FEDERAL ENERGY REGULATORY COMMISSION
Washington, D. C. 20426

OFFICE OF ENERGY PROJECTS

Docket No. HB81-09-2-000
Headwater Benefits Determination
Hudson River Basin, New York

MAY 1 0 2011

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Subject: Headwater Benefits Determination - Hudson River Basin

Gentlemen:

1. By a letter dated August 4, 2009, we informed you that the Commission initiated a headwater benefits determination study for the Hudson River Basin. The purpose is to establish headwater benefits charges due from the owners of downstream hydropower projects to Hudson River-Black River Regulating District from the district's regulation of streamflows.

2. The study is being conducted under contract with the Oak Ridge National Laboratory (Oak Ridge). At Oak Ridge's request you provided your project's engineering and operation data for the study.

3. In cases where data required for energy gains computations are unavailable, data must be revised, estimated and validated. In such cases water balance computations form the basis for data validation. A water balance computation preserves the conservation of volume relationship between aggregate inflows and outflows, changes in reservoir storage, and corresponding changes in pool elevations for reservoir. To analyze intra-project and inter-project inconsistencies in water balance for the headwater and downstream projects, Oak Ridge used the RIVERWARE Computer Model for water balance computations.

4. Enclosed is a draft Basin Scoping and Data Sufficiency Assessment report for headwater benefits determination in the Hudson River Basin, and a CD with details on the water balance analysis of available data for storage and generation. The draft report also includes preliminary relationships between flow and generation, i.e. rating curves at the downstream hydroelectric projects. The rating curves have not been calibrated so that the difference between modeled and actual generation are within the accuracy limits for energy gains determination using the Commission's Headwater Benefits Energy Gains Model (HWBEG). The report identifies the adequacy of the data provided, and additional data needed to determine the energy gains using HWBEG model.

5. Please review and provide your comments on the report within 45 days from the data of this letter. If you have any questions, please contact Mr. Vedula Sarma at (202) 502-6190.

Sincerely,

William Guey-Lee

William Guey-Lee, Chief
Engineering Resources Branch
Division of Hydropower Administration
and Compliance

Enclosures

Hudson River Basin

Headwater Benefits Determination

Draft

Basin Scoping Report and

Data Sufficiency Assessment

Prepared by

Oak Ridge National Laboratory

for the

Federal Energy Regulatory Commission

May 2011

1 INTRODUCTION

This report is the first of two reports to the Federal Energy Regulatory Commission (Commission) and interested parties on an investigation of headwater benefits in the Hudson River Basin. The report presents the findings of Oak Ridge National Laboratory (ORNL) staff concerning the network structure of the Hudson River Basin, the existence of dams, impoundments, and power production facilities within the Basin, and the routing of water through the Basin. In addition, the report briefly describes the plan for analysis of headwater energy benefits and the sufficiency of the available data.

Staff configured and used an object-oriented, user-friendly, and transparent basin operations model (RiverWare) to analyze the intra-Project and inter-Project inconsistencies in water balance (volume conservation) for the headwater and potential beneficiary Projects in the basin. The availability of this model significantly reduced the time required to analyze inconsistencies in data from different sources within the basin. Significant work remains to produce a set of consistent flow, elevation, and generation data necessary for an acceptable energy gains analysis for Projects in the basin. These data needs and future work are discussed in the concluding section of this report.

This report is presented in draft form to afford Commission staff and interested parties the opportunity to resolve with ORNL staff any errors or omissions in ORNL findings about the basin structure, Project inventory, and water routing. This draft report also permits the Commission and the other parties to comment on the analysis plan, and to identify additional data that ORNL will use for the headwater benefits energy gains (HWBEG) analysis.

The Commission conducts headwater benefits studies and determinations under Section 10(f) of the Federal Power Act. These determinations provide the basis for the Commission to assess charges to a licensee that are related to benefits provided by an upstream, or headwater, Project. Headwater benefits are the additional energy ("energy gains") made possible at downstream Project due to a storage reservoir or headwater improvement. The payments for headwater benefits are based on an equitable apportionment of the annual costs of interest, maintenance and depreciation of the joint-use facilities of the headwater Project allocated to power function.

The Commission regulations at 18 C.F.R. 11.14(a) provides that owners of downstream and headwater Projects may negotiate a settlement for headwater benefits charges and file for Commission approval according to the provisions of §385.602. However, if the owners of a headwater or downstream Projects cannot come to an agreement, any owner of a headwater or downstream Project can request the Commission to determine headwater benefits charges.

The principal headwater Project in the Upper Hudson River Basin is Great Sacandaga Lake, owned by the Hudson River-Black River Regulating District (HRBRRD). The HRBRRD also manages Indian Lake, another state-owned facility, for flood control and Hudson River flow regulation. The HRBRRD charged downstream users a fee to cover operational costs until a federal judge ruled that the State of New York lacked the authority to charge the fee. As a result of that decision, the HRBRRD and the downstream users requested that the Commission perform a headwater energy benefits study to determine appropriate payments that downstream users to pay the district for maintenance of Lake Sacandaga. This study is part of the Commission effort to estimate appropriate charges for the energy benefits of the HRBRRD headwater Projects.

2 UPPER HUDSON RIVER BASIN

The scope of this analysis is the Hudson River upstream of the Troy Lock and Dam #1 (also called Green Island Dam and Lock), but excluding the Mohawk River (USGS hydrologic unit 02020004). This part of the Hudson River Basin has a drainage area of about 5,540 square miles. The USGS divides the area into three hydrologic units (02020001, 02020002 and 02020003). Green Island Dam is located just downstream of the lowest hydrologic unit called the Hudson-Hoosic (USGS hydrologic unit 02020003; 1,880 mi^2). Upstream, the Hudson River drains the Upper Hudson hydrologic unit (02020001; 1,630 mi^2) into unit 02020003 at the point where the Sacandaga River drains the Sacandaga hydrologic unit (02020002; 1,050 mi^2).

2.1 Adirondack Park

The Hudson and Sacandaga Rivers rise in the Adirondack Park. Most of the Upper Hudson and Sacandaga hydrologic units (02020001 02020002, respectively) and are within the Adirondack Park boundaries, including Great Sacandaga Lake, Indian Lake, and multiple run-of-river Projects. The Adirondack Park was created in 1892 by the State of New York amid concerns for the preservation of water and timber resources of the region. The Adirondack Park Agency reports that the park is the largest publicly protected area in the contiguous United States (http://www.apa.state.ny.us/about_park/index.html, accessed November 16, 2010). The boundary of the Park encompasses approximately 6 million acres, nearly half of which belongs to the New York State public. The balance of the Park area is private land. The park has a year-round population of about 130,000 people.

2.1.1 Precipitation and Hydrology

Precipitation in the Upper Hudson Basin is fairly constant throughout the year. The wettest weather occurs during the summer, May through September. The least precipitation falls in the winter, December through March. The annual precipitation normal at Conklingville Dam is 46.5 inches. The monthly precipitation normals at Conklingville Dam range from slightly less than 2.9 inches for February to 4.2 inches for May. At Indian Lake, the annual precipitation normal is 40.8 inches, with a monthly low of 2.3 inches for February and a monthly high of 4.2 inches for September. At Glens Falls, the annual precipitation normal is 38.6 inches. The monthly precipitation normals range from a low of 2.2 inches for February to a high of 3.8 in for May. (NCDC 2002)

While normal precipitation varies only modestly throughout the year, natural stream flows show much more variation. Winter Hudson River flows tend to be low because much of the precipitation falls as snow and because low temperatures retard melting. Late summer flows tend to be low because warm temperatures cause evapotranspiration to be at its highest levels. Stream flows rebound in the fall as plants go dormant. Peak natural flows normally occur in April and early May as snow melts but low temperatures prevent plants from returning to heavy evapotranspiration.

2.2 Sources of Configuration Data for the Upper Hudson Basin

ORNL began this effort by reviewing the river basin schematic provided by the Commission. ORNL requested comments from Project owners on the Commission's schematic and requested specific information about the configuration and operations of the several hydropower facilities in the basin.

Using the U.S. Army Corps of Engineers National Inventory of Dams (NID) database, ORNL staff identified 166 dams within the Hudson River Basin upstream of Green Island Dam, excluding the Mohawk River. The principal source consulted for the existence of dams within the basin was the NID (2009). ORNL used data from the National Hydrography Dataset (NHD 2010), Google Earth, and information from the Project owners to clarify the relationships between related dams identified in the NID database. Not all of these Projects alter the timing and magnitude of inflows to downstream Projects. Many of those Projects are small and unlikely to contribute to energy benefits to downstream hydropower developments.

ORNL accessed publicly-available gauge station data maintained on-line by the U.S. Geologic Survey (USGS). The USGS gauge stations in the basin provide a valuable baseline for confirming the validity of data provided by parties.

2.3 Potentially Significant Water Control Facilities in the Basin

As described in Section 4, ORNL further selected the water control Projects and monitoring sites within the basin that may be relevant to the headwater benefits analysis. The Projects are described in Section 3, and their locations are indicated on the river basin schematic (Figure 1). While the focus is on beneficiary plants on the Hudson and Great Sacandaga Lake, the major tributaries and the largest storage reservoirs are shown to support discussion in subsequent parts of this report.

All relevant stream gauges that had data for the study period are shown in Figure 1. While nearly all downstream Projects are operated as run-of-river (ROR) plants, some of the beneficiary plants have sufficient storage that incorporating storage effects may be necessary for the headwater energy benefits analysis. These are noted as "ROR Power w storage" on the figures. Several tributary hydroelectric projects are identified in the figures because their flow (or generation) data may be important for the analysis.

2.3.1 Overview of Upper Hudson River Facilities

The overall structure of the basin is summarized in this section. The narrative progresses from the lower to upper reaches of the basin.

The Green Island Project is located at the Troy Lock and Dam (NID number NY00951; also sometimes called "Federal Lock and Dam") is the last water control facility above tidewater on the Hudson. USGS gauge station 01358000 is located a short distance upstream of the dam.

The Mohawk River joins the Hudson just upstream of the Troy Lock and Dam. The Mohawk is not in the scope of this study, but its flow affects Green Island Project. The Mohawk River contributions to the flow at Green Island Project will be accounted for by USGS gauge stations 01357500 and 0135499.

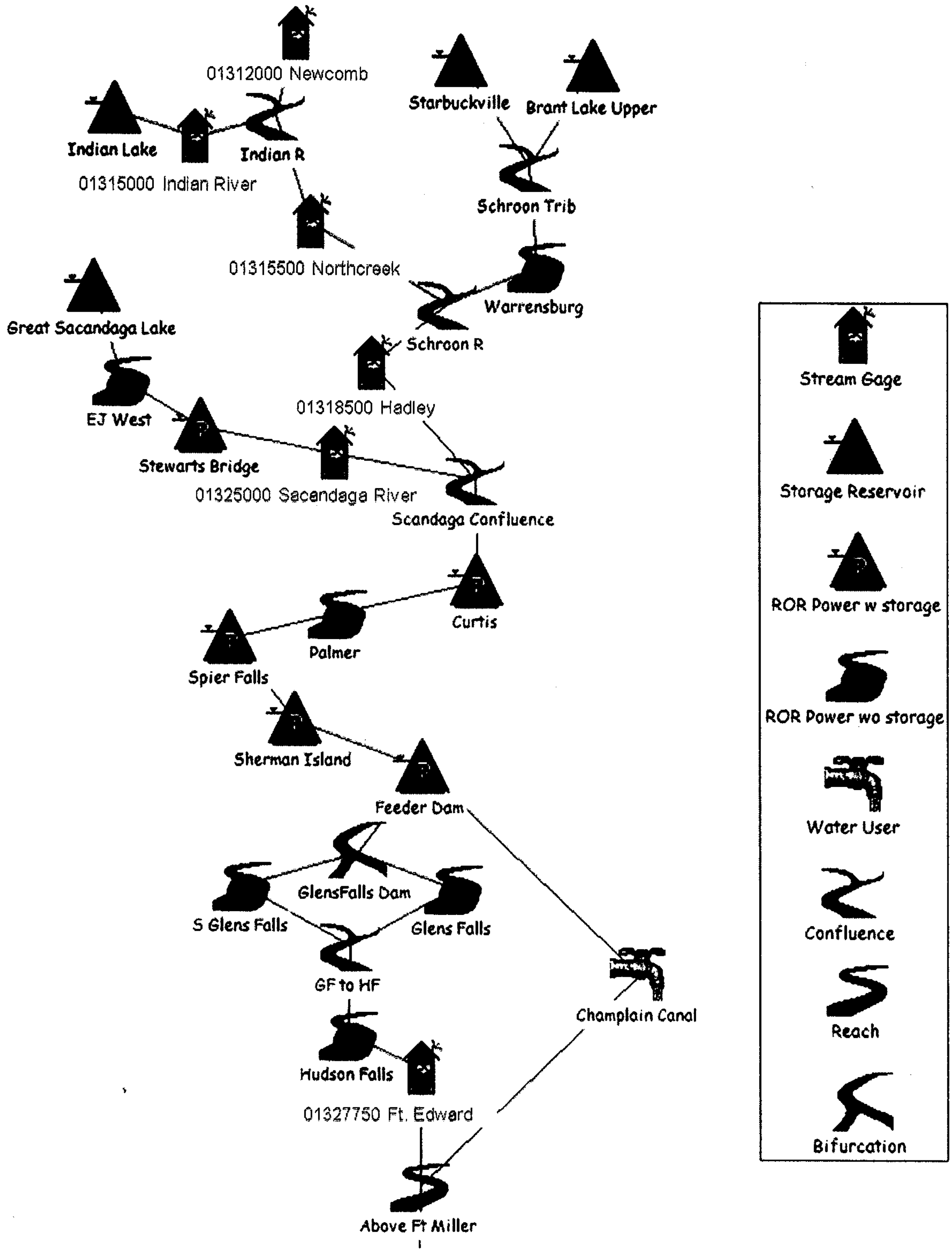

Figure 1. Schematic of the Hudson River Basin

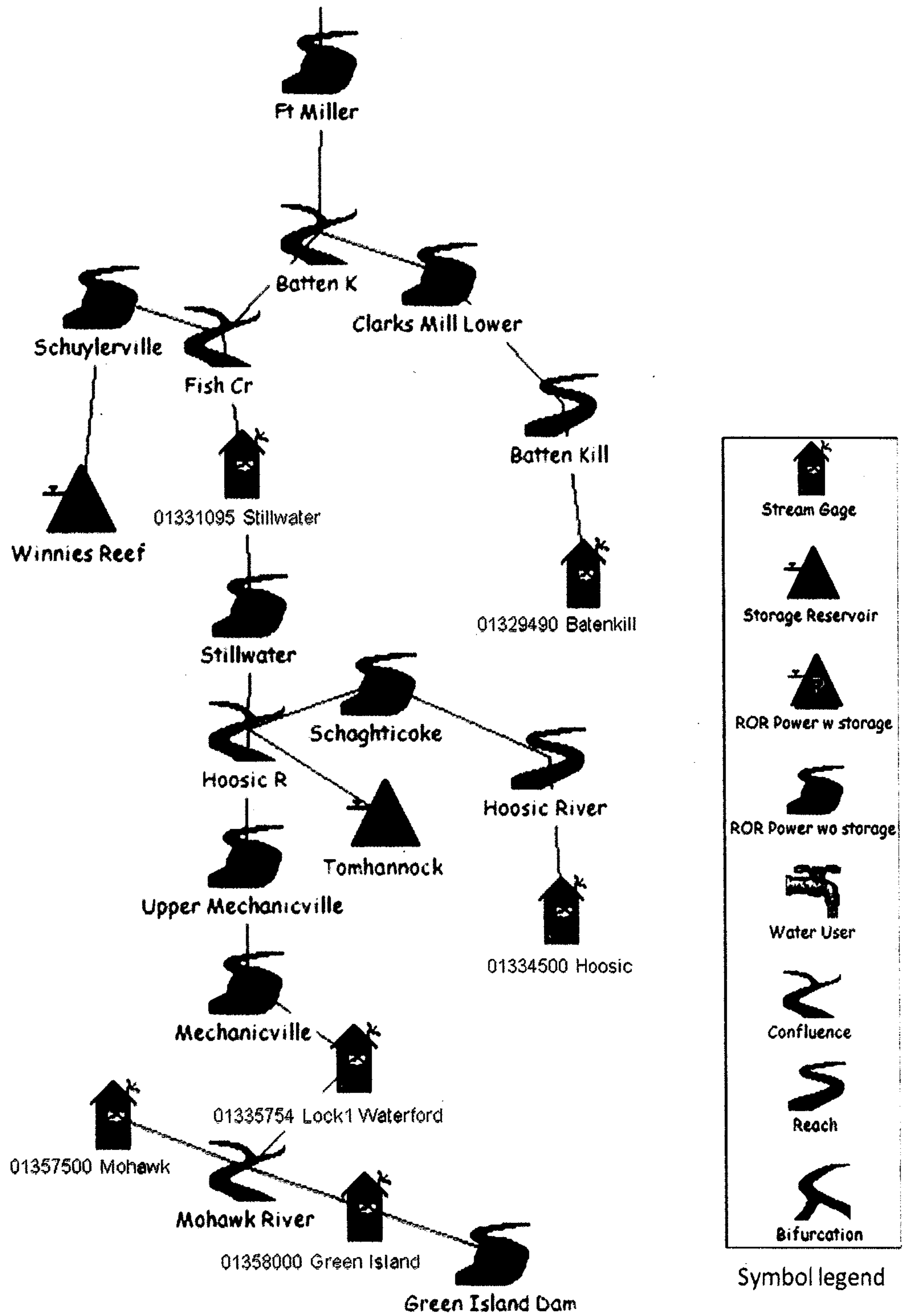

Figure 1 (continued).

Lock C-1 and Dam at Waterford (NY00950) is approximately five miles upstream of Green Island. The NID lists it as a hydroelectric and navigational facility, but ORNL has found no records or other indications that there are any hydroelectric developments at the facility.

The Mechanicville Project is located at the Lock C-2 Dam (NY00988), approximately 4 miles upstream of Lock C-1.

The Upper Mechanicville Project is located about 2 miles upstream at the Lock C-3 dam (NY00215).

The Stillwater Project is located at the Lock C-4 Dam (NY00162) about 2 miles upstream. The Hoosic River joins the Hudson from the east, immediately downstream of Lock C-4.

Northumberland Dam (NY01076), located about 16 miles upstream, serves Lock C-5. The Batten Kill joins the Hudson immediately downstream of Lock C-5 from the east. Fish Creek joins the Hudson from the west about half a mile downstream of the Batten Kill confluence.

The Fort Miller Project is Located at Fort Miller Dam at Lock C-6 (NY01073) a little over 2 miles upstream of the Northumberland Dam. The Thompson Island Dam (NY01074) and Crocker's Reef Guard Station are located about 1.5 miles upstream of the Fort Miller Dam. The Crocker's Reef Guard Station guards the upstream entrance to the channel that leads to Lock C-6. The Fort Miller Dam impounds the reach of the Hudson below the Thompson Island Dam.

Lock C-7, approximately 7.5 miles upstream of the Fort Miller Project, is the point at which the Champlain Canal diverges from the Hudson River.

USGS Gauge Station 01327750 is located about one mile upstream of Champlain Canal confluence at Lock C-7.

The Hudson Falls is located at Hudson Falls Dam (NY00144) is located about 2.5 miles upstream of Station 01327750.

Glens Falls Dam (NY00140) is located about 3 miles upstream of Hudson Falls Dam. Glens Falls Dam supports two hydroelectric facilities, Glens Falls Project and South Glens Falls Project which split the water retained by the dam.

The Feeder Dam Project is located at Feeder Dam (NY00143) about 2 miles upstream of Glens Falls Dam. In addition to supporting the Feeder Dam Hydroelectric Project, the Feeder Dam is the diversion point for the Feeder Canal which serves the Champlain Canal. The Feeder Canal discharges to the Champlain Canal at its high point to provide water at the divide between the Hudson and Champlain basins.

Sherman Island Dam (NY00141) is located about 6.4 miles upstream of the Feeder Dam. Sherman Island Hydroelectric Project is located downstream of the dam at the end of a 3/4 mile long canal.

Spier Falls Dam (NY00136) and Spier Falls Project are located about 3.5 miles upstream of Sherman Island Dam.

The Curtis and Palmer Falls Project is located about 5 miles upstream of Spier Falls Dam. The Curtis and Palmer Falls Project includes the Warren Curtis (NY00138), and the Palmer Falls Dam (NY00145), located about ½ mile downstream of Curtis Dam.

The confluence of the Sacandaga and Hudson Rivers is approximately 6 miles upstream of the Curtis and Palmer Falls Project.

With a drainage area of 1,664 mi^2, USGS station 01381500 is just upstream on the Hudson, near Hadley, NY.

The Schroon River joins the Hudson about 15 miles upstream of the Sacandaga confluence.

USGS station 01315500 is located approximately 22 miles upstream of the Schroon River confluence, near North Creek, NY.

The confluence of the Indian River with the Hudson is approximately 18 miles upstream of Station 01315500.

USGS station 01312000, Near Newcomb, NY, is the highest Hudson River gauge station. It is located approximately 11 miles upstream of the Indian River confluence.

2.3.2 Mohawk River

With a drainage area of more than 3,450 mi^2, the Mohawk is a major contributor to the lower Hudson River. While the Mohawk has no effect on the hydroelectric facilities on the Upper Hudson, it can be expected to have significant effects on the Green Island Project which is just downstream of its mouth. The Mohawk has numerous water control facilities, but they have little to no bearing on the purposes of this study. The Mohawk is included in this discussion because of its effects on the Green Island Project. For the current study, the Mohawk's contribution to operations of the Green Island Project will be characterized by discharges reported by USGS stations 01357500 and 01357499.

2.3.3 Hoosic River

The Hoosic River rises in Western Massachusetts and joins the Hudson just downstream of Lock C-4 and the Stillwater Project. The Hoosick River has a drainage area of something over 650 mi^2. There are three hydroelectric dams between the mouth of the river and USGS station 01334500, about 23 miles upstream of the confluence with the Hudson. The USGS reports that the station has a drainage area of 510 mi^2. The three dams (all hydroelectric facilities) between the mouth of the Hoosic and the USGS station are:

- Schaghticoke Dam, NY00118,
- James Thompson Dam, NY00164, and
- Johnsonville Dam, NY00119.

There are three hydroelectric facilities upstream of the gauge station:

- Hoosick Falls Dam, NY00705,
- North Hoosick Dam (on the Walloomsac River), NY14430, and
- Walloomsac Dam (on the Walloomsac River), NY14050.

Farther upstream, the USGS also operates a gauge station (01332500) near Williamstown, MA. The USGS reports that this station has a drainage area of 126 mi^2.

2.3.4 *Fish Creek*

Fish Creek rises from the west of the Hudson and joins the Hudson River about 1 mile downstream of Lock C-5. It has a drainage area of about 250 mi^2. The lowest dam on Fish Creek is Schuylerville Dam (NY00002), a hydroelectric facility located about ¼ mile upstream of the confluence of Fish Creek with the Hudson River.

Winnies Reef Dam (NY00712) is a flood control and recreation dam that regulates the level of Lake Saratoga. The dam is located about 6 miles upstream of Schuylerville Dam and has a drainage area of about 240 mi^2. Between Winnies Reef and Schuylerville Dams is Victory Mills Dam (NY13697), a run-of-river hydroelectric facility.

2.3.5 *Batten Kill*

Batten Kill rises in Western Vermont and joins the Hudson just downstream from Lock C-5. It has a drainage area a little over 441 mi^2. Batten Kill has 7 dams between the confluence with the Hudson and USGS gauge station 01329490, approximately 12.5 miles upstream. The USGS reports that the gauge station has a drainage area of 396 mi^2. From the mouth of Batten Kill, the seven dams are:

- Clarks Mills Lower Dam, NY00927,
- Clarks Mills Upper Dam, NY00120,
- Middle Falls Dam, NY01429,
- Middle Falls Dam, NY00121,
- Lower Greenwich Dam, NY13698,
- Middle Greenwich Dam, NY01070, and
- Center Falls Dam, NY01071.

Except Lower Greenwich Dam which is an irrigation dam, the Batten Kill dams are run-of-river hydroelectric facilities.

2.3.6 *Sacandaga River*

USGS station 01325000 is located 1.5 miles up the Sacandaga River from its confluence with the Hudson.

The Stewarts Bridge Project is located at the Stewarts Bridge Dam (NY00149), approximately 3 miles upstream of the confluence with the Hudson.

The E.J. West Project is located at Conklingville Dam (NY00146) which forms Great Sacandaga Lake, a flood control, hydroelectric and recreation facility. Great Sacandaga Lake is the largest storage reservoir in the Hudson River Basin and the principal source of headwater benefits.

USGS station 01321000 is located near New Hope, NY about 5 miles upstream of Great Sacandaga Lake.

Lake Algonquin Dam (NY00172) is recreation and hydroelectric facility located about 3.7 miles upstream of station 01321000. The dam forms a 275-acre reservoir.

Christine Falls Dam (NY12831) is a small run-of-river hydroelectric facility located about 11 miles upstream of Lake Algonquin.

2.3.7 Schroon River

With a drainage area of about 565 mi^2, the Schroon River has only one hydroelectric facility, the Warrensburg Board and Paper Corp Dam (NY00010). The dam is located about 1 mile upstream of the Schroon confluence with the Hudson.

2.3.8 Indian River

The principal water control structure on Indian Creek is Indian Lake Stone Dam (NY00155), about 7.5 miles upstream of the confluence with the Hudson. Indian Lake is a large storage, flood control and recreation reservoir. USGS station 01314500 records the stage of Indian Lake and 01315000 records flow in Indian River a short distance downstream of the dam.

Lake Abanakee is a recreation reservoir downstream of Indian Lake with modest storage capacity.

3 CONFIGURATION AND OPERATION OF HEADWATER AND BENEFICIARY PROJECTS

The focus of this study is the energy benefits that may accrue to downstream hydroelectric generating stations as a result of flow regulation by upstream storage Projects. More specifically, the study will determine energy benefits that may accrue to 15 run-of-river Hudson River and Sacandaga River facilities as a result of flow regulation provided by storage reservoirs. Section 3.1 provides brief descriptions of the storage Projects that may be relevant to the headwaters benefits assessment. Section 3.2 describes beneficiary Projects.

3.1 Storage Reservoirs

For headwater energy benefits, the most important reservoirs are Great Sacandaga Lake and Indian Lake. Both storage Projects are owned by the district. The district is a New York State public benefit corporation intended to protect public health and safety by regulating the flow of waters in the Upper Hudson River and the Black River in the Adirondack Region. The Regulating District manages two Hudson storage reservoirs and three Black river storage reservoirs to reduce flooding caused by excess runoff and augment river flow when river flows are low.

3.1.1 Great Sacandaga Lake

The Great Sacandaga Lake (GSL) Project includes Conklingville Dam (NY00146) and Great Sacandaga Lake located in Saratoga, Fulton, and Hamilton Counties, New York. The Project is entirely within the boundaries of New York's Adirondack State Park. The E.J. West Project (P-2318) is attached to Conklingville Dam but operated by Brookfield Renewable Power Inc.

The Great Sacandaga Lake Project includes: the earth fill embankment dam, a water conveyance channel, a concrete outlet structure consisting of two siphon spillways and three outlet valves (Dow Valves), spillway, and Great Sacandaga Lake. The Conklingville Dam was built between 1928 and 1930 by the Hudson River Regulating District, an agency of New York State (NYS), to provide flood protection and low flow augmentation for the Hudson River. The dam is located on the northeastern arm of the lake.

3.1.1.1 Reservoir Data

The normal maximum surface area is 25,940 acres (at 771.0 ft NGVD27). The normal maximum surface elevation is 771.0 ft. The lake's usable storage (748 ft to 771 ft) is 20.10 billion cubic feet (461,000 ac-ft). The storage-elevation relationship is shown in Figure 2.

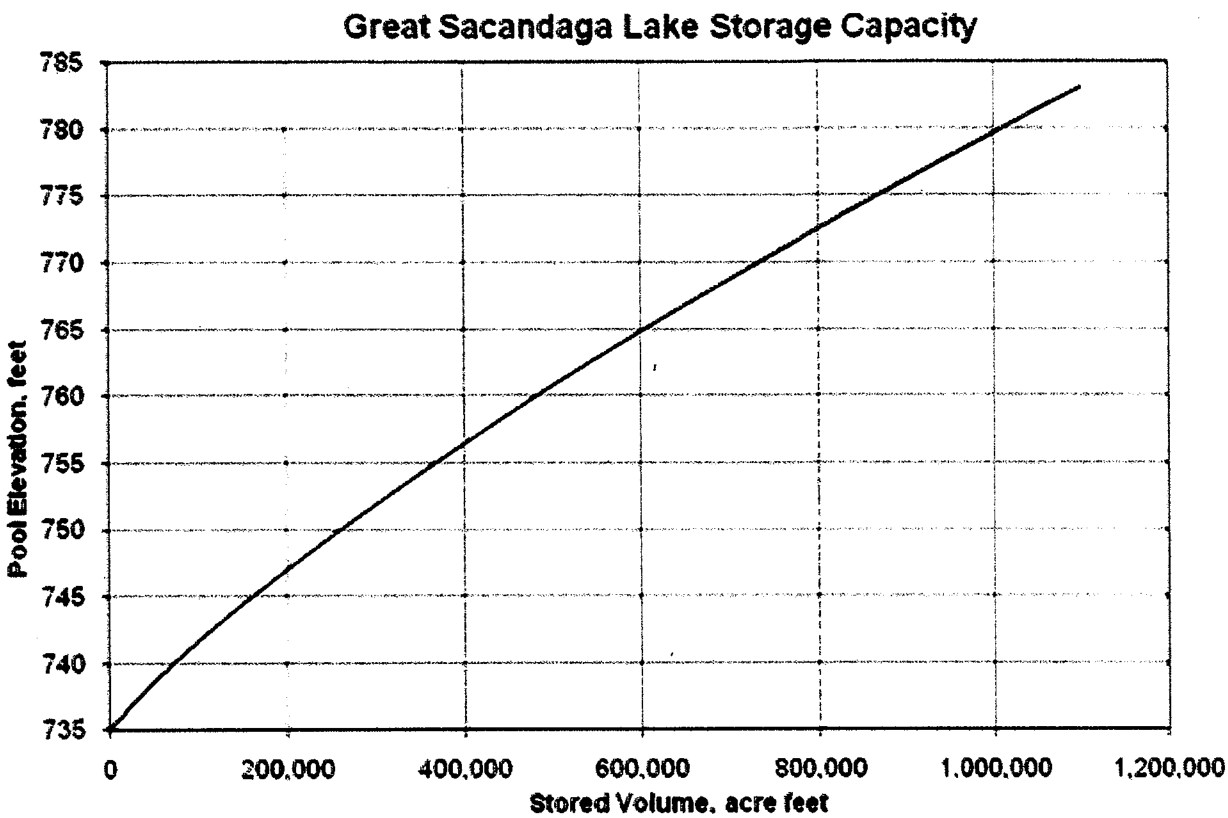

Figure 2. Storage-elevation curve for Great Sacandaga Lake.

3.1.1.2 Reservoir Operations

The district operates the Great Sacandaga Lake for flood protection and low flow augmentation in accordance with the terms of the April 2000 Upper Hudson / Sacandaga River Offer of Settlement and a September 22, 2002 license from Commission (P-12252). The Offer of Settlement establishes long-term environmental protection measures intended to meet and balance the diverse power and non-power objectives of the parties involved. The Commission license for the Great Sacandaga Lake Project expires in 2042. Historic average and Settlement target reservoir elevations are displayed in Figure 3.

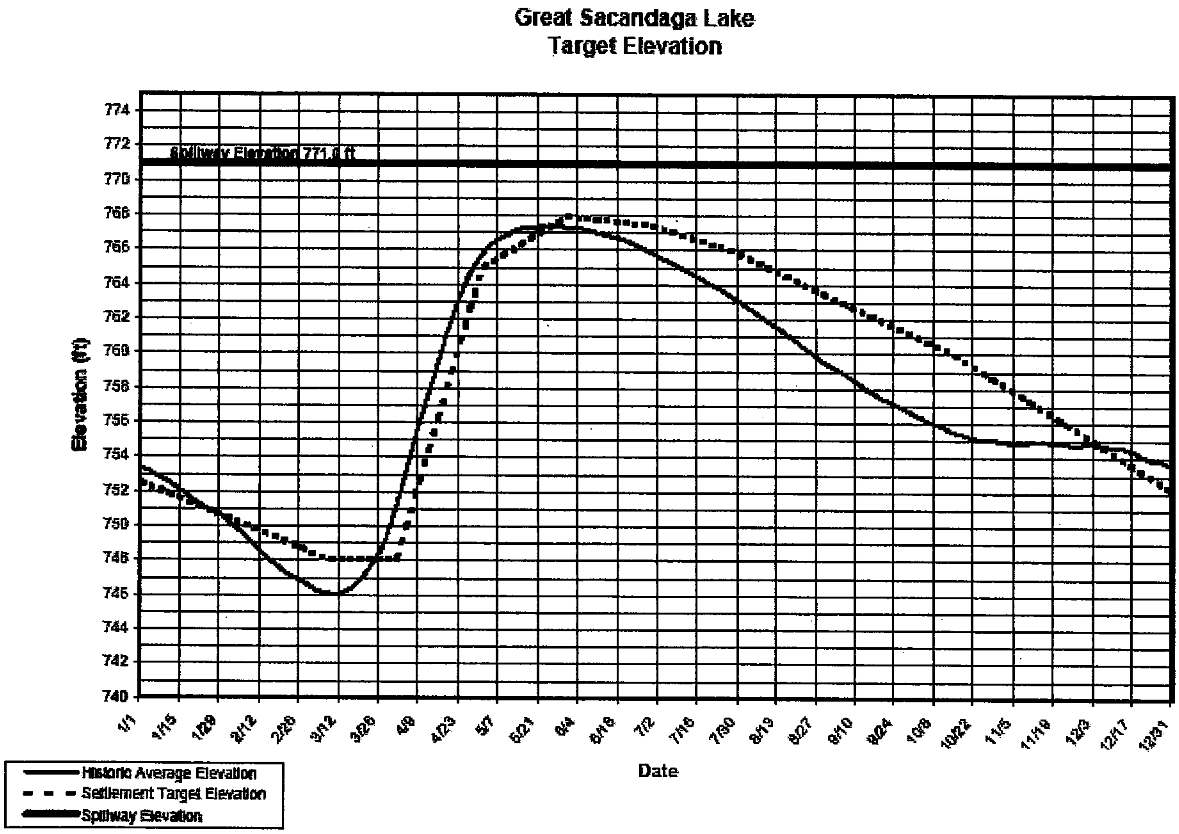

Figure 3. Reservoir Rule Curve for Great Sacandaga Lake

3.1.2 Indian Lake

Indian Lake Stone Dam (NY00155) was completed in 1898. It forms the 4,365-acre Indian Lake on the Indian River, a tributary of the Hudson River upstream of the Sacandaga River. The district manages the lake for flood control and storm water management, and recreation. Indian Lake Stone Dam has no hydroelectric capacity.

3.1.2.1 Reservoir Data

Indian Lake has a normal area of 4,365 acres. The lake has a storage capacity of 170,235 ac-ft. The lake's drainage area is 131 mi^2.

The USGS maintains a stage gauge (USGS 0131450) on the lake and a discharge gauge (USGS 01315000) a short distance downstream of the dam.

3.1.2.2 Reservoir Operations

Historic average and target reservoir elevations are displayed in Figure 4.

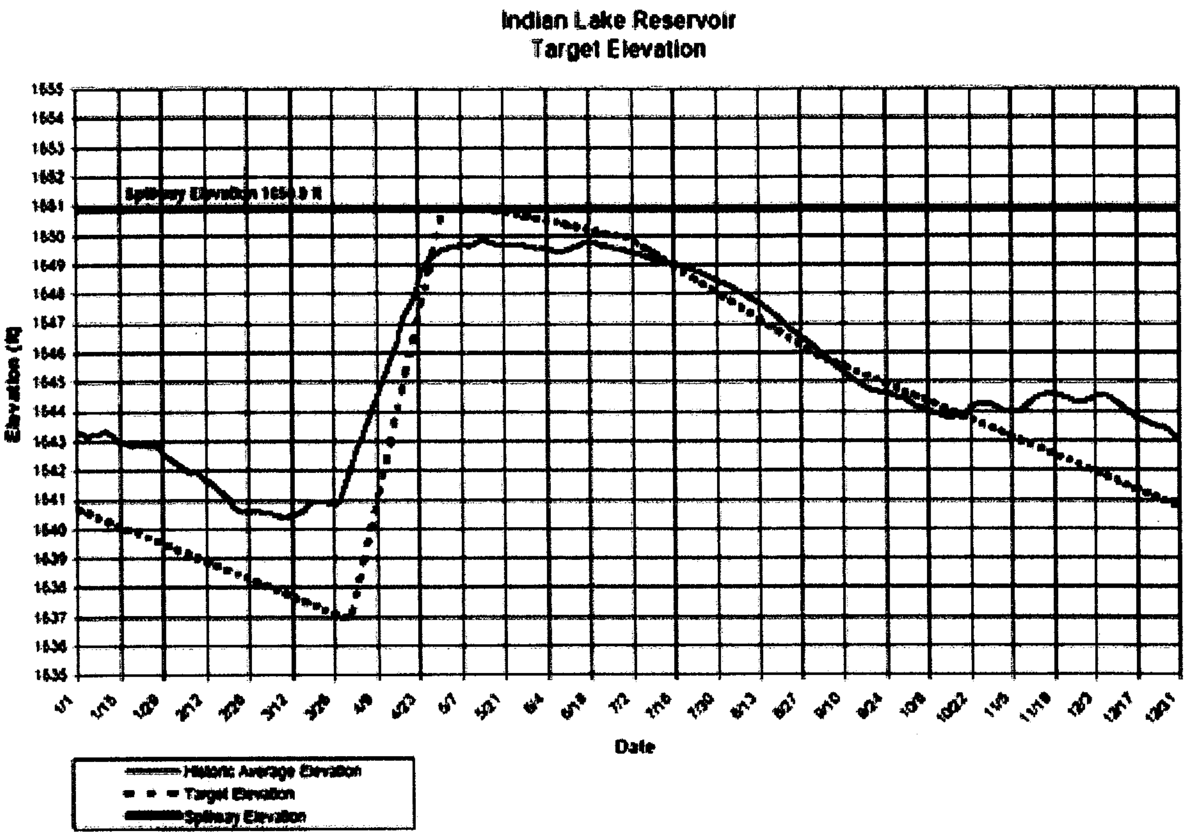

Figure 4. Reservoir Rule Curve for Indian Lake Reservoir

3.1.3 Winnies Reef Dam

Winnies Reef Dam (NY00712), on Fish Creek, is owned by Consolidated Hydro, Inc. controls a large flood control and water management reservoir in the upper Hudson Basin. Fish Creek joins the Hudson River about a mile below Ft. Miller Project. Discharges from Fish Creek affect operations of Stillwater, Upper Mechanicville, Mechanicville, and Green Island Projects. Winnies Reef Dam is listed in the NID as having a storage capacity of 100,700 ac-ft, a surface area of 4,028 acres, and a drainage area of 244 mi^2. Completed in 1979, the dam is

That company also owns Victory Mills Dam (NY13697) approximately 5 miles downstream. Victory Mills Dam is a run of river hydroelectric facility (P-7153). Victory Mills Dam discharges into the reservoir formed by Schuylerville Dam (NY00002). Victory Mills Dam was built in 1846 (New York State Inventory of Dams).

Schuylerville Dam (NY00002) is a hydroelectric facility (P-8606) operated by Brookfield Renewable Power. Schuylerville Dam was built in 1918. It has a normal storage volume of 350 ac-ft, and a normal pool surface area of 13 acres (NID 2009). Discharges from Victory Mills Dam enter the Schuylerville Dam reservoir.

ORNL has no information on how any of these facilities are operated. No USGS gauge stations are located in the Fish Creek Drainage.

3.2 Beneficiary Projects

Thirteen Hudson River hydropower Projects and two Sacandaga River Projects may benefit from operations of headwater Projects. This section describes those Projects. The Projects are described beginning with Green Island Project, the lowest in the basin.

3.2.1 Green Island, P-0013

The Green Island Project is located at Federal Lock and Dam at Troy, NY (NY00951; The NID lists its name as Troy Lock and Dam #1). It is located about 0.7 mi below the Mohawk confluence with the Hudson. Normal pool elevation is 16.33 feet. The tailwater is tidal with a normal elevation variation of -2 to +5 ft. Green Island has four generating units for a total capacity of 6,000 kW. The total hydraulic capacity of the four units is 9,828 cfs at 13 feet head. The impoundment has a storage capacity of 3,500 ac-ft, but the facility is run of river and does not use the storage. There are no bypass flow requirements at the Green Island Project. All flow in excess of generation and navigation needs is passed over the dam.

ORNL is in possession of daily generation data for 2002 through 2008. By using the ratio of generation capacity to the hydraulic capacity, ORNL estimated that the average Project efficiency is 0.61 kW/cfs.[1] From the estimated turbine efficiency and the reported daily generation, ORNL estimated daily turbine flow for Green Island Project. Total daily average flow past the lock and dam is available from USGS station 01358000.

The NID reports that the dam was built in 1903 and is owned by Green Island Power Authority.

3.2.2 Mechanicville Project, P-6032

The Mechanicville Project is located at the Lock C-2 dam of the Champlain Canal system at Mechanicville, NY. The Project is a run of river generating facility. The crest elevation is fixed at 46.42 ft. The dam impounds about 1,375 ac-ft, but does not vary the pool to utilize storage. The license requires a minimum spill of 500 cfs. Water used by lock operations bypass the generators from May 1 through November 30.

Albany Engineering Corporation acquired the Mechanicville Project in July 2003 from Niagara Mohawk Power Corporation (now National Grid).[2] Albany Engineering performed structural rehabilitation work prior to returning generating units to operation. The restored plant began generating electricity in November 2003. Consistent production and production records were not

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[1] Because the tailwater elevation varies with tides, it is not clear that converting generation into flow based on capacities is accurate. However, in the absence of additional information, ORNL will use constant Project efficiency.

[2] Wendy Jo Carey, Albany Engineering Corporation, personal communication to Glenn Cada, ORNL, January 20, 2010.

archived until May 2004. Albany has provided ORNL daily generation data for May 1, 2004 through December 2008.

The facility has six units, each of 750-kW capacity, for a total capacity of 4,500 kW. However, the operational capacity did not reach that level during the study period. During the study period, the plant was in the process of being refurbished. It produced its first power in November 2003 with one operating unit. Additional units were brought on line during the study period until a maximum of five units were operational. One of the units, Unit 5, was operated with only two of five runners (turbines) during the study period.[3] Unit 5 did not begin operating with all five runners until June 2010.

The total hydraulic capacity of the six units is 5,820 cfs at 17.5 ft of head. Using these parameters, ORNL estimates that the average generating efficiency of the plant is 0.773 kW/cfs. Albany Engineering reports that tests of one unit showed a generating efficiency of 0.741 kW/cfs after a minimum flow of 367.42 cfs.

The dam was completed in 1899. The power plant is listed on the National Register of Historic Places because it retains much of the original equipment in use. The listing imposes certain constraints on modifications or upgrades to the plant. The old technology gives the operators less control of the generation than newer plants. Essentially, each unit is either on or off—no throttling is possible.

3.2.3 Upper Mechanicville Project, P-2934

The Upper Mechanicville Hydroelectric Redevelopment Project (P-2934) is owned and operated by New York State Electric and Gas (NYSEG). The power plant is located on the west bank of the Hudson River at the dam at Champlain Barge Canal Lock C-3 just north of Mechanicville, New York. Originally constructed circa 1882 by the Hudson River Water Power and Paper Company, title went to the West Virginia Pulp and Paper Company, and was transferred to the State of New York in 1922.[4] The Commission issued a license in 1981 and construction of the new powerhouse was completed in 1983.

The license requires that the pond elevation be "72.6 MSL as a maximum outside of minor variations allowed because of instrumentation and equipment response times." The normal pool surface area is 260 acres. Normal storage is 3,425 ac-ft, but as a run-of-river plant, this storage is normally not active. However, at the request of the New York State Canal Corporation, the pool is sometimes lowered about 1 ft to allow tall vessels to pass under a bridge upstream of the dam.

The tailwater elevation is normally 49.3 ft. The minimum tailwater elevation is 47.0 ft. The maximum tailwater elevation is 73.4 ft.

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[3] Each unit consists of one generator connected to five runners.

[4] The 2009 NID lists the New York State Canal Corporation as owner of the dam at Lock C-3.

The two turbine units each have a rated capacity of 8,700 kW with a rated flow capacity of 6,000 cfs. Total rated capacity of the station is 17,400 kW at a rated flow of 12,000 cfs. However, NYSEG estimates that the actual performance of the station is 19.98 MW at 12,620 cfs (Robert Vanderweel, NYSEG/RGE, personal communication with Lance McCold, ORNL, December 2, 2010). On the basis of the latter parameters, ORNL estimates that the generation efficiency is 1.58 kW/cfs.

The Commission license requires that the plant maintain a minimum discharge of 1000 cfs, including turbine discharge and bypass flow.

The owners of this Project have no measured flow data for river at their site. They estimate river flow at Upper Mechanicville to be equal to (Ft. Edwards Flow + Hoosic River Flow + Batten Kill Flow) divided by 0.87. They use that flow to estimate operational efficiency of the station.

3.2.4 Stillwater, P-4684

The Stillwater Project is located at the Lock C-4 dam (NID00162) at Stillwater, New York. The dam is owned by the New York State Canal Corporation. The dam was completed 1955. The hydropower facilities are owned by Stillwater Associates, LLC.

The Stillwater Project is located on the northwest side of the dam. The dam is located approximately two miles upstream of Lock C-3 Dam, and the Upper Mechanicville Project. The Project has two units each with a capacity of 1.75 MW at 3,500 cfs for a plant capacity of 3.5 MW at 7,000 cfs. Using these parameters, ORNL estimates generation efficiency to be 0.5 kW/cfs.

The plant maintains a minimum bypass flow of 500 cfs.

The owners do not collect or maintain flow data at the plant. Operators estimate flow rates once each day. However, the USGS maintains gauge station 01331095 which measures daily flow in the vicinity of the dam. ORNL will use data from this gauge station in modeling flow on the Hudson at this location.

3.2.5 Fort Miller, P-4226

The Fort Miller Project is located near Lock C-6 at Fort Miller Dam in the town of Northumberland. The dam is owned by Fort Miller Pulp & Paper Company (NID 2009), but managed by Mercer Asset Management Corp (Mercer). The dam was built in 1985.

Fort Miller Dam (NY01073) is located about 2.2 miles downstream of Thompson Island Dam (NY01074). Thompson Island Dam supports operation of Lock C-6 by maintaining the water level at the upper end of the 2.5-mi-long canal that connects to the upper end of Lock C-6. By impounding the water that passes over Thompson Island Dam, the Ft. Miller Dam allows generation of electricity from the main flow of the Hudson.

The plant consists of two double regulated horizontal Kaplan turbines. Mercer reports that the net head is 13.5 ft.[5] The two units are rated to produce 5 MW (total) at 6,600 cfs. These values suggest an efficiency of 0.76 kW/cfs.

The NID (2009) reports that the normal storage is 1,150 ac-ft and the normal pool surface area is 230 acres. However, because the dam operates as a run-of-river facility, the storage is not normally used. The normal pool elevation is 117 ft.[6] The Commission license requires that the minimum flow over the dam be 500 cfs.

3.2.6 *Hudson Falls, P-5276*

Hudson Falls Dam (NID) is located 2.5 miles upstream of the Ft. Edward gauge station, and about 3.5 miles upstream of the point at which the Champlain Canal and the Hudson River diverge. Hudson Falls is owned and operated by Boralex Hydro Operations Inc.

Hudson Falls generating equipment includes two 22.0-MW units, for a total capacity of 44 MW. Boralex reports a reservoir storage capacity of 410 ac-ft. The NID (2009) reports a storage capacity of 480 ac-ft. The NID lists the surface area of the pool as 220 acres. Boralex reports that the historical operating range of the reservoir is 206.5 to 206.9 ft.

Hudson Falls Dam was completed in 1914.

3.2.7 *South Glens Falls Dam*

South Glens Falls Dam (NID00140) is owned by Finch Hydro Holdings, LLC. The water regulated by the dam is shared equally by South Glens Falls Project (P-5461) and Glens Falls Project (P-2385), discussed below.

South Glens Falls Dam was completed in 1923.The dam created a reservoir with a storage capacity of 1,083 ac-ft. The license requires that the dam maintain the water level between 269.0 and 269.6 ft. The pool has a surface area of 167 acres, and the usable storage within license limits is less than 100 ac-ft.

The dam discharges a minimum bypass flow of 25 cfs at all times.

3.2.7.1 South Glens Falls Project, P-5461

The South Glens Falls Project is located on the south side of the dam. South Glens Falls Limited Partnership and National Grid are co-licensees of the South Glens Falls Project. The facility is operated by Boralex Hydro Operations Inc.

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[5] NID (2009) reports the height of the Ft. Miller dam to be 7 ft, and the Thompson Island Dam height to be 15 ft. While there is an apparent inconsistency with the height reported by the owner of Ft. Miller dam, the dam height is not essential information for headwater benefits analysis.

[6] The operator reports that the pool is kept at 115.1 ft, plus or minus 0.2 ft (Dave Crandell, Mercer Asset Management, personal communication with Lance McCold, ORNL, December 2, 2010).

The South Glens Falls Project has two 7.85-MW units for a total capacity of 15.7 MW at approximately 2,200 cfs discharge rate per unit for a total of 4,400 cfs turbine discharge rate.

3.2.7.2 Glens Falls, P-2385

The Glens Falls Project is located on the north side of South Glens Falls Dam. It is owned by Brookfield Renewable Power Inc.

The Project consists of five units with a total capacity of 12.2 MW at 4,400 cfs.

3.2.8 Feeder Dam, P-2554

The Feeder Dam is owned by the NYS Canal Corporation. The Feeder Dam Project (P-2554) hydroelectric facilities are managed by Brookfield Renewable Power Inc. The dam is 36 ft high. The facility has five units with a total generating capacity of 5 MW at 5,000 cfs.

The impoundment is 717 acres. The pond elevation is allowed to vary within a 1-ft range during walleye spawning season (approximately March 15 through June 15) and may vary within a 2-ft range during the remainder of the year. The dam has about 700 ac-ft of useable storage during walleye spawning season. The dam has about 1,400 ac-ft of useable storage the remainder of the year.

The dam is required to release a minimum bypass flow of 25 cfs. In addition, the Project is required to meet a minimum instantaneous discharge of 1,500 cfs, with a minimum daily average discharge of 1,760 cfs.

The Feeder Dam was completed in 1913.

3.2.9 Sherman Island & Spier Falls, P-2482

Sherman Island and Spier Falls facilities are licensed as a single Project. The two dams are about four river miles apart. Spier Falls is upstream of Sherman Island Dam, and has the larger reservoir. These facilities are owned by Brookfield Renewable Power.

3.2.9.1 Sherman Island

Sherman Island Project is located in West Glens Falls, New York, upstream of Feeder Dam and downstream of Spier Falls Dam. During the study period, it had four operational units. Each unit had a generating capacity of 7,750 kW and 1,600 cfs, for a total generating capacity of 31 MW at 6,400 cfs.

Sherman Island Dam creates a 305-ac pond. It has a useable storage capacity of approximately 300 ac-ft during walleye spawning season (approximately March 15 through June 15). For the remainder of the year, it has a useable storage capacity of about 600 ac-ft.

During walleye spawning season, the dam is required to release a minimum of 675 cfs of bypass flow. For the remainder of the year, the bypass flow must be at least 250 cfs.

Sherman Island Dam was completed 1923.

3.2.9.2 Spier Falls

Spier Falls Project is located west of West Glens Falls, New York, upstream of Sherman Island Dam. It has two units. Unit 8 has an 8.5 MW generating capacity at 1,440 cfs. Unit 9 has a 44 MW generating capacity at 7,560 cfs. The total plant generating capacity is 52.5 MW at 9,000 cfs.

Spier Falls Dam creates a 638-ac pond. It has useable storage of approximately 630 ac-ft during walleye spawning season (approximately March 15 through June 15). For the remainder of the year, it has about 1260 ac-ft of useable storage.

The Project is required to discharge a minimum bypass flow of 25 cfs year round through the trash sluice for fish passage.

Spier Falls Dam was completed in 1903.

3.2.10 Curtis & Palmer Falls, P-2609

The Curtis and Palmer Project hydroelectric facilities are located on the Hudson River near the southeastern boundary of the Adirondack Park. The Curtis and Palmer facilities consist of two separate developments, Curtis Falls and, a half mile downstream, Palmer Falls, Corinth, New York. Both are run of river facilities.

3.2.10.1 Curtis Facility

The Curtis facility consists of a 25-ft high 743-ft long concrete dam. Curtis Dam created a 5.9-mile impoundment with a surface area of 390 acres at normal elevation of 548.8 feet. The storage capacity is 585 ac-ft at a drawdown of 1.5 ft. Drawdown of 1.5 ft is permitted from June 15 until March 1. From March 1 until June 15, drawdown is limited to 1 ft by the Commission license, allowing a useable storage of 390 ac-ft. Drawdowns are used to supplement river flow during times when the river flow is below the 1000 cfs (Steven Denton, Capital Power Corporation, personal communication to Lance McCold, ORNL, March 3, 2011).

The total installed capacity is 9.9 MW at 24 ft head and 6500 cfs turbine discharge. The station looses output above 7000 cfs because the tailrace elevation rises due to topographical flow restrictions. The five units are:

Units 1 and 2 are Allis Chalmers S-type turbines, with flow capacities of 500 to 1585 cfs and generating capacities of 2600 kW each.

Unit 3 is a 1500-cfs Allis Chalmers S-type turbine with a generating capacity of 2500 kW.

Units 4 and 5 are 100- to 875-cfs S. Morgan Smith Camelback turbines with generating capacities of 1100 kW each.

Curtis is required to maintain a minimum bypass flow of 18 cfs.

3.2.10.2 Palmer Facility

The Palmer facility consists of a 37-ft high, 486-ft long concrete dam. The Palmer impoundment has a surface area of 28 acres at normal elevation of 522.9 feet. Usable storage capacity is negligible because the Commission license requires a constant pond level.

The total installed capacity is 48 MW at rated 85 feet of head and 7500 cfs. Units 1 and 2 are Toshiba Vertical Kaplan turbines with flow capacities of 1000 to 3750 cfs, and a rated generating capacity of 24 MW

International Paper Company is permitted to withdraw up to 15 cfs from the Palmer impoundment for process water (license condition 3).

3.2.11 Stewarts Bridge, P-2047

Stewarts Bridge Dam (NID 00149) is a 112 ft tall dam on the Sacandaga River downstream of Conklingville Dam. The Project is owned by Brookfield Power. The pond surface area is 480 acres. Because the pond elevation is maintained between 704.0 and 705.0 ft elevation, the useable storage is 480 ac-ft.

Stewarts Bridge Project has a single 34.5 MW generating unit with a hydraulic capacity of 5,460 cfs. ORNL used these parameters to estimate the efficiency of the Project at 6.32 kW/cfs.

The Project is required by license to maintain a 25-cfs minimum bypass flow.

The dam was completed in 1951.

3.2.12 E.J. West, P-2318

E.J. West Project is located at Conklingville Dam which created Great Sacandaga Lake. While the dam is owned by the State of New York and operated by the district, the E.J. West Project is owned by Brookfield Power.

E.J. West Project has two 9.8-MW units with a total generating capacity of 19.6 MW at 4,800 cfs when Great Sacandaga Lake is at full pool. Great Sacandaga Lake elevation varies significantly during a year. Consequently, the generating capacity of E.J. West also varies through the year. The relationship between lake level and generating capacity is given in Table 1.

Table 1. E. J. West generating capacity at specified lake levels

Elevation (ft)	Capacity (MW)	Elevation (ft)	Capacity (MW)
740.0	9.4	756.0	15.2
741.0	9.7	757.0	15.5
742.0	10.1	758.0	15.8
743.0	10.5	759.0	16.0
744.0	10.8	760.0	16.1
745.0	11.2	761.0	16.2
746.0	11.6	762.0	16.3
747.0	11.9	763.0	16.4
748.0	12.3	764.0	16.5
749.0	12.6	765.0	16.7
750.0	13.0	766.0	16.8
751.0	13.4	767.0	16.9
752.0	13.7	768.0	17.0
753.0	14.1	769.0	17.1
754.0	14.4	770.0	17.4
755.0	14.8	771.0	17.5

Source: Brian Dugan, Brookfield Power, personal communication to Lance McCold, ORNL, January 11, 2011.

E.J. West is required to be operated in a manner consistent with the district operation of Great Sacandaga Lake, and with the flow management requirements on Stewarts Bridge Project. No other flow requirements are specified for E.J. West.

4 OTHER STORAGE PROJECTS POTENTIALLY RELEVANT TO HEADWATER BENEFITS ANALYSIS

Many storage and hydropower s in the Hudson River Basin have only minor effects on headwater energy benefits. Headwater energy benefits accrue when upstream storage projects reduce river flows during high flow periods and augment river flows during the times of the year when river flows are naturally low. In the Hudson River Basin, natural river flows are usually highest in April and May as spring rains coincide with rapid snow melt. Natural river flows are usually lowest in July, August and September when warm temperatures and long days permit plants to move huge amounts of water from the ground into the atmosphere. On unregulated streams, average flows in April or May can be as much as ten times as high as those seen in August or September.

The existing schematic maintained by the Commission for the Hudson River Basin identifies 40 hydroelectric and storage projects in the basin. ORNL identified 166 NID-listed dams in the Upper Hudson River Basin, but considered as relevant to headwater benefits only those dams listed as having at least 12,000 acre-ft of storage (Table 2).[7]

Table 2. Hudson River Dams with more than 12,000 acre-ft of storage potentially capable of providing more than 100 cfs of flow for a 60 day period.

Dam name	NID number	Stream name	Owner or operator	Storage Acre-Ft
Ft. Miller	NY01073	Hudson River	Fort Miller Associates	14,995
Starbuckville Dam	NY00159	Schroon River	Town of Chester, Horicon, Schroon	18,208
Stewarts Bridge Dam	NY00149	Sacandaga River	Brookfield Renewable Power	18,565
Spier Falls	NY00136	Hudson River	Brookfield Renewable Power	30,942
Tomhannock Reservoir Dam	NY00117	Tomhannock Creek	City of Troy	39,511
Brant Lake Upper Dam	NY00158	Schroon River tributary	Town of Horicon	41,296
Winnies Reef Dam	NY00712	Fish Creek	Consolidated Hydro, Inc.	100,681
Indian Lake Stone Dam	NY00155	Indian River	Hudson River-Black River Regulating District	170,182
Conklingville Dam	NY00146	Sacandaga River	Hudson River-Black River Regulating District	681,084

Source: NID 2009

Three of these projects, Ft. Miller, Stewarts Bridge and Spier Falls, are run of river facilities that are constrained by license conditions from operating in a manner that would provide headwater energy benefits to downstream facilities.

While Tomhannock Reservoir could provide modest headwater energy benefits to the three lowest projects on the Hudson, because it is a water supply facility there is no reason to expect it to be managed for headwater energy benefits.

Starbuckville and Brant Lake Upper Dam reservoirs could provide headwater energy benefits to all the hydropower projects on the Hudson River. However, because both are recreation facilities operated by local governments, it is unlikely that they would be managed to discharge meaningful quantities of water during the low-flow periods in August and September.

Winnies Reef Dam reservoir has modest capacity to augment flow for the four lowest hydropower projects on the Hudson. Because it is owned by a hydropower operator; because the NID lists the purposes of the dam as "flood control and storm water management, and

[7] 12,000 acre-ft of storage was selected as the cutoff because the normal lowest-flow period on the Hudson is approximately 60 days and because it was judged that additions of less than 100 cfs would be too small to provide meaningful benefits to downstream Projects during low-flow periods.

recreation;" and because Brookfield Renewable Power successfully operates Schuylerville Hydroelectric Project a few miles downstream of the dam; it is possible that Winnies Reef Dam could provide headwater energy benefits to projects on the Hudson River.

Indian Lake is owned by the State of New York and operated by the district, a state agency on Indian River, a tributary of the Hudson. It is managed for recreation, and flood control and storm water management. It has a significant potential for providing headwater energy benefits to hydropower projects on the Hudson River.

Conklingville Dam, which controls Great Sacandaga Lake, is the largest and most significant storage reservoir in the basin. It is the most important contributor to headwater energy benefits to downstream hydropower projects.

5 PREPARATION FOR HEADWATER BENEFITS ENERGY GAINS ANALYSIS

Headwater storage projects such as Great Sacandaga Lake benefit downstream projects by holding back water during high-flow periods and releasing it during low-flow periods. The effect is to transfer water that would exceed the capacity of downstream hydroelectric projects to periods of time when natural flows would be lower than the projects' generating capacities.

Headwater benefits energy gains analysis proceeds by comparing the energy generated under current developed conditions with the energy that would be generated under flow conditions that would exist if the headwater projects did not exist. Because the only data available is for current conditions, flows for the hypothetical condition without the headwater projects have to be modeled. Figure 5 illustrates the comparison between hypothetical flows in the absence of Great Sacandaga Lake to the flows recorded at the USGS station at Stewarts Bridge. Clearly, the flows are much more volatile without Great Sacandaga Lake than under current conditions.

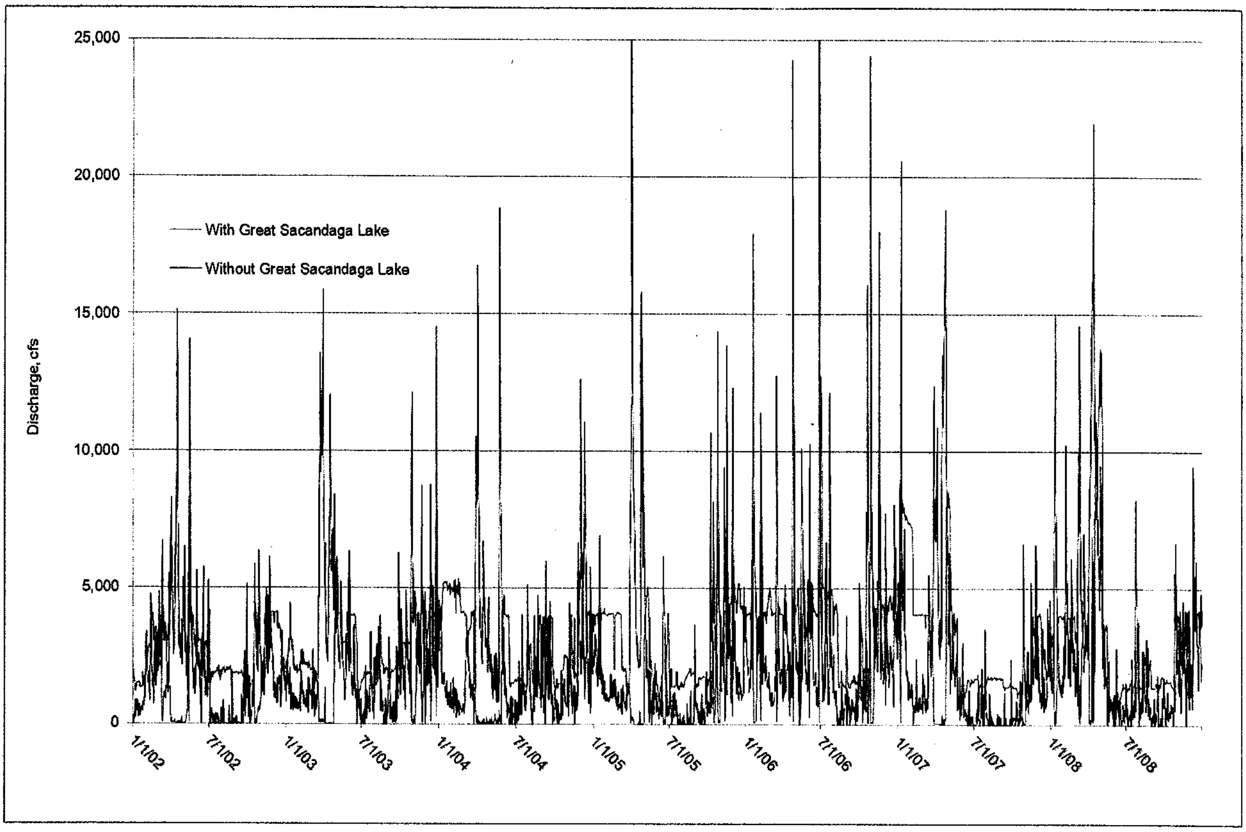


Figure 5 Comparison of measured flows with hypothetical flows without Great Sacandaga Lake

5.1 Data Sufficiency for Headwater Benefit Assessment

On behalf of the Commission, ORNL requested engineering and operational data for Great Sacandaga Lake and each of the downstream projects. Table 3 is a summary of generation, flow, and storage data received that are related to headwater energy benefits analysis.

Table 3. Data received from the parties

Project	River	Elevation-storage curve	Pond elevation	Storage	Inflow	Outflow	Generation
Green Island	Hudson	No	No	No	No	No	Yes
Mechanicville	Hudson	No [a]	No [g]	No [b]	No	No	May 2004 - 2008
Upper Mechanicville	Hudson	No [a]	No [g]	No [b]	No	Hourly	Hourly
Stillwater	Hudson	No [a]	Yes [g]	No [b]	Estimates	Estimates	Yes
Fort Miller	Hudson	No [a]	No [g]	No [b]	No	No	No, annual only
Hudson Falls	Hudson	No [a]	No	No	No	Yes	Yes
South Glens Falls	Hudson	No [a]	No	No	No	Yes	Yes
Glens Falls	Hudson	No [a]	No	No	No	No [d]	No
Feeder Dam	Hudson	No [a]	2004-2009 [e]	No [b]	No	Partial [i]	2003-July 2008 [e]

Sherman I.	Hudson	No [a]	2004-2009 [e]	No [b]	No	Partial [i]	2003-July 2008 [e]
Spier Falls	Hudson	No [a]	2004-2009 [e]	No [b]	No	Partial [i]	2003-July 2008 [e]
Palmer	Hudson	No [a]	Yes	No [b]	Yes [h]	Yes [h]	Yes
Curtis	Hudson	No [a]	Yes	No [b]	Yes [h]	Yes [h]	Yes
Setwarts Bridge	Sacandaga	No	2004-2009 [e]	No	No	Partial [i]	2003-July 2008 [e]
E.J. West	Sacandaga	- NA -	- NA -	- NA -	- NA -	Partial [i]	2003-July 2008 [e]
Great Sacandaga Lake	Sacandaga	Yes	Yes	No [b]	Yes	No	- NA -
Indian Lake	Indian	No	No [j]	No	No	No [j]	- NA -

- NA - not applicable

[a] Can be estimated within normal operating range from pool surface area.

[b] Can be calculated from elevation and storage curve.

[c] No inflow data was provided, but inflows can be calculated as the sum of flows at USGS stations 01325000 and 01318500.

[d] Outflows for Glens Falls Project were provided by Boralex.

[e] Additional data has been requested.

[f] Flow data from station 01358000 will serve.

[g] Data for the navigation season is available from the Canal corporation.

[h] Curtis Palmer Hydroelectric Co., LP provided river flow data for the vicinity of the projects. However, the data proved to be unreliable.

[i] BRP-outflow = Brookfield provided hourly turbine discharge 2003-July22,2008 & hourly non-turbine discharge 2003-Nov2005. Additional information has been requested.

[j] Data is available from USGS gauge stations.

The remainder of this section is a project by project discussion of data sufficiency, and an explanation of how ORNL intends to analyze the various reaches of the basin. As in the remainder of this report, the description begins with Green Island Project at the bottom of the basin.

5.1.1 Below Fort Edward Gauge Station

Below the Fort Edward gauge station, the Hudson River flows through a broad valley. The major tributaries are the Batten Kill, Fish Creek, the Hoosic River, and the Mohawk River which joins the Hudson just above the Green Island Dam and Project. The Stillwater gauge station (01331095) is located at Lock C-4 in the town of Stillwater, about 15 miles below the confluences of Batten Kill and Fish Creek. The Hoosic River joins the Hudson just below Lock C-4. The gauge station (01335754) at Lock C-1, near Waterford, is about 8 miles downstream of the Stillwater gauge station. The Mohawk River joins the Hudson about three miles downstream, and the gauge station at Green Island (01358000) is about two miles farther downstream.

5.1.1.1 Green Island Project

The owners of the Green Island Project provided daily generation data for the study period. Because the gauge station is located at Green Island Dam, the flow data is the best available flow data for the Green Island Project.

ORNL has sufficient data to perform the HWBEG analysis for the Green Island Project.

5.1.1.2 Upper Mechanicville and Mechanicville Projects

The Upper Mechanicville Project is located at Lock C-3, about a mile downstream of the Hoosic River confluence. The Mechanicville Project is located about two miles farther downstream. The owners of the Mechanicville Project provided daily generation data for the period May 2004 through 2008. The owner of the Upper Mechanicville Project provided hourly generation data for the study period.

The gauge station Lock C-1 is located about three miles downstream of the Mechanicville Project. Because the Hoosic River joins the Hudson just below Stillwater, the Stillwater gauge data is suitable for estimating flows at the Mechanicville or Upper Mechanicville Projects. However, because only minor tributaries join the Hudson between the Upper Mechanicville Project and the Lock C-1 gauge station, the gauge station flow data is suitable for analysis of the Mechanicville Projects.

By use of the flow data at Lock C-1 and the generation data provided by the owners of the Upper Mechanicville and Mechanicville Projects, ORNL has sufficient data to perform the HWBEG analysis for the Mechanicville Projects. Because the Mechanicville Project was not operating consistently before May 2004, ORNL intends to assume that the Project received negligible headwater benefits before that date.

5.1.1.3 Hoosic River

The Hoosic River joins the Hudson River below the Stillwater Project. It has a drainage area greater than 700 square miles. Schaghticoke Dam, approximately 5 miles from the mouth, has a drainage are of 635 square miles. Upstream of Schaghticoke Dam is the James Thompson Dam, the Johnsonville Dam, and gauge station 01334500 near Eagle Bridge, New York. The largest reservoir associated with these and other upstream dams, is the approximately 6000 ac-ft reservoir impounded by the Johnsonville Dam. None of these has large enough storage to contribute to meaningful headwater benefits for Hudson River Projects.

Tomhannock Reservoir Dam is located on Tomhannock Creek, a tributary of the Hoosic that joins the Hoosic below Schaghticoke Dam. The National Inventory of Dams reports that the dam has a drainage area of 66 square miles, and a maximum storage of 56,000 ac-ft. However, because the reservoir is the primary water supply reservoir for the city of Troy, it is unlikely to be managed in a manner that would provide headwater benefits to Hudson River Projects.

For the reasons discussed above and because Hudson River gauge stations adequately characterize flows, ORNL does not believe that additional data about Hoosic River facilities is needed.

5.1.1.4 Stillwater Project

About 4 miles downstream of Lock C-6, two significant tributaries join the Hudson River. Batten Kill joins the Hudson from the east and Fish Creek enters from the west. The Stillwater Project is located about 15 miles downstream of the confluences adjacent to the Stillwater gauge station. The manager of the Stillwater Project provided daily generations and estimated flows for the study period.

With the daily generation data and the flow data from the USGS station, ORNL has sufficient data to perform the HWBEG analysis for the Stillwater Project.

5.1.1.5 Fish Creek

Fish Creek has a drainage area of about 250 square miles and joins the Hudson from the west a short distance below the mouth of the Batten Kill River. Fish Creek has two potentially significant facilities. Schuylerville Dam is a hydroelectric facility located near the mouth of Fish Creek. This facility is owned by Brookfield Power. Approximately five miles upstream is Winnies Reef Dam which controls a 100,000 ac-ft reservoir that, according to the National Inventory of Dams, is operated for flood control and stormwater management, and recreation.

Because Schuylerville Dam has a pool capacity of only 380 ac-ft, it seems unlikely that it could operate economically unless Winnies Reef Dam were operated to provide summer flows. This line of reasoning suggests that Winnies Reef Dam might be providing headwater benefits to Hudson run-of-river Projects downstream of Fish Creek.

Because it has no additional information about facilities on Fish Creek, ORNL has assumed that Winnies Reef Dam does not contribute to headwater benefits to downstream Hudson Projects.

5.1.1.6 Batten Kill

The Batten Kill is one of the larger tributaries of the Hudson River between the Sacandaga River and the Mohawk River. Its drainage area at Clarks Mill Lower Dam near its mouth is 441 square miles. It has seven hydroelectric facilities on its lower 10 miles. Each of the hydroelectric Projects has a small pool, but none are large enough to achieve seasonal storage. There are a few small recreation and other reservoirs, none of them has appreciable storage. There is a USGS gauge station (01329490) upstream at Battenville that could provide data. However, because all the hydroelectric facilities are downstream better flow data would come from Clarks Mill Lower Dam, if such data exists.

Because there are adequate Hudson River gauge stations and because there is no meaningful storage on the Batten Kill River, ORNL does not anticipate needing data from the Batten Kill River.

5.1.1.7 Fort Miller Project

The Fort Miller Project is located about eight miles downstream of the Fort Edward gauge station at Champlain Canal Lock C-6. Mercer Asset Management provided no operational data. ORNL will estimate generation based on the rated generation capacity, 5 MW, at the rated flow capacity, 6600 cfs. ORNL will assume the flow at Ft. Edward gauge station adequately represents the flow at the Fort Miller Project location.

By using the above assumptions, ORNL has sufficient information to perform the HWBEG analysis for the Fort Miller Project.

5.1.2 *Hudson River between the Sacandaga River and the Fort Edward Gauge Station*

Eight run of river hydroelectric facilities operate on the Hudson River gorge between the Sacandaga River confluence and the Ft. Edward gauge station (01327750). From upstream, the eight Projects are Curtis, Palmer, Spier Falls, Sherman Island, Feeder Dam, Glens Falls and South Glens Falls Projects which share the South Glens Falls dam and its flow, and Hudson Falls. Except for the Glens Falls Project, sufficient generation data is available for the HWBEG analysis. For the Glens Falls Project, ORNL will use flow and generation capacities of the five units provided by Brookfield, and assume that the generators are dispatched starting with the most efficient unit.

This reach experiences very little local inflow. The drainage area that feeds Ft. Edwards gauge station is 2810 square miles. The combined drainage areas that feed Hadley and Stewarts Bridge stations 2719 square miles, 96.8% of the drainage area contributing to the Ft. Edwards gauge flow. For the period 2002 through 2008, the total flow reported from Stewarts Bridge and Hadley stations accounts for 95.3% of the flow reported at the Ft. Edwards gauge. Either gauge would serve for the flow on this reach.

By use of the USGS gauge station data, the supplied generation data, and the assumptions about the Glens Falls Project; ORNL has sufficient data to perform the HWBEG analysis for the Projects on this reach.

5.1.3 *Sacandaga River and Great Sacandaga Lake*

The significant elements on the Sacandaga River are Great Sacandaga Lake, E. J. West Project, and Stewarts Bridge Project (Figure 1). Great Sacandaga Lake is the most important storage element in the upper Hudson River Basin. ORNL has received good quality generation data from Brookfield Power for E. J. West and Stewarts Bridge Projects. ORNL will use flow data from USGS station 01325000 located a short distance downstream of Stewarts Bridge Project. The USGS operates elevation gauge station 01323500 on Great Sacandaga Lake. ORNL will use data from 01323500 and the elevation-storage relationship provided by the district to calculate changes in storage at Great Sacandaga Lake.

With the above data, ORNL has the data necessary for HWBEG analysis of projects on the Sacandaga River.

5.1.4 Hudson River above Sacandaga River Confluence

The USGS gauge station at Hadley (01318500) measures all the flow from the Hudson River above the confluence with the Sacandaga River. The Schroon River is the principal tributary of the Hudson River above Hadley. The USGS station at North Creek (0135500) measures flow of the Hudson River above the Schroon River confluence. Above the North Creek gauge, the USGS maintains a station (0135000) on the Indian River upstream of its confluence with the Hudson River. Upstream of the Indian River confluence with the Hudson, USGS maintains a station (01312000) at Newcomb.

5.1.4.1 Schroon River

The only conceivably significant projects on the Schroon River are Warrensburg dam and generating station, a run-of-river facility, and Starbuckville Lake and Brand Lake Upper. Both reservoirs are reported to be recreation facilities and have only modest storage. Warrensburg dam has negligible pool storage. Consequently, none of these facilities has meaningful contributions to headwater benefits to downstream hydroelectric projects.

ORNL has no operational data on these facilities, but does not believe any such data is needed for the HWBEG analysis because the facilities are managed for recreation.

5.1.4.2 Indian Lake and Indian River

With a storage capacity of about 170,000 ac-ft, Indian Lake is the second most important storage facility in the Hudson River Basin. It is operated by the district for flood control and river flow regulation. The USGS operates an elevation station (01315000) on Indian Lake and a flow gauge (01314500) on the Indian River below Indian Lake. However, ORNL does not have an elevation-storage relationship for Indian Lake.

Due to the availability of USGS gauge data, ORNL lacks only the elevation-storage relationship required to incorporate Indian Lake into the HWBEG analysis.

5.2 Water Balance Modeling

ORNL relies upon the RiverWare modeling system to provide a rigorous, flexible, and transparent implementation of a water balance model for the Hudson River Basin. The RiverWare model will not be used to compute directly energy gains within the Hudson River Basin. Internally-consistent and volume-conserving output from the RiverWare model will be provided as input to the Headwater Benefits Energy Gains (HWBEG) model once information needs and problematic results outlined herein are addressed among the interested parties.

RiverWare simulates river system operation through a collection of link and node network objects representing river reaches and control points, respectively, within a river basin. Links route water flows between control points using a variety of user-selectable methods, ranging in complexity from simple fixed lag times to fully-dynamic solutions of the equations governing one-dimensional stream flow. Only fixed lag times are used for routing in the RiverWare model described herein because the HWBEG model requires the use of fixed lag times. Control points include a variety of types, including a simple storage reservoir with no power facilities, a level-pool hydropower reservoir, and a sloped-pool hydropower reservoir capable of modeling wedge storage. Only the simple storage reservoir and the level pool power reservoir were used in the RiverWare model described herein. The reservoir objects implement the basic storage equation:

$$\frac{\Delta S}{\Delta t} = I - Q$$

in which S is the reservoir storage, I is the sum of inflows to the reservoir, and Q is the sum of outflows from the reservoir. Reservoir objects can receive inflows from upstream tributaries and return flows from withdrawals. Reservoir outflows from an object include spillway releases, turbine releases, and water supply withdrawals. Run-of-river projects may be modeled as "inline power objects" or as hydropower reservoirs for which ΔS is forced to zero for all time steps. The time step, Δt, used in the Hudson water balance modeling was either one week for the preliminary data analysis or one day for the detailed water balance modeling described herein. Objects are linked by specifying a specific outflow component (known as a slot in RiverWare nomenclature) of one object or link to a specific inflow component of another object or link. Successful execution of a RiverWare model simulation solves a set of coupled storage equations for the unknown time series, enforcing the water balance for all objects and between linked objects throughout the network.

Application of water balance modeling using RiverWare, or any other network operations model, with historical data from disparate sources always produces imbalances between projects and sometimes within projects (i.e. net inflows do not equal storage changes). These imbalances are evident in different model outputs depending on how the objects are configured and which components are specified as known and unknown time series in the aforementioned storage equation. Most of the Hudson storage projects were modeled by specifying S (or the corresponding elevation) and Q and allowing RiverWare to compute the "local inflow" time series, I_L, based upon the known (regulated) inflows to the project, I_R:

$$I_L = \frac{\Delta S}{\Delta t} - I_R + Q\,.$$

This local inflow time series includes true local ungaged inflows to a project, but also includes imbalances arising from errors in reported inflow or release time series. Such errors may be the result of imperfect storage-elevation relationships or imperfect generation versus turbine release relationships used to compute historical data. Alternatively, the local inflow may be assumed to be zero and the reservoir storage (or corresponding water surface elevation) computed as a model output for comparison to historical data or operating limits. The flexibility of RiverWare allows either of these methods to be used with original and adjusted reservoir storage-elevation or generation-release relationships. Menus associated with the objects in the RiverWare software allow for efficient and unambiguous selection of these methods and alternative rating relationships, followed by re-execution of the network model and examination of results.

5.2.1 Water Balance Upper Hudson Reaches

The water balance is performed in sections as shown in Figure 6 for the Upper Hudson projects shown below. The over-arching assumption in the Hudson River Basin water balance modeling is that the USGS stream gauges throughout the system are the most accurate source of historical streamflows. The inflow to the system of Starbuckville, Brant Upper Lake, Warrensburg, and Indian Lake Projects are determined from water balance from USGS flow gauges.

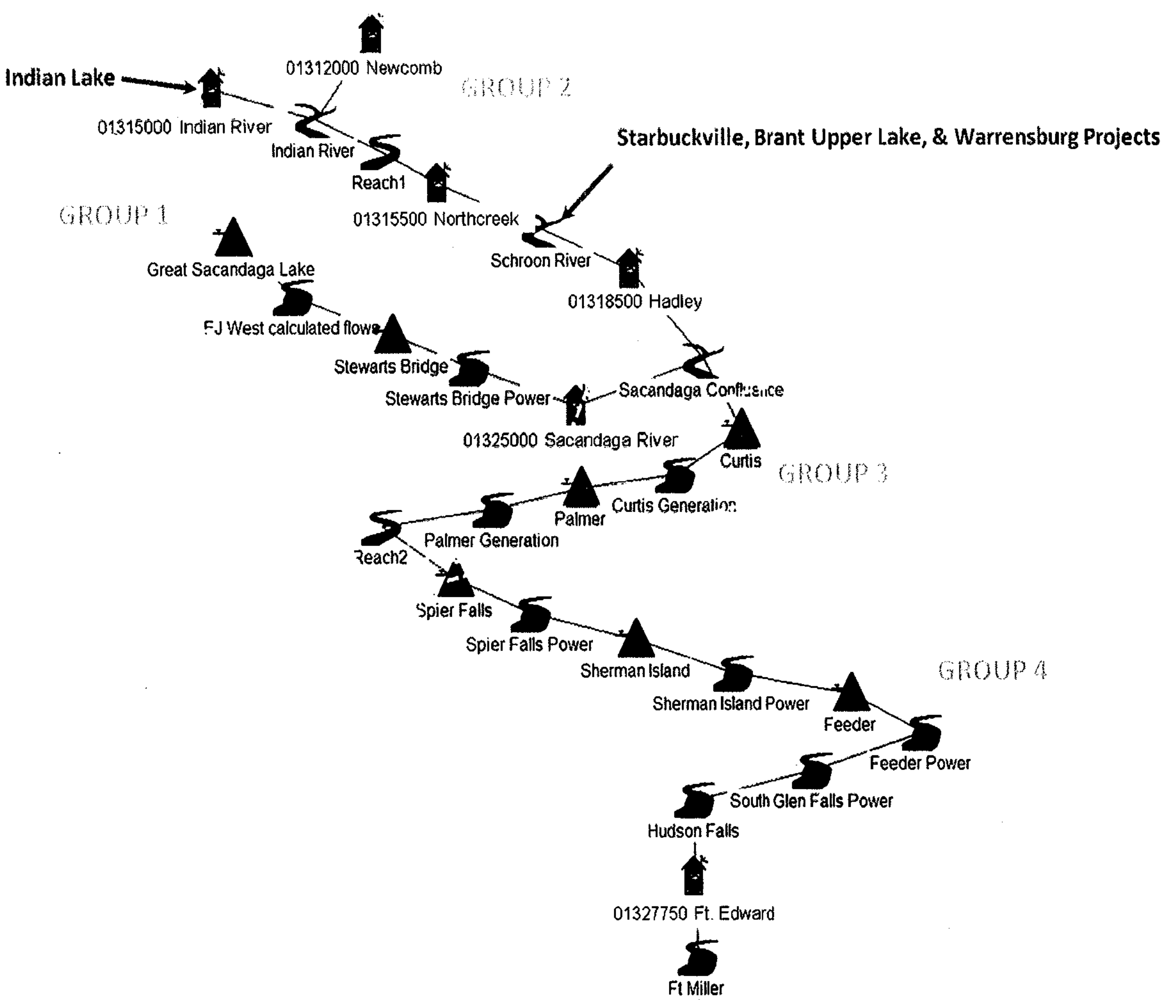


Figure 6. Upper basin project and sub-basin groupings for the water balance analysis

5.2.1.1 Water Balance for Stewart's Bridge, E.J. West, and the Great Sacandaga Lake Projects – Group 1

The water balance for this group of projects is governed by the USGS Stream Gauge 01325000 (Sacandaga River). Flows in excess of turbine flows for E.J. West are calculated and provided in the graph below. The positive flows indicate flows related to bypass, spill, etc. The only negative flows occur on Dec. 25 and 28 2004 and are -8.5 cfs and -18 cfs respectively. This indicates that the reported generation flows are greater than the downstream flow as required by the routed flow from the USGS stream gauge.

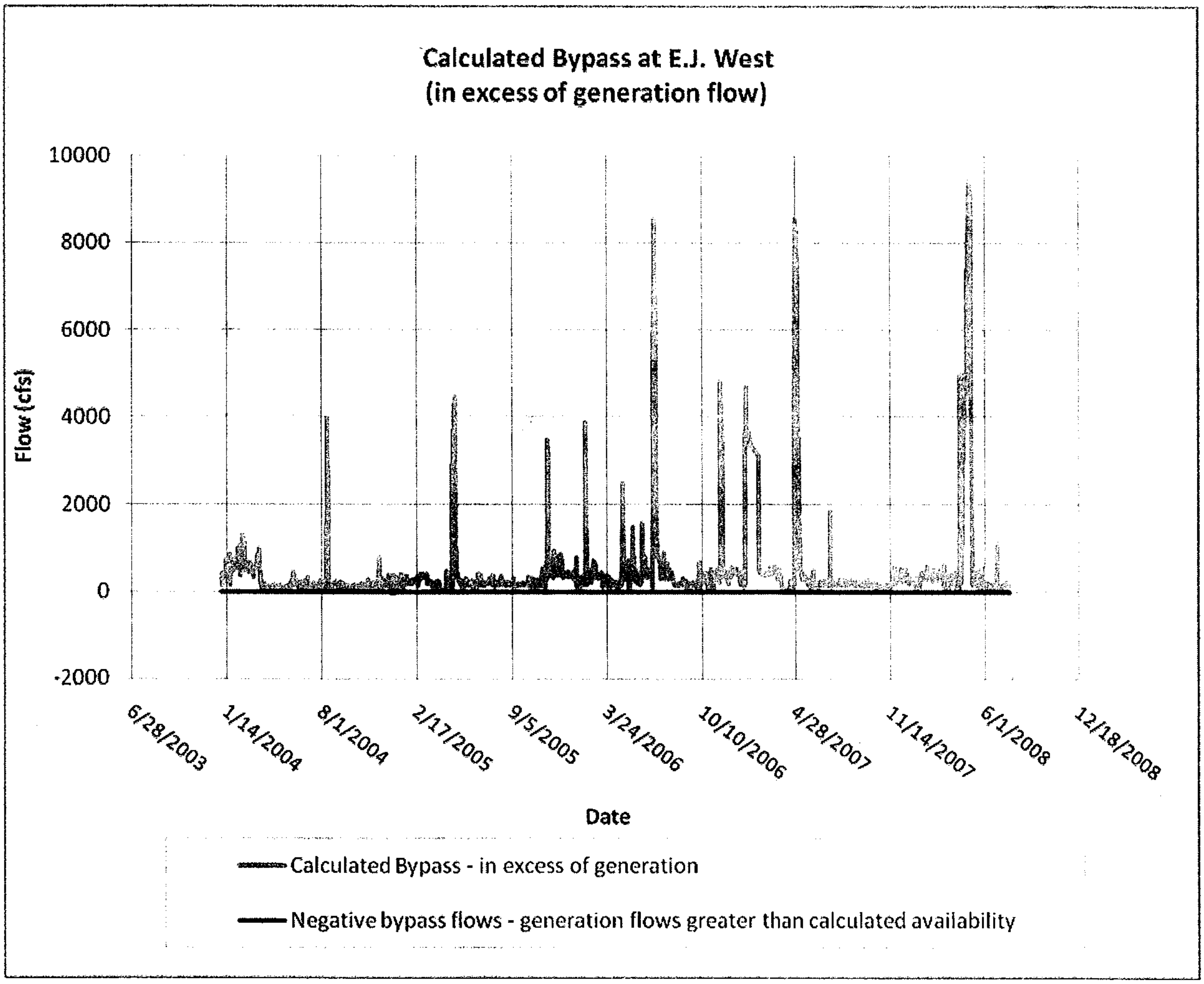


Figure 7. Calculated bypass at E. J. West.

Flows routed upstream to Lake Sacandaga in combination with provided reservoir elevation data yield the calculated regulated inflows to Lake Sacandaga as shown in the plot below (Figure 8). The plot also includes inflows provided by the owner which appear to occur during similar time periods as that calculated. Figure 9 below illustrates the differences between the inflows provided by the owner and the calculated inflows.

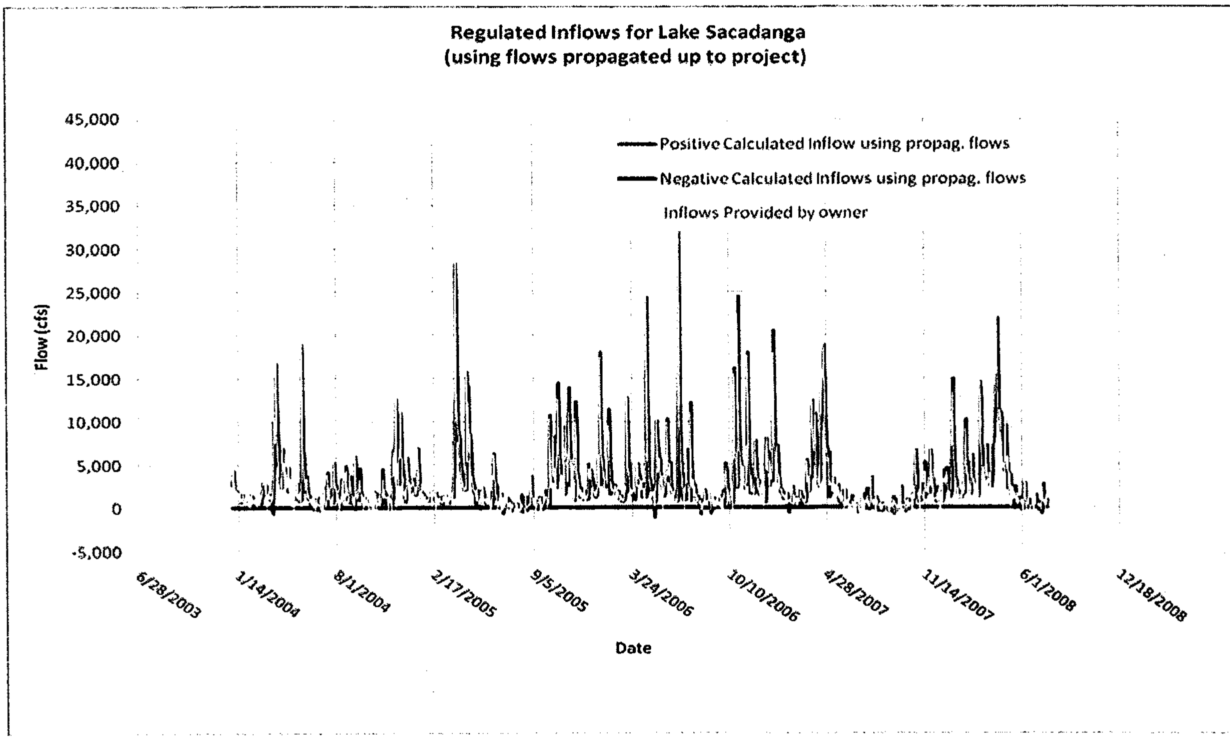


Figure 8. Regulated inflows for Lake Sacandaga.

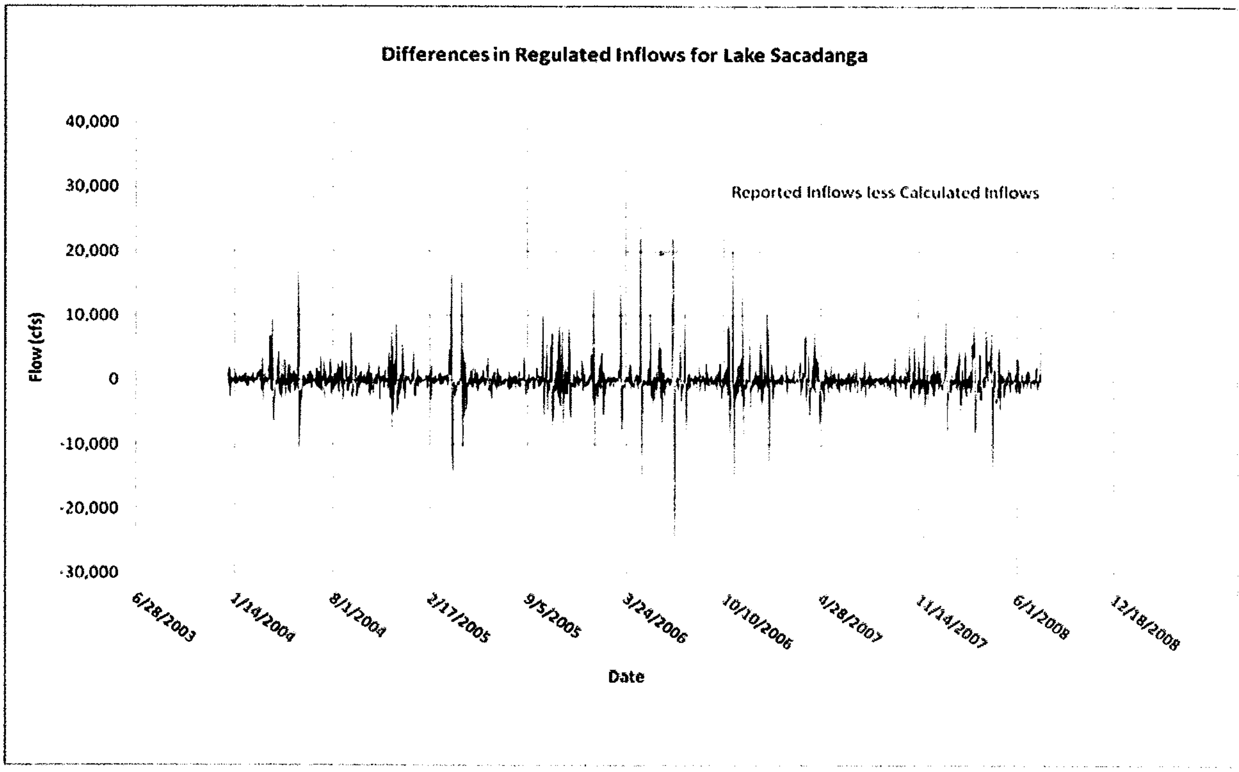


Figure 9. Differences in regulated inflow to Lake Sacandaga

5.2.1.2 Water Balance for Indian Lake and Starbuckville, Brant Upper Lake, & Warrensburg Projects – Group 2

The water balance for this group is governed by USGS Streamflow gauges 01315000 (Indian River), 01312000 (Newcomb), 01315500 (Northcreek), and 01318500 (Hadley). Flow contribution from Indian Lake is defined by the Indian River gauge and the Starbuckville, Brant Upper Lake, & Warrensburg Project flow contribution is defined by the Northcreek and Hadley gauges. The only anomalies in flow occur between the Indian River, Newcomb, and Northcreek streamflow gauges in the form of negative local inflows perhaps due to timing of flows. This is illustrated in Figure 10.

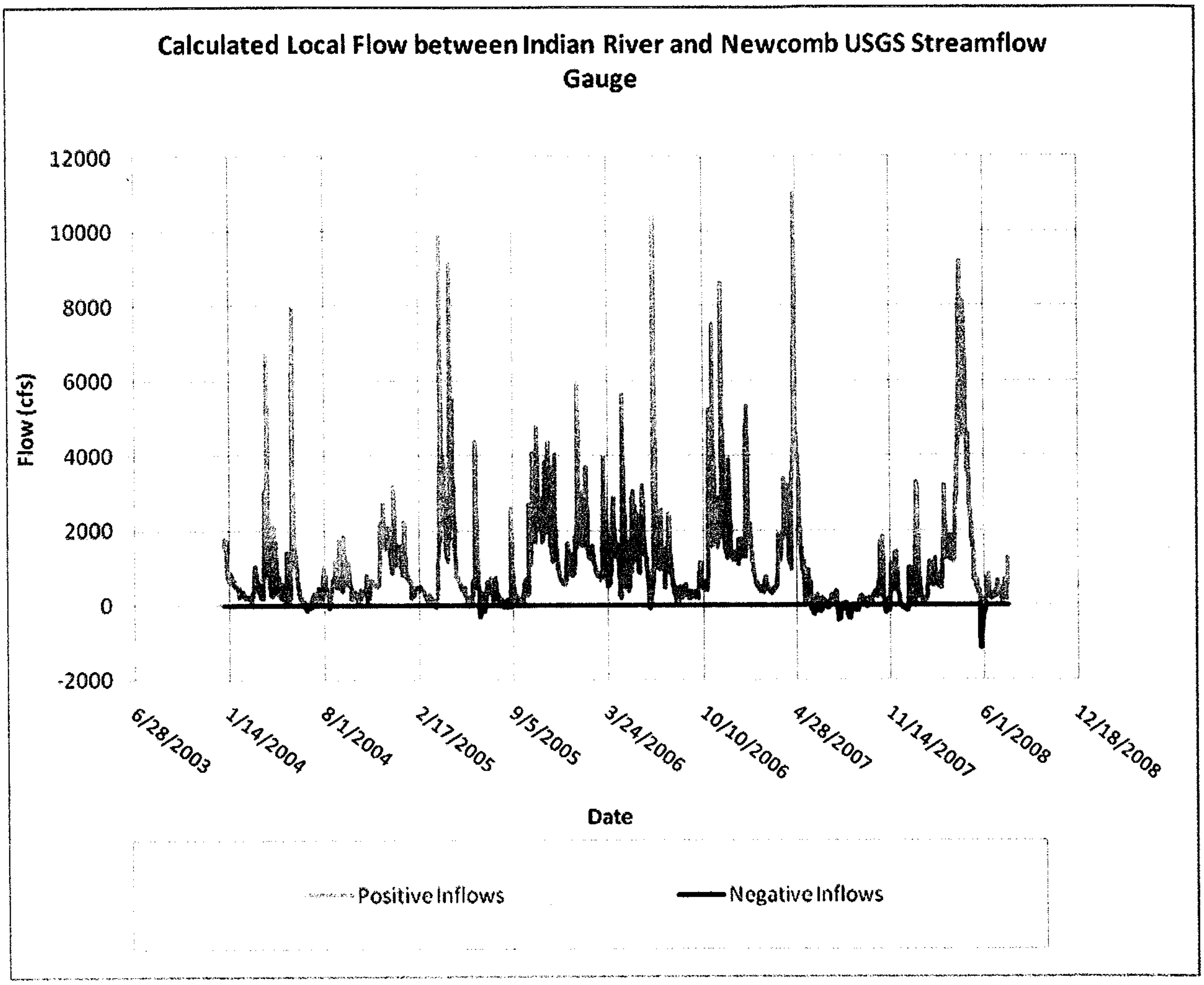


Figure 10. Calculated Local Inflow Between Indian River and Newcomb USGS Streamflow Gage.

5.2.1.3 Water Balance for Curtis and Palmer Projects – Group 3

The water balance for this group is governed by propagation of streamflows from all USGS streamflow gauges above the Sacandaga confluence. Turbine flows, pool elevation data in conjunction with estimated elevation/storage curve and aggregated flows from Groups 1 and 2 was used to determine outflow from Curtis. Figure 11 below illustrates the bypass, spill, etc. flows beyond the generation flows. There are some minor negative bypass flows present. This indicates that the reported generation flows are greater than the available calculated flow out of Curtis. This could be due to a poorly defined elevation/storage curve or degradation of flow/generation relationships used to determine plant flow.

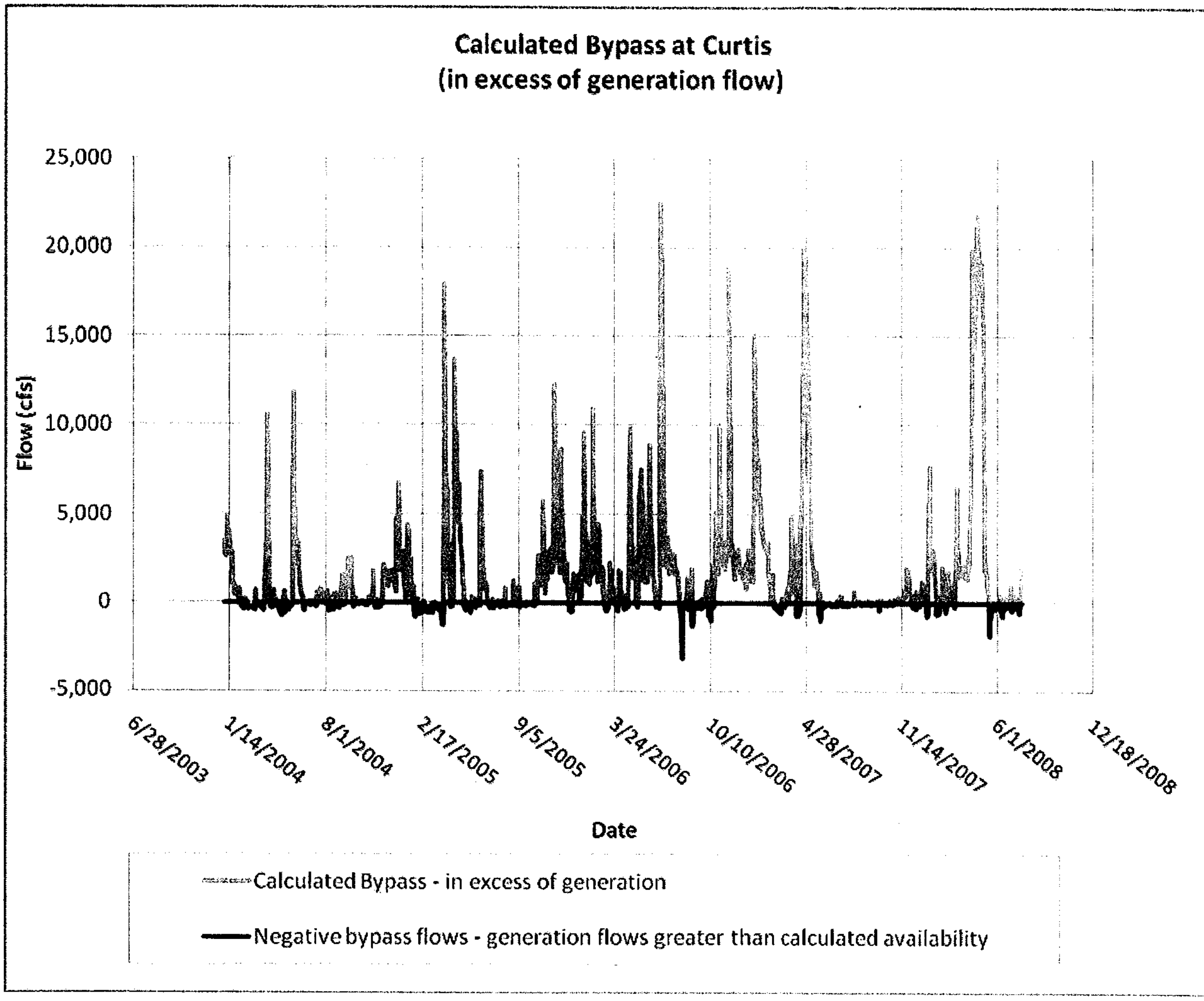


Figure 11. Calculated Bypass at Curtis

Similar to that of Curtis, the Palmer plant has some minor negative bypass flows as indicated in Figure 12.

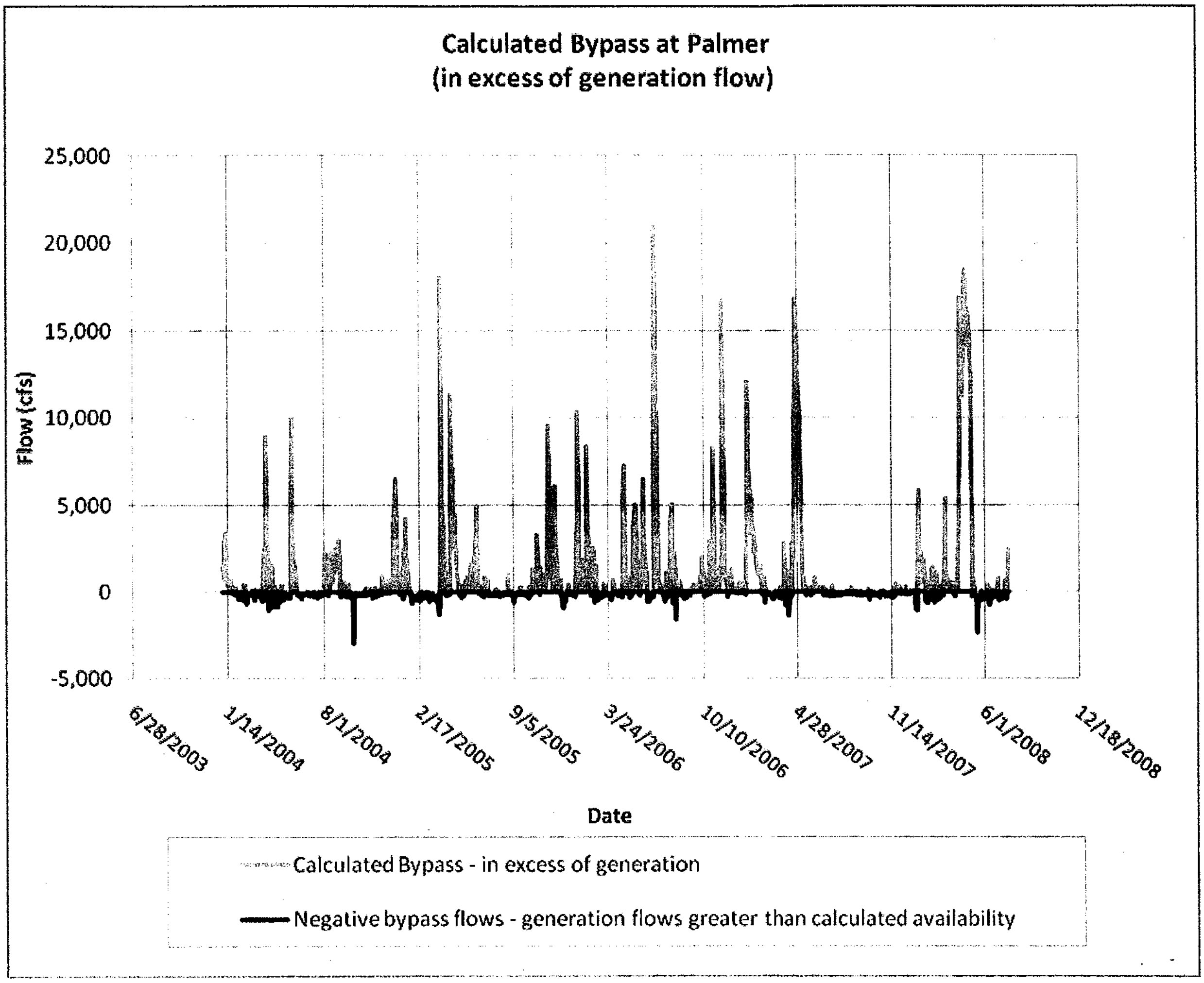


Figure 12. Calculated Bypass at Palmer.

An in-system water balance check is performed downstream of Palmer and upstream of Spier Falls indicates the cumulative local inflows downstream of the Sacandaga Confluence and upstream of the Spier Falls Project Ft. Edwards stream flow gauge (Figure 13). The flows for projects in Group 4 are determined in an "upstream-fashion" from the USGS Stream flow gauge 01327750 (Ft. Edward). The resulting local inflows are depicted in Figure 14. The negative inflow values are likely attributed mostly to issues associated with plant data or elevation/storage curves in Groups 3 and 4 or absence of lag times. The water balance for Group 4 is discussed in the next section. Figure 14 is a plot of local inflows between Spier Falls and Ft. Edwards stream flow gauge below indicates negative inflow as well.

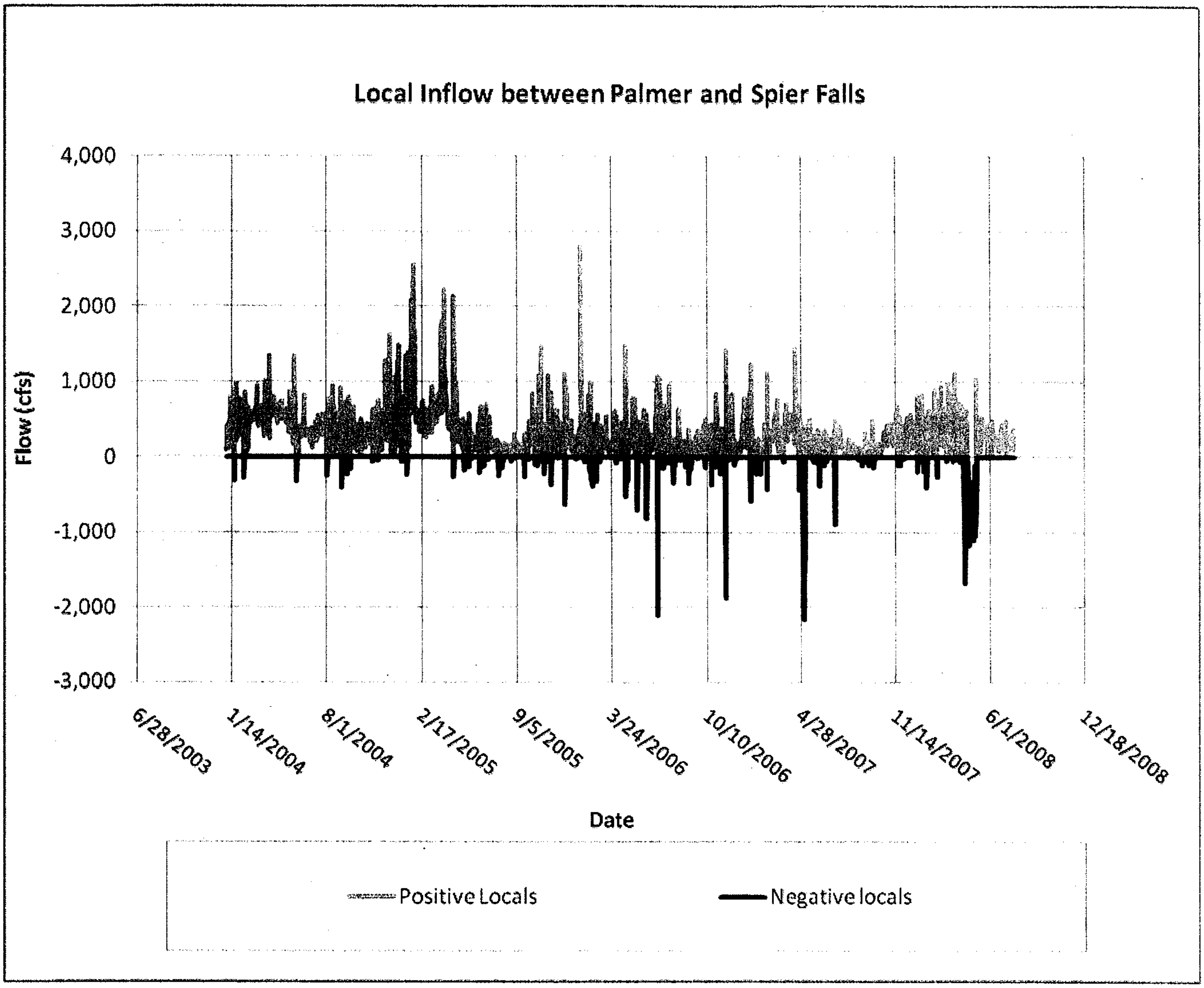


Figure 13. Local inflow between Palmer and Spier Falls

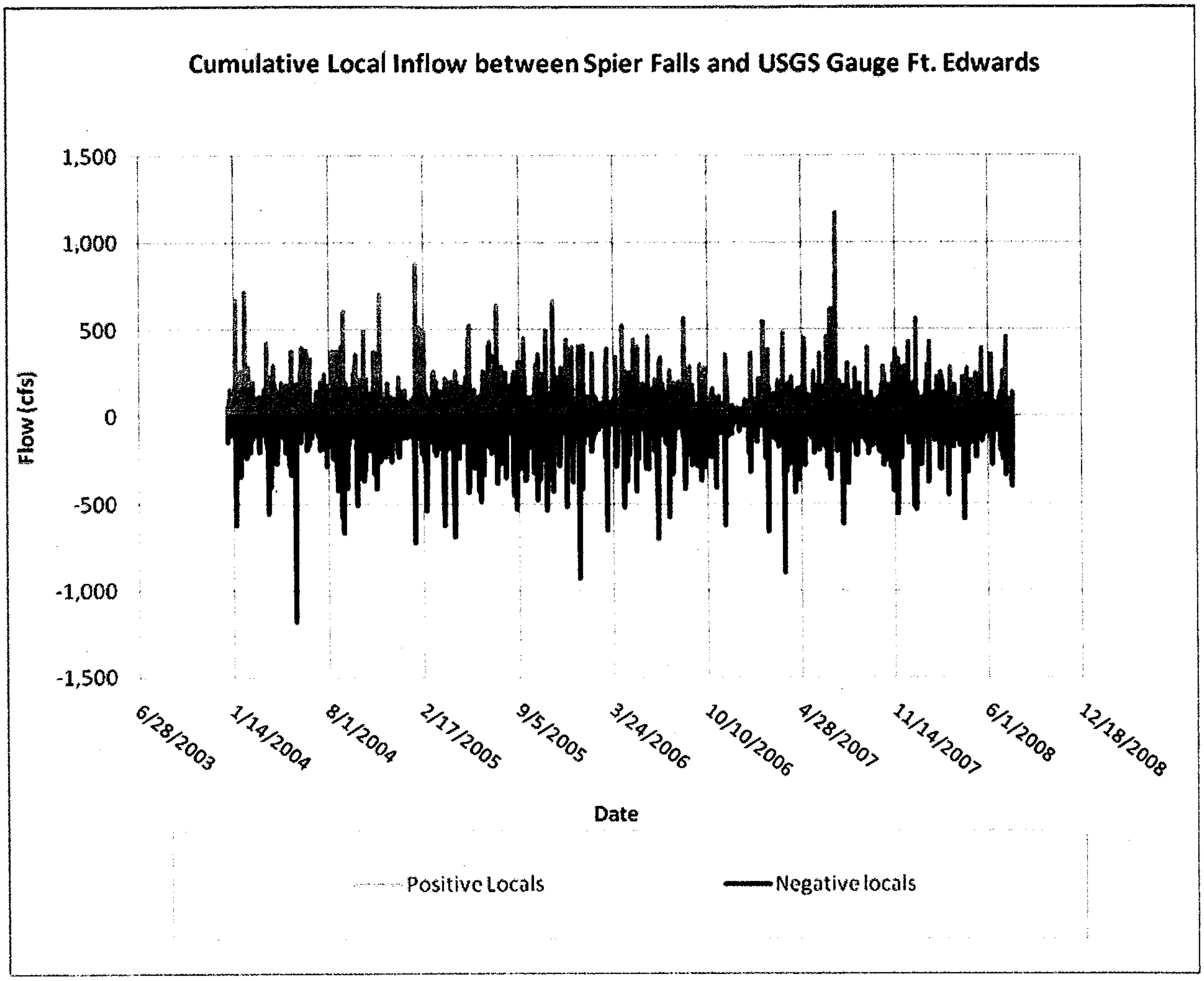


Figure 14. Cumulative local inflow between Spier Falls and the Ft. Edwards Gage.

5.2.1.4 Water Balance for Hudson Falls, South Glen Falls, Feeder, Sherman Island, and Spier Falls Projects – Group 4

The water balance for this group of projects is governed by the USGS Stream Gauge 01327750 (Ft. Edward). Flow data provided by the owner indicated that the flows are all inclusive – i.e., they include flows related to generation, spill, bypass, etc. However, according to the plot (Figure 15) of local inflows between Hudson Falls and the USGS streamflow gauge 01327750 (Ft. Edward) just a short distance downstream, periods of significant flows are present. No other river or creeks are found in this area that could possibly provide such flows nor any information on local inflow. Therefore, is it assumed that it is probably spill from Hudson Falls and treated as such in the water balance. Some minor negative local inflows are present which indicate that the downstream flow required to pass the generation flow is insufficient or the actual generation flows are greater than reported.

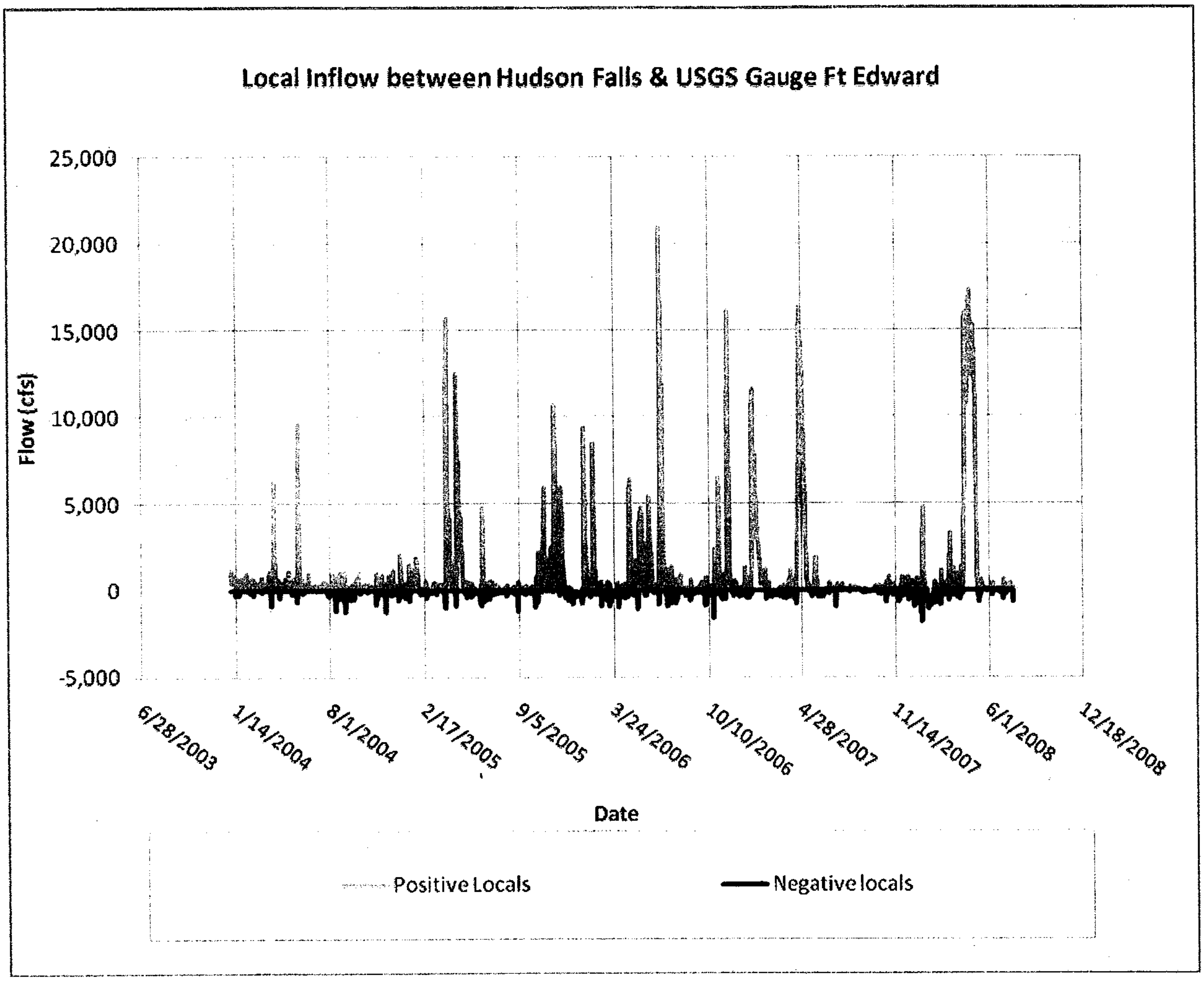


Figure 15. Local inflow between Hudson Falls and the Ft. Edward Gage.

Flow data propagated upstream and generation flow through South Glen are used to determine spill over Glen Dam. Generation flows are available for the study time period for Feeder, Sherman Island, and Spier Falls. However, the bypass flows are only available for a short period of the study period. Therefore, the water balance of these three projects only uses the generation flows while the bypass flows for the entire study period are calculated from downstream flows.

The plots below indicate the positive bypass flows in excess of generation flows as well as the negative bypass flows for Feeder Dam, Sherman Island and Spier Falls Projects.

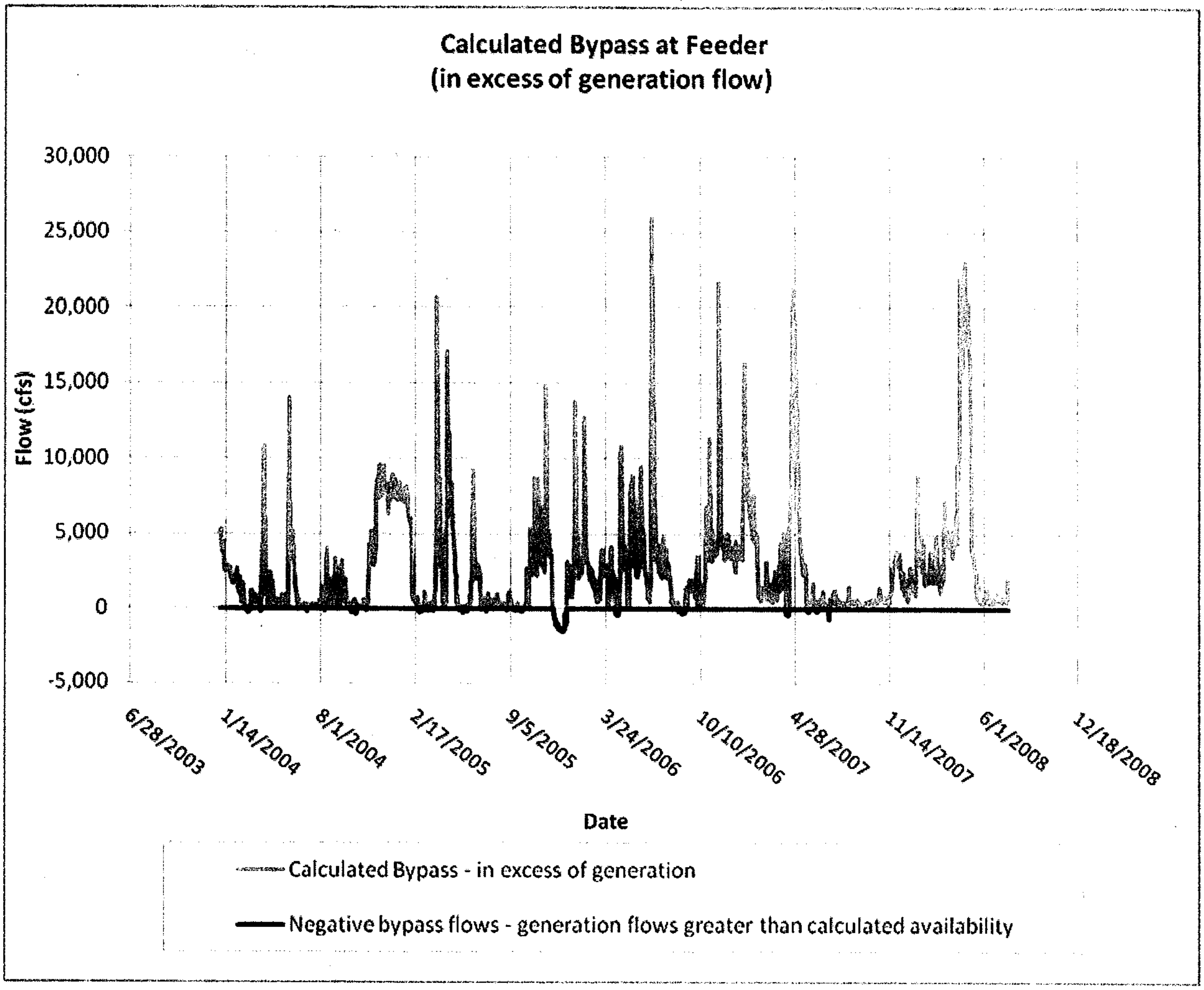


Figure 16. Calculated bypass at Feeder Dam.

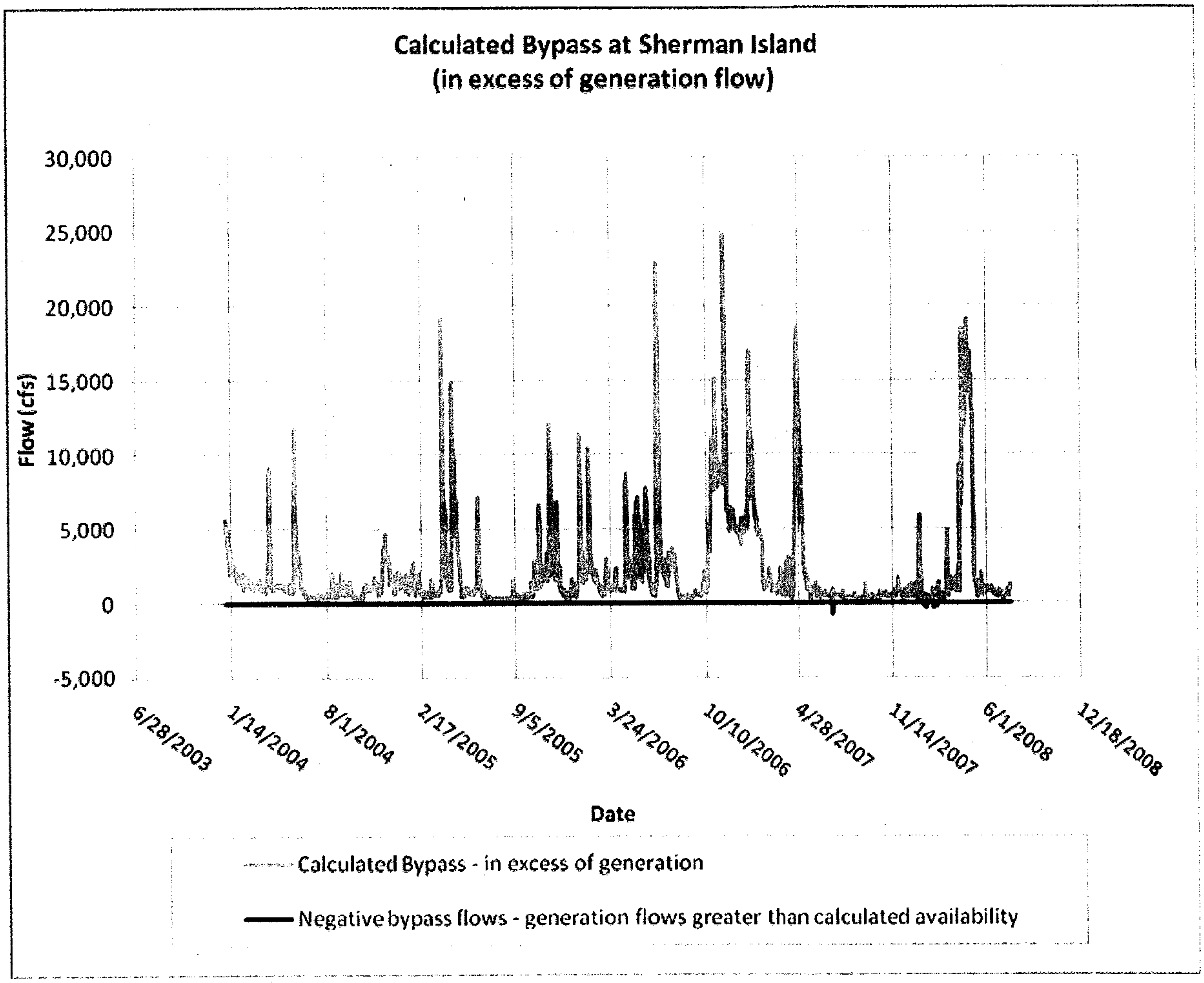


Figure 17. Calculated bypass at Sherman Island.

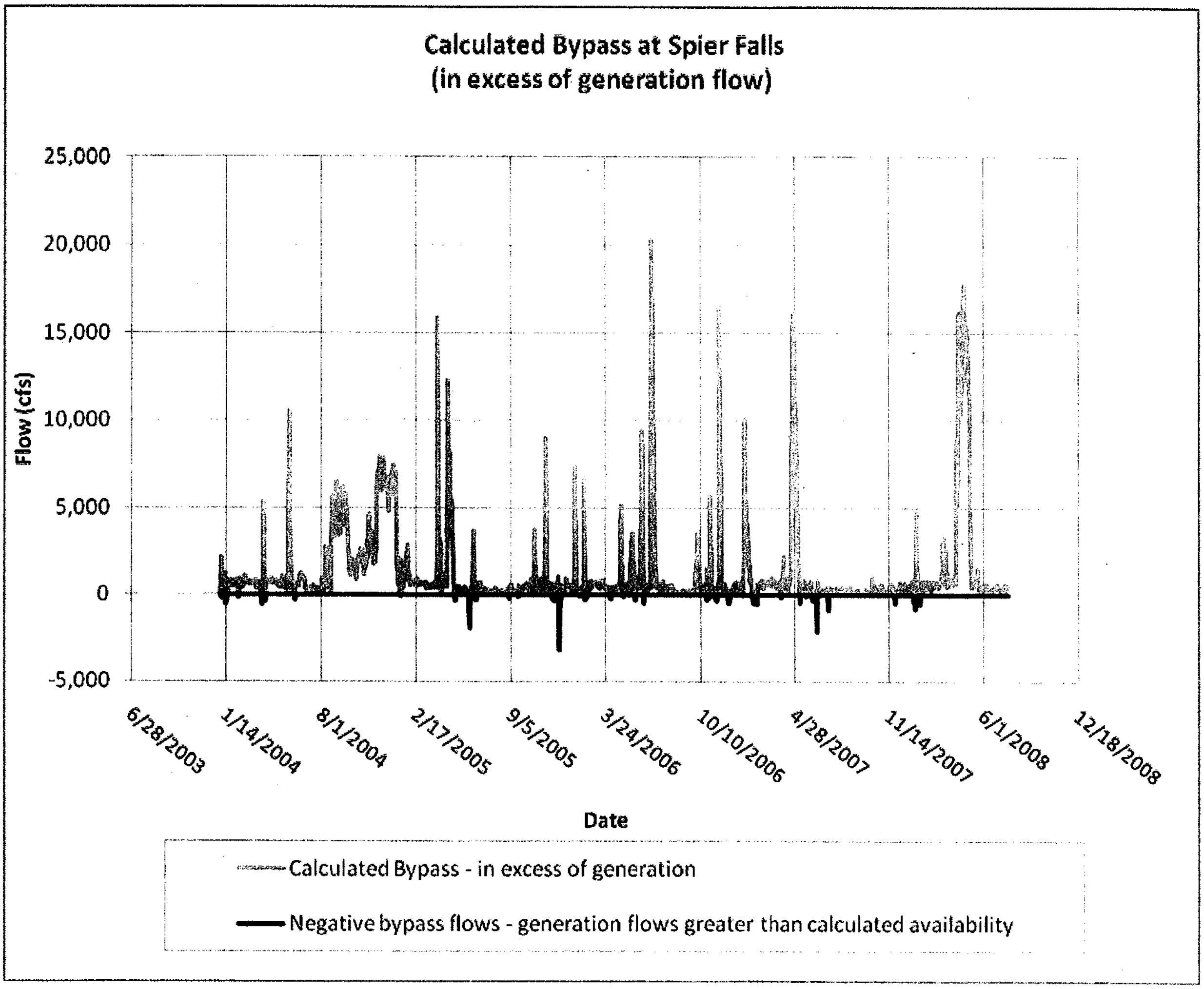


Figure 18. Calculated bypass at Spier Falls

5.2.2 Water Balance for the Lower Hudson Reaches

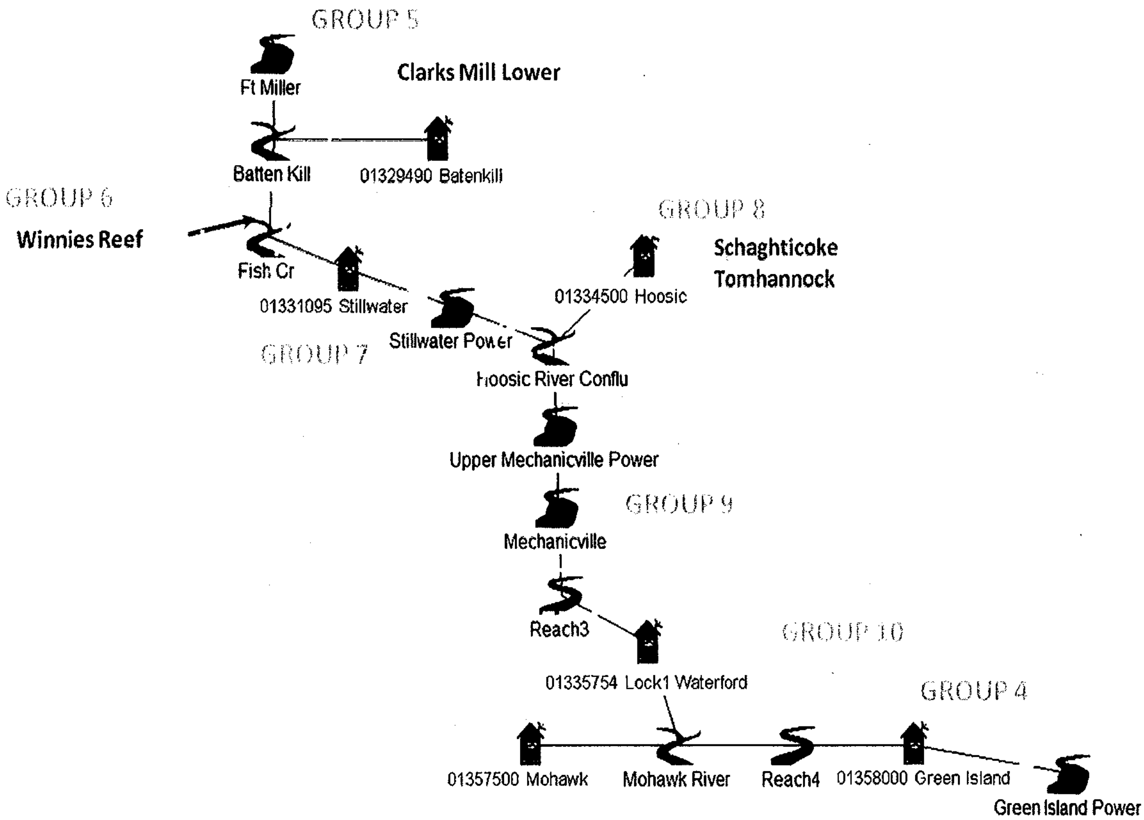


Figure 19. Project grouping and sub-basin definitions for the lower Hudson reaches.

5.2.2.1 Water Balance for Ft.Miller, Clarks Mill Lower, Winnies Reef, Stillwater, Schaghticoke, and Tomhannock – Groups 5, 6, 7,and 8.

The water balance for this group of projects is governed by flow from upstream and the USGA Stream Gauges 01329490 (Batenkill), 01331095 (Stillwater), and 01334500 (Hoosic). The upstream flow gauge, Ft. Edward, provides flow data for Ft. Miller Project. Flow contribution from Winnies Reef basin is determined using the Stillwater gauge. Some minor negative inflows are present as indicated in Figure 20. Stillwater gauge is used to determine flow generation past the Stillwater Project as the inflow contribution of Schaghticoke and Tomhannock Projects are provided by the Hoosic River gauge.

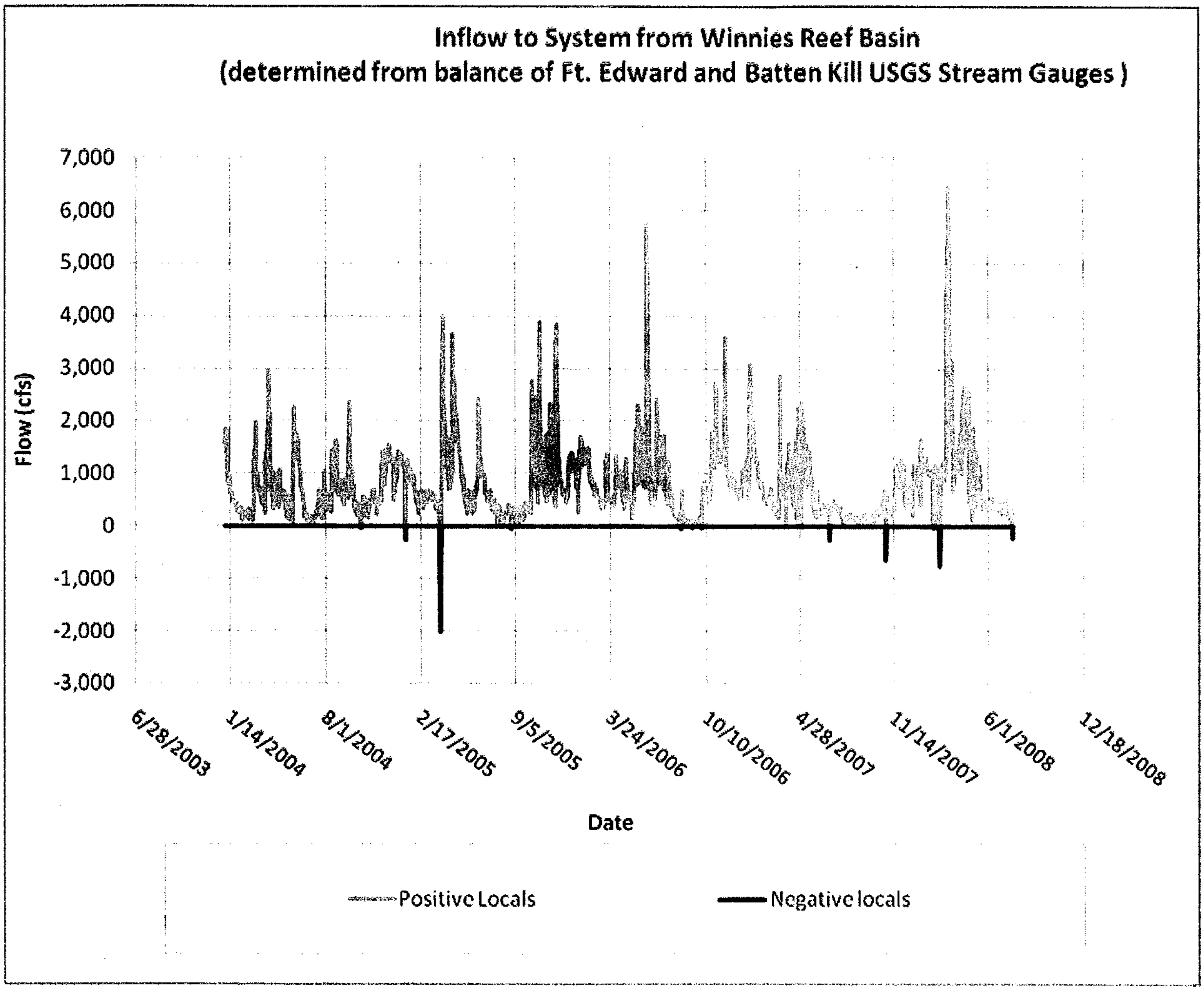


Figure 20. Inflow to the lower reaches from Winnies Reef Basin.

5.2.2.2 Water Balance for Upper Mechanicville, Mechanicville, and Green Island Projects – Groups 9 and 10.

The water balance for this group of projects is governed by flow from upstream at the Hoosic River Confluence and the USGA Stream Gauges 01335754 (Lock 1 Waterford), 01357500 (Mohawk), and 01358000 (Green Island). An in-system water balance check between Mechanicville and the USGS stream flow gauge 01335754 (Lock 1 Waterford) indicates the cumulative local inflows downstream of the Stillwater and Hoosic River streamflow gauges and upstream of the Lock 1 Waterford gauge. There are some negative inflows indicative of possible cumulative effects of evaporation, unknown withdrawals, or minor storage changes in the Stillwater and Mechanicville Projects that have not been investigated herein.

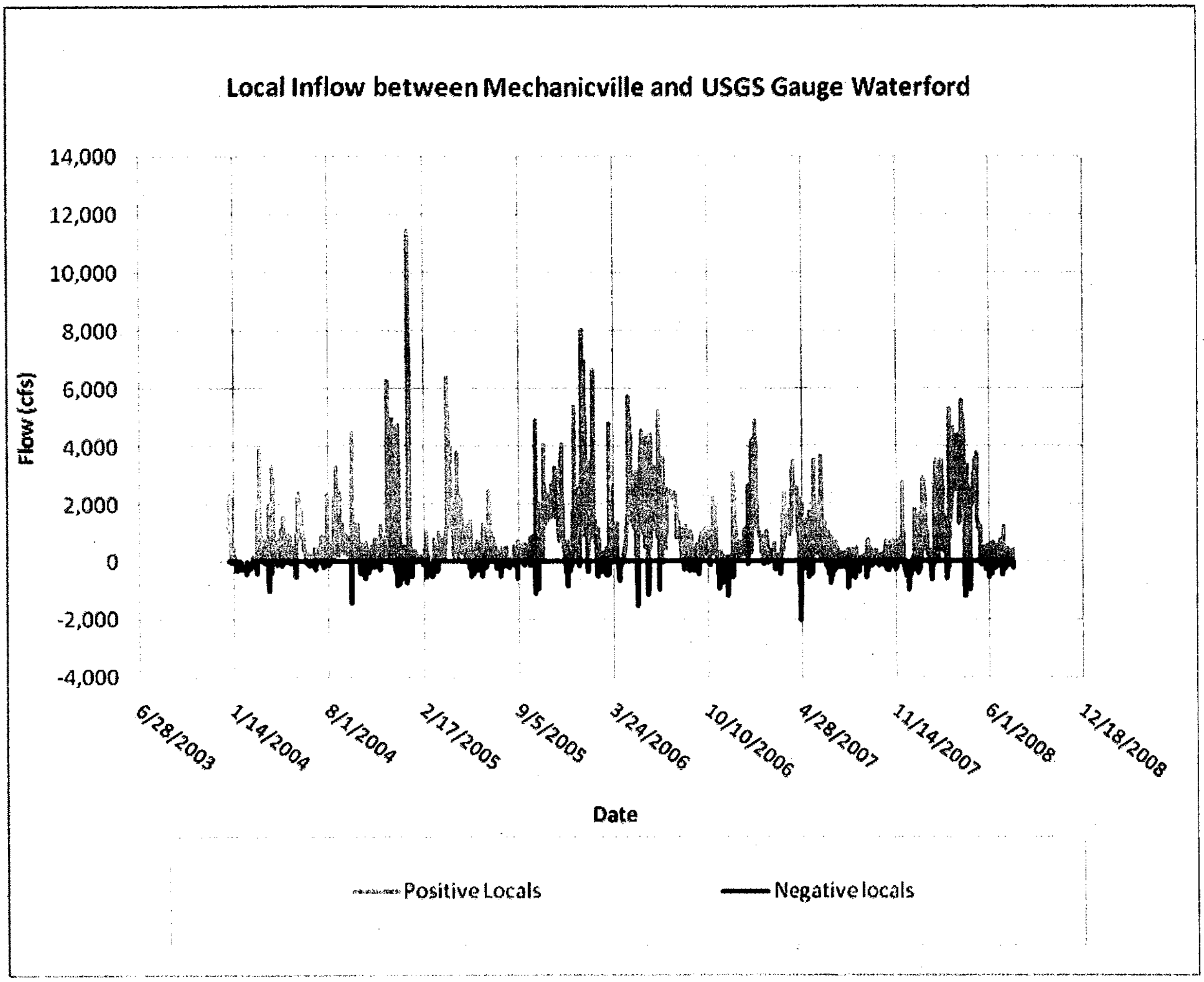


Figure 21. Local inflow between Mechanicsville and the Waterford USGS Gage

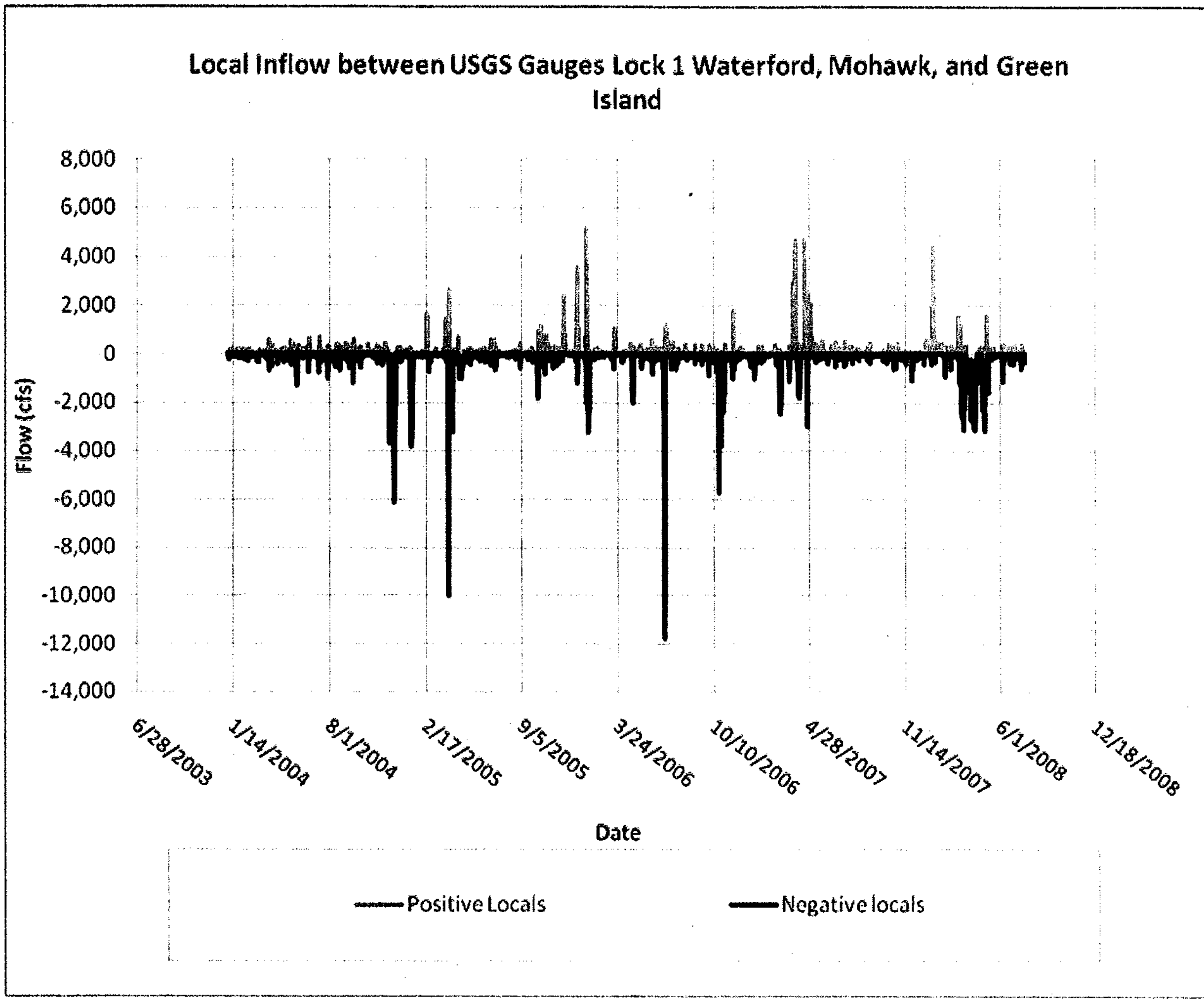


Figure 22. Local inflow between the Lock 1 Waterford Gage, Mohawk, and Green Island.

Another in-system water balance check is performed between USGS stream flow gauges 01335754 (Lock 1 Waterford), 01357500 (Mohawk), and 01358000 (Green Island). There are periods of negative inflows of some significance on the order of 4,000 to as much as 12,000 cfs. This plot is also representative of local inflows upstream of the Green Island Project as it utilizes the gauge flow from Green Island as its generation flow.

5.3 Beneficiary Project Generation Rating Relationships

In order to model generation at run of river projects that benefit from storage projects, the relationship between river flow at the project and generation must be characterized. Generation is primarily a function of turbine flow, but it also is affected by pond and tailwater elevations, outages due to maintenance or faults, debris in the trash racks, and so on. Because it is impractical to model all such parameters, the headwater energy benefits analysis uses an generation to flow relationship that is intended to represent an average of the many conditions experienced by plants in operation. The analyses that follow include generation versus daily flow plots and proposed piecewise linear rating curves. These piecewise linear rating curves are, at present, uncalibrated, meaning that their exact break points (corresponding generation and daily flow values) have not yet been adjusted to so differences between modeled and actual generation monthly and annual totals are minimized. The target for calibration is that the difference between modeled annual generation should be within 1 percent of the actual, and that the modeled monthly generation should be within 5 percent of the actual. To meet these targets, annual or shorter-duration curve fits may be necessary. These adjustments are in progress at the time of this report release.

The plots also include owner-reported generation capacities plotted against rated turbine discharge capacities (plus minimum bypass flows, when appropriate). In some cases, the owners reported manufacturer-supplied ratings. In other cases, owners provided experience-based capacities. ORNL used the supplied capacities as a guide to the placement of the piecewise linear fit inflection points in cases where the data were generally consistent with the supplied capacities. In other cases, ORNL ignored the supplied capacities.

5.3.1 E. J. West Generation

E. J. West is located on Conklingville Dam, the structure that creates Great Sacandaga Lake. E. J. West has two 9.8-MW units for a total capacity of 19.6 MW at 4,800 cfs. However, because it is located on Conklingville Dam, its capacity varies with the elevation of Great Sacandaga Lake. The owner reports that project generating capacity ranges from 9.4 MW at a lake elevation of 740 feet to 17.5 MW at 771 feet.[8]

The owner provided daily generation data for 2003 through 2008. ORNL used river flow data from the Stewarts Bridge gauge. The data are plotted on Figure 23. ORNL's tentative fit to the data is displayed by a purple line on the figure. The inflection points are indicated by the purple triangles. However, this fit would not serve for characterizing performance for the scenario of no Great Sacandaga Lake. Without Great Sacandaga Lake, the water level would always be lower than the minimum necessary to operate turbines at E. J. West Project. Thus, the fit to the data indicated by the purple line will not be used for evaluating headwater benefits at E. J. West because all power produced at E. J. West is a benefit of the operation and maintenance of

[8] ORNL recognizes that these two estimates of generating capacity are inconsistent. As the figure shows, the maximum generation in operation is somewhat higher than either capacity provided by the owner.

Great Sacandaga Lake. [For reference, the inflection points for the fit shown in the figure are 0 (zero) MWh at 0 (zero) average daily flow, 521 MWh at 5,100 cfs, and 519 MWh at 14,000 cfs.]

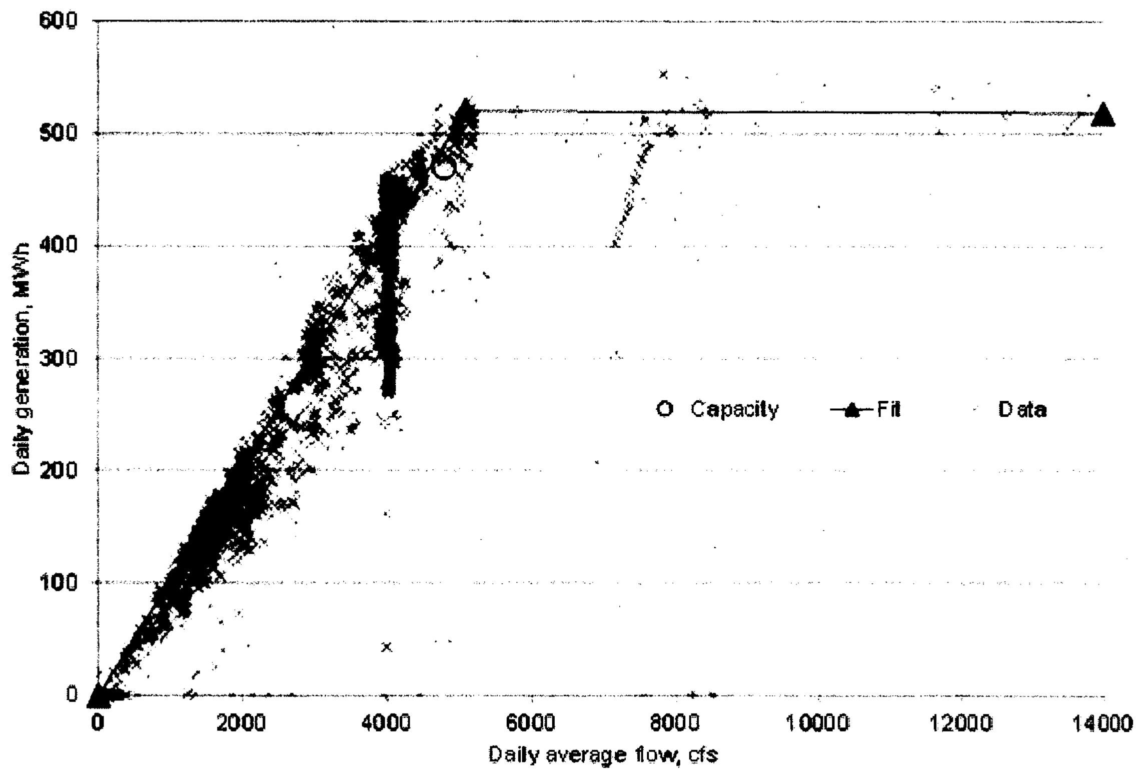


Figure 23. E. J. West generation vs. river flow. Generation data and capacity provided by owner. The fit to the data was generated by ORNL.

5.3.2 Stewarts Bridge Generation

Stewarts Bridge Project is located a short distance upstream of the Stewarts Bridge gauge station (USGS 01325000). Stewarts Bridge generating facilities consist of a single 34.5 MW generating unit with a hydraulic capacity of 5,460 cfs. The project is required by license to maintain a 25-cfs minimum bypass flow.

The owner, Brookfield Power, provided hourly and daily generation for 2003 through 2008. Those data are plotted in Figure 24. The point corresponding to the rated daily generation and daily average flow is indicated by a red circle on the figure. ORNL's tentative fit to the data is indicated by a purple line. The inflection points are denoted by purple triangles. The inflection points are 0.5 MWh at a daily average flow of 51 cfs, 697 MWh at 4,080 cfs, 766.7 at 4,500 cfs, 841.3 MWh at 5,240 cfs, and 802 MWh at 14,000 cfs.

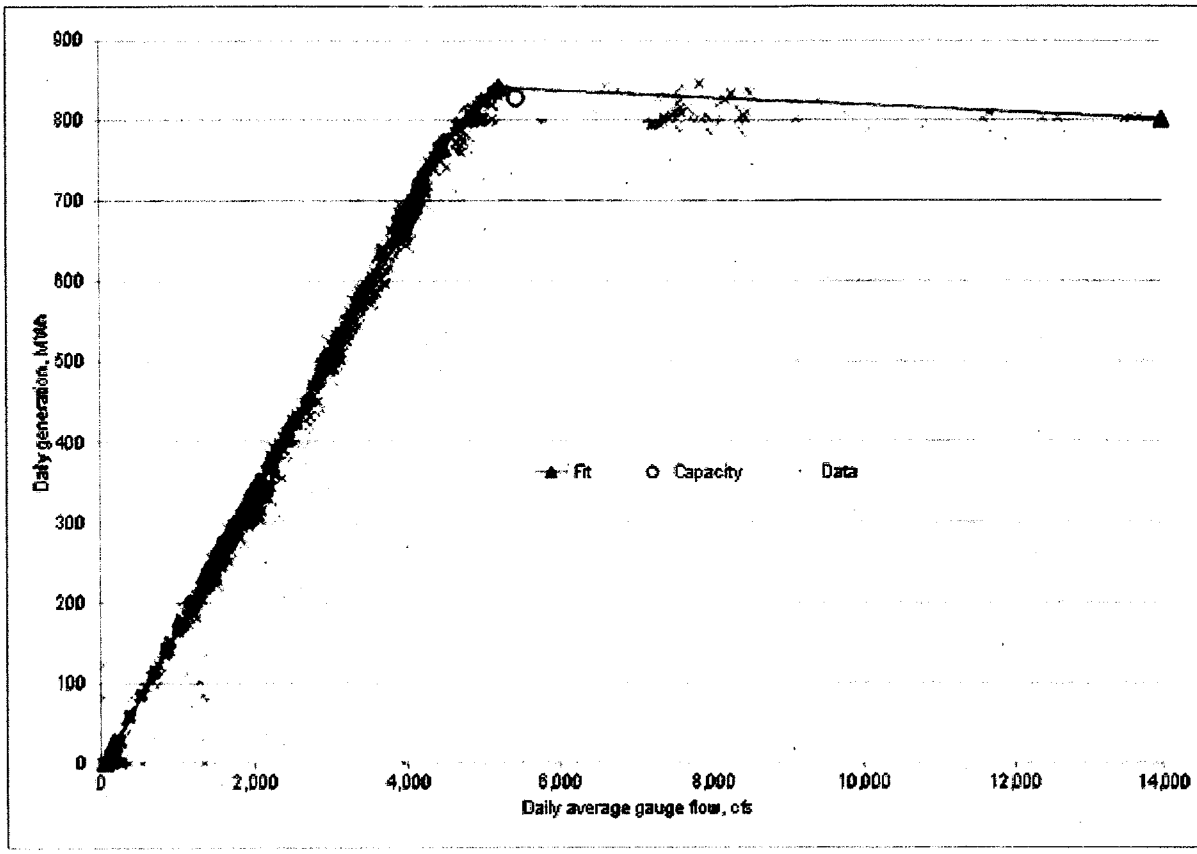


Figure 24. Stewarts Bridge daily generation vs. daily average river flow. Generation data and plant rating was provided by project owners. The flow is from the USGS gauge station at Stewarts Bridge. The tentative fit was developed by ORNL.

5.3.3 Curtis and Palmer Generation

Curtis and Palmer facilities are located a short distance downstream of the confluence of the Sacandaga River with the Hudson River. Both rivers are gauged a short distance upstream of the confluence. The flow on the Hudson River is gauged by the Hadley station (01318500) and the Sacandaga River is gauged by the Sacandaga River station (01325000). ORNL summed the daily flows of the two stations and used those sums to represent flows at the Curtis and Palmer facilities.

Curtis Palmer Hydroelectric Company, the owner and operator of the facilities provided daily generation for each station. Plots of generation vs. flow are displayed as Figure 25 and Figure 26. Individual points on the figures represent individual daily flow-generation points for each day of the seven years from January 1, 2002 through December 31, 2008.

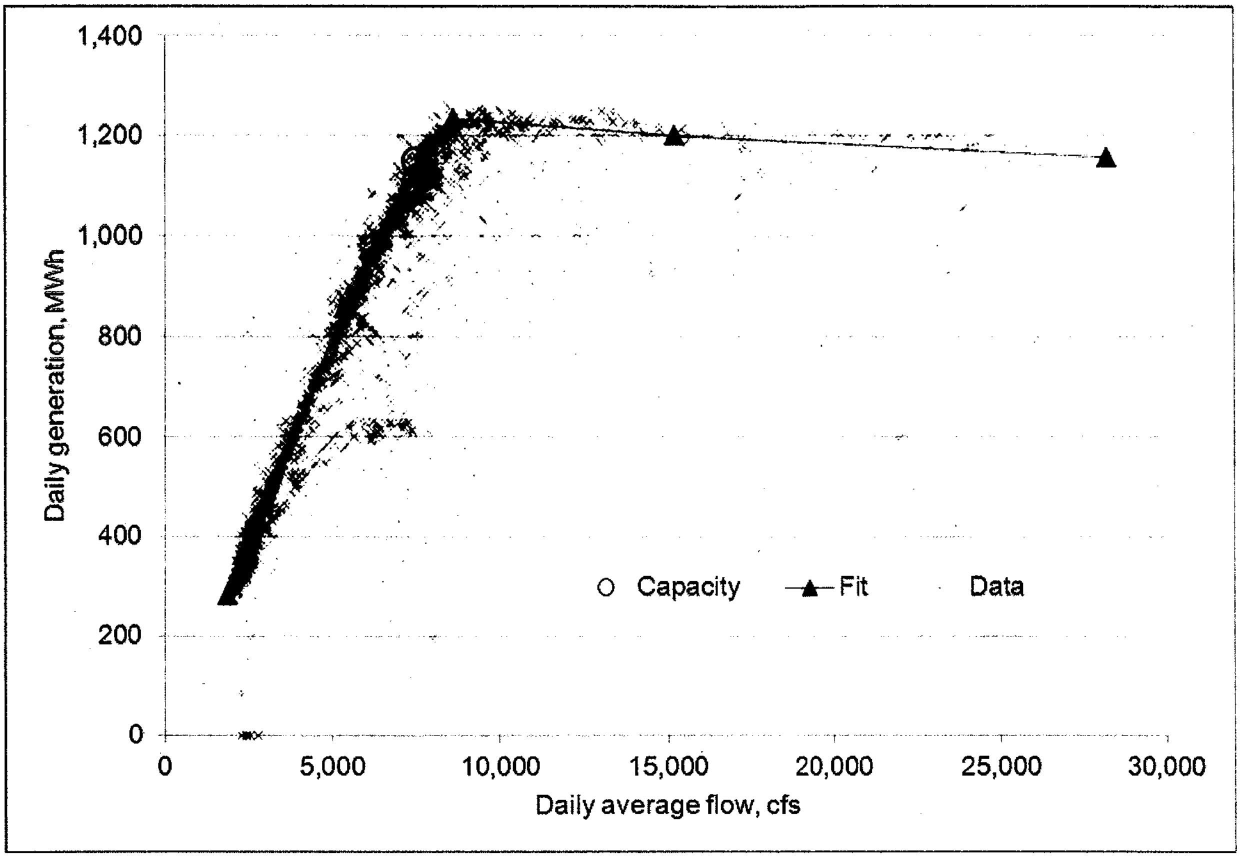


Figure 25. Palmer daily generation vs. daily average river flow

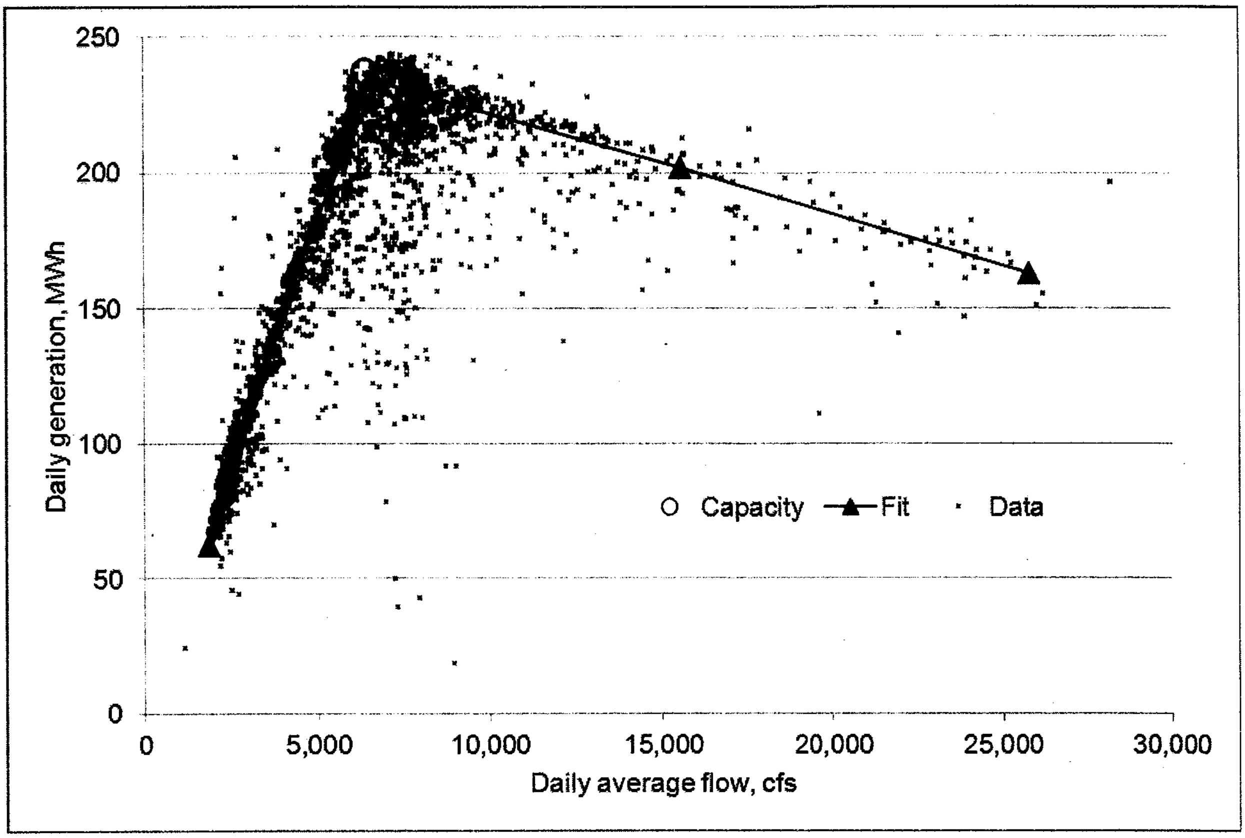


Figure 26. Curtis daily generation and daily average river flow.

HWBEG uses a multi-segment linear equation to characterize the generation-flow relationships for hydroelectric plants. ORNL manually selected inflection points to give a good match to the data for each facility. The inflection points and the resultant line segments are displayed on Figure 25 and Figure 26. The line segments were intended to represent the approximate midpoint of the data. The inflection points selected to characterize the data for HWBEG are listed in Table 4.

Table 4. Proposed Palmer and Curtis inflection points

			Palmer			
Flow, cfs-days	1,875	5,383	7,935	8,660	15,218	28,200
Generation, MWh	282	855	1,179	1,233	1,200	1,157
			Curtis			
Flow, cfs-days	1,856	4,450	6,760	15,580	25,780	
Generation, MWh	62	167	234	202	163	

Palmer

The Palmer data is generally well behaved (Figure 25). The line segments were intended to represent the approximate midpoint of the data. Points with generation below the bulk of the points probably represent days during which one or the other of the units was out of service for a time, or periods when ice or debris partially blocked the water intakes. ORNL has no explanation for the points that are substantially above the bulk of the points at a certain flow. ORNL ignored these points assuming that transcription or other errors were responsible for the divergent data points. Figure 25 shows a string of data that lies below the main cluster between about 3000 cfs and 800 cfs. These points appear to be the result of days when one of the two Palmer units was out of service. ORNL did not develop a set of inflection points for this cluster because it corresponded to a flow range that was already characterized by the main data points.

Curtis

The generation data for Curtis is also well behaved (Figure 26). Perhaps because the data shows no clear evidence of long periods of operations with one or more units out of service. As for Palmer, the line segments were intended to represent the approximate midpoint of the data. The data points that are substantially below the bulk of the points are likely the result of intermittent outages, or periods when debris or ice blocked the intakes. The data points that are above the bulk of the points may represent days when the level of the pond is especially high.

Combined with USGS flow data from the Stewarts Bridge station on the Sacandaga River and Hadley station on the Hudson River, the generation data provided by Curtis Palmer Hydroelectric Company are sufficient to begin the HWBEG analysis for the headwater benefits study.

5.3.4 Spier Falls Generation

Spier Falls Project is located downstream of the confluence of the Sacandaga with the Hudson River. The owners provided generating data for 2003 through 2008, plotted on Figure 27 against flow data calculated by summing average daily flow for the Sacandaga River at Stewarts Bridge (USGS 01325000) and the Hudson River at Hadley (USGS 01318500).

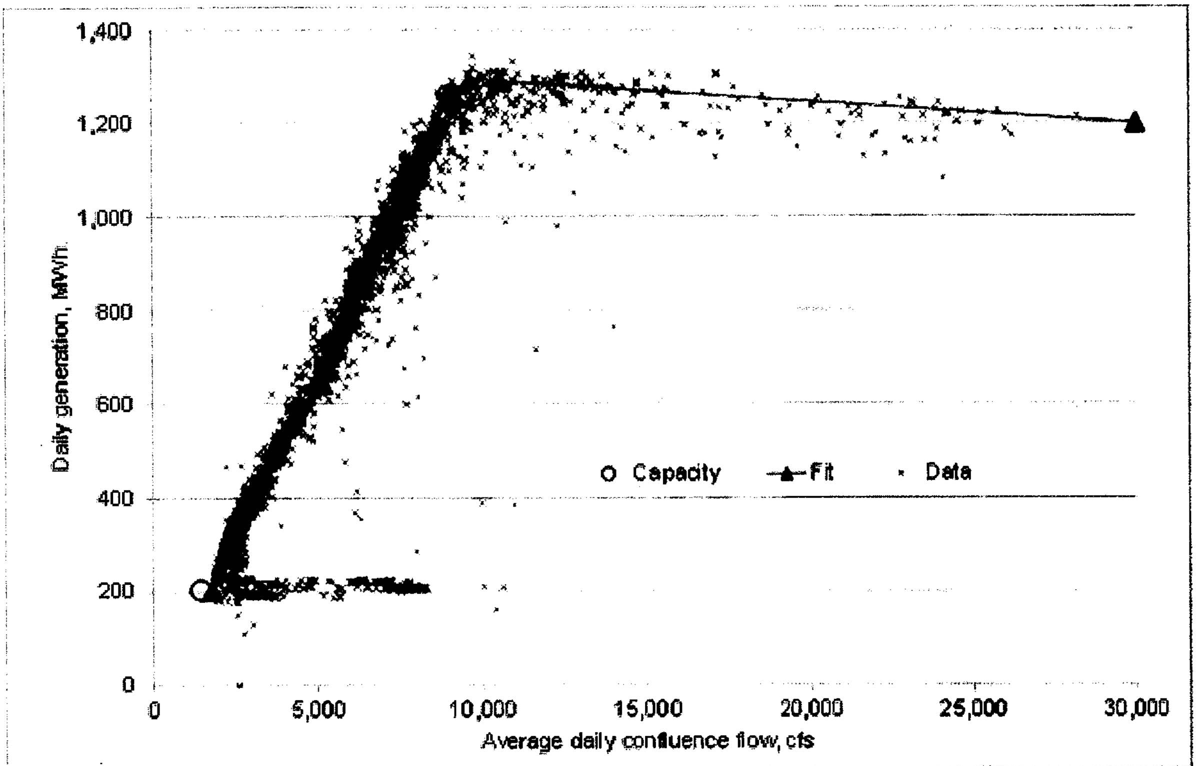


Figure 27. Spier Falls daily generation and daily average river flow. Daily generation and unit capacities were provided by the owner. Daily average river flow is the sum of flows reported at Stewarts Bridge and Hadley gauge stations.

The project has two generating units. Unit 8 has an 8.5 MW generating capacity at 1,440 cfs. Unit 9 has a 44 MW generating capacity at 7,560 cfs. The total plant generating capacity is 52.5 MW at 9,000 cfs. The capacity of the facility with both units and the capacity with just Unit 8 operating are indicated on the figure as red circles.

ORNL's tentative fit to the data is indicated by the purple line. The inflection points are 204 MWh per day at a daily average flow of 1,800 cfs, 350 MWh at 2,500 cfs, 643.4 MWh at 5150 cfs, 1,260 MWh at 9,000 cfs, 1,291 MWh at 10,590 cfs, and 1,200 MWh at 30,000 cfs.

Most generation data follows the fitted line well, however, the figure shows a time period during which only Unit 8 was operating. The time period during which most of these points occurred was August 24, 2004 through January 6, 2005. It seems likely that Unit 9 was out of service during this period.

5.3.5 Sherman Island Generation

Sherman Island Project is located downstream of the confluence of the Sacandaga River with the Hudson. During the study period, it had four operational units. The owner reports that each unit has generating capacity of 7.75 MW at 1,600 cfs turbine flow. License conditions require that a minimum 250 cfs bypass flow be released except during the walleye spawning season when the minimum bypass flow is 675 cfs. The generation data provided by the owner are plotted against the river flow on Figure 28. River flow at Sherman Island Project used for this analysis is the sum of river flow at Stewarts Bridge and Hadley gauge stations.

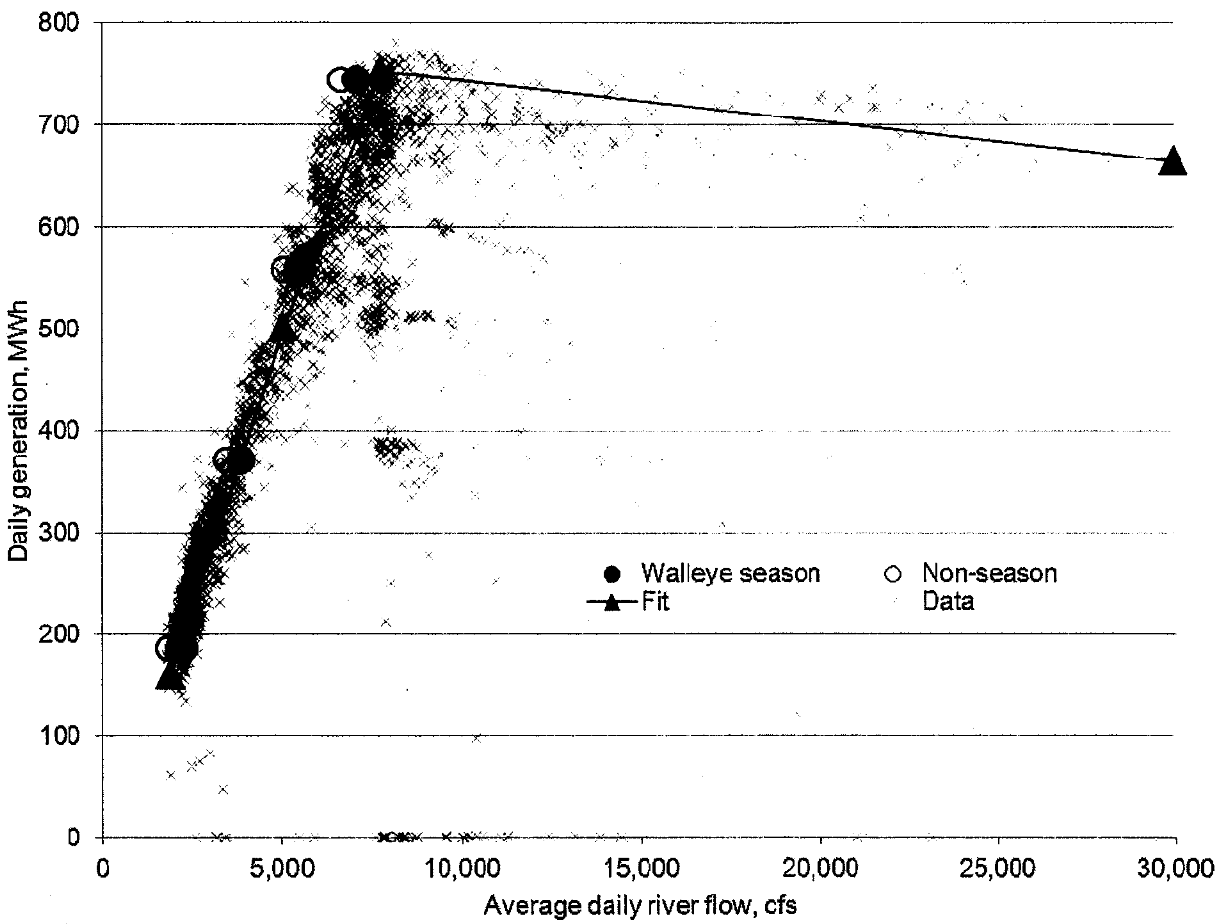


Figure 28. Sherman Island daily generation vs river flow. The red circles locate generating capacity for 1, 2, 3 or 4 units plotted against non-walleye season bypass flows. The red disks locate generating capacity during walleye breeding season.

The red circles and disks represent the rated capacities for 1, 2, 3 and all operating units. The disks are located at rated flows plus 675 cfs bypass flow during walleye breeding season. The red circles are located at the rated flows plus 250 cfs bypass flow during the remainder of the year.

ORNL's tentative fit to the generation data is displayed as a purple line. The purple triangles are located at the inflection points. The inflection points are 159 MWh/day at a daily average river flow of 1,900 cfs, 502 MWh at 5,070 cfs, 752 MWh at 7,770 cfs, and 664 MWh at 30,000 cfs.

The zero generation values displayed in the figure are for the period October 14, through November 18, 2006.

5.3.6 *Feeder Generation*

The Feeder Dam Project consists of five units with a total capacity of 5 MW at 5,000 cfs. The Feeder Dam Project is located downstream of the confluence of Sacandaga River and the Hudson River. The owners provided generation data for 2003 through 2008. ORNL generated the river flow at Feeder Dam by summing the flows at Stewarts Bridge and Hadley gauge stations. The generating data are plotted against river flow is displayed in Figure 29.

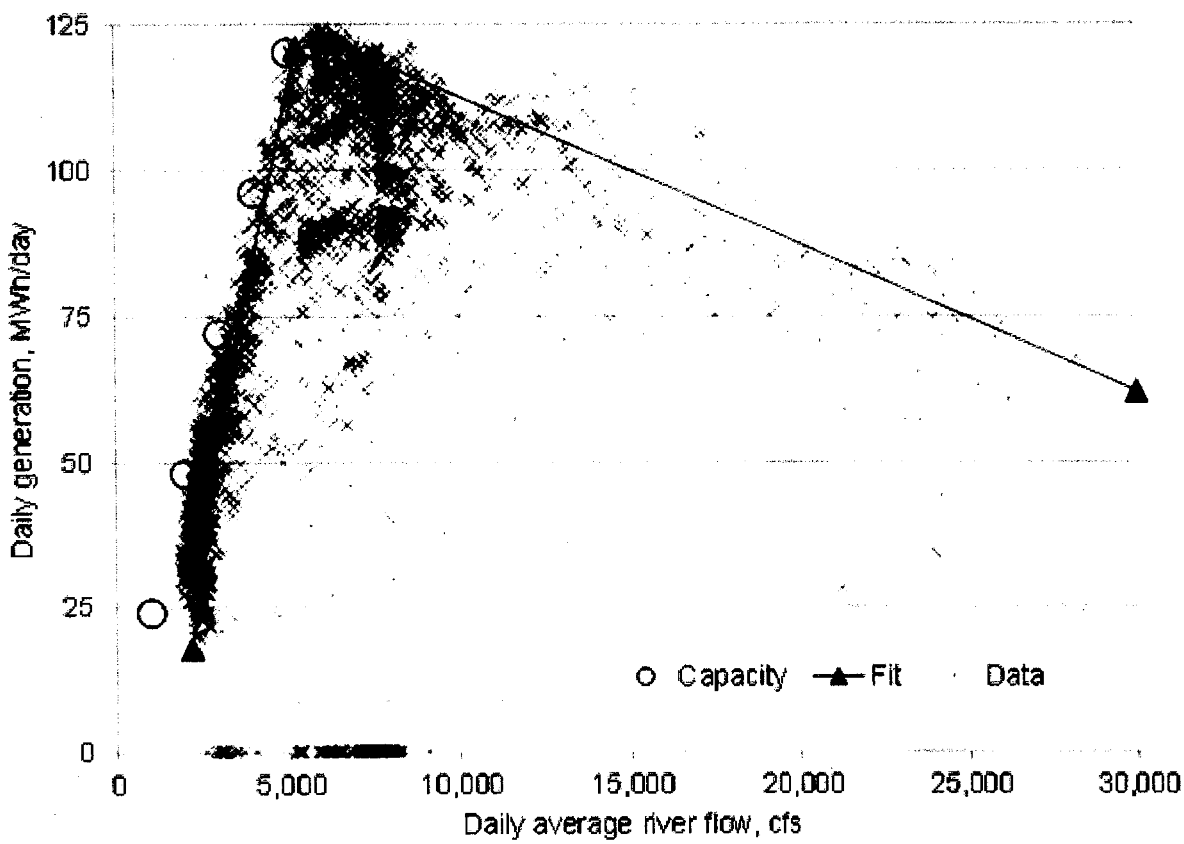


Figure 29. Feeder Dam generation vs. daily average river flow. The owner provided capacities and generation data. The river flow is the sum of flows at Stewarts Bridge and Hadley gauges. The red circles indcate reported capacities for one through 5 units.

License conditions require a minimum bypass flow of 25 cfs, and a minimum daily-average discharge is 1,760 cfs. The rated capacities of 1, 2, 3, 4 and all units are displayed in the figure as red circles. The flows incorporate the 25 cfs minimum bypass flow.

ORNL's tentative fit to the data is indicated by the purple line. Inflection points are indicated by purple triangles. The inflection points are 17.8 MWh per day at an average daily flow of 2,200 cfs, 56.2 MWh at 2,970 cfs, 120.7 MWh at 5,280 cfs, 122 MWh at 6,300 cfs, and 62 MWh at 30,000 cfs.

Generation was zero for the period November 11, 2004 through February 11, 2005.

5.3.7 South Glen Falls Generation

The South Glens Falls Project is located on the South Glens Falls dam; about six miles upstream of the Ft. Edward gauge (01327750). The Glens Falls Project (discussed elsewhere) is also located at the South Glens Falls dam. The South Glens Falls Project has two 7.85-MW units with a total capacity of 15.7 MW at a turbine discharge of approximately 4,400 cfs. The owner provided daily generation data for the 2002 to 2008 period. That data is plotted against flow at Ft. Edward gauge in Figure 30. South Glens Falls daily generation and **daily average Ft. Edward flow. Generation data and capacities were provided by the owner. The rated capacity is shown as occurring at 8,825 cfs river flow based on the assumption that Glens Falls and South Glens Falls discharge the same flow rates, and that a 25 cfs bypass flow is maintained.**

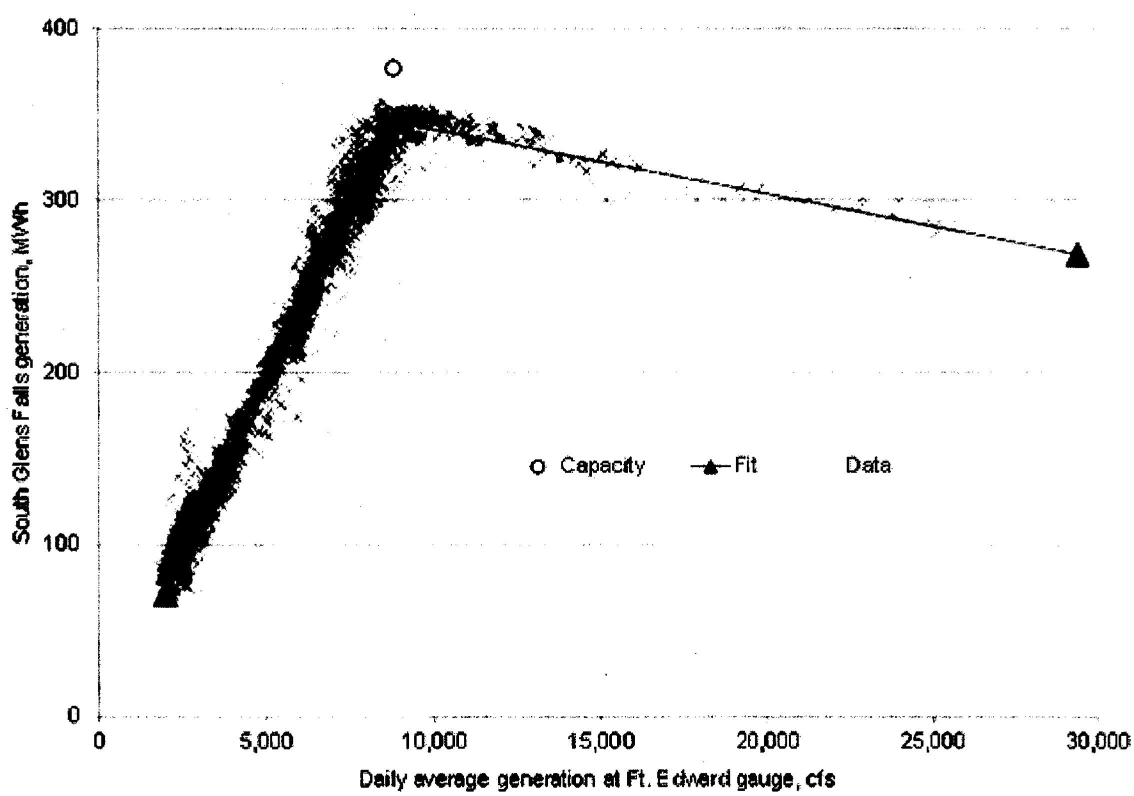


Figure 30. South Glens Falls daily generation and daily average Ft. Edward flow. Generation data and capacities were provided by the owner. The rated capacity is shown as occurring at 8,825 cfs

river flow based on the assumption that Glens Falls and South Glens Falls discharge the same flow rates, and that a 25 cfs bypass flow is maintained.

The tentative fit to the generation and flow data is displayed in Figure 30 by purple lines. The inflection points, indicated by purple triangles, are 71.4 MWh at a daily average flow of 2,000 cfs, 346.4 at 8,600 cfs, and 268.4 at 29,400 cfs.

5.3.8 Glens Falls Generation

Glens Falls project is located on the South Glens Falls Dam. Approximately six miles upstream of the Ft. Edward gauge (01327750). The south Glens Falls project (discussed elsewhere) is also located at the South Glens Falls dam. The Glens Falls project has five units with a total capacity of 12.2 MW at 4,400 cfs. The owner did not provide daily generation data.

ORNL produced a generation-flow relationship by scaling from the fit to the South Glens Falls data. Figure 31 displays the reported project capacity and the tentative generation-flow relationship ORNL developed. The inflection points for the tentative generation-flow relationship are 55.5 MWh per day at a daily average flow of 2,000 cfs, 269.2 MWh at 8,600 cfs, and 208.6 MWh at 29,400 cfs.

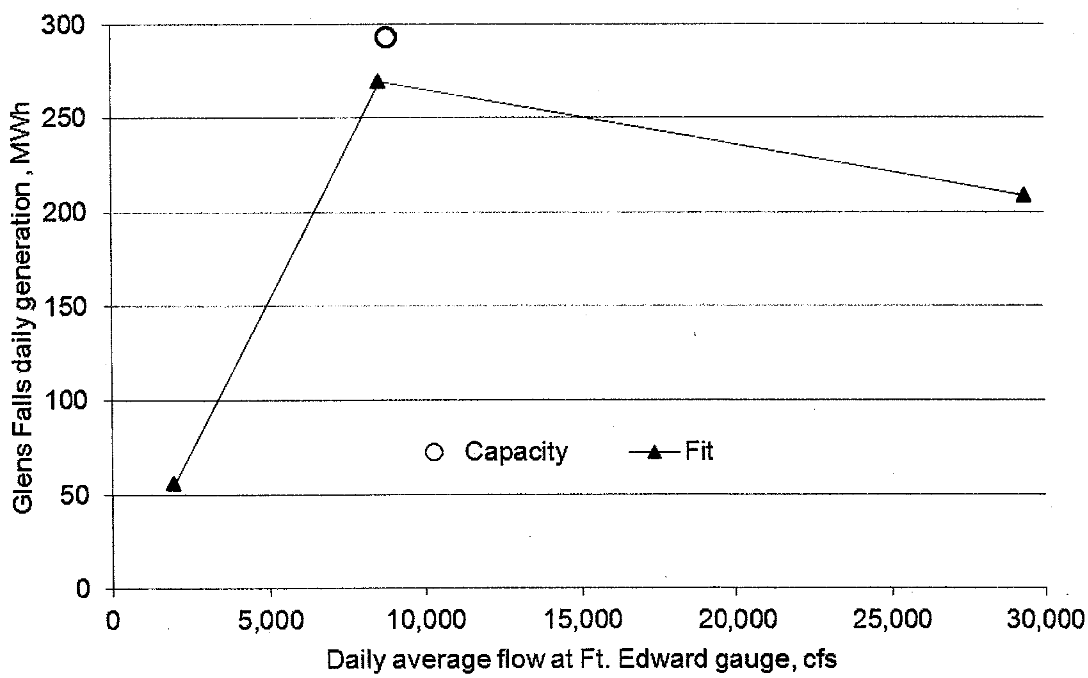


Figure 31. Glens Falls Project generation and daily average flow at Ft. Ewards gauge. No generation data provided by owner. Tentative generation-flow relationshipw was scaled from the South Glens Falls Project characteristics.

5.3.9 Hudson Falls Generation

The Hudson Falls Project is located 2.5 miles upstream of the Ft. Edward gauge. The project has two units rated at 22 MW for a total capacity of 44 MW; the owners did not provide the turbine flow required to achieve the rated power. Figure 32 displays a plot of daily project generation against river flow as measured at Ft. Edward gauge (01327750).

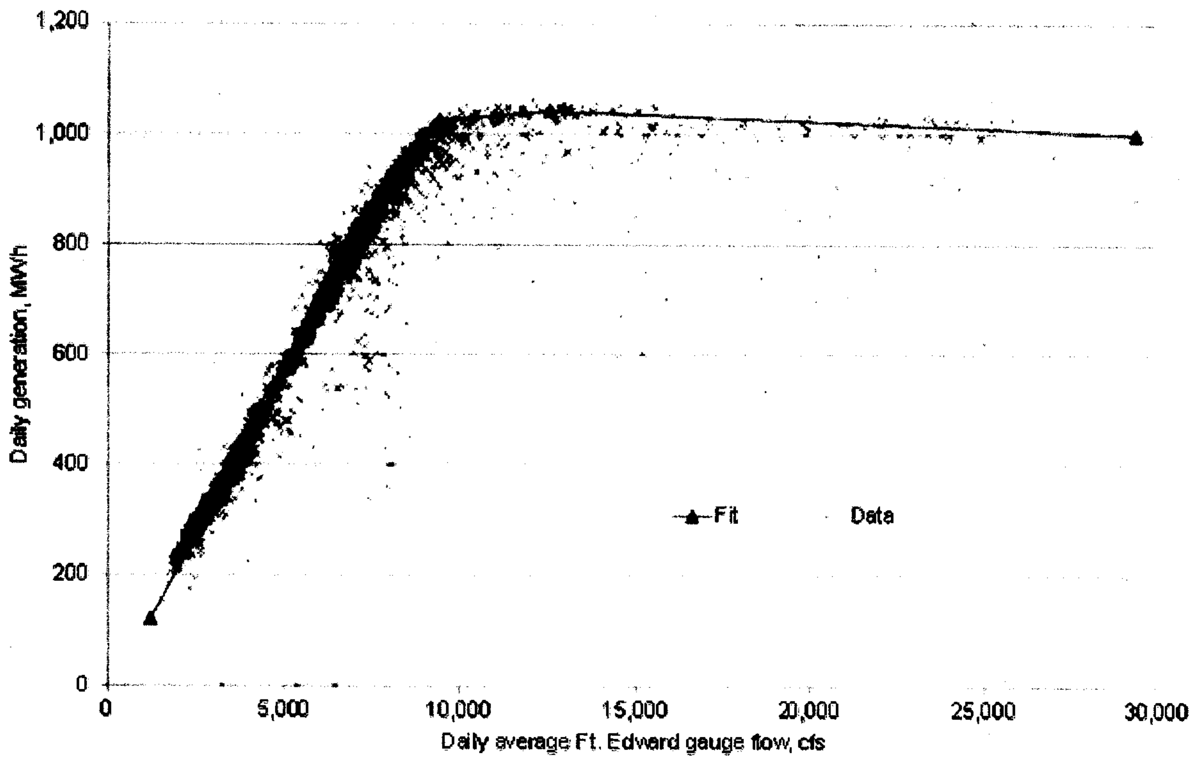


Figure 32. Hudson Falls generation and daily average flow as measured at Ft. Edwards gauge. Generation data provided by owner.

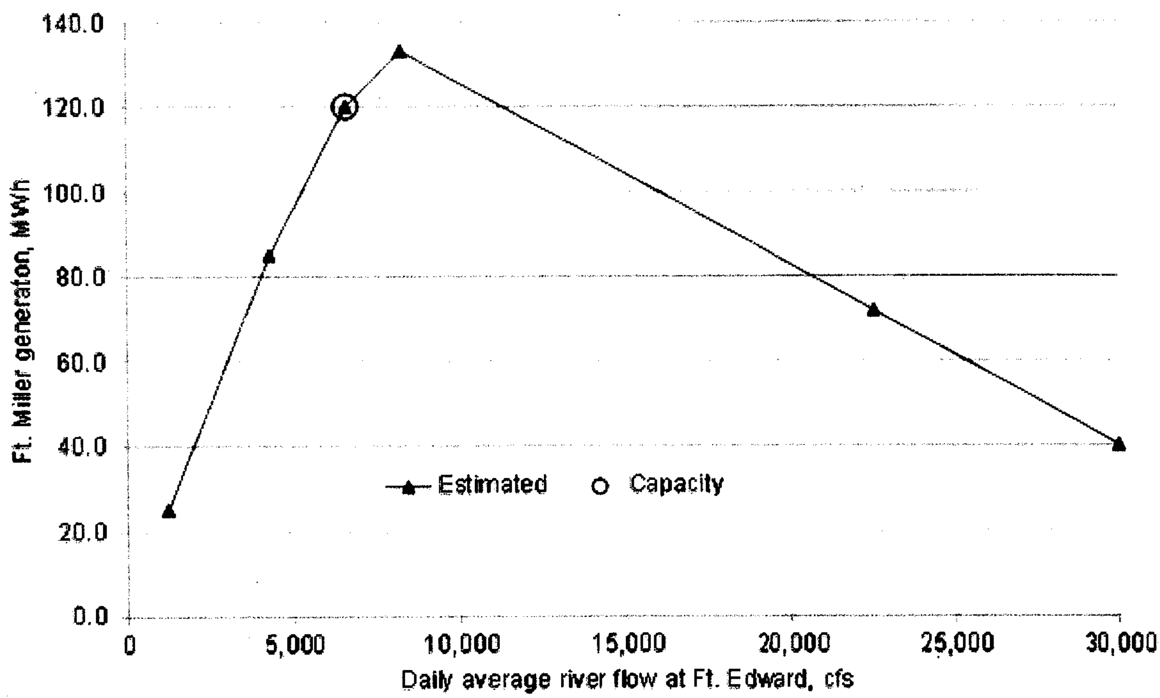
The tentative fit to the data is indicated in Figure 32 by a purple line. The inflection points (indicated by purple triangles) are 122 MWh at a daily average flow of 1,220 cfs, 932 MWh at 8,130 cfs, 1,025 at 9,450 cfs, 1,042 MWh at 12,600 cfs, and 1,000 MWh at 29,400 cfs.

5.3.10 Ft. Miller Generation

The Fort Miller Project is located at Champlain Canal Lock C-6. The project has two units with a combined rated generating capacity of 5 MW at 6,600 cfs. The dam has a minimum spillage requirement of 500 cfs. The project owner provided annual generation for the study period, but did not provide other generation data.

The nearest gauge station, Fort Edward (01327750), is approximately 16 river miles upstream. Because there are no large tributaries between the project and the gauge station, Station 01327750 provides a reasonable estimate of flow at the Ft. Miller Project.

In the absence of data for Ft. Miller Project, ORNL used the generating and hydraulic capacity to estimate the generation-flow relationship. The relationship was scaled from the Upper Mechanicville Project fit to the generation-flow data. Figure 33 displays the result. The Inflection points are 25.1 MWh at a daily average flow of 1,227 cfs, 84.9 MWh at 4,296 cfs, 120 MWh at



6,600 cfs, 133.2 MWh at 8,250 cfs, 71.8 MWh at 22,550 cfs, and 40.2 MWh at 30,000 cfs.

Figure 33. Ft. Miller estimated generation-flow curve. The rated capacity is the only data provided by the owner. The curve is base on the rated capacity and a typical run-of river facility curve shape.

5.3.11 Stillwater Generation

Stillwater Project is located at the Champlain Canal Lock 4 just upstream of the Hoosic River confluence. USGS gauge station 01331095 is located at the dam. The owners provided daily generation data for the period 2002 through 2008. Those generation data are plotted against USGS reported flows in Figure 34.

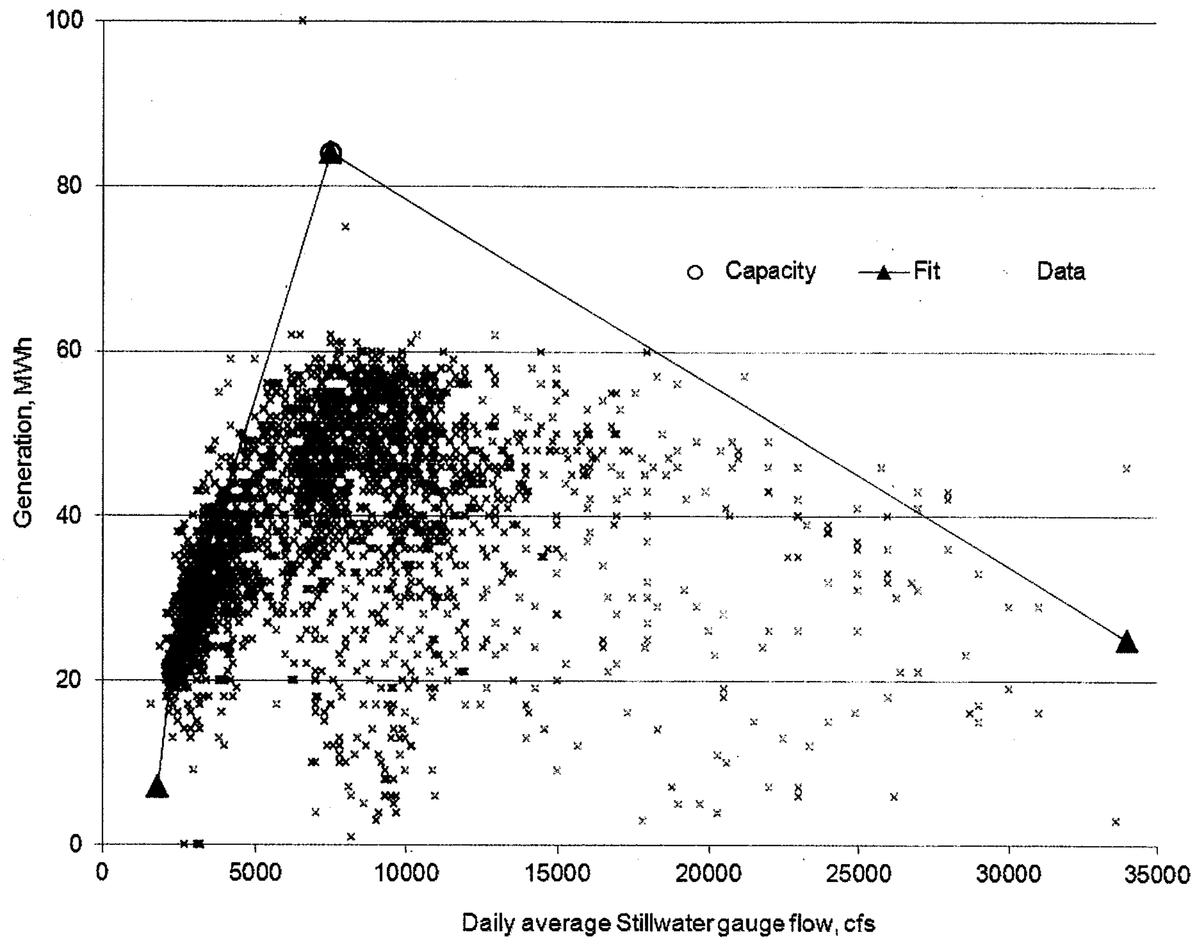


Figure 34. Stillwater Project daily generation and daily average flow data. Rated capacity (red circle) and generation data were provided by the owner. Flow data is from USGS gauge 01331095. Tentative fit to the data is indicated by the purple line.

The owner reported that the facility had a capacity of 3.5 MW at a turbine flow of 7000 cfs. Because the project is required to maintain a minimum bypass flow of 500 cfs, the facility capacity is plotted at a river flow of 7,500 cfs in Figure 34. The tentative fit to the generation data is displayed in Figure 34 as a purple lineFigure 34. Stillwater Project daily generation and daily average flow data. Rated capacity (red circle) and generation data were provided by the owner. Flow data is from USGS gauge 01331095. Tentative fit to the data is indicated by the purple line. The inflection points are 7 MWh per day at an average daily flow of 1,800 cfs, 23 MWh at 2,300 cfs, 39 MWh at 3,700 cfs, 51 MWh at 7,100 cfs, 51 MWh at 10,400 cfs, and 25 MWh at 34,000 cfs.

5.3.12 Upper Mechanicsville Generation

Upper Mechanicville Project is located at Lock 3 of the Champlain Canal. The nearest USGS gauge station that well characterizes the flow at the project is the station at Lock 1. The project operates two turbines rated at 8,700 kVA at a flow of 6,000 cfs. The project total rated capacity is 18,400 kVA at 12,000 cfs.

The project owner provided hourly generation data for the study period. ORNL converted the data to daily generations. (The data for the year 2006 is not included because ORNL has not yet converted that hourly data to daily data). Figure 35 displays a plot of daily generation vs. flow at Lock 1. The rated capacity is denoted by the red circle. ORNL's proposed piecewise linear fit to the data is displayed as a purple line with triangular inflection points. The inflection points are 87.5 MWh at a daily average flow of 2,230 cfs, 295.5 MWh at 7,810, 418 MWh at 12,000, 463.4 MWh at 15,000 cfs, and 250 MWh at 41,000 cfs.

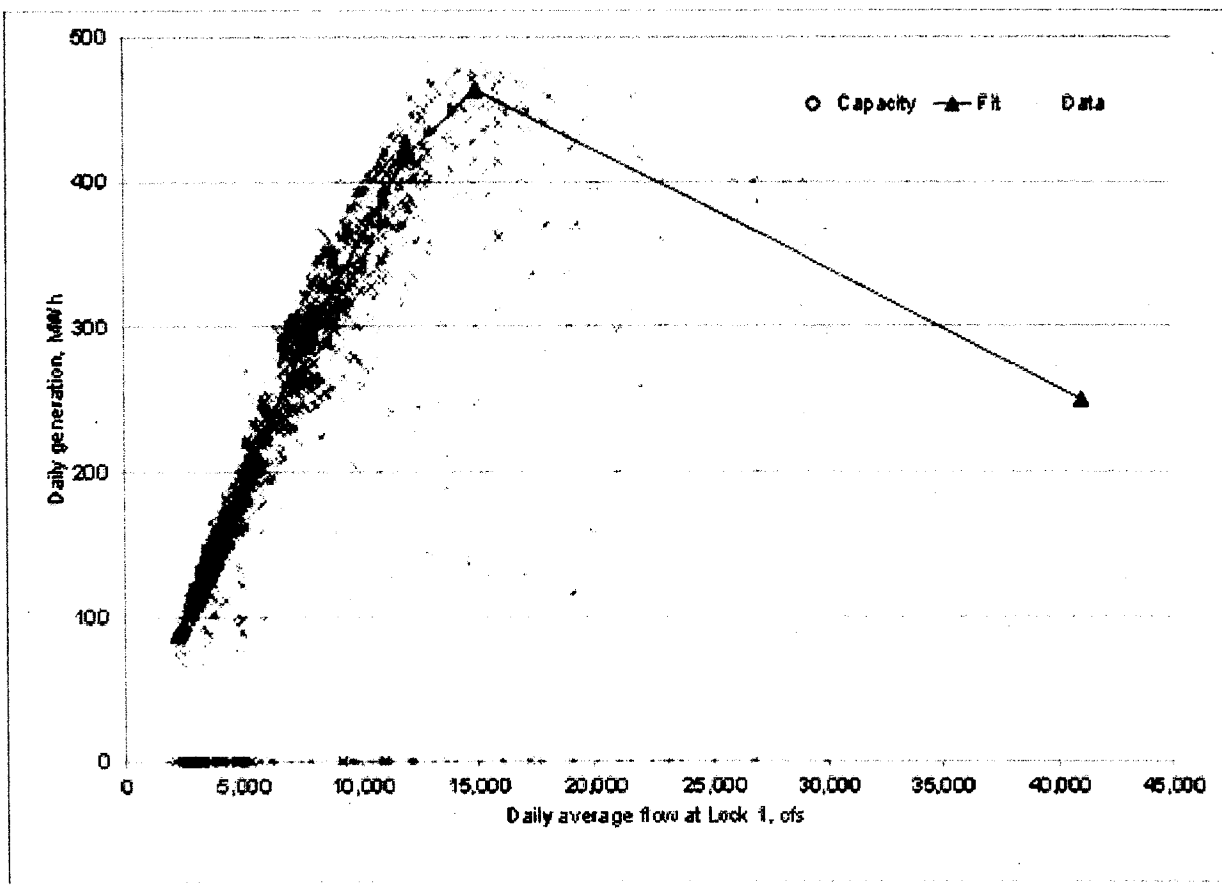


Figure 35. Upper Mechanicville Project daily generation and daily average flow measured at Lock 1. Daily generation data was calculated from hourly data provided by the owner. The rated capacity (red circle) was provided by owner. The tentative fit is shown in purple.

5.3.13 Mechanicsville Generation

Mechanicville Project has six units, each with a rated 750-kW generating capacity at 970 cfs. This facility was built in a manner that allows half units to be operated. Mechanicville Project was not operational at the beginning of the study period; the owners began bringing units to operational status in November 2003. The owners provided generation data beginning May 1, 2005 when one and one half units were operational. During the course of the study period, the number of units operating varied considerably. The maximum number of units deployed at any one time was five.

Figure 36 displays the daily generation data reported by the project owners for the period May 1, 2005 through 2008 plotted against the daily average flow at Lock 1 at Waterford, downstream of the project. The red circles indicate the reported generating capacity of the project with one through six units operating. The data shows that generation was always below the rated capacity with six units operating. As noted above, the maximum number of operating units was five. Most often, during the study period, 3, 3.5 or 4 units operated. In the HWBEG analysis, a refined piecewise linear fits to the data will account for the variation of generating capacity with time. The horizontal locations of the circles are affected by assuming that project discharged the required 500 cfs minimum bypass spill in addition to the generation flows.

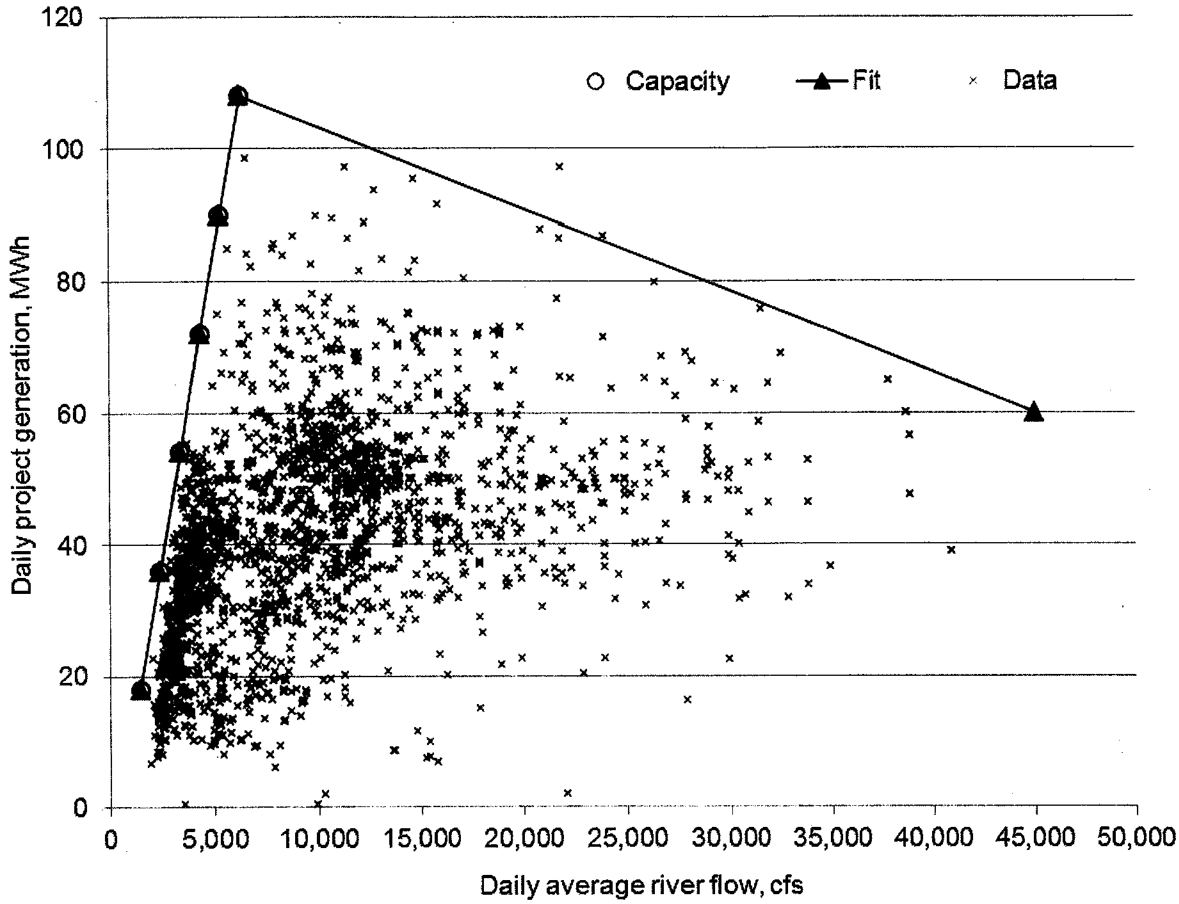


Figure 36. Mechanicville Project daily generation and rive flow. Capacities and generation data were provided by the owner. The river flow is from the Lock 1 gauge station. The red circles denote the rated capacity of the facility for one through six turbines operating.

The purple line and triangular marks in Figure 36 illustrate the tentative curve fit for use in the HWBEG model. The inflection points for the curve fit are 6.8 MW at an average daily flow of 2,050 cfs, 52.2 MW at 4,470 cfs, 50.4 MW at 16,000 cfs, and 47.4 MW at 41,000 cfs.

5.3.14 Green Island Generation

The Green Island Project is the lowest project in the Upper Hudson River Basin. USGS gauge station 01358000 is located immediately upstream. The owners provided daily generation for the 2002 through 2008 period. Those data are plotted against the USGS reported flows in Figure 37 except for the days July 2 through 11, 2008 for which the generation data were clearly erroneous.[9]

[9] The reported daily generation for each of the first 9 of these days was nearly 7 GWh. The last day was negative 62 GWh.

The owner reported that the facility has a capacity of 6,000 kW at a flow of 9,828 cfs. This point in noted in Figure 37. The tentative fit to the data is displayed in Figure 37 as a purple line. The inflection points are 22.1 MWh at a daily average flow of 2,500 cfs, 96.0 MWh at 5,470 cfs, 144.0 MWh at 9,828 cfs, and 95.5 MWh at 117,000 cfs.

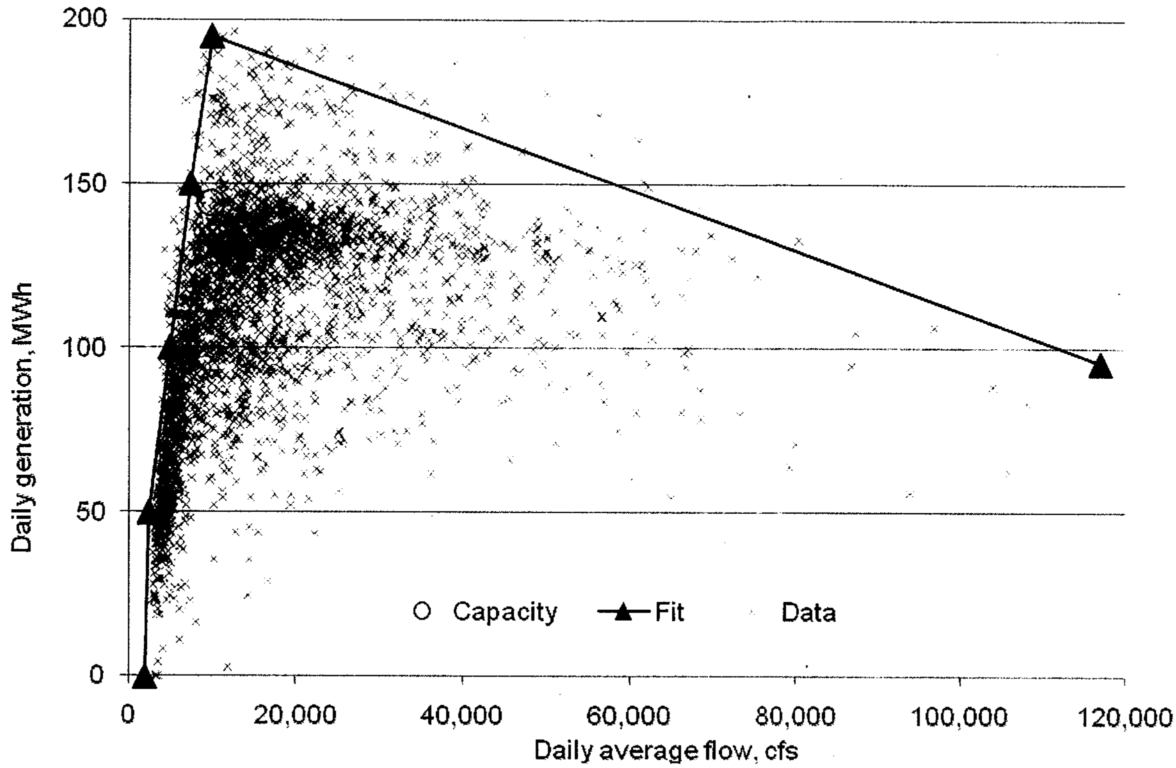


Figure 37. Green Island Project daily generation and daily average flow. Rated capacity and daily generation were provided by the owner.

Interpretation of the daily generation data provided the owners will require additional analysis and discussion, including observation that the many daily generation values exceed the rated capacity of the project.

6 SUMMARY AND CONCLUSIONS

Only three storage facilities have the potential for contributing significantly to headwater energy benefits of the run of river projects on the Hudson River. Great Sacandaga Lake-Conklingville Dam is known to be the primary storage reservoir in the basin. Indian Lake is the second largest reservoir and there is good evidence that it is managed in a manner that would create benefits downstream projects. Winnies Reef Dam on Fish Creek appears to be a potential contributor to energy benefits at three farthest downstream projects, but ORNL lacks sufficient information to confirm or reject this hypothesis. ORNL has sufficient data to perform the headwater energy benefits analysis for Great Sacandaga Lake. ORNL has elevation and discharge data that would enable analysis of Indian Lake benefits, ORNL needs the storage-elevation relationship for Indian lake that would allow analysis of its benefits to downstream projects. ORNL has no

information about the operation of Winnies Reef Reservoir, but it is uncertain that it is operated in a manner that would produce downstream benefits. ORNL has sufficient data on all potentially beneficiary plants to estimate the headwater energy benefits derived by all downstream hydropower projects. In one case, Fort Miller Project, data daily generation data unavailable, but ORNL will use rated flow and generation capacities to estimate a flow generation relationship.

6.1 Next Steps

- ORNL has no information on Victory Mills Dam (NID NY13697 and State ID 224-0245), other than its location on Fish Creek between Winnies Reef Dam and Schuylerville Dam. It is listed in some records but not in others. For completeness, ORNL continues to seek information on ownership and configuration of this facility.
- ORNL is in the process of adjusting the exact values of piecewise linear generation rating curve break points to obtain optimal agreement between actual and modeled generation totals.
- ORNL will revise basin and/or project descriptions in response to comments from the Commission and the parties.
- ORNL will need storage-elevation data or an accurate storage-elevation curve to include Indian Lake in HWBEG modeling of energy gains.[10]
- After assembling the input data, ORNL will perform the headwater energy benefits analysis using HWBEG and prepare a report on the analysis and results.

7 REFERENCES

NID 2009. https://rsgis.crrel.usace.army.mil/apex/f?p=397:1:4181081442674089::NO:::

USGS 2010: Boundary Descriptions and Names of Regions, Subregions, Accounting Units and Cataloging Units. http://water.usgs.gov/GIS/huc_name.html. Accessed February 5, 2010.

NCDC (National Climatic Data Center) 2002. Climatography of the United States No. 81; Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971-2000; 30 New York. National Oceanic and Atmospheric Administration, Ashville, NC, February.

[10] If comments on the basin description leads to the conclusion that Winnies Reef Dam reservoir should be analyzed, ORNL would need data on operation of that facility before completing the headwater benefits analysis of the lowest three projects in the basin, Upper Mechanicville, Mechanicville, and Green Island.