BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION APPLICATION FOR EXEMPTION OF SMALL HYDROELECTRIC PROJECT FROM LICENSING - EXISTING DAM

Neversink Hydroelectric Development

FERC Project No. 13287

VOLUME 4

Appendix E-2: Impact of Hydropower Development Construction Activities on Wildlife and Botanical Resources, including Wetlands, Riparian, and Littoral Habitat, and Rare, Threatened and Endangered Species

City of New York

Environmental Protection

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City of New York
West of Hudson Hydroelectric Project

Project No. 13287

Impact of Construction-Related Activities on Wildlife and Botanical Resources, including Wetlands, Riparian, and Littoral Habitat, and Rare, Threatened, and Endangered Species

Cannonsville, Pepacton, and Neversink Developments

June 2011

EXECUTIVE SUMMARY

The City of New York ("City"), acting through the New York City Department of Environmental Protection ("DEP") has filed with the Federal Energy Regulatory Commission a Notice of Intent to develop hydroelectric generation at the West of Hudson Hydroelectric Project. As part of the licensing process for the Project, the DEP conducted a study to evaluate the impact of proposed construction-related activities on wetlands, wildlife, and botanical resources at the Cannonsville, Pepacton, and Neversink Reservoirs.

The geographic scope of this study included the proposed construction areas at each development and a buffer area of up to 100 feet surrounding the construction areas. A field assessment was conducted in June 2010 and April 2011 to document existing habitat conditions in the proposed construction areas and to evaluate how construction-related activities could impact wetlands, wildlife, and botanical resources, including rare, threatened, and endangered ("RTE") species. A team of two field biologists visited the proposed construction areas to document the existing habitat conditions including vegetative cover type, RTE species and habitat, invasive plant species, and wetlands.

At the Cannonsville development, impacts to upland botanical resources during construction-related activities will be limited to (a) temporary disturbances to existing mowed fields which will serve as the construction staging areas and spoils disposal location; and (b) selective trimming and removal of trees during construction of the substation and related electrical interconnection facilities. Clearing related to the proposed substation and interconnection facilities will result in minor fragmentation of the upland forest; however, this area is isolated from surrounding continuous forest blocks due to the river channels and dam. Therefore, the fragmentation is not expected to cause impacts to wildlife passage routes. No impacts to upland botanical resources within the buffer locations are expected.

The emergent wetland proposed for excavation in the tailrace area at the Cannonsville development is approximately 1.05 acres. Impacts to this wetland will result in a change of wetland type from a shallow emergent to deep riverine type. Additionally, two small emergent wetlands were found in the buffer zones adjacent to the staging areas at the Cannonsville development, ranging in size from 0.1 to 0.6 acres; these two wetlands will be demarcated and avoided during the use of the adjacent staging areas and therefore, no adverse impacts to these areas are anticipated as a result of the construction activities.

Three vernal pools ranging in size from 600 to 7,500 square feet were found at the Cannonsville development during the April 2011 field survey. The larger pool was found to contain amphibian egg masses and may potentially serve as habitat for the longtail and Jefferson's salamander. These vernal pools, however, were either outside of the study area or only partially located within the outer limits of a buffer zone around a construction location at the Cannonsville development. These vernal pools will be demarcated and avoided during construction and therefore, no adverse impacts are anticipated.

Potential temporary impacts to riparian and littoral areas of the river channel below the release works may occur during construction at the Cannonsville development. Such potential temporary impacts include lowered stream velocities and reduced depths in areas below the release works. Because this area will remain wetted during construction from backwater provided from the spillway channel, impacts to the riparian and littoral areas, as well as the plant and animal species that use such areas as habitat, are not expected to be significant.

To maintain downstream river flows during construction, a temporary siphon is proposed to convey water over the existing spillway and into the spillway channel at the Cannonsville development. The spillway channel is excavated in bedrock and is typically dry except when the dam is spilling; therefore, this channel does not support vegetation and aquatic life. The temporary siphon will extend into the littoral

zone of Cannonsville Reservoir and any short term impacts to this area, such as avoidance of or entrainment through the temporary siphon intake by aquatic organisms, are unavoidable due to the need to maintain flows downstream. Overall, it is expected that construction-related activities at the Cannonsville development will not result in any material impacts to environmental resources.

The construction-related work at the Pepacton development will be limited in scope and occur within and immediately adjacent to the existing release works building. The proposed construction areas consist of mowed turf and paved roads. Impacts to upland botanical resources will be limited to disturbances to existing mowed fields which will serve as the construction staging area and location of new electrical equipment. To maintain downstream river flows during construction, a temporary siphon is proposed to convey water over the existing spillway and into the spillway channel at the Pepacton development. The spillway channel is excavated in bedrock and is typically dry except when the dam is spilling; therefore, this channel does not support vegetation and aquatic life. The temporary siphon will extend into the littoral zone of Pepacton Reservoir, however any short term impacts to this area, such as avoidance of or entrainment through the temporary siphon intake by aquatic organisms, are unavoidable due to the need to maintain flows downstream. It is anticipated that construction-related activities at the Pepacton development will not result in any material impacts to environmental resources.

Similar to the Pepacton development, the construction-related work at the Neversink development will be limited in scope and occur within and adjacent to the existing release works building. The proposed construction areas at the Neversink development consist of mowed turf and paved roads, as well as forest plantation, and successional field where an existing underground conduit will be utilized for the electrical connection. Based on the site visits, the areas proposed for construction at the Neversink development are currently disturbed and it is expected that construction-related activities at the Neversink development will not result in any material impacts to botanical and wildlife resources.

To maintain downstream river flows during construction, a temporary siphon is proposed to convey water over the existing spillway and into the spillway channel at the Neversink development. The spillway channel is excavated in bedrock, is typically dry except when the dam is spilling, and, thus, does not support vegetation and aquatic life. The temporary siphon will extend into the littoral zone of Neversink Reservoir; however, as with the other two developments, any short term impacts to the littoral zone related to this temporary siphon, such as avoidance of or entrainment through the temporary siphon intake by aquatic organisms, are unavoidable due to the need to maintain flows downstream. It is anticipated that construction-related activities at the Neversink development will not result in any material impacts to environmental resources.

Bald eagles were observed at each of the three developments during the field surveys. Based on the field observations, there does not appear to be any nesting or roosting habitat (*e.g.*, tall trees) in the proposed construction areas or buffer zones. In terms of bald eagle foraging activities, at the Cannonsville development, the tailrace excavation area is localized to a relatively small area (~1 acre), and there are other undisturbed areas that would afford ample alternative foraging opportunities, such as Cannonsville Reservoir, the channel downstream of the spillway, and other downstream locations. At Pepacton and Neversink, the construction activities will be limited to inside and adjacent to the existing intake buildings. Such activities are not expected to affect bald eagle foraging opportunities at the three proposed developments.

Nevertheless, prior to construction, DEP will identify any bald eagle nests in the vicinity of the construction-related activities at each development. DEP will then establish, and incorporate into the final construction plans, any necessary additional buffer zones and restrictions around nests, foraging areas, and roosting areas, as appropriate, and in consultation with the U.S. Fish and Wildlife Service ("USFWS") and the New York State Department of Environmental Conservation ("NYSDEC").

The need for and appropriateness of potential mitigation measures to protect environmental resources are discussed for each proposed development including avoidance of sensitive areas, wetlands permitting, sediment and erosion control practices, invasive species transport prevention, and bald eagle protection practices. Additional details on protection and mitigation measures will be developed prior to construction in consultation with appropriate resource agencies (*i.e.*, USFWS, NYSDEC and U.S. Army Corps of Engineers, as applicable) and other interested parties. With any necessary and appropriate protection and mitigation measures, construction-related activities at the three proposed developments are not expected to result in any material impacts to environmental resources.

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LIST OF ABBREVIATIONS

City	City of New York
DEP	New York City Department of Environmental Protection
FERC	Federal Energy Regulatory Commission
kV	kilovolt
NWI	National Wetland Inventory
NYSDEC	New York State Department of Environmental Conservation
NYSEG	New York State Electric & Gas Corporation
Project	West of Hudson Hydroelectric Project, FERC Project No. 13287
RTE	rare, threatened and endangered
sq. ft.	square feet
SWPPP	Stormwater Pollution Prevention Plan
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

1.0 INTRODUCTION

The City of New York ("City"), acting through the New York City Department of Environmental Protection ("DEP") has filed with the Federal Energy Regulatory Commission ("FERC") a Notice of Intent to develop hydroelectric generation at four sites that together comprise the West of Hudson Hydroelectric Project ("Project"), FERC Project No. 13287. The four sites are owned by the City and operated by the DEP, as part of the City's water supply system. The City seeks to develop hydroelectric facilities at those sites while simultaneously maintaining its primary water supply function and adhering to the statutory and regulatory requirements governing its water supply operations, conservation releases, directed releases, water quality standards, and other related activities.

In accordance with the Preliminary Permit issued to the City by the FERC, the DEP is evaluating the technical and economic merit and feasibility for each proposed hydroelectric development. Based on the feasibility analysis completed to date, the City has suspended the completion of environmental studies at the Schoharie development while it continues to evaluate the economic feasibility of any hydroelectric facility at that site. The City will proceed with appropriate studies in the event such an alternative is identified. Accordingly, this study is limited to the following three proposed developments:

Development	Dam	River
Cannonsville	Cannonsville Dam	West Branch Delaware River
Pepacton	Downsville Dam	East Branch Delaware River
Neversink	Neversink Dam	Neversink River

During the study plan development process, DEP proposed to conduct a study to evaluate the impact of construction-related activities at the Cannonsville, Pepacton, and Neversink Reservoirs on: (a) wildlife and botanical resources; (b) wetlands, riparian and littoral habitat; and (c) rare, threatened and endangered ("RTE") species. The U.S. Fish and Wildlife Service ("USFWS") and New York State Department of Environmental Conservation ("NYSDEC") concurred with this approach.

The geographic scope of the study includes the proposed construction areas and a buffer of up to 100 feet around each construction area. The field work for this study was completed in June 2010 and April 2011.

The goals of this study are to document the existing botanical and wildlife resources, including wetlands, riparian and littoral habitat conditions and RTE species at the three developments and to determine the potential impacts of construction-related activities thereon. Preliminary appropriate protection and mitigation measures to account for any identified potential impacts are also discussed herein. A related, separate report has been prepared which describes the proposed sediment and erosion control measures at each development; therefore, sediment and erosion control-related issues are not addressed in this report.

2.0 SUMMARY OF PROPOSED CONSTRUCTION ACTIVITIES

This section summarizes the expected construction-related activities at the three developments. The activities are subject to change as the City's proposal and licensing process advances. However, the areas to be disturbed are not likely to materially change.

Prior to performing the field investigations, base maps were prepared showing the proposed construction areas at each development. Buffer zones of up to 100 feet were established around temporary or permanent impact areas and included in the field assessment. The base maps are shown as Figure 2-1 through Figure 2-3.

Cannonsville Development

The Cannonsville development includes the construction of a separate powerhouse adjacent to the existing low-level outlet works. The turbine discharges would flow through steel draft tubes into concrete chambers beneath the powerhouse floor. Water from these chambers will be discharged into the common tailrace channel and into the West Branch of the Delaware River.

Figure 2-1 presents an overview of the proposed Cannonsville development, showing the location of the powerhouse, tailrace, the spoils area where excavated material from the powerhouse and tailrace construction will be disposed, and the temporary staging areas for equipment and material storage during construction. Located adjacent to Staging Area 3 will be a temporary sedimentation pond. Standing water in the channel and tailrace work area will be pumped into the pond to facilitate sediment deposition while allowing water to filter.

Additional work involves relocating the sewer pump station and leach field, installing a temporary cofferdam in the river, installing a temporary siphon over the spillway to maintain conservation flows during the tie-in to the existing conduit, constructing a generator lead from the powerhouse to an indoor switchgear, and installing the interconnection facilities from the substation to New York State Electric & Gas Corporation's ("NYSEG") transmission system. The route for the generator lead is proposed to run underground from the powerhouse indoor switchgear to the first pole, then overhead on new poles (replacing the existing poles) to the existing service building where a new substation will be constructed. From the new substation, the new overhead electric line and associated new poles will be constructed and tied into the existing 46 kV transmission lines.

Access to Cannonsville Dam is controlled by a DEP gate from State Route 10. All roads located inside the gate are non-public and are owned by the City. All equipment ingress and egress will occur through the DEP gate. From the DEP gate, the road is paved and extends across the access bridge located downstream of the release works building. After traversing the access bridge, there are three road branches as follows: a) a paved road extends northerly to the top of the dam, b) a paved road extends easterly to the release works building, and c) an existing dirt road runs westerly to the proposed spoils location. Staging Areas 1 and 2 as well as the spoils disposal area will be accessed from the existing dirt road. Along the existing dirt road, some minimal clearing, grubbing, and grading may be required to permit construction vehicle access to Staging Areas 1 and 2 and the spoils location.

Pepacton Development

The Pepacton development consists of installing a turbine in one of the two pipe and valve assemblies in the existing release water chamber. Figure 2-2 is the site plan showing the release water chamber, the proposed location of the associated electrical equipment (which will occupy an area approximately 9 feet wide by 12 feet long and include a small building), construction staging area, and interconnection with the NYSEG distribution system. Access to the electrical equipment will be from the existing City-

owned roadway leading to the release water building and spillway crest. The interconnection lines connecting the facility to NYSEG's distribution system will be approximately 80 feet long and will be buried, if practical.

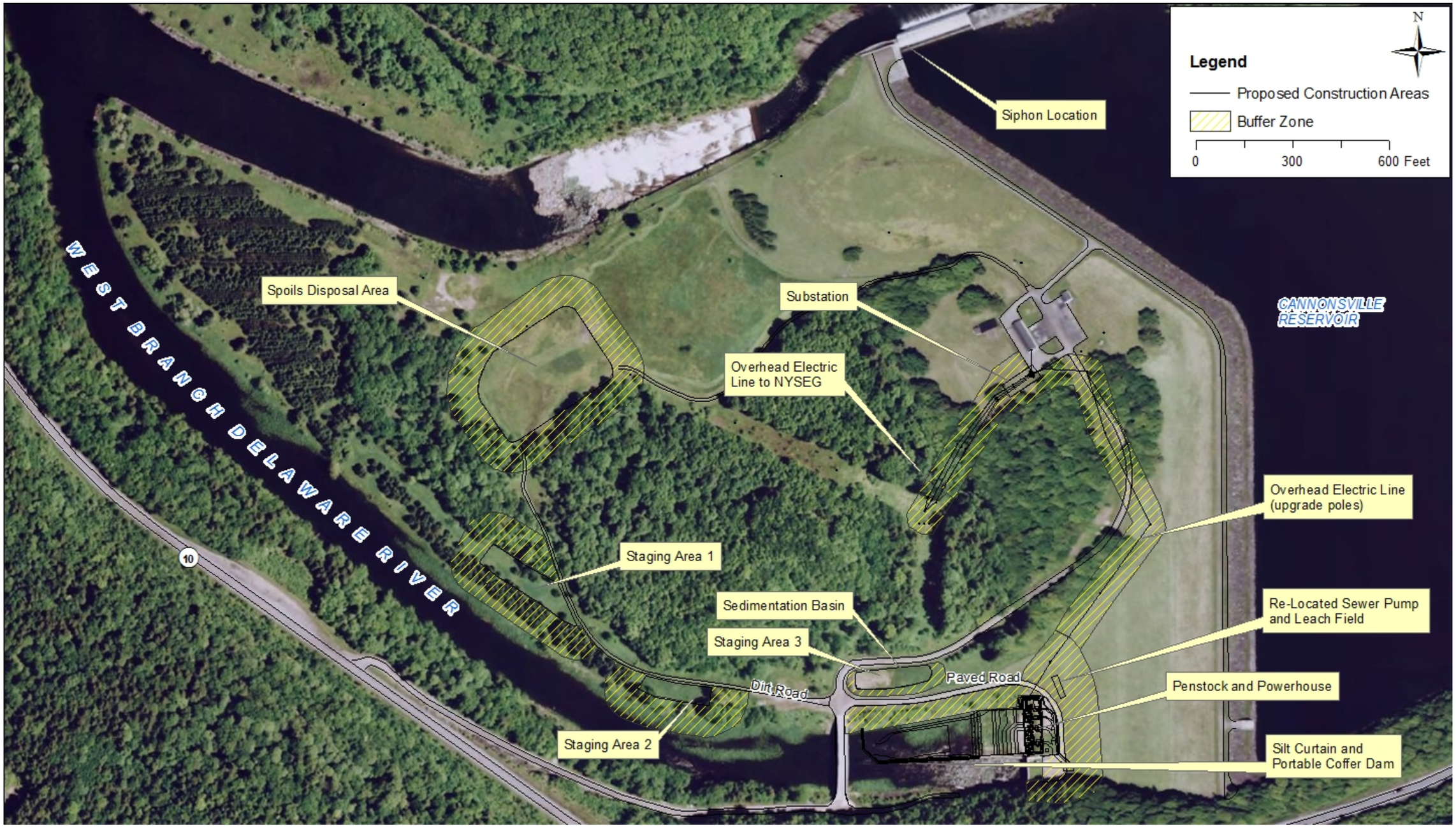
Access to the Downsville Dam is controlled by a DEP gate from State Route 30. The road located inside the gate is non-public and owned by the City. All equipment ingress and egress will occur through the DEP gate. From the DEP gate, the road is paved and extends along the top of the dam ending at the release water chamber.

Neversink Development

The Neversink development consists of installing a turbine in one of the two pipe and valve assemblies in the valve chamber of the existing intake structure. Figure 2-3 presents an overview of the proposed construction area showing the staging area, the location of the associated electrical equipment (which will occupy an area approximately 8 feet wide by 20 feet long and include a small building), and the interconnection with the NYSEG distribution system. Access to the electrical equipment will be from the existing parking area adjacent to the intake chamber. A staging area will be established south of the intake chamber, in an area which consists of a mowed lawn. Separate from the Project, the DEP is installing three three-inch conduits in an underground duct bank from State Route 55 to the intake chamber. One of those conduits will be used for the interconnection of the facility with NYSEG's distribution system.

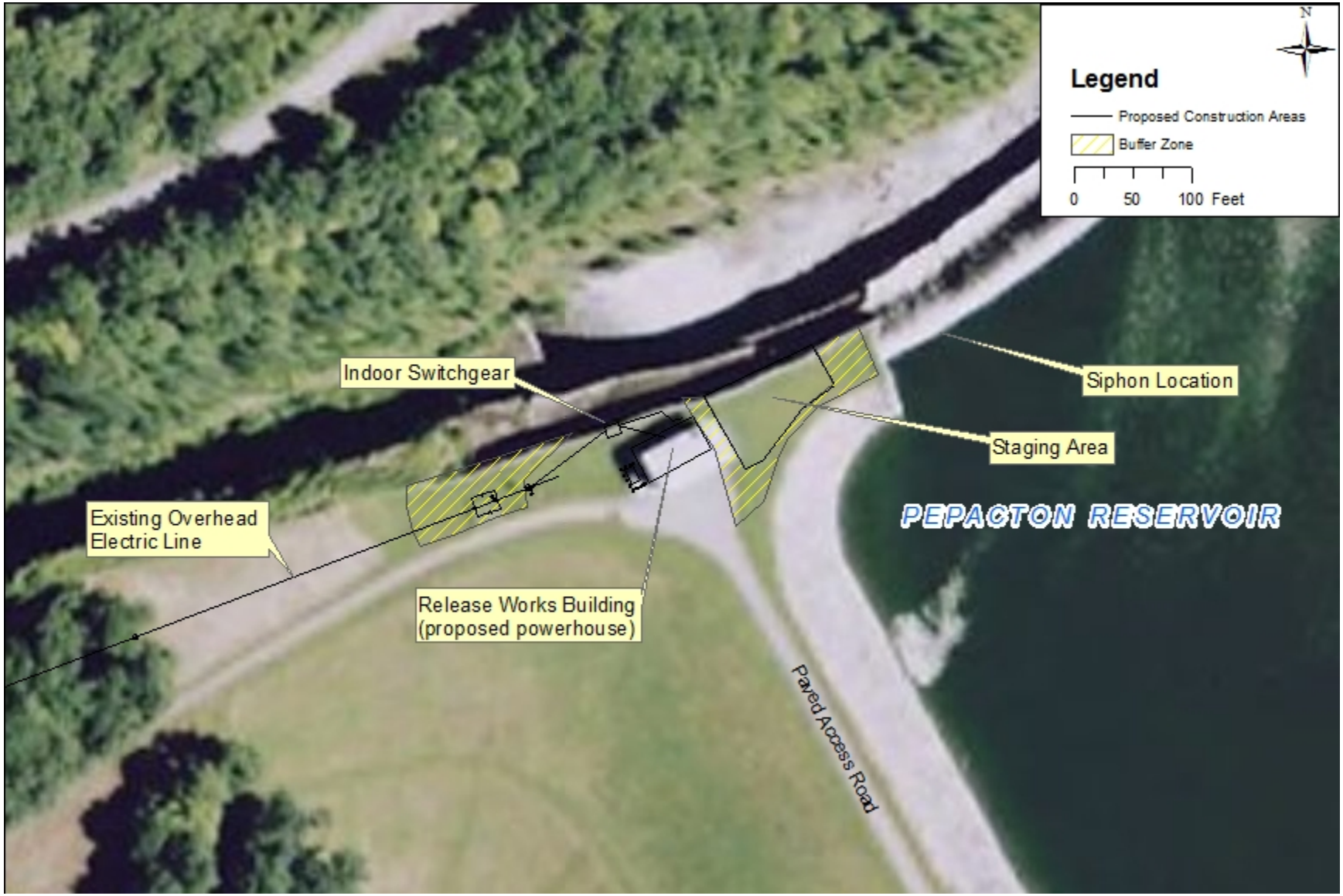
Access to the Neversink Dam is controlled by a DEP gate from State Route 55 (Plate 57). The road located inside the gate is non-public and owned by the City. All equipment ingress and egress will occur through the DEP gate. From the DEP gate, the road is paved and extends directly to the intake structure.

Figure 2-1: Cannonsville Development Study Area: Proposed Construction Areas and Associated Buffer Zones.



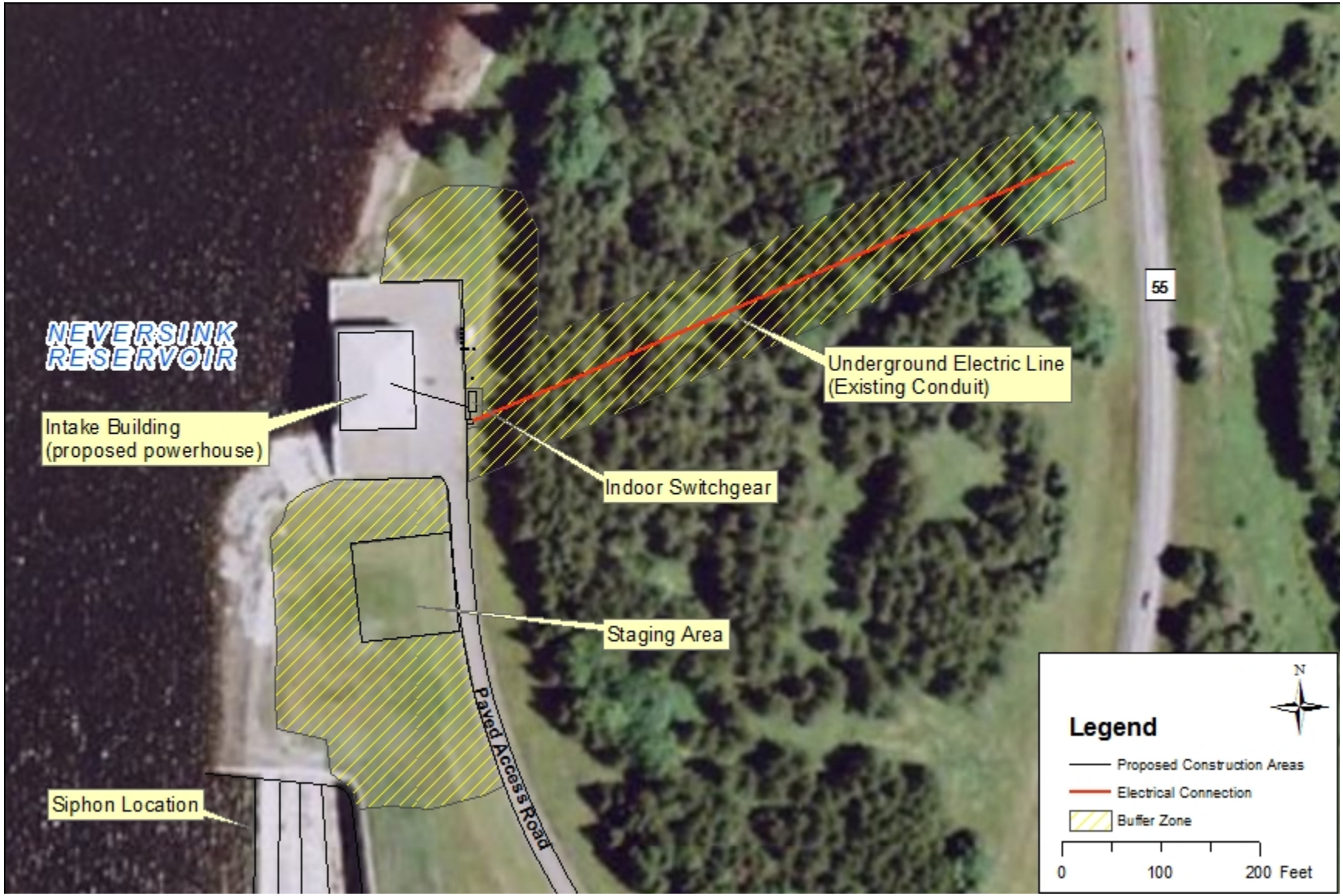
Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

Figure 2-2: Pepacton Development Study Area: Proposed Construction Areas and Associated Buffer Zones.



Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

Figure 2-3: Neversink Development Study Area: Proposed Construction Areas and Associated Buffer Zones.



Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

3.0 STUDY METHODS

The methods employed for the study included compiling existing information, developing maps of areas to be surveyed, conducting field surveys, and developing conclusions related to the potential impacts of construction activities on environmental resources. Recommended mitigation measures based on any potential identified impacts are also discussed in this report. It is important to note that the erosion and sediment control measures proposed for protecting environmental resources from construction-related activities associated with the Project are presented in a separate report (DEP, 2011).

3.1 Review Existing Data

The proposed construction and buffer zone areas, along with ingress and egress routes used for the construction activities, were loaded into GIS computers with aerial imagery for use in the field surveys. The buffer zones of up to 100 feet were established around temporary or permanent impact areas and included in the field assessment. Ingress and egress routes used for the construction activities are shown on each base map as paved or dirt roads.

Existing information relative to wildlife and botanical resources, including RTE species, wetland, riparian and littoral habitats was presented in the Pre-Application Document and will be supplemented based on the results of this study for the purposes of any license application(s) related to the Project.

Wetlands and Deepwater Habitats

Geographic Information System data showing National Wetland Inventory ("NWI") and NYSDEC wetlands for each development were reviewed prior to the field survey. The NWI wetland and deepwater habitat types were confirmed during the field assessment. Additional wetland areas found within or adjacent to the proposed construction areas were delineated according to the NYSDEC Freshwater Wetlands Delineation Manual (1995) and the U.S. Army Corps of Engineers ("USACE") Wetlands Delineation Manual (1987). The technical guideline for wetlands requires that a positive wetland indicator be present for each parameter (vegetation, soils, and hydrology), except in limited instances identified in the USACE manual. Wetlands are classified in this report using the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin *et al.*, 1979). The Cowardin classification system was developed as a basis for identifying, classifying, and mapping wetlands, other special aquatic sites, and deepwater aquatic habitats.

RTE Species

During the study plan development process, existing data relative to RTE species was gathered. The New York Natural Heritage Program was consulted to verify and update RTE information for the proposed Project area. The RTE species having the potential of being found at the three developments based on their respective geographic range and habitat preferences are described below.

Northern wild monkshood (federally-listed Threatened plant species)

The Northern wild monkshood is noted for its very distinctive, blue hood-shaped flowers which bloom between June and September. The plant is typically found on shaded to partially shaded cliffs, algific talus slopes, or on cool, streamside sites. These areas have cool soil conditions, cold air drainage, or cold groundwater flowage. On algific talus slopes, these conditions are caused by the outflow of cool air and water from ice contained in underground fissures. These fissures are connected to sinkholes and are a conduit for the air flows.

Bicknell's thrush (state-listed Special Concern bird species).

The Bicknell's thrush is an elusive neotropical migrant that breeds in the high elevation forests of northeastern North America and winters in the Caribbean. It is a habitat specialist restricted to montane forests of balsam fir. In New York, the Bicknell's thrush breeds at high elevations in the Adirondack and Catskill Mountains, which represent the southern-most boundary of its breeding range. Because of its preference for stands of dense fir trees on ridgelines, the Bicknell's thrush is often associated with recently disturbed areas characterized by standing dead conifers and dense regrowth of balsam fir.

Timber rattlesnake (state-listed Threatened reptile species)

Populations of the timber rattlesnake were once found on Long Island and in most mountainous and hilly areas of New York State, except in the higher elevations of the Adirondacks, Catskills, and Tug Hill region. They are now found in isolated populations in southeastern New York, the Southern Tier, and in the peripheral eastern Adirondacks. Timber rattlesnakes are generally found in deciduous forests in rugged terrain in these areas. In the summer, pregnant females seem to prefer open, rocky ledges where temperatures are higher, while the males and non-pregnant females seem to prefer cooler, thicker woods where the forest canopy is more closed.

Jefferson salamander (state-listed Special Concern amphibian species)

The geographic range of the Jefferson salamander includes southern New York, northern New Jersey, and most of Pennsylvania to Ohio and southern Indiana. Jefferson salamanders have a strong affinity for upland forests and prefer to reside most of the year in well drained deciduous or mixed forest, within 250 to 1600 meters of a small vernal pool or pond, commonly surrounded by alder, red maple, buttonbush, and dogwood. They hide beneath leaf litter, loose soil, and stones, or in rotting logs, rodent burrows, or subterranean burrows which they excavate. Vernal pools, or temporary ponds, are necessary for reproduction and need to be full of dead and decaying leaves for cover and overhanging bushes or grass for egg deposition.

Jefferson salamanders hibernate underground in the winter months, usually near breeding sites. In March and April (sometimes as early as February), they begin to migrate to breeding ponds which is thought to be triggered by the first early warm spring rains or other conditions of high humidity and above-freezing temperatures. Adult Jefferson salamanders are rarely seen outside of the breeding season, but are presumed to eat earthworms and other invertebrates underground. The ideal time of year to locate the Jefferson salamander is during the breeding months of March and April.

Longtail salamander (state-listed Special Concern amphibian species)

The range of the longtail salamander extends from southern New York and northern New Jersey southwest through southern Illinois, southeastern Missouri, as well as western Tennessee. Longtail salamanders can be found near streams or around caves, where they seek shelter under rocks, rotting logs, or in shale banks. Adults are found in moist or wet terrestrial situations, usually along the borders of streams, seeps, or wetlands. Breeding presumably occurs in late autumn and early winter. Eggs are laid in the winter, but are rarely found, probably because they are attached to rocks in dark, subsurface streams or seepages. The aquatic larvae hatch in 4-12 weeks and probably complete metamorphosis in the same year, although some may remain as larvae until the following spring or summer.

Bald eagle (state-listed Threatened bird species)

Historically, bald eagles nested in forests along the shorelines of oceans, lakes or rivers throughout most of North America, often moving south in winter to areas where water remained open. Wintering grounds are from southern Canada south, along major river systems, in intermountain regions, and in the Great Plains. In the northern United States, bald eagles will typically begin courting and nest building in the winter. The typical breeding season for the bald eagles in the vicinity of the Project begins with nest

construction in January and ends with the last chick fledged in early summer. The locations of existing nesting areas of bald eagles in the vicinity of the Project were identified from DEP records prior to conducting any field work. As shown in Table 3.2-1, DEP located 12 bald eagle nests in the vicinity of the Project in 2009.

Table 3.2-1: Bald Eagle Nest Locations in the Project Vicinity (2009).

Nest ID	Reservoir	County	Town	Distance To Dam (Miles)
NY 13	Cannonsville	Delaware	Deposit	1.5
NY 34	Cannonsville	Delaware	Tompkins	5.8
NY 88	Cannonsville	Delaware	Deposit	1
NY 89	Cannonsville	Delaware	Tompkins	8.7
NY 89	Cannonsville	Delaware	Tompkins	9
NY 93	Cannonsville	Delaware	Tompkins	1
NY 12	Pepacton	Delaware	Colchester	1.15
NY 36	Pepacton	Delaware	Middletown	13.5
NY 72	Pepacton	Delaware	Andes	11.6
NY 75	Pepacton	Delaware	Tompkins	6.15
NY 90	Pepacton	Delaware	Colchester	3.7
NY 15	Neversink	Sullivan	Neversink	3.7

3.2 Field Surveys

Field work was conducted from June 28-30, 2010, and April 25-26, 2011 at the three proposed developments. The field surveys consisted of observing the areas that will be temporarily or permanently disturbed as part of the Project, as well as the surrounding buffer zones. A team of two field biologists traversed the areas designated on the site maps (Figures 2-1 through 2-3) to document the botanical resources and wildlife resources.

Botanical and wildlife resources are described in this report as ecological community types in accordance with the classification system contained in the NYSDEC publication *Ecological Communities of New York State* (Edinger *et al.*, 2002). An ecological community is a variable assemblage of interacting plant and animal populations that share a common environment. Definitions of the systems and subsystems used in Edinger *et al.*, 2002 are adapted from the U.S. Fish and Wildlife Service wetland classification (Cowardin *et al.*, 1979), and U.S. Department of Agriculture ecological land use categories. Systems include riverine (rivers and streams), lacustrine (lakes and ponds), palustrine (wetlands), and terrestrial (uplands). This classification also includes a comprehensive treatment of cultural communities (human modified) along with the natural types. Notes were added to the classification of community types at the study area for each respective proposed development to provide additional, relevant details and/or describe unique occurrences.

Habitat and cover type documentation was conducted using a pentop field computer with pre-loaded aerial images and ArcGIS software. As mentioned, wetland areas found within or adjacent to the proposed construction areas were delineated according to the NYSDEC and USACE methods. Wetland boundaries were recorded using a Trimble ProXH handheld Global Positioning System unit, which generally provides sub-meter accuracy.

During the field surveys all observed animals, or signs of their presence, were documented within the proposed construction areas and buffer zones associated with each development. Photographs of each

vegetative cover type in the respective construction areas and buffer zones were collected and included as Appendix A. Note that the photographs include parcel numbers such as C-1 (Cannonsville-1), C-2, P-1 (Pepacton-1), N-1 (Neversink-1), etc.

While collecting information on the botanical and wildlife resources in the Project area, special attention was given to the habitat conditions preferred by the RTE species. Specifically, the field surveys were performed to check for the presence of RTE species and associated habitat (described above) that could be impacted by construction activities, including:

- Northern wild monkshood and associated habitat;
- recording any visual/auditory evidence for the presence of Bicknell's thrush and identifying any balsam fir stands;
- bald eagle including nesting, roosting, and feeding areas;
- timber rattlesnake presence and associated habitat;
- the presence of Jefferson's and longtail salamanders and associated habitat.

The 2011 field survey was conducted in April specifically for the purposes of identifying and documenting any vernal pool habitat in the study area that could potentially be utilized by Jefferson's and longtail salamanders.

The data collected during the field surveys were evaluated to determine if the proposed construction activities could result in (a) potential direct impacts to plant or animal species or their habitats, (b) potential fragmentation of continuous habitats used by any such species, (c) potential impacts to passage corridors used by any species, and (d) potential spread of invasive plant species.

4.0 RESULTS

The results of the field survey are presented below for each proposed development. Botanical resources are described as vegetative cover types with additional details provided with regard to wetland, riparian, and littoral habitats and invasive plant species found. Wildlife resources are generally described based on the cover types found and observations of wildlife (including RTE) species in the study area. Photographs collected during the survey are presented in Appendix A. A list of plant species observed at the three proposed developments is contained in Appendix B, and a list of animal species observed at the three proposed developments is contained in Appendix C.

4.1 Cannonsville Development

Field surveys at the Cannonsville development were conducted on June 29-30, 2010, and April 26, 2011. Weather during the June 2010 survey was hot and humid, Cannonsville Reservoir was not spilling and the downstream release was 423 cfs. The night prior to the April 2011 field survey brought heavy thunderstorms to the region; on the date of survey, Cannonsville Reservoir was spilling 958 cfs (Plate 47) and the downstream release was approximately 1,500 cfs (Plate 38).

Botanical Resources

Vegetative cover types in the areas proposed for disturbance (*i.e.*, construction-related activities) and the buffer zones consist of open fields, mixed forest and, in the area of the tailrace excavation, emergent and riverine wetlands and deepwater habitats. Table 4.1-1 provides a description of construction and buffer areas at Cannonsville development and Figure 4.1-1 presents this information on a map. Table 4.1-2 lists the ecological community types observed during the field assessment at the proposed Cannonsville development. Note that wetland, riparian and littoral resources are described in more detail below.

Impacts to upland botanical resources will be limited to temporary disturbances to existing mowed fields which will serve as the construction staging areas. No impacts to upland botanical resources within the buffer locations are expected. The locations of the generator lead, substation, and interconnection facilities are not expected to cause or lead to any adverse environmental impacts. However, selective trimming and removal of adjacent trees will occur, as necessary. Clearing this corridor will result in minor fragmentation of the upland forest, but this area is isolated from surrounding continuous forest blocks due to the river channels and dam. Therefore, the fragmentation is not expected to cause impacts to wildlife passage routes.

Invasive Plant Species

The invasive plants species found at the Cannonsville development are listed below and the locations are shown on Figure 4.1-2:

- Reed canarygrass
- Black locust
- Common mullein
- Multiflora rose
- Japanese knotweed
- Common mugwort
- Japanese barberry
- Honeysuckle
- Hairy willow herb
- Autumn olive

Deepwater, Wetlands, Riparian and Littoral Habitats

The NWI mapped deepwater habitats at the Cannonsville development include the Cannonsville Reservoir and the West Branch Delaware River. The Cannonsville Reservoir is classified as *lacustrine, limnetic, unconsolidated bottom, permanently flooded and impounded* (L1UBHh). Downstream of Cannonsville Reservoir, the north channel immediately below the spillway of the West Branch Delaware River is classified as *riverine, upper perennial, unconsolidated bottom, permanently flooded* (R3RBH). Starting approximately 600 meters below the spillway, the north channel is classified as *riverine, lower perennial, unconsolidated bottom, permanently flooded* (R2UBH). The south channel (below the release works) of the West Branch Delaware River is *riverine, lower perennial, unconsolidated bottom, permanently flooded* (R2UBH). There are no NYSDEC regulated wetlands present in or adjacent to the proposed construction areas.

During the field study, three wetlands were identified and delineated: two were found in buffer zone adjacent to construction staging areas and one wetland complex was located in the area proposed for tailrace excavation, as shown on Figure 4.1-1. A small wetland (parcel no. C-4a) of less than 0.1 acre is located in the buffer areanorth of Staging Area 1 in a depressional, spring-fed location. Although surrounded by upland forest, this wetland is classified as *palustrine, persistent emergent, saturated wetland* (PEM1B) due to the emergent vegetation and saturated soil conditions found there. Dominant wetland plants found included jewelweed, sensitive fern, marsh bedstraw, horsetail and foxtail sedge.

The floodplain (parcel no. C-10) in the buffer area adjacent to Staging Area 2 is classified as *palustrine, persistent emergent, seasonally flooded wetland* (PEM1E). This wetland is 0.6 acres and is classified as a palustrine system due to the presence of persistent emergent plants, primarily reed canarygrass, and is a seasonally flooded riparian system. Other dominant plants found in this location included jewelweed, sensitive fern, and spotted joe pye weed.

The area proposed for tailrace excavation consists of two wetland types. The open water channel (C-18) is classified as *riverine, lower perennial, unconsolidated bottom, permanently flooded,* as described above, because there were no submerged aquatic vegetation species found in this area and the bottom substrate was a mix of gravel and cobble overlain by silt. Adjacent to the channel, in the area proposed for excavation, is a wetland of approximately 1.05 acres classified as *palustrine, persistent emergent, seasonally flooded* (PEM1E). This wetland is classified as a palustrine system due to the presence of persistent emergent plants, such as reed canarygrass and yellow rocket, and is a seasonally flooded riparian area. Additional wetland plants found in this location include jewelweed and shrub willows.

To maintain downstream river flows during construction, a temporary siphon is proposed to convey water over the existing spillway and into the spillway channel. The spillway channel is excavated in bedrock and is typically dry except when the dam is spilling; therefore, this channel does not support vegetation and aquatic life. The temporary siphon will extent into the littoral zone of Cannonsville Reservoir, however any short term impacts to this area, such as avoidance of or entrainment through the temporary siphon intake by aquatic organisms, are unavoidable due to the need to maintain flows downstream.

The riparian and littoral areas of the tailrace channel were observed during the April site visit (Figure 4.1-4). Starting at the release works and looking downstream, the river right riparian area downstream to the bridge (C-13) is a riprapped shore with moderately sloped 10 feet high banks dominated by shrub cover. Downstream of the bridge, the riparian area remains moderately sloped and high, but is naturally vegetated and contains an expansive sidebar containing herbaceous vegetation (dominated by reed canarygrass). The river right shoreline vegetation consists of a mix of plantation trees (Norway spruce), white pine, black locus, sycamore, multiflora rose and invasive Japanese knotweed. Staying on river right from a point approximately 2,500 feet from the release works downstream to the confluence with the spillway channel, the bank slope flattens out and the riparian vegetation transitions to herbaceous cover. The river left riparian area consists of moderately steep riprapped bank with shrubby vegetation from the

release works to a point just downstream of the bridge. Beyond this point, the bank becomes extremely steep and forested. The spillway channel riparian zone of both riversides consists of riprap banks.

The tailrace channel is a long deep run containing extensive sidebars on river right, and one riffle area approximately 1,000 feet downstream of the release works. The littoral area was composed of very fine silt and clay lacking any submerged vegetation. The sidebars were submerged during the April visit due to relatively high flows occurring at this time.

The current release works will be closed for a period when the construction phase involves integrating the turbines with the discharge through the dam. This will result in a change to the water depths and velocities of the tailrace channel. The immediate tailrace area will be dewatered for excavation. Downstream areas will remain wetted due to the backwater received from the spillway channel. Based on hydraulic modeling of the tailrace channel, assuming a flow of 200 cfs, when water is provided to the spillway channel via the temporary siphon during construction and the tailrace channel flow is shut-off, the water depths in the tailrace channel will be slightly lower (one foot or less) for approximately 1,600 feet downstream of the release works (see Figure 4.1-4). Downstream of this point, water depths will be at or above levels related to the same flow provided through the release works. Normal velocities in tailrace channel vary according to the flow releases, and water velocity is expected to be zero during the time the release works are closed. Because this area will remain wetted during construction, impacts to the riparian and littoral areas, as well as the plant and animal species that use these areas as habitat, are not anticipated.

Wildlife Species and Habitat Observations

Wildlife observations in the proposed construction areas and buffer zones included: American crow, red-winged blackbird, pileated woodpecker, Eastern cottontail, white-tailed deer, common merganser, Northern flicker, Canada goose, American robin, and black-capped chickadee. Hermit thrush was also recognized as being present based on sound/auditory observation.

Three vernal pools were identified during the April 2011 field work. Vernal Pool 1 is located in a mixed upland forest with little ground cover (parcel C-27) adjacent to a mowed area near the paved road (Figure 4.1-1). This small depression was approximately 200 sq. ft. and part of a man- made drainage ditch and contained cinder blocks and old road signs at the outlet (Plate 31). No signs of biological life were observed in Vernal Pool 1.

Vernal Pool 2 was located outside of the buffer zone adjacent to the proposed overhead electric line (C-28). This pool was approximately 600 sq. ft. and supported wildlife, as a Northern red-backed salamander was observed. Because Vernal Pool 2 is located outside of any of the proposed construction areas and/or buffer zones, no material impacts to Vernal Pool 2 are anticipated to occur as a result of construction-related activities.

Vernal Pool 3 is approximately 7,500 sq. ft. and a small portion thereof is located with the outer limits of the buffer zone associated with proposed Staging Area 1 (parcel C-5). This vernal pool is fed by seasonal groundwater seepage which is captured in a long, ditch-like depression adjacent to the mowed field, and it extends well beyond the study area (see Figure 4.1-1). Approximately 20 amphibian egg masses were found in this pool (Plate 33).

Based on the site visits, many of the areas proposed for construction at the Cannonsville development are currently disturbed (mowed). The upland forest areas in the buffer zones around the construction areas provide very good wildlife habitat as do the vernal pools found at the site. However, the vernal pools found in the buffer zones at the Project will be avoided and left undisturbed during construction activities. The boundaries of each will remain demarcated and instructions will be provided to the construction personnel to avoid these areas. Given that the areas will not be disturbed during construction, their

relative character is not expected to be materially impacted by construction-related activities at the Cannonsville development.

RTE Species and Habitat Observations

Adult and juvenile bald eagles were observed flying in the vicinity of the Cannonsville Dam during the field assessment on June 29-30, 2010. No nesting, roosting or feeding activities were observed near the proposed construction areas and/or buffer zones. Bald eagles were also observed during the April 26, 2011 field work. Juvenile and adult bald eagles were observed perched downstream of the tailrace channel, two adult eagles were perched above the spillway, and a few others were observed soaring around the reservoir. However no nesting or feeding activities were observed near the proposed construction areas and/or buffer zones.

Vernal Pool 3 described above could potentially serve as suitable habitat for the Jefferson's and longtail salamanders. As mentioned, this vernal pool, as well as the other two vernal pools, were found in the buffer zone at the Project and will be demarcated and avoided during construction activities. Therefore, no impacts to this habitat are anticipated.

No other RTE species or habitats were observed in the proposed construction areas and/or buffer zones at the Cannonsville development.

Table 4.1-1: Description of Proposed Construction and Buffer Areas at Cannonsville Development.

Parcel No.	Description	Notes
C-1	Spoils disposal area	Mowed field
C-1a	Spoils disposal area buffer zone	Primarily mowed turf, with a few scattered trees; Stone-lined drainage ditch present
C-2	Spoils disposal area buffer zone	Mixed upland forest with areas of brush understory; Contains existing unpaved access road
C-3	Spoils disposal area buffer zone	Primarily mowed turf, with areas of shrub and scattered ornamental trees
C-4	Staging Area 1 buffer zone	Deciduous forest
C-4a	Staging Area 1 buffer zone	Groundwater-fed wetland
C-5	Staging Area 1	Open field containing a few coniferous trees
C-5a	Staging Area 1 buffer zone	Open field, adjacent to and inclusive of a portion of Vernal Pool 3
C-6	Staging Area 1 buffer zone	Mature Norway spruce plantation; very little understory
C-7	Staging Area 1 buffer zone	Riverbank. Vegetated riparian zone, primarily herbaceous plants
C-8	Staging Area 2	Mowed field, bordered by drainage swales on east and west
C-9	Staging Area 2 buffer zone	Mature Norway spruce plantation; very little understory
C-10	Staging Area 2 buffer zone	Floodplain wetland; dominant plant species is reed canarygrass
C-11	Staging Area 2 buffer zone	Shrubby upland, bordered by drainage swale
C-12	Staging Area 2 buffer zone	Riverbank. Mix of tree, shrub and herbaceous riparian plants. Contains drainage swale
C-13	Shoreline buffer zone	Shrubby shoreline dominated by black locust seedlings (invasive species)
C-14	Tailrace excavation area	Emergent wetland, dominated by reed canarygrass
C-15	Access road and release works	Paved area
C-16	Buffer zone between access road and riverbank	Mowed turf
C-17	Septic tank & underground electric line	Mowed turf
C-18	Open channel of Delaware River	Free-flowing, shallow, no submerged vegetation
C-19	Buffer zone adjacent to penstock/powerhouse	Mixed mature forest, extremely steep

Table 4.1-1 (Cont.): Description of Proposed Construction and Buffer Areas at Cannonsville Development.

Parcel No.	Description	Notes
C-23	Staging Area 3	Mowed turf
C-24	Overhead electric line buffer zone	Thin strip of mixed upland forest with a small seep along edge toward a man-made drainage ditch
C-25	Existing overhead electric line	Mowed turf with drainage ditch
C-26	Overhead electric line buffer zone	Mixed upland forest with minimal ground cover
C-27	Overhead electric line buffer zone	Mixed upland forest containing Vernal Pool 1
C-28	Proposed Overhead electric line from substation to NYSEG poles	Mixed upland forest
C-29	Proposed substation location	Mowed turf

Table 4.1-2: Ecological Communities at the Cannonsville Study Area.

Parcel	System	Subsystem	Ecological Community
C-1	Terrestrial	Terrestrial Cultural	Mowed lawn
C-1a	Terrestrial	Terrestrial Cultural	Mowed lawn
C-2	Terrestrial	Forested Upland	Rich mesophytic forest
C-3	Terrestrial	Forested Upland	Rich mesophytic forest
C-4	Terrestrial	Forested Upland	Rich mesophytic forest
C-4a	Palustrine *	Forested Mineral Soil Wetlands	Persistent emergent, saturated wetland
C-5/5a	Terrestrial	Terrestrial Cultural	Mowed lawn
C-6	Terrestrial	Terrestrial Cultural	Spruce/fir plantation
C-7	Terrestrial	Open Upland	Herbaceous riparian riverbank**
C-8	Terrestrial	Terrestrial Cultural	Mowed lawn
C-9	Terrestrial	Terrestrial Cultural	Spruce/fir plantation
C-10	Palustrine *	Open Mineral Soil Wetlands	Persistent emergent, seasonally flooded wetland
C-11	Terrestrial	Open Upland	Successional shrubland
C-12	Terrestrial	Open Upland	Shrub/tree riparian riverbank**
C-13	Terrestrial	Terrestrial Cultural	Riprap artificial shore**
C-14	Palustrine*	Open Mineral Soil Wetlands	Persistent emergent, seasonally flooded wetland
C-15	Terrestrial	Terrestrial Cultural	Paved road/path
C-16	Terrestrial	Terrestrial Cultural	Riprap artificial shore**
C-17	Terrestrial	Terrestrial Cultural	Mowed lawn
C-18	Riverine*	Natural Stream	Lower perennial, unconsolidated bottom, permanently flooded
C-19	Terrestrial	Forested Upland	Hemlock-northern hardwood forest
C-23	Terrestrial	Terrestrial Cultural	Mowed lawn
C-24	Terrestrial	Forested Upland	Hemlock-northern hardwood forest
C-25	Terrestrial	Terrestrial Cultural	Mowed lawn
C-26	Terrestrial	Forested Upland	Hemlock-northern hardwood forest
C-27	Terrestrial	Forested Upland	Hemlock-northern hardwood forest
C-28	Terrestrial	Forested Upland	Hemlock-northern hardwood forest
C-29	Terrestrial	Terrestrial Cultural	Mowed lawn

Notes: * Indicates wetland community type classified using Cowardin *et al.*, 1979. ** Indicates riparian community type not found in Edinger *et al.*, 2002.

4.2 Pepacton Development

Field surveys at the Pepacton development were conducted on June 28, 2010 and April 25, 2011. Weather during the June 2010 survey was hot and humid and Pepacton Reservoir was not spilling. Weather during the April 2011 was warm with occasional rain and fog and Pepacton Reservoir was spilling at a rate of 1,064 cfs.

Botanical Resources

Vegetative cover types in the areas proposed for disturbance and the buffer zones at the Pepacton development consist exclusively of mowed turf and paved roads. A description of these cover types and the associated ecological communities (Edinger *et al*., 2002) at the Pepacton development are listed in Table 4.2-1 and shown in Figure 4.2-1. Impacts to upland botanical resources will be limited to disturbances to existing mowed fields which will serve as the construction staging area and switchgear location.

Table 4.2-1: Cover Types and Ecological Communities at the Pepacton Study Area.

Parcel Number	Description	System	Subsystem	Community
P-1	Staging Area	Terrestrial	Terrestrial Cultural	Mowed lawn
P-2	Switchgear and interconnection facilities	Terrestrial	Terrestrial Cultural	Mowed lawn

Invasive Plant Species

No invasive plants species were found at the Pepacton development study area.

Deepwater, Wetlands, Riparian and Littoral Habitats

The NWI mapped deepwater habitats at the Pepacton development include the Pepacton Reservoir and the East Branch Delaware River. The Pepacton Reservoir is classified as *lacustrine, limnetic, unconsolidated bottom, permanently flooded and impounded* (L1UBHh). Downstream of the reservoir, the river channel is classified as *riverine, lower perennial, unconsolidated bottom, permanently flooded* (R2UBH). There were no other wetlands found in the proposed construction areas or buffer zones at the Pepacton development.

To maintain downstream river flows during construction, a temporary siphon is proposed to convey water over the existing spillway and into the spillway channel. The spillway channel is excavated in bedrock and is typically dry except when the dam is spilling; therefore, this channel does not support vegetation and aquatic life (Plates 51 and 54). The temporary siphon will extend into the littoral zone of Pepacton Reservoir, however any short term impacts to this area, such as avoidance of or entrainment through the temporary siphon intake by aquatic organisms, are unavoidable due to the need to maintain flows downstream. No other impacts to wetland, riparian or littoral habitats are anticipated during construction.

Wildlife Species and Habitat Observations

Cliff swallows nest in the corners of the window openings on the existing intake building release water chamber. These birds were not disturbed by presence of personnel during the field surveys and , it is not anticipated that construction activities at the Project would cause any long-term impacts. Other incidental wildlife observations included: white-tailed deer, common mergansers, European starlings, American robin, great blue heron, wild turkey, ring-billed gull, American crow, and double-crested cormorants.

Based on the site visits, all of the areas proposed for construction at the Pepacton development are currently disturbed with limited wildlife habitat.

RTE Species and Habitat Observations

Bald eagles were observed flying in the vicinity of the Downsville Dam during the field assessment. An adult eagle and a juvenile were spotted together flying over the dam. However, no nesting, roosting or feeding activities were observed near the proposed construction areas and/or buffer zones.

No other RTE species or associated habitats were observed in the proposed construction areas and/or buffer zones at the Pepacton development.

4.3 Neversink Development

Field surveys at the Neversink development were conducted on June 28, 2010 and April 25, 2011. Weather during the June 2010 survey was hot and humid and Neversink Reservoir was not spilling. Weather during the April 2011 survey was warm with occasional rain and fog and Neversink Reservoir was not spilling.

Botanical Resources

Vegetative cover types in the areas proposed for disturbance and the buffer zones at the Neversink development consist of mowed turf, paved roads, and a forest plantation. A description of these cover types and the associated ecological communities (Edinger *et al*., 2002) are listed in Table 4.3-1 and shown in Figure 4.3-1. Potential construction-related impacts at this development are expected to be minimal. With the exception of the proposed underground electrical interconnection through the forest plantation and field, the construction work will involve the use only of a mowed area as a staging location. The majority of the construction work will occur within or adjacent to the existing intake structure.

Table 4.3-1: Cover Types and Ecological Communities at the Neversink Study Area.

Parcel Number	Description	System	Subsystem	Community
N-1	Staging Area	Terrestrial	Terrestrial Cultural	Mowed lawn
N-2	Access road and parking lot	Terrestrial	Terrestrial Cultural	Paved road/path
N-3	Buffer zone around powerhouse construction area	Terrestrial	Terrestrial Cultural	Mowed lawn
N-4	Electrical interconnection corridor	Terrestrial	Terrestrial Cultural	Pine plantation
N-5	Electrical interconnection corridor	Terrestrial	Open Uplands	Successional old field
N-6	Existing overhead electrical line	Terrestrial	Terrestrial Cultural	Mowed roadside/pathway

During the April 25, 2011 site survey it was observed that some of the forest plantation trees were cleared to install an underground electric line connection between the intake building and the existing electrical pole on Route 55 as part of a separate, unrelated upgrade project (Plates 69-73) at Neversink. The clearing-activities associated with this unrelated project at Neversink, ultimately, reduce the potential for impacts associated with the Neversink development because the proposed underground electric line associated with the development will utilize this same corridor, and, thus, not require additional clearing of forest plantation trees within such corridor.

Invasive Species

The only invasive plant species found at the Neversink development was multiflora rose, as shown on Figure 4.3-2.

Deepwater, Wetlands, Riparian and Littoral Habitats

The NWI mapped deepwater habitats at the Neversink development include the Neversink Reservoir and the Neversink River. Based upon field observations, the Neversink Reservoir is classified as *lacustrine, limnetic, unconsolidated bottom, permanently flooded* (L1UBHh). The Neversink spillway and stilling basin below are classified as *riverine, lower perennial, unconsolidated bottom, permanently flooded, excavated* (R2UBHx). There were no other wetlands found in the proposed construction areas or buffer zones at the Neversink development.

To maintain downstream river flows during construction, a temporary siphon is proposed to convey water over the existing spillway and into the spillway channel. The spillway channel is excavated in bedrock and is typically dry except when the dam is spilling; therefore, this channel does not support vegetation and aquatic life (see Plates 56 and 65). The temporary siphon will extend into the littoral zone of Neversink Reservoir, however, as with the other two sites any short term impacts related to this area, such as avoidance of or entrainment through the temporary siphon intake by aquatic organisms, are unavoidable due to the need to maintain flows downstream. No other impacts to wetland, riparian or littoral habitats are anticipated during construction.

Wildlife Species and Habitat Observations

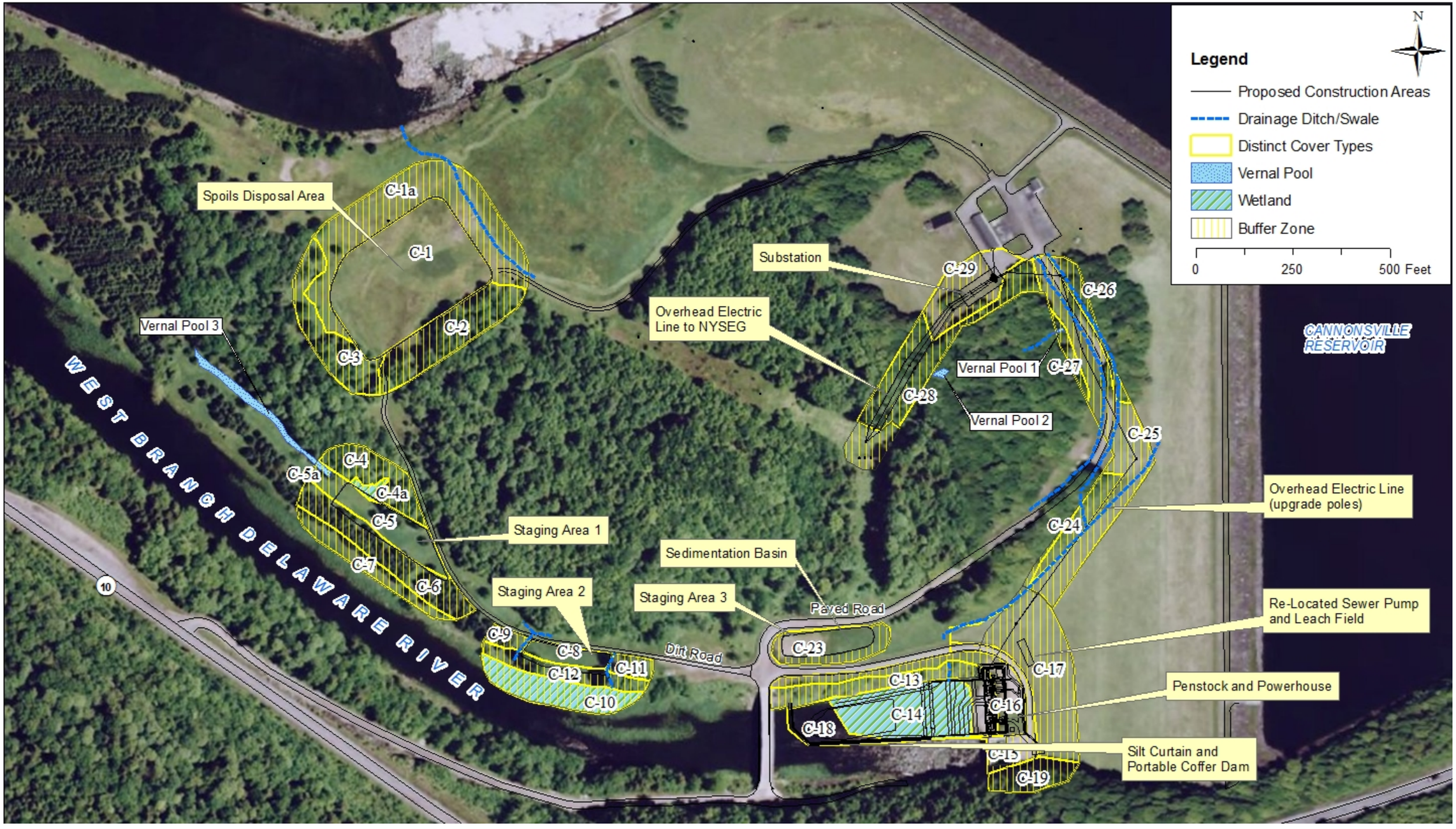
As at Pepacton, cliff swallows nest in the corners of the windows of the intake structure. These birds were not disturbed by presence of personnel during field studies and, it is not anticipated that construction activities related to the Neversink development would cause any long-term impacts. Other wildlife observations included: American crow, Canada goose, and white-tailed deer (scat). Based on the site visits, most of the areas proposed for construction at the Neversink development are currently disturbed. As noted above, the corridor for the proposed underground electrical line has already been cleared as part of a separate, unrelated project at Neversink to install underground electrical connections from an existing NYSEG pole on Route 55 to the existing release works structure. Accordingly, construction of the proposed underground line associated with the proposed Neversink development will not require additional clearing of trees from this corridor.

RTE Species and Habitat Observations

Bald eagles were observed soaring over the Neversink Reservoir during both field assessments. However, no nesting, roosting, or feeding activities were observed near the proposed construction areas and/or buffer zones.

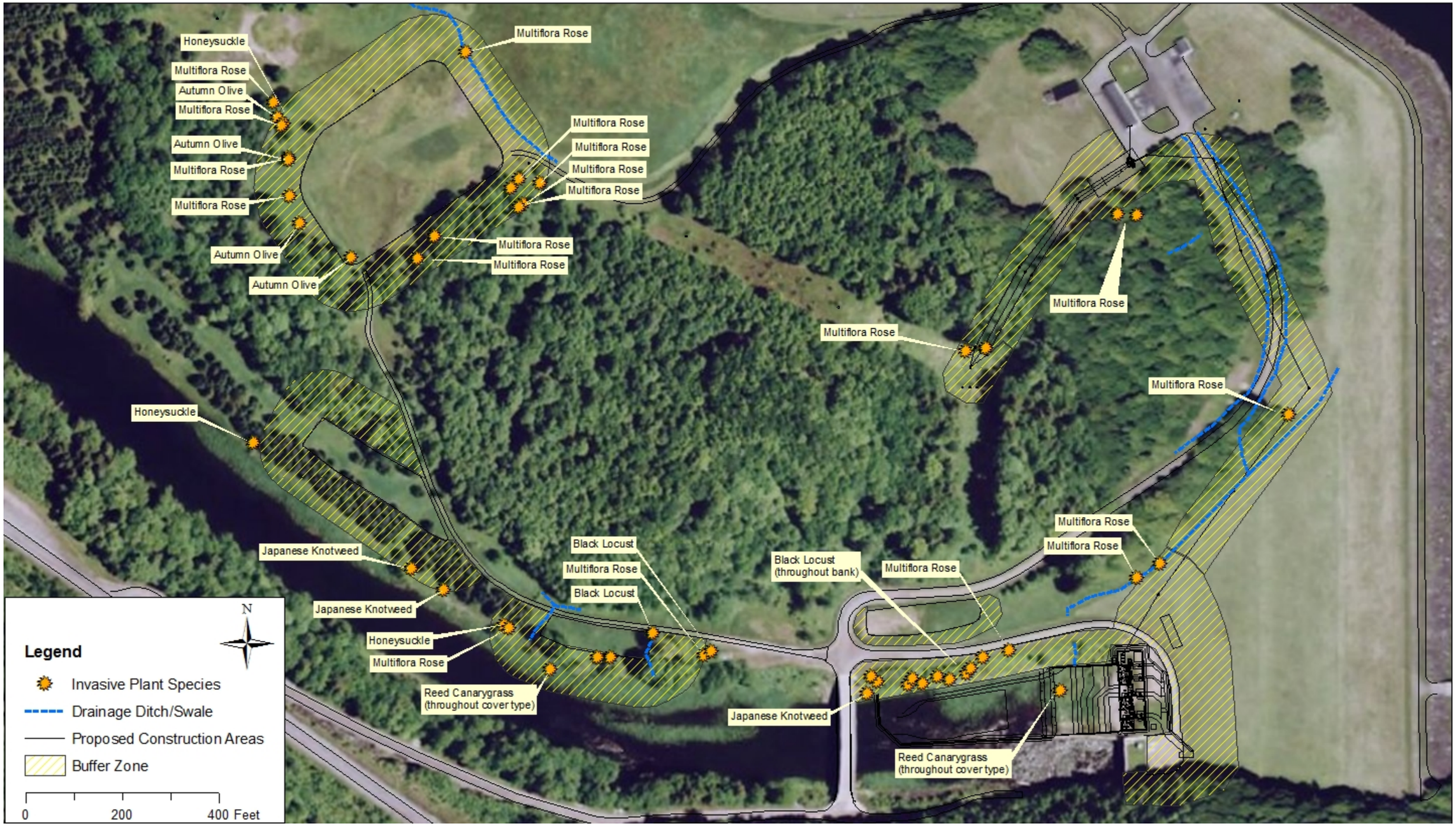
No other RTE species or associated habitats were observed in the proposed construction areas and/or buffer zones at the Neversink development.

Figure 4.1-1: Vegetative Cover Types, Wetlands and Vernal Pools at the Proposed Cannonsville Development.



Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

Figure 4.1-2: Invasive Plant Species Found at the Proposed Cannonsville Development.



Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

Figure 4.1-3: Riverine Shoreline Characteristics of the Proposed Cannonsville Development.

Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

Figure 4.1-4: Hydraulic Model of Tailrace Channel at Cannonsville.

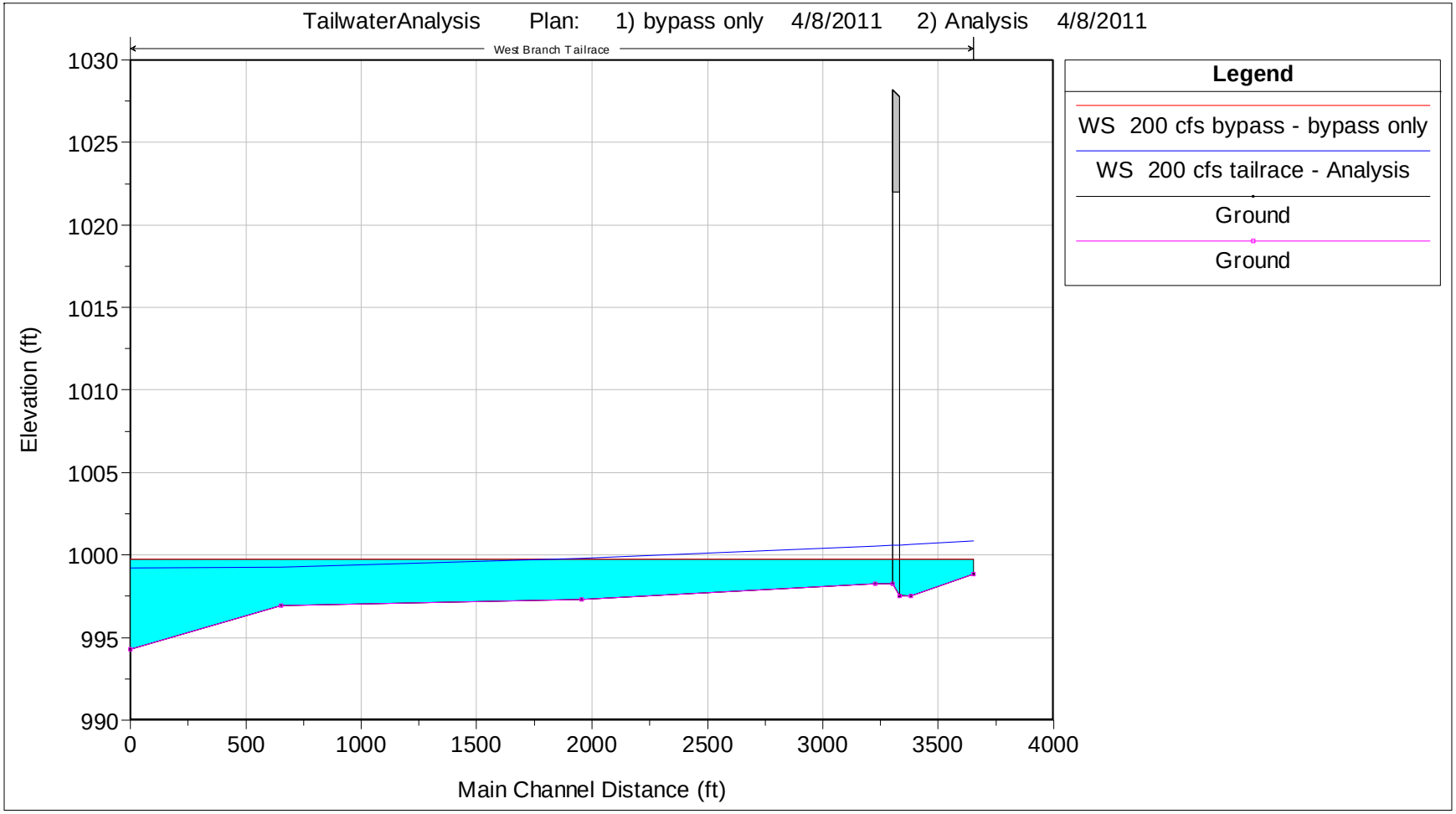
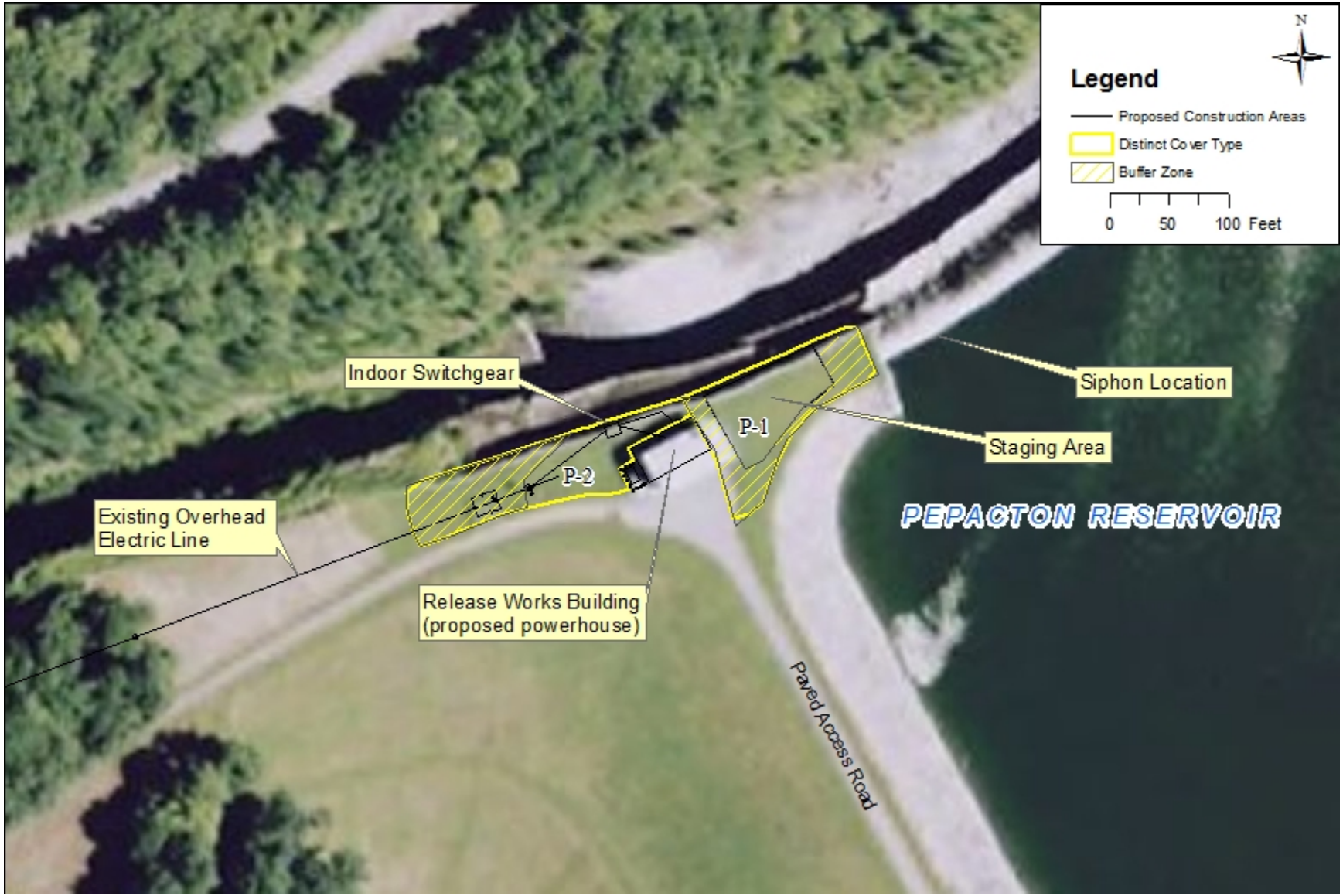
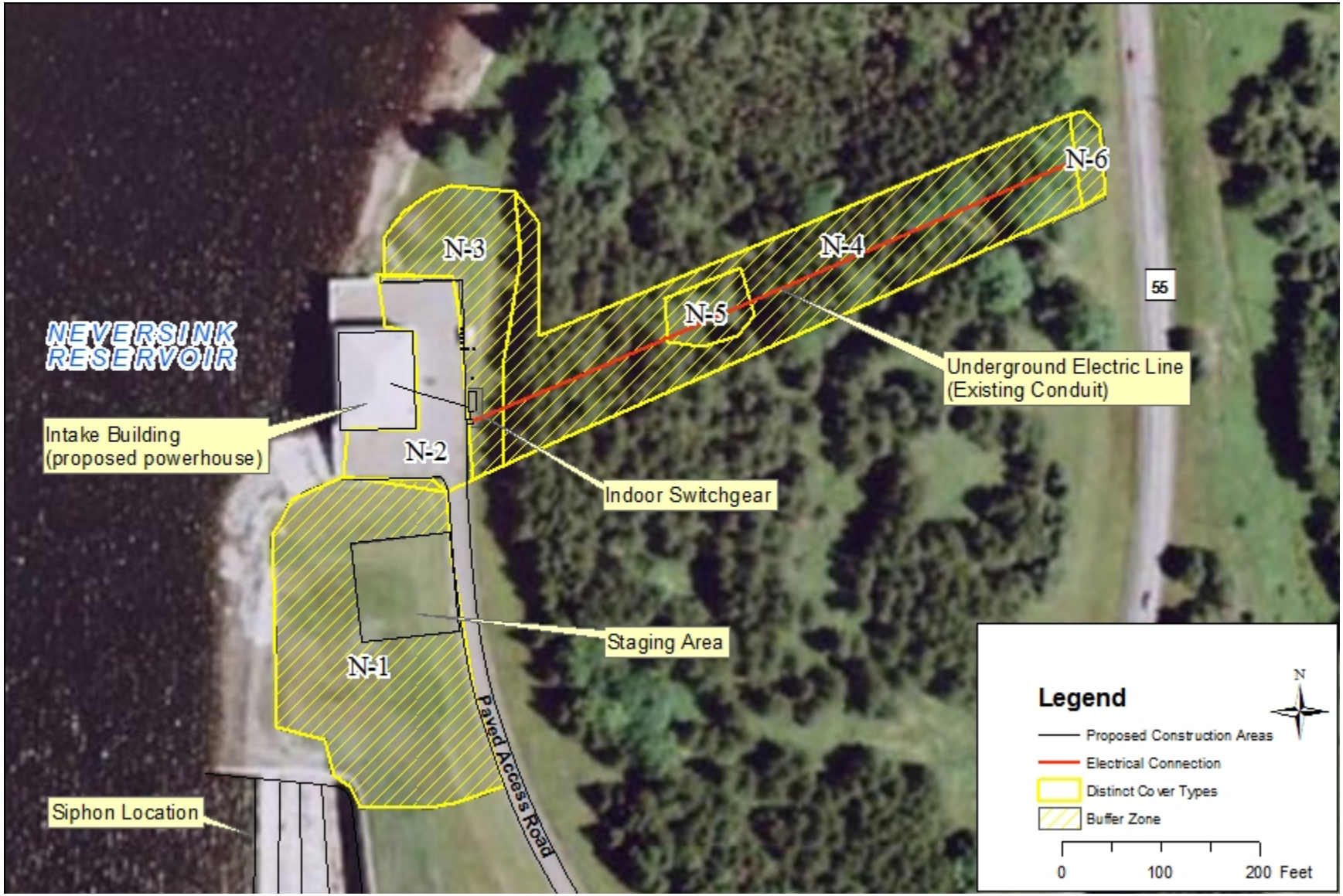


Figure 4.2-1: Vegetative Cover Types at the Proposed Pepacton Development.



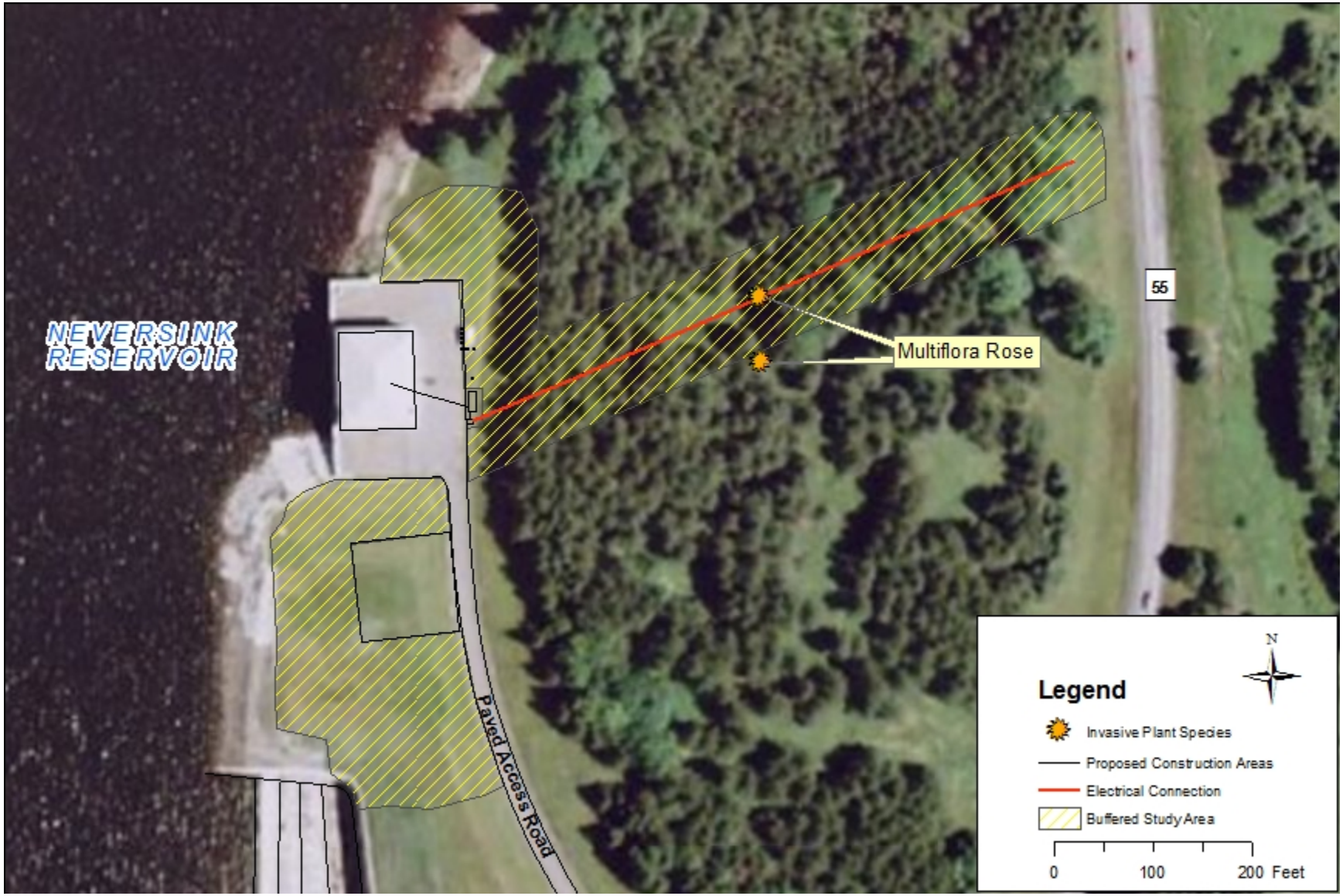
Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

Figure 4.3-1: Vegetative Cover Types at the Proposed Neversink Development.



Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

Figure 4.3-2: Invasive Plant Species Found at the Proposed Neversink Development.



Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers, P.C.

5.0 SITE-SPECIFIC MITIGATION MEASURES

Based on the potential impacts of construction-related activities on wetlands, wildlife, botanical resources, and RTE species previously described in Section 4, this section provides potential mitigation measures to protect these resources from such impacts. These measures will be developed further prior to construction, in consultation with NYSDEC, USFWS, and other interested parties.

5.1 Protection and Avoidance of Sensitive Resources

Three wetlands and three vernal pools were identified in the study area at the proposed Cannonsville development. Only one of these wetlands (C-14/C-18 complex) is located in an area proposed for construction. The other two wetlands as well as the three vernal pools were found to be at least partly located in the buffer zone areas adjacent to the construction areas, as follows:

Resource	Location
Emergent Wetland C-4a	Buffer zone adjacent to Staging Area 1
Floodplain Wetland C-10	Buffer zone adjacent to Staging Area 2
Vernal Pool 1	Buffer zone adjacent to existing electric line
Vernal Pool 2	Buffer zone adjacent to new transmission lines
Vernal Pool 3	Buffer zone adjacent to Staging Area 1

The wetlands and vernal pools found in the buffer zones at the Project will be avoided and left undisturbed during construction activities. The boundaries of each will remain demarcated and instructions will be provided to the construction personnel to avoid these areas.

5.2 Wetlands Permitting

Impacts to certain wetlands at the Cannonsville development due to construction activities are unavoidable. Just over one acre of emergent wetland (parcel C-14) will be impacted by the construction of the powerhouse and tailrace at the Cannonsville development. Impacts will include excavation and removal of the vegetation and substrate to allow for a deeper tailrace area to accommodate the proposed turbine draft tube. The existing riverine deepwater habitat (parcel C-18) will also be excavated to allow for a deeper tailrace channel. There will be no net loss of wetlands due to this construction. However, the currently existing emergent wetland will be transformed into deepwater habitat.

The emergent wetland is currently of poor value due to the incursion of the invasive plant species reed canarygrass. Unlike native wetland vegetation, dense stands of reed canarygrass have little value for wildlife. Few species eat the grass, and the stems grow too densely to provide adequate cover for small mammals and waterfowl. Accordingly, no mitigation measures are proposed at this time. However, prior to construction, DEP will obtain all necessary permits from the USACE and the NYSDEC. Consultation with the applicable resource agencies will occur during the process of obtaining any permits required for the Project.

The DEP intends to complete a joint application for permit(s) for submittal to NYSDEC and USACE for wetlands and waterways disturbances prior to construction of the proposed developments. Applicable rules, regulations and permit requirements may include:

- Section 10 of the Rivers and Harbors Act of 1899 which prohibits the obstruction or alteration of navigable waters of the United States without a permit from the USACE. Activities related to Project construction that require a Section 10 permit include dredging and excavation.

- Section 404 of the Clean Water Act which prohibits the discharge of dredged or fill material into waters of the United States without a permit from the USACE. Activities related to Project construction that may require a Section 404 permit include the in-channel work proposed at the Cannonsville development.

In addition, New York State's freshwater wetlands are protected under Article 24 of the New York State Environmental Conservation Law, commonly known as the Freshwater Wetlands Act (the Act or Article 24). Wetlands protected under Article 24 are known as New York State "regulated" wetlands. The regulated area includes the wetlands themselves as well as a protective buffer or "adjacent area" extending 100 feet landward of the wetland boundary. Title 3 of the Act mandates that all freshwater wetlands with an area 12.4 acres[1] or greater be depicted on a set of maps promulgated by DEC. There are no New York State regulated wetlands in the study area at the Project.

5.3 Sediment and Erosion Control Plan

A sediment and erosion control plan has been developed as specified in the study plan (Issue No. 3: Impact of Construction-Related Activities on Erosion). During construction, sediment and erosion control measures and stormwater management practices will be employed to minimize erosion and sedimentation in wetland, littoral and riparian areas at the project. The conceptual planning for erosion control presented in the Erosion Control Report (DEP 2011) are based on the proposed location of structures (powerhouse, transmission lines, substation) and the proposed locations for staging areas, spoils, sedimentation basin, and access routes. It is expected once final design plans are developed, detailed erosion and sediment control plans and stormwater pollution prevention plans ("SWPPP") will be prepared. In addition to providing for erosion and sediment control, the measures identified in the plan will serve to alert construction personnel of "avoidance areas" related to sensitive areas such as vernal pools and wetlands.

5.4 Invasive Species Control

The invasive plant species found at the Cannonsville and Neversink developments are shown in Figures 4.1-2 and 4.3-2, respectively. There were no invasive plants found at the Pepacton development. The invasive plants found at the Cannonsville and Neversink developments are largely naturalized and established in the region. There were no new invasive plants discovered at the Project which are on the regional "Early Detection" or "Approaching Region" lists (Invasive Plant Council of New York State, 2007). Nevertheless, measures will be taken to avoid the spread of the existing invasive species during construction.

At the Cannonsville development, fill from the excavated tailrace channel will be transported and deposited in the spoils disposal area. In order to prevent invasive species from being spread within the property, excavated material will be covered with clean, weed-free top soil, mulch, and seeded. Newly

[1] Wetlands less than 12.4 acres in size may also be mapped if they have unusual local importance or are located within the Adirondack Park.

seeded areas will be watered as needed to establish grass. If the season prohibits the establishment of grass, a temporary cover, such as straw, will be used to prevent vegetative growth until the weather permits. Additional management practices will be implemented to prevent invasive plant species from being transported off-site, including cleaning vehicles, boots and tools prior to moving them off-site.

At the Neversink development, the invasive species multiflora rose is limited to areas along the existing underground conduit. No additional disturbances to this area are anticipated during construction and therefore, no measures to avoid the spread of the existing invasive species during construction are proposed at Neversink.

5.5 Bald Eagle Protection Measures

The proposed developments are home to breeding populations of bald eagles. The bald eagle is protected under the Bald and Golden Eagle Protection Act (16 U.S.C. §§ 668-668d) and the Migratory Bird Treaty Act (16 U.S.C. §§ 703-712), and continues to be listed as a threatened species in New York State under the NYS Endangered Species Act (6 NYCRR Part 182 §11-0535).

The DEP monitors bald eagle activity at the proposed developments and will continue to do so during construction. Based on the field observations, there does not appear to be any nesting or roosting habitat (*e.g.*, tall trees) in the proposed construction areas or buffer zones. However, bald eagle habitat use may change from year to year. As shown previously in Table 3.2-1, bald eagle nests identified in 2009 were located at least one mile or more from the respective dam locations at each development. Therefore, maps of the nesting locations were not prepared. However, prior to construction, DEP will identify any bald eagle nests in the vicinity of the proposed construction activities at each respective development. DEP will provide this information to the USFWS and NYSDEC, maps will be developed, and conceptual buffer zones around nests will be established, as appropriate.

Further, to prevent disturbances to nests, foraging areas, and roosting areas, restrictions, as described below, may be incorporated into the construction plan associated with the Project, as appropriate, consistent with the suggested measures in the USFWS Bald Eagle Management Guidelines (USFWS, 2007). These measures may include:

- Avoid clear cutting or removal of overstory trees within 330 feet of eagle nests at any time.

- If nests are found within 330-660 feet of the proposed construction areas, construction sequencing may be altered to occur outside of the nesting season (typically January – July), in consultation with the USFWS and NYSDEC, depending on whether the construction activity will be visible from the nest.

- Currently it is not anticipated that blasting will be required for the tailrace excavation at the Cannonsville development. If site conditions require shallow blasting, DEP will consult with the USFWS and NYSDEC, as necessary, regarding any required blasting plans.

- Additionally, DEP envisions working with USFWS and NYSDEC to implement protective measures for bald eagles, and other raptors, that may choose to perch on the new overhead electric lines and poles at the Cannonsville development. Several options exist, but the purpose is to create an exclusion zone at each pole so that an outstretched wing cannot make contact with a high-voltage line. Extensions affixed to the pole above the power lines would allow for safe perching opportunities.

Construction activities are not likely to adversely affect foraging activities of bald eagle at the three proposed developments. At the Cannonsville development, the excavation area is localized to a relatively small area (~1 acre), and there are other undisturbed areas that would afford ample alternative foraging opportunities, such as Cannonsville Reservoir, the channel downstream of the spillway, and other downstream locations. At Pepacton and Neversink, the construction activities will be limited to inside and adjacent to the existing intake buildings; such activities are not expected to affect bald eagle foraging opportunities.

Based on the foregoing, no specific mitigation measures are proposed at this time. New information regarding bald eagle nest locations at the time of construction may warrant additional protection measures as indicated above.

6.0 REFERENCES

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APPENDIX A – PHOTOGRAPHS

APPENDIX B – LIST OF PLANT SPECIES OBSERVED

Scientific Name	Common Name	Neversink						Pepacton		Canonnsville																												
		N-1	N-2	N-3	N-4	N-5	N-6	P-1	P-2	C-1	C-1a	C-2	C-3	C-4	C-4a	C-5/5a	C-6	C-7	C-8	C-9	C-10	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18	C-19	C-23	C-24	C-25	C-26	C-27	C-28	C-29	Invasive
Fagus grandifolia	American beech																															X		X				
Ulmus americana	American elm													X				X						X														
Carpinus caroliniana	American hornbeam																					X	X													X		
Platanus occidentalis	American sycamore																				X		X															
Malus domestica	Apple				X																			X														
Elaeagnus umbellata	Autumn olive									X			X																									Yes
Populus balsamifera	Balsam poplar				X																																	
Lotus corniculatus	Birdsfoot trefoil				X					X	X					X		X						X														
Rumex obtusifolius	Bitterdock																						X	X						X								
Betula lenta	Black birch																																	X	X	X		
Prunus serotina	Black cherry				X					X	X	X		X									X	X								X		X	X	X		
Sambucus canadensis	Black elderberry																							X														
Robinia psuedoacacia	Black locust																					X		X														Yes
Picea pungens	Blue spruce				X																																	
Verbena hastata	Blue vervain										X													X														
Acer negundo	Boxelder																	X					X	X														
Typha latifolia	Broadleaf cattail																							X														
Trifolium spp.	Clover	X		X	X	X			X	X	X					X			X												X							
Asclepias syriaca	Common milkweed				X	X				X	X		X		X	X		X			X	X	X	X														
Artemisia vulgaris	Common mugwort												X									X																Yes
Verbascum thapsus	Common mullein																	X																				Yes
Hypericum perforatum	Common St. Johnswort																							X														Yes
Achillea millefolium	Common yarrow									X	X					X		X						X														
Vicia cracca	Cow vetch									X	X							X																				
Lysimachia nummularia	Creeping jenny																					X																Yes
Dianthus armeria	Deptford pink											X																										
Tsuga canadensis	Eastern hemlock				X																									X		X		X	X	X		
Toxicodendron radicans	Eastern poison ivy																					X	X	X														
Pinus strobus	Eastern white pine				X								X	X																				X				
Convolvulus arvensis	Field bindweed																					X		X														
Penstemon digitalis	Foxglove beardtongue											X																										
Carex alopecoidea	Foxtail sedge														X																							
Solidago spp.	Goldenrods				X	X				X	X	X		X		X		X				X	X							X								
Not identified	Grasses (mowed)	X		X			X	X	X	X	X					X			X									X			X		X				X	
Betula populifolia	Gray birch										X																							X	X	X		
Cornus racemosa	Gray dogwood											X											X	X														
Fraxinus pennsylvanica	Green ash				X									X								X	X	X										X		X		
Epilobium hirsutum	Hairy willowherb														X							X		X														Yes
Crataegus spp.	Hawthorn											X	X	X	X			X														X				X		
Galeopsis tetrahit	Hemp nettle											X				X		X				X																
Vaccinium corymbosum	Highbush blueberry					X																																
Lonicera spp.	Honeysuckle												X					X					X															Yes
Equisetum spp.	Horsetail														X																							
Castilleja mutis	Indian paintbrush				X																																	
Apocynum cannabinum	Indianhemp																	X																				

Scientific Name	Common Name	Neversink						Pepacton		Canonnsville																													
		N-1	N-2	N-3	N-4	N-5	N-6	P-1	P-2	C-1	C-1a	C-2	C-3	C-4	C-4a	C-5/5a	C-6	C-7	C-8	C-9	C-10	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18	C-19	C-23	C-24	C-25	C-26	C-27	C-28	C-29	Invasive
Berberis thunbergii	Japanese barberry											X																											Yes
Fallopia japonica	Japanese knotweed																	X						X															Yes
Impatiens capensis	Jewelweed														X						X	X		X	X					X									
Galium palustre	Marsh bedstraw														X																								
Podophyllum peltatum	Mayapple																					X																	
Spiraea latifolia	Meadowsweet				X							X			X	X		X					X	X	X														
Acer spicatum	Mountain maple																													X									
Rosa multiflora	Multiflora rose				X						X	X	X									X	X	X				X				X				X		Yes
Quercus rubra	Northern red oak													X																		X							
Picea abies	Norway spruce				X							X				X	X			X																			Yes
Leucanthemum vulgare	Oxeye daisy																	X				X		X															
Anaphalis margaritacea	Pearly everlasting																							X															
Solanum xanti	Purple nightshade																							X	X														
Rubus odoratus	Purple-flowering raspberry																							X						X									
Populus tremuloides	Quaking aspen											X												X															
Rubus spp.	Raspberry/blackberry					X						X	X					X					X	X						X					X	X			
Acer rubrum	Red maple				X							X	X									X		X								X			X	X			
Phalaris arundinacea	Reed canarygrass															X					X				X														Yes
Vitis riparia	Riverbank grape												X									X																	
Pinus sylvestris	Scotch pine				X	X																																	
Onoclea sensibilis	Sensitive fern														X			X			X		X							X									
Amelanchier spp.	Serviceberry													X																									
Acer saccharinum	Silver maple																																	X					
Mentha spicata	Spearmint											X																											
Acer saccharum	Sugar maple												X	X								X	X									X		X					
Lysimachia terrestris	Swamp candles														X			X																					
Comptonia peregrina	Sweet fern																							X															
Phleum pratense	Timothy									X	X					X																							
Parthenocissus quinquefolia	Virginia creeper				X					X	X	X						X				X	X	X															
Fragaria virginiana	Virginia strawberry									X	X																												
Lysimachia quadrifolia	Whorled yellow loosestrife											X																											
Salix spp.	Willow																						X		X														
Barbarea vulgaris	Yellowrocket																								X														
Betula alleghaniensis	Yellow birch																					X	X	X						X		X							
Oxalis stricta	Yellow woodsorrel														X																								

Notes: Invasive according to New York State Early Detection Invasive Plants by Region, Assessment of Naturalized Invasive Plants, REGION: CRISP, October, 2007. Mowed grasses not identified to species.

APPENDIX C – LIST OF ANIMAL SPECIES OBSERVED

Scientific Name	Common Name	Neversink	Pepacton	Cannonsville
Birds				
Corvus brachyrhynchos	American crow	X	X	X
Turdus migratorius	American robin		X	X
Haliaeetus leucocephalus	Bald eagle	X	X	X
Parus atricapillus	Black-capped chickadee			X
Branta canadensis	Canada goose	X		X
Petrochelidon pyrrhonota	Cliff swallow	X	X	
Mergus merganser	Common merganser		X	X
Phalacrocorax auritus	Double-crested cormorant		X	
Sturnus vulgaris	European starling		X	
Ardea herodias	Great blue heron		X	
Catharus guttatus	Hermit thrush			X
Colaptes auratus	Northern flicker			X
Dryocopus pileatus	Pileated woodpecker			X
Agelaius phoeniceus	Red-winged blackbird			X
Larus delawarensis	Ring-billed gull		X	
Meleagris gallopavo	Wild turkey		X	
Mammals				
Sylvilagus floridanus	Eastern cottontail			X
Odocoileus virginianus	White-tailed deer	X	X	X
Amphibians				
Plethodon cinereus	Northern red-backed salamander			X

Cannonsville Development: Photographs Taken June 29 - 30, 2010

Plate 1: View of the proposed spoils disposal area at Cannonsville development (C-1).

Plate 2: Drainage swale on the edge of the proposed spoils disposal area at Cannonsville development.

Plate 3: Mixed upland forest cover type (C-2) adjacent to the proposed spoils disposal area at Cannonsville development.

Plate 4: Mixed field/shrub cover type (C-3) adjacent to the proposed spoils disposal area at Cannonsville development.

Plate 5: Spillway at Cannonsville Reservoir.

Plate 6: Spillway at Cannonsville Reservoir.

Plate 7: Proposed Staging Area 1 at Cannonsville development. Open field cover type (C-5) with forest plantation on left (C-6).

Plate 8: Riverbank adjacent to proposed Staging Area 1 (C-7) at Cannonsville development.

Plate 9: Floodplain wetland (C-10) dominated by reed canarygrass at Cannonsville development.

Plate 10: Proposed Staging Area 2 (C-8) at Cannonsville development. Mowed field.

Plate 11: Drainage swale located west of proposed Staging Area 2 at Cannonsville development.

Plate 12: Emergent wetland (C-4a) adjacent to proposed Staging Area 1 at Cannonsville development.

Plate 13: Proposed Staging Area 3 at Cannonsville development.

Plate 14: Upstream view of existing release works and adjacent emergent wetland (C-14) at Cannonsville development.

Plate 15: Emergent wetland (C-14) adjacent to existing release works (looking east) at Cannonsville development.

Plate 16: Downstream view of West Branch Delaware River and adjacent emergent wetland (C-14) from existing release works at Cannonsville development.

Plate 17: View of the cross-channel weir downstream of existing release works at Cannonsville development.

Plate 18: Mixed forest buffer area (C-19) south of existing release works at Cannonsville development.

Plate 19: Proposed location of new powerhouse (C-16) at Cannonsville development.

Plate 20: Existing transmission line corridor at Cannonsville development.

Plate 21: Emergent wetland (C-14) located within the proposed tailrace excavation area at Cannonsville development.

Plate 22: Upstream view of emergent wetland (C-14) and West Branch Delaware River channel (C-18) in the proposed tailrace excavation area at Cannonsville development.

Plate 23: Downstream view of West Branch Delaware River channel (C-18) in the proposed tailrace excavation area at Cannonsville development.

Plate 24: Downstream view of West Branch Delaware River channel downstream of bridge at Cannonsville development.

Cannonsville Development: Photographs Taken April 26, 2011

Plate 25: Uphill view of mixed upland forest (C-24) at Cannonsville development.

Plate 26: Uphill view of mowed turf (C-25) with drainage ditch adjacent to C-24 at Cannonsville development.

Plate 27: Mixed upland forest (C-26) at Cannonsville development.

Plate 28: Mixed upland forest (C-27) (see photo left) at Cannonsville development. Mowed grass along road (C-25).

Plate 29: Mixed upland forest (C-28) in area of proposed overhead transmission line at Cannonsville development.

Plate 30: Mixed upland forest (C-28) looking back at proposed substation location at Cannonsville development.

Plate 31: Vernal Pool 1 at Cannonsville development: small man-made depression made with road signs and cinder blocks found in mixed upland forest (C-27).

Plate 32: Vernal Pool 2 at Cannonsville development; adjacent to mowed access road in mixed upland forest (C-28).

Plate 33: Vernal Pool 3 containing egg masses.

Plate 34: West-facing view of mowed area (C-29) near proposed substation location at Cannonsville development.

Plate 35: Proposed substation location mowed area (C-29) at Cannonsville development.

Plate 36: West-facing view of access road parallel with West Branch Delaware River channel at Cannonsville development.

Plate 37: Spillway channel when dam is spilling (958 cfs) at Cannonsville development.

Plate 38: Downstream Release (approximately 1,500 cfs) at Cannonsville development.

Plate 39: River right upstream view of channel and riverbank adjacent to proposed Staging Area 1 (C-7) at Cannonsville development.

Plate 40: River right downstream view of channel and riparian area adjacent to proposed Staging Area 1 (C-7) at Cannonsville development; moderately sloped 10 feet high banks.

Plate 41: Downstream view of river left at Cannonsville development; steep forested area.

Plate 42: Downstream view where river right bank slope flattens out at Cannonsville development.

Plate 43: Downstream river right Japanese knotweed stalks from last summer's growth at Cannonsville development.

Plate 44: River right upstream view at peninsula point of West Branch of Delaware River and rocky shoreline at Cannonsville development.

Plate 45: River right downstream view of convergence of West Branch of the Delaware River with spillway channel at Cannonsville development.

Plate 46: Upstream view of spillway channel from peninsula at Cannonsville development.

Plate 47: Spillway overflow at Cannonsville Reservoir.

Plate 48: Downstream view of spillway channel at Cannonsville development.

Pepacton Development: Photographs Taken June 28, 2010

Plate 49: Proposed Staging Area at Pepacton development (P-1).

Plate 50: Existing overhead electric lines at Pepacton development.

Plate 51: Spillway at Pepacton Reservoir.

Pepacton Development: Photographs Taken April 25, 2011

Plate 52: Spillway overflow at Pepacton Reservoir - view from paved access road.

Plate 53: Pepacton Reservoir spillway overflow.

Plate 54: Spillway channel at Pepacton development.

Plate 55: Spillway channel ledge with current release works building (this structure will house the proposed powerhouse) in background at Pepacton development.

Neversink Development: Photographs Taken June 28, 2010.

Plate 56: Neversink Reservoir Spillway viewed from Rt. 55.

Plate 57: Gated access road at Neversink Reservoir (19.3 feet wide).

Plate 58: Proposed Staging Area at Neversink development (N-1).

Plate 59: Weather station adjacent to the proposed Staging Area (N-1) at Neversink development.

Plate 60: Weather station, propane tank, and intake building at Neversink development (cover types N-2 and N-3).

Plate 61: Looking east into forest plantation (N-4) at Neversink development.

Plate 62: Forest plantation (N-4) at Neversink development, proposed route of underground transmission line.

Plate 63: Successional field cover type area (N-5) near proposed route of underground transmission line at Neversink development.

Plate 64: Road shoulder (N-6) containing existing electrical pole at Route 55 at Neversink development.

Neversink Development: Photographs Taken April 25, 2011.

Plate 65: Spillway at Neversink Reservoir.

Plate 66: Current intake building (this existing structure will house the proposed powerhouse) at Neversink development.

Plate 67: South view of proposed Staging Area buffer zone at Neversink development (N-1).

Plate 68: South view of paved access road drainage ditch at Neversink development.

Plate 69: East view of proposed underground electrical line at Neversink development. Note that the clearing depicted in this photograph pertains to a separate, unrelated project at Neversink to install an underground electrical connection to the existing intake structure at the site.

Plate 70: Westward view of cleared forest plantation (N-4) for proposed underground electrical line at Neversink development. Note that the clearing depicted in this photograph pertains to a separate, unrelated project at Neversink to install an underground electrical connection to the existing intake structure at the site.

Plate 71: Eastward view of cut plantation pines along corridor for the proposed underground electric line at Neversink development. Note that the clearing depicted in this photograph pertains to a separate, unrelated project at Neversink to install an underground electrical connection to the existing intake structure at the site.

Plate 72: East view of existing electrical pole on Route 55 and corridor for the proposed underground electric line at Neversink development. Note that the clearing depicted in this photograph pertains to a separate, unrelated project at Neversink to install an underground electrical connection to the existing intake structure at the site.

Plate 73: Westward view of existing electrical pole on Route 55 and corridor for the proposed underground electric line at Neversink development. Note that the clearing depicted in this photograph pertains to a separate, unrelated project at Neversink to install an underground electrical connection to the existing intake structure at the site.

BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION APPLICATION FOR EXEMPTION OF SMALL HYDROELECTRIC PROJECT FROM LICENSING - EXISTING DAM

Neversink Hydroelectric Development

FERC Project No. 13287

VOLUME 5

Appendix E-3: Fish Entrainment Report, Literature Based Characterization of Resident Fish Entrainment and Mortality

City of New York

Environmental Protection

September 2011

City of New York
West of Hudson Hydroelectric Project

Project No. 13287

Fish Entrainment Report

Literature Based Characterization of Resident Fish Entrainment & Mortality

Cannonsville, Pepacton, and Neversink Developments

Final Report
June 2011

EXECUTIVE SUMMARY

The City of New York ("City"), acting through the New York City Department of Environmental Protection ("DEP") has filed with the Federal Energy Regulatory Commission ("FERC") a Notice of Intent ("NOI") to develop hydroelectric generation at the West of Hudson Hydroelectric Project ("Project"), FERC Project No. 13287. As part of the licensing process for the Project, DEP conducted a literature-based fish entrainment study at three proposed developments at Cannonsville, Pepacton, and Neversink Reservoirs. This report presents the results of this study and is being submitted to FERC in support of the license application for the proposed Project.

The DEP intends to continue operating the Cannonsville, Pepacton, and Neversink Reservoirs according to the applicable operating protocol agreed to by the parties to the 1954 U.S. Supreme Court Decree.[1] Accordingly, the water available for hydroelectric generation at Cannonsville, Pepacton, and Neversink will be comprised of conservation releases, directed releases, and water that would otherwise spill to the extent that such releases are consistent with discharge mitigation releases as outlined in such operating protocol. The DEP is currently not proposing to modify the magnitude, frequency, duration, and/or timing of discharges due to the addition of the hydropower facilities associated with the Project.

This study was done in consultation with the United States Fish and Wildlife Service ("USFWS") and the New York State Department of Environmental Conservation ("NYSDEC"), collectively referred to as "the agencies." The primary goals and objectives of the study, as developed during the study planning process with the agencies, are to: 1) evaluate the potential for fish entrainment, impingement and mortality at each of the three proposed developments; 2) provide an analysis of the need for, appropriateness, and feasibility of intake protection measures at each development; and 3) determine the propriety of downstream fish passage.

Entrainment

The DEP used an incremental analysis approach to determine the potential for fish entrainment, including: 1) evaluating which fish species and life stages have the potential to be present in the vicinity of the intake structures[2] at each proposed development, based on habitat preferences; 2) evaluating water quality conditions at the intake locations and reservoir water levels to determine how these factors affect the potential for fish entrainment; and 3) comparing swimming speeds of fish that may be susceptible to entrainment to the calculated water velocities at the intake structures at each proposed development. Another component to this study included reviewing the results of field-based entrainment and survival studies at other hydroelectric projects where quantitative sampling was conducted, and applying these results to site-specific conditions at the three proposed developments to evaluate the potential impacts of entrainment on the identified fish species of potential concern in each reservoir.

Water quality factors may influence the distribution and movements of coldwater fish in the Cannonsville and Pepacton Reservoirs. Because the reservoir capacities are often reduced during hot, dry summers, entrainment potential is the greatest during these situations. When the volume of the bottom layer of the reservoirs decrease, fish may be forced to concentrate near intake areas where cooler, more oxygenated water is located, thereby increasing entrainment potential. Thus, the potential for fish entrainment and impingement peaks during dry summer drawdowns, and the fish species most likely subject to entrainment are those seeking deep, cool water as thermal refuge, such as brown and brook trout, rainbow

[1] *New Jersey v. New York*, 347 U.S. 995 (1954). The parties to the decree are the City of New York, the States of Delaware, New Jersey and New York, and the Commonwealth of Pennsylvania (hereinafter, the "Decree Parties").

[2] Intake structures referred to throughout this report include intakes that convey water downstream of the dams and not the water supply intakes, which at Cannonsville and Pepacton are located elsewhere in the reservoirs. However, at Neversink, there is one common intake, which then directs flow for water supply and downstream releases.

smelt, and alewife. Likewise in winter, because the bottom layer of the reservoir is warmer than the surface, fish may tend to congregate near the bottom and stay active throughout the winter, thus having a moderate potential of being in the vicinity of the intake structures during winter.

Water level drawdowns at Neversink Reservoir are generally not as dramatic compared to those at Cannonsville and Pepacton and the water quality in Neversink Reservoir is such that all reservoir layers remained well oxygenated throughout the year. Accordingly, given the depth of the intake structure and excellent water quality, it is very unlikely that entrainment potential is affected by water quality factors in Neversink Reservoir.

Fish that spend at least part of their life cycle in deep, cool waters have the potential to be found in the vicinity of the deep water intake structures of the proposed developments. As part of the entrainment analysis, literature-based swim speed data for these fish were compared to the intake velocities at the three developments. Although some species may exhibit behavior that would potentially expose them to entrainment at the proposed developments due to the potential for being found within the vicinity of the intake structures (such as trout seeking out cool, deep water during summer, or deep-water refuge during winter) such species generally exhibit swimming performance that exceeds the expected velocities at the intake structures associated with the proposed developments.

Based on the current turbine designs being considered, the maximum proposed hydro capacity[3] at each proposed development is as follows: (a) 1,500 cfs at Cannonsville with a resulting intake velocity of 2.9 ft/s; (b) 162 cfs at Pepacton with a resulting intake velocity of 1.69 ft/s; and (c) 100 cfs at Neversink with a resulting intake velocity of 1.39 ft/s. As demonstrated by the foregoing, with the exception of Cannonsville, at the current maximum hydro capacities being considered for each of the proposed developments, the resulting intake velocity is below the USFWS intake velocity design criteria of 2 ft/s. Moreover, in considering conservation and directed release flows associated with the operating protocol in effect at the time this analysis was conducted (*i.e.*, the flows that would be utilized for hydropower generation) the expected velocities in front of the intakes at each of the proposed developments based on the median annual flows associated with such operating protocol are as follows: (a) 275 cfs at Cannonsville with a resulting intake velocity of 0.54 ft/s; (b) 140 cfs at Pepacton with a resulting intake velocity of 1.46 ft/s; and (c) 90 cfs at Neversink with a resulting intake velocity of 1.25 ft/s – all below the USFWS criteria of 2 ft/s. Furthermore, during the summer months when the reservoirs are normally being drawn down (*i.e.*, July, August, and September), thereby increasing the potential for entrainment (as noted above), based on historical data utilizing the operating protocol in effect at the time this analysis was conducted provides that: (a) intakes velocities at Cannonsville have been at or below 1.2 ft/s more than 90% of the time; (b) intake velocities at Pepacton have been at or below 1.6 ft/s nearly 90% of the time; and (c) intake velocities at Neversink are below 2.0 ft/s approximately 90% of the time.

Based on the habitat and life history requirements and swimming speeds of the fish species found in the three reservoirs, fish entrainment at the proposed developments is expected to be low for all species. Additionally, because there is no shoreline habitat near the intake structures at the three reservoirs, and the intake structures are located in deep-water habitat, the risk of entrainment for fry and juvenile fishes—regardless of intake velocities—is minimal.

[3] The maximum hydroelectric station capacities cited herein are based on the most current information available at the time of this report. It is conceivable that the hydraulic capacities could change slightly based on any design modifications identified by the ongoing feasibility analysis related to the Project and/or any agreed to modifications of the current operating protocol, which could have the potential to impact the current turbine designs being considered for each of the proposed developments.

Mortality

Fish mortality due to entrainment through the proposed hydroelectric developments, pressure differentials between the intake locations and the downstream release points, and impingement on intake protection devices at the proposed developments was also evaluated.

Due to the water depths at the intake structure locations (deep intakes) at the three proposed developments, the pressure differentials between the intake location and the release works experienced by a potentially entrained fish are likely to cause significant fish mortality regardless of whether hydropower facilities were added at these sites. Under most reservoir water level conditions, it is likely that any fish entrained through the release structures at the three proposed developments would not survive due solely to the pressure differentials that would be experienced between the intakes and the release works. Therefore, the addition of turbines and their potential effects on entrained fish is unlikely to materially affect mortality at the proposed developments because the primary cause of mortality is likely to be the pressure differentials existing between the intake structures and the release works regardless of whether hydropower facilities were added at these sites.

Intake Protection

The intake structures at each of the proposed developments already utilize intake protection in the form of bar racks. Regardless, as part of this analysis, various options for providing additional intake protection at the proposed developments were evaluated. A brief overview of the common physical and behavioral barriers for intake protection was provided, including an assessment of the feasibility and constructability of several measures (such as bar racks, angled bar racks, and barrier nets); however, the majority of these measures were not considered viable for any of the three proposed developments.

Based on the assessment of potential entrainment and mortality at the Project, DEP is not proposing the use of additional intake protection measures at any of the three proposed developments. NYSDEC has indicated its concurrence with DEP's proposal based on the findings of this report, the operational characteristics proposed for the hydropower facilities, and the additional information that was provided to NYSDEC as part of the consultation process related to this report.

Fish Passage

At the specific request of USFWS, the need for downstream fish passage and any appropriate mechanisms to facilitate passage at each development was examined as part of this analysis, including an assessment of the feasibility of providing downstream fish passage either through a low-level outlet or at the surface of the proposed developments.

Because of high fish mortality rate associated with the large pressure differentials between the intake structure and the release works identified as part of this analysis, the low-level fish passage alternative was determined to be impractical. The potential for providing surface-oriented downstream fish passage facilities at the Project was also evaluated. Furthermore, with respect to the potential for surface-oriented passages, it was determined that the changes to downstream temperature regimes arising from the conveyance flows associated with surface-oriented passages would likely adversely affect the downstream coldwater fisheries associated with the Project by warming up the rivers. Because the fisheries management objective for the three river systems associated with the Project is focused on providing coldwater trout fisheries, such a result would be inconsistent with the management objectives. Additionally, downstream fish passage is not required to complete the life cycles of any fish species in the reservoirs.

For these reasons, constructing downstream fish passages at any of the three proposed developments is neither desirable nor warranted. USFWS has indicated that this analysis adequately characterizes the

likelihood of fish entrainment and mortality, as well as the potential options available for fish passage. Accordingly, USFWS has concluded that no additional studies are required regarding these matters at this time.

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LIST OF ABBREVIATIONS

City	City of New York
cfs	cubic feet per second
DEP	New York City Department of Environmental Protection
DO	dissolved oxygen
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
FFMP	Flexible Flow Management Plan
FFMP-OST	Flexible Flow Management Plan with the Operations Support Tool
ft	feet
ft^2	square feet
ft/s	feet per second
gpm	gallons per minute
mm	millimeters
msl	mean sea level
MW	megawatt(s)
N	number in sample size
NYSDEC	New York State Department of Environmental Conservation
OASIS	Operational Analysis Simulation of Integrated Systems
OST	Operations Support Tool
ppm	parts per million
Project	West of Hudson Hydroelectric Project, FERC Project No. 13287
psi	pounds per square inch
rpm	revolutions per minute
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

1.0 INTRODUCTION

The City, acting through DEP has filed with FERC a Notice of Intent to develop hydroelectric generation at four sites that together comprise the Project. The four sites are owned by the City and operated by the DEP, as part of the City's water supply system, to provide potable water to meet the water supply needs of the City and DEP's upstate customers.[4] The City seeks to develop hydroelectric facilities at those sites while simultaneously maintaining its primary water supply function and adhering to the statutory and regulatory requirements governing its water supply operations, conservation releases, directed releases, water quality standards, and other related activities.

In accordance with the Preliminary Permit issued to the City by FERC, DEP is evaluating the technical and economic merit and feasibility for each proposed hydroelectric development. Based on the analysis completed to date, the City has not yet identified an economically viable project for the Schoharie development. As such, there are no additional studies proposed for the Schoharie development at this time. However, the City will continue to investigate whether there is a technically and economically feasible option for this site, and will proceed with appropriate FERC licensing studies in the event such an alternative is identified. Accordingly, this assessment discusses the following three proposed developments:

Development	Dam	River
Cannonsville	Cannonsville Dam	West Branch Delaware River
Pepacton	Downsville Dam	East Branch Delaware River
Neversink	Neversink Dam	Neversink River

1.1 Study Objectives

During the study plan development process, NYSDEC and USFWS, collectively referred to as the "agencies" requested that the DEP evaluate the impact of the Project on fish entrainment and impingement. The purpose of this report is to respond to those requests and evaluate the potential for fish entrainment and impingement at each of the above-referenced proposed developments. The report then provides an analysis of the need for, appropriateness, and feasibility of intake protection measures at each development. Finally, in response to a request from the USFWS, the report discusses the propriety of downstream fish passage. The analyses contained herein are based on a combination of historical data maintained by the DEP and studies performed at other hydroelectric sites, as reported in the literature cited in Section 11.

Factors that can influence the potential for entrainment and impingement at a hydropower project include the size and depth of the intake structure, the velocity of water as it enters the intake structure, the location of the intake structure relative to fish habitat, and the characteristics (*e.g.*, size and habitat preferences) and specific life stage of fish species present. Survival rates can be affected by factors such

[4] The City's water supply is comprised of three watersheds – Catskill, Croton, and Delaware – which are operated as an integrated system. Three of the potential units of development are part of the Delaware system: Cannonsville – Cannonsville Reservoir and Dam; Neversink – Neversink Reservoir and Dam; and Pepacton – Pepacton Reservoir and Downsville Dam. The fourth potential unit of development, Schoharie – Schoharie Reservoir and Gilboa Dam, is part of the Catskill system. In total, the water supply system provides approximately 1.1 billion gallons of high quality drinking water daily to approximately nine million New York State residents (about 50% of the State's total population), as well as the millions of tourists and commuters who visit New York City each year.

as the type of turbine, the number of blades, the blade spacing, the rotation speed of the turbine, and the water pressure created in the penstock, turbine, or tailwater.

The objectives of this report are to:

- Summarize the fish species and life stages present in each reservoir;
- Evaluate which fish species and life stages have the potential to be present in the vicinity of the intake structures at each proposed development, based on habitat preferences;
- Evaluate water quality conditions—specifically dissolved oxygen (DO) and temperature—at the intake locations to determine how these factors affect the potential for fish entrainment and impingement;
- Evaluate the likelihood of fish entrainment and impingement based on the fish species and life stages present in the reservoirs, and water quality conditions, water depth, and water velocities at the intake structures;
- Review existing DEP records for existing data or information on known entrainment occurrences at the three reservoirs associated with the proposed developments;
- Characterize the proposed turbine configurations (*e.g.*, size, runner diameter, and speed) being analyzed;
- Develop literature-based estimates of fish entrainment, impingement, and mortality;
- Evaluate likely differences in entrainment potential in each reservoir based on the time of year, water temperatures, water levels, the location of the thermoclines, and stratification; and
- Evaluate options for additional intake protection and downstream fish passage.

1.2 Consultation

A prior draft of this study report was submitted to NYSDEC and USFWS for their review on August 17, 2010. A meeting was convened on August 23, 2010 by DEP at their offices in Kingston, New York to present the findings of this study to personnel from NYSDEC and USFWS. During such meeting, NYSDEC and USFWS personnel requested certain additional information relating to the analysis.

Subsequently, DEP prepared an addendum to the prior draft, which served to supplement and clarify the information contained in the prior draft report and to provide the additional requested information. Such addendum was submitted to NYSDEC and USFWS for review on September 8, 2010. The information previously contained within such addendum has been consolidated into this final report.

USFWS provided a formal response to the report and addendum by letter dated September 15, 2010. In its response, USFWS concluded that the report (together with the addendum) adequately characterizes the likelihood of fish entrainment and mortality, as well as the potential options available for fish passage. Thus, USFWS has concluded that no additional studies are required regarding these matters at this time.

NYSDEC provided initial formal comments on the report and addendum by letter dated September 24, 2010. Such initial comments indicated a continued concern regarding the potential impacts associated

with the proposed hydroelectric development at the Neversink Reservoir, and requested additional information on fish mortality due to pressure differentials of potentially entrained fish.

DEP provided the additional requested information to the NYSDEC on October 19, 2010. The substance of this additional information has also been consolidated into this final report. After review of this additional information, NYSDEC, by letter dated December 8, 2010, concluded that under the current flow regime, the addition of hydroelectric facilities, as proposed, will not have a significant impact on fisheries mortality at the Cannonsville, Pepacton and Neversink Reservoirs. Accordingly, NYSDEC concluded that no further field studies are necessary at this time. Additionally, based on these factors, NYSDEC agreed that no additional intake protection measures were necessary in conjunction with the Project.

The initial entrainment analysis discussed with NYSDEC and USFWS was based on the Flexible Flow Management Plan ("FFMP") – the operating protocol agreed to by the Decree Parties and in effect from October 1, 2007 through May 31, 2011. Effective June 1, 2011, the FFMP was superseded by the Flexible Flow Management Plan with the Operations Support Tool ("FFMP-OST") – the operating protocol the Decree Parties have agreed to utilize until at least May 31, 2012.[5] Accordingly, subsequent to the discussions with NYSDEC and USFWS, this analysis was updated to reflect the change in the applicable operating protocol. However, although the FFMP-OST generally results in a slightly greater overall volume of releases from the reservoirs associated with the proposed developments compared to the FFMP, the findings and conclusions based on the FFMP, which were previously discussed with NYSDEC and USFWS and served as the basis for their respective conclusions regarding the lack of need for additional studies at this time, remain valid and are unchanged by the revised analysis based on the FFMP-OST. In particular, the change in operating protocol has no impact on the fact that the pressure differentials between the intake structures and the release works associated with the proposed developments experienced by any potentially entrained fish are likely to cause significant fish mortality regardless of whether hydropower facilities are added to these sites.

The formal correspondence letters relating to the consultation process with NYSDEC and USFWS relating to this analysis are included in Appendix A.

[5] The Decree Parties have the option, by unanimous consent, to elect to extend operation of the FFMP-OST for at least one additional year (i.e., until May 31, 2013).

2.0 STUDY APPROACH

The following section summarizes the approach of this study and provides an outline for the analysis contained in this report.

Intake and Proposed Turbine Configurations

The first step in evaluating the potential for fish entrainment was to consider the physical features of the reservoirs, dams, intake structures, and proposed turbines that may affect entrainment. Section 3 describes the water intake structures and the proposed turbine configurations.

Water Level & Water Quality Data

Water level and water quality data were analyzed because the potential for fish entrainment can be affected by the following related factors: the reservoir water level (or storage capacity), the vertical temperature profile and location of the thermocline, and the dissolved oxygen ("DO") concentration near the intake structures. In lieu of plotting the water quality data for all 17 years of available electronic data (1993-2009), NYSDEC recommended selecting data from each reservoir for three years out of this period which represented wet, dry, and average summers, based on the storage capacity at the Cannonsville Reservoir. This data set is considered to provide a reasonable representation of the range of potential conditions at the three reservoirs. Details regarding this methodology are provided in Section 4.1. Although the selection criteria reflect summer conditions only, for the purposes of this report, the selected years are referred to as representative wet, dry, or average years.

Reservoir elevation duration curves were developed on an annual and monthly basis for each reservoir. These curves were based on the entire period of record from the Operational Analysis Simulation of Integrated Systems ("OASIS") model (1948-2008). Additionally, the water quality data at the Cannonsville, Pepacton, and Neversink Reservoirs were evaluated for the selected wet, dry, and average years. This evaluation included developing DO and temperature profiles for the sampling locations closest to the intake structures for the selected years. The profiles were then analyzed to identify trends in factors, such as the depth of the thermocline compared to the intake elevation, DO concentrations near the intake structures, and how these trends affect the potential for fish entrainment.

Finally, proportional water usage *(i.e.*, water supply compared to conservation and directed releases) at each reservoir is presented. The results of the water use and water quality analysis are provided in Section 4.

Fish Species

After gaining an understanding of the water quality and operations of the reservoirs at issue, the next step in characterizing potential fish entrainment was to identify the species of fish present in each reservoir. A summary of the existing fisheries at each development is provided in Section 5. Life history characteristics for each species are discussed in relation to reservoir intake configuration and water quality parameters. The evaluation considered the habitat preferences of the fish in different life stages relative to food sources and water quality conditions. Based on these considerations, the fish species for the entrainment analysis were selected by determining which fish species, at which life stages, are most likely to be present near the intake structures at various times of the year.

Entrainment Analysis

Literature Review

More than 40 entrainment field studies have been conducted in the United States in recent years (FERC, 1995), as well as numerous studies to specifically estimate turbine passage survival (EPRI, 1992 & 1997). Although the site characteristics were variable between these studies, they provide an extensive database

from which to estimate potential entrainment and survival. Such estimates, together with a characterization of the proposed developments, were utilized to evaluate the potential impacts of entrainment on the identified fish species at each proposed development.

Some common trends in fish entrainment and correlations thereof with a number of biological, environmental, and physical site conditions have been identified (FERC, 1995). Physical factors influencing the potential for entrainment include water quality, reservoir size, dam height, depth of intake, and intake velocity. Biological factors influencing the potential for entrainment include fish species habitat preferences, fish size, swim speed, and seasonal and diurnal movements. General trends influencing the potential for entrainment are discussed in Section 6.1. Turbine attributes, intake depth, and fisheries composition at the proposed developments were used to identify similar projects in the literature, as described in Section 6.2.

In addition, to determine site-specific entrainment occurrences, existing DEP records such as fish kill investigation reports at the three reservoirs were reviewed.

Intake Velocities

DEP's proposed hydroelectric installations will utilize some portion of water already being provided downstream for conservation and directed releases. The water velocities at the existing intakes were evaluated by developing monthly intake velocity duration curves based on conservation and directed flow releases for the entire period of record from the OASIS model (1948-2008). Intake velocities based on hydropower flow only were also determined from the proposed maximum station capacities at each development. Water velocities at each intake were evaluated in relation to USFWS velocity guidelines of less than two feet per second (ft/s), and then compared with known fish swimming speeds to evaluate entrainment potential for different species. Section 6.3 provides details regarding the intake velocity duration curves for the proposed developments.

Entrainment Assessment

Based on the fish species/life stages, water quality data, intake velocities, intake depths, turbine configuration, and a literature review of prior entrainment studies, a general qualitative assessment of the likelihood of fish entrainment at each proposed development was conducted. The results of that assessment are described in Section 6.4.

Mortality

Mortality due to the following three mechanisms was evaluated:

Turbine Passage

Based upon studies that evaluated the identified species associated with the proposed developments, and existing hydroelectric facilities with similar turbine types to those being analyzed for the proposed developments, relevant fish survival estimates were summarized, both by species and by size class (less than 8 inches, 8 to 15 inches, and greater than 15 inches).

Pressure Differential

The difference in pressure between the intake structure locations and the downstream release locations at each proposed development was evaluated to determine whether pressure differential alone could cause mortality in any potentially entrained fish. This information was also utilized in determining whether it is reasonable to evaluate downstream fish passage alternatives. Pressure at each intake was calculated, and general schematic pressure scenarios at the proposed developments were compared to literature-based information to evaluate the potential impact of the estimated pressure differentials on mortality of any

entrained fish. In addition, the context and frequency of water depths and pressures experienced by potentially entrained fish at each reservoir was evaluated.

Impingement

Impingement is defined as the involuntary contact and entrapment of fish on the surface of an intake protection device due to the approach velocity exceeding the fish's swimming capability. Impingement on an intake protection device may result in injury or death for fish. After determining which fish species have the potential to be present in the area of the intake structures, the sizes of fish species that could physically fit through the existing intake protection devices, based on body dimensions, was evaluated.

An analysis was performed to estimate the body length of fish that would be physically excluded by the bar rack spacing at each intake structure, and, thus, at risk for potential impingement. Proportional measurements for the fish species were obtained from Smith (1985) and used to calculate a scaling factor of body width to total length for each species. Based on this ratio, the estimated body lengths of each fish that would be physically excluded by the existing bar racks were calculated.

The results of the mortality assessment are described in Section 7.

Intake Protection

Various options for providing intake protection at the proposed developments were evaluated. The feasibility and constructability of intake protection alternatives, including physical barriers such as bar racks, angled bar racks, and barrier nets, as well as behavioral barriers were assessed for each proposed development. Section 8 describes the intake protection evaluation that was conducted.

Fish Passage

The need for downstream fish passage and any appropriate mechanisms to facilitate passage at each development was also examined relative to the resource agencies' expressed objectives for downstream fisheries management. The feasibility of providing downstream fish passage either through a low-level outlet or at the surface of the proposed developments is discussed in Section 9. In addition, temperature measurements taken downstream of the dams associated with the proposed developments were compared to surface readings taken concurrently from the respective reservoirs near each dam. This evaluation was conducted primarily to evaluate the temperature difference that would be experienced by fish in a potential surface-oriented fish passage scenario.

3.0 PROJECT CHARACTERISTICS

3.1 Proposed Operation

The DEP intends to continue operating the Cannonsville, Pepacton, and Neversink Reservoirs according to the operating protocol agreed to by the Decree Parties; effective June 1, 2011, the applicable operating protocol is the FFMP-OST. Additional details regarding the FFMP-OST are included in the Agreement of the Decree Parties to the 1954 U.S. Supreme Court Decree dated June 1, 2011 available at:

http://water.usgs.gov/osw/odrm/documents/ffmp_ost_052511_final.pdf.

The initial draft of this report that was discussed with NYSDEC and USFWS was based on the prior FFMP operating regime which had been in effect since October 1, 2007, but, by unanimous agreement of the Decree Parties, was superseded by the FFMP-OST effective June 1, 2011 . The figures, velocities, and flow values contained herein have been revised to reflect the FFMP-OST operating protocol. In general, although the FFMP-OST results in a slightly greater overall volume of releases below the dams associated with the proposed development compared to the prior FFMP protocol, the findings and conclusions based on the FFMP operating protocol, which were previously discussed with NYSDEC and USFWS and served as the basis for their respective conclusions regarding the lack of need for additional studies at this time, remain valid and unchanged by the revised analysis accounting for the FFMP-OST operating protocol.

The water available for hydroelectric generation at Cannonsville, Pepacton, and Neversink will be comprised of conservation releases, directed releases, and water that would otherwise spill to the extent that such releases are consistent with discharge mitigation releases as outlined in the applicable operating protocol. The DEP is currently not proposing to modify the magnitude, frequency, duration, and/or timing of discharges due to the addition of the hydropower facilities associated with the Project.

The characteristics of each proposed development, including details on the reservoir morphology, intake configuration, and proposed turbines, are provided below. In addition, Table 3.1-1 provides a summary of the existing intake structures associated with the proposed developments.

As part of this stage of the FERC licensing process, the City is analyzing the feasibility of the Project and developing conceptual designs and turbine configurations for each hydroelectric facility. Table 3.1-2 provides information regarding the number of turbines, type, rated net head, flow capacities, generation capacity, runner diameter, and rated speed provided by each vendor with respect to the conceptual turbine designs being analyzed for the Cannonsville development. Table 3.1-3 provides similar information with respect to the Neversink and Pepacton developments. Turbine-generator alternatives are still being evaluated by the City, and, thus, the information provided herein remains subject to change. In the event that any such changes in design occur and such changes result in materially different impacts than those discussed herein, a supplement to this report will be prepared.

3.2 Cannonsville Development

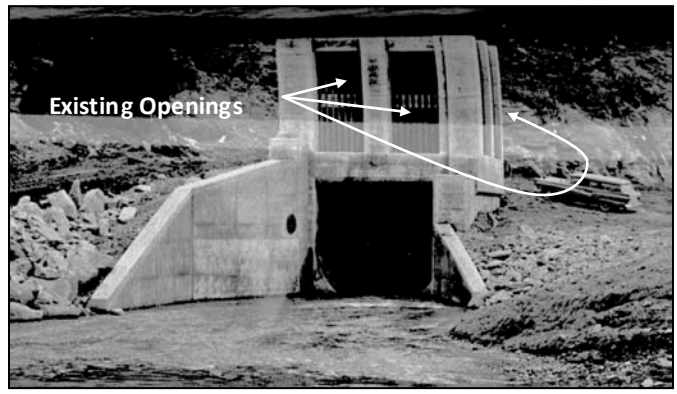
Reservoir Characteristics

The Cannonsville Dam is located on the West Branch of the Delaware River ("West Branch") in the Town of Deposit, Delaware County, New York. The impoundment, known as the Cannonsville Reservoir, is approximately 12 miles long and has a normal storage capacity of 300,000 acre-feet, a surface area of 4,800 acres at the spillway crest elevation of 1,150 feet above mean sea level ("msl"), and a mean depth of approximately 61 feet.

Generally, the Cannonsville Reservoir experiences a controlled drawdown in the fall/early winter to meet conservation and directed release requirements, and is refilled in the spring due to runoff from snow melt and precipitation. The average maximum drawdown over the last 25-year period is approximately 53.7 feet;[6] during this period, the maximum drawdown of 98.2 feet occurred on November 27, 2001 due to drought conditions. Reservoir water level and water quality data are presented in Section 4.

Intake Configuration

Low-level release works provide conservation releases to the West Branch downstream of the dam and are located at the southerly end of the dam (see Figure 3.2-1). Water supply diversions are provided from a separate intake structure location within the reservoir. The intake structure (pictured in a dewatered state below) is 41 feet above the floor of the reservoir, which is at an elevation of 999 feet above msl. The intake structure contains four individual intakes, each with a base elevation of 1020.5 feet above msl. Two intakes are 10 feet wide by 15 feet high, and the other two intakes are 7 feet wide by 15 feet high, for a total gross area of 510 ft^2. There are bar racks on each intake with clear spacing of approximately 7.5 inches. There is an additional 17.5-foot-wide by 18.75-foot-high (328 ft^2) opening at the base of the structure, which is blocked with stoplogs.[7]



Proposed Turbine Arrangement

The proposed Cannonsville development being analyzed by DEP would require the construction of a separate powerhouse adjacent to the existing low-level outlet works. Three turbine configurations are being evaluated: (a) four equal-sized large turbines; (b) two equal-sized large turbines plus two equal-sized small turbines; and (c) three equal-sized large turbines plus one minimum flow turbine. For each configuration, the turbines are horizontal-shaft with Francis-type runners, each in a pressure case.

The turbine discharges would be released through steel draft tubes into concrete chambers beneath the powerhouse floor. Water from these chambers will be discharged into the common tailrace channel. Bulkhead slots will be provided outside of the draft tube openings to enable bulkheads to be placed and the draft tube sections to be dewatered for maintenance.

Three turbine vendors have been contacted for the purposes of establishing preliminary layouts and capacities for the proposed Cannonsville development. Each vendor proposed different maximum hydraulic capacities: (a) Mavel – 950 cfs; (b) Andritz – 1,300 cfs; and (c) Voith – 1,500 cfs. Additional turbine details are provided in Table 3.1-2. Each turbine can be operated at various settings individually or in combination throughout their flow ranges, as necessary, based on varying reservoir water level conditions (head) and downstream discharge. Under the existing intake surface area of 510 ft^2, the maximum intake velocities for each of these turbine capacities range from 1.9 ft/s (Mavel) to 2.9 ft/s (Voith). Additional data regarding intake velocities is presented in Section 6.3.

3.3 Pepacton Development

Reservoir Characteristics

[6] Average maximum drawdown was calculated based on the lowest water level elevation recorded at each reservoir, averaged over the data recorded for the last 25 years.

[7] This opening was used to divert water during the construction of the dam and is no longer used.

The Downsville Dam is located on the East Branch of the Delaware River (East Branch) in the Town of Downsville, Delaware County, New York. The impoundment, known as the Pepacton Reservoir, is approximately 18 miles long, has a normal storage capacity of 441,000 acre-feet, a surface area of 5,700 acres at the spillway crest elevation of 1,280 feet above msl, and a mean depth of 67 feet. By volume (140.2 billion gallons), the reservoir is the largest within the DEP's water supply system.

Generally, a controlled drawdown occurs in the fall/early winter, and the reservoir is refilled in the spring due to runoff from snow melt and precipitation. The average maximum drawdown over the last 25-year period is approximately 51 feet; during this period, the maximum drawdown of 66 feet occurred on January 24, 2002 during drought conditions. Reservoir water level and water quality data are presented in Section 4.

Intake Configuration

The elevation at the bottom of the Pepacton intake structure (pictured in dewatered state below) is 1,106 feet above msl, approximately 174 feet below the spillway crest. Water conveyed below Downsville Dam passes through a portion of the original diversion tunnel (Figure 3.3-1). The diversion tunnel is 40 feet in diameter and has a concrete bulkhead at the inlet. There are four 8-foot by 3-foot rectangular openings that narrow to 6 feet by 2 feet, for a gross area of 96 ft^2. Bronze bar racks with clear spacing of 2.75 inches are located in front of the four openings. The diversion tunnel was blocked near its midpoint after dam completion and a separate 8-foot-diameter pipe was constructed off the diversion tunnel to route water to the bypass valves. The reservoir side of the bulkhead contains two sets of stop log guides. Each set of these guides blocks two intake tunnels and can be utilized during downstream maintenance. Water supply diversions are provided from a separate intake structure location within the reservoir.

Proposed Turbine Arrangement

The proposed Pepacton development being analyzed by DEP would consist of replacing one of the two valves within the existing outlet works with a turbine. To maintain required flows pursuant to the applicable operating protocol in effect, in the event that the turbine became inoperable, a bypass system around the proposed turbine is being proposed.

Two options are being evaluated for the Pepacton development, both involving a single horizontal Francis turbine; the maximum hydraulic capacity of the two options range from 92 cfs and 162 cfs. Additional turbine details are provided in Table 3.1-3. Under the maximum hydraulic capacity of 162 cfs, the intake velocity in front of the racks is 1.69 ft/s, which is below the USFWS velocity criteria of 2 ft/s. Additional data regarding intake velocities, including total intake velocity considering conservation and directed releases, is presented in Section 6.3.

3.4 Neversink Development

Reservoir Characteristics

The Neversink Dam is located on the Neversink River in the Town of Neversink, Sullivan County, New York. The impoundment, known as the Neversink Reservoir, is approximately five miles long, has a normal storage capacity of 112,000 acre-feet, a surface area of 1,477.8 acres at the spillway crest elevation of 1,440 feet above msl, and a mean depth of 72 feet.

Generally, a controlled drawdown occurs in the fall/early winter, and the reservoir is refilled in the spring due to runoff from snow melt and precipitation. The average maximum drawdown over the last 25-year period is approximately 58 feet; during this period, the maximum drawdown of 90 feet occurred on November 22, 1991 due to drought conditions. Reservoir water level and quality data are presented in Section 4.

Intake Configuration

At the proposed Neversink development, there is a common intake structure (pictured in a dewatered state below) that withdraws water from the impoundment and directs it either through the Neversink Tunnel for water supply purposes or through control valves and passes it downstream to maintain flows below the dam. The intake works are located north of the spillway weir (see Figure 3.4-1), and consist of a long submerged intake channel, a surface gatehouse structure, an intake structure, and control works.

The common intake structure includes eight openings located at different depths within the reservoir. Each opening is 9 feet wide by 16 feet high, for a total area of 1,152 ft^2. Because the Neversink Reservoir fluctuates seasonally, some intake openings may be above the reservoir elevation during certain times of the year.

Beyond these openings are two sets of bar racks, each 9 feet wide by 126 feet deep, that extend from the floor of the intake to above the reservoir water surface (*i.e.*, from elevation 1,314 ft above msl to elevation 1,440 feet above msl) for a total gross area of 2,268 ft^2. The clear spacing between the bars is 2 inches.

Water being diverted for water supply purposes via the Neversink Tunnel flows through stop shutters placed at four separate elevations within the intake structure (beyond the bar racks). Water released to the Neversink River is directed downward prior to the tunnel stop shutters through two trough openings in the floor of the intake structure (each four feet wide by nine feet long, for a total gross area of 72 ft^2). The elevation of the trough entrance is 1310.5 feet above msl.

From the trough openings, the water flows down and takes three 90 degree bends prior to entering the 36" intake pipes, travels through the release valves, and is discharged into the Neversink River. The centerline elevation of the 36" intake pipes is 1289 feet above msl. Diagrams depicting how water for water supply purposes and downstream releases flows through the intake structure at Neversink are provided in Figure 3.4-2, Figure 3.4-3a, and Figure 3.4-3b.

Proposed Turbine Arrangement

The proposed Neversink development being analyzed by DEP would consist of replacing one of the two valves within the existing gatehouse with a turbine. Flows through the remaining valve should be sufficient to maintain the flows required by the applicable operating protocol in effect; however, a bypass pipe around the turbine is proposed in the event that the turbine becomes inoperable.

A horizontal Francis turbine with a maximum hydraulic capacity of 100 cfs is being evaluated for the Neversink development. Additional turbine details are provided in Table 3.1-3. At the proposed maximum hydro discharge capacity of 100 cfs, the intake velocity in front of the two trough openings would equal 1.39 ft/s, below the USFWS velocity criteria. Additional data regarding intake velocities, including total intake velocity considering conservation and directed releases, is provided in Section 6.3.

Table 3.1-1: Intake size, velocity, and depth information.

Statistic	Cannonsville	Pepacton	Neversink
Spillway crest elevation	1150 ft above msl	1280 ft above msl	1440 ft above msl
Intake near Racks			
Intake dimensions and gross area	2 racks @ 10 ft x 15 ft 2 racks @ 7 ft x 15 ft Gross Area = 510 ft^2	4 racks @ 3 ft x 8 ft Gross Area = 96 ft^2	2 trough openings @ 4 ft x 9 ft Gross Area = 72 ft^2
Elevation at bottom of intake and depth from spillway crest to bottom of intake	1020.5 ft above msl (129.5 ft deep)	1106 ft above msl (174 ft deep)	1289 ft above msl (151 ft) (represents intake to 36" pipes)
Elevation at top of intake and depth from spillway crest to top of intake	1035.5 ft above msl (114.5 ft deep)	1131.75 ft above msl (148.25 ft deep)	1310.5 ft above msl (129.5 ft deep) (represents trough intake)
Intake racks	Yes	Yes	Yes
Bar rack clear spacing	~7.5 in	2.75 in	2 in
Velocity in front of intake under maximum hydro discharge capacity	1,500 cfs/510 ft^2 = 2.9 ft/s *(Voith)* 1,300 cfs/510 ft^2 = 2.5 ft/s *(Andritz)* 950 cfs/510 ft^2 = 1.9 ft/s *(Mavel)*	92 cfs/96 ft^2 = 0.96 ft/s (*Andritz 1*) 162 cfs/96 ft^2 = 1.69 ft/s (*Andritz 2*)	100 cfs/72 ft^2 = 1.39 ft/s *(Mavel)*
Velocity in front of intake under median annual FFMP-OST flows	275 cfs/510 ft^2 = 0.54 ft/s	140 cfs/96 ft^2 = 1.46 ft/s	90 cfs/72 ft^2 = 1.25 ft/s

Notes: The velocities in front of the intake structures are based on the turbine hydraulic capacities of each proposed development (as noted in Section 3.1, these capacities are subject to change). Additional data regarding intake velocities, including total intake velocity considering conservation and directed releases, and draft, if applicable, is provided in Section 6.3.

Table 3.1-2: Turbine vendor equipment statistics – Cannonsville development.

Characteristic	Vendor: Andritz	Vendor: Voith	Vendor: Mavel
No. of Turbines	4 equal size	2 large, 2 small	3 equal size, 1 small
Turbine Type	Horizontal Francis	Horizontal Francis	Horizontal Francis
Rated Net Head	122 ft	122 ft	122 ft
Min and Max Turbine Flow Capacity	130-325 cfs/turbine 1,300 cfs total max	Sm. Turbines – 50-125 cfs Lg. Turbines – 250-625 cfs 1,500 cfs total max	Sm. Turbine – 70-140 cfs Lg. Turbines – 140-270 cfs 950 cfs total max
Max Turbine Generation Output	3.0 MW/unit Total = 12.0 MW	Sm. Turbines – 1.185 MW Lg. Turbines – 5.855 MW Total = 14.08 MW	Sm. Turbine – 1.287 MW Lg. Turbines – 2.547 MW Total = 8.928 MW
Runner Diameter	3.67 ft	Sm. Turbines – 2.92 ft Lg. Turbines – 5.77 ft	Sm. Turbine –2.36 ft Lg. Turbines –3.44 ft
Rated Speed	450 rpm	Sm. Turbines – 450 rpm Lg. Turbines – 257.1 rpm	Sm. Turbine – 720 rpm Lg. Turbines – 450 rpm

Table 3.1-3: Turbine vendor equipment statistics – Pepacton and Neversink developments.

Characteristic	*Pepacton* Vendor: Andritz 1	*Pepacton* Vendor: Andritz 2	*Neversink* Vendor: Mavel
No. of Turbines	1	1	1
Turbine Type	Horizontal Francis	Horizontal Francis	Horizontal Francis
Rated Net Head	136 ft	136 ft	125 ft
Min and Max Turbine Flow Capacity	25-92 cfs	65-162 cfs	50-100 cfs
Max Turbine Generation Output	0.950 MW	1.700 MW	0.940 MW
Runner Diameter	2.0 ft	2.62 ft	1.96 ft
Rated Speed	900 rpm	600 rpm	900 rpm

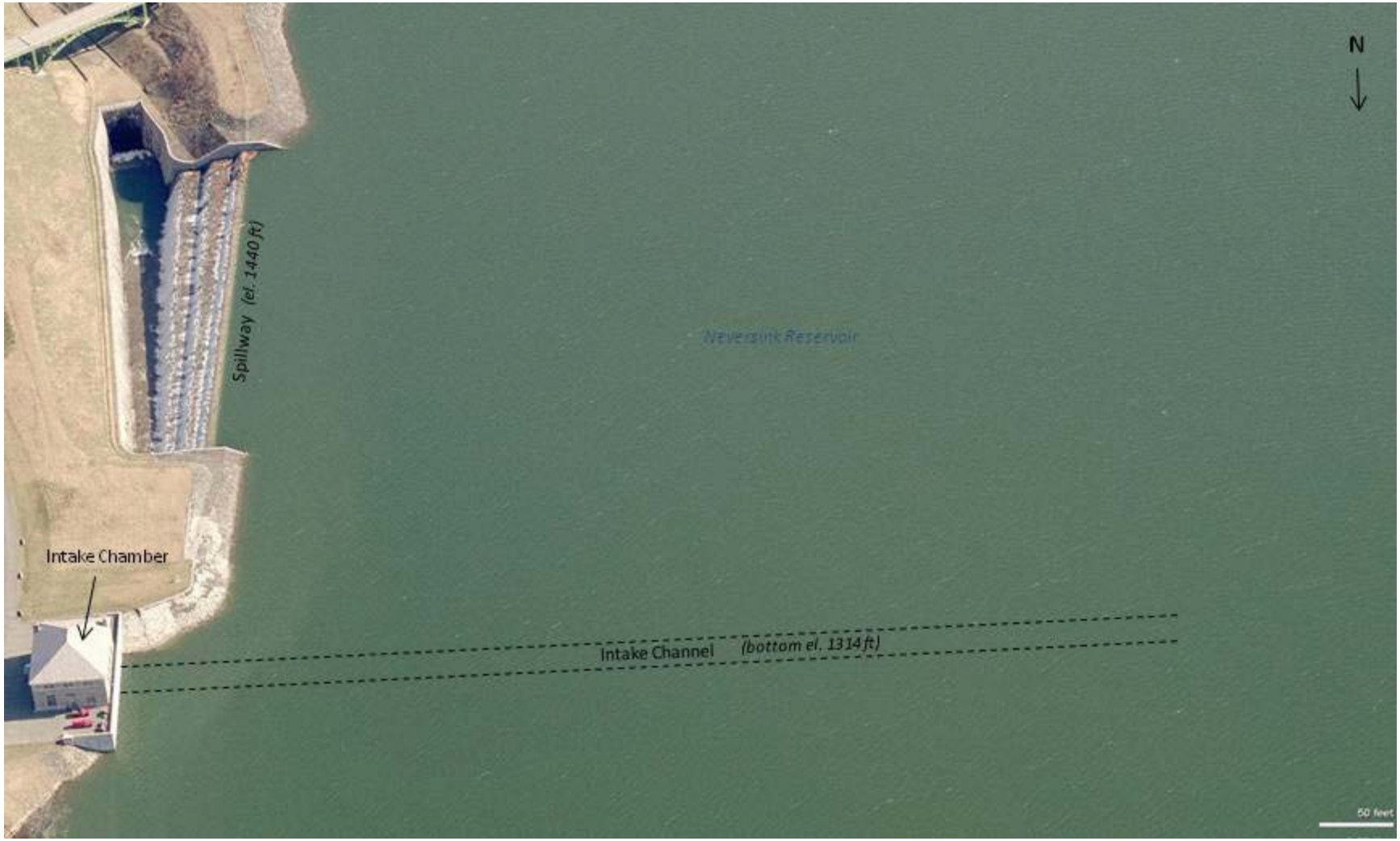
Figure 3.2-1: Cannonsville intake structure location.

Note: Not to scale. Locations of intake structures are approximate for schematic purposes. **Imagery Source:** Microsoft Bing Maps, 2010.

Figure 3.3-1: Pepacton intake structure location.

Note: Not to scale. Locations of intake structures are approximate for schematic purposes. **Imagery Source:** Microsoft Bing Maps, 2010.

Figure 3.4-1: Neversink intake structure location.



Note: Not to scale. Locations of intake structures are approximate for schematic purposes. **Imagery Source:** Microsoft Bing Maps, 2010.

Figure 3.4-2: Cross section of Neversink intake structure.

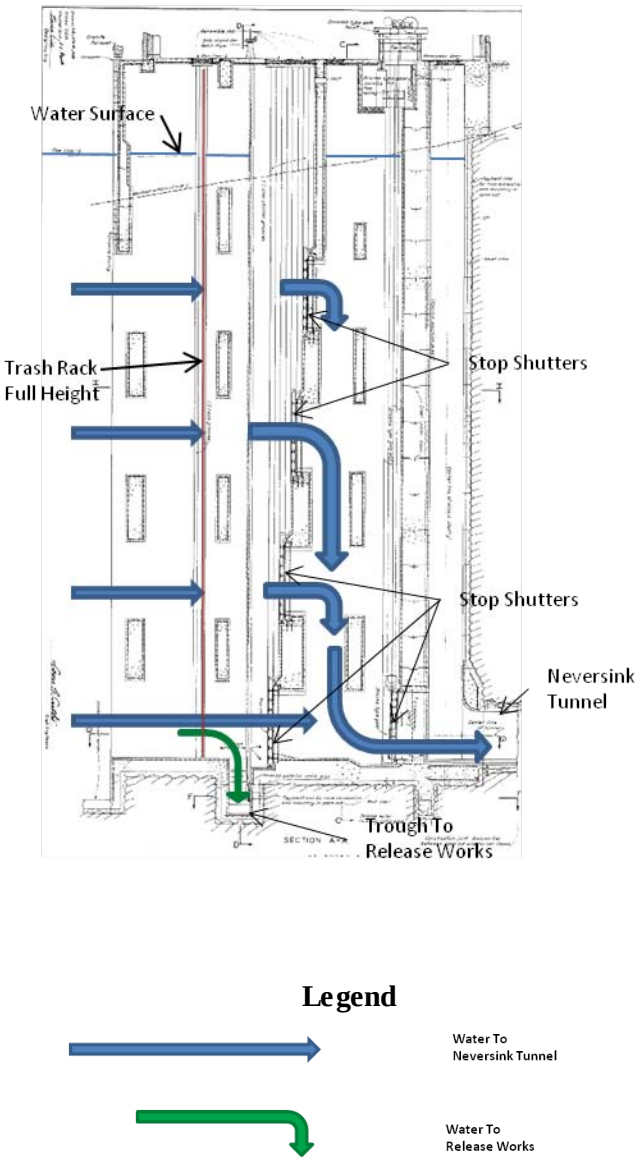
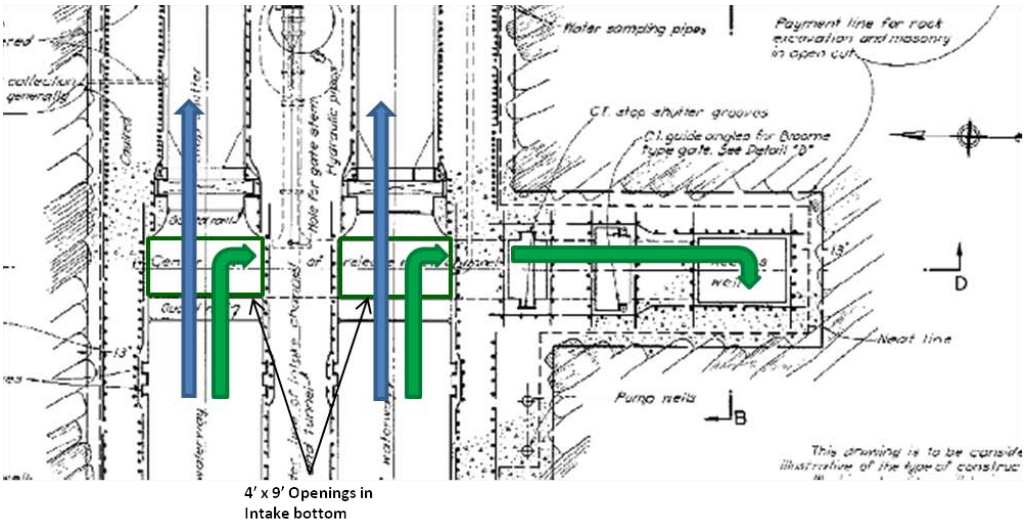
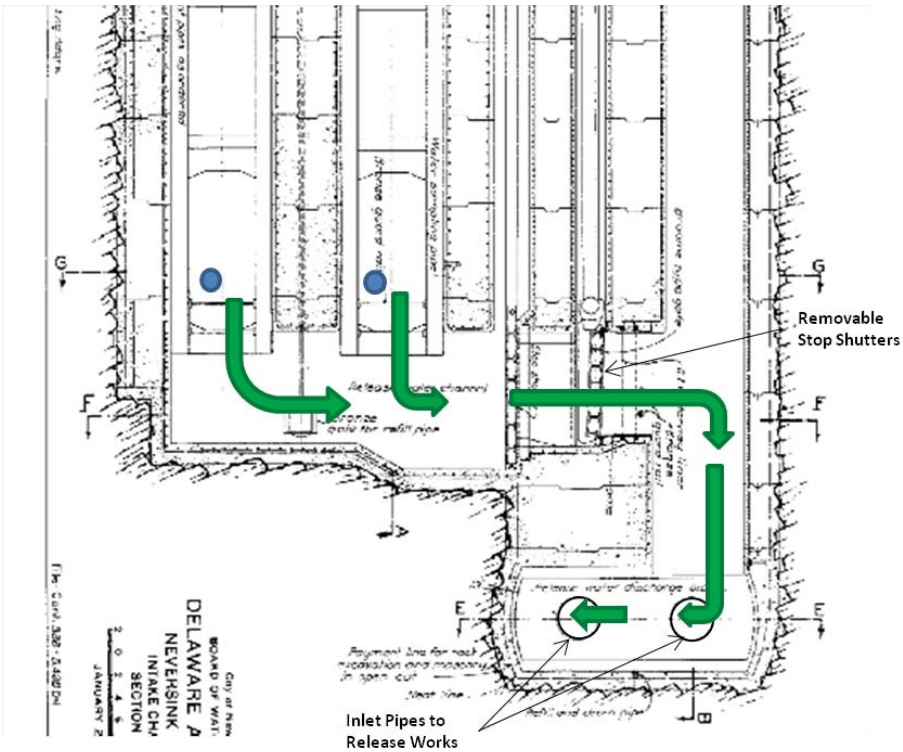


Figure 3.4-3a: Plan view of Neversink intake troughs.



The plan view above is looking down at the bottom of the intake and release valve channel. Water flowing to the release works enters the intake troughs horizontally and bends to the south (right) and enters the access well located on the far right.

Figure 3.4-3b: Cross section of Neversink intake troughs.



The section view above shows the flow of water to the release works looking from the front face of the intake structure.

4.0 WATER LEVEL AND WATER QUALITY ANALYSIS

Water quality can be an important factor affecting fish distribution in reservoirs. This section summarizes the water level and water quality conditions in the Cannonsville, Pepacton, and Neversink Reservoirs.

The DEP maintains a water quality database with data from 1987 to the present (in electronic format since 1992). The database includes DO and temperature profiles measured at various locations (and at various depths at each location) in each reservoir, including one sampling location in close proximity to each intake structure. Typically, the sampling is conducted twice per month during ice-out conditions, with the exception of 1993, when samples were collected approximately once per month. In addition, DEP collects DO and temperature data immediately below the three dams. The DEP also records the daily water level of each reservoir, which can be converted to storage capacity. Discharges are recorded at the United States Geological Survey (USGS) gages that are located immediately below each dam.

In lieu of plotting the water quality data for all 17 full years of available electronic data (1993-2009), NYSDEC recommended selecting three years from the period representing wet, dry, and average summers, based on the storage capacity at the Cannonsville Reservoir (see Section 4.1 below).

Water level elevation duration curves were developed on an annual and monthly basis for each reservoir. These curves were based on the entire period of record from the OASIS model (1948-2008). Monthly duration curves were broken into four quarters for clarity. The plots show the spillway crest elevation, as well as the top and bottom, as appropriate, of the intake structures in each reservoir. Further information regarding the water level duration curves for each proposed development is provided in Sections 4.2 through 4.4.

DO and temperature profiles were developed for the sampling locations closest to the intake structures for the selected wet, dry, and average years. DO and temperature profile data were typically collected by DEP in intervals of one meter; however, it is important to note that the interval does vary. Recorded sample depths (in meters) were converted to actual elevations (in feet above msl) using daily reservoir water level elevation data. The profiles were then analyzed to identify trends in factors such as the depth of the thermocline compared to the intake structure elevation, as well as DO concentrations near the intake structures. Results of the DO and temperature analysis for each reservoir are provided in Sections 4.2 through 4.4.

Although water quality profiles were not collected during winter conditions at the three reservoirs, typical vertical patterns of temperature and DO levels in reservoirs during winter are predictable. Because water is most dense at 4 °C, during winter the bottom layer of the lake will remain warmer than the surface. Assuming the bottom layer is well oxygenated, fish tend to prefer this relatively warmer layer and can congregate there.

Some limnological terms used in this section are defined here to understand the following analysis:

> Thermocline: The specific elevation in the water column where the change in temperature over depth is the maximum.
>
> Thermal stratification: Existence of a layer of warm water (epilimnion) overlying a colder mass of relatively stagnant water (hypolimnion) in a water body due to cold water being denser than warm water.
>
> Epilimnion: The upper, wind-mixed layer of a thermally stratified lake.

Metalimnion: The middle or transitional zone between the epilimnion and the colder hypolimnion layers in a stratified lake. This layer contains the thermocline.

Hypolimnion: The bottom, and most dense layer of a stratified lake. It is typically the coldest layer in the summer and warmest in the winter. It is isolated from wind mixing and typically too dark for much plant photosynthesis to occur.

4.1 Selection of Representative Wet, Dry, and Average Years

During the study plan development process, NYSDEC recommended selecting representative wet, dry, and average years from the period for which electronic data is available (1993-2009) based on the storage capacity at the Cannonsville Reservoir, with a wet year having a storage capacity above 80% during the summer, an average year having a storage capacity above 60% during the summer, and a dry year having a storage capacity of less than 40% by mid-August.[8] However, NYSDEC requested that the years 2004-2007 be eliminated from consideration as the representative years due to major flooding during those years.

To select the representative years, daily water level data at the Cannonsville Reservoir for the period 1993-2009 were converted to percent storage capacity. Percent capacity and time were plotted for the summer period (July through mid-September) of each year, as shown in Figure 4.1-1. Based on this data, 1996 was selected as the representative wet year because the storage capacity did not fall below 80% during the summer months. 1998 was selected as the representative average year because the capacity did not fall below 60% during the summer months (although it did drop below this level by late September). Finally, although the reservoir did not drop below 40% capacity in mid-August in any of the years in the period, 1993 showed the earliest drop below 40% (occurring in late August); therefore it was selected as the representative dry year.

Hydrographs for USGS Gage No. 01425000 on the West Branch below the Cannonsville Dam were plotted for the selected wet, dry, and average years to evaluate corresponding water discharge rates (see Figure 4.1-2). As depicted in Figure 4.1-2, mid-summer discharges were highest during the representative dry year (1993) due to directed releases.

4.2 Cannonsville Development

The annual reservoir elevation duration curve at the Cannonsville Reservoir based on the OASIS model for the period of record 1948-2008 is shown in Figure 4.2-1. Monthly water level duration curves, broken into four quarters, are shown in Figures 4.2-2 through 4.2-5. Temperature and DO profiles for the representative wet, dry, and average years are shown in Figures 4.2-6 through 4.2-8. On all of these graphs, dashed lines representing the spillway crest elevation (1,150 ft above msl), the top of the intake (1,035.5 ft above msl), and the bottom of the intake (1,020.5 ft above msl) are shown for reference.

The top of the temperature/DO profiles represent the reservoir water level on the sampling date, which can be compared to the spillway crest elevation (top dashed line) to approximate drawdown.

Reservoir Water Level

Figure 4.2-1, the annual water level duration curve, shows that 50% of the time, the maximum amount the Cannonsville Reservoir is drawn down is approximately 30 feet by the end of October. The overall maximum amount it is drawn down is about 87 feet by early December. For reference, this latter level is

[8] The storage capacity of the Cannonsville Reservoir is 300,000 acre-feet. The percentages refer to the remaining reservoir volume.

about 27.5 feet above the top of the intake structure. The monthly water level duration curves for the Cannonsville Reservoir (Figures 4.2-2 through 4.2-5) show that reservoir drawdowns greater than 80 feet occur less than 5% of the time. During the months of July, August, and September (Figure 4.2-4), the reservoir is drawn down approximately 8, 16, and 23 feet, respectively, 50% of the time.

Dissolved Oxygen and Temperature Profiles

Wet Year

Temperature and DO profiles measured in the Cannonsville Reservoir near the intake structure during the representative wet year (1996) are shown in Figure 4.2-6. Readings were taken approximately twice a month from May through November. The reservoir began to show thermal stratification in June, lasting through October. The depth of the thermocline was generally about 100 feet above the intake in June, dropping to about 50 feet above the intake by October.

Low DO levels (approximately five ppm or lower) were observed at the bottom of the profiles during September and October. The lowest DO levels, however, were observed within the metalimnion. This phenomenon, referred to as a metalimnetic oxygen minimum, was investigated by Effler *et al.* (1998) and determined to be caused by respiration of relatively high concentrations of phytoplankton biomass located below the compensation depth (the depth at which photosynthetic production matches respiratory or metabolic consumption) within the metalimnion.

In the Cannonsville Reservoir, this layer of minimum DO began to develop in June and intensified throughout the summer, resulting in an anoxic condition in the metalimnion by mid-September. The location of the layer of minimum DO also dropped lower in the reservoir throughout the year, starting around 90 feet above the intake structure at the beginning of July. Although the reservoir was no longer thermally stratified in November, the metalimnetic oxygen minimum was still present, located around 40 feet above the intake structure. Despite the anoxic condition in the metalimnion, the hypolimnion remained cool and well-oxygenated.

Dry Year

Temperature and DO profiles for the representative dry year (1993) are shown in Figure 4.2-7. Readings were taken about once per month from the end of April through the beginning of November. Thermal stratification began to develop by May 10 and intensified through the summer. The location of the thermocline was about 100 feet above the intake structure in May. Due to a reservoir drawdown throughout the summer, the thermocline dropped to approximately 17 feet above the intake structure; by September 13 the metalimnion, having the lowest DO, essentially replaced the hypolimnion.

The metalimnetic oxygen minimum was less pronounced during the months of July and August in comparison to the representative wet year, and DO levels in the metalimnion never fell to 0 ppm, as occurred during the representative wet year. The lowest reading was 1.2 ppm in mid-September.

Average Year

Temperature and DO profiles for the representative average year (1998) are shown in Figure 4.2-8. Readings were taken approximately twice per month from mid-April through mid-December. Thermal stratification began in May and persisted throughout the summer, with the thermocline located about 100 feet above the intake structure in May. Similar to the dry year, the thermocline location decreased in elevation to within approximately 25 feet above the intake structure by October due to reservoir drawdown. The metalimnetic oxygen minimum pattern was again observed, beginning in late June with DO levels decreasing through September; the lowest DO reading being 0.7 ppm on September 21. Low DO levels (below 5 ppm) were also observed in September and October.

Similar to the situation during the dry year, but occurring later in the year, the hypolimnion volume was being diminished during the representative average year during reservoir drawdown. By October 5 the metalimnion, having the lowest DO, essentially replaced the hypolimnion. However, the reservoir was well-mixed by November 2.

4.3 Pepacton Development

The annual water level duration curve at the Pepacton Reservoir based on the OASIS model for the period of record 1948-2008 is shown in Figure 4.3-1. Monthly water level duration curves are shown in Figures 4.3-2 through 4.3-5. Temperature and DO profiles for the representative wet, dry, and average years are shown in Figures 4.3-6 through 4.3-8. On all of these graphs, dashed lines representing the spillway crest elevation (1,280 ft above msl), the top of the intake structure (1,131.75 ft above msl), and the bottom of the intake structure (1,106 ft above msl) are shown for reference.

Reservoir Water Level

Figure 4.3-1, the annual water level duration curve, shows that 50% of the time, the maximum amount the Pepacton Reservoir is drawn down is approximately 34 feet by mid-November. The overall maximum amount it is drawn down is about 105 feet by mid-November. For reference, this latter level is about 43 feet above the top of the intake structure. The monthly water level duration curves for the Pepacton Reservoir (Figures 4.3-2 through 4.3-5) show that reservoir drawdowns greater than 80 feet occur less than 5% of the time. During the months of July, August, and September (Figure 4.3-4), the reservoir is drawn down approximately 9, 16, and 24 feet, respectively, 50% of the time.

Dissolved Oxygen and Temperature Profiles

Wet Year

Temperature and DO profiles measured near the intake structure during the representative wet year (1996) are shown in Figure 4.3-6. Readings were taken approximately twice a month from mid-April through the beginning of December. The reservoir began to thermally stratify in June, lasting through October. The depth of the thermocline was generally 100 to 140 feet above the intake structure, as the reservoir remained at full capacity during the year.

DO levels near the intake structure never dropped below 6 ppm, with the lowest reading observed in late September. A metalimnetic oxygen minimum area was present from late July through September, while the hypolimnion remained well-oxygenated. The lowest DO reading of 2.1 ppm was measured in the metalimnion in late September, at a depth approximately 95 feet above the intake structure.

Dry Year

Temperature and DO profiles measured near the intake structure during the representative dry year (1993) are shown in Figure 4.3-7. Readings were taken about once per month from the end of May through November. Thermal stratification began in May and became more pronounced with a greater range of temperatures across the water column through the summer. The depth of the thermocline increased as the reservoir was drawn down throughout the summer. In October, the thermocline was located approximately 45 feet above the intake structure. A moderate metalimnetic oxygen minimum area was observed during the months of August through October, with the lowest DO reading being 5.6 ppm in September.

The extent of this drawdown and its effects on water quality were not as severe as observed in the Cannonsville Reservoir during the representative dry year. In the Pepacton Reservoir, there was a metalimnetic DO minimum and a “sinking” thermocline, but a hypolimnetic DO deficit was not evident.

Average Year

Temperature and DO profiles measured near the intake structure during the representative average year (1998) are shown in Figure 4.3-8. Readings were taken approximately twice per month from April through the beginning of December. Thermal stratification began in May and intensified throughout the summer, with the depth of the thermocline increasing as the reservoir was drawn down. The metalimnetic oxygen minimum area was observed, beginning in July, intensifying throughout the summer, and diminishing by November. The lowest DO reading was 4.69 ppm, recorded from the metalimnion on September 16, when the thermocline depth was located approximately 100 feet above the intake structure. During the average year, DO levels never dropped below 6 ppm at elevations near the intake structure, with the lowest observation being 6.8 ppm on November 10.

4.4 Neversink Development

The annual water level duration curve at Neversink Reservoir based on the OASIS model for the period of record 1948-2008 is shown in Figure 4.4-1. Monthly water level duration curves are shown in Figures 4.4-2 through 4.4-5. Temperature and DO profiles for the representative wet, dry, and average years are shown in Figures 4.4-6 through 4.4-8. On all of these graphs, dashed lines representing the spillway crest elevation (1,440 ft above msl), and the elevation of the intake trough openings for releases (1310.5 ft above msl) are shown for reference.

Reservoir Water Level

Figure 4.4-1, the annual water level duration curve, shows that 50% of the time, the maximum amount the Neversink Reservoir is drawn down is approximately 32 feet by the beginning of November. The overall maximum amount it is drawn down is about 99 feet by mid-November. The monthly water level duration curves for the Neversink Reservoir (Figures 4.4-2 through 4.4-5) show that reservoir drawdowns greater than 80 feet occur less than 5% of the time. During the months of July, August, and September (Figure 4.4-4), the reservoir is drawn down approximately 5, 9, and 19 feet, respectively, 50% of the time.

Dissolved Oxygen and Temperature Profiles

Wet Year

Temperature and DO profiles measured near the intake structure during the representative wet year (1996) are shown in Figure 4.4-6. Readings were taken approximately twice a month from the end of April through the beginning of December. The reservoir began to show thermal stratification in May, lasting through October. The depth of the thermocline increased as the summer progressed. In May, the thermocline was located approximately 100 feet above the intake trough openings, whereas in October, the thermocline was located approximately 40 feet above the intake trough openings.

DO concentrations were fairly high, with the lowest reading of 5.4 ppm occurring in a slight metalimnetic oxygen minimum area on October 7. The reservoir was well-mixed by late October.

Dry Year

Temperature and DO profiles for the representative dry year (1993) are shown in Figure 4.4-7. Readings were taken about once per month from mid-May through mid-November. Thermal stratification began in June and intensified through the summer, with the thermocline dropping from approximately 100 feet above the intake trough openings in June to approximately 15 feet above the intake trough openings by October 18, due to a reservoir drawdown. DO levels were relatively high throughout the summer, with the lowest reading being 7 ppm in August.

Average Year

Temperature and DO profiles for the representative average year (1998) are shown in Figure 4.4-8. Readings were taken approximately twice per month from mid-April through mid-December. Thermal stratification began in May and intensified throughout the summer, with the depth of the thermocline dropping from approximately 110 feet above the intake trough openings in May to approximately 20 feet above the intake trough openings by October 19, again due to a reservoir drawdown. A metalimnetic oxygen deficit was slightly more pronounced than during the representative wet or dry years, but still not as prominent as that observed in the Cannonsville Reservoir. The lowest DO level of 5 ppm was recorded on September 22.

In the Neversink Reservoir, the thermocline depth was related to reservoir drawdown and the amount of precipitation each year. All reservoir layers remained well oxygenated throughout the year.

4.5 Proportional Water Uses

In response to a specific request from NYSDEC, the quantity of water that is being proposed for hydropower use was compared to withdrawals for water supply purposes, as well as downstream conservation and directed releases at each proposed development.

Figures 4.5-1 through 4.5-3 depict, on an annual basis, the average withdrawal volumes in cfs for water supply compared to directed and conservation releases. The data is based on the OASIS model results and excludes water spilling over the dams in the downstream flow releases.

As noted in Sections 3.2 and 3.3, the water supply withdrawal points in the Cannonsville and Pepacton Reservoirs are at different locations than the intake structures for the downstream releases.

Figure 4.1-1: Selection of representative wet, dry, and average summers.

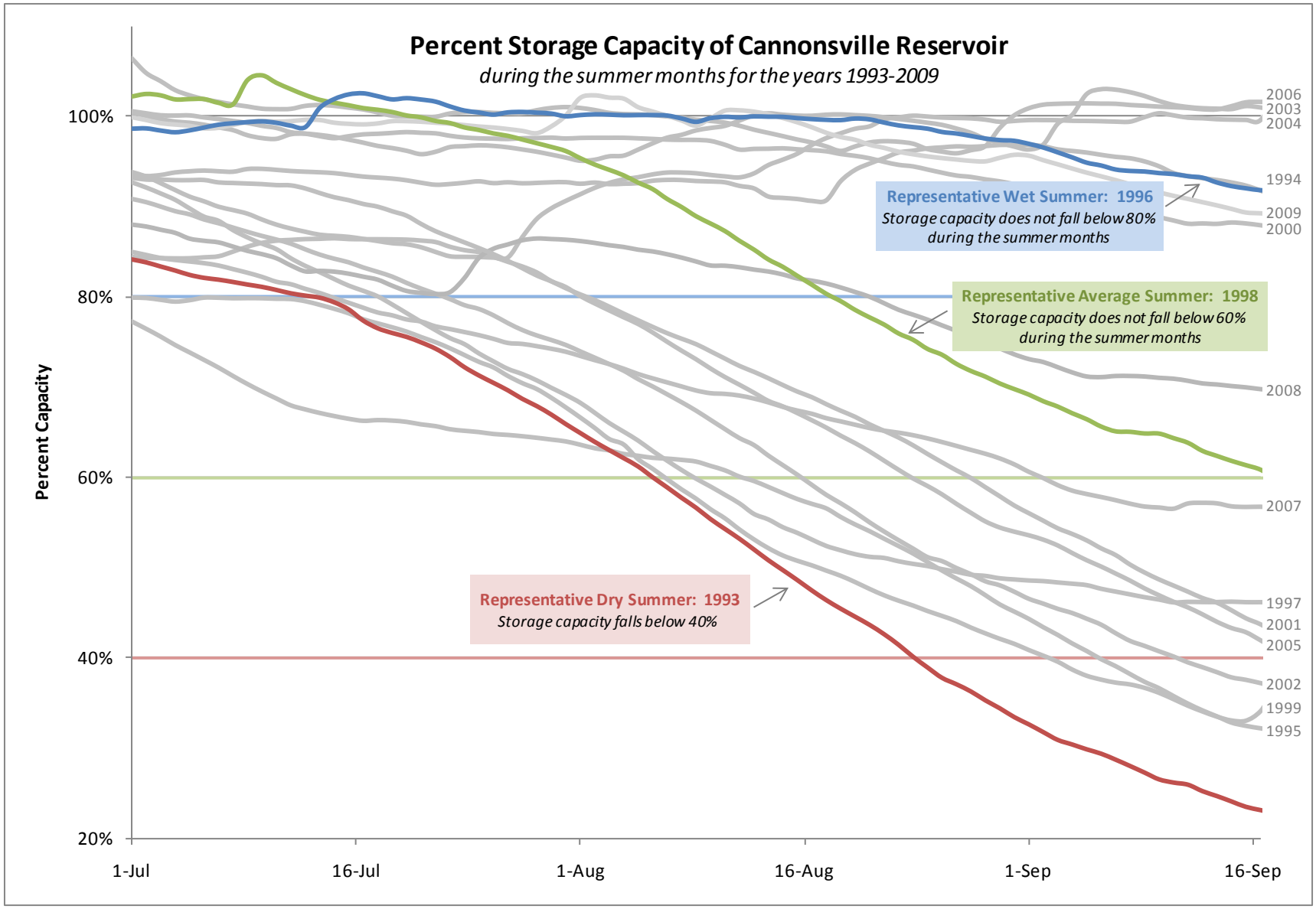


Figure 4.1-2: Hydrographs for representative wet, dry, & average summers.

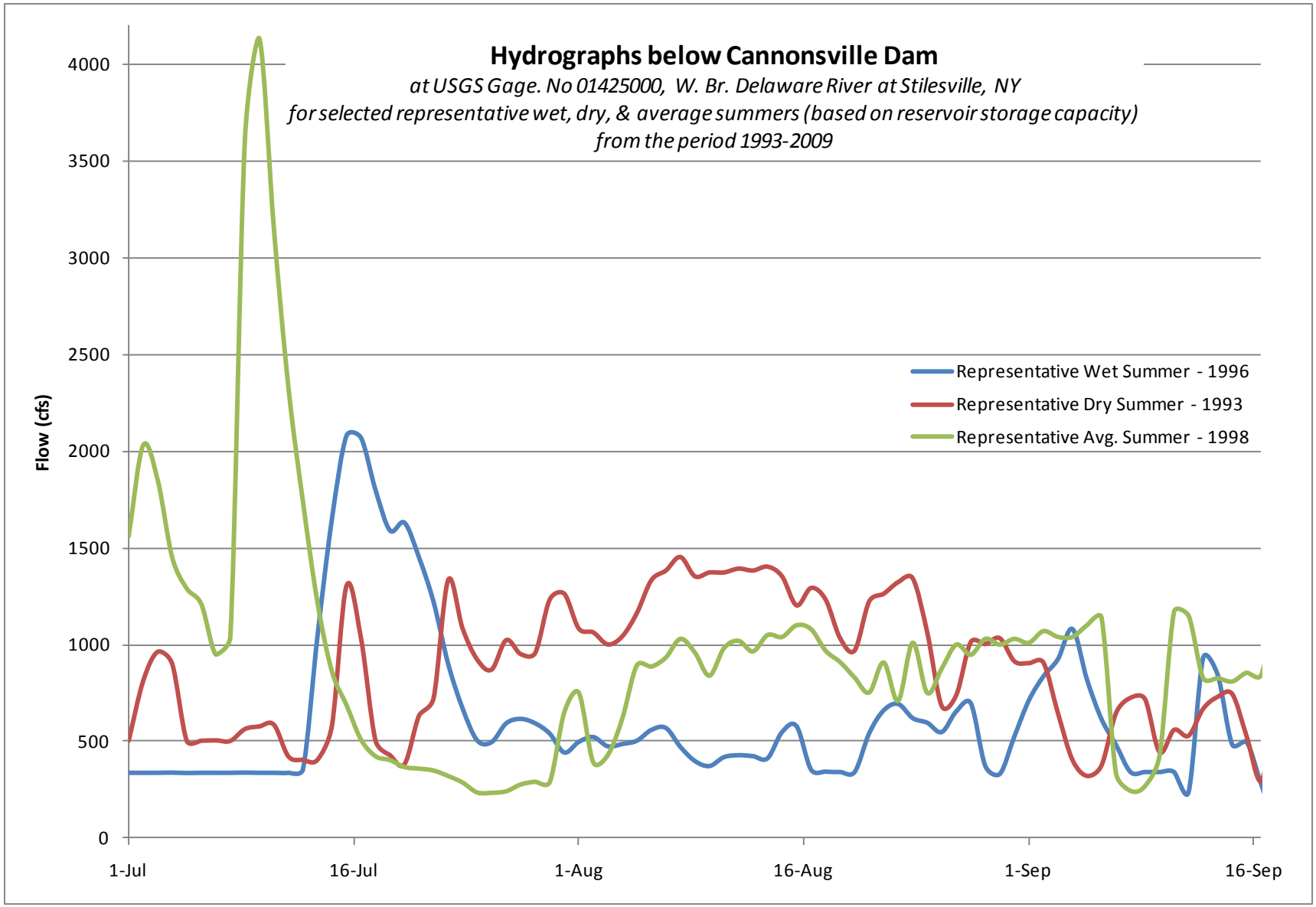


Figure 4.2-1: Annual water level duration curves at Cannonsville Reservoir.

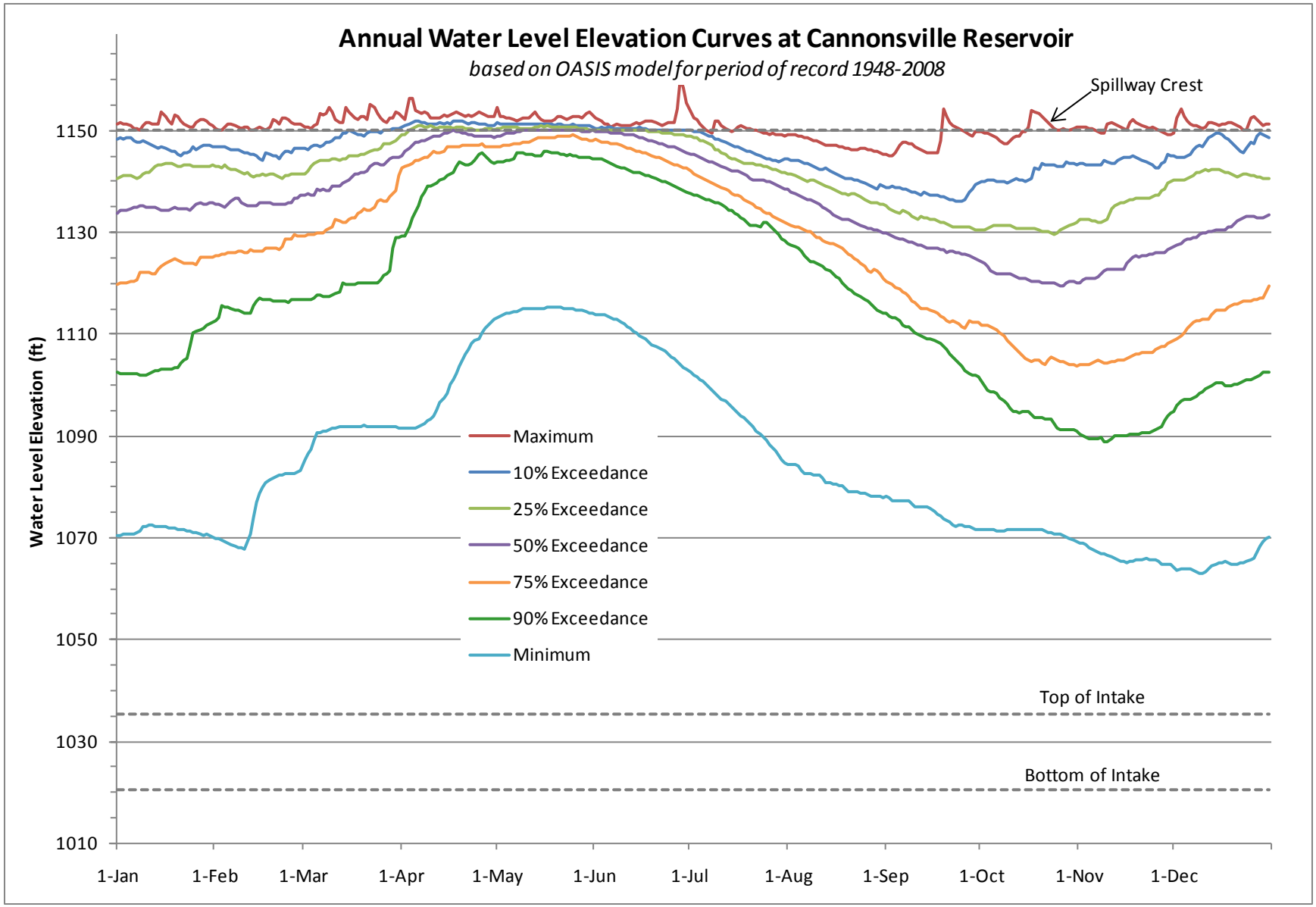


Figure 4.2-2: Water level duration curves at Cannonsville Reservoir for Jan, Feb, and Mar.

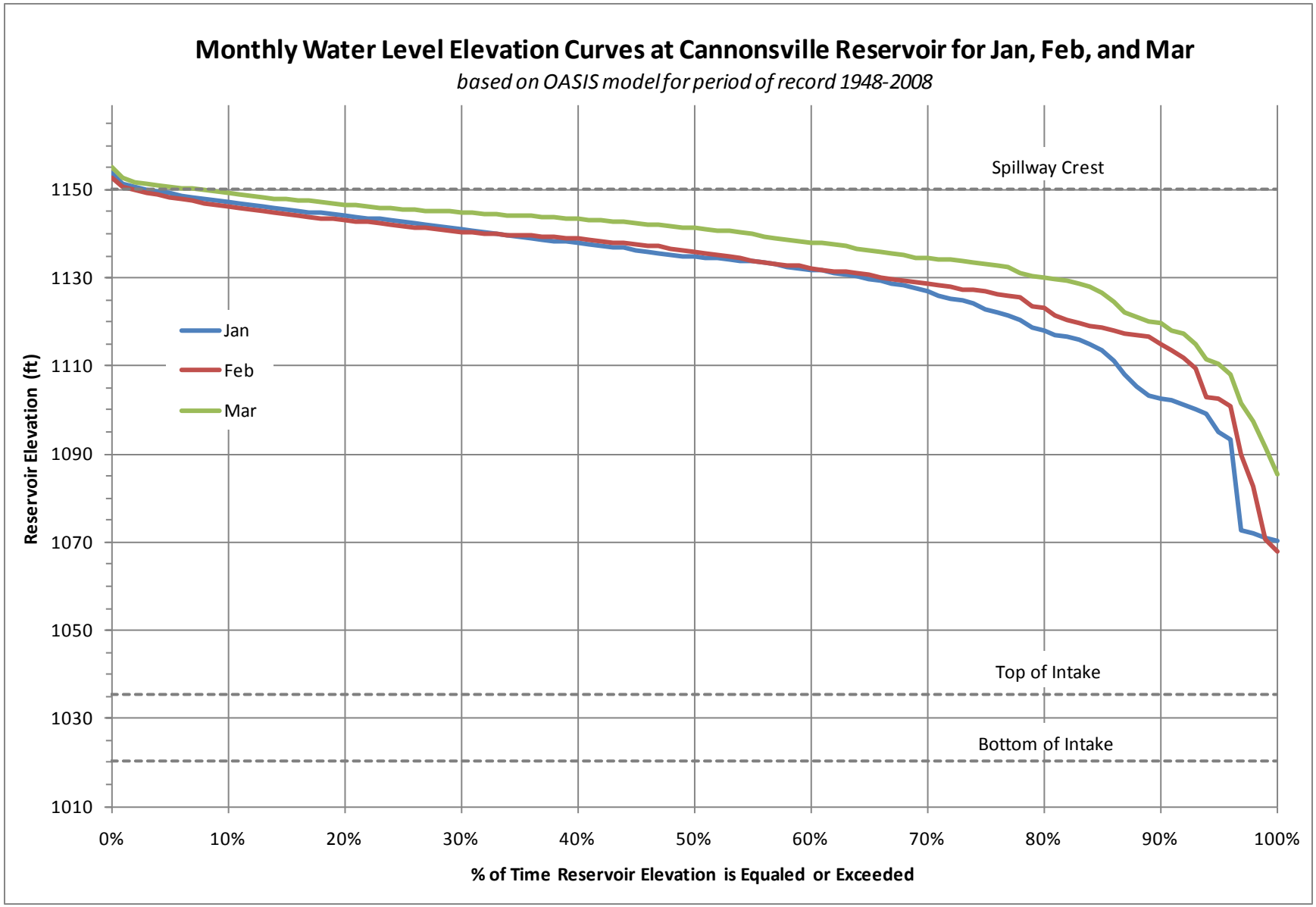


Figure 4.2-3: Water level duration curves at Cannonsville Reservoir for Apr, May, and Jun.

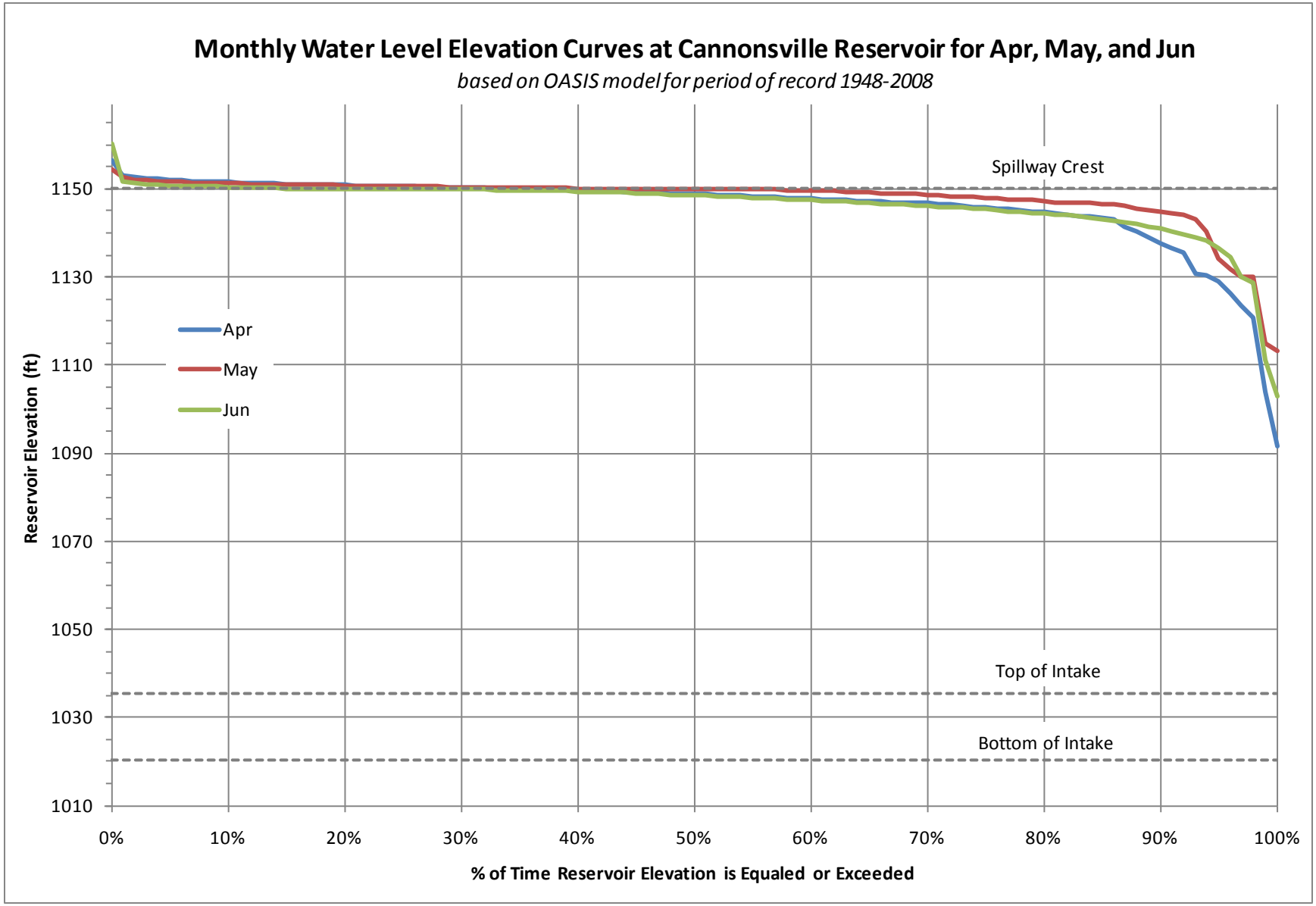


Figure 4.2-4: Water level duration curves at Cannonsville Reservoir for Jul, Aug, and Sep.

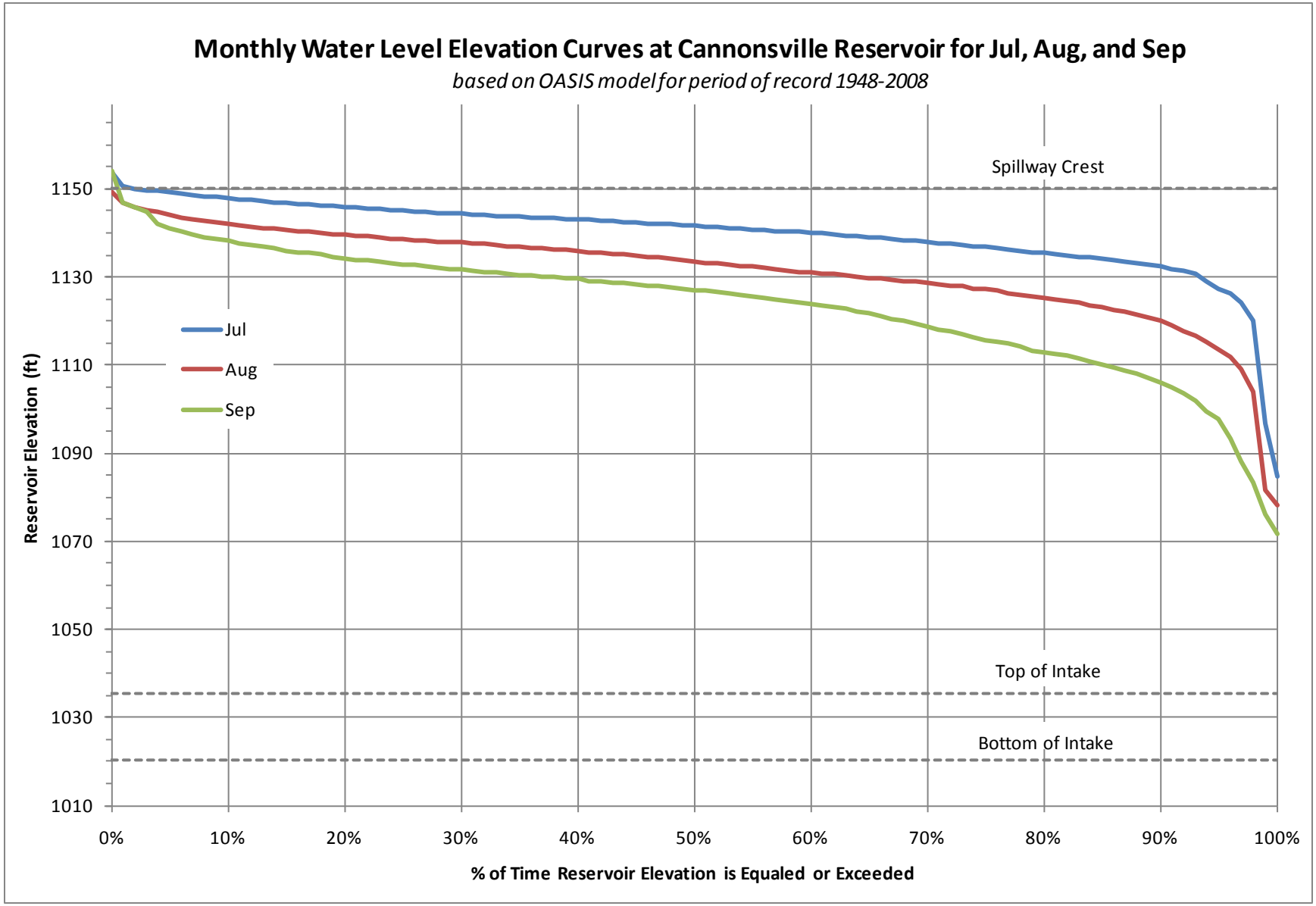


Figure 4.2-5: Water level duration curves at Cannonsville Reservoir for Oct, Nov, and Dec.

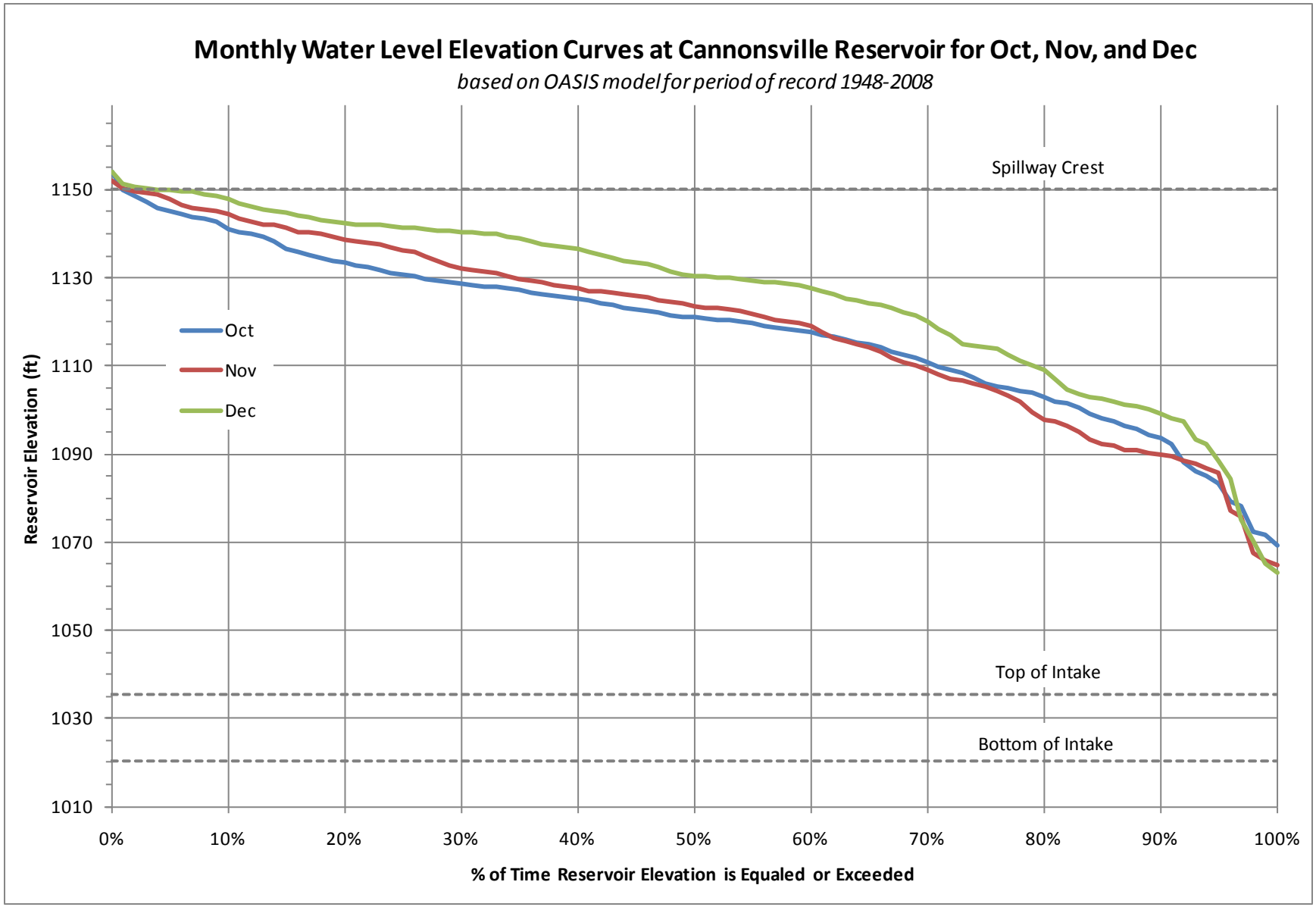
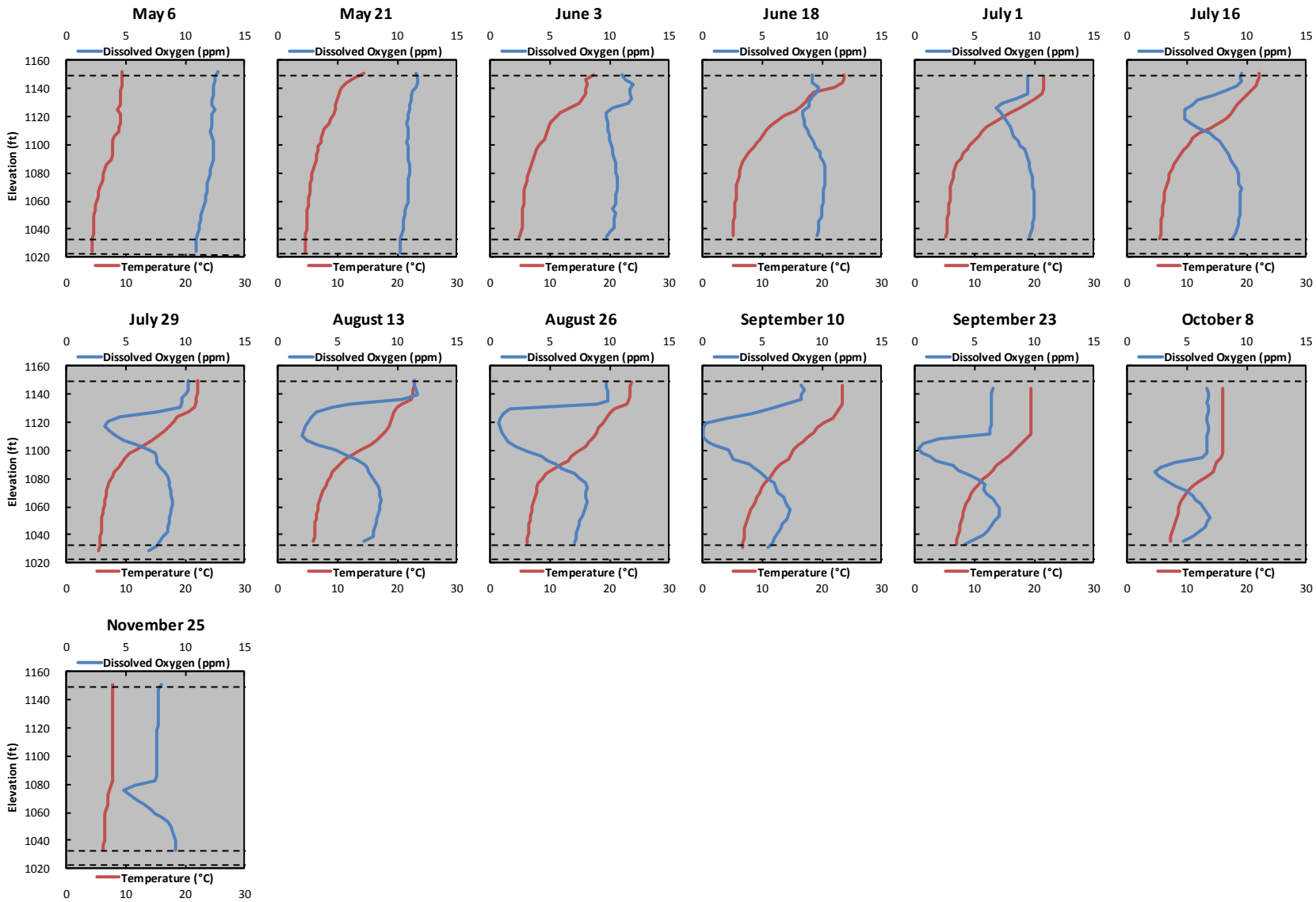
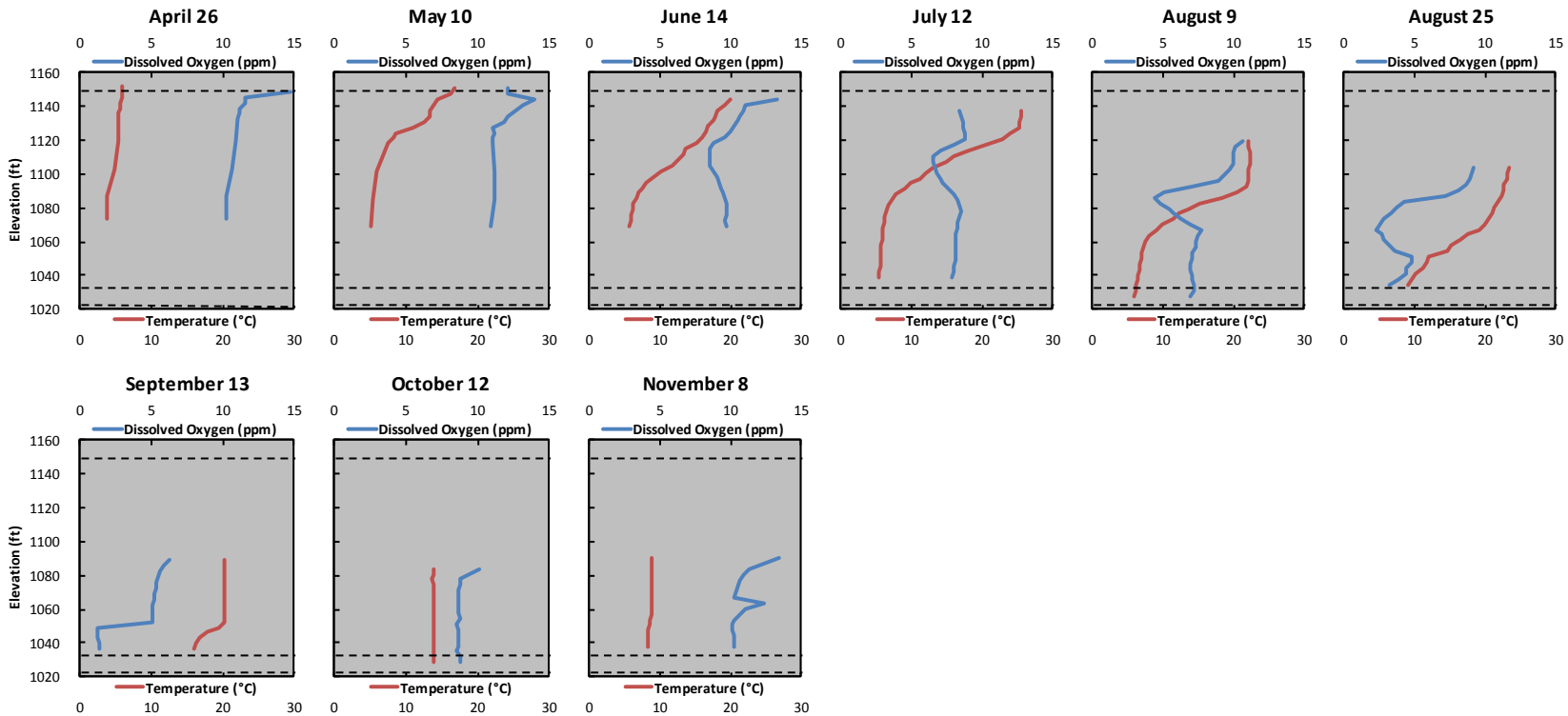


Figure 4.2-6: Temperature & DO profiles at Cannonsville Reservoir for the wet year (1996).



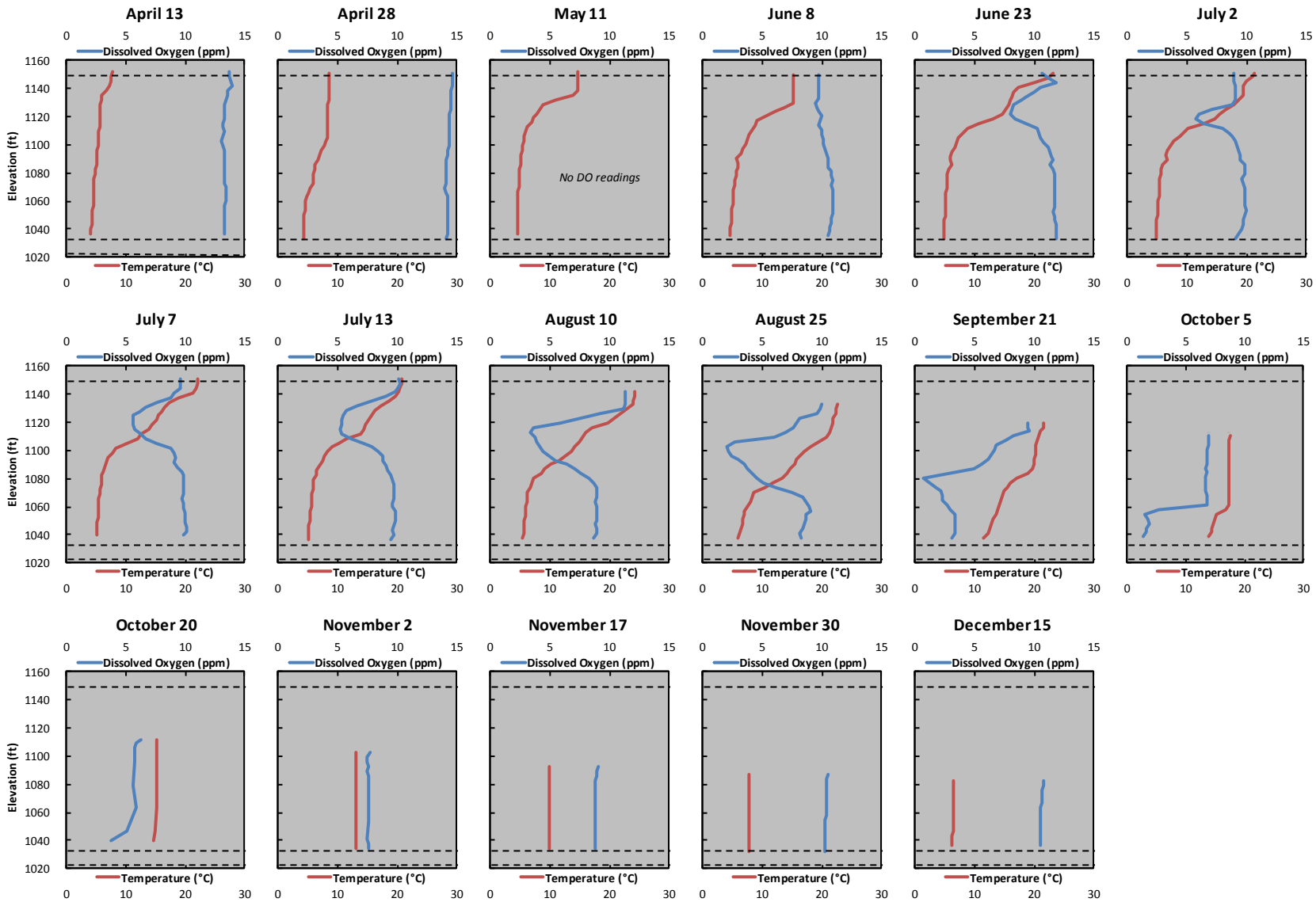
Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1150 ft above msl), top of intake (1035.5 ft above msl), and bottom of intake (1020.5 ft above msl).*

Figure 4.2-7: Temperature & DO profiles at Cannonsville Reservoir for the dry year (1993).



Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1150 ft above msl), top of intake (1035.5 ft above msl), and bottom of intake (1020.5 ft above msl).*

Figure 4.2-8: Temperature & DO profiles at Cannonsville Reservoir for the avg. year (1998).



Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1150 ft above msl), top of intake (1035.5 ft above msl), and bottom of intake (1020.5 ft above msl), from top to bottom.*

Figure 4.3-1: Annual water level duration curves at Pepacton Reservoir.

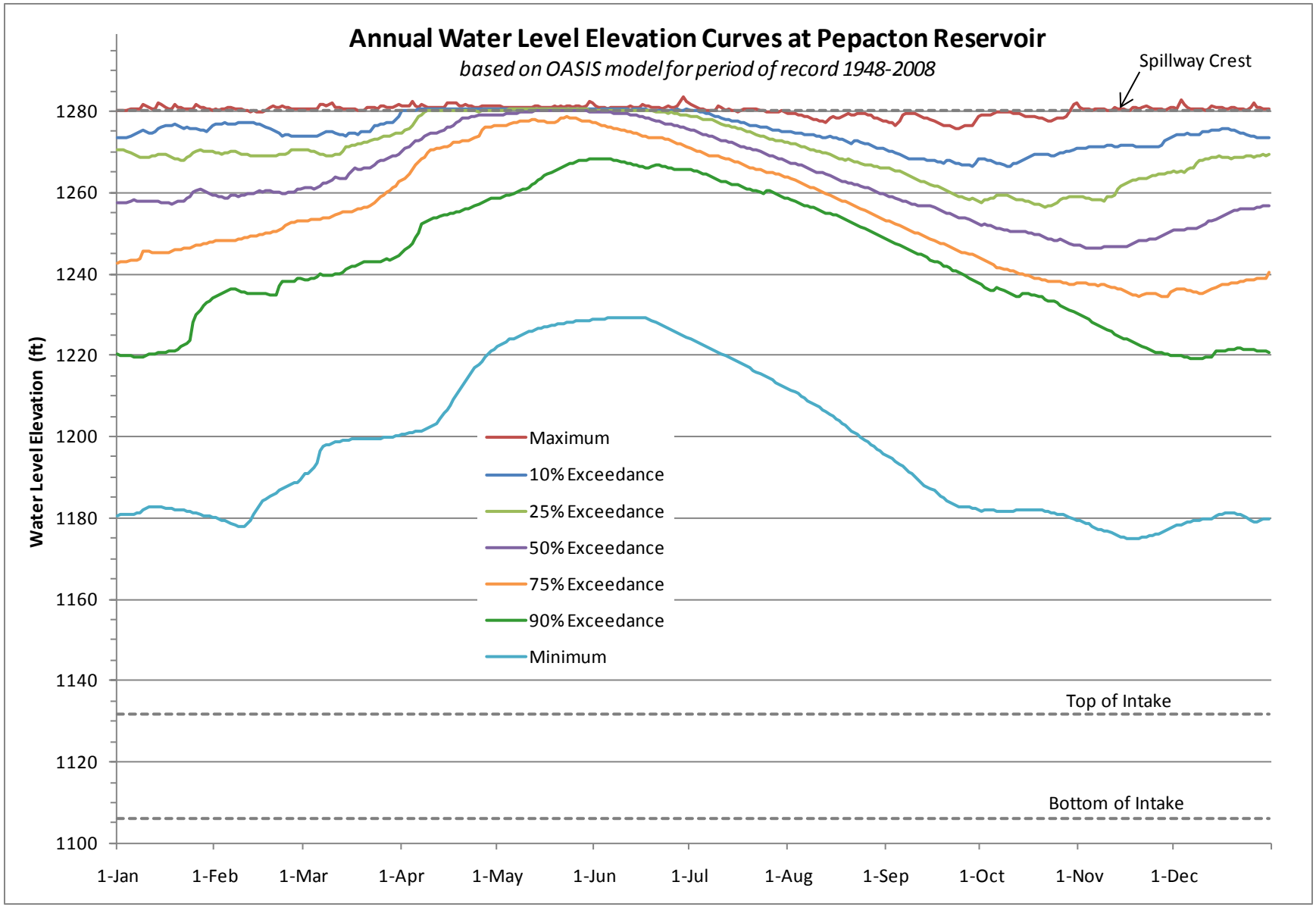


Figure 4.3-2: Water level duration curves at Pepacton Reservoir for Jan, Feb, and Mar.

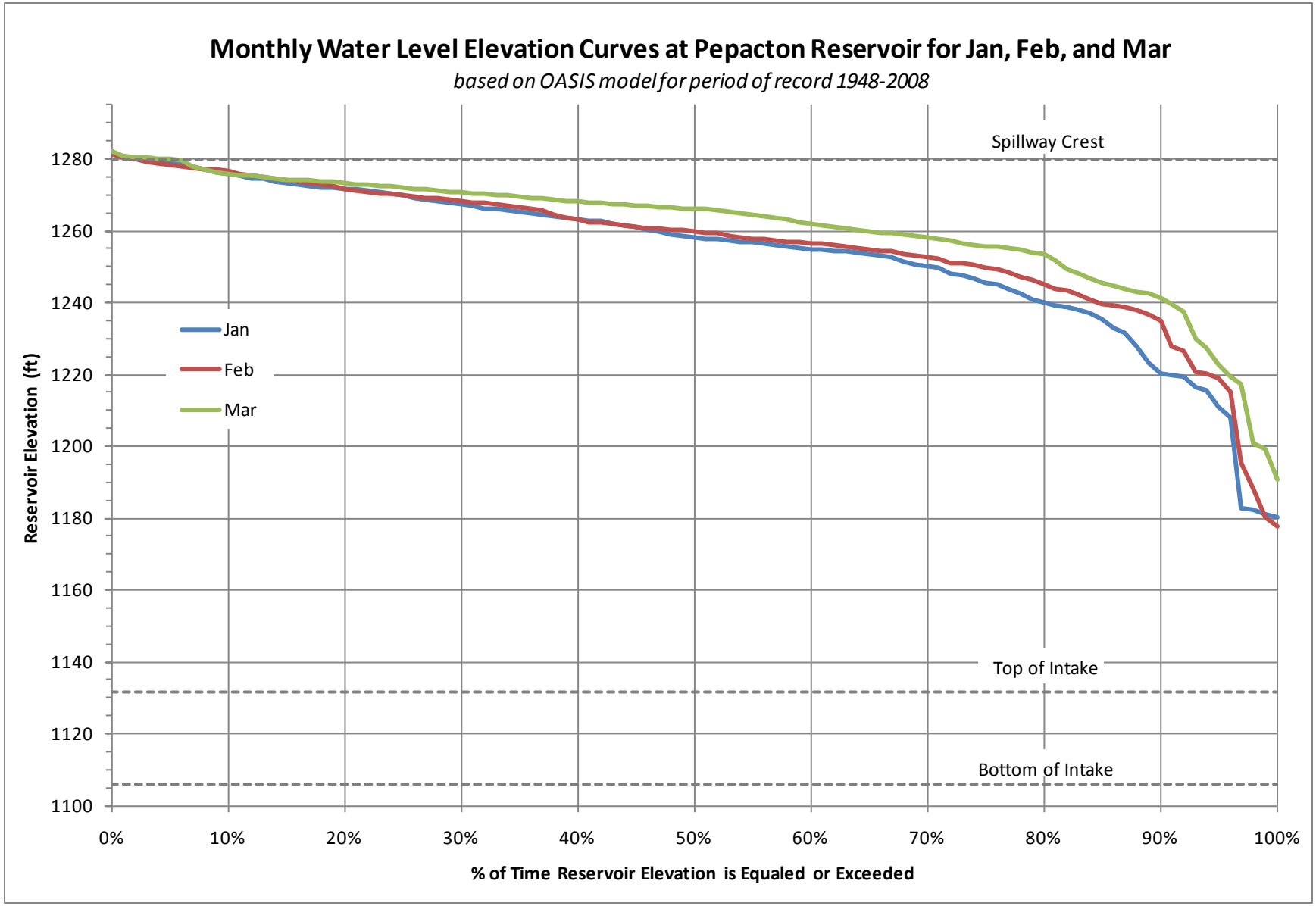


Figure 4.3-3: Water level duration curves at Pepacton Reservoir for Apr, May, and Jun.

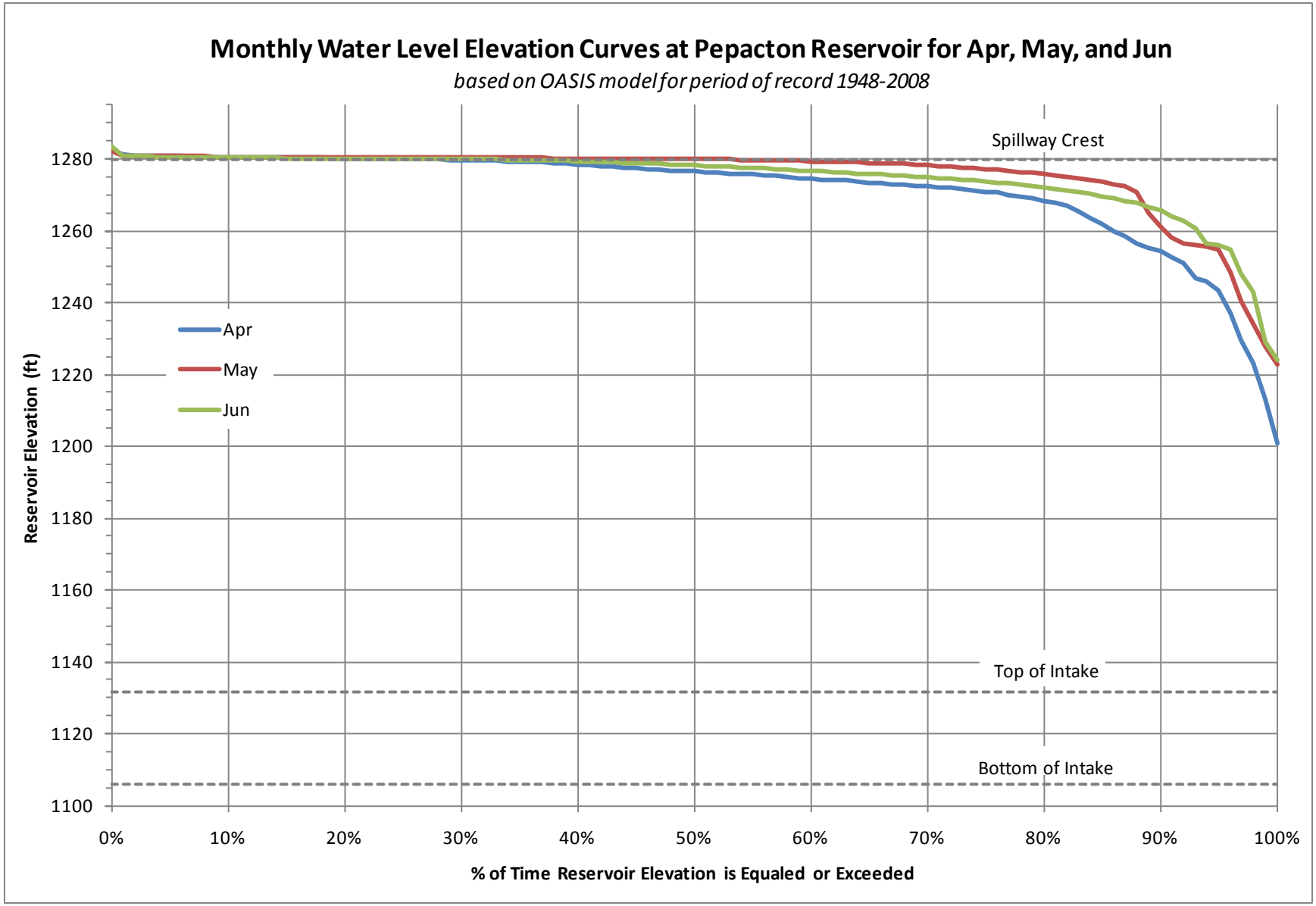


Figure 4.3-4: Water level duration curves at Pepacton Reservoir for Jul, Aug, & Sep.

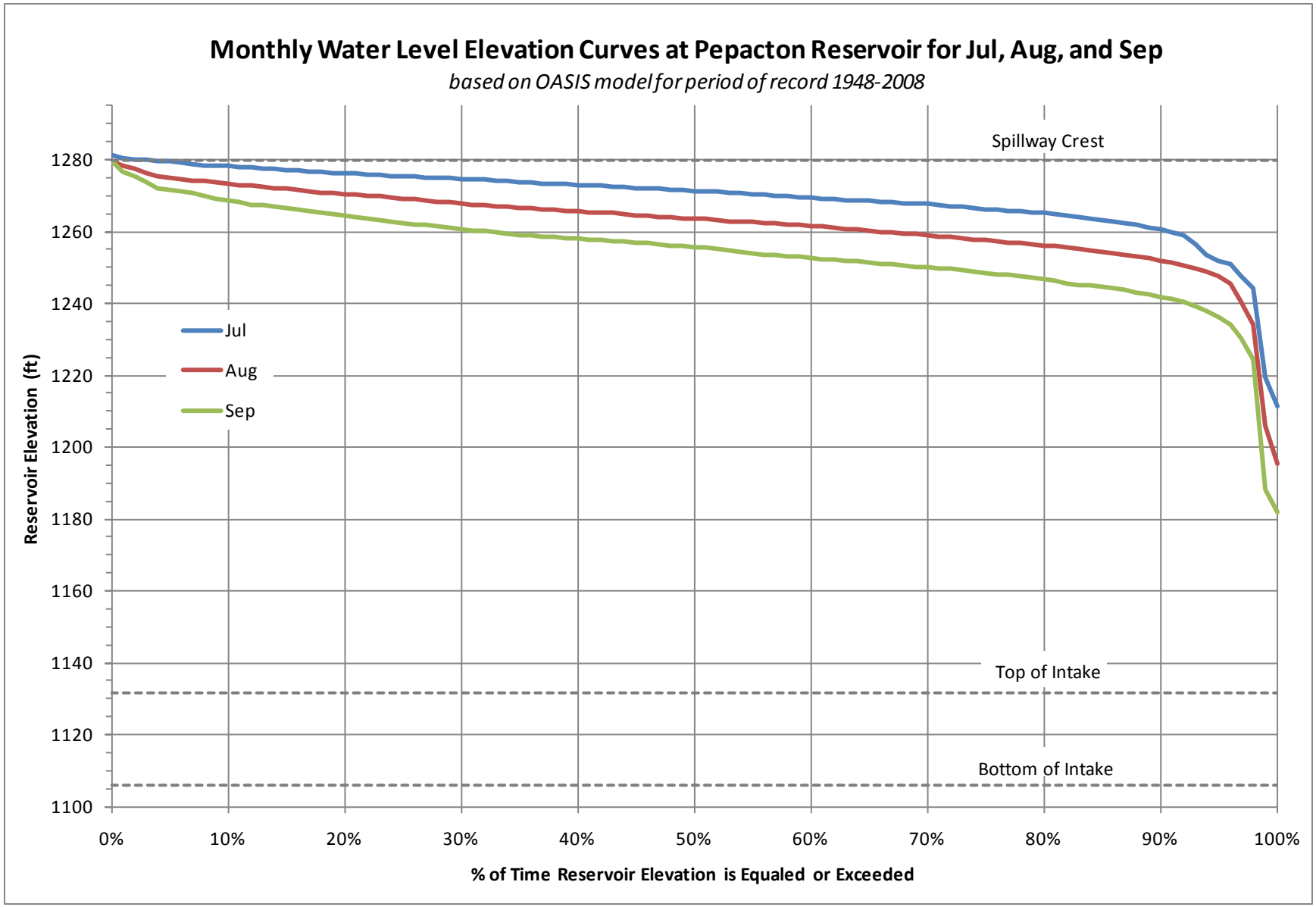


Figure 4.3-5: Water level duration curves at Pepacton Reservoir for Oct, Nov, and Dec.

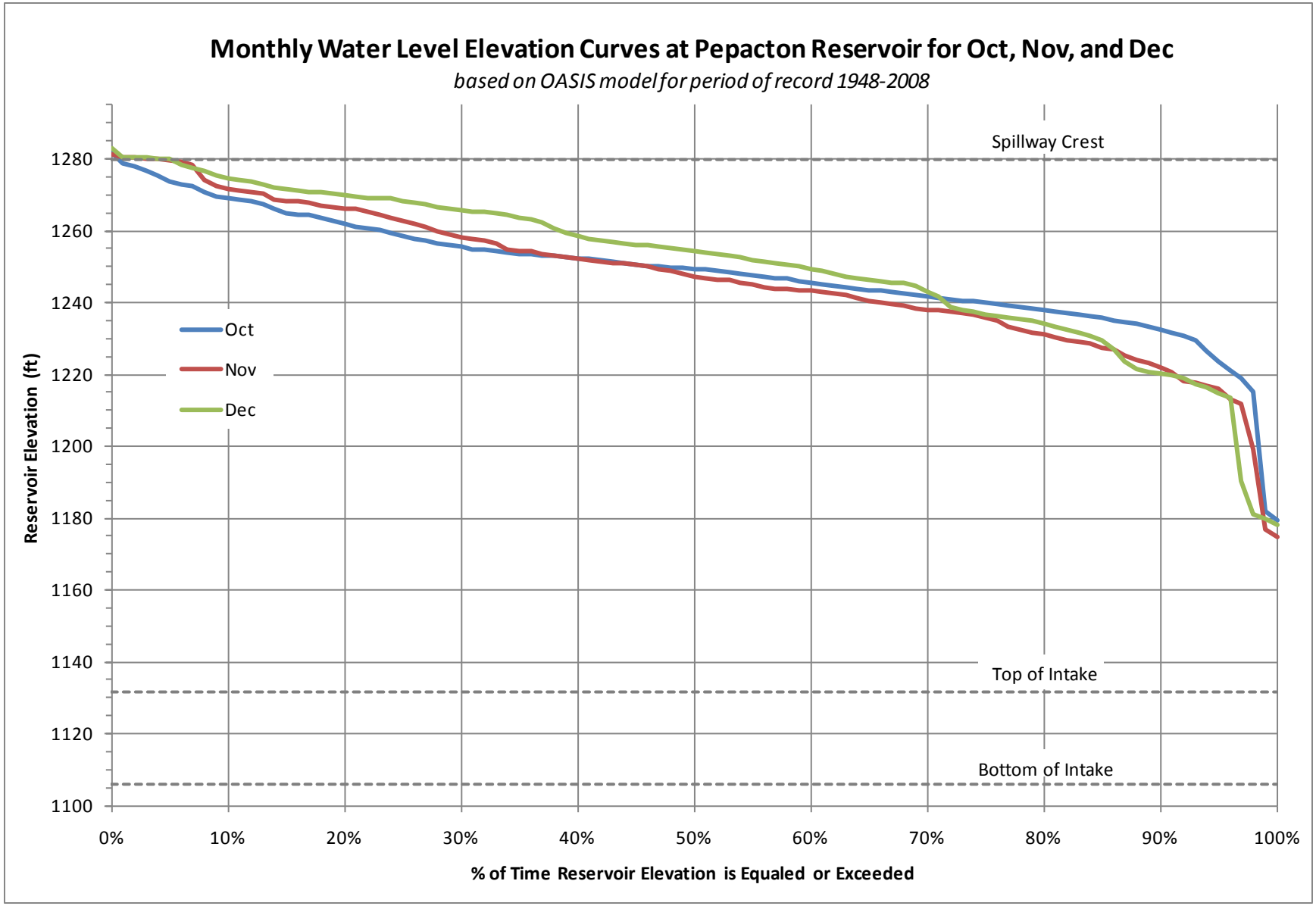
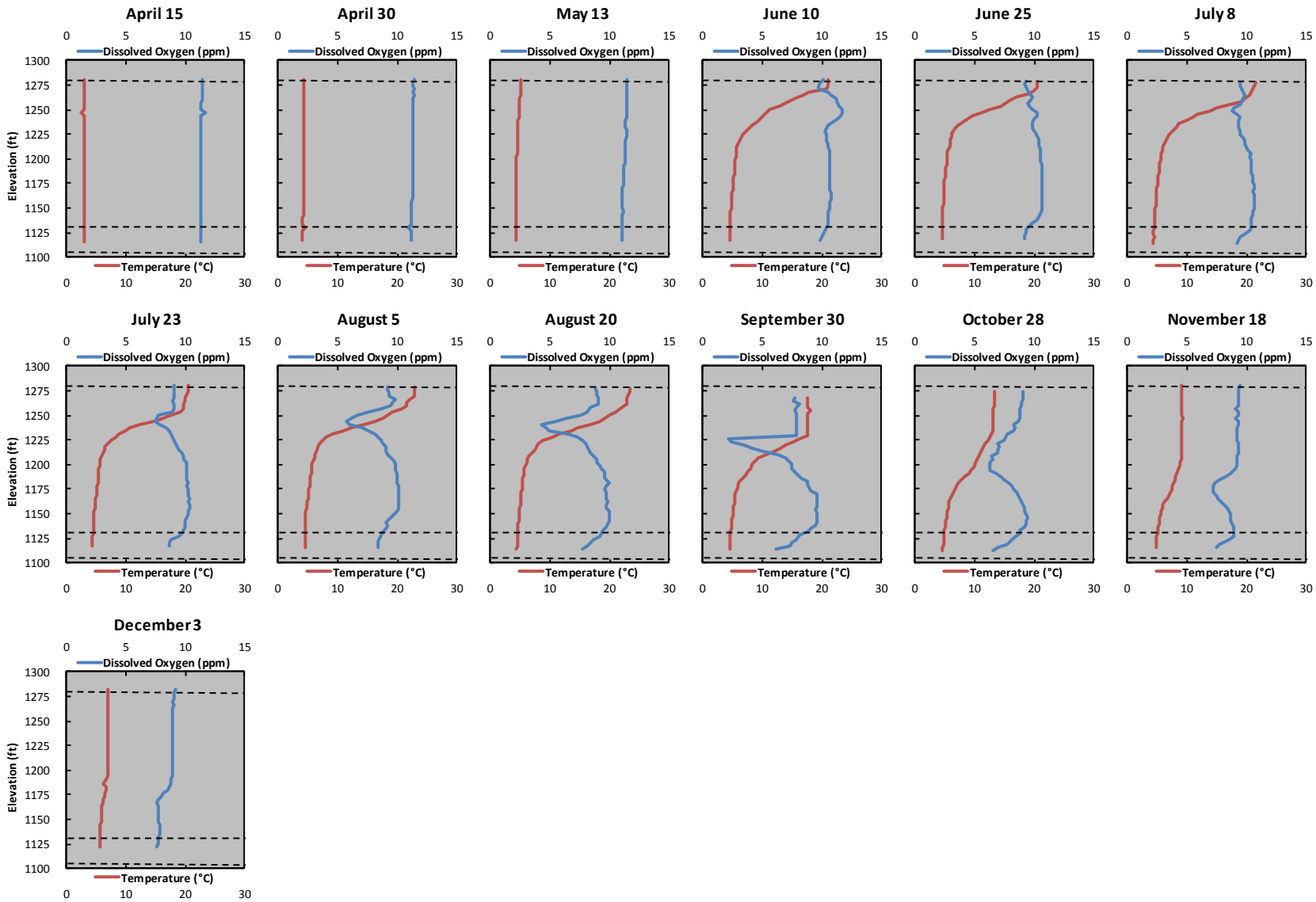
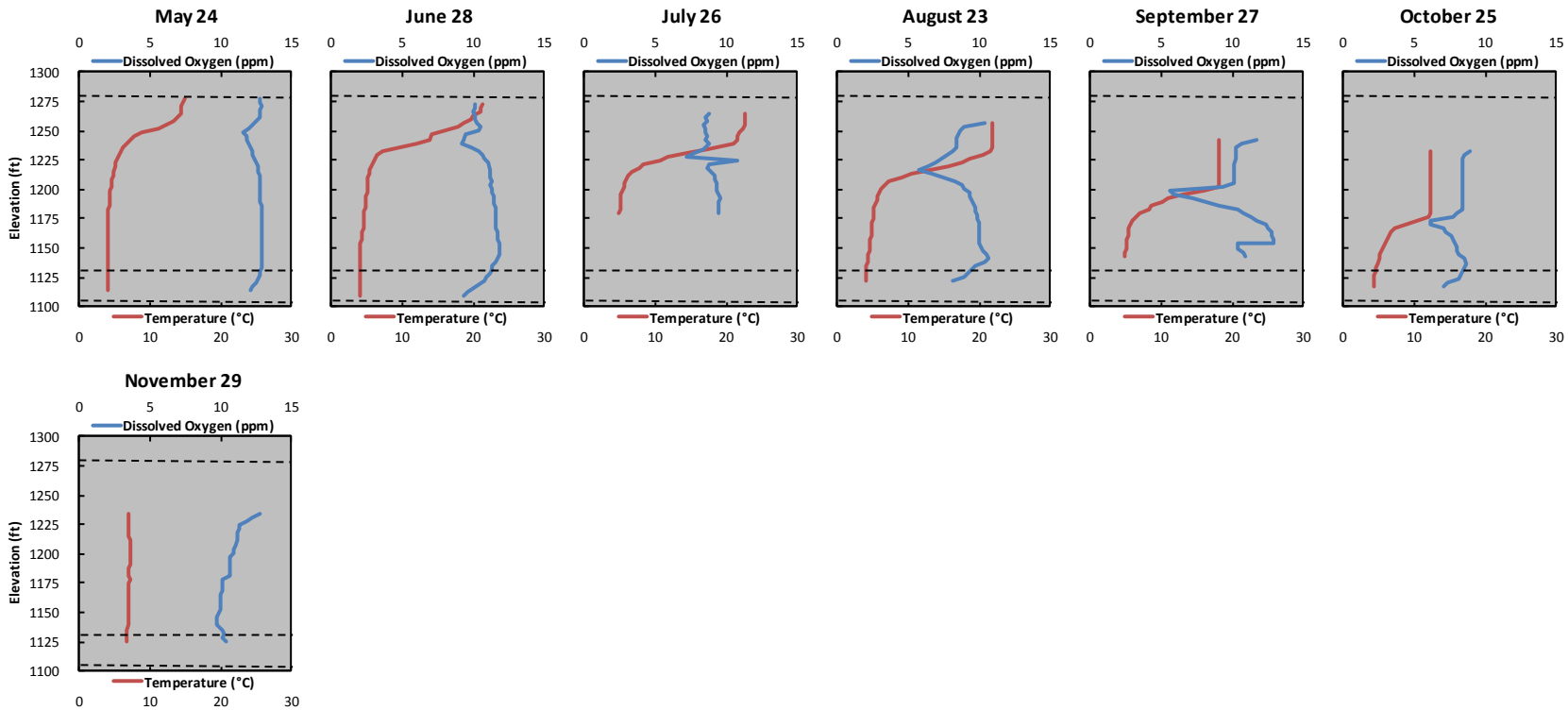


Figure 4.3-6: Temperature & DO profiles at Pepacton Reservoir for the wet year (1996).



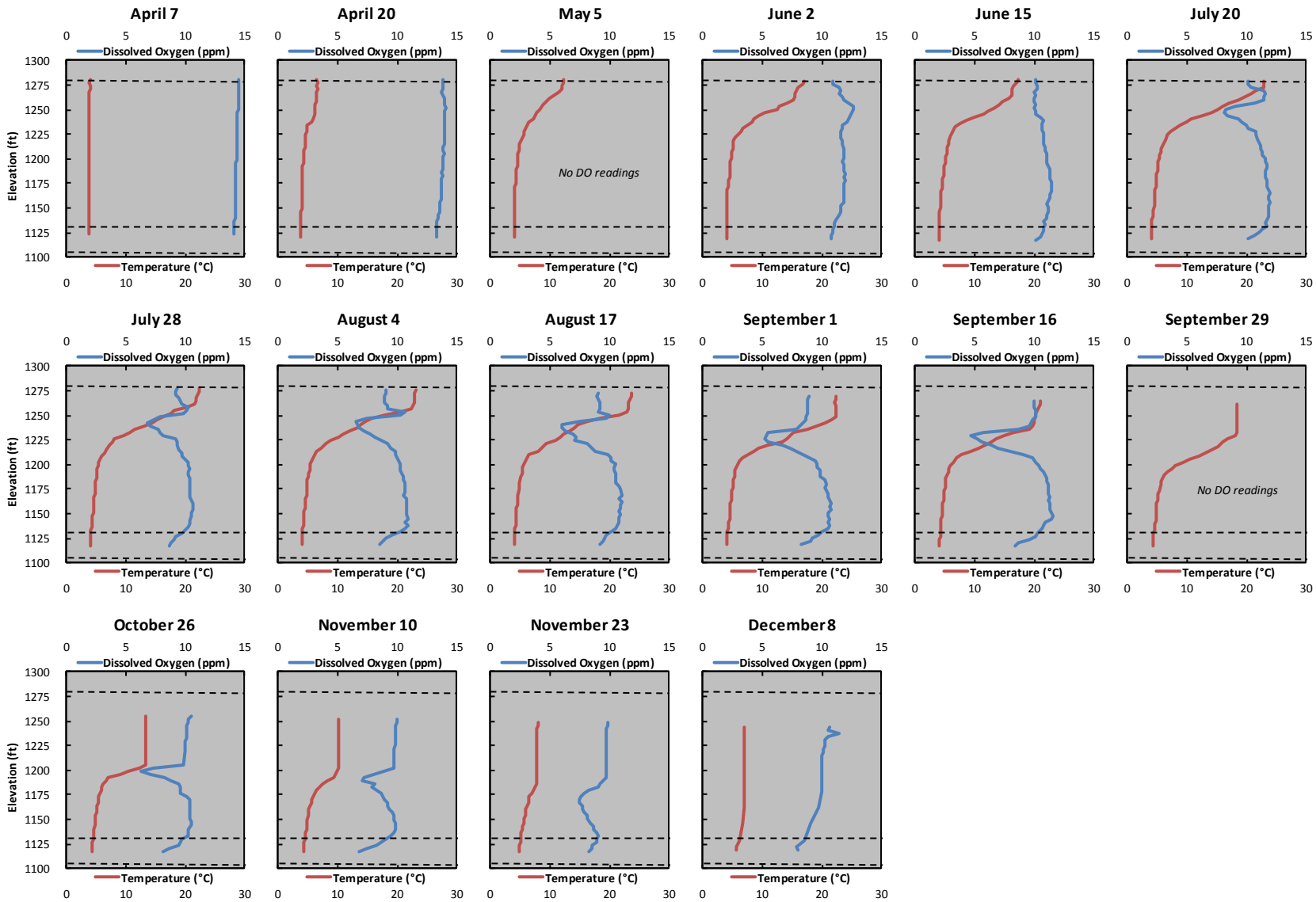
Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1280 ft above msl), top of intake (1131.75 ft above msl), and bottom of intake (1106.0 ft above msl).*

Figure 4.3-7: Temperature & DO profiles at Pepacton Reservoir for the dry year (1993).



Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1280 ft above msl), top of intake (1131.75 ft above msl), and bottom of intake (1106.0 ft above msl).*

Figure 4.3-8: Temperature & DO profiles at Pepacton Reservoir for the avg. year (1998).



Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1280 ft above msl), top of intake (1131.75 ft above msl), and bottom of intake (1106.0 ft above msl).*

Figure 4.4-1: Annual water level duration curves at Neversink Reservoir.

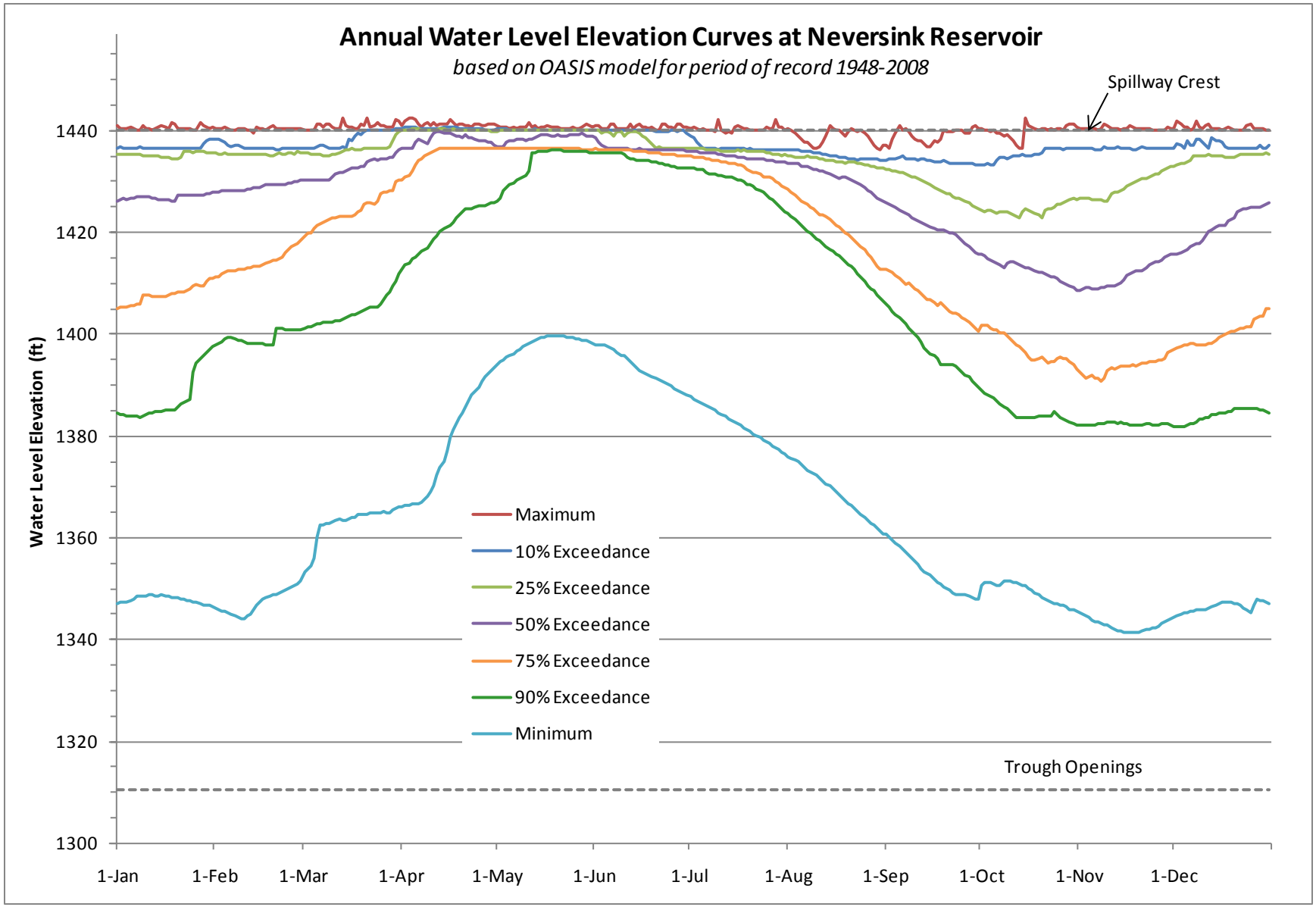


Figure 4.4-2: Water level duration curves at Neversink Reservoir for Jan, Feb, and Mar.

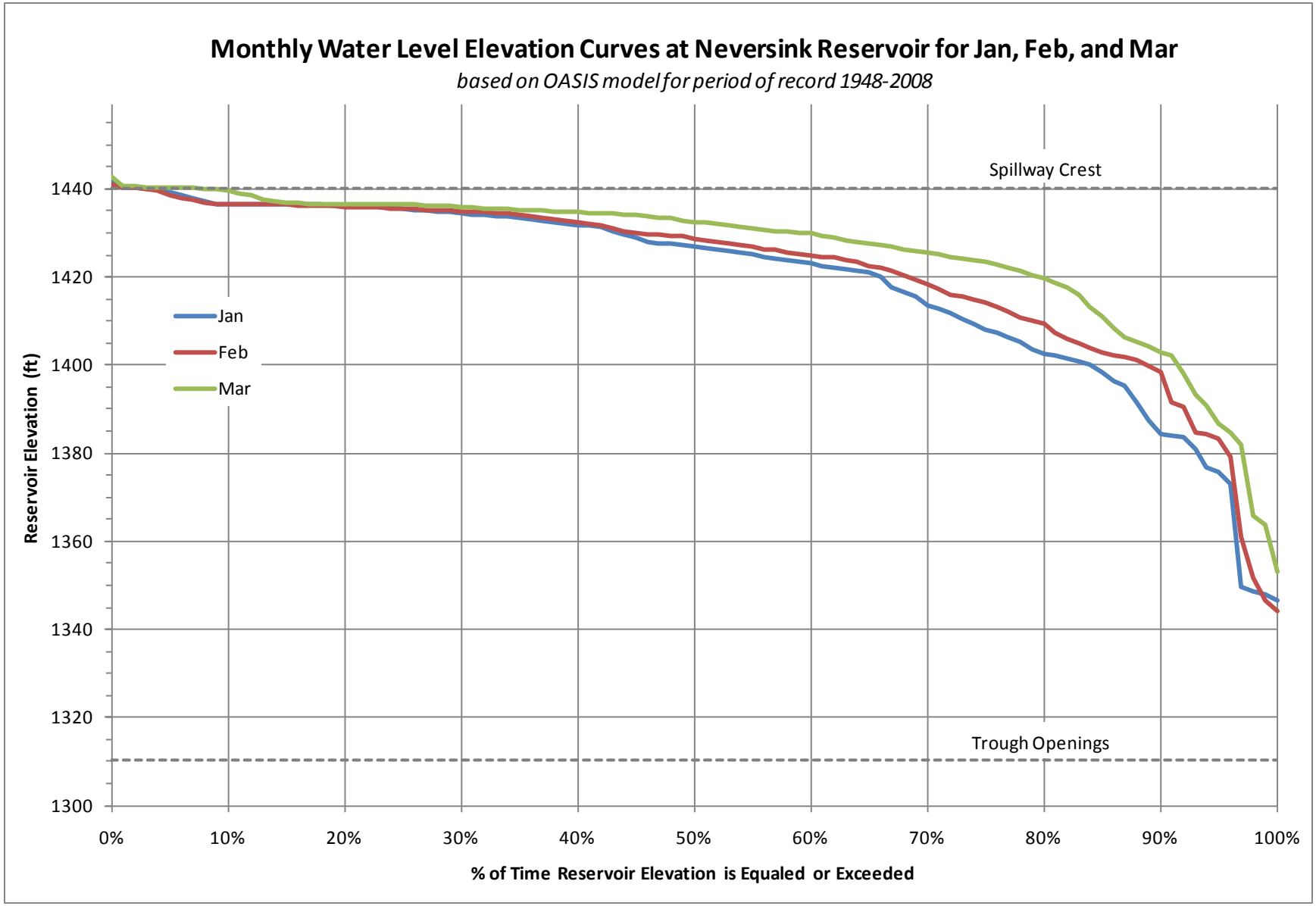


Figure 4.4-3: Water level duration curves at Neversink Reservoir for Apr, May, and Jun.

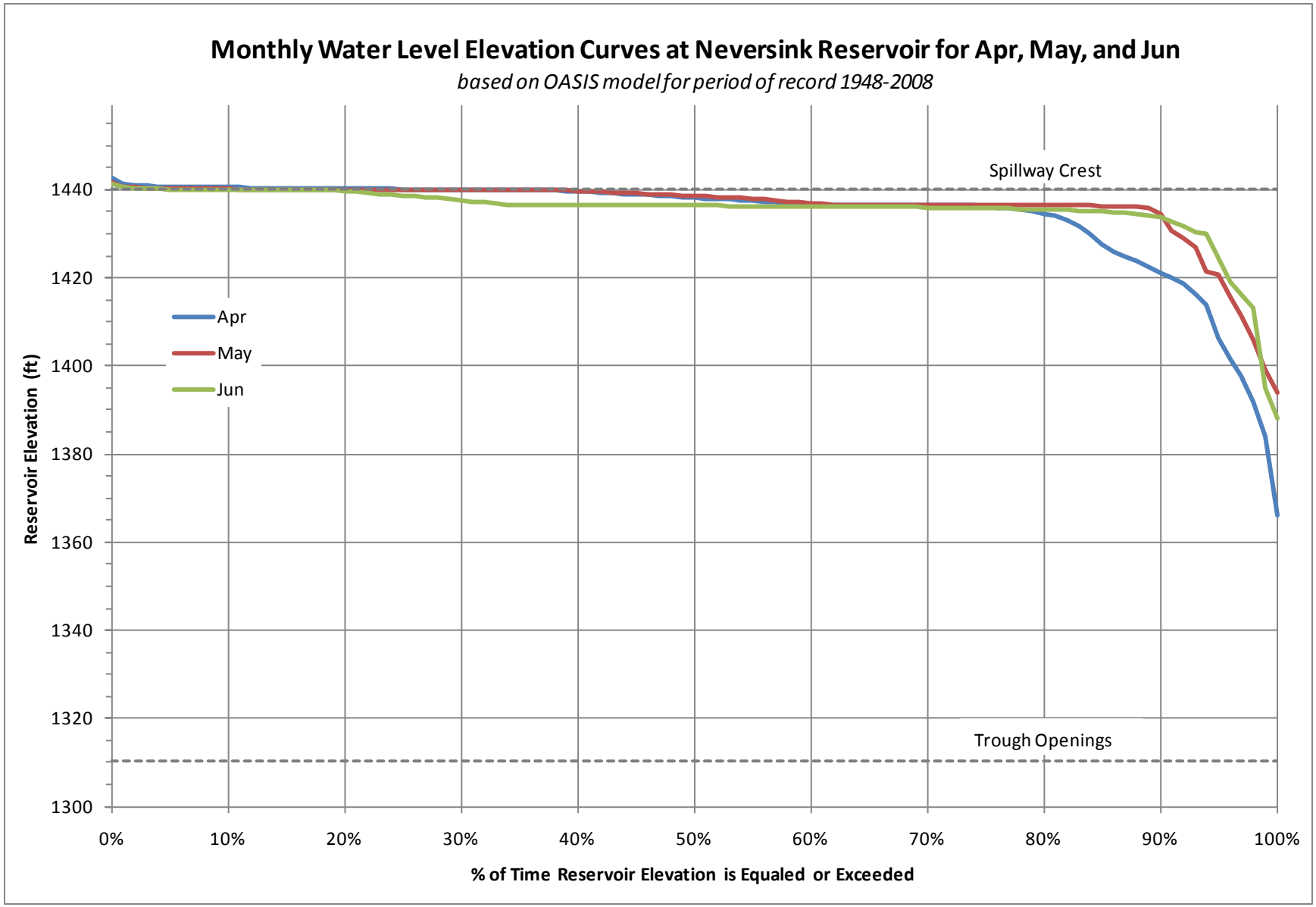


Figure 4.4-4: Water level duration curves at Neversink Reservoir for Jul, Aug, and Sep.

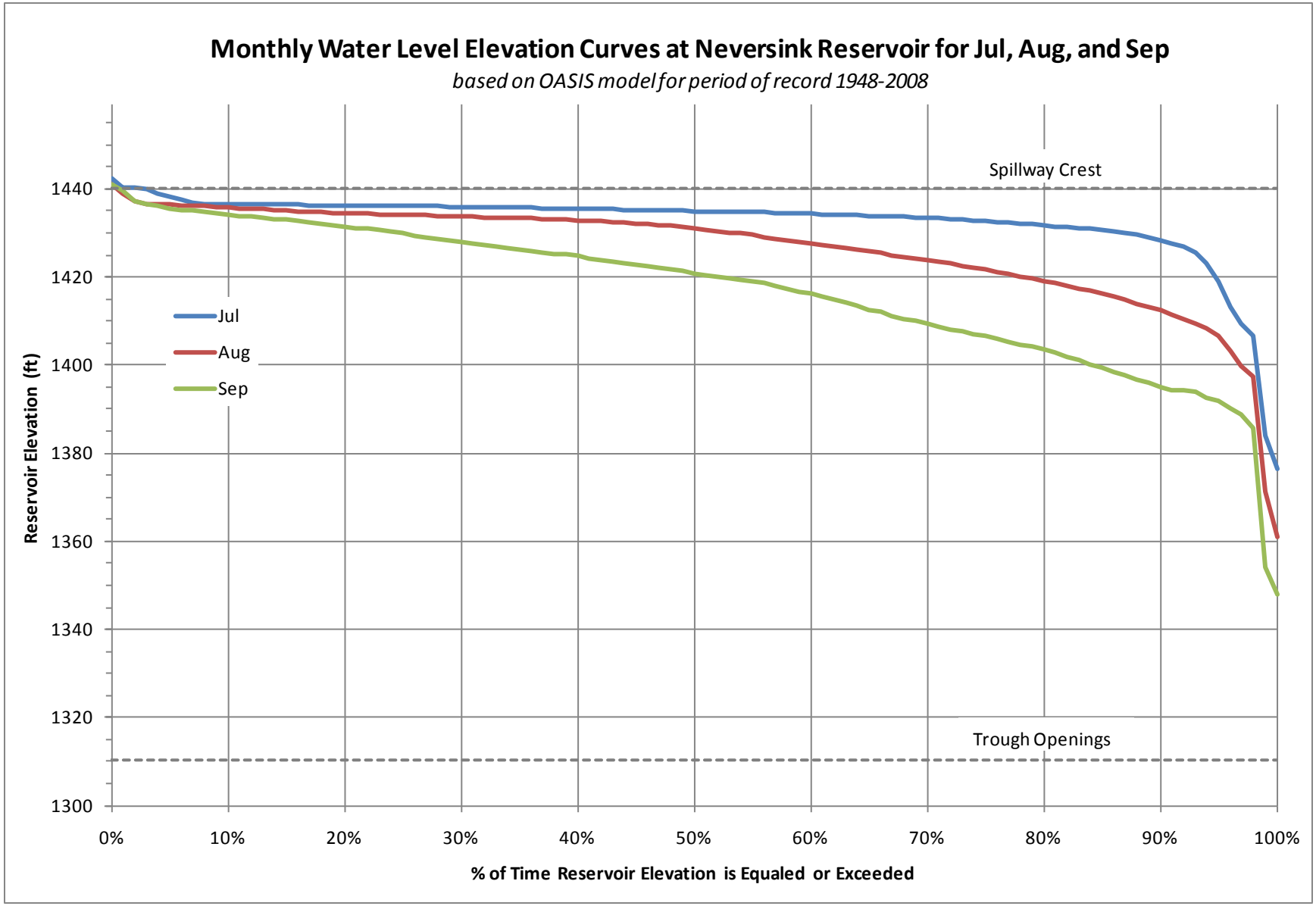


Figure 4.4-5: Water level duration curves at Neversink Reservoir for Oct, Nov, and Dec.

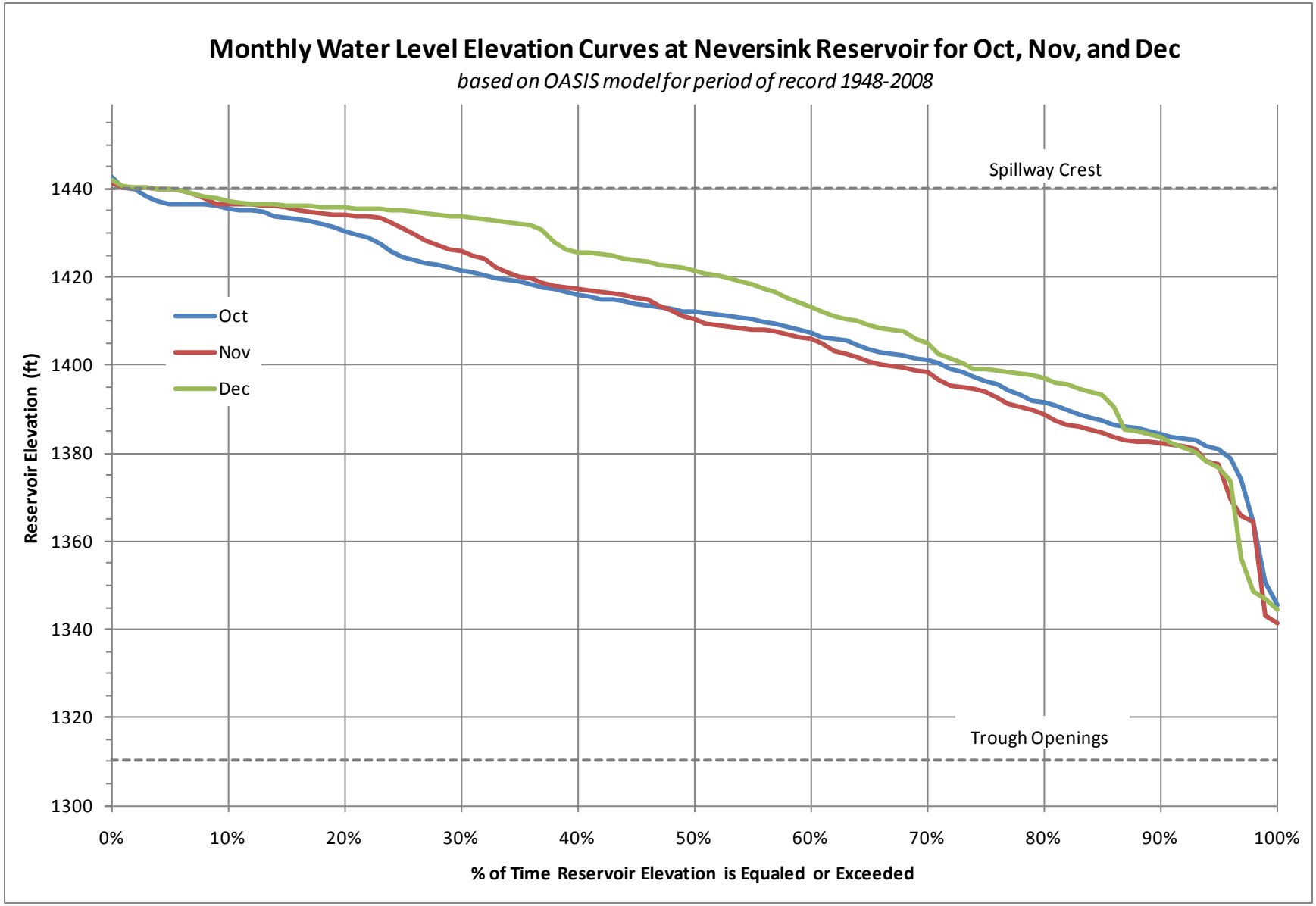
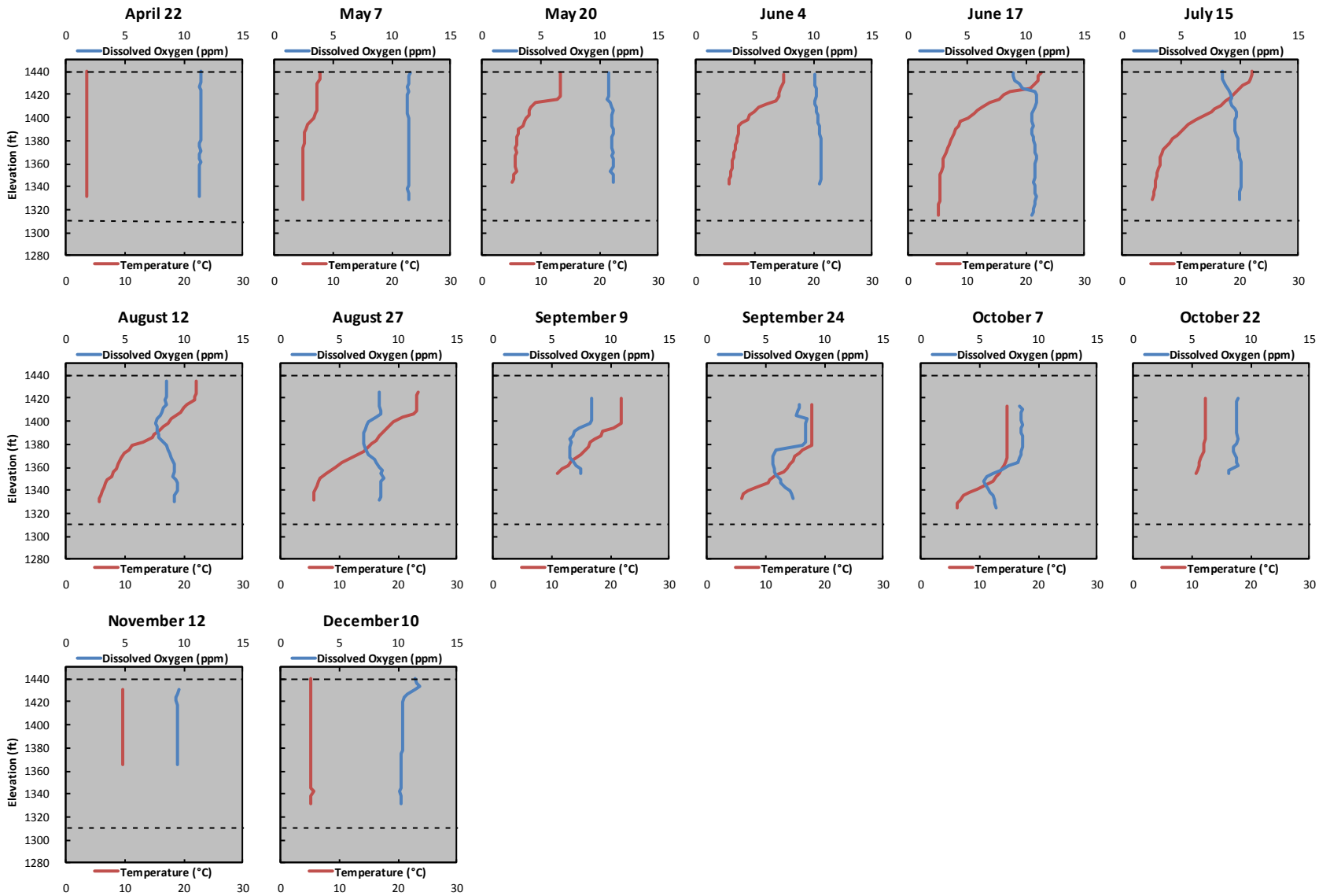
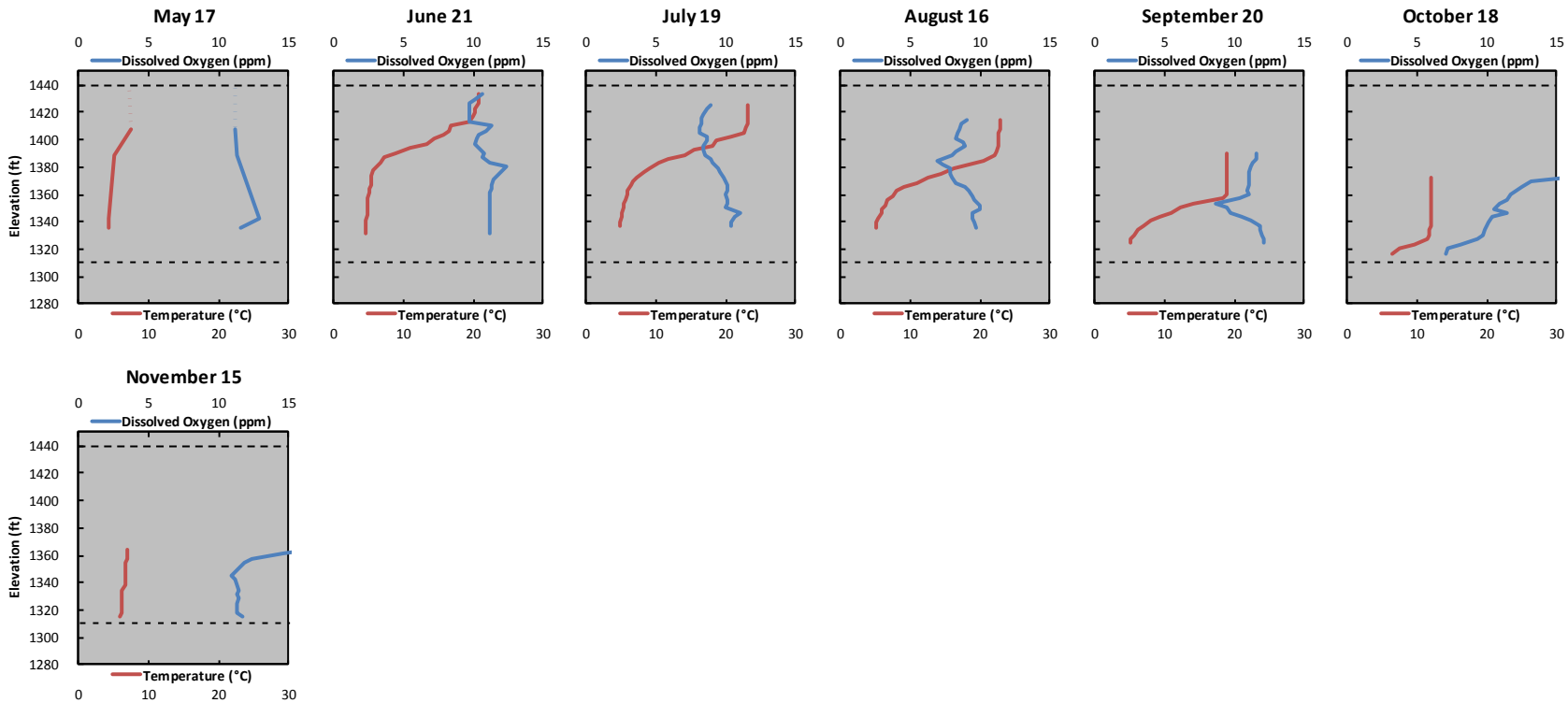


Figure 4.4-6: Temperature & DO profiles at Neversink Reservoir for the wet year (1996).



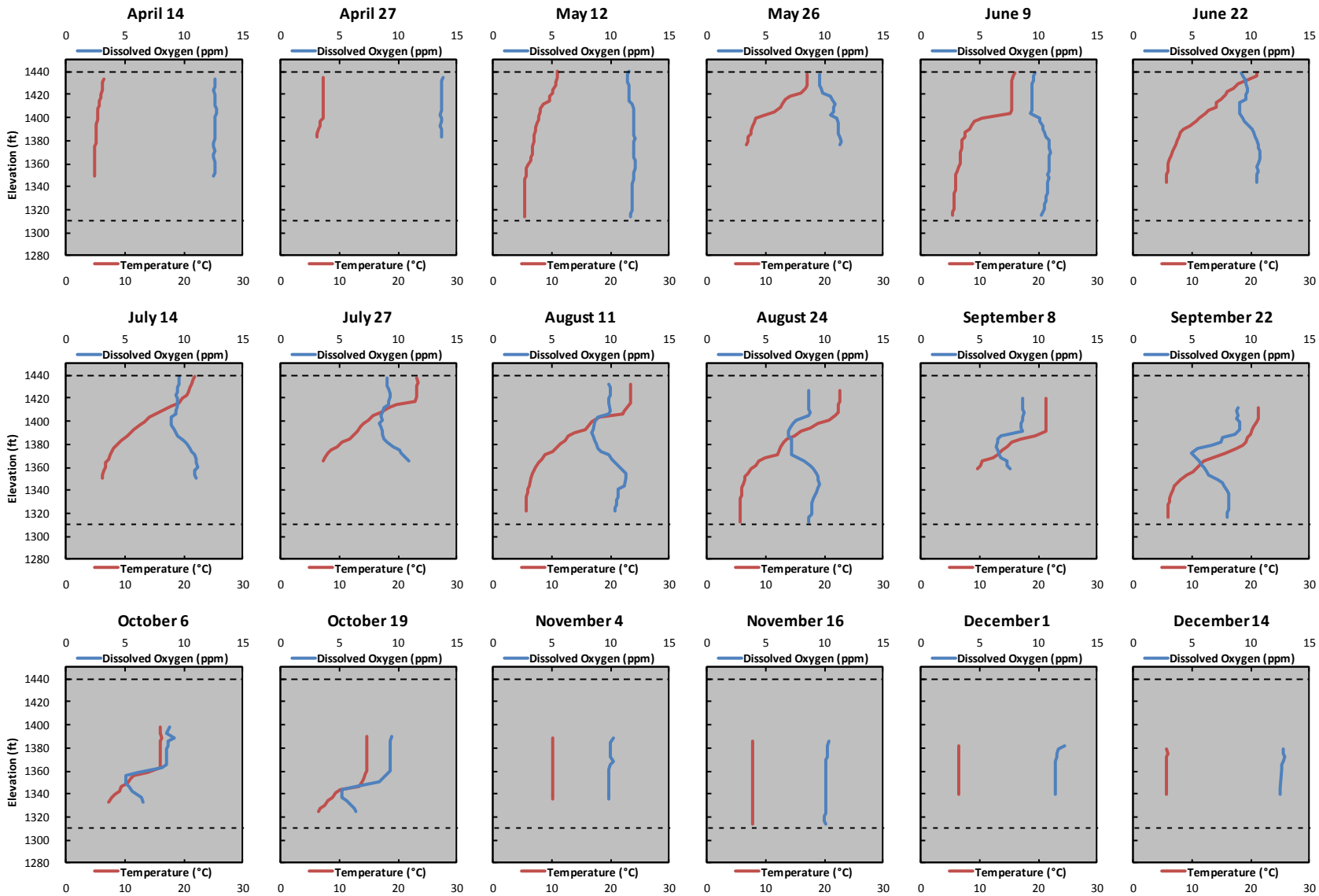
Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1440 ft above msl), and the intake trough openings for releases (1310.5 ft above msl).*

Figure 4.4-7: Temperature & DO profiles at Neversink Reservoir for the dry year (1993).



Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1440 ft above msl), and intake trough openings for releases (1310.5 ft above msl).*

Figure 4.4-8: Temperature & DO profiles at Neversink Reservoir for the avg. year (1998).



Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1440 ft above msl), and intake trough openings for releases (1310.5 ft above msl).*

Figure 4.5-1: Cannonsville Reservoir average water supply and downstream flows.

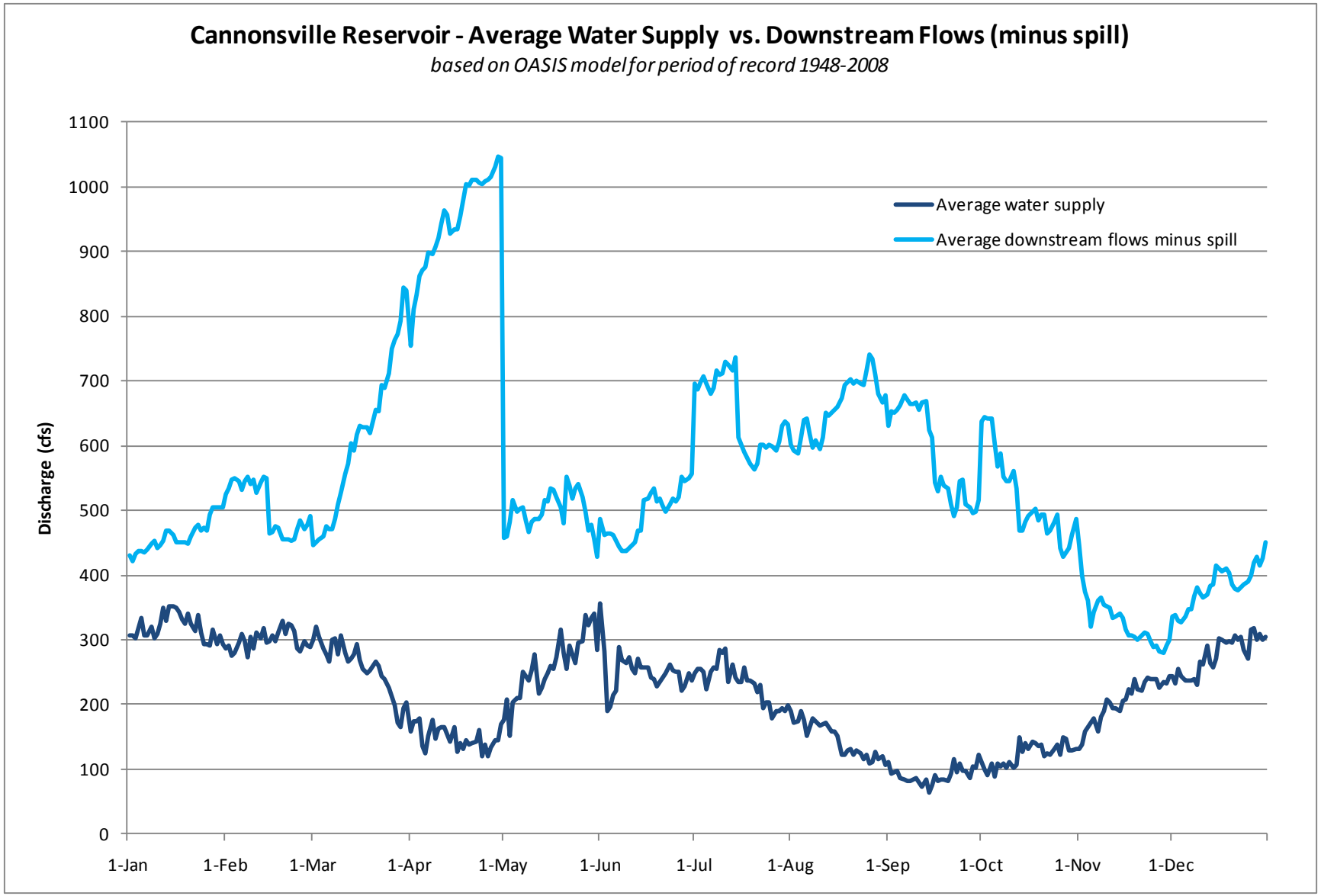


Figure 4.5-2: Pepacton Reservoir average water supply and downstream flows.

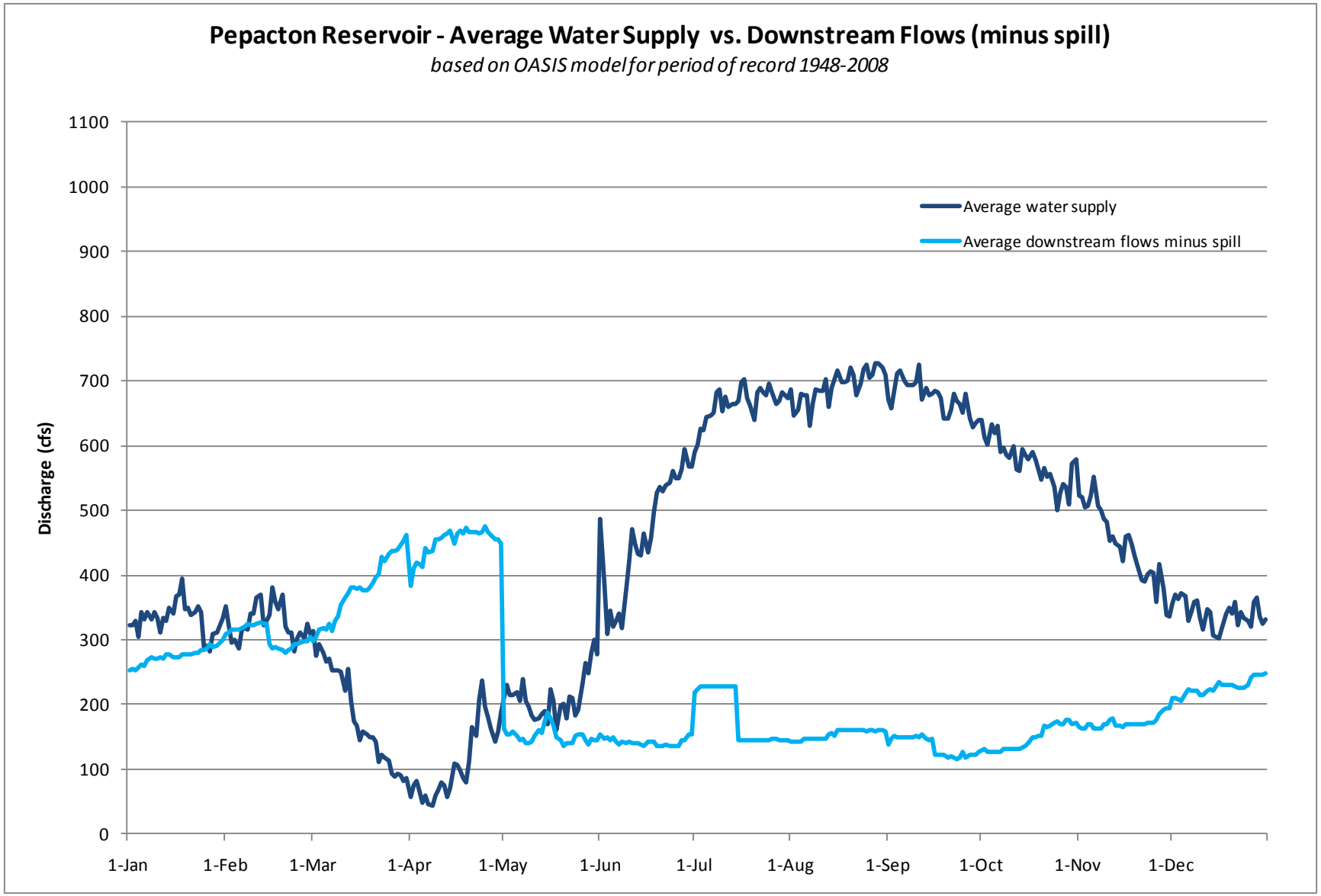
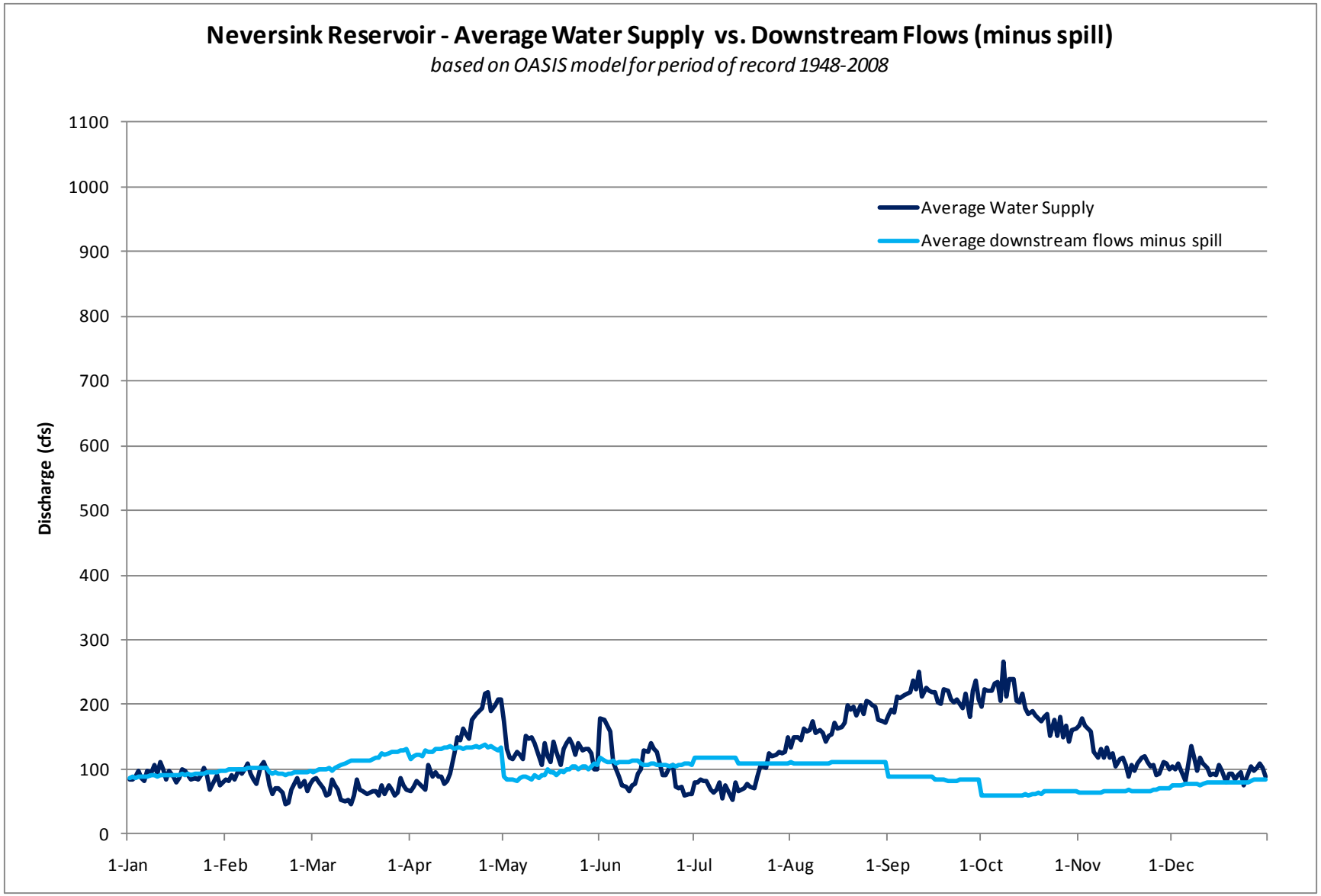


Figure 4.5-3: Neversink Reservoir average water supply and downstream flows.



5.0 FISH SPECIES

This section describes the fish species in the three reservoirs associated with the proposed developments. First, background information on the existing fisheries is summarized. Then, based on the fishes' expected habitat usage within the three reservoirs, the fish species and life stages that are most likely to be present near the intake structures at various times of the year are identified. The evaluation considers the habitat preferences of the fish and life stages relative to food sources and water quality conditions. The water quality data evaluated in Section 4 is referenced to consider the location of the thermocline and DO/temperature conditions near the intake structures. Swimming speed data available in the literature is also presented in this section.

5.1 Fish Species Present

The fish species present in each reservoir are listed in Table 5-1. Because this study also evaluates downstream fish passage at the three proposed developments, a summary of the fisheries downstream of each reservoir is also provided. In the downstream reaches, an emphasis is placed on trout species because these river systems are managed by the NYSDEC as high quality, coldwater fisheries.

Cannonsville Development

The West Branch is generally separated into two areas—above and below the Cannonsville Reservoir. The Cannonsville Reservoir supports both warm and coldwater fisheries. The NYSDEC manages the upper West Branch as a coldwater trout fishery and has been monitoring trout populations in the reservoir through angler creel surveys and angler diaries. Brown trout were stocked in the reservoir from 2005 to 2008 to determine whether the population would respond to enhancement efforts. The results of the four-year study indicate that the population has responded well to the stocking and has provided additional opportunities to catch trout. Additionally, trout continue to be stocked in the river above the reservoir, and may utilize the reservoir at certain times of the year. There are wild brown and brook trout in the tributaries to the Cannonsville Reservoir.

Cold water releases in the summer from the Cannonsville Reservoir provide suitable temperatures for trout to reside in the entire 17.7 miles to the confluence with the East Branch. Consequently, the West Branch below the Cannonsville Reservoir supports a renowned trout fishery. Fish population sampling has shown that brown trout are the most abundant trout species followed by rainbow trout and lastly a small number of brook trout.

Pepacton Development

The Pepacton Reservoir is managed as a coldwater fishery. The reservoir also supports both warm and coolwater fish species, as well as a variety of forage fish species. Brook trout and rainbow trout have been stocked in the past, but are no longer stocked in favor of stocking brown trout. A NYSDEC angler diary study conducted from 2002 through 2007 at the Pepacton Reservoir indicated that stocked brown trout are an important component of the Pepacton Reservoir fishery.

Cold water releases in the summer from the Pepacton Reservoir provide suitable temperatures for coldwater fish. Wild brook trout, wild and stocked brown trout, and the occasional wild rainbow trout reside in the East Branch below the Downsville Dam, with brown trout being the dominant species.

Neversink Development

The NYSDEC actively manages the Neversink Reservoir for sport fishing opportunities. The reservoir supports both warm and coldwater fisheries. The landlocked Atlantic salmon program began in 1971 with the collection and planting of rainbow smelt eggs in order to establish a food base for the salmon.

Salmon stocking was initiated in 1973 with the introduction of 3,000 eight-inch fish into the upper Neversink River. Survival of these fish was poor, as indicated by creel surveys and netting by NYSDEC. As these fish were a sea-run variety from the Gaspé Peninsula in Québec, NYSDEC decided to raise and release a landlocked strain in 1975. The Neversink Reservoir now supports a naturally reproducing and hatchery augmented landlocked salmon fishery. Currently, brown trout are the only trout species stocked in addition to salmon, and can be caught in the tributaries to the reservoir.

As at Cannonsville and Pepacton, the cold water releases from the Neversink Reservoir create a high-quality tailwater fishery. The river maintains a very good population of wild brown trout, and NYSDEC stocks the river with brown trout annually. There is also a wild brook trout population established in the tributaries below the dam.

5.2 Life History and Habitat Requirements of Fish Species

When assessing entrainment potential of fish species, one of their most important life history characteristics is diadromy. There are resident populations of trout and other species existing in the three reservoirs associated with the proposed developments that are not migrants. Although individuals within these populations move upstream into tributaries to the reservoirs for spawning and downstream incidentally during periods of spillage, these movements are not necessarily required to maintain the population. This is particularly true of populations that are supplemented by stocking, such as the brown trout discussed above. Although there are landlocked strains of otherwise anadromous fish species in the reservoirs, including Atlantic salmon, alewife, and rainbow smelt, the life histories of these landlocked species do not include a period of migration downstream to an estuary or ocean.

A brief description of the life histories and behaviors of the fish species are provided below to evaluate their likelihood to be located in the vicinity of the intake structures at the three proposed developments. Although the common intake structure at the Neversink development ranges in elevation from the surface to deep water, the intake trough leading to the proposed hydropower development is located in deep water. Therefore, this analysis evaluates the likelihood that a fish species/life stage will be located near the deepwater intake structures at the three proposed developments.

Fish are grouped by similar life history characteristic, which include but are not limited to:

- Spawning timing;
- Where they are generally found in the water column;
- DO requirements;
- Swimming speed; and
- Movement (migration) patterns

Some fish species are grouped together for this analysis based on similar habitat preferences and life history characteristics (Table 5-2). The potential for each species to be susceptible to entrainment was determined based on their life history characteristics in relation to the location of the intake structures at each proposed development, as shown in Table 5-3. Swimming speeds obtained from the available literature are set forth in Table 5-4.

Categories of entrainment potential, based on the likelihood that a fish species/life stage will be located near the intake structures, are described as:

- **None** – never found near intake structures
- **Minimal** – species only occasionally found near intake structures
- **Moderate** – species routinely or seasonally found near intake structures
- **High** – species likely to be found near the intake structures

Each fish species or group of similar species is described below.

Salmonids (trout and salmon)

Brown trout, brook trout, rainbow trout, and landlocked Atlantic salmon are grouped together for the purposes of this analysis. Brown trout and landlocked Atlantic salmon have the most similar life history characteristics among these four species. Brown trout generally move upstream into tributaries to spawn over gravel, typically from October to December (Smith, 1985). For lake populations, the young may remain in the tributaries for several years before migrating to the reservoir (Werner, 2004). Because their preferred temperature is 10-18.3°C (Becker, 1983), brown trout likely seek out thermal refuge in the tributaries. The upper lethal limit of water temperature for brown trout is 27.2°C. Preferred DO levels are 9 ppm or greater and brown trout tend to avoid waters with levels less than 5 ppm (Raleigh *et al.*, 1986).

Landlocked salmon also spawn over gravel in streams just upstream or downstream of pools (Clark *et al.*, 1993). They typically spawn from October to December. Juveniles hatch and rear for one to four years in a stream before moving to a lake or reservoir. Landlocked salmon tend to be found near the thermocline as surface water temperatures increase. Water temperatures of 28°C and above are lethal, and landlocked salmon avoid temperatures greater than 20°C (Danie *et al.*, 1984). Optimal temperatures for adult landlocked Atlantic salmon range from 11-18.5 °C. Landlocked salmon avoid water with DO levels less than 5 ppm, and generally require DO levels to be greater than 8 ppm (Osmond *et al.*, 1995; Danie *et al.*, 1984).

Brook trout also typically spawn from September to November and they prefer cold, clear, and deep lakes and ponds. As with the majority of the trout and salmon species, brook trout prefer to spawn over gravel and require well-oxygenated water. The preferred water temperature range for brook trout is 11-16 °C with an upper lethal limit of 24°C, making them the least tolerant of high temperatures of any of the salmonids found in or downstream from the proposed developments (Osmond *et al.*, 1995). Optimum DO levels are 9 ppm and greater (Raleigh, 1982). Brook trout avoid water with less than 5 ppm, and are particularly sensitive to low oxygen levels (Osmond *et al.*, 1995).

Rainbow trout are present in Pepacton Reservoir, but they are not believed to be present in great numbers. Rainbow trout spawn in the late winter or spring and lacustrine populations typically migrate to tributaries. Optimal DO levels are approximately 9 ppm or greater and they survive best when levels are at least approximately 7 ppm (Raleigh *et al.*, 1984). Rainbow trout juveniles typically spend two summers in their natal streams before moving to a lake or reservoir. The depth distribution of rainbow trout in lakes or reservoirs is a function of the interaction between DO, temperature and food availability. Adults remain at the 18 °C or lower isotherm if DO concentrations are adequate and food is available (Raleigh *et al.* 1984).

Based on their life history characteristics, adult salmonids have a moderate potential of being in the vicinity of the intake structures during the summer and fall stratification. This potential can be higher during extreme drought or drawdown conditions. Although the salmonids tend to move during their spawning runs, the movement is directed upstream rather than downstream, thus spawning trout are not likely to be found near the intake structures. Juvenile trout typically rear in the spawning tributaries before migrating to the reservoirs as sub-adults. Therefore, juvenile trout are unlikely to be exposed to significant entrainment potential.

In winter, because the bottom layer of the reservoirs are warmer than the surface, trout species may tend to congregate near the bottom and stay active throughout the winter. Therefore, salmonids have a moderate potential of being in the vicinity of the intake structures during winter.

Rainbow smelt

Of the three proposed developments, rainbow smelt are found only in the Pepacton and Neversink Reservoirs. These fish tend to be an important forage species, especially for the landlocked Atlantic salmon in the reservoir. Rainbow smelt spawn in the spring shortly after ice-out in tributary streams. They are typically found in mid-water habitats of lakes and reservoirs in temperatures between 7.2 and 15.6°C, generally near the thermocline (Allen & Smith, 1988). Diel vertical migrations by adult and juvenile smelt are common; this movement is thought to be a response to predators, DO concentration, and the distribution of important prey, particularly plankton (Osmond *et al.*, 1995).

Based on life history characteristics, adult rainbow smelt have minimal potential of being in the vicinity of the Pepacton and Neversink intake structures, except during extreme drawdown situations.

Alewife

Alewife move into tributaries or shallow waters in the spring or early summer and spawn at night. Otherwise, the fish generally are found in open water and tend to overwinter in deep water (NatureServe, 2010). Alewives avoid water with DO levels less than 2 ppm and prefer water with greater than 3 ppm (Bozeman & Van Den Avyle, 1989). Alewives prefer water temperatures ranging from 15-20°C (Pardue, 1983). As they move from deeper water to the warmer shallows to spawn, fluctuations in the water temperatures can cause mortality. Due to their life history characteristics, alewives have a high potential of being in the vicinity of the intake structures when seeking out thermal refuge in deeper areas of the reservoirs.

Percids (walleye and yellow perch)

Yellow perch often travel in schools (Smith, 1985). They are most abundant near vegetation in lakes, but they also occur in streams. They feed actively during the day and rest motionless at night. Adult perch usually occupy deeper waters than juveniles do. Spawning takes place in the spring. Yellow perch begin spawning migrations from open water into tributaries, lake shallows, or low velocity areas of rivers from April to June. Adults can be found in moderate currents but prefer sluggish currents or slack water habitat, particularly during spawning (Krieger *et al.*, 1983).

The preferred DO level for yellow perch is 5 ppm or greater, and they tend to avoid water with levels lower than 5 ppm. Lower lethal limits are 3.1 ppm. Preferred temperatures range from 19-24°C, with an upper lethal limit of 32°C (Krieger *et al.*, 1983). Based on the foregoing, adult yellow perch are considered to have minimal potential of being in the vicinity of the intake structures at the three proposed developments.

Walleye are found in Pepacton Reservoir in limited numbers. Walleye can tolerate a wide variety of conditions but tend to prefer moderate to large lakes, reservoirs, or rivers with cool temperatures, moderate turbidities, extensive littoral zones, and substantial areas of rocky substrate. Walleye are primarily piscivorous when suitable forage fish are available. Walleye avoid bright light and tend to prefer slightly turbid water or deep, clear lakes or reservoirs with abundant food. They spawn in the spring during periods of rapid water column warming when temperatures reach 7 to 9°C. Spawning typically occurs at night and is often concentrated into a short time period. Preferred substrate can include shallow shoreline areas, shoals, riffles and dam faces that provide rocky substrate for the broadcast eggs to be protected and suitable water circulation for DO requirements. Lacustrine populations of walleye will often migrate up tributaries to spawn (McMahon *et al.*, 1984).

Adult walleye tend to be found in areas of slight current except in the winter where they avoid any turbulence. Feeding generally occurs in water less than 50 feet deep at night. Walleye prefer temperatures of 20 to 24 °C and tend to avoid temperatures greater than 24 °C if possible. Walleye can

tolerate DO levels as low as 2 ppm for short periods of time but tend to prefer minimum levels greater than 3 to 5 ppm. Because of their preference for cool water, walleye have a moderate potential of being in the vicinity of the intake structure at Pepacton Reservoir.

Tessellated darter is a member of the perch family and is found in Pepacton Reservoir, but this species is usually found in streams and, thus, is not considered to have entrainment potential at the three proposed developments.

Chain pickerel

Chain pickerel can live in a variety of habitats and can tolerate a variety of conditions. They generally spawn in late winter and early spring. Chain pickerel adults may be found in deeper portions of lakes and reservoirs at times and often become sedentary in the summer. Juveniles prefer shallow water with abundant cover. Chain pickerel have the ability to tolerate DO levels down to 1 ppm and warm water temperatures of greater than 30°C (NatureServe, 2010; Osmond *et al.*, 1995). These fish may also move to deeper water during the winter when residing in lakes and reservoirs. Therefore, adult chain pickerel have a moderate potential of being in the vicinity of the intake structures when seeking out thermal refuge in deeper areas of the reservoirs.

Catastomids (suckers)

White sucker and longnose sucker both spawn from early spring to early summer, generally in tributary streams. Longnose suckers may also spawn in shallow areas of lakes and reservoirs. Juvenile suckers tend to stay in streams or lake margins and the adults inhabit lakes and reservoirs. The adults inhabit the bottom waters of cold, deep, oligotrophic waters and can tolerate DO levels less than 3 ppm but avoid levels less than 2.4 ppm (Twomey *et al.*, 1984). Adult white and longnose suckers have high entrainment potential due to their habitat preferences because they may be in the vicinity of the intake structures at nearly any point of the year.

Cyprinids (minnows)

Fallfish, shiners, minnows are members of the cyprinid family. These fish spawn from spring to early summer and are found in the margins of lakes or reservoirs. Therefore, these species are not expected to be subjected to entrainment at the deepwater intake structures at the three proposed developments.

Common carp is also a member of the minnow family, although they can grow much larger than other species of the minnow family. Carp are only found in the Cannonsville Reservoir. They spawn in the spring and may have a prolonged spawning period in warm waters. These fish prefer warm shallow water with abundant cover and silt/mud substrate. Adults will move to slightly deeper water as temperatures decrease in the winter. Optimum temperature ranges from 20-28°C and the upper lethal limit is 34.5°C. Common carp can tolerate DO levels below 2 ppm and will resort to gulping air at levels below 0.5 ppm (Edwards & Twomey, 1982). As common carp tend to stay in warm shallow water most of the year and move to slightly deeper water in the winter, they are not considered to have entrainment potential.

Centrarchids (sunfish, crappie, black bass)

Black crappie, rock bass, redbreast sunfish, and pumpkinseed are all members of the sunfish family and are grouped together for this analysis. Redbreast and pumpkinseed sunfishes exhibit similar habitat preferences. In both these species, the body is deep and compressed, and they occur in a wide variety of habitats. They are littoral spawners, building nests near shore in 6-12 inches of water, close to aquatic vegetation. Redbreast and pumpkinseed sunfish are restricted to areas of low velocity. Black crappie also prefer areas of low velocity, such as quiet, sluggish rivers with a high percentage of pools and backwater areas. The species also uses these areas for spawning and nurseries.

Rock bass have a deeply compressed body and are generally found in rocky-bottom streams where there is abundant shelter and considerable current, although the young are frequently found in areas with abundant aquatic vegetation(Smith, 1985).

Water temperature and DO tolerances, though not identical, are similar for these species. All of these species prefer DO levels greater than 5 ppm but can tolerate levels of 3 ppm and lower for short periods (Stuber *et al.*, 1982; Edwards *et al.*, 1982; and NatureServe, 2010). The sunfishes found in the three reservoirs associated with the proposed developments may seek deep water overwintering areas and therefore have minimal potential for being in the vicinity of the intake structures.

Smallmouth and largemouth bass are also members of the sunfish family. Optimum habitat of the smallmouth bass is characterized by cool, clear, mid-order streams with abundant shade and cover, deep pools, moderate current, and a gravel or rubble substrate. Juvenile and adult smallmouth bass both prefer low velocity water near a current, but juveniles are often found in shallower water than adults (Edwards *et al.*, 1983).

Lacustrine habitat for smallmouth bass includes large, clear lakes with an average depth of approximately 30 feet or greater and rocky shoals with limited vegetation. Preferred DO levels for normal activity are greater than 6 ppm, and they avoid water with less than 4 ppm (Edwards *et al.*, 1983). The optimal temperature range is 21-27°C with an upper lethal limit of 32°C (Osmond *et al.*, 1995). Adults may tend to seek deeper water during the day (NatureServe, 2010). Smallmouth bass spawn in spring on rocky lake shoals, river shallows, or backwaters, or move into tributaries to spawn.

Largemouth bass are found in Pepacton Reservoir. This species prefer littoral habitat with extensive cover such as vegetation and woody debris. Spawning occurs in the spring when water temperatures reach 12 to 15 °C. Gravel is the preferred spawning substrate but they will settle for vegetation, roots, sand, mud and cobble. Nests are constructed by males in shallow water, however, nests as deep as 25 feet have been found in reservoirs. Stable water levels during spawning are beneficial to survival and fluctuations can increase mortality (Stuber *et al.*, 1982).

Given their habitat preferences, adult smallmouth and largemouth bass have minimal potential for being in the vicinity of the intake structures.

Catfishes (bullhead, margined madtom, channel catfish)

Both brown and yellow bullhead are bottom feeding fish and are tolerant of high turbidity and low oxygen levels. They typically spawn in late spring and early summer. They generally inhabit warm, eutrophic waters usually in vegetated shallows over sand, mud, or silt, and can tolerate temperatures up to 32°C. Bullhead can tolerate DO levels below 1 ppm, and will burrow in the substrate to escape undesirable environmental conditions (NatureServe, 2010). Although bullhead generally prefer warm water, they are considered to have moderate entrainment potential due to their benthic nature as they may venture into the vicinity of the deep water intake structures when the reservoirs are thermally mixed.

Margined madtom are also a benthic species and are usually found in rivers and streams. The species is found in Cannonsville and Pepacton Reservoirs and is likely a remnant population. Individuals are relatively small (maximum length of five inches) (NatureServe, 2010). As with the bullhead species, margined madtom are considered to have a moderate entrainment potential due to their benthic nature as they may venture into the vicinity of the deep water intake structures when the reservoirs are thermally mixed.

Channel catfish, which are found in Pepacton Reservoir, are habitat generalists and occur in a wide range of environmental conditions. Optimal lake and reservoir habitat includes a large open water surface area,

warm water temperatures, high productivity, low to moderate turbidity levels and ample cover. Lake or reservoir habitat should include a minimum of 20% littoral zone to provide suitable habitat for all life stages of channel catfish (McMahon & Terrell, 1982).

Generally, channel catfish spawn from late spring to early summer when water temperatures reach approximately 21 °C. Nesting cover is critical to spawning success and is a major factor in determining habitat. DO levels of greater than or equal to 7 ppm are optimal, however levels of 5 ppm are adequate for sustained growth (McMahon & Terrell, 1982). As with the bullhead species, channel catfish are considered to have moderate entrainment potential due to their benthic nature as they may venture into the vicinity of the deep water intake structures when the reservoirs are thermally mixed.

5.3 Swimming speeds

Another factor affecting the entrainment and impingement potential of a fish is its swimming speed capabilities, particularly in short bursts. Although a particular fish species may have a likelihood of being found near the intake structure, it may also have a strong enough swimming speed to be able to overcome the velocity of water flowing into the intake structures, and thus swim away.

A literature review was conducted to compile known swimming speeds for the fish species found in the Cannonsville, Pepacton, and Neversink Reservoirs. Available swim speeds are presented in Table 5-4. Species are grouped in the guilds set forth in Table 5-2. Species that were ruled out as having no entrainment potential due to the habitat preferences listed in Table 5-3 were not included in Table 5-4. A summary of swimming speed information for each guild is described below.

Both prolonged (sustainable) and burst swim speeds are reported in Table 5-4 for reference, although the burst speeds are most important for this analysis. For some species, prolonged and/or burst speed data were not available in the literature reviewed, so one or more representative "surrogate" species were used. For a few species, no data could be obtained, even for a surrogate species. It should be noted that swim speed data were obtained from a variety of sources, and therefore, the results were determined under different environmental conditions. Swimming speeds are affected by available oxygen, and water temperatures at either end of a fish's optimum thermal range (Bell, 1991). During colder water temperatures in winter or when fish may be faced with stress related to low DO, actual swim speeds may be slower.

Swim speeds for each species or group are compared to velocities at each intake structure in Section 6 to determine the overall potential for entrainment at each development.

Salmonids (trout and salmon)

Brown trout, brook trout, rainbow trout, and landlocked Atlantic salmon have similar body types. Brown trout, with reported burst speeds of 4.5 to 10 ft/s, were used as a surrogate species for both brook trout and landlocked salmon (Beamish, 1978). Rainbow trout show a slightly broader range of burst speeds, from 2.4 to 11.5 ft/s (Froese & Pauley, 2010).

Rainbow smelt

Rainbow smelt, which are present in the Neversink and Pepacton reservoirs, generally swim at a rate of 1.3 to 1.9 ft/s. They can burst for short distances up to 5 ft/s (Katapodis & Gervais, 1991).

Alewife

Alewives have a high chance of being near the intake structures when seeking out thermal refuge in deeper areas. However, their burst speed, at 15.5 ft/s, is the fastest reported burst speed for all of the species found in the three reservoirs associated with the proposed developments (Froese & Pauley, 2010).

Percids (walleye and yellow perch)

Walleye can sustain a swimming speed of 1.0 to 3.7 ft/s, and can burst up to 8.5 ft/s (Furniss *et al.*, 2008). Walleye was used as a surrogate species for yellow perch.

Chain pickerel

Northern pike was used as a surrogate species for chain pickerel. Northern pike can sustain swimming speeds of 4.8 to 6.9 ft/s and can reach burst speeds of 14.8 ft/s (Beamish, 1978).

Catastomids (suckers)

Adult white and longnose suckers have a high likelihood of being found near the intake structures due to their habitat preferences. Prolonged swimming speeds for white and longnose suckers range from 1.3 to 4.9 ft/s, while burst speeds can reach 10.2 ft/s for white suckers and 7.9 ft/s for longnose suckers (Ontario Ministry of Transportation, 2006 and Bell, 1991).

Centrarchids (sunfish, crappie, black bass)

Pumpkinseed prolonged swimming speeds are reported as 1.2 ft/s (Furniss *et al.*, 2008). Burst speeds up to 4.9 ft/s were reported for green sunfish (Beamish, 1978), which was used as a surrogate species for pumpkinseed, redbreast sunfish, black crappie, and rock bass.

Smallmouth and largemouth bass have a similar range of prolonged swim speeds which were reported as 1.8 to 3.9 ft/s, but no burst speed data could be found for either smallmouth or largemouth bass or a surrogate species (Furniss *et al.*, 2008).

Catfishes (bullhead, margined madtom, channel catfish)

No prolonged or burst swim speed data could be found for adults of these species in the available literature. Channel catfish juveniles are reported to have prolonged swim speeds of 1.3 ft/s and burst speeds of 3.9 ft/s (Venn Beecham *et al.*, 2007).

Table 5-1: Fish species found in the Cannonsville, Pepacton, and Neversink Reservoirs.

Common Name	Scientific Name	Cannonsville	Pepacton	Neversink
Alewife	*Alosa pseudoharengus*	x	x	x
Black crappie	*Pomoxis nigromaculatus*	x	x	
Bluntnose minnow	*Pimephales notatus*		x	
Brook trout	*Salvelinus fontinalis*	x	x	
Brown bullhead	*Ameiurus nebulosus*	x	x	x
Brown trout	*Salmo trutta*	x	x	x
Chain pickerel	*Esox niger*	x	x	x
Channel catfish	*Ictalurus punctatus*		x	
Common carp	*Cyprinus carpio*	x	x	
Eastern silvery minnow	*Hybognathus regius*		x	
Fallfish	*Semotilus corporalis*		x	x
Golden shiner	*Notemigonus crysoleucas*	x	x	x
Landlocked Atlantic salmon	*Salmo salar*			x
Largemouth bass	*Micropterus salmoides*		x	
Longnose sucker	*Catostomus catostomus*	x	x	x
Margined madtom	*Noturus insignis*	x	x	
Pumpkinseed	*Lepomis gibbosus*		x	x
Rainbow smelt	*Osmerus mordax*		x	x
Rainbow trout	*Oncorhynchus mykiss*	x	x	
Redbreast sunfish	*Lepomis auritus*		x	
Rock bass	*Ambloplites rupestris*	x	x	x
Smallmouth bass	*Micropterus dolomieu*	x	x	x
Spottail shiner	*Notropis hudsonius*		x	x
Tessellated darter	*Etheostoma olmstedi*		x	
Walleye	*Sander vitreus*		x	
White sucker	*Catostomus commersonii*	x	x	x
Yellow bullhead	*Ameiurus natalis*	x		
Yellow perch	*Perca flavescens*	x	x	x

Source: List of fish species found in Cannonsville and Pepacton Reservoir was provided by NYSDEC and fish species found in Neversink Reservoir is from DEP records.

Table 5-2: Representative fish species guilds used for this evaluation.

Fish Species/Family	Temperature Guild	Habitat Guild
Salmonids (salmon, trout)	Coldwater	Pelagic predator
Rainbow smelt	Coldwater	Pelagic prey
Alewife *Juvenile* *Adult*	 Coolwater Coldwater	 Littoral prey Pelagic prey
Percids *Walleye* *Yellow perch*	 Coolwater Coolwater	 Littoral predator Littoral prey
Pickerel	Coolwater	Littoral predator
Catostomids (suckers)	Coolwater	Benthic
Cyprinids (minnows)	Warmwater	Littoral prey
Centrarchids *Smallmouth bass* *Sunfishes*	 Coolwater Warmwater	 Littoral predator Littoral prey
Ictalurids (Bullhead, madtom, channel catfish)	Warmwater	Benthic

Table 5-3: Entrainment potential of reservoir fish species based on habitat requirements.

Fish Species	Life Stage	Ecological Requirement	Migration Pattern	Likelihood of Proximity to Intakes		
				Cannonsville	*Pepacton*	*Neversink*
Alewife	Adult Spawning	Shallow water	Moves to tributaries or nearshore areas in spring to spawn	Minimal	Minimal	Minimal
	Adult	Deep water in winter	Local migration to deep water in winter	High	High	High
	Juvenile	Shallow water	Juveniles may be local migrants	None	None	None
Black crappie	Adult Spawning	Littoral areas in reservoirs	Moves to nearshore vegetation	None	None	Not present
	Adult	Shallow water or high in water column over deep water	May move to deeper water in winter	Minimal	Minimal	
	Juvenile	Shallow water with abundant cover	None	None	None	
Bluntnose minnow	Adult Spawning	Streams or margins of lakes	Moves to nearshore areas to spawn	Not present	None	Not present
	Adult	Shallow areas with vegetation	None			
	Juvenile					
Brook trout	Adult Spawning	Gravel with upwelling water	Moves to tributary streams or shallow gravel bars	None	None	Not present
	Adult	Cool, well oxygenated water	Moves to cool water in summer	Moderate	Moderate	
	Juvenile	Calm, cool water	None	None	None	
Brown bullhead	Adult Spawning	Close to shore, in coves or creek mouths	Moves to nearshore vegetation	None	None	None
	Adult	Wide ranging bottom feeder	Stays close to the bottom	Moderate	Moderate	Moderate
	Juvenile	Bottom feeder	May move to deeper water when rearing	Moderate	Moderate	Moderate
Brown trout	Adult Spawning	Rivers/Streams	Moves to tributary streams	None	None	None
	Adult	Cool, well oxygenated water	Moves to cool water in summer	Moderate	Moderate	Moderate
	Juvenile	Calm, cool water	None	None	None	None
Chain pickerel	Adult Spawning	Shallow water beaches	Moves to nearshore vegetation	None	None	None
	Adult	Variety of habitats, and may inhabit deep water	May make local migrations	Moderate	Moderate	Moderate
	Juvenile	Shallow water with abundant cover	None	None	None	None

Table 5-3: Entrainment potential of reservoir fish species based on habitat requirements. *(cont.)*

Fish Species	Life Stage	Ecological Requirement	Migration Pattern	Likelihood of Proximity to Intakes		
				Cannonsville	*Pepacton*	*Neversink*
Channel Catfish	Adult Spawning	Nesting cover is critical	Moves to nearshore areas of cover	Not present	None	Not present
	Adult	Habitat generalist, with some littoral zone habitat needed	May move to deeper water in winter		Moderate	
	Juvenile					
Common carp	Adult Spawning	Shallow water with abundant cover	Little directed movement	None	None	Not present
	Adult					
	Juvenile					
Eastern silvery minnow	Adult Spawning	Streams or margins of lakes	Moves to tributaries or nearshore areas to spawn	Not present	None	Not present
	Adult	Shallow water	None			
	Juvenile					
Fallfish	Adult Spawning	Streams or margins of lakes	Moves to tributaries or nearshore areas to spawn	None	None	None
	Adult	Shallow water	None			
	Juvenile					
Golden shiner	Adult Spawning	Shallow water	Moves to tributaries or nearshore areas to spawn	None	None	None
	Adult		None			
	Juvenile					
Landlocked salmon	Adult Spawning	Rivers/Streams	Moves to tributary streams	Not present	Not present	None
	Adult	Cool, well oxygenated water	Stays close to thermocline in summer			Moderate
	Juvenile	Rivers/Streams	None			None
Largemouth bass	Adult Spawning	Shallow water over gravel substrate	Moves to shallow water to spawn	Not present	None	Not present
	Adult	Littoral zone in summer, deep water in winter.	Local migration to deep water in winter		Minimal	
	Juvenile	Shallow water	None		None	

Table 5-3: Entrainment potential of reservoir fish species based on habitat requirements. *(cont.)*

Fish Species	Life Stage	Ecological Requirement	Migration Pattern	Likelihood of Proximity to Intakes		
				Cannonsville	*Pepacton*	*Neversink*
Longnose sucker	Adult Spawning	Streams or margins of lakes	Moves to tributaries, nearshore shoals, or river mouths to spawn	Minimal	Minimal	Minimal
	Adult	Moderately deep to deep water	Stays close to the bottom	High	High	High
	Juvenile	Shallow water with abundant cover	None	None	None	None
Margined madtom	Adult Spawning	Gentle runs in streams/rivers under rocks	Spawns in streams	None	None	Not present
	Adult	Wide ranging bottom feeder	Stays close to the bottom in moving water	Moderate	Moderate	
	Juvenile	Bottom feeder	Generally found in moving water near bottom	Moderate	Moderate	
Pumpkin-seed	Adult Spawning	Shallow water	None	None	None	None
	Adult	Shallow water or high in water column over deep water	Local migration to deep water in winter	Minimal	Minimal	Minimal
	Juvenile	Shallow water	None	None	None	None
Rainbow smelt	Adult Spawning	Rivers/Streams	Moves to tributary streams	Not present	None	None
	Adult	Cool, well oxygenated water	Stays close to thermocline in summer		Minimal	Minimal
	Juvenile	Diurnal column movements	May make local migrations		None	None
Rainbow trout	Adult Spawning	Gravel with upwelling water	Moves to tributary streams or shallow gravel bars	Not present	None	Not present
	Adult	Cool, well oxygenated water	Moves to cool water in summer		Moderate	
	Juvenile	Calm, cool water	None		None	
Redbreast sunfish	Adult Spawning	Shallow water	None	Not present	None	Not present
	Adult	Littoral zone in summer, deep water in winter.	Local migration to deep water in winter		Minimal	
	Juvenile	Shallow water	None		None	
Rock bass	Adult Spawning	Shallow water	None	None	None	None
	Adult	Littoral zone in summer, deep water in winter.	Local migration to deep water in winter	Minimal	Minimal	Minimal
	Juvenile	Shallow water	None	None	None	None

Table 5-3: Entrainment potential of reservoir fish species based on habitat requirements. *(cont.)*

Fish Species	Life Stage	Ecological Requirement	Migration Pattern	Likelihood of Proximity to Intakes		
				Cannonsville	*Pepacton*	*Neversink*
Smallmouth bass	Adult Spawning	Gravel or broken rock	May travel to streams to spawn	None	None	None
	Adult	Clear water with rocky shoals; epilimnion in summer	Occasionally moves to deep water during the day	Minimal	Minimal	Minimal
	Juvenile	Calm water with cover	None	None	None	None
Spottail shiner	Adult Spawning	Streams or margins of lakes	Moves to tributaries or nearshore areas to spawn	Not present	Not present	None
	Adult	Shallow water	None			
	Juvenile					
Tessellated darter	Adult Spawning	Shallow water	Moves to tributaries or nearshore areas to spawn	Not present	None	Not present
	Adult		None			
	Juvenile					
Walleye	Adult Spawning	Shallow shoreline areas, shoals, riffles	Moves to nearshore areas or tributaries to spawn	Not present	None	Not present
	Adult	Lakes with moderate turbidities and substantial areas of rocky substrate	Moves to nearshore areas at night to feed		Moderate	
	Juvenile					
White sucker	Adult Spawning	Riffles of streams	Moves to tributaries, nearshore shoals, or river mouths to spawn	None	None	None
	Adult	Bottom feeder	Stays close to the bottom	High	High	High
	Juvenile	After sac-fry, moves to bottom feeding	May spend time in stream and then move to lake	Minimal	Minimal	Minimal
Yellow bullhead	Adult Spawning	Shallow areas of lakes with abundant vegetation and clear water	Moves to nearshore vegetation	None	Not present	Not present
	Adult	Wide ranging bottom feeder	Stays close to the bottom within preferred temperature range	Moderate		
	Juvenile					
Yellow perch	Adult Spawning	Shorelines with vegetation	Moves to nearshore vegetation	None	None	None
	Adult		May occasionally move to deep water to feed	Minimal	Minimal	Minimal
	Juvenile		None	None	None	None

Table 5-4: Prolonged and burst swimming speeds of selected fish species.

Fish Species	Swim Speed (ft/s)		Surrogate Species	
	Prolonged	*Burst*	*Prolonged*	*Burst*
Salmonids				
Landlocked salmon	3.0[1]	4.5 - 10.0[1]	Brown trout	Brown trout
Brown trout	3.0[1]	4.5 - 10.0[1]		
Brook trout	3.1[4]	4.5 - 10.0[1]		Brown trout
Rainbow trout	0.9 - 6.9[3]	2.4 - 11.5[3]		
Rainbow smelt				
Rainbow smelt	1.3 - 1.9[5]	2.6 - 5.0[5]		
Clupeids				
Alewife	1.7[2]	15.5[3]	Juvenile American shad	
Percids				
Walleye	1.0 - 3.7[4]	5.2 - 8.5[4]		
Yellow perch	1.0 - 3.7[4]	5.2 - 8.5[4]	Walleye	Walleye
Esocids				
Chain pickerel	4.8 - 6.9[1]	11.8 - 14.8[1]	Northern pike	Northern pike
Catastomids				
White sucker	1.3 - 4.9[6]	5.2 - 10.2[6]		
Longnose sucker	1.3 - 4.9[6]	4.0 - 7.9[2]		
Centrarchids				
Black crappie	1.2[1]	4.9[1]	Pumpkinseed	Green sunfish
Rock bass	1.2[1]	4.9[1]	Pumpkinseed	Green sunfish
Redbreast sunfish	1.2[1]	4.9[1]	Pumpkinseed	Green sunfish
Pumpkinseed	1.2[1]	4.9[1]		Green sunfish
Smallmouth bass	1.8 - 3.9[4]	No data		
Largemouth bass	1.8 - 3.9[4]	No data		
Ictalurids				
Brown/yellow bullhead	No data	No data		
Margined madtom	No data	No data		
Channel catfish	1.3[7]	3.9[7]		

Data Sources

1. Beamish, 1978
2. Bell, 1991
3. Froese & Pauley, 2010
4. Furniss *et al.*, 2008
5. Katapodis & Gervais, 1991
6. OMOT, 2006
7. Venn Beecham *et al.*, 2007

6.0 ENTRAINMENT ANALYSIS

This section presents a summary of the factors affecting fish entrainment.[9] For each development, differences in entrainment potential based on the time of year, intake velocities, water temperatures, water levels in each reservoir, the location of the thermoclines, and stratification of the reservoirs were evaluated. Entrainment potential based on rates observed at other relevant sites is also discussed.

6.1 Overview

Fish entrainment and survival studies are a typical component of FERC licensing proceedings. Consequently, many studies evaluating the entrainment and turbine passage survival of fish at hydroelectric projects have been completed, with most of the field-based studies occurring in the 1990s. More recently, entrainment assessment at hydroelectric developments has been performed using a literature-based approach due to the high costs and uncertainty of field studies. For this report, the results of field studies at other sites where quantitative sampling of entrainment was conducted, as summarized by EPRI (1997) and FERC (1995), were reviewed to develop estimates of entrainment potential at the three proposed developments. More specifically, the estimates are based on the following factors:

- **Intake proximity to shoreline** – Entrainment tends to be higher at near-shore intakes due to a tendency for fish to follow the shoreline.

- **Intake located in littoral zone** – The littoral zone is the most productive region of a reservoir and is inhabited by many fish species during their early life stages.

- **Intake depth** – Fish are usually more abundant in shallower portions of a reservoir throughout most of the year. The exception is during winter, when fish may move to the warmer bottom layer of a reservoir.

- **Seasonal drawdown** – Seasonal drawdown of a reservoir may place fish in closer proximity to water intakes.

- **Water Quality Factor** – Fish have distinct temperature and DO preferences, and will therefore base their position in the water column on thermal stratification and oxygen levels.

- **Hydraulic capacity** – The entrainment rate is a function of the volume and velocity of water passing through the intake structure.

Most of the entrainment studies reviewed in the EPRI database had intake depths of less than 25 feet, but some general trends were apparent. First, entrainment potential is inversely related to the amount of head. That is, the potential is greater at the lower head projects than at high head projects. This makes intuitive sense in that shallow water species (*e.g.*, sunfish and minnows), which are the most commonly entrained species, are less likely to be occupying deeper water habitats.

Second, entrainment potential is a function of fish size. The literature indicates that entrainment is highest for fish less than four inches (FERC, 1995; Winchell *et al.*, 2000), and approximately 94% of all fish entrained are less than eight inches (Winchell *et al.*, 2000; Table 6.1-1). The literature also indicates that bar rack clear spacing bears little relationship to the proportion of each fish size that is entrained (*Id.*).

[9] In this section, entrainment potential also includes the potential for impingement irrespective of intake protection measures. Mortality due to impingement is discussed in Section 7.3.

In other words, because most entrained fish are small, wide bar rack spacing does not appear to affect entrainment rates.

6.2 Literature Review of Entrainment at Deep Water Intake Structures

The proposed developments are fairly unique due to the following factors: the depth of the intake structures, the primary use of the water is for drinking water supply, and the flows used for hydropower would come from directed and conservation releases. As a result, some of the entrainment information in the EPRI (1997) and FERC (1995) reports was only marginally applicable because many of the sites have shallow intakes and are located in warmer climates, compared to the Project. Therefore, the literature review was expanded to include other projects with deep intake structures and/or particular focus on trout impacts. The majority of these studies relate to hydroelectric facilities in the western United States.

The FERC and EPRI entrainment databases generally include warm and coolwater species, but information concerning coldwater species such as trout and salmon is somewhat lacking. Recent FERC licensing reports were queried to identify entrainment studies at deep water intake structures. The Jackson Hydroelectric Project in Snohomish County, Washington ("Jackson Project") recently compiled a summary of entrainment studies at projects with deep water intake structures.

Similar to the Project, the Jackson Project has a diversion tunnel near the bottom of a reservoir at 200 to 230 feet deep. Like the Project's conservation releases, the Jackson Project's releases are performed to maintain cool temperatures in the Sultan River. During the relicensing of the Jackson Project, the licensee performed an entrainment evaluation that involved studies where the reservoirs were over 200 feet deep, the intake structures were in deep water, and salmon and trout were the primary species of interest. At the Jackson Project, the goal was not to allow passage of fish, but to keep them in the reservoir.

Spada Lake (the reservoir impounded by the Jackson Project) thermally stratifies in April and de-stratifies in November. The mean surface and bottom temperatures in the summer are approximately 18°C and 4°C, respectively. The intake structure has 20-foot-high removable panels that allow selective withdrawal of water to control the water temperature.

The Jackson Project entrainment report (CH2M Hill, 2007) included a review of 12 projects that conducted entrainment studies. This information, summarized below, was the most recent and relevant information located with regard to fish entrainment studies at hydroelectric projects with deep water intake structures.

Lake Lemolo

Lake Lemolo is a 415-acre reservoir on the North Fork Umpqua River in southern Oregon. It is operated as a storage-release reservoir for hydropower generation. The depth of the intake structure is 110 feet when full and 60 feet at low pool elevation. These depths are similar, but not as deep as those for the reservoirs associated with the proposed Project developments when full.

Trout entrainment was evaluated with the use of fyke nets that sampled the entire flow in the diversion canal leading to the powerhouse. The net was deployed two to four days a week seasonally over a five-year period, for a total of 226 weeks. In terms of sampling frequency and sampling gear efficiency, this was one of the best-designed and best-implemented trout entrainment studies reviewed.

The samples were then used to develop annual entrainment estimates. For the years studied, the average annual entrainment was 1,319 trout. During years in which there was a high drawdown (36 to 44 feet), the annual entrainment estimate was 1,632 trout. During years in which there was a low drawdown (11 to

22 feet), the annual entrainment estimate was 1,005 trout. By far, most of the entrainment occurred in the fall just as the reservoir was reaching maximum drawdown. In the high drawdown years, the lake volume at low pool was only 12 percent of the volume at the year's maximum pool elevation.

Most (86 percent) of the entrainment occurred at night, and the average size of entrained trout was four inches. The total estimated trout population within the reservoir was 51,000. Therefore, the average annual entrainment rate was 2.6 percent of the population.

Tieton Dam

Tieton Dam forms Rimrock Lake on the Tieton River, a major tributary of the Yakima River in eastern Washington. The reservoir consists of 2,526 surface acres and has a total storage volume of 198,000 acre-feet. The intake depth is 200 feet at full pool. The intake capacity is 2,760 cfs, but flows ranged from 300 cfs to 2,200 cfs during the period of the entrainment study. The depth of the intake is similar to those for the proposed Project developments.

The dominant fish species in Rimrock Lake is kokanee salmon, followed by rainbow trout. Entrainment sampling was done by deploying fyke nets on each side of the river in the tailrace approximately 0.25 miles below the dam. The investigators were not able to estimate the proportion of flow sampled. The sampling occurred from August 27 through October 17, 2001 to coincide with the maximum seasonal water withdrawal for downstream irrigation. This was also the season when kokanee were most susceptible to entrainment based on previous studies at the site.

A total of 10,943 mostly sub-adult kokanee salmon were captured during the seven-week sampling period. The mortality rate (81%) was high as the fish passed through a jet valve. The sampling also resulted in the collection of 37 rainbow trout, only nine of which were dead. This proportion, as compared to that for the salmon, suggested that most of the live trout had been residing in the tailrace and, thus, had not been entrained.

The study results indicate that sub-adult kokanee are highly susceptible to entrainment through the deep intake at Tieton Dam due to their preference for deep water. Kokanee entrainment was minimal when approach velocities were less than 4 ft/s. Kokanee entrainment increased significantly as approach velocities reached their maximum of 10 ft/s. The study concluded that rainbow trout entrainment was minimal.

Timothy Lake

Timothy Lake is on the upper Clackamas River system in Oregon. The lake surface area is 1,280 acres and has an outlet depth of 80 feet at full pool. The intake structure is not as deep as those for the proposed Project developments. Water passes through a Howell-Bunger valve with a maximum discharge capacity of 300 cfs. The reservoir is used for seasonal storage of water that eventually passes through several downstream powerhouses of the Clackamas River Hydroelectric Project. The water level is maintained near full during the summer recreation season and is then drawn down in the fall. The reservoir supports a popular trout fishery.

The most common fish in Timothy Lake is a naturally reproducing brook trout population. Rainbow trout is the second most common fish, but they are supported entirely by hatchery plants, as the Oregon Department of Fish and Wildlife stocks the lake with 12,000 to 34,000 catchable-sized rainbow trout annually. The lake also contains naturally reproducing cutthroat trout and kokanee salmon. The total trout population in the lake is estimated at over 100,000 fish.

Entrainment sampling was conducted at Timothy Lake in August, September, and October of 2000, April of 2001, and May and June of 2002. Sampling gear included a screw trap and several gill nets deployed

in the tailrace just downstream of the dam discharge. After a total sampling effort of 211 hours of gill netting and 814 hours of screw trapping, only one trout (cutthroat) was determined to have been entrained through the outlet works. This is a miniscule number when compared to the lake's trout population.

Barney Reservoir

Barney Reservoir is a water supply reservoir on the upper North Fork Trask River in the coastal range of Oregon. It stores water for transfer to the upper Tualatin River for municipal water supply. The 200-acre reservoir supports a naturally reproducing population of cutthroat trout and non-native yellow bullhead. Water is withdrawn at a maximum rate of 68 cfs from the bottom of the reservoir at a depth of 70 feet. As part of studies to assess impacts of enlarging the dam, discharge water was sampled with an inclined-plane trap positioned in a concrete receiving basin below the outlet. Approximately half of the discharge passed through the fish trap. Continuous sampling from June through October (sampling year not specified, date of report is 1994) collected 26 4- to 7-inch yellow bullhead but no cutthroat trout. The study concluded that trout did not appear to be susceptible to entrainment, most likely due to the depth of the intake.

Cooper Lake

Cooper Lake is a reservoir in Alaska that supplies flow to a hydroelectric project. The powerhouse intake is set back from the lake shore by approximately 100 feet. The intake flow capacity is 380 cfs, and the top of the intake is 32 feet deep at full pool and 8 feet deep at minimum pool. Maximum approach velocity at the intake trash racks is 1.57 ft/s. Cooper Lake supports populations of naturally reproducing arctic char and rainbow trout. Entrainment studies were done with use of an underwater camera positioned in the intake channel. The study concluded that, for rainbow trout, entrainment risk was low because of that species' preference for shallow water, lack of observations in the intake area, and low approach velocity at the intake structure.

Libby Reservoir (Lake Koocanusa)

The Libby Reservoir/Lake Koocanusa is on the Kootenai River in Montana. The lake is 29,000 acres, and the powerhouse has a discharge capacity of 28,000 cfs. The powerhouse has a selective withdrawal intake and typical depths are approximately 50 feet in the spring and summer, 140 feet in the winter, and 90 feet in the fall.

Lake Koocanusa supports large populations of kokanee salmon, as well as rainbow and cutthroat trout. While there is some natural reproduction of trout, the State of Montana and the Province of British Columbia release approximately 100,000 rainbow and cutthroat trout into the lake annually.

Entrainment sampling was conducted from 1992 to 1994 to determine the potential for entrainment of kokanee salmon, rainbow trout, and cutthroat trout. The sampling was conducted using fyke nets at the exits of the powerhouse draft tubes. Hydroacoustic monitoring also was deployed in the forebay to observe fish behavior. Following 501 hours of netting, distributed from January 1992 through June 1994, a total of 13,186 fish were captured. Of these, 97.5 percent were kokanee, of which 74 percent were subyearlings. Only nine rainbow trout and seven cutthroat trout were captured. However, most of the trout were believed to have been tailrace residents rather than entrained individuals. The study concluded that kokanee (especially sub-yearling) salmon are highly susceptible to entrainment through the intake at the Libby Dam. The study also concluded that trout are not susceptible to entrainment at this facility.

Butt Valley Reservoir (North Fork Feather River)

Butt Valley Reservoir is a large reservoir in northern California on Butt Creek, which is a tributary to the North Fork Feather River. The reservoir is 1,600 acres, the intake capacity is 1,114 cfs, and the intake

depth is approximately 60 feet. The primary fish species in the lake are rainbow trout and non-native pond smelt. Fish entrainment sampling was conducted using a rigid-framed fyke net deployed in the tailrace below the powerhouse. It was estimated that 40 to 60 percent of the discharge flow passed through the net. Sampling was done for two 24-hour periods per month from June through November of 2001. During the study period, over 35,000 pond smelt and 4 prickly sculpin were captured. No trout were captured. Pond smelt were introduced into this system in 1972, and are now highly abundant. The study indicated that large numbers of pond smelt tended to be aggregated at or near the thermocline. The study concluded that although large numbers of pond smelt were entrained, the population was stable and no impacts to native or recreational fisheries were apparent.

Lake Almanor (North Fork Feather River)

Lake Almanor is a large reservoir impounding the North Fork Feather River. The reservoir is 28,252 acres and has a maximum intake depth of 100 feet. The primary fish species include rainbow trout, pond smelt, smallmouth bass, and sculpin. Entrainment sampling was conducted using tailrace netting during two 24-hour periods per month from June through October of 2001. During the 5-month sampling period, fish captures included over 91,000 pond smelt and three rainbow trout, indicating limited trout entrainment. Being part of the same river system as the Butt Valley Reservoir, pond smelt are highly abundant in Lake Alomar and the entrainment study reached the same conclusion as that of the Butt Valley Reservoir study.

Florence Lake (Big Creek Hydroelectric Project)

Florence Lake is a 970-acre reservoir in the upper San Joaquin River basin of central California. The facility has an intake depth of 107 feet. Florence Lake supports populations of brown trout and rainbow trout. Entrainment sampling was conducted using fyke nets in the tailrace. The sampling schedule consisted of one day per month in January, March, July, August, September, and December of 2001 to 2003. During the sampling period, only two brown trout and one rainbow trout were captured, indicating limited entrainment potential for trout.

Huntington Lake (Big Creek Hydroelectric Project)

Huntington Lake is a 1,538-acre reservoir on Big Creek, a tributary of the San Joaquin River. Maximum depth of the intake is 128 feet. The powerhouse intake capacity is 675 cfs. The lake supports brown trout, hatchery-stocked rainbow trout, Sacramento sucker, and sculpin. The tailrace was netted three days per month, every other month, between July 2003 and August 2004. During the sampling period, no fish of any species were captured.

Shaver Lake (Big Creek Hydroelectric Project)

Shaver Lake is on Stevenson Creek, a tributary of the San Joaquin River. The lake is 2,141 acres in size and the intake is located in 136 feet of water with a flow capacity of 670 cfs. The lake supports rainbow trout, as well as some warmwater fish species. Entrainment sampling was conducted using tailrace netting for three days every other month, from 2003 to 2004. During the sampling period, no fish of any species were captured.

Mammoth Pool (Big Creek Hydroelectric Project)

Mammoth Pool is an impoundment on the upper San Joaquin River. It is 1,287 acres in size and the intake at full pool is 225 feet deep. The lake supports mostly brown trout and some hatchery-stocked rainbow trout. Entrainment sampling was conducted using tailrace netting for three days every other month, from 2003 to 2004. No fish of any species were captured during the study period.

In summary, trout entrainment at each of the facilities was minimal with the only exception being the Lake Lemolo Project. However, most of the entrainment at the Lake Lemolo Project involved brown trout and occurred when the lake level was approaching its seasonal drawdown limit.

6.3 Intake Velocities

Water velocities at each intake structure are summarized in this section. Intake velocity is calculated by dividing the total release flow (conservation and directed releases) from the reservoir by the intake area. Monthly intake velocity duration curves were developed based on the entire period of record from the OASIS model (1948-2008). As with the water level duration curves, monthly intake velocity curves were broken into four quarters. Velocity curves by reservoir are shown in Figures 6.3-1 through 6.3-12.

The intake areas are fixed at Cannonsville (510 ft^2), Pepacton (96 ft^2), and Neversink (72 ft^2).[10] Maximum turbine capacities and intake velocities based on hydropower flow only are noted on the graphs for reference.

Cannonsville Reservoir

Monthly intake velocity duration curves at the Cannonsville Reservoir for the first, second, third, and fourth quarters are shown in Figures 6.3-1 through 6.3-4, respectively. Based on the FFMP-OST, the maximum discharge capacity at Cannonsville when the storage capacity is in zone L1-a (full) is 1,500 cfs. At that discharge capacity, the maximum water velocity at the intake structure is equal to 2.9 ft/s.

In the summer months when the reservoir is normally being drawn down (*i.e.*, July, August, and September), water velocities have been at or below 1.2 ft/s over 90% of the time. Intake velocities during the fall months (*i.e.*, October, November, and December) have been even lower—only 0.4 ft/s or less at least 75% of the time. The highest velocities (near 3 ft/s) occurred about 10% of the time during the fall and about 8% of the time during the summer.

Pepacton Reservoir

Monthly intake velocity duration curves at the Pepacton Reservoir are shown in Figures 6.3-5 through 6.3-8. The water velocities range from 0.3 ft/s to 7.3 ft/s over the course of the year. The highest velocity occurs under the maximum FFMP-OST flow of 700 cfs. In the summer months when the reservoir is drawn down, intake velocities have been at or below 1.6 ft/s 90% of the time. Water velocities during the fall months have been at or below 1.6 ft/s 75% of the time. The highest velocities (around 7 ft/s) occurred less than 16% of the time during the fall and less than 7% of the time during the summer.

Neversink Reservoir

The point of entrance for fish is at the openings along the wall of common structure. However, flow velocities in this area are very low, ranging from 0.02 ft/s to 0.9 ft/s depending on the water level of the reservoir.

The design of the intake structure at Neversink is such that all occurrences of potential fish entrainment to the proposed hydroelectric development would occur at the troughs on the floor of the intake structure. At the proposed maximum hydro discharge capacity of 100 cfs, the intake velocity in front of the 72 ft^2 trough opening would equal 1.39 ft/s. At the maximum combined conservation and directed release of 190 cfs (based on OASIS data), the maximum intake velocity equals 2.64 ft/s. Monthly intake velocity

[10] Although the common intake structure at Neversink is a vertical tower with eight segments that span the length of the water column, the intake that conveys water from the forebay to the stream release is at a fixed location at the bottom of the water column (as described in Section 3.4). It is from this point that water will be conveyed to the proposed hydroelectric turbine.

duration curves at the Neversink Reservoir, based on conservation and directed flow releases through the trough opening are shown in Figures 6.3-9 through 6.3-12. During the summer months, intake velocities have been below 2.0 ft/s (*i.e.*, the USFWS velocity criteria) approximately 90% of the time.

6.4 Assessment of Entrainment Potential

The effects of site specific factors previously discussed (*e.g.*, water levels, water quality, resident fish species and intake velocities) on entrainment potential at each development are examined in this section. Table 6.4-1 presents the overall potential for entrainment for each fish species and life stage based on the habitat requirements presented in Table 5-3 and the swim speeds presented in Table 5-4. The water velocity at each intake structure was factored into the analysis by comparing the velocities with the swimming speeds of fish that have a potential for being in the vicinity of the intake structures. Burst swim speeds and intake velocities are shown in the table for reference.

For this analysis, most species identified as having a likelihood of being found near the intake structures were ruled out from having a potential for entrainment or impingement due to strong burst swimming capabilities relative to approach velocities, particularly at Neversink and Cannonsville Reservoirs. For some species, juveniles could not be ruled out because they typically do not exhibit the same swimming performance as adults. For other species, no burst swimming speed data was found in the literature, so potential for entrainment or impingement could not be ruled out based on swimming performance alone.

A review of existing DEP records at the three reservoirs associated with the proposed developments indicated that there was one recent occurrence (2005) of fish entrainment documented at Cannonsville Reservoir, as described below. No additional records of fish entrainment at the three reservoirs were found.

Cannonsville Reservoir

Because the Cannonsville Reservoir is often reduced to 25-30% of its capacity during hot, dry summers, entrainment potential is the greatest at this proposed development during these situations. However, during consultations relating to the study plan development process, NYSDEC has noted that there have been no complaints of fish mortality downstream, even during these extreme drawdown periods.

Poor water quality (low DO) in the metalimnion could provide a barrier to fish entrainment. However, fish may find the cooler, relatively oxygenated hypolimnion more desirable than warmer surface waters and seek refuge there. In dry years, as a result of directed releases, the cooler hypolimnion is essentially depleted and fish residing there are forced to move to avoid facing stressed conditions from the “sinking” poor water quality in the metalimnion. Effler *et al.* (1998) suggested that the prevailing vertical patterns of DO undoubtedly influence the distribution and movements of coldwater fish in the Cannonsville Reservoir. When the volume of the hypolimnion decreases, fish may be forced to concentrate in intake areas where cooler, more oxygenated water is located, thereby increasing entrainment and impingement potential. Thus, the potential for fish entrainment and impingement peaks during dry summer drawdowns, and the fish species most likely subject to entrainment and impingement are those seeking deep, cool water as thermal refuge, such as brown and brook trout, rainbow smelt, and alewife. Likewise in winter, because the bottom layer of the reservoir is warmer than the surface, fish may tend congregate near the bottom and stay active throughout the winter, thus having a moderate potential of being in the vicinity of the intake structures during winter.

DEP records indicate only one occurrence of a fish entrainment event at Cannonsville Reservoir. In response to a report of dead fish found downstream of the Cannonsville Dam on September 25, 2005, DEP conducted a fish kill investigation where hundreds of dead and dying yellow perch and alewives were found below the dam. At the time of the event, the reservoir was drawn down approximately 50 feet

to elevation 1099 feet above msl, and water quality data collected from near the dam showed very low DO levels below the thermocline at 46 feet. Some of the yellow perch collected for analysis had distended swim bladders consistent with being exposed to rapid pressure change, thus indicating entrainment. The DEP concluded that the cause of mortality was likely due to a combination of low DO below the thermocline and entrainment through the dam. The flow release through the dam was increased by 100 MGD the day before the kill. The low DO may have either killed the fish outright or impaired their ability to escape from being entrained.

Per the USFWS design criteria, the intake velocity one foot in front of the racks should be 2 ft/s or less. Intake velocities during the summer months are greater than 2 ft/s most frequently in July (but only approximately 7 percent of the time), while during August and September intake velocities are above 2 ft/s less than 2 percent of the time.

Even though adults and large juveniles of some species may exhibit behavior that would potentially expose them to entrainment during generation at the proposed Cannonsville development (such as trout seeking out cool, deep water during summer, or deep-water refuge during winter) adult life stages generally exhibit swimming performance that exceeds intake velocities at the proposed Cannonsville development. In general, however, swimming performance may be inhibited in winter which could lead to increased potential for entrainment during this season.

Swimming speed data are not available for all species/life stages. For example, juvenile white suckers were identified as having minimal likelihood of being found near the intake structure based on habitat preferences but could not be ruled out from the potential for entrainment because their swimming speed is unknown based on the available literature. Additionally, adult and juvenile catfishes, including bullheads and margined madtom, have the potential to be found near the intake structure at Cannonsville, and could not be ruled out from being entrained due to a lack of swim speed data in the available literature.

Because there is no shoreline habitat near the intake structure at the Cannonsville Reservoir, and the intake structure is located in deep-water habitat, the risk of entrainment for fry and juvenile fishes—regardless of intake velocities—is minimal.

Pepacton Reservoir

Similar to Cannonsville, Pepacton has a deep water intake structure but with a smaller hydraulic capacity. Even though the Pepacton Reservoir experiences a seasonal drawdown, it is less pronounced than the Cannonsville drawdown. Figure 4.3-1 shows that 90 percent of the time, the intake depth is still over 100 feet deep in the Pepacton Reservoir. During the months of July, August, and September (Figure 4.3-4), the median reservoir drawdown is approximately 9, 16, and 24 feet, respectively. The highest median drawdowns of the Pepacton Reservoir occur in November and are approximately 33 feet (Figure 4.3-5).

The extent of reservoir drawdown and the effects on water quality were not as severe as was observed in the Cannonsville Reservoir during the dry summer. In the Pepacton Reservoir, similar trends were observed, such as metalimnetic DO deficiency and a “sinking” thermocline, but a hypolimnetic DO deficit was not evident. For these reasons operations of the Pepacton Reservoir are not expected to increase entrainment potential, except during extreme drought conditions resulting in low reservoir water surface elevations and a depleted or diminished hypolimnion, when certain fish species would likely tend to concentrate near the intake structure.

Due to the relatively small area of the intake opening, intake velocities in front of the intake structure can be over 7 ft/s at times. This velocity represents a maximum flow for conservation and directed releases of 700 cfs. The maximum proposed hydro capacity is 162 cfs and results in an intake velocity at the turbine

of 1.69 ft/s. Any fish that are not entrained by the turbine will be diverted through the existing release works as part of a directed or conservation release.

The trout species present in the Pepacton Reservoir were all identified as having moderate likelihood for adults to be found in vicinity of the intake structure. Although these species may be able to swim in bursts at speeds exceeding Pepacton's maximum intake velocity of 7.3 ft/s (up to 10.0 ft/s for brook and brown trout and 11.5 ft/s for rainbow trout), their reported burst speed ranges fall below the intake velocity as well, and therefore these species cannot be confidently ruled out from entrainment potential. The same is true for adult yellow perch (minimal likelihood of being found near the intake structure), adult and juvenile walleye (moderate likelihood), and adult and juvenile white suckers (high and minimal likelihood, respectively).

The maximum burst swimming speed for adult rainbow smelt (5 ft/s) is less than the maximum intake velocity (7.3 ft/s) at Pepacton. This species may be located near the intake structure only in extreme drawdown situations and therefore has minimal potential for entrainment. Similarly, adult sunfishes may be located near the intake structure only in extreme drawdown situations, and have burst swim speeds just under those of rainbow smelt (4.9 ft/s), so they cannot be ruled out from the potential for being entrained. However, it is very rare that sunfishes would be found that deep in the reservoir. Finally, the catfishes have a moderate likelihood of being in the vicinity of the intake structure and, due to a lack of swim speed data in the available literature, cannot be ruled out from the potential for being entrained.

During times when the reservoir is drawn down in the fall and winter, total intake velocities are greater than 2 ft/s ranging from approximately 8 percent of the time October to 39 percent of the time in February. In April, when total intake velocities can be above 7 ft/s over 55 percent of the time, the reservoir is usually full, thus decreasing the likelihood that most fish species would be entrained by this deep water intake. As with Cannonsville, there is no shoreline habitat near the intake structure, and therefore, the risk of entrainment, regardless of intake velocities, is low for juvenile fishes in the reservoir. Additionally, the intake structure is located in deep-water habitat, which further reduces the chance of entraining fry or juvenile fishes.

Fish may tend to congregate near the bottom of Pepacton Reservoir in winter and stay active, thus having a moderate potential of being in the vicinity of the intake structures during winter.

Neversink Reservoir

Maximum intake velocities in front of the low level intake trough openings can be 2.6 ft/s. This velocity represents a maximum flow for conservation and directed releases of 190 cfs, and includes water that would be utilized for the proposed hydropower generation. The maximum hydro capacity alone, without consideration of conservation and directed releases, is 100 cfs and results in an intake velocity of 1.39 ft/s. In order to reach the intake trough openings leading to the proposed hydroelectric turbine, fish would first have to enter the common intake structure openings and pass through the existing bar racks.

As described in Section 4, the Neversink Reservoir remains well oxygenated throughout the year. Accordingly, given the depth of the intake structure and excellent water quality, it is very unlikely that entrainment potential is affected by water quality factors in Neversink Reservoir.

Similar to Cannonsville, even though adults and large juveniles of some species may exhibit behavior that would potentially expose them to entrainment during generation at the proposed Neversink development, adult life stages generally exhibit swimming performance that exceeds intake velocities at the proposed Neversink development. As shown in Table 6.4-1, juvenile white suckers were identified as having minimal likelihood of being found near the intake structure based on habitat preferences but could not be entirely ruled out from the potential for entrainment because their swimming speed is unknown based on

the available literature. Similarly, adult and juvenile brown bullhead have a moderate likelihood of being in the vicinity of the intake structure and could not be entirely ruled out from the potential for being entrained due to a lack of swim speed data in the available literature.

Based on the habitat and life history requirements and swimming speeds of the fish species found in the Neversink Reservoir, fish entrainment at the proposed Neversink development is expected to be low.

Table 6.1-1: Size composition of entrainment catch (all species) by trashrack spacing from sites included in the entrainment database.

Clear Spacing (inches)	**N**	**Average Composition (%) by Size Class** (inches)					**Representative Developments**
		0 to 4	*4 to 8*	*8 to 15*	*15 to 30*	*> 30*	
1	3	61.5	32.2	5.5	0.9	0	
1.5 - 1.8	10	64.8	27.1	7.5	0.6	0	
2.0 - 2.75	12	68.9	25.3	5.1	0.7	0	Pepacton and Neversink
3.0 - 10.0	14	80	15.7	3.9	0.3	0	Cannonsville
All	**39**	**71.3**	**22.9**	**5.3**	**0.5**	**0**	

Source: Winchell *et al.*, 2000

Figure 6.3-1: Intake velocity duration curves at Cannonsville Reservoir for Jan, Feb, and Mar.

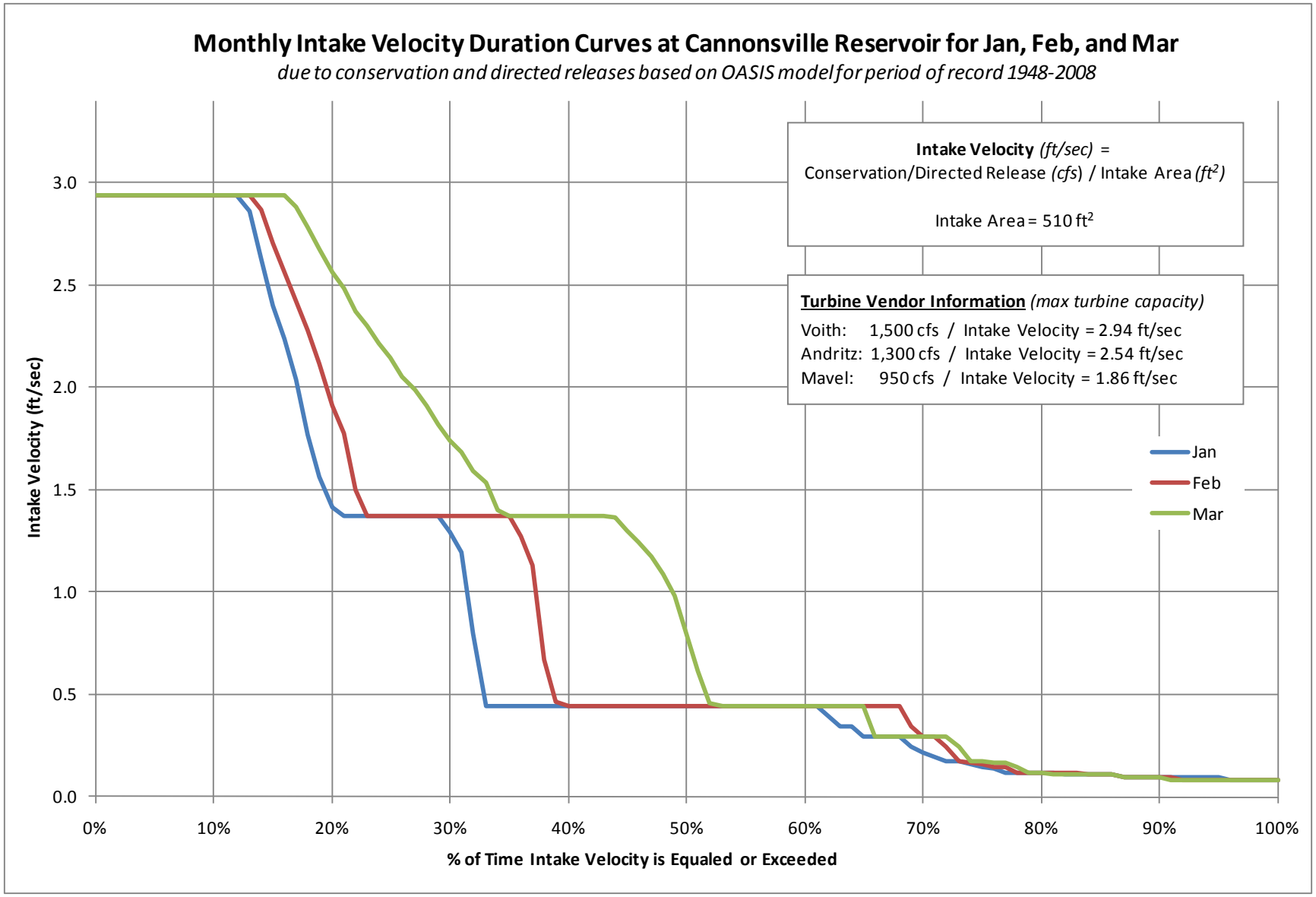


Figure 6.3-2: Intake velocity duration curves at Cannonsville Reservoir for Apr, May, and Jun.

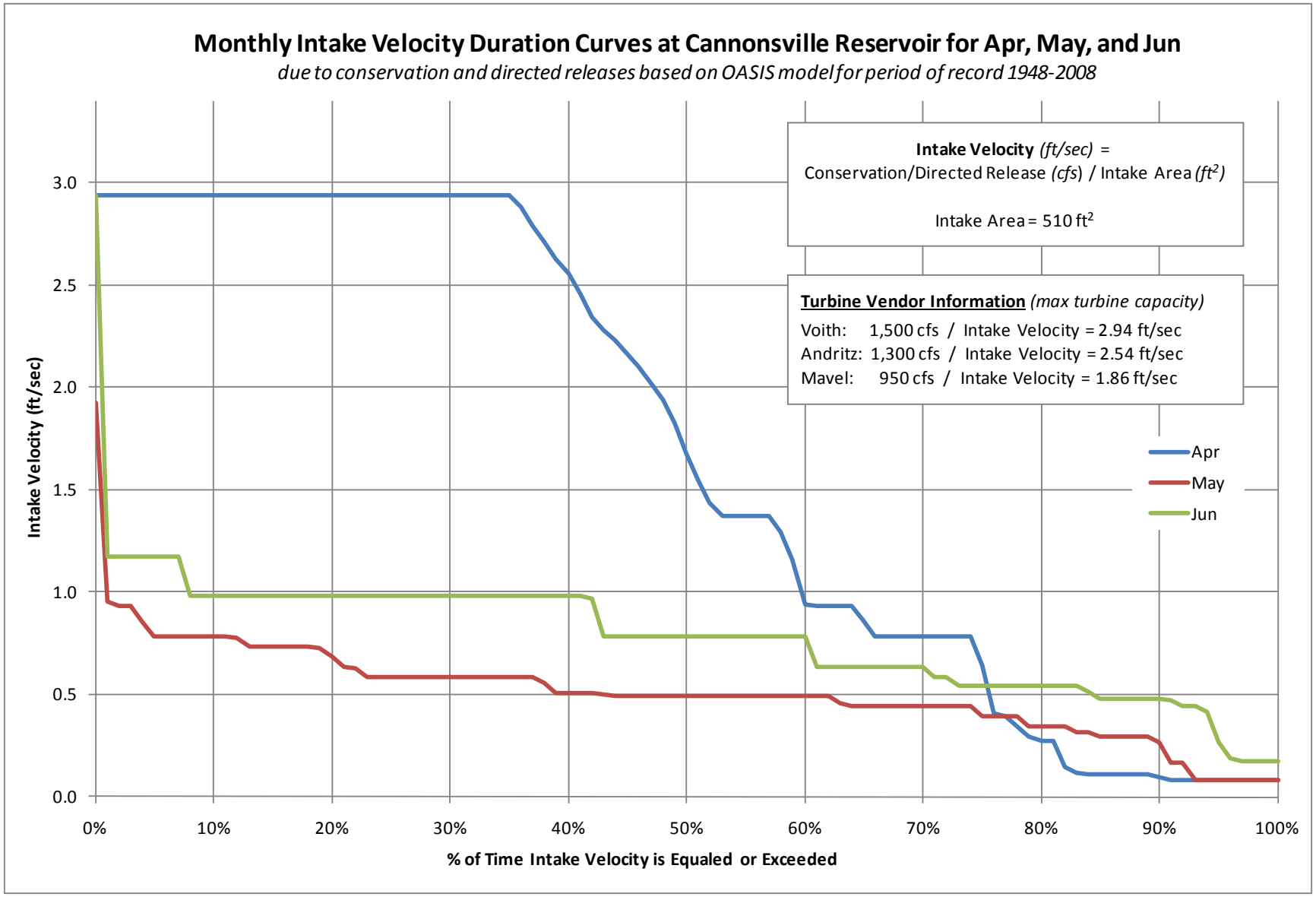


Figure 6.3-3: Intake velocity duration curves at Cannonsville Reservoir for Jul, Aug, and Sep.

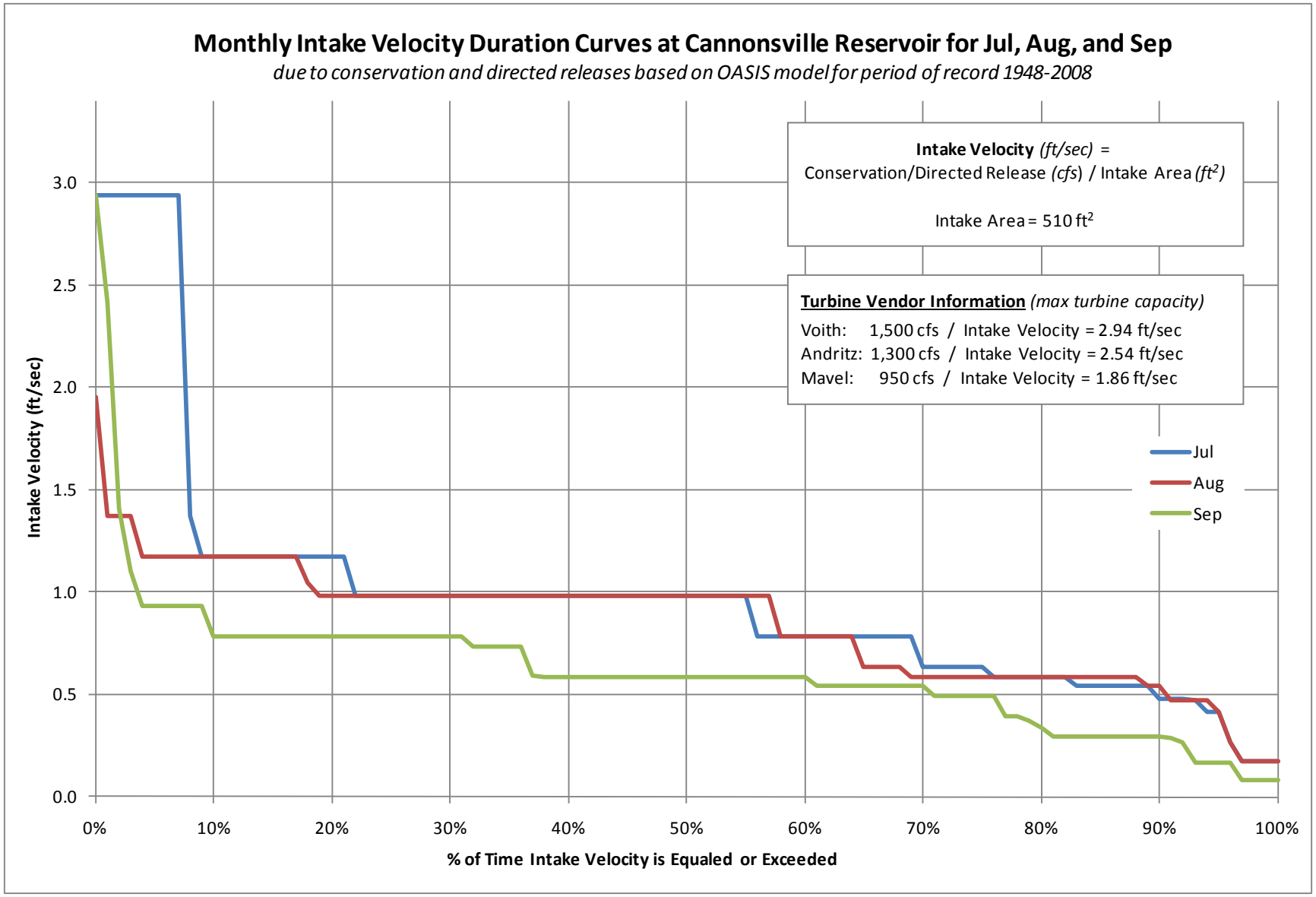


Figure 6.3-4: Intake velocity duration curves at Cannonsville Reservoir for Oct, Nov, and Dec.

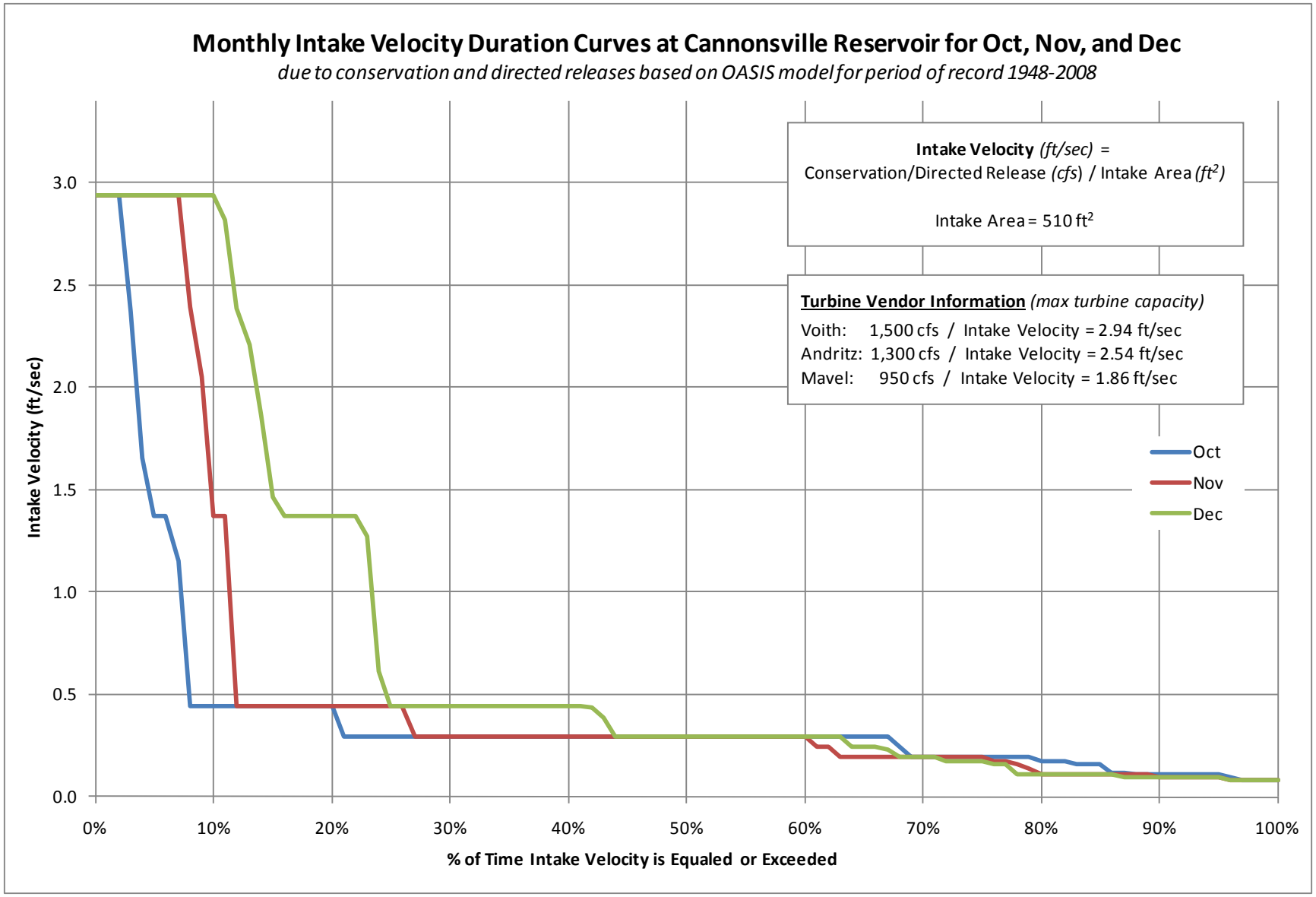


Figure 6.3-5: Intake velocity duration curves at Pepacton Reservoir for Jan, Feb, and Mar.

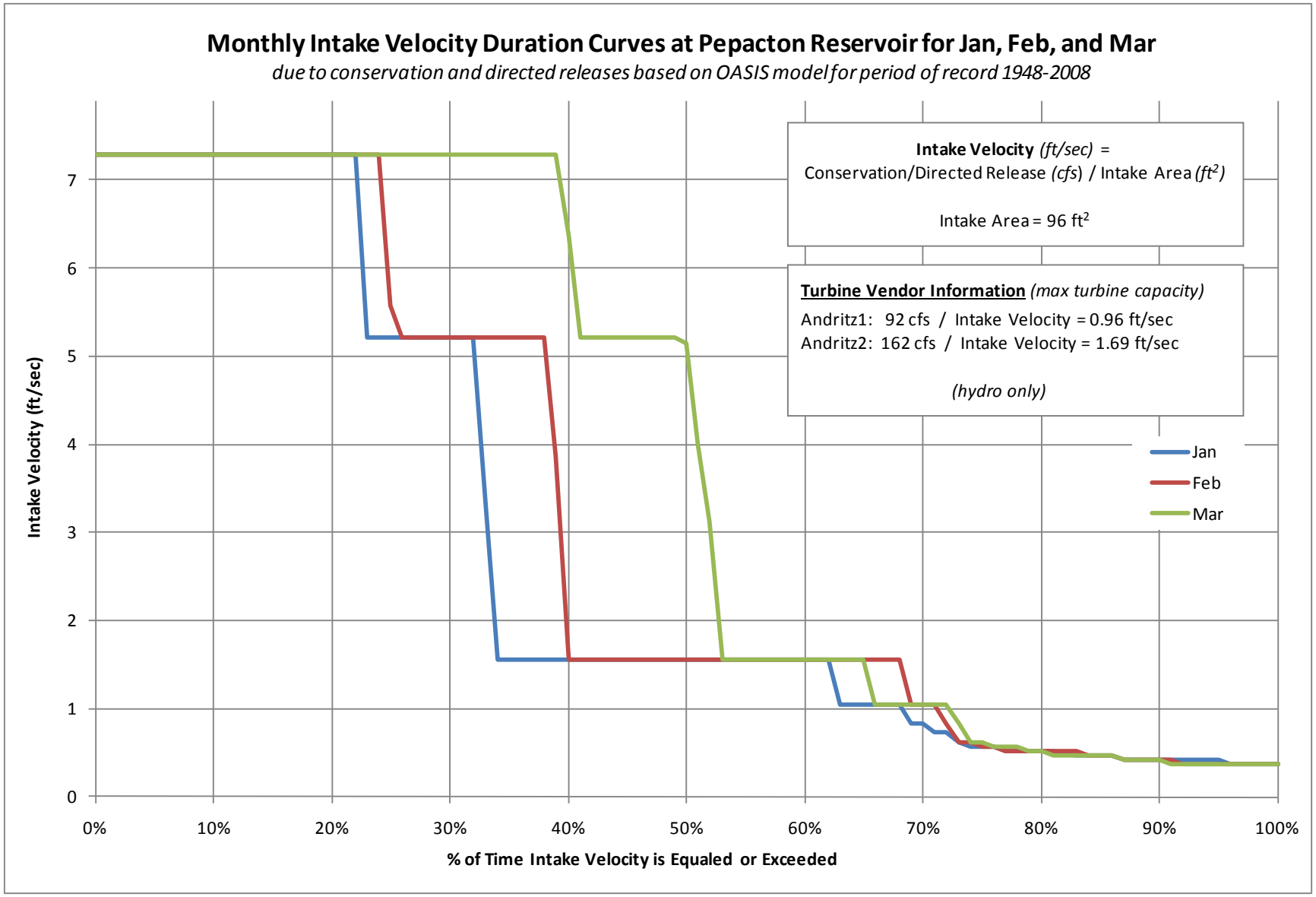


Figure 6.3-6: Intake velocity duration curves at Pepacton Reservoir for Apr, May, and Jun.

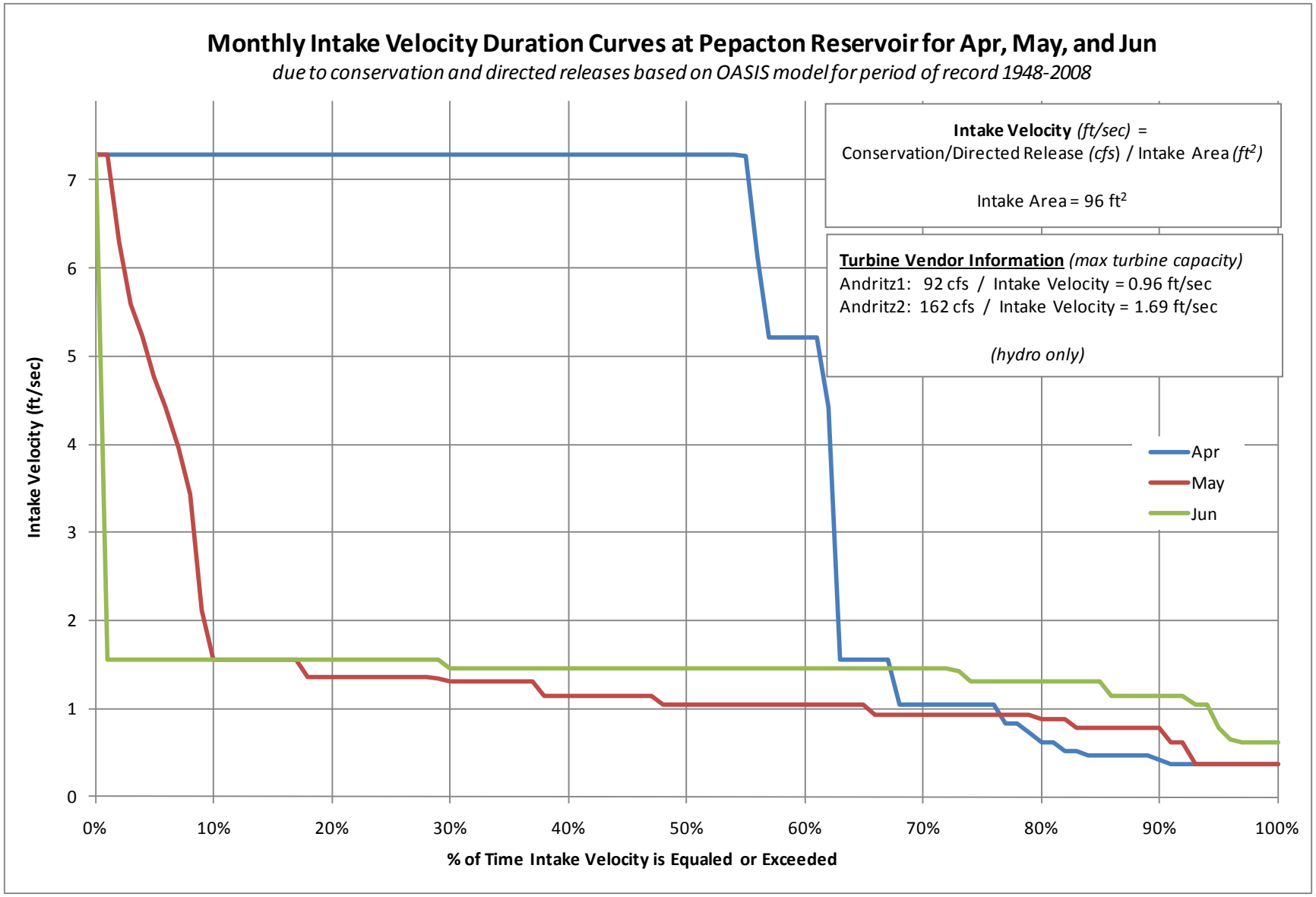


Figure 6.3-7: Intake velocity duration curves at Pepacton Reservoir for Jul, Aug, and Sep.

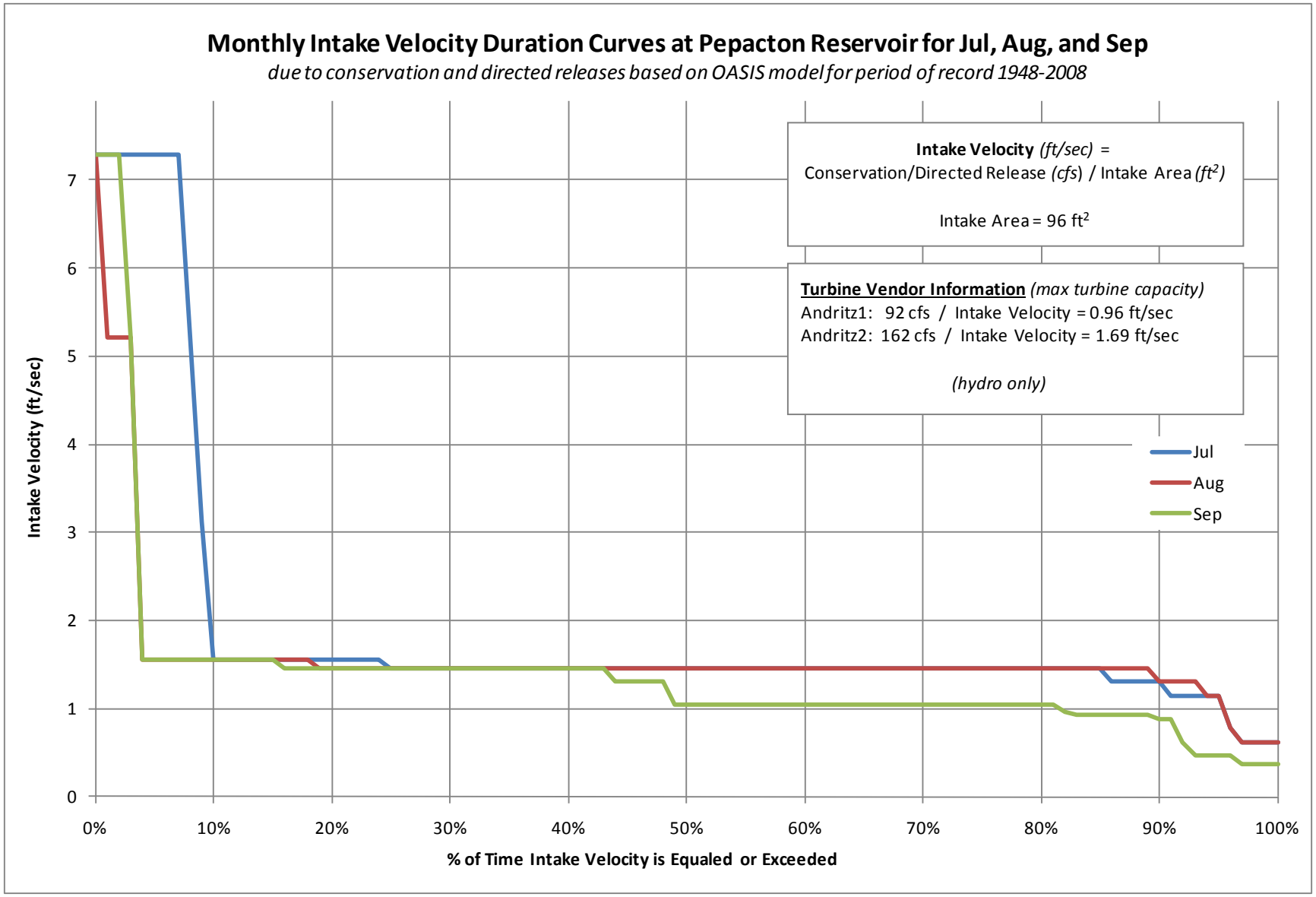


Figure 6.3-8: Intake velocity duration curves at Pepacton Reservoir for Oct, Nov, and Dec.

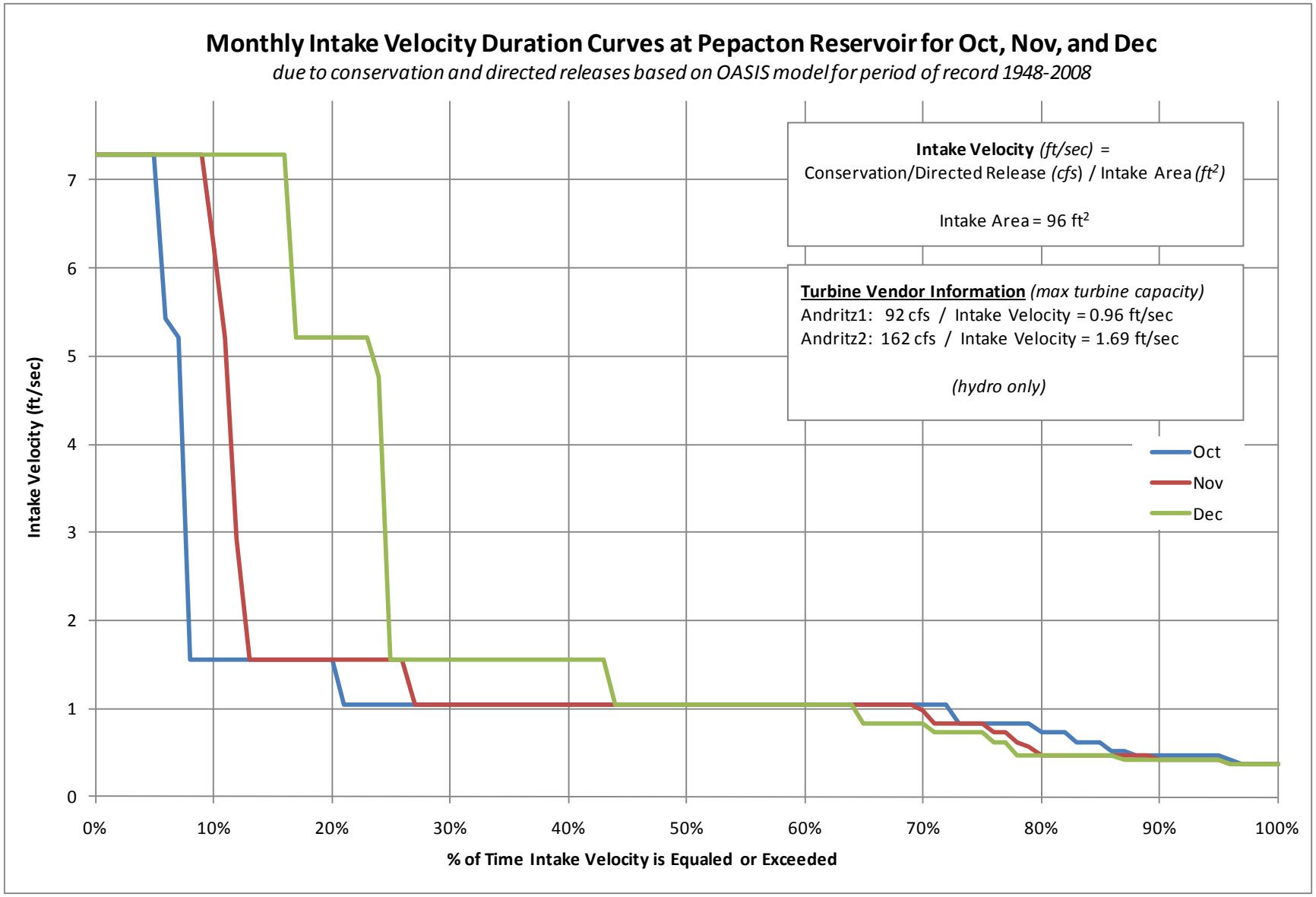


Figure 6.3-9: Intake velocity duration curves at Neversink Reservoir for Jan, Feb, and Mar.

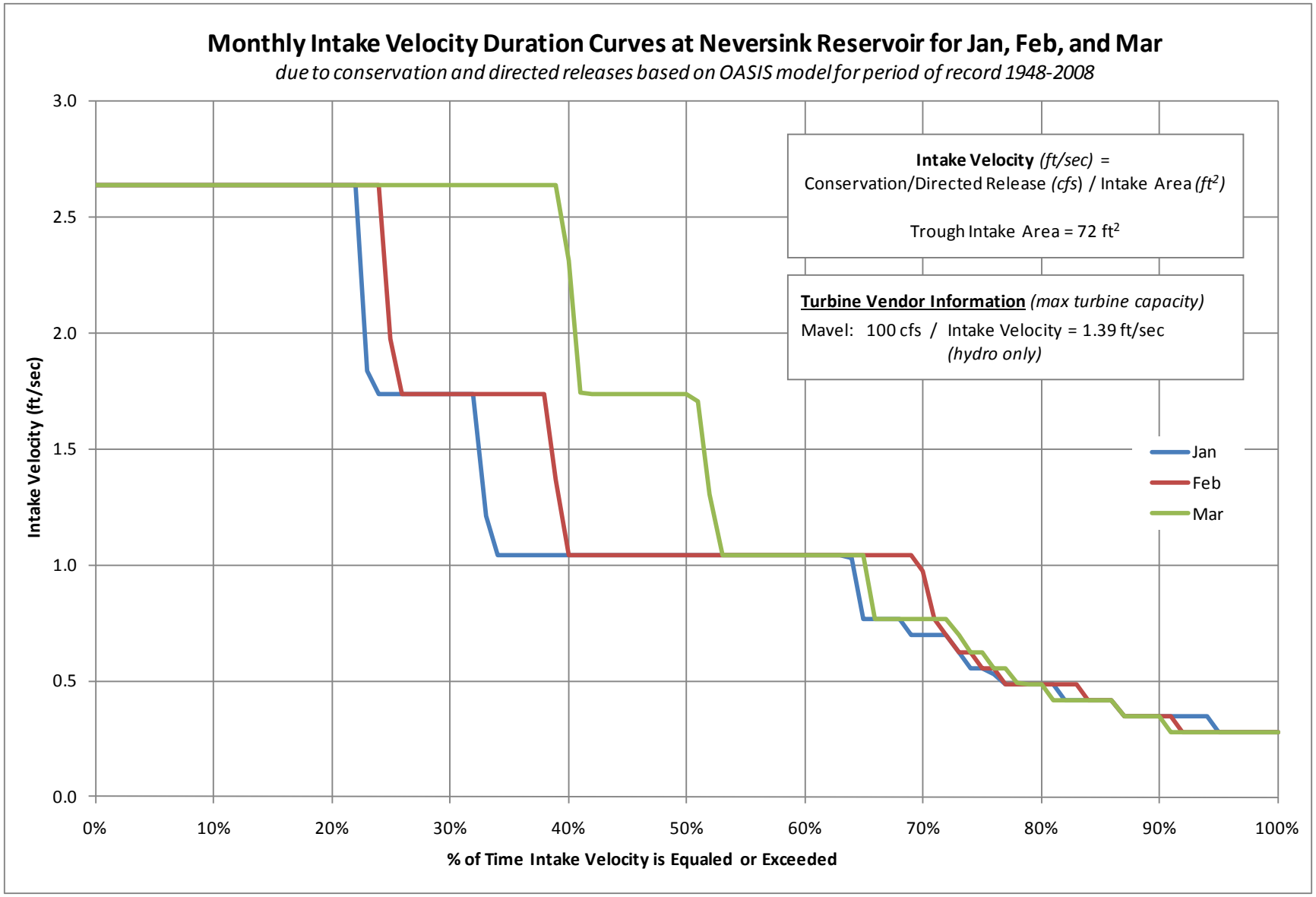


Figure 6.3-10: Intake velocity duration curves at Neversink Reservoir for Apr, May, and Jun.

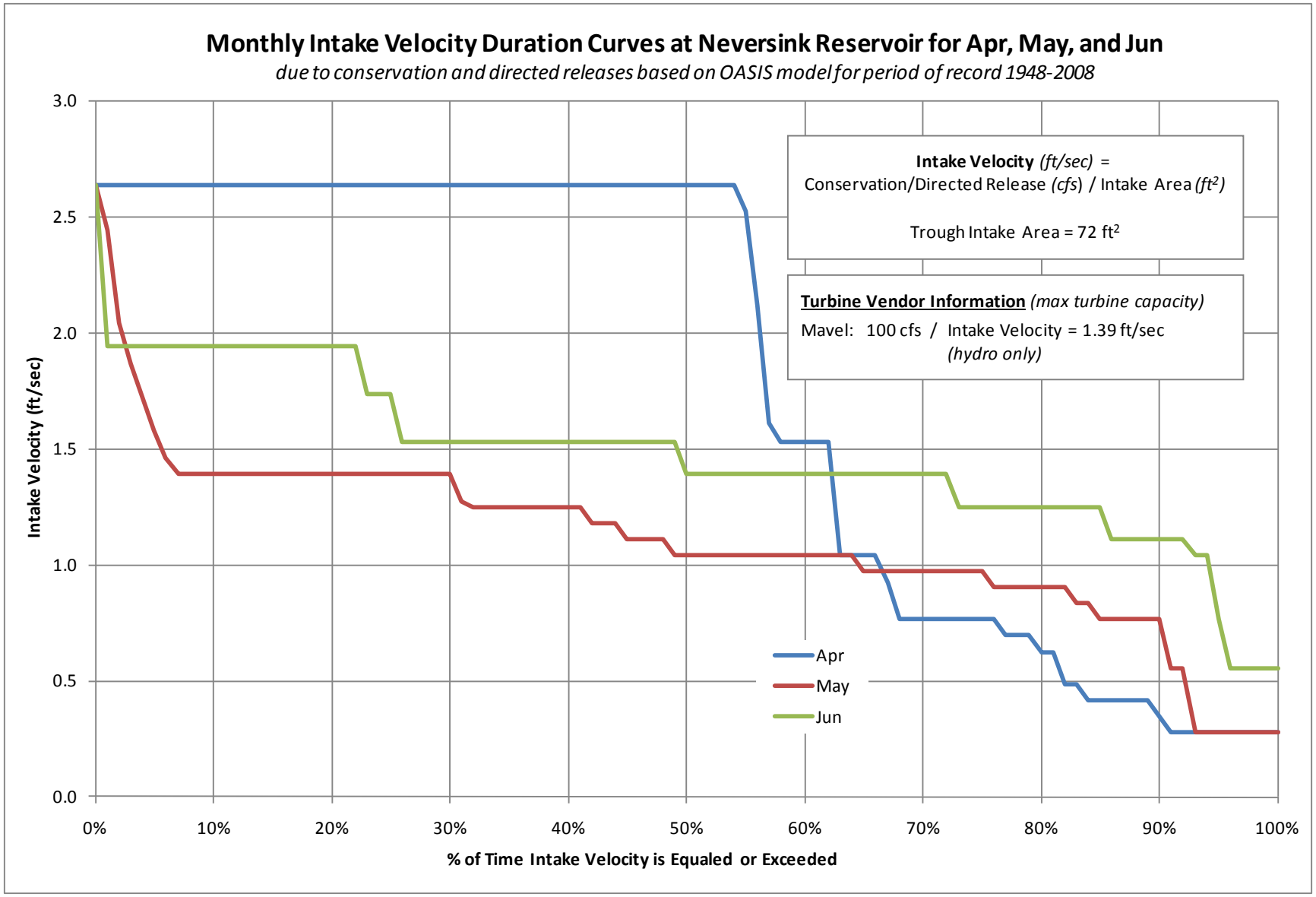


Figure 6.3-11: Intake velocity duration curves at Neversink Reservoir for Jul, Aug, and Sep.

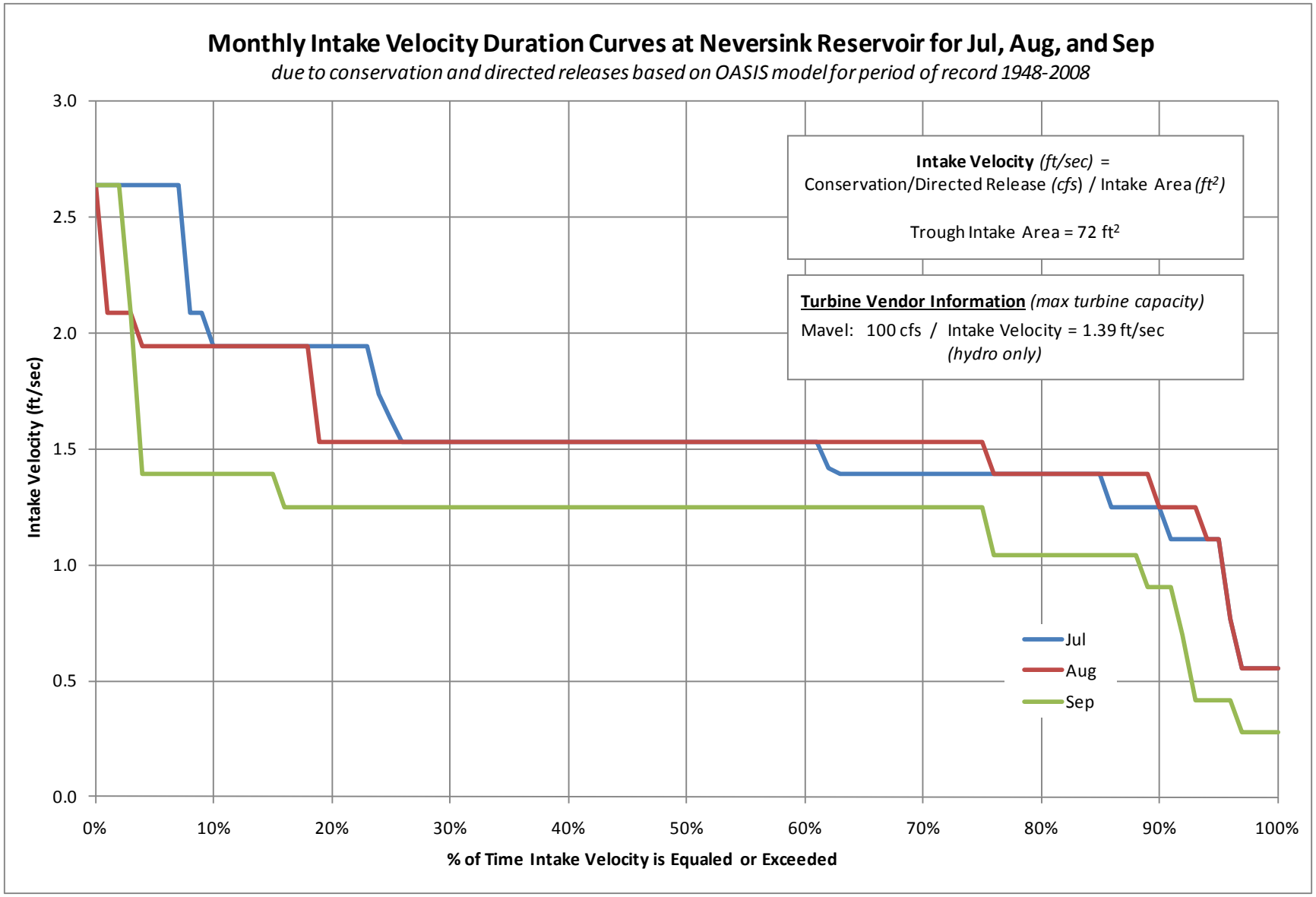


Figure 6.3-12: Intake velocity duration curves at Neversink Reservoir for Oct, Nov, and Dec.

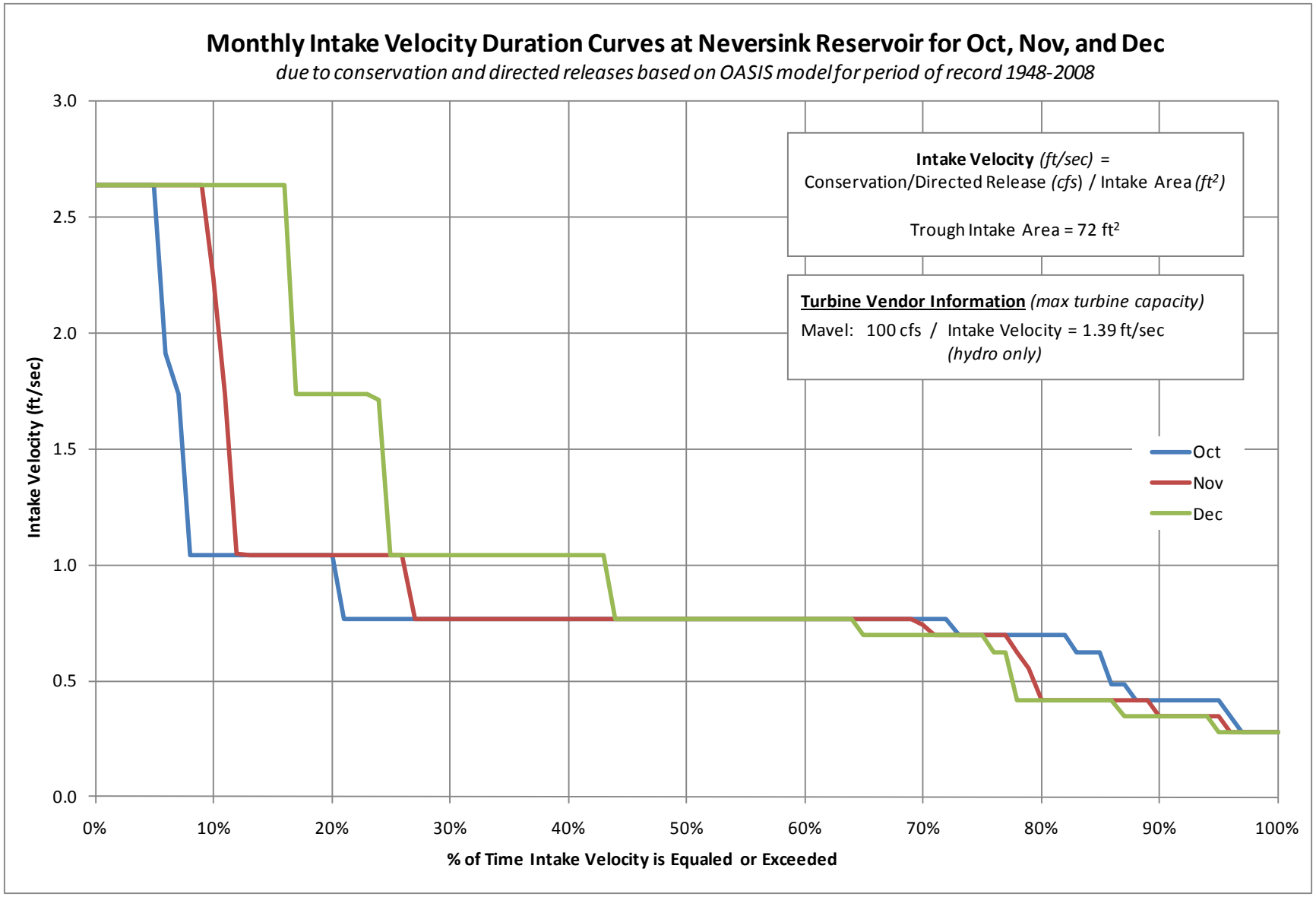


Table 6.4-1: Entrainment potential of fish species found in the three reservoirs.

Guild	Fish Species	Life Stage	Adult Burst Swim Speed (ft/s)	Entrainment Potential		
				Cannonsville ≤ 2.9 ft/s	*Pepacton ≤ 7.3 ft/s*	*Neversink ≤ 2.6 ft/s*
Salmonids	Landlocked salmon	Adult Spawning	4.5 - 10.0	Not present	Not present	None
		Adult				
		Juvenile				
	Brown trout	Adult Spawning	4.5 - 10.0	None	None	None
		Adult			Moderate	
		Juvenile			None	
	Brook trout	Adult Spawning	4.5 - 10.0	None	None	Not present
		Adult			Moderate	
		Juvenile			None	
	Rainbow trout	Adult Spawning	2.4 - 11.5	Not present	None	Not present
		Adult			Moderate	
		Juvenile			None	
Smelt	Rainbow smelt	Adult Spawning	2.6 - 5.0	Not present	None	None
		Adult			Minimal	
		Juvenile			None	
Clupeids	Alewife	Adult Spawning	15.5	Minimal*	None	None
		Adult				
		Juvenile				
Percids	Walleye	Adult Spawning	5.2 - 8.5	Not present	None	Not present
		Adult			Moderate	
		Juvenile			Moderate	
	Yellow perch	Adult Spawning	5.2 - 8.5	Minimal*	None	None
		Adult			Minimal	
		Juvenile			None	

Intake velocities at each proposed development reflect maximum flow for conservation and directed releases.

* Although alewife and yellow perch exhibit swimming speeds strong enough to avoid the intake velocities at Cannonsville Reservoir, there is evidence of entrainment mortality occurring at this site once in 2005 due to a combination of relatively low water surface, anoxic hypolimnion and increase in water releases.

Table 6.4-1: Entrainment potential of fish species found in the three reservoirs. *(cont.)*

Guild	Fish Species	Life Stage	Adult Burst Swim Speed (ft/s)	Entrainment Potential		
				Cannonsville ≤ 2.9 ft/s	*Pepacton ≤ 7.3 ft/s*	*Neversink ≤ 2.6 ft/s*
Esocids	Chain pickerel	Adult Spawning	11.8 - 14.8	None	None	None
		Adult				
		Juvenile				
Catastomids	White sucker	Adult Spawning	5.2 - 10.2[7]	None	None	None
		Adult			High	
		Juvenile		Minimal	Minimal	Minimal
	Longnose sucker	Adult Spawning	4.0 - 7.9	Not present	Not present	None
		Adult				
		Juvenile				
Cyprinids	Fallfish	Adult Spawning	3.3 - 5.7	None	None	None
		Adult				
		Juvenile				
	Golden shiner	Adult Spawning	3.3 - 5.7	None	None	None
		Adult				
		Juvenile				
	Spottail shiner	Adult Spawning	3.3 - 5.7	Not present	Not present	None
		Adult				
		Juvenile				
	Bluntnose minnow	Adult Spawning	3.3 - 5.7	Not present	None	Not present
		Adult				
		Juvenile				
	Eastern silvery minnow	Adult Spawning	3.3 - 5.7	Not present	None	Not present
		Adult				
		Juvenile				
	Tessellated darter	Adult Spawning	3.3 - 5.7	None	Not present	Not present
		Adult				
		Juvenile				
	Common carp	Adult Spawning	5.3	None	Not present	Not present
		Adult				
		Juvenile				

Intake velocities at each proposed development reflect maximum flow for conservation and directed releases.

Table 6.4-1: Entrainment potential of fish species found in the three reservoirs. *(cont.)*

Guild	Fish Species	Life Stage	Adult Burst Swim Speed (ft/s)	Entrainment Potential		
				Cannonsville ≤ 2.9 ft/s	*Pepacton ≤ 7.3 ft/s*	*Neversink ≤ 2.6 ft/s*
Centrarchids	Black crappie	Adult Spawning	4.9	None	Not present	Not present
		Adult				
		Juvenile				
	Rock bass	Adult Spawning	4.9	None	None	None
		Adult			Minimal	
		Juvenile			None	
	Redbreast sunfish	Adult Spawning	4.9	Not present	None	Not present
		Adult			Minimal	
		Juvenile			None	
	Pumpkinseed	Adult Spawning	4.9	None	None	None
		Adult			Minimal	
		Juvenile			None	
	Largemouth bass	Adult Spawning	No data (prolonged = 1.8 - 3.9)	Not present	None	Not present
		Adult			Minimal	
		Juvenile			None	
	Smallmouth bass	Adult Spawning	No data (prolonged = 1.8 - 3.9)	None	None	None
		Adult			Minimal	
		Juvenile			None	
Ictalurids	Brown bullhead	Adult Spawning	No data	None	None	None
		Adult		Moderate	Moderate	Moderate
		Juvenile		Moderate	Moderate	Moderate
	Yellow bullhead	Adult Spawning	No data	None	Not present	Not present
		Adult		Moderate		
		Juvenile		Moderate		
	Margined madtom	Adult Spawning	No data	None	None	Not present
		Adult		Moderate	Moderate	
		Juvenile		Moderate	Moderate	
	Channel catfish	Adult Spawning	3.9 (juvenile)	Not present	None	Not present
		Adult			Moderate	
		Juvenile			Moderate	

Intake velocities at each proposed development reflect maximum flow for conservation and directed releases.

7.0 MORTALITY

This section discusses and provides estimates of entrainment mortality. Turbine attributes, head, and fisheries composition at each proposed development were used to identify similar projects in the literature. An estimate of turbine passage survival was developed based on rates observed at other sites, as reported in the literature.

7.1 Turbine Passage

Contact of a fish with a turbine unit component does not always result in injury or mortality (Bell, 1991). Based on the consistency of results from numerous studies, it has become apparent that fish size rather than species is the primary variable in determining the probability of survival through turbines (Franke *et al.*, 1997 and Winchell *et al.*, 2000). Smaller fish are more likely to survive turbine passage. To estimate survival of fish that may be entrained and passed through the proposed turbines at the three developments, mortality studies conducted at similar hydro facilities were examined. The criteria used for comparison were large and small Francis type turbines with high head.

Species-specific estimates of fish mortality through Francis type turbines (EPRI, 1992) indicate that survival rates across species are generally uniform. Table 7.1-1 shows average survival rates of several species. Although this list is not identical to the list of species found in the three reservoirs associated with the proposed developments (see Table 5-2), the results suggest that the survival rates for the other species would not be materially different. Because survival rates do not appear to be species-dependent, analyses then looked at survival as a function of size. Winchell *et al.* (2000) summarized turbine passage survival data reported in the EPRI (1997) database by turbine type and characteristics and fish size. The survival rates reported were based on field tests at up to 19 turbines per size class of test fish that met specific acceptability criteria for control fish mortality (could not exceed 10%). The data for the high speed Francis turbine types proposed for the three developments is reproduced below in Table 7.1-2.

Immediate survival rates were used in the field tests since they enabled use of a larger sample size (N). The mean rates are reported irrespective of local site conditions, such as shallow or deep intake structures or tailrace configuration, which could affect ultimate fish survival after turbine passage. Additionally, because of the prior findings from the species-specific studies, the survival rates are reported for all species combined.

7.2 Pressure Differential

The abrupt reduction in pressure experienced by fish passing from low-level intake structures at high head dams to the release waters below the dams is a significant source of fish mortality. This fact remains true whether the dams are equipped with hydropower turbines or not (Franke *et al.*, 1997). Injuries caused by pressure appear to be related to the difference between the acclimation pressure upstream of the turbine and the exit pressure within the draft tube zone (Odeh, 1999).

Two separate pressure differentials come into play with fish entrainment at a hydropower dam with a low-level intake structure. The major pressure gradient is between the high pressure at the low-level intake structure and the low pressure at the downstream release. The second pressure gradient is in the turbine; there is a relatively high level of pressure prior to entering the turbine followed by a short low pressure region on the downstream side of the runner blades. However, it is important to note that the fate of entrained fish is much more strongly dictated by the former pressure differential (Franke *et al.*, 1997). Moreover, the critical factor is not the head, but the depth at which fish are entrained (acclimation depth).

Site-Specific Conditions

Atmospheric pressure is equal to 14.7 pounds per square inch (psi). Each foot of water depth is equivalent to 0.43 psi. Table 7.2-1 compares the differences in pressure a fish would experience passing through the respective dams, assuming entrance at the intake center line elevation (or, in the case of Neversink, at the elevation of the 36" intake pipes) and the reservoirs are full.

After consultation regarding a prior draft report, NYSDEC requested additional details regarding the frequency of acclimation depths and pressures that would be experienced by potentially entrained fish at each proposed development, including the pressure differential between the reservoir and downstream release under maximum reservoir drawdown conditions. To provide context on water depths and pressure differences at all three developments at different elevations, Figures 7.2-1 through 7.2-6 were developed. Using the OASIS model data on reservoir elevations in relation to the intake elevation, maximum, median and minimum acclimation depths were determined on an average daily basis for the entire year. The maximum actual reservoir drawdowns during the last 25 years are also shown on each figure for reference.

At the Cannonsville Reservoir, the water depth at the center line of the intake structure at full pond (1150 feet above msl) is 122 feet. Figure 7.2-1 shows that the median annual water depth is 110 feet. At the maximum observed reservoir drawdown, based on the last 25 years, the water depth was approximately 24 feet. The approximate pressure at the centerline of the intake structure under full pond conditions at the Cannonsville Reservoir is 67.2 psi. Figure 7.2-2 shows the acclimation pressures that potentially entrained fish would experience at the Cannonsville development. The proposed draft tube opening would release any entrained fish at a depth of approximately 17 feet and a pressure of 22 psi. The existing structure releases any entrained fish at a depth of approximately 30 feet and a pressure of 27.6 psi.

At the Pepacton Reservoir, the water depth at the center line of the intake structure at full pond (1280 feet above msl) is 161 feet. Figure 7.2-3 shows that the median annual water depth is 146 feet. At the maximum observed reservoir drawdown, based on the last 25 years, the water depth was approximately 95 feet. The approximate pressure at the centerline of the intake structures under full pond conditions at the Pepacton Reservoir is 83.9 psi. Figure 7.2-4 shows the acclimation pressures that potentially entrained fish would experience at the Pepacton development. The water pressure downstream of the release at the proposed Pepacton development would be approximately equal to atmospheric pressure (*i.e.*, 14.7 psi).

At the Neversink Reservoir, the design of the intake structure is such that all occurrences of potential fish entrainment to the proposed hydroelectric development would occur at the troughs on the floor of the intake structure. The water depth at the center line of the 36" intake pipes at full pond (1440 feet above msl) is approximately 151 feet. Figure 7.2-5 shows that the median annual water depth at this location is 146 feet. At the maximum observed reservoir drawdown, based on the last 25 years, the water depth was approximately 61 feet. Under full pond conditions the water pressure at the entrance of the 36" intake pipes is approximately 79.6 psi. Figure 7.2-6 shows the acclimation pressures that potentially entrained fish would experience at the proposed Neversink development. The water pressure downstream of the release would be approximately equal to atmospheric pressure.

Pressure Mortality

Different species of fish respond to abrupt changes in pressure differently. Species can either be physostome or physoclist. Physostomous species (*e.g.*, salmon, minnows, and catfish) have a pneumatic duct which connects the air bladder to the esophagus and allows for venting air from the swim bladder within seconds, resulting in the ability to rapidly adjust to changing water pressure. Physoclists (*e.g.*, basses, sunfish, perch), must adjust pressure within the swim bladder via diffusion into the blood, which

takes hours. Therefore, physoclists are more readily injured when exposed to abrupt pressure differentials (Franke *et al.*, 1997).

Based on the pressure differentials between the intake structures and the release works at the three developments, as well as the 2005 observation of fish entrained at the Cannonsville Reservoir, under most conditions, it is likely that any fish entrained through the release structures or future hydropower facilities at the three proposed developments would not survive due solely to pressure differential-related mortality regardless of whether hydropower facilities are added to the sites at issue. During consultation related to a prior draft report, NYSDEC requested that additional information be provided as to what depth/pressure causes fish mortality approaching 100%. In response, additional literature research was conducted to address NYSDEC's request, and is summarized below.

Most of the research conducted on this topic is related to turbine-passage mortality as there is a pressure gradient through a turbine (*i.e.*, a relatively high level of pressure prior to entering the turbine followed by a short low pressure region on the downstream side of the turbine runner blades). However, these studies can be applied to generally predict the effects of pressure differences on fish passing from deep water reservoirs to shallower stream environments as would be case with respect to the proposed Project developments.

Cada *et al.*, 1997 reviewed several experiments that examined the effects of pressure increases and decreases on fish and reports that there is considerable variation in the response of fish to pressure reductions[11]. In their review, Cada *et al.*, 1997 summarized percent mortality among test fishes versus the ratio of exposure pressure[12] (P_e) to acclimation pressure[13] (P_a), expressed as ratio = P_e /P_a.

Based on these studies of a variety of fish, Cada *et al.*, 1997 suggested that, as a general fish protection measure, exposure pressures should fall to no less than 60% of the value to which entrained fish are acclimated. This factor serves as a guideline for zero mortality for all fish species studied. Back calculating[14] to determine acclimation depth using this ratio results in an acclimation depth of 23 feet. Accordingly, at acclimation depths less than 23 feet, all fish passed downstream to atmospheric pressure would be expected to show no direct mortality from pressure effects.

However, with respect NYSDEC's inquiry regarding the depth/pressure that would cause mortality approaching 100%, one study (Hogan, 1941 cited in Cada *et al.*, 1997) reported that a P_e /P_a ratio of 40% resulted in 100% mortality in crappie (a sunfish). In the case of the Project, this ratio translates to an acclimation depth of 51 feet. This value is supported by a separate pressure study that reported swim bladders in four inch long perch burst, thus leading to mortality, when pressure was reduced to 40% of acclimation values (Jones 1951, cited in Cada *et al.*, 1997).

In addition to being species-specific, pressure mortality is dependent on several variables, such as time of exposure, dissolved gas levels and other factors related to indirect mortality. Nevertheless, the 2005 observation of yellow perch mortality due to entrainment at Cannonsville Reservoir occurred at an acclimation depth of 71 feet, consistent with the findings above.

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[11] Cada *et al.*, 1997 suggested that the variation in fish responses may have been due to differing test methods and small sample sizes.

[12] Exposure pressure is analogous to the water pressure experienced by fish after release into the downstream environment.

[13] Acclimation pressure is the water pressure experienced by fish at the point of entrance to the intake structure.

[14] Acclimation depth was determined first by solving the ratio equation for P_a (P_a = P_e/ratio) then converting P_a to water depth.

Information on mortality relative to pressure changes in salmonids indicates that a minimum P_e /P_a ratio of 30% or higher may be appropriate as protective criteria for physostomous fish (Abernathy, *et al.* 2001). Back calculating to determine acclimation depth using this ratio results in an acclimation depth of 80 feet. On an annual basis, acclimation depths of 80 feet or less occur less than 10 percent of the time in Cannonsville Reservoir, and less than 3 percent of the time in both Pepacton and Neversink Reservoirs.

Based on the pressure differentials between the intake structures and the release works at the three proposed developments, as well as the prior recent observation (2005) of fish entrained at the Cannonsville Reservoir, it is likely that any fish entrained through the current release structures will not survive due solely to the pressure differentials that would be experienced between the intakes and the release works. Therefore, the addition of turbines and their potential effects on entrained fish is unlikely to materially affect mortality at the proposed developments because the primary cause of mortality is likely to be the pressure differentials existing between the intake structures and the release works regardless of whether hydropower facilities were added at these sites.

7.3 Impingement

Impingement refers to the involuntary contact and entrapment of fish on the surface of an intake protection device due to approach velocity exceeding swimming capability. Impingement may result in some level of injury or death. Fish species that have no entrainment potential in the three reservoirs, as described in Section 6.4, would not be subjected to impingement.

The likelihood of a fish to become impinged rather than entrained is a function of the spacing between the bars on an intake structure, as well as the size and body shape of the fish.[15] To determine the potential for the fish species in the three reservoirs associated with the proposed developments to become impinged, the correlation between fish size and bar rack spacing was investigated. Proportional measurements for the fish species described in Section 5 were obtained from Smith (1985) and are based on the standard length of each species from a random sample from New York State. These proportional measurements were used to calculate a unit-less scaling factor of body width to total length (*i.e.*, scaling factor equals width divided by total length) for comparison of body shape between species. Fish species that are relatively small when full grown, such as minnows, were excluded from this analysis because they could fit through the existing rack openings at the three reservoirs, as well as through rack openings designed to the USFWS criteria of 1-inch clear spacing, and would not be subjected to impingement.

The scaling factor was applied to body widths equal to the rack spacings to estimate the length of each fish that would be physically excluded by the existing bar racks at Neversink and Pepacton (and therefore subject to impingement) as shown in Table 7.3-1 below. The intake protection at Cannonsville is spaced around 7.5 inches and therefore would allow all but the largest fish to pass through. There are not likely any fish in the reservoir big enough to be impinged.

The table illustrates that reducing the spacing from 2-inch to 1-inch racks will roughly reduce the size of fish potentially impinged in half and reducing the spacing from 2.75-inch to 1-inch reduces the size of fish by two-thirds. Note that all the theoretical fish sizes calculated are shown in Table 7.3-1, but some of the reported sizes of fish that are excluded by the 2-inch and 2.75-inch racks are larger than the respective fish species' maximum size. For example, the maximum length of alewives is 15 inches (Smith, 1985); therefore, all alewives found in Project reservoirs could physically fit through the intake racks.

Another important factor in the impingement potential of a fish is the approach velocity at the intake structure and the burst speed of the fish. Table 6.4-1 summarizes the potential for fish entrainment based

[15] This analysis of impingement assumes fish would not get impinged sideways on the racks.

on several factors including intake velocities and swim speeds. In order to determine the potential for impingement, the body size analysis described above is considered. Fish whose total lengths are greater than those listed in Table 7.3-1 are susceptible to impingement only if they are unable to escape the velocities associated with each intake structure.

Table 7.1-1: Average fish survival rates through Francis turbines.

Species / Group	Average Percent Survival Rate (all sizes)
Salmonids (salmon, trout)	81.8
Clupeids (alewife) *Adults* *Juveniles*	 84.0 71.4
Centrarchids (bass, sunfish)	88.3
Percids (yellow perch)	76.4
Esocids (pickerel)	77.7
Catostomids (suckers)	76.0
Cyprinids (minnows, carp)	80.0

Source: EPRI, 1992

Table 7.1-2: Fish survival rates for Francis turbine types and fish sizes.

Turbine Type	**Runner Speed** (rpm)	**Hydraulic Capacity** (cfs)	**Fish Size** (inches)	**Average Immediate Survival** *(all species combined)*			
				N	*Minimum (%)*	*Maximum (%)*	*Mean (%)*
Francis	> 250	275-695	3.9	6	31.0	97.6	70.1
			3.9-7.8	7	34.3	82.7	60.0
			7.9-11.8	7	22.8	82.9	39.3
			11.8+	3	3.5	35.4	19.1

Source: Winchell *et al*., 2000

Table 7.2-1: Pressure differences experienced by fish passing though the existing and proposed developments.

Development	Acclimation Depth (ft)	Acclimation Pressure (psi)	Exposure Depth (ft)	Exposure Pressure (psi)	Pressure Differential (Exposure – Acclimation) (psi)
Cannonsville - existing	122	67.2	30	27.6	-39.6
Cannonsville - proposed	122	67.2	17	22.0	-45.2
Pepacton	161	83.9	surface	14.7	-69.2
Neversink	151	79.6	surface	14.7	-64.9

Table 7.3-1: Theoretical sizes of fish species excluded by 2-inch, 2.75-inch, and 1-inch clear-spaced bar racks.

Fish Species	**Standard Length (SL) (in)**	**Total Length Proportion** (% of SL)	**Body Width Proportion** (% of SL)	**Total Length (TL) (in)**	**Body Width (BW) (in)**	**Scaling Factor** (BW/TL)	**Fish Size Excluded by 2" Racks *Neversink Existing*** (TL, in)	**Fish Size Excluded by 2.75" Racks *Pepacton Existing*** (TL, in)	**Fish Size Excluded by 1" Racks *USFWS Criteria*** (TL, in)
Alewife (Cayuga)	4.1	124.0	10.7	5.1	0.4	0.09	23	32	12
Black crappie	2.6	133.8	13.3	3.5	0.4	0.10	20	28	10
Brook trout	4.0	119.7	14.6	4.8	0.6	0.12	16	23	8
Brown bullhead	4.6	123.8	20.6	5.7	0.9	0.17	12	17	6
Brown trout	3.2	120.8	14.3	3.8	0.5	0.12	17	23	8
Chain pickerel	4.6	116.5	10.3	5.4	0.5	0.09	23	31	11
Channel catfish	4.7	129.7	20.3	6.1	1.0	0.16	13	18	6
Common carp	4.3	125.9	20.4	5.5	0.9	0.16	12	17	6
Landlocked salmon	3.9	118.8	12.4	4.6	0.5	0.10	19	26	10
Largemouth bass	4.0	123.4	16.5	5.0	0.7	0.13	15	21	7
Longnose sucker	3.0	126.5	15.9	3.9	0.5	0.13	16	22	8
Pumpkinseed	1.6	129.8	16.1	2.1	0.3	0.12	16	22	8
Rainbow smelt	5.9	117.7	10.7	7.0	0.6	0.09	22	30	11
Rainbow trout	4.8	121.6	13.9	5.8	0.7	0.11	17	24	9
Rock bass	2.5	124.6	19.4	3.2	0.5	0.16	13	18	6
Smallmouth bass	2.8	123.6	15.8	3.5	0.4	0.13	16	22	8
Walleye	4.1	120.2	15.0	4.9	0.6	0.12	16	22	8
White sucker	4.1	121.9	17.8	4.9	0.7	0.15	14	19	7
Yellow perch	2.4	123.4	14.1	2.9	0.3	0.11	18	24	9

Source: Smith, 1985. Standard length is defined as the measurement from the most anterior tip of the fishes' body to the base of the caudal fin, not including the tail. The standard lengths in this table are from a randomly sampled population in New York State. Total length and body width are shown in relation to the standard length, and are used to determine a unit-less scaling factor. Note that some smaller fish (*e.g.*, minnows) were not included in this table.

Figure 7.2-1: Acclimation depth duration curve at Cannonsville Reservoir.

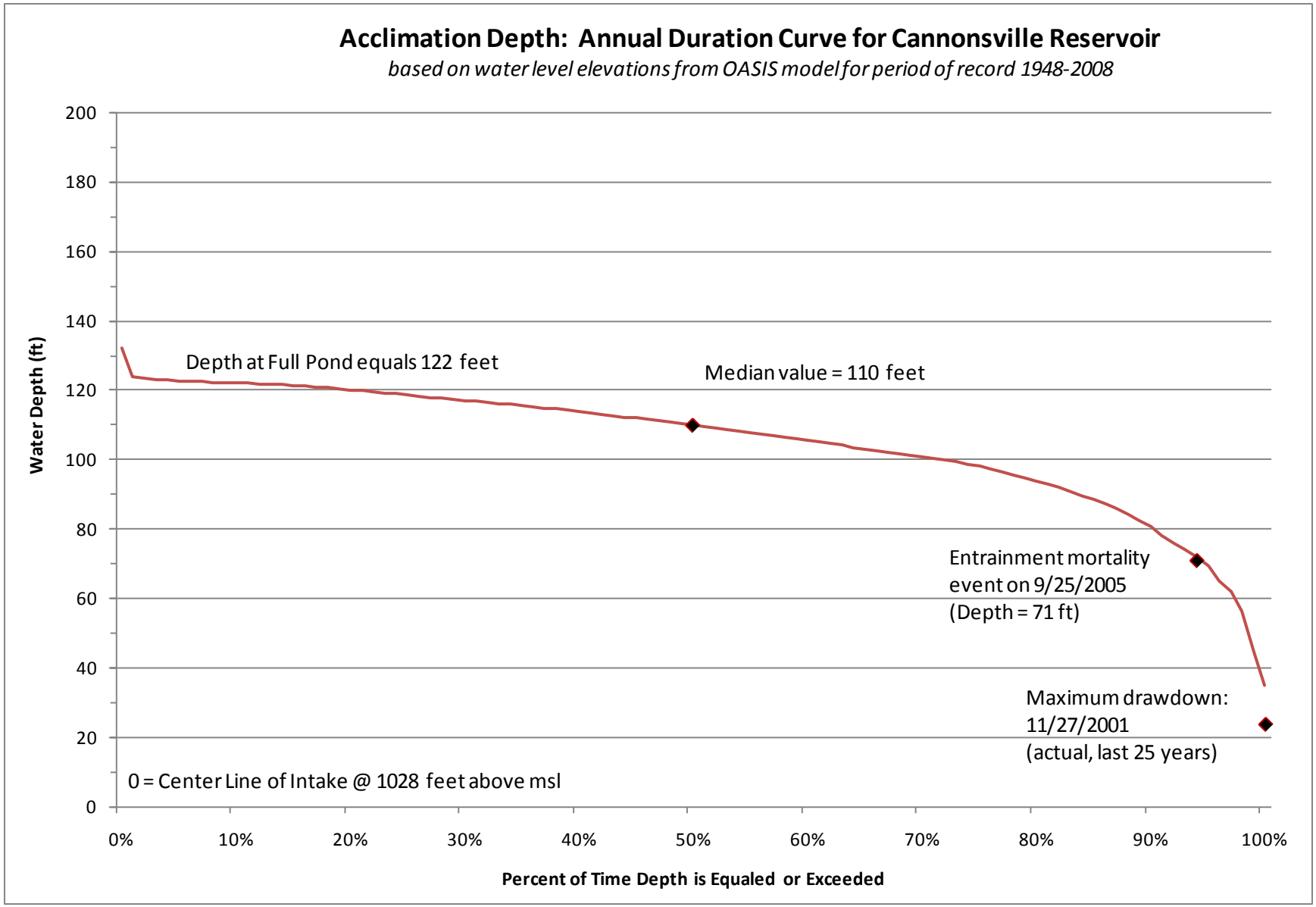


Figure 7.2-2: Acclimation pressure duration curve at Cannonsville Reservoir.

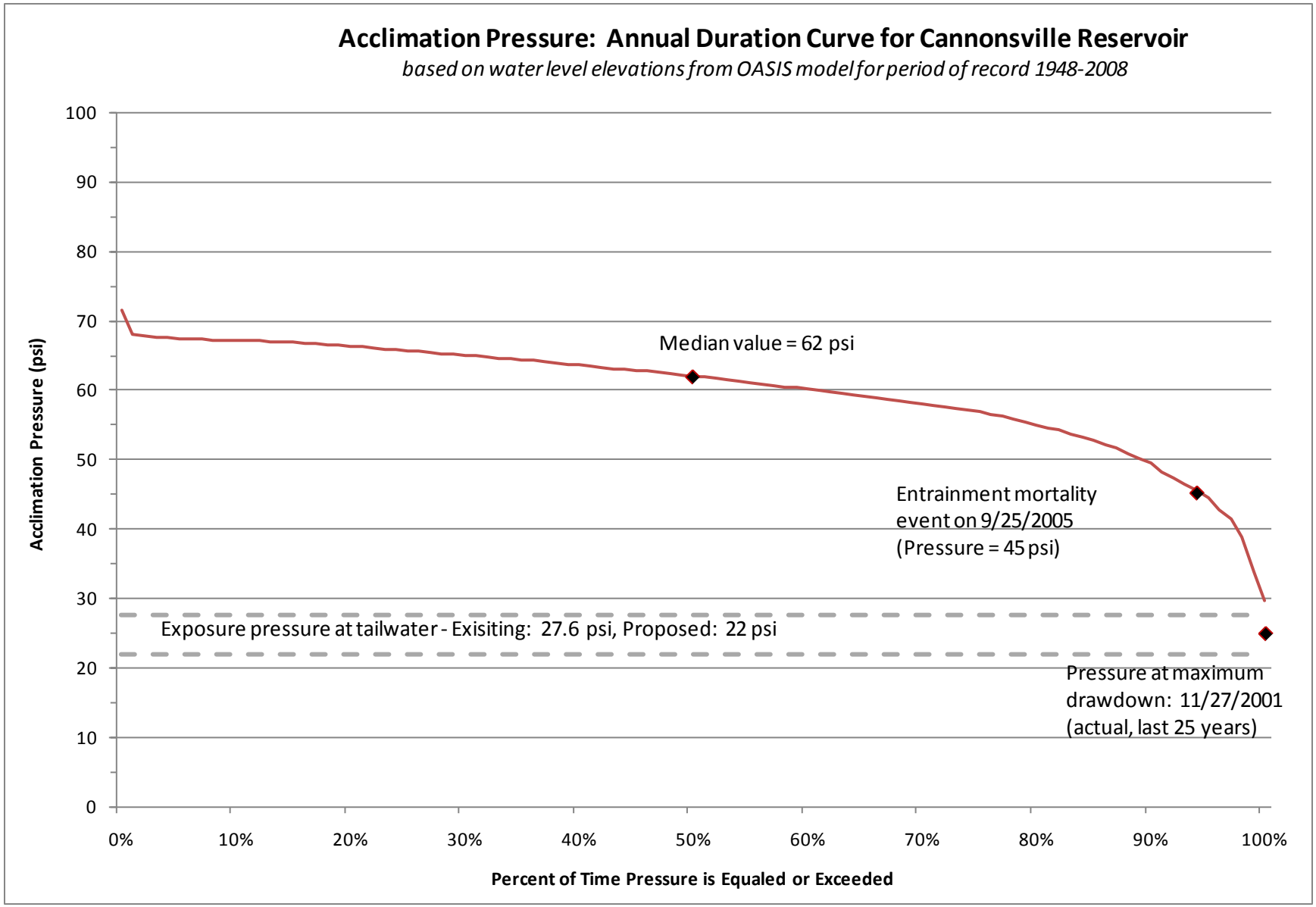


Figure 7.2-3: Acclimation depth duration curve at Pepacton Reservoir.

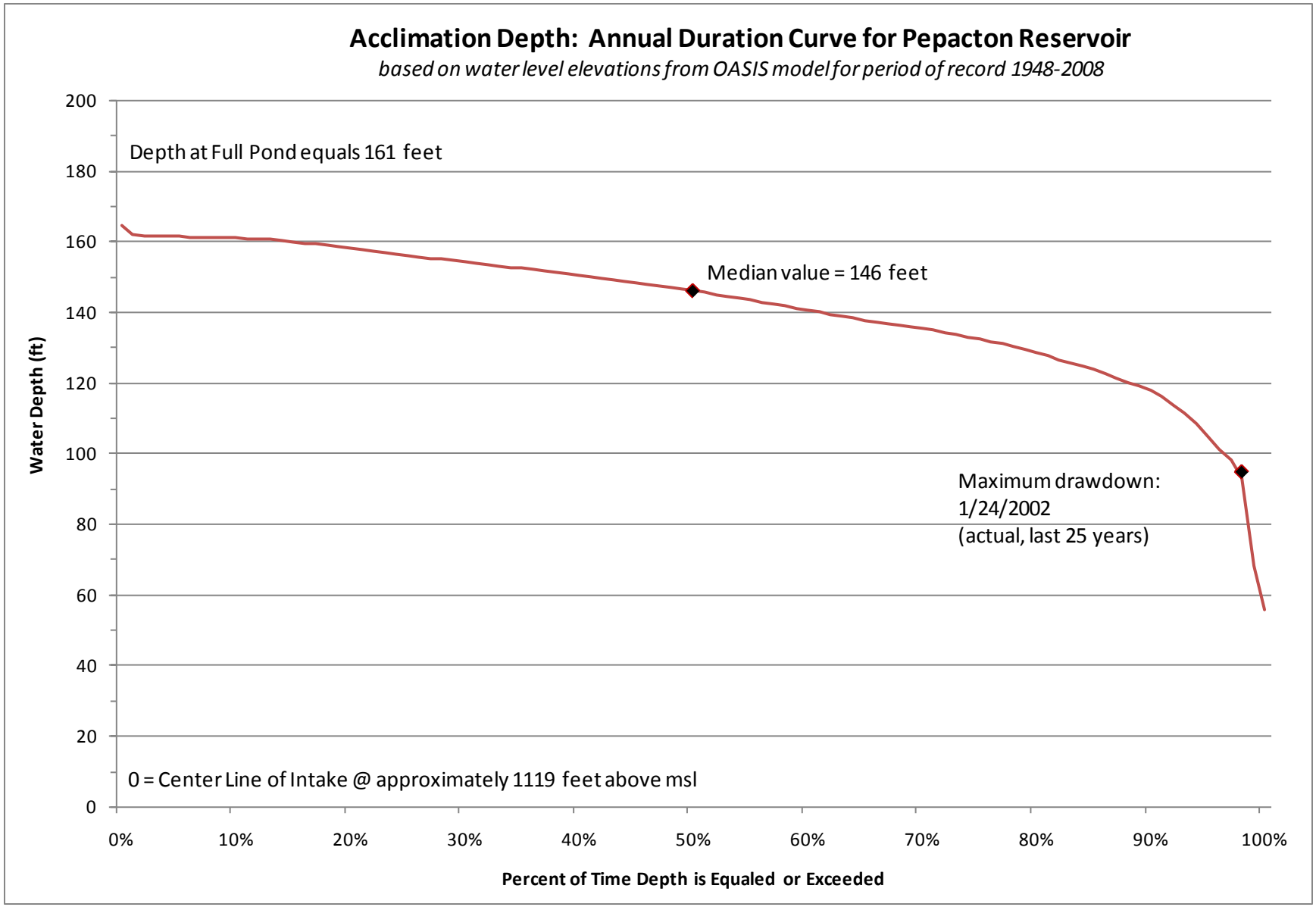


Figure 7.2-4: Acclimation pressure duration curve at Pepacton Reservoir.

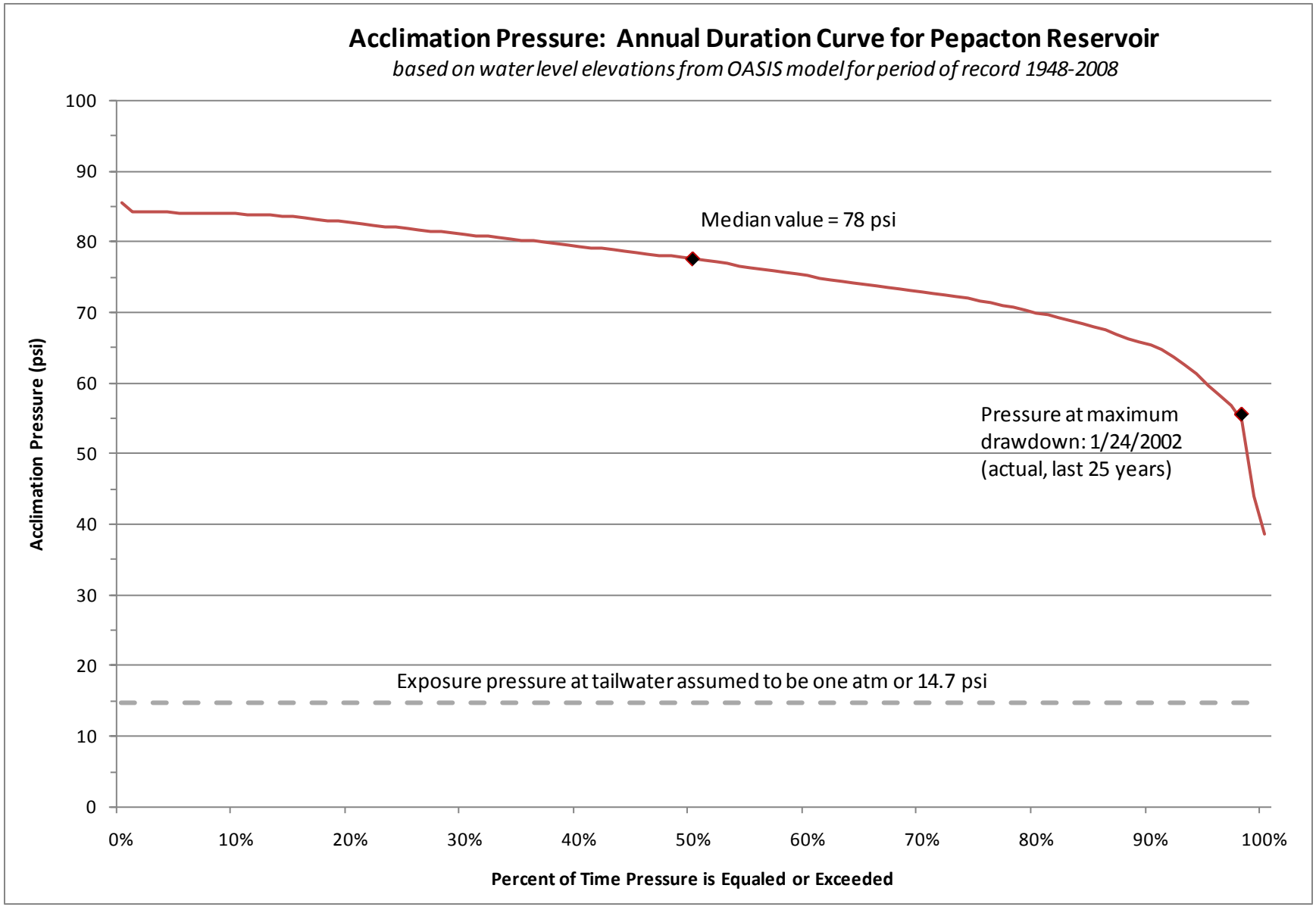


Figure 7.2-5: Acclimation depth duration curve at Neversink Reservoir.

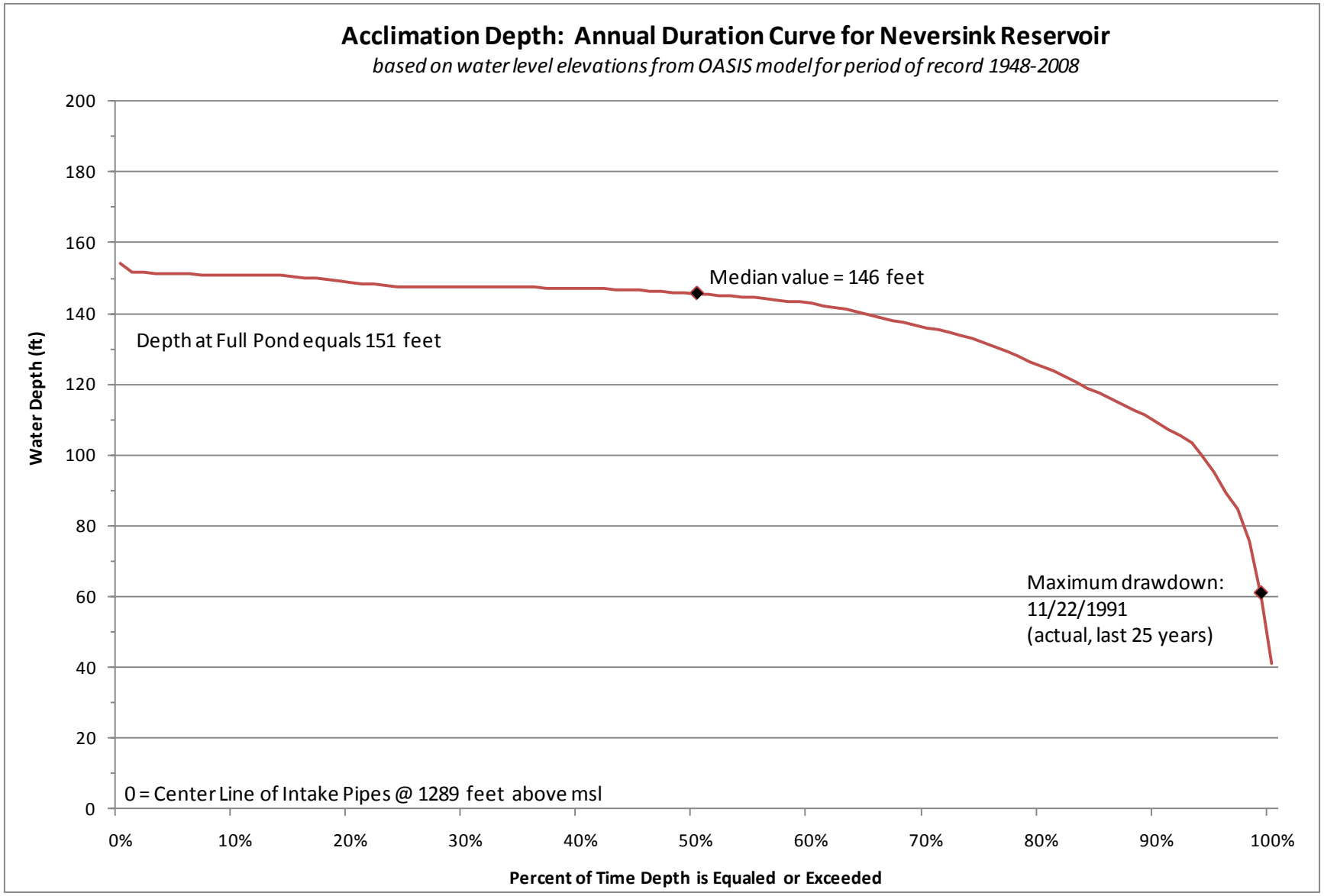
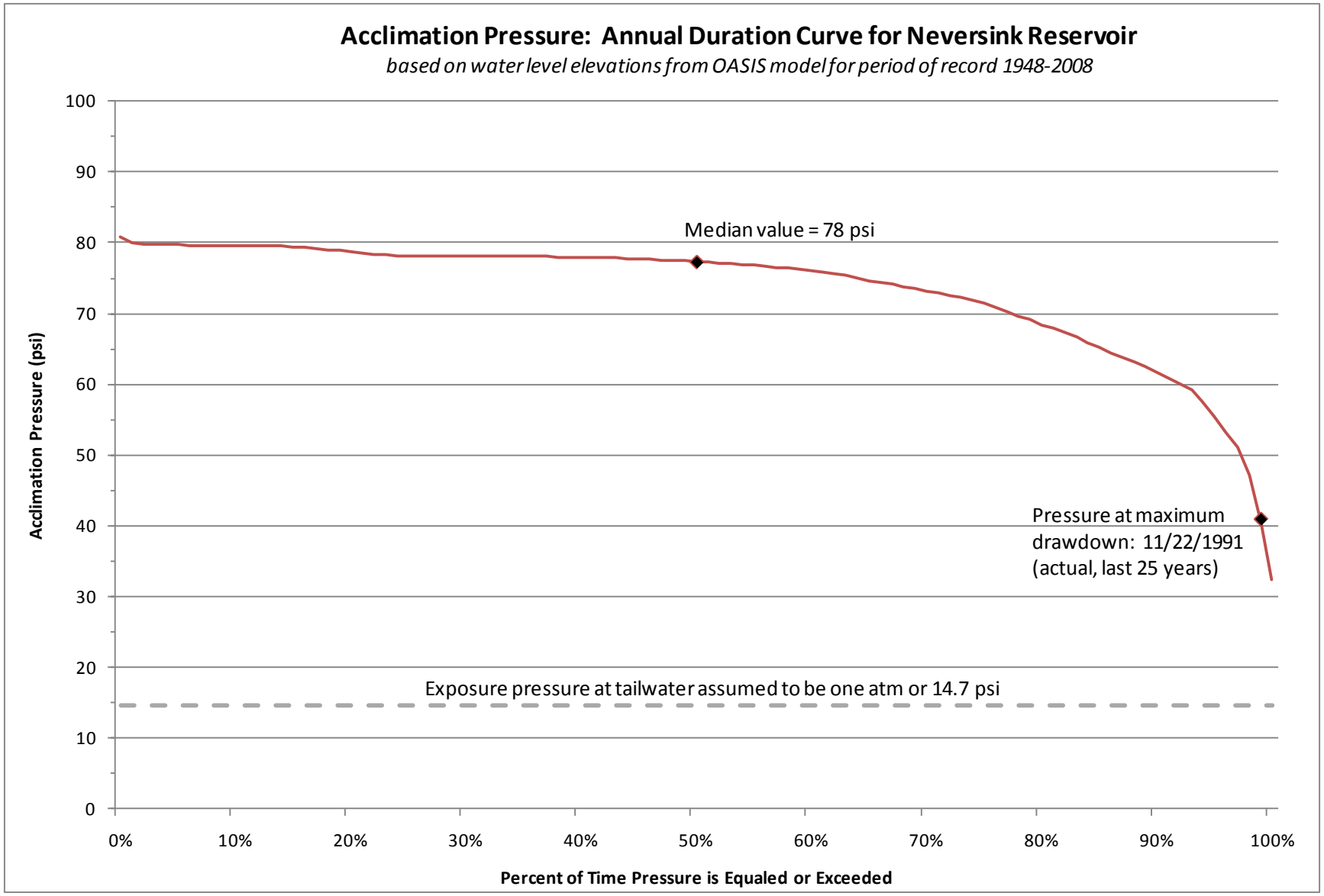


Figure 7.2-6: Acclimation pressure duration curve at Neversink Reservoir.



8.0 INTAKE PROTECTION

This section evaluates the feasibility and constructability of various options for providing intake protection at the three developments. First, a brief overview of the common physical and behavioral barriers for intake protection is provided. Then, the alternative examined in further detail for each development is discussed. These alternatives include close-spaced bar racks, angled bar racks, and barrier nets. For background information on the existing intake structures, refer to Section 3.

Physical Barriers

Physical barriers are the most common entrainment protection measures prescribed by resource agencies for protecting fish at hydroelectric and water supply intakes. These installations endeavor to preclude the passage of some or all fish species through an intake and can be used to concurrently address downstream fish passage objectives. Some physical barriers are installed seasonally, others remain year-round. For bar racks and screens, the clear openings are sized to preclude the targeted fish species and life stages. The design of these barriers must take into consideration the velocities they create at the entrance of the intake structures and ensure that the velocities will not cause fish entrainment or impingement.

FERC (1995) describes four main categories of physical barriers that have been installed at hydroelectric and water supply intakes in North America, including: 1) low velocity fish screens; 2) high velocity fish screens; 3) close-spaced bar racks, angled bar racks and louvers; and 4) barrier nets.

Low Velocity Fish Screens

These screen systems are typically designed with sufficient surface area to provide low approach velocities to minimize the potential for entrainment or impingement and are commonly used in conjunction with downstream bypasses. Oftentimes, the screens and the downstream bypass are designed and constructed to operate as an integrated system in that the screens guide fish directly into the bypass (the screen are set at an angle to the flow). Common types of low velocity screens include: rotary drum screens, vertical traveling screens, and stationary screens. Most, if not all, are equipped with debris removal systems such as traveling brushes, high pressure backwash or air-burst systems. The screen mesh opening size is typically quite small and the prescribed approach velocity is on the order of 0.4 ft/s or less.

These systems are accepted by many resource agencies in the Pacific Northwest and are relatively well proven for juvenile anadromous salmonids. Maintenance requirements and associated costs are often high due the mechanical operating equipment and potential for significant debris loading. Low velocity screens have been used at riverine hydroelectric projects with small, surface-oriented water intakes and relatively shallow canals with low flow volumes and low velocities. Low velocity screens have not been previously used in association with deep water intake structures like those located at the proposed developments, and therefore, their viability in this case is questionable. Moreover, because none of the intake structures have adjacent bypass facilities, the use of low velocity screen systems at the proposed developments would not be an appropriate application of this technology.

High Velocity Fish Screens

High velocity fish screens are a newer concept for entrainment and impingement protection at hydroelectric and water supply intakes. High velocity screen systems deployed or in the experimental stage include: the Vee screen, the Eicher screen, and the modular inclined screen. These systems use wedge wire or profile bars to provide a smooth contact surface to minimize impingement and injury. Like the low velocity screen systems, high velocity screen are often designed and integrated with downstream bypasses. Additionally, these systems are also commonly employed at riverine hydroelectric projects with surface-oriented intakes and bypasses and are intended primarily to guide fish away from the intakes

and into the bypasses. Therefore, for the same reasons discussed above, high velocity screen systems generally are not suitable for the proposed developments.

Further analysis of the feasibility and propriety of constructing an Eicher screen for downstream fish passage at each of the proposed development is presented in Section 9.2.

Close-Spaced Bar Racks and Angled Bar Racks

Since the early 1980s, close-spaced bar racks and/or angled bar racks have been one of the most commonly utilized fish protection measures installed at hydroelectric projects in the Northeast. This alternative has been successful for anadromous clupeids and salmonids and has also been commonly prescribed by resource agencies for entrainment protection of resident (*i.e.*, non-anadromous) species.

The installation typically consists of a set of partial or full depth bar racks installed at the intake entrance. In the case of the angled bar rack, the upstream face of the racks are orientated at a relatively shallow angle to the direction of flow. The "standard" design prescribed by most resource agencies consists of vertical or slightly inclined rack panels with a maximum one inch clear spacing between adjacent bars. A fish passage facility is generally located within or at the downstream end of the rack structure. The bypass can be either a pipe or overflow weir, depending on site conditions.

Resource agencies typically prescribe a maximum approach velocity of 2 ft/s perpendicular to and measured one foot upstream of the racks. The bypass flow is typically based on a percentage of the station discharge or a set minimum flow, which usually equates to 2 % of the station discharge or 20 cfs, whichever is greater.

Racks with one inch clear spacing are believed to be effective for entrainment and impingement protection of larger fish. Although smaller fish may be physically capable of passing through the racks, they may avoid the turbulence caused by the narrow spacing of the racks. Therefore, the racks may serve as a behavioral barrier as well. Depending on the approach velocity, species with weak swimming abilities can become impinged on the racks, particularly in areas of debris plugging and localized high velocity.

Where seasonal installations are required, rack sections or overlays can be installed during the fish passage season and removed for the remainder of the year. The effectiveness of a reduced spacing or angled bar rack can be influenced by approach velocities, flow turbulence, debris loading, and lighting conditions.

The viability of utilizing close-spaced bar racks and/or angled bar racks are discussed below.

Louvers

Louvers are structural guidance devices designed for riverine hydroelectric developments to divert rather than exclude fish from intake structures and are considered by some to be both a physical and a behavioral deterrent. Louvers are similar to angled bar racks in their orientation and means of guidance. Their characteristics however, result in turbulence upstream of the louver panels. The concept is for fish to sense and avoid this turbulence and move downstream laterally along the face of the louver and, typically, into a bypass facility. Louver systems are comprised of an array of evenly spaced vertical slats installed at a set angle to flow entering a canal or intake. The spacing between slats can vary from installation to installation, depending on site conditions and biological constraints. Some louver systems have been installed on floating platforms that can be installed and removed seasonally. Louvers are typically installed at partial depth in the upper 2/3 of the water column. Depending on site conditions, considerable maintenance may be required to prevent debris loading and/or damage to the louver system.

Because louvers are generally designed for riverine hydroelectric projects and shallow water intake structures, and because they are employed primarily to guide fish away from the intake structures and towards downstream bypasses, they are not an appropriate option for any of the proposed developments. Moreover, louvers have not been previously used in association with deep water intake structures like those located at the proposed developments; so their viability and suitability are unproven and questionable.

Barrier Nets

Barrier nets are considered to be a less expensive method for reducing fish entrainment and impingement and have the potential to exclude a large number of species. Barrier nets are typically deployed in a wide open area of the water body to prevent fish from accessing intake structures. A few successful applications were achieved at steam electric generating stations where there was a low debris load and relatively low flow velocity (less than 0.5 ft/s) through the net (EPRI, 1986, FERC, 1995, and Acres International Corporation, 2005). However, FERC (1995) reported that approximately half of the installations of barrier nets are ineffective and/or require extensive maintenance due to bio-fouling, debris plugging, or undesired movement resulting from high velocities and wave action. The viability of this option is discussed below.

Behavioral Barriers

The most common types of behavioral barriers are lights, sound, and electrical fields. Other methods that have been tested, but are usually considered highly experimental, include air bubble curtains and hanging chains. Results obtained with most behavioral barriers have been highly variable.

Lights

Experiments with lighting systems have been undertaken to evaluate their ability to repel fish from hydroelectric and water supply intakes (*e.g.*, using strobe lights) and to attract fish to bypass facilities (*e.g.*, using mercury lights). Important considerations for the effectiveness of light as a behavioral deterrent include: ambient lighting, water clarity, water velocity, and the species being targeted. The installation of strobe lights has shown promising results for diverting the passage of American shad and Atlantic salmon smolts from turbine intakes.

Studies indicate that success with strobe lights appear to be project specific indicating that hydraulic and environmental conditions as well as project layout and operation influence the effectiveness of lights for entrainment protection (U.S. Congress Office of Technology Assessment, 1995). Although many studies have evaluated strobe lights as a primary barrier system, they are often evaluated as part of an integrated fish protection and passage system that includes other devices such as screens, narrow-spaced bar racks, bypasses, and/or other behavioral systems. As a secondary system, strobe lights have the potential to incrementally increase fish protection effectiveness (EPRI, 2002). As part of an integrated system, a recent study conducted at a relatively shallow water (16-42 feet) cooling water intake structure in Alabama (Baker, 2008) concluded that that sound and light (strobe lights) deterrents were ineffective at preventing fish entrainment and impingement at that particular facility, but no specific factor for ineffectiveness was identified.

Although the Alabama study could not substantiate the effectiveness of strobe lights, it revealed that strobe lights are not an attractive or preferable option because they require frequent, unplanned maintenance. Baker (2008) reported that almost biweekly repair or replacement of flash-heads and power converters were required. Leading causes of strobe light failures include blown flash tubes, faulty transformers inside the flash-head, and faulty underwater cable connectors.

Finally, the use of strobe lights in deep water applications has not been studied, tested, or implemented.

The questionable usefulness and viability of this technology in a deep water application, coupled with the high maintenance requirements and costs, precludes their use at any of the three proposed developments.

Sound

Experiments with sound have been conducted to evaluate its ability to repel fish at water intakes and attract fish to bypass facilities. Two types of sound technology have been used: poppers, which create a high-energy acoustic output ("pop") to startle fish and cause an avoidance response, and sound generating transducers, which create frequencies and amplitudes that also cause an avoidance response in fish. Both types of sound systems have been used with some success at thermal plant intakes and in laboratory tests. However, only transducer-based sound systems have been applied at hydroelectric projects, and their effectiveness in eliciting avoidance behaviors from fish has been variable. They have shown promising results for deterring anadromous salmonids and clupeids.

Impact sound generators have not been shown to effectively and consistently repel any species in actual field applications. It does not appear that impact sound generators have the potential for effective application at hydroelectric facilities (EPRI, 2002).

In the case of the proposed developments, there are multiple species that may be found near the intake structures and the species present changes seasonally. Sound affects fish species differently so one species or life stage may be deterred while another is unaffected. Additionally, installing, maintaining, and powering a sound deterrent device in the area of deep water intakes or throughout the entire water column would be extremely costly and logistically problematic. For these reasons, sound as a fish deterrent is not considered a viable alternative for any of the three proposed developments.

Electric Fields

Electric fields have been experimented with as a means of entrainment protection at hydroelectric intakes. The electric field can be installed in an array upstream of the intake where the strength of the field increases with proximity to the intake entrance. The system is typically designed to elicit an avoidance response without incapacitating the fish; however, the chance that the fish may be "stunned" increases the further they move into the current field. This technology has been used at the Holyoke Project in Massachusetts to temporarily incapacitate shad and divert them into a bypass facility. Electrical fields have not been previously used in association with deep water intake structures like those located at the proposed developments, and therefore, their use in this case as a reasonable fish deterrent is unproven and suspect.

An important consideration for the use of electric fields is that different species of fish have varying degrees of sensitivity to electric current. Their reaction may also be proportional to the size of the fish (*e.g.*, larger fish are more susceptible to the current than smaller fish). As a result, small or juvenile fish are much less likely to be affected by the electric field and therefore, more likely to be entrained.

Several problems have been identified with using this technology to deter fish movement. Available data indicates that electric fields may be most effective in shallow streams and relatively narrow confines where sufficient field strength can be set-up across the electrodes and that biological response at hydroelectric intakes has generally been poor (U.S. Congress Office of Technology Assessment, 1995).

Maintaining and powering an electric field over a large area, such as surrounding the Cannonsville intake, would be very difficult. The relative density of the water throughout the area, turbidity, and other factors that can change the specific conductivity can have significant effects on the electric field strength. As a result, the field strength may be highly variable, reducing its effectiveness. While the areas at Pepacton and Neversink are more limited than at Cannonsville, the depth, water density, and other factors would likely have similar impacts of the effectiveness of the electric field.

For all of the foregoing reasons, electric field systems are not considered a viable alternative for any of the three proposed developments.

Air Bubble Curtains

Air bubble curtains are created by pumping air through a submerged diffuser pipe system to create a dense curtain of bubbles in the water column. The objective is to elicit an avoidance response by fish based on a number of behavioral cues (*e.g.*, visual, tactile, and noise created by bubbles). These curtains generally have been ineffective in blocking or diverting fish in a variety of field applications. Additionally, they may be highly species-specific as some species have actually been attracted to the device (EPRI, 2002).

Additionally, pumping air into the deep water area near the intakes associated with the proposed developments may have an unintended adverse effect. If the deep water periodically goes through periods of anoxia, fish species will not voluntarily be in the vicinity of the intakes. If air is pumped in to develop a bubble curtain, the water may become oxygenated enough to be more attractive to some fish species. In this case, the bubble curtain may become an unintentional attractant. Additionally, installing, maintaining, and powering bubble curtains near deep water intakes would be costly and difficult. Therefore, the use of bubble curtains as a fish deterrent is not considered a viable alternative for any of the three proposed developments.

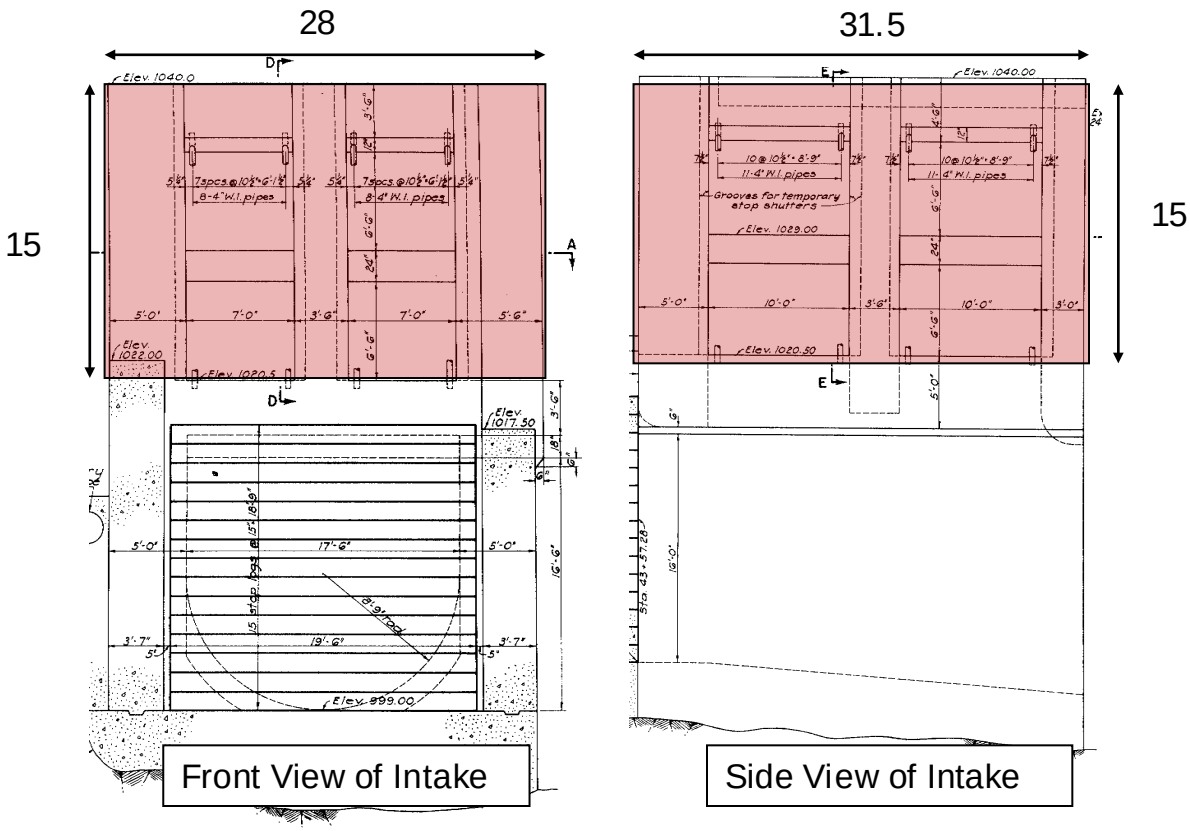
8.1 Cannonsville Development

The DEP is evaluating three turbine configurations for the proposed Cannonsville development. Based on information provided by turbine vendors, the maximum hydraulic capacities for each configuration are 950 cfs, 1,300 cfs, and 1,500 cfs. Per the USFWS design criteria, the intake velocity one foot in front of the racks should be 2 ft/s or less. The intake area sizes necessary to meet the 2 ft/s requirement for flows of 950 cfs, 1,300 cfs and 1,500 cfs are 475 ft^2, 650 ft^2, and 750 ft^2, respectively. The total gross area of the existing intake (510 ft^2) is not large enough to meet the 2 ft/s criteria for the 1,300 cfs and 1,500 cfs configurations. In addition, the existing bar rack spacing (approximately 7.5 inches) is greater than the USFWS design criteria of 1-inch clear spacing.

Bar Racks

Intake protection could be provided at Cannonsville by mounting a bar rack one foot in front of the entire intake structure (including the front and side of the intake structure), which would yield a greater intake surface area. The bar racks would be comprised of 5/8-inch vertical bars with 1-inch clear spacing between the bars and would be manufactured to fit into the existing stop log slots.

Below are reproductions of the as-built drawings of the front and side of the intake structure. The gross area of the proposed intake racks is shown in red shading and equates to 892.5 ft^2. This gross area is sufficient to meet the 2 ft/s design criteria for all three proposed turbine configurations. Fabricating the bar racks to slide into the existing stop log slots would allow the bar racks to be removed for maintenance or when the stop logs must be put into place for downstream or tunnel maintenance. An automatic cleaning system could be installed to periodically clean the bar racks if required due to biofouling. The system would consist of rotating brushes that move on a track located over the face of each bar rack.



Cannonsville – Front and Side View of Intake Structure

Angled Bar Racks

Angled bar racks would allow for diverting fish away from the intake; however, they require more area in front of the intake and an additional structure to be installed to support the racks. The racks are normally installed at a 45-50° angle; the slope diverts fish upward and away from the intake. At such an angle, the bar racks would extend out from the intake structure over 40 feet.

Angled bar racks are not a feasible alternative at Cannonsville because the intake structure is elevated from the reservoir floor. Therefore, wing walls and a lower structure would be necessary to support the racks. Because of the significant costs associated with these structures, the angled bar rack option was not explored further.

Barrier Nets

Barrier nets require relatively slow velocity rates compared to close-spaced or angled bar racks. Velocity rates of 0.4 ft/s and less could be accomplished with the use of a barrier net around the intake, but would require a large surface area. Shown in the table on the following page are the hydraulic capacities for the three proposed configurations, the equivalent flow rate, and the estimated size of the barrier net. To achieve the 0.4 ft/s velocity rate, the net size was based on a maximum flow through velocity of 10 gpm/ft^2. Given that the Cannonsville Reservoir experiences seasonal fluctuations, maintaining the effectiveness of a barrier net for intake protection would be troublesome. The net must be deep enough at full pool to reach the reservoir surface to prevent fish from swimming over the net towards the intake structure. During periods of low water, the net may collapse on itself, or get entrained into the intake structure.

Another major consideration with barrier nets is continual maintenance. The nets must be periodically cleaned and repaired, which is difficult at depths that may exceed 100 feet. Seasonal installation and removal for winter storage would also be required due to and the net's susceptibility to damage from ice at the surface. For these reasons, barriers nets are not considered a viable alternative for intake protection at Cannonsville.

Cannonsville Barrier Net Sizing

Maximum Station Flow (cfs)	**Maximum Station Flow** (gpm)	**Square footage of barrier net needed to maintain velocities at a maximum of 10 gpm per ft^2**
950 cfs	426,360	~43,000
1,300 cfs	583,440	~59,000
1,500 cfs	673,246	~68,000

Summary

Based on the physical barriers evaluated, installation of a close-spaced vertical bar rack is the most feasible option for the proposed Cannonsville development in the event that additional protective devices deemed necessary. Based on the drawings, plans, and photographs of the intake structure, it appears that the close-spaced bar rack can be installed without major modifications to the existing structure. The angled bar rack option would require major structural modifications, and the barrier nets alternative would require continual maintenance and repair.

8.2 Pepacton Development

The DEP is evaluating two turbine configurations for the proposed Pepacton development. Based on information provided by turbine vendors, the maximum hydraulic capacity of the unit is 162 cfs. The total gross area of the existing intake structure is 96 ft^2. The maximum intake velocity is calculated at 1.69 ft/s, which is within the USFWS design criteria of 2 ft/s. However, the existing bar rack spacing (2.75 inches) is greater than the USFWS design criteria of 1-inch clear spacing.

Bar Racks

As at Cannonsville, intake protection could be provided by installing a new close-spaced bar rack that is larger than the existing four intakes and designed with a frame that utilizes the existing stop log slots. The new bar rack would have a surface area of 368 ft^2, with a height of 16 feet and a width of 23 feet, as pictured below. The maximum intake velocity, under the maximum FFMP-OST flow of 700 cfs, would be 1.90 ft/s. The bar rack would consist of 5/8-inch vertical bars with a clear opening of 1-inch. The bar rack would be manufactured using a frame that places the rack one foot from the face of the intake structure.

Also similar to the bar rack evaluated for Cannonsville, fabricating the bar rack with a frame that can slide into the existing stop log slots would allow the bar rack to be removed for maintenance or when the stop logs must be put into place for downstream or tunnel maintenance. An automatic cleaning system could be installed to periodically clean the bar rack if required due to biofouling.

Angled Bar Racks

An angled bar rack could be utilized at Pepacton. The rack would be affixed to the top of the bulkhead and extend to the floor of the reservoir at a slope of 45-50°. The length from the base of the intake structure to the bottom of the bar rack would be approximately 50 feet, and the width would vary from 40

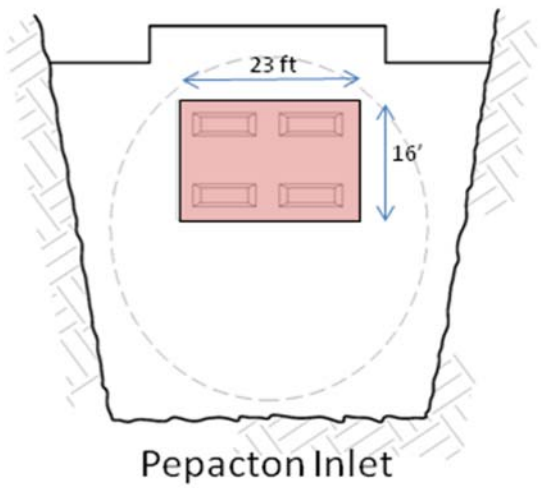
feet at the base to 57 feet at the top. The total surface area would be 3,400 ft^2. Water velocities through angled racks would be 0.21 ft/s. This option would require structural work and the construction of concrete footings to support the rack on the reservoir floor.

Barrier Nets

The barrier net option would require installing nets that encompass the entire area around the bulkhead structure. The depth of the barrier net, as well as the difficulty of maintaining, cleaning, and removing it, makes this option infeasible.

Summary

Based on the physical barriers evaluated, installation of a close-spaced bar rack outside the existing intake structure is the most feasible option for the Pepacton development. The rack would incorporate a frame that will utilize the existing stop log slots for support, thereby eliminating the need for major modifications to the intake structure. Racks could be removed at a later date by crane if required for installation of the stop logs.



Pepacton – Front View of Intake

8.3 Neversink Development

As previously noted, the point of entrance for fish is at the openings along the wall of the common structure. However, flow velocities in this area are very low, ranging from 0.02 ft/s to 0.9 ft/s depending on the water level of the reservoir. Because these velocities are so low, it is highly unlikely that any fish, including juveniles and very small fish, would unwillingly pass through these openings. It is important to note that there are existing bar racks (spaced 2 inches) beyond these openings which provide an additional measure of protection against fish entrainment.

Any fish that get past the bar racks would then need to travel to the bottom of the common structure to where the intake troughs leading to the proposed hydropower development are located. Based on the turbine design being considered, the maximum proposed hydro capacity at Neversink is 100 cfs. This equates to an intake velocity of 1.39 ft/s, which is below the USFWS intake velocity design criteria of 2 ft/s. Furthermore, during the summer months, historical data utilizing the operating protocol in effect at

the time this analysis was conducted demonstrates that the velocities in front of the intake troughs are below 2.0 ft/s approximately 90% of the time.

Based on the information set forth herein regarding the habitat and life history requirements and swimming speeds of the fish species found in the Neversink reservoir, the potential for fish entrainment is expected to be low for all species. Moreover, because there is no shoreline habitat near the intake troughs at Neversink, and such troughs are located in deep-water habitat, the risk of entrainment for fry and juvenile fishes—regardless of intake velocities—is minimal.

Because of these reasons, it is highly unlikely that fish would become entrained to the proposed hydropower development at Neversink. Therefore, additional intake protection measures are not warranted at this location.

9.0 DOWNSTREAM FISH PASSAGE

This section examines the need for downstream fish passage and possible mechanisms to facilitate passage at each proposed development. The need analysis includes identifying the objectives for downstream fisheries management and evaluating the implications of allowing the reservoir and downstream fisheries to mix. With respect to the mechanisms, the feasibility of providing downstream fish passage either through a low-level outlet or at the surface of the developments is discussed. Additionally, physical factors related to water quality impacts of downstream fish passages at the developments are addressed.

9.1 Management Objectives for the Downstream Fisheries

Cold water releases from all three reservoirs provide suitable cool temperatures to support trout fisheries downstream. The West Branch below the Cannonsville Reservoir supports a renowned trout fishery, with the fish population composed primarily of wild and hatchery stocked brown trout and including rainbow trout and brook trout. Cold water releases from the Pepacton Reservoir support wild brook trout, wild and stocked brown trout, and wild rainbow trout. Cold water releases from the Neversink Reservoir support a high quality brown and brook trout fishery in the lower Neversink River. As requested by USFWS, DEP contacted NYSDEC to determine whether the mixing of the reservoir fisheries with the downstream riverine fisheries at the three proposed developments is within the management plans for the three river systems.

According to NYSDEC, alewives from the Cannonsville and Pepacton Reservoirs provide forage for downstream trout populations. However, water temperatures in the rivers are too cold to support alewife spawning requirements.

During periods when water spills over the spillways, reservoir brown trout move downstream, but generally in low numbers. Therefore, these fish do not significantly contribute to the downstream trout fisheries.

Although providing downstream fish passage will not enhance the downriver fish populations and is not otherwise necessary to implement the management plans for the river systems, a brief discussion of the considerations related to constructing downstream fish passages is provided below in order to fully respond to the request of USFWS.

9.2 Low-Level Downstream Fish Passage

The feasibility of constructing an Eicher screen for downstream fish passage at each proposed development was evaluated. An Eicher screen is used to divert fish from a penstock to a bypass pipe as shown in the picture below. The Eicher screen is fitted within the penstock and operates on a pivot, where it can be backwashed if tipped in a different direction.

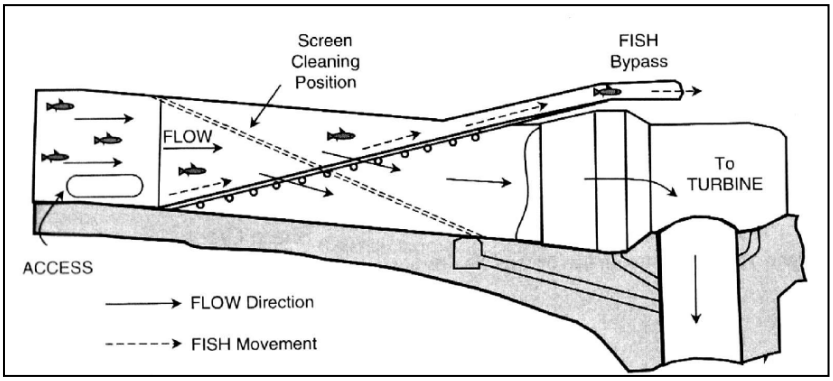
For the proposed Cannonsville development, the Eicher screen would be located within the 17.5-foot-diameter diversion pipe located between the intake and the proposed powerhouse. The installation of the screen would require a section of the existing pipe to be opened and retrofitted to create a fish bypass conduit system that directs fish back to the reservoir or downstream. Because of the high mortality rate associated with the large pressure differentials between the intake structure and the tailrace, further investigation of this alternative as a means of providing downstream passage was abandoned.

At the proposed Pepacton development, water flows through the bulkhead and then into the original diversion tunnel. The diversion tunnel is 40 feet in diameter and has been sealed beyond the station

18+71.46. At that point (456 feet beyond the bulkhead), the water is diverted into an 8-foot-diameter pipe that directs water into the valve chamber and through two valves.

An Eicher screen option would require installing the screen in this 8-foot-diameter pipe to divert fish moving downstream. The velocity through this pipe under a flow of 700 cfs is 13.9 ft/s. Because of this high velocity and a high mortality rate associated with the large pressure differentials between the intake structure and the tailrace, further investigation of this alternative as a means of providing downstream passage was abandoned.

At the Neversink development, the distance between the inlet head structure and the valves is not adequate to allow the installation of an Eicher screen. Moreover, with respect to fish entering the inlet head structure through the low-level intake structure, similar pressure differentials as noted above obviate the viability of a low-level downstream fish passage.



Typical Eicher Screen

9.3 Surface-Oriented Downstream Fish Passage

Many options are available for fish passage over spillways. However, the temperature differences of the reservoirs and the river systems must be evaluated to determine potential adverse effects on the downstream fisheries.

Surface water temperature readings from the profiles collected near the intake structures in each reservoir were compared with water temperature readings collected downstream of each dam for the selected wet, dry, and average years (described in Section 4). The purpose of this analysis is to quantify the temperature differences in order to evaluate the thermal effects on fish and downstream fish habitat from a surface-oriented fish passage.

Temperature versus time was plotted for the months of April through November for each reservoir and each year. Also, the flow over the spillways was plotted on the same graphs to indicate times when the reservoirs were spilling and how this affected the downstream temperature regimes. Results by reservoir are shown in Figures 9.3-1 through 9.3-9 and described below. The sampling locations are described on each graph for reference.

Cannonsville Reservoir

Temperature comparisons above and below the Cannonsville Dam for the selected wet, dry, and average years are shown in Figures 9.3-1 through 9.3-3, respectively. In all three graphs, a significant temperature

difference can be seen during the summer and fall months when there is no spillage. The maximum temperature difference was about 17.5°C in August of the average year, and maximum differences around 16°C and 15°C were observed during the wet and dry years, respectively.

Summer water temperatures downstream of the Cannonsville Dam, when there is no spillage, range from 6°C to 12°C, being higher during the dry year. Flow over the spillway results in significantly higher water temperatures downstream, compared to periods of no spillage.

Pepacton Reservoir

Temperature comparisons above and below the Downsville Dam for the selected wet, dry, and average years are shown in Figures 9.3-4 through 9.3-6, respectively. As at Cannonsville, all three graphs show significant temperature difference during the summer and fall months when there is no spillage. The maximum temperature difference was about 18.5°C in August of the wet year, with differences around 18°C and 14.5°C during the average and dry years, respectively. When there is no spillage over Downsville Dam, summer water temperatures downstream are consistently around 5°C, and only reached 10°C during the dry year.

Neversink Reservoir

Temperature comparisons above and below the Neversink Dam for the selected wet, dry, and average years are shown in Figures 9.3-7 through 9.3-9, respectively. Consistent with the proposed Cannonsville and Pepacton developments, a significant temperature difference can be seen during the summer and fall months when there is no spillage. The maximum temperature difference was about 16°C in June of the wet year, with maximum differences around 15°C and 13°C during the average and dry years, respectively.

Summer water temperatures downstream of Neversink Dam, when there is no spillage, range from 6°C to 13°C, being higher during the dry year. Although less frequently than at the other two reservoirs, spillage over Neversink Dam resulted in significantly higher water temperatures downstream compared to periods of no spillage. Downstream warming is apparent even during short-duration spillage events (*e.g.*, mid-July 1996 and mid-June 1998).

The data presented above focuses on the warming of downstream water temperatures after spillage events, which can have proportionally higher flows compared to normal conservation flow requirements. With surface-oriented downstream fish passages, conveyance flows will be required to pass fish downstream of the dams. These conveyance flows are dependent on the type of downstream passage facility that is considered. When considering surface collectors for downstream passage, an attraction flow is normally required to lure surface-oriented fish away from a surface intake and towards a surface collector for downstream fish passage. For the proposed developments, however, attraction flows are not required because there are no surface intake structures. At other projects where surface intake structures have been an issue, the facilities have been designed using a conveyance flow of 20-25 cfs. A similar design with a similar flow could be used here.

A theoretical conveyance flow of 25 cfs is compared to the median downstream flows at the three proposed developments based on USGS gage data, as shown in Table 9.3-1. At Pepacton and Neversink, August median flows are 87 cfs and 49 cfs, respectively. The warmer conveyance flows would undoubtedly affect the thermal regimes of the rivers below these two reservoirs. At Cannonsville, August median flows are 551 cfs. Mixing 25 cfs of warmer surface water to the cooler tailwaters below the Cannonsville Dam may not significantly warm the river enough to affect the coldwater fishery.

However, fish seeking downstream passage during summer months, when the temperatures differences between the reservoir surface and downstream are the greatest (above 15°C), may experience cold shock.

Using rainbow smelt as an example, exposure to a rapid decrease in water temperature of -8.5°C at an acclimation temperature of 17°C was documented to cause 50% mortality (Wismer & Christie, 1987).

9.4 Discussion

Facilitating the mixing of the reservoir and downstream fisheries through fish passage is not directly contrary to the fisheries management objectives for the three river systems. However, the changes to downstream temperature regimes arising from the conveyance flows associated with surface-oriented passages could adversely affect the downstream fisheries by warming up the rivers, particularly at the proposed Pepacton and Neversink developments. This warming could cause a change in fisheries composition by causing trout to seek cooler areas, allowing warmwater fish to dominate. Because the fisheries management objective for the three river systems is focused on providing coldwater trout fisheries, such a result would be inconsistent with the management objectives. Additionally, downstream fish passage is not required to complete the life cycles of any fish species in the reservoirs.

Summer water temperatures are too cold in the East and West Branches of the Delaware River and the Neversink River for warmwater species to thrive. The NYSDEC reported that, following the 2006 flood event, there were record numbers of smallmouth bass, carp, and panfish in the West Branch. The numbers of these fish declined annually. By 2009, warmwater fish numbers were back to normal (*i.e.*, present but very sparse).

Low-level fish passage options, including Eicher screens, would not be feasible because of fish mortality concerns due to changes in pressure from the reservoirs to the tailraces. Further investigation of this alternative was abandoned for this reason.

Downstream fish passage would not alleviate any mortality concerns due to entrainment for two reasons: 1) fish that move downstream through a low-level passageway would be subjected to mortality regardless of turbine presence, and 2) fish compelled to move downstream through a surface-oriented passageway would not otherwise be subjected to turbine mortality because the existing intake structures are in deep water.

For all of the foregoing reasons, constructing downstream fish passages at any of the three proposed developments is neither desirable nor warranted.

Table 9.3-1: Flow statistics for USGS gages in downstream of the three developments.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
West Branch Delaware River at Stilesville, NY, Drainage Area = 456 mi^2, Period of Record: Jan 1964-Sep 2007													
Median	51	95	299	973	419	346	427	551	498	320	47	47	333
East Branch Delaware River at Downsville, NY, Drainage Area = 372 mi^2, Period of Record: Jan 1955-Sep 2007													
Median	41	39	42	67	75	76	87	87	73	69	44	37	57
Neversink River at Neversink, NY, Drainage Area = 92.6 mi^2, Period of Record: Oct 1941-Sep 2007													
Median	16	13	9	23	43	44	51	49	46	28	22	15	24

Notes: The Cannonsville Dam was constructed in 1964, the Downsville Dam was constructed in 1954, and the Neversink Dam was constructed in 1953. All flows are in cfs.

Figure 9.3-1: Temperature above and below dam at Cannonsville Reservoir for the wet year (1996).

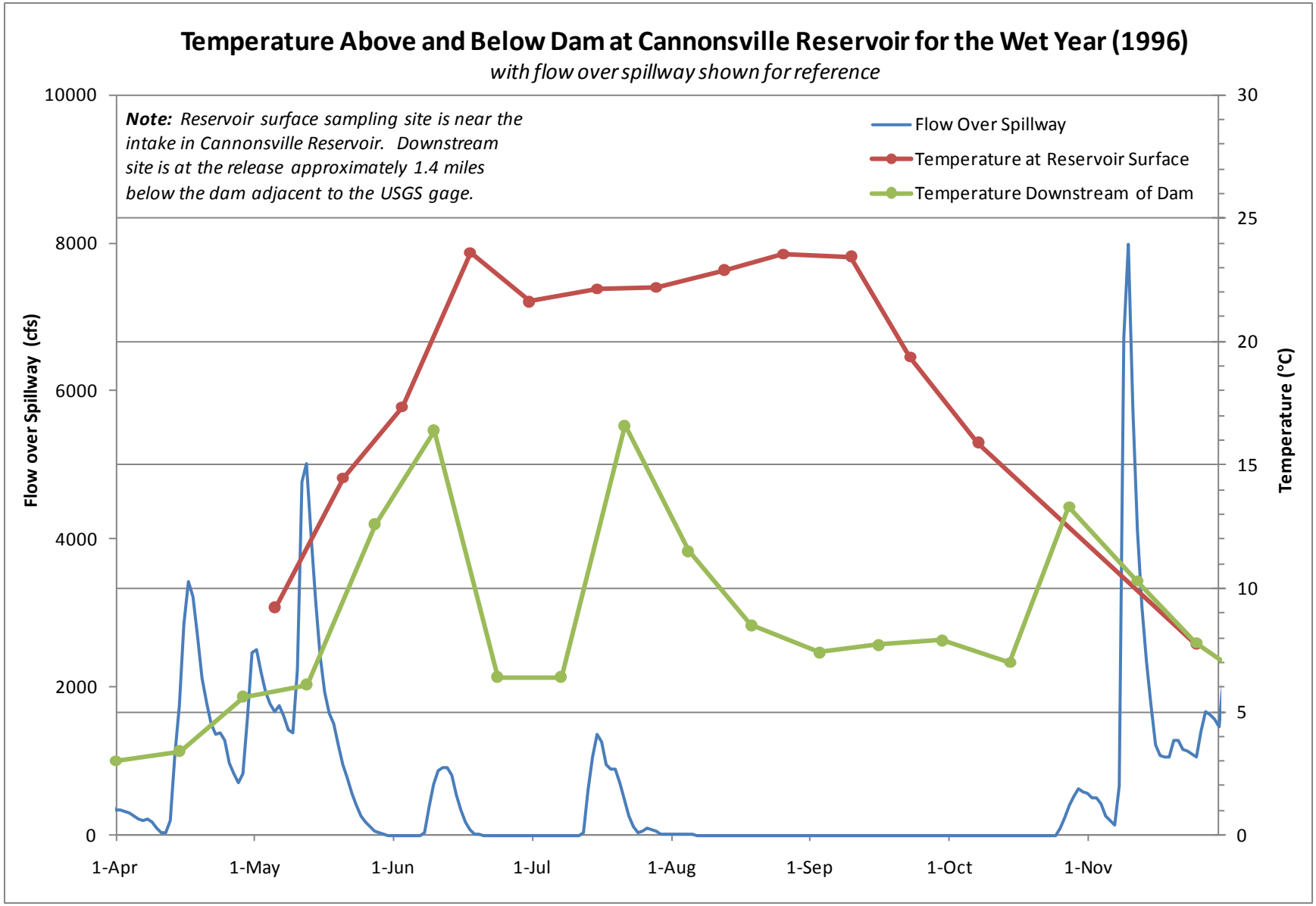


Figure 9.3-2: Temperature above and below dam at Cannonsville Reservoir for the dry year (1993).

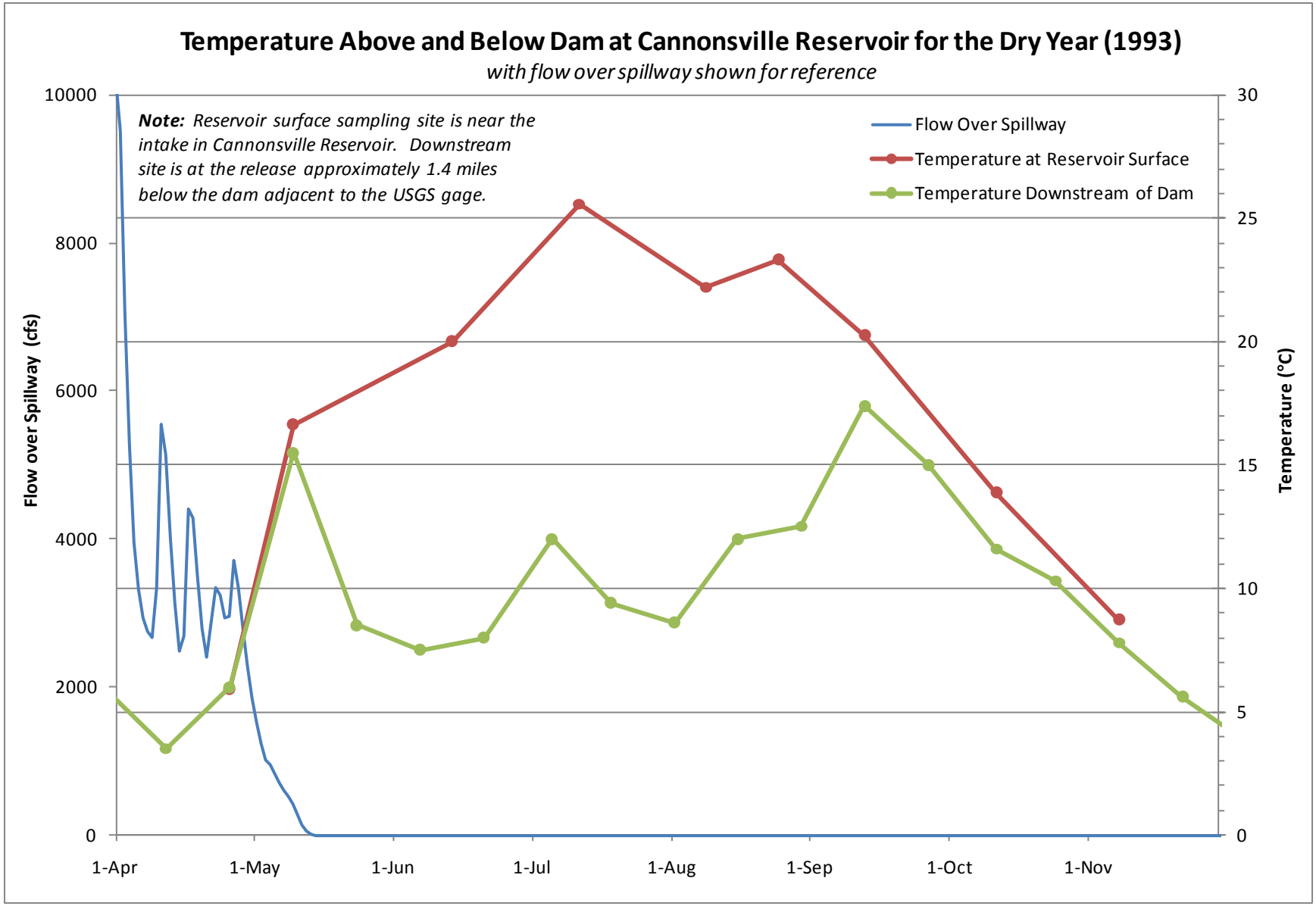


Figure 9.3-3: Temperature above and below dam at Cannonsville Reservoir for the avg. year (1998).

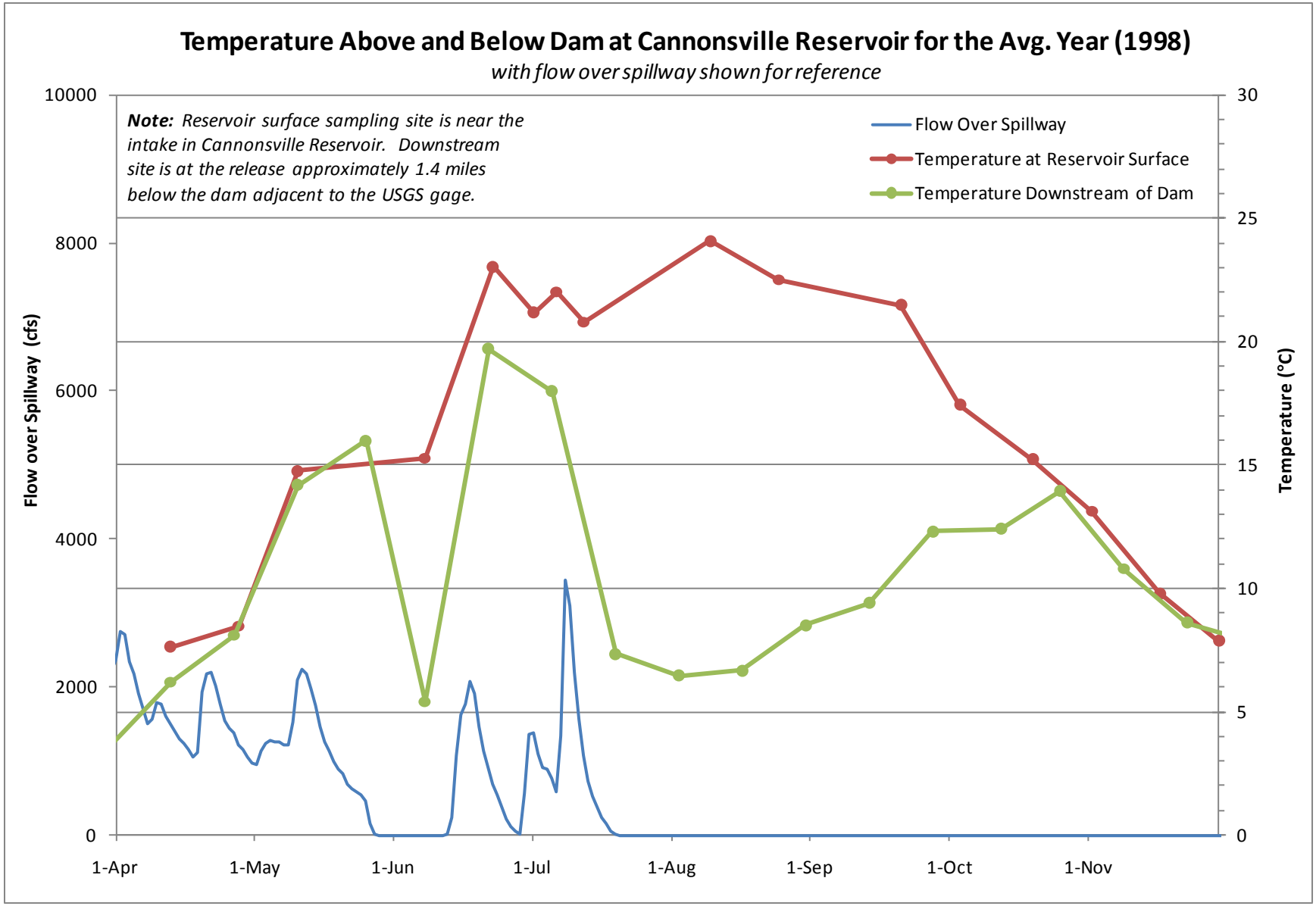


Figure 9.3-4: Temperature above and below dam at Pepacton Reservoir for the wet year (1996).

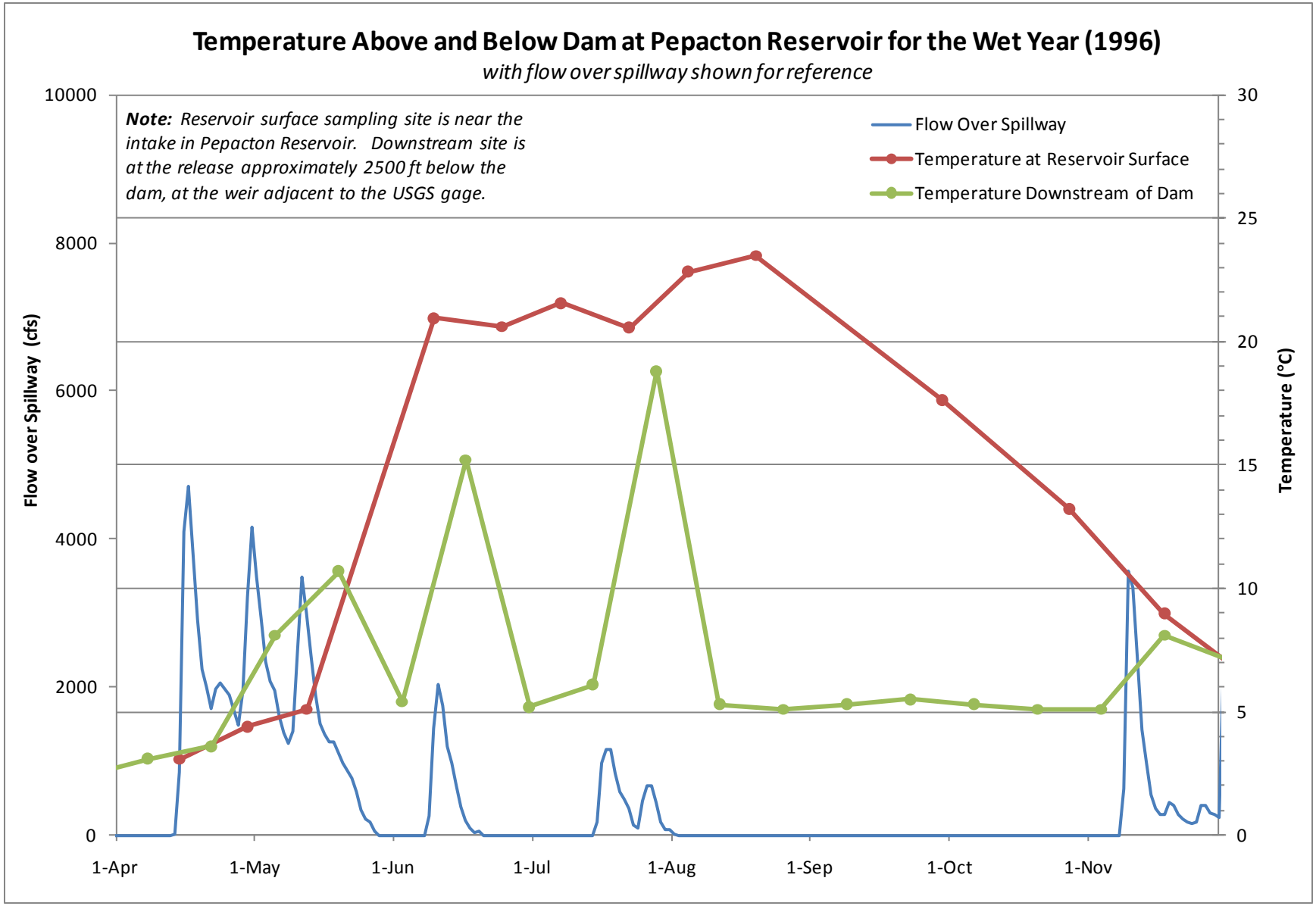


Figure 9.3-5: Temperature above and below dam at Pepacton Reservoir for the dry year (1993).

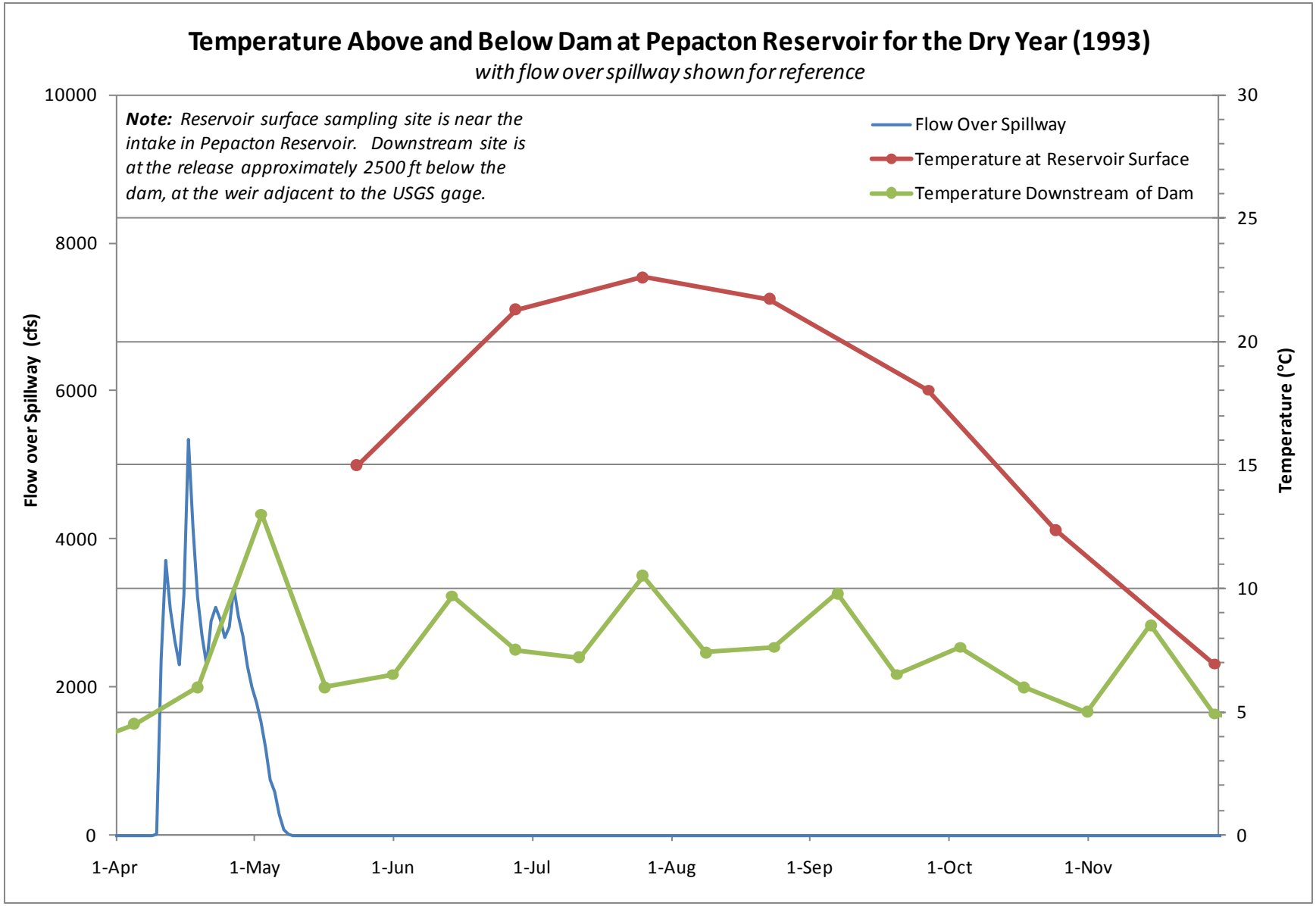


Figure 9.3-6: Temperature above and below dam at Pepacton Reservoir for the avg. year (1998).

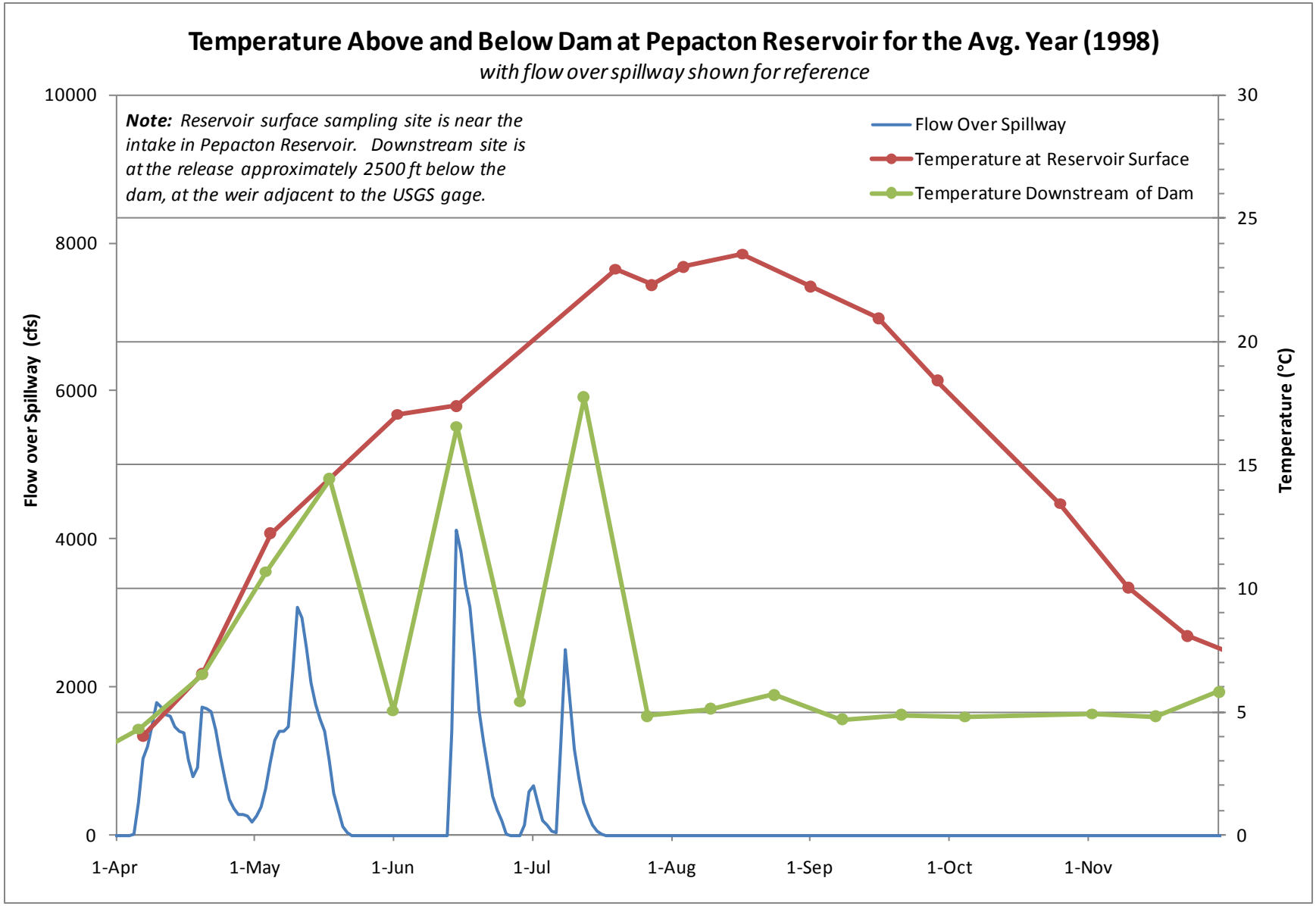


Figure 9.3-7: Temperature above and below dam at Neversink Reservoir for the wet year (1996).

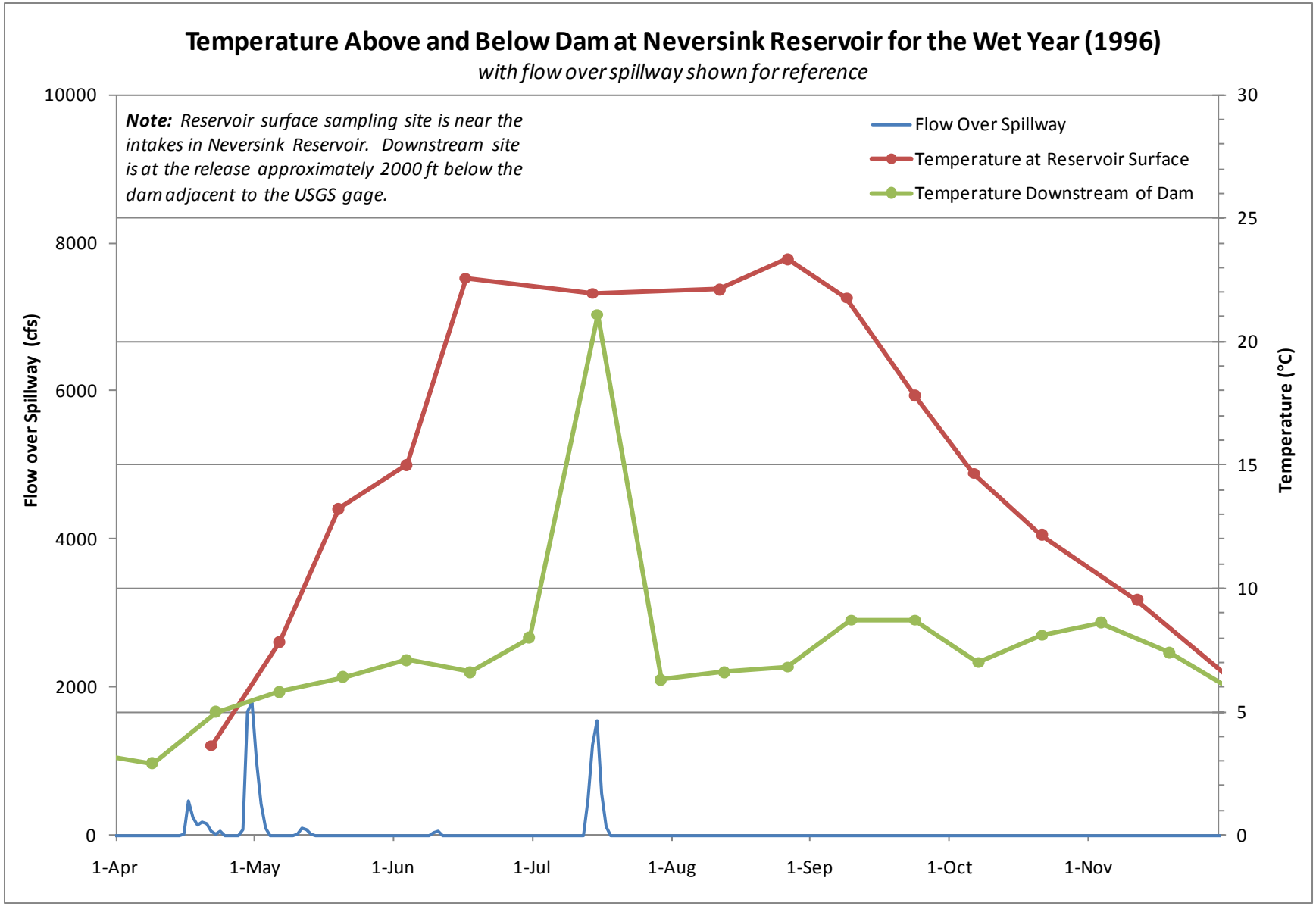


Figure 9.3-8: Temperature above and below dam at Neversink Reservoir for the dry year (1993).

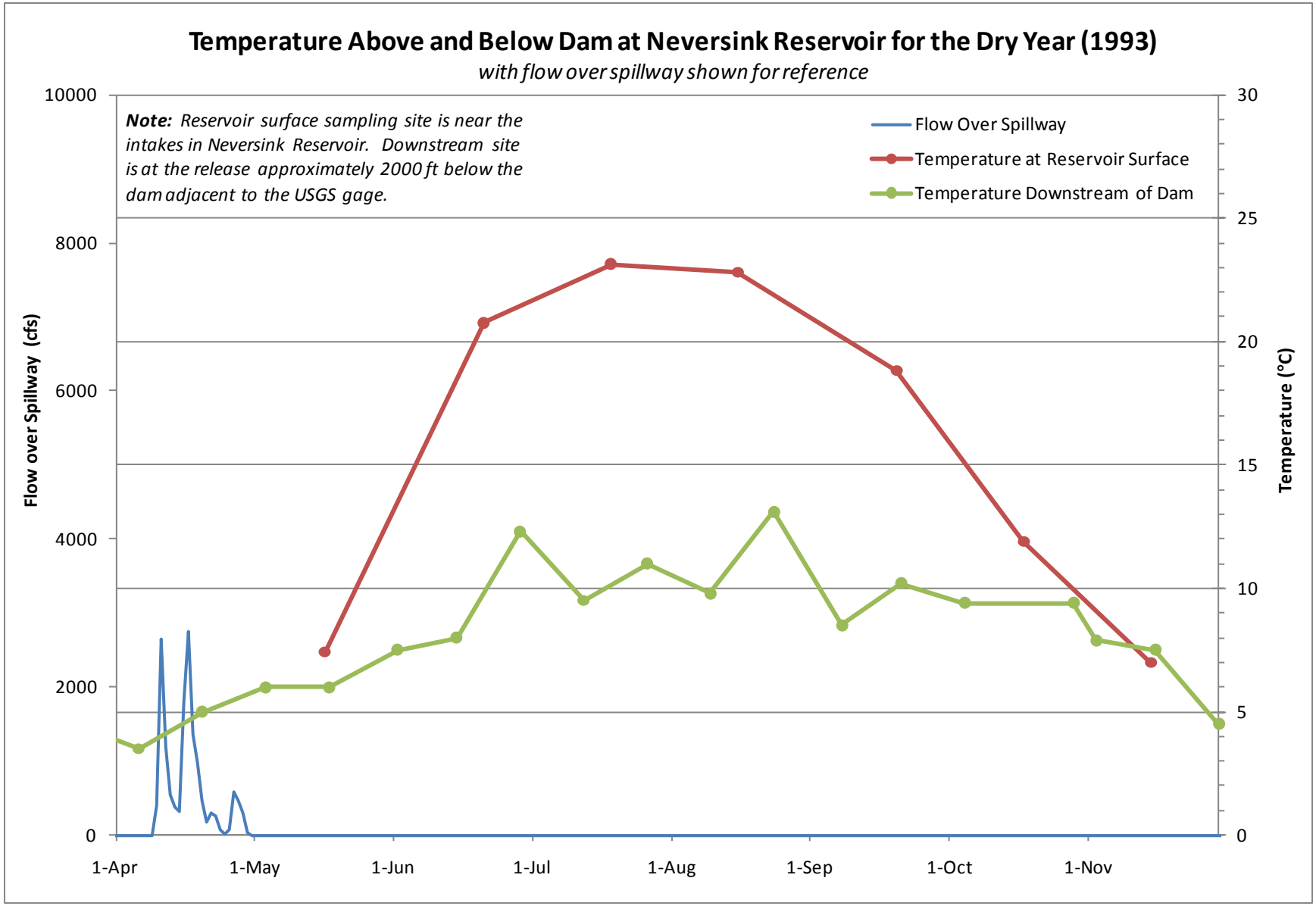
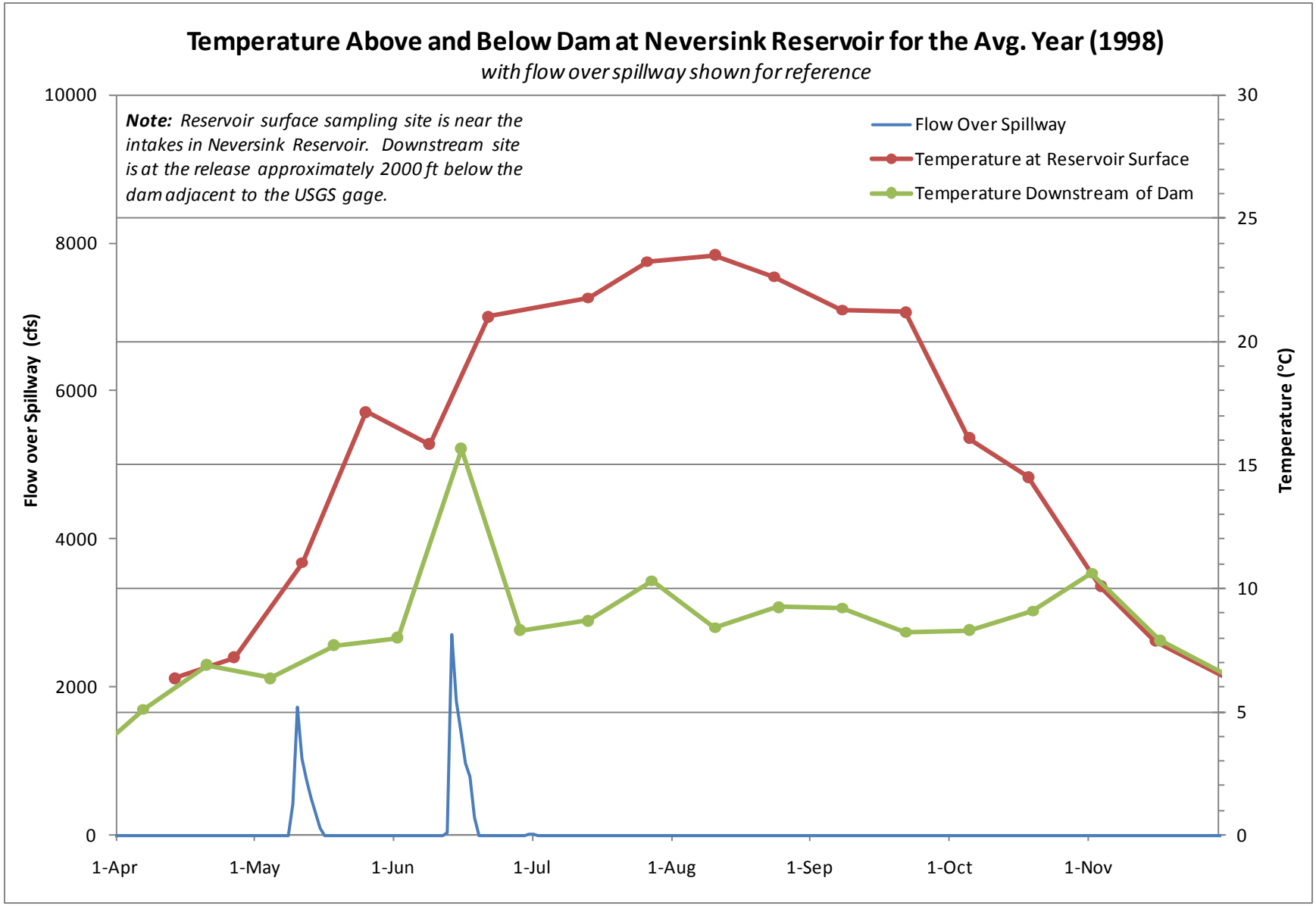


Figure 9.3-9: Temperature above and below dam at Neversink Reservoir for the avg. year (1998).



10.0 SUMMARY & CONCLUSIONS

Entrainment and Mortality

Because the intake structures at the Cannonsville, Pepacton and Neversink Reservoirs are in deep water, the proposed hydro capacities are low, ranging from 92 to 1,500 cfs, and expected intake velocities based on the operational protocol in effect at the time this analysis was conducted are generally below the USFWS velocity criteria of 2 ft/s, the overall potential for fish entrainment and impingement is minimal at these proposed developments.

However, the combination of several factors may place certain fish species in closer proximity to the intake structures and increase their potential for entrainment or impingement. The factors include, but are not limited to, seasonal drawdown of reservoir levels, comparatively higher intake velocities when directed and conservation release flows are at maximum levels, and changes in temperature, DO, and the depth of the thermocline.

Additionally, as reservoir water is passed downstream for directed/conservation releases and the reservoirs are drawn down, the cooler hypolimnion can be diminished and fish may be forced to seek alternate refuge or face stressed conditions from the "sinking" poor water quality in the metalimnion. The fish species most likely to see increased entrainment potential during dry summer drawdowns are brown and brook trout, landlocked salmon, rainbow smelt, and alewife. Thus, the maximum potential for fish entrainment and impingement at the proposed developments will be during the months of July through November. This potential would be exacerbated in dry summers when the reservoirs are substantially drawn down.

Likewise in winter, because the bottom layer of reservoirs are warmer than the surface, fish may tend to congregate near the bottom and stay active throughout the winter, thus having a greater potential for being in the vicinity of the intake structures during winter.

Some species may exhibit behavior that could subject them to entrainment or impingement. However, if the species' swimming speeds exceed the water velocities in front of the intake structures, their potential for entrainment or impingement is reduced or eliminated.

The literature review performed, as described in this report, indicates that entrainment rates are highest for fish less than eight inches in length. The literature also indicates, however, that fish this size would generally not be found near the deep-water intake structures.

To the extent such fish are entrained, the reviewed literature also indicates that fish less than eight inches in length are more likely to survive passage through high-speed Francis type turbines, with mortality rates increasing in direct correlation with fish size.

Other factors, such as the effects of differential pressure on fish passing from deep water areas to shallow tailwaters, are expected to result in high fish mortality. These mortality rates are generally unaffected by the presence or type of hydroelectric turbines installed at the proposed developments.

Intake Protection

The intake structures at each of the three proposed developments already contain intake protection measures comprised of bar racks. Although the existing bar racks do not meet the USFWS criterion of 1-inch clear spacing, based on the analysis set forth in this report, additional intake protections due to the proposed hydropower facilities are not warranted.

Fish Passage

At the specific request of USFWS, DEP evaluated the potential for adding downstream fish passages at each of the three proposed developments. Such passages were found not to be feasible or advisable from a fisheries management perspective. The Delaware and Neversink River systems associated with the proposed developments primarily support coldwater fisheries. Providing fish passages through surface water releases will add warm water to the downstream portion of the river systems. This warm water may adversely affect the trout populations and could cause a change in the downstream fisheries composition.

Moreover, because of high fish mortality rate associated with the large pressure differentials between the deep-water intake structures and the shallow release works associated with proposed developments, low-level fish passage alternatives were also determined to be impractical.

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APPENDIX A - CORRESPONDENCE

1404

United States Department of the Interior

FISH AND WILDLIFE SERVICE
3817 Luker Road
Cortland, NY 13045

September 15, 2010

Mr. Anthony J. Fiore
Director of Planning and Sustainability
59-17 Junction Boulevard, 19th Floor
Flushing, NY 11373-5108

RE: West of Hudson Hydroelectric Project (FERC #13287)
Review of Study Plans

Dear Mr. Fiore:

The U.S. Fish and Wildlife Service (Service) has reviewed a variety of documents related to the licensing of the West of Hudson Hydroelectric Project. These documents include the June 14, 2010, *Study Plans*, the August 2010 *Fish Entrainment Report – Literature Based Characterization of Resident Fish Entrainment and Mortality*, and the September 2010 *Addendum to the Fish Entrainment Report*. We also participated in the August 23, 2010, meeting to discuss the Study Plans and the Entrainment Report.

The Study Plans, as described in the report and presented at the meeting, are acceptable to the Service. The Entrainment Report and Addendum adequately characterize the likelihood of fish entrainment and mortality and the potential options available for fish passage. The Service does not foresee any further studies at this time.

We appreciate the opportunity to review the documents. If you have any questions or desire additional information, please contact Steve Patch at 607-753-9334.

Sincerely,

David A. Stilwell
Field Supervisor

cc: Gomez and Sullivan, Henniker, NH (M. Wamser)
NYSDEC, Albany, NY (M. Woythal)
NYSDEC, Stamford, NY (K. Sanders)

New York State Department of Environmental Conservation
Division of Environmental Permits, Region 4
65561State Highway 10, Stamford, New York 12167-9503
Phone: (607) 652-7741 • **FAX:** (607) 652-2342
Website: www.dec.state.ny.us

Alexander B. Grannis
Commissioner

September 24, 2010

Mr. Anthony Fiore
New York City Department of Environmental Protection
59-17 Junction Blvd
Flushing, NY 11373

RE: DECID# 0-9999-00143
West of Hudson Hydro Project
Fisheries Study Plans

Dear Mr. Fiore:

Thank you for the opportunity to review the Literature Review and Addendum. Based on that information and Department records the Department does not believe that entrainment at the Pepacton and Cannonsville Reservoirs is a significant issue under the current flow regime.

The Department remains concerned over the proposals fisheries impacts at the Neversink Reservoir. In order to bring this process forward the Department has the following proposal:

The level of mortality of entrained fish due rapid decompression at all three reservoirs is assumed to be high. However, no actual documentation is presented as to that the rate may actually be. Either additional documentation as to what depth/ pressure would cause mortality approaching 100% should be provided or the information should be developed during the field season.

As indicated in the reports submitted by NYC DEP, the intake configuration at the Neversink dam is somewhat unique. The intake is a vertical tower equipped with eight ports. The literature review dated September 2010, does not adequately address a facility with this intake design.

This Department requests that a site specific study be conducted for the proposed new Neversink hydroelectric facility. The study should be designed to provide the following information:

1. An estimate of the number of fish drawn into the conduit
2. The species of fish drawn into the conduit
3. An estimate of the mortality rate for fish drawn into the conduit

4. Determine if there are assemblages of fish in the zone of withdrawal

5. If there are assemblages provide information on their seasonal and diurnal movements.

The NYS DEC feels that hydro-acoustic equipment or the use of Didson cameras may be particularly useful in answering some of these questions

Please submit a proposed monitoring plan to this Department for review and approval by October 22, 2010. If you have any questions or need further information, please don't hesitate to contact me.

Sincerely,

Kent P. Sanders

Kent P. Sanders
Deputy Regional Permit Administrator
Region 4 – Stamford

CC: WOH Review Team
S. Patch, USF&WS

Environmental Protection

Caswell F. Holloway
Commissioner

Anthony Fiore
Chief of Staff for Operations
afiore@dep.nyc.gov

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T: (718) 595-6529
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October 19, 2010

Kent P. Sanders
Deputy Regional Permit Administrator
NYSDEC
Region 4 Sub-office
65561 State Highway 10, Suite 1
Stamford, NY 12167

Re: DEP West of Hudson Hydroelectric Project (FERC Project No. 13287)
Fisheries Study Plans

Dear Mr. Sanders:

The New York City Department of Environmental Protection (DEP) is in receipt of your letter dated September 24, 2010 providing comments on the West of Hudson Hydroelectric Project (Project) Fisheries Study Plan, and Entrainment Report and Addendum thereto. The Study Plans were submitted to the New York State Department of Environmental Conservation (NYSDEC) and the United State Fish and Wildlife Service (USFWS) on June 14, 2010, and the *Fish Entrainment Report - Literature Based Characterization of Resident Fish Entrainment and Mortality* (Entrainment Report) was submitted for review on August 17, 2010. A meeting was held with NYSDEC and USFWS on August 23, 2010 to discuss the Study Plans and the Entrainment Report. As a result of that meeting, DEP prepared an *Addendum to the Fish Entrainment Report* (Addendum), which was distributed for review on September 8, 2010.

In your letter, you indicated that the NYSDEC remains concerned with the potential impacts to fisheries from the proposed hydroelectric development at the Neversink Reservoir, and requested additional information on fish mortality due to pressure differentials of potentially entrained fish. The purpose of this letter is to respond to your concerns and address your requests for additional information.

Pressure Mortality

The NYSDEC requested that either additional documentation be provided as to what depth/pressure causes fish mortality approaching 100%, or the information should be developed during the field season. In the Entrainment Report and Addendum, focus was given to mortality related to the pressure gradient between the high pressure present at the low-level intake structures and the low pressure present at the downstream releases. To supplement the information provided in the Entrainment Report and Addendum, additional literature research was conducted to address NYSDEC's request, and is summarized below.

Most of the research conducted on this topic is related to turbine-passage mortality as there is a pressure gradient through a turbine, *i.e.*, a relatively high level of pressure prior to entering the turbine followed by a short low pressure region on the downstream side of the turbine runner blades. However, these studies can be applied to generally predict the effects of pressure differences on fish passing from deep water reservoirs to shallower stream environments.

Cada, *et al.* 1997 reviewed several experiments that examined the effects of pressure increases and decreases on fish and reports that there is considerable variation in the response of fish to pressure reductions[1]. In their review, Cada, *et al.* 1997 summarized percent mortality among test fishes versus the ratio of exposure pressure[2] (P_e) to acclimation pressure[3] (P_a), expressed as ratio $= P_e / P_a$.

Based on these studies of a variety of fish, Cada, *et al.* 1997 suggested that, as a general fish protection measure, exposure pressures should fall to no less than 60% of the value to which entrained fish are acclimated. This factor serves as a guideline for zero mortality for all fish species studied. Back calculating[4] to determine acclimation depth using this ratio results in an acclimation depth of 23 feet. Accordingly, at acclimation depths less than 23 feet, all fish passed downstream to atmospheric pressure would be expected to show no direct mortality from pressure effects.

However, with respect to NYSDEC's inquiry regarding the depth/pressure that would cause mortality approaching 100%, one study (Hogan, 1941 cited in Cada, *et al.* 1997) reported that a P_e / P_a ratio of 40% resulted in 100% mortality in crappie (a sunfish). In the case of the Project, this ratio translates to an acclimation depth of 51 feet. This value is supported by a separate pressure study that reported swim bladders in four inch long perch burst, thus leading to mortality, when pressure was reduced to 40% of acclimation values (Jones 1951, cited in Cada, *et al.* 1997).

In addition to being species-specific, pressure mortality is dependent on other factors such as time of exposure, dissolved gas levels and other factors related to indirect mortality. Nevertheless, the 2005 observation of yellow perch mortality due to entrainment at Cannonsville Reservoir occurred at an acclimation depth of 71 feet, consistent with the findings above.

Information on mortality relative to pressure changes in salmonids indicates that a minimum P_e / P_a ratio of 30% or higher may be appropriate as protective criteria for physotomous fish[5] (Abernathy, *et al.* 2001). Back calculating to determine acclimation depth using this ratio results

---

[1] Cada, *et al.* 1997 suggested that the variation in fish responses may have been due to differing test methods and small sample sizes.

[2] Exposure pressure is analogous to the water pressure experienced by fish after release into the downstream environment.

[3] Acclimation pressure is the water pressure experienced by fish at the point of entrance to the intake structure.

[4] Acclimation depth was determined first by solving the ratio equation for P_a ($P_a = P_e$/ratio) then converting P_a to water depth.

[5] Physostomous species such as salmon, trout, minnows, and catfish have a pneumatic duct which connects the air bladder to the esophagus and allows for venting air from the swim bladder within seconds, resulting in the ability to rapidly adjust to changing water pressure. Physoclists such as bass, sunfish, and perch must adjust pressure within the swim bladder via diffusion into the blood, which takes hours.

in an acclimation depth of 80 feet. As presented in the Addendum, the acclimation depth for fish entering the intake to the proposed hydroelectric development at Neversink Reservoir is 151 feet at full pond. Acclimation depths of 80 feet or less in Neversink Reservoir occurs less than 3 percent of the time on an annual basis, thereby indicating that there is a very limited time during the year when acclimation depths would be expected to be equal to or less than the applicable criteria for protection.

Site Specific Information for Neversink Reservoir

The NYSDEC letter states, "As indicated in the reports submitted by DEP, the intake configuration at the Neversink dam is somewhat unique. The intake is a vertical tower equipped with eight ports. The literature review dated September 2010, does not adequately address a facility with this intake design."

Although the common intake is a vertical tower with eight segments that span the length of the water column, the intake that conveys water from the forebay to the stream release is at a fixed location at the bottom of the water column (see Attachment 1). It is from this point that water will be conveyed to the proposed hydroelectric turbine. DEP believes that because: (a) the intake to the proposed hydroelectric development is in deep water with an acclimation depth under full pond equal to 151 feet; (b) the intake velocities are very low under all conditions; and (c) acclimation depths consistent with even the less limiting protective criteria associated with physostomous species occurs less than 3% of the time in the Neversink Reservoir fish entrained in the stream release would suffer high mortality rates due to pressure differentials. However, regardless of this expectation DEP believes based on the configuration outside and within the Neversink intake structure the likelihood of entrainment to the stream release is low.

The Addendum (see page 11) clarified a statement made in the Entrainment Report that misrepresented the entrainment potential of fish entering the common intake. DEP revised this statement to indicate that the design of the intake structure is such that all occurrences of potential fish entrainment to the proposed hydroelectric development at Neversink Reservoir would occur at the horizontal troughs on the floor of the intake structure and not from fish entering the common intake in the upper portions of the water column (see Attachment 1).

DEP has evaluated the life history and habitat preferences of the fish species living in the Neversink Reservoir to predict their likelihood of fish being in the vicinity of the intake and to determine the potential for entrainment of any such fish likely to be found in the vicinity of the intake. DEP concluded that fish entrainment at the proposed Neversink development is expected to be low for all species based on the following factors:

1. Lack of littoral zone habitat in the vicinity of the intake structure. The intake structure is located in an excavated channel—an approximately 600-foot-long and 22- to 32-foot-wide intake channel excavated in rock, with vertical bedrock walls. Because of this lack of littoral habitat, smaller fish are not expected to be in the vicinity of the common intake structure.

3. Low intake velocities. Approach velocities at the common intake are very low: 0.35 ft/s at maximum reservoir drawdown and 0.09 ft/s at full pond. At these velocities, most fish can swim away from the intake thus avoiding entrainment.

4. Intake protection. Neversink has close-spaced bar racks (2-inch clear spaced), affording protection to fish that may be in the vicinity of the Neversink intake structure.

NYSDEC also requested that the report include "An estimate of the mortality rate for fish drawn into the conduit." Based on the additional information provided above, DEP contends that, while entrainment potential is low for all species, mortality of potentially entrained fish will be significant – with or without the proposed hydroelectric development – due to pressure effects. Based on the pressure differentials between the intake structure and the release works it is likely that any fish entrained through the release structure at the proposed Project development will not survive.

It is the opinion of DEP that the information provided to date to evaluate fish entrainment at the proposed Neversink development appropriately and adequately addresses the questions posed by NYSDEC in their study request. Accordingly, based on the totality of the information provided to date, including the information provided herein, DEP contends that a site specific fisheries study at Neversink Reservoir is not warranted and, therefore, respectfully requests NYSDEC's concurrence with this approach.

If you have any questions regarding the information herein or would like to discuss it further, please do not hesitate to contact me at (718) 595-6529 or via email at afiore@dep.nyc.gov. Thank you in advance for your prompt attention to, and careful consideration of, this matter. DEP looks forward to continuing to work with NYSDEC regarding this Project.

Respectfully submitted,

Anthony J. Fiore

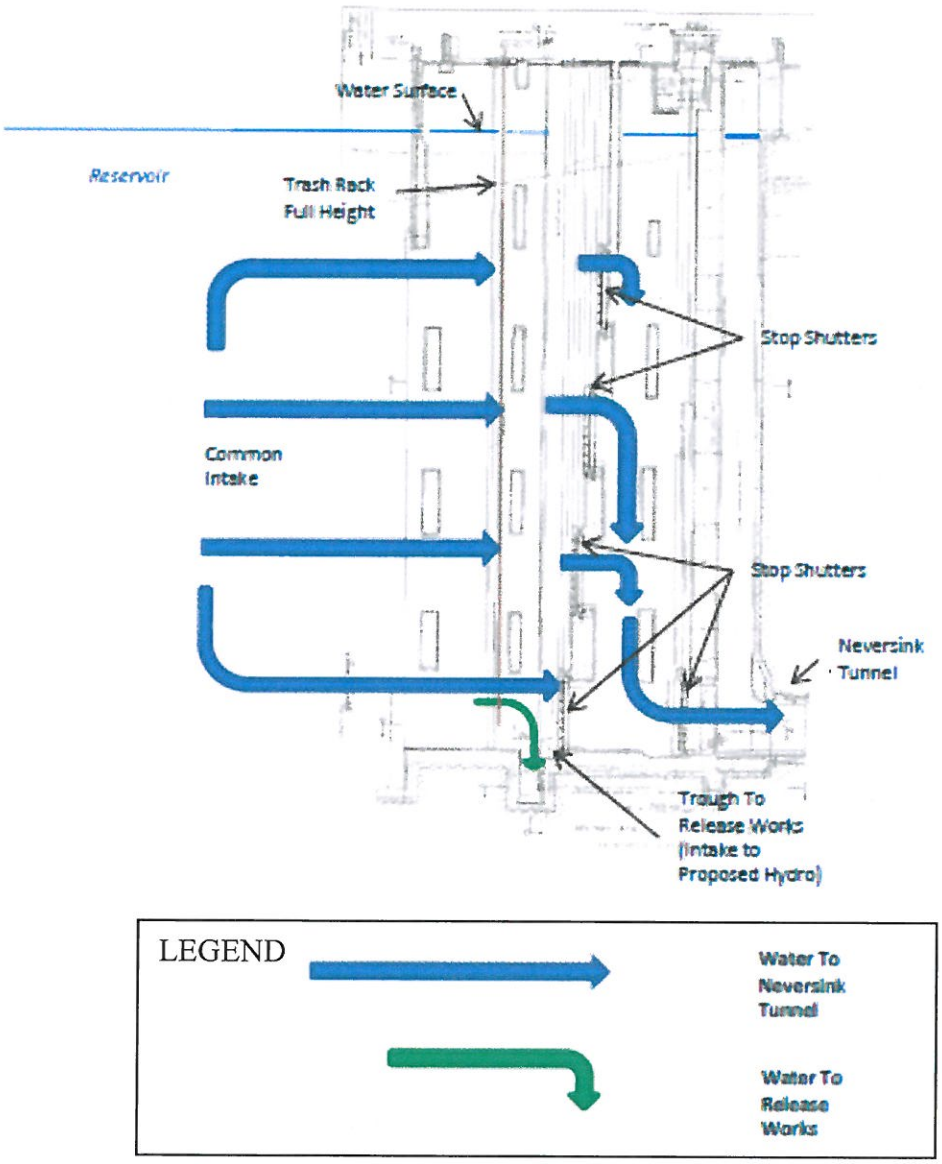
c: Dave Sampson, Associate Counsel, NYSDEC
Mark Woythal, Director In-Stream Flow Unit, NYSDEC
Larry Wilson, Biologist, NYSDEC
Michael Flaherty, Biologist, NYSDEC
Norman McBride, Biologist, NYSDEC
David A. Stilwell, Field Supervisor, USFWS
Steven Patch, Fish and Wildlife Biologist, USFWS
Kevin Lang, Partner, Couch White
Mark Wamser, P.E., Water Resource Engineer, Gomez and Sullivan

References:

Abernathy, C.S, B.G. Amidan, and G.F. Cada. 2001. Laboratory studies of the effects of pressure and dissolved gas supersaturation on turbine- passed fish. Pacific Northwest National Laboratory. PNNL-13470. Hydropower Program, U.S. Department of Energy, Idaho Falls, Idaho.

Cada, G.F., C.C. Coutant, and R.R. Whitney. 1997. Development of biological criteria for the design of advanced hydropower turbines. DOE/ID-10578. Hydropower Program, U.S. Department of Energy, Idaho Falls, Idaho.

Attachment 1: Cross Section of Neversink Intake Structure



New York State Department of Environmental Conservation
Division of Environmental Permits, Region 4
65561State Highway 10, Stamford, New York 12167-9503
Phone: (607) 652-7741 • **FAX:** (607) 652-2342
Website: www.dec.state.ny.us

Peter M. Iwanowicz
Acting Commissioner

December 8, 2010

Mr. Anthony Fiore
New York City Department of Environmental Protection
59-17 Junction Blvd
Flushing, NY 11373

RE: DECID# 0-9999-00143
West of Hudson Hydro Project
Fisheries Study Plans

Dear Mr. Fiore:

Thank you for your October 19, 2010 response to our latest information request
After reviewing the additional information provided, the Department has determined that under the current Flexible Flow Management Plan (FFMP) flow regime, the addition of hydroelectric facilities as proposed will not have a significant impact on fisheries mortality at the Cannonsville, Pepacton and Neversink reservoirs and no further field studies are necessary.

However, this determination is based upon the NYCDEP's assertion that "…The NYCDEP is not proposing to modify the magnitude, frequency, duration, or timing of discharges due to the proposed hydropower facilities. Flows available for generation at these facilities will be based on the conservation or directed releases..." and the information provided that entrainment mortality under the current FFMP approaches 100%. If there is a change in proposed operations that would increase the flow through the turbines and release structures, then further studies or protective measures may be warranted.

The Department reserves the right to revisit this issue if the project changes in a way that would lead to additional fish mortality.

If you have any questions or need further information please don't hesitate to contact me.

Sincerely,

Kent P. Sanders
Deputy Regional Permit Administrator
Region 4 - Stamford

Cc: WOH Review Team
S. Patch, USF&WS

United States Department of the Interior

FISH AND WILDLIFE SERVICE
3817 Luker Road
Cortland, NY 13045

August 3, 2011

Mr. Kevin M. Lang
Couch White, LLP
PO Box 22222
Albany, NY 12201-2222

RE: West of Hudson Hydroelectric Project (FERC #13287)
Review of Study Reports

Dear Mr. Lang:

The U.S. Fish and Wildlife Service (Service) has reviewed the five study reports for the West of Hudson Hydroelectric Project that were provided to us on July 11, 2011. These reports were discussed at a July 21, 2011, public meeting which the Service attended. The reports we reviewed are as follows:

- Phase IA Archeological Literature Review and Sensitivity Assessment
- Impact of Construction-Related Activities on Wildlife and Botanical Resources, including Wetlands, Riparian, and Littoral Habitat, and Rare, Threatened, and Endangered Species
- Aesthetics Report
- Impacts of Construction-Related Activities on Erosion
- Fish Entrainment Report

The Service has no comments on the first four studies. We have the following comments on the Fish Entrainment Report.

In Section 8.1 (2nd paragraph), the report indicates that intake protection could be achieved "...by enclosing the intake areas with close-spaced bar racks *larger* than the current openings [emphasis added]." This appears to imply that the new racks would have larger spacing than the existing racks, which is not what is intended. This statement should be clarified. In addition, the photos showing the front and side views of the Cannonsville intake structure are supposed to appear on page 114 but are missing.

We appreciate the opportunity to review the study reports and look forward to reviewing your draft license application. If you have any questions or desire additional information, please contact Steve Patch at 607-753-9334.

Sincerely,

for David A. Stilwell
Field Supervisor

cc: NYSDEC, New Paltz, NY (M. Flaherty)

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August 11, 2011

Mr. David A. Stilwell
Field Supervisor
United States Department of the Interior
Fish and Wildlife Service
3817 Luker Road
Cortland, NY 13045

Re: FERC Project No. 13287 – West of Hudson Hydroelectric Project

Dear Mr. Stilwell:

We are in receipt of the U.S. Fish and Wildlife Service's ("Service") August 3, 2011 letter regarding the study plans prepared on behalf of the City of New York ("City") in connection with the above-entitled project. In that letter, the Service provided two comments on the Fish Entrainment Report. Please accept this letter as the City's response to those comments.

Comment 1:

In Section 8.1 (2nd paragraph), the report indicates that intake protection could be achieved "...by enclosing the intake areas with close-spaced bar racks *larger* than the current openings [emphasis added]." This appears to imply that the new racks would have larger spacing than the existing racks, which is not what is intended. This statement should be clarified.

Response:

The Service is correct that the sentence should be clarified to more accurately convey that the reference was to a larger bar rack structure, not a larger spacing between the bar racks. We have modified the Fish Entrainment Report as follows to address this comment:

> Intake protection could be provided at Cannonsville by mounting a bar rack one foot in front of the entire intake structure (including the front and side of the intake structure), which would yield a greater intake surface area. The bar racks would be comprised of 5/8-inch vertical bars with 1-inch clear spacing between the bars and would be manufactured to fit into the existing stop log slots.

Please let me know if you have any concerns with this modified language.

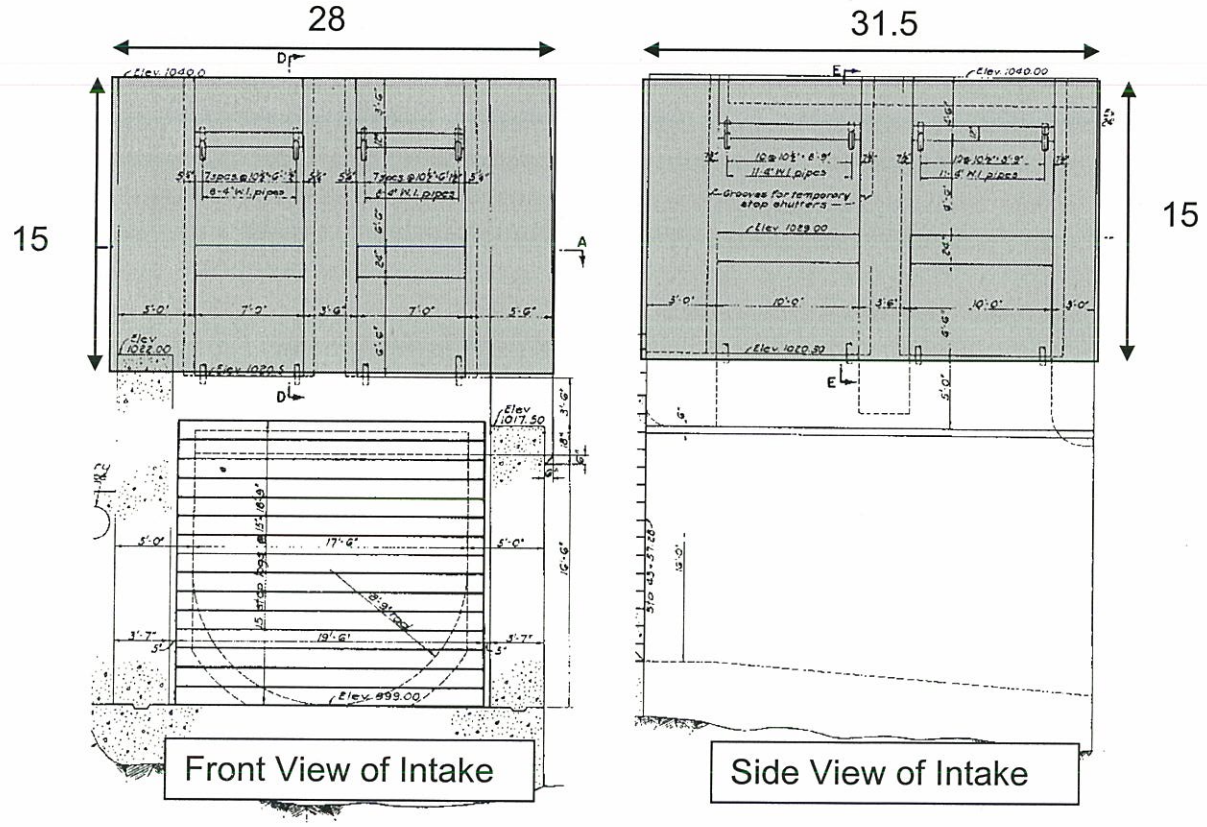
Comment 2:

In addition, the photos showing the front and side views of the Cannonsville intake structure are supposed to appear on page 114 but are missing.

Response:

We apologize for the confusion. It appears that the diagrams were inadvertently omitted from the report. Also, the Service's comment caused us to review and modify the language to more accurately describe the information presented. The corrected language and the drawings are as follows:

> Below are reproductions of the as-built drawings of the front and side of the intake structure. The gross area of the proposed intake racks is shown in red shading and equates to 892.5 ft^2. This gross area is sufficient to meet the 2 ft/s design criteria for all three proposed turbine configurations. Fabricating the bar racks to slide into the existing stop log slots would allow the bar racks to be removed for maintenance or when the stop logs must be put into place for downstream or tunnel maintenance. An automatic cleaning system could be installed to periodically clean the bar racks if required due to biofouling. The system would consist of rotating brushes that move on a track located over the face of each bar rack.



A corrected version of the Fish Entrainment Report is included with this letter. If you have any further questions or concerns, please do not hesitate to contact me.

Sincerely,

COUCH WHITE, LLP

Kevin M. Lang

KML/glm
cc: Mr. Anthony J. Fiore
Ms. Martha Bellinger (w/ enc.)
Mr. Michael Flaherty (w/ enc.)
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BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION
APPLICATION FOR EXEMPTION OF SMALL HYDROELECTRIC PROJECT FROM LICENSING - EXISTING DAM

Neversink Hydroelectric Development

FERC Project No. 13287

VOLUME 6

Appendix E-4: Impact of Construction Related Activities on Erosion

City of New York

Environmental Protection

September 2011

City of New York
West of Hudson Hydroelectric Project

Project No. 13287

Impact of Construction-Related Activities on Erosion

Cannonsville, Pepacton, and Neversink Developments

June 2011

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1.0 INTRODUCTION

The City of New York ("City"), acting through the New York City Department of Environmental Protection ("DEP") has filed with the Federal Energy Regulatory Commission ("FERC") a Notice of Intent to develop hydroelectric generation at four sites that together comprise the West of Hudson Hydroelectric Project ("Project"), FERC Project No. 13287. The four sites are owned by the City and operated by the DEP as part of the City's water supply system. The DEP seeks to develop hydroelectric facilities at those sites while simultaneously maintaining its primary water supply function and adhering to the statutory and regulatory requirements governing its water supply operations, conservation releases, directed releases, water quality standards, and other related activities.

In accordance with the Preliminary Permit issued to the City by the FERC, the DEP is evaluating the technical and economic merit and feasibility for each proposed hydroelectric development. Based on the feasibility analysis completed to date, the DEP has suspended the completion of environmental studies at the Schoharie development while it continues to evaluate the economic feasibility of any hydroelectric facility at that site. The DEP will proceed with appropriate studies for that development in the event such an alternative is identified. Accordingly, this study is limited to the following three proposed developments:

Development	Dam	River
Cannonsville	Cannonsville Dam	West Branch Delaware River
Pepacton	Downsville Dam	East Branch Delaware River
Neversink	Neversink Dam	Neversink River

During the study plan development process, the DEP proposed to conduct a study to evaluate the impact of construction-related activities on erosion at the Cannonsville, Pepacton, and Neversink Developments. The goal of this study is to conceptually describe the proposed sediment and erosion control measures at each development. The narrative is supplemented with conceptual level drawings showing the proposed location of the erosion control measures.

The conceptual planning for erosion control discussed in this report is based on the proposed location of structures (powerhouse, transmission lines, switchgear and substation) and the proposed locations for staging areas, spoils, sedimentation basin, and access routes. It is expected once final design plans are developed, detailed erosion and sediment control plans and stormwater pollution prevent plans ("SWPPP") will be prepared.

.

2.0 SUMMARY OF PROPOSED CONSTRUCTION ACTIVITIES

This section summarizes construction related activities, which are subject to change as the DEP's proposal and licensing process advances. No work on or around the reservoir or lands surrounding the reservoirs (except as noted below) is expected to occur. The Projects should not cause or lead to any erosion in such areas.

2.1 Cannonsville Development

The Cannonsville development includes the construction of a separate powerhouse adjacent to the existing low-level outlet works. The existing penstock would be extended into the powerhouse, with the turbine discharges flowing through steel draft tubes into concrete chambers beneath the powerhouse floor. Water from these chambers will be discharged into a widened common tailrace channel and into the West Branch of the Delaware River. The powerhouse will be longer and slightly taller than the existing low-level outlet works. The approximate powerhouse dimensions are 168 feet long, 54 feet high and 52 feet high. The outside walls of the powerhouse will be constructed in a manner that creates the same granite look as the existing release works building.

Figure 2.1-1 presents an overview of the proposed Cannonsville development, showing the location of the powerhouse, tailrace, the spoils area where excavated material from the powerhouse and tailrace construction will be disposed, and the temporary staging areas for equipment and material storage during construction. Additional work involves relocating the sewer pump station and leach field, installing a temporary cofferdam in the river, installing a temporary siphon over the spillway to maintain conservation flows during the tie-in to the existing conduit, constructing a generator lead from the powerhouse to an indoor switchgear, and installing the interconnection facilities from the substation to NYSEG's transmission system. The route for the generator lead is not yet finalized, but it is likely to run underground from the powerhouse indoor switchgear to a pole, then overhead approximately 1200 feet to the substation (approximately 43 feet wide by 115 feet long). There are existing poles in this area which will be replaced with 50-foot poles, of which approximately 10 feet will be below ground. The interconnection facilities between the new substation and the transmission line, approximately 460 feet, will consist of new overhead poles approximately 40 feet above ground. Access to the new structure and appurtenances will be from existing roadways at the site.

2.2 Pepacton Development

The Pepacton development consists of installing a turbine in one of the two pipe and valve assemblies in the existing release water chamber. Figure 2.2-2 is the site plan showing the release water chamber, the proposed location of the associated electrical equipment (which will occupy an area approximately 9 feet wide by 12 feet long and include a small building), construction staging area, and interconnection with the NYSEG distribution system. Access to the electrical equipment will be from the existing roadway leading to the release water chamber and spillway crest. The interconnection lines connecting the facility to NYSEG's distribution system will be approximately 80 feet long and will be buried, if practical.

2.3 Neversink Development

The Neversink development consists of installing a turbine in one of the two pipe and valve assemblies in the valve chamber of the existing intake structure. Figure 2.3-1 presents an overview of the proposed construction area showing the staging area, the location of the associated electrical equipment (which will occupy an area approximately 8 feet wide by 20 feet long and include a small building), and the interconnection with the NYSEG distribution system. Access to the electrical equipment will be from the

existing parking area adjacent to the intake chamber. Separate from the Project, the DEP is installing three three-inch conduits in an underground duct bank from State Route 55 to the intake chamber. One of those conduits will be used for the interconnection of the facility with NYSEG's distribution system.

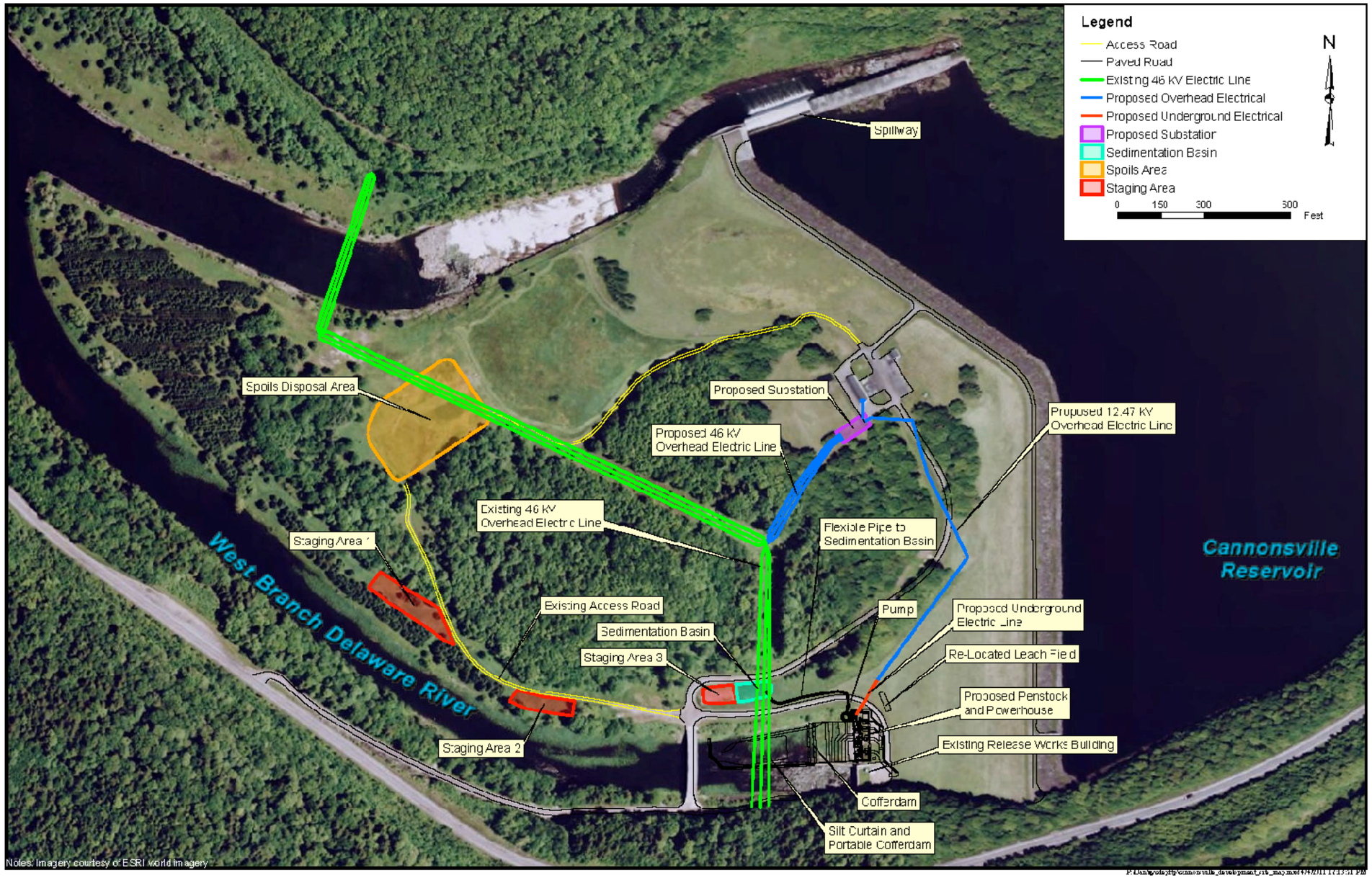


Figure 2.1-1: Cannonsville Development Study Area. Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers. P.C.

Figure 2.2-1: Pepacton Development Study Area. Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers. P.C.

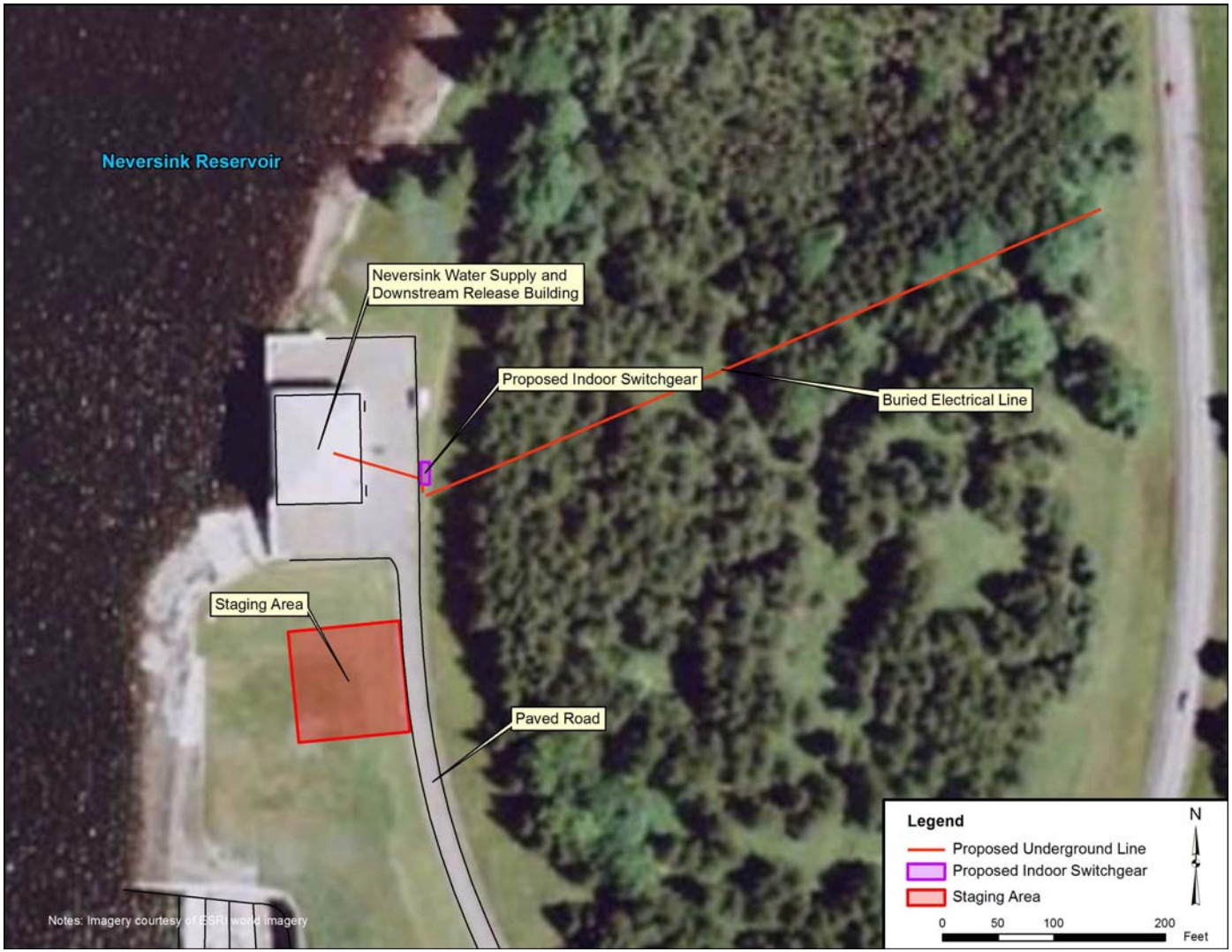


Figure 2.3-1: Neversink Study Development Area. Notes: Imagery source: ESRI world imagery. All other data layers created by Gomez and Sullivan Engineers. P.C.

3.0 EROSION CONTROL MEASURES

The conceptual measures described herein will be submitted with the license application and refined as the proposal progresses. Detailed sediment and erosion control measures and stormwater management practices will be developed and incorporated into the final design plans for each development.

During construction, sediment and erosion control measures and stormwater management practices will be employed to minimize erosion and prevent sedimentation in surface waters. All erosion and sediment control measures will be designed and implemented in accordance with the *New York State Standards and Specifications for Erosion and Sediment Control* (NYSDEC, 2005). A NYSDEC State Pollution Discharge Elimination System ("SPDES") General Permit for Stormwater Discharges will be required for each Project that results in an area of soil disturbance of one or more acres. As part of this permit, a stormwater pollution prevention plan ("SWPPP") will be required for the Cannonsville development because the area of disturbance is greater than one acre. In addition to the SPDES permit, the Project will be required to comply with DEP's stringent erosion control rules and regulations.

Prior to any ground disturbing activities, all applicable soil erosion and sediment controls (silt fencing, temporary berms, turbidity curtains, portable dams, hay bales, sedimentation basins, etc.) will be installed and maintained. Upon the completion of construction, all disturbed areas will be restored. As appropriate, the areas will be repaved, covered with gravel, or covered with top soil, mulch, and seed. Newly seeded areas will be watered as needed to establish grass. If the season prevents repaving or the establishment of grass, a temporary cover, such as straw, will be used to control erosion.

3.1 Cannonsville Development

Figures 3.1-1 and 3.1-2 were developed to show the locations of proposed sediment and erosion control measures.

The proposed measures to control erosion are conceptually described.

Access Road

Access to Cannonsville Dam is controlled by a DEP gate from State Route 10. All roads located inside the gate are non-public and are owned by the City. All equipment ingress and egress will occur through the DEP gate. From the DEP gate, the road is paved and extends across the access bridge located downstream of the release works building. After traversing the access bridge, there are three road branches as follows: a) a paved road extends northerly to the top of the dam, b) a paved road extends easterly to the release works building and c) an existing dirt road runs westerly to the proposed spoils location. Staging Areas 1 and 2 as well as the spoils disposal area will be accessed from this dirt road.

Along the existing dirt road, some minimal clearing, grubbing, and grading may be required to permit construction vehicle access to Staging Areas 1 and 2 and the spoils location. Silt fencing will be placed on both sides of the dirt road to prevent eroded soils from migrating into the West Branch of the Delaware River.

Staging Areas

Staging Area 1*:* Silt fencing will be installed around the staging area to protect the emergent wetland to the north and to control potentially eroded soils from migrating into the West Branch of the Delaware River.

Staging Area 2*:* Silt fencing will be installed around Staging Area 2 to control potentially eroded soils from migrating into the West Branch of the Delaware River.

Staging Area 3*:* Staging Area 3 includes a portion of existing paved road as well as a gravel platform. Silt fencing will be installed around the staging area to control potentially eroded soils from migrating into drainage ditches that eventually lead to the river.

Excavation

Sedimentation Pond: Located adjacent to Staging Area 3 will be a temporary sedimentation pond. Standing water in the channel and tailrace work area will be pumped into the pond to allow sediment deposition while allowing water to filter. A silt fence will be placed around the proposed pond perimeter. To create the pond, dredging will be required; this material will be placed temporarily in the spoils disposal area. After the sediment pond is no longer needed and is fully dewatered, the excavated material will be placed in the pond to re-establish the existing grade. The surface area will be topsoiled, mulched, seeded and watered as necessary to establish grass. The silt fence placed around the area will be maintained until permanent grass is established.

Tailrace and Channel: A cofferdam approximately 4-feet high, 12-feet wide, with 2:1 side slopes will be placed downstream of the proposed powerhouse. The existing concrete tailrace wall will adjoin the cofferdam, sectioning off the work area. The majority of channel excavation will occur in this work area.

Below the cofferdam, a pre-fabricated cofferdam will run downstream parallel with the river, and then turn northerly, to surround the tailrace excavation work area. This pre-fabricated cofferdam will be similar to a Portadam. Outside the entire length of the pre-fabricated cofferdam will be a turbidity curtain to prevent any sediment from escaping the work area. The turbidity curtain is necessary when the pre-fabricated cofferdam is installed and removed such that any eroded soils are not conveyed to the West Branch of the Delaware River. During construction, access will be maintained to the existing release chamber.

Within the tailrace and channel excavation areas, a pump will be used to maintain a dry work area. Water pumped from the work area will be placed in a sedimentation basin as described earlier. Water will be allowed to percolate through soils to filter any suspended sediments.

Proposed Spoils Disposal Location

Fill from the excavated powerhouse, tailrace channel and sedimentation pond will be transported and deposited in this spoils disposal area as shown in Figure 2.1-1. It is estimated that the excavated fill will be approximately 23,000 cubic yards ("CY"), average 6.5 feet deep and cover approximately 2.3 acres. Potential impacts to this location are minimal as this site is a mowed field. However, silt fencing will be installed around the perimeter of the spoils to contain excavated materials and prevent them from migrating into the West Branch of the Delaware River.

After all excavated material is placed at the spoils location area, it will be topsoiled, mulched, seeded, and watered as needed to establish grass. If the season prevents the establishment of a temporary cover, the spoils area will be mulched with straw.

Substation and Interconnection Facilities

The generator lead will run from the powerhouse to the substation. New poles will be installed to run the overhead wiring. It is estimated that there will be 40-foot poles for 12.47 kV and 50-foot poles for 46 kV

lines; the exact location of the poles has not been determined. Because of the steep slope in this area, it is important to establish grass on newly exposed areas to prevent erosion. Silt fencing will be placed around all work areas to contain excavated materials and prevent them from migrating into the West Branch of the Delaware River, and maintained until grass is well-established. The substation will be located near the existing service building in an existing grassed area. Silt fencing will be placed around the work area.

Relocated Leach Field

The existing leach field must be relocated due to the location of the powerhouse. Silt fencing will be placed around the relocated leach field until such time that grass becomes established.

3.2 Pepacton Development

Figure 3.2-1 shows the locations of proposed sediment and erosion control measures. The proposed measures to control erosion are conceptually described.

Access Roads

Access to the Downsville Dam is controlled by a DEP gate from State Route 30. The road located inside the gate is non-public and owned by the City. All equipment ingress and egress will occur through the DEP gate. From the DEP gate, the road is paved and extends along the top of the dam ending at the release water chamber. Because the only ground disturbing activity for the Pepacton development will be for the indoor switchgear building, underground electric lines, and the staging area, silt fencing along the paved access road is not needed.

Staging Area

A staging area will be established east of the existing release water chamber, which consists of a mowed lawn. Silt fencing will be installed around the staging area to contain excavated materials and prevent them from entering the reservoir or spillway channel.

Indoor Switchgear Building

An indoor switchgear building and underground electric lines will be constructed just north of the existing release water chamber, in an area which consists of a mowed lawn. Silt fencing will be installed around the disturbed areas to contain excavated materials and prevent them from entering the reservoir or spillway channel.

Interconnection Facilities

Underground electric lines will be constructed between the new indoor switchgear building and the existing distribution line, in an area which consists of a mowed lawn. Silt fencing will be installed around the disturbed areas to contain excavated materials and prevent them from entering the reservoir or spillway channel.

All disturbed areas will be topsoiled, mulched, seeded and watered to establish grass. Once grass is established, the silt fencing will be removed.

3.3 Neversink Development

Figure 3.3-1 shows the locations of proposed sediment and erosion control measures. The proposed measures to control erosion are conceptually described.

Access Roads

Access to the Neversink Dam is controlled by a DEP gate from State Route 55. The road located inside the gate is non-public and owned by the City. All equipment ingress and egress will occur through the DEP gate. From the DEP gate, the road is paved and extends directly to the intake structure. Because the only ground disturbing activity for the Neversink Development will be located in and around the parking area adjacent to the intake structure, and in the staging area, silt fencing along the paved access road is not needed.

Staging Area

A staging area will be established south of the intake chamber, in an area which consists of a mowed lawn. Silt fencing will be installed around the staging area to prevent eroded soils from migrating into the reservoir.

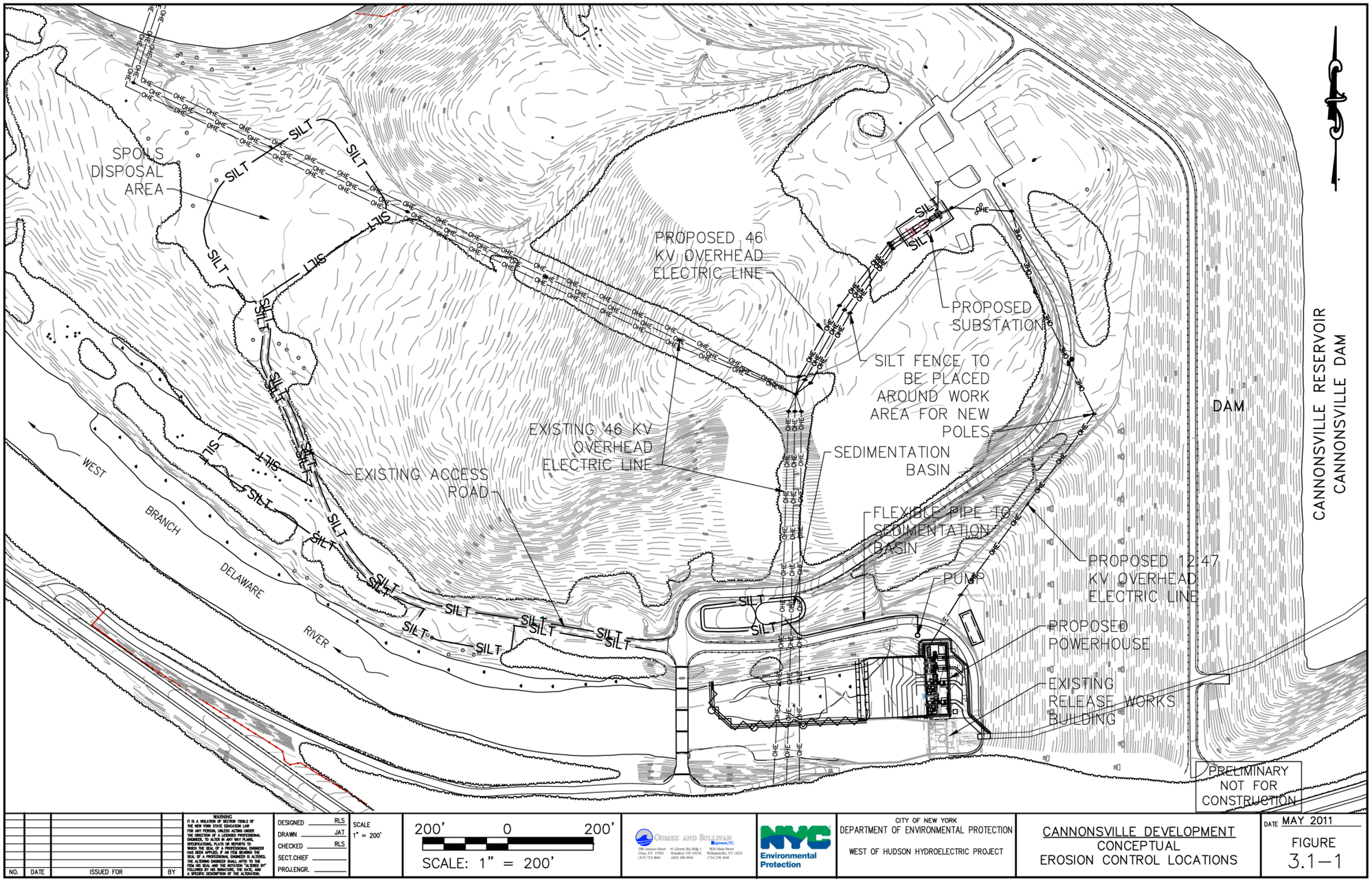
Indoor Switchgear Building

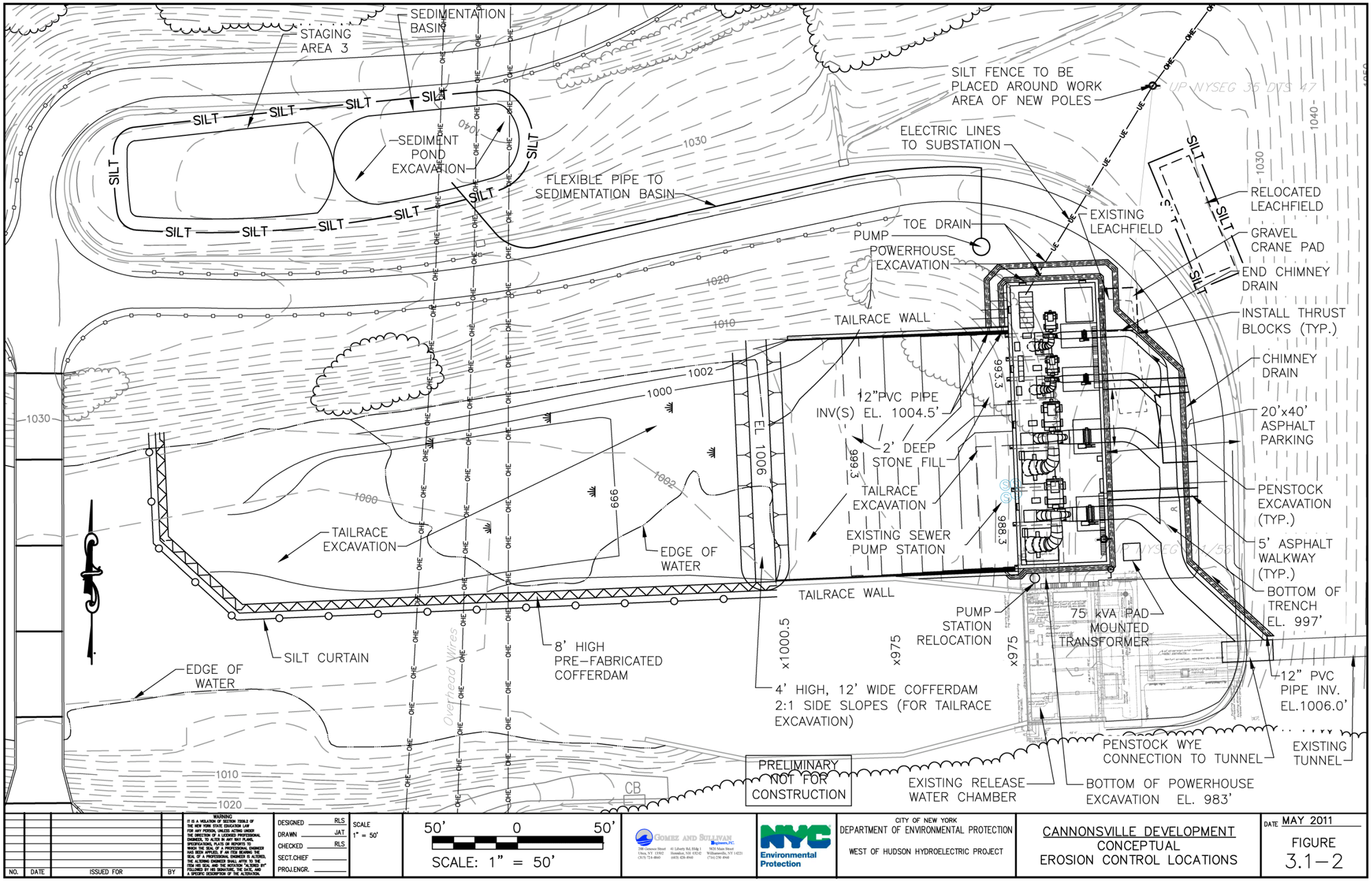
An indoor switchgear building and underground electric lines will be constructed east of the intake structure in an area consisting of a mowed lawn immediately adjacent to the parking lot. Silt fencing will be installed around the switchgear to contain excavated materials and prevent them from migrating into the reservoir.

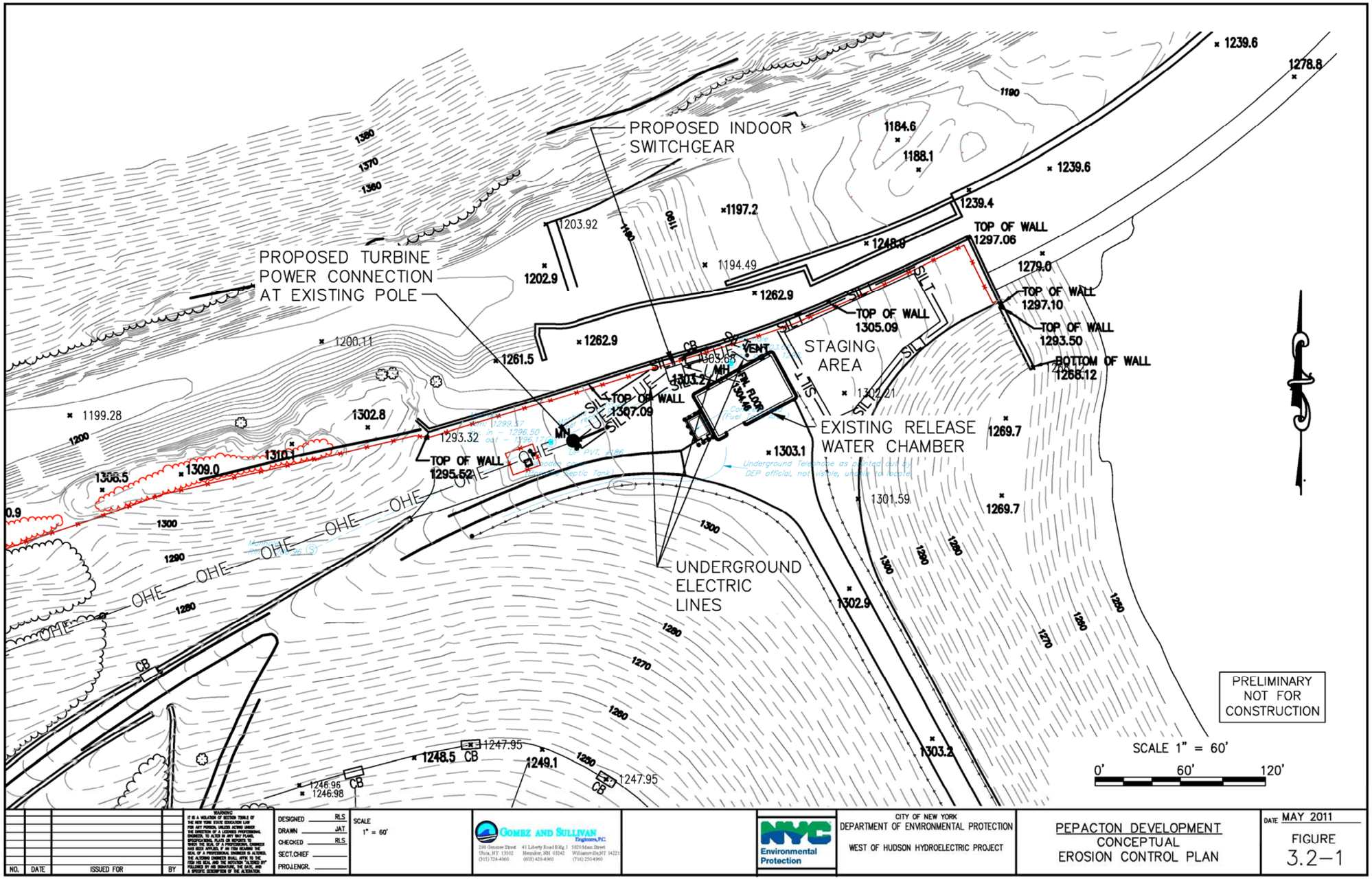
Interconnection Facilities

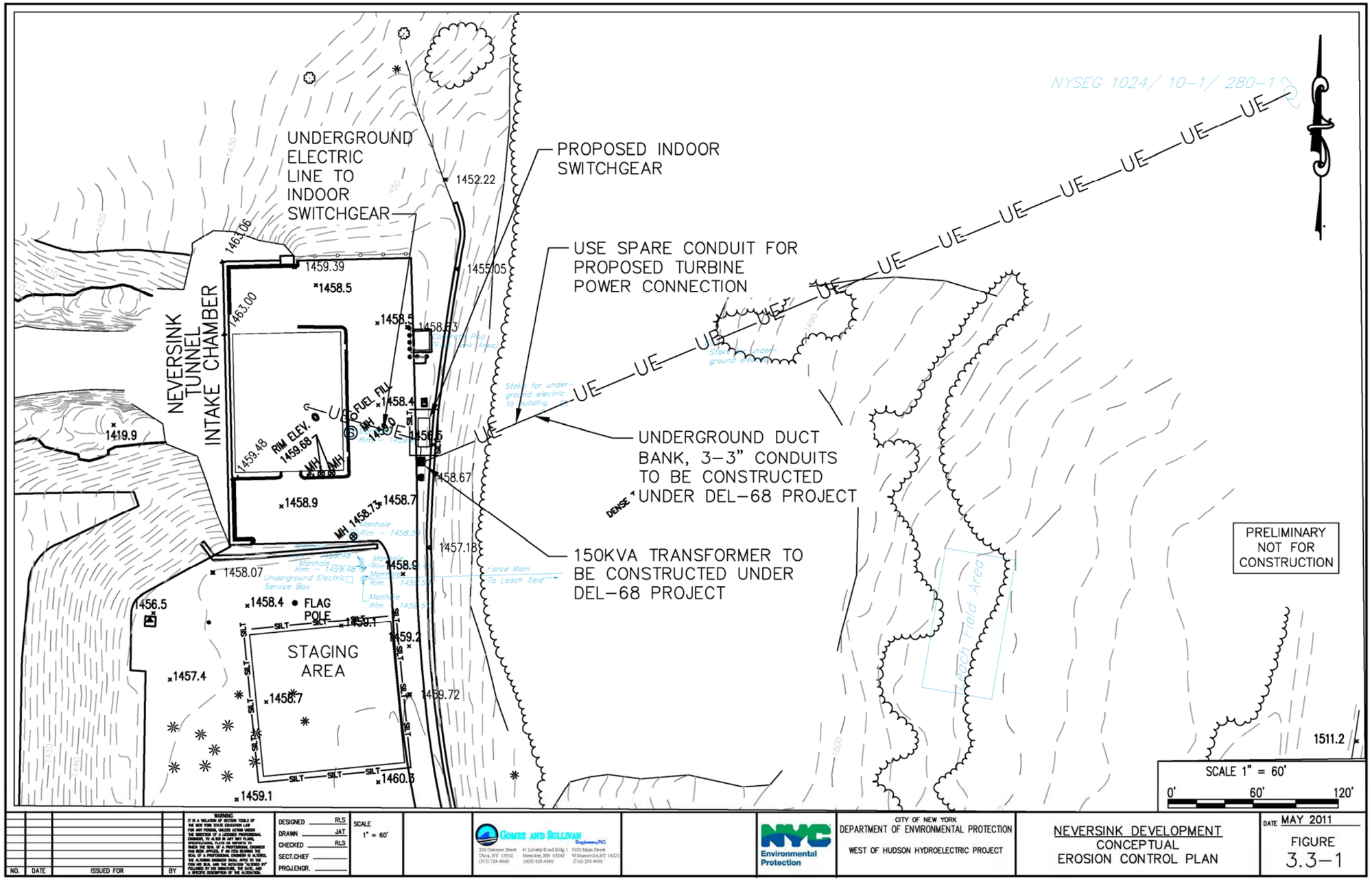
The wires connecting the switchgear to the NYSEG distribution system will be placed in existing underground conduits running from the location of the switchgear building to an existing pole located on State Route 55. Because no ground will be disturbed except in the switchgear building, no erosion protection measures are proposed for this aspect of the construction.

All disturbed areas will be topsoiled, mulched, seeded and watered to establish grass. Once grass is established the silt fencing will be removed.


SPOILS DISPOSAL AREA
SILT
PROPOSED 46 KV OVERHEAD ELECTRIC LINE
PROPOSED SUBSTATION
SILT FENCE TO BE PLACED AROUND WORK AREA FOR NEW POLES
EXISTING 46 KV OVERHEAD ELECTRIC LINE
SEDIMENTATION BASIN
EXISTING ACCESS ROAD
FLEXIBLE PIPE TO SEDIMENTATION BASIN
PUMP
PROPOSED 12.47 KV OVERHEAD ELECTRIC LINE
PROPOSED POWERHOUSE
EXISTING RELEASE WORKS BUILDING
DAM
CANNONSVILLE RESERVOIR
CANNONSVILLE DAM
WEST BRANCH DELAWARE RIVER
OHE
PRELIMINARY NOT FOR CONSTRUCTION
NO. DATE ISSUED FOR BY
WARNING
IT IS A VIOLATION OF SECTION 7209.2 OF THE NEW YORK STATE EDUCATION LAW FOR ANY PERSON, UNLESS ACTING UNDER THE DIRECTION OF A LICENSED PROFESSIONAL ENGINEER, TO ALTER IN ANY WAY PLANS, SPECIFICATIONS, PLATS OR REPORTS BEARING THE SEAL OF A PROFESSIONAL ENGINEER. WHEN ALTERATIONS HAVE BEEN APPLIED, IF AN ITEM BEARING THE SEAL OF A PROFESSIONAL ENGINEER IS ALTERED, THE ALTERING ENGINEER SHALL AFFIX TO THE ITEM HIS SEAL AND THE NOTATION "ALTERED BY" FOLLOWED BY HIS SIGNATURE, THE DATE, AND A SPECIFIC DESCRIPTION OF THE ALTERATION.
DESIGNED RLS
DRAWN JAT
CHECKED RLS
SECT.CHIEF
PROJ.ENGR.
SCALE 1" = 200'
200' 0 200'
SCALE: 1" = 200'
GOMEZ AND SULLIVAN
NYC Environmental Protection
CITY OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WEST OF HUDSON HYDROELECTRIC PROJECT
CANNONSVILLE DEVELOPMENT
CONCEPTUAL
EROSION CONTROL LOCATIONS
DATE MAY 2011
FIGURE
3.1-1


STAGING AREA 3
SEDIMENTATION BASIN
SILT
SEDIMENT POND EXCAVATION
FLEXIBLE PIPE TO SEDIMENTATION BASIN
SILT FENCE TO BE PLACED AROUND WORK AREA OF NEW POLES
UP NYSEG 35 DTS 47
ELECTRIC LINES TO SUBSTATION
EXISTING LEACHFIELD
RELOCATED LEACHFIELD
GRAVEL CRANE PAD
END CHIMNEY DRAIN
TOE DRAIN
PUMP
POWERHOUSE EXCAVATION
TAILRACE WALL
INSTALL THRUST BLOCKS (TYP.)
CHIMNEY DRAIN
12"PVC PIPE INV(S) EL. 1004.5'
2' DEEP STONE FILL
20'x40' ASPHALT PARKING
TAILRACE EXCAVATION
EXISTING SEWER PUMP STATION
PENSTOCK EXCAVATION (TYP.)
5' ASPHALT WALKWAY (TYP.)
BOTTOM OF TRENCH EL. 997'
EL 1006
993.3
988.3
999.3
666
1030
1040
1020
1010
1002
1000
TAILRACE EXCAVATION
EDGE OF WATER
TAILRACE WALL
PUMP STATION RELOCATION
75 kVA PAD MOUNTED TRANSFORMER
SILT CURTAIN
8' HIGH PRE-FABRICATED COFFERDAM
x1000.5
x975
4' HIGH, 12' WIDE COFFERDAM 2:1 SIDE SLOPES (FOR TAILRACE EXCAVATION)
12" PVC PIPE INV. EL.1006.0'
PENSTOCK WYE CONNECTION TO TUNNEL
EXISTING TUNNEL
PRELIMINARY NOT FOR CONSTRUCTION
EXISTING RELEASE WATER CHAMBER
BOTTOM OF POWERHOUSE EXCAVATION EL. 983'
Overhead Wires
CB
NO. | DATE | ISSUED FOR | BY
WARNING
IT IS A VIOLATION OF SECTION 7209.2 OF THE NEW YORK STATE EDUCATION LAW FOR ANY PERSON, UNLESS ACTING UNDER THE DIRECTION OF A LICENSED PROFESSIONAL ENGINEER, TO ALTER IN ANY WAY PLANS, SPECIFICATIONS, PLATS OR REPORTS TO WHICH THE SEAL OF A PROFESSIONAL ENGINEER HAS BEEN APPLIED. IF AN ITEM BEARING THE SEAL OF A PROFESSIONAL ENGINEER IS ALTERED, THE ALTERING ENGINEER SHALL AFFIX TO THE ITEM THE WORDS "ALTERED BY" FOLLOWED BY HIS SIGNATURE, THE DATE, AND A SPECIFIC DESCRIPTION OF THE ALTERATION.
DESIGNED RLS
DRAWN JAT
CHECKED RLS
SECT.CHIEF
PROJ.ENGR.
SCALE 1" = 50'
50' 0 50'
SCALE: 1" = 50'
GOMEZ AND SULLIVAN Engineers, P.C.
388 Genesee Street Utica, NY 13502 (315) 724-4860
41 Liberty Rd, Bldg 1 Horsham, NJ 07042 (609) 426-4960
9630 Main Street Williamsville, NY 14221 (716) 236-4960
NYC Environmental Protection
CITY OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WEST OF HUDSON HYDROELECTRIC PROJECT
CANNONSVILLE DEVELOPMENT
CONCEPTUAL
EROSION CONTROL LOCATIONS
DATE MAY 2011
FIGURE 3.1-2


PROPOSED INDOOR SWITCHGEAR
PROPOSED TURBINE POWER CONNECTION AT EXISTING POLE
STAGING AREA
EXISTING RELEASE WATER CHAMBER
UNDERGROUND ELECTRIC LINES
TOP OF WALL 1297.06
TOP OF WALL 1297.10
TOP OF WALL 1293.50
BOTTOM OF WALL 1266.12
TOP OF WALL 1305.09
TOP OF WALL 1307.09
TOP OF WALL 1295.52
SILT
OHE
CB
MH
VENT
PRELIMINARY NOT FOR CONSTRUCTION
SCALE 1" = 60'
0' 60' 120'
DESIGNED RLS
DRAWN JAT
CHECKED RLS
SECT.CHIEF
PROJ.ENGR.
SCALE 1" = 60'
GOMEZ AND SULLIVAN Engineers, P.C.
NYC Environmental Protection
CITY OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WEST OF HUDSON HYDROELECTRIC PROJECT
PEPACTON DEVELOPMENT
CONCEPTUAL
EROSION CONTROL PLAN
DATE MAY 2011
FIGURE
3.2–1
NO. DATE ISSUED FOR BY


UNDERGROUND ELECTRIC LINE TO INDOOR SWITCHGEAR
PROPOSED INDOOR SWITCHGEAR
USE SPARE CONDUIT FOR PROPOSED TURBINE POWER CONNECTION
UNDERGROUND DUCT BANK, 3-3" CONDUITS TO BE CONSTRUCTED UNDER DEL-68 PROJECT
150KVA TRANSFORMER TO BE CONSTRUCTED UNDER DEL-68 PROJECT
NYSEG 1024/ 10-1/ 280-1
NEVERSINK TUNNEL INTAKE CHAMBER
STAGING AREA
FLAG POLE
RIM ELEV. 1459.68
PRELIMINARY NOT FOR CONSTRUCTION
SCALE 1" = 60'
0' 60' 120'
NO. DATE ISSUED FOR BY
DESIGNED RLS
DRAWN JAT
CHECKED RLS
SECT.CHIEF
PROJ.ENGR.
SCALE 1" = 60'
GOMEZ AND SULLIVAN Engineers, P.C.
NYC Environmental Protection
CITY OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WEST OF HUDSON HYDROELECTRIC PROJECT
NEVERSINK DEVELOPMENT
CONCEPTUAL
EROSION CONTROL PLAN
DATE MAY 2011
FIGURE 3.3-1

BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION
APPLICATION FOR EXEMPTION OF SMALL HYDROELECTRIC PROJECT FROM LICENSING - EXISTING DAM

Neversink Hydroelectric Development

FERC Project No. 13287

VOLUME 7
Appendix E-5: Socioeconomic Study Report

City of New York

Environmental Protection

September 2011

City of New York
West of Hudson Hydroelectric Project

Project No. 13287

Socioeconomic Study Report

Cannonsville, Pepacton, and Neversink Developments

Study Conducted By:

Hugh O'Neill Ltd d/b/a Appleseed

and

Bates White, LLC

August 2011

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APPENDIX A

APPENDIX B

EXECUTIVE SUMMARY

The City of New York ("City"), acting through the New York City Department of Environmental Protection ("DEP") has filed with the Federal Energy Regulatory Commission ("FERC") a Notice of Intent ("NOI") to develop hydroelectric generation at the West of Hudson Hydroelectric Project, FERC Project No. 13287 ("Project"). As part of the licensing process for the Project, the City commissioned the conduct of a socioeconomic study with respect to the three developments (i.e., Cannonsville, Neversink and Pepacton) associated the Project. This report presents the results of such study and is being submitted to FERC in support of the license application for the proposed Project.

The objective of the socioeconomic study was to identify and quantify the impacts of constructing and operating the three Project developments on factors such as employment, local government services, local tax revenues, and other relevant factors with respect to the municipalities and counties in the vicinity of the Project ("Impact Area"). In addition, other factors such as Project-related impacts on wholesale electricity prices and pollutant emissions were analyzed.

The City engaged the services of Hugh O'Neill Ltd d/b/a Appleseed ("Appleseed") and Bates White, LLC ("Bates White") to conduct the socioeconomic study of the Project. Appleseed conducted an analysis of Project impacts of traditional socioeconomic factors considered by FERC (e.g., employment, population, local tax revenues and local government services). The analysis conducted by Bates White primarily focused on the potential Project-related impacts on wholesale electricity prices and pollutant emissions associated with electricity production in New York.

Economic Impact of Project Construction and Operation

Using the IMPLAN input-output modeling system – an econometric modeling system commonly used in the analyses of economic impacts – the direct, indirect and induced (or "multiplier") effects of Project construction and ongoing operation were estimated.

Cannonsville Development

Of a total estimated construction cost of approximately $42.5 million, it is projected that nearly $3.1 million would be paid either to Delaware County subcontractors or to Delaware County residents employed by non-local contractors and subcontractors, generating 49 person-years of employment for Delaware County residents in construction and related industries during the anticipated 36 month construction period associated with the Cannonsville development. Through the multiplier effect, construction of the Cannonsville development is estimated to generate approximately $1.2 million in additional economic output in Delaware County and ten person-years of employment.

Once fully operational, ongoing operation of the Cannonsville development is estimated to increase Delaware County's annual economic by more than $2.7 million.

Pepacton Development

Of a total estimated construction cost of approximately $8.1 million, it is projected that approximately $491,000 would be paid either to Delaware County subcontractors or to Delaware County residents employed by non-local contractors and subcontractors, generating 8 person-years of employment for Delaware County residents in construction and related industries during the anticipated 21 month construction period associated with the Pepacton development. Through the multiplier effect, construction of the Pepacton development is estimated to generate approximately $192,000 in additional economic output in Delaware County and two person-years of employment.

Once fully operational, ongoing operation of the Pepacton development is estimated to increase Delaware County's annual economic by approximately $454,000.

Neversink Development

Of a total estimated construction cost of approximately $4.4 million, it is projected that approximately $274,000 would be paid either to Sullivan County subcontractors or to Sullivan County residents employed by non-local contractors and subcontractors, generating 5 person-years of employment for Sullivan County residents in construction and related industries during the anticipated 21 month construction period associated with the Neversink development. Through the multiplier effect, construction of the Neversink development is estimated to generate approximately $120,000 in additional economic output in Sullivan County and one person-years of employment.

Once fully operational, ongoing operation of the Neversink development is estimated to increase Delaware County's annual economic by slightly less than $273,000.

Impact on Local Tax Revenues and Local Governmental Services

Assuming that: (a) the market value of each Project development is roughly equal to the respective construction costs of each development; and (b) equalization rates and tax rates for each of the three respective towns in which each development is located are the same as they were in 2010, an estimate of the applicable town, county and school property taxes to be paid with respect to each development was calculated. Utilizing these assumptions, the estimated town, county and school property taxes to be paid with respect to each development during its respective first year of operation are as follows: (a) approximately $1.7 million for the Cannonsville development; (b) approximately $158,000 for the Pepacton development; and (c) approximately $112,000 for the Neversink development.

Due primarily to the relatively small number of new jobs associated with ongoing operations at each Project development, the respective impact of each development on local government services is expected to be minimal.

Impact on Recreation and the Character of the Affected Communities

Because: (a) the City is merely seeking to generate power from the discharges it is already obligated to provide and will continue to provide such discharges in accordance with the requirements of the operating protocol applicable to the operation of the reservoirs associated with each Project development; and (b) the Project developments are being constructed at existing facilities, the Project developments are expected to neither create new recreational opportunities nor impair existing recreational activities undertaken on the reservoir or downstream environs associated with each Project development.

Furthermore, the impact of each Project development on the character of the affected communities is expected to be minimal for several reasons, including: (a) the small increase in labor demands associated with the developments is unlikely to affect wages in either the directly affected industries or the labor force more broadly; (b) because the resident labor force in the two affected counties (i.e., Delaware and Sullivan counties) and surrounding areas would easily absorb the small increase in labor demands generated by the Project developments, the developments are not anticipated to affect demand for housing or housing costs in such areas; and (c) due to their small impact on labor demands, the developments are not expected to affect other aspects of community character such as the predominantly low-density, rural character of the affected communities, existing patterns of land use and development, or the overall mix of local economic activity.

Impacts on Wholesale Energy Prices, Pollutant Emissions and System Reliability

In addition to the traditional socioeconomic impact assessment, three additional analyses were performed to assess the effects of the Project developments on reducing wholesale energy prices, reducing pollutant emissions and supporting reliability of the electric system.

Wholesale Energy Market Impacts

Electricity generated from the Project developments would lower wholesale market energy prices by displacing higher cost marginal generation in some hours. The estimated annual dollar benefit of such price reductions for the western region of the control area administered by the New York Independent System Operator, Inc. ("NYISO") is approximately $13.6 million annually.

Environmental Externality Benefits

Generation from the Project developments, estimated to be approximately 57,000 megawatt-hours ("MWh") per year of emissions-free electricity, would provide environmental benefits by displacing generation of electricity from fossil fuels. Electricity generated from the Project developments will result in reductions in emissions by fossil-fueled generation sources by as much as 64,000 tons of carbon dioxide ("CO_2"), 170 tons of nitrogen oxides ("NOx"), and 370 tons of sulfur dioxide ("SO_2") annually, depending on the type of fossil-fuel generation displaced by the electricity produced from the Project developments. The estimated CO_2 emissions reductions are equivalent to removing between 5,600 and 11,100 vehicles from the road, depending on the type of fossil-fuel generation displaced.

Electric System Reliability Benefits

Interconnection of the Project developments may provide additional reliability and power quality benefits at both the local and the Statewide level, including the provision of certain ancillary services. These ancillary services are typically used by the transmission system operator to balance supply and demand and maintain the reliability and security of the system within acceptable standards. The ancillary services that the Project developments may be suited to provide include regulation service and frequency control, and reactive power supply and voltage support. Additionally, the proposed Project developments may have the effect of delaying the need for New York State Electric & Gas Corporation ("NYSEG") to invest in upstream capacity needed to meet future load growth along the feeders to which they are connected.

1.0 INTRODUCTION

On September 15, 2008, the City, acting through DEP, filed an application for a preliminary permit with FERC to develop hydroelectric generation at four sites (i.e., Project developments) that together comprise the Project.[1] Through the Project, the City is considering developing hydroelectric facilities at the Project developments, while simultaneously maintaining its crucial water supply operations in accordance with long-term sustainable drinking water needs, conservation releases, directed releases, water quality standards, and various other conditions affecting the City's water supply system, including determinations by and/or agreements with the U.S. Environmental Protection Agency, the New York State Department of Health, the New York State Department of Environmental Conservation, and the Delaware River Basin Commission. The delivery of high quality drinking water to approximately one-half of New York State's total population will remain the primary purpose and function of DEP's operations at the reservoirs and dams associated with the Project. All of the existing dams and reservoirs associated with the Project are owned by the City and operated by DEP to provide water for New York City and four nearby counties. The water supply system provides approximately 1.1 billion gallons of unfiltered high quality drinking water daily to approximately nine million New York State residents (approximately half of the State's total population), as well as the millions of tourists and commuters who visit New York City each year.[2]

By order issued March 20, 2009, FERC issued a Preliminary Permit to the City, facilitating its ability to proceed with its data collection, studies, and evaluation of the Project. On August 13, 2009, the City commenced the pre-filing process for the Project with the filing of its Notification of Intent and Pre-Application Document ("PAD"). In accordance with the Preliminary Permit, DEP is evaluating the technical and economic merit and feasibility for each proposed hydroelectric development. Based on the analysis completed to date, the City has not yet identified an economically viable project for the Schoharie Development. Accordingly, there are no additional studies proposed for the Schoharie Development at this time. However, the City will continue to investigate whether there is a technically and economically feasible option for this Project development, and will proceed with appropriate FERC licensing studies in the event such an alternative is identified.

Based on the foregoing, this socioeconomic study analyzes only the following three proposed Project developments: (1) Cannonsville Development; (2) Neversink Development; and (3) Pepacton Development.[3]

---

[1] The Project, as initially proposed by the City, consisted of the following four developments: (1) the Cannonsville Dam and Reservoir in Delaware County, New York ("Cannonsville Development"); (2) the Neversink Dam and Reservoir in Sullivan County, New York ("Neversink Development"); (3) the Downsville Dam and Pepacton Reservoir in Delaware County, New York ("Pepacton Development"); and (4) the Gilboa Dam and Schoharie Reservoir in Schoharie and Greene Counties, New York ("Schoharie Development").

[2] The City's water supply is comprised of three watersheds – Catskill, Croton, and Delaware – which are operated as an integrated system. The Cannonsville, Neversink and Pepacton Developments are part of the Delaware system. The Schoharie Development is part of the Catskill system.

[3] For the purposes of this socioeconomic study, references to the "Project" herein are references to the Project inclusive of the three proposed Project developments assessed as part of this study.

2.0 SOCIOECONOMIC IMPACTS

In connection with the licensing process, the City elected to conduct a socioeconomic study regarding the Project. The overall objective of the socioeconomic study was to identify and quantify the impacts of constructing and operating the Project developments on employment, population, housing, personal income, local government services, local tax revenues and other relevant factors with respect to the Impact Area.

In order to accomplish this objective, the following activities were included in the socioeconomic study of the Project:

- Identify the appropriate Impact Area for conducting the socio-economic study, based on the Project location, existing demographic and economic linkages;

- Identify demographic and economic trends for the Impact Area, including:
  - Population;
  - Employment;
  - Personal income;
  - General economic condition;
  - Real estate characteristics;
  - Government Services and Facilities (e.g., police, fire, health, roads, education);

- Identify the economic impacts (direct, indirect, and induced) of Project construction and on-going Project operation on the demographic and economic trends for the Impact Area, including:
  - Evaluating whether the existing supply of housing (temporary and permanent) is sufficient to meet the needs of any additional population resulting from Project construction and operation;
  - Identifying any additional revenues (e.g., taxes) provided to the Impact Area resulting from Project construction and operation;

- Evaluate the incremental local government expenditures in the Impact Area (including school operating costs, road maintenance and repair, public safety costs and public utility costs) compared to the local government revenues in the Impact Area that would result from Project construction and operation;

- Evaluate the impact of the Project on recreational activities and character of the communities within the Impact Area;

- Identify and quantify, to the extent practicable, environmental externality benefits to the public, generally, associated with Project construction and operation (e.g., air pollution reduction resulting from the offset of fossil-fuel generation by the power generated by the Project); and

- Evaluate the potential impacts of the Project on wholesale electricity prices and system reliability in the Impact Area.

To conduct the socioeconomic study of the Project, the City engaged the services of two consultants: (1) Appleseed; and (2) Bates White. Appleseed conducted an assessment of the traditional socioeconomic impacts required by FERC regulations,[4] while Bates White conducted an assessment relating to potential environmental externality benefits, reliability benefits and wholesale electricity price impacts associated with the Project. Accordingly, Appleseed is responsible for the content of Section 3.0 of this report, and Bates White is responsible for the content of Section 4.0.

3.0 ASSESSMENT OF TRADITIONAL SOCIOECONOMIC FACTORS

3.1 Introduction

Section 3 of this report assesses the economic impact of the proposed Cannonsville, Pepacton and Neversink Developments. In order to understand the socioeconomic context within which the Project developments would be constructed, an analysis of current demographic and economic conditions and recent trends in the towns most likely to be affected by the Projects are presented below.

3.2 Areas of Analysis and Sources of Data

Two of the proposed Project developments – Cannonsville and Pepacton – would be located in Delaware County. The Neversink Development would be located in Sullivan County. For purposes of this analysis, the towns in which socioeconomic conditions are most likely to be affected by the developments are as follows:

- The towns in which the proposed facilities would be located (i.e., Deposit, Colchester and Neversink);

- Other towns that, when added to the three cited above, account for more than half of all of the workforce of the towns in which the proposed facilities would be located. For example, about 54 percent of all those whose place of work is in the Town of Deposit live either in the town itself or in the Towns of Walton or Sanford; and

- Any other towns that directly border Deposit, Colchester or Neversink.

Figure 3.1 shows the fifteen towns that are included in the review of demographic and economic conditions and trends.

Data used in preparing profiles of each of these fifteen towns were taken primarily from several sources:

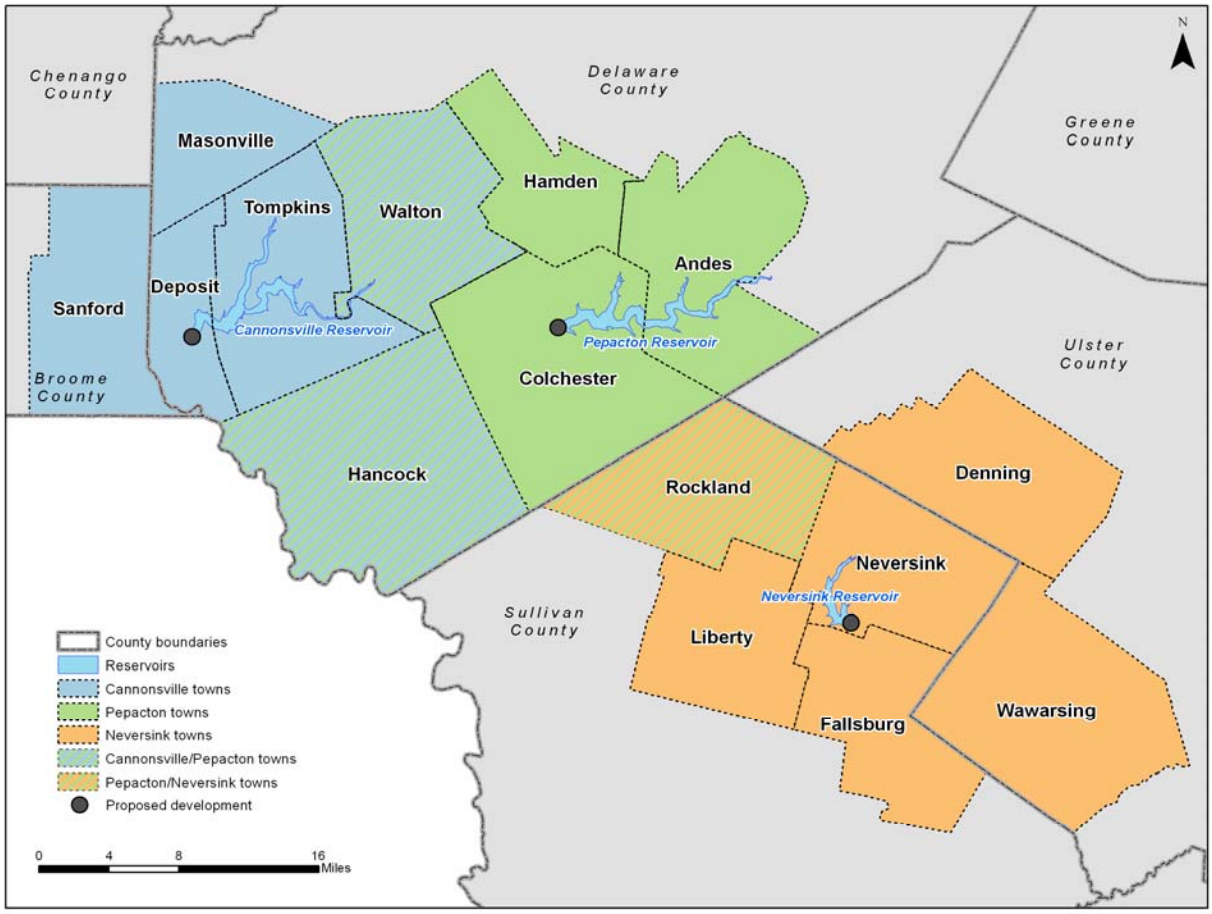
[4] *See* 18 C.F.R. § 4.41(f)(5).

- U.S. Census data for 2000 and 2010 was used to show population, median age, and housing trends.

- The Census Bureau's American Community Survey for 2005-2009 provides the most recent available data on educational attainment, employment and unemployment, industry employment characteristics, and educational attainment rates.

- The Census Bureau's journey-to-work data for 2000 provides the most recent available data showing on a small-area basis where people live and work.

Figure 3.1: Map of Reservoirs Project Developments in Relation to Towns and Counties Assessed



3.3 Socioeconomic Conditions and Trends

This section describes the town-level socioeconomic conditions and trends during the past decade, organized by Project development.

3.3.1 Cannonsville Development

The following sections describe socioeconomic conditions and trends in six towns (five in Delaware County and one in Broome County that could potentially be affected by the Cannonsville facility: (1) Deposit, (2) Hancock, (3) Masonville, (4) Tompkins, and (5) Walton in Delaware County; and (6) Sanford in Broome County.

3.3.1.1Town of Deposit

According to the 2010 Census, the population of the Town of Deposit was 1,712 – an increase of 1.5 percent since 2000. This represents a slightly slower rate of growth than for New York State as a whole, but is more positive than the overall trend in Delaware County, which experienced a slight decline in population during the same period (Table 3.1). The Town had a population density of 39.8 persons per square mile, which reflects the Town's rural character.

Table 3.1: Town of Deposit Population, 2000 and 2010

Geography	2000	2010	% Change
Deposit	1,687	1,712	1.5%
Delaware County	48,040	47,980	-0.1%
New York	18,976,457	19,378,102	2.1%

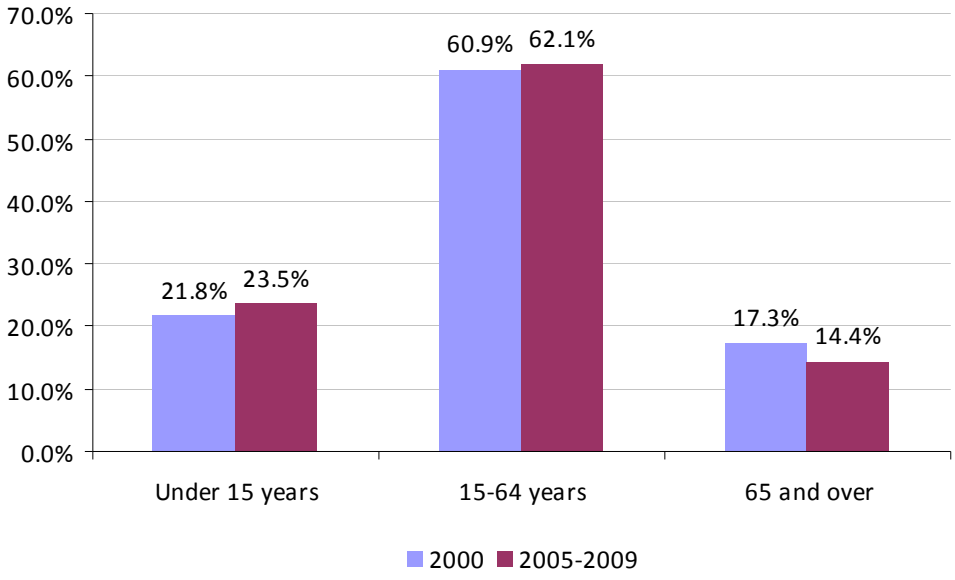
As shown by Table 3.2, the number of housing units in the Town of Deposit increased by 11.8 percent between 2000 and 2010 – an increase of 119 units. Housing for seasonal or recreational use accounted for 31.2 percent of all housing units in 2010; and such units accounted for almost all housing growth in the Town between 2000 and 2010.

Table 3.2: Town of Deposit Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Deposit	1,048	1,131	7.9%
Delaware County	28,943	31,222	7.9%
New York	7,679,307	8,108,103	5.6%

According to the Census Bureau's American Community Survey ("ACS"), the median age in Deposit during the years 2005-2009 was 37.6 – a slight decrease from the 38.3 reported in the 2000 Census. As depicted by Figure 3.2, the age distribution of the Town of Deposit changed significantly between 2000 and 2009. The population age 15-and-under and aged 15-64 increased by about 10 percent and 15 percent, respectively. More dramatically, the population 65-and-over decreased by about 30 percent.

Figure 3.2: Town of Deposit Age Distribution, 2000 and 2005-2009



Resident employment, as shown in Table 3.3, decreased by slightly more than 13 percent in the Town of Deposit between 2000 and 2005-2009. The reduction in employment is significant considering that employment in the State actually increased during the same time period by 8.6 percent.

Table 3.3: Town of Deposit Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Deposit	709	615	-13.3%
Delaware County	20,840	21,111	1.3%
New York	8,382,988	9,102,596	8.6%

As Figure 3.3 shows, the largest number of employed residents of the Town of Deposit – about 29 percent – worked in education, health care and social assistance. The manufacturing sector accounted for 15 percent of all resident employment, reflecting a strong concentration of manufacturing firms in western Delaware County. Another 12 percent of the Town's employed residents worked in construction; 11 percent in retail trade; and 61 percent in the arts, entertainment and hospitality sector.

Figure 3.3: Town of Deposit Resident Employment - Top Employment Sectors, 2005-2009

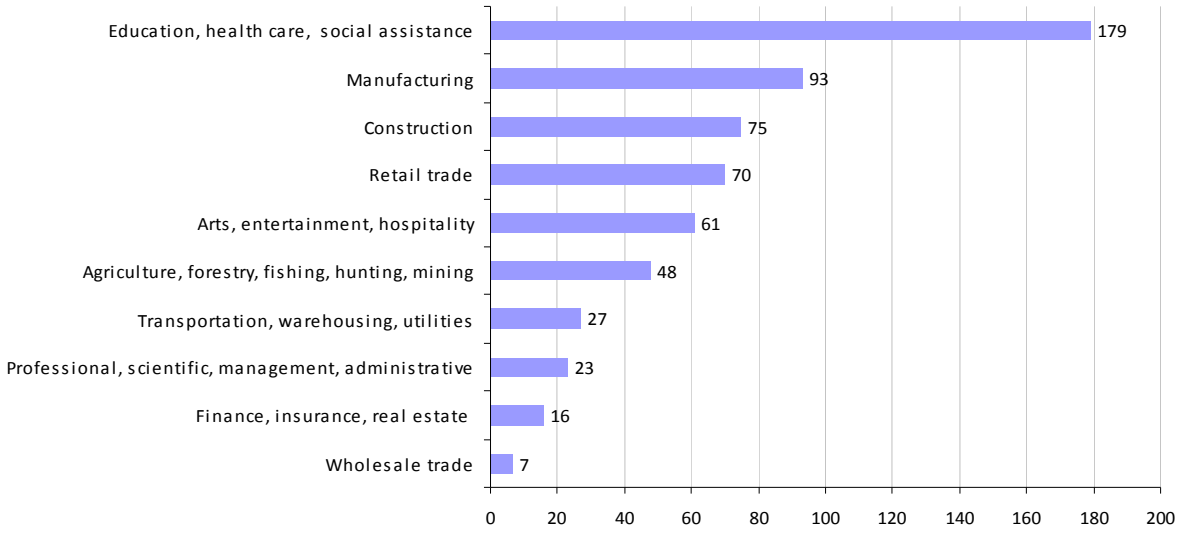


Table 3.4 shows that the unemployment rate for the Town of Deposit during the years 2005-2009 averaged 8.1 percent – higher than the overall rate for Delaware County or for New York State.[5]

Table 3.4: Town of Deposit Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Deposit	7.2%	8.1%
Delaware County	6.2%	7.1%
New York	7.1%	7.0%

As shown in Table 3.5, the median household income ("MHI") for the Town of Deposit for the years 2005-2009 was $34,621 – 83 percent of the median household income for Delaware County, and just 63 percent of the statewide median household income for the same period. Moreover, after adjusting for inflation, the Town's MHI fell by 6.5 percent between 2000 and 2005-2009, indicating that the Town fell further behind the rest of the County and the State during this period.

Table 3.5: Town of Deposit Median Household Income (2009 dollars), 2000 and 2005-2009

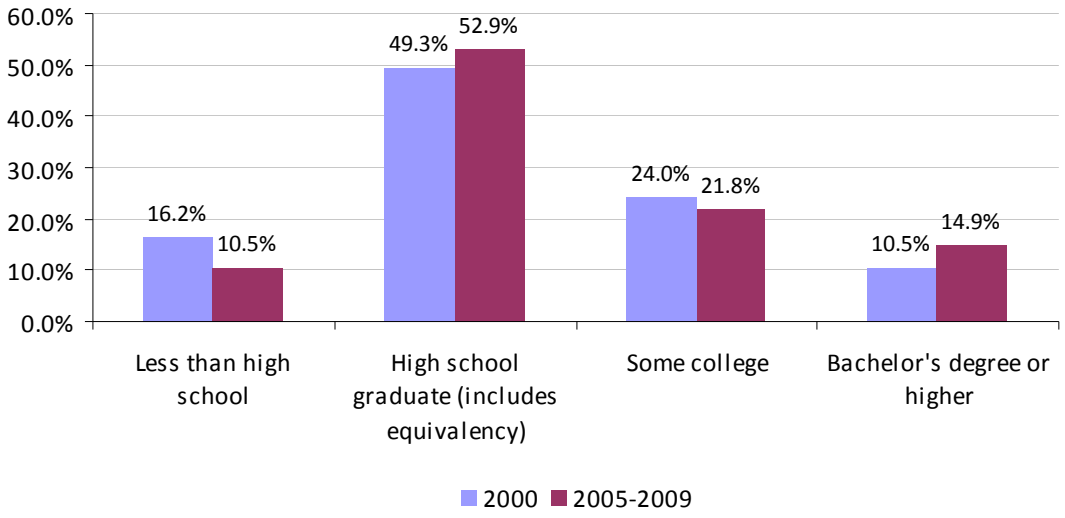
Geography	2000	2005-2009	% Change
Deposit	$37,022	$34,621	-6.5%
Delaware County	$41,801	$41,656	-0.3%
New York	$55,879	$55,233	-1.2%

As Figure 3.4 shows, the Town of Deposit has experienced some positive changes in the areas of secondary and post-secondary educational attainment. The percentage of residents age 25 and over who lack a high school diploma fell between 2000 and 2005-2009, while the percentage of

[5] It should be noted that with respect to all of the unemployment data presented in this report, the percentage unemployment rate for 2005-2009 does not fully reflect the impact of the economic recession that commenced in 2008 and the continuing economic downturn that has followed thereafter.

residents who held at least a bachelor's degree rose. Nevertheless, in the area of college and advanced degree attainment, the Town still trails both Delaware County (18.2 percent) and New York State (31.8 percent).

Figure 3.4: Town of Deposit Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.1.2 Town of Hancock

As shown in Table 3.6, in 2010 the population of the Town of Hancock was 3,224 (with a population density of 20.3 persons per square mile), a decline of 6.5 percent since 2000. The Town's population loss was, thus, significantly larger in percentage terms than the 0.1 percent decline in Delaware County's population.

Table 3.6: Town of Hancock Population, 2000 and 2010

Geography	2000	2010	% Change
Hancock	3,449	3,224	-6.5%
Delaware County	48,040	47,980	-0.1%
New York	18,976,457	19,378,102	2.1%

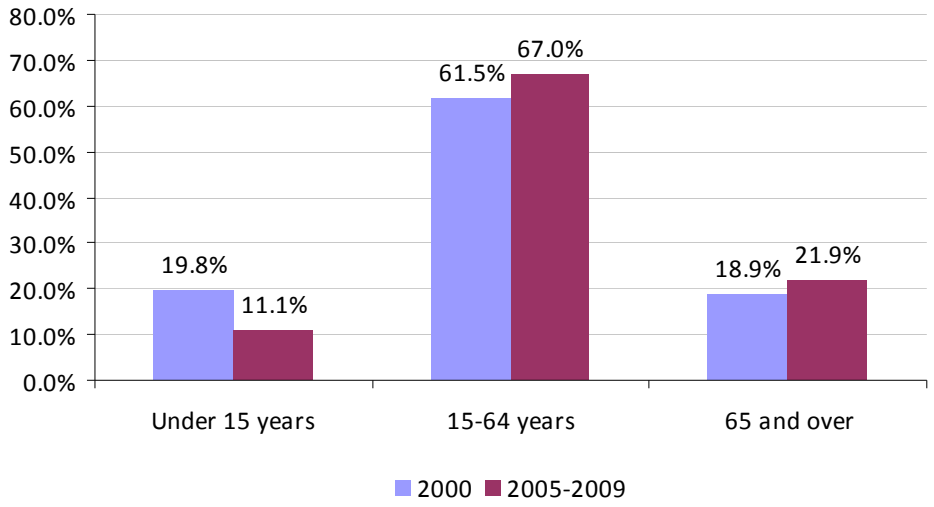
While its resident population declined between 2000 and 2010, Hancock's housing stock grew by 9.2 percent, as shown in Table 3.7. As of 2010, seasonal and recreational housing accounted for 45 percent of all units in Hancock, an increase of about 23 percent since 2000.

Table 3.7: Town of Hancock Housing Units, 2000 and 2010

Geography	2,000	2010	% Change
Hancock	2,512	2,743	9.2%
Delaware County	28,943	31,222	7.9%
New York	7,679,307	7,950,035	3.5%

As demonstrated by Figure 3.5, the population of the Town of Hancock aged between 2000 and 2005-2009. During this period, the median age increased to 48.2 years. The share of the population under the age of 15 fell by 8.7 percentage points. while the share of the population between 15 and 64 rose by 5.5 percentage points, and the population older than 65 increased by 3 percentage points.

Figure 3.5: Town of Hancock Age Distribution



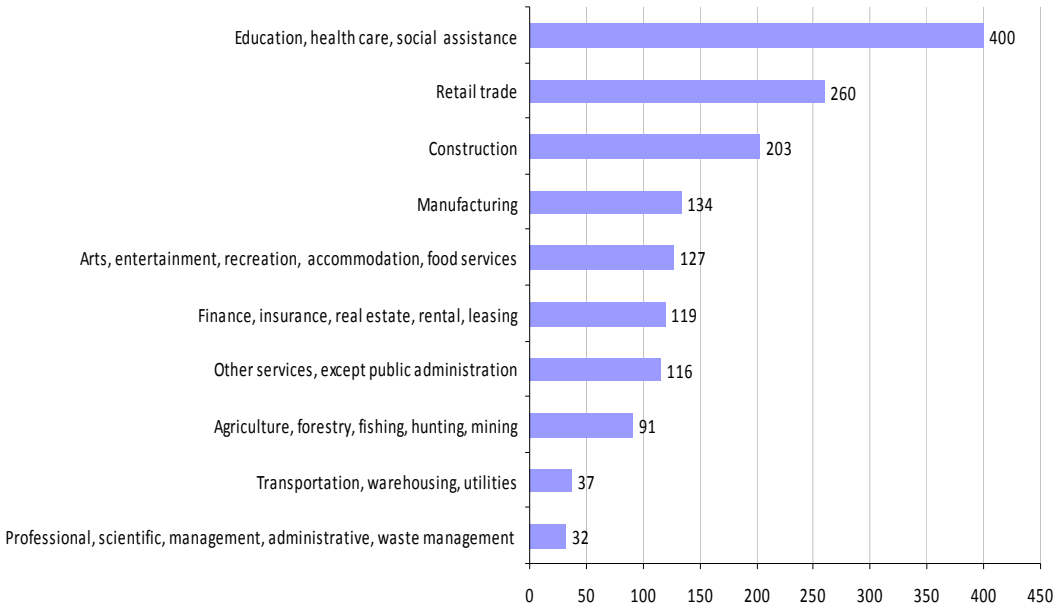
Resident employment in the Town of Hancock increased by nearly 19 percent between 2000 and 2005-2009. This growth rate was more than double the growth in the State during this period, as depicted in Table 3.8.

Table 3.8: Town of Hancock Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Hancock	1,338	1,593	19.1%
Delaware County	208	21,111	1.3%
New York	8,382,988	9,102,596	8.6%

As depicted by Figure 3.6, approximately 25 percent of employed residents of the Town of Hancock worked in education, health care and social assistance in 2005-2009, 16 percent in retail trade; nearly 13 percent in construction; and 8 percent in manufacturing.

Figure 3.6: Town of Hancock Resident Employment - Top Employment Sectors, 2005-2009



As Table 3.9 shows, the Town of Hancock's unemployment rate declined by 3 percentage points between 2000 and 2005-2009, and was below the unemployment rates of both Delaware County and the State for 2005-2009.

Table 3.9: Town of Hancock Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Hancock	8.9	5.9%
Delaware County	6.2%	7.1%
New York	7.1%	7.0%

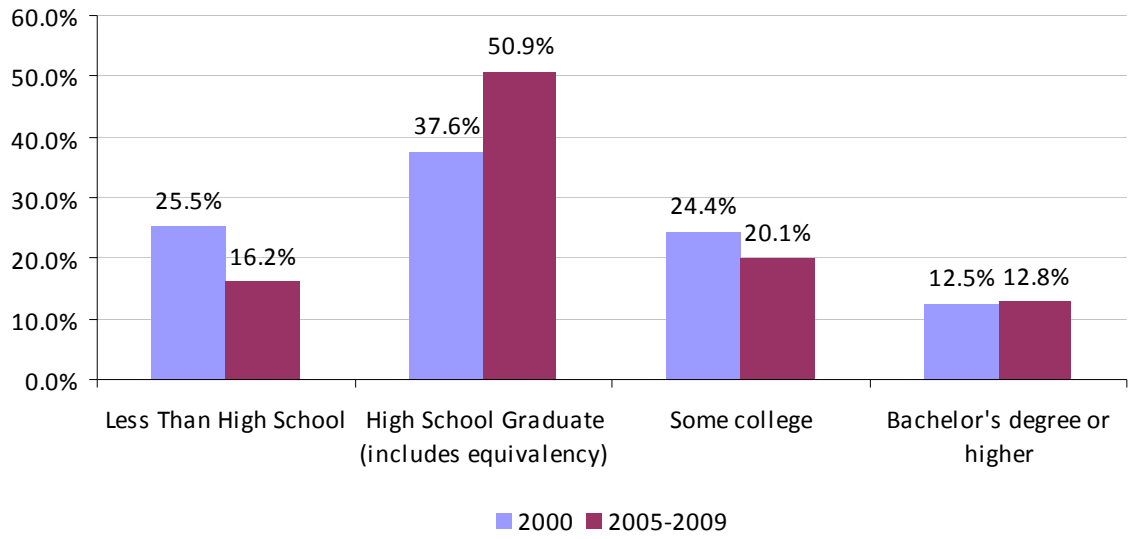
The MHI in the Town of Hancock decreased by slightly less than one percent between 2000 and 2005-2009, as shown in Table 3.10. While a decrease in MHI during this period is consistent with trend in Delaware County and the State, the Town's MHI remained slightly below the level in Delaware County and well below the level in the State.

Table 3.10: Town of Hancock Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Hancock	$39,853	$39,583	-0.7%
Delaware County	$41,801	$41,656	-0.3%
New York	$55,879	$55,233	-1.2%

As depicted in Figure 3.7, educational attainment increased in the Town of Hancock between 2000 and 2005-2009 as the number of high school graduates increased, while the number with less than a high school degree or some college experience decreased considerably. The percentage of people age 25-and-older who held a bachelor's degree or higher remained flat (and relatively low) between 2000 and 2005-2009.

Figure 3.7: Town of Hancock Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.1.3 Town of Masonville

As shown by Table 3.11, the population of the Town of Masonville declined by 6 percent between 2000 and 2010 – a sharper decline than the nominal change that Delaware County experienced during the same period. The town had a primarily rural character with a population density of 24.3 persons per square mile.

Table 3.11: Town of Masonville Population, 2000 and 2010

Geography	2000	2010	% Change
Masonville	1,407	1,320	-6.2%
Delaware County	48,040	47,980	-0.1%
New York	18,976,457	19,378,102	2.1%

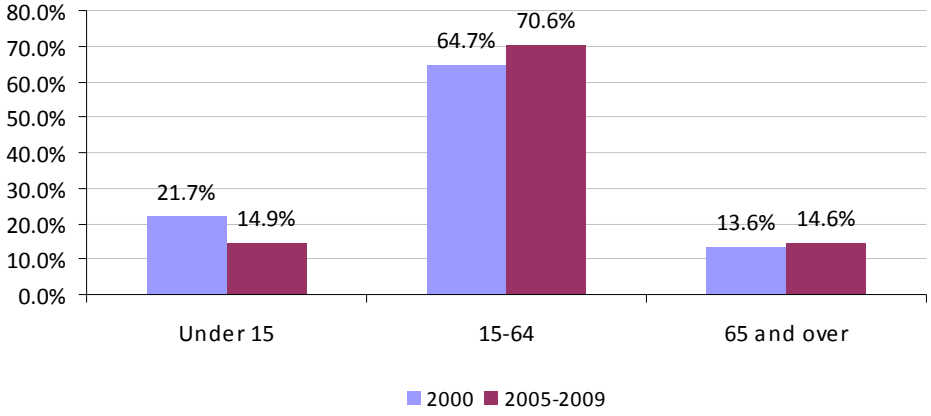
While the population of the Town of Masonville decreased between 2000 and 2010, the town experienced strong growth (15.5 percent) in its housing stock. Seasonal and recreational housing accounted for more than half the growth in the Town's housing stock during this period; and as of 2010, such units made up 28.9 percent of all housing in Masonville (Table 3.12)

Table 3.12: Town of Masonville Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Masonville	716	850	18.8%
Delaware County	28,943	31,222	7.9%
New York	7,679,307	8,108,103	5.6%

As demonstrated by Figure 3.8, between 2000 and 2005-2009 Masonville's population aged 15-64 increased slightly (by about 3 percent), while the population aged 15 and under decreased more significantly (by about 35 percent). The share of the population 65 and over remained virtually unchanged during the same time period

Figure 3.8: Town of Masonville Age Distribution, 2000 and 2005-2009



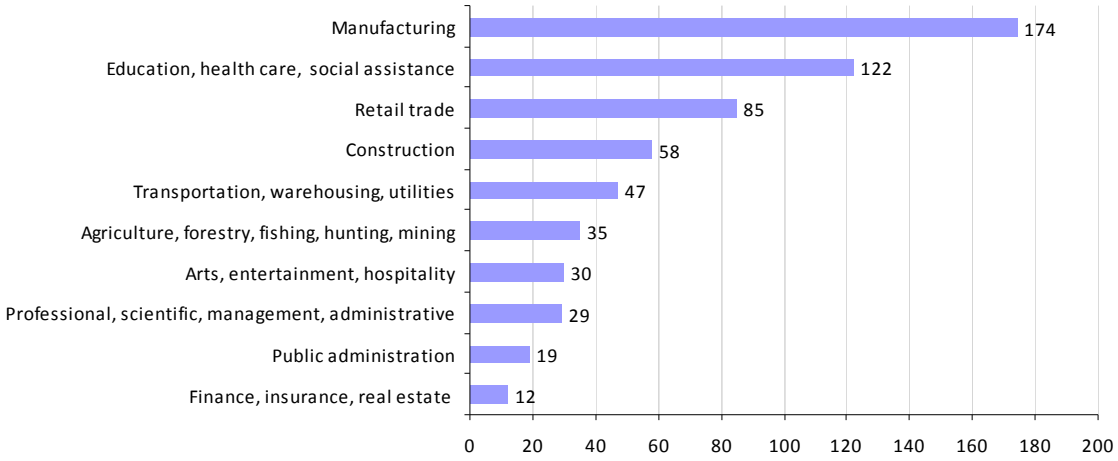
Resident employment in Masonville by nearly 1.5 percent between 2000 and 2005-2009, which was in contrast to the slight growth that Delaware County and the more significant growth that the State experienced in 2005-2009, as demonstrated by Table 3.13.

Table 3.13: Town of Masonville Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Masonville	633	624	-1.4%
Delaware County	20,840	21,111	1.3%
New York	8,382,988	9,102,596	8.6%

As Figure 3.9 shows, the Census Bureau's ACS data indicate that between 2005 and 2009, an average of 174 Masonville residents worked in manufacturing – about 28 percent of the town's employed residents. The relatively high percentage of all employees working in manufacturing reflects this sector's continued importance in the economy of Delaware County. Other major employers of Masonville residents include the education, health and social assistance sector (nearly 20 percent of the town's employed residents), retail trade (14 percent) and construction (more than 9 percent).

Figure 3.9: Town of Masonville Resident Employment - Top Employment Sectors, 2005-2009



As Table 3.14 shows, between 2005 and 2009 the Town's unemployment rate averaged 8.5 percent – significantly higher than the rates for Delaware County as a whole, or for New York State. Moreover, the average rate for 2005-2009 (as reported by ACS) does not reflect the full impact of the recession.

Table 3.14: Town of Masonville Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Masonville	5.1%	8.5%
Delaware County	6.2%	7.1%
New York	7.1%	7.0%

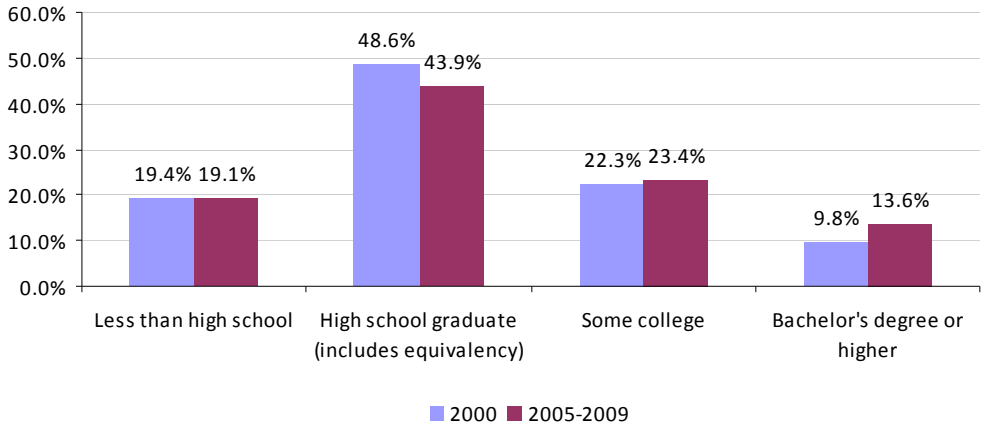
As depicted in Table 3.15, the Town of Masonville's MHI grew by 17 percent between 2000 and 2005-2009, while MHI declined at both County and State levels during the same period. As a result of this growth, the Town's MHI is 19 percent higher than the County's – and lags the statewide MHI by 10 percent.

Table 3.15: Town of Masonville Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Masonville	$42,495	$49,702	17.0%
Delaware County	$41,801	$41,656	-0.3%
New York	$55,879	$55,233	-1.2%

The percentage of all Masonville residents age 25-and-older who have at least a bachelor's degree rose between 2000 and 2005-2009, but at 13.6 percent is still relatively low. At the same time, the percentage of those 25-and-older who have not completed high school is still relatively high (Table 3.10).

Figure 3.10: Town of Masonvile Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.1.4 Town of Tompkins

In 2010, the population of the Town of Tompkins was 1,247 – as shown in Table 3.16, an increase of 12.9 percent since 2000. The Town's population density (12.7 persons per square mile) had increased from its 2000 level, at a rate that mirrors the rate of population growth that the Town of Tompkins experienced.

Table 3.16: Town of Tompkins Population, 2000 and 2010

Geography	2000	2010	% Change
Tompkins	1,105	1,247	12.9%
Delaware County	48,040	47,980	-0.1%
New York	18,976,457	19,378,102	2.1%

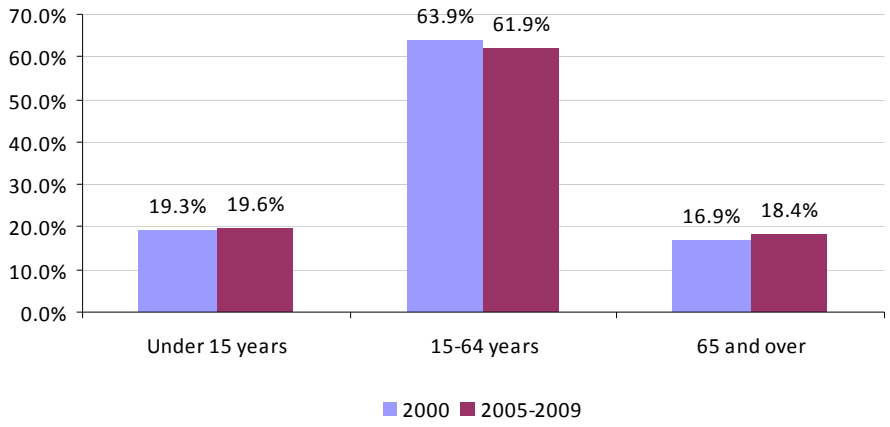
As shown in Table 3.17, the number of housing units in the Town of Tompkins grew by 13 percent between 2000 and 2010. Seasonal and recreational housing accounted for about 38 percent of all units in 2010.

Table 3.17: Town of Tompkins Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Tompkins	768	884	15.1%
Delaware County	28,943	31,222	7.9%
New York	7,679,307	8,108,103	5.6%

For 2005-2009, the median age in Tompkins was 37.2. As shown in Figure 3.11, the overall age distribution in the Town was relatively unchanged between 2000 and 2005-2009.

Figure 3.11: Town of Tompkins Age Distribution, 2000 and 2005-2009



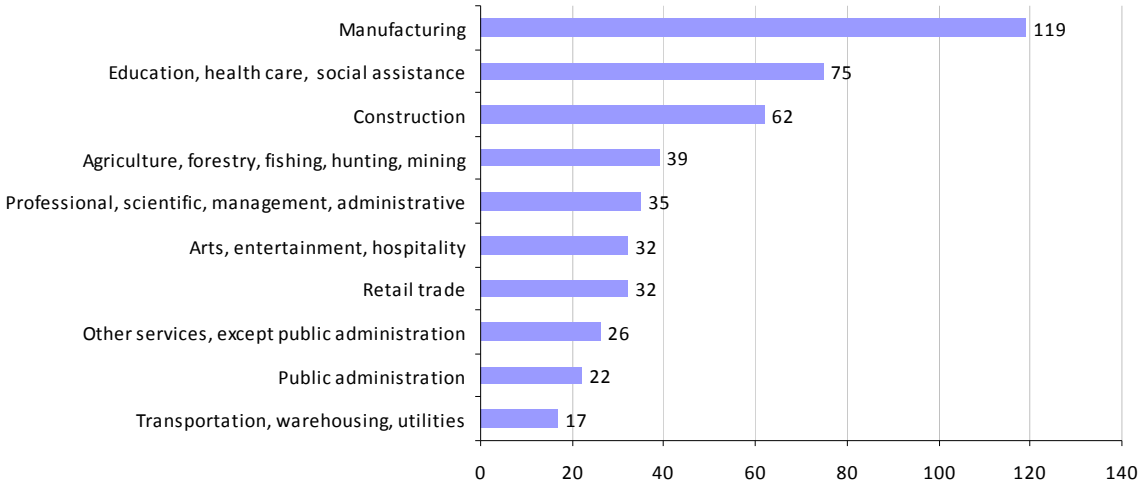
As shown by Table 3.18, resident employment in the Town of Tompkins decreased by more than 3 percent between 2000 and 2005-2009, whereas resident employment increased in both Delaware County and the State during the same period.

Table 3.18: Town of Tompkins Resident Employment, 2000 and 2005-2009

Geography	2,000	2005-2009	% Change
Tompkins	506	489	-3.4%
Delaware County	20,840	21,111	1.3%
New York	8,382,988	9,102,596	8.6%

As Figure 3.12 shows, the manufacturing sector was the leading employer of Tompkins residents during 2005-2009, accounting for 24 percent of the Town's employed residents. Other leading sectors include education, health and social assistance (15 percent), construction (13 percent), and agriculture and natural resources (8 percent).

Figure 3.12: Town of Tompkins Resident Employment - Top Employment Sectors, 2005-2009



As Table 3.19 shows, the Town of Tompkins's unemployment rate for 2005-2009 was 5.2 percent – considerably lower than the County-wide and State-wide rates for the same period.

Table 3.19: Town of Tompkins Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Tompkins	6.8%	5.2%
Delaware County	6.2%	7.1%
New York	7.1%	7.0%

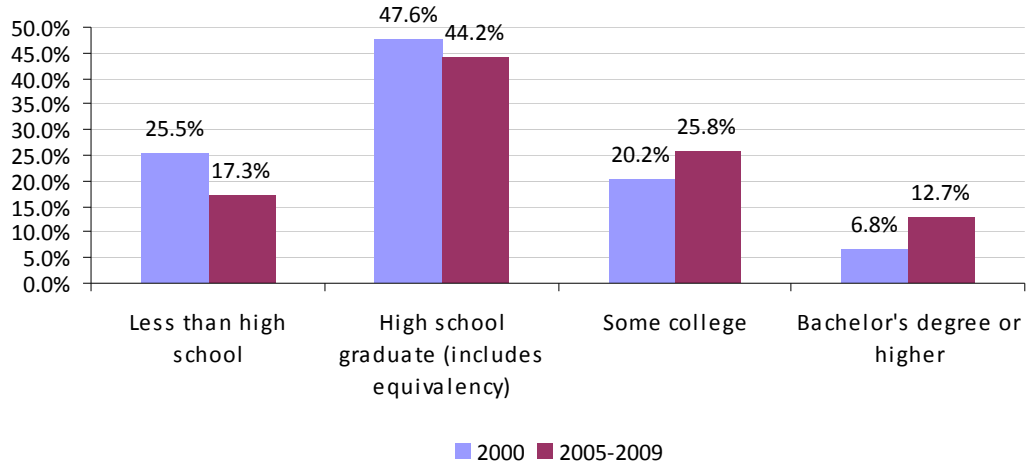
The Census Bureau's ACS data indicates that in real terms, the Town's median household income declined by 11 percent between 2000 and 2005-2009, as depicted in Table 3.20. In 2000 the Town's MHI had been 8.5 percent higher than that for Delaware County; for 2005-2009, it was 3 percent lower.

Table 3.20: Town of Tompkins Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Tompkins	$45,363	$40,378	-11.0%
Delaware County	$41,801	$41,656	-0.3%
New York	$55,879	$55,233	-1.2%

As in other towns in the region, the level of educational attainment in Tompkins rose between 2000 and 2005-2009, with 38.5 percent of all residents age 25-and-older having had at least some college experience. Nevertheless, even with this increase the percentage of all 25-and-older residents who have earned at least a bachelor's degree (12.7 percent) is still relatively low (Figure 3.13)

Figure 3.13: Town of Tompkins Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.1.5Town of Sanford

As shown in Table 3.21, the Town of Sanford's population declined slightly between 2000 and 2010, while the population in Broome County and the State increased slightly during that same period. In 2010, the Town's population density was 26.7 persons per square mile reflecting the

Town's primarily rural nature, which was much lower than the County's population density (284.2 persons per square mile).

Table 3.21: Town of Sanford Population, 2000 and 2010

Geography	2000	2010	% Change
Sanford	2,477	2,407	-2.8%
Broome County	200,534	200,600	0.03%
New York	18,976,457	19,378,102	2.1%

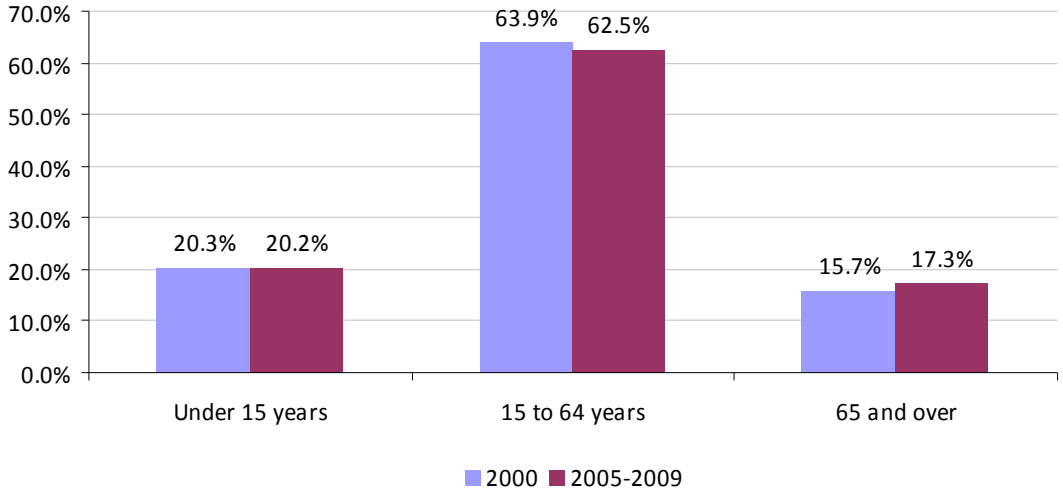
Despite the decline in its resident population, Sanford experienced growth in the number of housing units. This growth rate exceeded the rate that Broome County and the State experienced, as shown in Table 3.22. Seasonal and recreational housing accounted for 44 percent of housing units.

Table 3.22: Town of Sanford Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Sanford	1,545	1,739	12.6%
Broome County	88,816	90,563	2.0%
New York	7,679,307	8,108,103	5.6%

The median age was 40.9 in 2005-2009. As depicted in Figure 3.14, the Town of Sanford is aging slightly. Between 2000 and 2005-2009, the share of the Town's population over age 64 increased, while the percentage age 15 through 64 decreased.

Figure 3.14: Town of Sanford Age Distribution, 2000 and 2005-2009



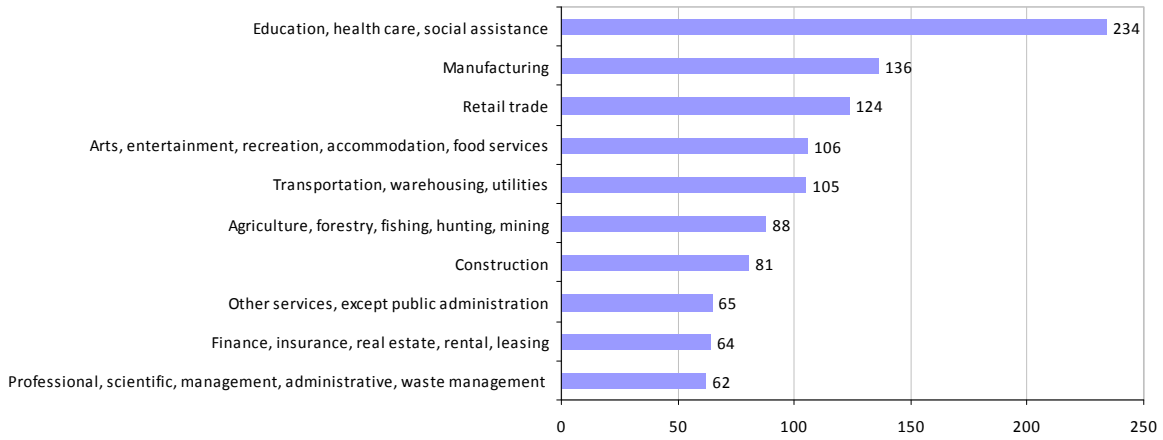
As shown in Table 3.23, resident employment in the Town of Sanford increased about 11 percent between 2000 and 2005-2009, which was a level that was greater than the State and Broome County.

Table 3.23: Town of Sanford Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Sanford	1,052	1,168	11.0%
Broome County	91,340	91,237	-0.1%
New York	8,382,988	9,102,596	8.6%

As demonstrated in Figure 3.15, in 2005-2009 about 20 percent of the Town of Sanford's employed residents worked in education, health care and social assistance. Manufacturing accounted for 12 percent, retail trade for 11 percent, and arts, recreation and hospitality for 9 percent.

Figure 3.15: Town of Sanford Resident Employment - Top Employment Sectors, 2005-2009



As shown in Table 3.24, unemployment in the Town of Sanford increased to more than 10 percent in 2005-2009 – higher than the unemployment rates in Broome County and the State during the same period, whereas in 2000 Sanford's unemployment rate was lower than the rates for the County and the State.

Table 3.24: Town of Sanford Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Sanford	3.7%	10.6%
Broome County	5.4%	6.1%
New York	7.1%	7.0%

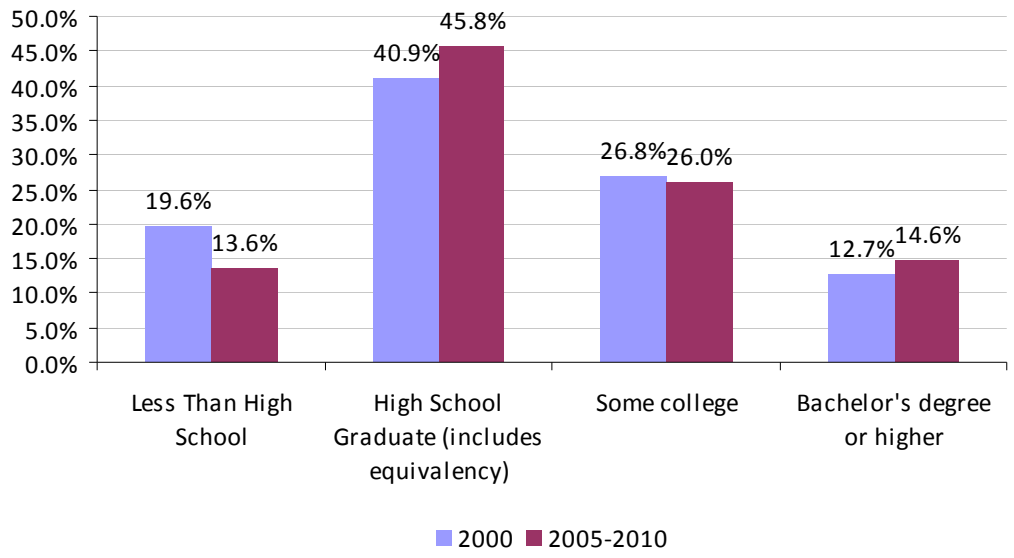
As Table 3.25 shows, the Town of Sanford experienced a drop in MHI greater than that which Broome County and State experienced during the same period. Sanford's MHI for 2005-2009 was 12 percent lower than Broome County's MHI and more than 30 percent below the State's.

Table 3.25: Town of Sanford Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Sanford	$42,893	$38,365	-10.6%
Broome County	$45,517	$43,467	-4.5%
New York	$55,879	$55,233	-1.2%

Figure 3.16 shows that the Town of Sanford made gains in the area of secondary and post-secondary educational attainment between 2000 and 2005-2009. The Town saw an increase in the share of residents aged 25-and-older with a high school diploma and in the percentage that had at least a bachelor's degree. Also, there were fewer people who had not completed high school.

Figure 3. 16: Town of Sanford Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.1.6Town of Walton

In 2010, the Town of Walton had a population of 5,576, making it the second largest town in Delaware County. As shown in Table 3.26, the Town of Walton's population declined by 0.6 percent between 2000 and 2010. The Town's low population density (57.6 persons per square mile) reflects its primarily rural character.

Table 3.26: Town of Walton Population, 2000 and 2010

Geography	2000	2010	% Change
Walton	5,607	5,576	-0.6%
Delaware County	48,040	47,980	-0.1%
New York	18,976,457	19,378,102	2.1%

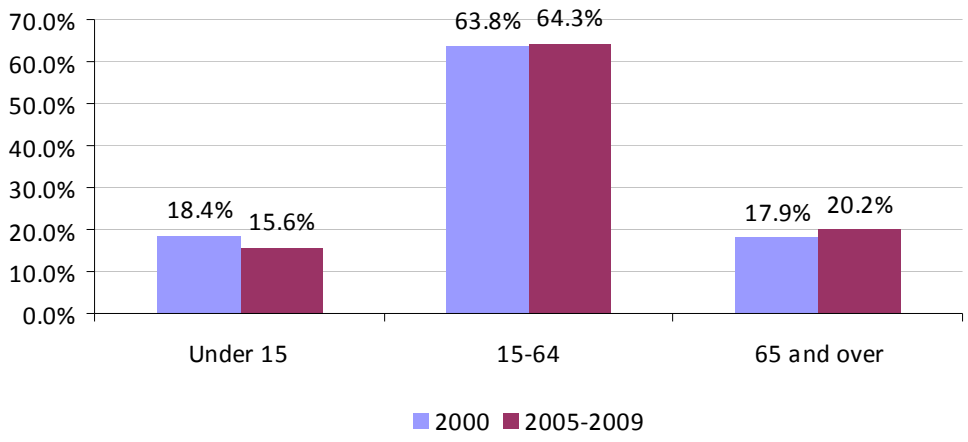
Between 2000 and 2010, as shown in Table 3.27, the Town's housing stock grew by 5 percent, to 3,106 units. In 2010, 14.5 percent of all units in the Town were for seasonal or recreational use – lower than the percentage of such units in many other towns in the region.

Table 3.27: Town of Walton Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Walton	2,958	3,106	5.0%
Delaware County	28,943	31,222	7.9%
New York	7,679,307	8,108,103	5.6%

The median age of Walton residents during 2005-2009 was 44.7 – slightly higher than the median age in 2000 which was 41.6. Between 2000 and 2009, the share of the Town of Walton's population under the age of 15 declined, while, during the same period, the share of the Town's population aged 65 and over increased, as shown in Figure 3.17.

Figure 3.17: Town of Walton Age Distribution, 2000 and 2005-2009



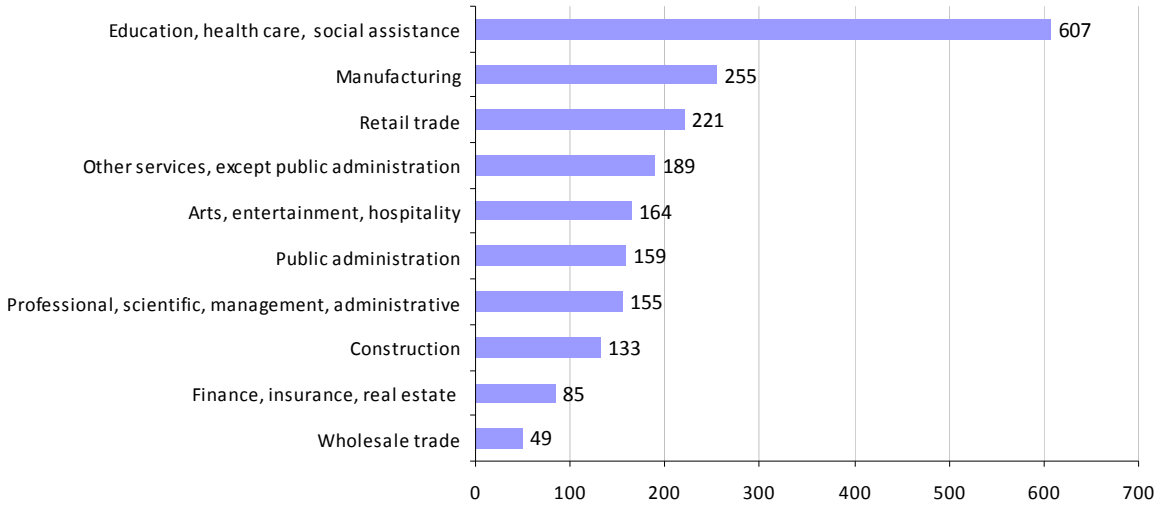
According to ACS data, as shown in Table 3.28, the number of employed Walton residents during the years 2005 through 2009 averaged 2,106 – a decline of 18.9 percent from the level reported in the 2000 census. This unusually steep decline may in part reflect the effects of severe flooding that occurred in Walton in 2006.

Table 3.28: Town of Walton Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Walton	2,596	2,106	-18.9%
Delaware County	20,840	21,111	1.3%
New York	8,382,988	9,102,596	8.6%

As shown in Figure 3.18, the education, health and social assistance sector accounted for about 29 percent of all jobs held by Walton residents in 2005-2009; manufacturing accounted for 12 percent; and retail trade accounted for nearly 11 percent.

Figure 3.18: Town of Walton Resident Employment - Top Employment Sectors, 2005-2009



As shown in Table 3.29, the unemployment rate among Walton residents averaged 10.2 percent between 2005 and 2009 – a sharp increase from the 5.4 percent rate reported in 2000, it is clear from data on resident employment and unemployment that that the employment prospects of Walton residents had deteriorated significantly even before the full effect recession had been felt.

Table 3.29: Town of Walton Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Walton	5.4%	10.2%
Delaware County	6.2%	7.1%
New York	7.1%	7.0%

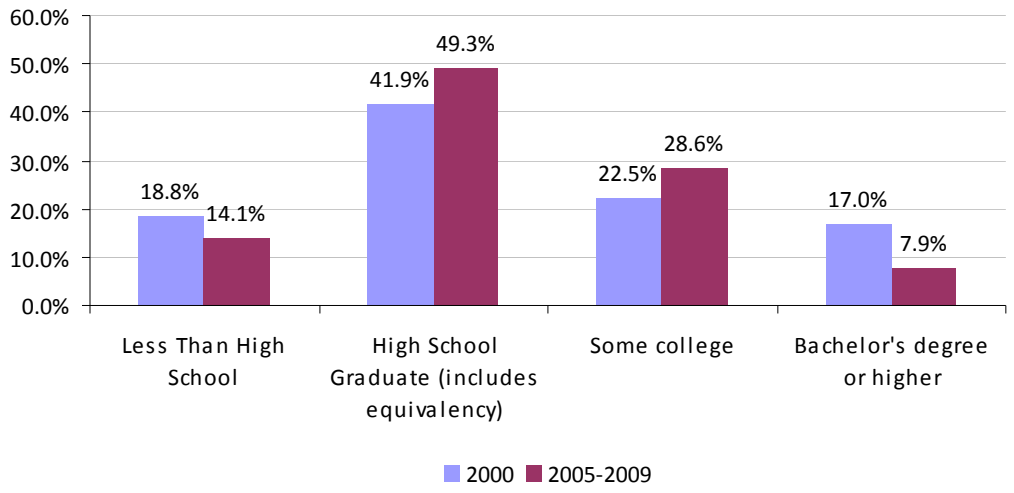
Consistent with the deterioration of the job market for Walton residents, the Town's MHI – already well below the County-wide and State-wide MHI as of 2000 – fell even further. Walton's MHI for 2005-2009 was 84 percent of the MHI for Delaware County and only 63 percent of the State MHI (Table 3.30).

Table 3.30: Town of Walton Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Walton	$39,340	$35,000	-11.0%
Delaware County	$41,801	$41,656	-0.3%
New York	$55,879	$55,233	-1.2%

With respect to educational attainment, ACS data for 2005-2009 (Figure 3.19) indicates that Walton is characterized by an unusual mix of strengths and weaknesses. Only 14.1 percent of all residents age 25-and-older lack a high school diploma; and about 78 percent have either a high school diploma or some education beyond high school. But only 7.9 percent of all 25-and-older Walton residents have at least a bachelor's degree.

Figure 3. 19: Town of Walton Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.2 Pepacton Development

This section focuses on socioeconomic trends of four towns in the vicinity of the Pepacton Development: (1) Andes, (2) Colchester, and (3) Hamden in Delaware County; and (4) Rockland in Sullivan County.

3.3.2.1Town of Andes

As Table 3.31 shows, the population of the Town of Andes in 2010 was 1,301 – a decline of 4.1 percent from 2000. Population density was 12.0 persons per square mile, which reflects the Town's extremely rural character.

Table 3.31: Town of Andes Population, 2000 and 2010

Geography	2000	2010	% Change
Andes	1,357	1,301	-4.1%
Delaware County	48,040	47,980	-0.1%
New York	18,976,457	19,378,102	2.1%

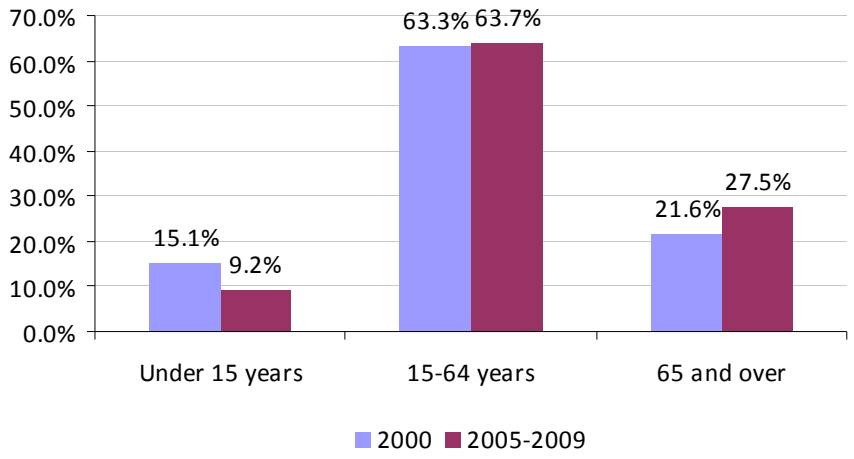
Despite the decline in the Town's resident population noted above, the number of housing units in Andes (as shown in Table 3.32) increased by about 10 percent between 2000 and 2010. This may be due in part to the large number of seasonal and recreational units in Andes. In 2010, such units accounted for 52.4 percent of the Town's housing stock; and between 2000 and 2010 they accounted for 88 percent of the total increase in housing units during that period.

Table 3.32: Town of Andes Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Andes	1,327	1,459	9.9%
Delaware County	28,943	31,222	7.9%
New York	7,679,307	8,108,103	5.6%

For 2005-2009, the median age of Andes residents was 52.3 – significantly older than the median age of 47.8 reported in the 2000 census, and among the oldest in the State. The share of the population below age 15 fell to just 9.2 percent, while those 65-and-older rose to 27.5 percent (Figure 3.20).

Figure 3.20: Town of Andes Age Distribution, 2000 and 2005-2009



ACS data indicates that between 2000 and 2005-2009, the number of employed Andes residents declined by more than 10 percent (Table 3.33). This trend may, in part, reflect the overall decline in the Town's population, as well as the relatively large share of the Town's population that is over 65.

Table 3.33: Town of Andes Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Andes	565	507	-10.3%
Delaware County	20,840	21,111	1.3%
New York	8,382,988	9,102,596	8.6%

As Figure 3.21 shows, nearly 26 percent of the Town's employed residents work in education, health and social assistance. The arts, entertainment and hospitality account for 15 percent – a figure that in part reflects the Town's large second-home sector, construction accounted for 12 percent and manufacturing accounted for 11 percent.

Figure 3.21: Town of Andes Resident Employment - Top Employment Sectors, 2005-2009

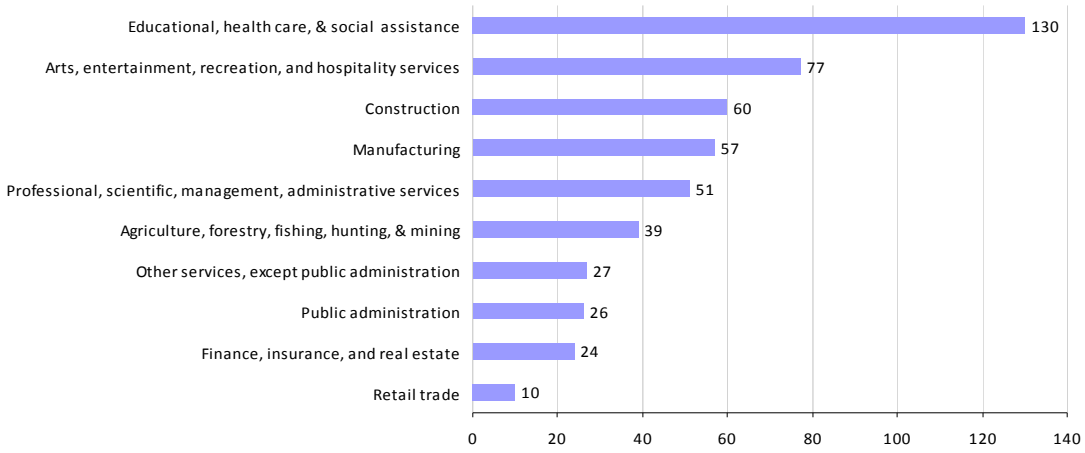


Table 3.34 shows that the unemployment rate for the Town of Andes – which had been very low in 2000 – rose sharply in the latter part of the decade; but for 2005-2009, was still only slightly higher than the unemployment rates for Delaware County and New York State.

Table 3.34: Town of Andes Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Andes	3.1%	7.3%
Delaware County	6.2%	7.1%
New York	7.1%	7.0%

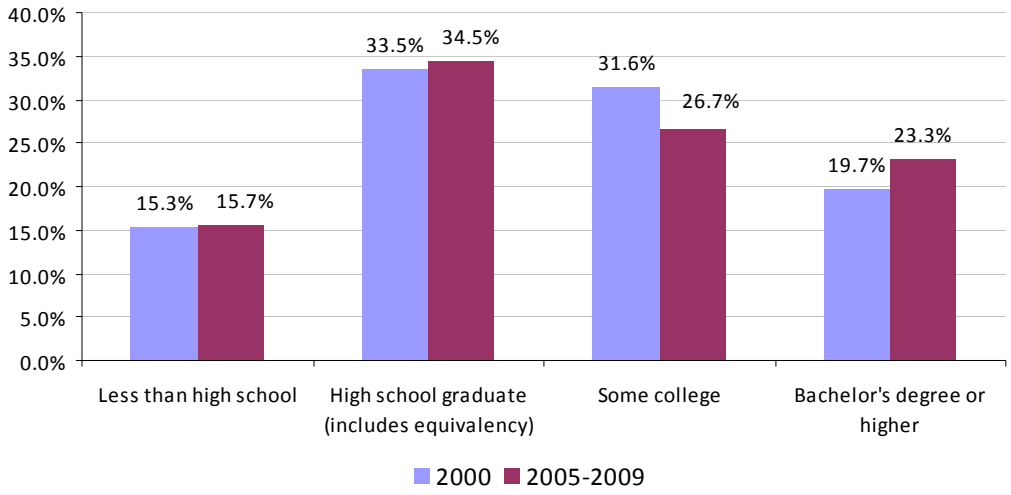
As shown in Table 3.35, the MHI for the Town of Andes was 8 percent higher than the MHI for Delaware County for 2005-2009, but still only 81 percent of the State-wide MHI. The Town's MHI declined by about 0.5 percent in real terms between 2000 and 2005-2009.

Table 3.35: Town of Andes Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Andes	$45,224	$45,000	-0.5%
Delaware County	$41,801	$41,656	-0.3%
New York	$55,879	$55,233	-1.2%

As demonstrated by Figure 3.22, the educational attainment rate for the Town of Andes' population increased for the post-secondary education categories of bachelor's and advanced degrees between 2000 and 2009. Additionally there were a higher percentage of people who were high school graduates.

Figure 3.22: Town of Andes Educational Attainment (population aged 25 and over), 2000 and 2005-2009



3.3.2.2 Town of Colchester

As Table 3.36 shows, the population of the Town of Colchester in 2010 was 2,077, an increase of 1.7 percent since 2000. Population density was 15.19 persons per square mile, making Colchester one of the lower density towns in Delaware County.

Table 3.36: Town of Colchester, 2000 and 2010

Geography	2000	2010	% Change
Colchester	2,042	2,077	1.7%
Delaware County	48,040	47,980	-0.1%
New York	18,976,457	19,378,102	2.1%

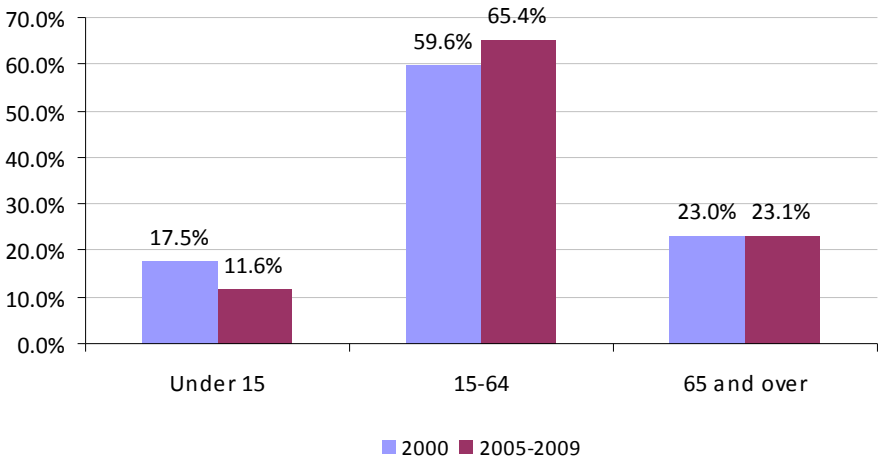
As shown in Table 3.37, the number of housing units in the Town of Colchester increased by 14.8 percent between 2000 and 2010. Seasonal and recreational units accounted for 45 percent of the Town's housing stock in 2010 – and for 79 percent of the total increase in housing units between 2000 and 2010.

Table 3.37: Town of Colchester Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Andes	1,327	1,459	9.9%
Delaware County	28,943	31,222	7.9%
New York	7,679,307	8,108,103	5.6%

As shown in Figure 3.23, between 2000 and 2005-2009 the share of Colchester's population below age 15 declined by nearly 6 percentage points, while those age 15 to 64 increased by a similar amount. Colchester's median age in 2005-2009 was 48.7, which was a about a four year increase from the median age in 2000.

Figure 3.23: Town of Colchester Age Distribution, 2000 and 2005-2009



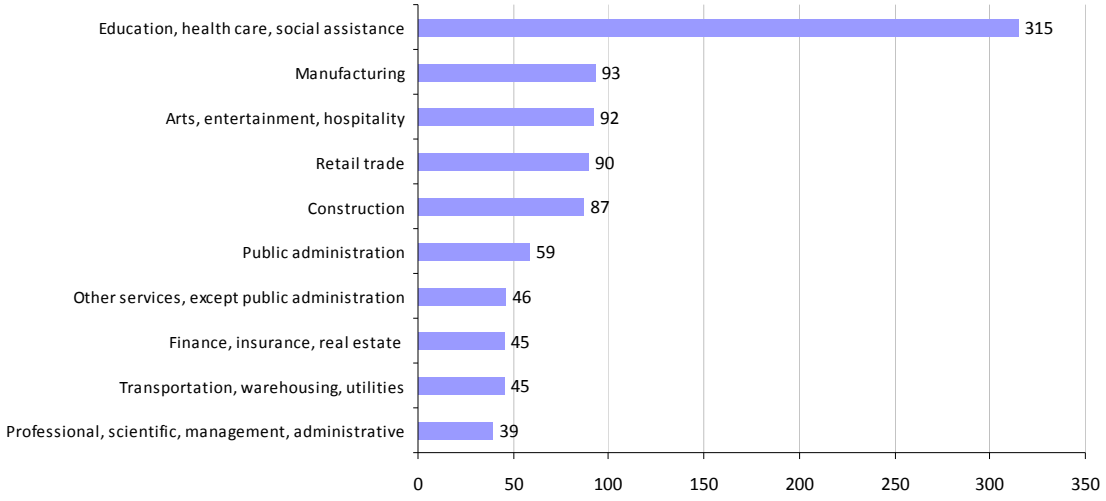
Between 2000 and 2005-2009 (according to ACS data), the number of employed residents of Colchester rose by nearly 22 percent, to 955 (Table 3.38)

Table 3.38: Town of Colchester Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	Growth
Colchester	784	955	21.8%
Delaware County	20,840	21,111	1.3%
New York	8,382,988	9,102,596	8.6%

As Figure 3.24 shows, in 2005-2009 approximately 33 percent of the Town of Colchester's employed residents worked in education, health and social assistance; nearly 10 percent each in manufacturing and arts, entertainment and hospitality; and 9 percent in retail trade.

Figure 3.24: Town of Colchester Resident Employment - Top Employment Sectors, 2005-2009



Consistent with the increase in resident employment, the Town's unemployment rate fell from 7.4 percent in 2000 to 6.6 percent in 2005-2009, as shown in Table 3.39.

Table 3.39: Town of Colchester Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Colchester	7.4%	6.6%
Delaware County	6.2%	7.1%
New York	7.1%	7.0%

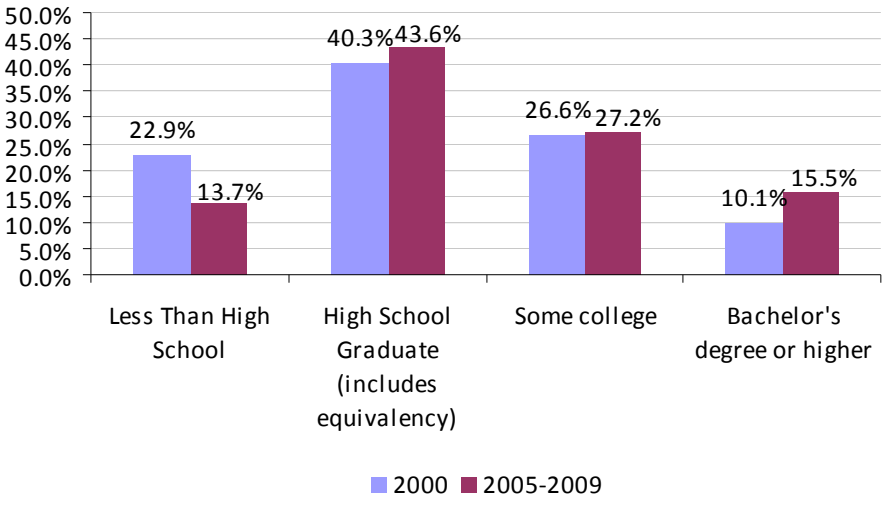
As shown in Table 3.40, the MHI for the Town of Colchester in 2005-2009 increased slightly from 2000, and virtually identical to the median income for Delaware County. The Town's MHI for 2005-2009 was about 25 percent below the MHI for New York State.

Table 3.40: Town of Colchester Median Household Income, 2000 and 2009 (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Colchester	$41,397	$41,696	0.7%
Delaware County	$41,801	$41,656	-0.3%
New York	$55,879	$55,233	-1.2%

As demonstrated by Figure 3.25, the Town of Colchester made gains in the level of secondary and post-secondary educational attainment, with the number of high school graduates, bachelor's and advanced degree earners increasing between 2000 and 2009. At the same time, the number of people with less than a high school education declined moderately.

Figure 3.25: Town of Colchester Educational Attainment (population aged 25 and over), 2000 and 2005-2009



3.3.2.3 Town of Hamden

As depicted in Table 3.41, the population of the Town of Hamden increased by 3.4 percent between 2000 and 2010, which was slightly higher than the rate that the State experienced during

the same period. The Town's population density was 22.1 persons per square mile, which was in line with many of the other towns in Delaware County.

Table 3.41: Town of Hamden Population, 2000 and 2010

Geography	2000	2010	% Change
Hamden	1,280	1,323	3.4%
Delaware County	48,040	47,980	-0.1%
New York	18,976,457	19,378,102	2.1%

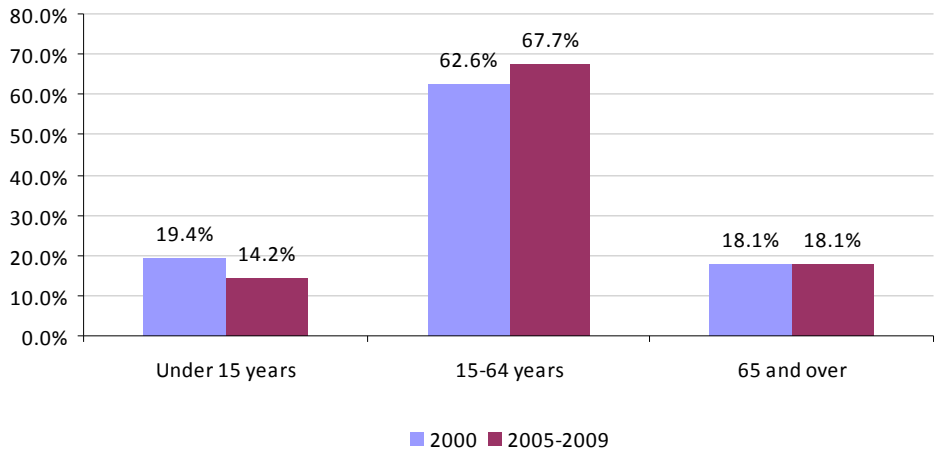
Between 2000 and 2010, the total number of housing units grew more slowly in the Town of Hamden than in Delaware County or in the State, as shown in Table 3.42.

Table 3.42: Town of Hamden Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Hamden	902	946	4.9%
Delaware County	28,943	31,222	7.9%
New York	7,679,307	8,108,103	5.6%

As depicted in Figure 3.26, the under-15 population of Hamden declined between 2000 and 2005-2009 as a share of total population, while the population age 15 through 64 increased in relative terms. The Town's median age has also increased slightly from 43 in 2000 to 45.4 in 2010.

Figure 3.26: Town of Hamden Age Distribution, 2000 and 2005-2009



As shown in Table 3.43, there was a slight increase in resident employment in the Town of Hamden, which almost matched the rate of change in Delaware County between 2000 and 2005-2009, unlike for the State which experienced an 8.6 percent increase in employment.

Table 3.43: Town of Hamden Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Hamden	604	614	1.7%
Delaware County	20,840	21,111	1.3%
New York	8,382,988	9,102,596	8.6%

As Figure 3.27 demonstrates, in 2005-2009 approximately 24 percent of all employed residents of Hamden work in education, health care and social assistance; 14 percent in retail trade; 11 percent in manufacturing; and nearly 10 percent in construction.

Figure 3.27: Town of Hamden Resident Employment - Top Employment Sectors, 2005-2009

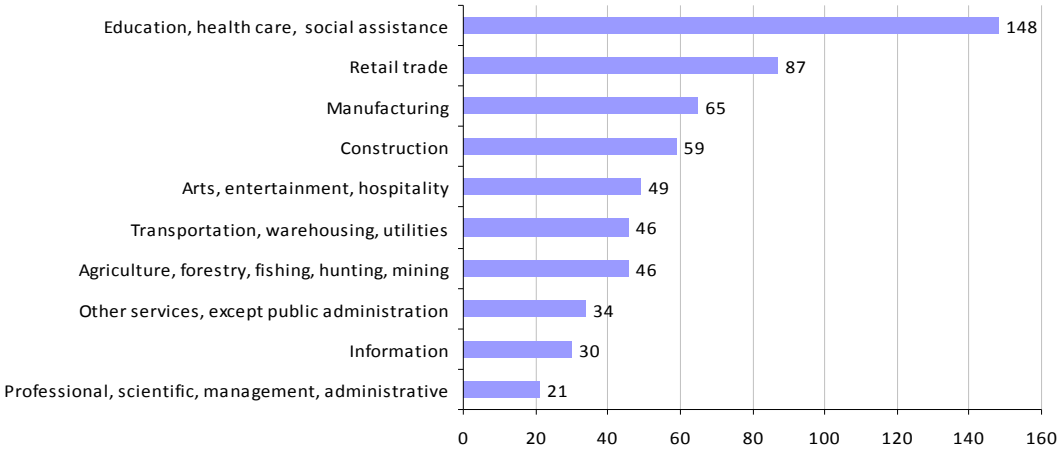


Table 3.44 shows that the unemployment rate for the Town of Hamden increased to 5.3 percent in 2005-2009 – significantly lower than the rates for the County and the State.

Table 3.44: Town of Hamden Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Hamden	3.1%	5.3%
Delaware County	6.2%	7.1%
New York	7.1%	7.0%

Table 3.45 shows that the MHI in the Town of Hamden fell by about 22 percent in real terms between 2000 and 2005-2009. The Town's MHI in 2005-2009 was 14 percent below the MHI for the County and 36 percent below the MHI for the State.

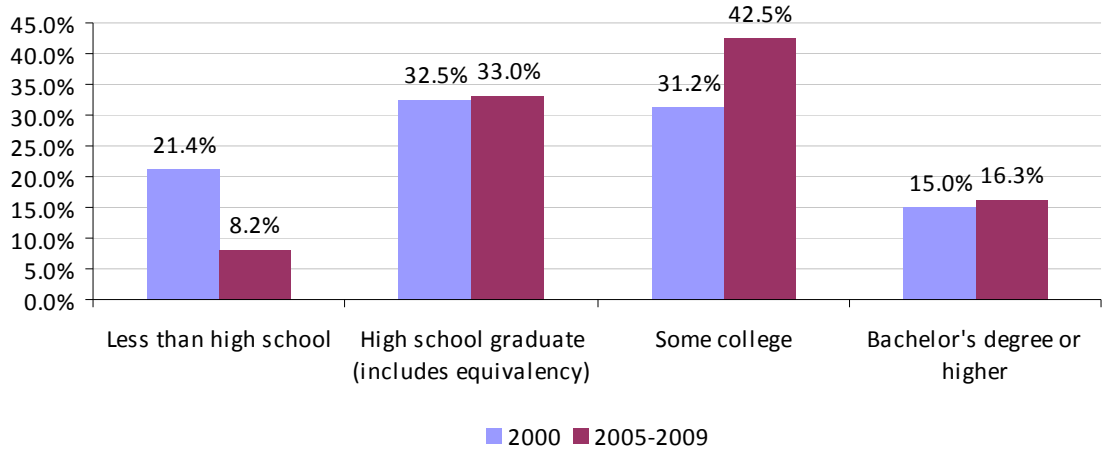
Table 3.45: Town of Hamden Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Hamden	$45,474	$35,625	-21.7%
Delaware County	$41,801	$41,656	-0.3%
New York	$55,879	$55,233	-1.2%

As Figure 3.28 shows, between 2000 and 2005-2009, the Town of Hamden made gains in the area of educational attainment. The percentage of all residents age 25-and-older who had not

completed high school dropped sharply, while the percentage of residents in this age group who had at least some college-level education rose correspondingly. The percentage of 25-and-older residents who have bachelor's or higher degrees nevertheless remained below the average for the State.

Figure 3.28: Town of Hamden Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.2.4 Town of Rockland

Table 3.46 shows that the population of the Town of Rockland decreased by a little fewer than 4 percent between 2000 and 2009, which was in contrast to the population growth that Sullivan County and the State experienced during the same period. Population density was 40.1 persons per square mile, which reflects its primarily rural character.

Table 3.46: Town of Rockland Population, 2000 and 2010

Geography	2000	2010	% Change
Rockland	3,915	3,775	-3.6%
Sullivan County	73,965	77,547	4.8%
New York	18,976,457	19,378,102	2.1%

As depicted in Table 3.47, the number of housing units in the Town of Rockland grew by 11.2 percent between 2000 and 2010, exceeding the rate of growth in Sullivan County and the State during the same period. There was significant growth in the number of seasonal and recreational units, which accounted for 34 percent of housing in the Town of Rockland in 2010, representing a 30 percent increase since 2000.

Table 3.47: Town of Rockland Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Rockland	2,477	2,755	11.2%
Sullivan County	44,730	49,186	10.0%
New York	7,679,307	8,108,103	5.6%

As demonstrated in Figure 3.29, the population of the Town of Rockland below age 15 declined between 2000 and 2005-2009, while the working-age and older population increased their share of the total. As a result of these changes, the Town's median age increased from 40.4 in 2000 to 45.6 in 2005-2009.

Figure 3.29: Town of Rockland Age Distribution, 2000 and 2005-2009

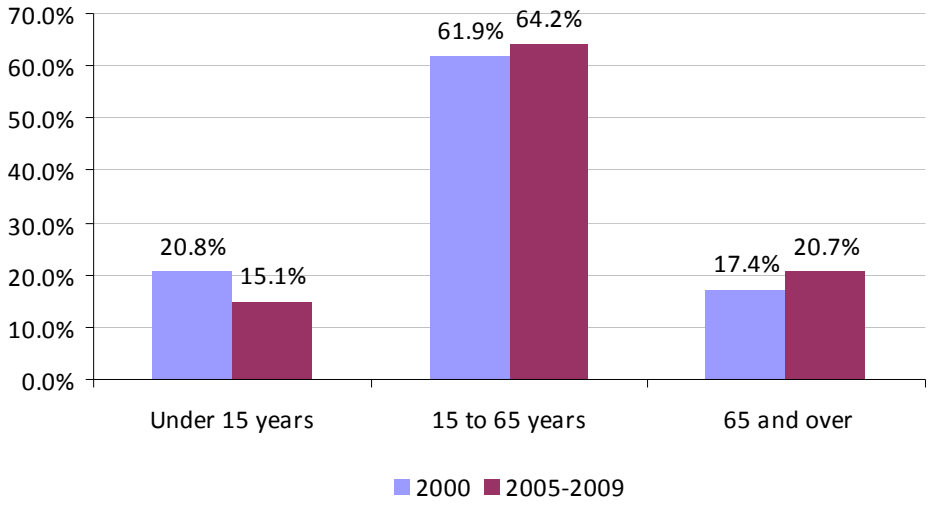


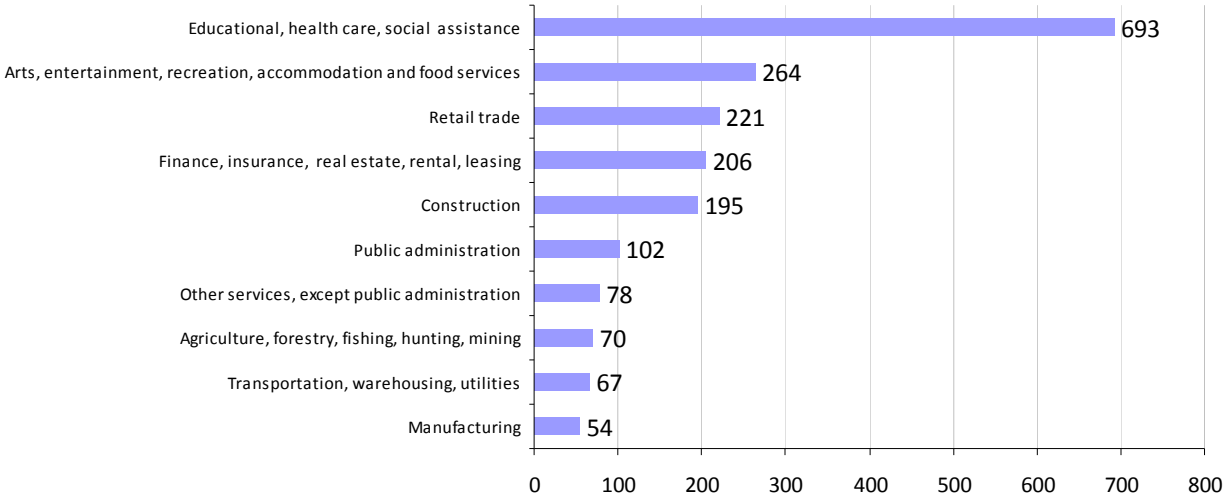
Table 3.48 shows that resident employment for the Town of Rockland increased between 2000 and 2005-2009 by almost 28 percent, which was almost double the rate of employment growth in Sullivan County and triple the growth rate experienced in the State during the same period.

Table 3.48: Town of Rockland Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Rockland	1,602	2,048	27.8%
Sullivan County	30,244	34,440	13.9%
New York	8,382,988	9,102,596	8.6%

Figure 3.30 shows that more than one-third of all employed Rockland residents work in education, health care and social assistance. Nearly 13 percent work in the arts, recreation and hospitality; and nearly 11 percent in retail trade. In contrast to the pattern found in much of Delaware County, the manufacturing sector accounts for less than 3 percent of resident employment in Rockland, which is located in Sullivan County.

Figure 3.30: Town of Rockland Resident Employment - Top Employment Sectors, 2005-2009



As depicted in Table 3.49, the unemployment rate for the Town of Rockland increased between 2000 and 2005-2009, growing to a rate that exceeded the rates for Sullivan County and for the State.

Table 3.49: Town of Rockland Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Rockland	5.4%	7.7%
Sullivan County	9.2%	6.5%
New York	7.1%	7.0%

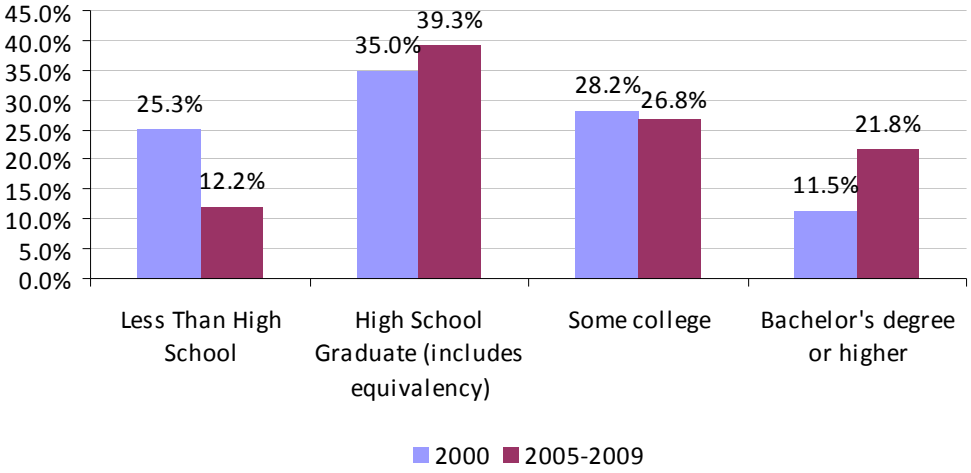
As shown in Table 3.50, the MHI for the Town of Rockland grew strongly in real terms between 2000 and 2005-2009, with growth exceeding that for both Sullivan County and the State. The Town's 2005-2009 MHI was about 91 percent of the State's.

Table 3.50: Town of Rockland Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Rockland	$42,339	$50,184	16.4%
Sullivan County	$47,644	$48,586	2.0%
New York	$55,879	$55,233	-1.2%

As shown in Figure 3.31 the Town of Rockland experienced significant gains in the areas of secondary and post-secondary educational attainment between 2000 and 2009, as reflected by a sharp drop in the percentage of all residents age 25-and-older who have not completed high school, and a sharp increase in the percentage of all residents in this age group who have a bachelor's degree.

Figure 3.31: Town of Rockland Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.3 Neversink Development

This section describes socioeconomic conditions and trends in five towns assessed in connection with the Neversink Development: (1) Neversink, (2) Fallsburg, and (3) Liberty in Sullivan County; and (4) Denning, and (5) Wawarsing in Ulster County.

3.3.3.1 Town of Denning

Table 3.51 shows that the population of the Town of Denning increased by 6.6 percent between 2000 and 2010 – although with just 551 residents in 2010 the Town is still very small. Population density in the Town of Denning was quite low, at a rate of 5.2 persons per square mile in 2010 – due in part to the fact that much of the Town's land area consists of State, City or privately-owned protected land.

Table 3.51: Town of Denning Population, 2000 and 2010

Geography	2000	2010	% Change
Denning	517	551	6.6%
Ulster County	177,749	182,493	2.7%
New York	18,976,457	19,378,102	2.1%

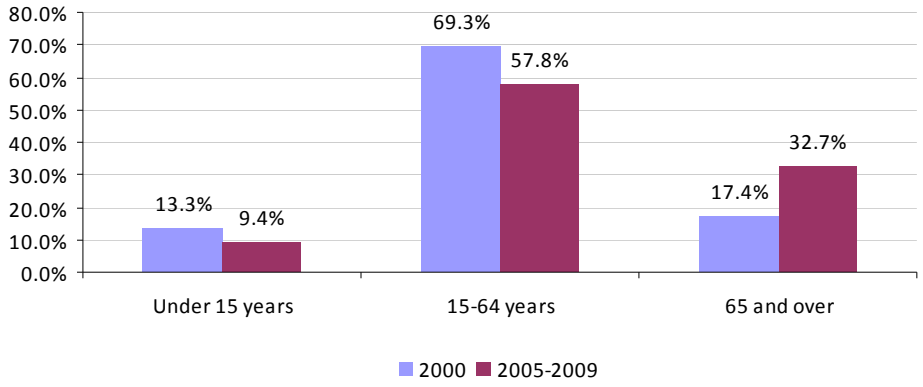
As depicted in Table 3.52, the number of total housing units in the Town of Denning rose by 2.5 percent between 2000 and 2010.

Table 3.52: Town of Denning Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Denning	518	531	2.5%
Ulster County	77,656	83,638	7.7%
New York	7,679,307	8,108,103	5.6%

For 2005-2009, the median age in Denning was 57.1, a sharp increase from 42.7 in 2000, which was considerably higher than Ulster County's median age of 40.6. Figure 3.32 shows a sharp shift in the Town's age mix during this period, with the under-15 population falling to a relatively low 9.4 percent of the total, while those age 65-and-older rose to a very large 32.7 percent of the total.

Figure 3.32: Town of Denning Age Distribution, 2000 and 2010



Resident employment in the Town of Denning decreased by almost 15 percent between 2000 and 2005-2009, as shown in Table 3.53, while resident employment in both Ulster County and the State rose by more than 8 percent. The decline in the number of employed residents no doubt reflects at least, in part, the growth of the Town's 65-and-older population.

Table 3.53: Town of Denning Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Denning	247	211	-14.6%
Ulster County	83,748	90,507	8.1%
New York	8,382,988	9,102,596	8.6%

As Figure 3.33 shows, approximately 25 percent of all employed residents of the Town of Denning worked in the public sector in 2005-2009.

Figure 3.33: Town of Denning Resident Employment - Top Employment Sectors, 2005-2009

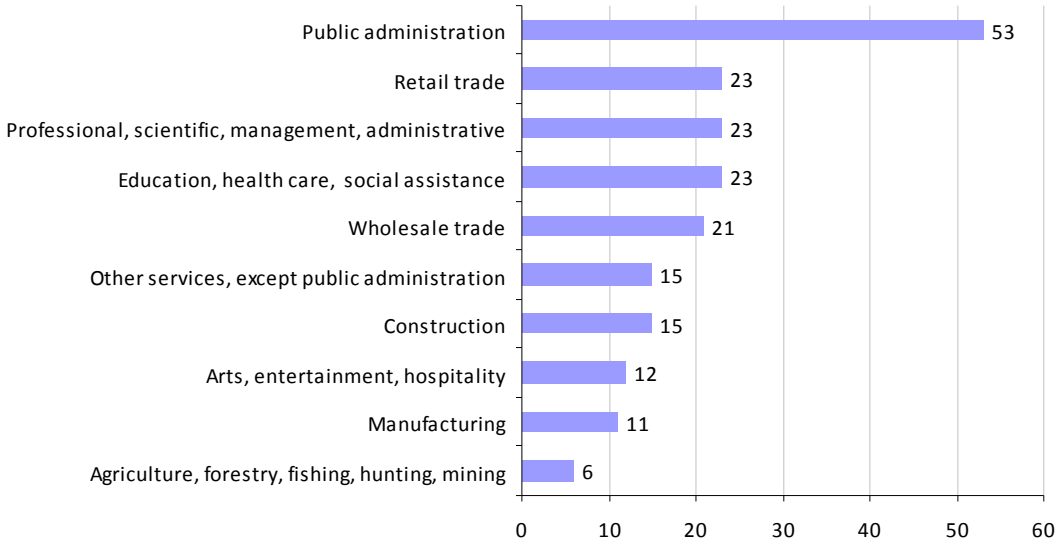


Table 3.54 shows that the unemployment rate for the Town of Denning more than doubled, to 6.6 percent, between 2000 and 2005-2009. The Town's unemployment rate in 2005-2009 was about a percentage point higher than the rate for Ulster County and slightly less than in the Statewide rate.

Table 3.54: Town of Denning Unemployment Rate, 2000 and 2010

Geography	2000	2005-2009
Denning	2.8%	6.6%
Ulster County	6.3%	5.6%
New York	7.1%	7.0%

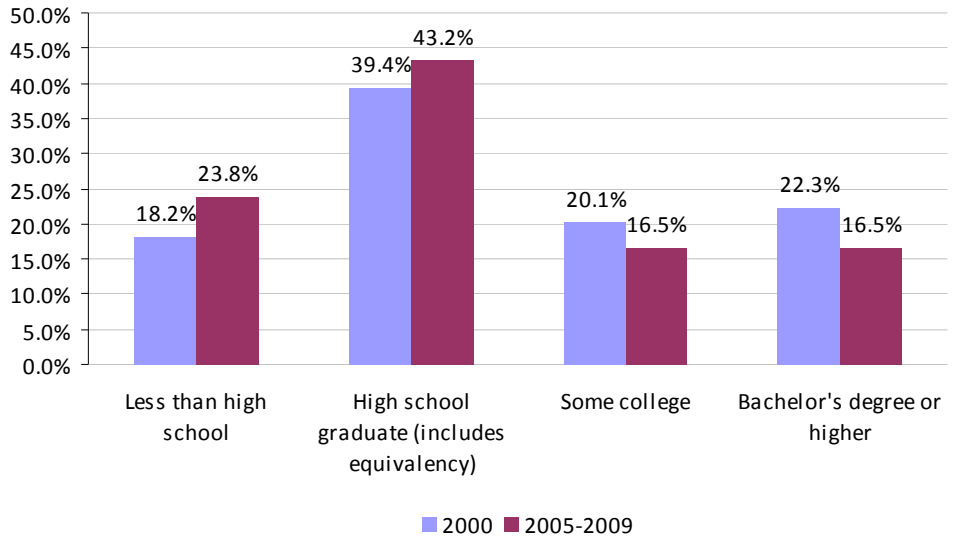
The MHI for the Town of Denning dropped by 9.2 percent between 2000 and 2005-2009, as shown in Table 3.55. This contraction was particularly notable in light of the increase recorded by Ulster County as a whole during the same period. It may reflect the decline in the number of employed residents, and the growth of the Town's older population.

Table 3.55: Town of Denning Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Denning	$52,659	$47,833	-9.2%
Ulster County	$54,795	$57,485	4.9%
New York	$55,879	$55,233	-1.2%

In contrast to most other towns in the region, ACS data indicates (Figure 3.34) that educational attainment in the Town of Denning declined between 2000 and 2005-2009, as the percentage of those age 25-and-older who have not completed high school increased, and the percentage with at least some college-level education declined.

Figure 3.34: Town of Denning Educational Attainment (population 25 and over), 2000 and 2005-2009



3.3.3.2 Town of Fallsburg

In 2010, as shown in Table 3.56, the population of Fallsburg was 12,780 – an increase of 5.3 percent from its population in 2000. At a rate of 165.8 persons per square mile, the Town of Fallsburg had a relatively high population density compared to the other towns profiled in this report.

Table 3.56: Town of Fallsburg Population, 2000 and 2010

Geography	2000	2010	% Change
Fallsburg	12,223	12,870	5.3%
Sullivan County	73,965	77,547	4.8%
New York	18,976,457	19,378,102	2.1%

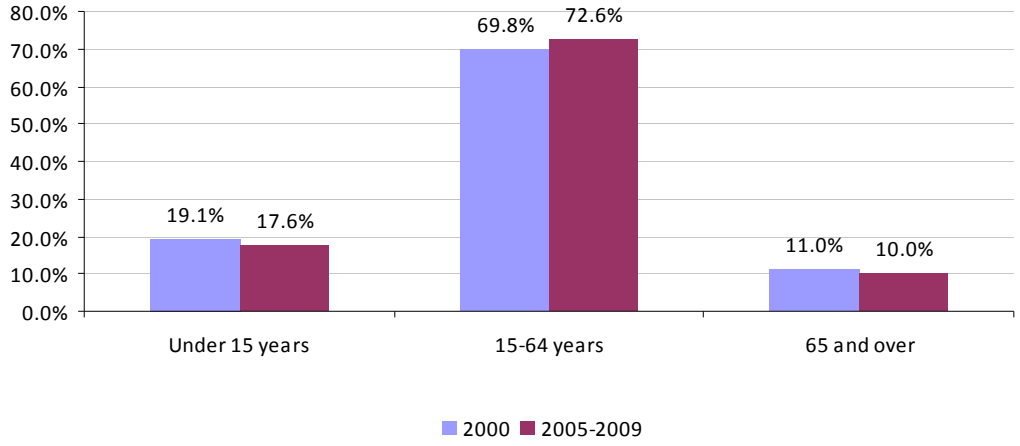
Since 2000, the Town of Fallsburg has experienced very strong growth in its housing stock, with the total number of units increasing by more than 28 percent between 2000 and 2010 (Table 3.57). This growth was driven primarily by growth in seasonal and recreational units. The number of such units in Fallsburg increased by nearly 58 percent over the course of the decade; and they accounted for more than two-thirds of the Town's total increase in housing units. As of 2010, seasonal and recreational units accounted for nearly 41 percent of the Town's housing stock.

Table 3.57: Town of Fallsburg Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Fallsburg	6,621	8,497	28.3%
Sullivan County	44,730	49,186	10.0%
New York	7,679,307	8,108,103	5.6%

As Figure 3.35 shows, the Town of Fallsburg has experienced modest change in terms of its age mix. Between 2000 and 2005-2009, the share of the population in the Town of Fallsburg under the age of 15 declined slightly, while the 15-64 age group increased to an unusually high 72.6 percent of the total population. The median age increased to about 40 years old, which represented an increase of approximately 6.2 percent from its 2000 level.

Figure 3.35: Town of Fallsburg Age Distribution, 2000 and 2005-2009



As shown in Table 3.58, the number of employed Fallsburg residents grew significantly between 2000 and 2005-2009, experiencing an increase of approximately 22 percent. This employment growth rate was greater than that experienced in Sullivan County and significantly more than the State's growth rate during this period.

Table 3.58: Town of Fallsburg Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Fallsburg	4,318	5,256	21.7%
Sullivan County	30,244	34,440	13.9%
New York	8,382,988	9,102,596	8.6%

As Figure 3.36 shows, more than 35 percent of all employed residents of the Town of Fallsburg worked in education, health and social assistance in 2005-2009. The miscellaneous services sector accounted for about 14 percent; arts, entertainment and hospitality accounted for nearly 8 percent; and retail trade accounted for 7 percent.

Figure 3.36: Town of Fallsburg Resident Employment - Top Employment Sectors, 2005-2009

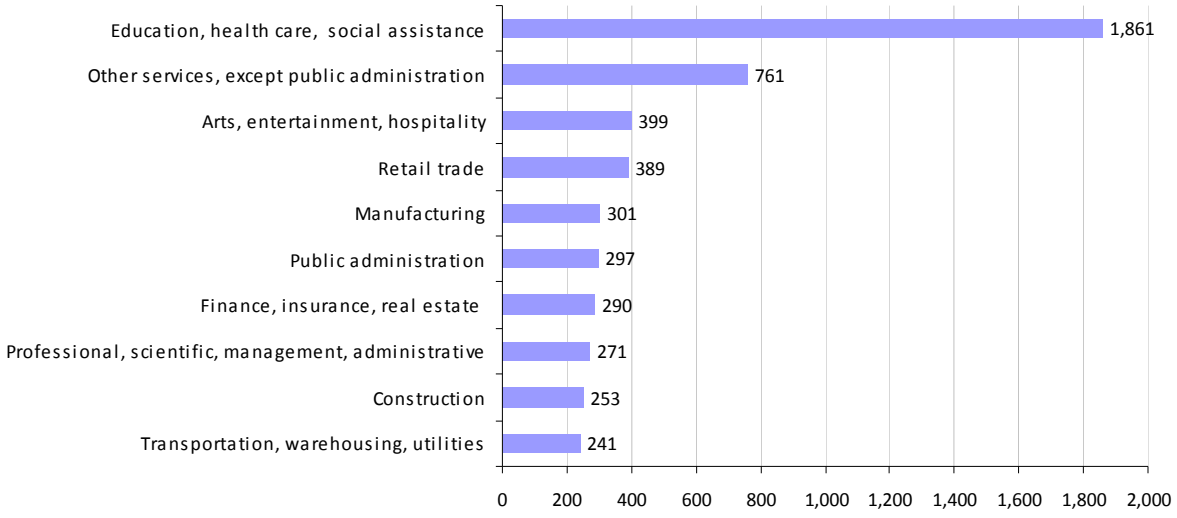


Table 3.59 shows that the unemployment rate for the Town of Fallsburg declined by 1.5 percentage points between 2000 and 2005-2009, which was slightly less than the rate for Sullivan County as a whole.

Table 3.59: Town of Fallsburg Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Fallsburg	8.8%	7.3%
Sullivan County	9.2%	6.5%
New York	7.1%	7.0%

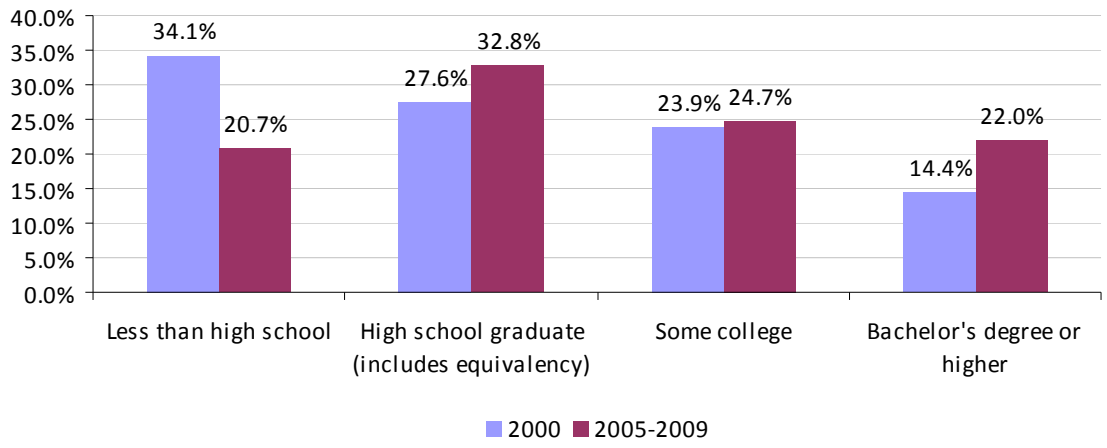
As shown in Table 3.60, the Town's MHI dropped by 3.2 percent between 2000 and 2005-2009. This slight decrease was opposite the trend experienced by Sullivan County during this period, which experienced a slight increase in MHI, but was more than the decline in MHI experienced in the State.

Table 3.60: Town of Fallsburg Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Fallsburg	$42,542	$41,178	-3.2%
Sullivan County	$47,644	$48,586	2.0%
New York	$55,879	$55,233	-1.2%

As shown in Figure 3.37, between 2000 and 2005-2009 the Town of Fallsburg progressed significantly in the area of secondary and post-secondary educational attainment, with an increase in the percentage of those who were high school graduates, had college experience, or bachelor's degrees or higher.

Figure 3.37: Town of Fallsburg Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.3.3 Town of Liberty

In 2010, the population of the Town of Liberty, as shown in Table 3.61, was 9,885 – an increase of 2.5 percent since 2000. The Town's population grew somewhat more slowly during this period than that of Sullivan County as a whole. In 2010, the Town had a relatively high population density of 124.2 persons per square mile.

Table 3.61: Town of Liberty Population, 2000 and 2010

Geography	2000	2010	% Change
Liberty	9,644	9,885	2.5%
Sullivan County	73,965	77,547	4.8%
New York	18,976,457	19,378,102	2.1%

Between 2000 and 2010, the Town of Liberty experienced a modest increase in its housing stock, with a growth rate of nearly 2 percent during this period (Table 3.62). Slow growth in Liberty may, in part, be related to the Town's relatively small second-home sector; in 2010 fewer than 17 percent of its housing units were used for seasonal or recreational purposes.

Table 3.62: Town of Liberty Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Liberty	5,391	5,495	1.9%
Sullivan County	44,730	49,186	10.0%
New York	7,679,307	8,108,103	5.6%

As demonstrated by Figure 3.38, the Town of Liberty experienced relatively few changes in its age distribution. The population under 64 years old declined slightly and the population 65 and over increased nominally (less than a percent). Meanwhile, the median age rose slightly from 39.3 in 2000 to 41.7 in 2005-2009.

Figure 3.38: Town of Liberty Age Distribution, 2000 and 2005-2009

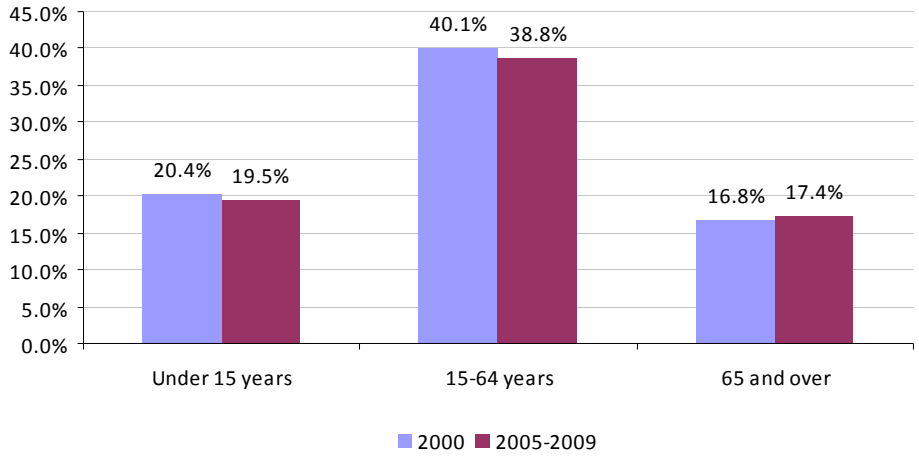


Table 3.63 shows that resident employment for the Town of Liberty increased by 9.6 percent between 2000 and 2005-2009 – not as fast as resident employment in Sullivan County as a whole, but faster than employment growth statewide.

Table 3.63: Town of Liberty Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Liberty	3,850	4,218	9.6%
Sullivan County	30,244	34,440	13.9%
New York	8,382,988	9,102,596	8.6%

As Figure 3.39 shows, nearly 30 percent of all employed residents of the Town of Liberty worked education, health and social assistance in 2005-2009. Nearly 11 percent were employed in retail trade; and a similar percentage in arts, entertainment and hospitality, reflecting the important role that the latter sector plays in Sullivan County's economy.

Figure 3.39: Town of Liberty Resident Employment - Top Employment Sectors, 2005-2009

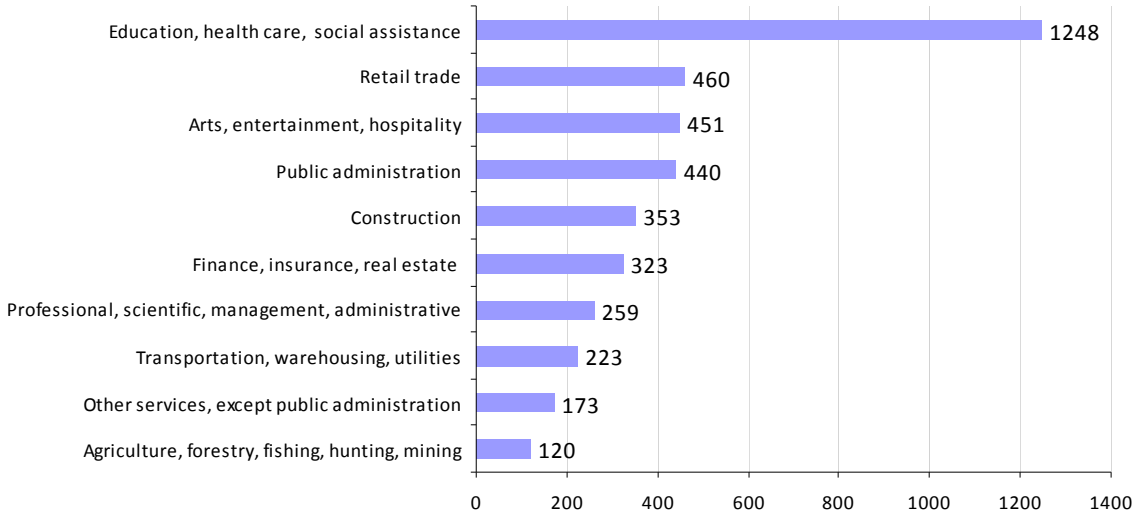


Table 3.64 shows that the unemployment rate for the Town of Liberty declined between 2000 and 2005-2009, consistent with the declining trend experienced in Sullivan County and the State during this period. However, the Town of Liberty's unemployment rate remained higher than in Sullivan County and the State.

Table 3.64: Town of Liberty Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Liberty	10.7%	8.6%
Sullivan County	9.2%	6.5%
New York	7.1%	7.0%

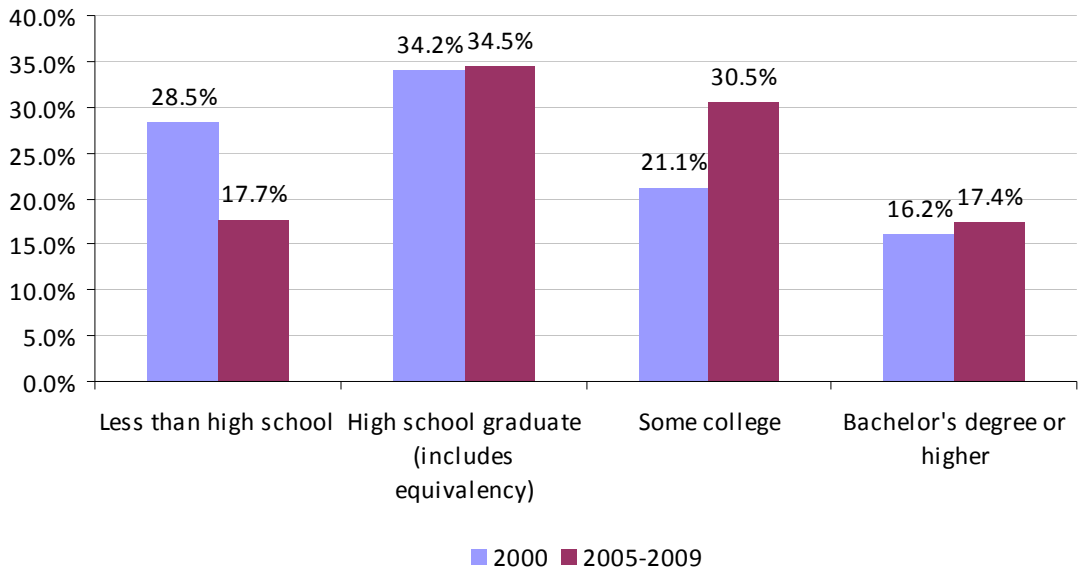
The MHI for the Town of Liberty increased by more than 18 percent in real terms between 2000 and 2005-2009 – far exceeding the increase in Sullivan County during this period, and contrasting sharply with the decline that occurred at the State level. Nevertheless, Liberty's MHI was still 12 percent below the MHI for New York State in 2005-2009 (Table 3.65).

Table 3.65: Town of Liberty Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Liberty	$41,236	$48,730	18.2%
Sullivan County	$47,644	$48,586	2.0%
New York	$55,879	$55,233	-1.2%

As shown in Figure 3.40, the Town of Liberty has experienced significant progress in the area of secondary and post-secondary educational attainment. Between 2000 and 2005-2009, the percentage of the Town's residents that were age 25-and-older who had not completed high school declined sharply, while the percentage of this age group with at least some college-level education increased.

Figure 3.40: Town of Liberty Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.3.4 Town of Neversink

At 3,557, as Table 3.66 shows, the population of the Town of Neversink was virtually unchanged between 2000 and 2010. Population density in 2010 was approximately 43.0 persons per square mile, reflecting a community more rural in nature than either the Towns of Liberty or Fallsburg.

Table 3.66: Town of Neversink Population, 2000 and 2010

Geography	2000	2010	% Change
Neversink	3,553	3,557	0.1%
Sullivan County	73,965	77,547	4.8%
New York	18,976,457	19,378,102	2.1%

The number of total housing units in the Town of Neversink grew by 4.3 percent between 2000 and 2010 (Table 3.67), a slower rate of growth than was experienced in Sullivan County. Seasonal and recreational units accounted for virtually all of this growth, and in 2010 accounted for more than 28 percent of Neversink's housing stock.

Table 3.67: Town of Neversink Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Neversink	1,960	2,045	4.3%
Sullivan County	44,730	49,186	10.0%
New York	7,679,307	8,108,103	5.6%

Neversink's median age rose slightly between 2000 and 2005-2009, to 40. Nevertheless, in contrast to many towns in the surrounding region, Neversink has a significantly larger number of residents below age 15 than of those age 65-and-older. Moreover, the under-15 group increased as a percentage of total population between 2000 and 2005-2009, while those over 65 declined (Figure 3.41).

Figure 3.41: Town of Neversink Age Distribution, 2000 and 2005-2009

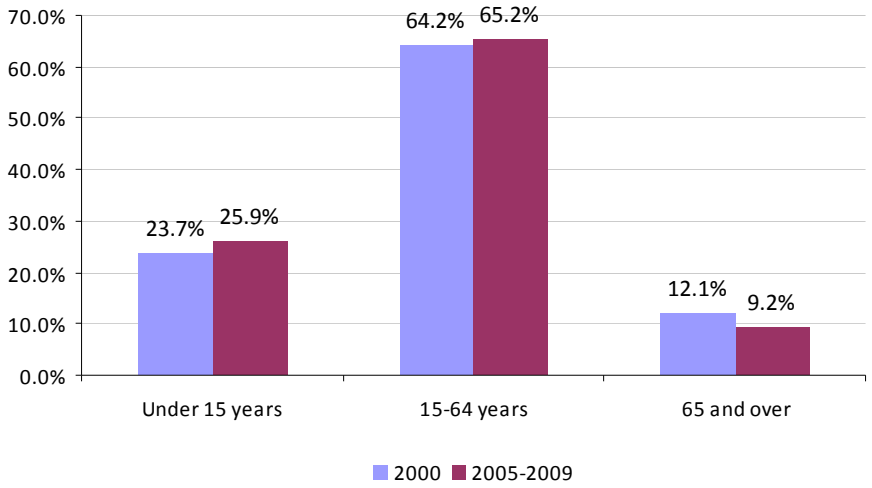


Table 3.68 shows that resident employment for the Town of Neversink increased by 4.9 percent between 2000 and 2005-2009, lagging somewhat behind the growth that occurred elsewhere in Sullivan County.

Table 3.68: Town of Neversink Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Neversink	1,483	1,556	4.9%
Sullivan County	30,244	34,440	13.9%
New York	8,382,988	9,102,596	8.6%

As Figure 3.42 shows, more than one-third of the employed residents of the Town of Neversink worked in education, health and social assistance in 2005-2009. About 14 percent worked for government agencies, nearly 11 percent in construction, and more than 9 percent in the arts, recreation and hospitality.

Figure 3.42: Town of Neversink Resident Employment - Top Employment Sectors, 2005-2009

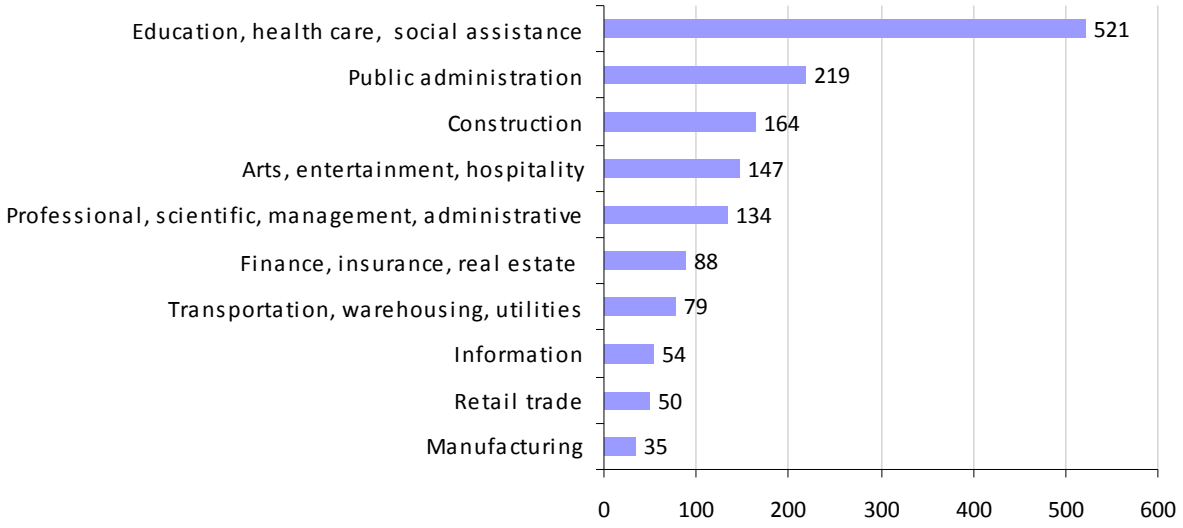


Table 3.69 shows that the unemployment rate for the Town of Neversink averaged 4.7 percent during 2005-2009, below the unemployment rates reported by ACS for both Sullivan County and the State during this period.

Table 3.69: Town of Neversink Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Neversink	5.8%	4.7%
Sullivan County	9.2%	6.5%
New York	7.1%	7.0%

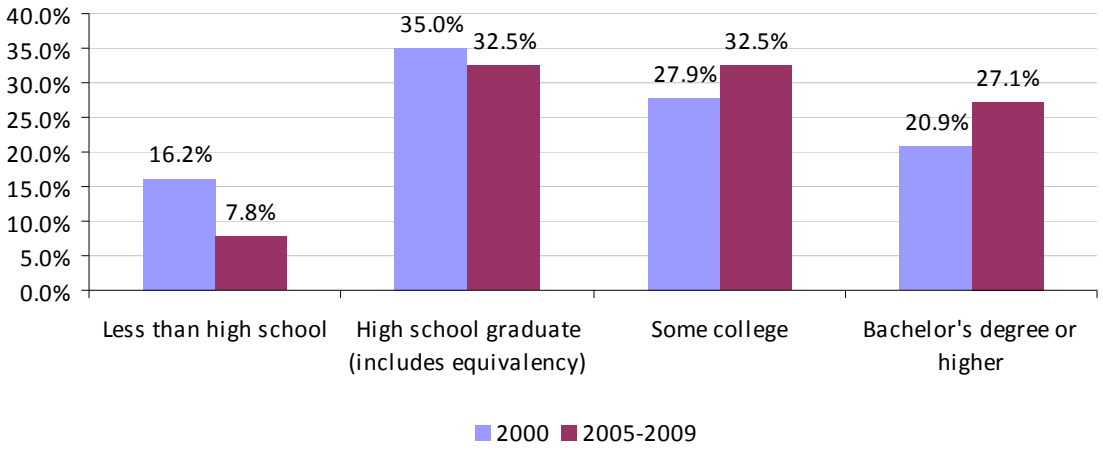
According to ACS data, the MHI for the Town of Neversink increased by more than 16 percent between 2000 and 2005-2009, as depicted in Table 3.70. The Town's MHI for 2005-2009 was 22 percent higher than the Statewide MHI, and 39 percent higher than that for Sullivan County.

Table 3.70: Town of Neversink Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Neversink	$58,172	$67,708	16.4%
Sullivan County	$47,644	$48,586	2.0%
New York	$55,879	$55,233	-1.2%

As shown in Figure 3.43, the percentage of Neversink residents age 25-and-older who lacked a high school diploma declined between 2000 and 2005-2009 to 7.8 percent, while the percentage of this age group that had at least some college-level education rose to nearly 60 percent, including 27.1 percent who had at least a bachelor's degree.

Figure 3.43: Town of Neversink Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.3.5 Town of Wawarsing

As shown in Table 3.71, the Town of Wawarsing's population in 2010 was 13,157 The Town's population grew by 2.1 percent between 2000 and 2010, slower than the growth rate for Ulster County as a whole, but equal to the growth rate for New York State. With a population density of 100.8 persons per square mile in 2010, Wawarsing is more densely populated than many of the more rural towns in vicinity of the Project, but less densely populated than Ulster County as a whole.

Table 3.71: Town of Wawarsing Population, 2000 and 2010

Geography	2000	2010	% Change
Wawarsing	12,889	13,157	2.1%
Ulster County	177,749	182,493	2.7%
New York	18,976,457	19,378,102	2.1%

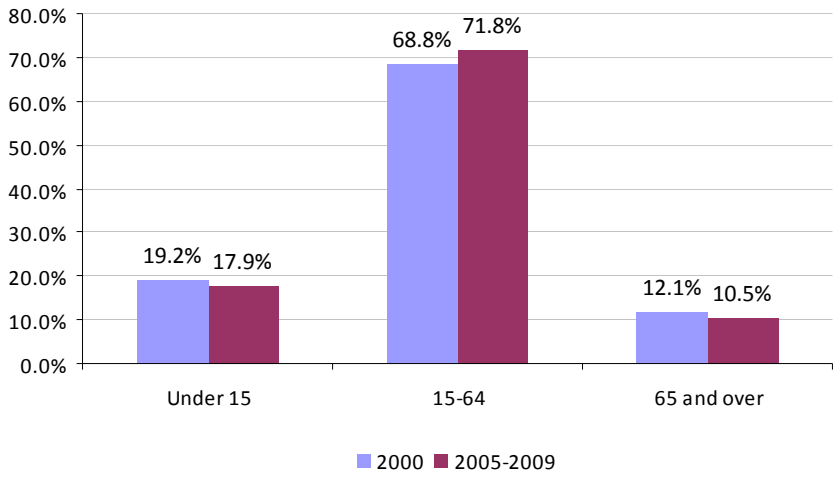
The number of housing units in the Town of Wawarsing grew by 6.7 percent between 2000 and 2010 (Table 3.72). About 16 percent of all housing units in the Town in 2010 were for seasonal or recreational use.

Table 3.72: Town of Wawarsing Housing Units, 2000 and 2010

Geography	2000	2010	% Change
Wawarsing	5,821	6,211	6.7%
Ulster County	77,656	83,638	7.7%
New York	7,679,307	8,108,103	5.6%

The median age in the Town of Wawarsing in 2005-2009 was 40.0 Figure 3.44 shows that between 2000 and 2005-2009, the under-15 and 65-and-older age groups both declined as a share of Wawarsing's population, while the share of all residents who are between 15 and 64 increased.

Figure 3.44: Town of Wawarsing Age Distribution, 2000 and 2005-2009



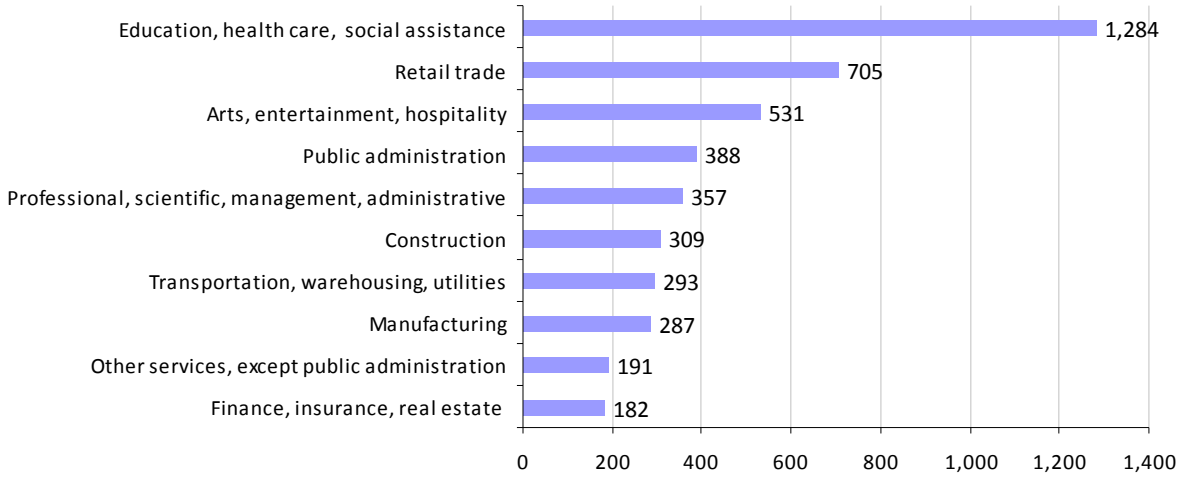
As shown in Table 3.73, resident employment in the Town of Wawarsing fell by 5.4 percent between 2000 and 2005-2009 – a sharp contrast with Ulster County as a whole, which saw an 8.1 percent increase in resident employment.

Table 3.73: Town of Wawarsing Resident Employment, 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Wawarsing	5,088	4,814	-5.4%
Ulster County	83,748	90,507	8.1%
New York	8,382,988	9,102,596	8.6%

As Figure 3.45 shows, in 2005-2009 nearly 27 percent of the Town of Wawarsing's employed residents worked in education, health care and social assistance. Nearly 15 percent worked in retail trade, 11 percent in arts, recreation and hospitality and 8 percent in government.

Figure 3.45: Town of Wawarsing Resident Employment - Top Employment Sectors, 2005-2009



As Table 3.74 shows, the unemployment rate in the Town of Wawarsing for 2005-2009 was 8.2 percent, exceeding the rates for both Ulster County and the State.

Table 3.74: Town of Wawarsing Unemployment Rate, 2000 and 2005-2009

Geography	2000	2005-2009
Wawarsing	6.6%	8.2%
Ulster County	6.3%	5.6%
New York	7.1%	7.0%

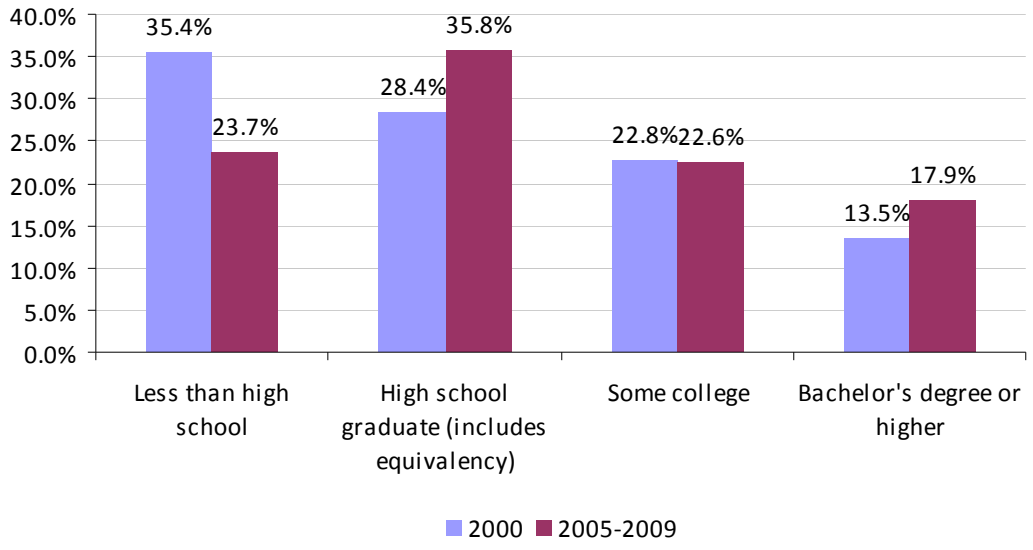
The MHI in the Town of Wawarsing dropped slightly in real terms between 2000 and 2005-2009, as shown in Table 3.75 – a trend that seems consistent with the decline in resident employment the Town experienced during this period, as well as its rising unemployment rate. For 2005-2009, the Town's MHI was 20 percent below the MHI for Ulster County as a whole.

Table 3.75: Town of Wawarsing Median Household Income (2009 dollars), 2000 and 2005-2009

Geography	2000	2005-2009	% Change
Wawarsing	$46,194	$45,813	-0.8%
Ulster County	$54,795	$57,485	4.9%
New York	$55,879	$55,233	-1.2%

As depicted in Figure 3.46, educational attainment improved significantly in the Town of Warwarsing between 2000 and 2005-2009, with a substantial decrease in the percentage of the Town's population age 25-and-older that had not earned a high school diploma, as well as a significant increase in the percentage of the Town's population in that age group that earned a high school diploma, a bachelor's or advanced degree. Despite this progress, the percentage of 25-and-older residents who have not completed high school remains relatively high, and the percentage of those with at least a bachelor's degree remained relatively low.

Figure 3.46: Town of Wawarsing Educational Attainment (population 25 years and over), 2000 and 2005-2009



3.3.4 Socioeconomic Conclusions

During the past decade, many of the fifteen towns profiled above have struggled with a variety of long-term structural problems, combined more recently with the effects of the recession and financial crisis that began in 2008. Long-term issues include:

- Population losses – 6 of the 15 towns experienced a decline in resident population between 2000 and 2010;
- Weak overall job growth – resident employment declined in 7 of the fifteen towns;
- Rising unemployment – in 8 of the 15 towns resident unemployment exceeded both their County and the State unemployment rates in 2005-2009;
- Low incomes – in 2005-2009, median household incomes were less than 80 percent of the statewide median income in 8 of the 15 towns; and
- Relatively low levels of educational attainment – in 11 of the 15 towns, fewer than 20 percent of all residents age 25 and older had bachelor's or higher degrees in 2005-2009 (as compared with 32 percent statewide); and 7 of the 15 towns have more residents who have not completed high school than they have four-year college graduates.

3.4 Economic Impact of Project Construction

The overall, anticipated economic impact of constructing the Project developments was assessed. For the Cannonsville and Pepacton Developments, the economic impact of constructing these Project developments on Delaware County was assessed. For the Neversink Development, the economic impact on Sullivan County was assessed. While the preceding description of current conditions and recent trends focused on town-level data, the analysis of the three developments'

economic impact focuses on county-level impact. This is because IMPLAN, like other input-output models, uses the county as its basic unit of economic analysis.

Based on the most recent estimates, the Cannonsville, Pepacton and Neversink Developments will cost approximately $42.5 million, $8.1 million and $4.4 million, respectively. A breakdown of estimated costs for each development is shown below in Table 3.76.

Table 3.76: Estimated Construction Costs, by Development

Costs	Cannonsville	Pepacton	Neversink
Mobilization& Demobilization (330)	$2,982,600	$454,500	$300,100
Powerplant Structures & Improvements (331)	$4,207,000	$181,000	$75,000
Reservoir, Dam & Waterway (332)	$6,330,000	$1,532,000	$842,000
Waterwheel, Turbines, and Generators (333)	$15,270,000	$1,828,000	$1,278,000
Accessory Electric Equipment (334)	$1,511,000	$457,000	$320,000
Substation and Switching Station Equipment (353)	$2,100,000	$542,000	$269,000
Transmission, Poles, and Conductors (335/336)	$408,000	$5,000	$217,000
Other Costs (including contingencies and services)	$9,734,000	$3,097,000	$1,135,000
Total	**$42,542,600**	**$8,096,500**	**$4,436,100**

In estimating the economic impact of construction of the Cannonsville, Pepacton and Neversink Developments in Delaware and Sullivan counties, as applicable, it is important to recognize that much of the work required for completion of the developments is likely to be performed by contractors and suppliers of specialized equipment that come from outside the two counties at issue. For purposes of this analysis, it was assumed that all of the major contracts for architecture, engineering, construction or procurement and installation of equipment will be awarded to firms based outside the county in which each respective development is located. It was further assumed that local economic impact of each development will be generated primarily through employment of local residents for part of the work done on-site, and to a lesser extent through local subcontracting.

Exactly how much work on any given project will be performed by local subcontractors or local workers is difficult to predict. Some assumptions can be made, however, based on information about the use of local subcontractors and local labor on other DEP construction projects in the vicinity of the Project region. For purposes of this analysis, the following assumption were utilized:

- None of the work done under waterwheels, turbines and generators (333), accessory electrical equipment (334), substation and switching station equipment (353), transmission poles and conductors (355/356), and other costs (including contingencies and services) will be contracted locally, or done by local workers;

- 10 percent of the work done under mobilization/demobilization (330), powerplant structures and improvements (331) and reservoirs, dams and waterways (332) will be done by local subcontractors; and

- 90 percent of the work done under mobilization/demobilization (330), powerplant structures and improvements (331) and reservoirs, dams and waterways (332) will be done by contractors from outside the local county, but 45 percent of all of the workers employed by these non-local contractors will be local residents.

Based on these assumptions, the direct and indirect and induced (or "multiplier") effects of projected payments to local subcontractors and construction workers associated with each development were estimated using the IMPLAN input-output modeling system – an econometric modeling system commonly used in analyses of economic impact.

3.4.1 Economic Impact of Construction of the Cannonsville Development

Based on the assumptions outlined above and using the IMPLAN input-output modeling system, of the $42.5 million estimated total cost of the Cannonsville Development, direct payments to Delaware County subcontractors and wages paid directly to Delaware County residents employed by contractors based outside the County would total approximately $3.1 million. The development would directly generate approximately 49 person-years of employment for County residents in construction and related industries, with compensation paid to these employees totaling approximately $2.1 million.

Through the multiplier effect, direct payments to local subcontractors and residents would generate approximately $1.2 million in additional economic output in Delaware County, and 10 additional person-years of employment, with employee compensation totaling nearly $380,000.

Taking into account both direct and indirect/induced effects, the Cannonsville Development would provide a one-time increase of approximately $4.3 million in economic output in Delaware County during the estimated 36 month construction period associated with the development, 59 person-years of work, and approximately $2.5 million in employee compensation.

Table 3.77: Impact of Cannonsville Development in Delaware County

Cannonsville (Delaware County)	*Impacts*	*Direct*	*Indirect and Induced*	*Total*
Subcontractors	Output	$1,351,960	$408,604	$1,760,564
	Employment	10	3	13
	Employee Compensation	$422,424	$139,953	$562,377
Non-local contractors' local employee spending	Output	$1,710,819	$790,066	$2,500,885
	Employment	39	7	46
	Employee Compensation	$1,710,819	$239,733	$1,950,552
Total	**Output**	**$3,062,779**	**$1,198,670**	**$4,261,449**
	Employment	**49**	**10**	**59**
	Employee Compensation	**$2,133,243**	**$379,686**	**$2,512,929**

3.4.2 Economic Impact of Construction of the Pepacton Development

Of the $8.1 million estimated total cost of the Pepacton Development, direct payments to Delaware County subcontractors and wages paid directly to Delaware County residents

employed by contractors based outside the County would total about $491,000. The development would directly generate approximately 8 person-years of employment for County residents in construction and related industries, with compensation paid to these employees totaling $342,000.

Through the multiplier effect, direct payments to local subcontractors and residents would generate approximately $192,000 in additional economic output in Delaware County, and 2 additional person-years of employment, with employee compensation totaling nearly $61,000. Taking into account both direct and indirect/induced effects, the project would provide a one-time increase of $683,000 in economic output in Delaware County during the estimated 21 month construction period associated with the development, 10 person-years of work, and $403,00 in employee compensation (Table 3.78).

Table 3.78: Impact of Pepacton Development in Delaware County

Pepacton (Delaware County)	*Impacts*	*Direct*	*Indirect and Induced*	*Total*
Subcontractors	Output	$216,750	$65,509	$282,259
	Employment	2	1	3
	Employee Compensation	$67,724	$22,438	$90,162
Non-local contractors' local employee spending	Output	$274,283	$126,665	$400,948
	Employment	6	1	7
	Employee Compensation	$274,283	$38,435	$312,718
Total	**Output**	**$491,033**	**$192,174**	**$683,207**
	Employment	**8**	**2**	**10**
	Employee Compensation	**$342,007**	**$60,873**	**$402,880**

3.4.3 Economic Impact of Construction of the Neversink Development

Of the $4.4 million estimated total cost of the Neversink Development, direct payments to Sullivan County subcontractors and wages paid directly to Sullivan County residents employed by contractors based outside the County would total more than $274,000. The development would directly generate approximately 5 person-years of employment for County residents in construction and related industries, with compensation paid to these employees totaling about $190,000.

Through the multiplier effect, direct payments to local subcontractors and residents would generate nearly $120,000 in additional economic output in Sullivan County, and one additional person-year of employment, with employee compensation totaling nearly $40,000.

Taking into account both direct and indirect/induced effects, the project would provide a one-time increase of $394,000 in economic output in Sullivan County during the estimated 21 month construction period associated with the development, 6 person-years of work, and $230,00 in employee compensation (Table 3.79).

Table 3.79: Impact of Neversink Development in Sullivan County

Neversink (Sullivan County)	*Impacts*	*Direct*	*Indirect and Induced*	*Total*
Subcontractors	Output	$121,710	$39,133	$160,843
	Employment	1	0.3	1.3
	Employee Compensation	$37,657	$13,288	$50,945
Non-local contractors' local employee spending	Output	$152,512	$80,629	$233,141
	Employment	4	1	5
	Employee Compensation	$152,512	$26,442	$178,954
Total	Output	**$274,222**	**$119,762**	**$393,984**
	Employment	**5**	**1**	**6**
	Employee Compensation	**$190,169**	**$39,730**	**$229,899**

3.5 Economic Impact of Project Operations

Estimates of the impact of operation of the three Project developments are based on the most recent estimates of operating revenues for each of the three facilities. Using IMPLAN, these revenue estimates can be translated into estimates of the number of people to be employed directly in the operation of the three facilities, their earnings, and the indirect and induced impact of spending within Delaware and Sullivan counties of plant operation and maintenance.

3.5.1 Economic Impact of Cannonsville, Pepacton, and Neversink Operations

Operating impacts for each of the three facilities in their first year of operation (assumed to be 2016 for Pepacton and Neversink and 2019 for Cannonsville) are shown below in Table 3.80.

- The Cannonsville Development operating revenue estimates would translate into the equivalent of approximately 5 full-time-equivalent ("FTE") jobs, create two additional FTE jobs in Delaware County through the multiplier effect, and would increase the County's total annual economic output in 2019 by more than $2.7 million.

- Because of its smaller scale, the Pepacton Development operating revenue estimates would translate into the equivalent of less than one FTE job (i.e., 0.6 FTE); and through the multiplier effect, would only generate 0.4 FTE jobs in Delaware County. The facility's operations would thus translate into an equivalent increase in employment in the County by one FTE job; and increase the County's total annual economic output in 2016 by about $454,000.

- The still-smaller Neversink Development operating revenue estimates would translate into the equivalent of only 0.3 FTE jobs, with 0.3 additional FTE jobs created in Sullivan County through the multiplier effect. The facility's operations would thus translate into an equivalent increase in employment by only 0.6 FTE, with the County's total annual economic output in 2016 increasing by slightly less than $273,000.

Table 3.80: Impact of Ongoing Operations, by Development

Project	Impact	Direct	Indirect and induced impacts	Total
Cannonsville (Delaware County)	Output	$2,473,177	$261,635	$2,734,812
	Employment	5	2	7
	Employee Compensation	$448,114	$78,295	$526,409
Pepacton (Delaware County)	Output	$408,939	$44,815	$453,754
	Employment	0.6	0.4	1
	Employee Compensation	$77,187	$13,487	$90,674
Neversink (Sullivan County)	Output	$241,644	$31,186	$272,830
	Employment	0.3	0.3	0.6
	Employee Compensation	$45,788	$10,170	$55,958

It should be noted that in contrast to the one-time impact of spending on construction (that is, lasting only for the duration of the Project-related construction activities for each development), the operating impacts cited above and summarized in Table 3.80 would be ongoing annual impacts.

3.5.2 Tax Impacts of Operations

Given potential changes in the market value of properties, variations in local assessment practices, and potential variability in local tax rates from year to year, estimates of the impact of the proposed developments on real property tax revenues are inevitably somewhat speculative. For purposes of this analysis, it was assumed that the market value of each facility is initially set at a level equal to the cost of construction. An estimated assessed value for each development was then calculated based on the equalization rate for the applicable town in which each development is located (as reported by the New York State Office of Real Property Services) and estimated real property taxes based on county, municipal and school tax rates for 2010.

As set forth in Table 3.81 the results of this analysis were as follows with respect to annual property tax payments for each development:

- The Cannonsville Development would pay approximately $1.7 million annually in county, municipal and school taxes;
- The Pepacton Development would pay approximately $158,000 annually in county, municipal and school taxes; and
- The Neversink Development would pay approximately $112,000 annually in county, municipal and school taxes.

Table 3.81: Estimated Real Property Tax Revenues Generated, by Development

Project	Town	Construction cost	Equalization rate, 2010	County tax rate (per $1,000), 2010	Municipal tax rate (per $1,000), 2010	School tax rate (per $1,000), 2010	Estimated property tax
Cannonsville	Town of Deposit	$42,542,600	10.0%	82.96	59.81	258.91	$1,708,851
Pepacton	Town of Colchester	$8,096,500	4.1%	126.31	82.26	268.50	$158,366
Neversink	Town of Neversink	$4,436,100	3.7%	141.64	105.27	443.98	$111,867

3.5.3 Impact on Local Government Services and Local Government Expenditures

Beyond their direct impact on real property tax revenues, the overall impact of the three Project developments on the overall financial condition of the affected local governments and school districts is likely to be positive. None of the development would displace any other, potentially more lucrative development projects in the vicinity of the Project area. Moreover, for reasons discussed below, any increases in demand for local public services associated with the operation of the developments are likely to be minimal.

Because of the relatively small number of equivalent jobs associated with the operations of the Project developments (fewer than 6.0 FTE jobs across all three proposed developments), and because neither the major inputs to nor major outputs from the facilities are transported by road, the impact on traffic and wear-and-tear on public roadways associated with the Project is likely to be minimal. Moreover, it is important to note that DEP maintains its own roadways in the immediate vicinity of the reservoirs associated with the Project developments. Thus none of the three developments would add significantly to local governments' road construction or maintenance costs – which in many of the region's towns constitute the single largest area of local government expenditure.

In addition, DEP maintains its own police force of approximately 185 officers to secure City-owned land and infrastructure in the watershed, including the lands and infrastructure associated with the Project. Accordingly, any additional local government expenditures for public safety incurred by local communities in the Impact Area as a result of the Project are likely to be minimal.

The number of equivalent jobs created by the developments is relatively small, and, thus, it is likely that they can be filled from within the existing work force of the affected communities. Because it is unlikely that the developments would draw new workers and their families from outside the region, they are unlikely to generate significant new demands on local school systems or for other local government services.

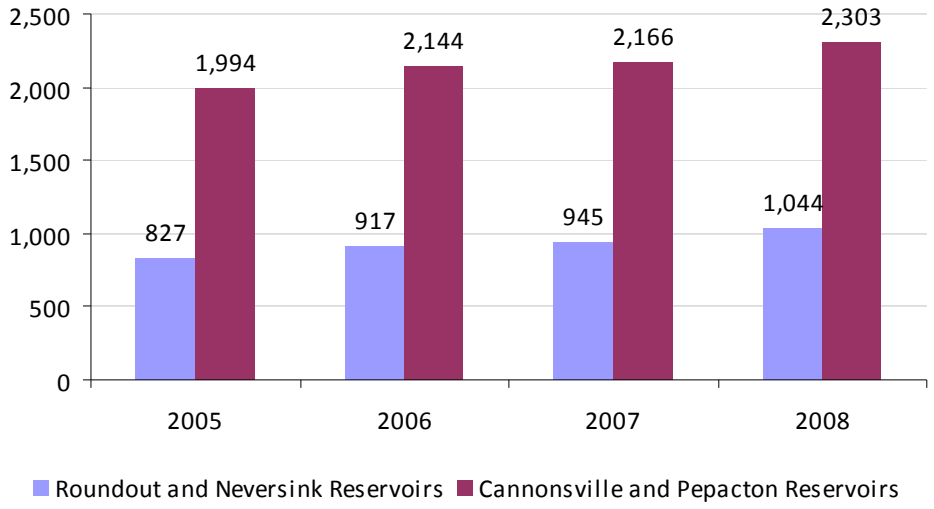
3.6 Project Impact on Community Character and Recreation

The DEP has made significant investments in opening up City-owned watershed lands for outdoor recreation during the past decade. The City's reservoirs and the streams into which they flow also comprise an important dimension of the region's recreational offerings – and thus a valuable asset for recreation and tourism-related businesses, which together constitute one of the most significant sectors of the economy in the vicinity of the Project area. One example of the City's investment and promotion of recreational use of the watershed is the Cannonsville

Recreational Boating Pilot Program. This three-year program was launched in 2008 to improve regional recreational activities and environmentally sound deveopment for activities that ranged from kayaking to canoeing and sailing.

Overall, the use of the watershed has been increasing. As Figure 3.47 shows, the number of active boating permits on the Cannonsville, Pepacton, Neversink, Reservoirs steadily increased between 2005 and 2008.

Figure 3.47: Active Boating Permit Holders for Cannonsville, Pepacton, Neversink, and Rondout Reservoirs[6]



DEP surveyed holders of its Access Permits in 2009, regarding the most common activity such permit holders participated in while on City-owned lands and/or reservoirs. As Figure 3.48 shows, about 60 percent of respondents' most common activity was fishing from shore or by boat.

In the same survey, DEP inquired of Access Permit holders that had fished (via shore or boat) on City-owned reservoirs which eservoir was used most by such permit holders for fishing purposes. Of those permit holders responding that they did use the reservoirs for fishing purposes, as shown in Table 3.82, Pepacton Reservoir ranked second among use, Cannonsville Reservoir ranked fourth, and Neversink Reservoir ranked eigth.

[6] Boating permits are issued for pairs of reservoirs. In the case of the Project, the applicable pairings are the Rondout and Neversink Reservoirs, and the Cannonsville and Pepacton Reservoirs. Accordingly, individual reservoir data regarding boating permits is not available.

Figure 3.48: 2009 Survey of Access Permit Holders Responses Regarding Most Common Activity Undertaken

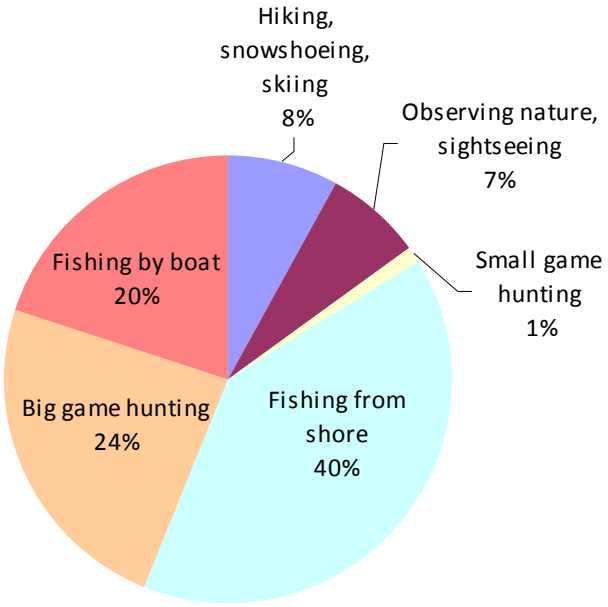


Table 3.82: Response to 2009 Survey of Access Permit Holders RegardingReservoir Use for Fishing

Reservoir	Used most
Ashokan	18%
Pepacton	14%
Kensico	10%
Cannonsville	8%
Croton Falls	8%
New Croton	7%
Rondout	7%
Neversink	4%
West Branch	4%
Cross River	3%
Schoharie	3%
All others	14%
Total	**100%**

The DEP intends to continue operating the Cannonsville, Pepacton, and Neversink Reservoirs according to the currently effective operating protocol agreed to by the parties to the 1954 U.S. Supreme Court Decree ("Decree Parties").[7] Accordingly, the water available for hydroelectric

[7] The Decree Parties are the City of New York, the States of Delaware, New Jersey, and New York, and the Commonwealth of Pennsylvania. In the event that the operating protocol is modified in the future, DEP intends to operate the reservoirs in accordance with any such modified protocol agreed to by the Decree Parties. For general information regarding the 1954 U.S. Supreme Court Decree please see *New Jersey v. New York*, 347 U.S. 995 (1954).

generation at the Cannonsville, Pepacton, and Neversink Developments will be comprised of conservation releases, directed releases, and water that would otherwise spill to the extent that such releases are consistent with discharge mitigation releases as outlined in such operating protocol. All such releases would be drawn by the existing release intake structures of the reservoirs associated with the Project developments, which are deep water intakes that draw from the deeper, cold portions of the water column. The City is currently not proposing to modify the magnitude, frequency, duration, and/or timing of discharges due to the addition of the hydropower facilities associated with the Project.

Accordingly, because (i) the City is not proposing to modify discharges as a result of the Project and is merely seeking to generate power from the discharges it is already obligated to provide; and (ii) the Project developments are being constructed at existing facilities, the Project is expected to neither create new recreational opportunities nor impair existing recreational activities undertaken on the reservoirs or downstream environs associated with the proposed Project developments.

3.6.1Conclusion: Overall Impact on Socioeconomic Conditions and Community Character

The preceding analysis indicates that construction and operation of the Cannonsville, Pepacton and Neversink Developments would have a modestly positive impact on demand for labor, employment and earnings, and overall economic output in Delaware and Sullivan counties.
For example, of the approximately 100 person-years of construction work that the Cannonsville Development would entail, 49 would be performed by Delaware County residents. Over the three-year construction period, this would equate to an average of about 16 FTE jobs per year. To put this number in context, between 2005 and 2009, according to the Census Bureau's ACS, an average of 2,051 Delaware County residents were employed in construction.

For the Pepacton and Neversink Developments, the direct impact of construction would be smaller during the less than two year estimated construction period associated with each development – fewer than three FTE jobs per year for Pepacton, and fewer than two FTE per year for Neversink (as compared with an average of 3,178 Sullivan County residents employed in construction between 2005 and 2009).

The impact of ongoing operations would similarly be modest, with the employment equivalent of the operating revenues at all three facilities totaling approximately 6 FTE jobs.

Because of the relatively small numbers of jobs the three developments would create and the following factors, other types of socioeconomic impacts are likely to be minimal or non-existent:

- Very small increases in labor demand are unlikely to affect wages in either the directly affected industries or in the labor force more broadly.

- Because the resident labor force in the two counties and in the surrounding area would easily absorb the modestly-increased demand for labor that the three projects would generate, they are unlikely to affect either housing demand or housing costs.

- The three developments are not expected to affect recreational opportunities either at the reservoirs themselves or downstream. They will neither create new recreational opportunities nor impair existing recreational uses.
- As noted above, the impact of the three developments on local government and school district finances is likely to be positive.
- Because they would not affect the rural character of the communities in which they are located, the population of those communities, local patterns of land use and development, or the overall mix of local economic activity, the three projects would have little or impact on the character of the towns in which they are located, or other nearby communities.

4.0 ASSESSMENT OF ENVIRONMENTAL BENEFITS, RELIABILITY BENEFITS AND WHOLESALE PRICE IMPACTS

The three proposed Project developments would be interconnected to the NYSEG transmission and distribution systems. Early design activities and a feasibility assessment are currently under way. According to the latest available information, the Cannonsville Development is currently anticipated to have a generating capacity of approximately 14.08 megawatts ("MW"), while the Pepacton and Neversink Developments are currently anticipated to have nominal generating capacities of 1.70 MW and .94 MW, respectively.

4.1 Impacts of Project Generation on Wholesale Energy Prices

The proposed Cannonsville, Pepacton and Neversink Developments are essentially zero variable cost generation resources. As such, they would be expected to operate whenever available (i.e., it will virtually always be economic to generate electricity from the facilities), [8] and whenever they do operate and generate electricity, they will displace an equivalent amount of generation from higher-cost, fossil-fuel fired generation sources. Such displacement not only reduces pollutant emissions from the burning of fossil fuels, which will be discussed in detail in the next section of this report, but in addition tends to reduce the overall wholesale market price of energy. This price reduction effect was estimated using a statistical analysis of actual NYISO historical wholesale market data.

The NYISO-administered day-ahead and real-time energy markets establish wholesale clearing prices for electricity based on supply and demand bids from market participants. These bids determine which generation resources will be dispatched to generate electricity, thereby meeting electricity demand at the lowest cost, while simultaneously protecting the transmission system from overload.[9] The price of electricity in any given hour (or fraction thereof) is determined by the price of the last generation unit needed to serve the load. Prices rise when demand increases (or when available low-cost generation decreases), because more expensive oil and gas units need to be run to serve customers.

Figure 4.1 shows a stylized illustration of how generation is deployed to serve load. The load curve represents hourly demand for electricity, ordered from low to high over a year.[10] Generation resources are ordered from low-cost to high-cost from the bottom of the figure to the top. Hydroelectric generation and nuclear generation have very low variable operating costs and so would run around the clock to the extent they are available. Coal generation has a wider variation in variable operating costs, with higher cost units operating less often. Large, natural

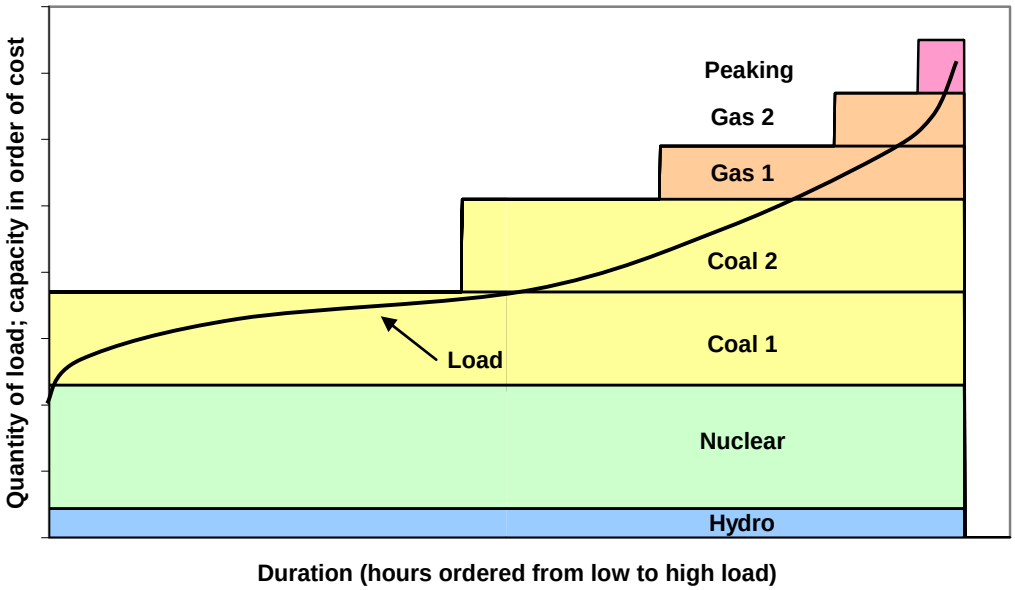
[8] There are occasional hours when NYISO locational energy prices are in fact negative, during which it would in principle be uneconomic to generate power from a zero variable cost resource.

[9] This is known as "security constrained economic dispatch."

[10] When load is considered chronologically it displays high variability within each day, in response to weather patterns, and according to season. The stylized figure shows load in order of increasing magnitude to illustrate how existing resources are deployed to meet load requirements at different levels.

gas-fired plants meet intermediate needs, while high variable cost peaking units, running on oil or natural gas, are used to meet peak demand.[11]

Figure 4.1: Illustration of Electricity Demand Supply



Hydroelectric generation can take several forms: (a) so-called "run-of-river", which is relatively constant; (b) peaking hydro, where generating is based on directed releases at periods of peak demand; and (c) pumped storage, where water is pumped up to a reservoir when electricity prices are low and then is released to generate electricity when prices are high. For the purposes of this assessment, it was assumed that output from the Project's hydroelectric generation facilities would not be actively adjusted based on market conditions, and, therefore, will effectively be run-of-river, corresponding to depiction of "Hydro" generation in **Figure 4.1**.

Consistent with other centralized markets, in the NYISO-administered markets, the going price for electricity is set by the price of the last generating unit needed to meet demand. The underlying logic of the model used to value the impact of generation from the Project can be illustrated with reference to **Figure 4.1**. If hydroelectric generation capacity is increased, there is reduced need to run higher cost generation resources, and the market will tend to clear at a lower corresponding price at each point on the load curve. Of course, this will not occur each and every hour, because the relatively small amount of generation output associated with the Project will often not be enough to displace the marginal (i.e., highest cost) generation unit required to meet load; however, on average and over time, such a price-reduction effect would be expected.

Because low-cost, hydroelectric generation is at the bottom of the supply resource stack, demand is always sufficient to justify its operation, and hydroelectric generation plants will run

[11] The relative capacity volumes in the figure are illustrative only, and, thus, are not intended to reflect the actual, current generation mix in New York. In reality, there are many more gradations in price, as well as overlap of fuel types.

regardless of the prevailing market clearing price. As a consequence of its place in the supply resource stack, an increase in the available quantity of hydroelectric generation has the same effect on the market clearing price as a decrease by the same amount in load.[12] In other words, changing the height of the hydroelectric segment in **Figure 4.1** has the same effect as would shifting the load curve.

To estimate the economic benefit of generation output from the Project, historical NYISO wholesale energy market data were used to develop a statistical model that describes the relationship between overall demand and prevailing market prices in western New York State for the period June 2008 to May 2011. This model estimates how wholesale energy prices change in response to a given change in load, while controlling for changes in natural gas prices.[13]

As noted above, the effect on market prices of an increase in hydroelectric generation is equivalent to that from a corresponding decrease in load, holding generation constant. Accordingly, the load-price model determines the value of an increase in hydroelectric output by estimating the price impact of an equivalent *decrease* in demand. The model controls for natural gas prices because natural gas-fired generation often sets the market clearing price in the NYISO-administered markets. By controlling for the effect of natural gas prices on market energy prices, the model is better able to isolate the effect of increased hydroelectric output.

To estimate the impact of increased hydro generation from the Project, expected market prices were first estimated from a regression of the load-price relationship based on historical data. Then, market prices were estimated again using the same function, but decreasing load each hour by an amount equal to the expected incremental hydro generation from the Project. The resulting price changes were then translated into an annual dollar value using the hourly load for western NYISO, by seasonal period.[14] The calculated reductions in wholesale power costs for the western NYISO region resulting from generation output is presented in **Table 4.1**.

[12] The same is true in the reverse: a decrease in hydroelectric generation capacity is equivalent in its effect on market clearing prices to an increase by the same quantity in load.

[13] The model covers the western NYISO region, comprising Zone A (West), Zone B (Genesee), Zone C (Central), and Zone E (Mohawk Valley). Appendix B includes a further discussion of the statistical model.

[14] The model distinguishes seasonal periods in two-month segments (e.g., January through February, March through April, etc.). Price impacts are calculated for each of these periods and applied across the corresponding average load.

Table 4.1: Estimated Reduction in Western NYISO Wholesale Power Costs Resulting from Project Generation

Model Sub-period	Historical Load Weighted LBMP, $/MWh	Estimated Decrease in Load-Weighted Avg Real-time price, $/MWh	Annual Reduction in NYISO Wholesale Energy Cost, $000s	% Reduction in Wholesale Energy Cost
Jan-Feb	$45.80	$0.30	$2,569	0.7%
Mar-Apr	$34.63	$0.27	$2,111	0.8%
May-Jun	$43.09	$0.31	$2,486	0.8%
Jul-Aug	$50.54	$0.35	$3,098	0.7%
Sep-Oct	$40.02	$0.23	$1,789	0.6%
Nov-Dec	$45.23	$0.19	$1,594	0.4%
Total	**$43.22**	**$0.27**	**$13,647**	**0.7%**

The benefit to the western New York region is estimated to be approximately $13.6 million annually, as indicated in **Table 4.1**. This value represents the benefit of lower electricity prices made possible by generation from the Project.

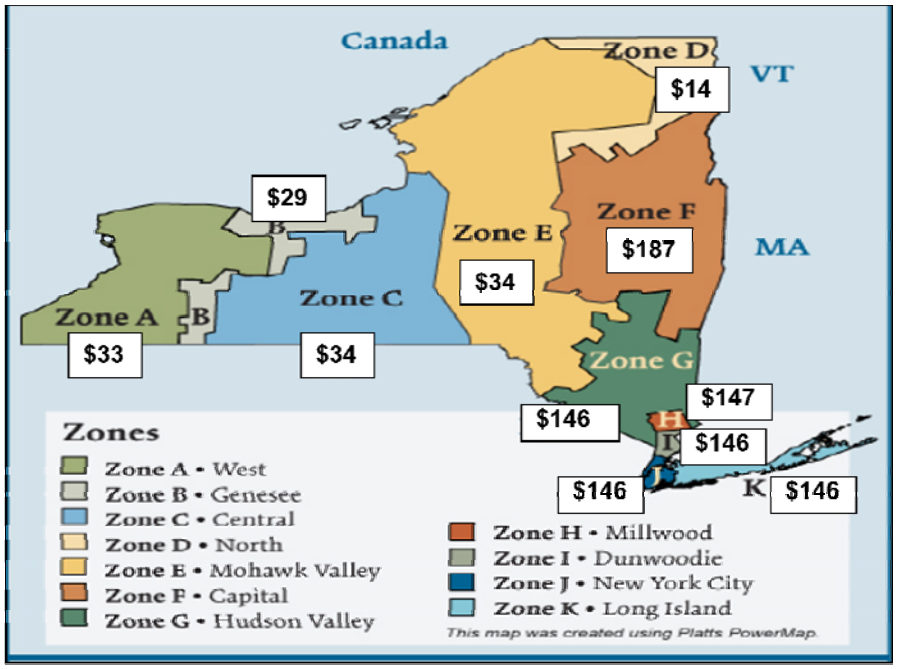
The model was constructed to cover the western portion of NYISO only,[15] because there is significant transmission congestion between this region and parts of NYISO to the east. During periods of transmission congestion, output from the Project would not be able to affect energy prices to the east and, consequently, the model of western NYISO was deemed to be more reliable than a NYISO-wide model. In addition to the estimated benefit to western New York presented above, there is likely an additional benefit to load in the east during zero-congestion periods that is not captured by the model.

4.2 Modeling Issues and Sensitivities

NYISO wholesale energy prices are determined on a locational basis, accounting for generation costs, transmission constraints and power losses when energy is moved over distance. Because regional demand is concentrated in New York City and the surrounding region in the southeast part of the State, power tends to flow from western New York State to the east. In periods of high demand, transmission from west to east is often constrained, meaning that it is not possible to move more power to the east. When this occurs, more expensive generating units must be operated in the east to meet demand, and locational market prices are consequently higher in the east than in western and northern parts of the State. This is illustrated in Figure 4.2, which shows actual real time energy prices for the various NYISO load zones on January 12, 2011 at 11 a.m. eastern time.

[15] The modeled region consists of the Mohawk Valley zone and market zones to the west (encompassing NYISO Zones A, B, C and E).

Figure 4.2: NYISO Real Time Energy Prices by Zone ($/MWh), Jan 12, 2011, 11AM



Adapted from NYISO system map; NYISO.

The significance of such price differences is that it indicates that the system is, in a sense, separated into distinct markets. When transmission congestion prevents more power from moving from the west to the east, increased generation in the west can affect prices in the "west market", but not in the "east market".

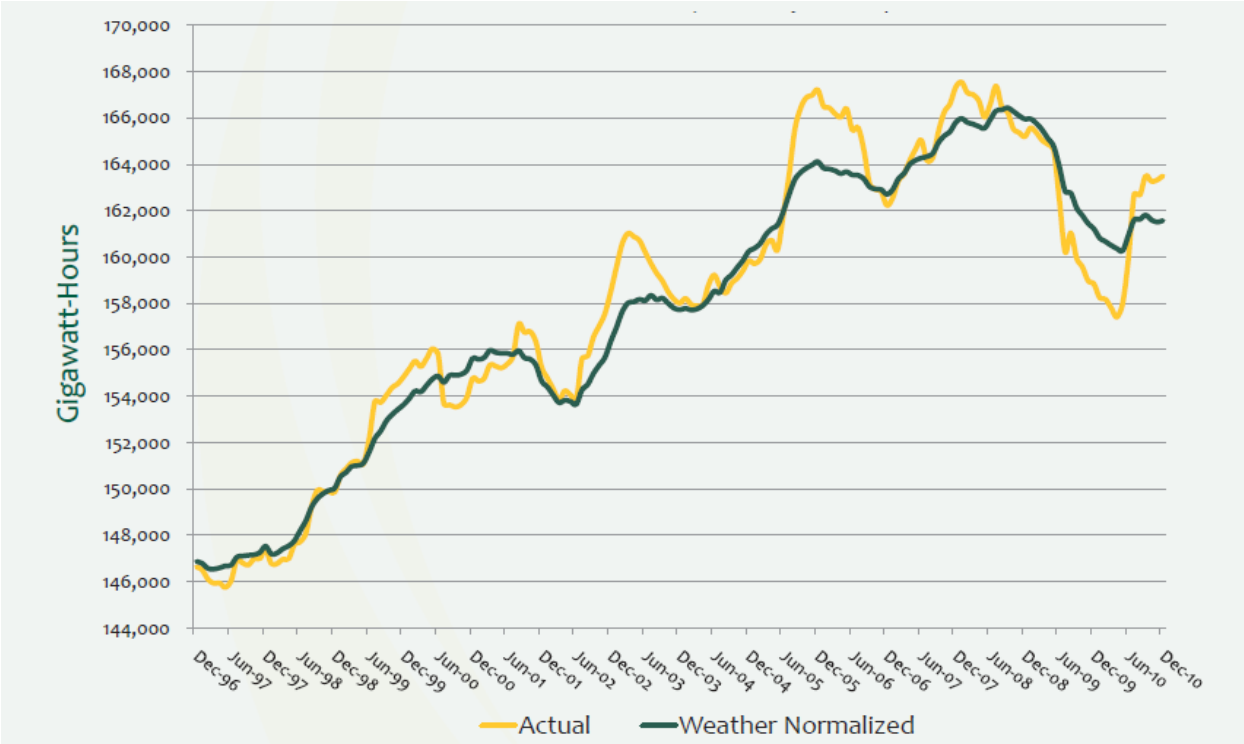
4.2.1 Model Sensitivity Case

Since power from the Project would be delivered into the NYISO Zone E (Mohawk Valley), and energy prices for this zone tend to correspond closely to those in zones to the west, but often show significant price separation with respect to prices in eastern NYISO zones, the load-price model was specified over Zones A, B, C and E only. This focus on the western NYISO region produces a more reliable estimate of price effects, but, by excluding benefits that may flow to eastern zones in some hours, would be expected to underestimate the effect for the NYISO as a whole. To examine the potential significance of such model-specification effects, a sensitivity case was run for all of NYISO. The sensitivity model showed an estimated dollar benefit $4 million greater than that estimated using the western New York model specification. However, part of this additional benefit results from the incorporation of periods when eastern NYISO energy prices are very high because of transmission congestion – periods when output from the Project could have no effect on prices in eastern zones. It is estimated that there may be up to $2 million of additional benefit, not captured in the estimates shown in **Table 4.1,** that accrues to load in eastern NYISO zones.

4.2.2 Decline in NYISO Demand During the Model Period

The data used in the load-price model cover a period during which there was a notable decline in electricity demand in NYISO, presumably reflecting the effects of the economic downturn. This decline can be seen in **Figure 4.3**, particularly during 2009.

Figure 4.3: NYISO Energy Usage, 12-month Rolling Total, 1996-2010[16]



Beginning in mid-2010, there was a sharp recovery in electricity demand, and load is currently trending roughly at 2007 levels (around 165,000 GWh over the past 12 months). The effect of this lull in demand on the model estimates of wholesale price effects is very modest. Alternative regressions were estimated excluding months from the decline period, and the results were found to be very similar to those for the full three-year data set. The price-load model does not include adjustments either to reflect unusual circumstances during the historical model period or to anticipate potential future market circumstances. Such an exercise would involve substantial speculation, and we believe the model results are more informative in unadjusted form. As discussed below, there are a number of factors that may influence the actual wholesale price impact of generation from the Project.

[16] NYISO, *Power Trends 2011: Energizing New York's Legacy of Leadership* at 20, available at http://www.nyiso.com/public/webdocs/newsroom/power_trends/Power_Trends_2011.pdf.

4.3 Interpretation of Benefits from Wholesale Energy Price Reduction

Factors Influencing Future Wholesale Price Benefits

There are a number of important factors to consider in interpreting the benefit estimates in Table 4.1. The statistical model utilized accounts for a variety of market factors over the historical period June 2008 to May 2011. For example, demand spikes, unexpected plant outages, variations in regional imports and exports, and the associated responses from market participants and the system operator are all reflected in the historical relationship of price and load, and this relationship is captured by the statistical model. Thus, the estimates are likely to be a reasonable estimate of short-term market impacts associated with the Project. However, the reliability of these estimates with respect to *future* generation from the Project depends on a number of factors, including:

- **Natural gas prices**. The statistical model reflects a period when there was substantial variation in natural gas prices, with a three year average of approximately $4.98/MMBtu.[17] Current natural gas futures prices for 2018 and 2019, the period during which the Project developments are currently anticipated to become operational, average approximately $6.46/MMBtu, 30% higher than the average over the historical period underlying the model.[18] Higher future natural gas prices will tend to increase the impact of hydroelectric generation on wholesale prices, because this will tend to magnify the cost difference between generators at the margin. The reverse is true for lower future natural gas prices.

- **Generation Supply.** During the modeled period, the summer capacity reserve margin (i.e., the excess of capacity relative to peak demand) for the New York Control Area as a whole averaged approximately 23%. However, NYISO forecasts show a higher projected summer reserve margin of greater than 30% for 2018 and beyond.[19] A higher capacity reserve margin means that marginal generating units that set the market clearing price for energy will generally be lower down the stack, and that the value of displacing that generation through increased hydroelectric generation will be lower, all else equal.

- **Electricity Demand.** As noted above, the historical data used to estimate the load-price model cover a period that includes a notable, if transitory, decline in electricity demand.

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[17] Calculated as a simple average of daily closing prices at Henry Hub for the model period, June 2008 through May 2011.

[18] Calculated as a simple average of NYMEX natural gas futures for the corresponding months, quoted June 29, 2011.

[19] NYISO, *2011 Load & Capacity Data* (April 2011), available at http://www.nyiso.com/public/webdocs/services/planning/planning_data_reference_documents/2011_GoldBook_Public_Final.pdf.

Higher demand levels and rates of load growth in the future would tend to increase the wholesale price benefit from Project generation.

- **Limited new baseload capacity**. Projected new baseload capacity (i.e., resources such as nuclear, coal and large run-of-river hydro, at the bottom of the resource stack) is quite limited, and is dwarfed by the expected growth of peak load. As load continues to grow beyond the existing volume of baseload capacity, the benefit from increased hydroelectric generation increases because there are an increasing number of hours when higher cost resources are necessary to serve load. This effect will tend to offset that of the projected increases in system reserve margin, discussed above.

- **Regulation of greenhouse gases**. The potential for new state and federal controls on greenhouse gas emissions, particularly a carbon tax or cap-and-trade limits on carbon output, will tend to increase the cost of generating electricity from fossil fuels, and reduce the viability of baseload coal generation. This will increase the value of the generation from the proposed Project development hydroelectric generation relative to that estimated in our model.

On balance, it is expected that the future market price reduction benefits of generation from the Project stated herein are likely to be conservative.

4.3.1 Interpretation of Economic Benefits

The estimated benefits of lower wholesale energy prices would be expected to flow over time to consumers, mediated by the various rate setting mechanisms that apply in New York's utility service territories. While lower electric energy costs would seem an unalloyed benefit to the economy, the interpretation of estimated cost reductions as a net economic impact must be approached with caution. It must be recognized, for instance, that the benefit to consumers of slightly cheaper electricity is mirrored by the dis-benefit to certain suppliers of reduced revenue. For the economy as a whole, it is difficult to determine the net economic impact. If one were to consider such effects by modeling them in an economic impact analysis model, such as IMPLAN, it might be possible to specify a slight increase in overall demand in the economy resulting from increased disposable income and increased business expenditures made possible by reduced expenditures on energy, but the reduced expenditures on energy would need to be modeled as reduced demand in the energy sector. It is very likely that there would be a net positive effect from an overall increase in economic efficiency resulting from decreased energy costs, but this net effect is difficult to quantify, and such an analysis was not conducted as part of this assessment.[20]

Another potential complication is that, all else equal, a price reduction will tend to increase energy consumption. This must be considered a net benefit to energy consumers (otherwise

[20] Evaluating the effect of changes in input costs is difficult in a model such as IMPLAN because it is effectively specified with fixed input prices. With IMPLAN, economic impacts are estimated from dollar changes in demand for each industrial sector, and it is difficult (or practically infeasible) to modify the model matrices and inputs to reflect a change in input prices.

there would be no increase in consumption), yet such an effect will tend to offset such benefits as reduced emissions of pollutants, addressed below.

4.4 Environmental Externality Benefits

Generation from the Project, estimated at approximately 57,000 MWh per year of emissions-free electricity, would provide environmental benefits by displacing generation of electricity from fossil fuels. **Table 4.2** shows the annual tons of emissions associated with generating an equivalent amount of energy from coal, oil and natural gas.

Table 4.2: Emissions from Generating 57,000 MWh of Energy from Fossil Fuels[21]

	Tons of emissions		
Fuel	**SO_2**	**NOx**	**CO_2**
Coal	370	171	64,066
Oil	342	114	47,629
Natural Gas	3	48	32,332

Source: U.S. Environmental Protection Agency, based on data from eGRID 2000

To provide some further context for the data in **Table 4.2**, the potential CO_2 emissions reductions resulting from output associated with the Project was translated into the number of passenger vehicles removed from the road that would provide an equivalent reduction, as shown in **Table 4.3**.

Table 4.3: Passenger Vehicle Equivalent Output of CO_2 Relative to Generating 57,000 MWh by Fuel Type[22]

	# of Passenger Vehicles
Coal	11,088
Oil	8,244
Natural Gas	5,596

The reduction in pollutant emissions from displaced fossil generation would be a very concrete benefit of generation by the Project developments. It is necessarily true that output from the plants, though small, would cause output from fossil-fueled generation that is virtually always on the margin in NYISO to be reduced. This highlights another, closely related, benefit of an

[21] Emissions rates used for calculation are the U.S. national average rates for electric generation for each fuel type.

[22] Motor vehicle equivalent of CO_2 output is based on U.S. EPA calculations, available at http://epa.gov/otaq/climate/420f05004.htm.

increase in hydroelectric generation, which is simply the reduced consumption of non-renewable fossil resources.

4.5 System Reliability Benefits

The City retained the services of PowerGem, LLC ("PowerGEM"), a power grid engineering and markets consulting firm, to perform a preliminary transmission assessment of the Project in order to determine whether there are any transmission limitations at the Project development sites that may restrict the dispatch of the full output of the proposed plants. The preliminary assessment was conducted by PowerGem in a manner reflecting system reliability interconnection study requirements and practices, concluded that the interconnection of the Cannonsville Development is feasible as proposed. However, the assessment of the feasibility of interconnecting the Pepacton and Neversink Developments has not been fully completed to date.

As analyzed by PowerGem, the Cannonsville Development would be connected to one of two 46 kV NYSEG local transmission lines connected to the Stiles 115 kV substation. Both lines serve load in rural communities well below the lines' normal pre contingency and post contingency capacity ratings, as established by NYISO reliability criteria. The transfer analysis and redispatch analyses performed by PowerGem indicate it is feasible to interconnect the Cannonsville Development and operate it at its full output without undue impact on the reliability of the NYISO bulk transmission system.

In the case of the Pepacton and Neversink Developments, PowerGem has preliminarily identified two nearby existing 4.8 kV lines as potential points of interconnection. Upon filing of an application by the City to request review of the proposed interconnections with NYSEG, NYSEG will determine whether interconnection to the selected points is feasible. However, it is important to note that the maximum output of each of these proposed Project developments (currently anticipated to be less than 2 MW each) is well below the typical 5-10 MVA rating of a 4.8 kV distribution network, thus, interconnection at this voltage would appear to be feasible.

In addition to not negatively affecting the reliability of the New York power grid, as preliminarily determined by PowerGem, the interconnection of the proposed Project developments may, in at least two of the three sites, provide additional reliability and power quality benefits to the grid. These benefits, derived from the design and operational characteristics of similar hydroelectric projects, and accrued at both the local and the Statewide level, are discussed in the following sections.

4.5.1 Ancillary Service Benefits

The balancing of supply and demand in the day-to-day operation of a power system in order to maintain reliability and security requires that the system's operators manage the provision of ancillary services. These services are physically supplied by the generators, transmitters, and loads that are connected to the system.

Table 4.4: Ancillary Service Capabilities of Hydroelectric Generation Facilities

Regulation and Frequency Control Ancillary Services from Hydroelectric Generation	
Fast reserves (6 second response)	Not Fast Enough Potential negative initial response due to pressure drop upon opening gate valve.
Slow Reserves (60 seconds response)	Good Up and Down
Delayed Rserves (300 seconds response)	Good Up and Down
Fast start Up	Good
Regulation	Good Up and Down

Hydroelectric generators have technical advantages over other types of generation with respect to the supply of ancillary services. These advantages include: fast response, better part-load efficiency, better controllability, lower maintenance costs and minimal to no startup (unit commitment) costs; as illustrated in Table 4.4.

Two of the proposed hydroelectric generation facilities are well suited to provide at least two of these services: reactive supply and voltage control, and regulation and frequency response. In New York, these reliability-related services are the responsibility of the NYISO in its role as the balancing authority for the New York Control Area. NYISO operates a regulation service market in which the Cannonsville Development, in theory, could sell regulation services. As with the sale of the energy produced by the Project, the sale of ancillary services may have a similar price reducing impact on the market price for such services in the applicable NYISO pricing region for such services.

The Cannonsville and Pepacton Developments, as further explained below, may be entitled to compensation for their contribution to reactive power supply and voltage control under one of NYSEG's tariffs.

Reactive power is a concept used by engineers to describe the background energy movement in an Alternating Current ("AC") system arising from the production of electric and magnetic fields in electrical machinery used at consumers facilities, generators and transmission and distribution equipment. Different types of devices either generate or absorb reactive power. Since reactive power does not produce useful work while taking up transmission capacity and contributing to energy loss, utilities and system operators actively manage their occurrence. Reactive power flows can give rise to substantial voltage changes across the system, which means that it is necessary to maintain reactive power balances between sources of generation and points of demand on a "zonal basis". Unlike system frequency, which is consistent throughout an interconnected system, voltages experienced at different points across the system at different times are uniquely related to constantly changing local generation and demand profiles. Thus, power flows, both actual and potential, must be carefully controlled for a power system to operate within acceptable voltage limits. The local transmission and distribution utility is obligated to secure the transmission network to closely defined voltage and stability criteria, mainly through varying circuit arrangements, transformers and reactive compensation.

Most consumer equipment connected to an electricity system will generate reactive power, necessitating the application of devices that will absorb it, such as capacitors and synchronous generators, in order to control voltage. Synchronous generators are capable of producing and consuming reactive power (VARs) by varying the intensity of the magnetic field (excitation level) of the generator. When a synchronous generator is overexcited, it generates reactive power and delivers it to the system. When the generator is under-excited, negative reactive power flows from the system into the generator. When the generator operates at unity power factor it will neither draw from nor deliver reactive power to the system. Thus, a synchronous generator can provide a boost to the voltage at the point of interconnection akin to that provided by capacitor banks, which are often used by electric utilities to improve voltage regulation on their transmission and distribution lines.

The Cannonsville and Pepacton Developments will utilize synchronous generators, and will thus be able to provide reactive power support services to NYSEG, if necessary. This feature may prove of significant value to NYSEG depending on the topology of the transmission and/or distribution system at the respective points of interconnection. As noted previously, the Pepacton Development is currently proposed to be connected to 4.8 kV distribution lines serving relatively sparse load. Typically, the design and operation of this type of rural line is driven by voltage drop constraints and will thus likely benefit from the reactive and voltage support provided by the hydroelectric generation facility associated with the proposed Pepacton Development.

Figure 4.4: Line Voltage Regulation Benefit of Local generation

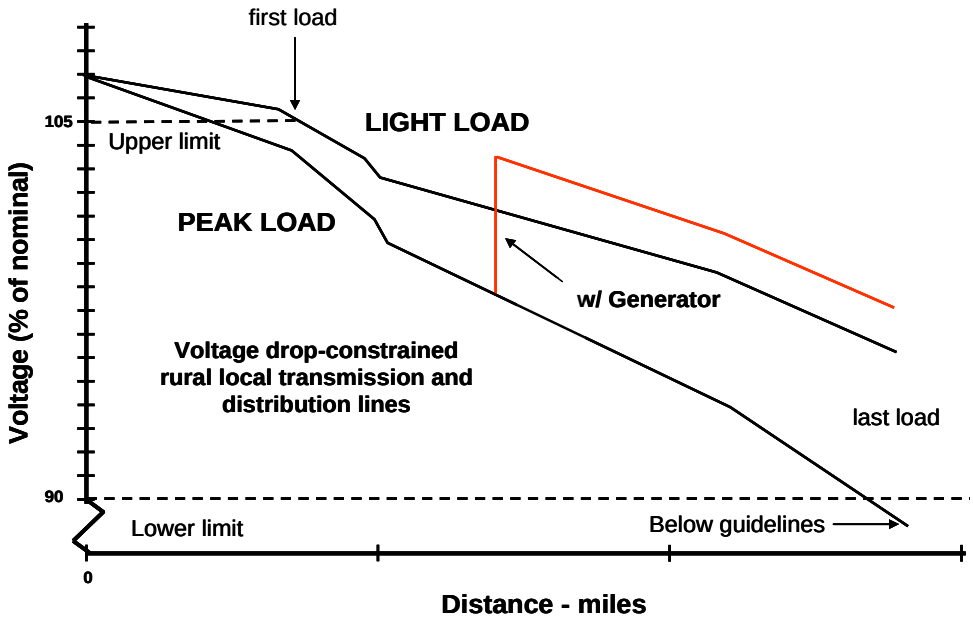


Figure 4.4 illustrates the potential impact of interconnecting a new synchronous generator to the voltage drop profile on an existing distribution line. Depending on the existing configuration of the distribution network and its capacity-demand balance, the Cannonsville and Pepacton

Developments may significantly improve the voltage regulation for the NYSEG customers downstream of the respective points of interconnection.

Another benefit potentially derived by NYSEG from the interconnection of the proposed Project developments may be the deferral of the need to add upstream capacity to meet growing demand. Distribution feeders, and the upstream transformers and switchgear that supply, are typically sized to accommodate growing demand for a number of years. As the growing load approaches the capacity limits of these components, the ability of the system to operate within the applicable service voltage standard during periods of high load, as illustrated in Figure 4.3, requires the utility to first rely on operational adjustments, such as raising the transformer's voltage at the substation where the feeder originates. As continued load growth eventually outstrips the capabilities of this solution, the utility can opt between adding capacitors and voltage regulators to keep all customers along the feeder within the minimum voltage standard; transferring part of the feeder's load to a new or existing feeder; or replacing the feeder's conductors with new ones of larger capacity (if the existing structures and conductor support hardware can accommodate it). The increasing load must also be accommodated by the existing switchgear, the voltage regulator and the distribution bus at the substation and, ultimately, by the substation transformer itself. As these components reach their capacity limits, additional substation equipment must be added to serve the increased load. In some cases, a new substation may be required.

With the exception of strictly operational methods to improve voltage regulation, the utility has to make capital investments to meet load growth for a number of years. However, upon interconnection, the energy and capacity produced by the Pepacton and Neversink Developments will help meet load growth, and, thus, may help to defer NYSEG's need for capital investment in upstream capacity.

5.0 CONCLUSION

The Cannonsville, Pepacton and Neversink Developments are projected to have a modestly positive impact on employment, earnings and economic output in Delaware and Sullivan counties. In part because of the relatively small number of jobs the three developments would create, adverse socioeconomic impacts are likely to be minimal or non-existent.

Moreover, the renewable electricity generated by the Project developments is expected to cause a small reduction in wholesale electricity market prices in New York and modest reductions in annual pollutant emissions from fossil-fuel fired generation sources by displacing the output from such sources. In addition, the Project developments may provide modest additional reliability and power quality benefits at both the local and statewide level.

APPENDIX A: IMPLAN MODEL AND THE MULTIPLIER EFFECT

Spending on the construction and operation of the Project – and the jobs associated with that spending – provide a direct measure of the Project's impact on the local economy. The regional impacts, however, go beyond these direct measures. Each dollar spent in connection with the Project produces what economists sometimes call indirect and induced effects – commonly referred to as the "multiplier effect."

The Project's *indirect impacts* are products of spending by the local companies, contractors and vendors from which the City and the Project's operators buy goods and services. Construction contractors, equipment suppliers, and other firms use the payments they receive to pay their employees, rent space, buy equipment, supplies and other services – all of these expenditures have an impact on the economy as well. The Project's *induced impacts* represent the impact of routine household spending by employees of the contractors, employees of the Project's operators, and by employees of the Project's suppliers (e.g., expenditures for rent, food, clothing, transportation and child care).

There are several quantitative economic models that can provide an approximate measure of indirect and induced effects. Using one of these models – IMPLAN – the impact of spending in connection with the Project on total economic output, wages and employment in Delaware County and Sullivan County was estimated.

The IMPLAN model allows for the tracking of the impact of each dollar of spending as it ripples through other industry sectors in Delaware ad Sullivan Counties, translating the allocation of spending across industries into estimates of employment and wages.

APPENDIX B: WHOLESALE ENERGY PRICE IMPACT MODEL

Consistent with other centralized markets, in the NYISO-administered markets, real-time energy prices are determined by the last generation unit required to meet demand, considering system transmission constraints. Output from the Project would reduce the need for higher-cost units to run in many hours, and thereby lower wholesale market-clearing prices. To assess the magnitude of the benefit of induced lower energy prices, a statistical model was developed to estimate the relationship between changes in generation capacity and changes in real-time energy prices. The statistical analysis for the NYISO-administered markets, the resulting model, and the underlying model logic are described in this Appendix B.

Fundamental to the estimation of economic benefits from the output of the Project is the fact that the generation facilities associated therewith are hydroelectric facilities with very low variable operating costs. It will therefore nearly always be economic to operate such facilities, and their output will displace generation of more expensive fossil-fuel fired generation setting the market price on the margin. The fact that the Project's proposed hydroelectric generation facilities operate at the bottom of the resource supply stack makes it possible to model the price impact of the generation output associated therewith as an equivalent, and opposite, change in load (i.e., electrical demand).

Using available historical market data (hourly loads, real-time clearing prices, and daily natural gas prices), a statistical model of the relationship between load and energy prices in the NYISO-administered markets was constructed. This relationship was then used to estimate the effect on prices of projected output from the Project.

For an arbitrary, short period of time, the availability of generation to serve load in a given area and the variable cost of such resources, can be considered fixed. In a system with economic dispatch and no transmission constraints, this amounts to a fixed supply curve, such that the market-clearing price is determined by the level of total demand. This is illustrated in Figure B.1, where a load of 8,500 MW results in a clearing price of approximately $50/MWh.

Figure B.1: Illustrative Load-Price Relationship

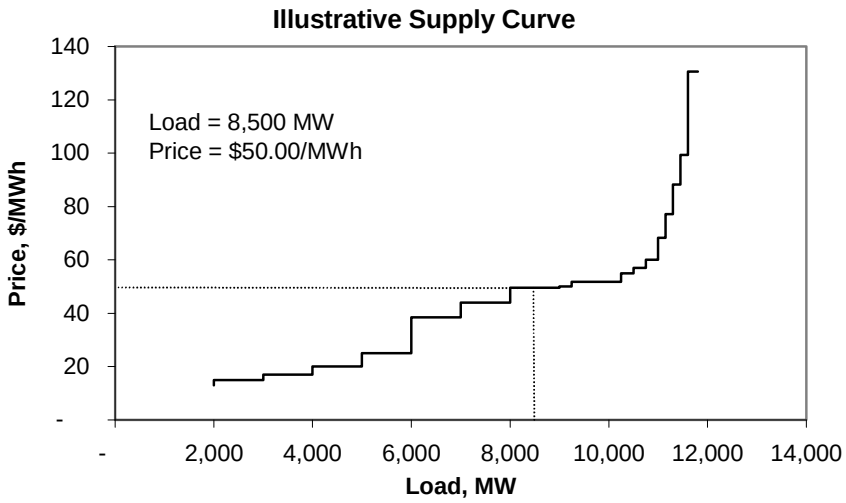
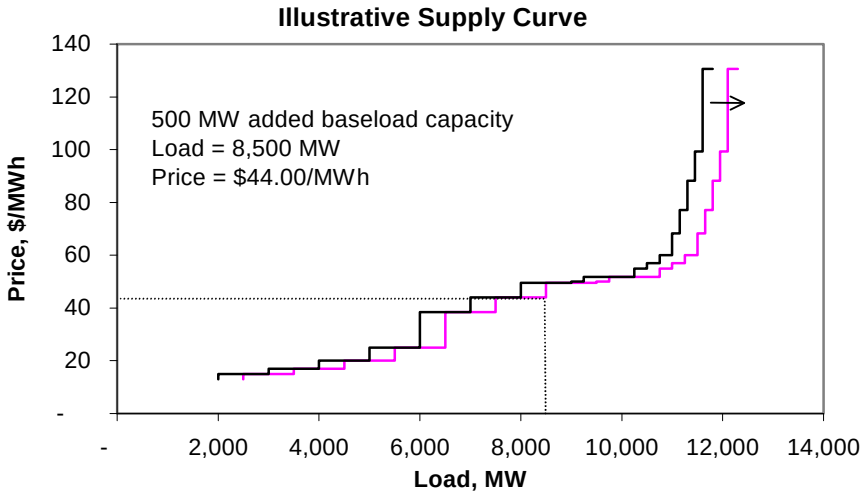


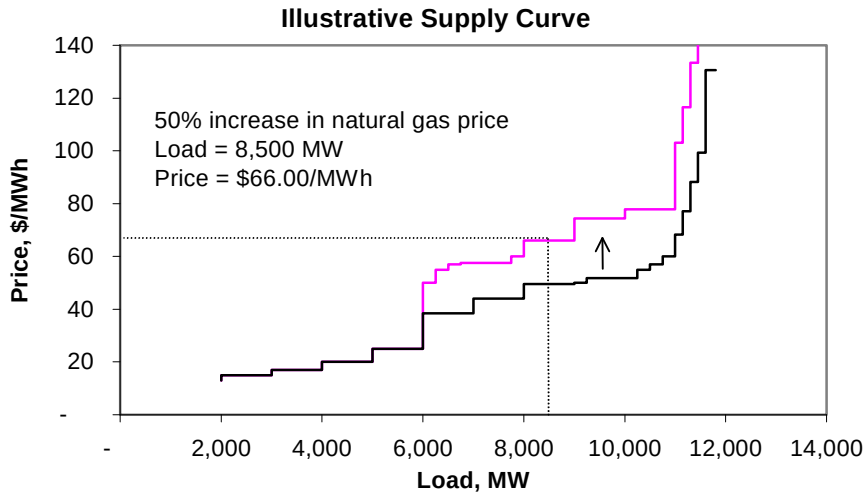
Figure B.2 illustrates what happens when baseload generation such as run-of-river hydroelectric or nuclear increases. The supply curve shifts to the right, eliminating the need for the $50.00/MWh resource to run in order to meet load, thereby, allowing the market-clearing price to be set by the next lowest cost resource at $44.00/MWh. This illustrative example shows the effect of adding 500 MW of baseload capacity, an amount far greater than the capacity associated with the proposed Project developments, in order to create a clear visual presentation. Though the magnitude of output from the proposed Project developments would be a fraction of that illustrated below, the fundamental principle is the same.

Figure B.2: Increased Baseload Generation



The shape of the supply curve is also sensitive to changes in fuel prices. The primary source of price volatility is the natural gas commodity price. Figure B.3 illustrates the impact on the supply curve of a 50% increase in natural gas prices.

Figure B.3: Natural Gas Price Increase



To account for changes in the shape of the supply curve, either resulting from fuel price changes or seasonal changes in resource capacity and availability, the load and price data were categorized by period and by the prevailing level of natural gas prices. Separate regressions of price on load were calculated for each grouping. The segmentation by natural gas price removes this factor as an explanatory variable and isolates changes in load as the explanatory variable determining price variation. The purpose of this analysis is not to forecast electricity prices, but, rather, to examine the relative impact of a change in baseload generation on energy prices.

This analytical approach offers some advantages over a structural model, particularly in reflecting market dynamics. For example, in a structural model (i.e., a model that attempts to simulate the operation of individual generation resources) shocks to the system, such as unforced generation outages, must be either ignored or specified as probabilities. Moreover, other factors, such as the ability of some plants to operate beyond nameplate capacity for short periods, or other dynamic responses by market participants, are difficult to incorporate in structural models. However, information about such influences is implicit in the historical market data utilized by the model, and the statistical approach can account for it as a matter of course.

NYISO Price-Load Model Specification

Hourly loads and hourly real-time locational-based marginal prices ("LBMPs") for the NYISO-administered markets were obtained from for the 36-month period June 2008 through May 2011. The 36-month period was selected to be long enough to encompass sufficient variation to produce meaningful statistical results, while not being so long as to invalidate the assumption of a reasonably stable generation supply curve.

The model was specified for the western part of NYISO, encompassing Zones A, B, C and E. Hourly load for the western region was determined as the simple sum of hourly zonal loads. Hourly prices were calculated on a load-weighted basis for the model region.

Daily natural gas spot prices at Henry Hub were obtained for the same June 2008 through May 2011 period.

The statistical model parses the year into six bimonthly groups. This segmentation accounts for seasonal differences in capacity availability and generation capability. The load and LBMP data were further parsed into subsets of the bimonthly groupings based on ranges of historical natural gas prices. Table B.1 shows the twelve parsed subgroups utilized by the model.

Table B.1: Regression Subgroups

Bimonthly Group	Gas Price Range, $/mmBTU	Hours in Subgroup	Average NG Price, $/MMBtu
Jan-Feb	Below $5.00	2496	4.60
	Above $5.00	1752	5.61
Mar-Apr	Below $4.00	2232	3.72
	Above $4.00	2160	4.27
May-Jun	Below $5.50	3672	4.13
	Above $5.50	696	12.64
Jul-Aug	Below $5.00	2976	3.86
	Above $5.00	1488	9.72
Sep-Oct	Below $5.50	2928	3.58
	Above $5.50	1464	7.20
Nov-Dec	Below $5.00	2352	3.74
	Above $5.00	2040	6.01

Regressions were then run for each of the subgroups, using the log-linear functional form shown below, where *LBMP* is taken to be the load-weighted average price,[23] and *Load* is the hourly New York Control Area load divided by 1,000.[24]

$$\ln(LBMP) = \alpha + \beta_1 Load + \beta_2 Load^2 + \beta_3 Load^3 + \beta_4 Load^4 + \beta_5 Load^5$$

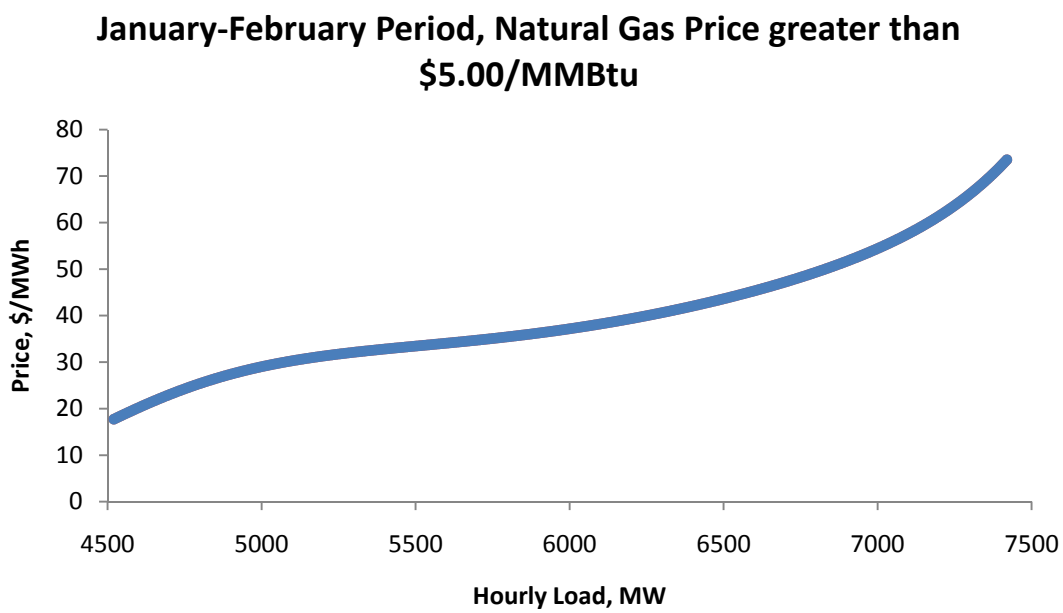
[23] Using the log of price in the regressions restricts the estimated prices to positive values. This is a commonly applied technique. In the occasional cases where negative hourly LBMPs occur (rendering the log of price meaningless) the previous hour's LBMP is used.

[24] The use of the divisor 1,000 prevents the power variables from exploding beyond the significant digit capability of Microsoft Excel, which was used to estimate the regressions.

The incorporation of the powers of load allows the estimated price curve to reflect the shape of the underlying, cost-based supply curve. For the NYISO-administered markets, the supply curve for a given period is generally characterized by: (1) a low and rising shape (i.e., low price) for lower levels of demand (corresponding to supply from hydroelectric, nuclear and baseload coal generation resources); (2) a middle plateau (corresponding to intermediate fossil–fuel fired generation); and (3) a sharp rise at high loads (corresponding to expensive, peaking resources).

Figure B.4 depicts the price-load function based on the regression results for the first January-February subgroup itemized in Table B.1. The X-axis represents the approximate range of actual load during the relevant periods (January and February of 2009, 2010, and 2011) when the price of natural gas was greater than $5.00/MMBtu.

Figure B.4: Example Estimated Price Curve



A reference series of hourly energy prices for each sub-period was first estimated to establish the status quo. Change cases were then calculated reflecting output from the Project. To do this, hourly loads for each estimation period were *reduced* by an amount corresponding to the projected average output from the Project.

The dollar benefit to load (consumers) in the western NYISO region from the generation associated with the Project was then calculated as the hourly price change, multiplied by the hourly load in each sub-period, summed over the three years of data and averaged to calculate an annualized value.

The base model assumed that daily generation associated with the Project would be spread evenly across all hours of each day.[25] An alternative representation of generation was also modeled as a sensitivity. For the purposes of such sensitivity, instead of modeling the impact of average hourly generation associated with the Project, the full capacity output of the Project's generation facilities was modeled for every hour, and the resulting impact was then reduced according to projected generator capacity factors.[26] The results of this alternative specification were very close to the base case results, reflecting the fact that total output and average output are both very small relative to the total NYISO system, and have effects at virtually the same part of the estimated load-price function.

[25] Daily generation was based on estimates provided by Gomez and Sullivan Engineers, PC – the City's lead consultant with respect to the Project – which was derived from 60 years of historical water release data.

[26] Capacity factor is a measure of actual or projected output as a percentage of theoretical maximum output across all hours.