EXETER RIVER STUDY
PHASE I FINAL REPORT

for the

TOWN OF EXETER, NH

March 2007

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Civil and Environmental Engineering Services

WOODLOT ALTERNATIVES, INC.
ENVIRONMENTAL CONSULTANTS

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INTRODUCTION

This report presents the results of the Phase I Exeter River Study. Because of annual funding limitations, this study was conducted over two years with nearly equal work efforts conducted during 2005 and 2006. This project's original work scope for 2005 and 2006 activities was presented in a letter dated September 15, 2005 (see Appendix A). In a letter dated June 20, 2006, the original 2006 work scope was revised based on the 2005 results to better reflect the goals of the study (see Appendix B). The 2006 work scope was further revised following an October 19, 2006 project status meeting, as summarized in letter dated November 13, 2006 (see Appendix C).

Results of the 2005 Phase I Exeter River Study were presented in a report titled *"Exeter River Study - Interim 2005 Report"* dated February 3, 2006. It is desired that this final report address all activities conducted in 2005 and 2006; therefore, this final report will summarize each 2005 activity and the activity results. This report will also include the conclusion and recommendations for the 2005 activities, some of which could not be made until the completion of 2006 activities. However, this report does not duplicate the entire text of the 2005 report. The 2005 report should be reviewed for a complete summary of 2005 activities.

The major 2005 Phase I activities included the following tasks:

- A field survey of each dam to produce input data for the hydraulic model;
- A backwater analysis of the Great Dam;
- Dissolved oxygen and temperature monitoring of the Exeter River;
- Assessment of funding opportunities for Exeter River infrastructure improvements;
- Develop a hydraulic model that predicts river profiles at 1, 10, 50 and 100-year storm events;
- Evaluate the feasibility and costs of automated impoundment level monitoring equipment; and
- Conduct a hydraulic analysis of the Great Dam low-level gate.

The 2006 activities build on and continue the work conducted in 2005. The primary purpose of activities conducted in 2005 and 2006 for the Exeter River Study was to produce information to better understand how the Great Dam affects water quality and quantity on the Exeter River. This information, in turn, has been used with 2006 activities to develop potential modification options to the Great Dam that would increase its discharge capacity and reduce upstream flooding. The Great Dam is presently in violation of New Hampshire Department of

Environmental Service (NHDES) rules that require all dams be able to pass the 50-year flood event with one foot of freeboard. The Exeter River Study Committee had previously identified the most important issue to be addressed on the Exeter River is to understand what changes are needed to the dam to mitigate the adverse affects of upstream flooding and to satisfy NHDES discharge requirements.

The major 2006 Phase I activities included the following tasks:

- Conduct a bathymetry survey of the Great Dam impoundment;
- Conduct a visual inspection of the Great Dam;
- Develop conceptual modifications to the Great Dam that would meet NHDES discharge requirements;
- Develop cost estimates for dam modification options, including complete removal of the Great Dam and fish passage; and
- Build a hydraulic model of the Exeter River in the impoundment area. Use model to select and evaluate adequacy of potential dam modifications. Use model to predict upstream flood water elevations of various storm events (10-year, 50-year, etc.).

The above 2006 activities were successfully completed as planned. An Executive Summary of the results of activities conducted during 2005 and 2006 are presented in Section 2, *Executive Summary and Recommendations*.

SECTION 2

EXECUTIVE SUMMARY AND RECOMMENDATIONS

As discussed in Section 1, Introduction, this report presents the results of Phase I Exeter River Study activities performed in 2005 and 2006. 2006 activities will be presented in detail while 2005 activities will be summarized. The details of 2005 activities can be found in a February 3, 2006 report titled, *"Exeter River Study Interim 2005 Report"*.

Major findings of the 2005 and 2006 Exeter River Study reports are as follows:

- The Great Dam does not presently comply with New Hampshire Department of Environmental Services (NHDES) Dam Bureau Rule Env-Wr 303.11 that requires Class A dams be able to pass the 50-year storm event with at least one foot of freeboard above the water surface and the top of the dam abutments (see NHDES Letter of Deficiency (LOD) to the Town of Exeter dated July 25, 2000 and LOD amendments dated June 1, 2004). Hydraulic analyses performed as part of this study indicate that the left and right abutments are overtopped by 3.0 feet and 1.6 feet, respectively, during a 50-year return interval hydrologic event.

- The Great Bridge substantially affects water surface elevations and results in increased flood water elevations upstream of the dam. Hydraulic analyses indicate that the hydraulic restriction imposed by the bridge increases upstream water surface elevations by approximately 1.2 feet during a 50-year return interval hydrologic event.

- The existing low-level discharge gate has very limited ability to mitigate flood water elevations. During the 10-year storm event (approximately 3,000 cfs) the difference in water elevation at the Great Dam with the low-level outlet open and closed is 0.34 feet or approximately 4 inches. The existing gate's ability to lower water elevations upstream of the Great Dam is even less. The existing low-level outlet's capacity to mitigate flooding decreases as flows increase. The low-level outlet gate is presently manually operated, and, therefore, by NHDES Dam Bureau rules, the discharge provided by this gate cannot be included in determining the dam's overall discharge capacity.

- The installation of a larger low-level outlet at Great Dam would also have relatively minimal effect in reducing upstream flooding. The larger low-level outlets proposed for the three dam modifications concepts would lower the water surface elevation at Court Street from between 0.0 and 0.29 feet during the one-year storm event (approximately 1,000 cfs). The ability of the proposed low-level outlets to lower water surface elevations at Court Street decreases with increased flows.

- The hydraulic analyses suggest the impact of pre-emptive drawdowns of the Great Dam impoundment to reduce upstream flooding is minimal.

- The Great Dam was not constructed to be a flood control structure. It was built originally to provide water power to mills. Flood control dams are designed to mitigate flooding downstream of the dam. The Great Dam, in its present or modified condition, has little ability to mitigate the impacts of upstream flooding.

- The hydraulic analysis results indicate the installation of the one-foot high "cap" on the dam crest and the fish passage facility caused the water surface elevation to be approximately 1.4 feet higher during the 50-year flood relative to conditions prior to their installation. The results also show that the dam abutments would be overtopped during the 50-year flood prior to the installation of the cap and fishpass (west abutment by 1.6 feet, east abutment by 0.2 feet).

- The Great Dam has been modified extensively through the years. Some of these modifications have decreased the dam's discharge capacity. Modifications that have decreased dam discharge capacity include construction of the fish passage facility, apparent loss of spillway length at the time the fish passage was constructed, construction of the one-foot cap on the spillway crest, and deactivation of the approximately 7-foot by 14-foot penstock. The dam's hydraulic capacity prior to the addition of the fishpass facility and the one-foot high cap on the spillway were evaluated as part of this study. The results of this analysis suggest that these modifications further diminished the dam's ability to pass the 50-year storm with one foot of freeboard, but that they had a minimal impact in increasing flood water elevations upstream of the dam.

- The presence of Great Dam on the Exeter River plays a limited role in upstream flooding. During the 50-year flood, the difference in water elevation at the Court Street Bridge with a dam and without a dam is approximately 1.2 feet. The natural river channel, ox-bows, bridge abutments and other restrictions to flow have a substantial affect in limiting river flows and backing up water as compared to the Great Dam.

- Three dam modification concepts were developed that would satisfy NHDES discharge capacity requirements and NHDES Dam Bureau Rule Env-Wr 303.11. The design criteria for the modifications included:

  a) Dam crest elevation to remain unchanged
  b) No increase in the east abutment elevation (west abutment elevation to match east abutment)
  c) Achieve NHDES discharge capacity requirements
  d) Maintain or improve performance of the existing fish passage facility

- The estimated cost of the three dam modification concepts range between 1 million and 1.4 million dollars.

The objective of the 2005 Exeter River Study activities was to generate information that would allow the Town of Exeter to better understand and quantify existing water quality and quantity concerns in the Exeter River. The following is a summary of 2005 activities.

Exeter River Study Interim 2005 Report

Task A: Preliminary Base Plans

Field surveys were performed at Great Dam, Colcords Pond Dam and Pickpocket Dam on November 15 and 16, 2005. The purpose of this work was to document existing conditions and to acquire elevation and dimensional details of the dams for hydraulic modeling. Preliminary existing condition base plans can be found in the 2005 interim report.

Task B: Great Dam Structural Evaluation

Persistent high water in the Exeter River during the fall of 2005 prevented a visual structure inspection. This task was postponed until September of 2006 and it is included in the 2006 activities section of this report.

Task C: Qualitative Backwater Assessment

A qualitative backwater analysis was performed on the Great Dam impoundment reach of the Exeter River in Exeter, New Hampshire. The primary purpose of this analysis was to quantitatively establish the limit of the backwater from the Great Dam on the Exeter and Little Rivers during low-flow conditions. In other words, this analysis was performed to attempt to determine how far the Great Dam impoundment extends up the Exeter and Little Rivers. The analysis was conducted by making observations of the impoundment area from a canoe on August 2 and November 21, 2005.

The results of the backwater analysis indicate the upstream limit of the Great Dam impoundment, using qualitative methods, may not be possible. Quantitative methods, such as hydraulic modeling, were suggested to help better establish the impoundment limits. It was estimated the Great Dam impoundment extents approximately to where the Exeter River and the Little River cross Court Street (NH Route 108). The backwater analysis is discussed in further detail in 2006 activities section.

Task D: Water Quality Sampling Analysis

Water quality monitoring was performed as part of the 2005 work. This work included in-situ temperature monitoring at five locations and biweekly temperature and dissolved oxygen monitoring at six locations in the Exeter and Little Rivers in and adjacent to the Great Dam impoundment. The purpose of this work was to collect baseline information on temporal and spatial variations of temperature and dissolved oxygen in and adjacent to the Great Dam impoundment. It was expected this information could help determine potential causes and remedial measures associated with impaired water quality.

A preliminary evaluation of water quality data obtained in the Great Dam impoundment during the 2005 project work was used to evaluate 1) thermal gain through the impoundment, 2) thermal stratification and "turnover" within the impoundment, 3) dissolved oxygen levels within the impoundment, and 4) apparent dissolved oxygen depletion within the impoundment. The bi-weekly sampling was used to determine the occurrence of thermal "turnover" within the impoundment. After the impoundment "turned over", 2005 water quality data collection ended and the in-situ temperature logging equipment was removed.

The temperature data indicated that the Great Dam impoundment does experience thermal gain, meaning water temperatures increase as water moves downstream through the impoundment. Thermal gain in impoundments is common and is typically caused by increased surface area and residence time in the river. These conditions in the impoundment allow the sun and ambient air to warm the water more than would be possible if the impoundment did not exist.

The temperature data also indicate the impoundment experiences thermal stratification, meaning water temperature varies from the bottom of the river to the surface. The data indicated that in 2005, the impoundment "turned over" on approximately September 26. Turn over occurs when the surface water temperature becomes cooler than the temperature of water on the bottom. The cooler water is denser and, therefore, sinks to the river bottom while the warmer water rises to the surface.

Six biweekly dissolved oxygen sampling events were performed as part of the 2005 project work. The purpose of this work was to document existing conditions in the Great Dam impoundment during the summer and through the fall turnover. The biweekly monitoring was performed at the following six locations:

Location 1. In the Exeter River where it passes under Court Street;

Location 2. In the Little River where it passes under Court Street;

Location 3. At the confluence of the Exeter and Little Rivers adjacent to the Town of Exeter's river pump station;

Location 4. At the bend in the Exeter River approximately 200 yards upstream of the Great Bridge;

Location 5. In the exit (upstream end) of the fishpass at the Great Dam; and

Location 6. Below String Bridge on the Exeter River.

The monitoring work was performed on the following dates in 2005:

Monitoring Round 1. August 2,
Monitoring Round 2. August 16,
Monitoring Round 3. August 30,
Monitoring Round 4. September 13,
Monitoring Round 5. September 27, and
Monitoring Round 6. November 7.

Sampling was not performed during the month of October due to persistent high water in the Exeter River.

The monitoring work documented a depletion of dissolved oxygen within the Great Dam impoundment. An in-depth discussion on the spatial and temporal variations in dissolved oxygen was presented in the 2005 report and included many figures and graphs. Dissolved oxygen levels typically decreased as water moved downstream through the impoundment. As the water warms while moving through the impoundment, it cannot hold as much dissolved oxygen as cooler water. Dissolved oxygen levels were often lower near the bottom of the river, especially in the downstream end of the impoundment. Oxygen depletion in these areas can be caused by biological oxygen demand (BOD) of the organic matter and accumulated sediments at the bottom of the impoundment.

Task E: Assessment of Relevant Funding Opportunities

An assessment of relevant funding opportunities for studies or improvements on Exeter River was presented in the 2005 report. The information was presented in a table format and identified potential state and federal funding agencies with applicable study or improvement categories. The study and improvement categories included Dam Safety, Dam Removal, Drinking Water Treatment / Protection, Fish Passage, Flood Hazard, Habitat Enhancement, Riparian / Wetland Restoration and Water Quality Improvement.

It was recommended that a more detailed review of these potential funding sources be conducted once the nature and scope of additional Exeter River studies or improvements are known.

Task F: Hydraulic Modeling of Great Dam

A preliminary hydraulic model of Great Dam was developed to determine the dam's discharge capacity during floods of various return intervals. This model was also used to estimate the discharge capacity of the existing low-level gate and its ability to reduce flooding.

NHDES rules require all Class A dams must be able to pass the 50-year flood with one foot of freeboard. The modeling indicated that with the low level gate completely open, the existing dam abutments are overtopped during the 50-year flood. This modeling indicates that Great Dam requires significant modifications to increase its discharge capacity to meet NHDES requirements and that the low level gate has a marginal impact on mitigating flood impacts.

Flow duration curves were also developed as part of the hydraulic modeling task. The flow duration analysis was performed to provide information on flows in the Exeter River in the vicinity of Great Dam during target fish species migration periods. This information is used to better understand typical river flows during the migration periods of various diadromous fish species.

Task G: Meetings

Representatives from Wright-Pierce and Woodlot Alternatives, Inc. attended the Exeter River Study public meeting on May 4, 2005 and the NHDES Dam Bureau public hearing on May 25, 2005. We also presented our findings of the Exeter River Study Interim 2005 Report to the Exeter River Study Committee on April 6, 2006.

Task H: Water Level Recording

An evaluation was performed on the feasibility and costs associated with installing remote automated impoundment level monitoring equipment at each dam. Though this equipment is most needed at Great Dam to better manage impoundment levels, this evaluation is also applicable to monitoring equipment for Colcords Pond Dam and Pickpocket Dam.

The total cost for an automated water level monitoring station at Great Dam would range from approximately $8,400 - $10,200. The cost for a water level monitoring station at Colcords Pond Dam and Pickpocket Dam could be higher due their increased distance from telephone and power utilities.

Task I: Low-Level Gate Hydraulics and Gate Operations

An in-depth hydraulic analysis was performed on Great Dam's existing low level discharge gate. The purpose of this analysis was to determine the low-level gate's discharge capacity at various river flows and to determine if the gate could be operated in a manner that would reduce upstream flooding. This analysis was performed with the assumption that the inlet dimensions of the low-level outlet were similar to those of the outlet, as the lack of plans and persistent high water during the 2005 work prevented measuring the dimensions of the inlet of the low-level outlet.

The results of this analysis indicated that the gate had a discharge capacity of between 264 cfs when the river flow was 750 cfs and 321 cfs when the river flow was 3,000 cfs. The affect on water surface elevation was 0.56 feet and 0.34 feet, respectively. These results confirm the low-level gate has a minimal impact on reducing the impacts of flooding.

Exeter River Study 2006 Activities

The objective of the 2006 Exeter River Study activities was to build on and continue the work conducted in 2005, with the ultimate goal of producing information to better understand how the Great Dam affects water quality and quantity on the Exeter River. Information gathered in 2005 and 2006 was used to develop potential modification options to Great Dam that would increase its discharge capacity. The following is a summary of 2006 activities.

Great Dam Inspection

On September 6, 2006, a visual structural inspection was performed on Great Dam. This inspection was purely structural in nature and did not include any hydraulic or mechanical considerations. Overall, the dam and associated concrete structures appeared to be in good condition. No deficiencies that require immediate repair were observed. The complete inspection summary and recommendations can be found in Section 3 of this report.

Bathymetric Survey of Great Dam Impoundment

A high resolution bathymetric survey on the Great Dam impoundment was conducted in July, 2006 using boat-mounted sonar and GPS equipment. This survey was performed to provide more detailed information on the channel bathymetry and volume of the Great Dam impoundment. This survey obtained bathymetric data from the general vicinity of Great Dam up to the vicinity of the Court Street Bridge. Bathymetry of the Little River was obtained from its confluence with the Exeter River to a point approximately 100 yards downstream of the Court Street Bridge. This survey indicated the impoundments hold approximately 62 million gallons in usable drinking water storage. The complete bathymetric survey summary can be found in Section 4 of this report.

Fish Passage Evaluation

Based on work conducted in 2005, it was assumed that potential dam modification options would impact the performance of the existing Great Dam fish passage facility. It was believed dam modification impacts to the fish ladder would need to be identified and solutions developed that would maintain or improve its existing performance.

During subsequent discussions with the Exeter River Study Committee, it was determined that the existing spillway elevation of 22.53 feet (NGVD) and associated impoundment elevation was to remain the same under normal flow conditions. Dam modification Concepts 1 and 2 include the installation of crest gates that would maintain a normal crest elevation of 22.53 feet. During storm events, these crest gates would open and lower the spillway height to a level below the upstream entrance elevation to the fish ladder. Depending on the depth of the water flowing over the lowered crest gate, water may or may not enter the upstream fish ladder entrance. Dewatering of the fishpass during seasonal upstream migration periods of target fish species would not be acceptable to the New Hampshire Fish and Game Department (NHFGD), and coordination with the NHFGD regarding crest gate operations is, therefore, recommended.

Dam modification Concept 3 consisted of replacing the existing dam with a labyrinth weir with a crest elevation of 22.53 feet. This concept also included an 8-foot by 8-foot discharge gate. Similar to Concepts 1 and 2, gate operations during storm flows could cause the fish passage to go dry. Therefore, coordination with the NHFGD regarding discharge gate operations is recommended.

The complete fish passage evaluation is presented in Section 5.

Great Dam Modification Concepts and Hydraulic Modeling

Through discussions with the Exeter River Study Committee, it was agreed that three dam modification concepts would be developed for evaluation. The Committee also requested two evaluations related to the dam, namely, impacts associated with complete dam removal and an estimate of how much discharge capacity was lost following the construction of the fish passage in the late 1960's.

The physical parameters of the three dam modification concepts were used as input data in the hydraulic model to predict how each option would discharge flood waters during various storm events. With respect to the two evaluations, the hydraulic model of the Exeter River was also run with estimated dam parameters that existed prior to the construction of the fish pass and with no dam at all.

A brief description of the three dam modification options and two evaluations are as follows:

Concept 1:

- Remove the 1-foot high concrete "cap" along the entire length of the spillway
- Install a 1-foot high crest gate along spillway length
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new appropriately sized discharge low-level gate

Concept 2:

- Remove 3 feet of dam crest along the entire length of the spillway
- Install a 3-foot high crest gate along spillway length
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new appropriately sized discharge low-level gate

Concept 3:

- Select one among the three alternative approaches below to increase spillway capacity:
    1) Extend spillway into Founders Park
    2) Construct an emergency spillway in Founders Park
    3) Replace the existing dam with a "labyrinth weir" style dam
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new appropriately sized discharge low-level gate

Evaluation 1:

- Estimate Great Dam discharge capacity prior to the construction of the fish pass in the late 1960's.

Evaluation 2:

- Evaluate the impacts and costs associated with complete removal of Great Dam

The hydraulic model used for this study is called Hydrologic Engineering Center's River Analysis System (HEC-RAS) that was developed by the U.S. Army Corps of Engineers. River geometry data used in the model was obtained from the bathymetric survey conducted as part of this study and digital elevation model (DEM) topographic data produced by the U.S. Geological Survey. The model was run with different river flows that included typical summer flow and the following return interval flood events: 1-year, 10-year, 50-year and 100-year.

The hydraulic analysis was conducted to evaluate the discharge capacity of the three dam conceptual options, the degree to which the Great Dam may hydraulically control river flows, and to estimate the extent of backwater impacts during various storm events. The model was also run with the two evaluation scenarios.

Hydraulic Analysis Results

Discharge Capacity of Dam Modification Options

The modeling confirmed previous analyses indicating the existing Great Dam configuration has inadequate spillway capacity to pass the 50-year storm event. The calculated water surface elevation for the 50-year storm is 28.7 feet, which would overtop the left and right dam abutments by 3.0 and 1.6 feet, respectively.

Concept 1 could pass the 50-year storm event with slightly less than the required one foot of freeboard required between the water surface and the top of the abutments (.77 feet of freeboard). Minor modifications to this design could be made to achieve the one foot of freeboard requirement. Concept 1 could pass the 100-year storm event without overtopping the dam abutments. An 8-foot tall by 16-foot long gate was used to model this concept.

Concept 2 could pass the 50-year storm and 100-year storm events with more than one foot of freeboard. A 6-foot tall by 8-foot wide discharge was used to model this concept.

The model results indicated Concept 3 could also pass the 50-year and 100-year storm events with more than one foot of freeboard. A discussion of how to interpret the model results for a labyrinth weir is included in Section 6. A 6-foot tall by 8-foot long gate was used to model this concept.

The model was run with Great Dam parameters that were believed to exist prior to the construction of the fish passage and the one-foot cap. The model results indicate that the Great Dam, prior to the construction of the fish passage and the cap, had inadequate spillway capacity for the 50-year storm event and that the abutments would be overtopped (west abutment by 1.6 feet, east abutment by 0.2 feet).

The construction of the fish ladder and cap increased calculated water surface elevations at the dam for the 50-year storm event by 1.4 feet. This result indicates that overtopping of both dam abutments would have occurred at both abutments during the 50-year storm event. A complete discussion of the discharge capacities of various dam modifications is included in Section 6.

Hydraulic Effects of Great Bridge

The model was run to predict the hydraulic effects of Great Bridge on river flows. The purpose of this analysis was to evaluate how the presence of the bridge impacts surface water elevations during various storm events.

The results of the analysis indicate the Great Bridge does act as a hydraulic restriction to river flows. The degree to which the Great Bridge restricts river flows is substantial and increases as river flows increase. During the 50-year and 100-year storm events, water elevations upstream of Great Bridge are between one and two feet higher than downstream elevations for the existing dam configuration and the three proposed dam modification concepts. A complete discussion of the Great Bridge hydraulic restriction is included in Section 6.

Backwater Analysis between Great Dam and Court Street Bridge

The model was run to conduct a backwater analysis to determine water surface profile elevations associated with the different dam modification concepts and with different operating conditions for each concept. This analysis would help determine how far impoundment limits extend up the river during different storm events and different dam operating conditions. The analysis was performed with: a) high flows and b) low flows subject to low level gate operations.

The study area for this backwater analysis consisted of the section of river from the Great Dam to where the Exeter River crosses Court Street. This area was selected because during the 2005 activities, this section of river was identified as the likely Great Dam impoundment area based on a qualitative analysis. In 2006, a bathymetric survey of the study area was performed for eventual use in the model. The model could not be run for sections of the Exeter River upstream of Court Street because no bathymetric data was obtained from this area.

The results indicate that the backwater imposed by Great Dam extends upstream of the Court Street Bridge (limit of study area) but that the increase in flood water elevations (hence, areal extent of backwater) caused by Great Dam diminishes substantially as flows increase. The difference in backwater elevation at the Court Street Bridge from the existing dam condition and the complete dam removal condition are approximately 1.25 feet for the 50-year and 100-year storm events. The differences in water surface elevations between the existing dam condition and dam removal condition likely diminish substantially upstream of the Court Street Bridge due to the restriction imposed by the Court Street Bridge and its adjacent approach embankments.

A low-flow analysis was conducted to determine to what degree low-level gate operations could affect upstream water levels. The model was run with the one-year storm event (1,000 cfs) on the various dam concepts in an effort to understand each low-level structure's ability to regulate upstream water levels. The results of this analysis indicate that the ability to manipulate water level in the Great Dam impoundment, using the low-level gate in the dam modifications, is limited. Therefore, the affect of pre-emptive drawdowns on upstream water levels is expected to be minimal. A complete discussion of the backwater analysis is included in Section 6.

Impoundment Limits

The upstream limit of the Great Dam impoundment will vary depending on the flow of the river. In addition, the definition of the upstream limit of the impoundment is subject to interpretation. One impoundment definition is to define the “level pool”, that is, the area defined by extending the Great Dam crest elevation (22.53’) to where the bottom of the river is 22.53 feet. Based on this definition, the impoundment would extend approximately 31,000 feet upstream, to approximately where the Boston and Maine railroad bridge crosses the Exeter River. In comparison, the bathymetric data indicated the natural high point on the bottom of the river between Great Dam and the Court Street Bridge is located approximately 1,000 feet downstream of the Lary Lane well (or 8,500 feet upstream of Great Dam). This location is confirmed from hydraulic modeling of the dam removal condition as river flow speed abruptly increases at this location.

Hydraulic analysis of river flows, produced by storms of various magnitudes, indicate the impoundment limits extend upstream of the Court Street bridge during high flows. The complete discussion on impoundment limits is included in Section 6.

Great Dam Modification Costs

Estimated construction costs for the three dam modification options and the dam removal evaluation were prepared. These costs are summarized in the following table. A complete cost break-down and cost preparation assumptions are presented in Section 7.

	Concept 1 1' Crest Gate 8' x 16' Tainter Gate	Concept 2 3' Crest Gate 8' x 8' Crest Gate	Concept 3 Labyrinth Weir 8' x 8' Crest Gate	Complete Dam Removal
TOTAL	**$ 1,005,000**	**$ 1,125,000**	**$ 1,430,000**	**$ 850,000**

RECOMMENDATIONS

Activities conducted for the Phase I Exeter River Study indicate that the Great Dam has a significant impact on water quantity issues, and, to a lesser degree, water quality issues, on the Exeter River. Significant modifications are needed to the Great Dam to satisfy NHDES rules that require Class A dams constructed prior to February 19, 1981 to be able to pass the 50-year flood event with at least one foot of freeboard remaining between the water surface and the top of the dam abutments. We recommend the Exeter River Study committee review the proposed dam modification options and solicit comment from local interest groups, Exeter Mill Apartments, NHDES-Watershed Bureau, NHDES-Wetlands Bureau, NHFGD and the U.S. Army Corps of Engineers. We also recommend the Town attorney review the report to determine the legal implications of proposed dam modifications on existing water right agreements. Based on feedback from local stakeholders and regulatory agencies, the most appropriate dam modification concept will need to be identified and a plan developed to design, fund and construct the selected dam modification concept.

SECTION 3

GREAT DAM INSPECTION

On September 6, 2006, senior structural engineer David Skidgel of Wright-Pierce conducted a visual structural inspection of the Great Dam. This inspection was purely structural in nature and did not include any hydraulic or mechanical considerations. This section presents a summary of his observations and recommendations. This inspection was coordinated to coincide with an underwater inspection of the dam. Exeter had contracted separately for an underwater inspection that was not part of this study. To facilitate these inspections, Exeter Department of Public Works staff had lowered the impoundment level in advance to approximately 8 inches below the crest of the dam. Pictures of the Great Dam taken during the inspection are included in Appendix D.

3.1 SUMMARY OF EXISTING DAM STRUCTURE

The dam is a concrete gravity retaining wall structure located on the Exeter River. It is believed the present dam was constructed around 1914. Existing design or construction drawings of the original dam are not known to exist.

The main spillway runs across the river in a north-south direction and is located just to the west of the High Street Bridge, which is known locally as the Great Bridge. The dam turns approximately 45 degrees to the northwest at the north end and frames into a concrete penstock structure and sluice gate structure containing a low-level gate. The low-level gate is used to discharge water from the impoundment area to downstream of the dam. A fish ladder is located on the west side of the river and its upstream end is located on the south end of the dam.

The upstream spillway face is a parabolic surface and the downstream face is a flat vertical surface. There is an 18-inch wide by 15-inch deep concrete cap above the dam spillway. It is believed the cap was installed in the late 1960's to replace flash pins and flash boards. It appears that when the cap was installed, the portion of the dam directly adjacent to the penstock gate structure was covered with the same thickness of concrete.

3.2 SUMMARY OF OBSERVATIONS

Due to the fact that there was water on both sides of the dam, the dam could only be observed from the concrete cap atop the dam spillway. Key observations include the following:

- The water level was about 8 inches from the top of the cap on the upstream face and about 7-8 feet from the top of the cap on the downstream face.
- A majority of the concrete cap was covered with mud and vegetation.
- A portion of the downstream spillway face of the dam was covered with mud but very little vegetation.
- It appeared the upper portion of the upstream face of the dam was covered with vegetation.

- The top surface of the north end of the dam adjacent to the penstock structure was covered with mud and vegetation.
- The top surfaces of the concrete cap and the north end of the dam adjacent to the penstock structure were very rough and it appeared that there was moderate exposed aggregate. Overall, the concrete in these areas appeared to be solid.
- The downstream spillway face of the dam was fairly smooth with little exposed aggregate. There appeared to be a series of horizontal cracks running most of the length of the dam. The cracks were not continuous. There was one vertical crack running through the dam and concrete cap about 12 feet from the fish ladder. It is not known if the crack is actually a construction joint. Overall, the concrete appeared to be very solid.
- An assessment of the upstream face of the dam could not be made. However, based on observations of the video taken from the diver and his accompanying commentary, it appears the concrete below the water surface is in good condition. The diver noted that it appeared that the concrete surface had been lined with a cementitious material and some of it was peeling. He also noted a few minor cracks in the concrete surface.
- There is a small section of the dam that extends to the south of the fish ladder. The dam is capped by a 3’-6” wide by 5’-0” deep concrete wall. The downstream spillway face of this portion of the dam is in very poor condition with severe exposed aggregate.
- The concrete penstock gate structure appeared to be in good condition. A portion of the east end overflow wall into the impoundment area is severely spalled.

3.3 RECOMMENDATIONS

Overall, the dam and associated concrete structures appeared to be in good condition. No deficiencies that require immediate repair were observed. However, to ensure the continued long-term use of the dam, the following repairs are recommended:

- The surface of the concrete cap and the north end of the dam should be thoroughly cleaned with a high pressure water blast to remove mud, vegetation and loose concrete and coated with a cementitious overlay.
- The cracks on the downstream face of the spillway should be thoroughly clean, routed and injected with an epoxy resin.
- The spalls in the east end overflow wall of the penstock gate structure should be repaired with concrete patching material.
- The surface of south end downstream face of the spillway should be thoroughly cleaned with a high pressure water blast to remove mud, vegetation and loose concrete and rebuilt with concrete. Unlike the other areas that will most likely only require a thin overlay, this area may require a thicker cementitious (or concrete) overlay to rebuild the surface.

Please note that the above-mentioned observations and recommendations were based on a limited visual inspection, especially given the fact that a lot of the concrete surfaces were covered with mud and vegetation. The most thorough means of inspecting the dam would be to lower the water level on both sides of the dam, thoroughly clean the surfaces with a high pressure water blast and inspect it concurrently. Please note that when a high pressure water blast is applied to a debris-covered concrete surface, it may reveal deficiencies that were not previously apparent.

SECTION 4

BATHYMETRIC SURVEY OF GREAT DAM IMPOUNDMENT

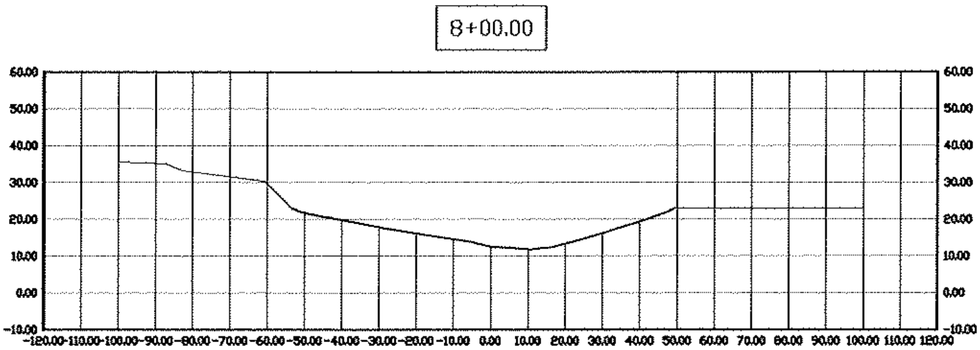
During 2005 Exeter River activities, it became apparent that the resolution of the Exeter and Little River bathymetric data obtained from the FEMA hydraulic model was insufficient to resolve project-specific needs. Therefore, a high resolution bathymetric survey on the Great Dam impoundment was conducted this past summer. This survey was performed to provide more detailed information on the channel bathymetry and volume of the Great Dam impoundment. This survey obtained bathymetric data from the general vicinity of the Great Dam to the upstream limits of the impoundment in the vicinity of the Court Street Bridge over the Exeter River.

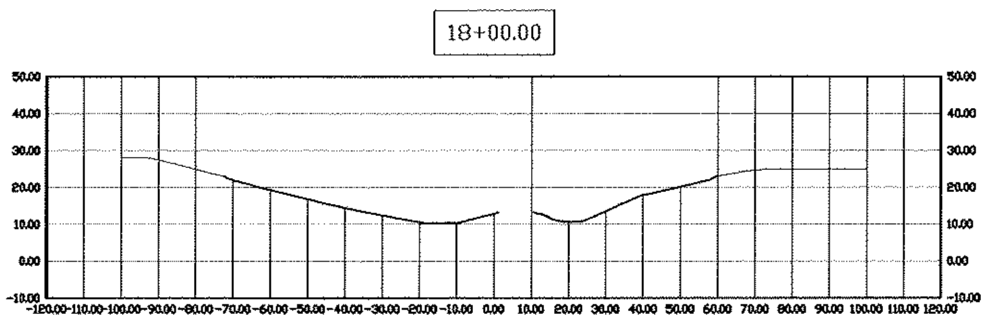
The intended use of the bathymetric data is to provide information for the development of a revised hydraulic model suitable for evaluating the effects of dam operations during periods of normal flow. Flood plain topography, needed to model flood events, was obtained from Digital Elevation Model (DEM) data produced by the United States Geological Survey (USGS).

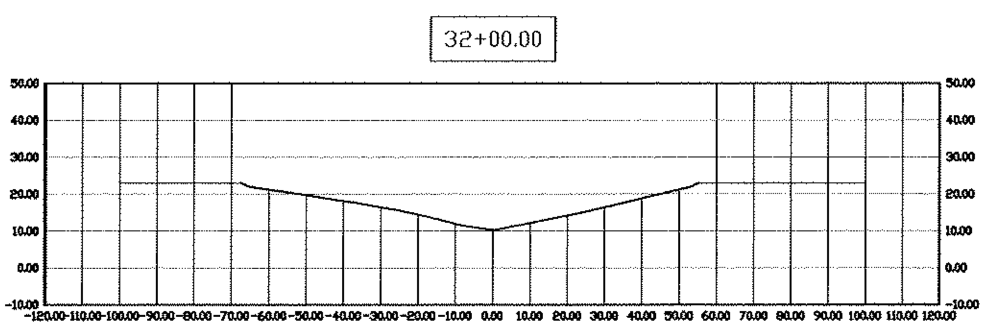
The bathymetric survey was performed over several days during the week of July 17, 2006 using a boat-mounted sonar for depth and Trimble Pro-XH GPS equipment for mapping the location of more than 4,000 depth readings. Exeter DPW staff and equipment assisted in this effort. Bathymetric data was collected on the Exeter River from the Great Dam to the Court Street Bridge. More than 4,400 depths were recorded during three traverses of the river. Data was collected in a repeated crisscrossing pattern to map the greatest amounts of variances in the river bottom. Due to its shallow depth and heavy weeds, bathymetric data on the Little River could only be obtained from its confluence with the Exeter River to a point approximately 100 yards downstream of where the Little River goes underneath Court Street.

The survey data was referenced to a common vertical datum (NGVD 1929) to allow integration of existing USGS topographic data and Digital Elevation Model (DEM) data. State of the art Leica 1202 precision GPS equipment was used to determine river water surface elevation at the time of the bathymetric survey. Water elevation was a steady 23.0 feet to 23.2 feet during the survey. Examples of river cross-sections developed from the bathymetric survey are included as Figures 1 through 4 in this section. Figure 5 depicts the locations of the river cross-sections.

Also included, as Figure 6, is a stage/storage curve developed from the bathymetric survey for the Great Dam impoundment. This curve depicts the volume of water in the Great Dam impoundment at different water levels. When the water level is at the crest of the dam, (22.53 feet), there is approximately 76 million gallons of water in the impoundment. The bottom of the existing water intake at the Exeter River pump station is located at approximately 15.0 feet. The impoundment surface needs to be at least 16.0 feet for the water to flow by gravity into a wet well. At 16.0 feet, the impoundment holds approximately 14 million gallons. Therefore, the "usable" storage for water supply purposes is the difference in these volumes, or approximately 62 million gallons. The usable storage volume calculated for this study, 62 million gallons, compares favorably to an April 2003 Aquarion Water Company study's volume of 63 million gallons.







EXETER RIVER CROSS-SECTIONS

PROJ NO: 10613B	Wright-Pierce	FIGURE: 1
DATE: DEC. 2006		
SCALE: 1"=50'		

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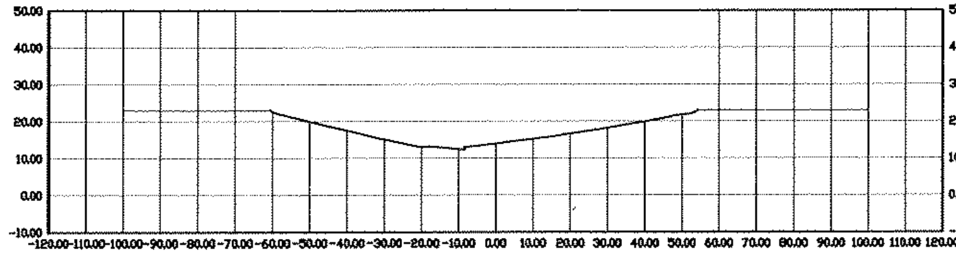

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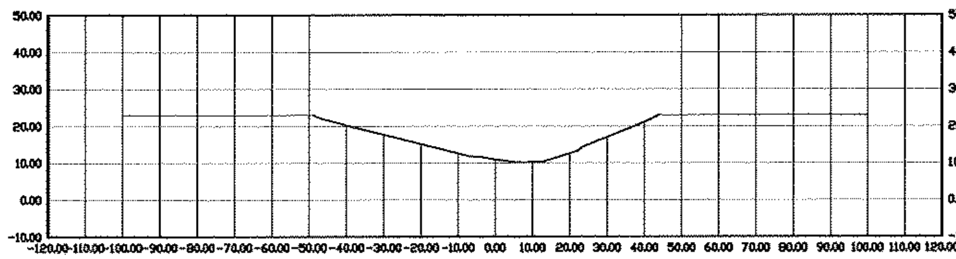

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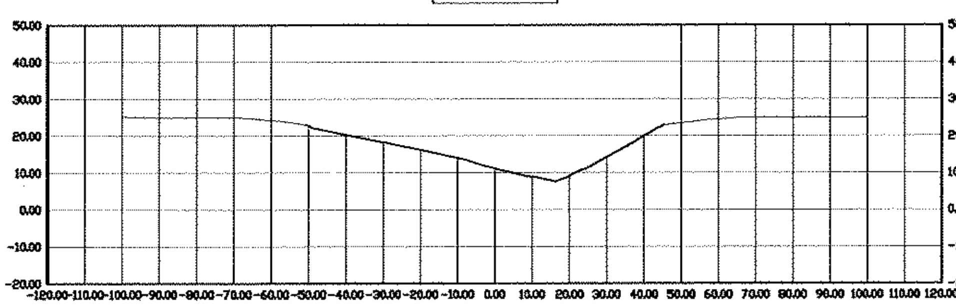

EXETER RIVER CROSS-SECTIONS

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DATE:	DEC. 2006		
SCALE:	1"=50'		

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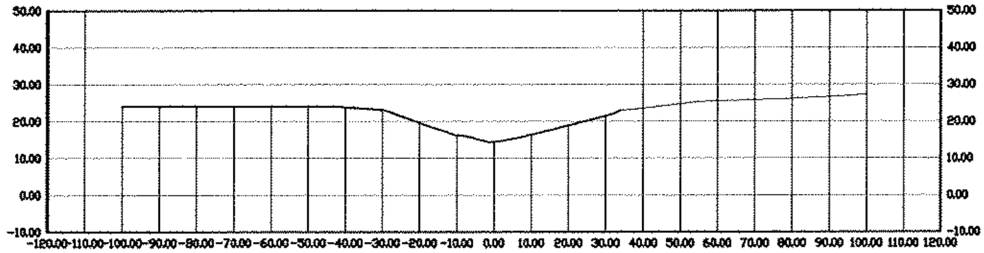

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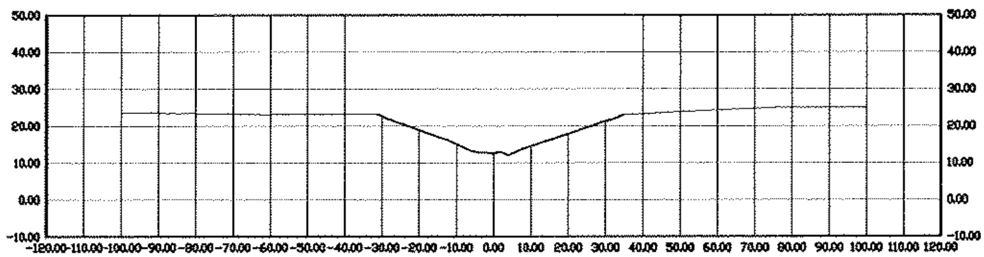

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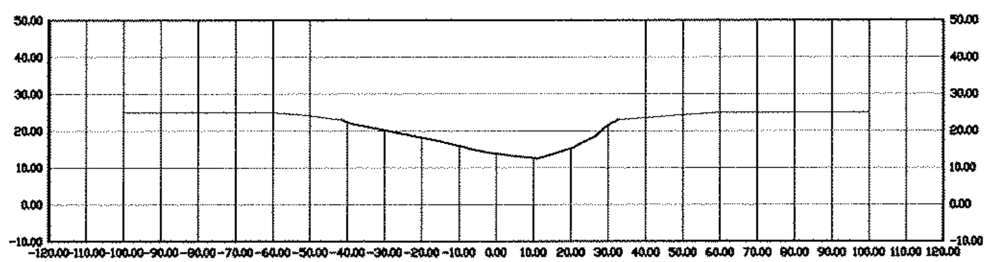


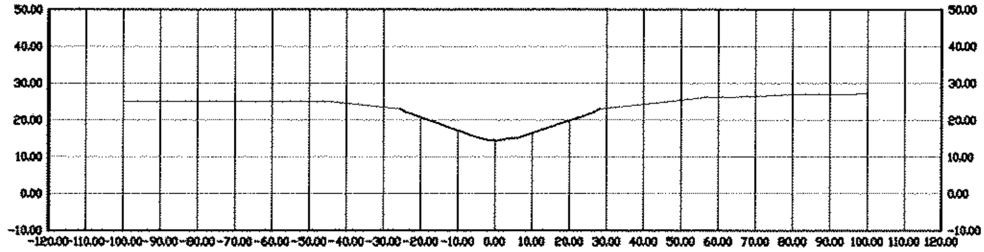
EXETER RIVER CROSS-SECTIONS

PROJ NO:	10613B
DATE:	DEC. 2006
SCALE:	1"=50'

Wright–Pierce

FIGURE: 3

146+00.00



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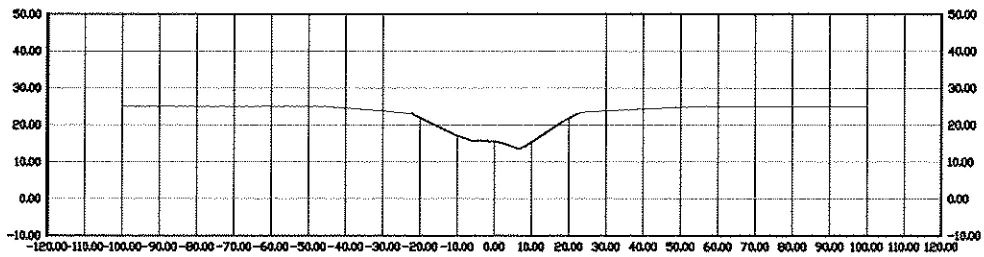

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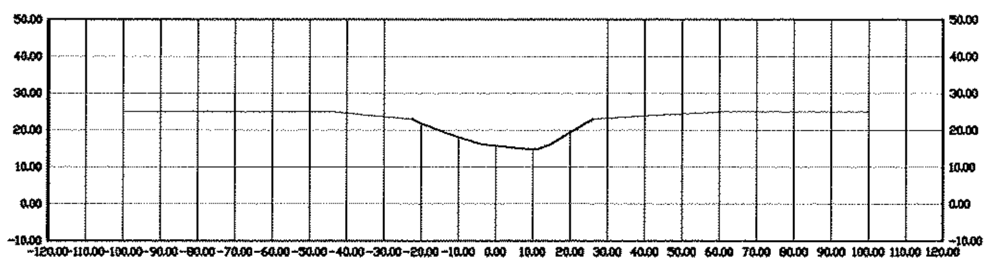


EXETER RIVER CROSS-SECTIONS

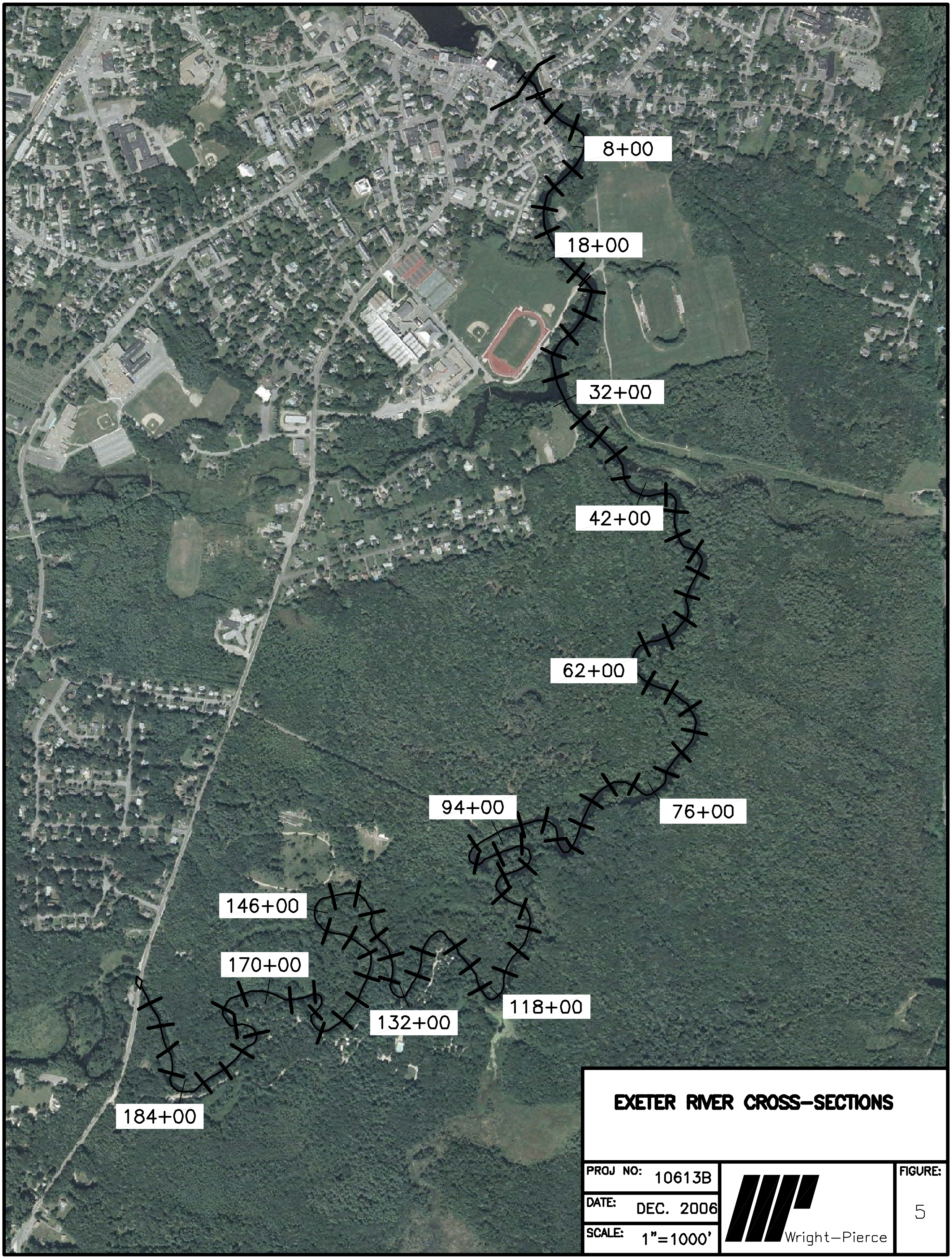
PROJ NO: 10613B

DATE: DEC. 2006

SCALE: 1"=50'

Wright-Pierce

FIGURE: 4



EXETER RIVER CROSS-SECTIONS

PROJ NO:	10613B	Wright-Pierce	FIGURE: 5
DATE:	DEC. 2006		
SCALE:	1"=1000'		

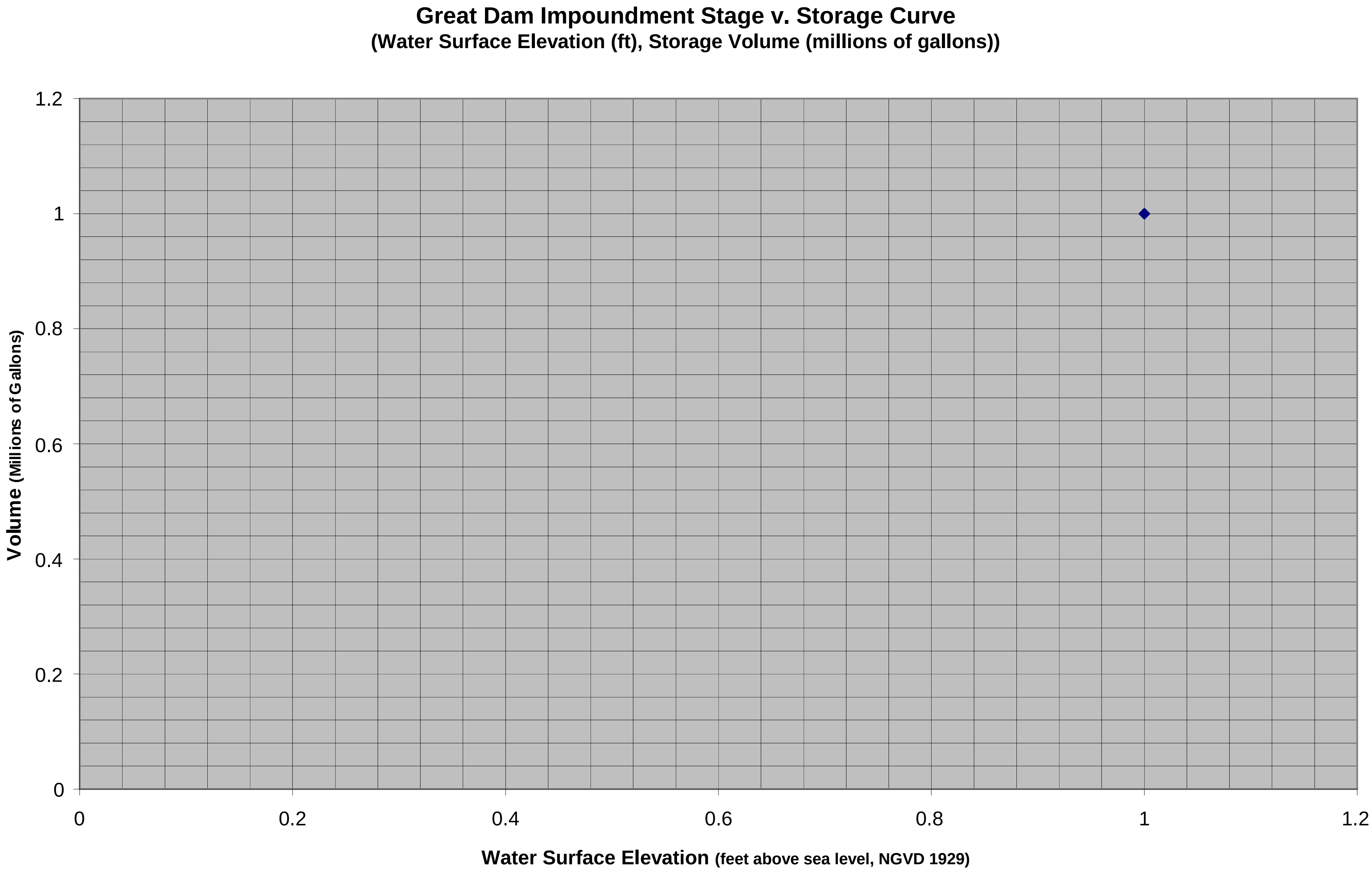

Great Dam Impoundment Stage v. Storage Curve
(Water Surface Elevation (ft), Storage Volume (millions of gallons))
Volume (Millions of Gallons)
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
Water Surface Elevation (feet above sea level, NGVD 1929)

FIGURE 6

SECTION 5

FISH PASSAGE EVALUATION

Impacts to the existing Great Dam fish passage facility from proposed dam modifications was identified as a constraint at the initiation of the 2006 project work. At the time, it was assumed that a potential method to increase spillway capacity might include permanently lowering the crest of the Great Dam. Through discussions with the New Hampshire Fish & Game Department (NHFGD), it was determined that permanently lowering the Great Dam spillway crest by less than one foot might still provide for effective upstream fish passage, but that lowering of the dam by more than one foot would require substantial modification/reconstruction of the fishpass. Based on this factor and the potential loss of water storage in the Great Dam impoundment associated with permanent lowering of the dam, the three conceptual alternatives, evaluated as part of the 2006 project work, were developed with the goal of maintaining the current normal impoundment level of approximately 22.53 feet. Discussions of specific factors relevant to fish passage at Great Dam are discussed below.

Evaluation 1 is not relevant here as it evaluates removal of the Great Dam fishpass. Similarly, Evaluation 2 is not relevant here as it evaluates removal of the Great Dam.

5.1 CONCEPT 1

Modifications to the spillway as part of this alternative would provide for automated lowering of the effective spillway elevation by approximately one foot. While lowering the normal impoundment by this amount (and opening the larger low-level outlet) would not overtly affect fishpass performance, coordination with NHFGD regarding operational regimes is recommended. In particular, the increased low-level outlet capacity associated with this alternative could increase the potential for drawdowns of the impoundment water levels to a point where the fishpass would not function properly. Ideally, automated flashboard and low-level outlet systems would be operated to optimize the performance of the fishpass for upstream passage. In addition, the tainter gate could be used to enhance downstream fish passage at Great Dam during periods of downstream migration of target fish species.

5.2 CONCEPT 2

Modifications to the spillway as part of this alternative would provide for automated lowering of the effective spillway elevation by approximately three feet. At normal flows, the fishpass would be inoperable with the spillway elevation lowered by this amount. Similarly, potential effects associated with operation of the larger low-level outlet would also require consideration. Coordination with NHFGD is, therefore, recommended regarding operational regimes for this alternative. As with Concept 1, the increased low-level outlet capacity associated with this alternative could also increase the potential for drawdowns of the impoundment water levels to a point where the fishpass would not function properly. Ideally, automated flashboard and low-level outlet systems would be operated to optimize the performance of the fishpass for upstream passage. In addition, the sluice gate could be used to enhance downstream fish passage at Great Dam during periods of downstream migration of target fish species.

5.3 CONCEPT 3

The proposed labyrinth weir would preserve the existing spillway elevation, and, therefore, would not alter fishpass performance during normal flows. Furthermore, the ability of the labyrinth weir to moderate upstream water surface elevations within a smaller range over a greater range of flows would likely result in more consistent flows through the fishpass. Potential effects associated with operation of the larger low-level outlet would also require consideration.

Coordination with NHFGD is, therefore, recommended regarding operational regimes for this alternative. As with Concept 1, the increased low-level outlet capacity associated with this alternative could increase the potential for drawdowns of the impoundment water levels to a point where the fishpass would not function properly. Ideally, low-level outlet systems would be operated to optimize the performance of the fishpass for upstream passage. In addition, the discharge gate could be used to enhance downstream fish passage at Great Dam during periods of downstream migration of target fish species.

SECTION 6

GREAT DAM MODIFICATION CONCEPTS

1.0 Conceptual Alternatives

The following is a discussion of three conceptual approaches to increase the spillway, or discharge capacity of Great Dam on the Exeter River, in Exeter, New Hampshire. Also included are evaluations related to the dam, namely, impacts associated with complete dam removal and an estimate of how much discharge capacity was lost following the construction of the fish passage in the late 1960's.

The purpose of the conceptual alternatives evaluation is to provide general guidance on potential feasible means to achieve spillway capacity requirements as set forth by the New Hampshire Department of Environmental Services (NHDES). NHDES requires that the Great Dam be able to pass the 50-year flood with at least one foot of freeboard at the dam abutments. The concepts presented here were developed with sufficient detail to be suitable to prepare preliminary cost estimates.

During a meeting on October 19, 2006, the Exeter River Study Committee asked that the following criteria be used to develop the conceptual alternatives:

Criterion A: Complete dam removal is not acceptable.

Criterion B: Existing normal impoundment volume will not change.

Criterion C: Achieving regulatory spillway capacity for the 50-year, and possibly the 100-year, return-interval hydrologic events.

Criterion D: Not adversely affect existing water quality in the Great Dam impoundment through increased detention time.

Criterion E: Discharge gates are to be automated. To satisfy NHDES discharge requirements, discharge provided by manually operated gates cannot be used in capacity calculations. DPW staff will determine when to operate gate, but the labor will be mechanized.

Criterion F: Maintain or improve the performance of the Great Dam fishpass.

This part of the analysis focused on means to achieve the required spillway capacity (Criterion C) while also substantially satisfying the remaining criteria. Detailed bathymetric data for the Exeter River obtained as part of this study was used for the detailed analysis.

The following means were evaluated to increase spillway capacity at Great Dam:

- Lowering of the spillway crest,
- Increased abutment heights and extents (i.e., wingwalls),
- Increased low-level outlet capacity, and
- Installation of a labyrinth weir.

The conceptual alternatives presented here address the above-listed means both individually and combined, with the goal of providing preliminary information on the merits of these approaches.

A preliminary analysis was performed to evaluate the feasibility of extending the Great Dam spillway into Founders Park adjacent to the right abutment of the dam. This was determined to be unfeasible as it would require a spillway length of over twice that of the existing dam.

Concept 1: Removal of the One-foot Cap from the Spillway Crest, Installation of Automated Flashboards (one foot crest gate) and Larger Low-Level Discharge Gate

Relevant features of this conceptual alternative include:

- Removal of the 1-foot cap from the spillway and installation of automated flashboards (crest gate).
- Increasing the height of the left abutment by 1.3 feet so it is the same elevation as the right abutment.
- Increasing the low-level outlet dimensions and installation of an automated tainter gate.

The purpose of this conceptual alternative is to evaluate potential benefits associated with increased low-level outlet capacity while minimizing changes to normal water levels in the upstream impoundment. This alternative could substantially increase the ability to control water levels in the Great Dam impoundment during flows produced by relatively frequent precipitation events.

The preliminary analysis evaluated a revised low-level outlet geometry comprised of an opening 8 feet high and 16 feet wide with the invert set at an elevation of 18 feet on the project vertical datum. The size of the opening would need to be re-evaluated as part of a final design based on 1) hydraulic characteristics of a selected low-level outlet gate structure, and 2) the potential for reduced spillway capacity associated with automated flashboards. Due to the relatively large size of the evaluated low-level outlet structure, a tainter gate is proposed as an appropriate means to control low-level outlets for this conceptual alternative.

Concept 2: Removal of 3 feet from the Spillway and Automated Flashboards

Relevant features of this conceptual alternative include:

- Removal of 3 feet along the entire spillway crest and installation of automated flashboards (crest gate).
- Increasing the height of the left abutment by 1.3 feet so it is the same elevation as the right abutment.
- Increasing the low-level outlet dimensions and installation of an automated sluice gate.

The purpose of this conceptual alternative is to evaluate potential benefits associated with reducing the spillway crest elevation and increasing the height of the left abutment to the elevation of the right abutment. Preliminary analyses indicate that removal of approximately 3 feet from the top of the spillway and increasing the height of the left abutment would result in the 50-year flood being contained within the abutments.

The preliminary analysis evaluated a revised low-level outlet geometry comprised of an opening 8 feet high and 8 feet wide with the invert set at an elevation of 15 feet on the project vertical datum. The size of the opening would need to be re-evaluated as part of a final design based on 1) hydraulic characteristics of a selected low-level outlet gate structure, and 2) the potential for reduced spillway capacity associated with automated flashboards. Based on the size of the proposed low-level outlet, a sluice gate is proposed for this conceptual alternative.

Concept 3: Alternative Approaches to Increase Spillway Capacity at Great Dam

Alternative approaches were preliminarily evaluated to increase the spillway capacity of Great Dam, including:

- Extending the spillway into Founders Park adjacent to the existing right abutment.
- An emergency spillway in Founders Park.
- A labyrinth weir structure on the existing spillway footprint.

Preliminary analyses indicate that there is not adequate space in Founders Park to provide sufficient spillway capacity using a spillway with hydraulic characteristics similar to the existing Great Dam spillway. This constraint precludes achieving regulatory spillway requirements by extending the spillway or creating an emergency spillway in Founders Park.

A conceptual design of a labyrinth weir with the crest set at the existing spillway elevation (22.53 feet on project datum) was developed to achieve the regulatory spillway capacity. This conceptual design is comprised of a five-cycle labyrinth weir situated between the right abutment and the existing fishpass, and is shown in Figure 2. Implementation of this conceptual approach would likely require removal of existing spillway to its foundation. Based on the size of the proposed low-level outlet, a sluice gate is proposed for this conceptual alternative.

Relevant features of this conceptual alternative include:

- Construction of a five-cycle labyrinth weir with cycle widths of 16 feet and a streamwise length of approximately 13 feet.
- Increasing the height of the left abutment by 1.3 feet so it is the same elevation as the right abutment.
- Increasing the low-level outlet dimensions and installation of an automated sluice gate mechanism.

Evaluation 1: Estimate Discharge Capacity of Great Dam Prior to the Construction of the Great Dam Fishpass.

The discharge capacity of Great Dam was evaluated for conditions intended to replicate spillway conditions prior to the construction of the existing fishpass and the addition of a one-foot high cap on the dam spillway. Limited information was available regarding the extents of the spillway prior to the construction of the fishpass. The length of the spillway prior to the installation of the fishpass was determined for this study as the distance between the existing outlet works on the right abutment of the dam and the existing masonry retaining wall adjacent to the left abutment of the dam. This distance was determined to be approximately 100 feet, which represents an increase in overall spillway length of approximately 20 feet, or 25 percent, from the existing spillway length of approximately 80 feet.

Evaluation 2: Great Dam Removal

Removal of Great Dam is considered as a reference for comparing costs associated with the conceptual designs presented above and to provide information on upstream flood water elevations without the influence of Great Dam. Removal of the dam would alleviate the need to address spillway capacity and eliminate the ability to manipulate upstream water levels under all conditions. Reversion of the upstream reach of the river to natural riverine (non-impoundment) conditions would largely eliminate water quality issues associated with the prevailing lacustrine conditions in the impoundment. However, this would preclude the use of the river as a drinking water supply source. Assuming that removal of Great Dam would include removal of the weir immediately upstream of the existing fishpass entrance; dam removal would eliminate the need for fish passage at the dam site.

Direct costs associated with removal of Great Dam may include the following:

- Removal of Great Dam, including spillway and abutments.
- Removal of the existing fishpass.
- Removal of the fishpass weir adjacent to the fishpass entrance.

A variety of indirect costs are also associated with removal of Great Dam, including those related to:

- Recreational use of the impoundment.
- Loss of drinking water supply storage in the Great Dam impoundment.
- Loss of water supply for fire suppression at the adjacent mill complex.
- Loss of cooling water rights to adjacent mill complex.
- Loss of waterfront to abutters on river.
- Impacts to recreation uses of the river.
- Socio-economic and cultural (historical) factors.

1.1 2006 Hydraulic Model

The three conceptual alternatives and two evaluation scenarios were evaluated using a hydraulic model (2006 model) developed with the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS). The area modeled extends from immediately downstream of the Great Dam to a point upstream where Court Street (State Route 108) Bridge crosses over the Exeter River. The weir adjacent to the Great Dam fishpass entrance was not incorporated into this model.

The 2006 model geometry was developed using cross-section and channel alignment information obtained from a bathymetric survey performed as part of the project work in 2006 during a period of typical mid-summer flow, and was augmented using digital elevation model (DEM) topographic data developed by the U.S. Geological Survey. The DEM data was used to extend the model floodplain into the approximate bounds of the Exeter River floodway (i.e., areas of hydraulic conveyance), but did not include the entire floodplain of the Exeter River.

This bathymetric and topographic data increased the resolution of the 2006 model relative to the hydraulic model used for the 2005 project work (2005 model), which was developed using data obtained from HEC-2 input files used in the development of the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for the Exeter River. In particular, the 2006 model included approximately twice as many channel cross-sections as the 2005 model and increased resolution of the meandering form of the primary channel of the Exeter River between the Court Street Bridge and the confluence of the Exeter and Little Rivers.

1.1.1 Hydrologic Parameters for 2006 Model

Hydrologic parameters for the 2006 model were obtained from the 2005 project work, where available (i.e., 10, 50, and 100-year flows), from a review of 15-minute hydrograph data from the period of record for the United States Geological Survey (USGS) stream gaging station on the Exeter River near Brentwood, New Hampshire (USGS No 01073587) (i.e., “1-Year”), and based on assumed values (i.e., “Summer”). This information is presented in Table 1.

The “One-Year” flow is intended to be representative typical storm events on the Exeter River, and was determined from peak flows associated with storm hydrographs at the USGS station. The “Summer” flow was used to provide quantitative information on the limit of the Great Dam backwater during typical summer flows on the Exeter River.

Table 1: Hydrologic Parameters

Profile	Q (cfs)
Summer	50
1-Year	1000
10-Year	2900
50-Year	4416
100-Year	4949

1.2 Hydraulic Analysis Results

Hydraulic analyses were performed to evaluate hydraulic capacity of the Great Dam spillway, hydraulic control at the Great Bridge (High Street Bridge), and backwater effects within the study reach. Analyzed conditions included the existing dam geometry, the three conceptual alternatives, and the two evaluation scenarios.

1.2.1 Great Dam Spillway Capacity

Spillway capacity was evaluated for the existing conditions (“Existing”), conceptual alternatives (“Concepts” 1, 2 and 3), and geometry of Great Dam prior to the installation of the Great Dam fishpass (“Evaluation 1”). Evaluation 2 was not evaluated for spillway capacity as this alternative is based on removal of Great Dam, and is addressed in this study only to provide a basis for comparison of the other evaluated alternatives.

The basis of this analysis was to evaluate spillway capacity for a 50-year hydrologic event, as currently required by the New Hampshire Department of Environmental Services. Other flow conditions are also presented here, including the 100-year hydrologic event, to provide information on spillway performance over a range of flow conditions.

This analysis was performed with the existing low-level outlet in the closed position for the Existing and Evaluation 2 scenarios, as these gates are manually operated. Operational structures (e.g., moveable flashboards, gate-systems) associated with Concepts 1, 2 and 3 were assumed to be automated, and were, therefore, evaluated in the "open" position.

Spillway coefficients were kept consistent for all of the analyses to provide a relative baseline for the evaluation of spillway capacity. Refinement of the spillway and gated-structure coefficients would be required as part of further design work based on selected appurtenances (e.g., moveable flashboards and gate systems).

The results of the spillway capacity analysis are presented in Table 2 and in the following subsections. Water surface profiles along the project reach are shown in Figure Set A in Appendix F of this report.

1.2.1.1 Existing conditions

The evaluation of the existing spillway geometry ("Existing") confirms prior analyses indicating that the Great Dam has inadequate spillway capacity for the 50-year hydrologic event. As previously noted, this analysis assumed that the existing low-level outlet was closed.

1.2.1.2 Concept 1

The evaluation of the proposed Concept 1 spillway and automated low-level outlet capacity indicates that this alternative has the potential to achieve regulatory spillway requirements for passage of the 50-year hydrologic event. While the specific geometry evaluated here has slightly less than the required one-foot of freeboard (0.77 feet), relatively minor modifications to the basic design presented here should be sufficient to achieve the required freeboard. This design would pass the 100-year hydrologic events without overtopping of the dam abutments.

A tainter gate was used to model the low-level outlet incorporated into this alternative due to the relatively large size of the gate (8 feet tall x 16 feet wide).

Table 2: Great Dam Spillway Capacity Analysis

Plan	Profile	River Sta.	Q Total (cfs)	W.S. Elev (ft)	Energy Grade Line Elev. (ft)	Q Weir (cfs)	Q Gates (cfs)
Typical Summer Flow							
Existing	Summer	140.4855	50	22.88	22.88	50	*closed*
Concept 1	Summer	140.4855	50	21.88	21.88	50	*closed*
Concept 2	Summer	140.4855	50	19.88	19.88	50	*closed*
Concept 3	Summer	140.4855	50	22.73	22.73	50	*closed*
Evaluation 1	Summer	140.4855	50	21.83	21.83	50	*closed*
Evaluation 2	Summer	188.4948	50	14.56	14.83	-	-
One-Year Storm Event							
Existing	1-Year	140.4855	1000	25.08	25.10	1000	*closed*
Concept 1	1-Year	140.4855	1000	24.07	24.10	1000	*closed*
Concept 2	1-Year	140.4855	1000	22.04	22.10	1000	*closed*
Concept 3	1-Year	140.4855	1000	23.96	23.99	1000	*closed*
Evaluation 1	1-Year	140.4855	1000	23.73	23.76	1000	*closed*
Evaluation 2	1-Year	188.4948	1000	16.35	17.18	-	-
Ten-Year Storm Event							
Existing	10-Year	140.4855	2900	27.48	27.58	2900	*closed*
Concept 1	10-Year	140.4855	2900	24.92	25.10	1640	1260
Concept 2	10-Year	140.4855	2900	23.97	24.21	2343	557
Concept 3	10-Year	140.4855	2900	24.99	25.16	2314	587
Evaluation 1	10-Year	140.4855	2900	25.93	26.07	2900	*closed*
Evaluation 2	10-Year	188.4948	2900	18.05	19.68	-	-
Fifty-Year Storm Event							
Existing	50-Year	140.4855	4416	28.66	28.83	4416	*closed*
Concept 1	50-Year	140.4855	4416	26.33	26.61	2780	1636
Concept 2	50-Year	140.4855	4416	25.49	25.84	3791	625
Concept 3	50-Year	140.4855	4416	25.74	26.08	3776	640
Evaluation 1	50-Year	140.4855	4416	27.28	27.50	4416	*closed*
Evaluation 2	50-Year	188.4948	4416	19.15	21.23	-	-
One-Hundred Year Storm Event							
Existing	100-Year	140.4855	4949	29.02	29.20	4949	*closed*
Concept 1	100-Year	140.4855	4949	26.87	27.18	3269	1680
Concept 2	100-Year	140.4855	4949	25.84	26.24	4292	657
Concept 3	100-Year	140.4855	4949	26.00	26.39	4298	651
Evaluation 1	100-Year	140.4855	4949	27.67	27.93	4949	*closed*
Evaluation 2	100-Year	188.4948	4949	19.52	21.71	-	-

1.2.1.3 Concept 2

The evaluation of the proposed Concept 2 spillway and automated low-level outlet capacity indicates that this alternative can achieve regulatory spillway requirements for passage of the 50 and 100-year hydrologic events with freeboard in excess of one-foot.

A sluice gate (6 feet tall x 8 feet wide) was used to model the low-level outlet incorporated into this alternative.

1.2.1.4 Concept 3

The evaluation of the proposed Concept 3 spillway and automated low-level outlet capacity indicates that this alternative can achieve regulatory spillway requirements for passage of the 50 and 100-year hydrologic events with freeboard in excess of one-foot. The evaluation of the labyrinth weir capacity was performed using a spreadsheet program. Due to limitations with the HEC-RAS model, the labyrinth weir spillway rating curve could not be directly applied to the evaluation of the spillway over a range of flows in the 2006 model. The approach used here to circumvent this limitation was to adjust the spillway coefficient for this scenario in the HEC-RAS model to achieve spillway performance similar to that determined from the spreadsheet analysis for the 50-year hydrologic event. This approach likely results in underestimating spillway capacity at lower flows and overestimating spillway capacity at higher flows. It should, therefore, be assumed that the predicted upstream water level for the 100-year hydrologic event is higher than presented here due to interference of flows over the labyrinth weir.

A sluice gate (6 feet tall x 8 feet wide) was used to model the low-level outlet incorporated into this alternative.

1.2.1.5 Evaluation 1

Evaluation 1 was performed to evaluate spillway capacity at Great Dam prior to the installation of the fishpass and one-foot high cap along the spillway crest, and assumed that the existing low-level outlet was closed. The evaluation of Alternative 1 indicates that it had inadequate spillway capacity for the 50-year hydrologic event and that overtopping of the dam abutments would occur during this event. Refinement of this analysis may be appropriate if it is determined that the profile of the dam conformed to a true “ogee” profile prior to the installation of the one-foot high cap, as this profile might warrant the use of a spillway coefficient greater than 3.0 used here, thereby increasing the calculated spillway capacity.

1.2.2 Great Bridge

Hydraulic affects of the Great Bridge (High Street Bridge) immediately upstream from Great Dam were analyzed using the 2006 model. The purpose of this analysis was to evaluate impacts on water surface elevations in the Exeter River associated with the presence of the bridge.

Hydraulic impacts associated with the Great Bridge can be attributed to two primary factors, including:

1) the geometry of the bridge opening relative to the adjacent channel of the Exeter River, and
2) encroachments on the adjacent floodplains associated with the approach embankments to the bridge and adjacent structures.

The bridge geometry for this analysis was obtained from the topographic survey of the Great Dam and adjacent areas performed as part of the 2005 project work. For this analysis the low-chord of the bridge was set as the bottom of the concrete arch, and did not include the existing water main that is suspended below the bridge. Encroachments on the adjacent floodplains were determined from field observations and a review of aerial photographs. For this case, it was assumed that adjacent structures (i.e., buildings), preclude flow on the across the adjacent floodplains at high flows.

Table 3 presents the results of the hydraulic analysis for Great Bridge. Results are presented for the 1, 10, 50, and 100-year hydrologic events. Lower flow events (e.g., "Summer" scenario) are not presented here as the hydraulic restriction imposed by the bridge diminishes substantially at lower flows. Information presented in Table 3 includes the total flow in the river ("Q Total"), water surface elevations upstream and downstream from the bridge ("US WSEL" and "DS WSEL", respectively), and the difference in these water surface elevations ("Diff. WSEL"). This difference can be interpreted as the magnitude of the hydraulic restriction imposed by the bridge and adjacent floodplain encroachments.

Table 3: Great Bridge Hydraulic Analysis

Scenario	Profile	Q Total (cfs)	US WSEL (ft)	DS WSEL (ft)	Diff. WSEL (ft)
One-Year Storm Event					
Existing	1-Year	1000	25.17	25.08	0.09
Concept 1	1-Year	1000	24.20	24.08	0.12
Concept 2	1-Year	1000	22.43	22.09	0.34
Concept 3	1-Year	1000	24.10	23.97	0.13
Evaluation 1	1-Year	1000	23.88	23.74	0.14
Evaluation 2	1-Year	1000	21.31	18.36	2.95
Ten-Year Storm Event					
Existing	10-Year	2900	27.95	27.47	0.48
Concept 1	10-Year	2900	25.79	24.95	0.84
Concept 2	10-Year	2900	25.22	24.04	1.18
Concept 3	10-Year	2900	25.83	25.01	0.82
Evaluation 1	10-Year	2900	26.54	25.93	0.61
Evaluation 2	10-Year	2900	24.78	20.82	3.96
Fifty-Year Storm Event					
Existing	50-Year	4416	29.79	28.63	1.16
Concept 1	50-Year	4416	27.68	26.31	1.37
Concept 2	50-Year	4416	27.26	25.50	1.76
Concept 3	50-Year	4416	27.37	25.75	1.62
Evaluation 1	50-Year	4416	28.42	27.26	1.16
Evaluation 2	50-Year	4416	26.95	21.98	4.97

One Hundred-Year Storm Event

Scenario	Profile	Q Total (cfs)	US WSEL (ft)	DS WSEL (ft)	Diff. WSEL (ft)
Existing	100-Year	4949	30.44	28.97	1.47
Concept 1	100-Year	4949	28.36	26.85	1.51
Concept 2	100-Year	4949	27.87	25.83	2.04
Concept 3	100-Year	4949	27.94	26.00	1.94
Evaluation 1	100-Year	4949	29.09	27.64	1.45
Evaluation 2	100-Year	4949	27.67	22.29	5.38

Water surface profiles in the vicinity of the Great Bridge are shown in Figure Set B in Appendix F of this report.

The results of this analysis indicate that the hydraulic restriction imposed by the Great Bridge and adjacent floodplain encroachments increases with increasing flows and with decreasing downstream water surface elevations. The former condition is evident in that the hydraulic restriction increases with increasing flows for each of the six evaluated scenarios. Similarly, the latter condition is evident in the results for the Evaluation 2 (Great Dam removed) scenario, which has a substantially lower downstream water surface elevation and greater hydraulic restriction relative to the other scenarios.

The overall magnitude of the hydraulic restriction imposed by Great Bridge and adjacent floodplain encroachments is substantial. For example, the results of this analysis indicate that the hydraulic restriction increases upstream water levels during the 50 and 100-year hydrologic events by between one and two feet for the evaluated scenarios (except the Evaluation 2 scenario).

1.2.3 Backwater between Great Dam and Court Street Bridge

A quantitative backwater analysis was performed using the 2006 model to determine changes in backwater conditions associated with the evaluated scenarios and varying operational conditions. Information presented here includes: 1) a high-flow backwater analysis and, 2) an analysis of backwater conditions during periods of low-flow subject to operation of the low-level outlet.

1.2.3.1 High-Flow Backwater Analysis

The high-flow analysis evaluated conditions associated with the five hydrologic conditions presented in Section 1.1.1 but is primarily intended to address conditions associate with the 10, 50, and 100-year flows. The purpose of this analysis was to evaluate flood water elevations upstream of the Great Dam associated with the six evaluated scenarios. The Evaluation 2 scenario evaluation provides a baseline for the comparison of effects associated with the other evaluated scenarios, including existing conditions.

Assumptions incorporated into this analysis include:

a) Moveable spillway flashboard systems associated with Concepts 1 and 2 are in the open (down) position, i.e., flowing condition.

b) The low-level outlet is in the closed position for the existing conditions scenario ("Existing") and the evaluation of spillway capacity prior to the installation of the Great Dam fishpass ("Evaluation 1"). This assumption is consistent with the manual operation associated with the existing low-level outlet.

c) Low-level outlets are open for Concepts 1, 2 and 3, as these are assumed to be automated operational systems.

The results of the high-flow backwater analysis are presented Table 4 and include data obtained from the 2006 model at the following locations:

- Between Great Dam and Great Bridge ("Great Dam").
- At the confluence of the Exeter and Little Rivers ("Little River").
- At the confluence of the Exeter River and Great Brook ("Great Brook").
- At the upstream limit of the study reach, located downstream from the Court Street Bridge over the Exeter River ("Court Street").

An explanation of Table 4 for the 50-year storm event for the "Existing Conditions" scenario is as follows: The "profile" indicates the particular storm event interval. The "Q Total" shows the volume of water flowing in the river for that storm event. The "WSEL" indicates the Water Surface Elevation at Great Dam in the dam's present condition. The "Difference in WSEL" shows the difference in water surface elevations between the two locations indicated. The "Energy Grade Line" is a hydraulics engineering term that represents the combined elevation energy and kinetic energy of the river over a unit distance. At very low river velocities, the slope of the energy grade line is very close to the slope of the river's water surface.

The comparison of the evaluated scenarios indicates that the backwater imposed by Great Dam extends upstream beyond the study limit immediately downstream of Court Street Bridge, but that the magnitude of the backwater diminishes substantially as flows increase. For example, the differences in water surface elevations at the upstream limit of the study reach for the existing dam relative to the dam removal (Evaluation 2) scenario for the 50 and 100-year hydrologic events are approximately 1.25 feet. The differences in water surface elevations between the existing and dam removal (Evaluation 2) scenarios likely diminishes substantially upstream of Court Street due to the restriction imposed by Court Street Bridge and its adjacent approach embankments.

Water surface profiles along the upper section of the project reach between the confluence of Great Brook and Court Street are shown in Figure Set C in Appendix F of this report.

Table 4: High Flow Backwater Analysis

Scenario	Profile	Q Total (cfs)	WSEL (ft) Great Dam	WSEL (ft) Little River	WSEL (ft) Great Brook	WSEL (ft) Below Court Street	Difference in WSEL (ft) Little River to Great Dam	Difference in WSEL (ft) Great Brook to Little River	Difference in WSEL (ft) Court Street to Great Brook	Energy Grade Line Slope (ft/ft) Little River	Energy Grade Line Slope (ft/ft) Great Brook	Energy Grade Line Slope (ft/ft) Court Street
Typical Summer Flow												
Existing	Summer	50	22.88	22.88	22.89	22.90	0.00	0.01	0.01	0.000001	0.000001	0.000005
Concept 1	Summer	50	21.88	21.88	21.89	21.93	0.00	0.01	0.04	0.000001	0.000002	0.000012
Concept 2	Summer	50	19.88	19.89	19.93	20.08	0.01	0.04	0.15	0.000007	0.000005	0.000054
Concept 3	Summer	50	22.73	22.73	22.74	22.76	0.00	0.01	0.02	0.000001	0.000001	0.000006
Evaluation 1	Summer	50	21.83	21.83	21.84	21.88	0.00	0.01	0.04	0.000001	0.000002	0.000012
Evaluation 2	Summer	50	14.56	17.37	17.77	18.80	2.81	0.40	1.03	0.029750	0.000022	0.000259
One-Year Storm Event												
Existing	1-Year	1000	25.08	25.30	25.65	26.66	0.22	0.35	1.01	0.000074	0.000059	0.000175
Concept 1	1-Year	1000	24.07	24.40	24.96	26.32	0.33	0.56	1.36	0.000123	0.000088	0.000257
Concept 2	1-Year	1000	22.04	22.87	24.06	25.95	0.83	1.19	1.89	0.000410	0.000161	0.000298
Concept 3	1-Year	1000	23.96	24.30	24.89	26.29	0.34	0.59	1.40	0.000130	0.000092	0.000266
Evaluation 1	1-Year	1000	23.73	24.10	24.76	26.22	0.37	0.66	1.46	0.000148	0.000101	0.000255
Evaluation 2	1-Year	1000	16.35	22.09	23.93	25.91	5.74	1.84	1.98	0.021192	0.000177	0.000306
Ten-Year Storm Event												
Existing	10-Year	2900	27.48	28.32	28.75	29.21	0.84	0.43	0.46	0.000233	0.000033	0.000146
Concept 1	10-Year	2900	24.92	26.57	27.56	28.58	1.65	0.99	1.02	0.000672	0.000069	0.000235
Concept 2	10-Year	2900	23.97	26.17	27.35	28.51	2.20	1.18	1.16	0.001042	0.000079	0.000248
Concept 3	10-Year	2900	24.99	26.57	27.55	28.58	1.58	0.98	1.03	0.000652	0.000069	0.000235
Evaluation 1	10-Year	2900	25.93	27.12	27.88	28.71	1.19	0.76	0.83	0.000427	0.000055	0.000212
Evaluation 2	10-Year	2900	18.05	25.88	27.21	28.48	7.83	1.33	1.27	0.017199	0.000087	0.000256

Fifty-Year Storm Event

Scenario	Profile	Q Total (cfs)	WSEL (ft)				Difference in WSEL (ft)			Energy Grade Line Slope (ft/ft)		
			Great Dam	Little River	Great Brook	Below Court Street	Little River to Great Dam	Great Brook to Little River	Court Street to Great Brook	Little River	Great Brook	Court Street
Existing	50-Year	4416	28.66	30.27	30.69	31.00	1.61	0.42	0.31	0.000360	0.000031	0.000111
Concept 1	50-Year	4416	26.33	28.54	29.36	30.00	2.21	0.82	0.64	0.000841	0.000055	0.000197
Concept 2	50-Year	4416	25.49	28.24	29.16	29.88	2.75	0.92	0.72	0.001155	0.000061	0.000213
Concept 3	50-Year	4416	25.74	28.32	29.22	29.91	2.58	0.90	0.69	0.001073	0.000060	0.000209
Evaluation 1	50-Year	4416	27.28	29.12	29.77	30.28	1.84	0.65	0.51	0.000581	0.000048	0.000167
Evaluation 2	50-Year	4416	19.15	28.02	29.04	29.81	8.87	1.02	0.77	0.015965	0.000066	0.000224

One-Hundred Year Storm Event

Existing	100-Year	4949	29.02	30.94	31.34	31.62	1.92	0.40	0.28	0.000403	0.000029	0.000101
Concept 1	100-Year	4949	26.87	29.24	29.99	30.54	2.37	0.75	0.55	0.000850	0.000053	0.000179
Concept 2	100-Year	4949	25.84	28.88	29.74	30.37	3.04	0.86	0.63	0.001250	0.000060	0.000198
Concept 3	100-Year	4949	26.00	28.92	29.78	30.39	2.92	0.86	0.61	0.001208	0.000059	0.000195
Evaluation 1	100-Year	4949	27.67	29.81	30.42	30.85	2.14	0.61	0.43	0.000633	0.000044	0.000150
Evaluation 2	100-Year	4949	19.52	28.73	29.65	30.31	9.21	0.92	0.66	0.015504	0.000063	0.000205

1.2.3.2 Low-Flow Backwater Analysis with Operation of Low-Level Outlet

The low-flow analysis evaluated conditions associated with the "One-Year" flow (1,000 cfs) and operation of the low-level outlet. The purpose of this analysis was to evaluate water levels upstream of the Great Dam associated with the six evaluated scenarios and to provide information relevant to the ability of the low-level outlet structures to regulate upstream water levels for each of the evaluated scenarios.

Assumptions incorporated into this analysis include:

a) Moveable spillway flashboard systems associated with Concepts 1 and 2 are in the open (down) position.
b) Low-level outlets are evaluated in both open and closed positions for existing conditions scenario ("Existing"), Concepts 1, 2 and 3, and for conditions at the dam prior to the installation of the fishpass (Evaluation 1). Evaluation 2 is not considered here as there is not a low-level outlet associated with this alternative.

The results of the low-flow backwater analysis with low-level outlet operation are presented Table 5, and include data obtained from the 2006 model at the following locations:

- Between Great Dam and Great Bridge ("Great Dam").
- At the confluence of the Exeter and Little Rivers ("Little River").
- At the confluence of the Exeter River and Great Brook ("Great Brook").
- At the upstream limit of the study reach, located downstream from the Court Street Bridge over the Exeter River ("Court Street").

Table 5: Backwater Analysis with Low-Level Outlet Operations (Flow of 1,000 cfs)

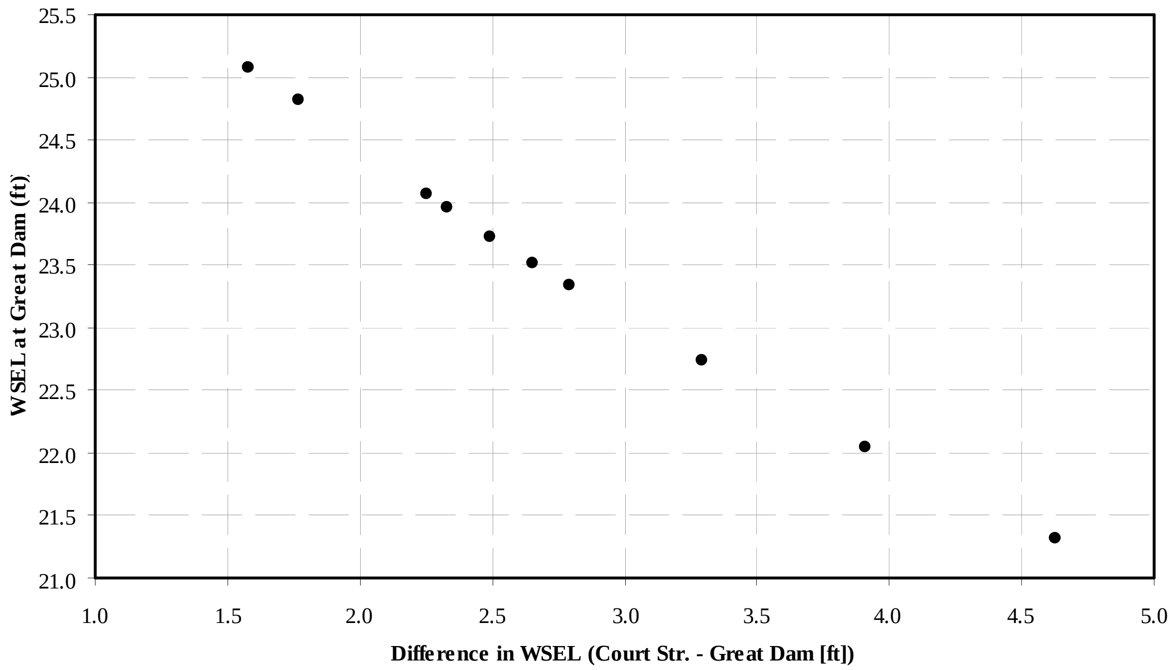
Scenario	Gate Status	WSEL (ft)				Difference in WSEL (ft)			
		Great Dam	Little River	Great Brook	Court Street	Great Dam	Little River	Great Brook	Court Street
Existing	*Closed*	25.08	25.3	25.65	26.66				
	Open	24.82	25.06	25.46	26.59	0.26	0.24	0.19	0.07
Concept 1	*Closed*	24.07	24.4	24.96	26.32				
	Open	22.74	23.33	24.29	26.03	1.33	1.07	0.67	0.29
Concept 2	*Closed*	22.04	22.87	24.06	25.95				
	Open	21.32	22.5	24.07	25.95	0.72	0.37	-0.01	0
Concept 3	*Closed*	23.96	24.3	24.89	26.29				
	Open	23.34	23.79	24.56	26.13	0.62	0.51	0.33	0.16
Evaluation 1	*Closed*	23.73	24.1	24.76	26.22				
	Open	23.52	23.94	24.65	26.17	0.21	0.16	0.11	0.05

Water surface profiles developed with this data are shown in Figure Set D in Appendix F of this report.

The results of this analysis indicate that the ability to manipulate water level in the Great Dam impoundment using the low-level outlet at the Great Dam under steady-state conditions is limited. Although this analysis is subject to constraints associated with a steady-state analysis, such as the inability to model a preemptive drawdown of the impoundment, the results of the steady-state analysis indicate that benefits of drawing down the impoundment are likely minimal in the upstream segment of the project reach. This condition is apparent in a comparison of water levels immediately upstream from Great Dam ("Great Dam") and at the upstream limit of the study reach downstream from Court Street ("Court Street"). While the difference between the minimum and maximum values in Table 5 for Great Dam is 3.76 feet, difference between the minimum and maximum values in Table 5 for Court Street is 0.71. Figure 7 is a plot of differences in water surface elevations between Court Street and Great Dam and water surface elevations at Great Dam. The inverse relation shown here indicates that as water levels decrease at Great Dam, the difference in water surface elevations between Court Street and the dam increase.

For example, during a typical flow, the water surface elevation at Great Dam is 23.0. From Figure 7 below, this corresponds to a difference in water elevations between Court and Great Dam of about 3.0 feet, so the Exeter River at Court Street would be at elevation 26.0 (23+3). At a much higher flow, the elevation at Great Dam would be 25.0 feet. From Figure 7, the water elevation at Court Street would only be 1.5 higher, or 26.5 feet. Conversely, at very low flows (Great Dam elevation at 21.5, one foot below crest), the corresponding water elevation at Court Street would be 4.5 feet higher, or 26.0 feet. The increased difference in water surface elevations between Court Street and Great Dam, as water levels decrease at Great Dam, again indicates that benefits associated with preemptive drawdowns of the Great Dam impoundment are likely minimal.

Figure 7: Water Surface Elevations - Court Street and Great Dam



1.3 Impoundment Limit

The upstream limit of the Great Dam backwater varies with the flow in the Exeter River. In addition, the definition of the backwater limit is subject to interpretation. The bathymetric data obtained as part of this study indicated that the elevation of the Great Dam spillway is higher than the bottom of the river channel within the study reach. Based on this criterion, impounded water at the elevation of the spillway, or "level pool", would extend upstream through the entire study reach. The extent of the level pool backwater extending upstream beyond the study limits can be determined from Profile 44P in the FEMA FIS at the point where the bottom of the channel is above the spillway elevation of 22.53 feet, and is approximately 31,000 feet upstream from the dam where the Boston and Maine railroad bridge crosses the Exeter River. By comparison, the bathymetric data indicates that a natural high point on the bottom of the Exeter River between Great Dam and Court Street Bridge resulted in an impoundment that extended approximately 8,500 feet upstream. The results of the dam removal (Evaluation 2) scenario for the "Summer" conditions (50 cfs) confirm the latter condition, as flow speeds abruptly increase at this location.

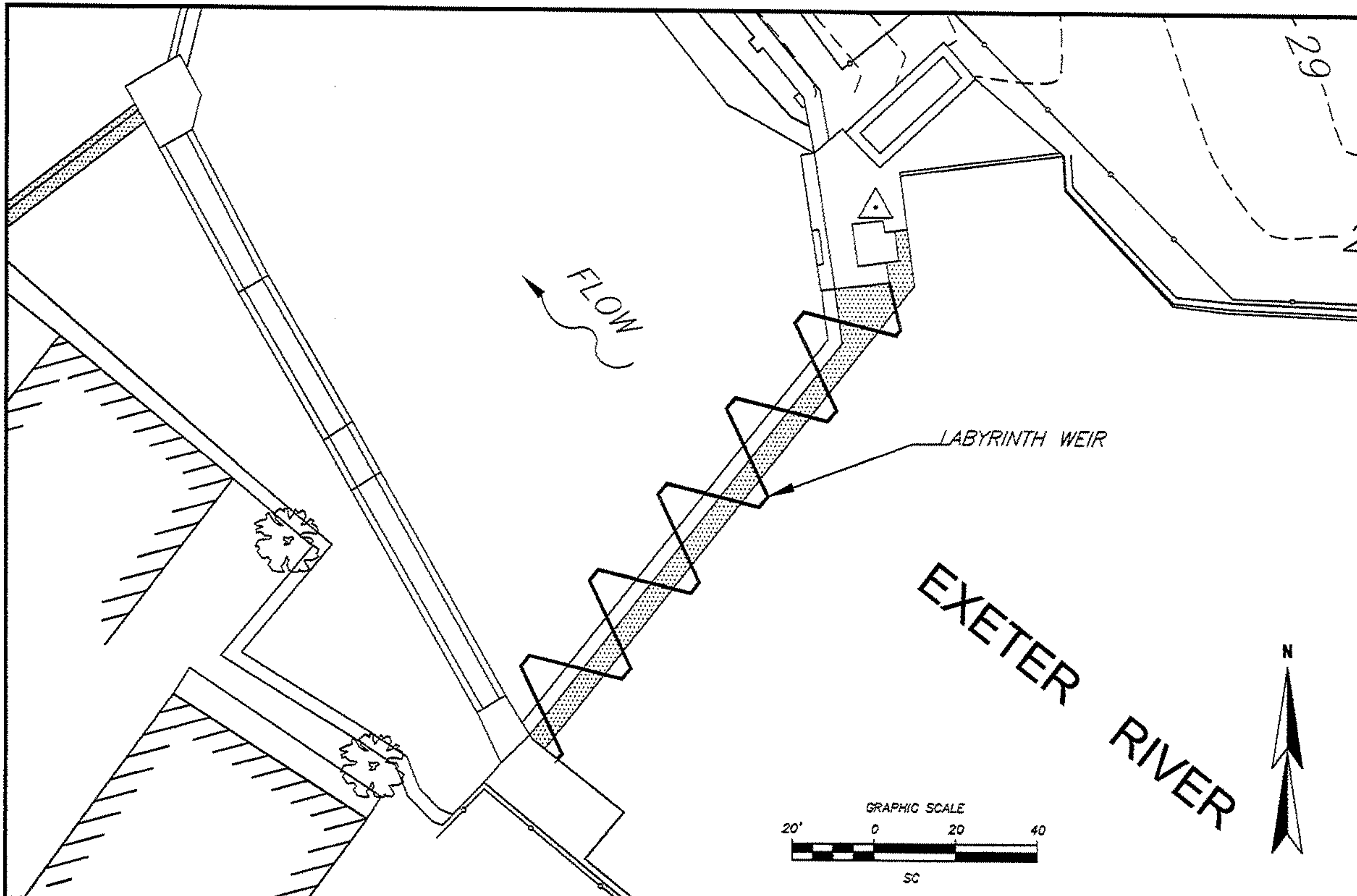
The backwater definition presented above does not account for relevant factors associated with flowing water; however, it does account for hydraulic control within the river channel. For example, the difference in calculated water surface elevations at the Great Dam for existing conditions, and for the Evaluation 2 scenario for the "Summer" conditions, is approximately 7 feet, while the difference at the upstream limit of the study reach is approximately 4 feet. This difference almost entirely results from channel control for the Evaluation 2, as the calculated water surface elevation for this scenario increases by almost 3 feet moving upstream between the two locations. At flows of 250, 500 and 1,000 cfs, the difference in calculated water surface elevations between these two scenarios at the upstream limit of the study decreases to approximately 2, 1.7, and 0.7 feet, respectively. Based on this analysis, it is apparent that the Great Dam backwater extends upstream beyond the study limit and upstream from the Court Street Bridge over the Exeter River.

1.4 Potential Downstream Impacts from Increased Discharge Capacity of Great Dam

The primary objective of the evaluated concepts is to provide spillway capacity in accordance with requirements established by NHDES. The evaluated concepts would not substantially affect the volume of flow passing the dam for a given event, but peak flows passing the dam could change. While this was not quantitatively evaluated as part of this study, a number of factors suggest that substantial increases in peak flows are likely minimal, with a single potential exception. Factors that would tend to minimize the potential for substantially-increased peak flows include attenuation of water levels upstream of the dam by storage in the Exeter River floodplain and partial hydraulic control exerted by the Great Dam Bridge. The potential exception noted above is that abrupt opening of the larger low-level outlets could result in substantial increases in peak flows. Because the proposed low-level outlet capacity is considered in the dam's overall spillway capacity, it is assumed that these gates would already be open during a high-flow event and, therefore, would not have the ability to surcharge the overall flow during periods of high flow.

Great Dam modification Concepts 1, 2 and 3 will all significantly increase the discharge capacity of Great Dam during storm events. These modifications, however, will not change the volume of water flowing over the dam during high flows. The modifications will allow flood waters to pass while keeping at least one foot of freeboard below the dam abutments. Flood waters on the existing dam frequently overtop dam abutments. Therefore, these modifications will make the dam safer by making it much less prone to abutment erosion and potential failure, but not increase over-all dam discharge.

Because the volume of water flowing over the dam will not change significantly from its pre and post-modified state, the downstream affects of increasing the discharge capacity will be negligible.



PREPARED BY: WOODLOT ALTERNATIVES, INC. ENVIRONMENTAL CONSULTANTS	DESIGN:	DATE: November 2006	SHEET TITLE: CONCEPTUAL ALTERNATIVE 3 LABYRINTH WEIR	FIGURE: 8
	DRAFT:	PROJ. NO.: 105071	PROJECT: EXETER RIVER STUDY	
	CHECKED:	SCALE: 1"=20'		
	FILE:			

SECTION 7

GREAT DAM MODIFICATION CONSTRUCTION COSTS

Estimated material and labor costs were developed for the three dam modification concepts and the dam removal evaluation. Key assumptions used in developing these costs for the modified dam concepts include the following:

- A detailed structural analysis of Great Dam, that includes destructive and non-destructive testing, will be required to evaluate its post-modified stability and to determine whether it would meet present structural codes. This evaluation may indicate the need for additional rehabilitation or strengthening of the dam. No construction costs are included if additional rehabilitation or strengthening of the dam is required.
- The costs of studies required to obtain federal and state permits were not included as the scope of permitting requirements cannot be determined until preliminary plans of the selected option are prepared.
- Construction can be accomplished in 6 months during one construction season after the spring fish migration (July to December). Bids would need to be opened by February 1 to provide lead time to manufacture discharge gates.
- Costs associated with keeping the penstock reservoir full for Exeter Mills apartment fire suppression and/or flowing for Exeter Mills air conditioning system during dam construction activities will be minimal.
- Costs summarized in the following tables are based on a December, 2006 ENR index of 7887.62.
- Assuming an inflation rate of 2.5%, construction costs for this project are expected to increase approximately $25, 000 each year the project is delayed.

TABLE 6

ESTIMATED CONSTRUCTION COSTS FOR DAM MODIFICATIONS

	Concept 1 1' Crest Gate 8'x16' Tainter Gate	Concept 2 3' Crest Gate 8'x8' Crest Gate	Concept 3 Labyrinth Weir 8'x8' Crest Gate
Mobilize	$ 15,000	$ 15,000	$ 15,000
Safety Cable and Nets	$ 10,000	$ 10,000	$ 10,000
Coffers Dams	$ 20,000	$ 45,000	$ 60,000
Remove Low Level Gate	$ 35,000	$35,000	$ 35,000
Construct Area for new Low Level Gate & N.E. Abutment	$ 35,000	$ 35,000	$ 35,000
New Low Level Gate	$130,000	$ 30,000	$ 30,000
Water Level Indicator	$20,000	$25,000	$25,000
Install Low Level Gate	$10,000	$10,000	$10,000
Construct Area for New Crest Gate	$25,000	$40,000	-
Crest Gate and Installation	$ 110,000	$225,000	-
Abutment Extensions / Armoring	$60,000	$ 60,000	$ 60,000
Remove 80 ft of Dam	-	-	$180,000
Construct Labyrinth Weir	-	-	$160,000
Fish Ladder modifications	$5,000	$5,000	$5,000
SCADA and Electrical	$20,000	$20,000	$20,000
Demobilization	$15,000	$15,000	$15,000
Miscellaneous	$10,000	$10,000	$10,000
Sub-Total Cost	$ 520,000	$ 580,000	$ 670,000
Difficulty Factor - 25 %	$130,000	$150,000	(40 %) $270,000
Contractor O/H & profit - 15 %	$100,000	$110,000	$140,000
Total Construction Cost	$ 750,000	$ 840,000	$1,080,000
Engineering Design Cost - 20 %	$ 150,000	$170,000	$220,000
Geotechnical Studies	$30,000	$30,000	$30,000
Construction Administration- 10 %	$ 75,000	$ 85,000	$100,000
TOTAL*	**$ 1,005,000**	**$ 1,125,000**	**$ 1,430,000**

* ENR index of 7887.62

TABLE 6 (CONTINUED)

ESTIMATED CONSTRUCTION COSTS FOR DAM REMOVAL

	DAM AND FISH LADDER REMOVAL
Mobilize	$ 15,000
Coffers Dams and By-Pass	$ 50,000
Demolish 120 ft of Dam	$ 200,000
Demolish Fish Ladder	$ 60,000
Demolish Fish Trap	$10,000
Demolish Lower Weir 115ft	$ 20,000
Excavate Fill in Impoundment	$5,000
Excavate / Restore Abutment Areas	$10,000
River Bed Restoration	$ 30,000
Demobilize	$15,000
Miscellaneous	$10,000
Sub-Total Cost	$ 430,000
Difficulty Factor - 35 %	$150,000
Contractor O/H & profit - 15 %	$ 90,000
Total Construction Cost	$ 670,000
Engineering Design Cost - 15 %	$ 100,000
Construction Admin. - 10 %	$ 70,000
TOTAL*	**$ 850,000**

* ENR index of 7887.62

APPENDIX A

LETTER FROM WRIGHT-PIERCE TO JENNIFER PERRY DATED SEPTEMBER 15, 2005 - REVISED PROPOSAL

Wright-Pierce

September 15, 2005
WP Project No. 10613A

Ms. Jennifer Perry, Town Engineer
Town of Exeter
10 Front Street
Exeter, NH 03833-2792

Subject: Exeter River Study - Engineering Services

Dear Ms. Perry:

Based on your August 31, 2005 letter, this letter serves as our revised proposal to provide the Town of Exeter with engineering services related to flow control improvements on reaches of the Exeter and Little Rivers located in Exeter. It also outlines tasks associated with an initial water quality study on these rivers using existing data and water quality data to be obtained this summer and fall. Based on information provided by the Town, the Exeter River Study public meeting on May 4, and the New Hampshire Department of Environmental Services (NHDES) Dam Bureau public hearing on May 25, we believe this proposal describes activities that are required to address the most immediate needs of the Town and the stakeholders.

As requested, this Phase I work scope is divided into activities to be conducted in 2005 and activities to be conducted in 2006.

With respect to Exeter River concerns, i.e., water quality, water quantity, flow control, fish passage, etc., we understand an engineering evaluation of Great, Colcords Pond and Pickpocket dams is the Town's first priority. The purpose of evaluating the dams will be to determine what structural and operational changes can be made that will minimize the adverse impacts of flooding. This preliminary evaluation will also inform the Town as to how dam operations may affect water quality and water quantity available for fish passage. We are aware that any recommended operational or structural modifications to the dams will need to be compatible with other demands for Exeter River water, such as fish passage and water supply.

The effects of dam modification options on water surface elevations upstream of the dams will be assessed at normal pool elevation (i.e., crest of dam) and for specific return interval hydrologic events using qualitative and quantitative methods. This assessment will provide information for the determination of backwater effects and flooding associated with the current and future dam configurations.

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Website: www.wright-pierce.com

A qualitative assessment of backwater effects is particularly applicable to the assessment of backwater effects at normal pool elevation, and will include visual observations of hydraulic controls along the Exeter River. The results of the qualitative assessment will include a delineation of the normal pool elevation. A quantitative assessment of backwater effects and flood stages will be performed using the one-dimensional HEC-RAS numerical hydraulic model developed by the United States Army Corps of Engineers. We anticipate that the initial model will be developed from the HEC-2 numerical model developed as part of the 1982 Federal Emergency Management Agency flood study for Exeter.

The evaluation of alternative geometries and operating regimes at the Great Dam will include a preliminary assessment of potential effects on fish passage. This assessment will include consultation with the New Hampshire Fish and Game Department (NHFGD) to determine their goals for the restoration of diadromous fisheries and any deficiencies of the existing fishpass at the Great Dam.

In addition, we propose to review existing Exeter River water quality data on file with the Town of Exeter, NHDES, Exeter River Local Advisory Committee (ERLAC) and other applicable sources. The purpose of this review will be to identify water quality data gaps that would otherwise help identify the cause(s) of low dissolved oxygen and other water quality impairments. We also plan to measure temperature and dissolved oxygen at various locations to gain a better understanding of the nature and extent of water quality issues on the Exeter River.

The services to be provided in this proposal include dam evaluation and water quality sampling. These preliminary services are a subset of the general scope of services outlined in our table dated May 24, 2005 (attached). An outline of Phase I-2005 and Phase I -2006 services and their associated costs are as follows. Note: the 2006 Scope and Fees may change depending on the results of the 2005 work and the direction the Town may decide to take.

<u>PHASE I - 2005</u>

<u>Dam Evaluations:</u>

A. Prepare preliminary existing condition plans of Great Dam, Colcords Pond Dam and Pickpocket Dam sufficient to establish critical elevation and dimensional details needed for hydraulic modeling.
   1. Conduct a review of existing plans for these dams. Conduct a preliminary field survey to obtain sufficient data for hydraulic modeling.

B. Conduct a visual inspection (above the waterline) of each dam. This inspection will note the general condition of the dam and describe any observed deficiencies. Review issues noted in any NHDES regulatory actions, e.g., Notice of Violations, Letter of Deficiencies, Administrative Orders, etc. Summarize results and recommendations.

   The Town of Exeter will assist in this effort by lowering the water levels in the dams to the maximum extent possible in the Fall of 2005.

Hydraulic Modeling and Backwater Analysis

C. Conduct qualitative assessment of backwater above Great Dam at normal pool elevation.
   1. Perform a site visit to assess backwater based on visual indicators; include flow speed, observable hydraulic controls and geomorphic characteristics.

Water Quality Sampling Data Analysis

D. Review existing water quality sampling data. Conduct dissolved oxygen and temperature measurements as described below:

   1. Dissolved oxygen will be measured with a manual probe at the following 6 locations every two weeks from late July until the first week in October: 1) Exeter River under Route 108, 2) Little River under 108, 3) Confluence of Exeter and Little Rivers, 4) Exeter River approximately 200 feet upstream of High Street Bridge, 5) Exit of fishpass at Great Dam, and 6) Head-of-tide on the Squamscott River.

      While it is assumed that the water at Locations 1 and 2 will be vertically and laterally well-mixed due to turbulence, three measurements will be taken across the stream channel adjacent to the bridges. Stratified measurements of dissolved oxygen will be taken at one-meter intervals from a small boat at Locations 3 and 4 in the Great Dam impoundment at the locations specified above. Measurements at Location 5 will be taken by manually deploying the probe into the exit (upstream end) of the New Hampshire Fish and Game Department (NHFGD) fishpass at the Great Dam. It is assumed that NHFGD will provide a key for access. Dissolved oxygen measurements will not be made in the pool below the dam due to the likelihood of re-aeration of flows over the dam. Measurements at Location 6 will be obtained at the head-of-tide on the Squamscott River.

   2. Temperature will be measured at fixed positions using datalogging equipment at the following five stations: 1) Exeter River under Route 108, 2) Little River under 108, 3) Confluence of Exeter and Little Rivers, 4) Exeter River approximately 200 feet upstream of High Street Bridge, and 5) In the pool on the Exeter River between the Great Dam and the downstream weir.

      Temperature data at the fixed monitoring stations at Stations 1, 2, and 5 will be obtained using a single temperature datalogger at each location. Vertical arrays comprised of three temperature dataloggers will be deployed at Stations 3 and 4. These arrays will be deployed on weighted lines from the bank to the center of the channel, with the dataloggers spaced along the lines to achieve measurements at the bottom, middle, and top of the water column.

   3. Dissolved oxygen and temperature data will be compiled using NHDES standard QA/QC protocols and submitted in NHDES Environmental Monitoring Database (EMD) format.

Assessment of Relative Funding Opportunities

E. Conduct an assessment of project financing opportunities that are relevant to the development and implementation of anticipated project components.
1. Research relevant state, federal and private funding sources (i.e., grants and low interest loans).
2. Categorize sources by potential project component: dam removal (see also Task J5), fish passage improvements, land acquisition, dam improvements, etc.
3. Summarize results.

Dam Modification Hydraulic Modeling

F. Develop numerical hydraulic model of the Exeter River in Exeter, NH.
1. Obtain 1982 FEMA HEC-2 model in electronic format.
2 Develop HEC-RAS model from 1982 FEMA HEC-2 model.
3. Review peak flows used in 1982 FEMA HEC-2 model. This work will include a statistical analysis of data obtained from United Stages Geological Survey Station No. 01073587 on the Exeter River and the application of revised regional peak flow regression equations.
4. Assess hydraulic adequacy of the existing Great Dam geometry and operational regime for the 1, 10, 50, and 100-year return interval hydrologic events.
5. Develop flow-duration curves during target fish species migration periods

Meeting

G. Meet with Exeter River Study Committee and other stakeholder groups to provide updates to the status and results of activities. Two appropriately timed meetings are planned for Phase I - 2005.

Investigate Automated Water Level Equipment

H. 1. Evaluate the feasibility and cost of installing automated water level monitoring equipment for the Great Dam, Colcord's Pond Dam, and the Pickpocket Dam

Hydraulic Analysis of Low Level Gate

I. 1. Conduct a hydraulic evaluation of the low level gate and low level gate operations on Great Dam. Conduct an evaluation on the penstock and penstock operations on the Great Dam. These evaluations will determine the existing discharge capacity of the low level gate and penstock, and associated changes in water levels immediately upstream of the dam. Summarize results and recommendations.

We propose to complete our work on a time charge basis. Estimated fees for the above-outlined services are as follows:

Task	Hours	Labor Cost	Expenses	Total Fee
DAM EVALUATIONS				
A. Preliminary Dam Base Plans	100	$8,000	$ 500	**$8,500**
B. Dam Structural Evaluations	56	$6,800	$200	**$7,000**
HYDRAULIC MODELING AND BACKWATER ANALYSIS				
C. Qualitative Backwater Assessment of Great Dam	28	$2,200	$100	**$2,300**
WATER QUALITY SAMPLING DATA ANALYSIS				
D. Existing Water Quality Data Review, Summary & Sampling Plan	115	$9,200	$200	**$9,400**
E. Assessment of Relevant Funding Opportunities				
1. Research funding opportunities	20	1600		$1600
2. Categorize sources	4	$300		$300
3. Report on findings	14	$1,100		$1,100
			TASK E Total	**$3,000**
DAM MODIFICATION HYDRAULIC MODELING - 2005				
F. Dam Modification Hydraulic Modeling				
1. Obtain 1982 FEMA Study	5	$400	$500	$900
2. Develop HEC-RAS Model from FEMA Study	50	$4,100		$4,100
3. Hydrologic Review	13	$1000		$1,000
4. Hydraulic Assessment for Existing Conditions at Great Dam	20	$1,500		$1,500
5. Develop flow duration curves	20	$1,500		$1,500
			TASK F TOTAL	**$9,000**

Task	Hours	Labor Cost	Expenses	Total Fee
MEETINGS - 2005				
G. Meetings with Stakeholder Groups	50	$4,800	$200	**$5,000**
WATER LEVEL EQUIPMENT EVALUATION				
H. Investigate Automated Water Level Equipment	16			**$ 1,500**
I. Conduct Low Level Gate Hydraulic Evaluation and Gate Operations.	45	$4,300		**$4,300**
			PHASE I - 2005 TOTAL	**$ 50,000**

PHASE I - 2006

Dam Modification Hydraulic Modeling (continued)

J. Complete numerical hydraulic model of the Exeter River and Little River in Exeter, NH started in 2005.

6. Assess limit of backwater on the Exeter River for three alternative Great Dam geometries or operational regimes for the 1, 10, 50, and 100-year return interval hydrologic events.
7. Assess limit of backwater on the Little River for existing Colcords Pond Dam geometry and operational regime for the 1, 10, 50, and 100-year return interval hydrologic events.
8. Assess limit of backwater on the Little River for three alternative Colcords Pond Dam geometries or operational regimes for the 1, 10, 50, and 100-year return interval hydrologic events.
9. Assess limit of backwater on the Exeter River for existing Pickpocket Dam geometry and operational regime for the 1, 10, 50, and 100-year return interval hydrologic events.
10. Assess limit of backwater on the Exeter River for three alternative Pickpocket Dam geometries or operational regimes for the 1, 10, 50, and 100-year return interval hydrologic events.
11. Assess potential changes to flood levels in the Exeter River downstream of the Pickpocket Dam without flood storage capacity currently provided by the upstream impoundment (i.e., dam removed). This assessment will be performed for the 1, 10, 50, and 100-year return interval hydrologic events.
12. Reporting of results.

Assess Fish Passage at Great Dam

K. Assess fish passage at the Great Dam

1. Evaluate conceptual fish passage schemes at the Great Dam for three alternative geometries or operational regimes.
2. Consultation with NHFGD.
3. Reporting of results.

MEETINGS - 2006				
Task	**Hours**	**Labor Cost**	**Expenses**	**Total Fee**
L. Meetings with Stakeholder Groups	75	$7,300	$200	**$7,500**
			PHASE I - 2006 TOTAL	**$46,300**

We look forward to working with the Town of Exeter on this important project. If you have any questions, please feel free to call us.

Very truly yours,

WRIGHT-PIERCE

Richard N. Davee, P.E.
Project Manager

James A. Hewitt, P.E.
Project Engineer

JAH/als

Enclosures

APPENDIX B

LETTER FROM WRIGHT-PIERCE TO JENNIFER PERRY DATED JUNE 20, 2006 - REVISED PHASE I 2006 SCOPE OF SERVICES

Wright-Pierce

June 20, 2006
WP Project No. 10613B

Ms. Jennifer Perry, Town Engineer
Town of Exeter
10 Front Street
Exeter, NH 03833-2792

Subject: Exeter River Study - Revised Phase I - 2006 Scope of Services

Dear Ms. Perry:

Based on our recent discussions and comments the Exeter River Study Committee made to the Exeter River Study Interim 2005 Report on April 6, 2006, this letter serves as our revised proposal for Phase I - 2006 Scope of Services. As you recall, the initial Phase I - 2006 Scope of Service was presented in a contract to you dated September 15, 2005 (attached). Based on the results of the Exeter River Study Interim 2005 Report and other considerations, we believe the work tasks as described below will provide information that will better help the Town of Exeter determine how to modify the Great Dam to address regulatory requirements and to reduce flood impacts.

Flooding throughout the Exeter River watershed during and after the weekend of May 13, 2006 was considered in the development of this Scope of Services. This flooding resulted in numerous road closures, including sections of Court Street in the vicinity of the Exeter and Little Rivers, and overtopping of the Great Dam. Information obtained during and after this event could be invaluable in the evaluation of dam modifications. While the USGS stream gaging station on the Exeter River provides a limited data set for the determination of the event magnitude in terms of return interval, a review of data from the USGS stream gaging station on the Lamprey River (USGS No. 01073500) suggests that peak flows may have exceeded the 100-year return-interval event. This information and that obtained from other watersheds in the vicinity of the Exeter River suggest that the Exeter River experienced flows in the range of the 100-year return-interval event. We, therefore, propose to use this information in our ongoing analysis of potential modifications at the Great Dam.

Activities in 2006 will focus on obtaining a bathymetric survey of the Great Dam impoundment and hydraulic modeling of various storm flows through the Great Dam impoundment. The hydraulic modeling will be conducted with the Great Dam in its present condition and also various dam modifications.

The effects of dam modification options on water surface elevations upstream of the Great Dam will be evaluated at normal pool elevation (i.e., crest of dam) and for specific return interval hydrologic events using qualitative and quantitative methods. This assessment will provide

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Website: www.wright-pierce.com

information for the determination of backwater effects and flooding associated with the current and future dam configurations.

A qualitative assessment of backwater effects is particularly applicable to the assessment of backwater effects at normal pool elevation, and will include visual observations of hydraulic controls along the Exeter River. The results of the qualitative assessment will include a delineation of the normal pool elevation. A quantitative assessment of backwater effects and flood stages will be performed using the project HEC-RAS numerical hydraulic model (United States Army Corps of Engineers) developed as part of the 2005 project work.

The evaluation of alternative geometries and operating regimes at the Great Dam will include a preliminary assessment of potential effects on fish passage. This assessment will include consultation with the New Hampshire Fish and Game Department (NHFGD) to determine their goals for the restoration of diadromous fisheries and any deficiencies of the existing fishpass at the Great Dam.

We will also schedule a dewatered visual inspection of Great Dam this summer that could not be conducted in the fall of 2005.

An outline of Phase I -2006 services and their associated costs are as follows.

PHASE I - 2006

Development of Conceptual Modifications to Great Dam

A. Conceptual alternatives to increase the discharge capacity of the Great Dam will be developed. A separate conceptual design for each alternative will be prepared that will pass the 50 year and 100 year flood. Target criteria used in the development of these alternatives will include: 1) achieving regulatory requirements for spillway capacity, 2) providing hydraulic capacity to allow management of impoundment levels during relatively frequent precipitation events, 3) enhancing water quality in the impoundment, and 4) maximizing the performance of the Great Dam fishpass. Alternative selection will be a collaborative effort with the Town of Exeter. Up to three alternatives will be evaluated and may include modifications to the abutments, penstock, dam crest and fish ladder. Estimated construction and engineering costs will be developed for each alternative.

   A preliminary evaluation of the feasibility of removing Great Dam will be will be prepared. This evaluation will summarize the environmental, legal, cultural, recreational, and water supply issues that would be associated with a complete dam removal. An estimated cost, including the costs of feasibility studies, engineering, permitting and demolition costs, will be prepared.

Great Dam Evaluation:

E. Conduct a visual inspection (above the waterline at dewatered conditions) of the Great Dam. This inspection will note the general condition of the dam and describe any observed deficiencies. Review issues noted in any NHDES regulatory actions, e.g., Notice of Violations, Letter of Deficiencies, Administrative Orders, etc. Summarize results and recommendations.

The Town of Exeter will assist in this effort by lowering the water levels in the Great Dam to the crest of the spillway in the late July / early August of 2006. This drawdown will coincide with an underwater inspection of the dam and penstock that the Town of Exeter has arranged with a contractor independent of this work scope.

Final Report

F. Prepare a final report that summarizes the results of activities conducted in 2006 and incorporates these results with the results of the 2005 interim report.

Meetings

G. Meet with Exeter River Study Committee and other stakeholder groups to provide updates to the status and results of activities. Two appropriately timed meetings are planned for Phase I - 2006.

We propose to complete our work on a time charge basis. Estimated fees for the above-outlined services are as follows:

Task	Hours	Labor Cost	Expenses	Total Fee
DEVELOPMENT OF CONCEPTUAL MODIFICATIONS TO GREAT DAM				
A.				
1. Develop Great Dam Modification Alternatives and Preliminary Dam Removal Evaluation	30	$4,600		**$4,600**
2. Consultation with NHDES	8	$1,000		$1,000
3. Develop modification cost estimates	25	$2,200		$2,200
4. Summarize Findings	8	$1,000		$1,000
			Task A Total	**$8,800**

Great Dam Evaluation:

E. Conduct a visual inspection (above the waterline at dewatered conditions) of the Great Dam. This inspection will note the general condition of the dam and describe any observed deficiencies. Review issues noted in any NHDES regulatory actions, e.g., Notice of Violations, Letter of Deficiencies, Administrative Orders, etc. Summarize results and recommendations.

The Town of Exeter will assist in this effort by lowering the water levels in the Great Dam to the crest of the spillway in the late July / early August of 2006. This drawdown will coincide with an underwater inspection of the dam and penstock that the Town of Exeter has arranged with a contractor independent of this work scope.

Final Report

F. Prepare a final report that summarizes the results of activities conducted in 2006 and incorporates these results with the results of the 2005 interim report.

Meetings

G. Meet with Exeter River Study Committee and other stakeholder groups to provide updates to the status and results of activities. Two appropriately timed meetings are planned for Phase I - 2006.

We propose to complete our work on a time charge basis. Estimated fees for the above-outlined services are as follows:

Task	Hours	Labor Cost	Expenses	Total Fee
DEVELOPMENT OF CONCEPTUAL MODIFICATIONS TO GREAT DAM				
A.				
1. Develop Great Dam Modification Alternatives and Preliminary Dam Removal Evaluation	30	$4,600		**$4,600**
2. Consultation with NHDES	8	$1,000		$1,000
3. Develop modification cost estimates	25	$2,200		$2,200
4. Summarize Findings	8	$1,000		$1,000
			Task A Total	**$8,800**

Task	Hours	Labor Cost	Expenses	Total Fee
GREAT DAM IMPOUNDMENT BATHYMETRIC SURVEY				
B. Conduct Bathymetric Survey of Great Dam Impoundment				
1. Conduct bathymetric survey	25	$2,100	$1,500	$3,600
2. Prepare Exeter River contour plan	30	$2,500		$2,500
3. Convert bathymetry data for model input	15	$1,400		$1,400
			Task B Total	**$7,500**
DAM MODIFICATION HYDRAULIC MODELING				
C. Dam Modification Hydraulic Modeling				
1. Update Hydraulic Model	24	$2,600		$2,600
2. Evaluation of Conceptual Modifications	24	$3,300		$3,300
3. Summarize findings	12	$1,600		$1,600
			Task C Total	**$7,500**
FISH PASSAGE EVALUATION				
D. Assess Fish Passage at Great Dam				
1. Assess conceptual fish passage schemes	38	$3,200		$3,200
2. Consultation with NHFGD	20	$1,600		$1,600
3. Summarize findings	26	$2,200		$2,200
			Task D Total	**$7,000**
GREAT DAM EVALUATION				
E. Great Dam Structural Evaluation				
1. Conduct structural inspection and review existing plans	20	$1,900		$1,900
2. Summarize Findings	15	$1,600		$1,600
			Task E Total	**$3,500**

Task	Hours	Labor Cost	Expenses	Total Fee
FINAL REPORT- 2006				
F. Prepare Final Report	40	$3,500		$ 3,500
			Task F Total	**$3,500**
MEETINGS - 2006				
G. Meetings with Stakeholder Groups	28	$3,000		$3,000
			Task G Total	**$3,000**
			PHASE I - 2006 TOTAL	**$40,800**

Schedule

We anticipate the tasks for the Phase I 2006 study will be complete within four months of contract execution. Assuming a July 1, 2006 start date, key task completion milestones are as follows:

- Impoundment Bathymetry - August 1, 2006
- Conceptual Great Dam Modifications and Inspection - September 1, 2006
- Great Dam Modeling and Fish Passage Assessment - October 1, 2006
- Final Report - November 1, 2006

We look forward to working with the Town of Exeter on this important project. If you have any questions, please feel free to call us.

Very truly yours,

WRIGHT-PIERCE

Richard N. Davee, P.E.
Project Manager

James A. Hewitt, P.E.
Project Engineer

JAH/als

Attachment

APPENDIX C

LETTER FROM WRIGHT-PIERCE TO JENNIFER PERRY DATED NOVEMBER 13, 2006 - ADDITIONS TO PHASE I 2006 SCOPE OF SERVICES

Wright-Pierce

November 13, 2006
WP Project No. 10613B

Ms. Jennifer Perry, Town Engineer
Town of Exeter
10 Front Street
Exeter, NH 03833-2792

Subject: Exeter River Study - Additions to Phase I - 2006 Scope of Services

Dear Ms. Perry:

During the status presentation of the Exeter River Study to the Exeter River Study Committee (ERSC) on October 19, 2006, the ERSC requested that Wright-Pierce expand its scope of services to include the evaluation of additional dam modifications. As you recall, our existing scope of services includes the evaluation of three dam modifications. Based on our preliminary efforts, the three modifications consisted of the following:

1) Removal of the one-foot high concrete "cap" on spillway and installation of moveable flashboards

2) Increasing the height and length of dam abutments to contain flood waters

3) Increasing the discharge capacity of the low level gate / construct larger gate

After our presentation and discussions with the Committee, the Committee asked that these modification scenarios be revised and new scenarios be added. The Committee requested that all scenarios incorporate the following design constraints:

a) Complete dam removal is not acceptable.

b) The modified dam will not reduce the existing volume of impounded water.

c) The modified dam will pass the 50-year flood (and the 100-year flood, if possible) in accordance with NHDES requirements.

d) Modifications to the dam will not exacerbate existing problems associated with water quality.

e) Any discharge control mechanisms are to be automated such that a person does not have to manually turn a valve or remove a flash board.

f) Maintain or improve the performance of the existing fish passage.

Based on these design constraints and our discussions, we understand dam modifications the Committee now wishes to be evaluated included the following:

Concept 1: Remove the one-foot, high concrete "cap", install one-foot high automated flashboards, and install an automated discharge gate of sufficient size such that the dam could pass the 50/100 year flood.

Concept 2: Lower the entire spillway approximately 3 feet, raise the east and west dam abutments an appropriate height, and install 3-foot tall automated flashboards such that the modified dam could pass the 50/100 year flood.

Concept 3: Increase the dam spillway length by constructing either a spillway extension through Founders Park, separate emergency spillway in Founders Park, or by constructing a labyrinth weir-type spillway on the existing dam. Based on the analysis of these three options, the most viable option of the three will be identified.

It was agreed that ultimately a combination of the above concepts may prove to be the best solution to resolving Great Dam's inadequate discharge capacity. Therefore, these concepts will be evaluated individually and in various combinations. The final report will include three dam modifications that incorporate one or more of the concepts outlined above.

All modifications will include a preliminary evaluation of the potential downstream affects of a particular dam modification.

Although the ERSC does not advocate removing the existing fish passage, it did express an interest in better understanding how the construction of the existing fish passage in the late 1960's reduced the discharge capacity of the dam. Therefore a discharge capacity evaluation of the dam prior fish passage construction will be preformed as summarized below:

Evaluation 1: Estimate discharge capacity of Great Dam prior to the construction by the New Hampshire Fish & Game of the existing fish passage.

Similarly, the ERSC does not wish the Great Dam to be removed. However, the ERSC is interested in knowing the implications and demolition costs of complete dam removal. Therefore the impacts of complete dam removal will be identified as summarized below:

Evaluation 2: Summarize the implications and the demolition costs of complete dam removal.

Wright-Pierce wishes to emphasize its desire to evaluate only viable and cost effective solutions as part of its work to resolve issues associated the discharge capacity at the Great Dam. We appreciate the many and often competing interests the Town of Exeter must balance when weighing the merits of each alternative, with cost being an important consideration.

We have communicated with Steve Doyon at the NHDES Dam Bureau regarding this project and NHDES' on-going lake level investigation of the Great Dam impoundment. According to Mr. Doyon, the lake level investigation will not be completed until NHDES has an opportunity to review the results of Phase I 2006 Exeter River Study.

We propose to complete the additional work requested during the October 19, 2006 meeting on a time charge basis. We proposed to replace the existing Task A and Task C from our June 20, 2006 proposal with the following:

DEVELOPMENT OF CONCEPTUAL MODIFICATIONS TO GREAT DAM

A. Conceptual alternatives to increase the discharge capacity of the Great Dam will be developed. A separate conceptual design for each alternative will be prepared that will pass the 50-year and 100-year flood. Target criteria used in the development of these alternatives will include: 1) achieving regulatory requirements for spillway capacity, 2) providing hydraulic capacity to allow management of impoundment levels during relatively frequent precipitation events, 3) enhancing water quality in the impoundment, and 4) maximizing the performance of the Great Dam fishpass. Alternative selection will be a collaborative effort with the Town of Exeter. Up to three modifications (and two evaluations) will be evaluated and may include modifications to the abutments, penstock, dam crest and fish ladder. Estimated construction and engineering costs will be developed for the three selected scenarios.

DAM MODIFICATION HYDRAULIC MODELING

C. The HEC-RAS hydraulic model of the Exeter River and Little River in Exeter, NH developed as part of the 2005 study work will be updated using the bathymetric data obtained in Task B. This model will subsequently be used to evaluate the backwater Exeter River for three alternative Great Dam geometries or operational regimes at typical summer flows and for the 1, 10, 50, and 100-year return interval hydrologic events. The hydraulic model will be designed to predict how river flows are affected by the Great Bridge and other hydraulic constrictions within the impoundment. In this manner, the degree of impact various modifications to Great Dam will have on river flows can be compared with natural and other fixed obstructions to flow.

Task	Hours	Labor Cost	Expenses	Total Fee
DEVELOPMENT OF CONCEPTUAL MODIFICATIONS TO GREAT DAM				
A.				
1. Develop Great Dam Modification Alternatives and Preliminary Dam Removal Evaluation	38	$5,800		$5,800
2. Consultation with NHDES	16	$1,400		$1,400
3. Develop modification cost estimates	50	$4,200		$4,200
4. Summarize Findings	8	$1,000		$1,000
			Task A Total	**$12,400**
DAM MODIFICATION HYDRAULIC MODELING				
C. Dam Modification Hydraulic Modeling				
1. Update Hydraulic Model	30	$3,100		$3,100
2. Evaluation of Conceptual Modifications	40	$5,500		$5,500
3. Summarize findings	16	$2,200		$2,200
			Task C Total	**$10,800**
INCREASE IN CONTRACT AMOUNT FROM JUNE 20, 2006 WORK SCOPE				**$6,900.00**

SCHEDULE

We anticipate the existing schedule for the Final Report submission will need to change from November 1, 2006 to December 8, 2006.

We look forward to continuing to work with the Town of Exeter on this important project. If you have any questions regarding this work scope modification, please feel free to call us.

Sincerely,

WRIGHT-PIERCE

Richard A. Davee, P.E.
Project Manager

James A. Hewitt, P.E.
Project Engineer

JAH/als

APPENDIX D

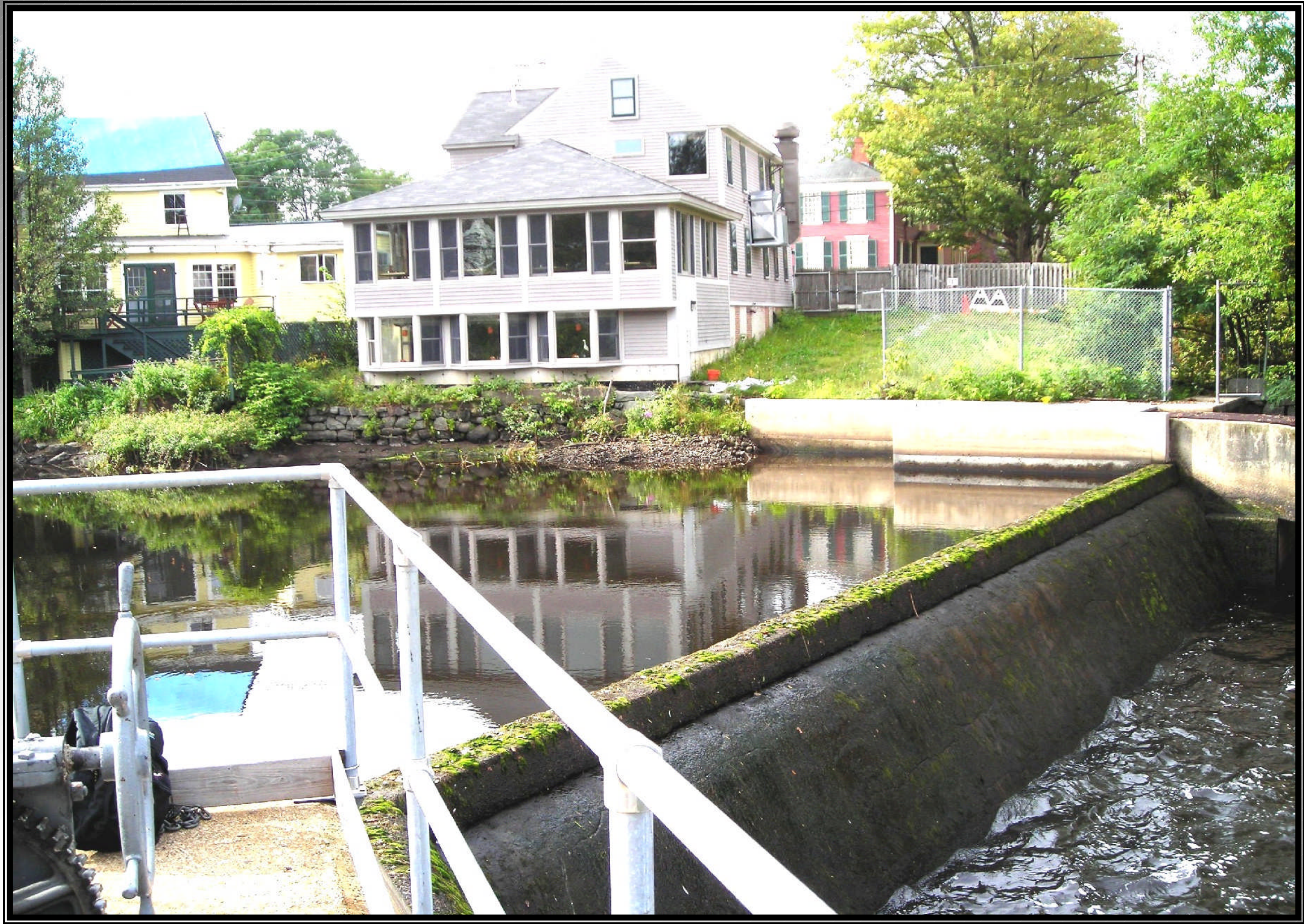
GREAT DAM STRUCTURAL INSPECTION PHOTOS

Great Dam Fish Ladder

Photo date: 9-6-06

Great Dam Penstock Baffle

Photo date: 9-6-06



Great Dam looking southwest

Photo date: 9-6-06

Great Dam

Photo date 9-6-06

Great Dam looking northeast

Photo date: 9-6-06

Great Dam Low Level Gate

Photo date: 9-6-06

Downstream face of Great Dam

Photo date: 9-6-06

Great Dam downstream face

Photo date: 9-6-06

Spalled area west of fish ladder

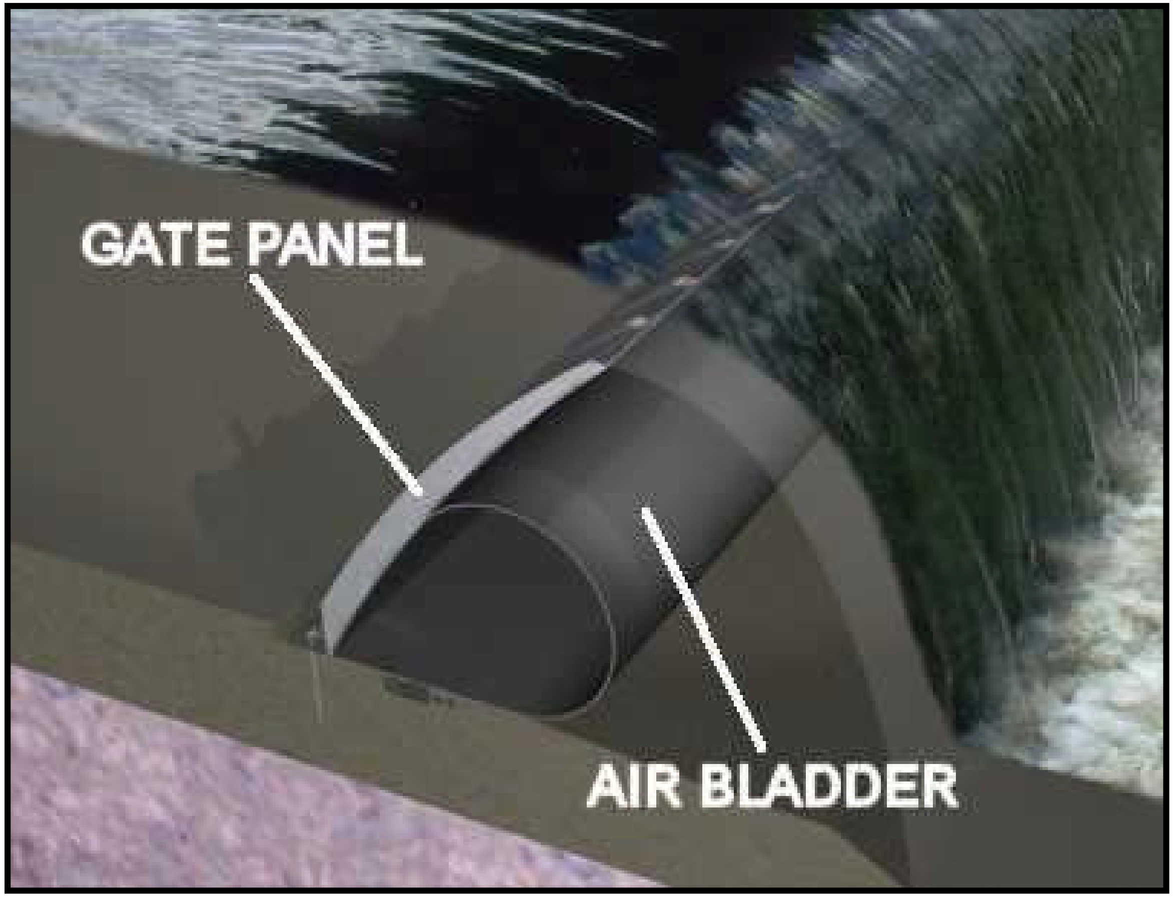
Photo date: 9-6-06

Structural Engineer Dave Skidgel

Photo date: 9-6-06

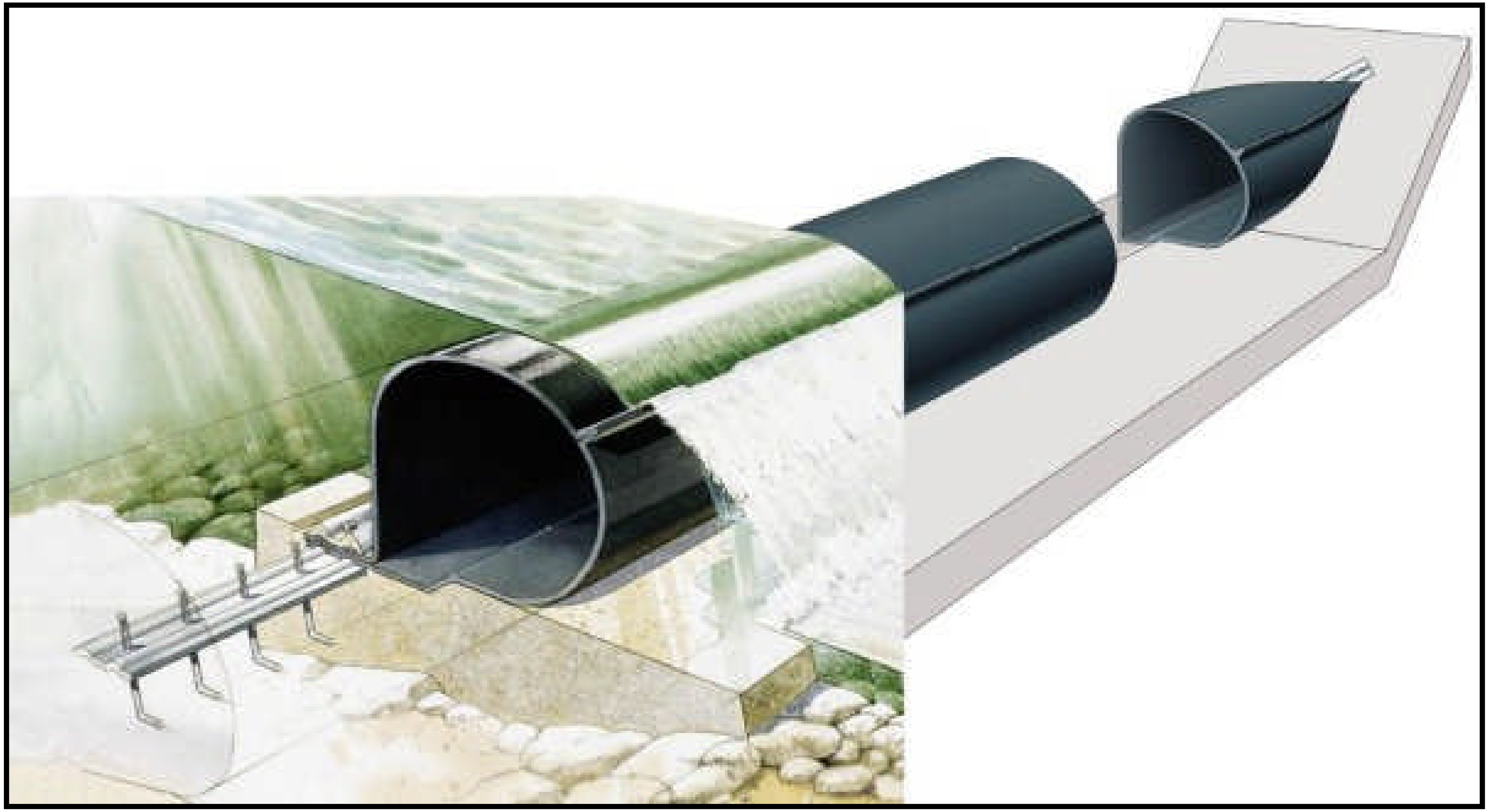
APPENDIX E

DISCHARGE GATE STYLES PHOTOS

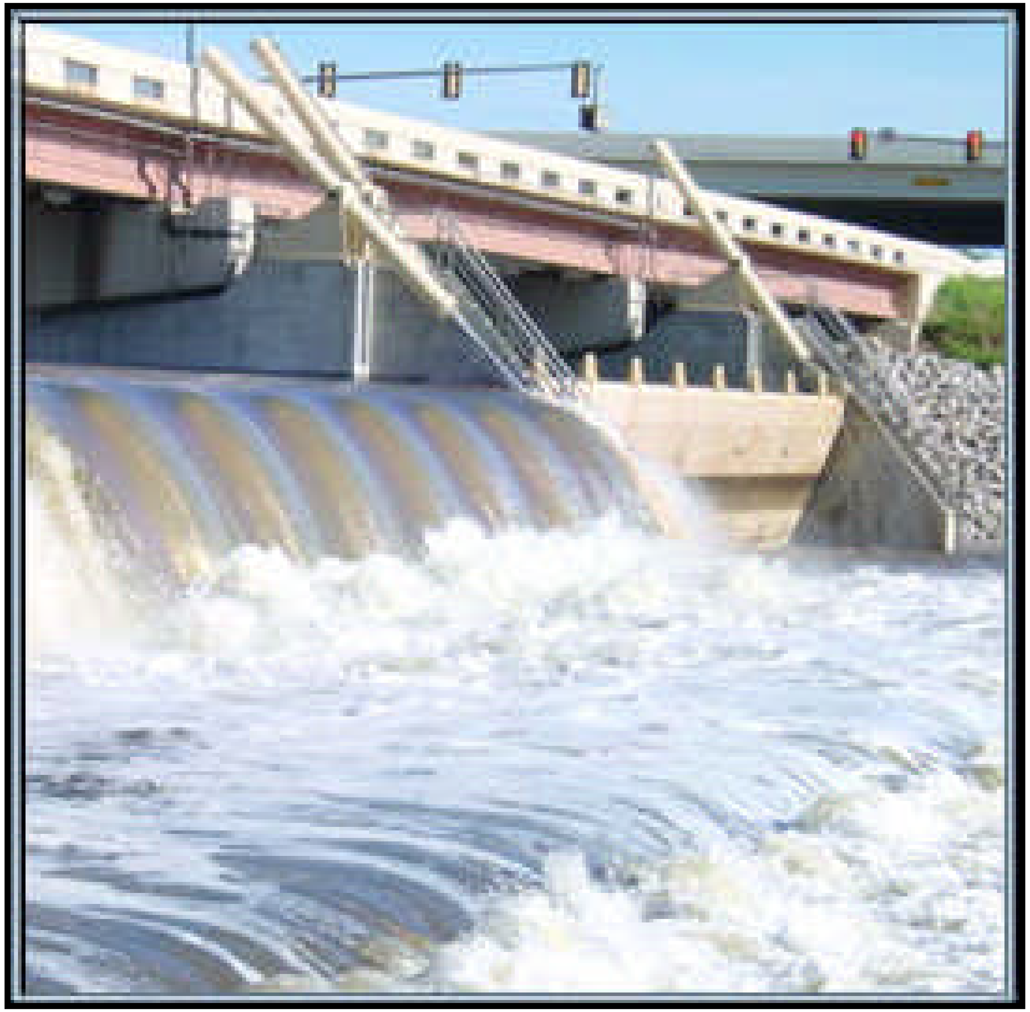


Crest Gate Operated from Below with Air Bladder

Crest Gate Operated from Below



Inflatable Crest Gate



“Crest Gate Operated from Above

“Tainter” Style Discharge Gate

Labyrinth Weir Style Dam

APPENDIX F

WATER SURFACE PROFILE FIGURES

Key For Water Surface Profile Figures

Description of Figure Sets

Figure Set A – Modeled Reach Water Surface Profiles: This set of figures is comprised of water surface profiles for the modeled reach of the Exeter River between Great Dam and the upper limit of the model below the Court Street Bridge. Reference locations for Great Bridge and the confluence of the Little River and Great Brook are shown along the bottom of each figure in this set. These figures are labeled "Figure Reach WSEL-1" through "Figure Reach WSEL-5", corresponding to five flow scenarios (i.e., "Summer" [50-cfs], "1-Year" [1,000 cfs], "10-year" [2,900 cfs], "50-Year" [4,416 cfs] and "100-Year" [4,949 cfs], respectively). These figures are representative of information presented in Table 4 of the 2006 project report.

Figure Set B – Great Bridge Water Surface Profiles: This set of figures is comprised of water surface profiles in the immediate vicinity of the Great Bridge. These figures are labeled "Figure GB-WSEL-1" through "Figure GB-WSEL-5", corresponding to five flow scenarios listed for Figure Set A. These figures are representative of information presented in Table 3 of the 2006 project report and information used to develop Figure 1 in the report.

Figure Set C – Upper Reach Water Surface Profiles: This set of figures is comprised of water surface profiles between the confluence of Great Brook and the upper limit of the model below the Court Street Bridge.. These figures are labeled "Figure Upper Reach WSEL-1" through "Figure Upper Reach WSEL-5", corresponding to five flow scenarios listed for Figure Set A. These figures are representative of information presented in Table 4 of the 2006 project report and the comparison of hydrologic event-specific water levels along the upper end of the project reach.

Figure Set D – Backwater Analysis with Low-Level Outlet Operations Water Surface Profiles: This set of figures is comprised of water surface profiles between the confluence of Great Brook and the upper limit of the model below the Court Street Bridge. These figures are labeled "Figure LL-Ops-1" through "Figure LL-Ops-5", corresponding to four of the five flow scenarios listed for Figure Set A. The Evaluation 2 scenario is not depicted here as it does not incorporate a low-level outlet. The information presented in this figure set if for a flow of 1,000 cfs. These figures are representative of information presented in Table 5 of the 2006 project report and the evaluation of low-level outlet operations. The blue and red lines in this set of figures are representative of the low-level outlet closed and open ("Gate Open" in the figure legends), respectively.

Key For Water Surface Profile Figures

Reference 1: Figure Legends

Evaluated Dam Geometry (see report text for description)	**Legend Abbreviation**
Existing Conditions (Low-Level Outlet Closed Unless Otherwise Noted)	*“ExRegimes”*
Concept 1 (Low-Level Outlet Open Unless Otherwise Noted)	*“C1Regimes”*
Concept 2 (Low-Level Outlet Open Unless Otherwise Noted)	*“C2Regimes”*
Concept 3 (Low-Level Outlet Open Unless Otherwise Noted)	*“C3Regimes”*
Evaluation 1 (Low-Level Outlet Closed Unless Otherwise Noted)	*“Ev1Regimes”*
Evaluation 1 (No Low-Level Outlet)	*“Ev1Regimes”*

Figure Set A – Modeled Reach Water Surface Profiles

Modeled Reach Water Surface Profiles (Reach WSEL)

Figure Reach WSEL-1: "Summer"

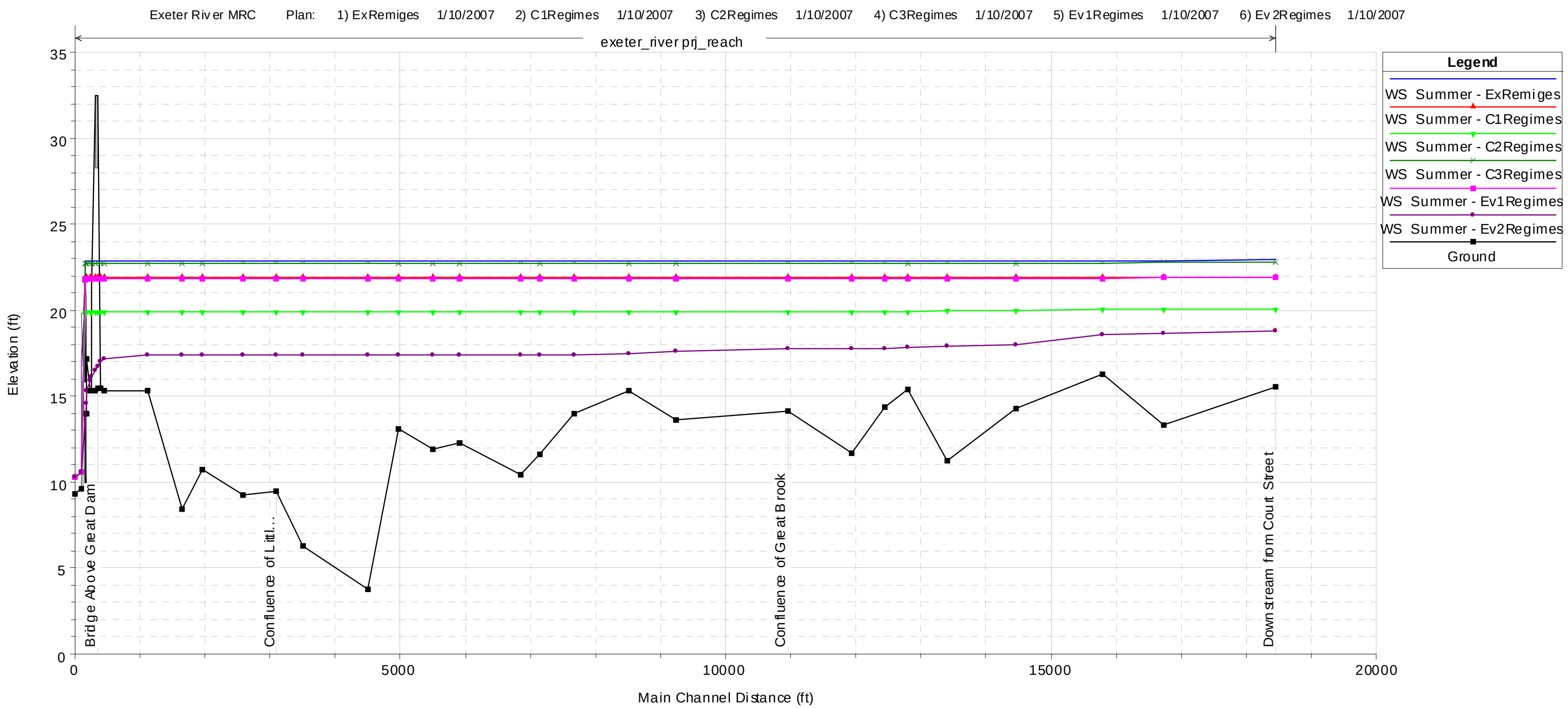


Figure Set A – Modeled Reach Water Surface Profiles

Figure Reach WSEL-2: "1-Year"

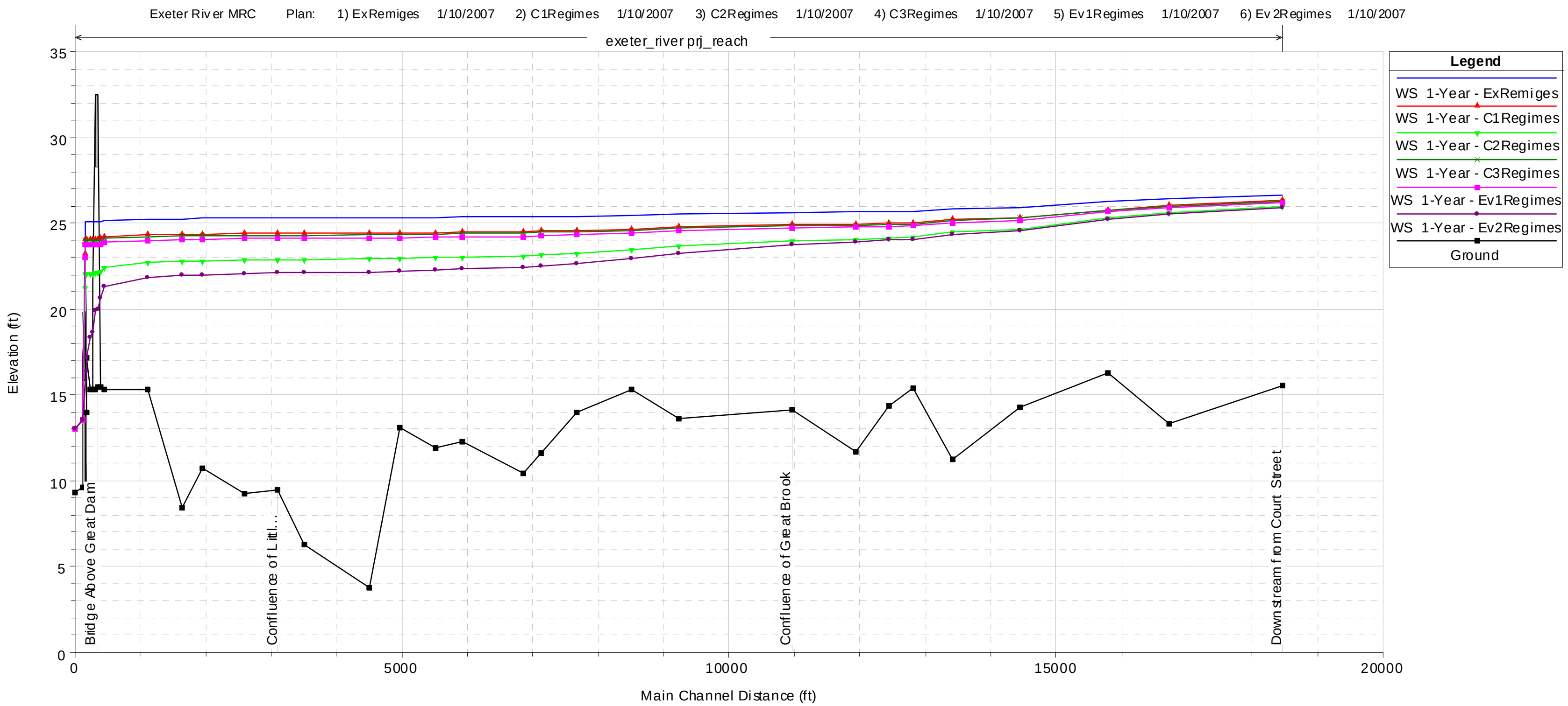


Figure Set A – Modeled Reach Water Surface Profiles

Figure Reach WSEL-3: "10-Year"

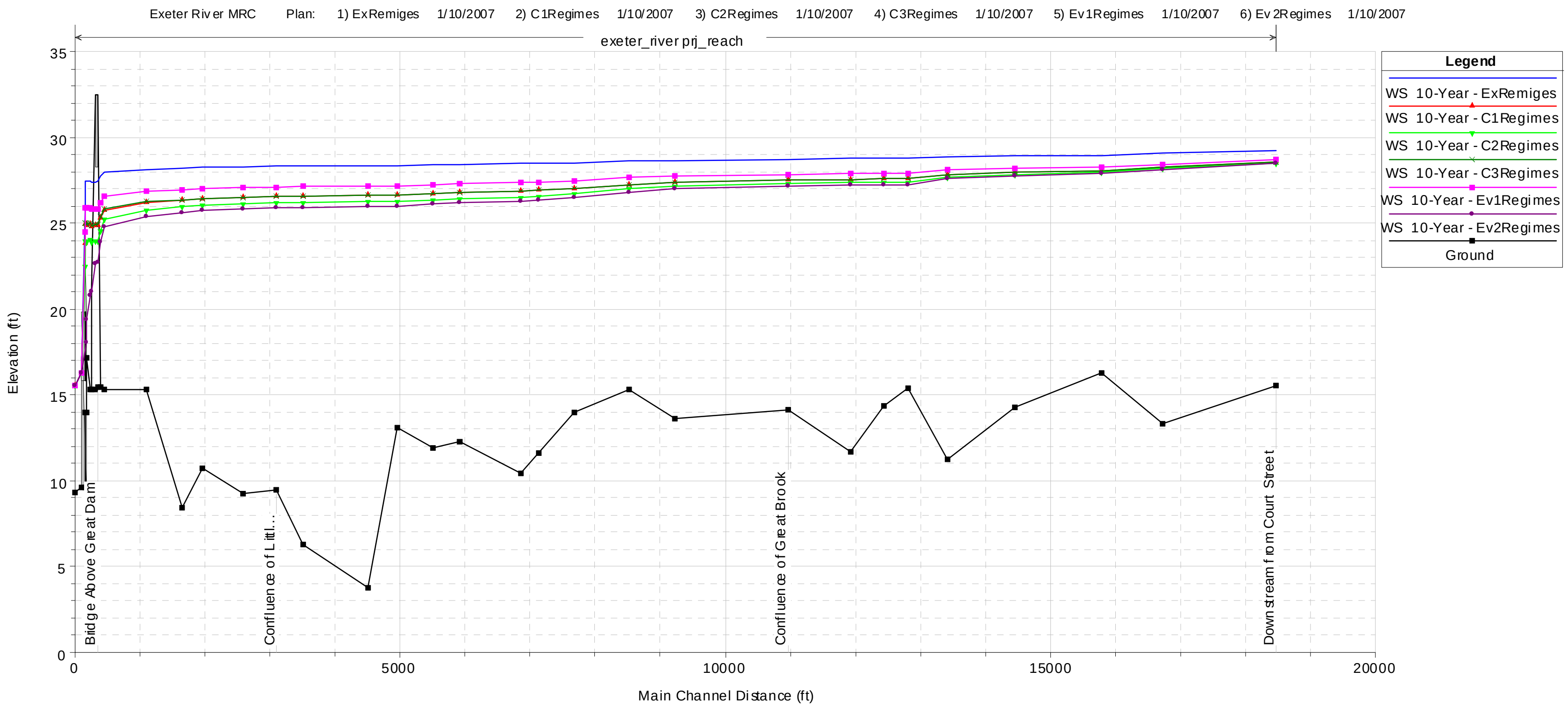


Figure Set A – Modeled Reach Water Surface Profiles

Figure Reach WSEL-4: "50-Year"

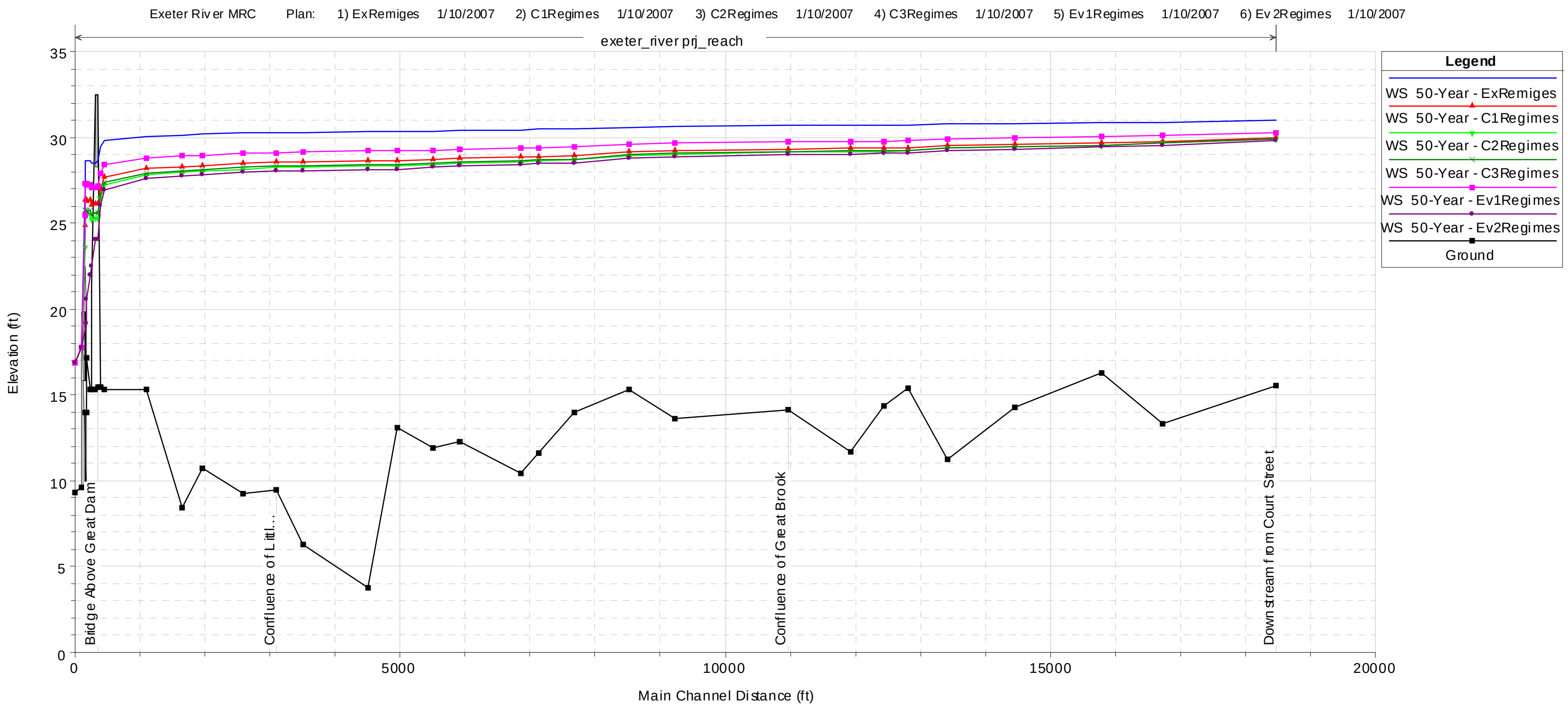


Figure Set A – Modeled Reach Water Surface Profiles

Figure Reach WSEL-5: "100-Year"

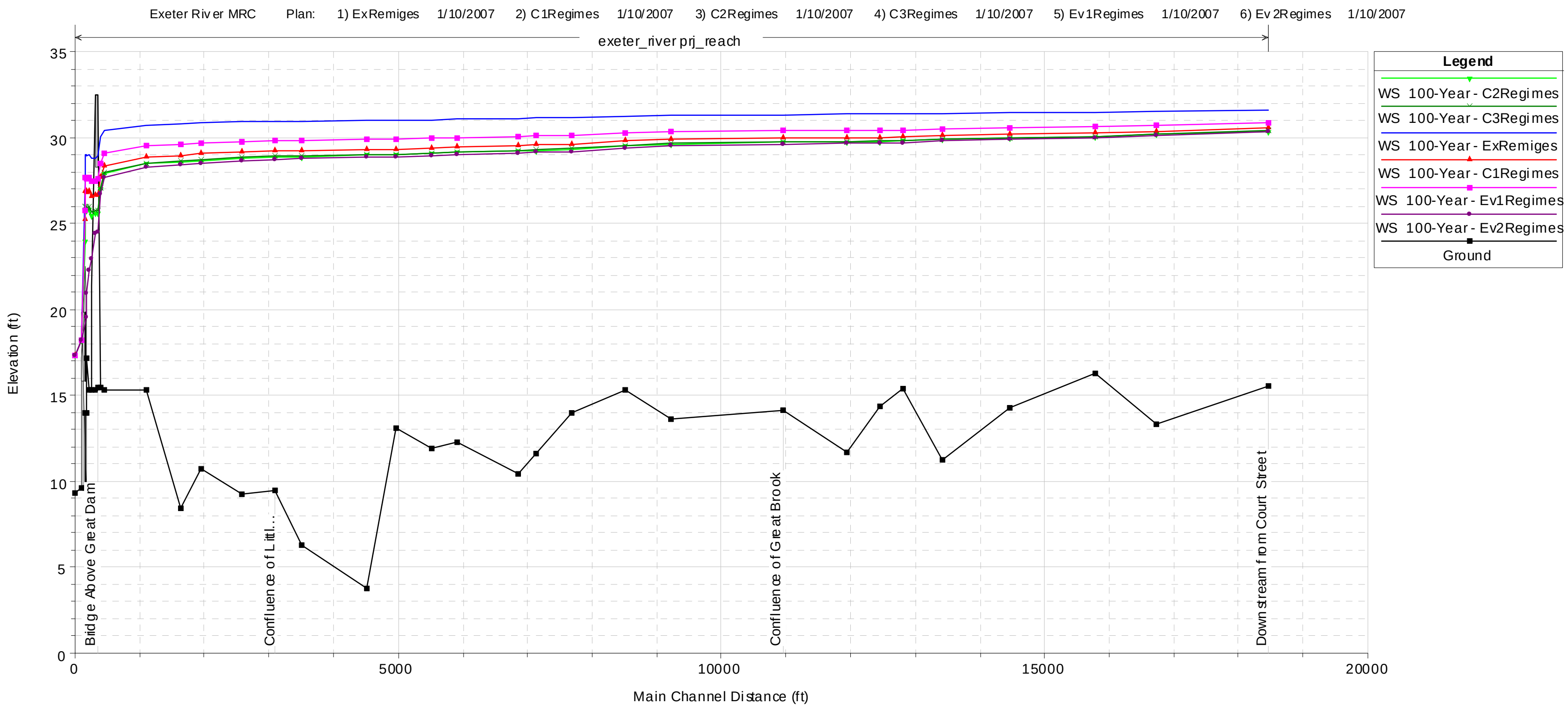


Figure Set B: Great Bridge Water Surface Profiles

Great Bridge Water Surface Profiles (GB WSEL)

Figure GB-WSEL-1: "Summer"

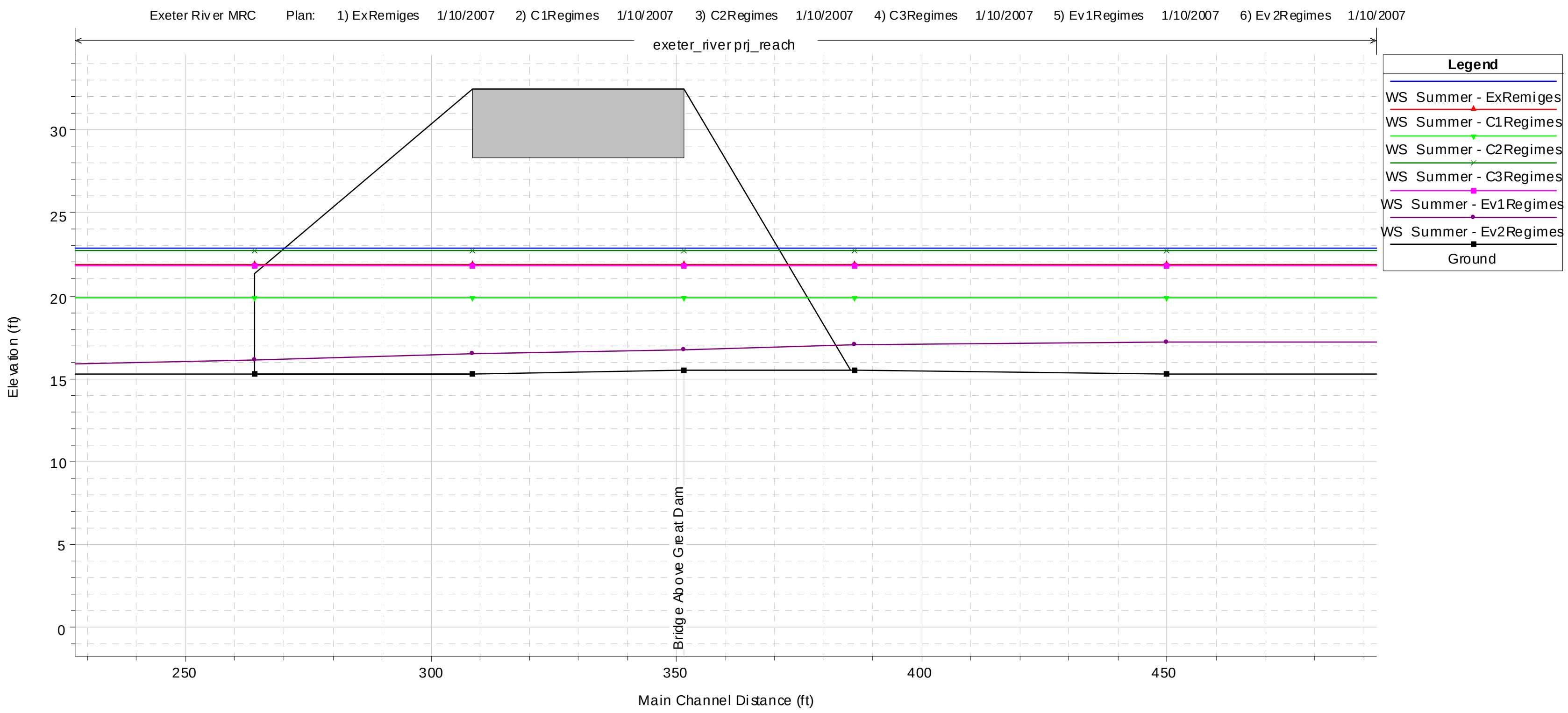


Figure Set B: Great Bridge Water Surface Profiles

Figure GB-WSEL-2: "1-Year"

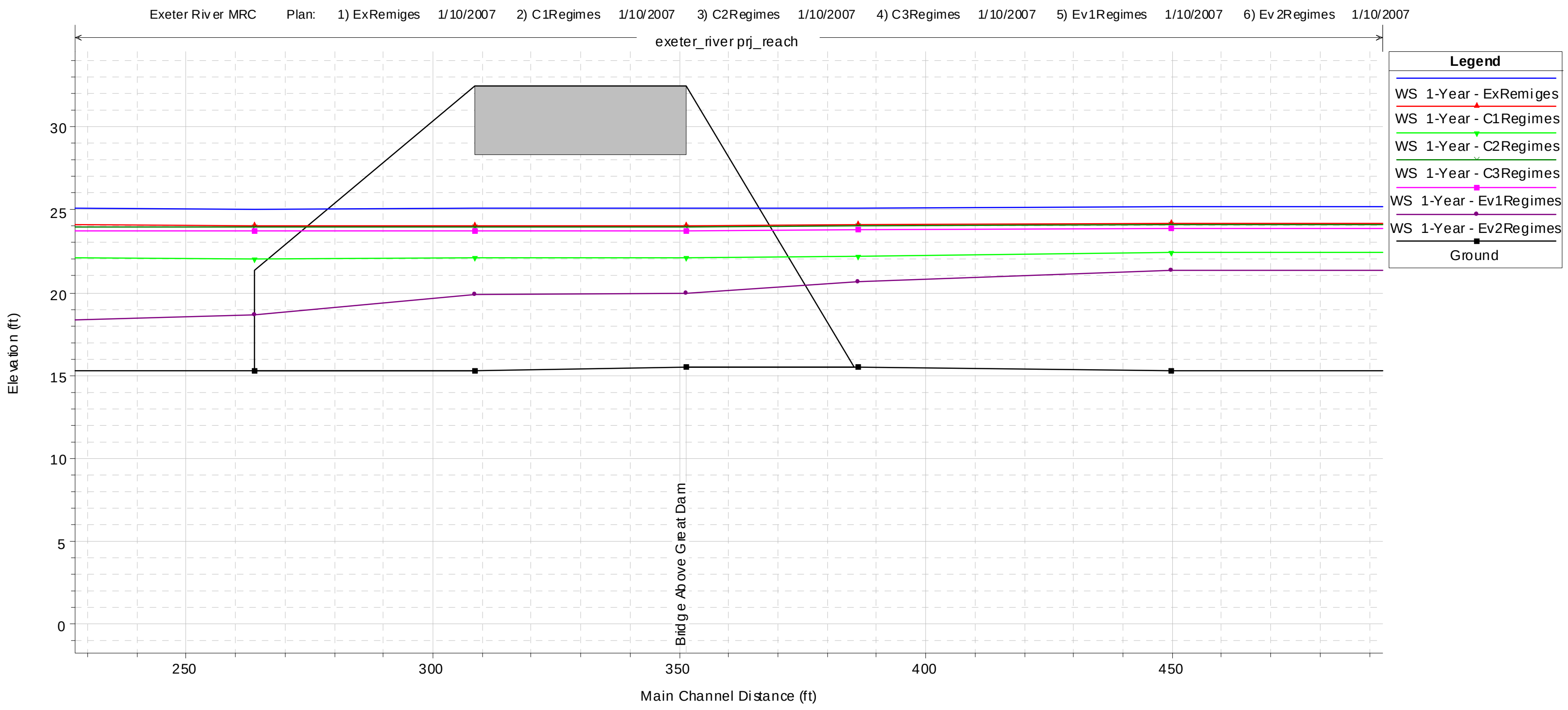


Figure Set B: Great Bridge Water Surface Profiles

Figure GB-WSEL-3: "10-Year"

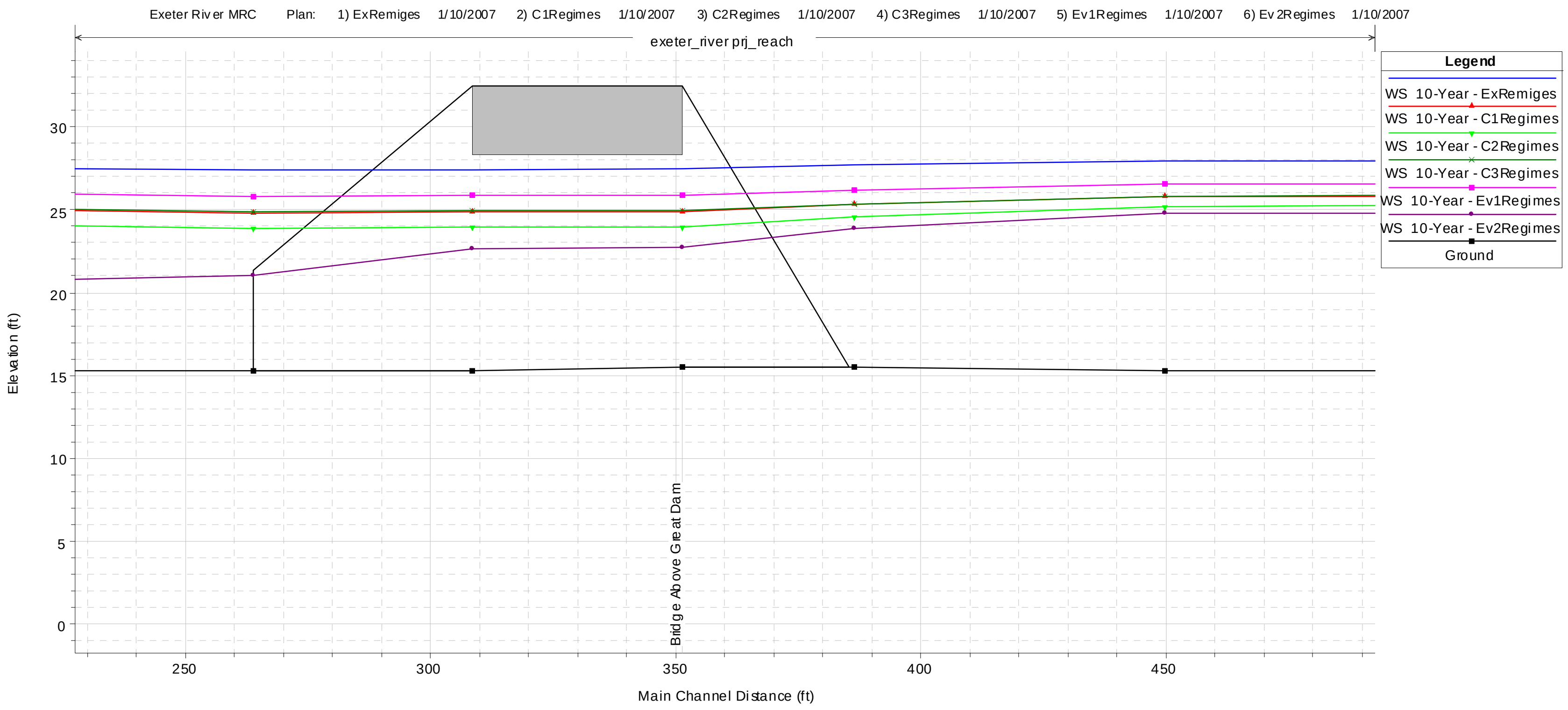


Figure Set B: Great Bridge Water Surface Profiles

Figure GB-WSEL-4: "50-Year"

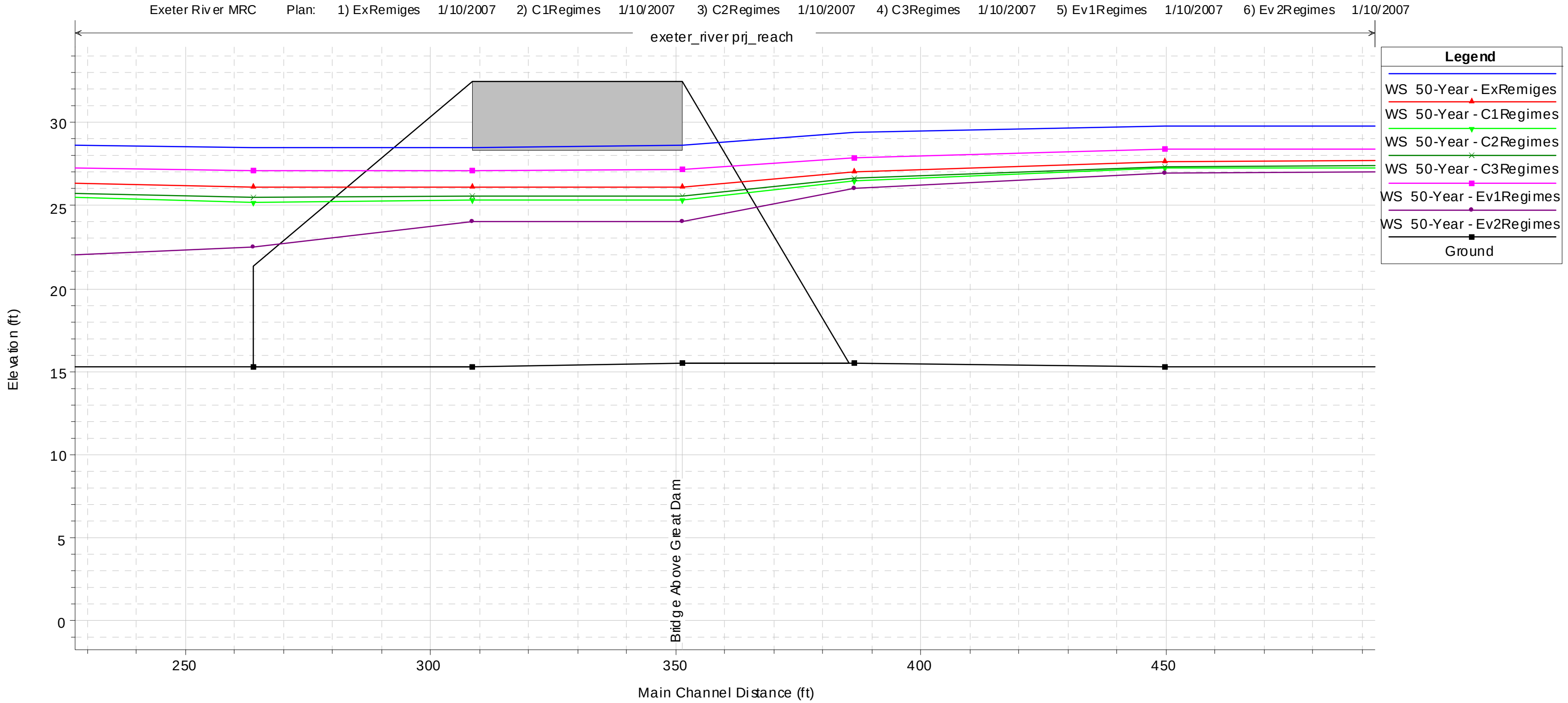


Figure Set B: Great Bridge Water Surface Profiles

Figure GB-WSEL-5: “100-Year”

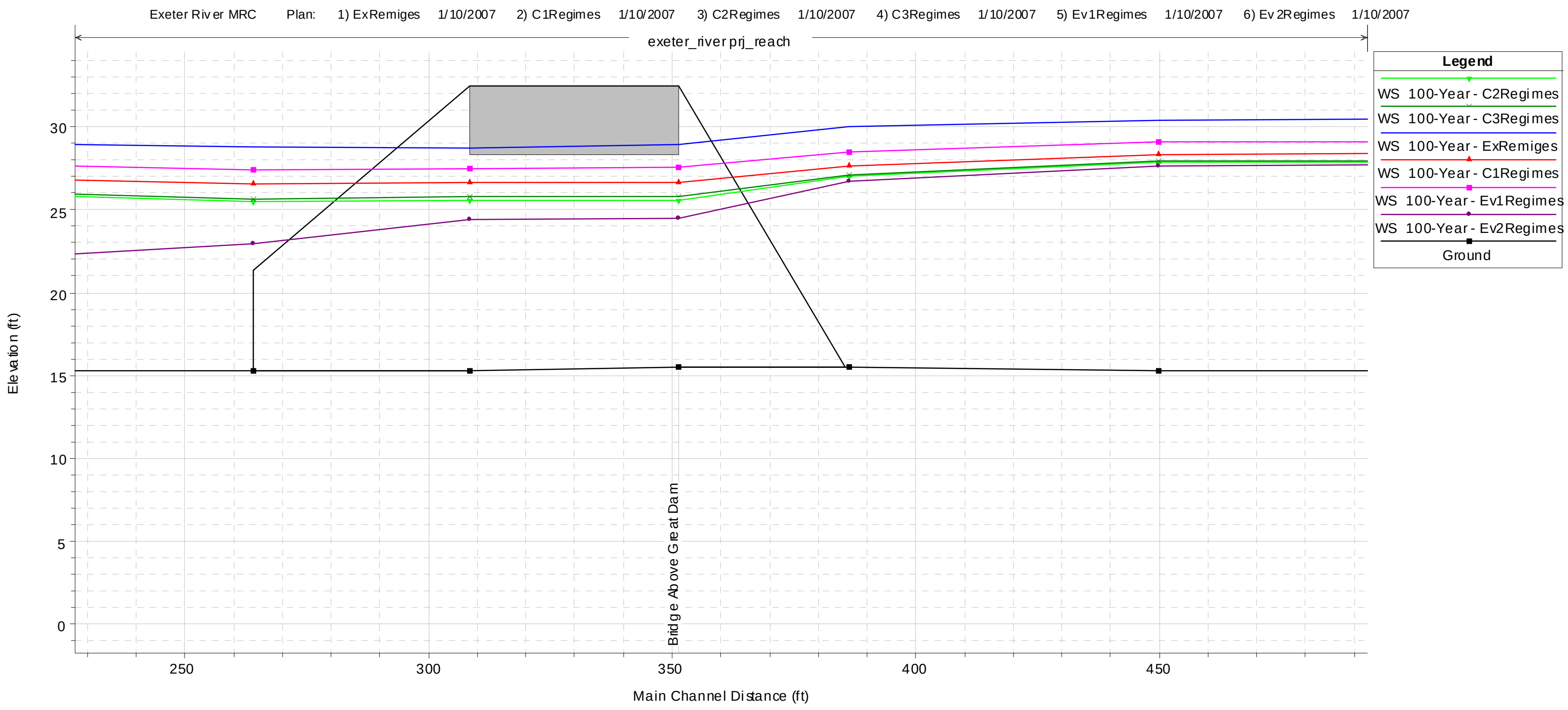


Figure Set C: High Flow Backwater - Water Surface Profiles

Upper Reach Water Surface Profiles (Upper Reach WSEL)

Figure Upper Reach WSEL - 1: "Summer"

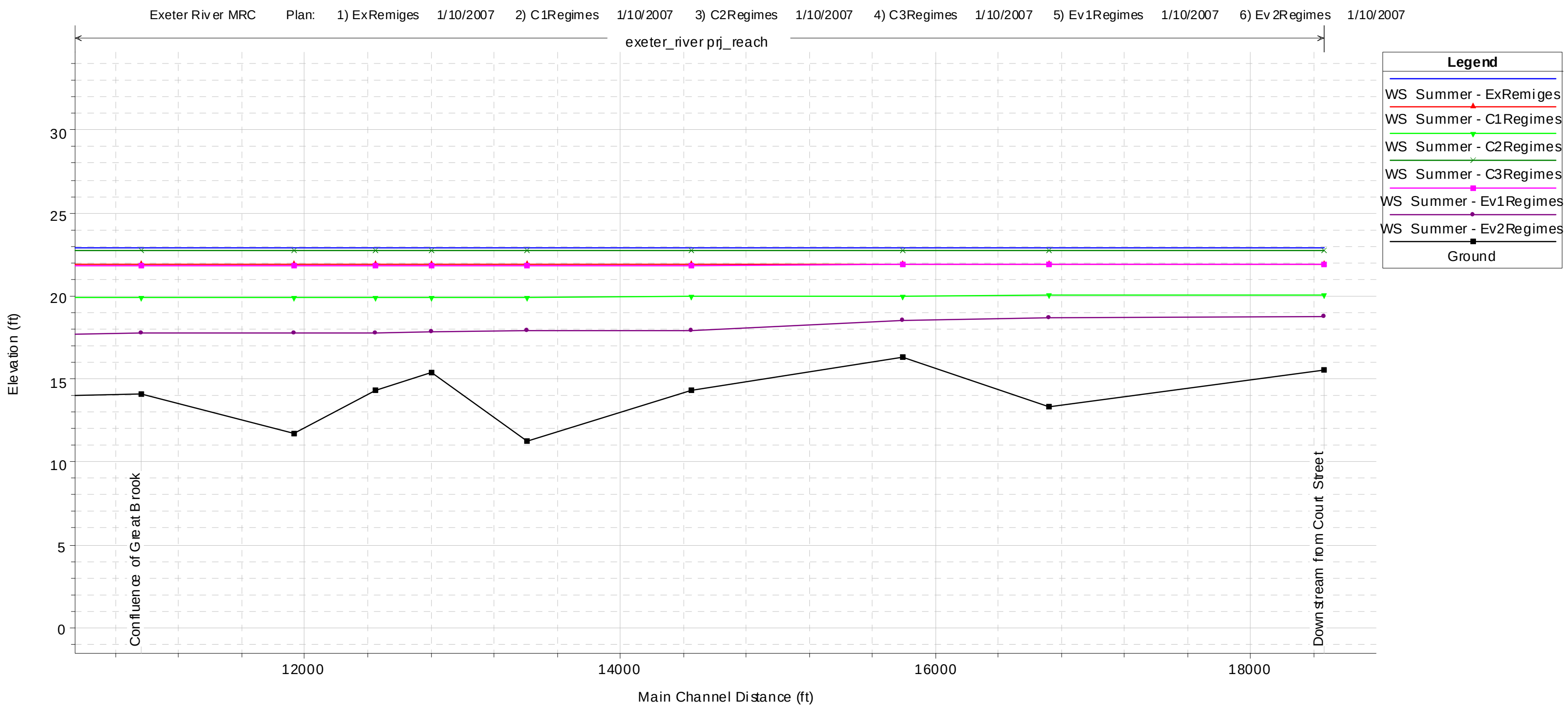


Figure Set C: High Flow Backwater - Water Surface Profiles

Figure Upper Reach WSEL - 2: “1-Year”

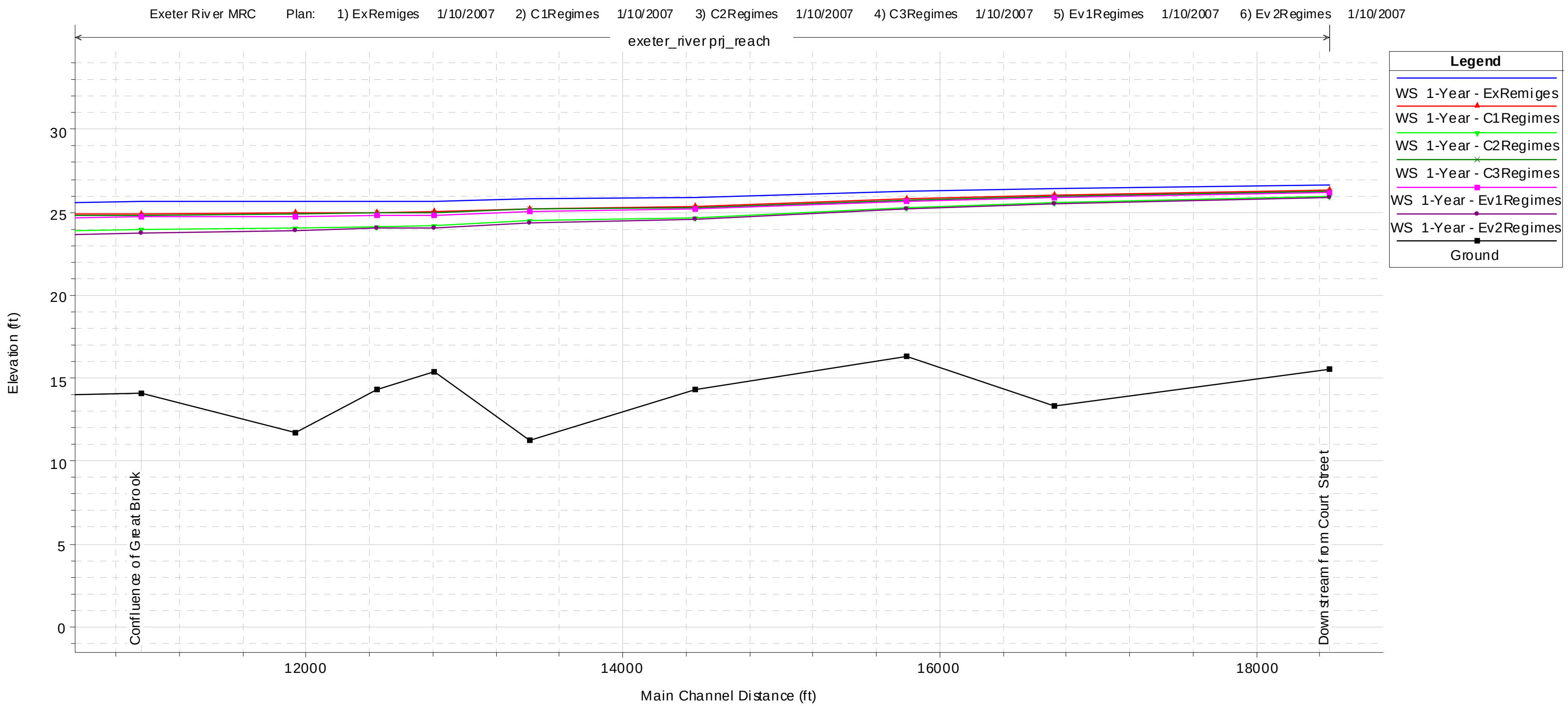


Figure Set C: High Flow Backwater - Water Surface Profiles

Figure Upper Reach WSEL - 3: "10-Year"

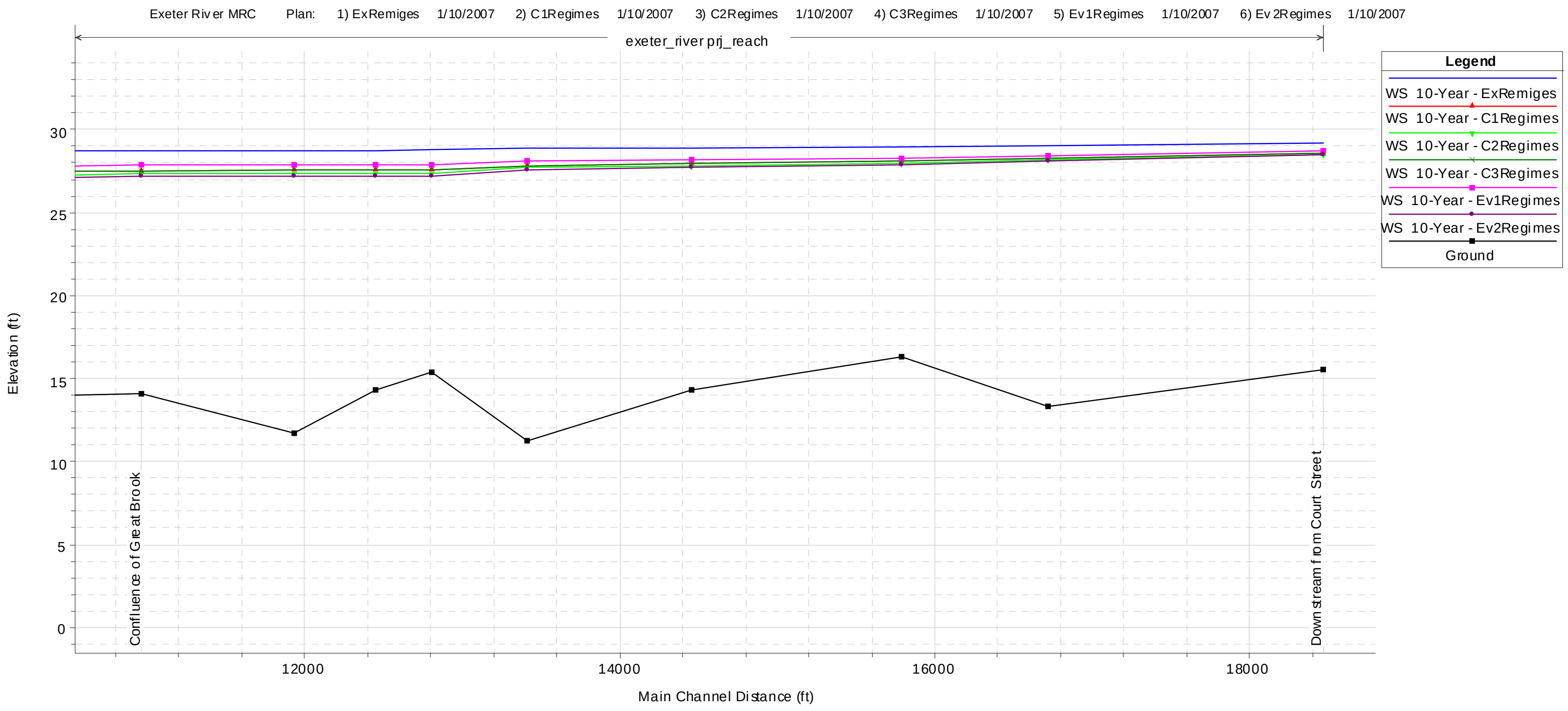


Figure Set C: High Flow Backwater - Water Surface Profiles

Figure Upper Reach WSEL - 4: "50-Year"

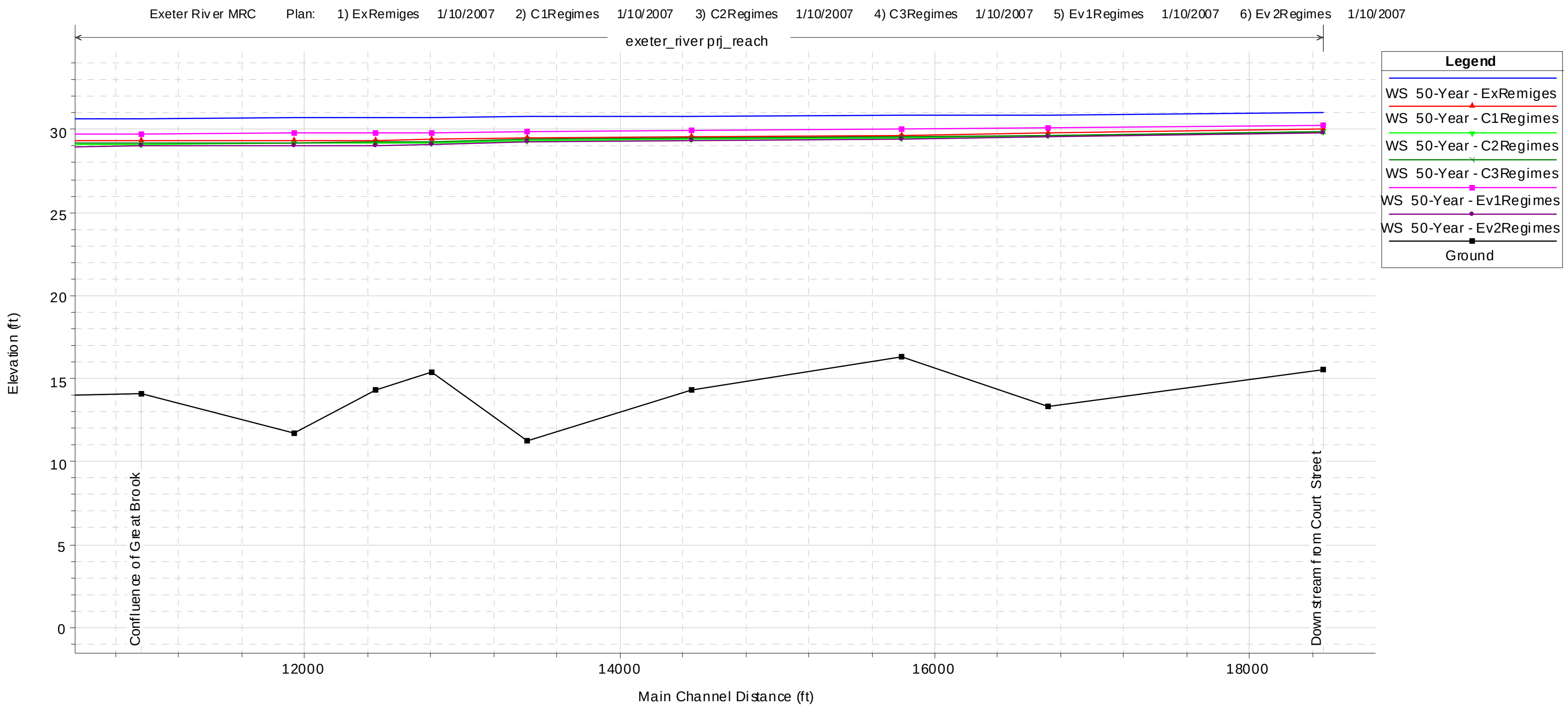


Figure Set C: High Flow Backwater - Water Surface Profiles

Figure Upper Reach WSEL - 5: "100-Year"

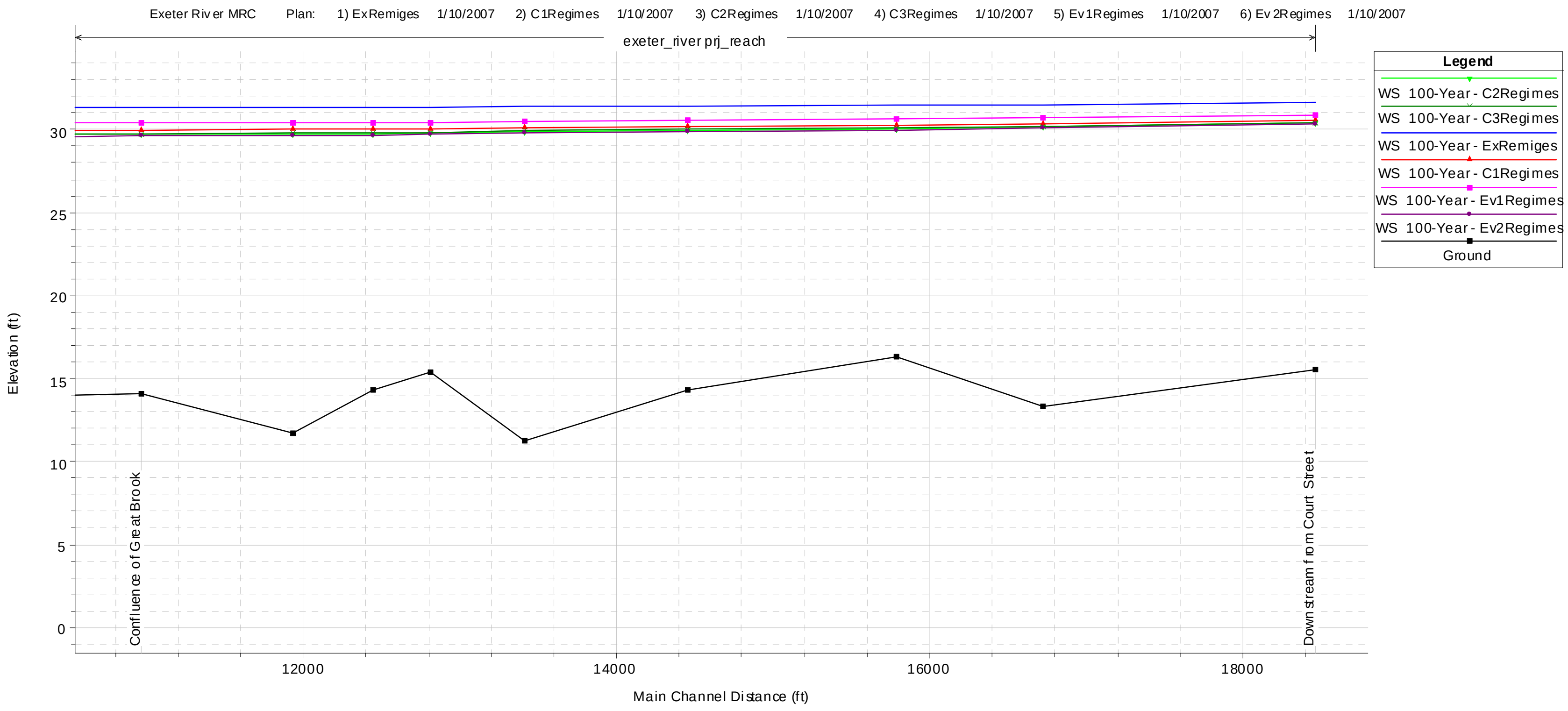


Figure Set D: One-Year Backwater Analysis with Gate Operations - Water Surface Profiles

Backwater Analysis with Low-Level Outlet Operations Water Surface Profiles - Flow of 1,000 cfs (LL-Ops)

Figure LL-Ops -1: Existing Conditions with Gate Closed (blue) and Open (red)

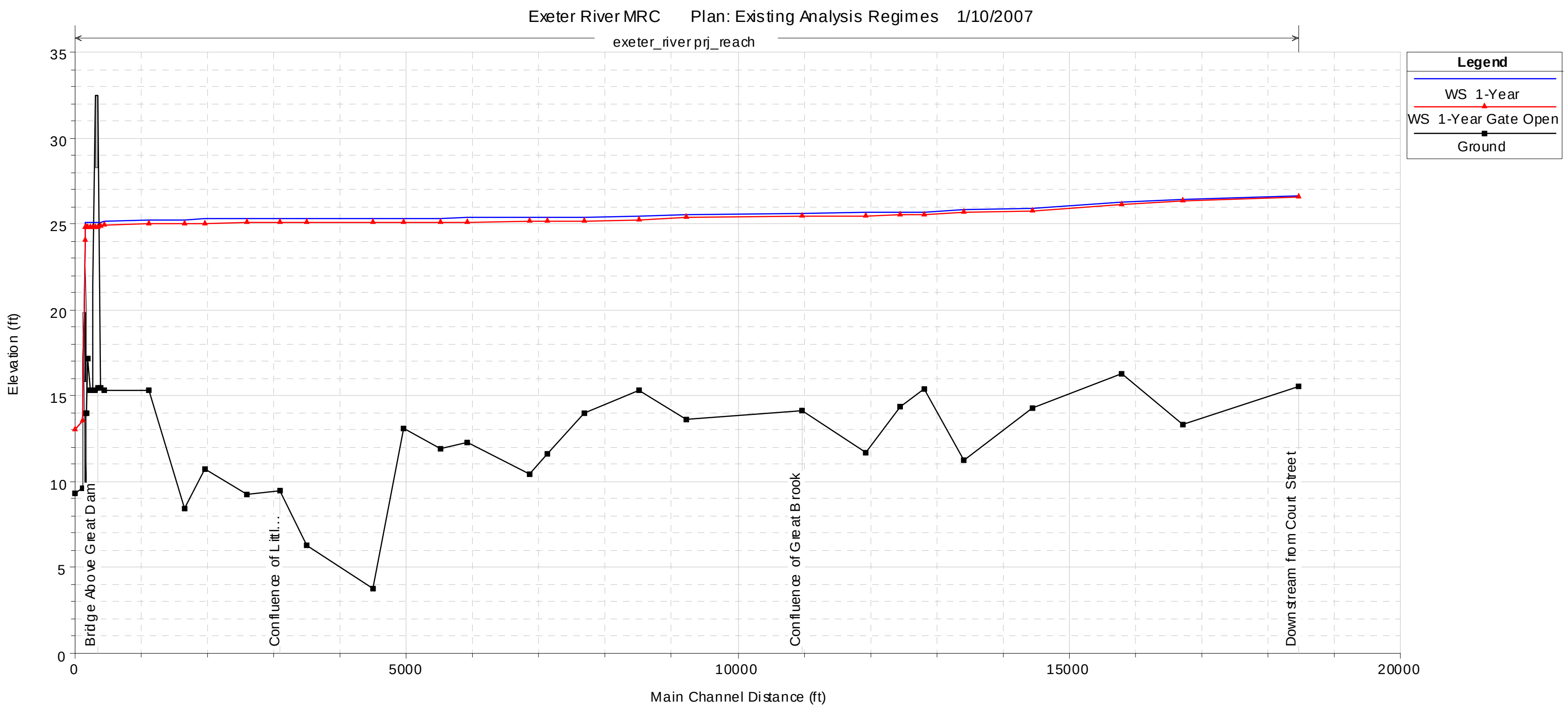


Figure Set D: One-Year Backwater Analysis with Gate Operations - Water Surface Profiles

Figure LL-Ops -2: Concept 1 with Gate Closed (blue) and Open (red)

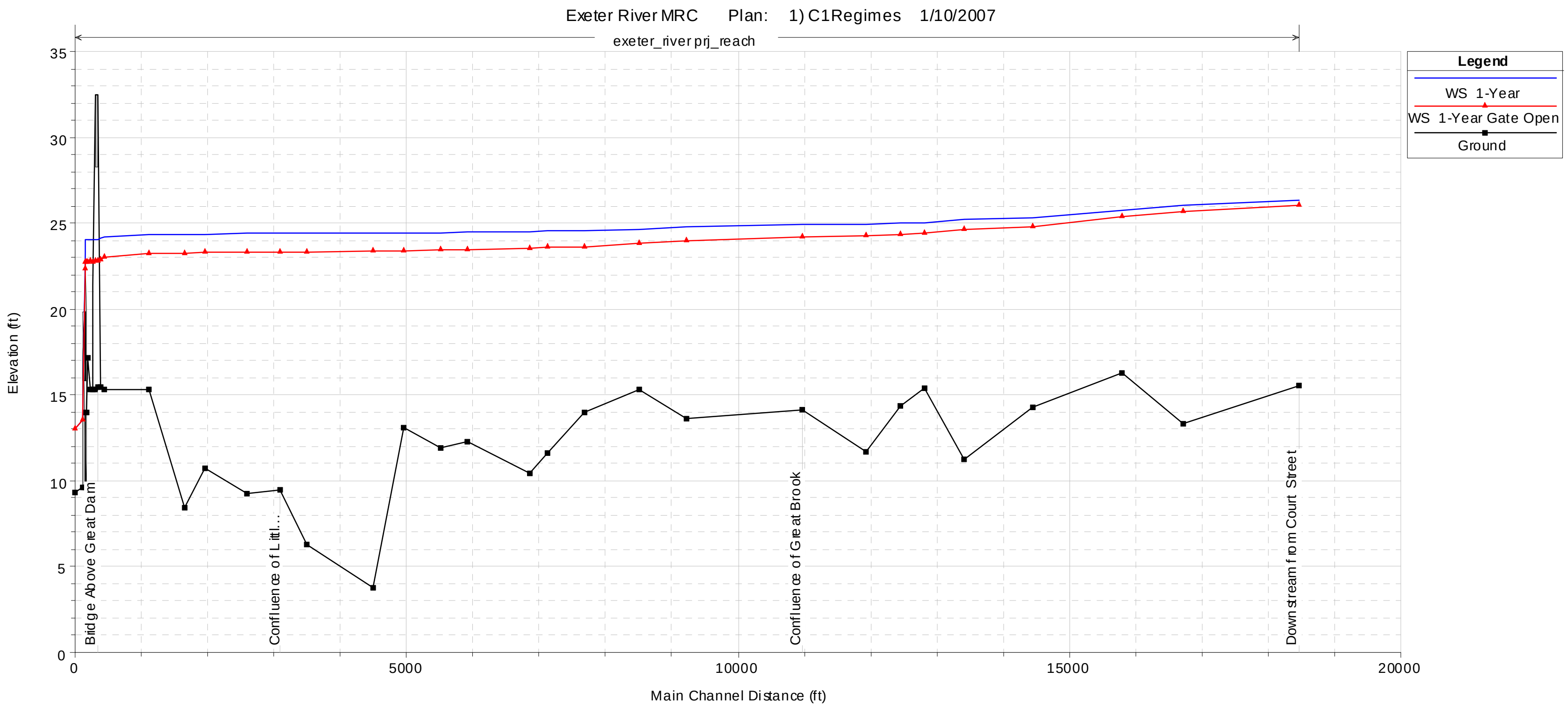


Figure Set D: One-Year Backwater Analysis with Gate Operations - Water Surface Profiles

Figure LL-Ops -3: Concept 2 with Gate Closed (blue) and Open (red)

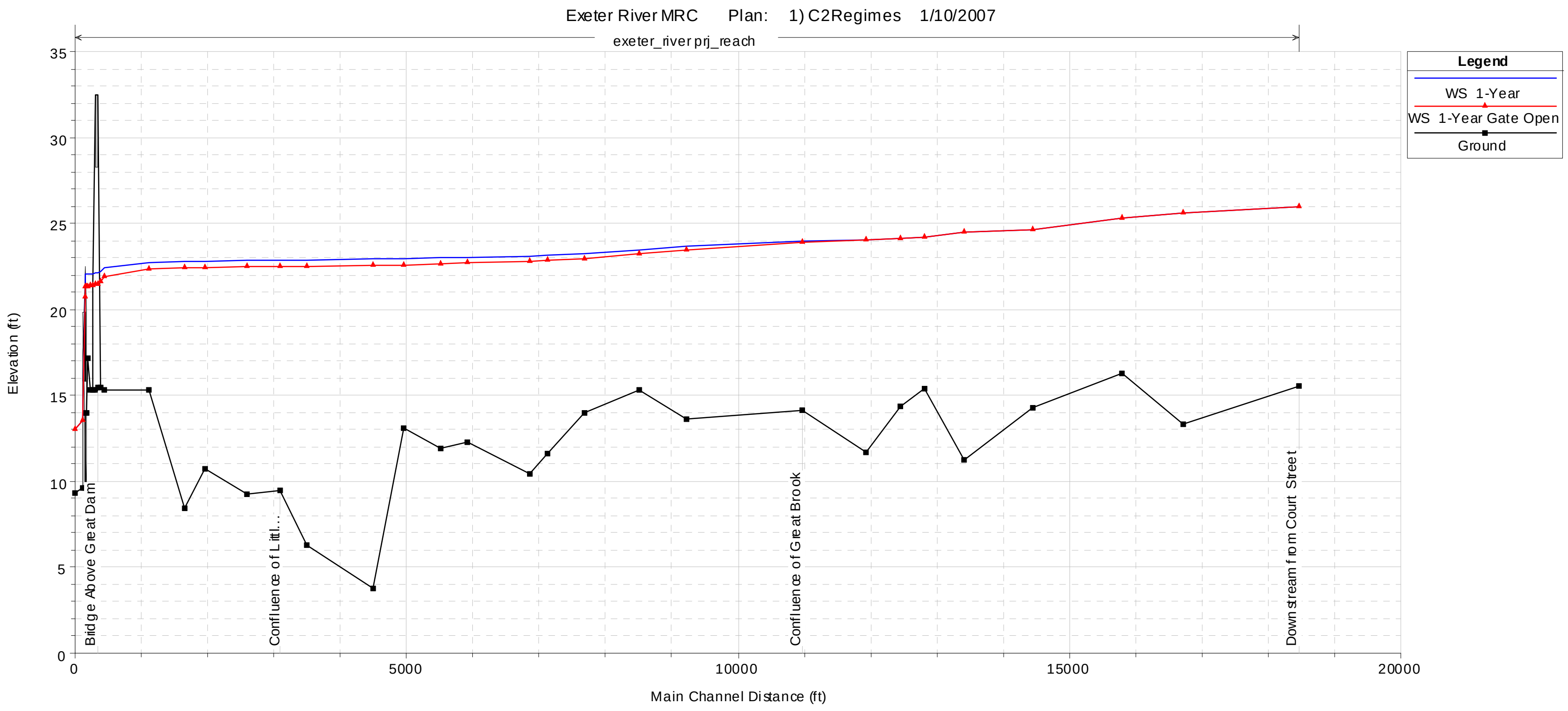


Figure Set D: One-Year Backwater Analysis with Gate Operations - Water Surface Profiles

Figure LL-Ops -4: Concept 3 with Gate Closed (blue) and Open (red)

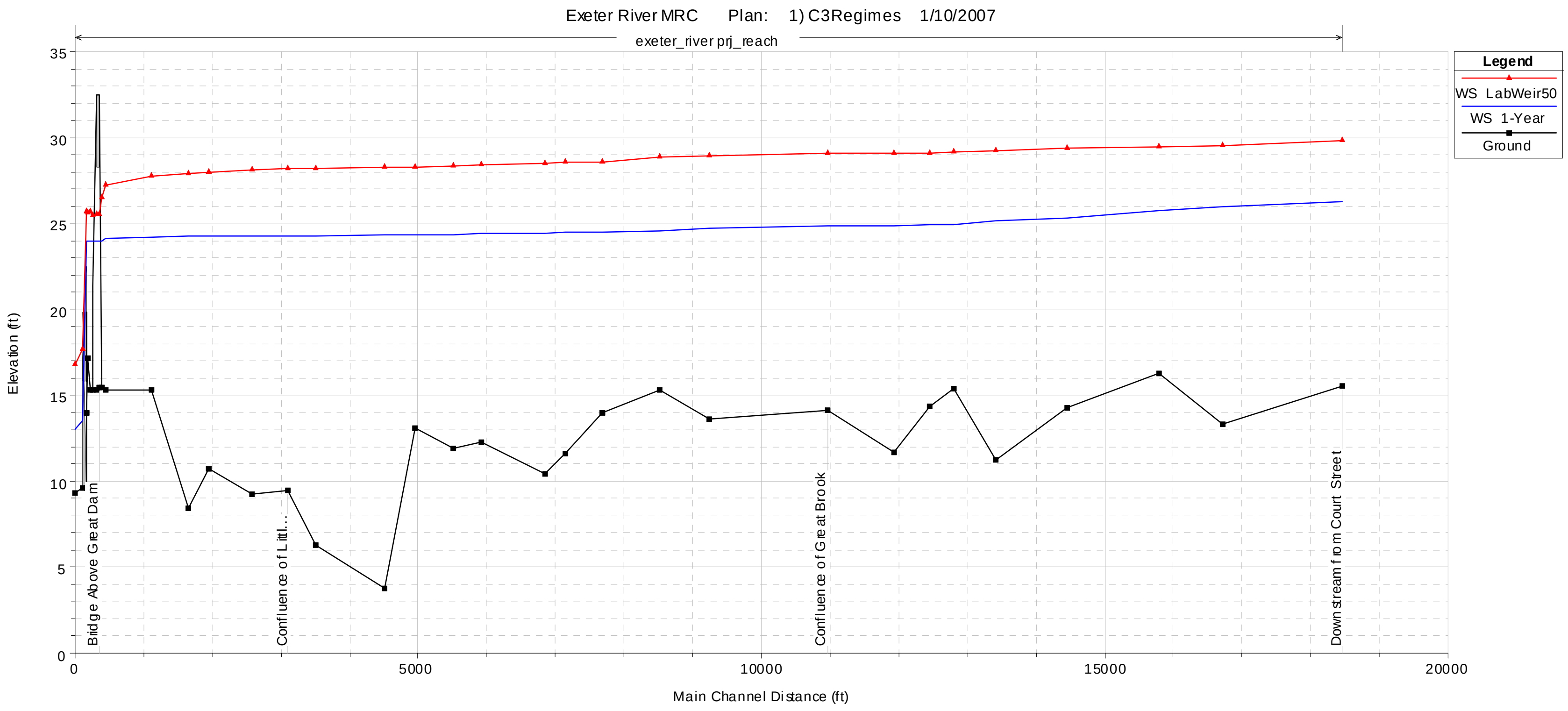
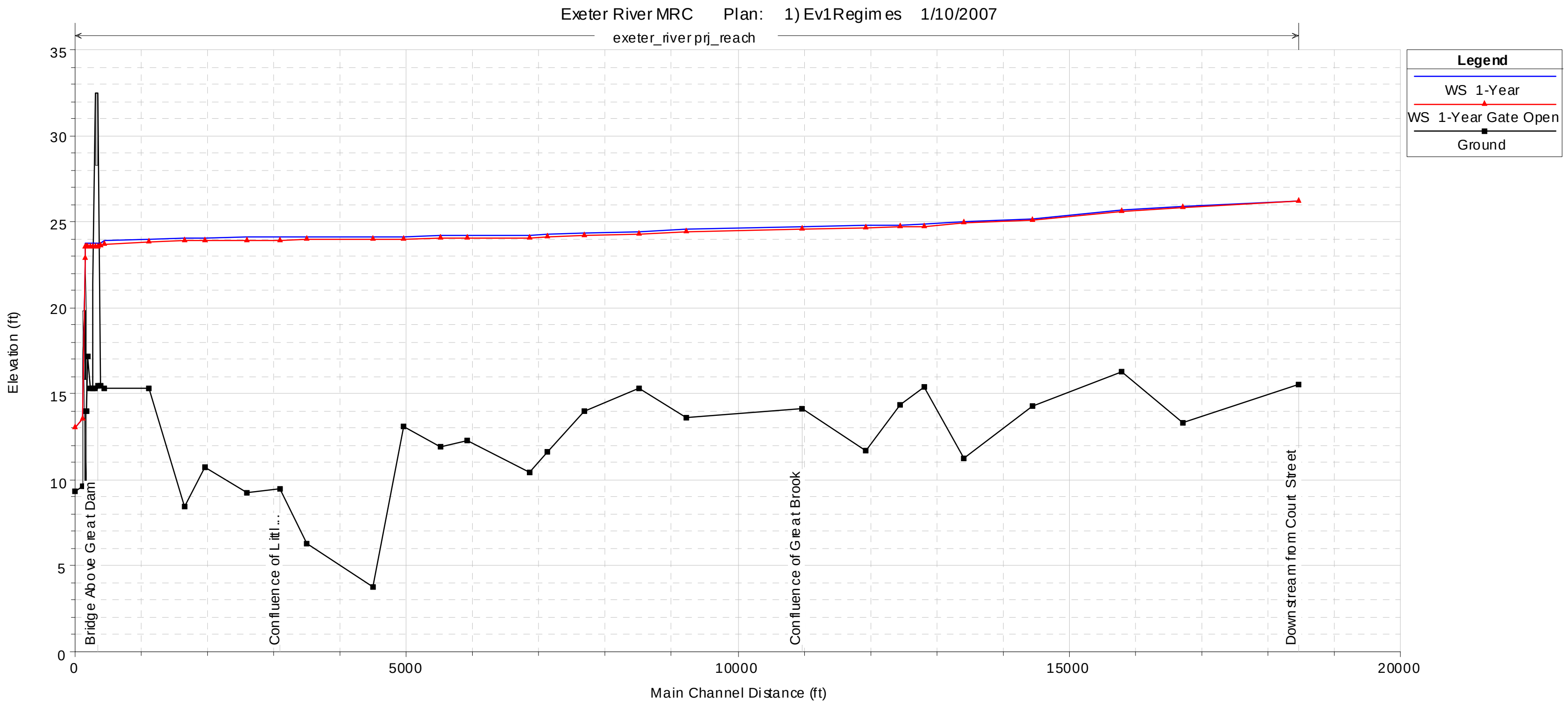


Figure Set D: One-Year Backwater Analysis with Gate Operations - Water Surface Profiles

Figure LL-Ops -5: Evaluation 1 with Gate Closed (blue) and Open (red)



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