Section 6
Sediment Transport Model and Evaluation

6.1 Background

A sediment transport model was included in the project scope of work to predict the future movement of sediment and soil in the streambed once the PFPD is removed.

6.2 Model Approach

A feasibility-level sediment transport simulation was performed to identify the need for geotechnical data collection and final design considerations. The most important determinate of long-term erosion upstream of the proposed dam removal is the depth to a non-erodible soil or bedrock layer. Site-specific information as to whether a non-erodible layer exists for the native material was not available. In the absence of detailed boring data in the affected area of the area upstream of the PFPD, average local soil characteristics were used to represent the native soil below the existing sediment accumulated behind the dam. The sediment transport modeling performed for this feasibility study is intended to provide a basis for identifying data needs and design options for future project phases.

Using the average area soil characteristics and a conservative assumption of depth to non-erodible soils, CDM Smith performed a sediment transport analysis using a MBH's HEC-6T model (MBH, 2010) to simulate short- and long-term changes in streambed elevation within the Poor Farm Pond and its upstream and downstream reaches.

HEC-6T is an advanced and proprietary version of U.S. Army Corps of Engineers' (USACE) HEC-6 model (USACE, 1993), which is a one-dimensional sediment transport model used to simulate a long-term average pattern of scour and deposition in rivers and reservoirs. HEC-6T predicts water surface and sediment bed surface profiles by computing the interaction between sediment material in the riverbed and the sediment carrying capacity of the river flow. As a dynamic model, it can be used to simulate the short- and long-term changes in channel and reservoir bed elevation, and can be used to evaluate existing and proposed river bed stability and sediment transport characteristics.

6.3 Model Development

The model input data for the HEC-6T consists of geometric, hydrologic, and sediment data. The model was run under the existing conditions, proposed conditions, long-term erosion, and short-term extreme flood scenarios.

6.3.1 Geometric Data

Geometric input data includes cross section geometry, reach lengths, Manning's roughness, and expansion/contraction coefficients. The HEC-RAS model developed for this study and described in Section 5 was used for geometric data. The cross sections of the developed HEC-RAS model were

converted into HEC-6T input file format. Figure 5-2 in the previous section shows the model cross sections. The existing and proposed removal geometries were both simulated.

6.3.2 Hydrology and Input Hydrograph

Hydrologic data required for HEC-6T model development includes time series flow data and a downstream flow boundary condition. For a short-term simulation, the 100-year storm hydrograph was used. For long-term simulation, daily average flow data was used as described in Section 5.3.2.

For short-term simulation it was necessary to develop a hydrograph from the peak flow estimate for the 100-year flood, which was done using a dimensionless-hydrograph derived by the USGS National Streamflow Statistics software program (Ries, 2007). The lag time used for the unit hydrograph (1.9 hours) was derived from basin characteristics taken from the National Streamflow Statistics database for Massachusetts.

6.3.3 Sediment and Transport Model

Sediment input data required for the HEC-6T model consists of streambed material gradations and inflowing sediment load data. At each location (cross sections modeled) a maximum depth to non-erodible ground is assumed. For the purposes of this feasibility study, a conservative depth to non-erodible material was selected that is likely lower than what will be found during any future boring exploration.

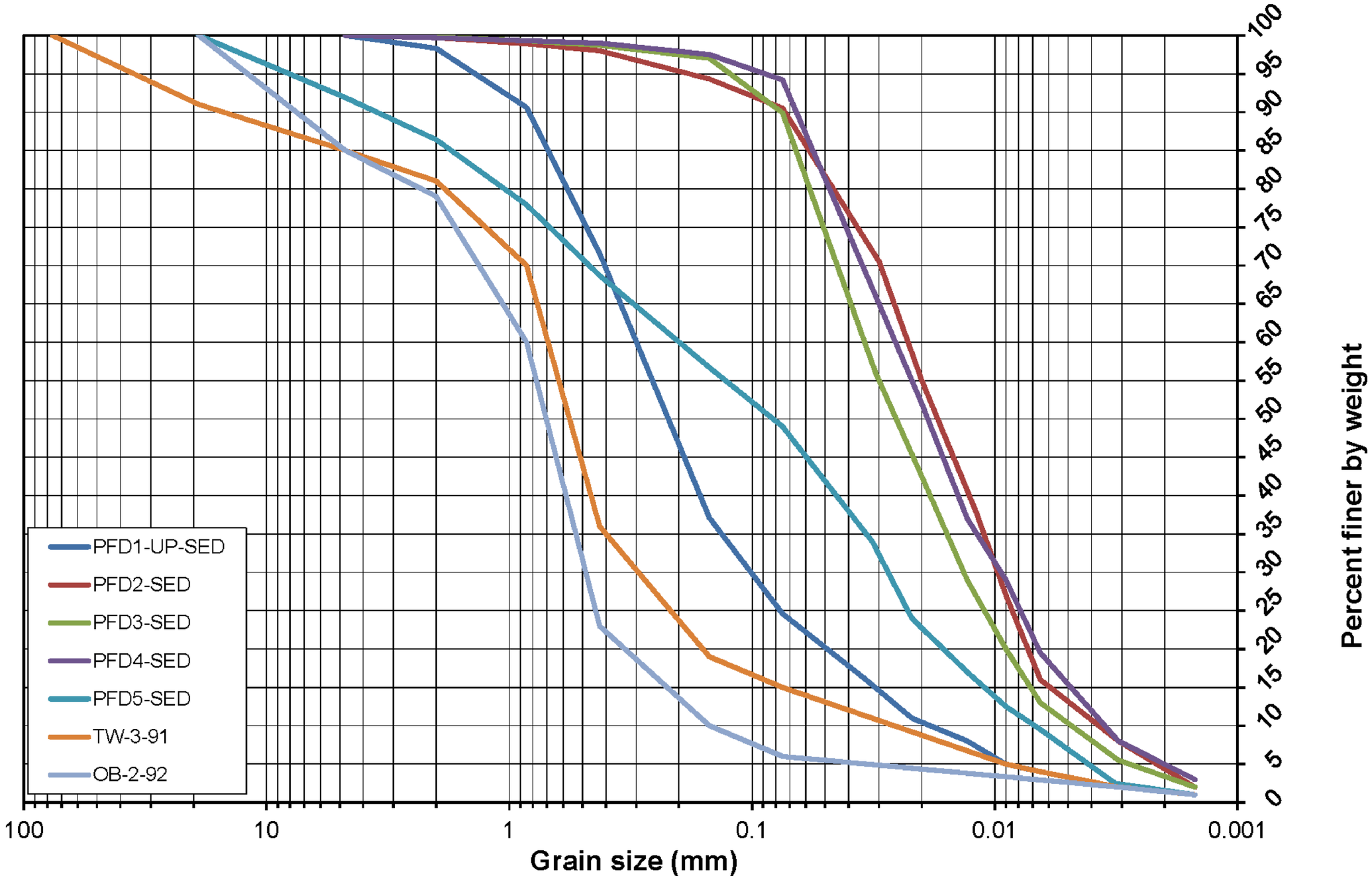
Streambed material gradation data was obtained from grain size distribution analyses for soil samples taken during the April 2013 field investigations, and from a 1999 well study performed by the City of Worcester (City of Worcester, 1999). Four samples all collected in 2013 by CDM Smith represent the accumulated sediment upstream of the existing dam structure:

- **PFD5-SED:** A sample collected within the dam impoundment; near RS 2171.1 (RS – river station)
- **PFD4-SED:** A sample collected within the dam impoundment; near RS 2299.0
- **PFD3-SED:** A sample collected within the dam impoundment; near RS 2356.9
- **PFD2-SED:** A sample collected within the dam impoundment; near RS 2402.0

Three samples including one from the 2013 CDM Smith field investigation and two from the near surface data collected in borings during the 1999 well study are considered the best available representation of the native soil below the accumulated sediment.

- **PFD1-UP-SED:** A sample collected upstream of the dam impoundment; near RS 2502.2
- **TW-3-91:** A sample collected upstream of the dam impoundment in 1999; near RS 2875.6
- **OB-2-92:** A sample collected upstream of the dam impoundment in 1999; near RS 3241.4

Figure 6-1 presents the bed material gradation curves of these seven samples.



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Worcester, Massachusetts
Poor Farm Pond Dam Removal Feasibility Study

Figure 6-1
Bed Material Gradation Curves of Soil Samples

CDM Smith

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The streambed of the reach downstream of the dam is covered with gravel and cobbles, based on field investigation. For the proposed conditions models, it was assumed that the streambed material gradation of the cross sections within the dam impoundment will be the same as that of PFD1-UP-SED after removal of the sediment within the impoundment.

In the HEC-6T model, the maximum depth below the initial streambed available for scour must be defined at each cross section. In the absence of any detailed boring data in the critical area upstream of the PFPD, a conservative depth of erodible soils was selected.

6.4 Sediment Transport Model Findings

The HEC-6T simulations of the proposed removal show that the native soil represented by the sample at PFD1-UP-SED will erode over time down to the non-erodible layer of the streambed. Without a more detailed, site-specific characterization of the native soil layer below the accumulated sediment including the depth to a non-erodible layer, the HEC-6T simulations cannot predict what the stabilized channel profile will look like after dam removal and sediment channelization.

6.5 Recommendations

Further investigation of the grain size characteristics of the native soil below the accumulated sediment to be removed during dam removal is recommended to better predict the stabilized channel profile in the Poor Farm Pond. Detailed boring information should be collected in final design to confirm the model results.

Depending on the findings of future borings consideration should be given to either: (1) allowing the stream to erode the native soil until a more resistant non-erodible streambed layer is reached, or (2) armoring the native soil in the channel to resist further erosion after the dam removal. For the purposes of estimating costs for dam removal in this feasibility study, it has been assumed that armoring the channel bottom will be necessary to resist further erosion after dam removal. Potential armoring is further discussed in Section 7 using natural channel design techniques.

6.6 References

U.S. Army Corps of Engineers (1993) *"HEC-6, Scour and Deposition in Rivers and Reservoirs, User's Manual."* Hydraulic Engineering Center (HEC), Davis, CA.

MBH Software, Inc (2010) *"HEC-6T, Sedimentation in Stream Networks; User's Manual."* Mobile Boundary Hydraulic. Clinton, MS.

Ries III, K.G. (2007) *"The National Streamflow Statistics Program: A Computer Program for Estimating Streamflow Statistics for Ungaged Sites."* U.S. Geological Survey Techniques and Methods 4-A6.

Worcester, City of (1999) *"Water Management Permit Application, Blackstone River Basin, Shrewsbury Well Development No. 215 and 359 Holden Street, Shrewsbury, MA."* Prepared by Maguire Group Inc. New Britain, CT.