APPENDIX G:

Tubbs and Ladd Brook Project Development Summaries

Pownal and Bennington, Vermont

River Corridor Plan for Tubbs and Ladd Brook - Project Development

The corridor planning partners reviewed and commented on the list of preliminary projects during a watershed tour in August, 2017, and via email. A total of 34 projects are described in the River Corridor Plan. A subset of 12 high-priority projects were discussed for further development. Five (5) project areas from the list of high-priority projects were chosen for further development. Project summaries are included in this appendix for the five highest priority project bundles. Each summary includes:

- A description of the site location and river reach
- A brief technical summary of the stressors on channel stability, aquatic habitat, and flooding
- A description of channel and floodplain restoration alternatives
- Preliminary cost opinions for restoration alternatives
- A list of current and potential technical partners and funding
- A review of regulatory requirements

The five project bundles chosen for further investigation were:

1. Project TB 6: Reach M01T1.02 on Tubbs Brook - A cross culvert carrying runoff from Skiparee Road and upstream areas has caused significant gully erosion of the valley wall and along the floodplain leading to Tubbs Brook.
    - *Active Restoration: Gully Stabilization and Culvert Replacement*
2. Project TB 10: Reach T8.01 on Tubbs Brook - Stormwater runoff from Fowlers Way and Mt Anthony Rd spill on the floodplain and into the channel through a ditch turnout. Large plumes of fine sediment are visible on the floodplain and into the channel.
    - *Active Restoration: Gravel Road Erosion BMPs*
3. Project LB 1: Reach M05S1.01 on Ladd Brook - The two undersized culverts (4ft diameter) under an old, abandoned crossing west (downstream) of the railroad crossing are causing sediment and debris deposition at the inlet, potentially exacerbating flooding in the nearby mobile home park.
    - *Active Restoration: Stream Crossing Removal, Stream Channel Restoration*
4. Project LB 2: Reach M05S1.01 on Ladd Brook - The railroad culvert is 6ft tall and 4ft wide, while the bankfull channel width is 17ft. This constriction causes aggradation and channel instability upstream, and exacerbates severe flooding in the adjacent mobile home park during large floods.
    - *Active Restoration: Culvert Replacement or Retrofit*
5. Project LB 3: Reach M05S1.01 on Ladd Brook - A makeshift dam built from railroad ties, stumps, and a rubber liner is located just upstream of the mobile home park. The dam is causing aggradation upstream and may exacerbate flooding to nearby mobile homes.
    - *Active Restoration: Dam Removal*

Project TB 6, Gully Along Skiparee Road

Existing Conditions

Project TB 6 is found at the intersection of Skiparee Road and Hemlock Hill Road in Pownal. Two culverts carry an intermittent tributary to Tubbs Brook, crossing first beneath Hemlock Hill Road through a 24-inch corrugated steel culvert, and then beneath Skiparee Road through an 18-inch corrugated plastic culvert (see Figure 6 on page 5). The outlet end of the 18-inch culvert is perched approximately 5 feet above a steep riprap slope (Figure 1), which then descends another 10-12 feet down a very steep embankment (approx. 1V:1H) into a gully. The gully flows to the west and into Tubbs Brook (Reach M01T1.02). It appears the gully has incised significantly through an erodible terrace feature along the brook over the years, as the outlet to the Tubbs Brook channel is V-shaped and 4-5 feet deep.

Figure 1: Perched culvert causing erosion and gullying along the embankment of Skiparee Road.

Figure 2: Gully downstream of the unstable culvert outlet. Tubbs Brook is in the background.

Problem Overview

This reach of Tubbs Brook shows signs of significant aggradation (i.e., accumulation) of gravel in the main channel, which has led to widening and bank erosion downstream. The gully has likely been a large source of sediment to the brook over the years, and continues to be a significant source today as the banks are unstable and the undersized culvert likely "jets" water at the banks during large runoff events. The soils at the site are a Georgia Loam, which are prone to erosion (i.e., classified as highly erodible), particularly in the river corridor where finer sediment deposits are found. We estimate that over 50 cubic yards of soil has eroded into Tubbs Brook from this location in the past, contributing to fine sediment loading and impaired status of the brook. This is equivalent to about 3 large dump trucks of sediment.

We evaluated the culverts beneath both roads for hydraulic capacity, and found that both culverts are undersized for the upstream watershed area of 35 acres. Culvert were analyzed with FHWA HY-8 software, and watershed hydrology was estimated using a rainfall-runoff model of the upstream area using NRCS TR-20 methods (i.e., HydroCAD). Based on this analysis, we estimated that a 36-inch diameter culvert would be required to accommodate the 25-year storm without overtopping the road. This is consistent with VTANR's culvert sizing recommendations for intermittent streams based on the upslope drainage area.

Scope of Work and Cost Estimate

The Town of Pownal and BCRC applied for and received funding from the VTDEC Watershed Grant Program to cover the costs of gully stabilization and culvert replacement. This work is slated for 2018. At this point the Town will be responsible for the culvert replacement and associated bank stabilization, and BCRC and the Town will coordinate a work crew (i.e., VYCC) to complete the downstream gully stabilization work, with oversight from FEA. The main components of the work are described below

<u>Culvert Replacement</u>

The existing 18-inch HDPE culvert will be replaced with a 36-inch HDPE culvert by the Town. We estimate the culvert will need to be at least 35 feet long to achieve the desired profile. Recommended design elements include:

- Maintain a similar inlet configuration, but drop the outlet elevation 4-5 feet to reduce the drop into the gully and thereby reduce future scour (see Figure 7 on page 6).
- Install appropriate gravel bedding beneath the new culvert, and use geotextile fabric as needed to separate native soils from bedding if saturated heavy soils are encountered.
- Install Type II stone riprap at the culvert outlet and continue 10-15 feet downstream to slope break. Avoid use of geotextile fabric to separate Type II stone from native soils (use gravel bedding as needed).
- Stabilize the upper banks between the Type II stone and the road edge with topsoil, erosion control fabric (or mulch hay on flatter slopes), and conservation seed.

<u>Gully Stabilization</u>

Based on our survey data and gully observations, and past experience with similar gully stabilization projects, we think a non-mechanized approach to gully stabilizing would be best. Machinery access is very challenging given the steep terrain, and would involve clearing trees on steep slopes close to the brook. Therefore, we recommend the work be completed with hand labor. The following design elements are recommended:

- Utilize a work crew such as Vermont Youth Conservation Corps (VYCC) or similar group for up to 2 days to install up to three (3) log check dams (see Figure 7 on page 6).
- Check dams will be made of a combination of decay-resistant logs and stone, along with rebar and timberlock screws for stabilizing and fastening the structures (see specifications on following page).

Figure 3: "V-type" log check dam designed and installed by FEA on a gully in Colchester, VT. Flow is from right to left.

Figure 4: "Straight" log check dam designed and installed by FEA on a gully in Colchester, VT. Flow is from left to right.

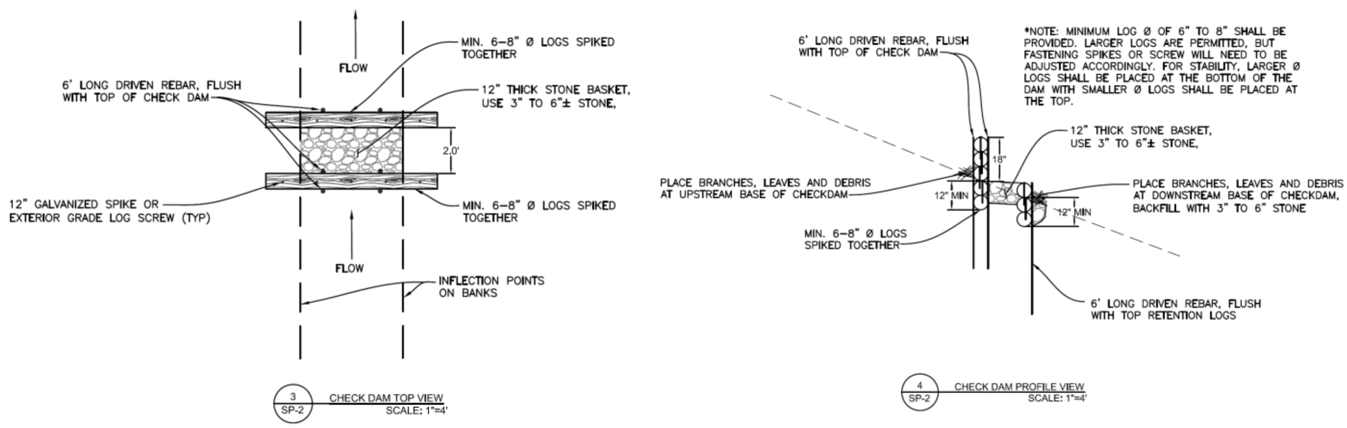


Figure 5: Log check dam top view (left) and profile view (right). Logs will be keyed into the banks and into the gully bottom to reduce the risk of erosion around or under the structure. A stone filled splash area will limit erosion on the downstream end of the structure. Drawings from a project completed by FEA in Colchester, Vermont.

<u>Project Cost Estimate</u>

Item Type	Description	Unit	Estimated Quantity	Unit Price	Cost
Labor & Equipment	Excavator and Operator	HR	16	$120.00	$1,920.00
	Trucking	HR	16	$90.00	$1,440.00
	Laborer	HR	32	$35.00	$1,120.00
	VYCC Crew	DAY	2	$1,800.00	$3,600.00
Materials	36" diameter HDPE Culvert	LF	40	$42.50	$1,700.00
	Stone Fill (2" minus; Type II)	CY	25	$20.00	$500.00
	Logs for Check Dams	LS	1	$500.00	$500.00
	Rebar	LF	100	$0.75	$75.00
	Timberlock Screws	LS	1	$200.00	$200.00
	Erosion Control Fabric	SQYD	50	$0.80	$40.00
	Conservation Mix	LS	1	$50.00	$50.00
	Topsoil	CY	5	$40.00	$200.00
		Labor & Equipment Subtotal:			$8,080.00
			Materials Subtotal:		$3,265.00
				Total:	**$11,345.00**
			Town In-kind Labor:		**$4,480.00**
		Needed from Watershed Grant:			**$6,865.00**

Regulatory Requirements

VTDEC River Engineer Josh Carvajal visited the site and determined the stream channel is intermittent, therefore VTDEC stream alterations clearances are not required. Proposed disturbances below ordinary high water (OHW) are well below the Army Corps of Engineers (USACE) reporting threshold of 3,000sqft, therefore USACE clearances are not required. At this time clearing of trees over 3 inches in diameter is not anticipated. If the scope of work changes, any proposed clearing of trees may need to be coordinated with USACE and other federal agencies (i.e., USFWS) to avoid or minimize impacts on potential habitat for threatened or endangered bat species.

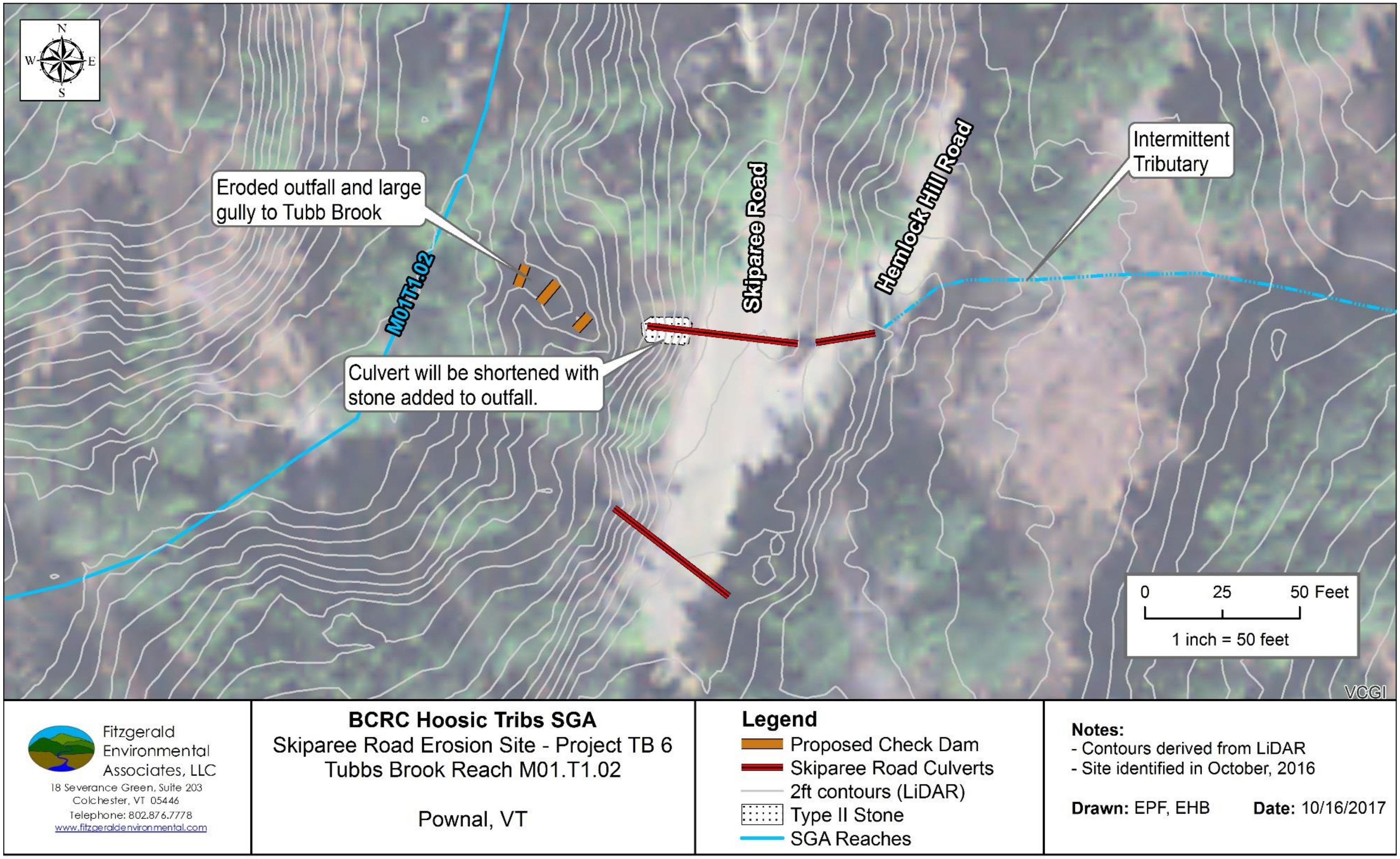
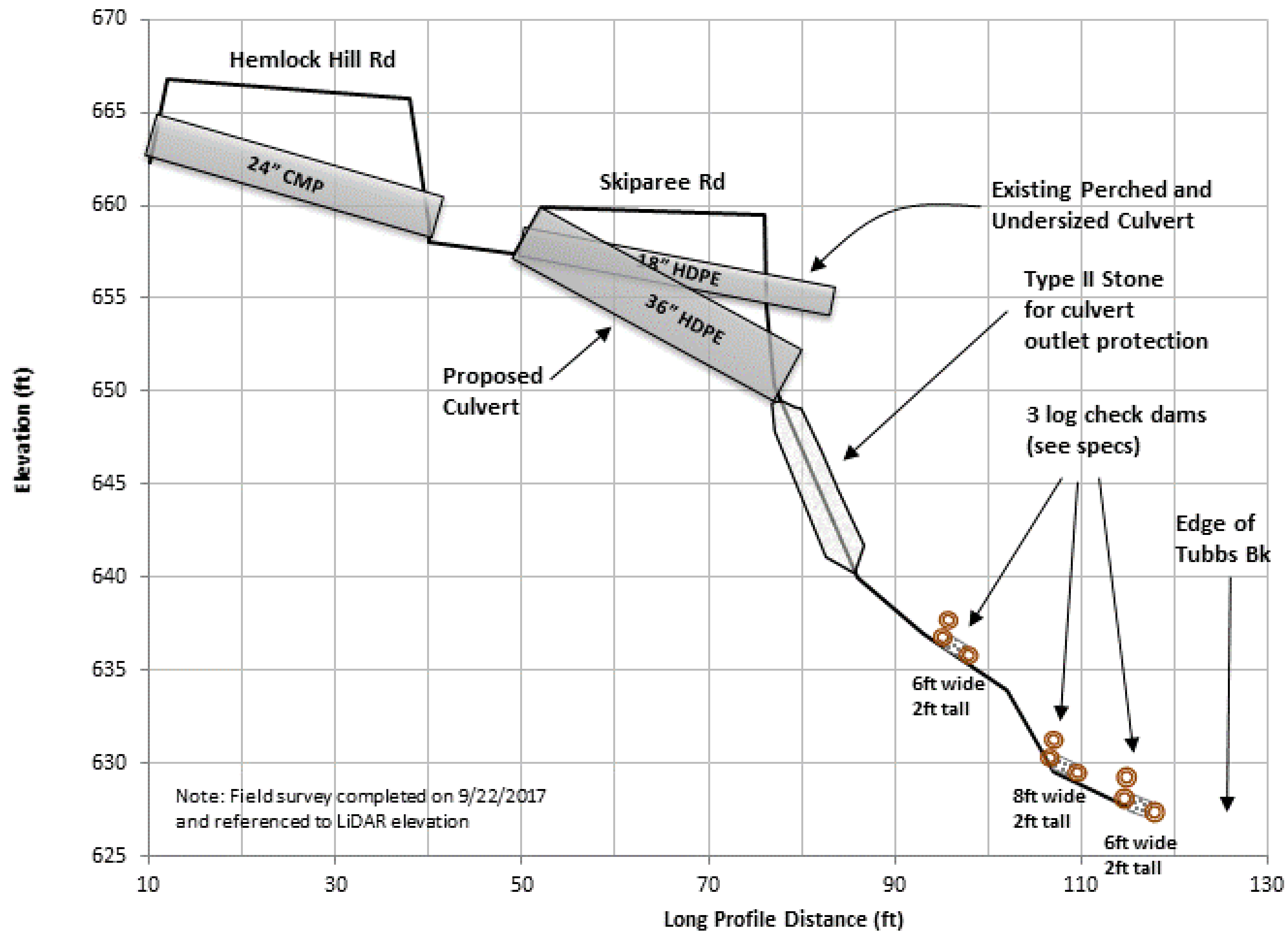


Figure 6: Site map of Hemlock Hill and Skiparee Road culverts and downstream gully to Tubbs Brook.



Fitzgerald Environmental Associates, LLC 18 Severance Green, Suite 203 Colchester, VT 05446 Telephone: 802.876.7778 www.fitzgeraldenvironmental.com	**BCRC Hoosic Tribs** **Project TB 6 – Skiparee Road** **Longitudinal Profile**	Vertical Scale: 1"= 10' Horizontal Scale: 1"= 20' October 16, 2017 Drawn: EPF

Figure 7: Longitudinal profile of Hemlock Hill and Skiparee Road culverts and downstream gully to Tubbs Brook.

Project TB 10, Tubbs Brook Segment M01T1.04.B

Existing Conditions and Problem Overview

Town: Pownal	**Road Name:** Mount Anthony Road & Fowlers Way	**Date Visited:** 9/21/2017

Existing Conditions

LiDAR Slope: 10% (Fowlers); 3-10% (Mt. Anthony)

Road Type: Gravel

Conveyance Area/Turnout: 3 Poor, 1 Stable

Erosion Types Present: Rill

Drainage Culverts: 1 Cross

Driveway Culverts: 0

Municipal Road General Permit Standards:

+ Meets Standard, **--** Partially Meets Standard (needs work), **X** Does Not Meet Standard

Roadway Crown/Travel Lane	--	Grader Berm/Windrow	--
Road Drainage	X	Conveyance Area/Turnout	X
Municipal Drainage Culverts	+	Driveway Culverts (within ROW)	+

Existing Conditions Notes: Approximately 500 feet of Fowlers Way has no ditch on the eastern side of the road and 350 feet of the western side of the road lacks effective turnouts, causing runoff to flow along the road and erode the roadway. The side slopes on the lower 200 feet of Fowler Road limit sheet flow off the road, exacerbating downslope erosion. Runoff along the road causes rill erosion and contributes to sediment loading at the turnoff downslope of the intersection with Mt. Anthony Road. This turnout is conveying sediment into Tubbs Brook. Approximately 175 feet of Mount Anthony Road is lacking a ditch on the north side of the road, further contributing to sediment loading at the turnout from runoff flowing on the road surface. This reach of Tubbs Brook shows signs of significant aggradation (i.e., accumulation) of gravel in the main channel, which has led to widening and bank erosion downstream. This turnout is a significant source of sediment to the brook.

Photo 1: A turnout near Tubbs Brook at the intersection of Fowlers Way and Mt. Anthony road is filling with sediment.

Photo 2: Rill erosion along the section of Fowlers Way with no ditches.

Proposed Scope of Work

Roadway/Travel Lane Practices

X	Improve Road Crown	X	Adjust Road Grade
X	Remove Grader Berm		Edge of Road Stabilization/Maintenance

Roadway Drainage Practices

X	Install New Ditch	X	Improve Existing Ditch
X	Side Slope Excavation for New Ditch		

Conveyance/Turnout Practices

X	Install Turnout	X	Stabilize/Improve Existing Turnout
X	Install Sediment Trap		Stone Armor on Bank/Slope
X	Install Check Dams in Existing Feature		

Culvert Practices

X	New Municipal Culvert		Upgrade Municipal Culvert
	New Driveway Culvert		Upgrade Driveway Culvert
	Headwall or Armor at Culvert Inlet/Outlet		Clean Sediment/Debris from Culvert

Estimated Project Costs

Practice	Units	Unit Cost	Quantity	Total
Improve Road Crown	Linear Foot	$ 5	200	$ 1,000
Raise Road Grade	Cubic Yard	$ 15		$ -
Remove Grader Berm	Linear Foot	$ 5	450	$ 2,250
Edge of Road Stabilization/Maintenance	Linear Foot	$ 8		$ -
New Stone-Lined Ditch	Linear Foot	$ 25	400	$10,000
New Grass-Lined Ditch	Linear Foot	$ 8	50	$ 400
Side Slope Excavation for New Ditch	Linear Foot	$ 20	400	$ 8,000
Improve Existing Ditch (Stone)	Linear Foot	$ 20	125	$ 2,500
Improve Existing Ditch (Grass)	Linear Foot	$ 5	200	$ 1,000
Install/Improve Turnout	Each	$ 200	2	$ 400
Install Sediment Trap	Each	$ 1,000	1	$ 1,000
Install Stone Armor (Bank/Slope)	Cubic Yard	$ 40		$ -
Install Check Dam	Each	$ 40	2	$ 80
New/Upgrade Cross-Culvert (18" to 24")	Each	$ 1,500	1	$ 1,500
New/Upgrade Conveyance Culvert	Each	$ 2,000		$ -
New/Upgrade Driveway Culvert	Each	$ 750		$ -
Install Culvert Headwall/Armor	Each	$ 300		$ -
Remove Sediment/Debris from Culvert	Each	$ 100		$ -
			Total Cost:	**$28,130**

Project Partners and Funding

Evan Fitzgerald has discussed this project with Pownal road foreman, Joel Burrington, and with BCRC planner Jim Henderson who has been assisting Pownal with Municipal Roads General Permit (MRGP) Grant-in-aid Assistance and compliance.

Regulatory Requirements

No in-stream or wetland permits are necessary to complete this work. The completed project will satisfy the MRGP requirements for these road segments.

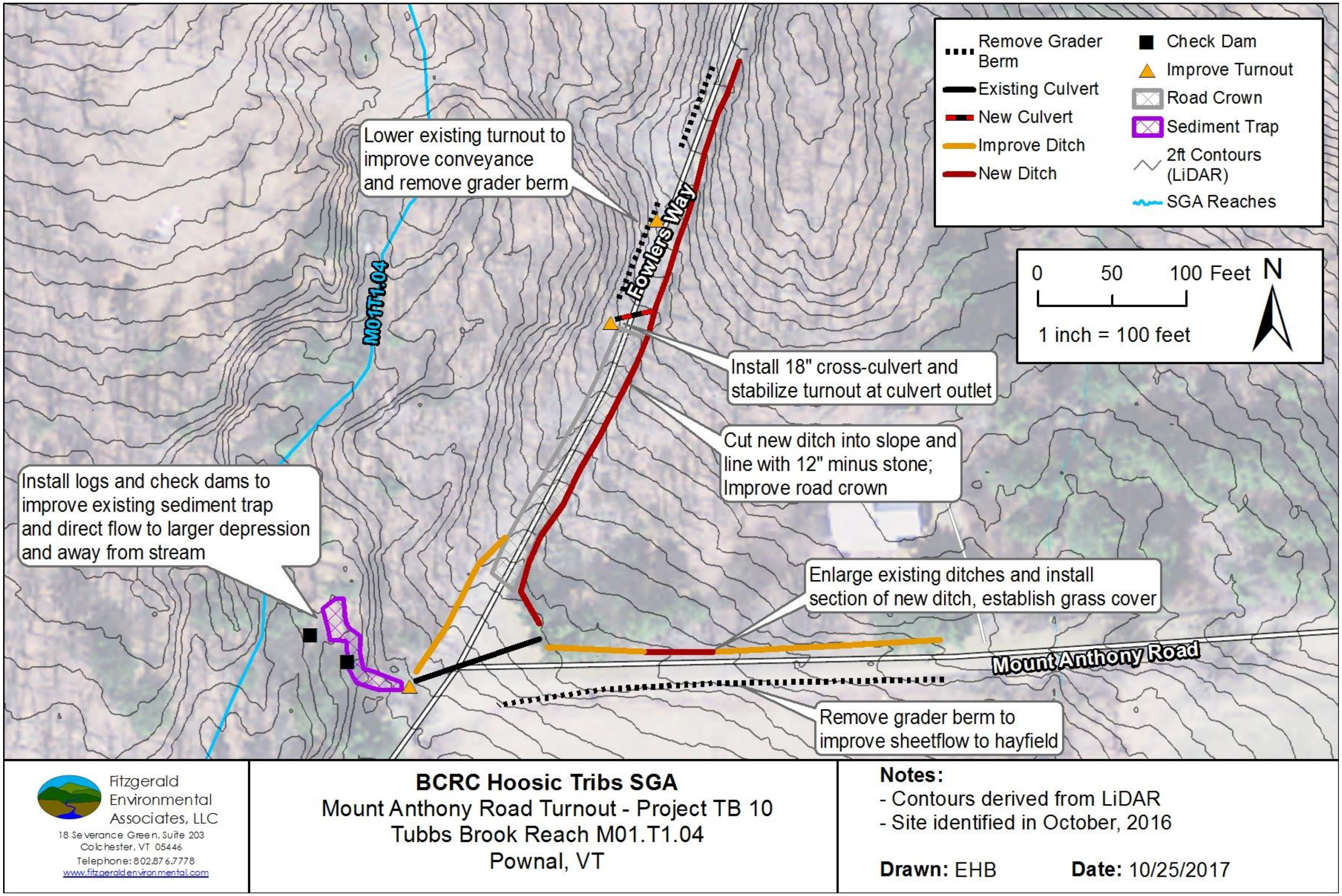


Figure 8. Proposed plan for the TB 10 project area.

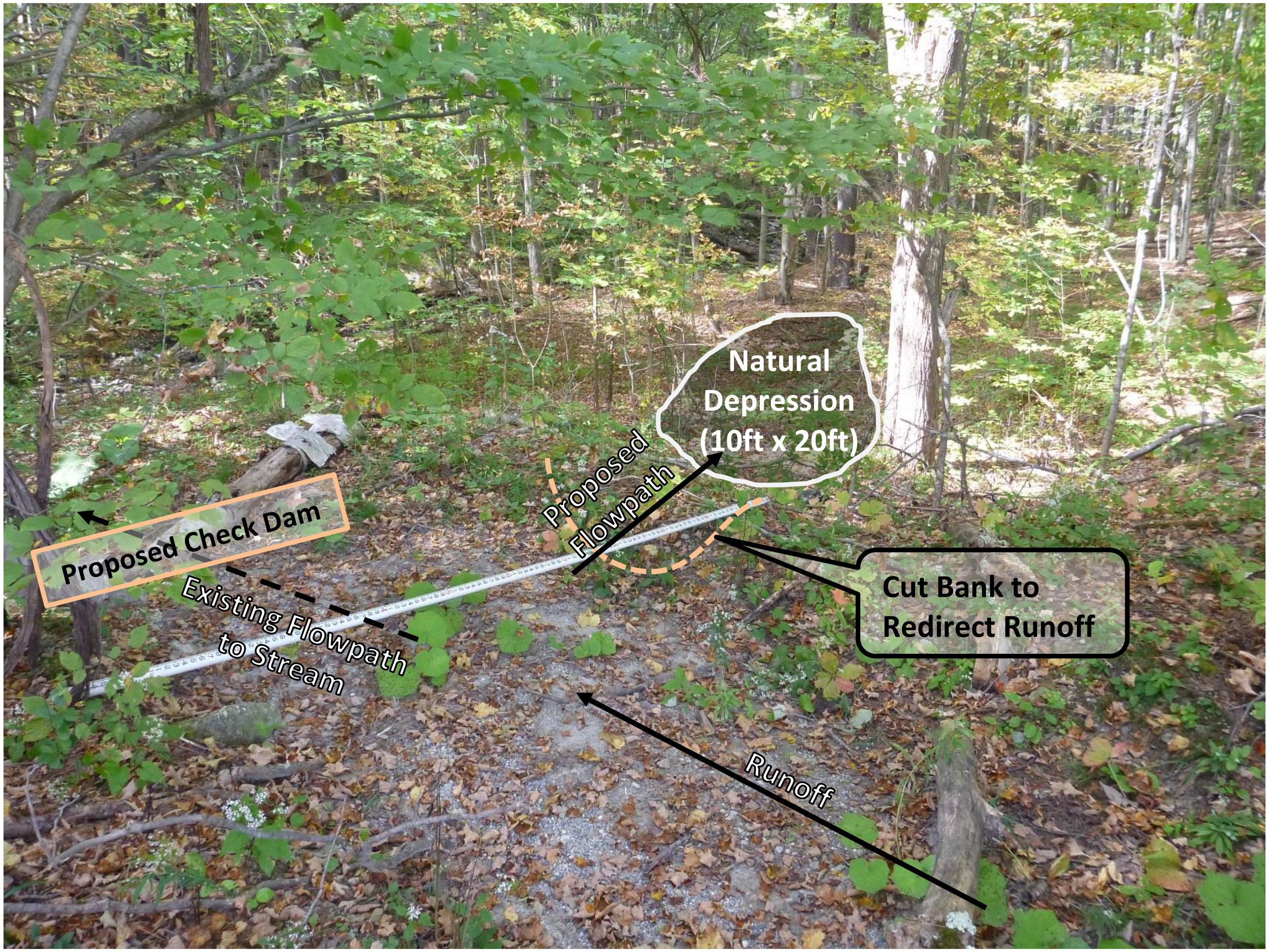


Figure 9. Proposed sediment trap retrofit in natural depression (10-foot stadia rod for scale).

Projects LB 1, LB 2, and LB 3, Ladd Brook Reach M05S1.01

Existing Conditions

The Alta Gardens mobile home park is located near the confluence of Ladd Brook with the Hoosic River. Downstream of the park, Ladd Brook flows through an undersized railroad culvert and then into an undersized double culvert at a currently unused crossing before joining the Hoosic River. Upstream of the park, Ladd Brook flows from a crossing at Route 7 through an incised channel that appears relatively stable. Ladd Brook was historically channelized and now makes two 90-degree bends, one upstream of Alta Gardens where it crosses under Church Street and flows parallel to the railroad tracks and one near Alta Gardens where the channel crosses under the railroad tracks to join the Hoosic River. A channel conveying stormwater runoff from Route 346 runs alongside the park and joins Ladd Brook just upstream of the railroad culvert. The elevation of the stormwater channel is at or slightly lower than the elevation of Ladd Brook with very low slope, and may take on flood waters as the undersized structures downstream back up during flood events. This channel is separated from Alta Gardens by a berm that is continuous except for a break at the driveway for the pump station, which crosses over the channel.

Problem Overview

<u>Project LB 1</u>

Two culverts (4ft diameter) convey the stream under an old, unused crossing west (downstream) of the railroad crossing (Figures 10 and 11). These structures are causing sediment and debris deposition at the inlet, and aggradation in the upstream channel. The culvert capacity is exceeded during flood events, backing up floodwaters and increasing flood depths upstream.

Figure 10: Undersized culvert inlets at an abandoned crossing.

Figure 11: Undersized culvert outlets at an abandoned crossing.

<u>Project LB 2</u>

A railroad culvert (6ft tall and 4ft wide) is undersized (Figures 12 and 13). The bankfull channel width for this reach is 17 feet, therefore the culvert width is 24% of the reference width. The culvert capacity is exceeded during flood events, backing up floodwaters and increasing flood depths upstream. A stormwater channel with low slope and an elevation at or slightly below that of Ladd Brook runs alongside the mobile home park converges with Ladd Brook just upstream of the culvert. Thus, when floodwaters back up at the crossing they likely flow into the stormwater channel and may spill out into the mobile home park.

Figure 12: Undersized railroad culvert inlet.

Figure 13: Undersized railroad culvert outlet.

Project LB 3

A makeshift dam constructed from railroad ties, stumps, and a rubber liner is found just upstream of the mobile home park (Figures 14 – 15). The structure is causing sediment aggradation upstream and raises the water level just upstream of the mobile home park. This may exacerbate flooding in the park.

Figure 14: Makeshift dam on Ladd Brook upstream of Alta Gardens.

Figure 15: Sediment accumulates behind the makeshift dam.

A hydrologic and hydraulic analysis of the project areas in relation to the mobile home park was performed to better understand the dynamics of two undersized stream crossings and one impoundment (Projects LB 1, LB 2, and LB 3 described above). The floodplain maps and data generated through hydrologic and hydraulic analyses can be used to better understand the resiliency of infrastructure to flooding and erosion. The one-dimensional, steady flow river and floodplain hydraulics model and maps developed in this study cover Ladd Brook from just upstream of the Church Street bridge in Pownal to the confluence with the Hoosic River. The flood elevations and flood extents generated by this modeling effort are intended for planning purposes only and do not supersede the effective FEMA flood hazard maps.

Hydrologic Analysis

We used the USGS StreamStats program (Olson 2014) to delineate the Ladd Brook watershed draining to the study area. Using regional regression equations based on watershed area, storage, and annual precipitation the 100-yr discharge was estimated at 336 cubic feet per second (cfs). Ladd Brook is steep with areas of poorly drained soils, which may result in lower infiltration and faster delivery of runoff to streams than the average conditions modeled by regional regression equations.

To account for the possibility that the regional regression equations may underestimate flow, we constructed a watershed-scale TR-20 hydrologic model using HydroCAD 9.0 software. This model estimates flow rates following simulated recurrence-interval rainfall events. The watershed was characterized by land cover, soils, and topography to estimate runoff volumes and peak flow rates. 24-hour rainfall depths for the recurrence interval storms were estimated using the Extreme Precipitation in New York and New England web tool created by the Northeast Regional Climate Center and the Natural Resources Conservation Service (Table 1). The HydroCAD model predicted a peak runoff of 360 cfs for the 100-yr discharge. This value is 7% higher than the regional regression flow prediction method described above (Table 2).

We also reviewed the hydrology data published in FEMA's Flood Insurance Study (FIS) for Ladd Brook (Table 2). After on our review of all three sources of discharge estimates, we chose 175 cfs, 225 cfs, 400 cfs, and 500 cfs as conservative estimates of the 10, 25, 50, and 100-year floods as inputs to the hydraulic model.

Table 1: Rainfall depths for return interval 24-hour storms.

Return Interval (years)	Rainfall Depth (inches)
2	2.70
5	3.33
10	3.91
25	4.84
50	5.70
100	6.70
200	7.89
500	9.80

Table 2: Flow estimates (cubic feet per second) for select recurrence interval floods on the Ladd Brook.

Return Interval (years)	HydroCAD (cfs)	StreamStats (cfs)	FEMA FIS Study (cfs)
2	42.5	81.2	-
5	77.7	131	-
10	116	170	175
25	189	229	-
50	264	280	400
100	360	336	500
200	483	399	-
500	690	493	780

Hydraulic Analyses

HEC-GeoRAS and HEC-RAS 5.0.3 software (USACE, 2016) were used to create a one-dimensional, steady flow river and floodplain hydraulics model for Ladd Brook from just upstream of the Church Street bridge in Pownal to the confluence with the Hoosic River. We created a floodplain digital elevation model (DEM) for the study area using high-resolution (1.7 m) LiDAR elevation surfaces from a dataset covering Bennington County in Vermont collected by Northrop Grumman in March and April of 2012. We converted the DEM vertical elevation units from meters to feet and used it to create a Triangulated Irregular Network (TIN). The TIN format is an alternate method to represent the elevation surface that is faster to process for hydraulic modeling purposes.

To set up the HEC-GeoRAS model, we digitized the stream centerline and the top of each bank using 2015 imagery from the Vermont Center for Geographic Information (VCGI) and a LiDAR hillshade of the study area to emphasize topographic relief. We constructed the hydraulic model as a single reach for the 1,983-foot-long study area. Next, we drew cross-sections perpendicular to channel and floodplain flow stretching across the valley to contain all areas of overbank flow at the cross-section (Figure 16). An accurate 3D lateral profile of the floodplain and channel was generated in HEC-GeoRAS by sampling the DEM along the cross-sections and correcting the bankfull channel dimensions with field survey data.

Field Survey

Field verification of the two stream crossings and a longitudinal profile of the study area was completed in September 2017. This verification effort is important when constructing a hydraulic model from LiDAR-derived DEMs which are typically less accurate at stream crossings and along steep road embankments where the DEM may be adjusted to reflect the “bare earth” condition. Culvert dimensions and accurate channel and bank geometry are critical components for HEC-RAS modeling.

Modeling Details

We imported the HEC-GeoRAS cross-section data into HEC-RAS 5.0.3 and assigned floodplain and channel roughness values (Manning’s N values) based on land cover from aerial imagery, and field survey observations. Roughness values ranged from 0.02 (paved roads, train tracks, and parking lots) to 0.08 (forest and Alta Gardens) following Chow (1959) and Arcement *et al.* (1989). To correct for LiDAR scatter at the water surface, channel bottom elevations were adjusted based on comparison to the channel survey data collected in September 2017. Typical channel bottom adjustments ranged from 0.5 to 1 feet based on elevations surveyed in the field. We also plotted the channel longitudinal profile and checked for any unnatural slope changes. We included a total of 23 cross-sections in the model. We extended cross sections as needed to contain all areas of overbank flow in between cross-sections in HEC-GeoRAS. To simulate tailwater from the Hoosic River, the downstream boundary condition was set to match the FEMA FIS flood elevation for the Hoosic River at Ladd Brook for each flow scenario. Levees were placed on the berms, roads, and railroad to prevent the model from flooding the area outside until it was overtopped. The steady flow model was run using a subcritical flow regime.

Alternatives Analysis and Flood Depth Mapping

The estimated benefits of implementing river corridor projects LB-1, LB-2, and LB-3 are described in Table 3 below. Additionally, connecting the two berms by raising the grade approximately 3 feet (from 447’ elevation to 550’ elevation) at the driveway to the pump station may reduce floodwaters spilling out of the stormwater channel that runs alongside Alta Gardens from Route 346. By adding this alternative to the scenario where the double culverts and dam have been removed (Projects LB-1 and LB-3), we estimate that floodwaters would be kept out of Alta Gardens for the 10 and 25-year floods (however the estimated flood depths are less than 0.5 feet from the top of the berm). Including this alternative in the scenario where the railroad culvert has also been widened to 17 feet (Projects LB-1, LB-2, and LB-3) yields the same results for the 10 and 25-year floods. In this scenario, the 50 and 100-year flood depths are approximately 1 foot or less above the berm, increasing the likelihood that these flows might be prevented from extending into Alta Gardens. **Please note that our modeling does not account for the accumulation of sediment in the channel or snagging of debris during floods, which is likely on Ladd Brook based on past flood observations, and will exacerbate flooding.**

Table 3: Alternatives Analysis for Projects LB-1, LB-2, and LB-3

<table>
<tr><th>Project</th><th>Flood</th><th>Downstream (LB-1 Area Around Abandoned Crossing)</th><th>Middle (LB-2 Area Around Railroad Culvert)</th><th>Upstream (LB-3 Area Upstream of the Dam)</th></tr>
<tr><td rowspan="2">Existing</td><td>10 to 25-year</td><td rowspan="2">Culverts are overtopped and back up flood elevations as far upstream as the outlet of the railroad culvert</td><td>Railroad culvert is overtopped and backs up flood elevations to the dam</td><td rowspan="2">Flood elevations upstream of the dam are increased due to the presence of the dam, especially in the 10 and 25-year floods, where the railroad culvert causes less tailwater</td></tr>
<tr><td>50 to 100-year</td><td>Railroad culvert exacerbates flooding, and backs up flood elevations to the pump station driveway. Flood depth is approx. 6-8 feet in park</td></tr>
<tr><td rowspan="2">LB-1: Stream Crossing Removal</td><td>10 to 25-year</td><td>Flood elevations approximately 3 – 4 feet lower, but only as far upstream as the outlet of the railroad culvert</td><td>No benefit compared to existing conditions from removal of lower stream crossing (LB-1)</td><td>No benefit compared to existing conditions from removal of lower stream crossing (LB-1)</td></tr>
<tr><td>50 to 100-year</td><td>No benefit compared to existing conditions (Hoosic tailwater is higher than the elevation of the crossing)</td><td>No benefit compared to existing conditions from removal of lower stream crossing (LB-1)</td><td>No benefit compared to existing conditions from removal of lower stream crossing (LB-1)</td></tr>
<tr><td rowspan="2">LB-2: Railroad Culvert Replacement with a 17-foot Wide Structure</td><td>10 to 25-year</td><td>No benefit in downstream area compared to existing conditions</td><td>Flood elevations approximately 3 – 4 feet lower, reducing the depth and extent of flooding in Alta Gardens</td><td>Flood elevation approximately 0.5 – 1 foot lower</td></tr>
<tr><td>50 to 100-year</td><td>No benefit in downstream area compared to existing conditions</td><td>Flood elevations approximately 6 feet lower, reducing the depth and extent of flooding in Alta Gardens</td><td>No significant benefit compared to existing conditions</td></tr>
<tr><td rowspan="2">LB-3: Dam Removal</td><td>10 to 25-year</td><td>No benefit in downstream area compared to existing conditions</td><td>No benefit near railroad culvert inlet compared to existing conditions</td><td>Flood elevations approximately 1 foot lower</td></tr>
<tr><td>50 to 100-year</td><td>No benefit in downstream area compared to existing conditions</td><td>No benefit near railroad culvert inlet compared to existing conditions</td><td>No significant benefit compared to existing conditions</td></tr>
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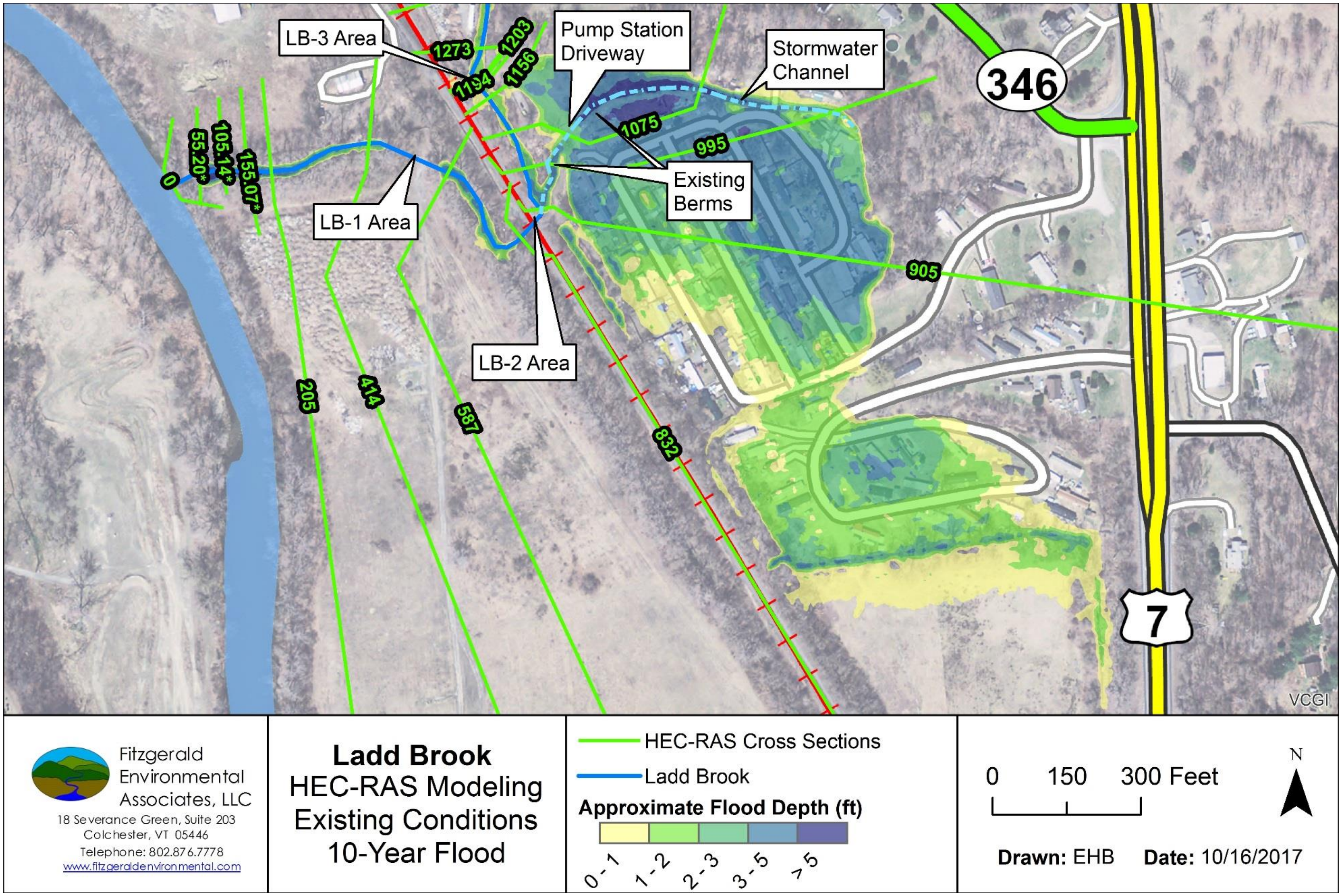

Figure 16: Ladd Brook approximate 10-year flood depths under existing conditions modeled with HEC-RAS.

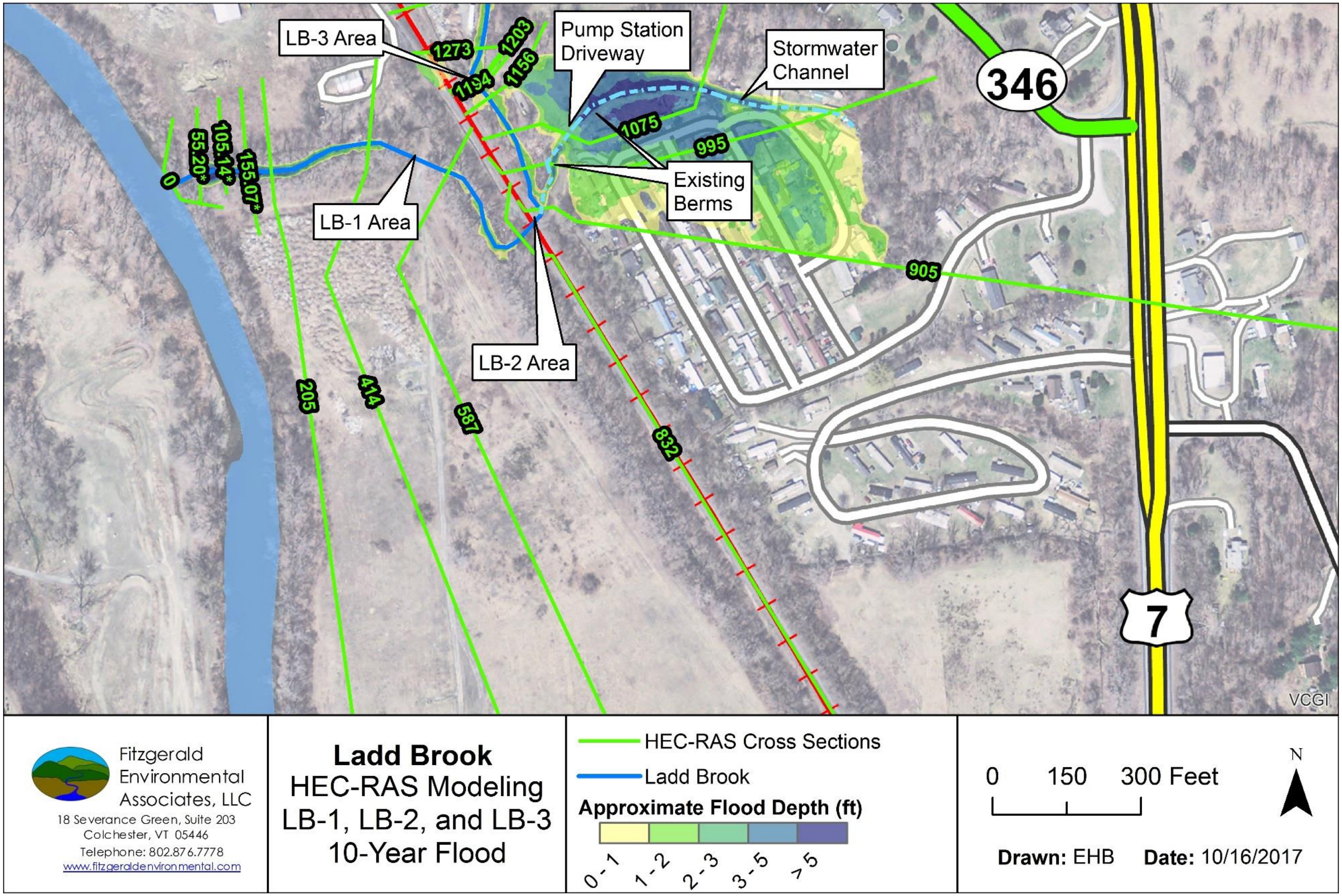

Figure 17: Ladd Brook approximate 10-year flood depths after implementation of LB-1, LB-2 and LB-3 modeled with HEC-RAS.

Project LB 1: Stream Crossing Removal, Stream Channel Restoration

Scope of Work and Cost Estimate

To increase the capacity of Ladd Brook to pass large floodflows, reduce sedimentation in the channel, and reduce the risk of debris snagging at the inlet, we recommend either: 1) removing the crossing including the two culverts and fill above them, or 2) replacing the undersized structures with a culvert or bridge with a bankfull-sized opening. The channel in this stretch can be widened in the direction of the Green Mountain Racetrack property with the addition of a flood bench to increase the capacity of the channel. The newly excavated slopes and bench would be planted with native woody vegetation appropriate for the setting (bare root or small container trees, or willow stakes/fascines depending on shading).

There is a steep drop-off of approximately one foot in channel elevation at the current inlet to one of the culverts at the crossing, so a low-profile grade control (i.e., boulder strainer) on the newly restored channel upstream and downstream of the former location may help prevent sediment losses and further incision of the channel (Figure 18). This project area can be accessed via the existing road from the Green Mountain Racetrack property. Final design and permitting work will be needed for this project. Our estimated cost to remove the crossing and restore the stream channel: $25,000 - $30,000.

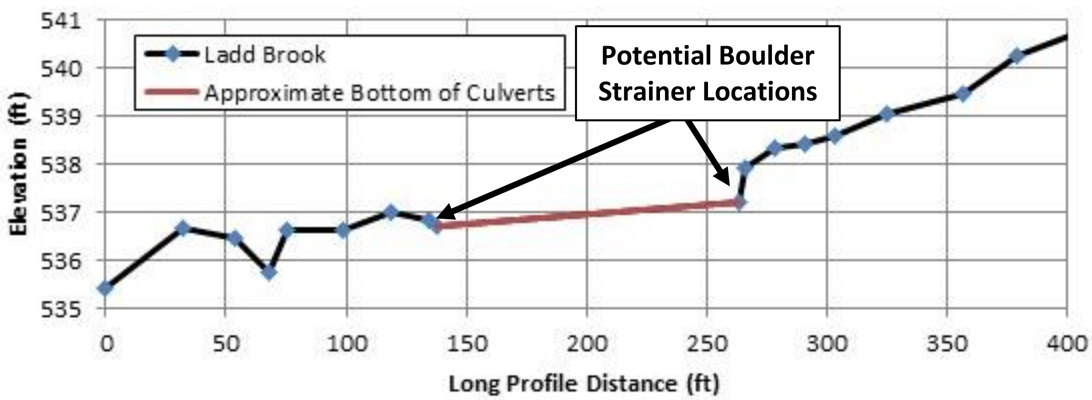

Figure 18. Long profile of Ladd Brook channel upstream and downstream of the double culverts.

Estimated Project Costs

Description	Unit	Estimated Quantity	Unit Price	Amount
1) Final Design and Permitting		**1**	$ 2,750.00	$ 2,750.00
2) Crossing Removal				
Mobilization	LS	1	$ 500.00	$ 500.00
Common Excavation	CY	1,125	$ 12.00	$ 13,500.00
3) Channel Restoration & Riparian Plantings				
Woody Debris Removal/Reuse	CY	20	$ 20.00	$ 400.00
Boulder Strainer Installation	Each	2	$ 250.00	$ 500.00
Misc Erosion and Sediment Control	LS	1	$ 500.00	$ 500.00
Riparian Plantings	LS	1	$ 1,000.00	$ 1,000.00
Engineer/Geomorphologist Oversight	LS	1	$ 3,000.00	$ 3,000.00
			Base Project Subtotal:	$ 22,150.00
			15% Contingency:	$ 3,322.50
			Total Base Project Cost for Planning Purposes:	**$ 25,472.50**

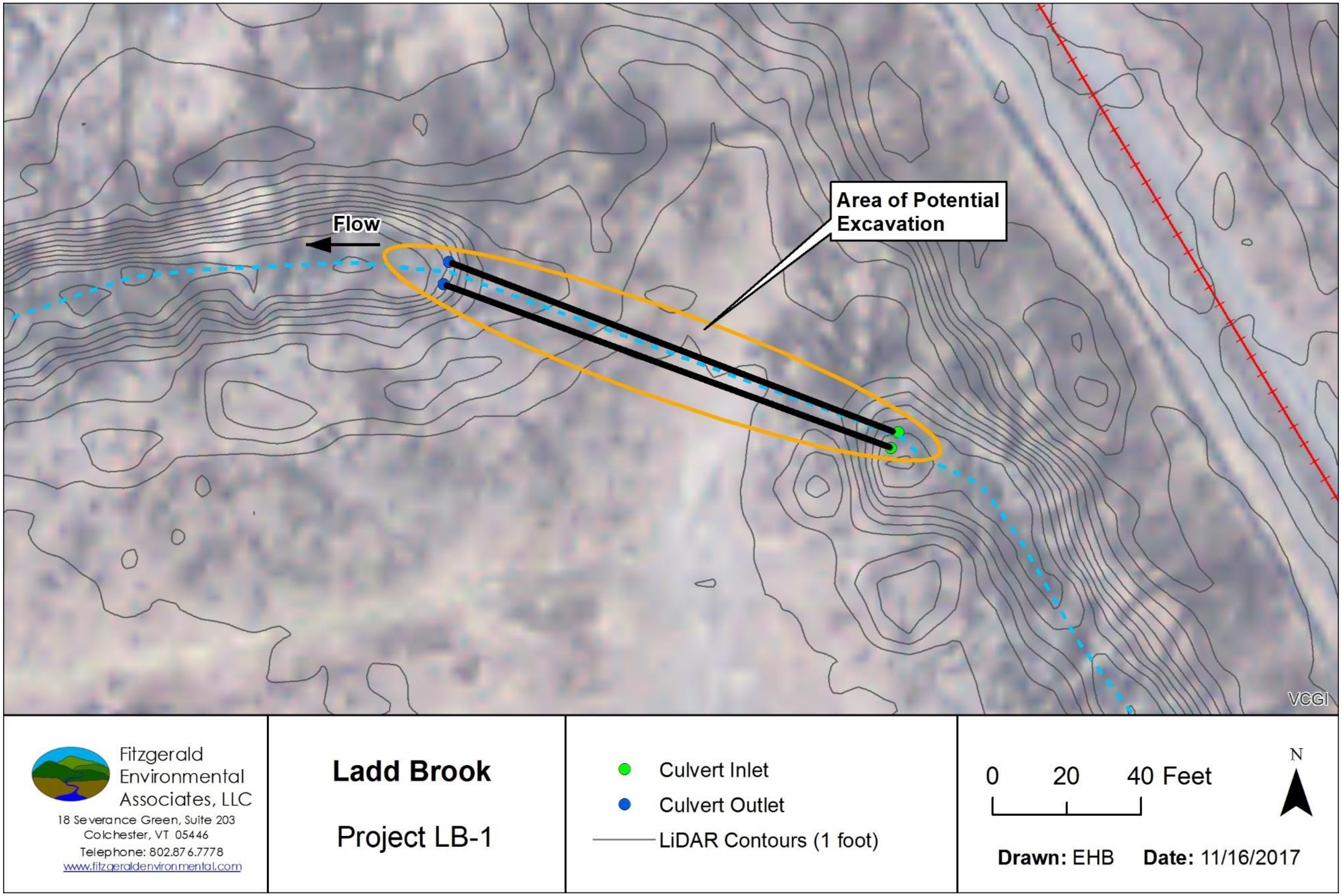

Figure 19. Location of double culverts and proposed area of excavation to remove the crossing.

Landowner Contacts

The stream crossing is on the Green Mountain Racetrack property and leads to a parcel owned by James Winchester on the north bank of Ladd Brook. A recycling facility (TAM) is located to the north of this property and improvements to the crossing could provide truck access to their facility via the racetrack property that bypasses nearby neighborhoods on local roads. Michael Batcher and Evan Fitzgerald met with Trevor Manse from TAM in December 2017 to discuss the project. TAM's plans for utilizing this crossing are uncertain at this time due to property access, easements, costs, and other factors, but they feel there would be significant benefits to the Town (less traffic on local roads, improved emergency access to the racetrack property) and their business (safer truck access). Therefore, TAM is hopeful the crossing can be utilized again in the future. Another point of discussion during the meeting was the potential high costs of replacing the two culverts with a bankfull-sized box culvert or bridge. The costs associated with a crossing of this size are often in the $200,000 to 300,00 range for municipal projects.

Potential Funding and Regulatory Requirements

The VTDEC Ecosystem Restoration Program would be a potential source of funding for the project if the culverts were to be removed and the stream restored. A VTANR stream alterations permit may be required for removal of the crossing and channel restoration. A U.S. Army Corps of Engineers permit likely will not be required as the project mainly involves removal of fill below OHW, however this should be confirmed during future project phases.

<u>Project LB 2: Culvert Replacement</u>

Scope of Work and Cost Estimate

In order to increase hydraulic capacity to pass large floodflows, reduce sedimentation in the channel, and reduce the risk of debris snagging at the inlet,, we recommend installing a larger structure to convey Ladd Brook underneath the railroad. The estimated bankfull width for this section of Ladd Brook is 17 feet. The existing structure causes the backup of floodwaters during the 10 and 25-year floods, raising flood depths upstream along the Alta Gardens mobile home park. The culvert and railroad are projected to overtop during the 50 and 100-year floods. Increasing the size of the railroad crossing to a bankfull structure is predicted to allow the crossing to pass all floods without backing up floodwaters and exacerbating flooding in Alta Gardens. The comparison of the existing and proposed structure width and water surface elevations from HEC-RAS modeling are shown in Figure 20. The costs associated with a crossing of this size are often in the $200,000 to 300,00 range for municipal projects. However, given the potential disruption of the railroad and other uncertainties with this project, it is possible the costs could exceed $500,000.

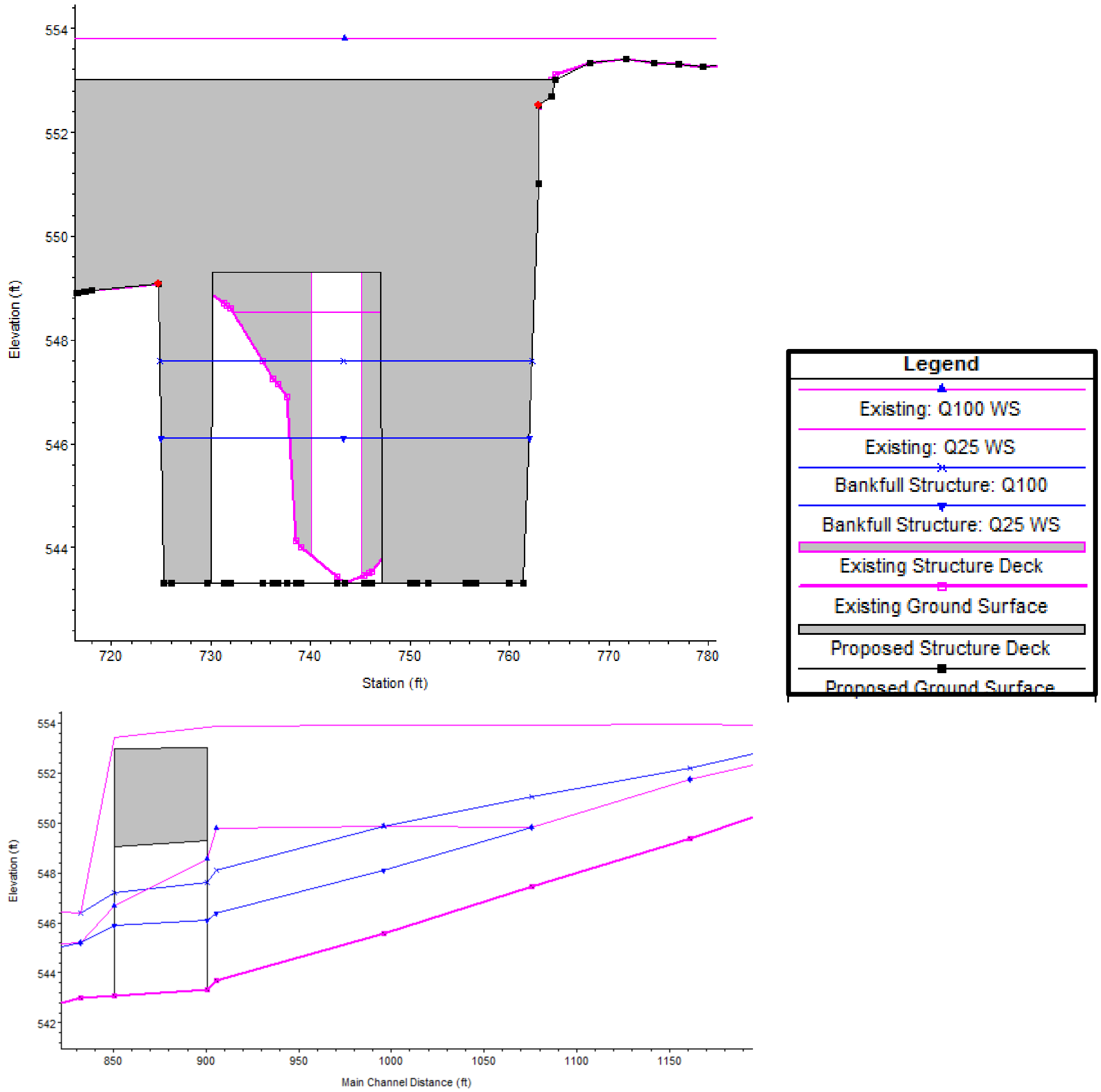

Figure 20. Cross section (top) and longitudinal profile (bottom) views of the Water Surface (WS) elevations in scenarios with the existing railroad culvert and a new bankfull structure. Pink lines show the existing ground and water surface as well as outline existing structure openings, black lines show the proposed ground surface as well as proposed structure openings and blue lines show the modeled water surface if the project were implemented. Q25 is the modeled 25-year flow event scenario and Q100 is the modeled 100-year flow event scenario. Gray shading shows the deck/abutments of existing and proposed structures.

Landowner Contacts

Evan Fitzgerald has corresponded by phone and email with Ted Krug of Pam Am Railway Engineering regarding the railroad's right-of-way and the age and condition of the structure. Pan Am has not indicated whether the structure would be considered for replacement to alleviate flooding upstream. The structure does not appear to be a priority for replacement.

Regulatory Requirements

A VTANR stream alterations permit will be required for replacing the crossing with a larger structure. A U.S. Army Corps of Engineers permit will also likely be required for structure replacement.

<u>Project LB3: Dam Removal</u>

Scope of Work and Cost Estimate

The small size of the dam suggests it can be removed by hand. We estimate it would take two (2) laborers and a truck one (1) day to remove the structure and haul away the wood and liners so they do not clog either of the culvert crossings downstream. At the time of the field survey, the channel upstream of the dam appeared to have been recently dredged, resulting in a limited amount of sediment accumulation behind the dam. Due to the similar slope of the channel upstream and downstream of the dam as shown in Figure 21, likely no regrading of the channel is needed and what sediment is accumulated immediately behind the dam can be allowed to fill the scour hole downstream of the dam and depression left after the dam removal. Estimated total cost: $1,000 - $2,000.

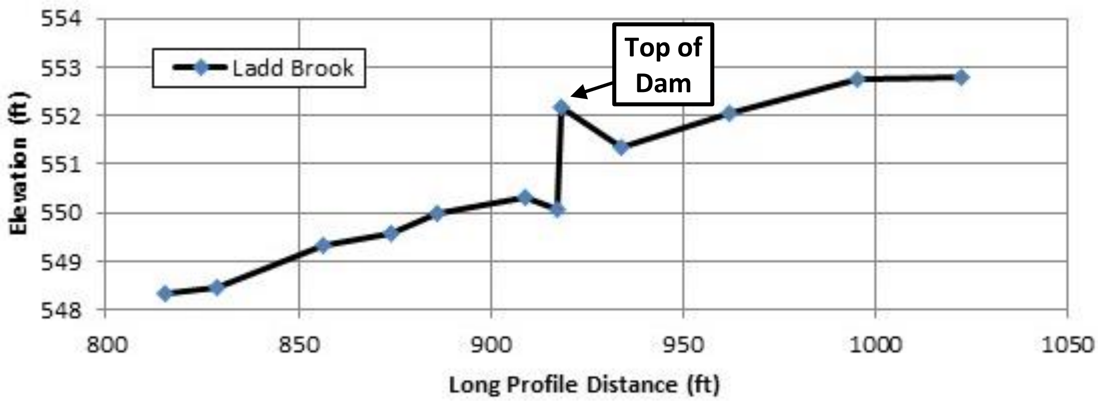

Figure 21. Long profile of Ladd Brook channel upstream and downstream of the makeshift dam.

Landowner Contacts

The dam is located on the Pan Am Railway property very close (< 10 feet) to the property boundary with the Town of Pownal parcel for the pump station. It is unclear who was responsible for building the dam, and therefore who should assume responsibility for removing it.

Potential Funding and Regulatory Requirements

Given the low project costs to remove the dam and the uncertainty around who "owns" the structure, it is unclear how the project would be funded. No permits should be required to remove the dam.

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