Section 5
Hydrologic and Hydraulic Analysis

5.1 Background

To evaluate the impacts removing the Poor Farm Pond Dam (PFPD) would have on the Poor Farm Brook and unnamed stream between the dam and Lake Quinsigamond, a hydrologic and hydraulic analysis was conducted using the average and the 100 year storm event flows.

5.2 Model Approach

To evaluate the hydraulic impact of the proposed dam removal, a steady flow hydraulic model of the existing conditions and proposed removal of the PFPD was constructed. Hydraulic modeling was performed using HEC-RAS version 4.1.0 published by the US Army Corps of Engineers (USACE) (2010). The HEC-RAS model was built in the HEC-GeoRAS environment, which integrates geospatial elevation data and facilitates flood inundation mapping if the need arises in future phases of this project. Design flows were developed from the regional regression available in the National Streamflow Statistics program.

The hydraulic simulations described in this section serve as the basis for the sediment transportation analysis in Section 6.

5.3 Model Development

From the best available data, a HEC-RAS model was built to simulate the hydraulic profiles of the existing conditions and proposed removal of the PFPD.

5.3.1 Data Sources

Data was obtained from several sources to build the geometry and other parameters of the hydraulic model.

- LiDAR with 3-foot-square cells from the Blackstone River Valley with coverage of the entire Poor Farm Pond area including the downstream reach to Lake Quinsigamond.

- 2 foot contours provided by the Town of Shrewsbury were used to verify the Blackstone LiDAR elevation data.

- Field survey of the project area conducted on April 27, 2013 provided bathymetric elevations in the Poor Farm Pond, elevations and dimensions of the Poor Farm Pond Dam, and several cross sections downstream of the dam spillway towards Lake Qunisigamond.

- Field soil samples taken by CDM Smith on April 26, 2013 at five locations provided grain size characteristics of the sediment in Poor Farm Pond, and an estimate of depth to native soil at each location in the pond.

- Aerial photographs

5.3.2 Hydrology and Peak Flow Rate

The discharge-frequency regime at the PFPD was estimated using the USGS National Streamflow Statistics (NSS) program (Ries et al., 2007). This program uses a regional regression to estimate the peak discharges at varying return periods based on the drainage area of a rural watershed in Massachusetts (Wandle, 1983). The drainage area of the PFPD is 3.7 square miles and was calculated using the Massachusetts StreamStats data base. The watershed area is shown in Figure 5-1. The peak discharge for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals is shown in Table 5-1. These peak discharge rates do not include any allowance for climate change in the flow rates.

Table 5-1
Discharge at Poor Farm Dam

Flow Condition	Discharge
2-year Peak Discharge	89 cfs
5-year Peak Discharge	133 cfs
10-year Peak Discharge	171 cfs
25-year Peak Discharge	227 cfs
50-year Peak Discharge	275 cfs
100-year Peak Discharge	330 cfs
500-year Peak Discharge	493 cfs
Annual Median (Q50)	3.6 cfs
August Median (AugQ50)	0.6 cfs

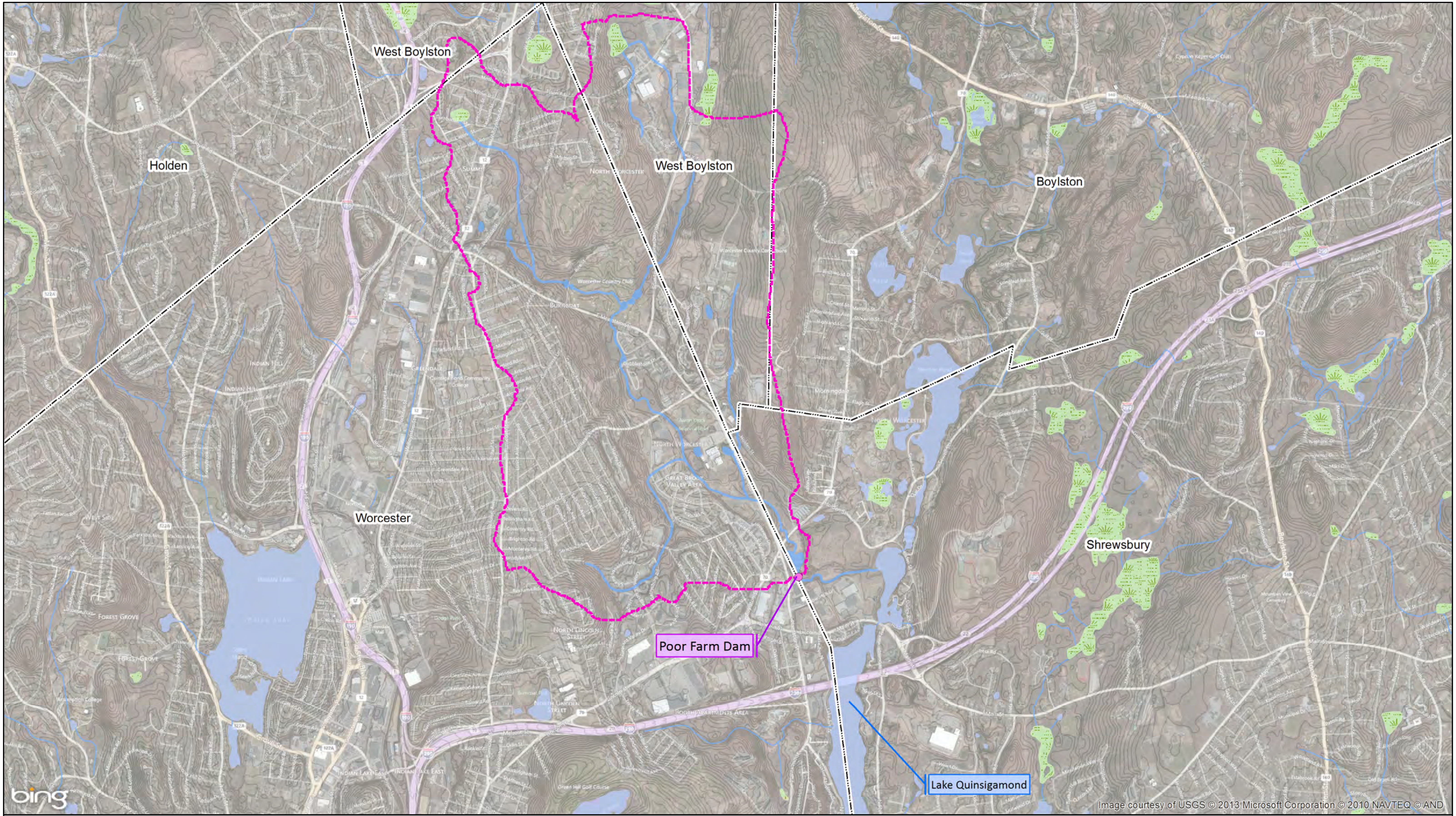
Low and average flow statistics were estimated using another NSS regional regression equation (Ries and Friesz, 2000), and are included in Table 5-1.

5.3.3 Hydraulic Model

A steady-flow hydraulic model of the existing conditions and proposed dam removal was built in HEC-RAS version 4.1.0. The model geometry was built in HEC-GeoRAS version 10 for ArcGIS 10. The model centerline extends from the culvert outlet at Clinton Street (Route 70), through the PFPD, over the dam, and down to Lake Quinsigamond as shown in Figure 5-2. The total centerline length is 3,220 feet. The cross sections and river centerline objects are geo-referenced in the state plane of Massachusetts.

5.3.3.1 Model Cross Sections

The HEC-RAS model includes 47 cross sections spaced an average of 70 feet apart with a maximum distance of 157 feet. The reach downstream of the existing Poor Farm Dam is relatively steep, dropping 1 foot in elevation every 100 feet of centerline distance.



Date: June 2013

Legend

- Poor Farm Dam Watershed
- Towns
- Streamlines
- Contours

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N

0 1,000 2,000 4,000 Feet

Figure 5-1
Poor Farm Pond Watershed

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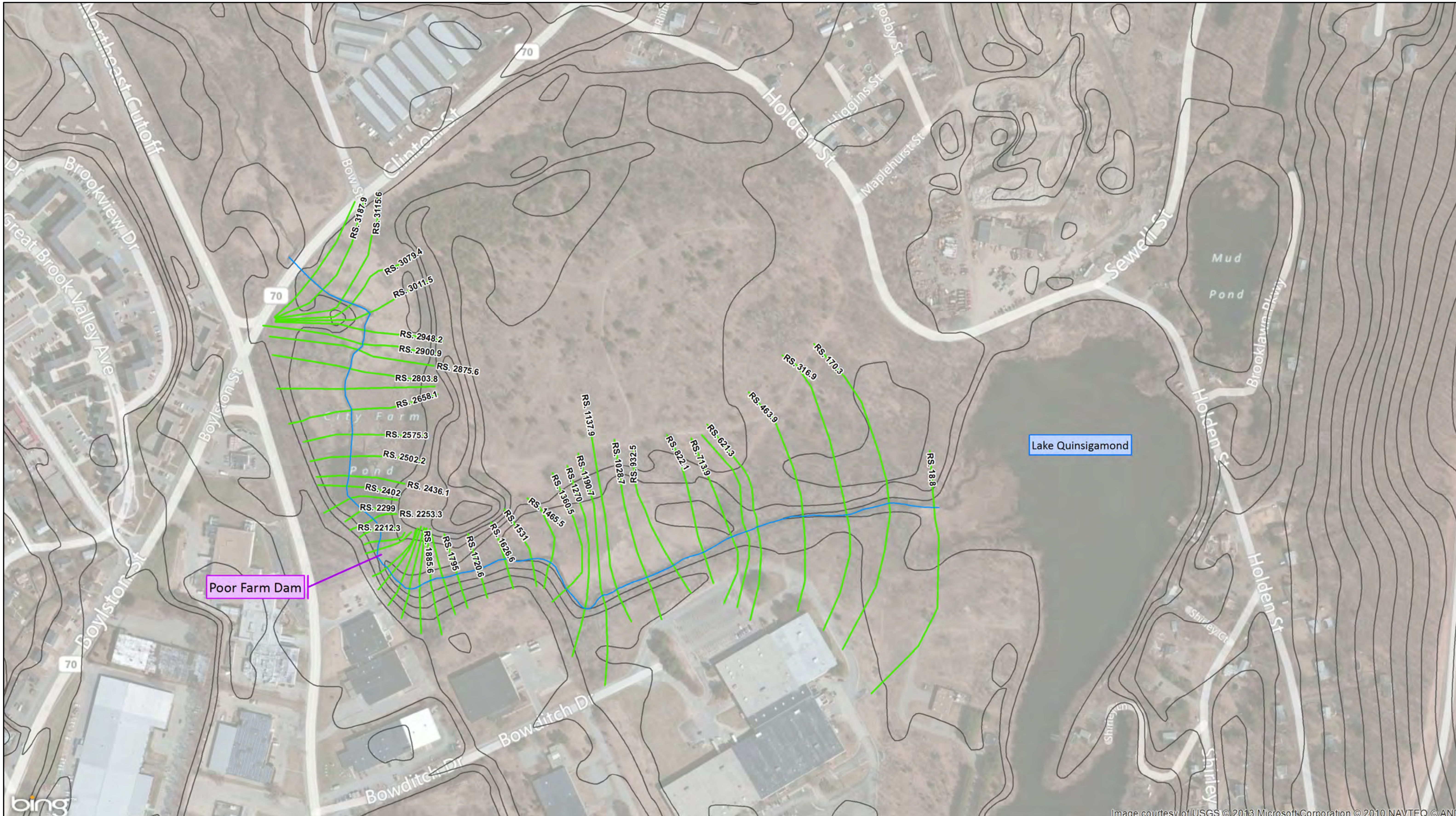

Date: June 2013

Legend

- HEC-RAS Model Centerline
- HEC-RAS Model Cross Sections
- Contours

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N

0 125 250 500 Feet

Figure 5-2
HEC-RAS Model Elements

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The overbank elevations in the cross sections are taken from the Blackstone River Valley 3-foot cell LiDAR data. Within the normal pool of the Poor Farm Pond, the cross sections are based on the bathymetric data collected in the April 2013 field survey. Upstream and downstream of the Poor Farm Pond, the channel bottom (thalwag) is based on 2013 field survey and interpolations between known elevations on upstream and downstream.

At the PFPD, the spillway is represented by an inline structure cross section based on the dimensions and elevations provided by the April 2013 survey.

5.3.3.2 Model Boundary Conditions

The downstream boundary condition of the hydraulic model is Lake Quinsigamond, the elevation of which was not explicitly modeled in the analysis. Since the reach downstream of the dam is very steep, the sensitivity of the profile in the Poor Farm Pond Brook to the elevation in the receiving waters at Lake Quinsigamond is very minimal.

The model is run in a subcritical flow regime and does not have an upstream boundary condition.

5.3.3.3 Hydraulic Parameters

Manning's roughness was used for energy loss calculations. In each cross section, roughness coefficients were assigned to the main channel defined by the bank stations selected from cross section geometry and the left and right banks. Manning's roughness coefficients for the main channel ranged from n = 0.035 to n = 0.05 based on based on field observations of the size of rocks in channel and vegetation, and the associated coefficients described by Chow (1959) and Arcement and Schneider (1989). The overbank Manning's coefficients were set at n = 0.07.

Ineffective flow areas were simulated upstream or downstream of where the flow stream was constricted such as near abutments.

5.3.3.4 Proposed Dam Removal

The proposed partial dam removal calls for the removal of the 14-foot wide spillway with a similar cut through the downstream apron. In the Poor Farm Pond, a channel with a 14-foot wide bottom and 3:1 slope sides will be cut into the sediment down to native soils. A second model geometry was built to represent the post-removal conditions. In the Poor Farm Pond, the elevation of native soils below the sediment was estimated from the 5 soil samples taken in April 2013. The hydraulics of the full dam removal alternative were not modeled separately since the full removal channel would be equal or slightly larger than the partial removal channel, resulting in negligible hydraulic differences.

5.4 Hydraulic Impact of Dam Removal

The HEC-RAS hydraulic model was run under two conditions representing the existing Poor Farm Pond and dam geometry and the proposal partial removal of the dam. The two conditions modeled (average flow and 100 year flood) are listed in Table 5-1 were run as steady flow regimes in the HEC-RAS model to produce hydraulic profiles for each scenario.

5.4.1 Hydraulics of Existing Conditions

The hydraulic profiles of the existing conditions for the average daily flow and 100-year flood are shown in Figures 5-3 and 5-4 respectively. The existing conditions model includes the bottom elevation associated with the existing sediment that has collected behind the dam. Figures 5-3 and 5-4 show the bottom elevation of the native soils that were found during the April 2013 preliminary field investigation.

5.4.2 Hydraulics of Proposed Removal

The hydraulic profiles of the Poor Farm Pond area after partial removal of the Poor Farm Dam for the average daily flow and 100-year flood are shown in Figures 5-5 and 5-6 respectively. In each proposed conditions profile, the existing profile is also shown for comparison. The post dam removal hydraulic profile is only affected in the vicinity of the Poor Farm Pond. In the area within 1000 feet upstream of the existing dam structure the hydraulic profile is lowered significantly.

The removal of the dam only decreases the peak flood stage. The impact on downstream peak flood discharge is thought to be minimal because the storage available behind the existing dam is negligible.

In the Poor Farm Pond area behind the existing dam, the velocities of the proposed condition are substantially greater from the removal of the dam. Table 5-2 shows the change in velocities at the cross section 100 feet upstream of the existing dam.

Table 5-2
Channel Velocity at RS. 2212.3 Upstream of Existing Dam

Model Scenario	Channel Velocity	
	Average Daily Flow	100-yr Flood
Existing Conditions	0.2 fps	2.0 fps
Proposed Dam Removal	1.1 fps	6.3 fps

5.4.3 Summary of Impact

The removal of the Poor Farm Dam will have little or no increase in the flood stage from the existing conditions. In the area immediately upstream of the Poor Farm Pond Dam, removal will increase the channel velocities and lower the peak flood stage.

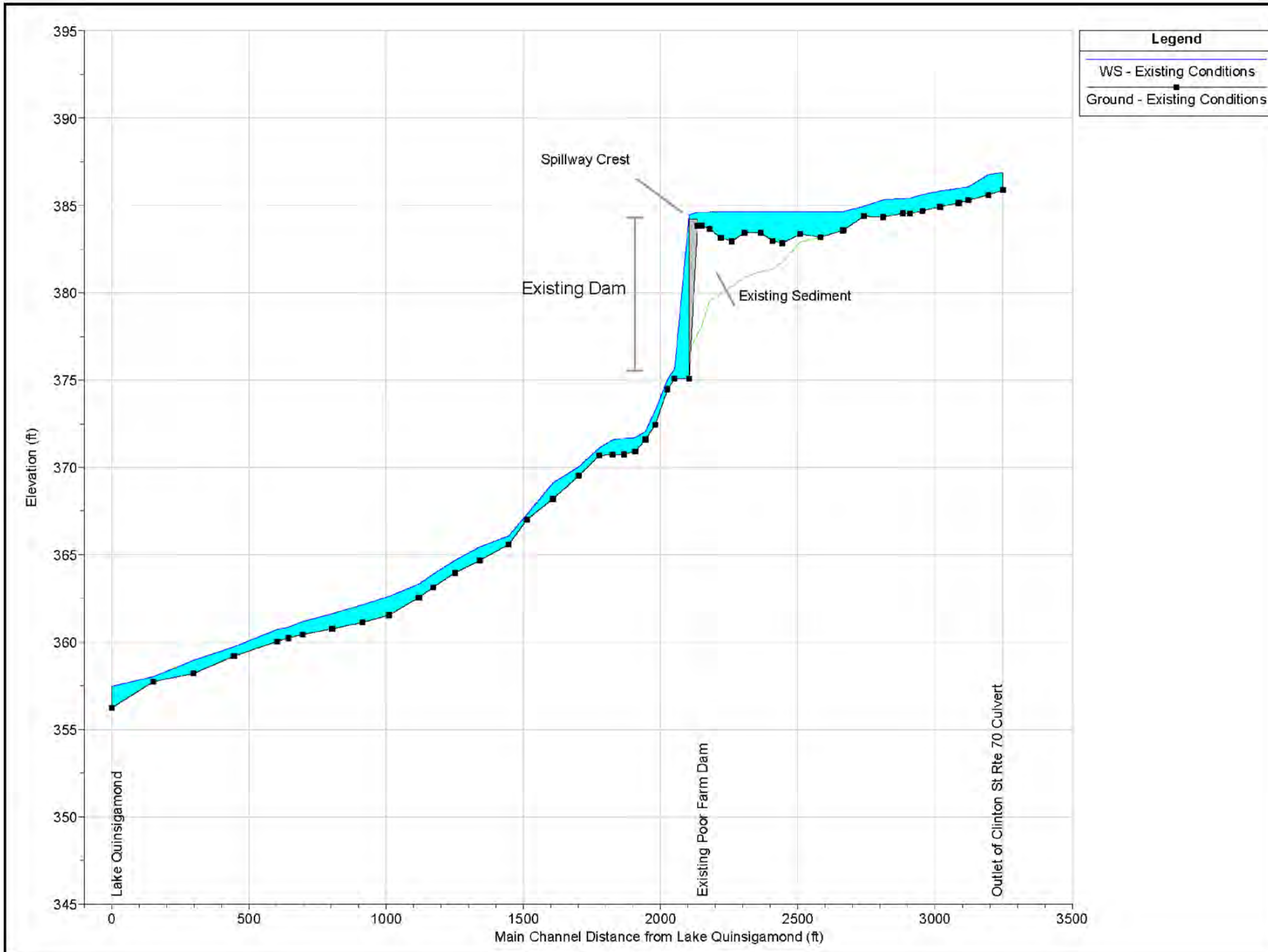

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Figure 5-3
Existing Conditions of Poor Farm Dam
Water Surface Profiles - Average Daily Flow

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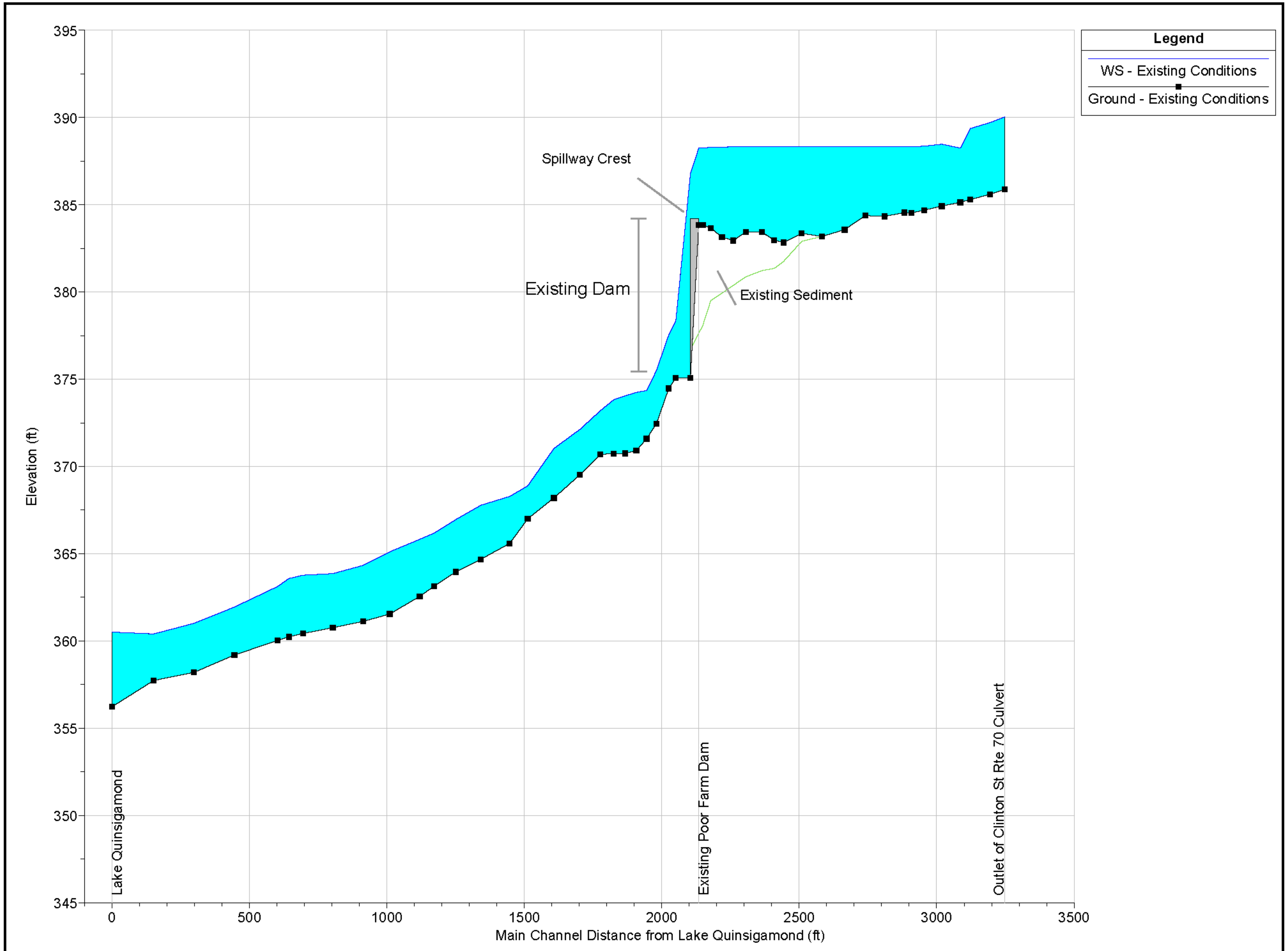

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Figure 5-4
Existing Conditions of Poor Farm Dam
Water Surface Profiles - 100-yr Flood

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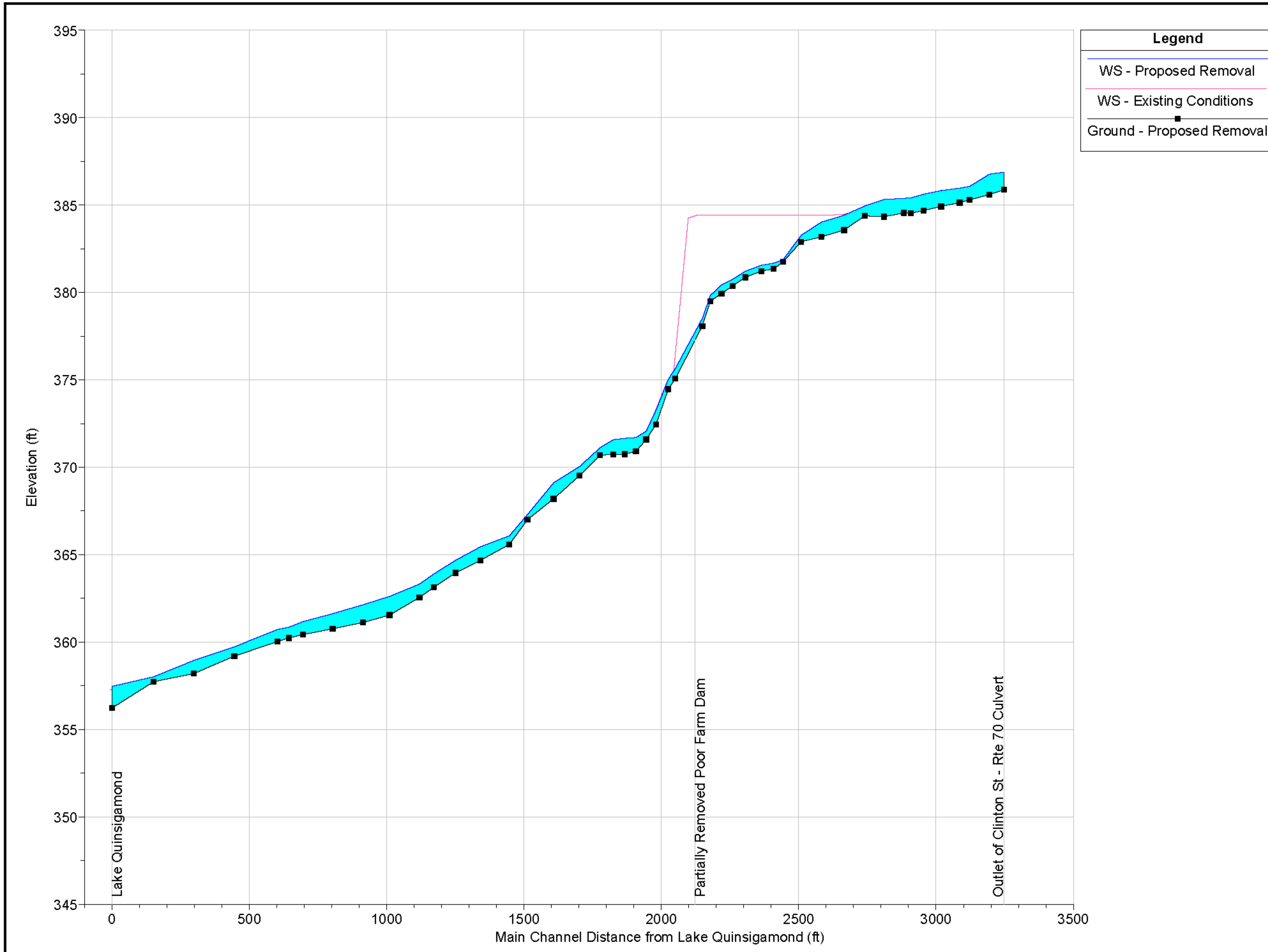

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Figure 5-5
Existing Conditions and Proposed Partial Removal of Poor Farm Dam Water Surface Profiles - Average Daily Flow

CDM Smith

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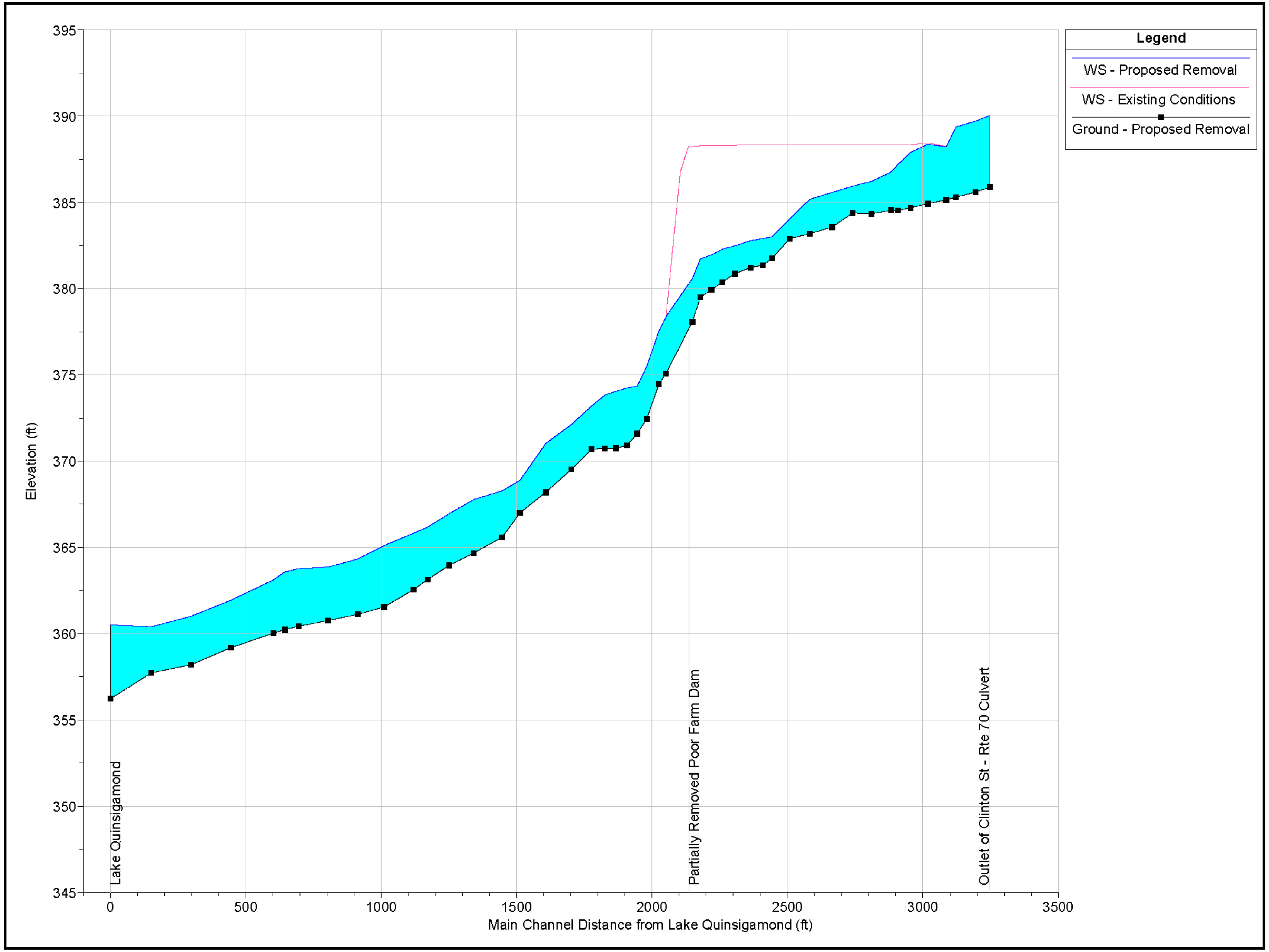

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Figure 5-6
Existing Conditions and Proposed Partial Removal of Poor Farm Dam Water Surface Profiles - 100-year Flood

CDM Smith

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5.5 References

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