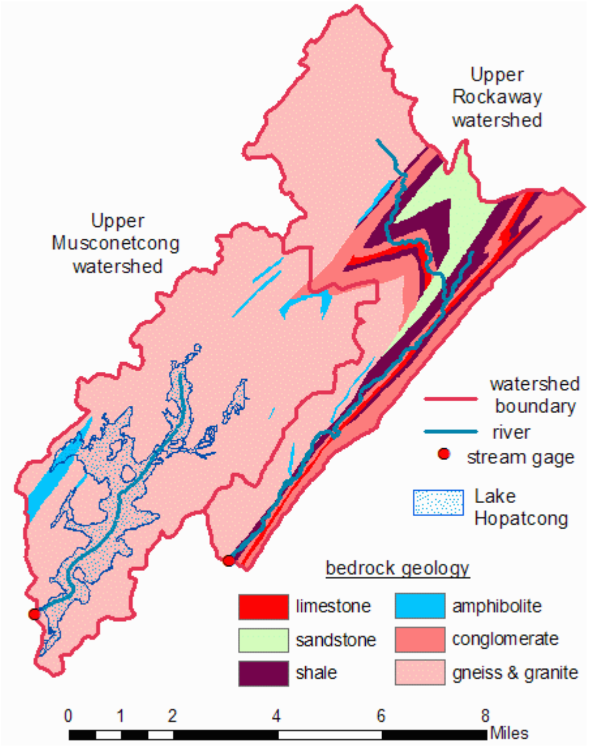


Figure 6. Bedrock geology in the upper Musconetcong and Rockaway River watersheds.

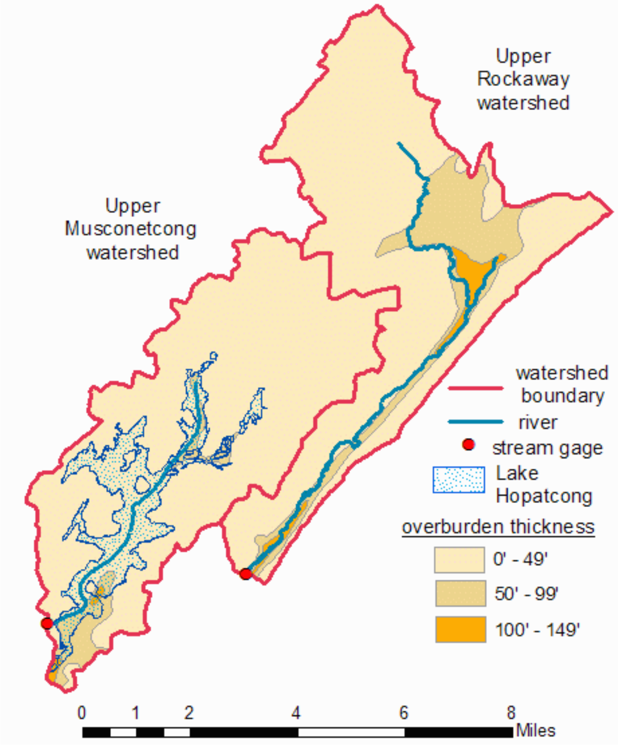


Figure 7. Overburden thickness in the upper Musconetcong and Rockaway River watersheds.

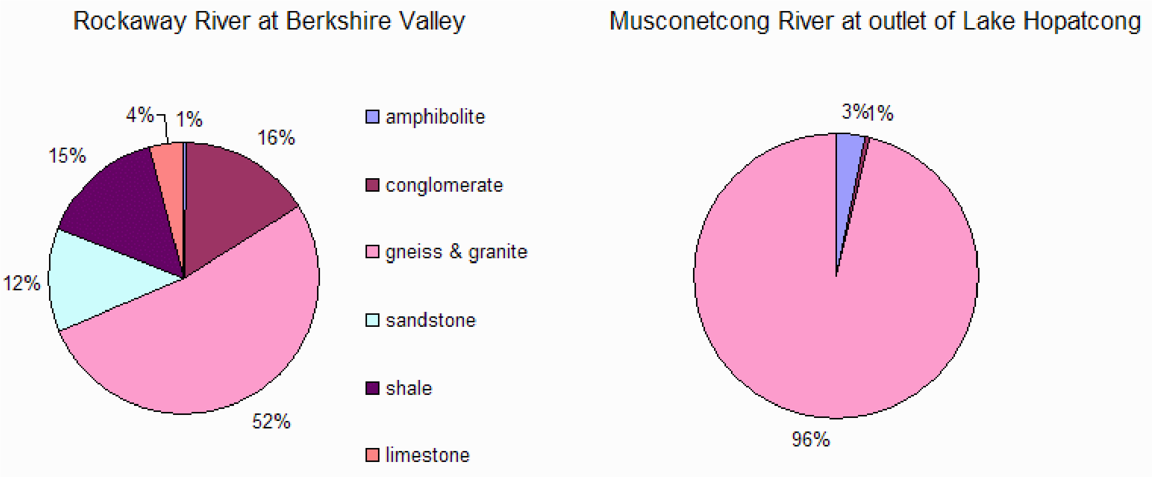


Figure 8. Bedrock geology ratios in upper Musconetcong and Rockaway River watersheds.

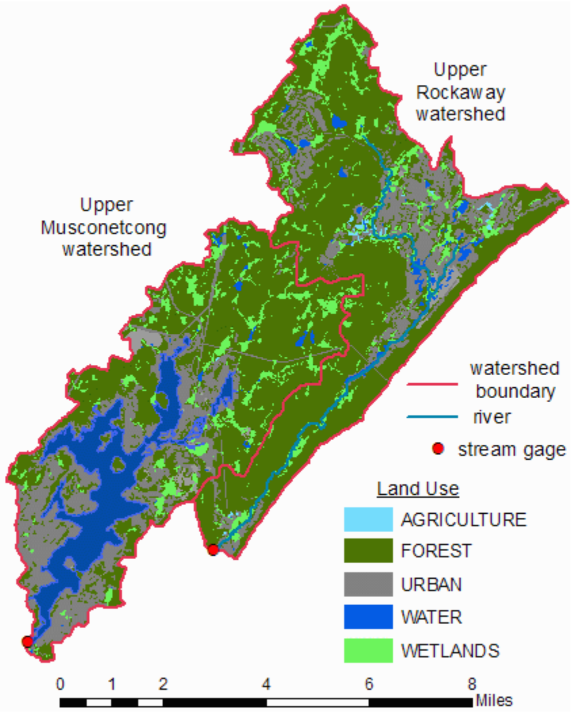


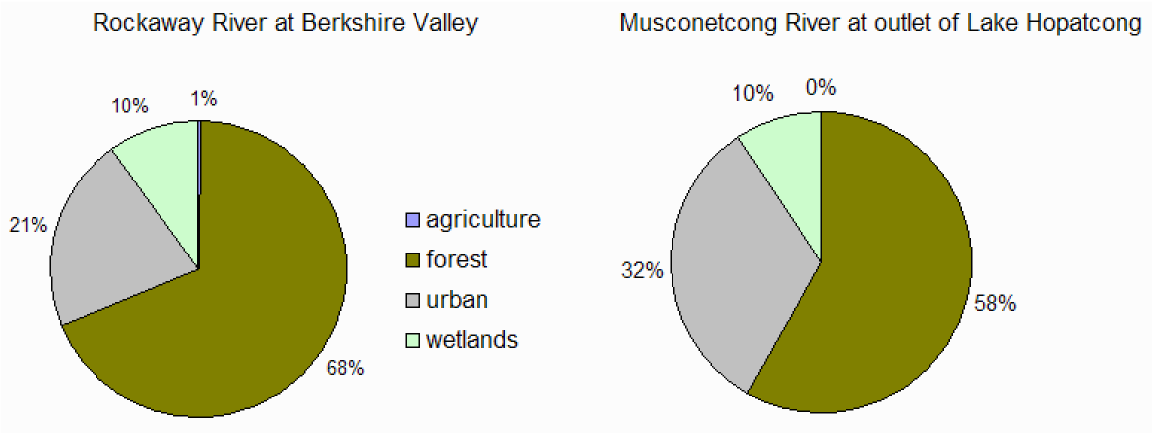
Figure 9. Land use in upper Musconetcong and Rockaway River watersheds.

Table 5. Bedrock formations in the upper Musconetcong and Rockaway watersheds

Bedrock formation	Acres	
	Upper Rockaway	Upper Musconetcong
amphibolite	105	537
conglomerate	2478	106
gneiss & granite	8,125	15,594
sandstone	1,953	-
shale	2,380	-
limestone	612	-
sum:	15,652	16,237

Table 6. Land use in the upper Musconetcong and Rockaway watersheds

Bedrock formation	Acres	
	Upper Rockaway	Upper Musconetcong
agriculture	84	3
barren lane	179	247
forest	10,362	7,871
urban	3,087	4,130
water	429	2,696
wetlands	1,511	1,291
sum:	15,652	16,237


Rockaway River at Berkshire Valley

Musconetcong River at outlet of Lake Hopatcong

Figure 10. Land use in upper Musconetcong and Rockaway River watersheds. Note: Surface water removed from analysis.

Streamflow Correlation and Reconstruction

It is impossible to state with certainty what flow in the Musconetcong River would have been if Lake Hopatcong had not been there. Using a reconstruction method, however, it is possible to make an estimate of these flows. Storck and Nawyn (2001), in a study of flows in the Passaic and Hackensack River, state:

> Natural streamflow is the quantity of water that would have flowed past the specified point without the influence of human activities. Reconstructed streamflow is an estimate of what streamflow would have been without major influences due to human activities. Reconstructed streamflow is the quantity of water that is determined by means of a mass-balance calculation, based on observed streamflow …

It is possible to estimate streamflow in the Rockaway River at Berkshire Valley based on flows in the Rockaway River above the Boonton Reservoir. Figure 11 shows observed flows for days on which flow was measured at both locations.

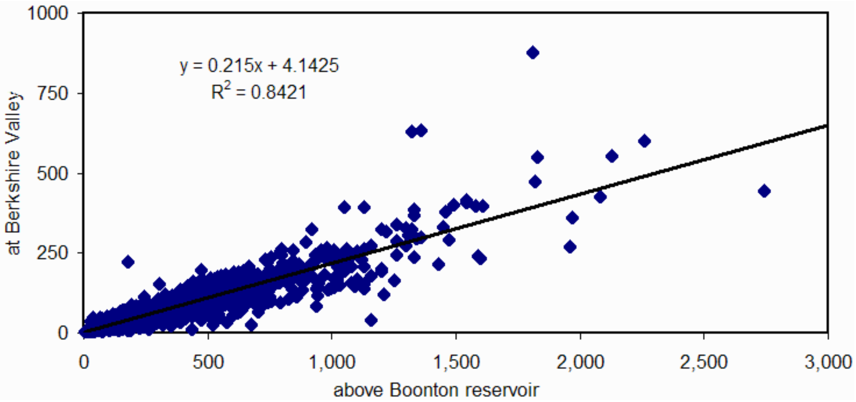


Figure 11. Correlation of mean daily flows in the Rockaway River at Berkshire Valley to flows above the Boonton Reservoir.

Correlating flows between the two gages yields an estimation equation for flow in the Rockaway River at Berkshire Valley:

$$Q_{bv} = 0.255*Q_{abr} + 4.1425$$

where

Q_{bv} = flow in the Rockaway River at Berkshire Valley (in cfs)
Q_{abr} = flow in the Rockaway River above Boonton reservoir (in cfs)

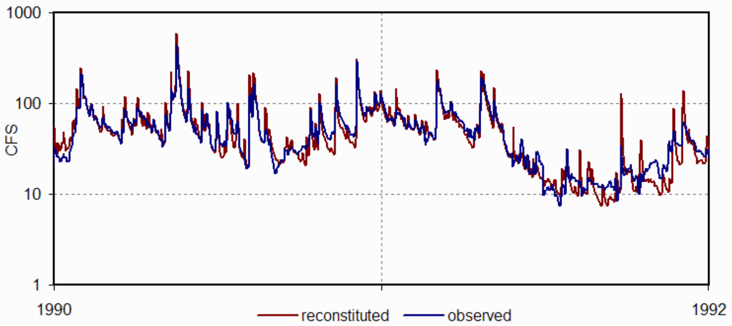


Figure 12. Observed and reconstructed flows in the Rockaway River at Berkshire Valley, 1990-1991.

This equation allows a reconstruction of flows in the Rockaway River at Berkshire Valley for every day flow was measured above the Boonton Reservoir. Figure 12 shows these the observed and reconstructed flows for the period 1990-1991. The match between reconstructed and observed streamflows in the Rockaway River at Berkshire Valley is good.

This method of reconstruction flows in the Rockaway River at Berkshire Valley is not the only possible approach. Other mass-balance approaches could use flows from one or more different gages in northern New Jersey with watersheds of a more similar size to the Berkshire Valley gage's. A more rigorous statistical approach could then yield a different equation that is based on flows at these other gages. However, the further away a gage is from the Berkshire Valley gage the more variation is introduced by changes in weather.

Another approach would be to build a rainfall-runoff model that generates streamflow as a function of the climate and land use. This model would involve many assumptions and require significantly more research and effort than the statistical mass-balance approach used above.

However, it is not clear that another approach would yield a substantially more useful result. As a test, the Berkshire Valley flows were correlated with flow in Flat Brook, which drains a pristine watershed in northwest New Jersey. The resulting correlation was not as an accurate a predictor of flows at Berkshire Valley as the correlation to flows in the Rockaway River above the Boonton reservoir.

In summary, there is a good match between the observed and reconstructed flows in the Rockaway River at Berkshire Valley. This approach yield acceptably accurate values for this application. There is no indication that using additional or different gages will substantially increase the correlation accuracy. For consistency, the reconstructed values for the Rockaway River at Berkshire Valley are used even for those dates for which flow was measured at the gage.

The reconstructed flows in the Musconetcong River at the outlet of Lake Hopatcong is based on an areal adjustment of the estimated flow in Rockaway River at Berkshire Valley.

The watershed above the Rockaway River at Berkshire Valley is 24.2 square miles. The watershed above the Musconetcong River at the outlet of Lake Hopatcong is 25.3 square miles. The reconstructed flow in the Musconetcong River is assumed to be 1.045 times as great as the reconstructed Berkshire Valley flows. Figure 13 shows the observed and reconstructed flows for the Musconetcong River at Lake Hopatcong for 1928-2009. Appendix A shows detailed graphs of observed and reconstructed flows, by decade, for the period 1920-2010.

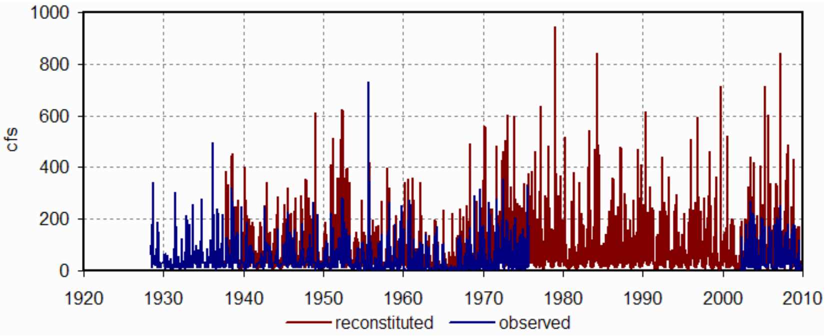


Figure 13. Observed and reconstructed flows in the Musconetcong River at outlet of Lake Hopatcong, 1928-2009. Reconstructed flows simulate absence of Lake Hopatcong.

Figure 14 is a more detailed graph that shows observed and reconstructed Musconetcong River flows for the period 2005-2009. It is clear that at numerous times during the summer the passing flow that is currently released over the dam at the outlet of Lake Hopatcong is less than the flow that would otherwise passed that point has the lake not been there. This represents storage of water in the lake. This is especially true in the spring of 2009 when Lake Hopatcong the passing flow was lessened so that the lake could fill after a very dry winter.

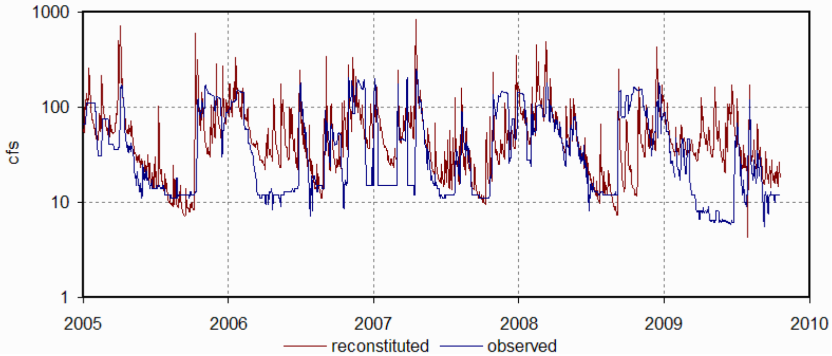


Figure 14. Observed and reconstructed flows in the Musconetcong River at outlet of Lake Hopatcong, 2005-2009. Reconstructed flows simulate absence of Lake Hopatcong.

At times releases from the lake are higher than would otherwise have occurred. In the fall of 2008 observed flows were significantly greater than what would have occurred if the lake were not present. This reflects the planned drawdown that has occurred about every five years.[2] This deliberate lowering of lake level is done to assist repair of docks and other structures. Normally the lake is then filled by winter and spring precipitation. However, early 2009 was very dry (fig. 16) and this led to lower-than-normal lake levels.

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[2] Previous drawdowns occurred in the fall of 1992, 1997, and 2003 (Helen Maurella, NJDEP, personal communication, 2009).

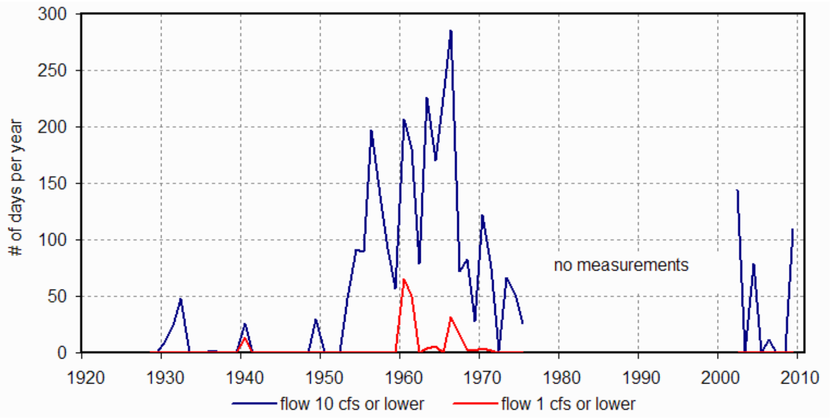


Figure 15. Number of days per year with observed streamflow less than 10 and 1 cfs, Musconetcong River at Lake Hopatcong.

The operating plan for releases from Lake Hopatcong calls for a passing flow of 12 cfs. That is the minimum flow that should be released under normal conditions. For various reasons releases sometimes are less than this rate. Figure 15 shows the number of days per year on which average daily flow in the Musconetcong River, as measured at the streamflow gage just downstream of Lake Hopatcong, was less than 10 and 1 cfs. Most of these low flows occurred during the severe 1960's drought.

Table 7. Number of days per year with no streamflow, Musconetcong River at Lake Hopatcong

Year	No. of days
1961	28
1963	2
1964	2
1966	15
1967	15

Note: Years not shown have streamflow on all days.

During the drought of the 1960's there was no flow reported in the Musconetcong River at the outlet of Lake Hopatcong on some days. Table 7 shows the number of days per year for those years in which this happened.

Precipitation

Streamflow depends on precipitation. In general, the more precipitation the greater the flow of the Musconetcong River. This pattern is moderated by Lake Hopatcong. During dry times water can be released from storage in the lake to sustain streamflows. During wet times water can be stored in the lake (assuming there is room) resulting in lower streamflows than would otherwise occur.

Currently the U.S. Geological Survey maintains an unheated rain gage (#405502074395601) at the outlet of Lake Hopatcong. It is located near the stream gage on the Musconetcong River at the outlet of Lake Hopatcong. The USGS reports the previous 60 days of precipitation data on its web site. However, these data are not quality assured and are not approved for publication. USGS does not distribute any precipitation data from this gage older than 60 days. They refer requests for information to the National Weather service. Also, since this gage is unheated it may incorrectly report the amount of precipitation in the winter that falls in the form of snow or ice (Robert Reiser, U.S. Geological Survey, personal communication, Nov. 2009). Thus while data from this gage may be useful for preliminary assessments of local conditions they are not suitable for a long-term analysis of historical conditions.

The New Jersey State Meteorologist maintains climate data for the State. These data are made available to the public through a web site (table 4). One data set available is average monthly precipitation for northern New Jersey, from January 1895 to the present. The data for January 2000 to October 2009 are shown in figure 16.

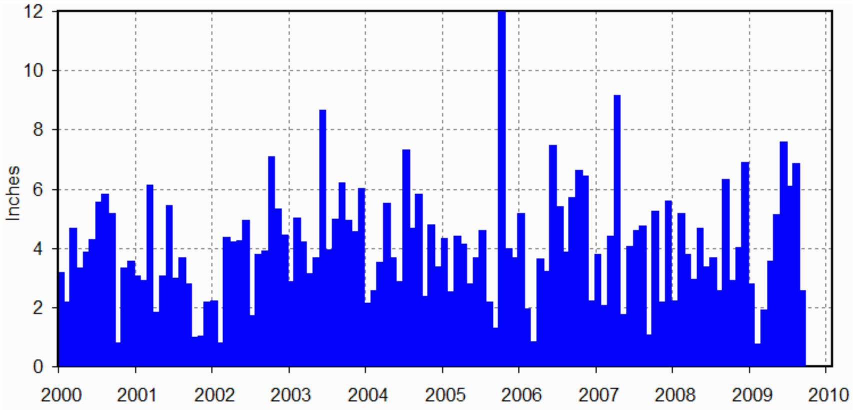


Figure 16. Observed monthly precipitation in northern New Jersey, 2000-2009 (Data from website of NJ State Meteorologist.)

These data provide a sufficient basis for analysis of precipitation frequencies in northern New Jersey. While a long period of accurate data from a station located at Lake Hopatcong would be preferable, this is not possible.

An ordering of each months data, from lowest to highest, provides the basis for a frequency analysis. Table 8 shows the results of this analysis. This table shows the exceedance probabilities for each calendar month, as well as minimum and maximum precipitations for each calendar month. For example, for January the minimum precipitation in northern New Jersey is 0.52", the maximum 9.09. In the table the 'Pnn' values are exceedance probabilities where the two digits 'nn' indicate the probability that precipitation is greater than that amount. For example, the P99 value for January is 0.72". The available data indicate that 99% of the reported average January precipitations in northern New Jersey were greater than this amount. The P90 value for January is 2.11"; 90% of reported average January precipitations were greater than this amount. The median value is equivalent to P50; half of all reported measurements were greater, half lesser.

Table 8. Exceedance frequencies of average monthly precipitation in northern New Jersey

Month	**Monthly Precipitation Frequencies (inches)**								
	Minimum	P99	P90	P75	Median	P25	P10	P01	Maximum
Jan	0.52	0.72	2.11	2.50	3.16	4.26	5.27	7.48	9.09
Feb	0.73	0.77	1.92	2.31	2.82	4.00	4.88	6.16	6.72
Mar	0.81	1.17	2.09	2.89	3.74	4.96	5.61	7.67	7.80
Apr	0.90	1.10	2.07	2.69	3.53	4.67	5.67	8.59	9.11
May	0.53	0.98	1.63	2.50	3.55	4.64	6.01	8.19	8.29
Jun	0.24	1.12	2.05	2.83	3.66	4.64	5.90	8.31	8.61
Jul	1.14	1.32	2.09	3.28	4.46	5.60	7.01	9.59	11.04
Aug	0.90	1.35	2.23	3.03	4.13	5.76	7.18	10.66	11.44
Sep	0.27	0.46	1.70	2.40	3.38	4.76	6.15	9.44	9.78
Oct	0.32	0.38	1.49	2.11	3.05	4.57	6.35	8.98	11.98
Nov	0.51	0.62	1.45	2.02	3.11	4.73	6.13	7.57	9.06
Dec	0.39	0.82	1.67	2.41	3.33	4.47	6.00	7.28	7.96

Explanation of terms: In this context 'P' is a precipitation frequency statistic. The two figures after the 'P" indicates what percentage of all monthly precipitation totals observed in that month were greater than that value. The median line is equivalent to P50; half of all monthly precipitation totals observed in that month were greater and half lesser.

The dry weather frequency statistics (P99, P90, and P75) along with the median precipitation (P50) are shown in figure 17. In this figure, the top of each colored bar shows the appropriate frequency statistic. The very bottom of the red bar shows the minimum average precipitation for that month in northern New Jersey.

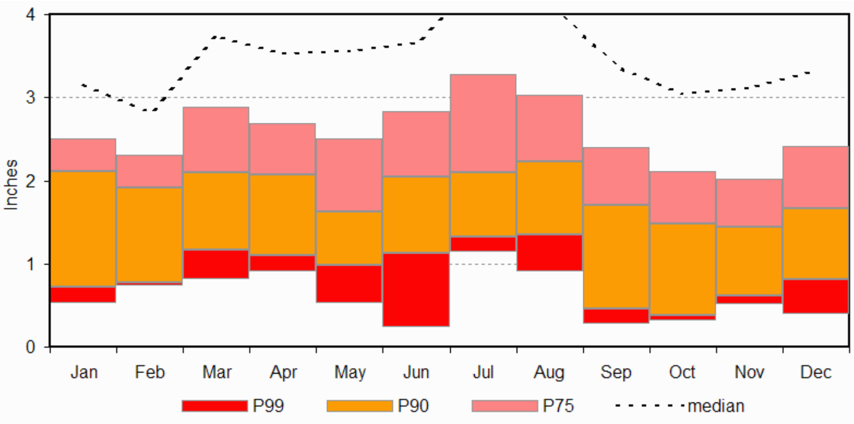


Figure 17. Dry-weather exceedance frequencies for monthly precipitation totals in northern New Jersey.

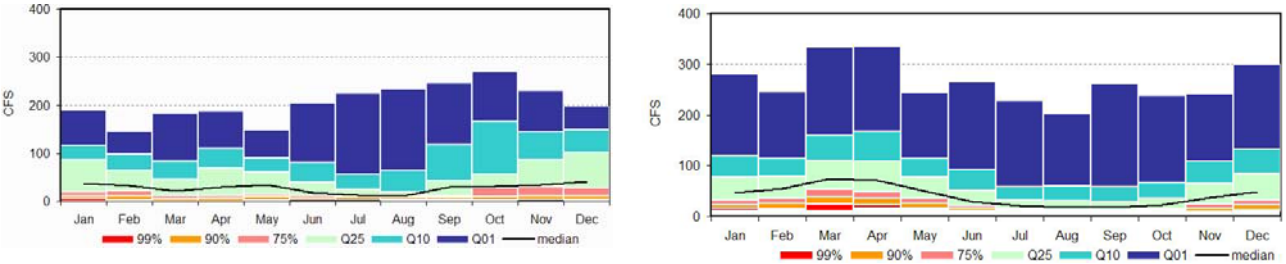
Explanation of terms: In this context 'P' is a precipitation frequency statistic. The two figures after the 'P" indicates what percentage of all monthly precipitation totals observed in that month were greater than that value. The bottom of the red bar is the minimum value for that calendar month.

Daily Streamflow Statistics

Daily flows in the Musconetcong River, both observed and reconstructed, provide a basis for a statistical analysis. This analysis defines, for each calendar month, the flow that is exceeded by a set percentage of all flows that month. Table 9 gives a summary of exceedance frequency statistics for daily streamflows, by calendar month. These data are shown graphically in figure 18.

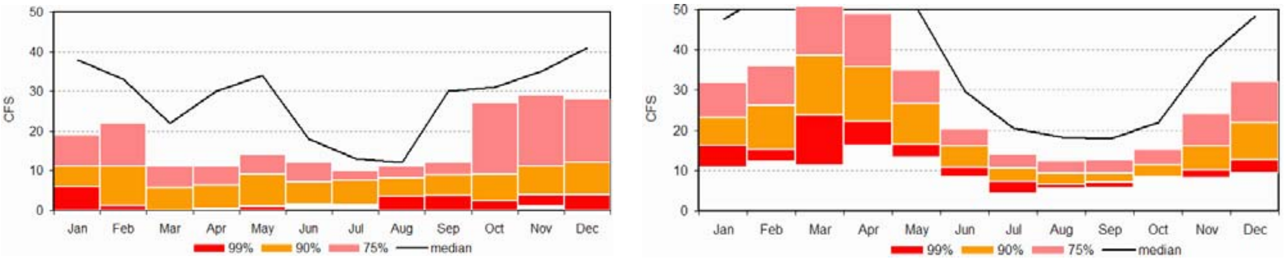
Figures 18a and 18c shows the Q99, Q90, Q75, Q25, Q10 and Q01 monthly flow statistics, for observed and reconstructed flow, respectively. The top of the colored bar is the appropriate value. In this context the Q99 flow is that flow for which 99% of all flows in that month were greater than. Thus Q99 is indicative of drought flows. The Q90 flow is that flow that 90% of all daily flows, in that month, were greater than. It is a dry-period flow. The solid line in figures 18a and 18c shows the median value. This is equivalent to the Q50 flow.

Figures 18c and 18d focus on low flows. They show the low-flow monthly flow statistics (Q99, Q90 and Q75) for observed and reconstructed streamflows, respectively. The distribution of monthly flow statistics in the reconstructed streamflow (fig. 18d) is typical of northern New Jersey streams. The dry-period monthly flow statistics of the observed flows (fig 18c) are skewed towards the lower end. This shows that lower streamflows is a result of holding back water in Lake Hopatcong.



18a. Observed streamflows, all frequencies

18b. Reconstructed streamflows, all frequencies



18c. Observed streamflow, low-flow frequencies

18d. Reconstructed streamflow, low-flow frequencies

Figure 18. Exceedance frequencies for observed and reconstructed daily streamflows, Musconetcong River at outlet of Lake Hopatcong.

Explanation of terms: In this context 'Q' is a streamflow frequency statistic. The two figures after the 'Q" indicates what percentage of all flows observed in that month were greater than that value. The median line is equivalent to Q50; half of all flows observed in that month were greater and half lesser. The red bars indicate drier-than-normal conditions, the blue wetter. At this scale some of the red bars are so thin they do not show up.

Table 9. Exceedance frequencies of observed and reconstructed daily streamflows in the Musconetcong River at Lake Hopatcong

-- Observed Flows ---

Month	Frequency statistic (cfs)								
	Minimum	Q99	Q90	Q75	Median	Q25	Q10	Q01	Maximum
Jan	0	6	11	19	38	86	116	190	205
Feb	0	1	11	22	33	64	98	145	153
Mar	0	0	6	11	22	45	83	183	496
Apr	0	0	6	11	30	69	110	187	265
May	0	1	9	14	34	60	89	148	218
Jun	1	2	7	12	18	40	80	205	355
Jul	1	1	8	10	13	24	56	225	329
Aug	0	4	8	11	12	20	63	233	731
Sep	0	4	9	12	30	43	117	246	318
Oct	0	2	9	27	31	56	167	270	348
Nov	1	4	11	29	35	86	144	230	257
Dec	0	4	12	28	41	102	149	197	289

-- Reconstructed Flows ---

Month	Frequency statistic (cfs)								
	Minimum	Q99	Q90	Q75	Median	Q25	Q10	Q01	Maximum
Jan	11	16	23	32	48	78	120	281	945
Feb	12	15	26	36	55	80	115	247	602
Mar	11	24	39	53	75	110	160	334	635
Apr	16	22	36	49	72	109	167	335	840
May	13	17	27	35	50	77	115	245	615
Jun	8	11	16	20	30	52	92	266	622
Jul	4	7	11	14	20	33	59	228	464
Aug	6	7	9	12	18	31	60	202	519
Sep	6	7	9	13	18	30	58	263	715
Oct	8	8	11	15	22	36	66	238	602
Nov	8	10	16	24	38	64	109	242	504
Dec	9	13	22	32	48	84	132	300	613

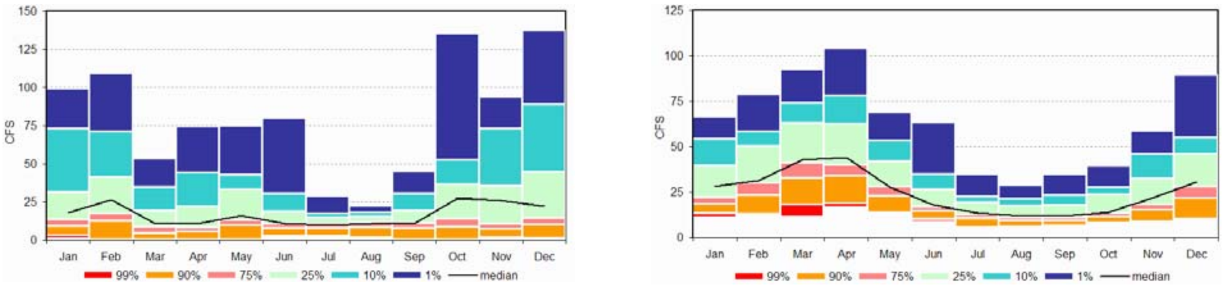
Notes:

(1) In this context 'Q' is a streamflow frequency statistic. The two figures after the 'Q" indicates what percentage of all flows observed in that month were greater than that value.
(2) 'Median' is equivalent to Q50; half of all flows for that month were greater and half lesser.
(3) 'Minimum' is the lowest flow observed or estimated for that month; 'Maximum' is the greatest.
(4) All flows rounded to the nearest integer value.
(5) Observed streamflow frequency statistics based on flows measured in the Musconetcong River at the outlet of Lake Hopatcong over the period 7/19/1928 - 9/30/1962 and 10/1/2002 - 10/20/2009.
(6) The procedure for creating the reconstructed streamflows is described in the report above.
(7) All values rounded to the nearest integer.

Monthly Low-Flow Streamflow Statistics

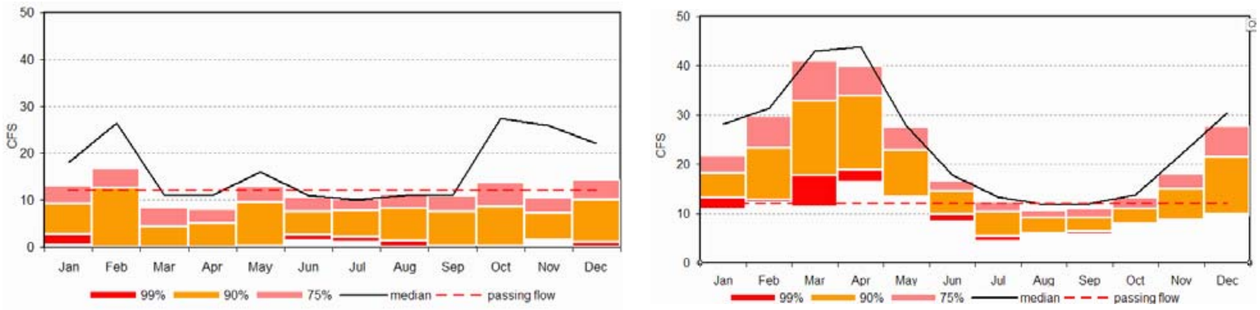
An analysis of the lowest daily flow reported in each month provides some insight into flows in the Musconetcong River at Lake Hopatcong. This is based on one value per month -- the lowest daily flow reported that month. The resulting data set has as many values as there are months in the data record. This shorter data set is then divided into calendar months. The results of an exceedance frequency analysis of each calendar month's values, for both the observed and reconstructed flows, are shown in table 10 and figure 19. The data presentation mirrors that as given for the daily streamflows in the previous section.

Figures 19c and 19d focus on the dry-weather monthly low-flow exceedance frequencies for the observed and reconstructed flows, respectively. It is clear that the 12 cfs passing flow has a dramatic effect on low flows. For March to September the median low flow is approximately the passing flow (fig. 19c). In contrast, the reconstructed flows (fig. 19d) suggest that only in August and September would the median monthly flow be about 12 cfs; monthly low flows would be greater in the other months. This shows the effect of holding water back in Lake Hopatcong to maintain water levels.



19a. Observed monthly low flows, all frequencies

19b. Reconstructed monthly low flows, all frequencies



19c. Observed monthly low flow, low-flow frequencies

19d. Reconstructed monthly low flow, low-flow frequencies

Figure 19. Exceedance frequencies for observed and reconstructed monthly low flows, Musconetcong River at outlet of Lake Hopatcong.

Explanation of terms: In this context 'Q' is a streamflow frequency statistic. The two figures after the 'Q" indicates what percentage of all flows observed in that month were greater than that value. The median line is equivalent to Q50; half of all flows observed in that month were greater and half lesser. The red bars indicate drier-than-normal conditions, the blue wetter. At this scale some of the red bars are so thin they do not show up.

Table 10. Exceedance frequencies of observed and reconstructed monthly low in the Musconetcong River at Lake Hopatcong

------------------------------------- Observed Monthly Low Flows ---

Month	Frequency statistic (cfs)								
	Minimum	Q99	Q90	Q75	Median	Q25	Q10	Q01	Maximum
Jan	0	3	9	13	18	31	73	99	102
Feb	0	0	8	13	27	37	67	105	113
Mar	0	0	1	4	11	15	31	49	56
Apr	0	0	2	5	11	19	41	71	76
May	0	0	6	10	16	30	39	71	82
Jun	1	3	5	8	11	16	27	77	85
Jul	1	2	5	8	10	12	14	26	27
Aug	0	1	5	8	11	12	15	19	22
Sep	0	0	4	8	11	16	27	42	49
Oct	0	0	3	8	28	31	47	130	166
Nov	1	1	4	7	26	32	70	90	91
Dec	0	1	6	10	22	40	84	133	148

-------------------------------------- Reconstructed Monthly Low Flows -----------------------------------

Month	Frequency statistic (cfs)								
	Minimum	Q99	Q90	Q75	Median	Q25	Q10	Q01	Maximum
Jan	11	13	18	22	28	39	54	66	80
Feb	12	13	17	23	31	43	52	72	73
Mar	11	18	25	33	43	55	66	84	89
Apr	16	19	28	34	44	56	72	98	118
May	13	13	18	23	28	37	48	64	68
Jun	8	10	12	14	18	24	32	61	65
Jul	4	5	8	10	13	17	20	32	41
Aug	6	6	8	9	12	16	20	27	28
Sep	6	6	7	9	12	16	21	33	47
Oct	8	8	9	11	14	21	25	37	41
Nov	8	9	12	15	22	29	43	55	56
Dec	9	10	15	21	30	39	48	83	84

Notes:

1. In this context 'Q' is a streamflow frequency statistic. The two figures after the 'Q" indicates what percentage of all monthly low flows observed in that calendar month were greater than that value.
2. 'Median' is equivalent to Q50; half of all montly low flows for that calendar month were greater and half lesser.
3. 'Minimum' is the lowest monthly low flow observed or estimated for that month; 'Maximum' is the greatest.
4. All flows rounded to the nearest integer value.
5. Observed monthly low flow frequency statistics based on flows measured in the Musconetcong River at the outlet of Lake Hopatcong over the period 7/19/1928 - 9/30/1962 and 10/1/2002 - 10/20/2009.
6. The procedure for creating the reconstructed streamflows is described in the report above.
7. All values rounded to the nearest integer.

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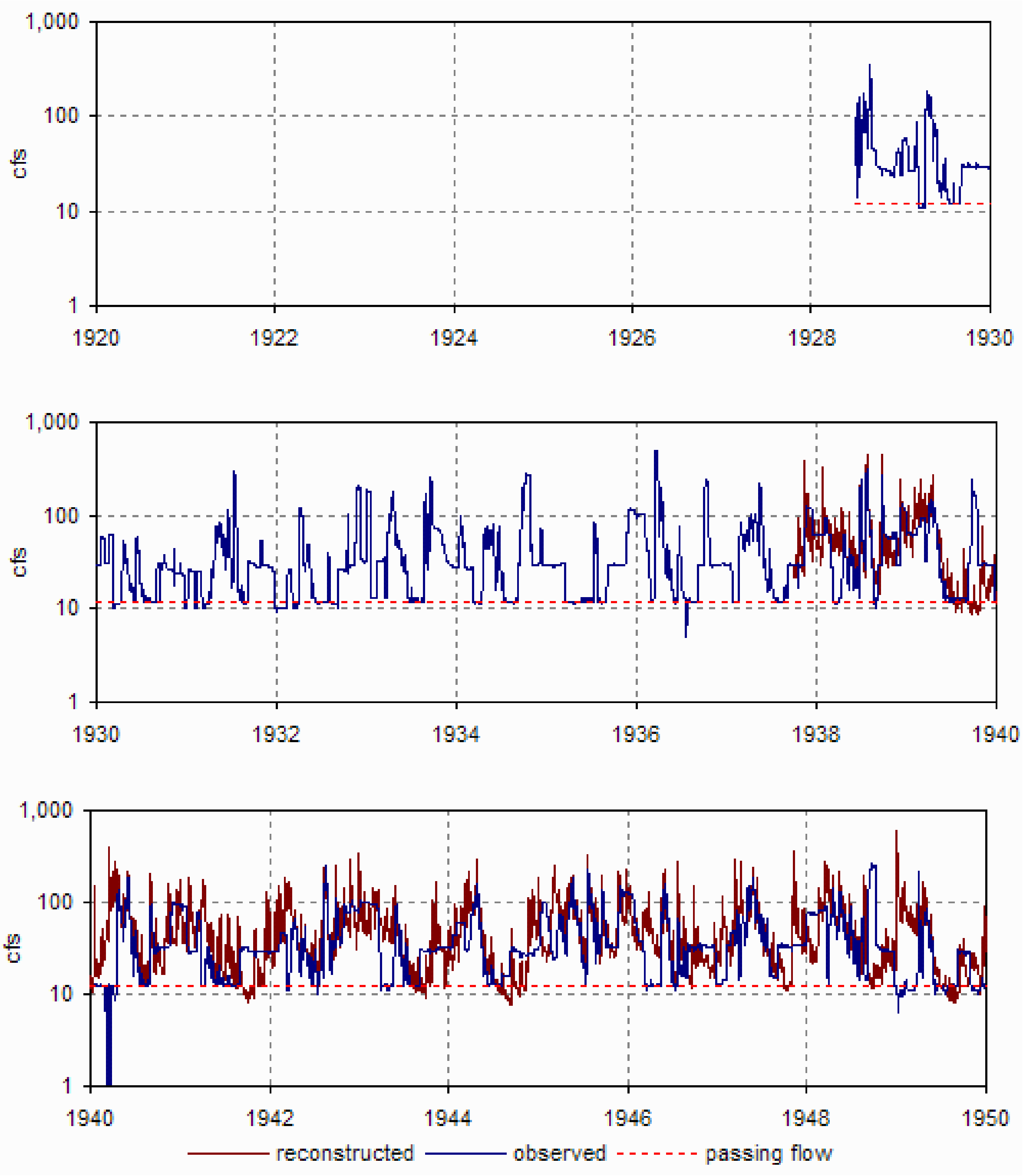
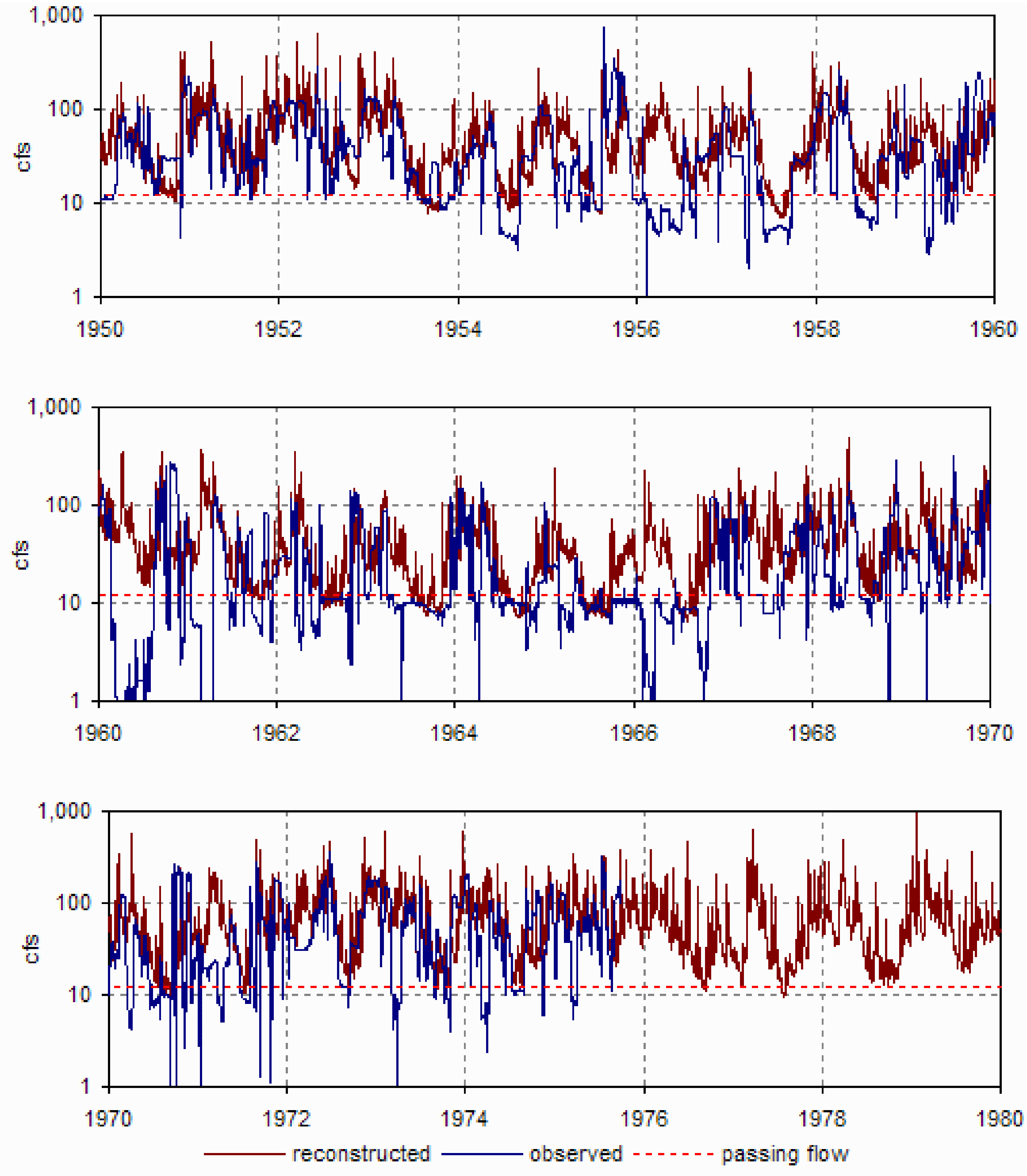
Appendix A.

Observed and Reconstructed Flows in the Musconetcong River at Lake Hopatcong

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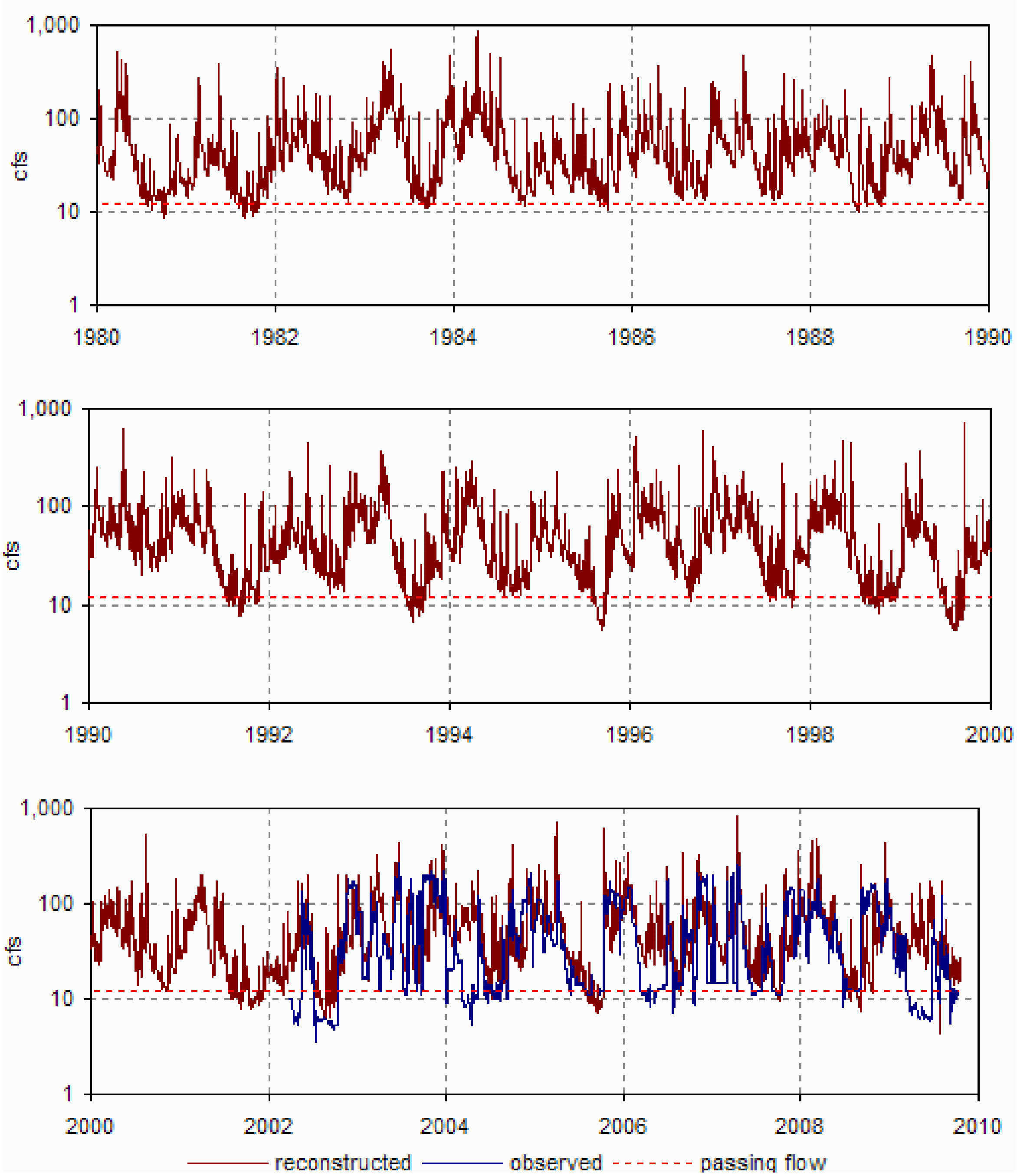
reconstructed
observed
passing flow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passing flow