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

NYC Environmental Protection

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.

<u>Entrainment</u>

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

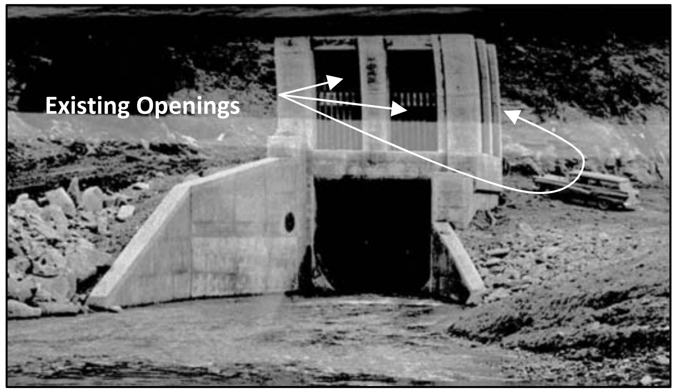
Reservoir Characteristics

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.

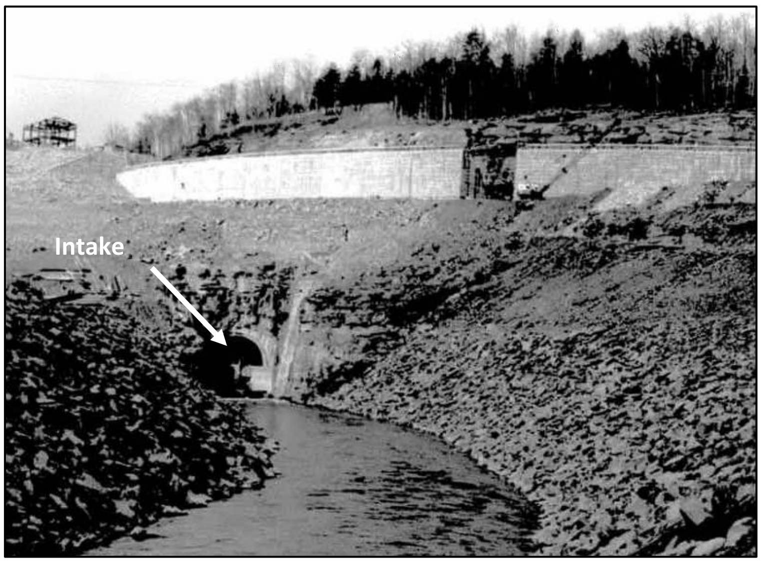
[7] This opening was used to divert water during the construction of the dam and is no longer used.

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

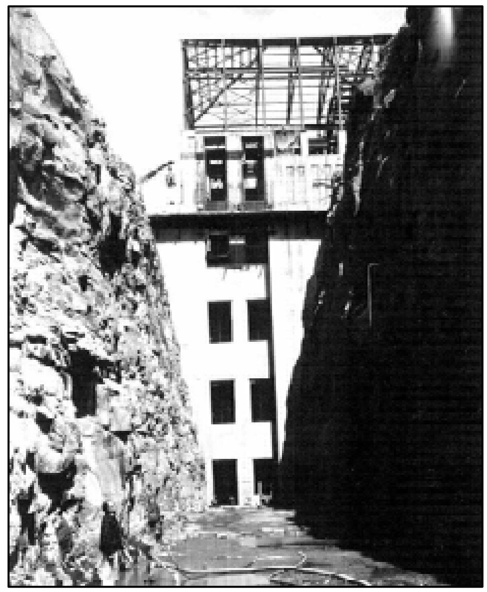
Reservoir Characteristics

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

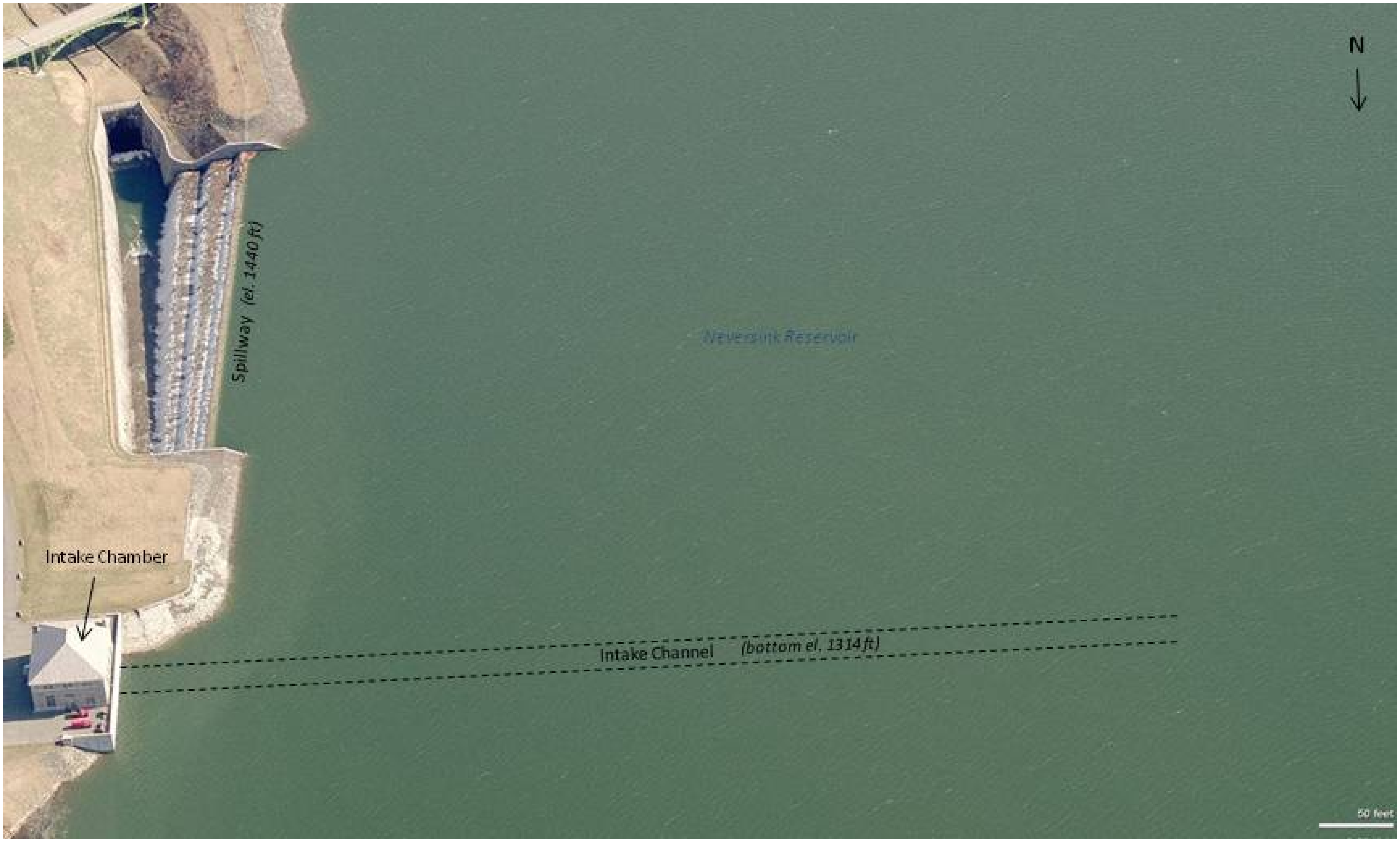
Figure 3.2-1: Cannonsville intake structure location.

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.

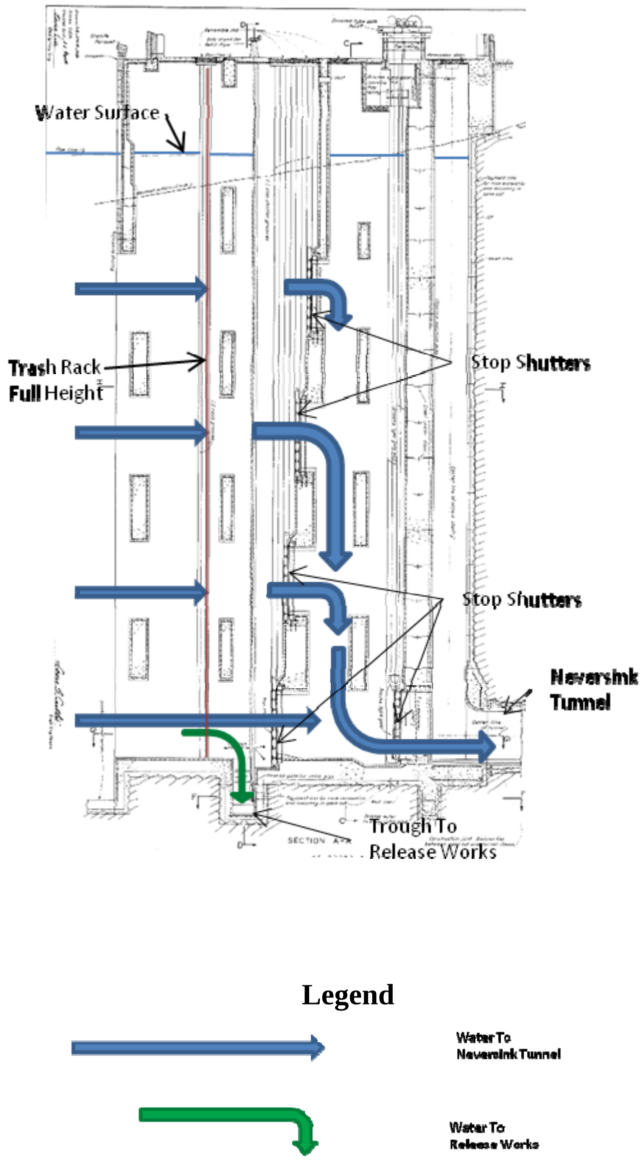
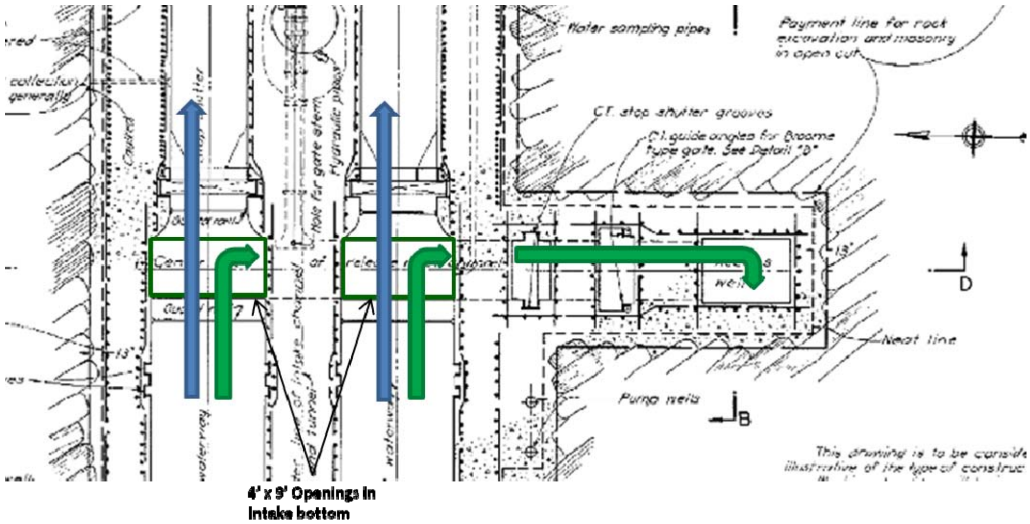
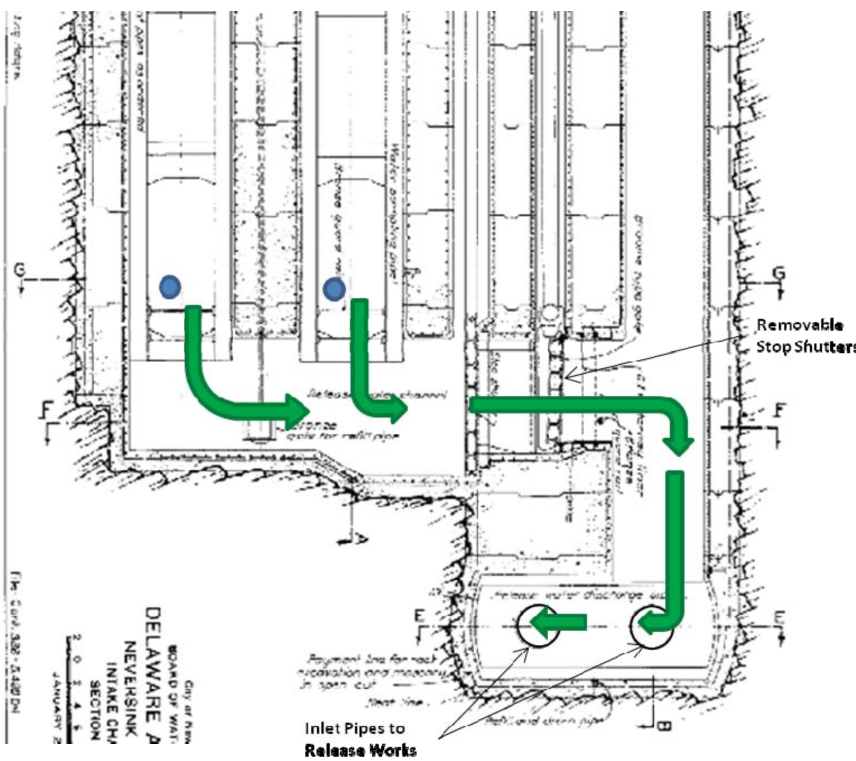


Figure 3.4-3a: Plan view of Neversink intake troughs.



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.

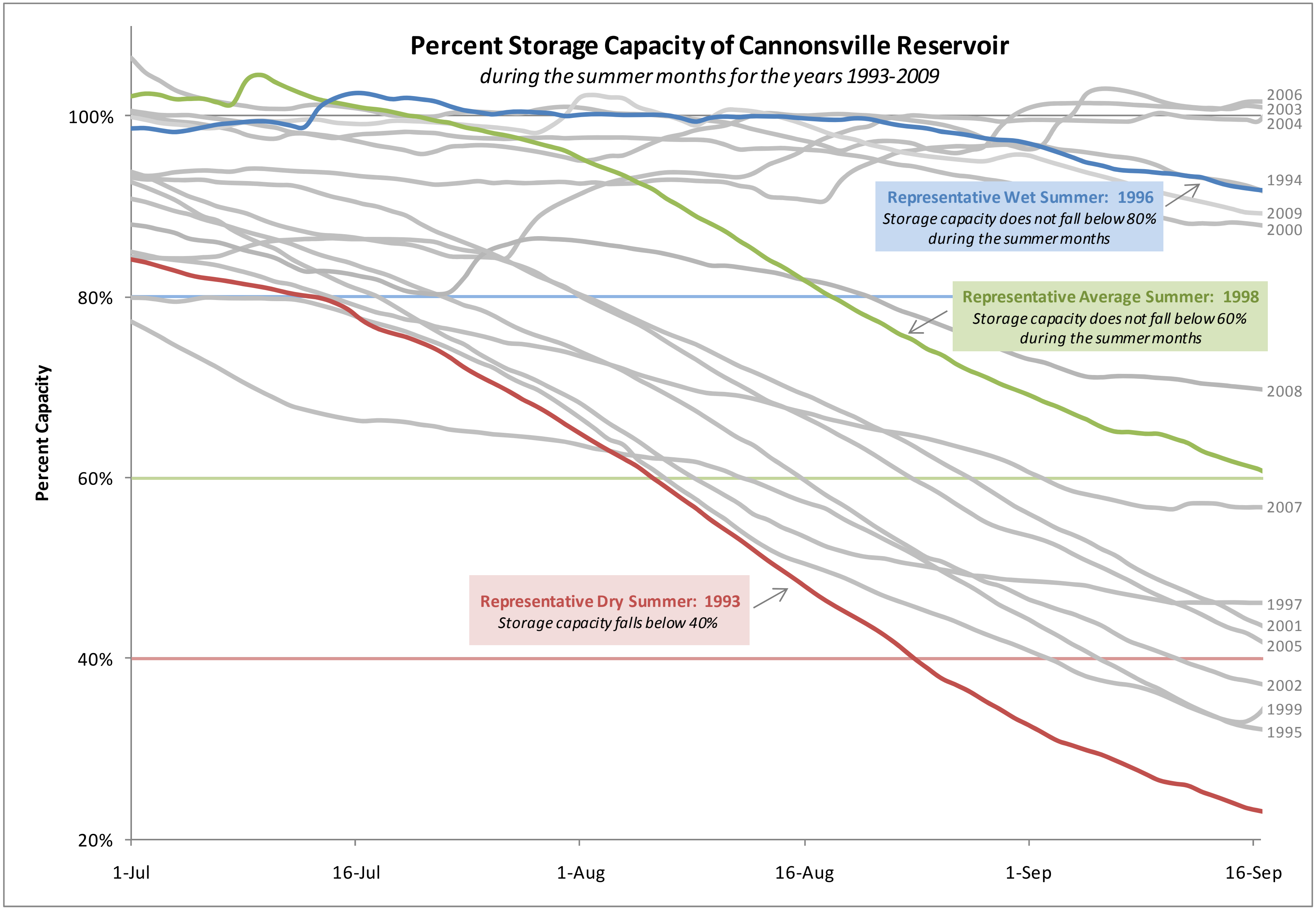


Figure 4.1-2: Hydrographs for representative wet, dry, & average summers.

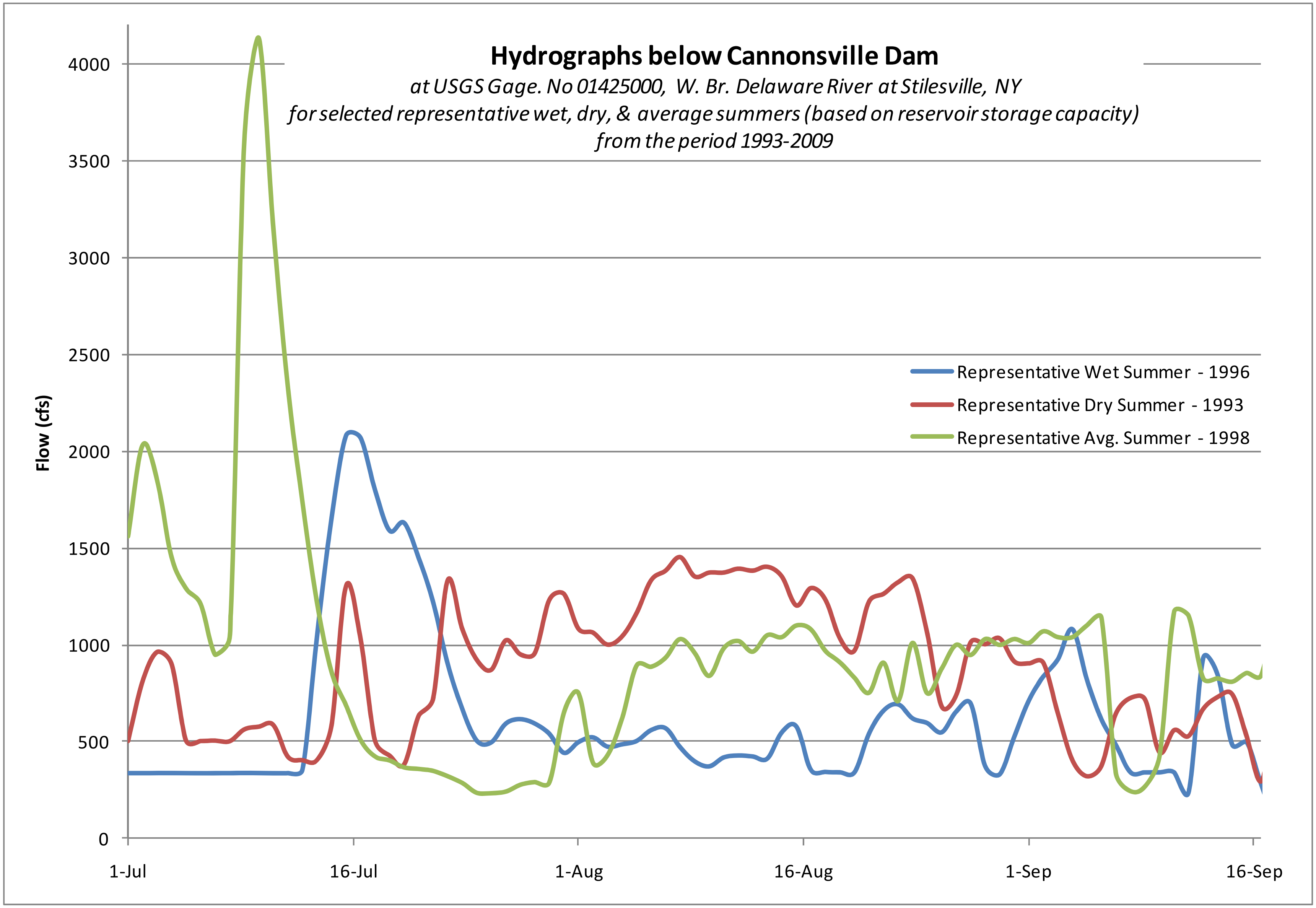


Figure 4.2-1: Annual water level duration curves at Cannonsville Reservoir.

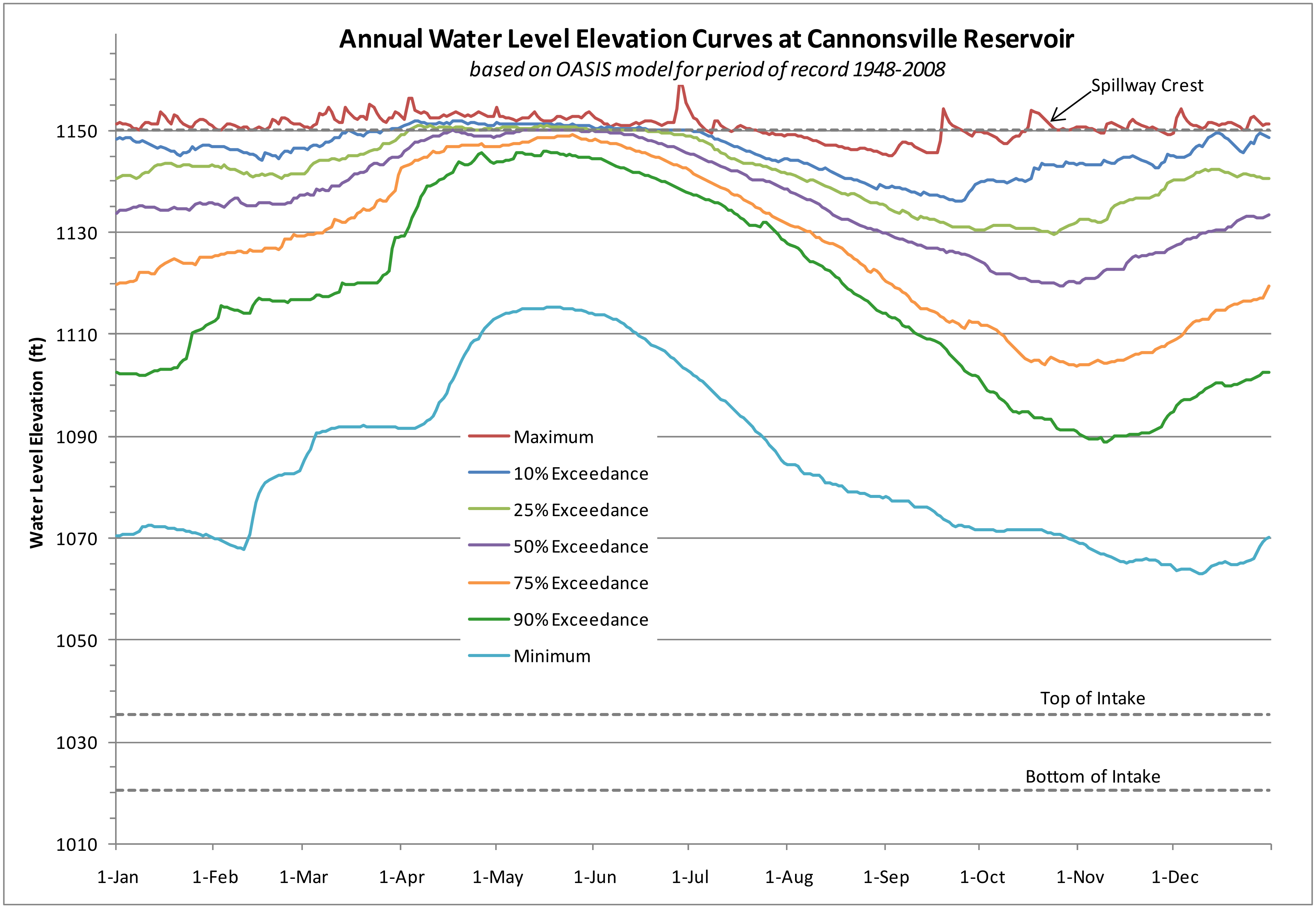


Figure 4.2-2: Water level duration curves at Cannonsville Reservoir for Jan, Feb, and Mar.

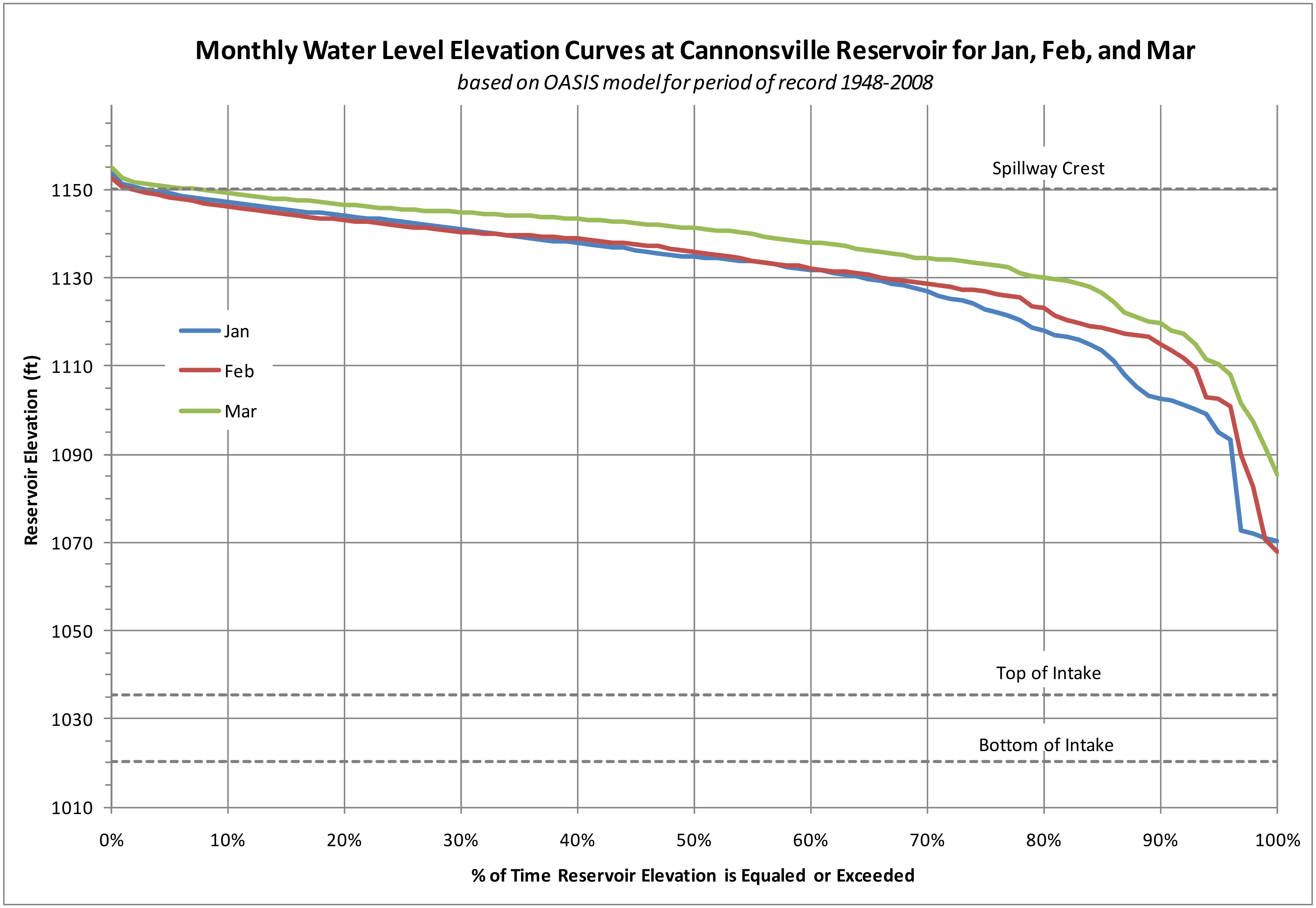


Figure 4.2-3: Water level duration curves at Cannonsville Reservoir for Apr, May, and Jun.

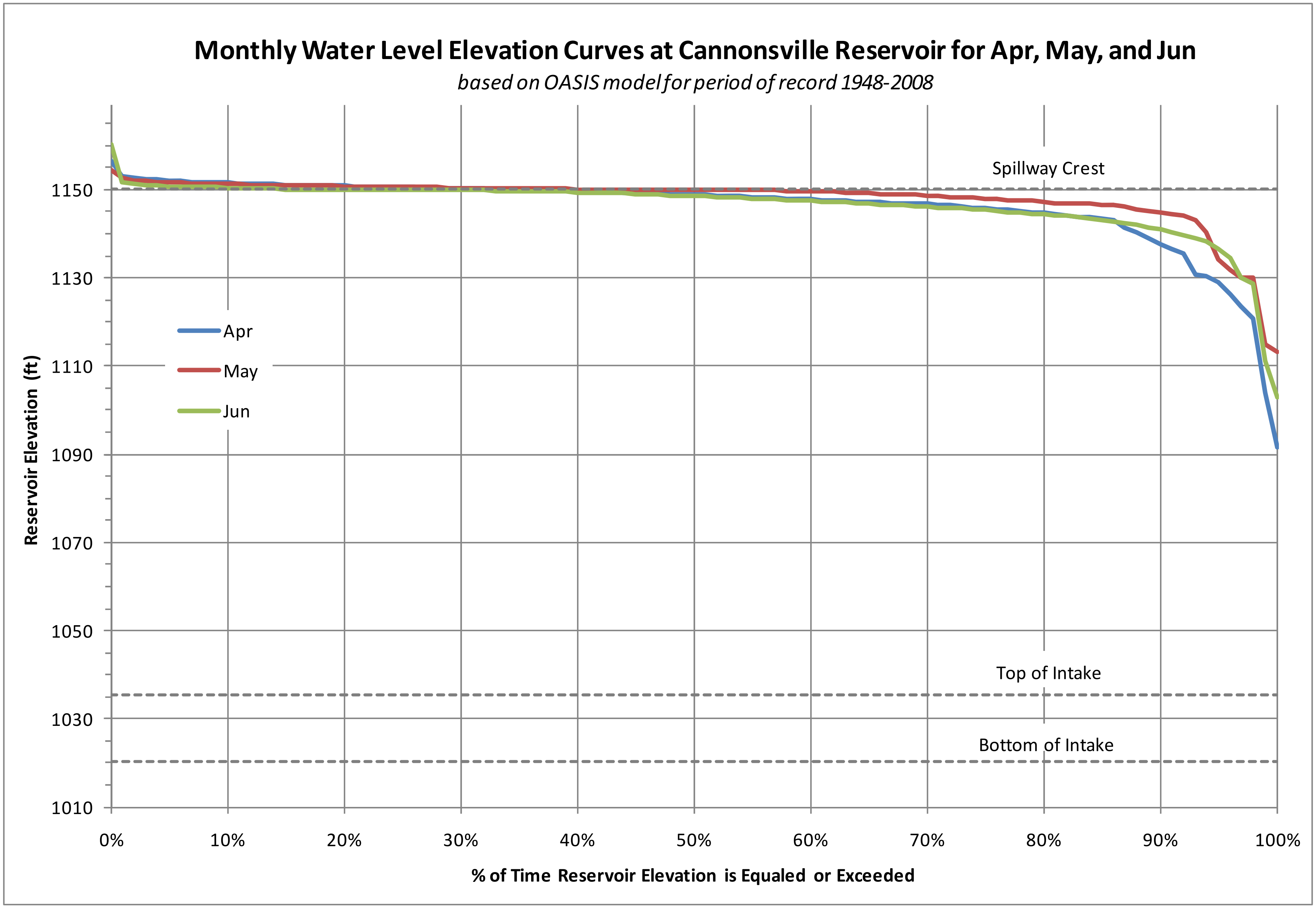


Figure 4.2-4: Water level duration curves at Cannonsville Reservoir for Jul, Aug, and Sep.

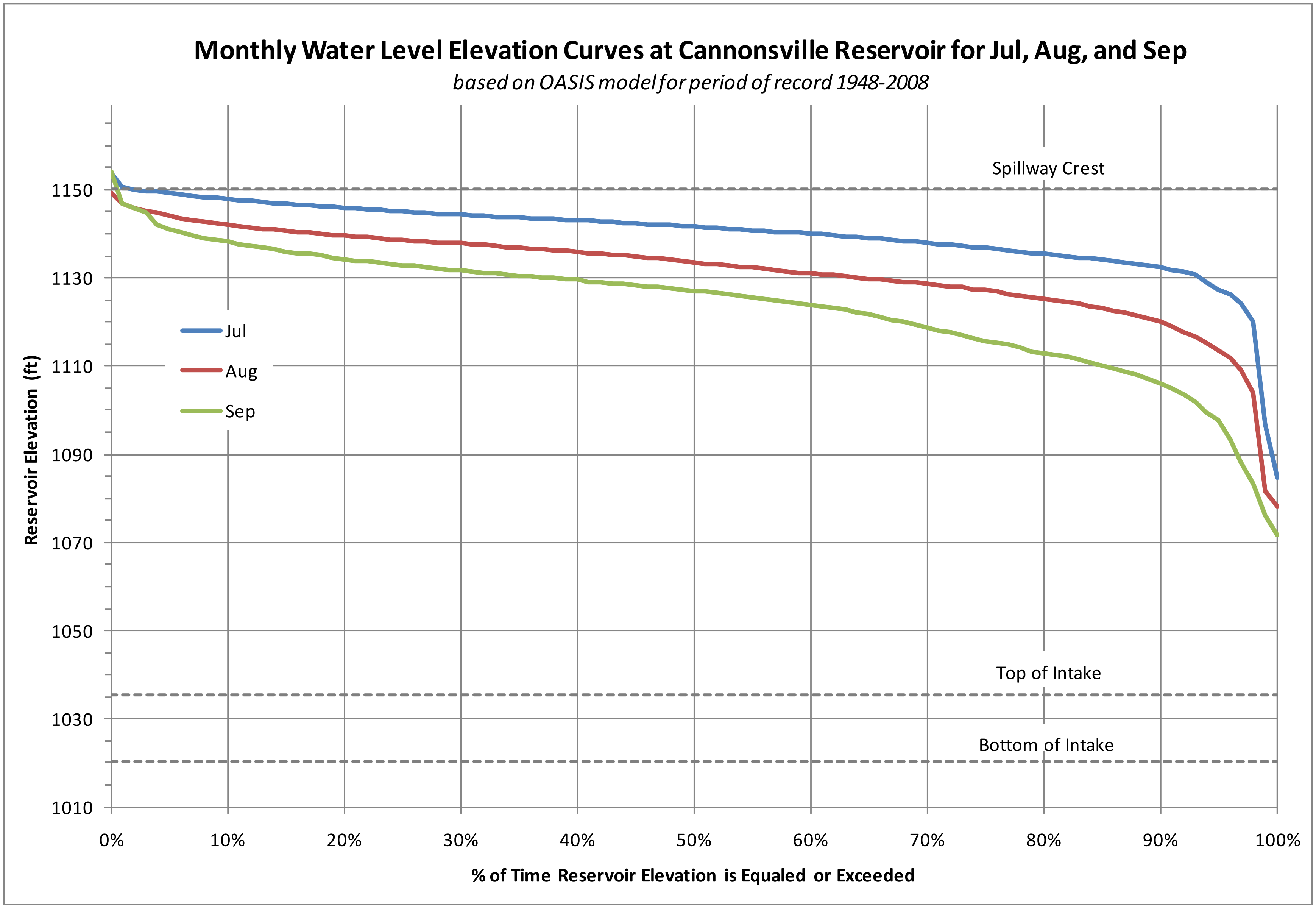


Figure 4.2-5: Water level duration curves at Cannonsville Reservoir for Oct, Nov, and Dec.

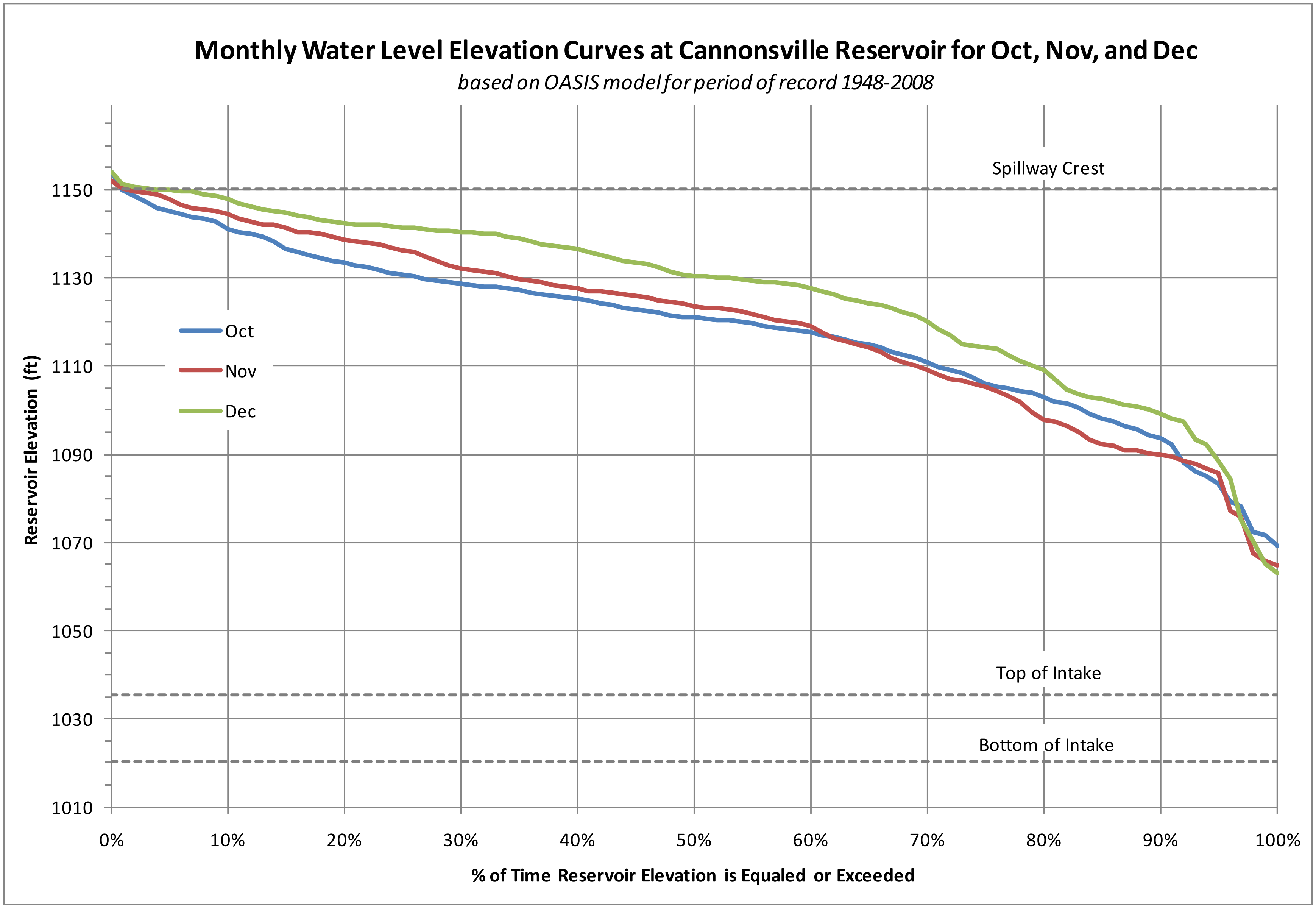
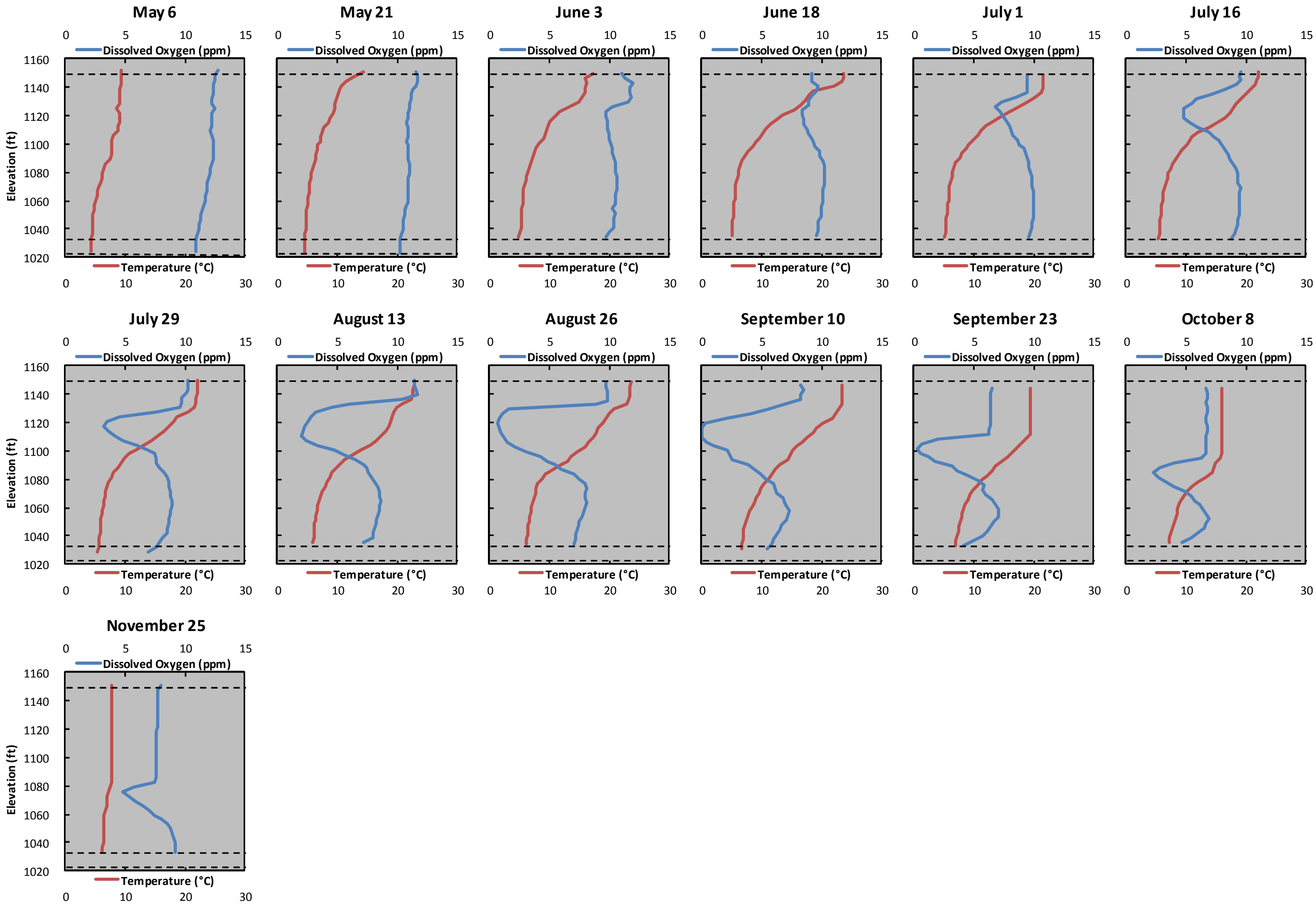
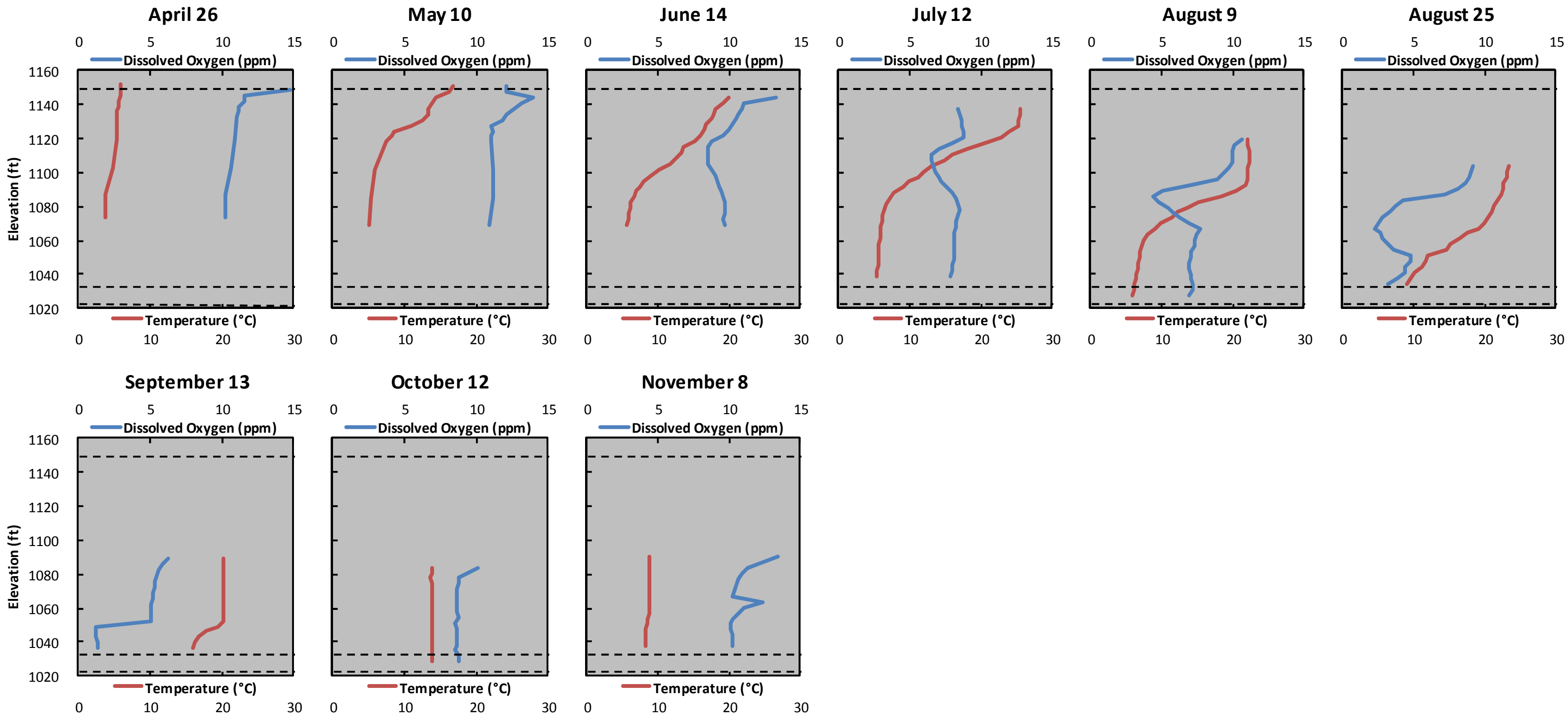


Figure 4.2-6: Temperature & DO profiles at Cannonsville Reservoir for the wet year (1996).



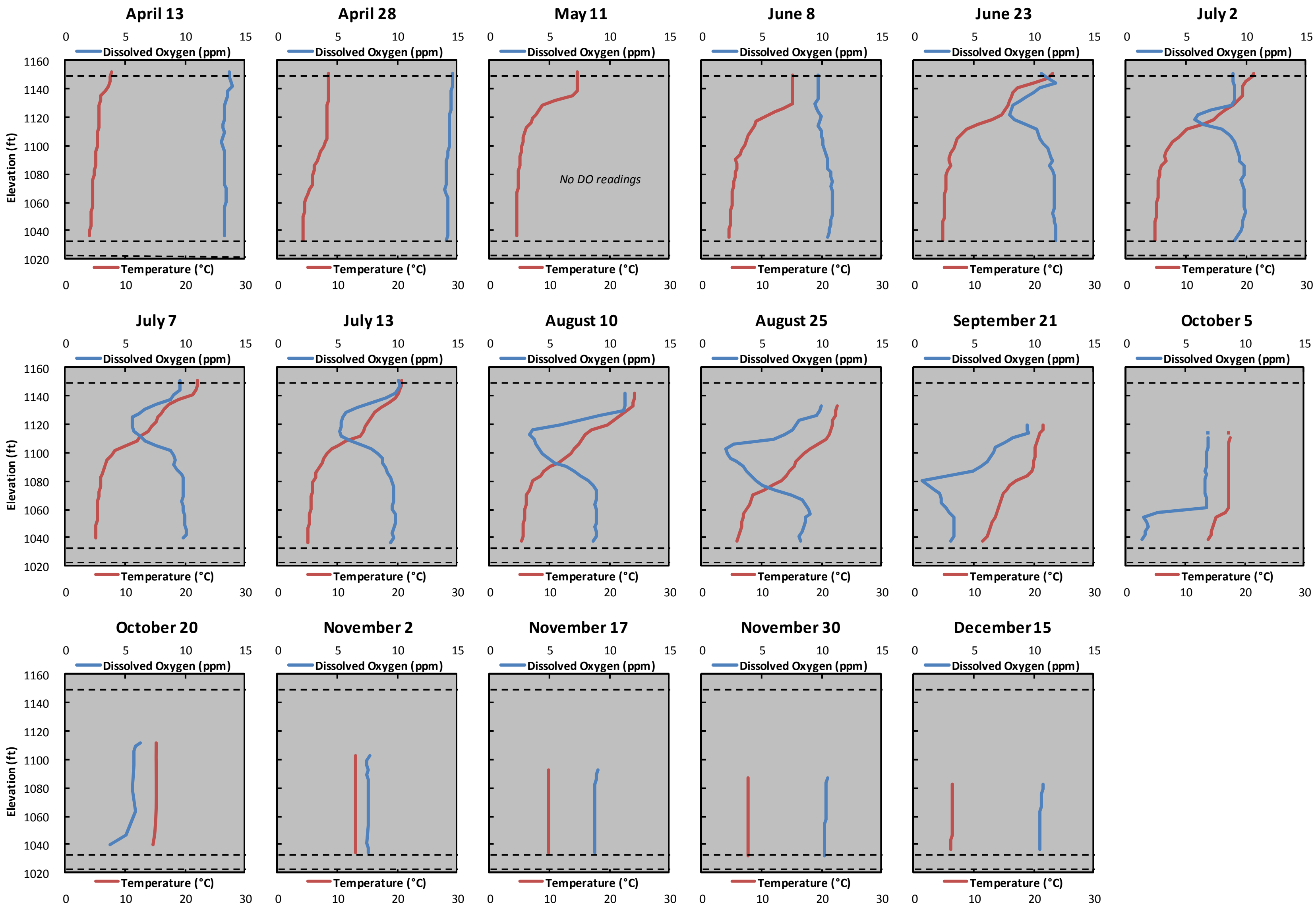
Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1150 ft above msl), top of intake (1035.5 ft above msl), and bottom of intake (1020.5 ft above msl).*

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.

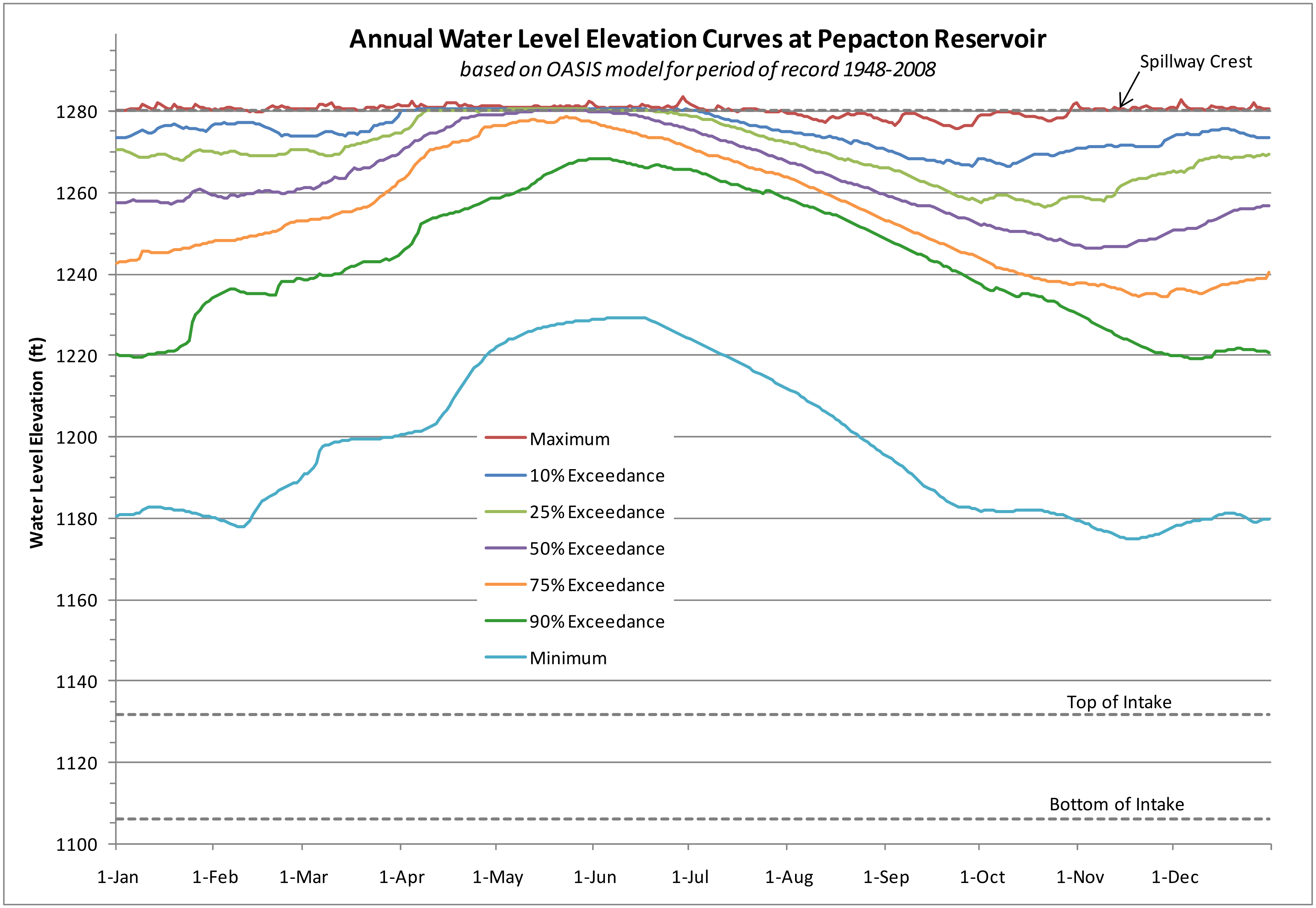


Figure 4.3-2: Water level duration curves at Pepacton Reservoir for Jan, Feb, and Mar.

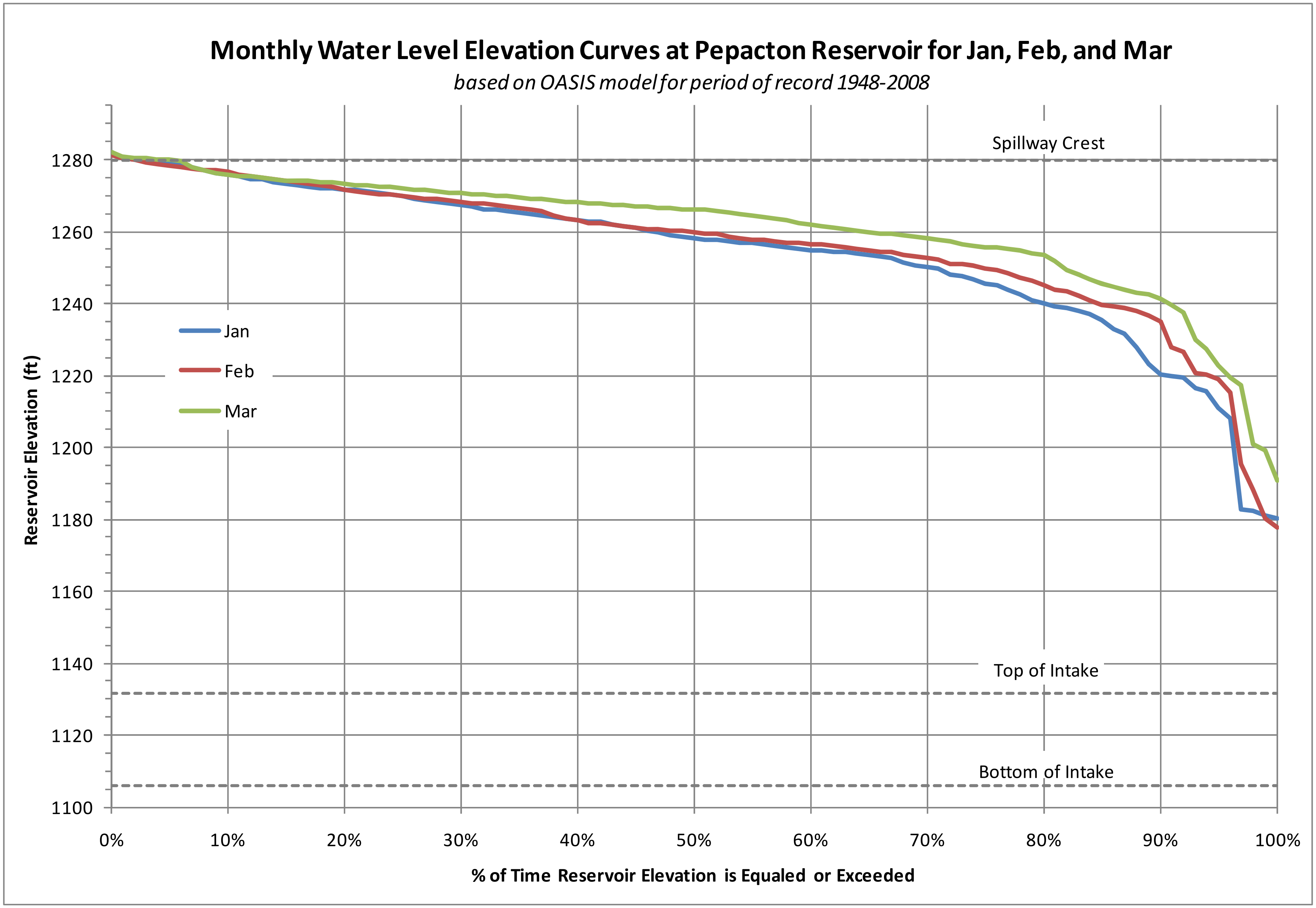


Figure 4.3-3: Water level duration curves at Pepacton Reservoir for Apr, May, and Jun.

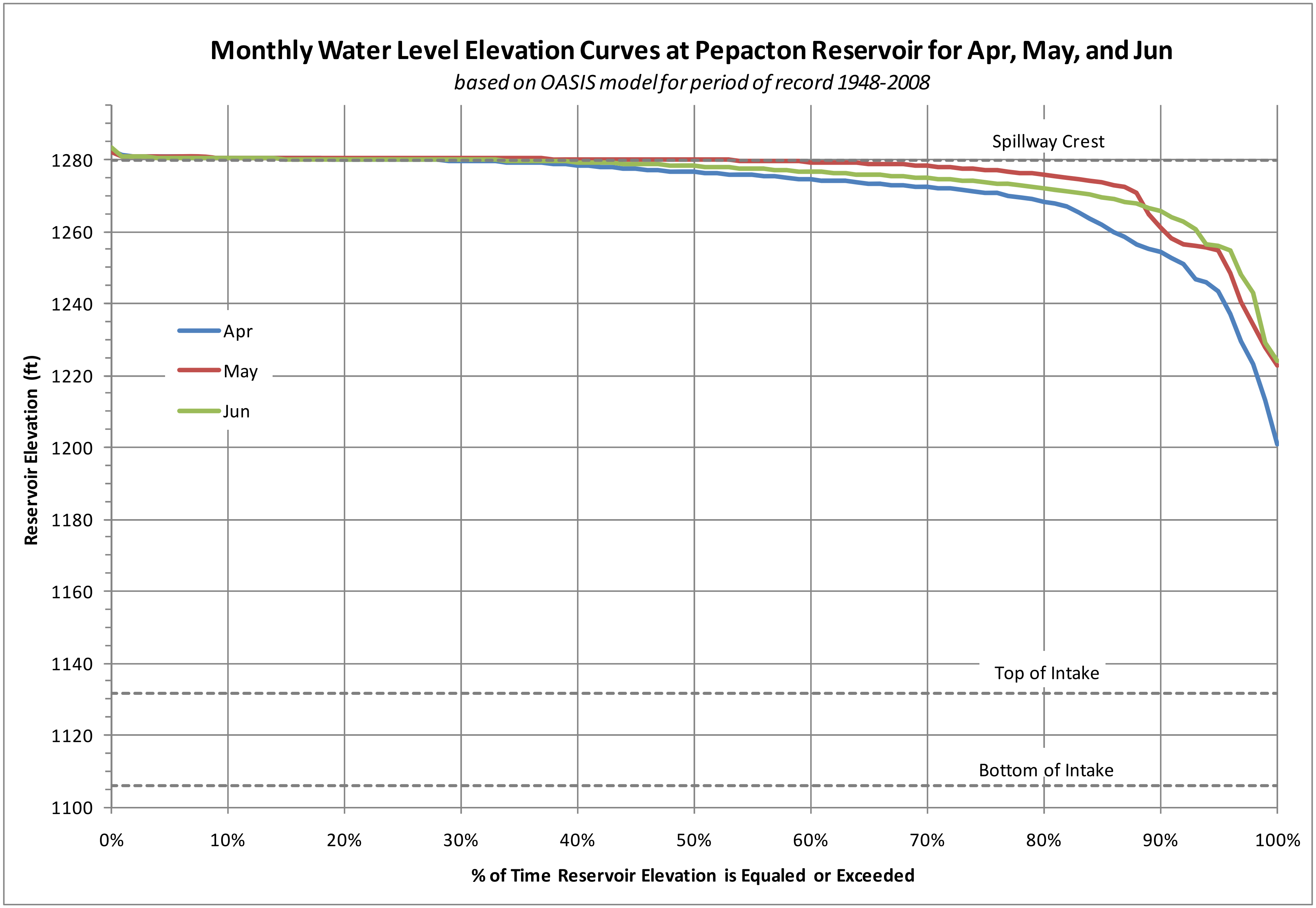


Figure 4.3-4: Water level duration curves at Pepacton Reservoir for Jul, Aug, & Sep.

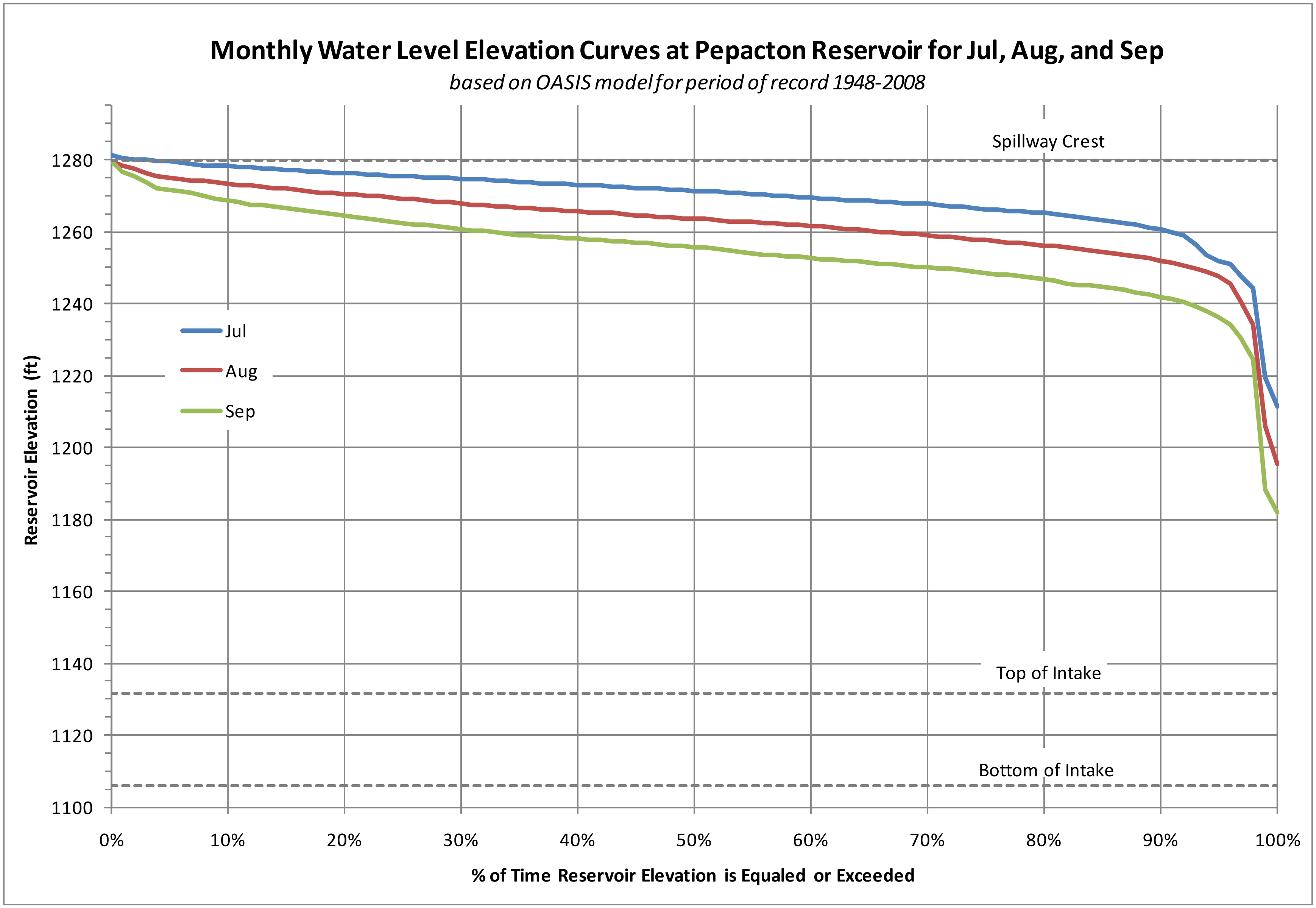


Figure 4.3-5: Water level duration curves at Pepacton Reservoir for Oct, Nov, and Dec.

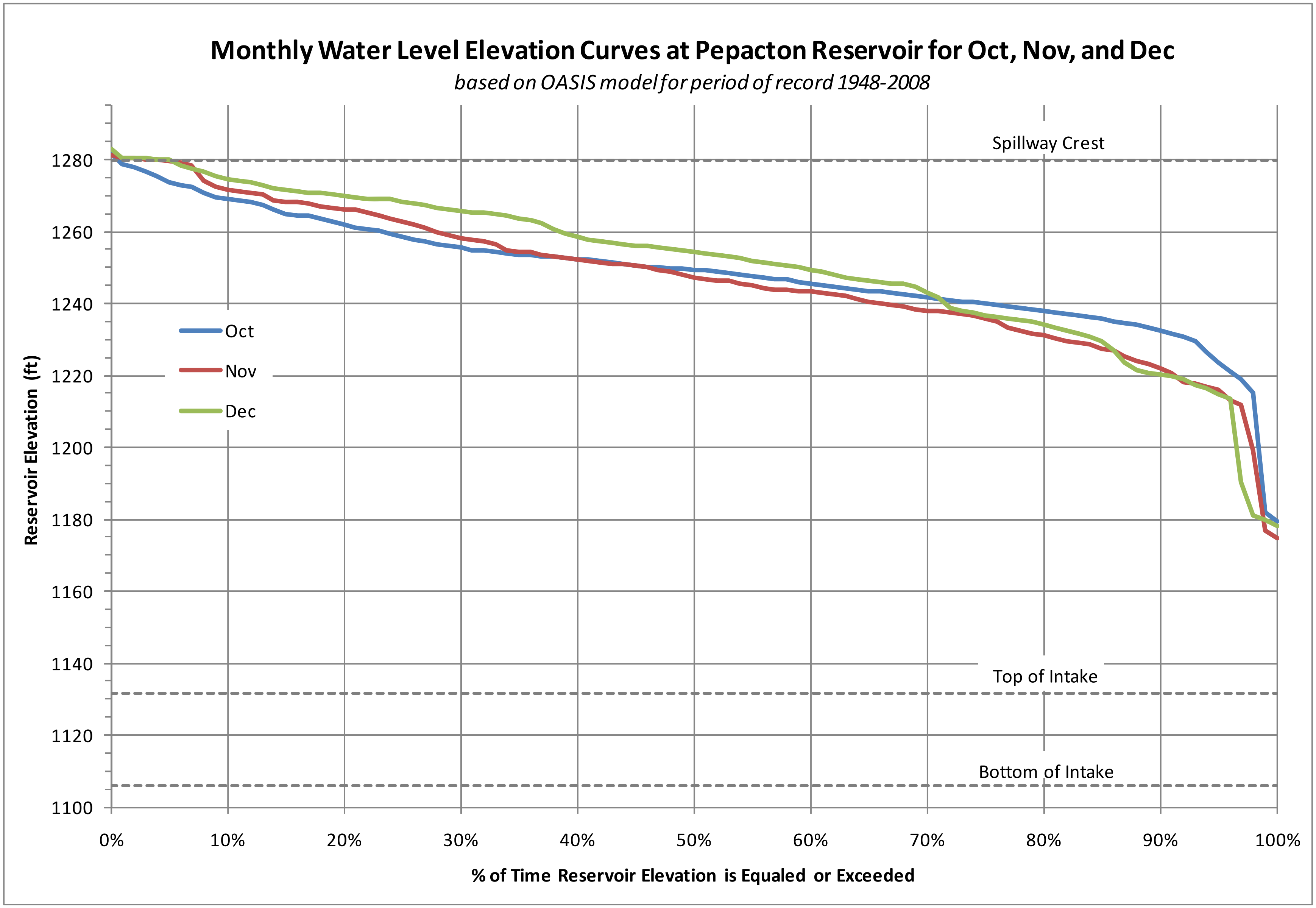
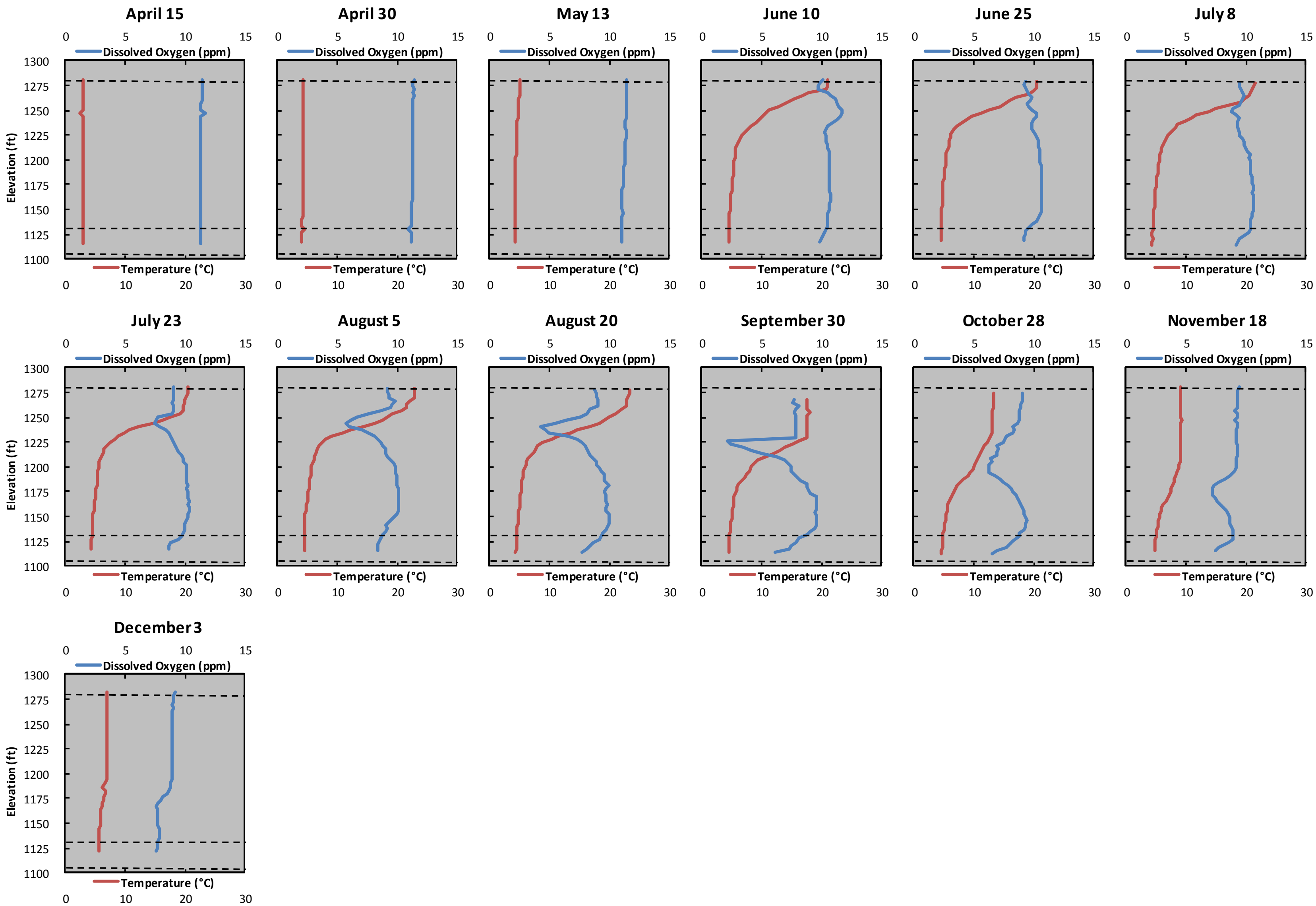
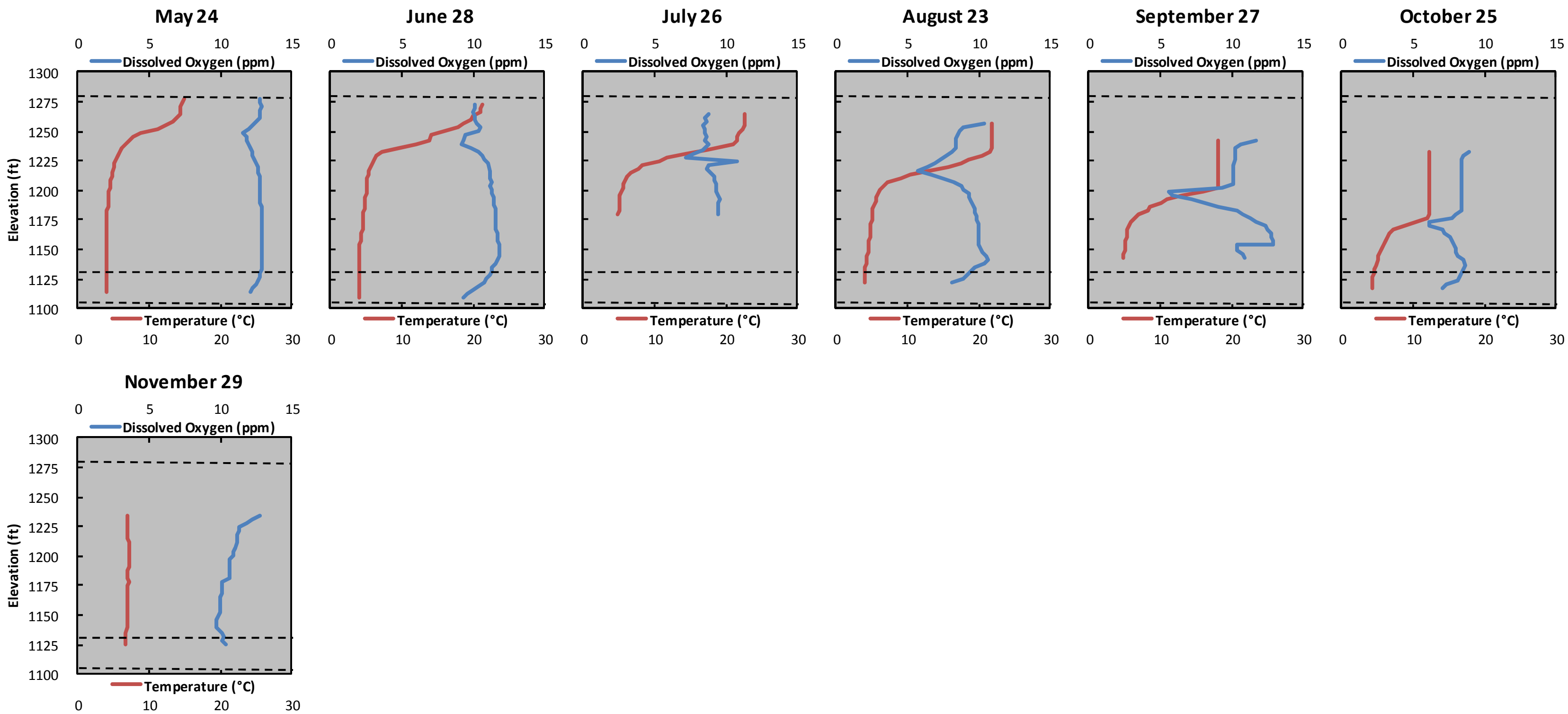


Figure 4.3-6: Temperature & DO profiles at Pepacton Reservoir for the wet year (1996).



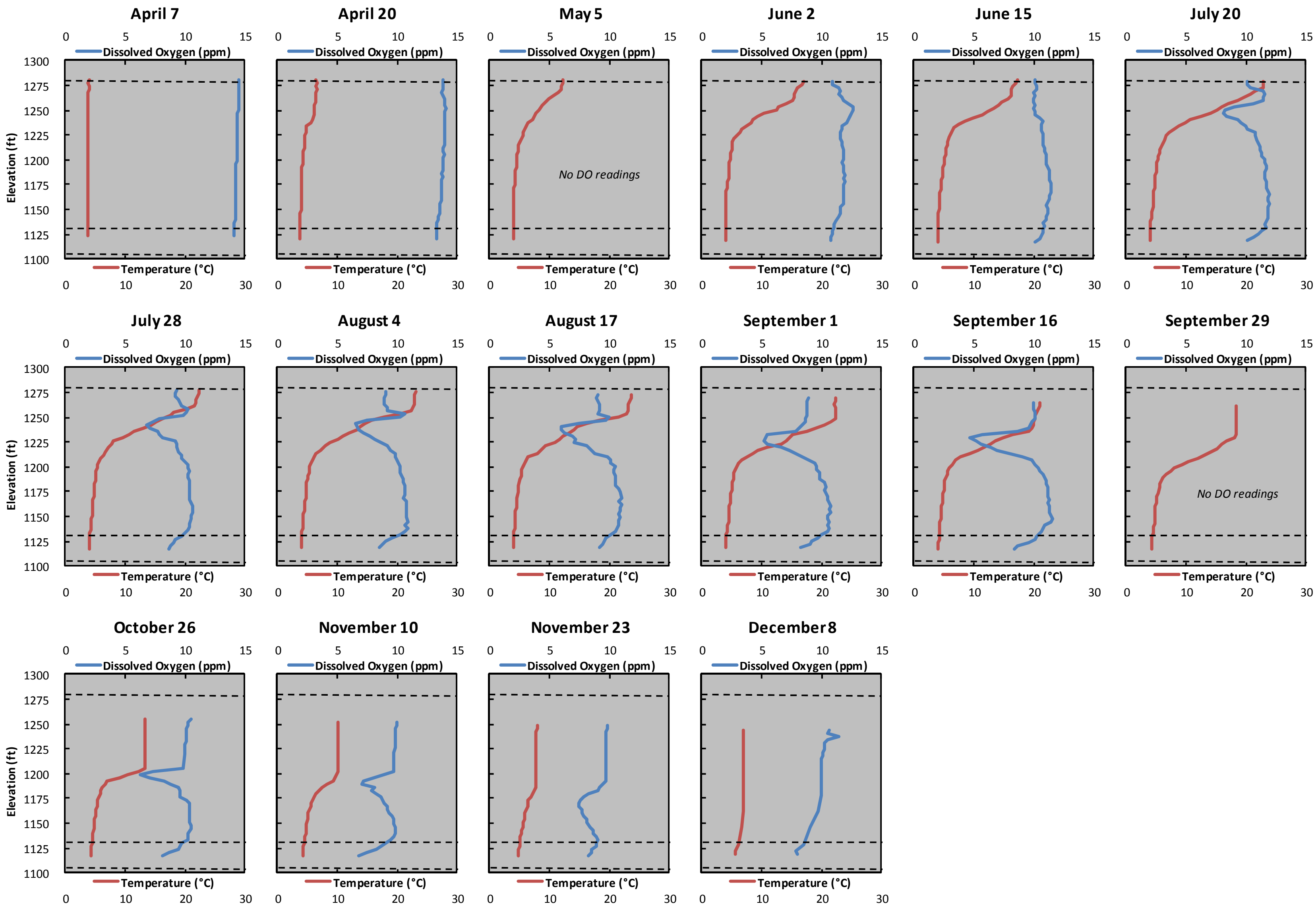
***Note:** The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1280 ft above msl), top of intake (1131.75 ft above msl), and bottom of intake (1106.0 ft above msl).*

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.

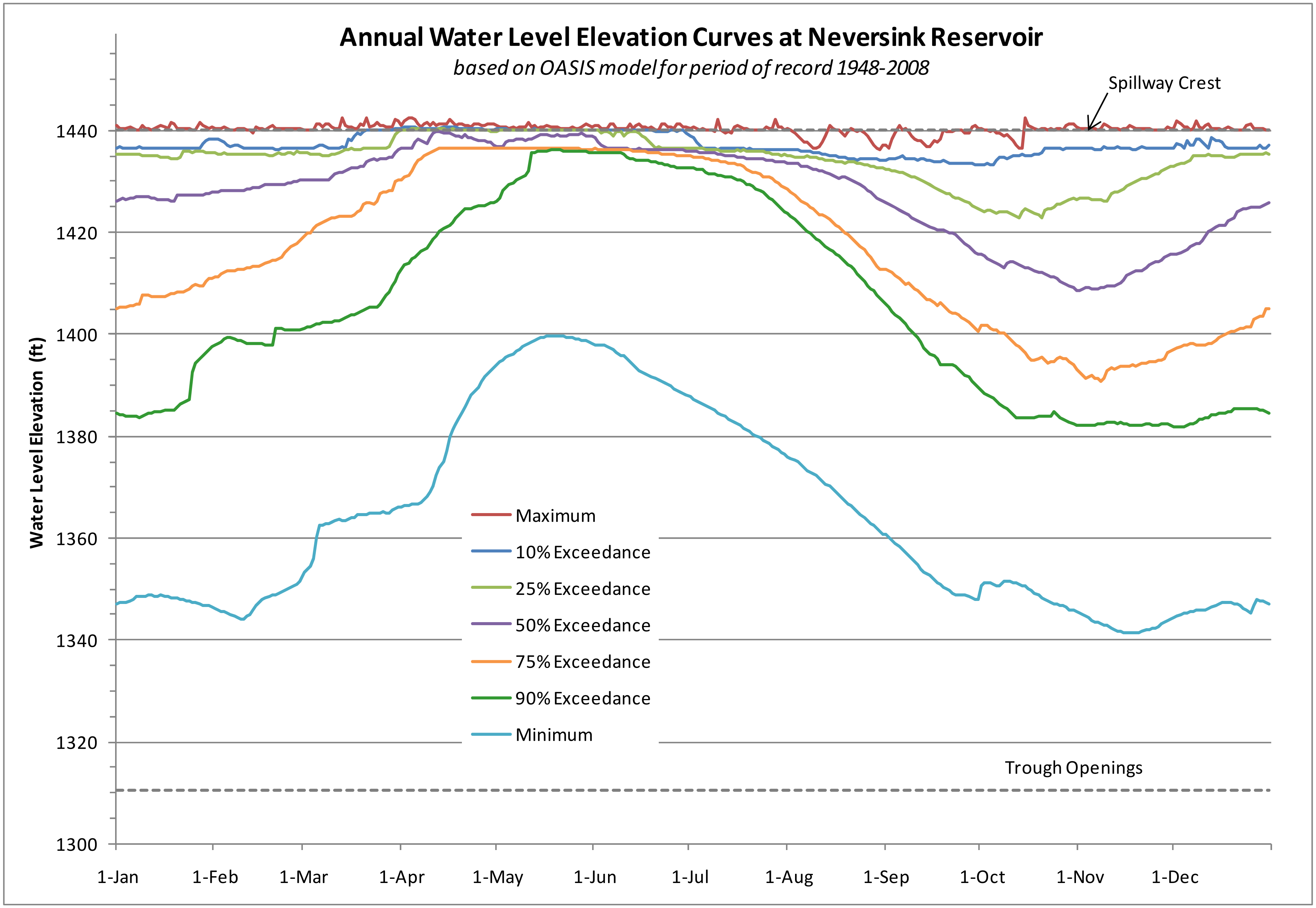


Figure 4.4-2: Water level duration curves at Neversink Reservoir for Jan, Feb, and Mar.

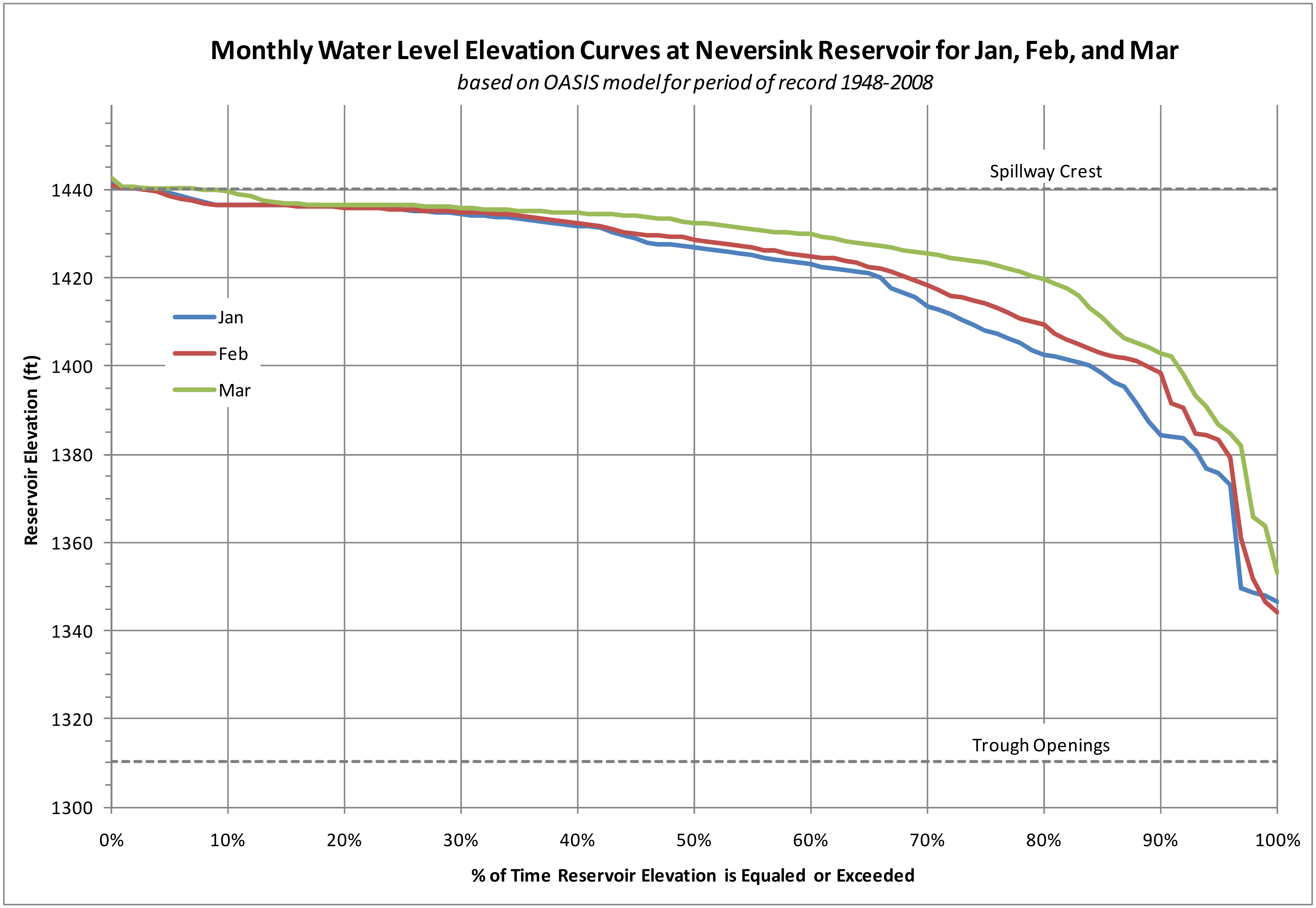


Figure 4.4-3: Water level duration curves at Neversink Reservoir for Apr, May, and Jun.

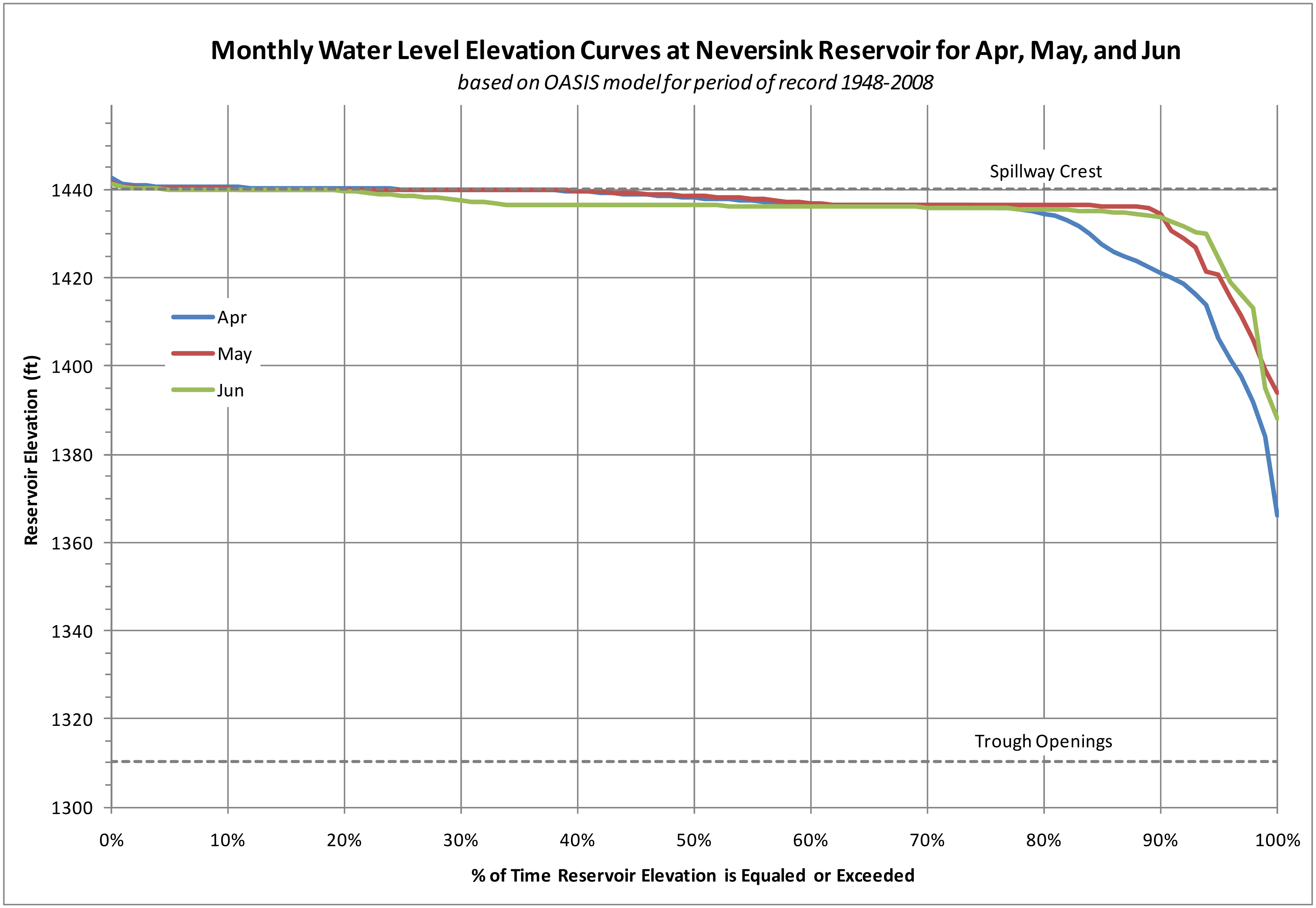


Figure 4.4-4: Water level duration curves at Neversink Reservoir for Jul, Aug, and Sep.

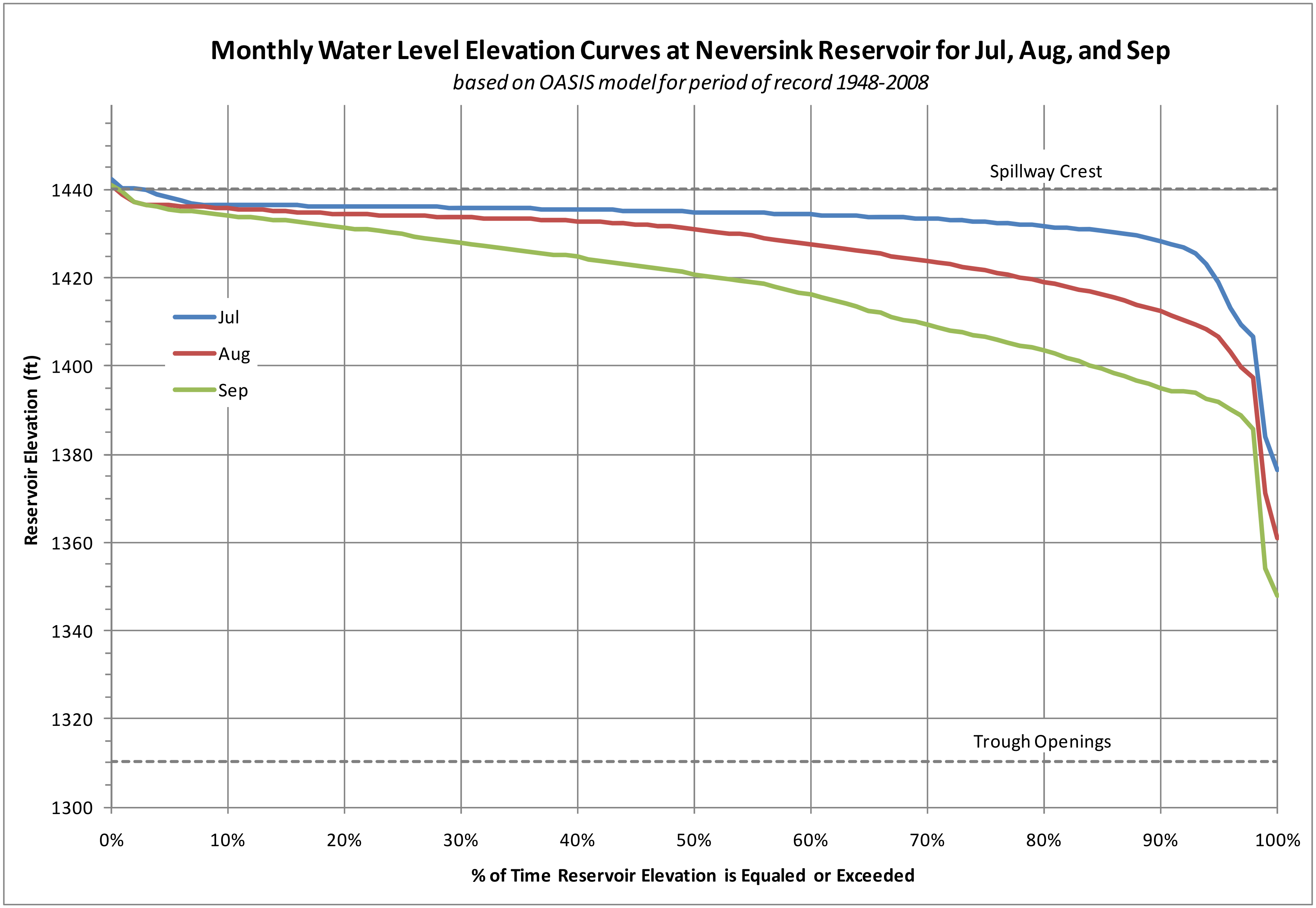


Figure 4.4-5: Water level duration curves at Neversink Reservoir for Oct, Nov, and Dec.

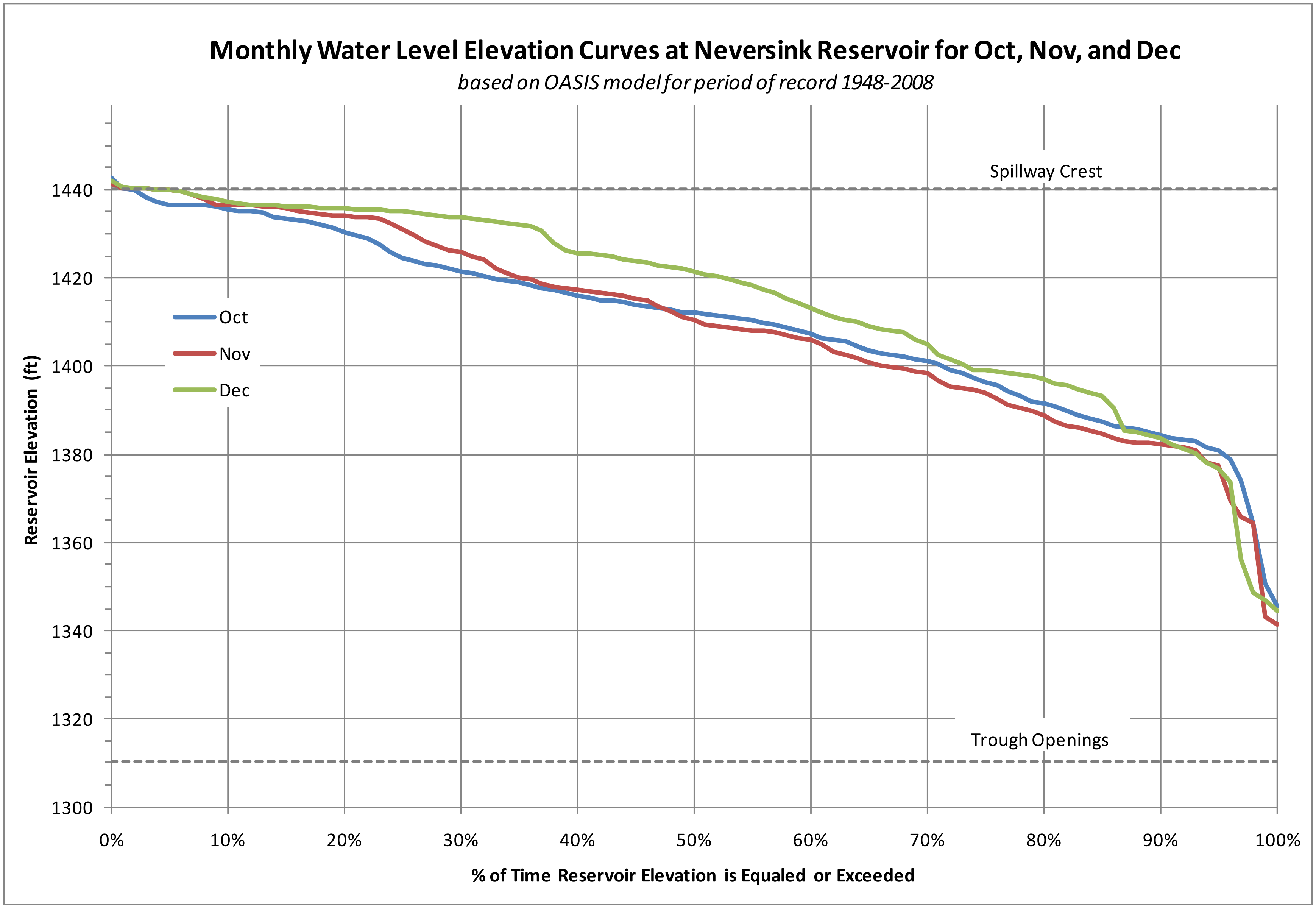
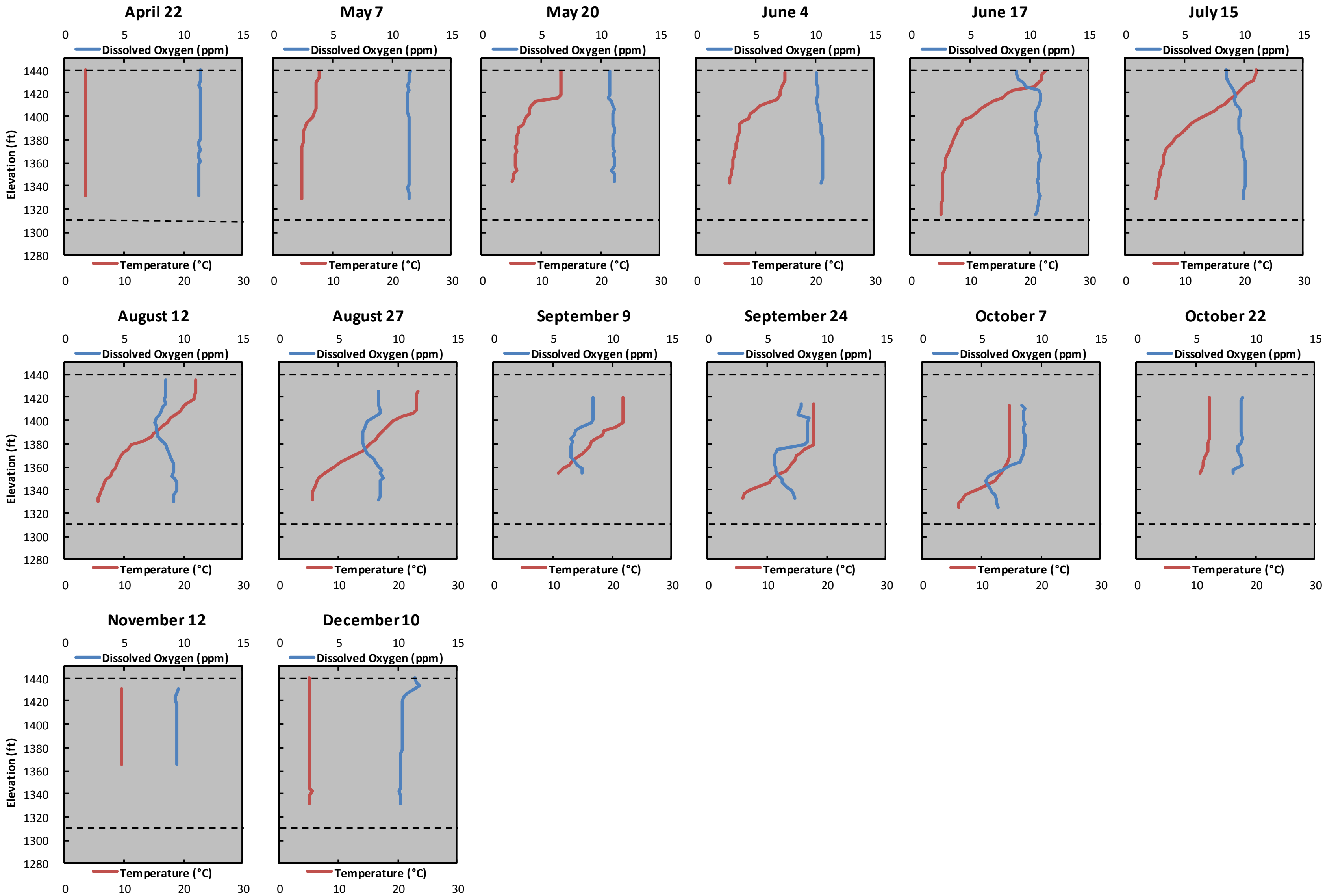
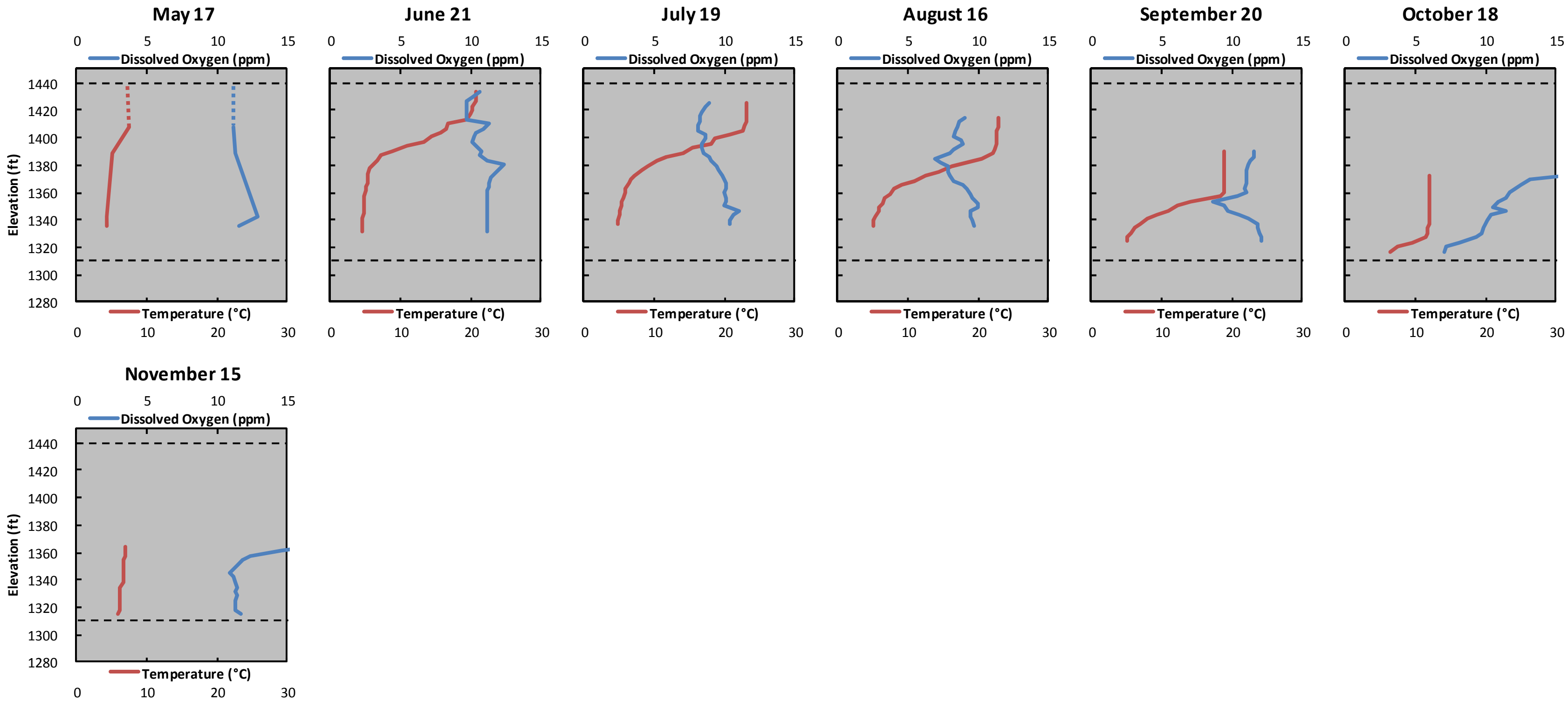


Figure 4.4-6: Temperature & DO profiles at Neversink Reservoir for the wet year (1996).



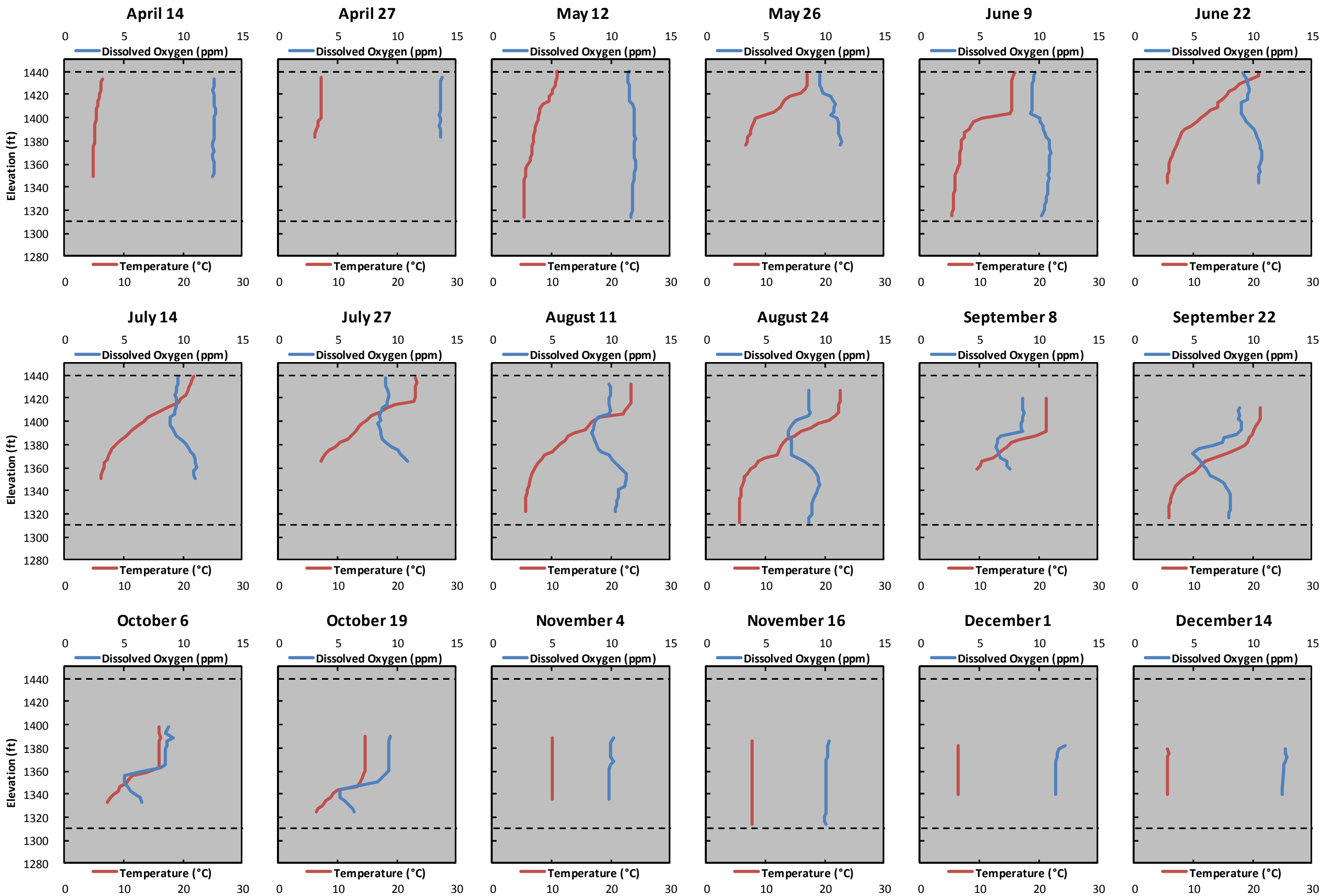
Note: *The dashed lines represent the following (in order from the top of each graph to the bottom thereof): spillway crest (1440 ft above msl), and the intake trough openings for releases (1310.5 ft above msl).*

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.

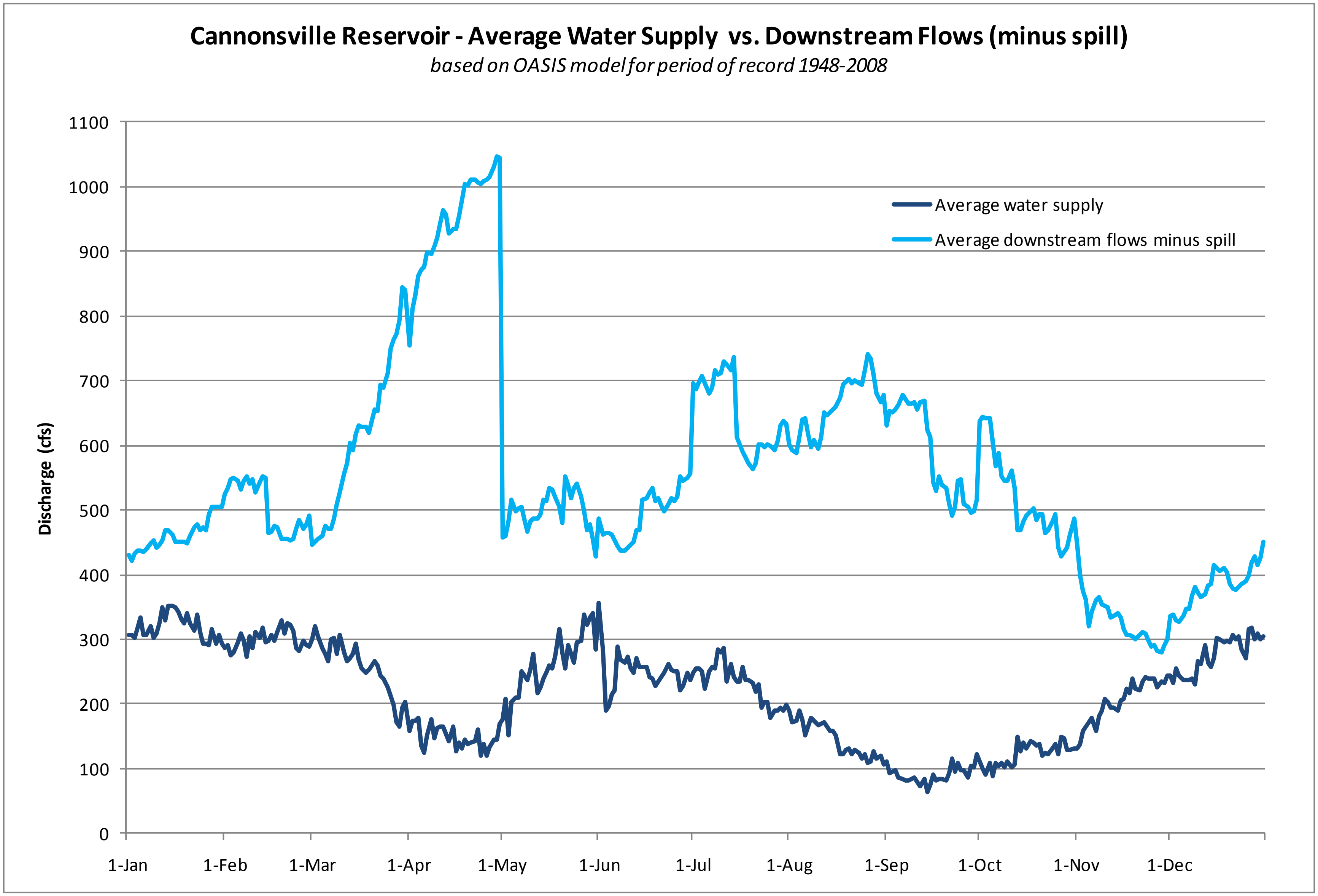


Figure 4.5-2: Pepacton Reservoir average water supply and downstream flows.

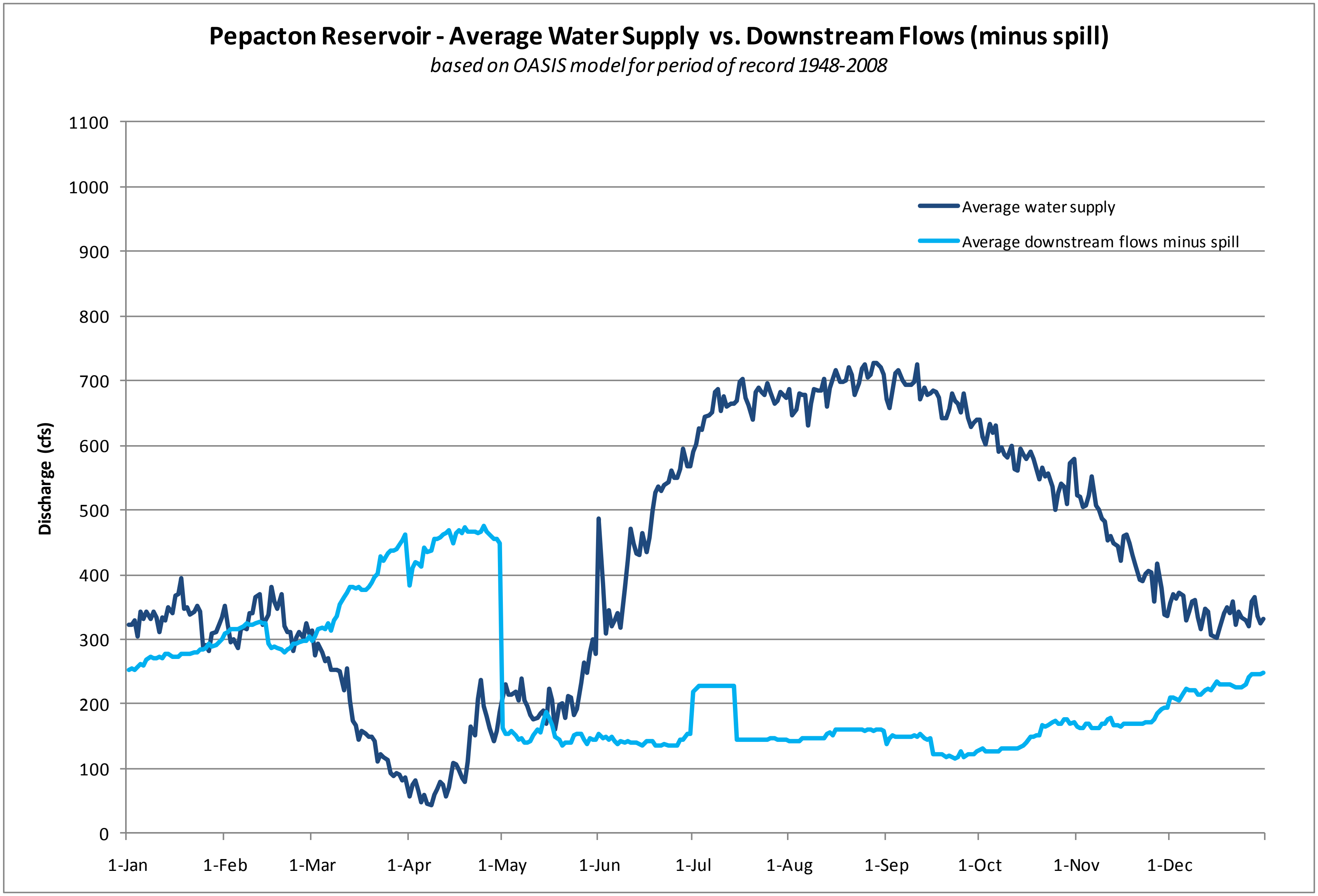
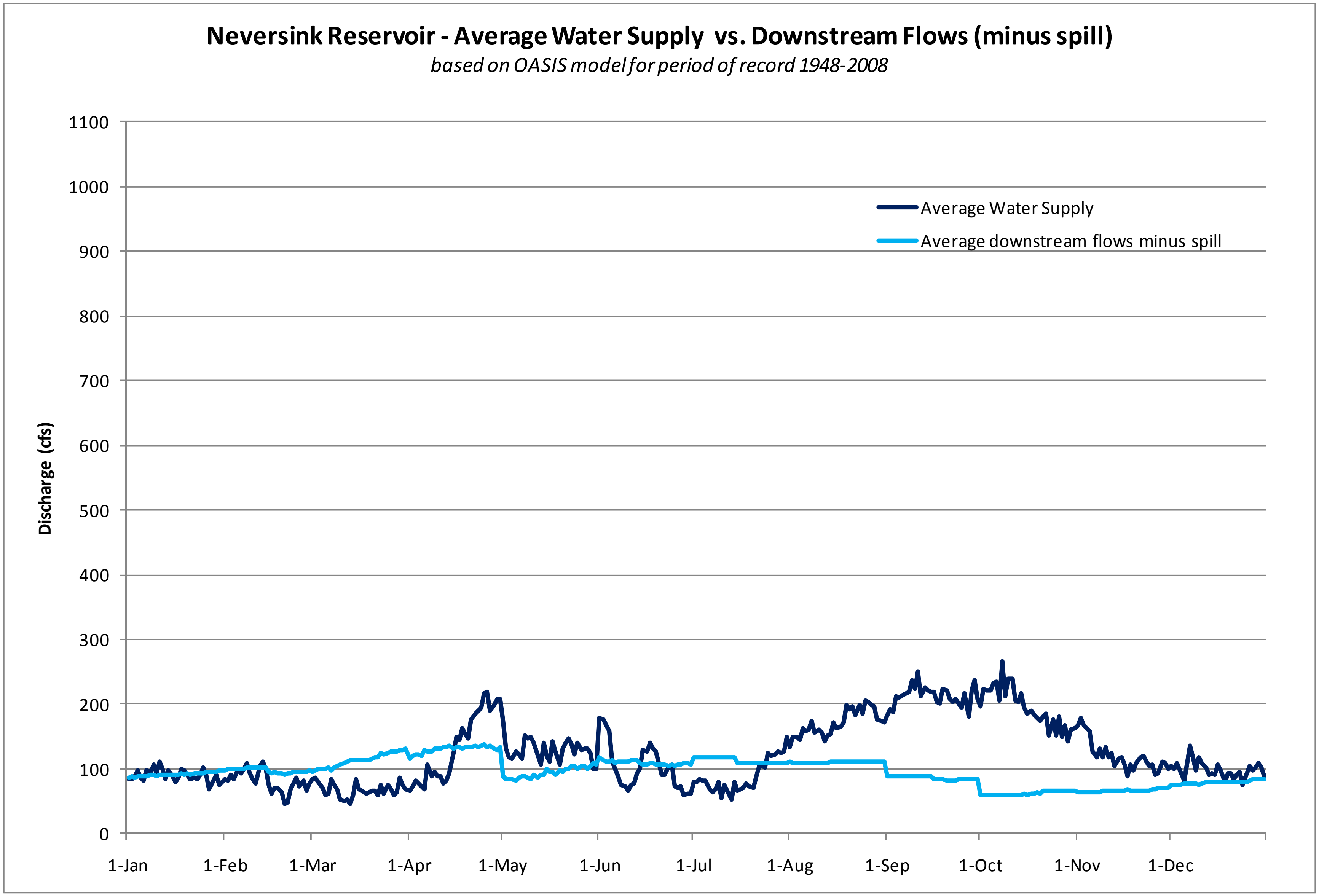


Figure 4.5-3: Neversink Reservoir average water supply and downstream flows.



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

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[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.

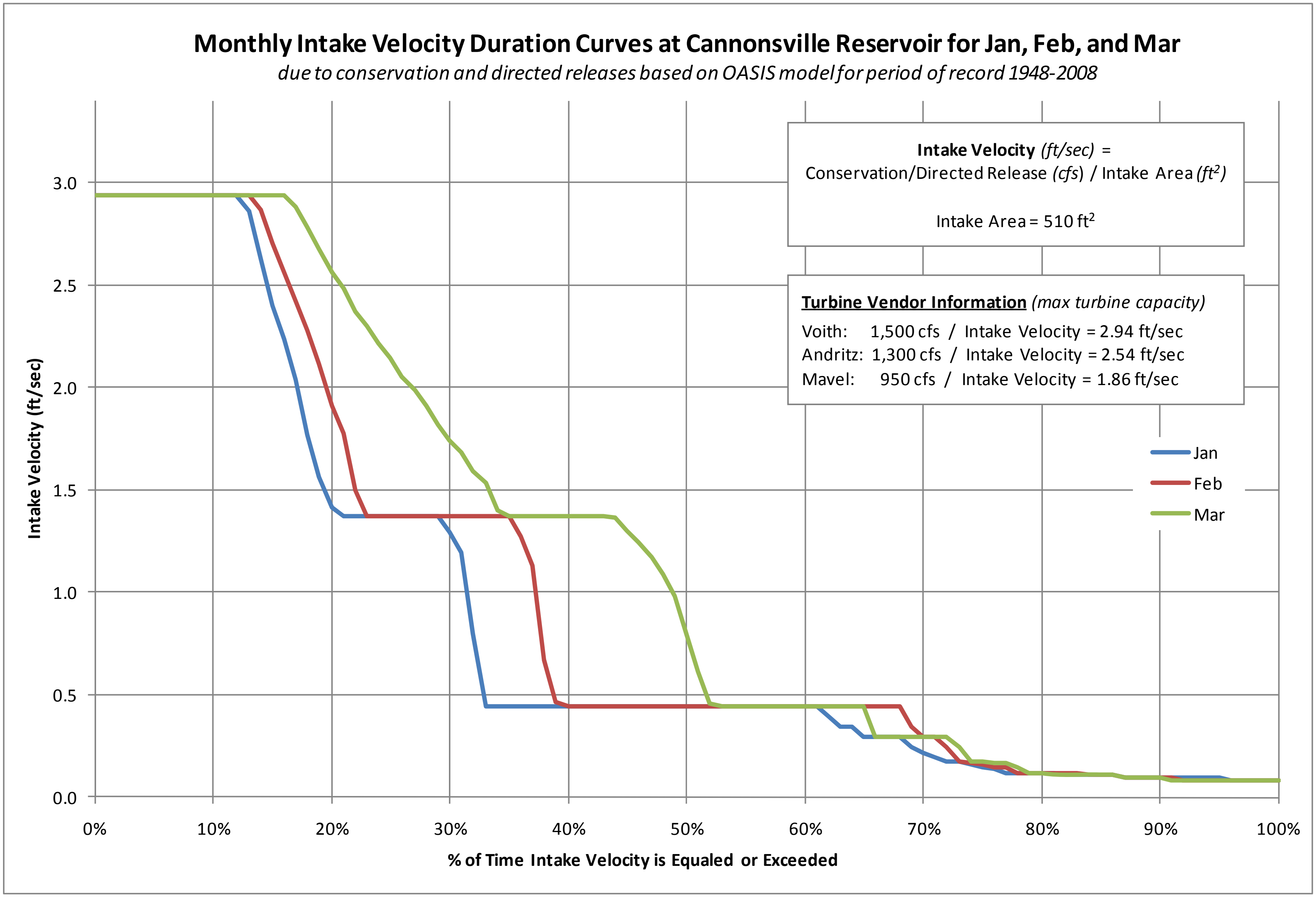

Figure 6.3-2: Intake velocity duration curves at Cannonsville Reservoir for Apr, May, and Jun.

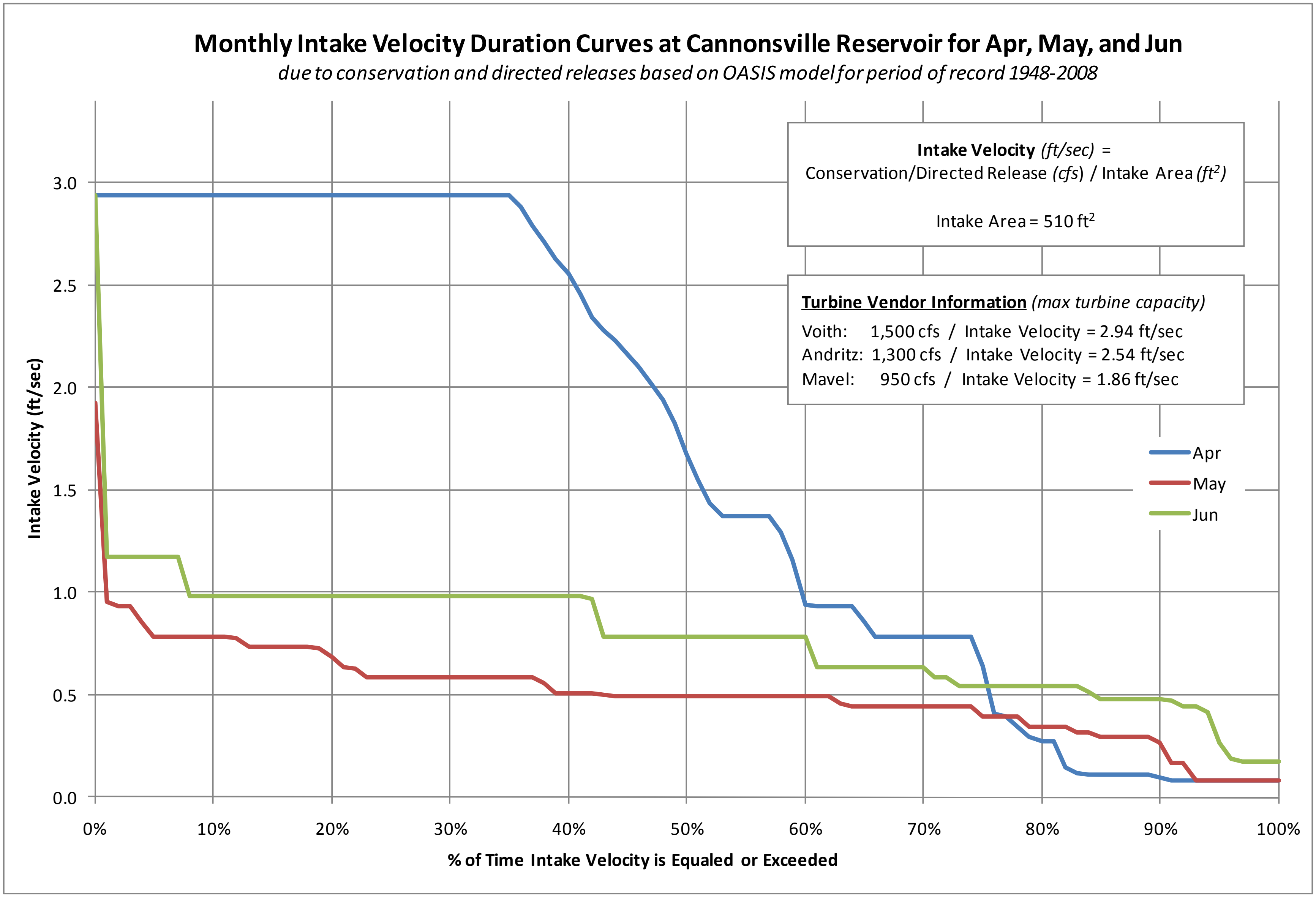

Figure 6.3-3: Intake velocity duration curves at Cannonsville Reservoir for Jul, Aug, and Sep.

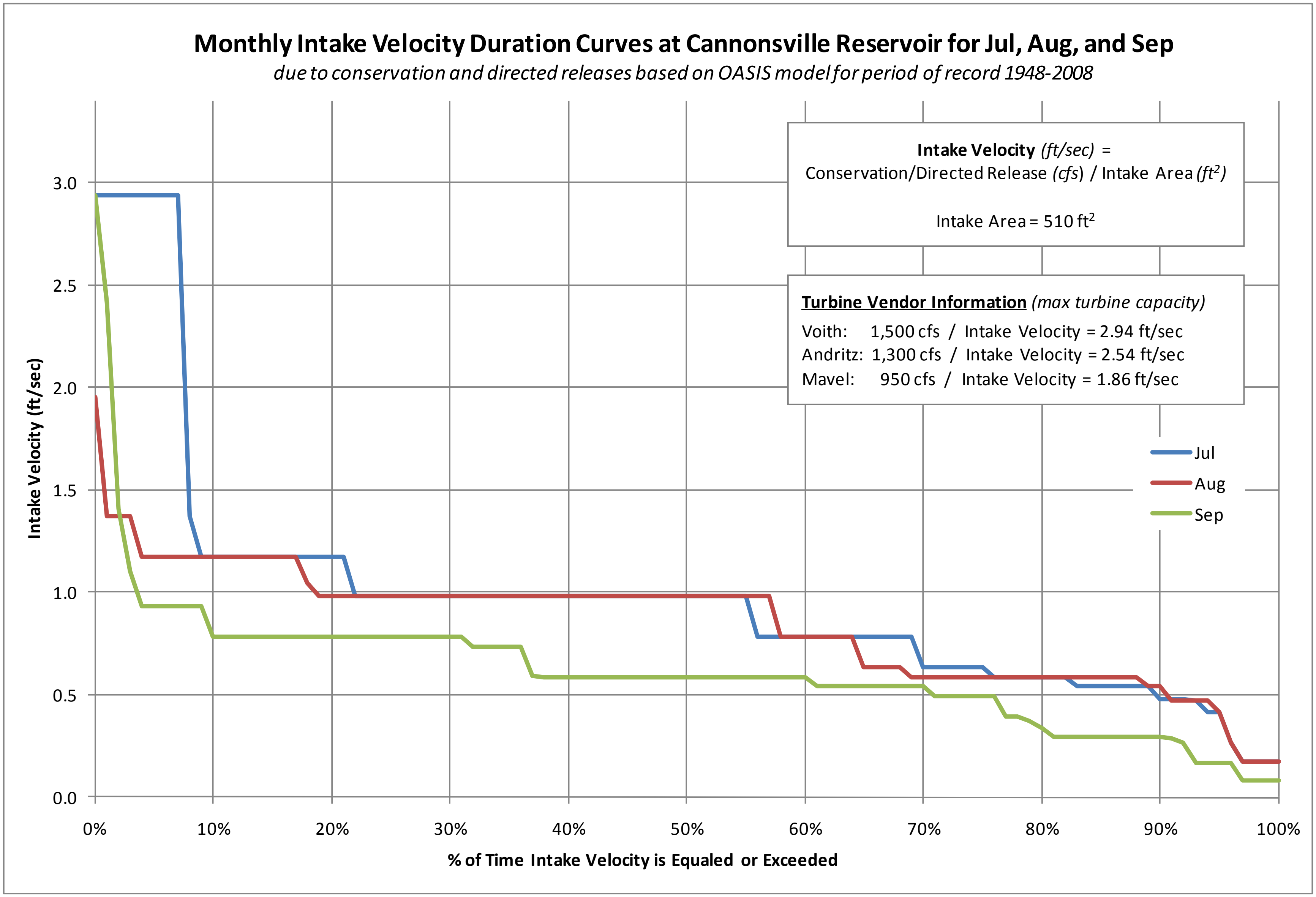

Figure 6.3-4: Intake velocity duration curves at Cannonsville Reservoir for Oct, Nov, and Dec.

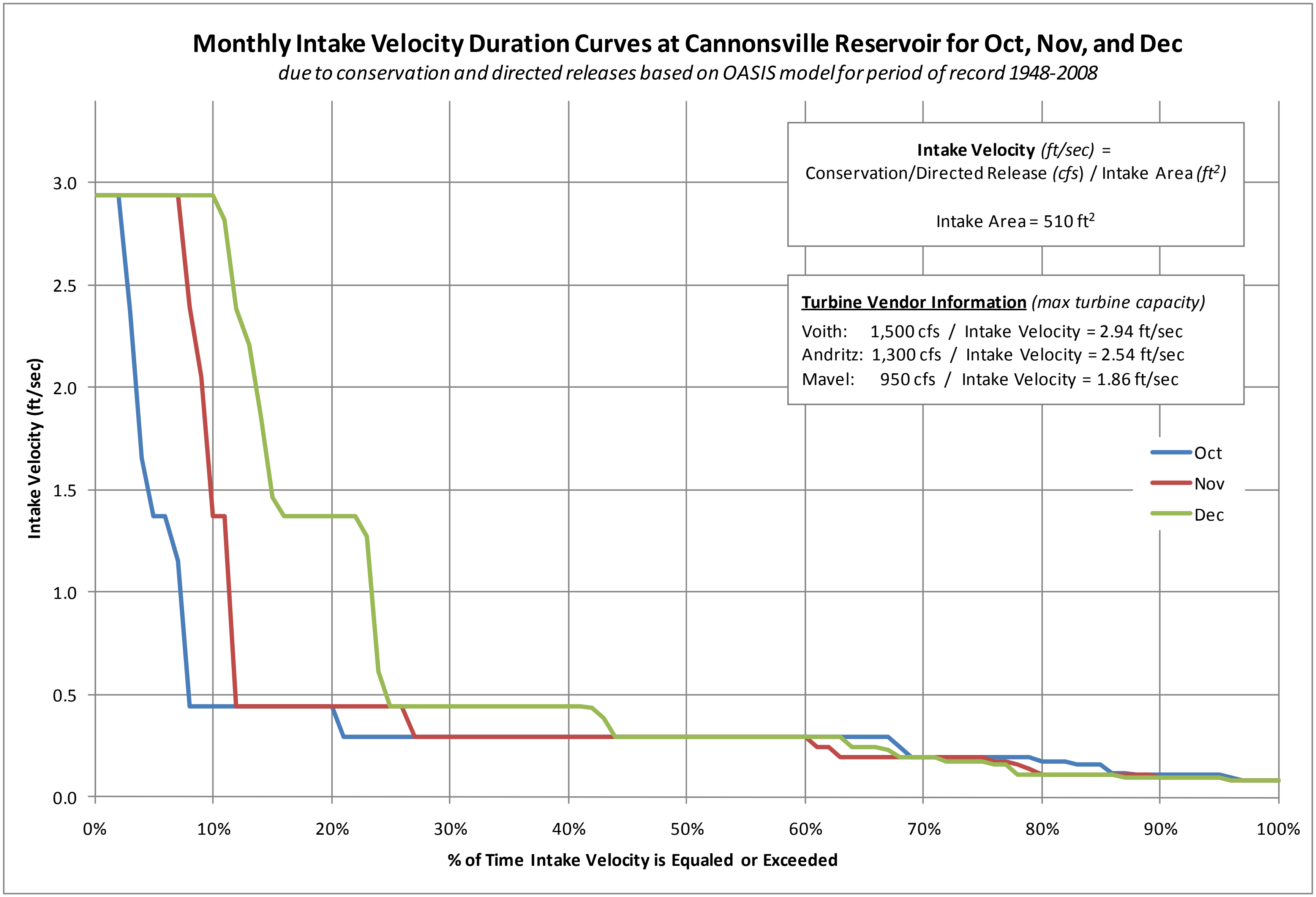

Figure 6.3-5: Intake velocity duration curves at Pepacton Reservoir for Jan, Feb, and Mar.

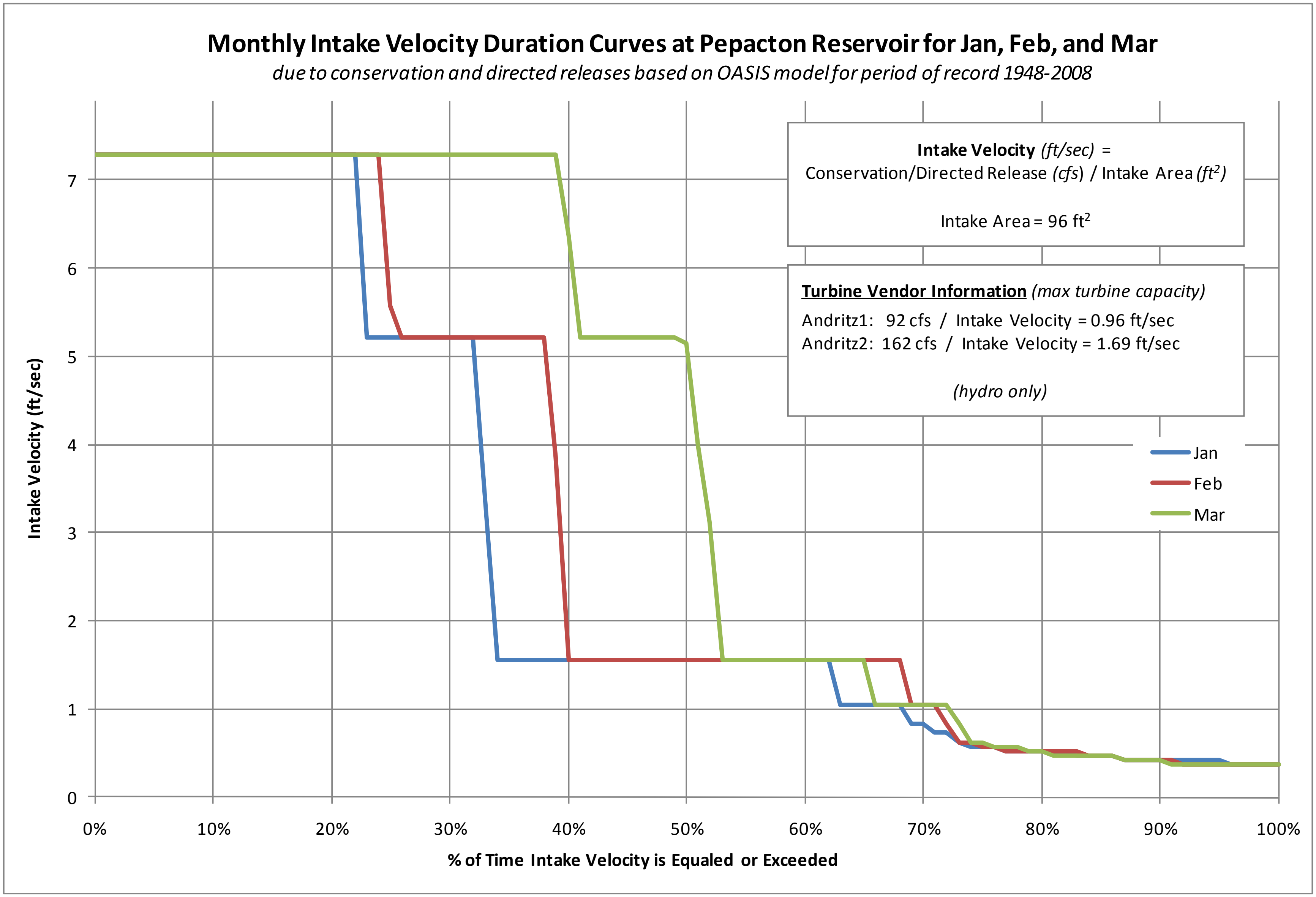

Figure 6.3-6: Intake velocity duration curves at Pepacton Reservoir for Apr, May, and Jun.

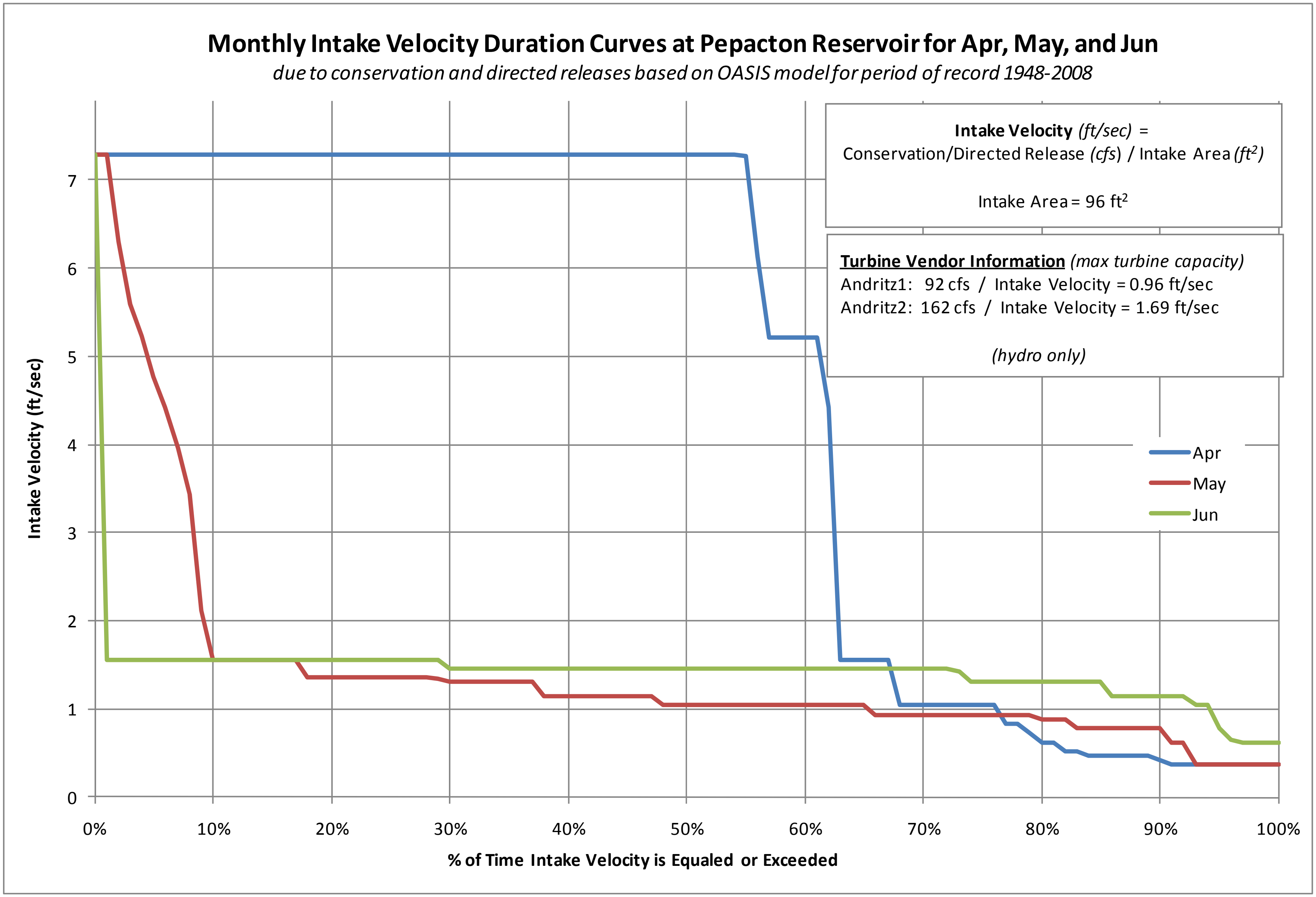

Figure 6.3-7: Intake velocity duration curves at Pepacton Reservoir for Jul, Aug, and Sep.

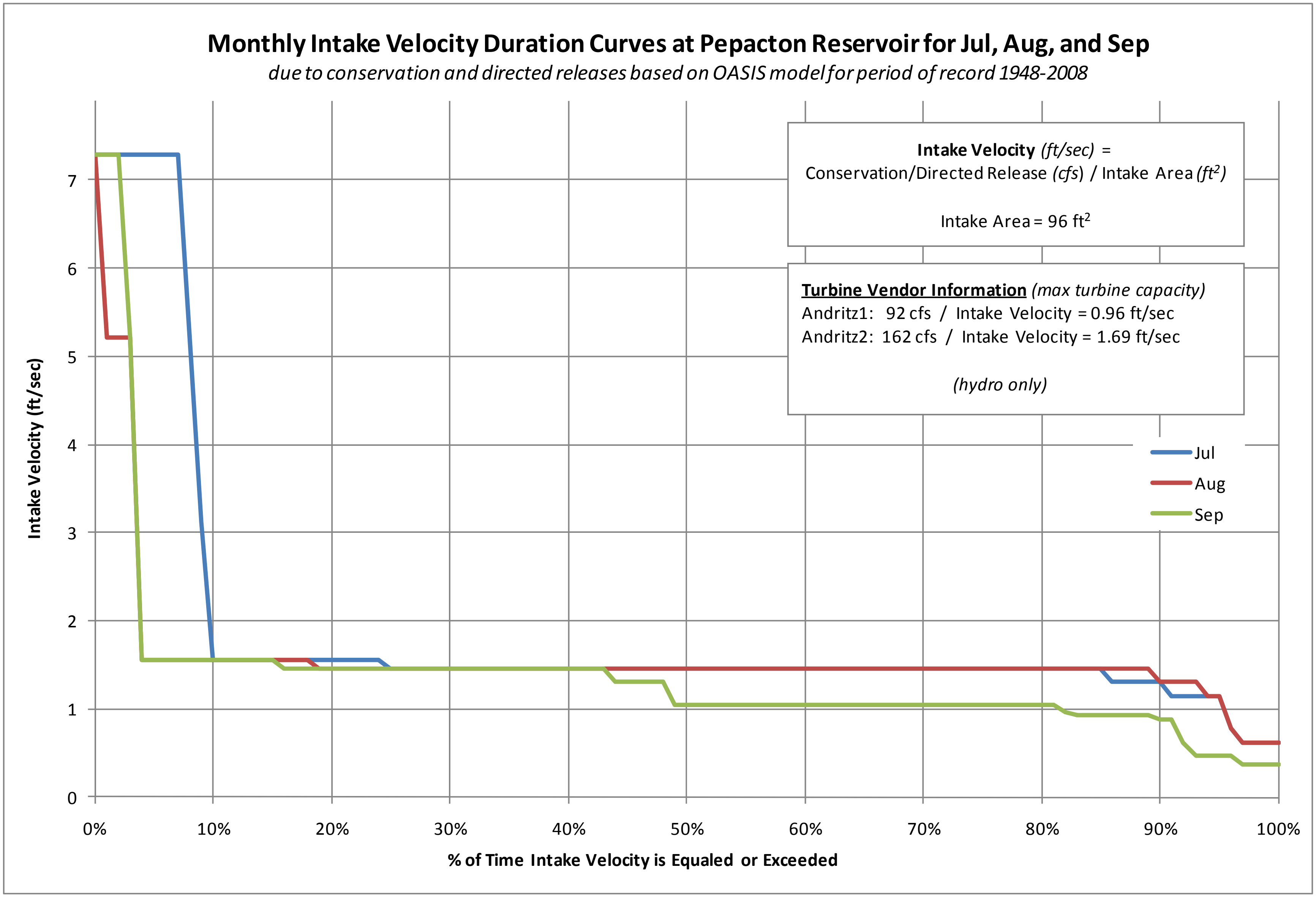

Figure 6.3-8: Intake velocity duration curves at Pepacton Reservoir for Oct, Nov, and Dec.

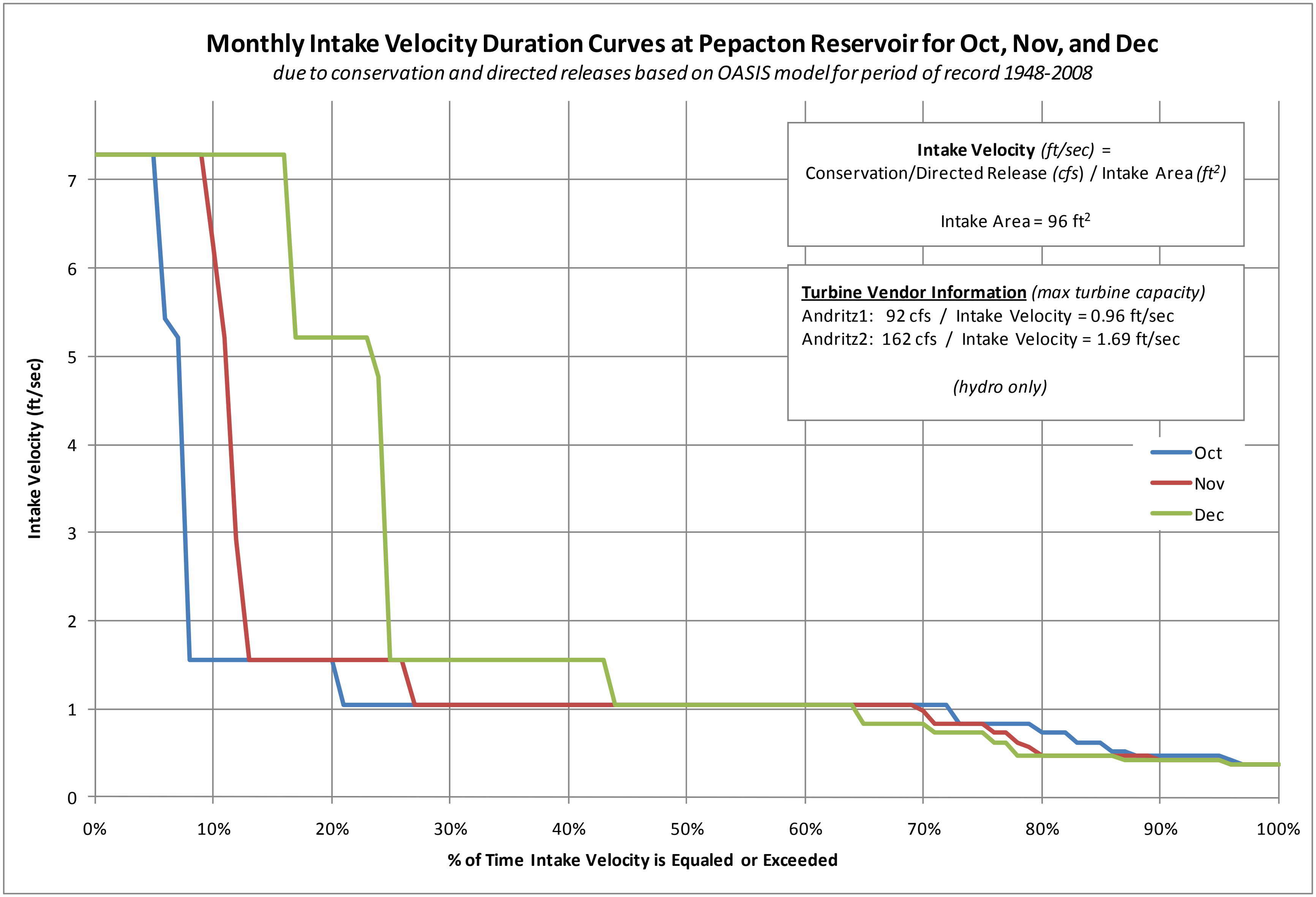

Figure 6.3-9: Intake velocity duration curves at Neversink Reservoir for Jan, Feb, and Mar.

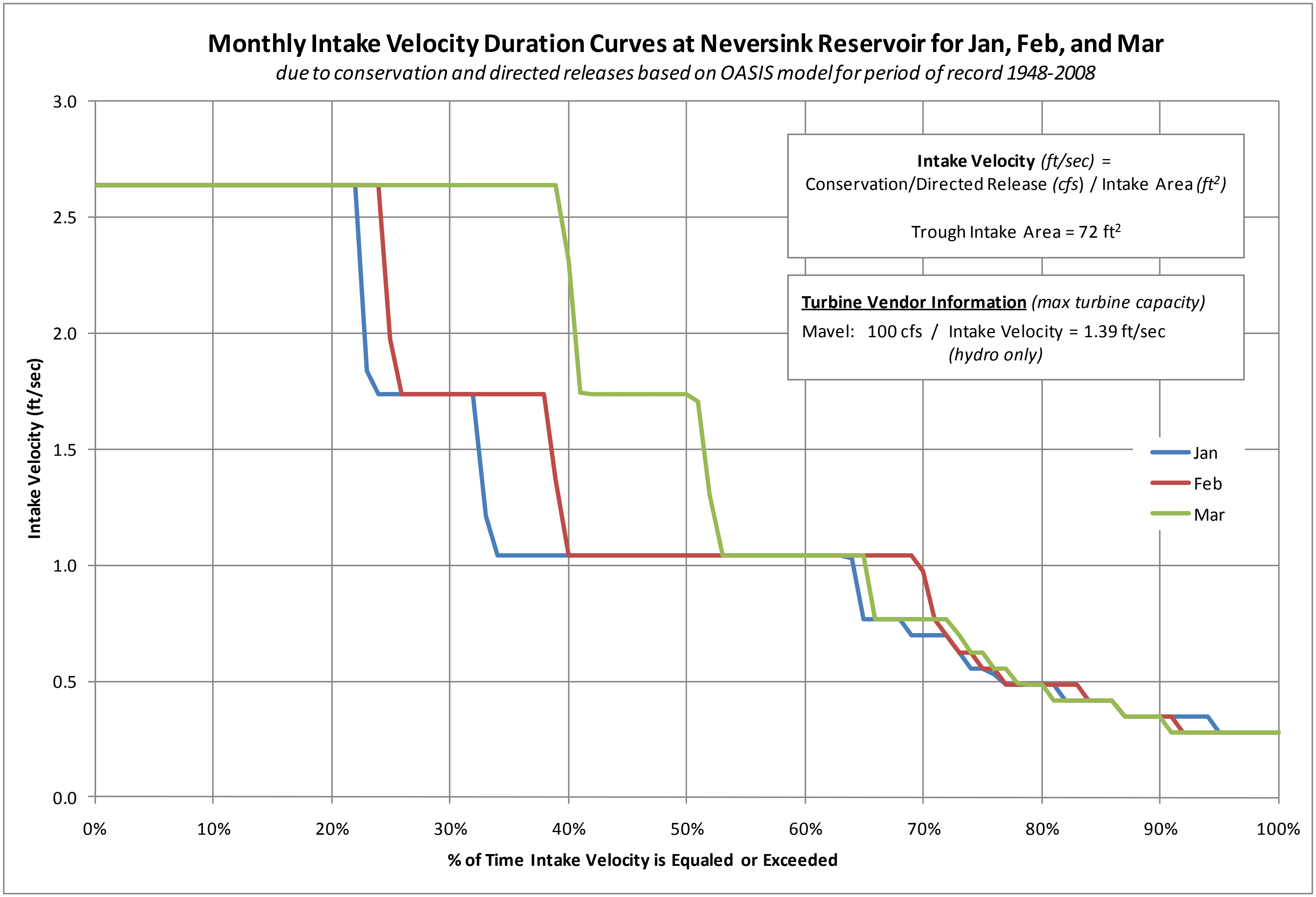

Figure 6.3-10: Intake velocity duration curves at Neversink Reservoir for Apr, May, and Jun.

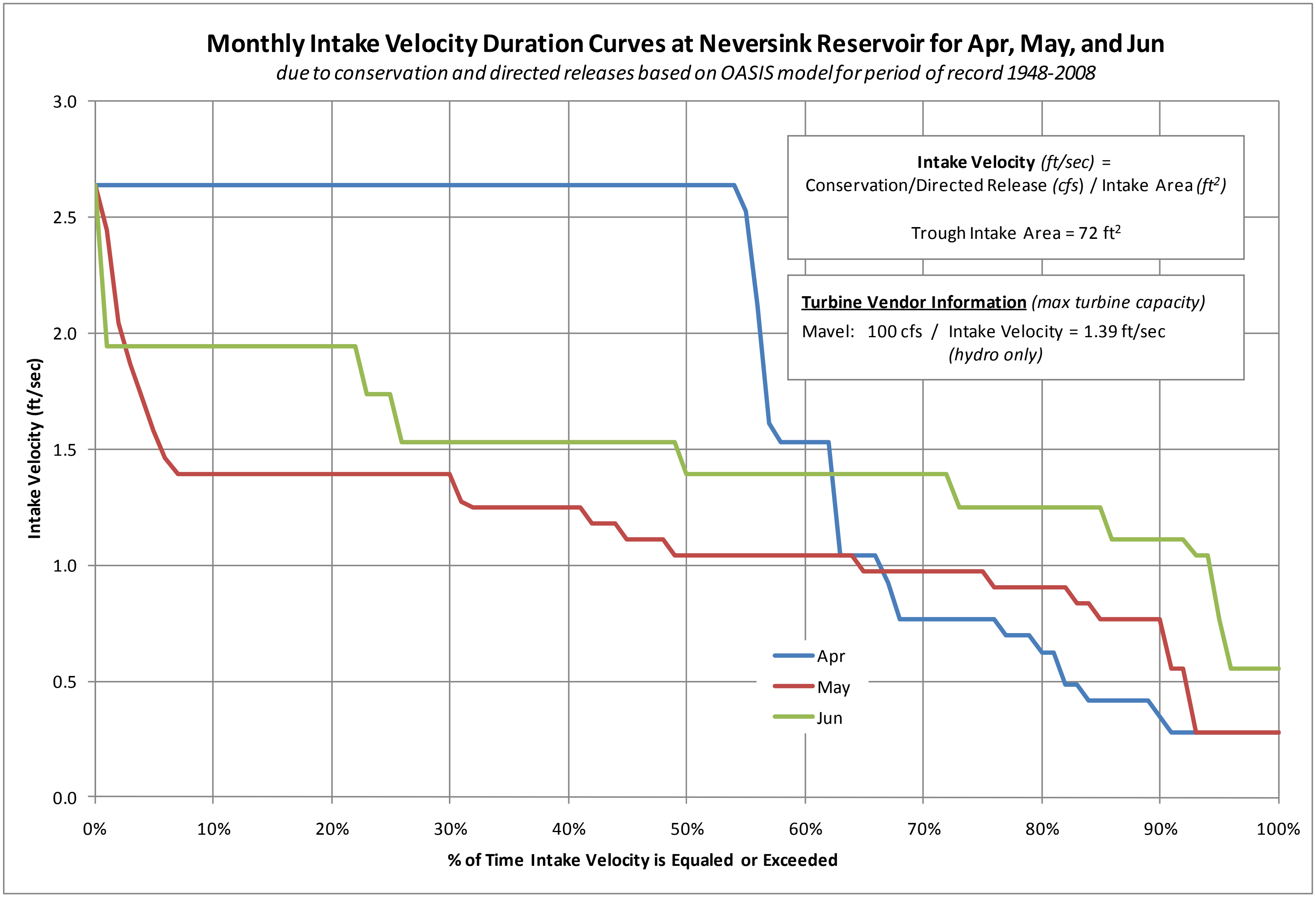

Figure 6.3-11: Intake velocity duration curves at Neversink Reservoir for Jul, Aug, and Sep.

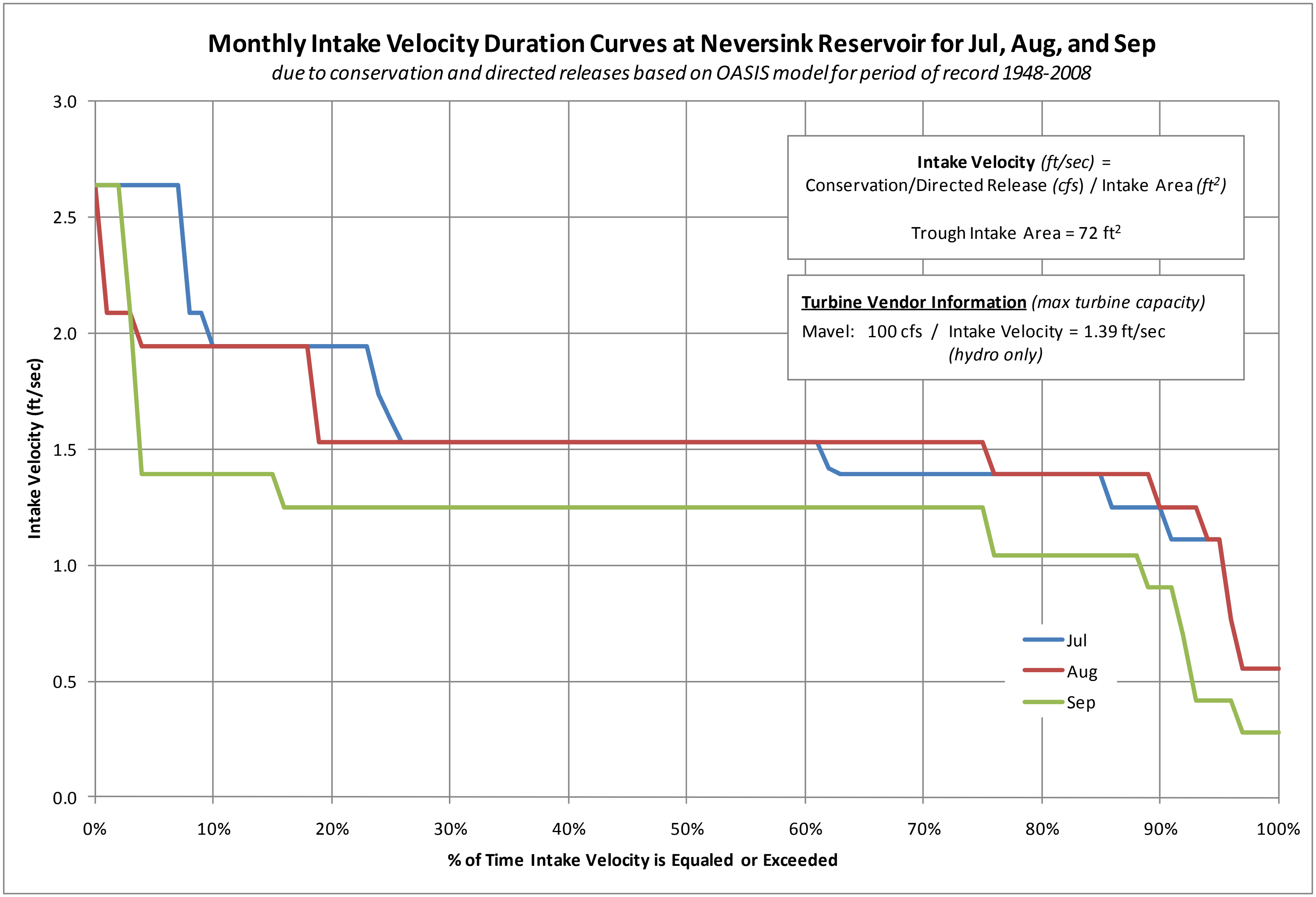

Figure 6.3-12: Intake velocity duration curves at Neversink Reservoir for Oct, Nov, and Dec.

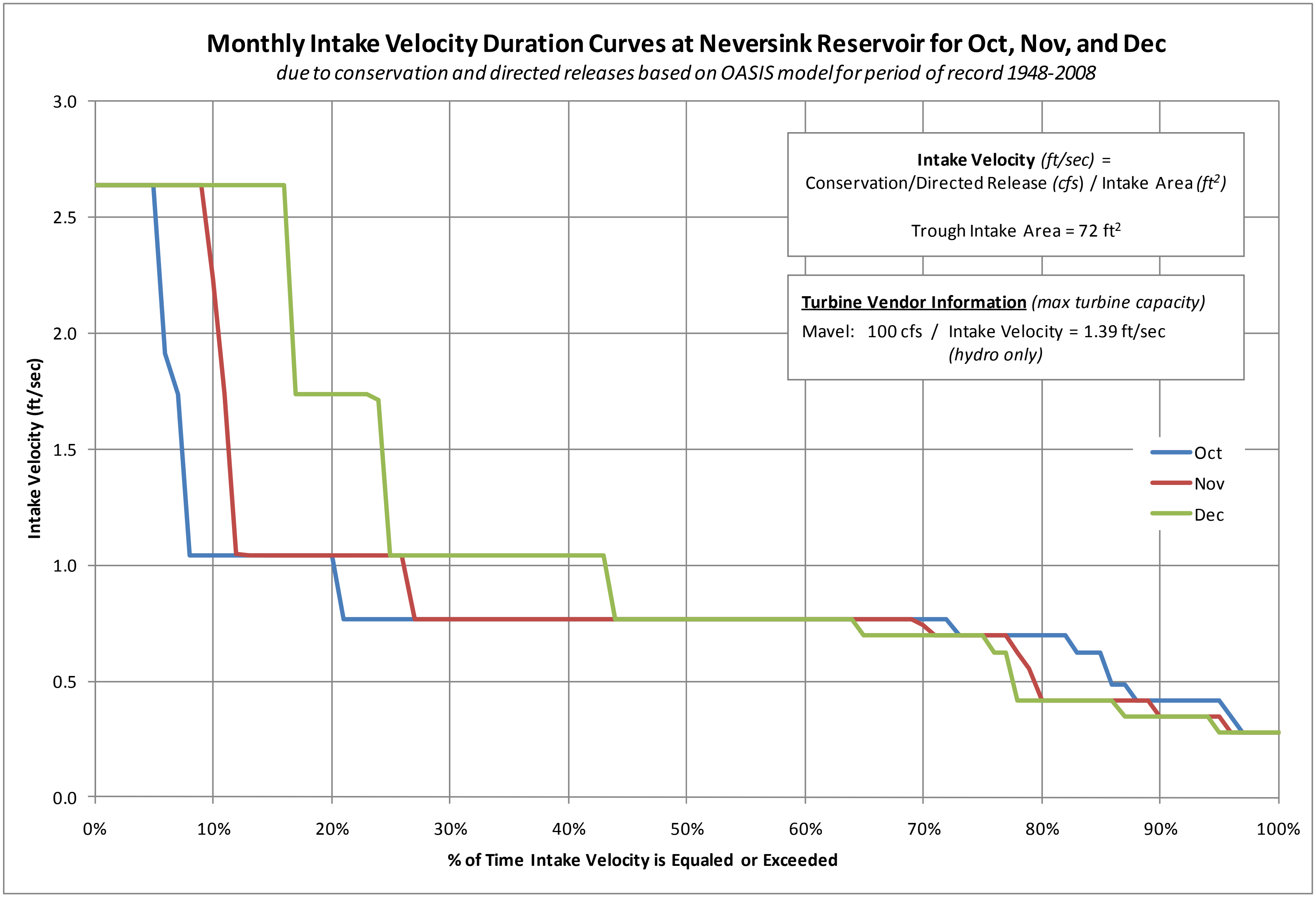

Table 6.4-1: Entrainment potential of fish species found in the three reservoirs.

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.

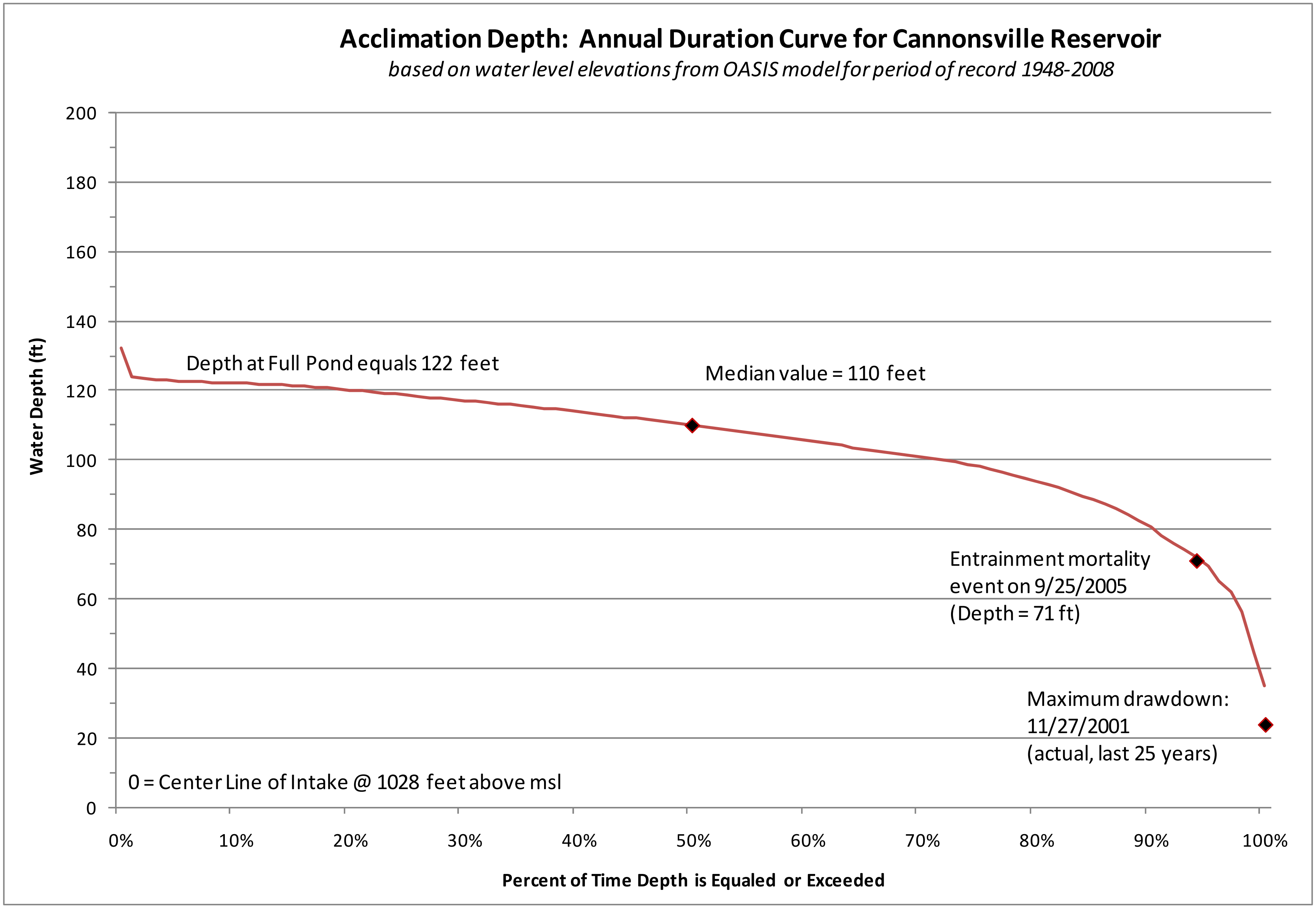


Figure 7.2-2: Acclimation pressure duration curve at Cannonsville Reservoir.

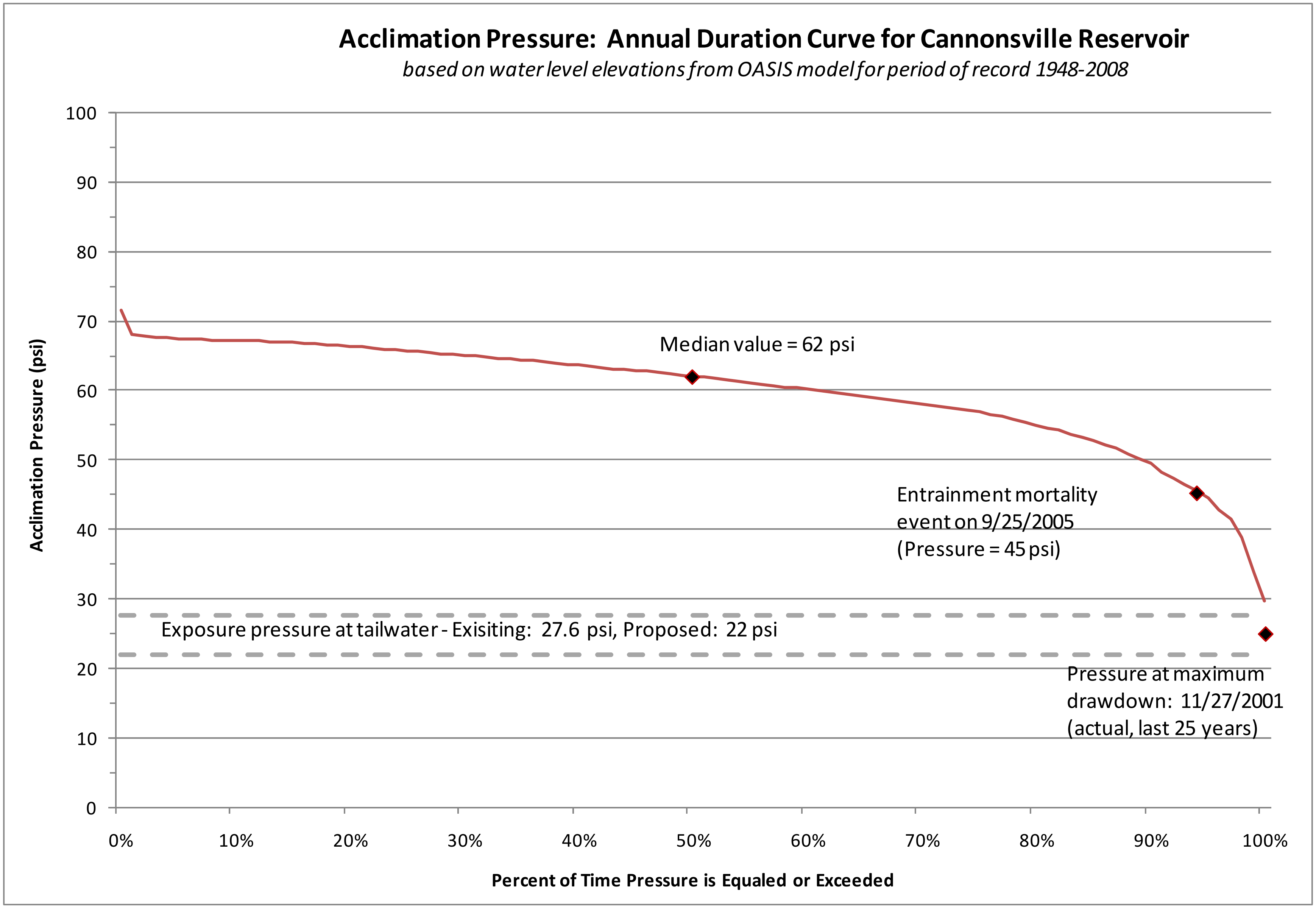


Figure 7.2-3: Acclimation depth duration curve at Pepacton Reservoir.

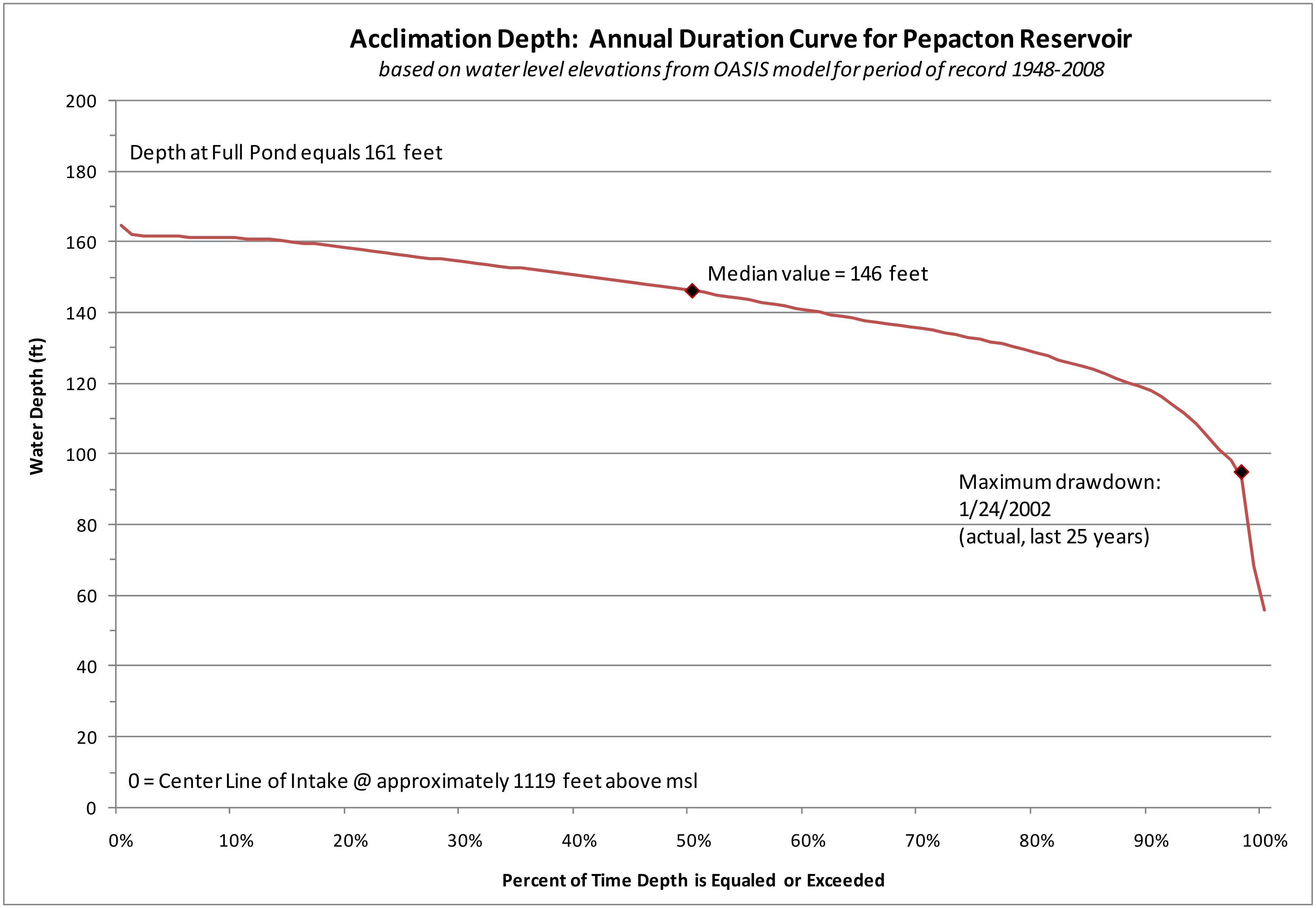


Figure 7.2-4: Acclimation pressure duration curve at Pepacton Reservoir.

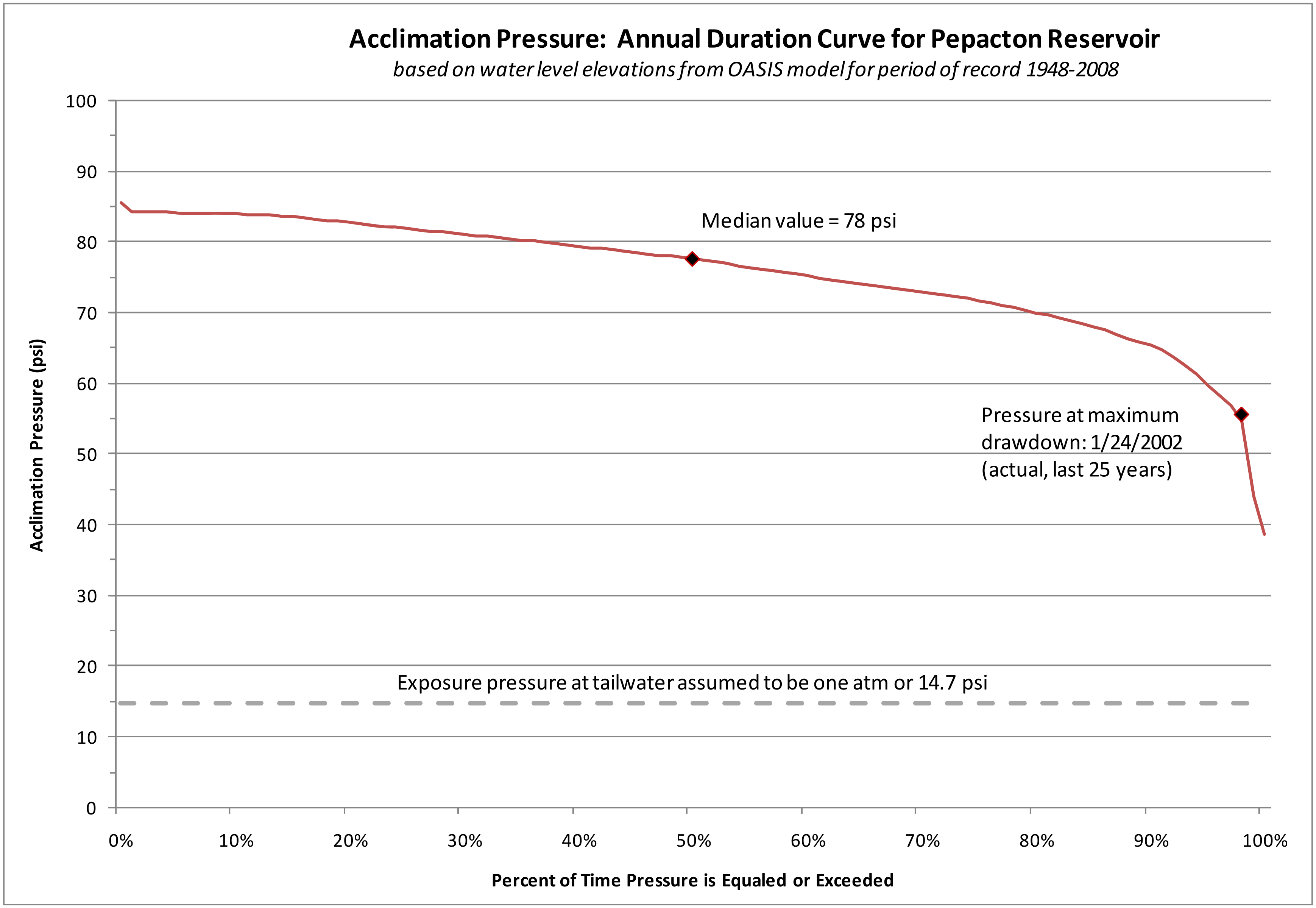


Figure 7.2-5: Acclimation depth duration curve at Neversink Reservoir.

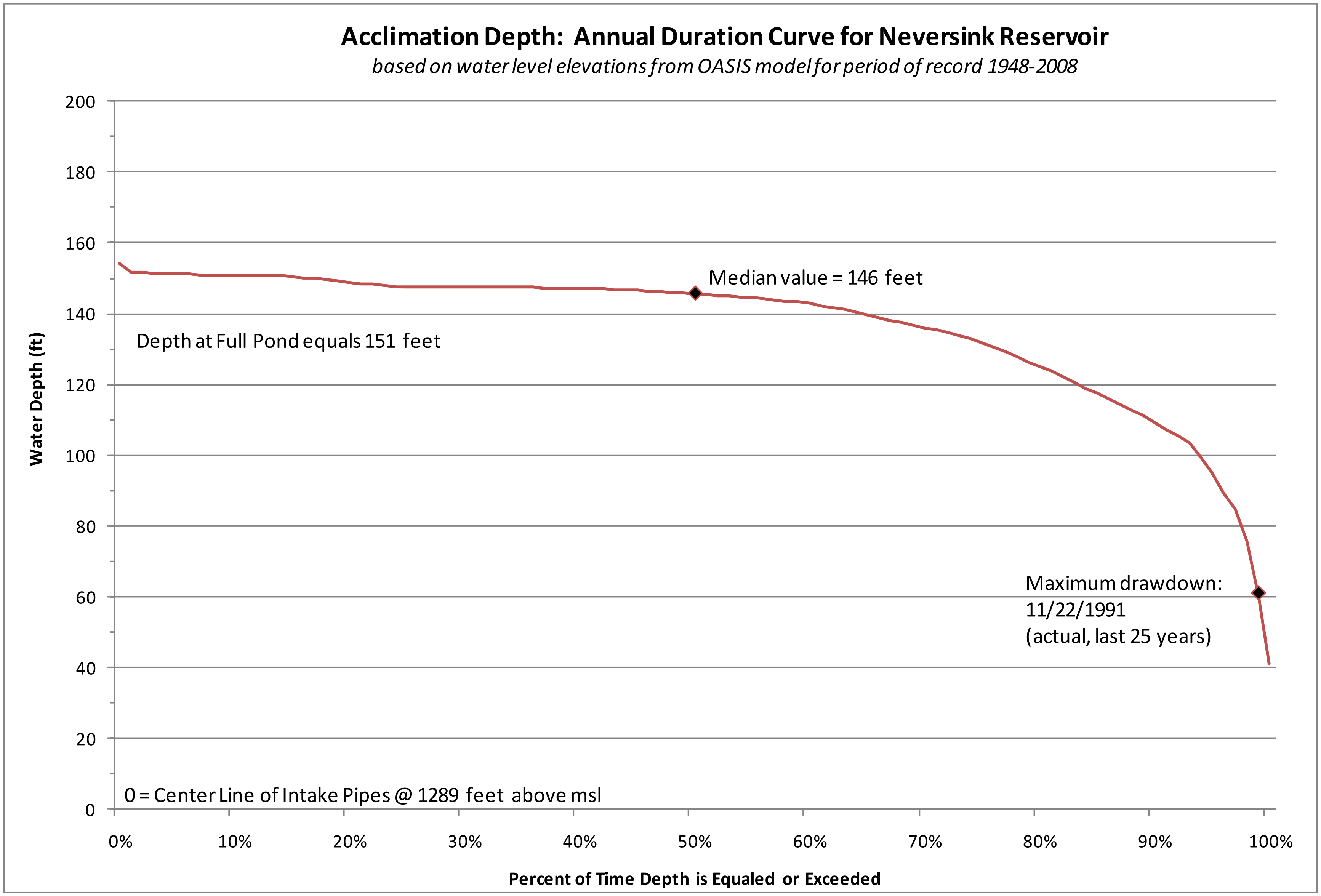
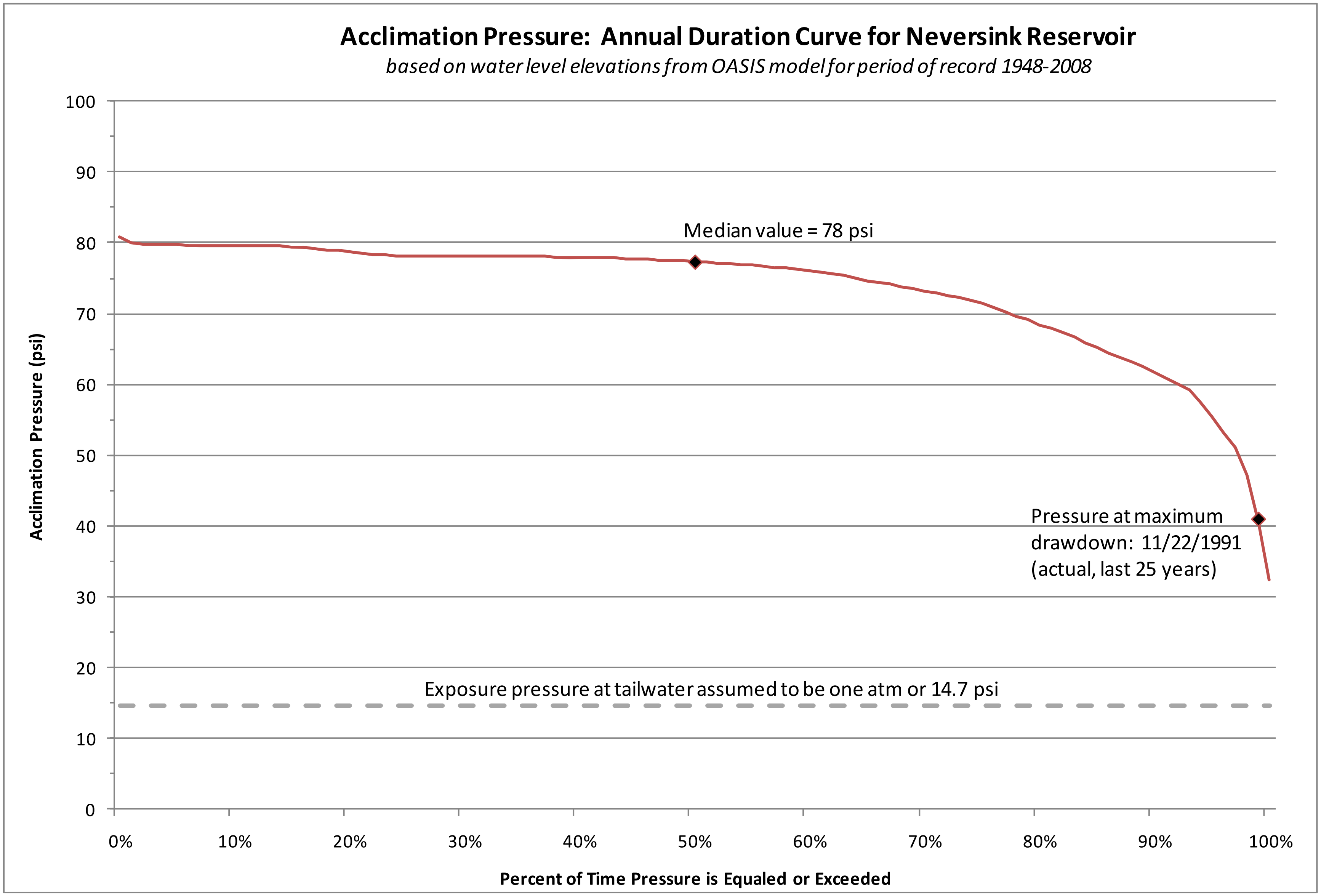


Figure 7.2-6: Acclimation pressure duration curve at Neversink Reservoir.



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.

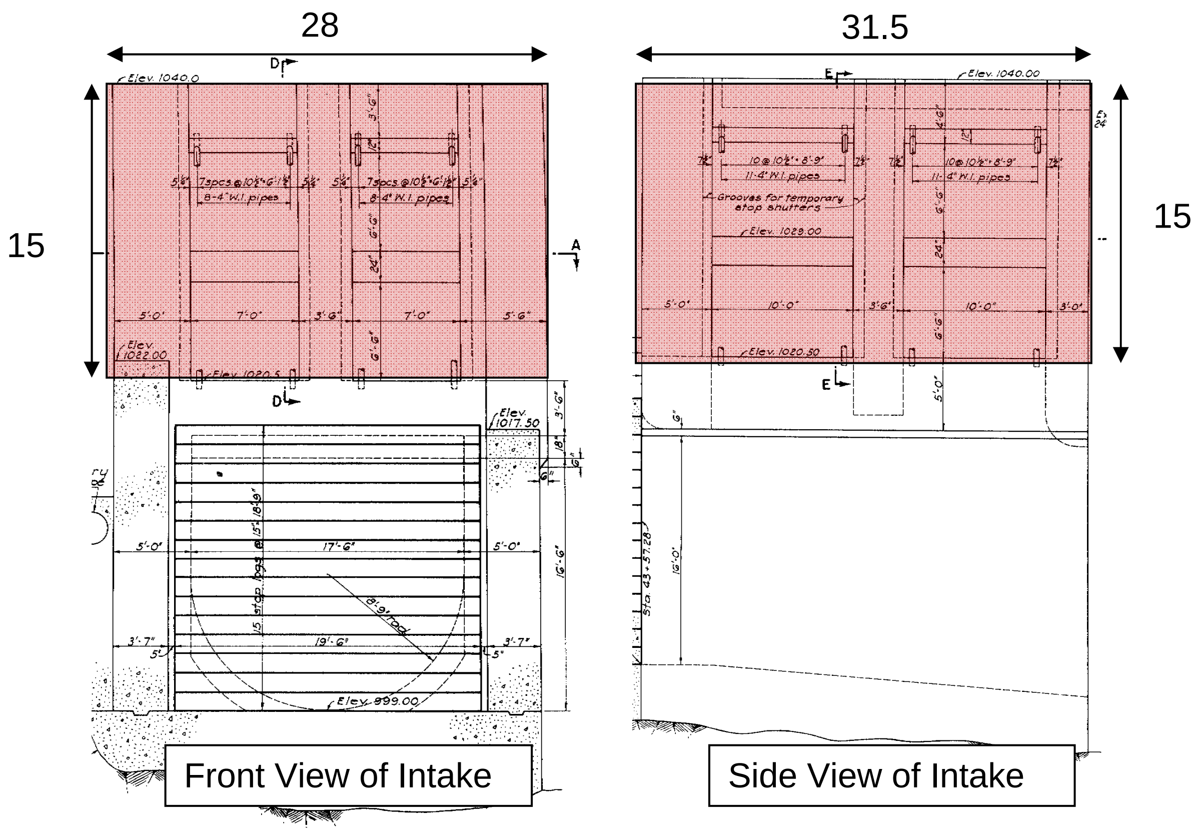
8.1 Cannonsville Development

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 enclosing the intake areas with close-spaced bar racks larger than the current openings. The bar racks would be comprised of 5/8-inch vertical bars with 1-inch clear spacing between the bars. The bar racks would be mounted one foot from the face of the intake structure and be manufactured to fit into the existing stop log slots.

Pictured below is a view of both 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

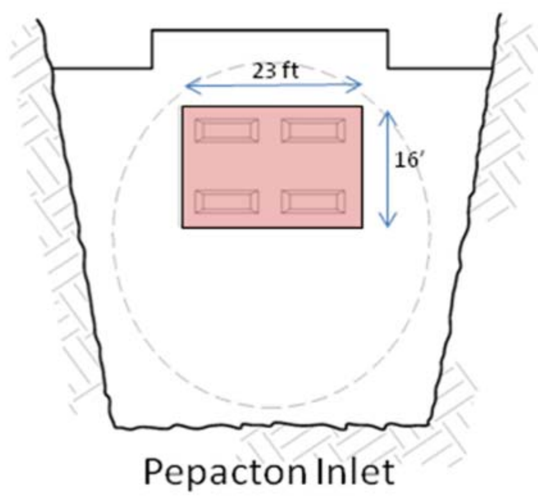
An angled bar rack could be utilized at Pepacton. The rack would be affixed to the top of the bulkhead and extend to the floor of the reservoir at a slope of 45-50°. The length from the base of the intake structure to the bottom of the bar rack would be approximately 50 feet, and the width would vary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

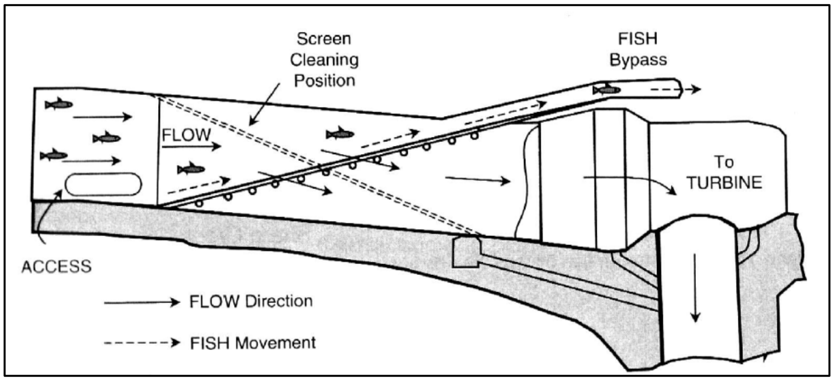
For the proposed Cannonsville development, the Eicher screen would be located within the 17.5-foot-diameter diversion pipe located between the intake and the proposed powerhouse. The installation of the screen would require a section of the existing pipe to be opened and retrofitted to create a fish 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).

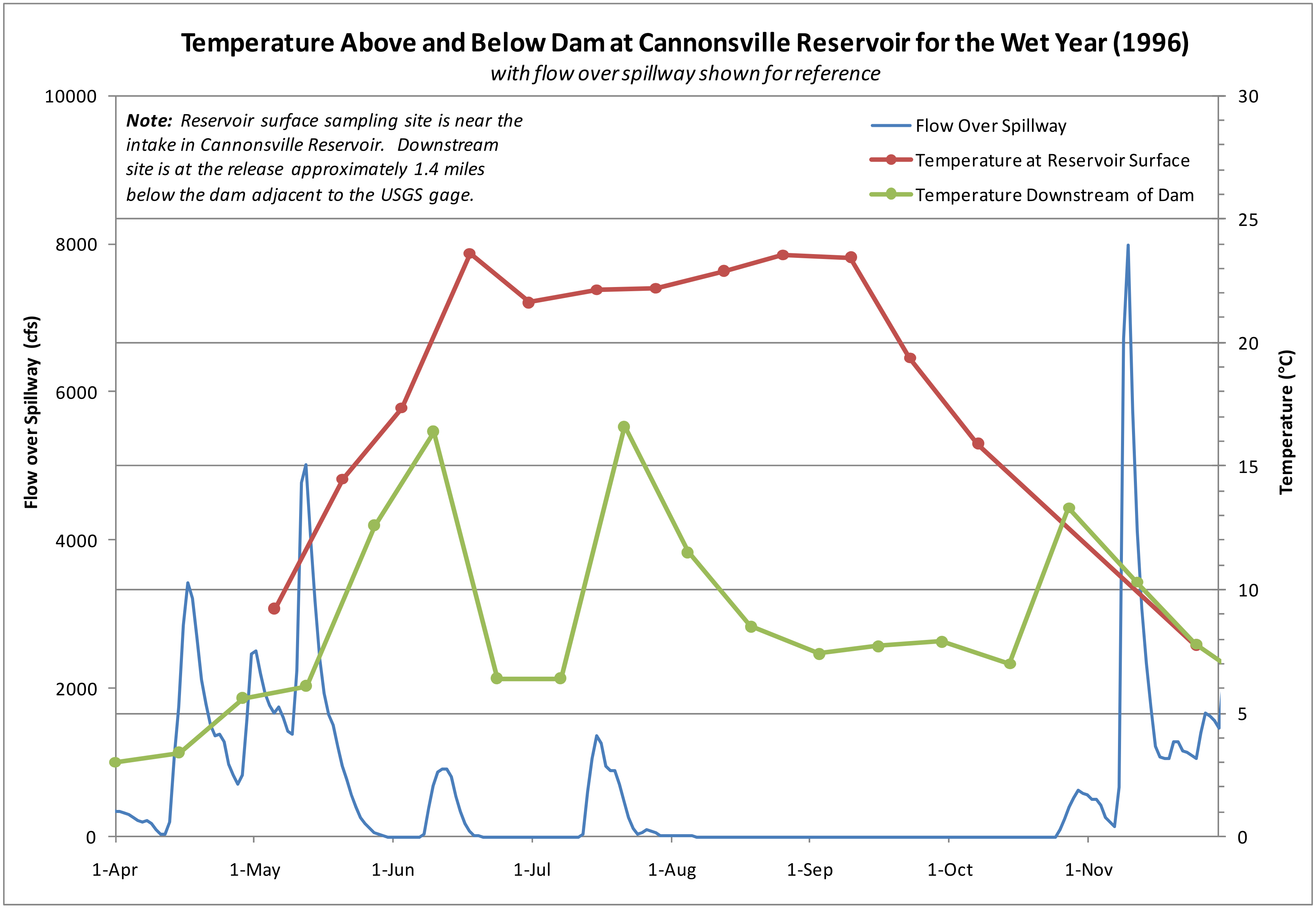


Figure 9.3-2: Temperature above and below dam at Cannonsville Reservoir for the dry year (1993).

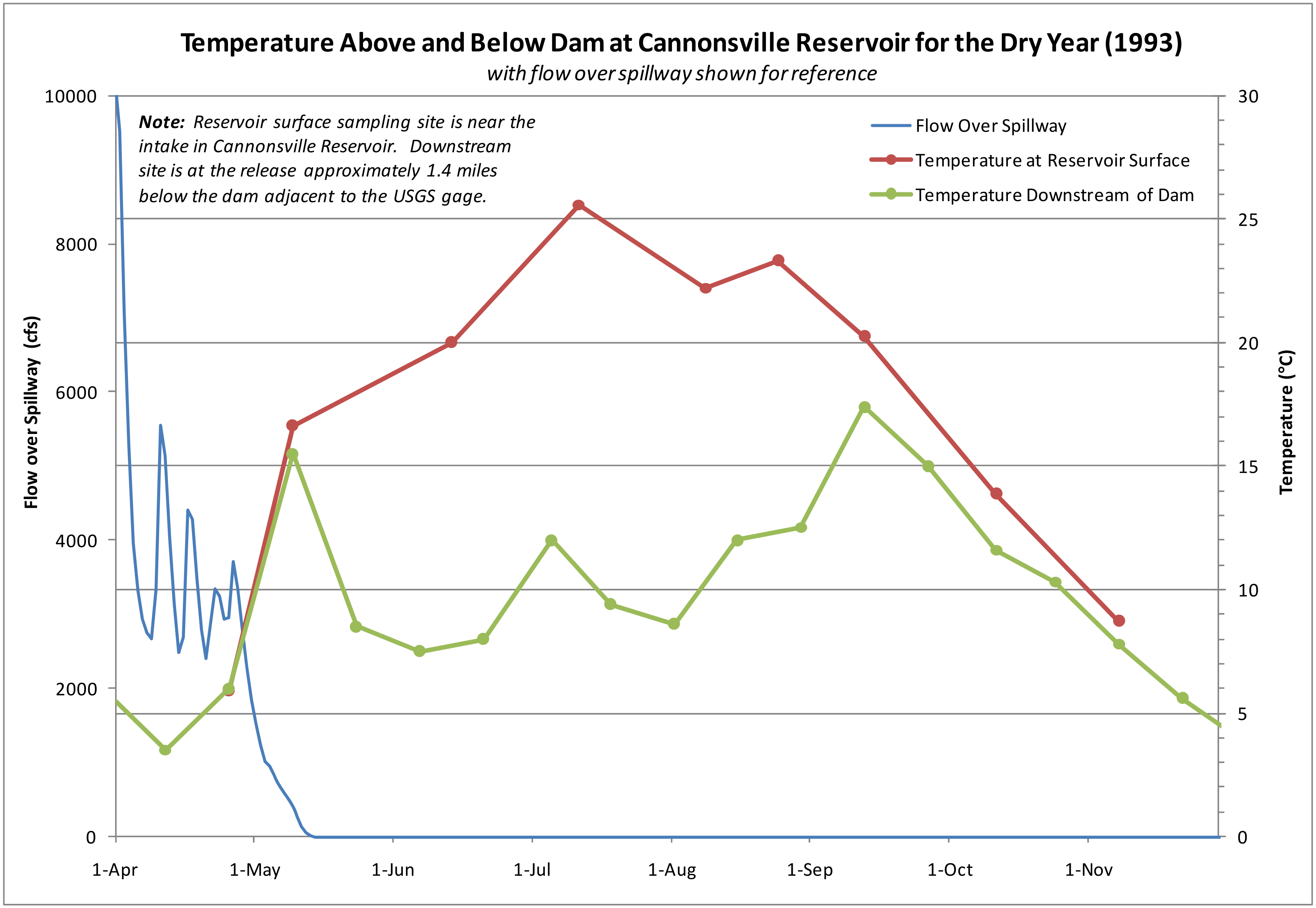


Figure 9.3-3: Temperature above and below dam at Cannonsville Reservoir for the avg. year (1998).

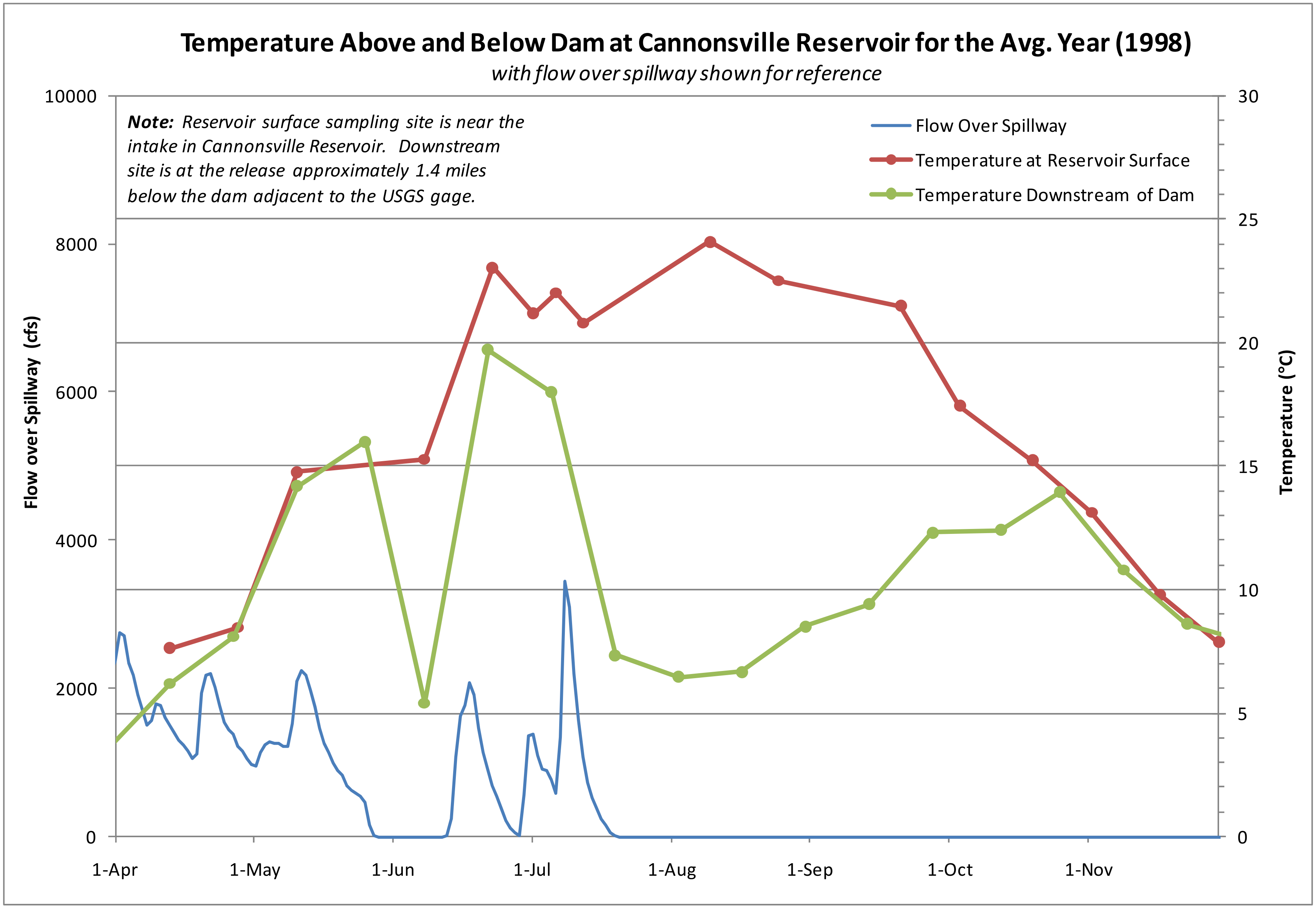


Figure 9.3-4: Temperature above and below dam at Pepacton Reservoir for the wet year (1996).

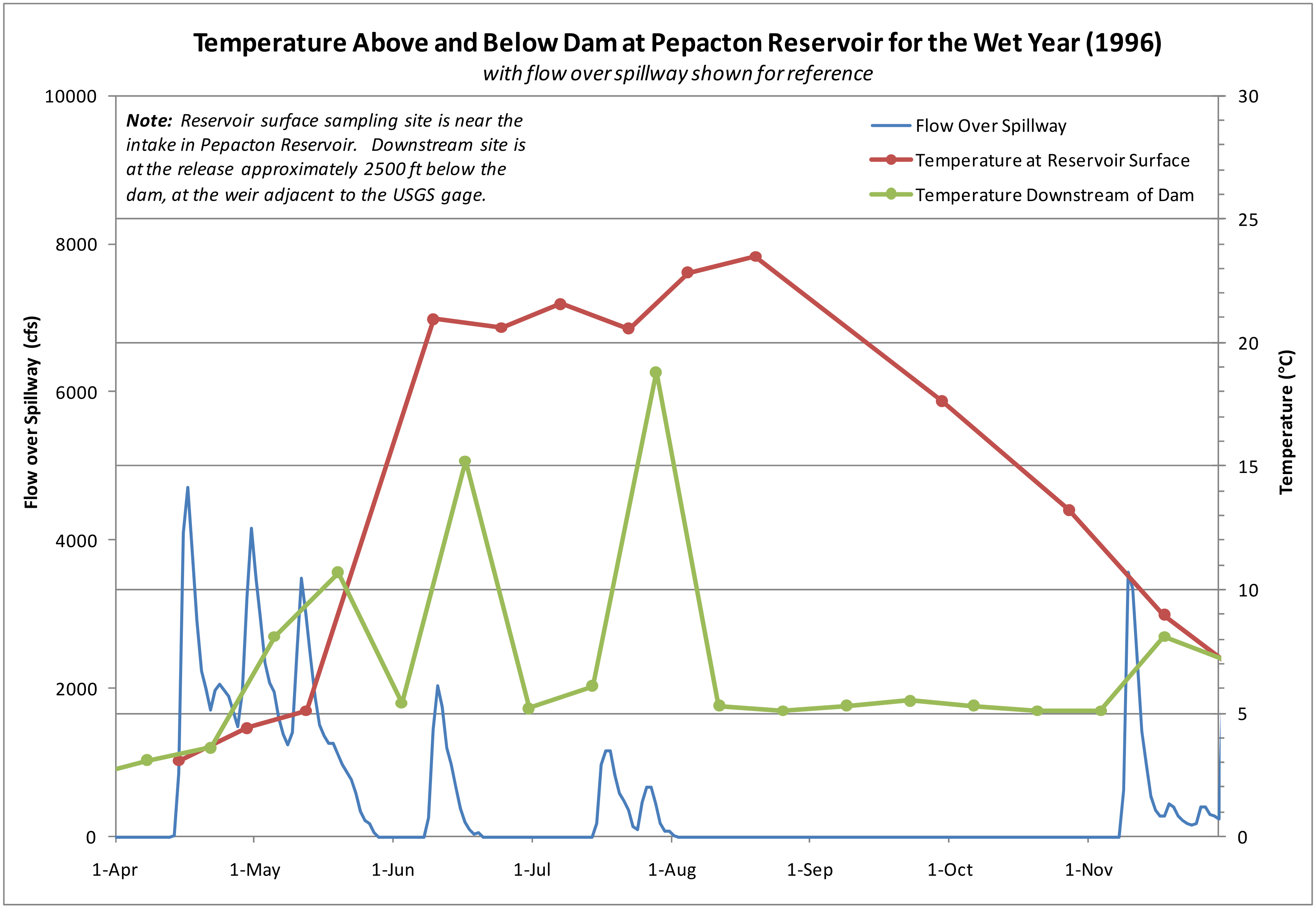


Figure 9.3-5: Temperature above and below dam at Pepacton Reservoir for the dry year (1993).

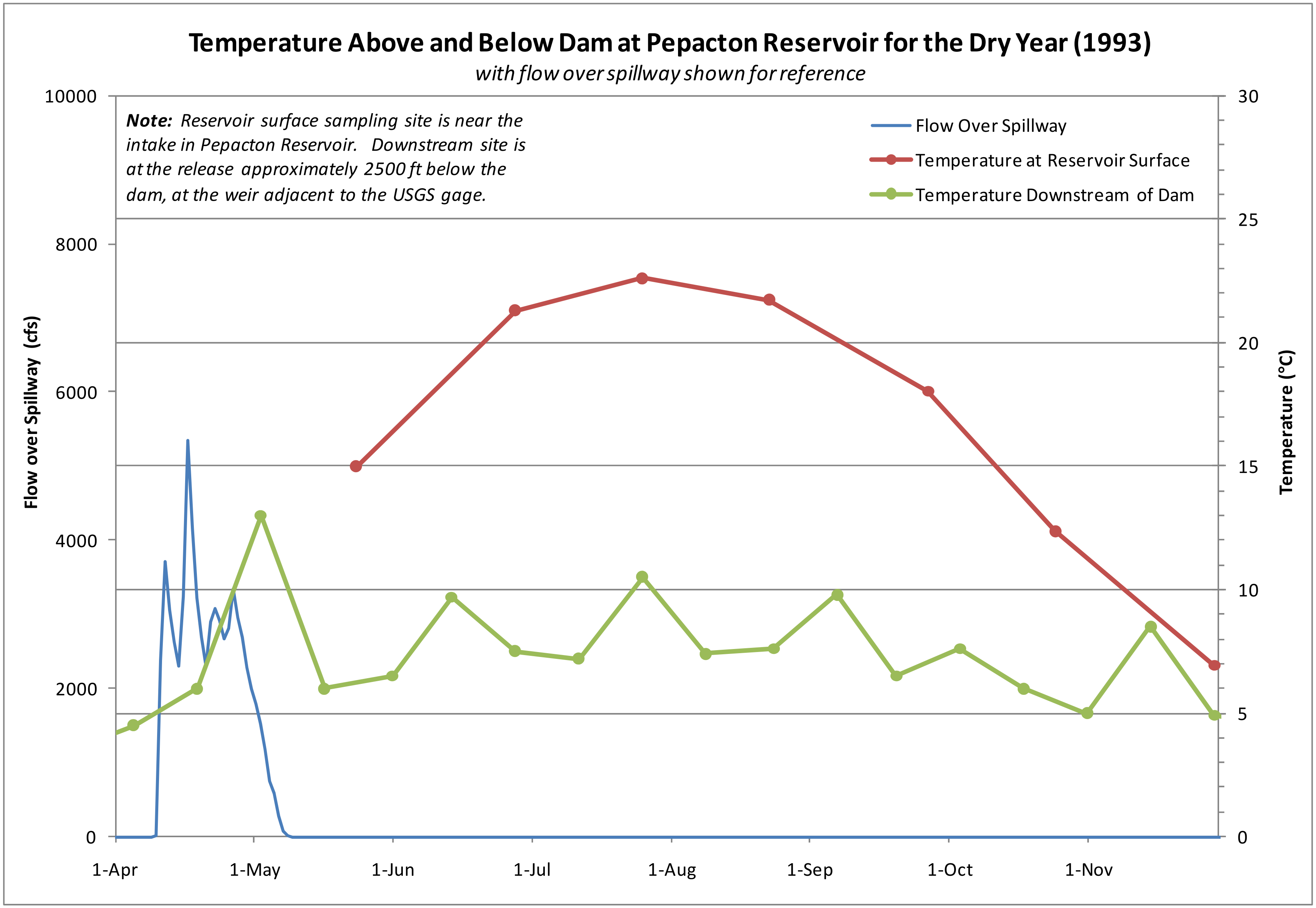


Figure 9.3-6: Temperature above and below dam at Pepacton Reservoir for the avg. year (1998).

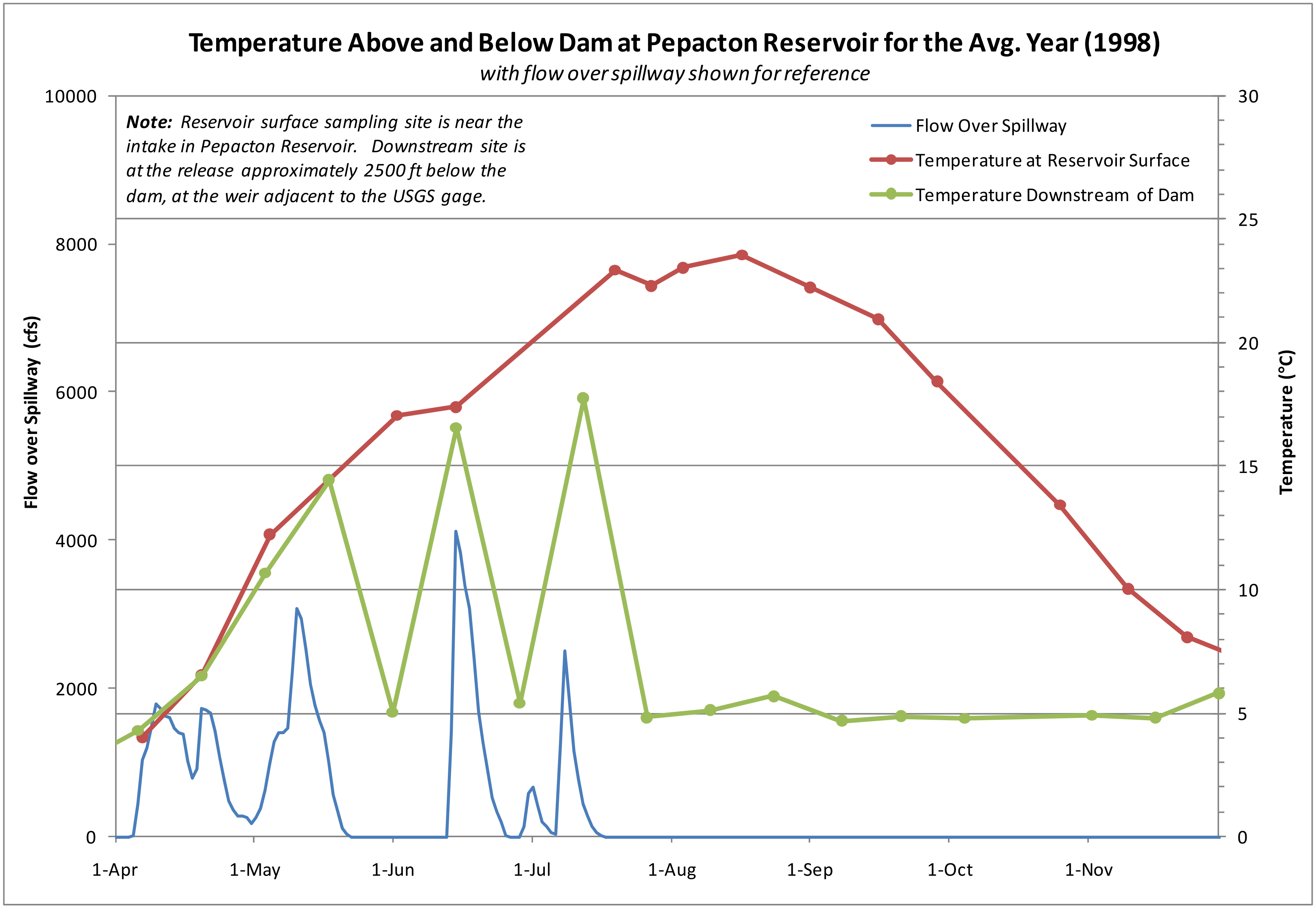


Figure 9.3-7: Temperature above and below dam at Neversink Reservoir for the wet year (1996).

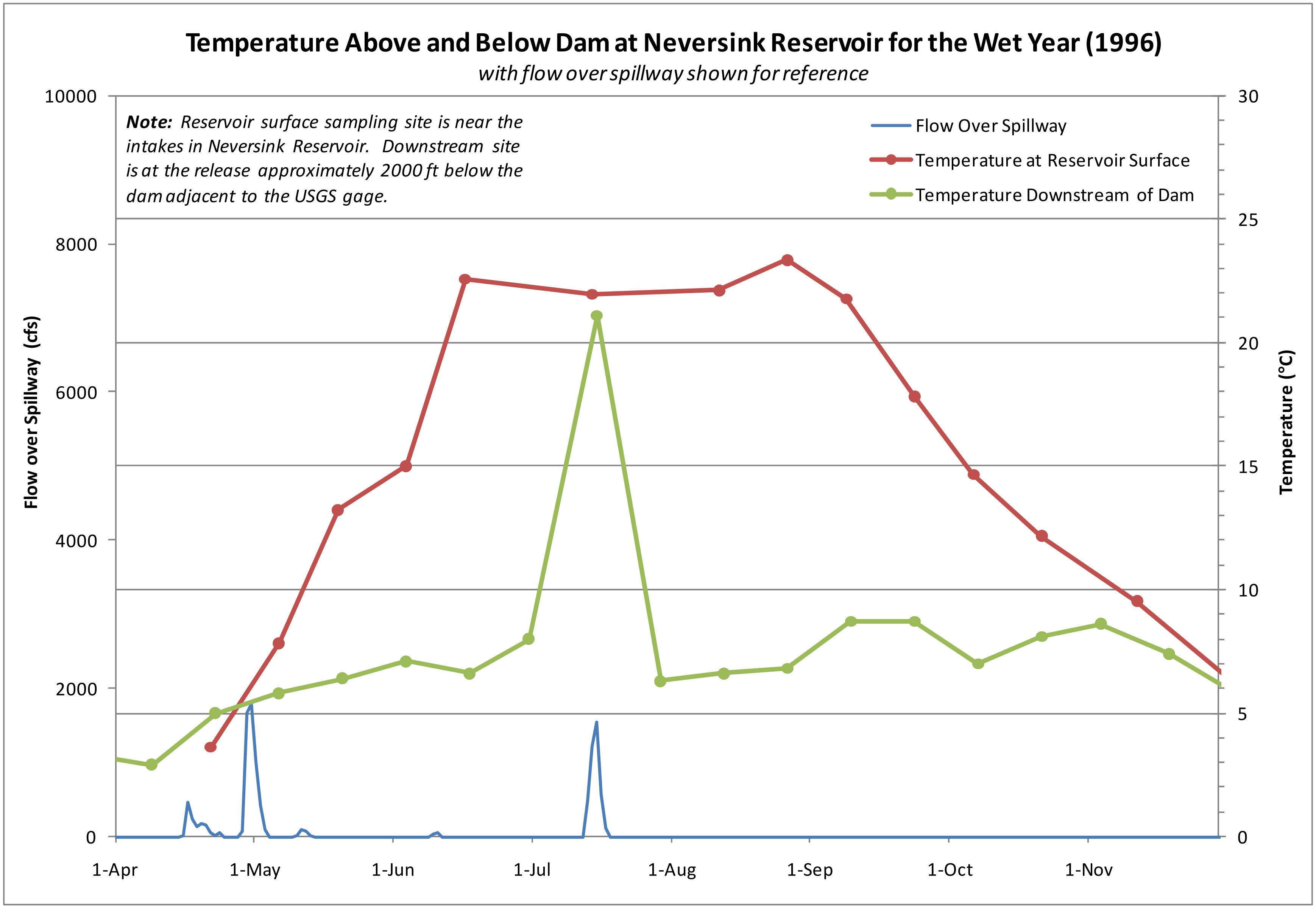


Figure 9.3-8: Temperature above and below dam at Neversink Reservoir for the dry year (1993).

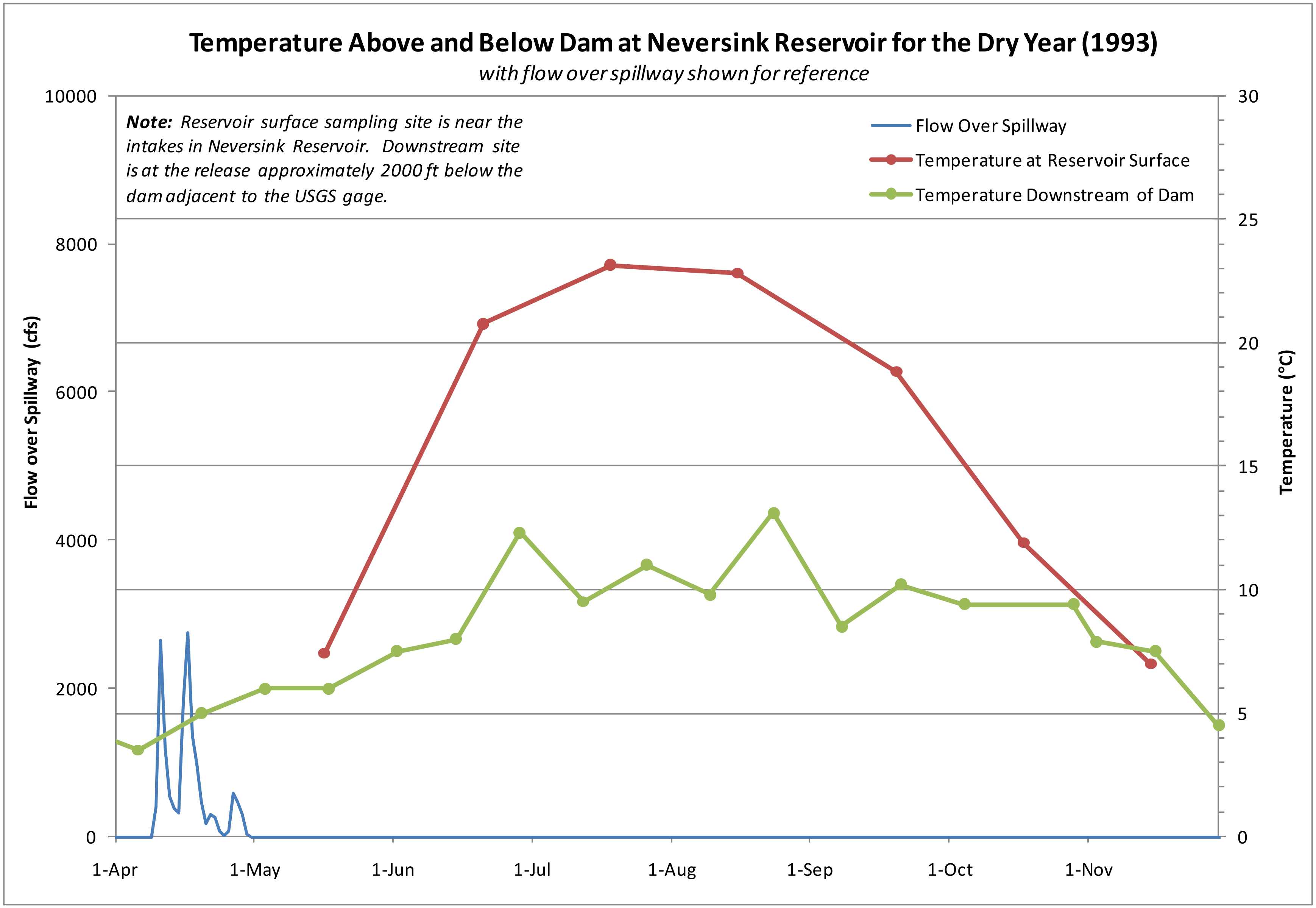
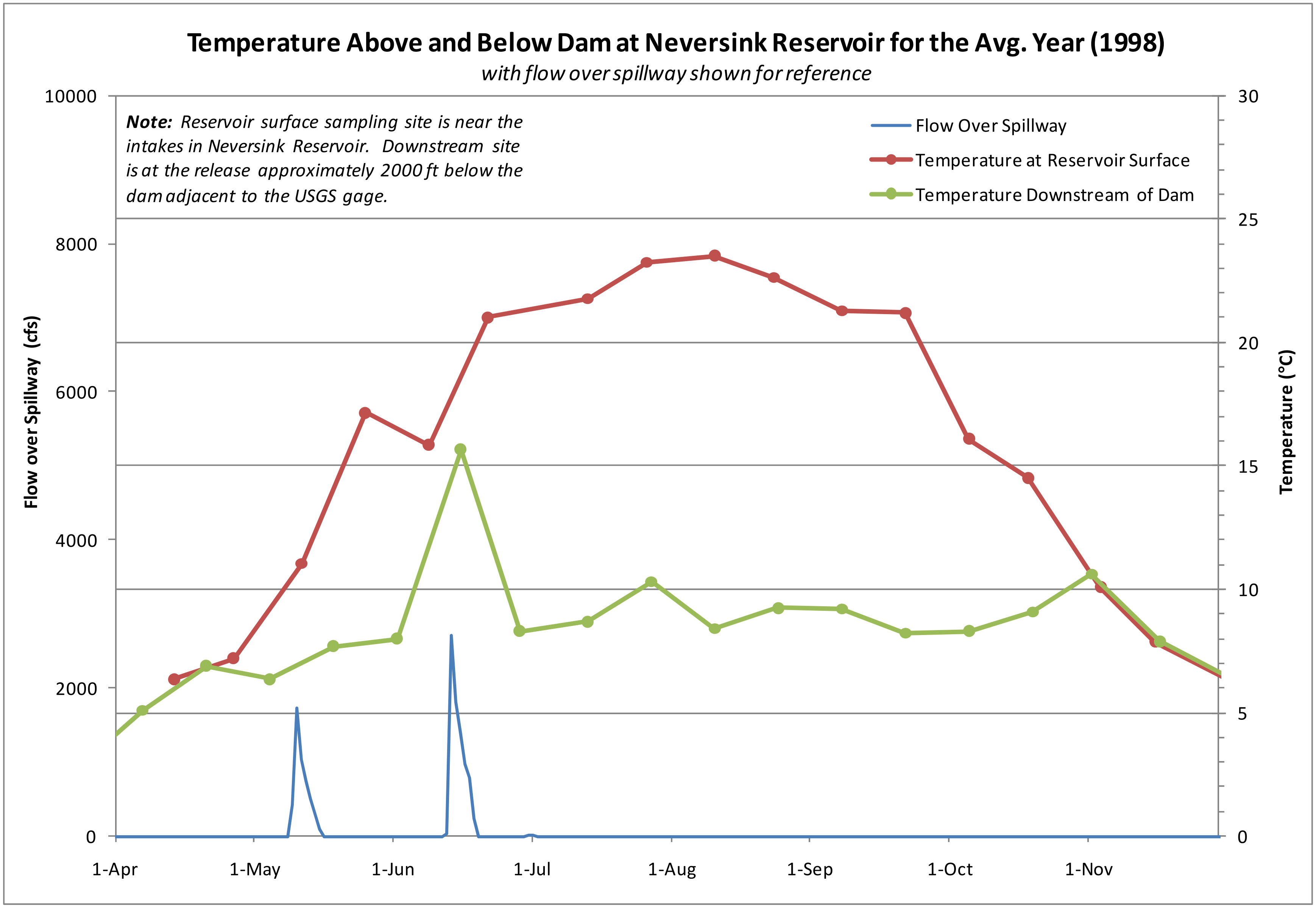


Figure 9.3-9: Temperature above and below dam at Neversink Reservoir for the avg. year (1998).



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.

11.0 LITERATURE CITED

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.

Acres International Corporation. 2005. Fish entrainment and mortality study: Volume 1 Public. Niagara Power Project. FERC No. 2216. Prepared for New York Power Authority.

Amaral, S. 2003. The use of angled bar racks and louvers for guiding fish at FERC-licensed projects. Presentation at FERC Fish Passage Workshop, Alden Research Laboratory, Holden, MA, November 13, 2003.

Allen, M.J. and G.B. Smith**.** 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. NOAA Tech. Rep. NMFS 66. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Baker, J.K. 2008. The Effects of Strobe Light and Sound Behavioral Deterrent Systems on Impingement of Aquatic Organisms at Plant Barry, Alabama. Auburn University Masters Thesis. December 19, 2008.

Beamish, F.W.H. 1978. Swimming Capacity. In Fish Physiology, vol. 7. (eds. W. S. Hoar and D. J. Randall), pp. 101-187. Academic Press, New York.

Becker, G. C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison.

Bell, M. 1991. Fisheries handbook of engineering requirements and biological criteria. Portland, OR: U.S. Army Corps of Engineers, Fish Passage Development and Evaluation Program, North Pacific Division.

Bozeman, E.L., Jr., and M.J. Van Den Avyle. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) --alewife and blueback herring. USFWS Biological Report 82: 11.111. U.S. Army Corps of Engineers, TR EL-82-4.

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.

CH2M Hill. 2007. Potential for trout entrainment in Spada Lake, Washington. Public Utility District No. 1 Snohomish County: Henry M. Jackson Hydroelectric Development. FERC No. 2157.

Clark, R., S. Dickerson, J. Houghton, K. Lawrence, S. Martin, M. Obedzinski, and M. Smallman. 1993. Status review of Atlantic salmon in Maine.

Clay, C. 1961. Design of fishways and other fish facilities. Department of Fisheries of Canada, Ottawa. Cat. No. Fs 31-1961/1.

Danie, D. S., J. G. Trial, and J. C. Stanley. 1984. Species profiles: life histories and environmental requirements o f coastal fish and invertebrates (North Atlantic) -- Atlantic salmon. USFWS OBS-82/11.22. U.S. Army Corps of Engineers, TR EL-82-4.

Electric Power Research Institute. 1992. Fish Entrainment and Turbine Mortality Review and Guidelines. Prepared by Stone & Webster Environmental Services. EPRI Report No. TR-1 01231, Final Report.

Electric Power Research Institute. 1997. Turbine entrainment and survival database - field tests. Prepared by Alden Research Laboratory, Inc. EPRI Report No. TR-108630.

Electric Power Research Institute. 2002. Upstream and Downstream Fish Passage and Protection Technologies for Hydroelectric Application: A Fish Passage and Protection Manual. EPRI Report No. TR-1005392.

Edwards, E.A. 1983. Habitat suitability index models: Longnose sucker. USFWS. FWS/OBS-82-10.35.

Edwards, E.A., D.A. Krieger, M. Bacteller, and O.E. Maughan. 1982. Habitat suitability index models: Black crappie. USFWS. FWS/OBS-82/10.6.

Edwards, E.A., G. Gebhart, and O.E. Maughan. 1983. Habitat suitability information: Smallmouth bass. USFWS. FWS/OBS-82/10.36.

Edwards, E.A. and K.A Twomey. 1982. Habitat suitability index models: Common carp. USFWS. FWS/OBS-82/10.12.

Effler, S.W.; R.K. Gelda; M. Perkins; D.A. Matthews; E.M. Owens; C. Stepczuk; and A.P. Bader. 1998. Characteristics and Origins of Metalimnetic Dissolved Oxygen Minima in a Eutrophic Reservoir. Lake and Reservoir Management, 1040-2381, Volume 14, Issue 2, Pages 332 – 343.

Federal Energy Regulatory Commission. 1995. Preliminary assessment of fish entrainment at hydropower projects. Vol. 1, A report on studies and protective measures. Report prepared by Stone & Webster Environmental Technology and Services for Office of Hydropower Licensing. Paper No. DPR-10, Washington, DC.

Franke, G.F., D.R Webb, R.K. Fisher, Jr., D. Mathur, P.N. Hopping, P.A. March, M.R. Headrick, I.T. Laczo, Y. Ventikso, and F. Sotiropoulos. 1997. Development of environmentally advanced hydropower turbine system design concepts. Prepared for U.S. Department of Energy, Idaho Operations Office Contract DE-AC07-94ID13223.

Froese, R. and D. Pauley. Editors. 2010. FishBase. World Wide Web electronic publication. www.fishbase.org, version (Accessed January 2010).

Furniss, M., M. Love, S. Firor, K. Moynan, A. Llanos, J. Guntle, and R. Gubernick. 2008. FishXing, Version 3.0. U.S. Forest Service, San Dimas Technology and Development Center, San Dimas, CA. http://www.stream.fs.fed.us/fishxing.

Katopodis, C. and R. Gervais. 1991. Ichthyomechanics: working document. Freshwater Institute, Department of Fisheries and Oceans, Winnipeg, Manitoba.

Krieger, D.A., J.W. Terrell, and P.C. Nelson. 1983. Habitat suitability information: Yellow perch. USFWS. FWS/OBS-83/10.55.

McMahon, T.E. and J.W Terrell. 1982. Habitat suitability information: Channel Catfish. USFWS. FWS/OBS-82/10.2 . 29 pp.

McMahon, T.E., J.W. Terrell, and P.C. Nelson. 1984. Habitat suitability information: Walleye. USFWS. FWS/OBS-82/10.56. 43 pp.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. http://www.natureserve.org/explorer. (Accessed April 20, 2010).

Odeh, M. 1999. A summary of environmentally friendly turbine design concepts. U.S. Department of Energy, Idaho Operations Office, DOE/ID/13741.

Ontario Ministry of Transportation 2006. Environmental Guide for Fish and Fish Habitat. Appendix 6.B: Fish Swimming Speeds.

Osmond, D.L., D.E. Line, J.A. Gale, R.W. Gannon, C.B. Knott, K.A. Bartenhagen, M.H. Turner, S.W. Coffey, J. Spooner, J. Wells, J.C. Walker, L.L. Hargrove, M.A. Foster, P.D. Robillard, and D.W.

Lehning. 1995. WATERSHEDSS: **Water**, **S**oil and **H**ydro-**E**nvironmental **D**ecision **S**upport **S**ystem, http://h2osparc.wq.ncsu.edu.

Pardue, G.B. 1983. Habitat suitability index models: alewife and blueback herring. USFWS. FWS/OBS-82/10.58.

Raleigh, R.F. 1982. Habitat suitability index models: Brook trout. USFWS. FWS/OBS-82-10.24.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow trout. USFWS. FWS/OBS-82/10.60.

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout, revised. USFWS. FWS/OBS-82/10.124. [First printed as: FWS/OBS-82/10.71, September 1984]

Smith, C.L. 1985. The inland fishes of New York State. NYSDEC, Albany, NY.

Stuber, R.J., G. Gephard, O.E. Maughan. 1982. Habitat suitability index models: Largemouth Bass. USFWS. FWS/OBS-82/10.16. 32 pp.

Twomey, K.A., K.L. Williamson, and P.C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: White Sucker. USFWS. FWS/OBS-82-10.64.

U.S. Army Corps of Engineers. 1991. Revised Compendium on the Success of Passage of Small Fish Through Turbines. North Pacific Division, Portland, Oregon.

Unites States Congress Office of Technology Assessment. 1995. Fish Passage Technologies: Protection at Hydropower Facilities. OTA-ENV-641 (Washington, D.C.: U.S. Government Printing Office, September, 1995).

Venn Beecham, R., C.D. Minchew, and G.R. Parsons. 2007. Comparative swimming performance of juvenile pond-cultured and wild-caught channel catfish. North American Journal of Fisheries Management 27: 729-734.

Werner, R.G. 2004. Freshwater fishes of the northeastern United States: a field guide. First edition. Syracuse University Press.

Winchell, F., S. Amaral, and D. Dixon. 2000. Hydroelectric turbine entrainment and survival database: an alternative to field studies. HydroVision Conference, Charlotte, NC.

Wismer, D.A., and A.E. Christie. 1987. Temperature Relationships of Great Lakes Fishes: A Data Compilation. Special Publication 87-3. Great Lakes Fishery Commission.

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
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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

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[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

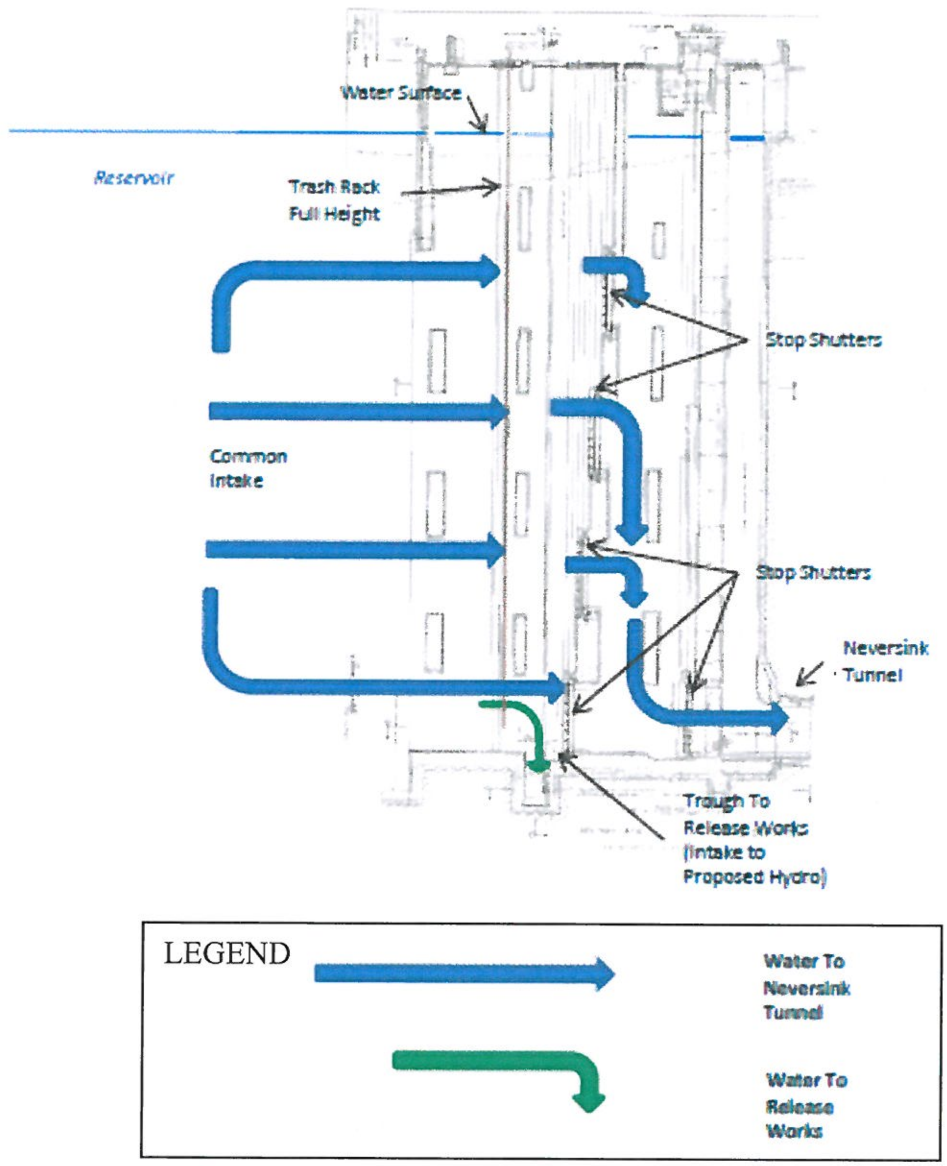
c: Dave Sampson, Associate Counsel, NYSDEC
Mark Woythal, Director In-Stream Flow Unit, NYSDEC
Larry Wilson, Biologist, NYSDEC
Michael Flaherty, Biologist, NYSDEC
Norman McBride, Biologist, NYSDEC
David A. Stilwell, Field Supervisor, USFWS
Steven Patch, Fish and Wildlife Biologist, USFWS
Kevin Lang, Partner, 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



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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