Lower Mohawk River Stream Restoration Planning in Colebrook, NH

Final Report

Prepared for

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EXECUTIVE SUMMARY

The feasibility of restoring natural flow patterns to the lower Mohawk River alluvial fan without increasing flood risks to the Town of Colebrook, NH were investigated through hydraulic modeling and sediment transport calculations. An earlier fluvial geomorphic assessment of the Mohawk River demonstrated that channel straightening on the lower Mohawk River in the 1960's increased sediment delivery to the Connecticut River. Consequent with this increased sediment loading, large gravel bars formed downstream of the Mohawk River confluence, which have diverted flow into the banks at the Colebrook Business Park, causing severe erosion. Restoring flow to the channels abandoned during straightening of the Mohawk River could improve aquatic habitat while alleviating the erosion problems at the Business Park by reducing sediment delivery to the Connecticut River.

One-dimensional HEC-RAS modeling demonstrates that a railroad bridge constricting the channel upstream of the proposed restoration exerts a stronger control on upstream flooding than the proposed restoration options, so restoration downstream of the bridge should not increase hazards in Colebrook. Two-dimensional hydraulic modeling using River2D was used to evaluate changes in flow velocities, depths, and locations for various flow discharges across the lower Mohawk River alluvial fan. The lowering of the bank between the currently active channel and channels abandoned during channel straightening in the 1960's would successfully spread flow over a wider area and decrease flow velocities within the active channel. The decreased flow velocities, in turn, will decrease the size and amount of sediment transported by the lower Mohawk River. The resulting deposition of sediment on the lower Mohawk River alluvial fan will increase habitat complexity across the fan surface while reducing sediment delivery to the Connecticut River. The placement of large woody material in the currently active channel will not appreciably decrease flow velocities in the main channel beyond that achieved by lowering the bank, but will inhibit flow from reentering the current channel as the abandoned channels adjust to the diverted flow. Consequently, restoration of the lower Mohawk River will be sustainable and improve conditions at the restoration site and downstream without increasing flooding risks upstream in Colebrook. With the feasibility of restoration demonstrated, detailed engineering plans can now be developed to determine the location of bank lowering and the position and size of large woody material prior to project implementation.

1.0 INTRODUCTION

This report describes the results and recommendations of stream restoration planning activities on the lower Mohawk River in Colebrook, NH (Figure 1). The Mohawk River has a drainage area of 56 mi^2 with the restoration planning focused on the river's alluvial fan at its confluence with the Connecticut River. Bank erosion near tributary confluences on the Connecticut River was linked to sediment inputs from the tributaries during the 2004 *Fluvial Geomorphology Assessment of the Northern Connecticut River* (Field, 2004). The goal of a subsequent assessment of the Mohawk River in 2005 (Field, 2006) was to identify restoration opportunities that could not only improve channel stability on the tributaries but could also positively impact conditions on the Connecticut River. Restoration of the lower Mohawk River was identified as a high priority for restoration because of the potential for creating habitat within abandoned channels on the alluvial fan while reducing sediment delivery to the Connecticut River. The growth of large gravel bars on the Connecticut River is responsible for bank erosion at the Colebrook Business Park just downstream of the Mohawk River confluence (Figure 1). The restoration planning effort reported on here consisted of hydraulic modeling and sediment transport calculations to determine if sediment delivery to the Connecticut River can be reduced by reestablishing access to abandoned channels without increasing flood hazards to the nearby town of Colebrook. Channel straightening was completed in the 1960's to reduce flooding, so hydraulic modeling of the proposed site was also needed to ensure that restoration of flow across the alluvial fan would not increase flooding in Colebrook or at the town's waste water treatment ponds located on the alluvial fan (Figure 1). The project's results as described below were discussed with the Connecticut River Joint Commissions' Technical Advisory Committee and presented to the public at a meeting at the Colebrook Town Hall on September 5, 2007.

2.0 RESTORATION SETTING AND PURPOSE

The alluvial fan on the lower Mohawk River was chosen as the priority restoration site in the Mohawk River watershed during a geomorphic assessment completed in 2005 (Field, 2006). Channel straightening through this reach in the 1960's led to the growth of gravel bars on the Connecticut River that have contributed to bank erosion at the Colebrook Business Park. The gravel bars have grown downstream of the confluence, because channel armoring to protect Vermont Route 102 on the bank directly opposite the confluence constricts the flow and forces most of the sediment further downstream. Small gravel bars are, however, found at the confluence (Figure 1). Long term success in controlling bank erosion at the Colebrook Business Park will depend on reductions in sediment supply from the Mohawk River. Since the diversion of flow into the banks resulting from bar development is the immediate cause for erosion, erosive pressures at the site will remain unless the growth of the gravel bars is curtailed.

Five management options were considered for reducing sediment loads on the Connecticut River during the 2005 assessment: do nothing; remove the gravel bar at the mouth of the Mohawk River; engineer a meandering channel that trends along the current flow path; restore flow to abandoned side channels south of the current channel; and restore flow to abandoned channels north of the current channel. Restoring flow to the abandoned channels on the north side of the current channel is the favored option for managing the site and its feasibility is further analyzed here. More area is available for restoration to the north side of the currently active channel and flow could enter the Connecticut River at multiple locations rather than at the present single location. Spreading flow out over multiple paths could lead to the deposition of sediment before it enters the Connecticut River, reduce flow velocities impacting the rock revetment protecting Vermont Route 102 on the opposite side of the Connecticut River, and create side channel rearing habitat and wetlands for the diverse fish and waterfowl species found on the Connecticut River. Flow could be returned to the abandoned channels by lowering the bank between the channels and by blocking flow in the current channel with an engineered log jam. Extensive excavation of new flow paths would not be required. Since natural flow conditions would be restored, the reduction in sediment inputs to the Connecticut River and resulting habitat improvements would be sustainable over the long term.

While sediment storage could be achieved elsewhere in the Mohawk River watershed where the channel has been artificially straightened, improvements to channel stability will be greatest immediately adjacent to a given project site. Therefore, in an effort to reduce sediment inputs and the resulting erosion on the Connecticut River, the lower Mohawk River is the best site to encourage deposition and long term sediment storage. The Town of Colebrook, which owns the land on the alluvial fan, supports the conceptual design and is interested in pursuing restoration if flood hazards are not increased by the diversion of flow to the abandoned channels. Hydraulic modeling and an evaluation of sediment transport are needed to establish if significant sediment storage will occur with a reconfiguration of flow paths and to assess if increased flooding might jeopardize human infrastructure in Colebrook.

3.0 HYDRAULIC MODELING

Quantitative hydraulic modeling was conducted to better understand the potential changes in direction, depth, and velocity of flow that will occur if flow is encouraged to reenter the abandoned side channels. The feasibility of restoring natural flows to the alluvial fan surface was considered for flows of varying flow magnitude; the 2, 5, 10, 50, and 100-year recurrence interval events were considered. Comparisons were made between the existing straightened channel condition and the expected flow conditions if the bank between the largest abandoned channel and the main channel were lowered (Figure 1). The hydraulic modeling also considered flow conditions that would result if the bed of the main channel immediately downstream of the lowered bank were raised 1.0 m (3.3 ft) and 1.5 m (4.9 ft), respectively. While the modeling assumed the channel bed was raised with an impermeable barrier, the modeled barrier was considered to mimic an engineered log jam built across the channel.

Both 1-dimensional (HEC-RAS) and 2-dimensional (River 2D) hydraulic computer models were utilized for the analysis. Aerial photographs (Appendix 1) taken by Eastern Topographics, Inc. of Wolfeboro, NH were used to generate a 1-foot contour map (Appendix 2) that provided, along with supplementary ground surveys, the necessary topographic information to complete the modeling. Details regarding model setup and the synthetic generation of the flow discharges used in the modeling are described in the hydraulic modeling report (Appendix 3). Woodlot Alternatives, Inc. of Topsham, Maine completed the hydraulic modeling.

The 1-dimensional modeling reveals that the railroad bridge upstream of the proposed restoration area but downstream of Colebrook (Figure 1) constricts flows. As such, water is impounded behind the bridge with the water surface upstream of the bridge as much as 3.0 ft higher than downstream of the bridge during a 100-year event (Figure 2). Given the control the railroad bridge has on flow depths, restoration activities undertaken downstream of the bridge should not increase flood hazards in Colebrook, located upstream of the bridge. The berms around the water treatment ponds are not overtopped during the 100-year event, so should not be impacted by restoration activities either.

The 2-dimensional modeling reveals that high velocity flows are focused within the main channel under the existing condition (Figure 3a). The creation of a notch in the bank between the current and abandoned channel results in a decrease in flow velocities within the current channel with high velocity flows focused through the lowered bank (Figure 3b). These flow velocities appear to rapidly dissipate downstream. The modeling provides an instantaneous snapshot of what flow conditions would look like immediately following restoration for the modeled discharge. The dramatic changes in flow velocities in a downstream direction along the abandoned channel would not persist with bank erosion and deposition likely to occur in various locations in order to ameliorate the rate of change in flow velocities over a longer distance. While the creation of a 1.0 m (3.3 ft) block in the main channel downstream of the lowered bank has little impact on flow velocities compared to a lowering of the bank only (Figures 3b and 3c), the presence of an engineered log jam in this position would likely discourage flow from reentering the main channel after flow is first reintroduced into the abandoned channel and adjusts to the rapid changes in flow velocities. The creation of a 1.5 m (4.9 ft) channel block would similarly discourage flow from reentering the main channel and also further reduce flow velocities in the main channel compared to simply lowering the bank without any blockage of the current channel (Figures 3b and 3d).

Although not included in the hydraulic modeling, large logs or partial log jams should likely be installed along the current channel downstream of the proposed lowered bank to further discourage flow from reentering the existing channel, reduce flow velocities, and encourage deposition within the channel. The channel bed elevation would increase with this deposition in the channel and ensure less and less flow continues down the existing channel over time.

4.0 EVALUATION OF SEDIMENT TRANSPORT

The hydraulic modeling shows that all of the proposed restoration options for all modeled discharges will reduce flow velocities in the existing channel and spread flow more evenly across the alluvial fan surface on the lower Mohawk River (Appendix 3). The potential volume of sediment that can be stored on the alluvial fan relative to the volume of sediment in the gravel bars on the Connecticut River downstream of the Mohawk River is an important consideration in determining the potential effectiveness of the proposed restoration. To determine if changes in flow velocity and location on the alluvial fan surface will lead to sediment deposition, the sediment transport competence and capacity were evaluated using shear stress calculations and sediment transport equations, respectively.

4.1 Comparison of Sediment Volumes

Long term reductions in sediment delivery to the large gravel bars causing erosion at the Colebrook Business Park will occur if a sufficient volume of sediment can be stored on the lower Mohawk River alluvial fan. The volume of sediment present in the gravel bars on the Connecticut River between the Mohawk River confluence and Colebrook Business Park (Figure 1) is estimated to be 8,200 m^3 (10,830 yd^3), assuming a uniform bar depth of 0.5 m (1.6 ft) for the entire area of gravel bars observed above the water surface seen on the 2003 aerial photographs (Table 1). While the bar depth may be greater than 0.5 m (1.6 ft) in some areas, the bar depth tapers to nothing at the water's edge, so the uniform depth assumption is considered reasonably accurate. In comparison, a total volume of 10,830 m^3 (14,160 yd^3) can be potentially stored on the lower Mohawk River through sediment infilling of the channel's cross sectional area along the length of the existing active channel and the largest abandoned channel to which flow is to be restored (Table 1). The estimated storage capacity should be considered a minimum as numerous smaller abandoned channels are not used in the calculation nor is the potential sediment storage on the alluvial fan surface itself considered. The fact that the potential sediment storage on the lower Mohawk River is greater than the volume of gravel present in the bars on the Connecticut River does not mean the gravel bars will disappear if restoration occurs on the lower Mohawk River, because some sediment will continue to be delivered from both the Mohawk River and Connecticut River. However, the potential for a large volume of sediment storage on the lower Mohawk River does suggest that the gravel bars on the Connecticut River downstream of the confluence are likely to diminish in size over time if restoration occurs.

4.2 Shear Stress Calculations

Shear stress calculations are used to determine a stream's competence or the maximum size of sediment that can be transported for a given discharge. The shear stress produced in the channel is a function of the river's depth and slope with deeper and steeper river flows capable of transporting larger particles. Shields equation is used to determine the critical shear stress needed to transport a particle of a given size (Shields, 1936). This can be compared with the shear stress generated in the channel for a given discharge to determine if sediment in the channel will be mobilized by the flow. Under existing conditions on the lower Mohawk River, the maximum particle size that can be transported for a 2-year recurrence interval discharge, a flow that will fill the channel to the top of its banks, is estimated to be 13 cm (5.1 in) in diameter (Table 2). With restoration, water will be diverted out of the existing channel, resulting in decreases in water depth, slope, and shear stress for the same 2-year discharge. Consequently, the maximum particle size that can be transported down the main channel will decline to 3.3 cm (1.3 in) diameter (Table 2). Particles between 13 cm (5.1 in) and 3.3 cm (1.3 in) in diameter that would currently be transported through the reach and into the Connecticut River would, under the restoration scenarios, no longer be transported through the reach and would be deposited along the lower Mohawk River.

4.3 Sediment Transport Equations

A stream's capacity is a measure of the amount of sediment, by weight, that a stream can move for a given discharge. Several sediment transport equations have been developed to calculate stream capacity, but none have proven particularly accurate (Gomez and Church, 1989). However, sediment transport equations can be useful for comparing relative, if not absolute, differences in sediment transport under different conditions along the same stream reach. The transport capacity on the lower Mohawk River for the 2-year recurrence interval discharge under existing conditions and for the various restoration scenarios was compared using the Meyer-Peter equation (Gomez and Church, 1989). The Meyer-Peter equation was chosen because of its relative ease of use and requires an input of discharge and slope, channel width, and size of sediment in transport – variables available from the hydraulic modeling, surveys, and pebble counts, respectively. The equation calculates sediment transport for a unit width of stream channel with the total sediment transport determined by multiplying the equation results with the total width of the channel. The transport calculations demonstrate that sediment transport will decrease by more than 50 percent in the main channel as the result of implementing the various restoration scenarios on the lower Mohawk River (Table 3). The total sediment transport calculated should be considered a minimum as transport was calculated for only the currently active channel. With restoration, some of the decreased transport capacity in the main channel would be transferred to the abandoned channels, but the increased length of channel (and consequent decrease in slope) and overall increased width of flow (as water spreads out into multiple channels) ensure that the transport capacity of the stream after restoration will not match that of the existing conditions. While the changes in calculated sediment transport cannot be readily equated to potential changes to the gravel bars on the Connecticut River downstream of the Mohawk River confluence, the decreases in transport capacity do demonstrate that the implementation of any of the modeled restoration options will lead to sediment deposition on the lower Mohawk River alluvial fan.

5.0 CONCLUSIONS

Hydraulic modeling was used to investigate the feasibility of restoring natural flow patterns to the lower Mohawk River alluvial fan without increasing flood hazards in the nearby town of Colebrook, NH. The presence of a narrow railroad bridge upstream of the proposed restoration area was demonstrated to exert a stronger control on upstream flooding than the proposed restoration options, so restoration downstream of the bridge should not increase hazards in Colebrook. The lowering of the bank between the currently active channel and channels abandoned during channel straightening in the 1960's would successfully spread flow over a wider area and decrease flow velocities within the active channel. The decreased flow velocities, in turn, will decrease the size and amount of sediment transported across the lower Mohawk River. The resulting deposition of sediment on the lower Mohawk River alluvial fan will increase habitat complexity across the fan surface while reducing sediment delivery to the Connecticut River. Gravel bars on the Connecticut River downstream of the Mohawk River confluence should be expected to decrease in size over time with restoration of the lower Mohawk River. The rate of bank erosion at the Colebrook Business Park caused by flow deflection around the gravel bars should also decrease and permit more effective stabilization of the banks.

While hydraulic modeling does not show dramatic differences in flow velocities occurring between the bank lowering scenario and those scenarios combining bank lowering with the creation of channel blocks immediately downstream on the active channel, the placement of engineered log jams in the current channel are recommended to ensure flows continue to be diverted into the abandoned channels following the initial restoration. The large volume of sediment potentially stored by adding large woody material and other roughness elements to the active channel and spreading flow over the wide alluvial fan surface will lead to sustainable habitat improvements on the lower Mohawk River while reducing sediment delivery to the Connecticut River. Both the Connecticut River Joint Commissions' Technical Advisory Committee and Town of Colebrook have expressed support for the project concept (Appendix 4). Therefore, restoration of the lower Mohawk River can proceed and will not only benefit the restored area but will also improve conditions downstream. With the feasibility of restoration of the lower Mohawk River demonstrated through hydraulic modeling and sediment transport calculations, detailed engineering plans showing the exact location of bank lowering and placement and size of large woody material can now be completed before final implementation.

6.0 REFERENCES

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Gomez, B., and Church, M., 1989, An assessment of bed load sediment transport formulae for gravel bed rivers: Water Resources Research, v. 25, p. 1161-1186.

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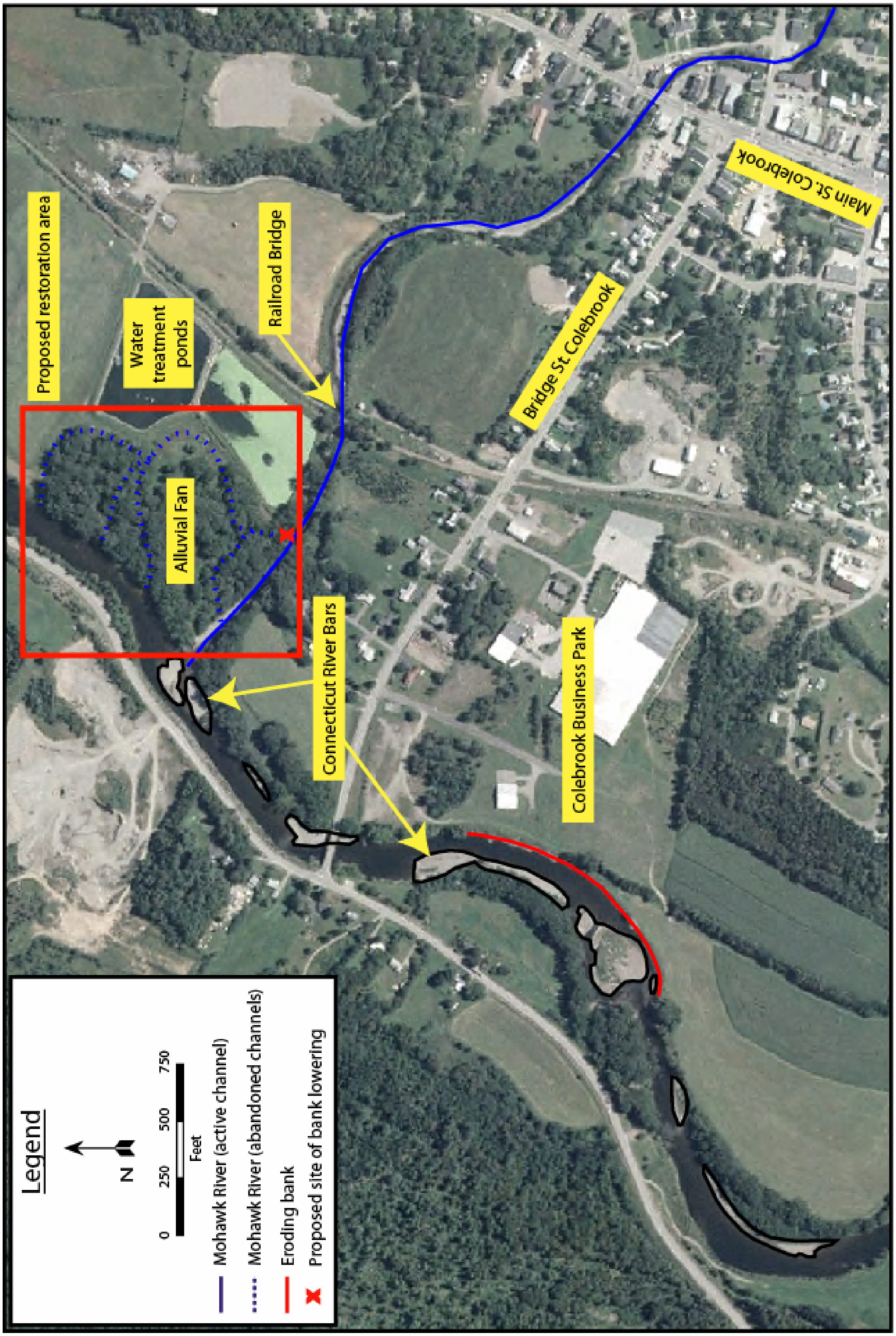

Figure 1. Location of lower Mohawk River alluvial fan and proposed restoration area showing key features mentioned in text.

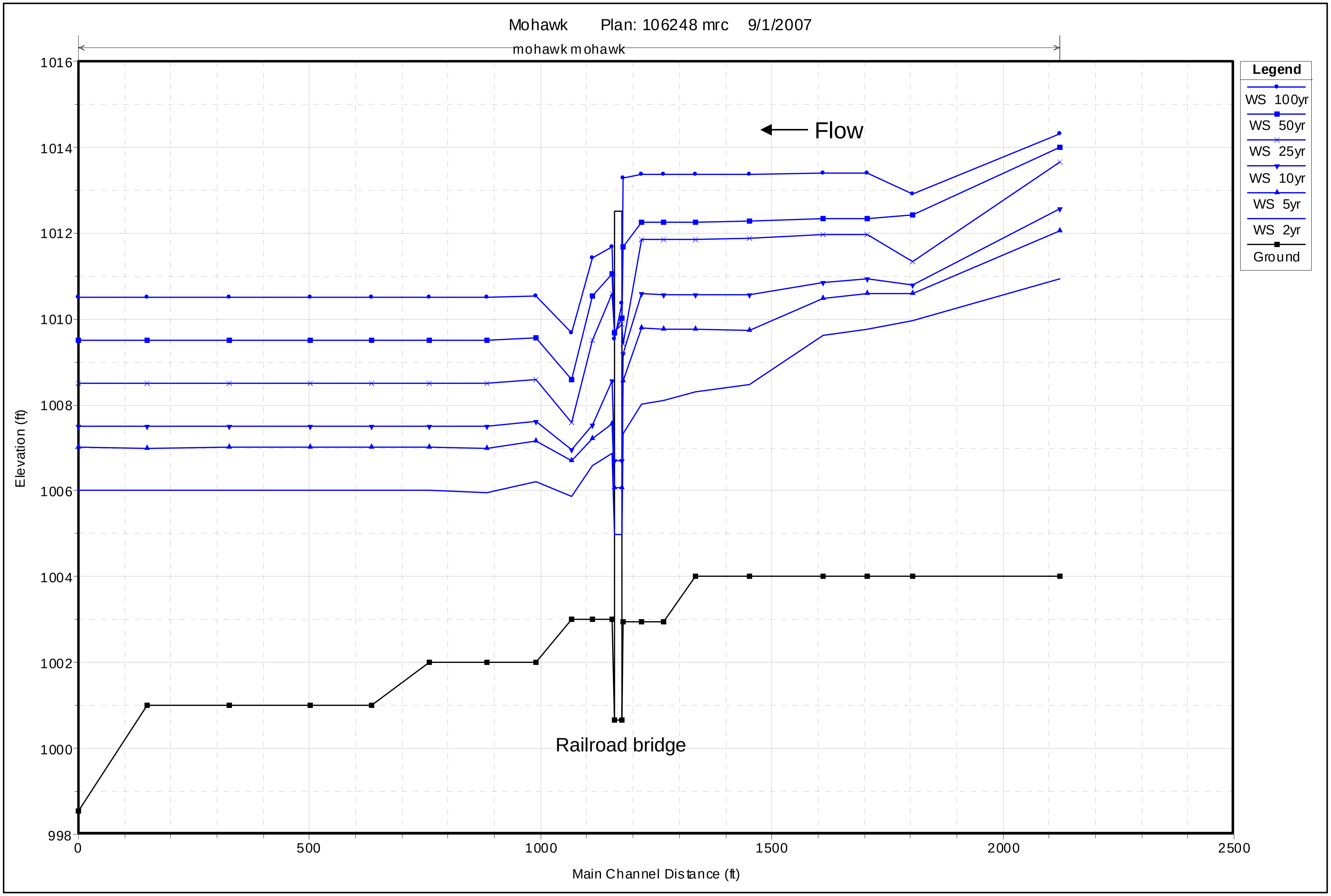

Figure 2. Water surface profile of the lower Mohawk River from HEC-RAS modeling for various recurrence interval flow events. Note how water surface is significantly higher upstream of the railroad bridge.

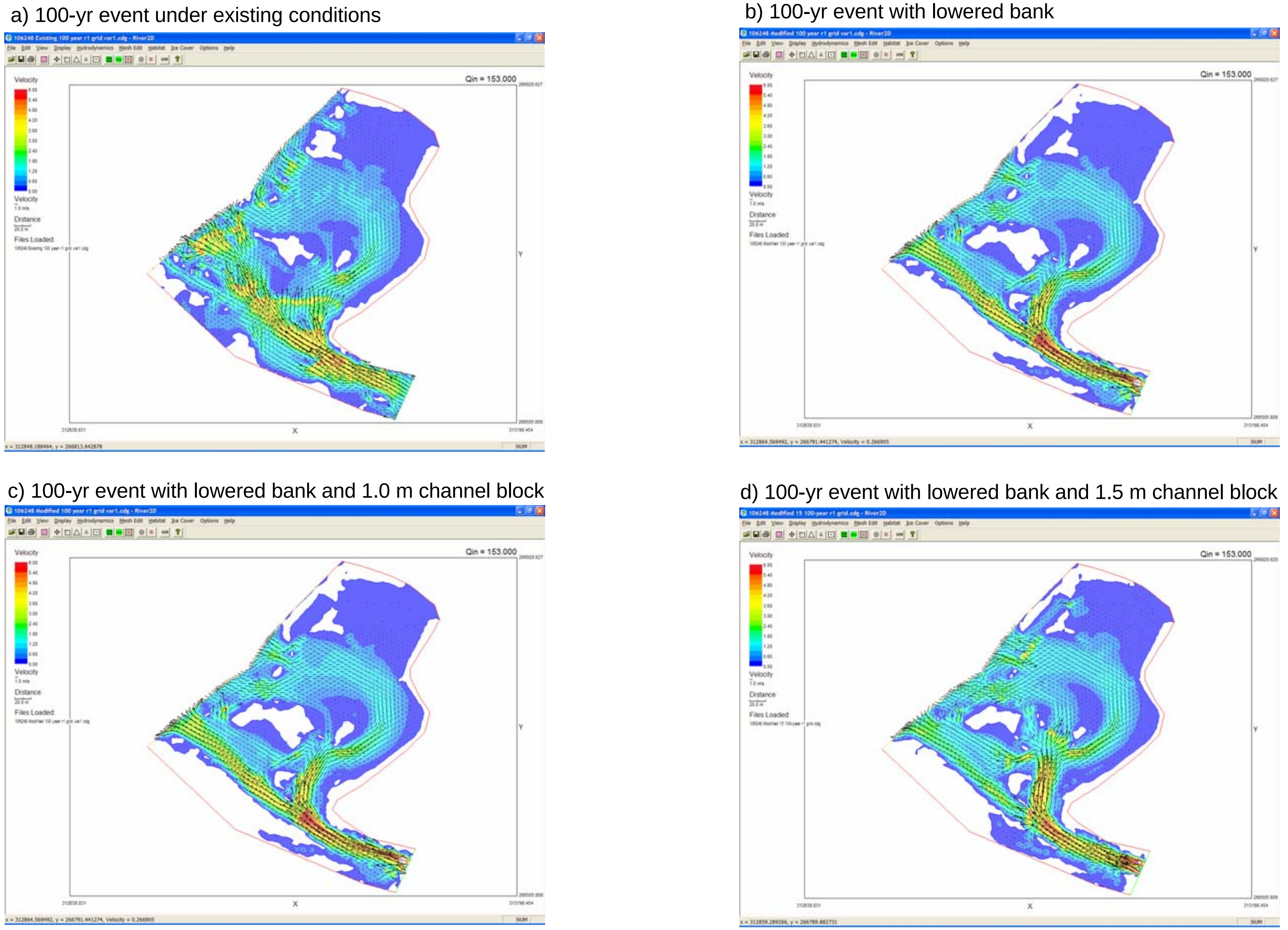

Figure 3. A comparison of predicted flow velocities during a 100-year recurrence interval event on the lower Mohawk River for the existing condition and various restoration options. Note that reds and yellows represent higher flow velocities and blues and greens lower velocities.

River	Feature	Area (m^2)*	Length/depth (m)**	Volume (m^3)
Mohawk River	Main channel	32.3	205.5	6,638.9
	Secondary channel	9.5	441.2	4,193.2
	Total potential storage	41.8	646.7	10,832.0
Connecticut River	Gravel bars	16,564.0	0.5	8,282.0

* Area of channels on Mohawk River is cross sectional area while area of bars on Connecticut River is planview area
** Channel length for Mohawk River and assumed uniform bar depth above water surface for Connecticut River bars

Table 1. Comparison of estimated gravel bar volume on Connecticut River with potential sediment storage along active and abandoned channel on lower Mohawk River.

Restoration option	Water depth (m)	Gradient (m/m)	Shear stress (N/m^2)	Maximum sediment size transported (cm)*
Existing conditions	1.62	0.00771	122.09	13.0
Lowered bank	0.63	0.00506	30.98	3.3
Lowered bank with 1.0 m channel block	0.69	0.00431	28.96	3.1
Lowered bank with 1.5 m channel block	0.61	0.00471	27.95	3.0

* Based on Shields equation for the given shear stress
Note: N = Newtons, the metric equivalent to pounds

Table 2. Changes in stream competence associated with different restoration options for a 2-year recurrence interval event along the active channel on the lower Mohawk River.

Restoration option	2-year discharge (ft^3/s)	Channel width (ft)	Gradient (ft/ft)	D_{50} (ft)*	Unit sediment transport (lbs/s/ft)**	Total sediment transport (lbs/s)
Existing conditions	1531	62.0	0.00771	0.052	2.99	185.03
Lowered bank	1531	62.0	0.00506	0.052	1.28	79.37
Lowered bank with 1.0 m channel block	1531	62.0	0.00431	0.052	0.90	55.53
Lowered bank with 1.5 m channel block	1531	62.0	0.00471	0.052	1.10	68.02

* D_{50} is the median particle diameter determined from a pebble count downstream of the proposed bank lowering where the intermediate particle diameter of 100 randomly selected particles on the channel bed were measured

** The sediment transport per unit width of channel was calculated using the Meyer-Peter equation: $qb = (39.25q^{0.65}*S-9.95*D50)^{1.5}$, where q is water discharge per unit width of channel, S is water surface slope or gradient, and D50 is the median particle diameter

Note: The total sediment transport per second is calculated by multiplying the unit sediment transport by the channel width. If the total duration of the flow is known the total weight transported can also be calculated.

Table 3. Changes in sediment transport capacity associated with different restoration options for a 2-year recurrence interval event along the active channel on the lower Mohawk River.