# Technical Memorandum

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| **To:** | Town of Lincoln, Vermont | **From:** | Brian Cote, PE, CFM<br>Osman Pekin<br>Elizabeth Richards |
| **Company:** | | | **SLR International Corporation** |
| **cc:** | Addison County Regional Planning Commission | **Date:** | September 18, 2023 |
| | | **Project No.** | 146.13928.00008 |

**RE: River Road Stabilization**
**Conceptual Design Alternatives**

## 1.0 Introduction

The following narrative has been prepared to document findings and data collection, and to provide conceptual alternatives to address roadway stability along the River Road project site located in Lincoln, Vermont. This memorandum summarizes findings and discusses site constraints, presents conceptual alternatives, and recommends next steps for the Town to consider moving forward.

The New Haven River travels through a narrow valley and is located directly adjacent to the embankment of River Road at the project site (Figure 1). The River Road embankment has historically been armored with large riprap to resist erosion that has occurred within the project reach. Maintaining the riprap slope has been challenging given the direct flow impingement, the steepness and height of the embankment, and dynamic nature of the New Haven River. There is also concern with the stability of the tall, steep slope on the north side of River Road may also be actively destabilizing this section of the roadway.


**Figure A: River Road Project Area**

A project kickoff meeting with the Town of Lincoln, the Addison County Regional Planning Commission, and SLR was conducted on March 29, 2023. During the meeting, the challenges that the Town has experienced along this section of River Road were discussed along with their thoughts of what may be causing some of the issues. Concern that the steep slope between River Road and Forge Hill Road was causing instability in the roadway was discussed, as well as damages that this site has faced during past flooding on the New Haven River. A nearby site that the Town recently repaired was also toured after the kickoff meeting. Notes that were taken at the meeting are attached (Appendix A).

# 2.0 Existing Conditions

The New Haven River channel through the project area is currently confined by the River Road roadway embankment to the north and a disconnected floodplain and flood chute to the south. Additionally, the roadway is located on the outside of a meander bend in the river, and a gravel bar is building on the inside of the bend. These conditions contribute to the instability and erosion risk of the River Road embankment.

The roadway embankment is currently lined with riprap along an approximately 250-foot section of the New Haven River within the project area. River Road is showing signs of settlement and movement (i.e., longitudinal cracking of roadway surface and leaning guardrail). Road drainage is causing localized rill erosion on the south side of the roadway where stormwater runoff leaves the roadway surface and collects before flowing down the steep slope to the river. Additionally, the steep slope between Forge Hill Road and River Road is showing signs of movement and instability that may be applying pressure to the roadway in the project area as well.

The New Haven River flows directly adjacent to the roadway embankment. The alignment is causing direct flow impingement on the base of the embankment contributing to the slope instability. To address the instability, a stacked riprap wall with steep armored upper bank has been implemented along this section of River Road within the limited space available between the roadway and river. Vegetation along the roadway embankment that has not been eroded away is limited to grasses and small shrubs within the section that is most vulnerable to erosion risks.

A gravel bar is building on the inside of the bend opposite the roadway to the south, adding to the pressure along the roadway embankment. Additionally, the forested floodplain and flood chute located to the south of channel appears to be largely disconnected from the river. When floods take place on the New Haven River in this location, most of the water is contained in the channel leading to increased erosion risk.

A site walk was conducted on June 14, 2023 by SLR staff to review conditions, collect field data, and document existing site constraints. Field notes taken during the site walk are attached (Appendix B). During the site walk, the erosion risk level was assessed along River Road within the project area (see plan sheets EX1 – EX4 of the plan set attached in Appendix C). Existing conditions and site features such as storm drainage, culverts, existing erosion, potential natural resources, and topographic data were collected and mapped during the site walk. Additional information and details regarding the existing conditions at the project site is provided in the subsections below.

## 2.1 Road Embankment

The road embankment through the project site is located on the outside of a bend in the New Haven River and is susceptible to erosion at the toe of slope that sits at the river's edge. The embankment is approximately 20 feet tall and is over-steepened with an average slope of 1V:1.5H. Vegetation is sparse on the steepest portion of the embankment where large riprap has been placed, consisting of grasses and small shrubs mostly at the top of the embankment. The embankment at each end of the project area appears more stable where there is less impingement and more vegetation to protect against erosion.

A metal-beam guiderail exists at the edge of the roadway along the length of the embankment within the project area. Sections of the guiderail are leaning towards the river indicating that the slope is unstable and likely moving. There is also cracking along the direction of travel in the road that is visible in the pavement of the roadway surface that also may be an indication of the road embankments instability. There are several small earth berms at the top of the slope just behind the guiderail that concentrate runoff flowing off the roadway surface. The berms may be the result of buildup of winter road sand and eroded sediment.

## 2.2 Fluvial Geomorphology

The New Haven River is a steep, high energy, riffle-pool channel with areas dominated by bedrock and cobble. The river channel has cut down (i.e., incised) in the project area leading to disconnected floodplains and over-steepened banks along River Road. This setting has led to high erosion risk and repeat damages along the road and ongoing damages to the road embankment.

A disconnected flood chute exists at the upstream end of the project site that is directing more flow towards the damaged road embankment. If reconnected, this chute could move some water away from the road during flood and reduce risk to the road.

Active sediment bar building is taking place at the upstream end of the project site that is leading to increased meandering and bank / road embankment erosion.

The measured bankfull channel width is 49 feet and the bankfull depth is 5.5 feet.

## 2.3 Hydrology

The River Road project site is approximately 10 miles downstream of the headwaters of the New Haven River watershed that originates on the western slopes of the Green Mountains. The New Haven River at the project site has a drainage area of approximately 43.5 square miles and is part of the Lake Champlain Otter-Lewis sub-basin. The majority of the basin draining to this point is mountainous with an average stream slope of approximately 5%. The local channel slope of approximately 1.2%. The basin is primarily forested with a small percentage of residential and agricultural land uses mixed in. The narrow, elongated watershed shape and existing land uses limit peak flow rates to this point, however, the steep sloped watershed indicates that a flashy characteristic would be anticipated at this location in the watershed, where peak flows pick up then recede relatively quickly during flood events.

**Table 1: Peak Flow Rates – USGS StreamSTATs**

| Recurrence Interval | | Peak Flow Rate (CFS) | Unit Peak Flow Rate (CSM) |
|---|---|---|---|
| Year | % Annual Chance | | |
| 2-year | 50.0% | 1,540 | 35.4 |
| 5-year | 20.0% | 2,370 | 54.5 |
| 10-year | 10.0% | 3,010 | 69.2 |
| 25-year | 4.0% | 3,950 | 90.8 |
| 50-year | 2.0% | 4,750 | 109.2 |
| 100-year | 1.0% | 5,610 | 129.0 |
| 500-year | 0.2% | 7,980 | 183.4 |
| CFS – cubic feet per second<br>CSM – cubic feet per second per square mile | | | |

## 2.4 Storm Drainage

Storm drainage within the project area generally consists of roadside swales and cross culverts that are often used in similar settings. The roadway surface is generally cross sloped to drain towards the top of the road embankment. When in the field, localized rill erosion was observed where runoff flowed off the road surface and concentrated against earth berms, before flowing down the embankment at gaps between berms. The runoff from the roadway surface appeared to be causing some issues with erosion and stability of the shoulder at the top of the road embankment.

At the eastern end of the project area, there is a watercourse that drains towards River Road from the north. An actively eroding gully was observed where the watercourse travels down the steep slope from Forge Hill Road. Flow from the watercourse passes under River Road in a 60-inch diameter corrugated metal pipe (CMP) culvert that appeared to be in fair to good condition. Riprap armoring has been placed at both the inlet and outlet of the culvert to protect against erosion. The inlet appeared to be stable, however some signs of erosion were observed at the outlet.

Along the northern edge of the roadway, there is a drainage swale that directs runoff to a series of three 18-inch diameter CMP cross culverts. The three culverts appear to primarily convey stormwater draining towards the road from the steep slope between River Road and Forge Hill Road, and the roadway surface itself is generally cross sloped towards the river to the south along this portion of River Road. As you move westerly through the project area, the steep slope leaves limited space for a drainage swale. Rill erosion was observed at the ends of all three 18-inch culverts where runoff flows around the end of the culverts and down the road embankment.

A drop inlet structure with an 18-inch diameter CMP culvert was observed at the western-most end of the project area. Erosion was observed at the outlet of the 18-inch CMP culvert that was projecting from the road embankment and several feet above grade. In this portion of the project area, the road surface was cross-sloped towards the north side of the roadway to a swale. The swale extends to the intersection between Forge Hill Road and River Road along the base of the slope between the two roads. A notable observation while in the field was that in this portion of the project area, the guiderail was not leaning towards the river, as it does through the remainder of the project area.

## 2.5 Utilities

There were no overhead utility lines or utility poles observed within the project area during the site visit. There were no signs of underground utilities observed within the project area also.

## 2.6 Natural Resources

There are several areas along the roadway (typically surrounding existing culverts) that may be designated wetlands. Additionally, there is a disconnected flood chute across the river that may be designated wetland.

Indicators of Ordinary High Water (OHW) along the New Haven River were surveyed while in the field. The survey points were used to approximate the limits of OHW along the river as shown on the plans. Additional field assessment will be required to finalize the OHW limits as design progresses.

# 3.0 SLOPE STABILITY

SLR's geotechnical team performed a limited review of the site conditions based on aerial images, photographs, and available geologic and topographic information. There are no available borings to indicate likely subsurface materials or groundwater conditions. The initial assessment aimed to postulate likely scenarios and corresponding investigative approaches, which were then narrowed down to the investigation plan currently proposed (see Section 9.3). Various investigative methods that were considered included geophysics, borings, Cone Penetration Testing, and slope movement monitoring options using inclinometers or Time Domain Reflectometry. Also, various boring locations and depths were considered.

Data provided on regional geology map was reviewed and indicates that there is underlying hard rock at the site (USGS Bedrock Geologic Map of Vermont (Ratcliffe et al., 2011)). This site is located approximately where the Forestdale Formation (light blue band) crosses the New Haven River (Figure B).

The regional geologic maps are a good source of data, however do not provide information on local variability. For example, the upper slope along Forge Hill Road may have been created by infilling a historic flow channel, in which case the materials within a potential slide zone could consist of soil, which is more susceptible to sliding than bedrock. Also, groundwater conditions, which are currently unknown, could influence slope stability.

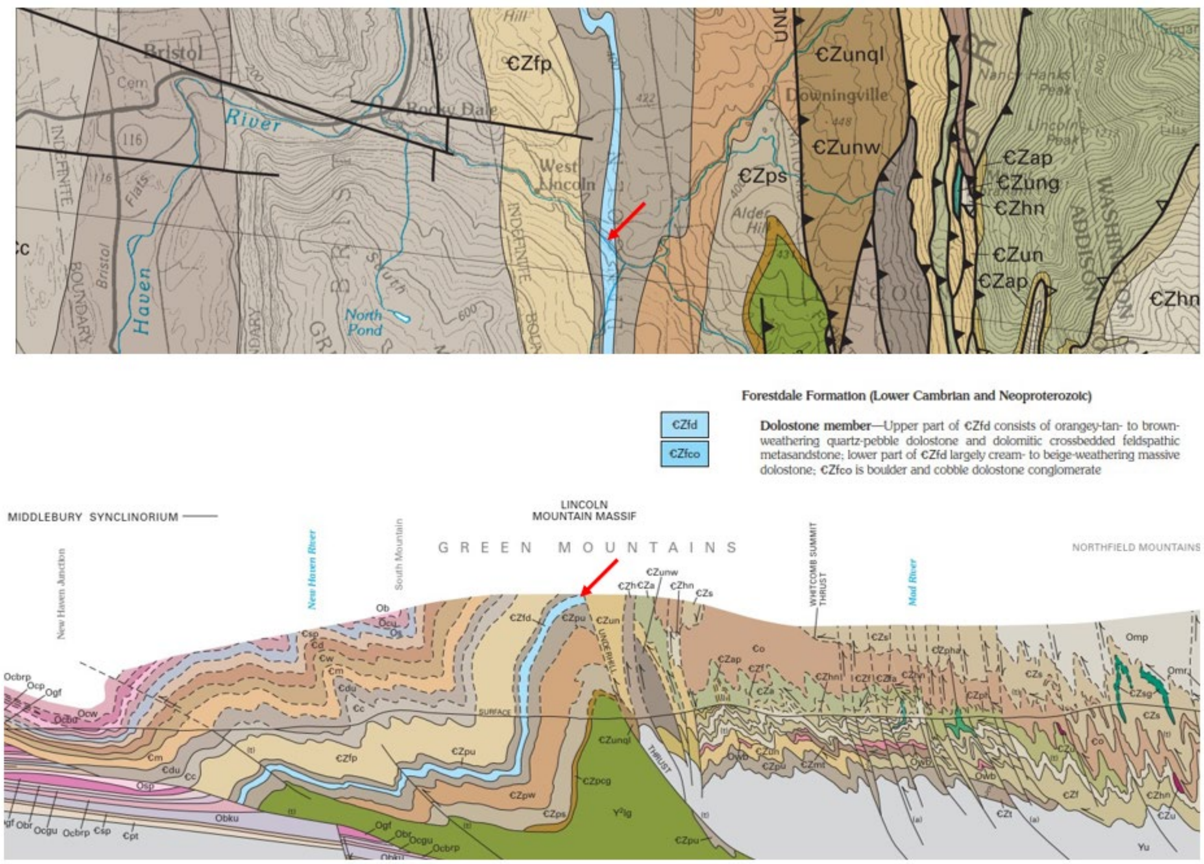



**Figure B: Regional Geological Map**

If hard rock is encountered within reasonably shallow depths in boring explorations, that would preclude the likelihood of deep-seated global failure. There could still be localized shallow and/or narrow weak zones, but geometrically, those would not lead to a global slope failure. The likelihood of rock being encountered during boring investigation is reasonably high given that occasional rock outcrops were observed at the site and considering the relatively steep gradient that this slope has endured. Based on this interpretation, an investigation plan that can be considered reasonable while providing required data needed to analyze the slope stability has been developed as outlined in Section 9.3 below.

Evidence was observed in the field that indicates that the lower portion of the slope between River Road and New Haven River is experiencing slope movement. This is likely triggered by scouring along the northeasterly bank of the river within its southwest-facing bend. It is less clear if potential slope instability extends further uphill, between River Road and Forge Hill Road. If there is any potential instability in the uphill portion of the slope, it is not clear if it has a shallow slide risk or a deep-seated slide (Figure C). The orange line depicts a slope toe failure, which is reasonably substantiated by observations in the field. The green line (i.e. – shallow slide) or red (i.e. – deep-seated slide) are unknown scenarios that involve the larger slope.

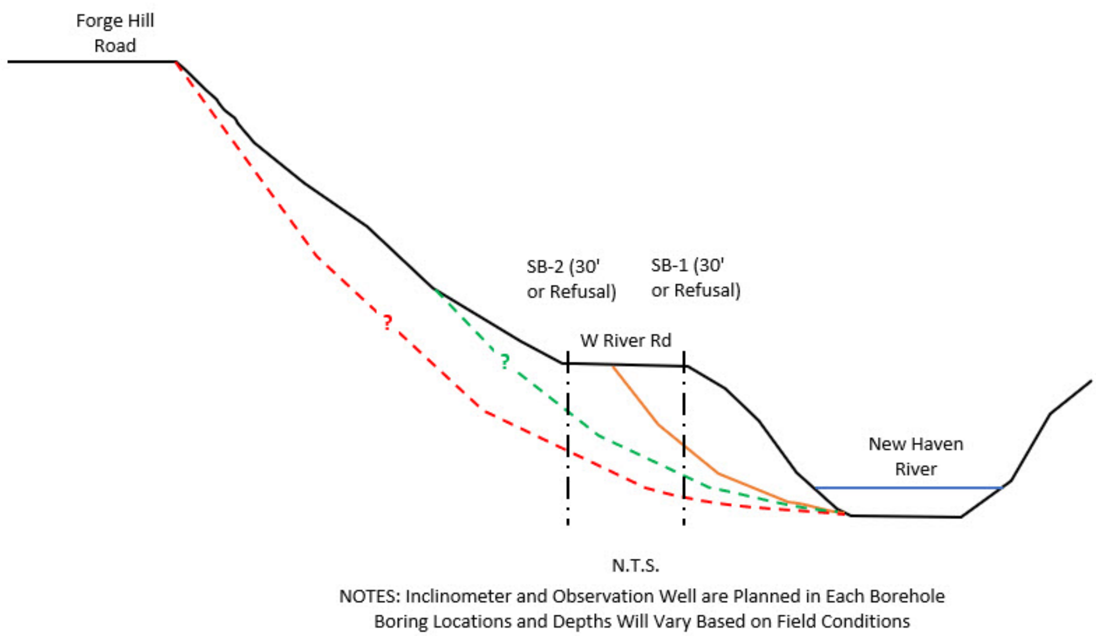



**Figure C: Schematic of Various Slope Failure Scenarios (Source: SLR)**

# 4.0 ALTERNATIVES ANALYSIS – ROAD EMBANKMENT

The following sections describe a number of alternatives that could be implemented within the project site to improve the stability of the road embankment. Several of the alternatives would be implemented along the road embankment that focus on slope stability, while others would primarily be related to increasing resiliency during flooding.

## 4.1 Alternative 1 - No Action

This alternative would leave the failing existing embankment in place. This alternative would minimize construction costs; however, it would not reduce the risk of damage to the roadway due to bank erosion, or improve water quality and habitat by stabilizing the channel bank. Although there wouldn't be construction costs for implementation associated with this alternative, the current need for maintenance and relatively frequent repairs would remain along with their associated costs. This alternative is not recommended due to the high risk associated with the roadway embankment failing completely since the existing armoring has been destabilized. The shifting of the guard rail and settling of the road embankment suggest that road failure could take place in the next large flood indicating that work is needed to reduce risks.

**Table 2: Alternative Matrix – No Action**

| Reduce flood and erosion risks to road | Stabilize river bank to improve water quality and habitat | Minimize construction costs | Minimize future maintenance needs | Total Score |
|---|---|---|---|---|
| 1 | 1 | 3 | 1 | 6 |
| Scoring based on 0 – 3 scale, 0 = not applicable, 1 = lowest goal achievement, 3 = highest goal achievement | | | | |

Although there are no construction costs associated with the no action alternative, costs associated with needed repairs and frequent maintenance would be anticipated.

**Figure D: Existing Roadway Embankment**

## 4.2 Alternative 2 – Repair Stone Armoring

This alternative consists of recovering stone that has fallen into the river and placing it back on the embankment. Portions of the existing armoring that have shifted and destabilized would need adjustment. Additional stone armoring would also be required.

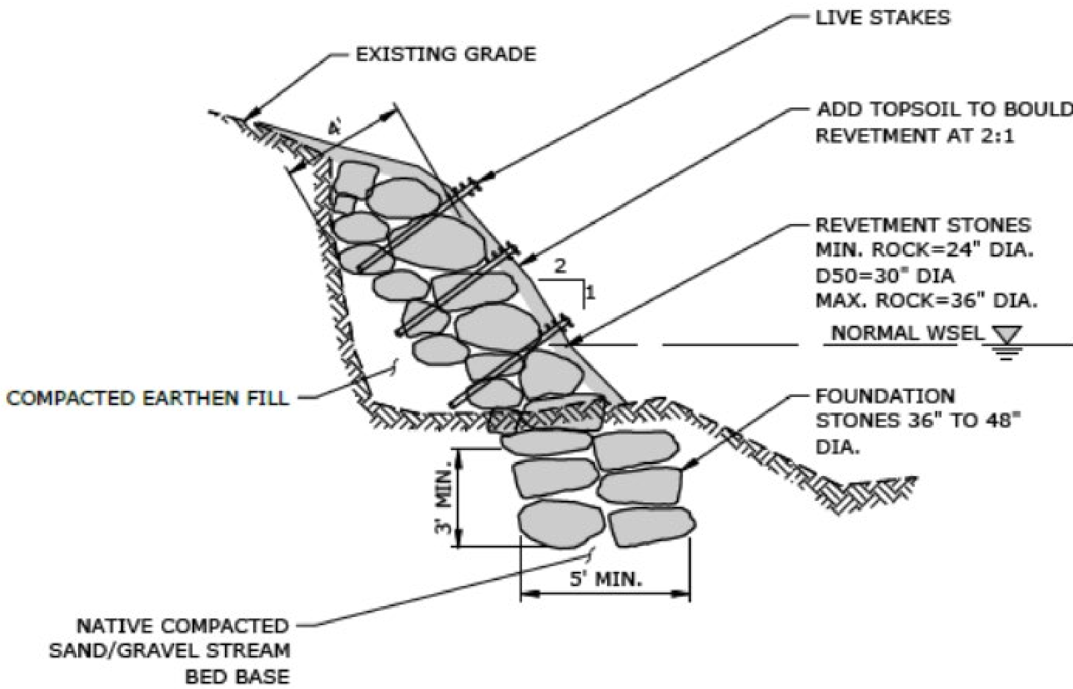
It is anticipated that permitting for this alternative would be straight forward since regulators would likely consider this to be maintenance with minimal temporary disturbance within ordinary high water (OHW) during construction. Construction would likely require closing at least one lane of traffic and lowering the embankment to reach the base of the slope. Impacts and clearing of vegetation would be limited to areas where armoring exists. Tree clearing would be required only if the extent of the existing armoring is extended up- and downstream to protect more of the roadway embankment.

This alternative would reduce flood and erosion risks to the road and would minimize construction costs relative to other alternatives. However, this alternative would not minimize future maintenance needs or naturalize the riverbank. This alternative is not recommended since this approach typically requires frequent maintenance and repairs of failing stone every 5 to 10 years following floods and heavy ice out events.

**Table 3: Alternative Matrix – Repair Stone Armoring**

| Reduce flood and erosion risks to road | Stabilize river bank to improve water quality and habitat | Minimize construction costs | Minimize future maintenance needs | Total Score |
|---|---|---|---|---|
| 2 | 2 | 3 | 1 | 8 |
| Scoring based on 0 – 3 scale, 0 = not applicable, 1 = lowest goal achievement, 3 = highest goal achievement | | | | |

This alternative is estimated to cost approximately $800 per linear foot for implementation. Based on the extents shown on the conceptual plan, this alternative would cost roughly $800,000 to construct. Note that this cost is based on 30% design, using a conservative approach, the scope and extents of the project would be refined as design advances. Although the construction cost is less than other alternatives presented, costs associated with repairs and maintenance costs would be more frequent. In addition, the rough cost provided for this alternative assumes that the full extent of the embankment stabilization area shown on the conceptual plan would be repaired, although a lesser extent likely requires immediate attention.




**BOULDER REVETMENT NOTES:**

1. EMBED STONE A MINIMUM OF 4 FEET INTO THE STREAM BANK TO KEY INTO THE BANK.
2. FINISHED ELEVATION OF THE STONES AS SHOWN ON CROSS SECTIONS AND GRADING PLAN.
3. IF BEDROCK IS ENCOUNTERED THE FIRST COURSE OF ROCK SHALL BE PINNED A MINIMUM OF 2 TIMES PER ROCK UNLESS OTHERWISE DIRECTED BY THE ENGINEER. THE DRILLED HOLES SHALL BE A MINIMUM OF 1 ½ INCHES IN DIAMETER AND EXTEND A MINIMUM OF 12 INCHES INTO THE ROCK BELOW. A #8 REBAR SHALL BE USED AS THE PIN IN EACH HOLE. THE REBAR SHALL BE CUT SO THAT IT IS RECESSED 2 TO 6 INCHES DOWN INTO THE ROCK.

**BOULDER REVETMENT KEY NOTES:**

1. EMBED THE STONE A MINIMUM OF 4 FEET INTO THE STREAM BED AND 8 FEET INTO THE STREAM BANK TO KEY.
2. FINISHED ELEVATION OF THE STONES AS SHOWN ON CROSS SECTIONS AND GRADING PLAN.

**Figure E: Typical Stone Armored Slope**

## 4.3 Alternative 3 – Rebuild Stone Armoring with Pinning

This alternative consists of dismantling the existing stone armoring on the roadway embankment and rebuilding the slope protection with a stacked stone wall on the lower slope and sloped armoring on the upper slope. The height of the stacked stone wall would be built to a point where the upper slope can attain a reasonable slope of 1.5H:1V to 2H:1V. Vegetation on the upper slope would be reestablished using joint plantings and live stakes. The vegetation would help increase habitat and help stabilize the slope by reducing surface erosion caused by stormwater runoff draining off the roadway surface.

The stacked stone wall would be keyed below the channel bed to protect against scouring, and large stone boulders used to create the wall would be pinned together using rebar dowels and grouting. If shallow bedrock, the base of the stacked stone wall would be pinned to the bedrock.

The stacked lower portion of the application can help maintain the bankfull width available to the channel, whereas sloped armoring would encroach into the channel.

It is anticipated that permitting for this alternative would be straight forward, since regulators would largely consider this to be maintenance, although temporary disturbance within OHW during construction would increase to allow keying of the stacked stone wall and for water control. A similar design was recently permitted downstream in Bristol. Construction would likely require closing of at least one lane of traffic and would require lowering the road embankment to reach the base of the slope to create the key and install pins. Impacts would be limited to areas where armoring exists, and tree clearing would be limited to the up- and downstream extents of the application in areas where stone armor protection is expanded along the roadway embankment.

This alternative would reduce flood and erosion risks to the road, minimize future maintenance needs and minimize construction costs but would not naturalize the riverbed. Comparatively, construction costs for this alternative would be more than Alternative 2, however maintenance costs would decrease since this approach would be more durable than stone armoring without the pinning.

**Table 4: Alternative Matrix – Rebuild Stone Armoring with Pinning**

| Reduce flood and erosion risks to road | Stabilize river bank to improve water quality and habitat | Minimize construction costs | Minimize future maintenance needs | Total Score |
|---|---|---|---|---|
| 3 | 2 | 2 | 3 | 10 |
| Scoring based on 0 – 3 scale, 0 = not applicable, 1 = low goal achievement, 3 = high goal achievement | | | | |

This alternative is estimated to cost approximately $1,500 per linear foot for implementation. Based on the extents shown on the conceptual plan, this alternative would cost approximately $1,500,000 to construct. Note that this cost is based on 30% design, using a conservative approach, the scope and extents of the project would be refined as design advances.

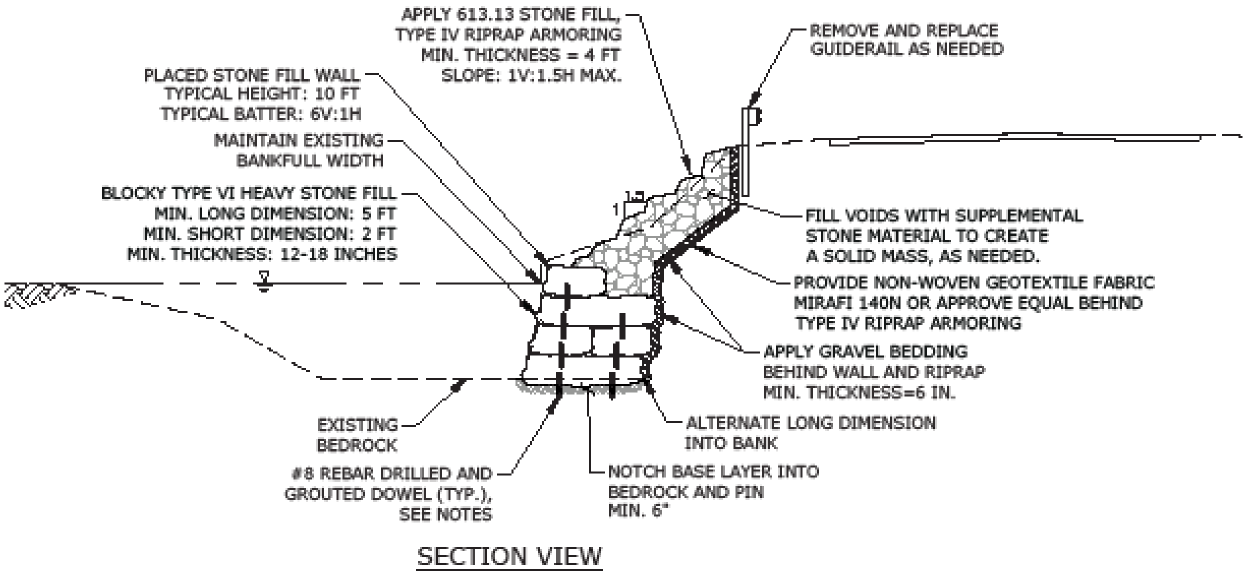



**Figure F: Typical Stacked Stone Wall with Pinning**

## 4.4 Alternative 4 – Concrete Flood Wall

This alternative would consist of constructing a concrete flood wall at the lower portion of the embankment, with sloped stone armoring placed above the flood wall. This alternative would require closing the roadway during construction to allow for the excavation required to construct the foundation and wall. The construction period would also be longer than Alternatives 2 and 3. In addition, the aesthetics of this alternative may be less desirable in the New Haven River setting that is more natural with stone and bedrock. Similar to Alternative 3, this approach can help maintain the bankfull width of the channel.

Although this alternative would be more durable than other alternatives using only stone armoring, the cost to implement would be comparatively much higher. Maintenance of a concrete wall, although potentially less frequent, would potentially be more expensive as well, especially given difficulties with access to the wall placed along the river's edge.

It is anticipated that permitting for this alternative would be more challenging, as regulators would consider permanent impacts as well as temporary disturbances during construction. Using this approach over less costly and impactful alternatives may be difficult to justify to regulators. Temporary disturbances within OHW during construction would be high due to extensive excavations and water control in the river. Required tree and vegetation clearing would likely be greater than other alternatives due to excavation requirements and potentially extending the portion of roadway embankment that is protected by the flood wall.

This alternative would reduce flood and erosion risks to the road and minimize future maintenance needs but would not minimize construction costs or provide a more natural riverbank.

**Table 5: Alternative Matrix – Concrete Flood Wall with Armored Upper Bank**

| Reduce flood and erosion risks to road | Stabilize river bank to improve water quality and habitat | Minimize construction costs | Minimize future maintenance needs | Total Score |
|---|---|---|---|---|
| 3 | 1 | 1 | 3 | 8 |
| Scoring based on 0 – 3 scale, 0 = not applicable, 1 = low goal achievement, 3 = high goal achievement | | | | |

This alternative is estimated to cost approximately $2,500 per linear foot for implementation. Based on the extents shown on the conceptual plan, this alternative would cost approximately $2,500,000 to construct. Note that this cost is based on 30% design, using a conservative approach, the scope and extents of the project would be refined as design advances.

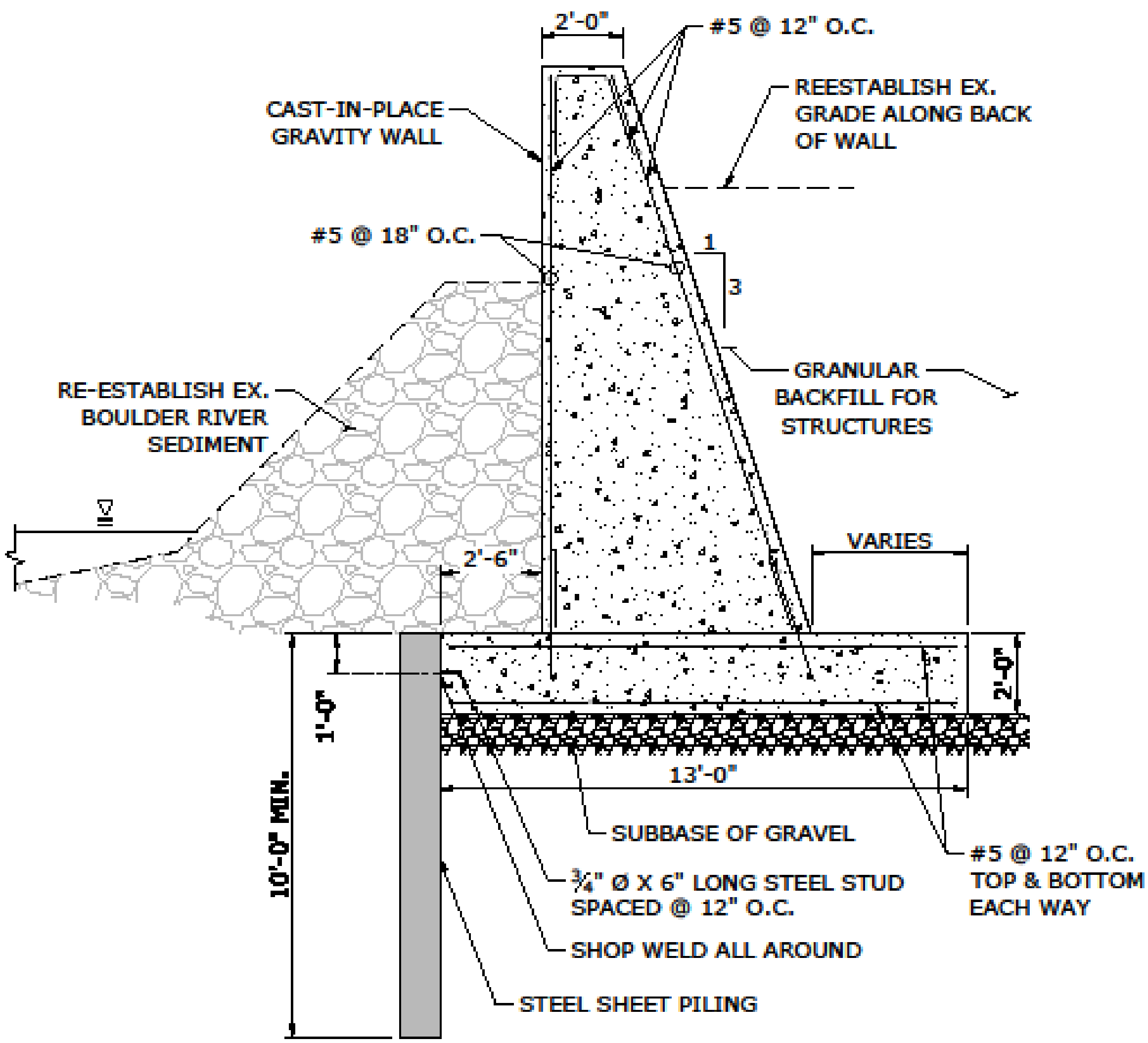


**Figure G: Typical Concrete Flood Wall Detail**

**Figure H: Concrete Flood Wall Example**

**Figure I: Concrete Flood Wall Example**

## 4.5 Alternative 5 – Mechanically Stabilized Earth Wall

This alternative would consist of constructing a Mechanically Stabilized Earth (MSE) wall along the lower portion of the roadway embankment. Like Alternative 4, sloped stone armoring would be placed above the wall on a more gradual slope up to the roadway surface. This alternative would likely require closing the roadway during construction to allow for the excavation required to construct the MSE wall, the construction period would also be comparatively longer than other alternatives, and the aesthetics of this alternative may be less desirable in the New Haven River setting. The MSE wall approach used in Alternative 5 would help maintain the bankfull width of the channel.

Although this alternative would be more durable than other alternatives using only stone armoring or just a gravity wall, the cost to implement would be higher, and potentially more costly than a flood wall. Maintenance requirements of a MES wall would be similar to a concrete flood wall with similar associated cost.

A variation of this alternative would be to use gabion baskets rather than concrete panels to create the wall. A geosynthetic material would be attached to the gabions to mechanically stabilize the lower wall portion. Gabion use would result in a less durable wall portion, however typically is less costly than concrete. The aesthetics of gabion baskets are often less desirable as well.

It is anticipated that permitting for this alternative would be more challenging, as regulators would consider permanent impacts as well as temporary disturbances during construction. Using this approach over less costly and impactful alternatives may be difficult to justify to regulators. Temporary disturbances within OHW during construction would be relatively high due to extensive excavation and water control. Required tree and vegetation clearing would likely be greater than other alternatives due to excavation requirements and potentially extending the portion of roadway embankment that is protected by the flood wall.

This alternative would reduce flood erosion risk to the road but would not minimize construction costs or naturalize the riverbank.

**Table 6: Alternative Matrix – Concrete Flood Wall with Armored Upper Bank**

| Reduce flood and erosion risks to road | Stabilize river bank to improve water quality and habitat | Minimize construction costs | Minimize future maintenance needs | Total Score |
|---|---|---|---|---|
| 3 | 1 | 1 | 3 | 8 |
| Scoring based on 0 – 3 scale, 0 = not applicable, 1 = lowest goal achievement, 3 = highest goal achievement | | | | |

This alternative is estimated to cost approximately $1,200 per linear foot for implementation. Based on the extents shown on the conceptual plan, this alternative would cost approximately

$1,200,000 to construct. Note that this cost is based on 30% design, using a conservative approach, the scope and extents of the project would be refined as design advances.

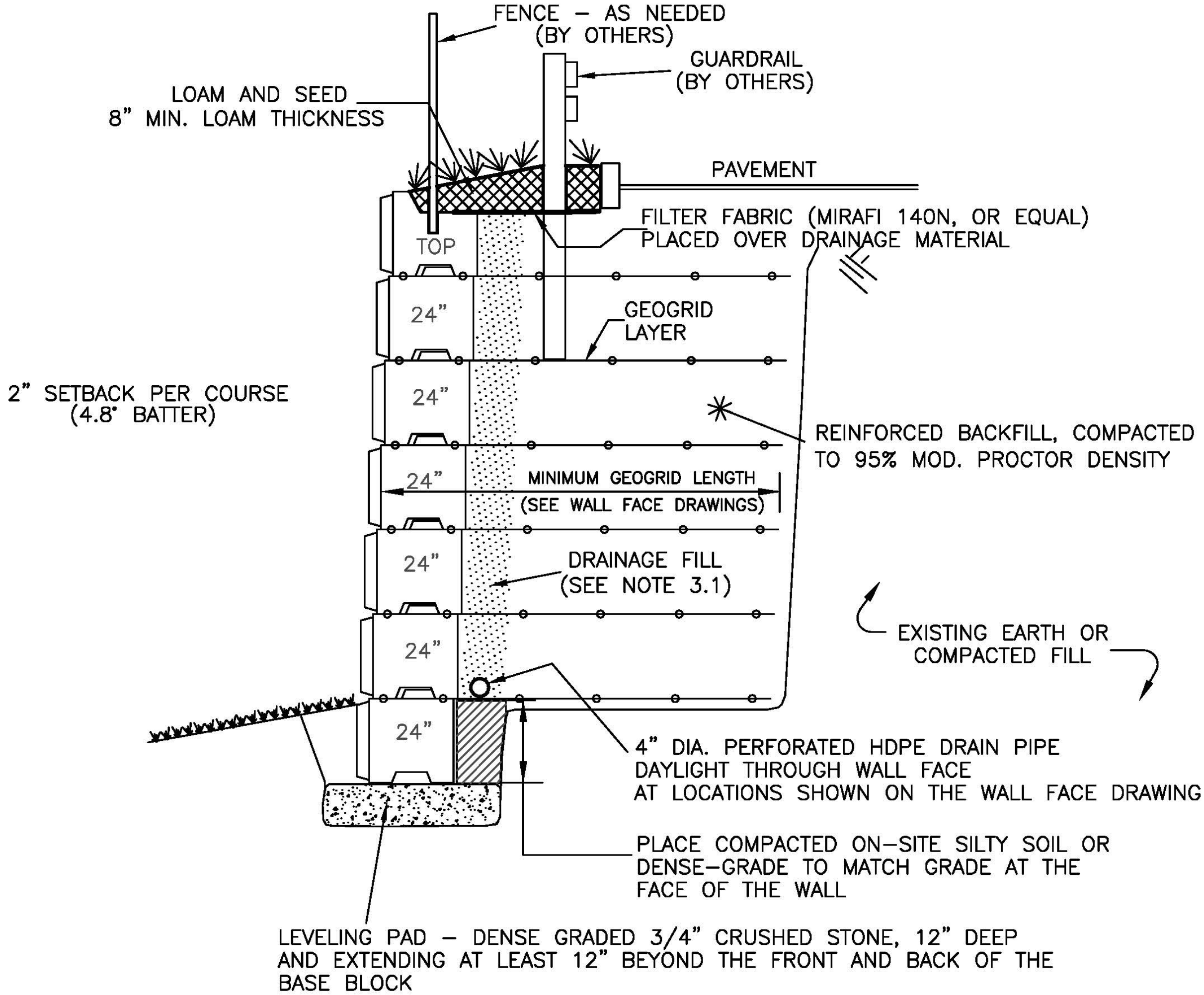



**Figure J: Typical Mechanically Stabilized Earth Wall Design Detail**

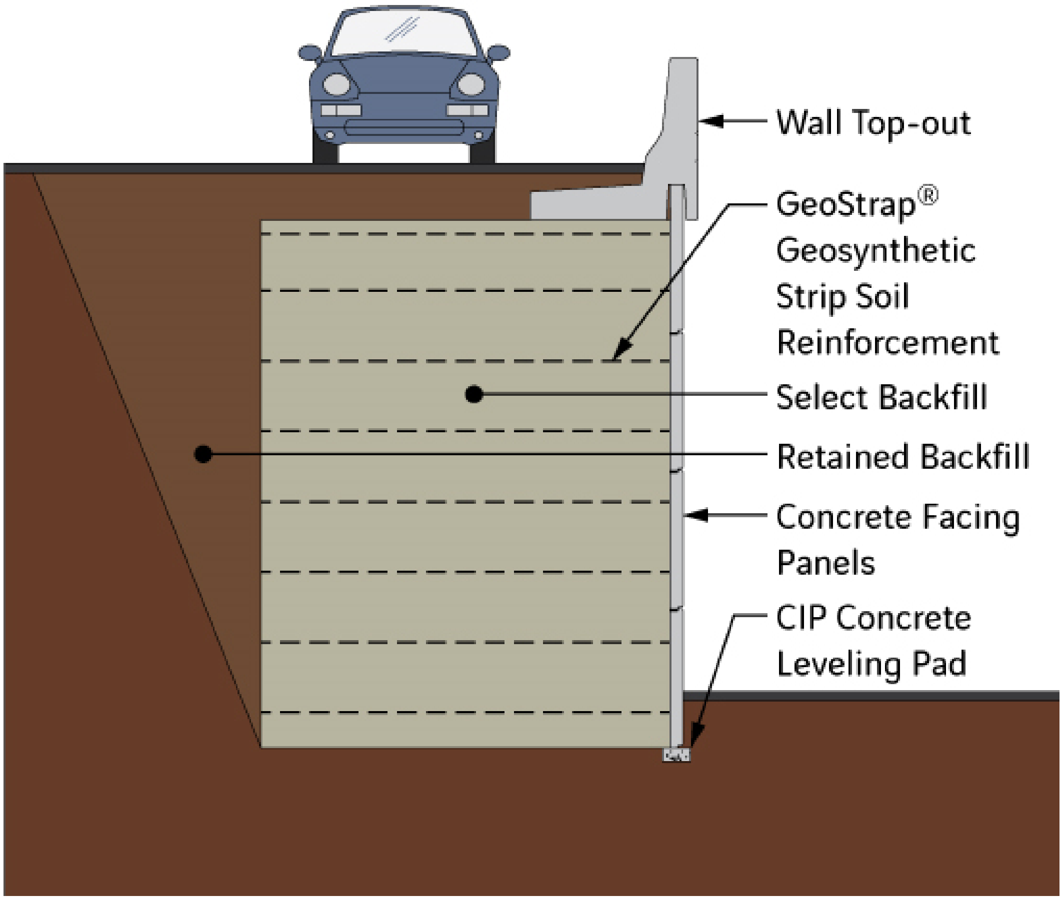



**Figure K: Typical Mechanically Stabilized Earth Wall Design Schematic**

**Figure L: Mechanically Stabilized Earth Wall Example**

## 4.6 Alternatives Matrix

| Alternative ID | Reduce flood and erosion risks to road | Stabilize river bank to improve water quality and habitat | Minimize construction costs | Minimize future maintenance needs | Total Score | Approximate Construction Cost |
|---|---|---|---|---|---|---|
| 1 - No Action | 1 | 1 | 3 | 1 | 6 | n/a |
| 2 - Repair Stone Armoring | 2 | 2 | 3 | 1 | 8 | $800,000 |
| 3 - Rebuild Stone Armoring with Pinning | 3 | 2 | 2 | 3 | 10 | $1,500,000 |
| 4 - Concrete Flood Wall | 3 | 1 | 1 | 3 | 8 | $2,500,000 |
| 5 - MSE Wall | 3 | 1 | 1 | 3 | 8 | $1,200,000 |
| Scoring based on 0 – 3 scale, 0 = not applicable, 1 = lowest goal achievement, 3 = highest goal achievement | | | | | | |

# 5.0 ALTERNATIVES ANALYSIS – RIVER CHANNEL

The following alternatives related to the river channel and floodplain could be implemented in addition to the selected road stabilization alternative to reduce erosion potential.

## 5.1 Alternative RC1 – Flood Chute Reconnection

Flood chute reconnection consists of removing material at the entrance of an existing flood chute so that it can be accessed during flood events. Currently, the flood chute that exists on the south side of the New Haven River appears to be largely disconnected from the river. During flooding, the disconnected entrance prevents floodwaters from accessing the chute. This alternative would consider lowering the existing grade at the chute entrance to allow floodwater to access the flood chute during a flood of a desired size or frequency. An evaluation of the river hydraulics during flooding would be required to determine at what flood level the chute would activate. Reconnecting the flood chute will allow a portion of the flow to enter the chute and bypass a portion of the main channel that flows along the road embankment, and therefore reduce pressure on the River Road embankment within the project site that is most susceptible to erosion. This approach has been implemented at numerous sites in Vermont in similar settings with similar constraints and conditions.

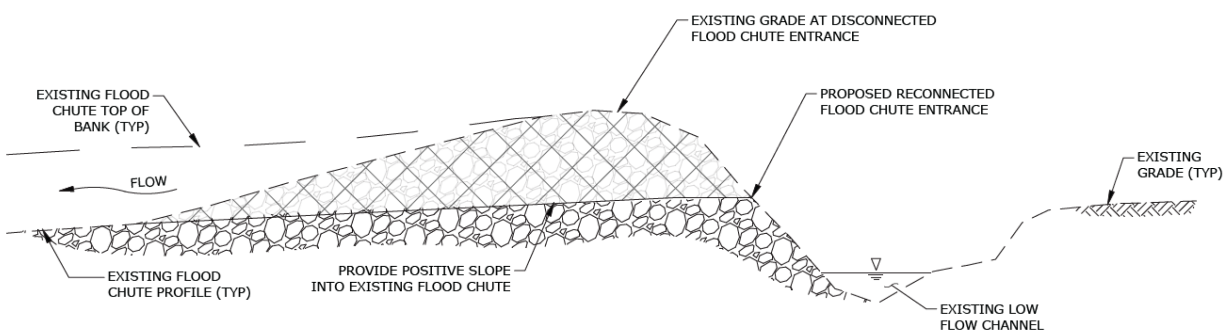



**Figure M: Typical Flood Chute Reconnection Detail**

## 5.2 Alternative RC2 – Channel Bed Armoring & Raising

This alternative consists of armoring the channel bed with large diameter stone armoring that will help reduce the risk of channel downcutting. When the channel bed is downcutting as observed at this site, the risk of undermining and destabilizing the armored slope increases. In addition, downcutting increases incision of the channel and disconnects the river from the adjacent floodplain during flood events.

Where feasible, raising the channel bed in conjunction with the armoring can help reduce incision and therefore reconnect the river to its floodplain. Allowing the river to access its floodplain during flooding helps spread flow and reduce velocity that is associated with stream power and erosion potential. Channel bed raising would also effectively increase the bankfull width available within the channel, while decreasing the overall height of the road embankment that would help with stability.

Channel bed armoring would be achieved by removing native river sediment and replacing it with a layer of stone riprap. The stone riprap would then be covered with native river sediment washed down into the large voids of the riprap. Choking the voids and establishing a layer of native sediment over the large riprap will prevent underflow (i.e., where flow drops into the voids of the riprap, rather than remain at the surface), maintain natural instream habitat in the channel, and allow the surface layer to erode and deposit naturally. Where bed raising is implemented, the top of the finished channel bed armoring would be set above existing if feasible. Additional evaluation would be required to determine if raising the channel bed would be feasible at this site. Both channel bed armoring and raising have been successfully permitted and constructed at numerous sites along Vermont roadways that have similar challenges found at the River Road project site.

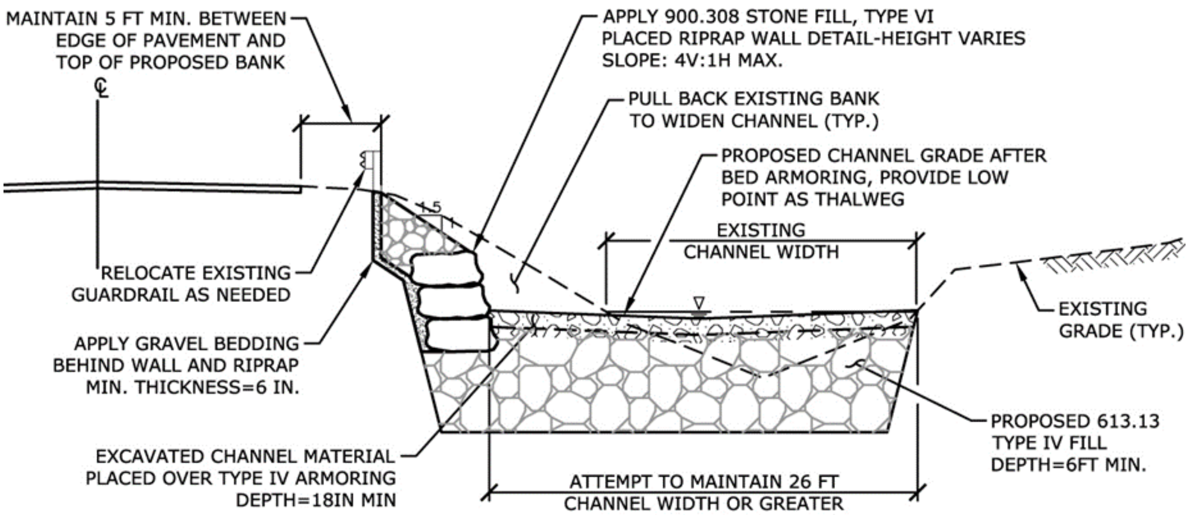



**Figure N: Typical Channel Bed Armoring Detail**

## 5.3 Alternative RC3 – Floodplain Reconnection

Floodplain reconnection consists of lowering existing grades adjacent to a river that would allow floodwaters access to the floodplain during an event of desired size or frequency. This alternative is often implemented in areas where the natural floodplain has historically been filled or in areas where floodplains have been disconnected from rivers where downcutting or incision has occurred. Reconnecting a river to a floodplain is beneficial because it allows floodwaters to spread and therefore velocity decreases along with related erosion hazards and risks. If the floodplain reconnection is large enough, another benefit would be a reduction in flood depth and water surface elevation during flooding due to providing additional storage volume on the floodplain.

A potential drawback to floodplain reconnection is clearing of vegetation and trees during construction. The clearing can sometimes create an adverse environmental impact by removing riparian buffer and shading of the river that trees provide. This impact can be offset by implementing a planting plan to restore the riparian buffer. Extensive planting plans for large floodplain reconnection projects can add a considerable amount of cost when implementing a floodplain reconnection project.

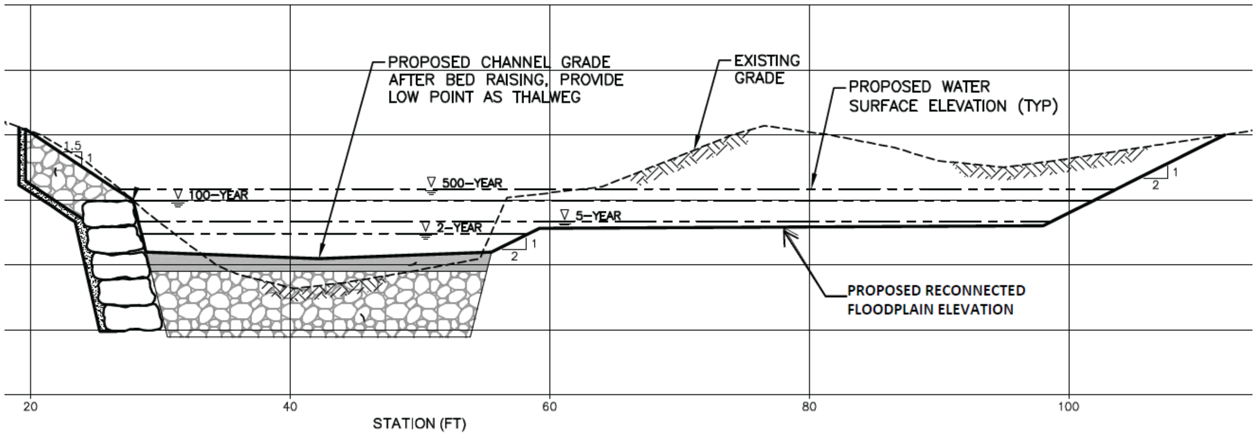



**Figure O: Typical Floodplain Reconnection Detail**

# 6.0 ALTERNATIVES ANALYSIS – DRAINAGE

The following alternatives related to drainage could be implemented in addition to the selected road stabilization alternative to reduce erosion potential.

## 6.1 Alternative D1 – Road Profile and Crown Adjustment

This alternative consists of adjusting the roadway profile or crown, or a combination of both, in order to direct runoff to a more suitable and stable location where the stormwater can be safely conveyed to the discharge point. The benefit of adjusting the road profile or crown would be to redirect stormwater away from the top of road embankment where localized erosion was observed. Changes to the profile and crown may be constrained by the limited space between the top of road embankment and steep slope on the north side of River Road. In addition, changes to the profile or crown would need to meet roadway design standards to maintain safe travel conditions.

## 6.2 Alternative D2 – Swale Reconnection

Swale reconnection would consist of reshaping the roadside swale along the northern side of River Road and conveying to cross culverts. The limited space available between the roadway edge and the steep slope on the north side of River Road may limit swale reconnection.

## 6.3 Alternative D3 – Flow Distribution

Flow distribution consists of evaluating how much stormwater runoff is draining to the existing cross culverts to determine if additional cross culverts should be installed to better distribute the runoff. Calculations would be performed to determine if the size of existing culverts are adequate or if they need to be upsized.

## 6.4 Alternative D4 – Stabilized Flow Paths

This alternative consists of evaluating existing and proposed flow paths created as part of drainage improvements to ensure that they are stable and not susceptible to erosion. New and existing swales would be stabilized using vegetation if site conditions and anticipated flow velocities allow, or be protected with stone riprap. Inlets and outlets would be protected with stone armoring to stabilize the areas along the roadway and embankment. Where stormwater sheet flows off the roadway surface, shoulders would be shaped to maintain sheet flow and stabilized with vegetation. Stabilizing flow paths would work in conjunction with stabilization measures proposed along the road embankment.

# 7.0 Permitting Requirements

The regulatory permits that will likely be required for this project include:

- Stream Alteration Permit – Vermont Department of Environmental Conservation
- VT General Permit – U.S. Army Corps of Engineers
- Local Zoning Permit – Town of Lincoln

In addition, the following permits may be required depending on the size and scope of the alternative(s) selected:

- Construction Stormwater Permit – Vermont Department of Environmental Conservation
- Wetland Permit – Vermont Department of Environmental Conservation

In addition, the proposed design of any drainage improvements would need to comply with the Vermont Municipal Roads General Permit (MRGP) requirements and standards.

# 8.0 Recommendations

The recommended alternative that the Town should consider exploring further in order to reduce erosion risks and increase stability of the River Road embankment at the project site is Alternative 3, Rebuild Stone Armoring with Pinning. This alternative balances construction costs and constructability with maintenance requirements, associated costs, and durability. Alternative 3 also minimizes temporary impacts during construction and therefore simplifies the permitting process compared to other alternatives.

In addition, it is recommended that the Town explore flood chute reconnection (RC1) and channel bed armoring (RC2). Implementation of these alternatives would help reduce erosion pressure on the roadway embankment during flood events and reduce impacts to the river channel with maintenance requirements.

Implementation of drainage improvements that will help reduce localized rill erosion at the top of the roadway embankment is also recommended (D1, D2, D3, and D4). Drainage improvements would include evaluation of road surface drainage by potentially modifying the crown, evaluating the capacity of culverts, adding culverts if needed, evaluating improvements to the roadside swale, and providing efficient culvert inlets and protected outlets. The design of improvements should promote distributed sheet flow off the roadway and down the embankment, rather than concentrated flow that increases the risk of erosion. Sheet flow through vegetation will also help filter stormwater. The opportunity to adjust the road surface to direct stormwater runoff to an improved swale along the north side of the road should also be explored. The roadway embankment appears to be more stable and has less rill erosion at the top of the bank in areas where the road surface sheds runoff to a swale at the northern edge of the roadway. This alternative may be limited by roadway profile requirements and the space available along the northern roadway edge for a swale.

The recommended alternatives have been shown on the attached conceptual design sketch with typical details (Sheets PR-1 and PR-2 of Appendix C).

# 9.0 Next Steps

The following next steps are recommended to advance the project.

## 9.1 Topographic and Boundary Survey

Conduct a more detailed survey of the project site to collect topographic data and the location of site features. The survey may need to include a boundary retracement to establish the Right-of-Way and adjacent parcels to determine temporary or permanent easement requirements. The cost to perform the topographic survey at the site is estimated to be approximately $10,000. If a boundary survey is required to establish the right-of-way and property boundaries, an additional $8,000 is estimated.

## 9.2 Wetland and Natural Resource Delineation

Conduct a wetland delineation and assessment to confirm if wetlands exist in the areas identified during this initial assessment and what their quality is. If wetlands are present, the formal delineation and assessment will guide design and permitting. The delineation of Ordinary High Water (OHW) should also be confirmed. Additional measurements can be taken to confirm bankfull dimensions while walking along the river channel. The cost to perform the wetland delineation at the site and provide the information required to guide design and permitting is estimated to be approximately $4,000.

## 9.3 Deep Soil Investigation and Geotechnical Analysis

The recommended method for investigating subsurface conditions is to conduct borings and install inclinometers and monitoring wells at each borehole location to monitor ground movement and groundwater levels. River Road traverses the subject slope at a lower elevation, along New Haven River, while Forge Hill Road is along the top of the subject slope. The elevation difference between the river and the lower road is about 20 to 25 feet and the elevation difference between the lower and the upper road is about 70 to 75 feet. The approximate 100-foot-tall slope has a gradient of about 2H:1V or steeper locally.

Two borings are proposed – one at the south edge of River Road closer to the river (Boring SB-1), and the other at the north edge of River Road (Boring SB-2), at the approximate locations depicted in Figure P. Each borehole will be fitted with a slope inclinometer casing and a small-diameter groundwater observation well. These borings will be drilled to approximately 30 feet depth each, or to refusal if encountered at a shallower depth.

An inclinometer at Boring SB-1 is expected to pick up ground movements from the localized toe failure (Figure C). An inclinometer at SB-2 is expected to provide information on whether or not ground movements are occurring that connect to the upper slope (Figure C). Note that the exploration plan may need to be modified based on conditions encountered during drilling.


**Figure P: Site Layout and Proposed Boring Locations**

The estimated cost for this investigation is approximately $25,000. This would include the borings, sampling, laboratory testing, inclinometer and observation well installations, monitoring of inclinometers and observation wells for three months, slope stability analysis, and preparation of a geotechnical report with recommendations for design of stabilization measures as applicable.

**Table 7: Next Steps Summary Table**

| Topographic Survey | Boundary Survey | Wetland Assessment | Subsurface Exploration & Geotechnical Analysis | Total |
|---|---|---|---|---|
| $10,000 | $8,000 | $5,000 | $25,000 | $48,000 |

# 10.0 REFERENCES

Ratcliffe, N. M., R. S. Stanley, M. H. Gale, P. J. Thompson, and G. J. Walsh, 2011. Bedrock Geologic Map of Vermont. U.S. Geological Survey Scientific Investigations Map 3184, 3 sheets, scale 1:100,000.

# APPENDIX A – KICKOFF MEETING NOTES

SLR global **environmental** and **advisory** solutions

JOB ____
SHEET NO. ____ OF ____ SCALE ____
CALCULATED BY ____ DATE ____
CHECKED BY ____ DATE 1

- Lincoln - River Road:
  March 29, 2023
  10 Am -

- Dave - Linch
- Tim M -
- Mike W - ACRPC
- Bill F.
- Alan - SB/

- Discuss Scope:
  - → Step 1: Data Collection
    Step 2: Concept Design
    - → How many alts?
    - → Wide range →
- Drainage from above? Town concerned w/ SWM.
- Planning → level for concept →
- traffic control → safety during field work
  ADA - town hires or sheriff.
  town doesn't have resources
  use town signage, SLR creates plan. Town not responsible
  - worse in town - sight lines bad.
- Length of Construction, road closures?
-
- Traffic Count - ACRPC

SLR global environmental and advisory solutions

JOB
SHEET NO. OF SCALE
CALCULATED BY DATE
CHECKED BY DATE 2

- Detour? - Forge Hill Rd - did not work well
  - → sharp corner on Quaker St.
  - → Traffic Plan
- Last wash out
  - → 2011 T.S. Irene → 1998 road destroyed
  - → not much to do until needs attention.
- Near by project - similar - trench in Rock to key.
- Conc block a consideration
  - → no marble blocks (1998)
- Hefermans Pit - Hard scrabble, Bristol
- wall on Rte 17 →

  Ripton Road - gabions
- Scope of Work - project Limits:

  targeted area → primary.
  - potential - "B"
- Discussed the gravel bar & flood chute
  - → pressure on road bank
  - → reviewed 1960 photo
- State would permit re-opening flood chute.
- FEMA Funding - documentation for 1998 & 2011?
  - → FEMA Claims?
  - → Road closures?

Would fit BRK funding source

SLR global **environmental** and **advisory** solutions

JOB
SHEET NO. OF SCALE
CALCULATED BY DATE
CHECKED BY DATE 3

→ Reach out to VEM → check on potential
Andrew eligibility

→ BRIC or HMGP (Pre-disaster mitigation)

→ 1938 → riprap in 1960 photo
→ dredged all the way to Bristol

→ 5 feet moved out into river at nearby site
↳ wide section of river.

→ Jason Borg – helped w/ other site, get on board

→ U/S gravel bar – town was mining to use

→ road washed out for 1 month. – 1998
↳ Both Bridges washed out 1998

→ TAC met 3rd weds of each month → Sept 20th

↳ funding hard deadline Sept 30th

→ Notify Town when in Field
↳ pull off

end: 11:00 AM

# APPENDIX B – FIELD WORK NOTES

River Rd - Lincoln

BMC
RKS

June 14 2023
on site: 8:50 am

partly cloudy - ±60°F
Flows below avg.

→ A - Low
- heavy veg, flood bench
no impingement, large trees
gravel bar

→ B - moderate - some large trees
- veg thinning, bar building
starts on opposite bank
begin impingement, cracking
in SB travel lane,
no flood bench
drainage off L.P. in small
pullout causing rill erosion

→ C - grass, knot weed, perennial
veg, saplings, more impingement
mod-high
some armoring, no flood
bench, bar building on
opposite side, outside bend
no shoulder, minor cracking in both travel lanes
fill some top slope

Rite in the Rain

- C - con't
  - still some slope, channel disconnect from bench on opposite side. narrow chnnl riffle
  - road drainage rill erosion @ top of slope
  - bottom/toe armored, steep
- D - High
  - steep upper bank, no veg upper only some perennial on
    steep armor @ toe, dislocations
    signs of erosion, disconnect from flood bench,
    rill erosion on upper from road drainage
  - cracking longitudinal in both travel lanes
  - bank erosion on opposite
  - narrow channel, riffle section
  - direct impingement, bar building on opposite
- E - High lower to medium
  - lower risk due to river
  - higher due to steepness & uncontrolled runoff, slope failure rills
  - no crown, HP on outside opposite river bank, all runoff goes over slope

- E - con't
  - veg cover on bank, saplings to med trees, grass, perennials
  - longitudinal cracking in road
  - Perpendicular cracking patches at culv crossings
  - Hist. armoring @ toe
  - river becomes parallel
  - deeper/pools in river

- F - moderate/medium
  drainage to other side
  w ditch/crown
  HP on river side
  - less runoff and slope
  - Still steep, some shoulder
  - railing not leaning
  - river parallel
  - veg, larger trees
  - armoring historic @ toe
  - begin bar building on road side

Rite in the Rain

- G - Low
  - drainage to other side of road, ditching
  - more shoulder, less steep
  - river moves away, bench & bar building on road side
  - slope / road embankment not as tall
  - drop structure w/ cross culv to control runoff
  - opposite slope is more gentle not as tall

Wet Section @ D. (M/s - signal lost on GPS)

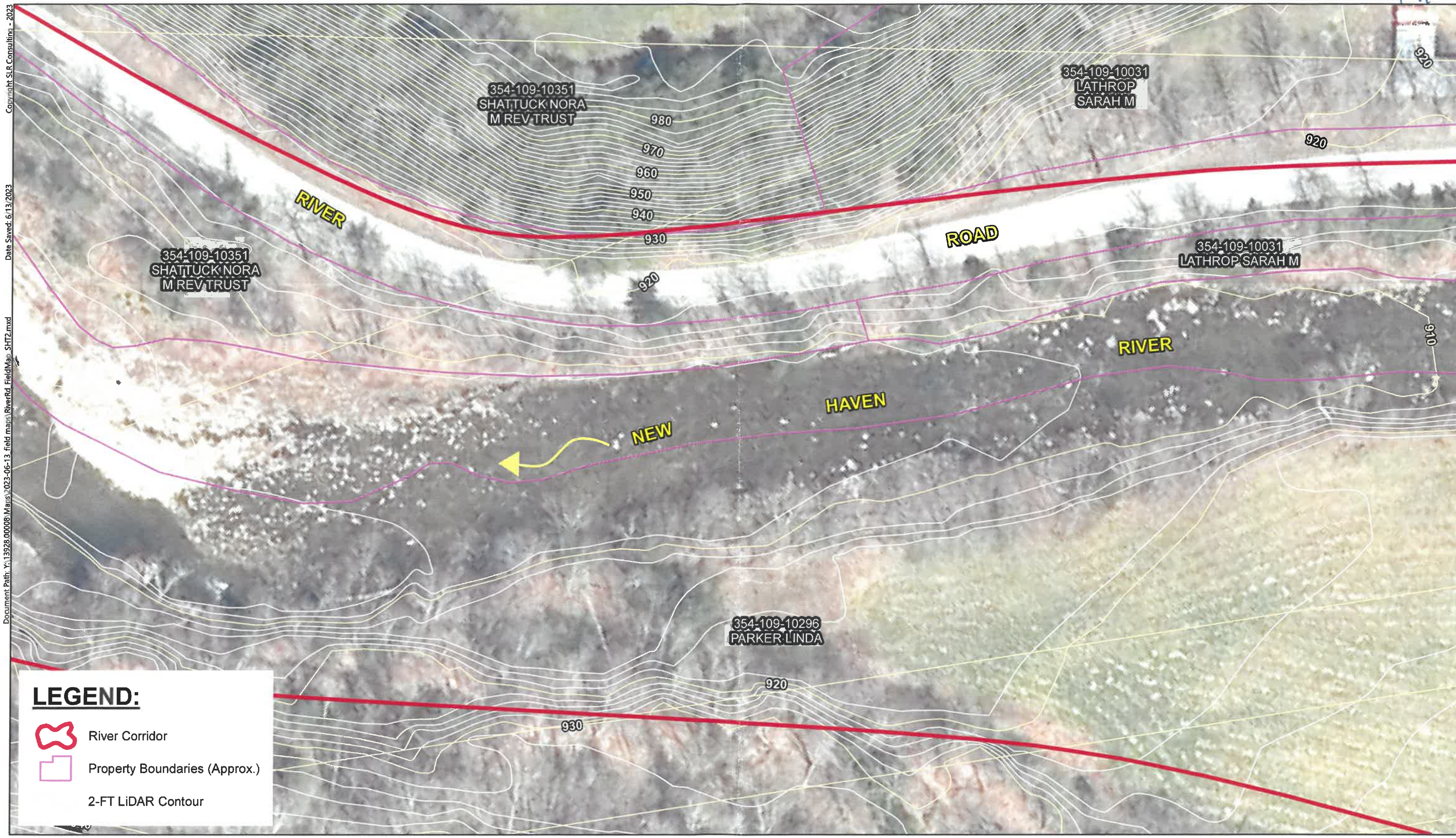
| Dist* | Rod^ | |
|---|---|---|
| 0.0' | -0.7' | ROW (use GPS pnt) |
| 4.0' | -2.5' | |
| 7.5' | -3.5' | |
| 14.5' | -2.0' | |
| 21.0' | -0.7' | |
| 27.0' | -0.0' | LOW |

BF width = 49 fts   BF depth = ±5.5' (2.0' above TW)

* - Dist from ROW pnt.
^ - rod reading below WSEL

Feild Notes - 06/14/2023

BWC
RKS
pg1.



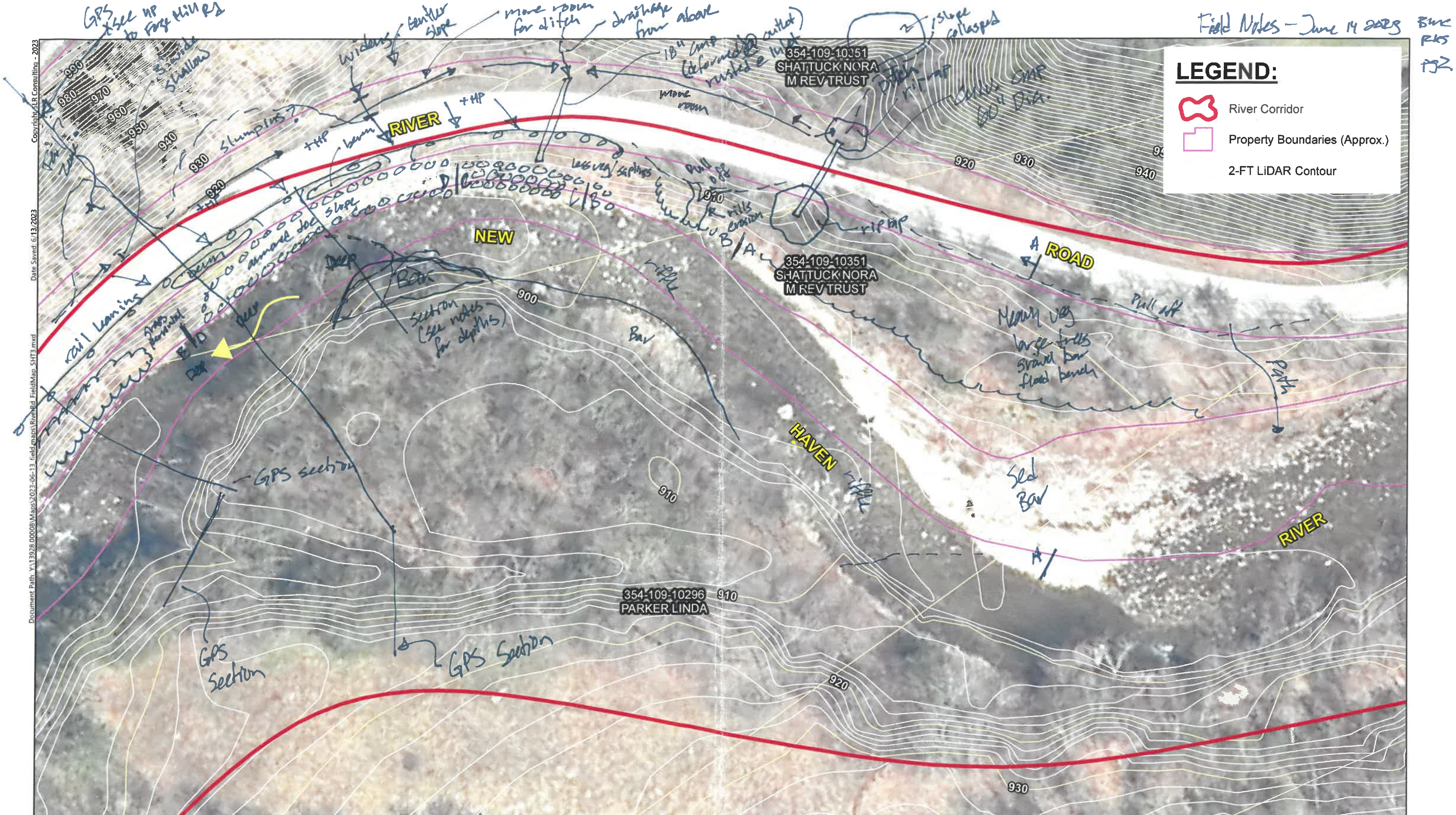

SHEET 2 - EXISTING CONDITIONS

RIVER ROAD STABILIZATION PROJECT
TOWN OF LINCOLN, VERMONT

0 25 50
Feet
1 in = 50 feet

N

SLR
1 SOUTH MAIN ST
WATERBURY, VT 05676
802.882.8335






Date Saved: 6/13/2023

## SHEET 3 - EXISTING CONDITIONS

RIVER ROAD STABILIZATION PROJECT
TOWN OF LINCOLN, VERMONT

0 25 50
Feet
1 in = 50 feet

N

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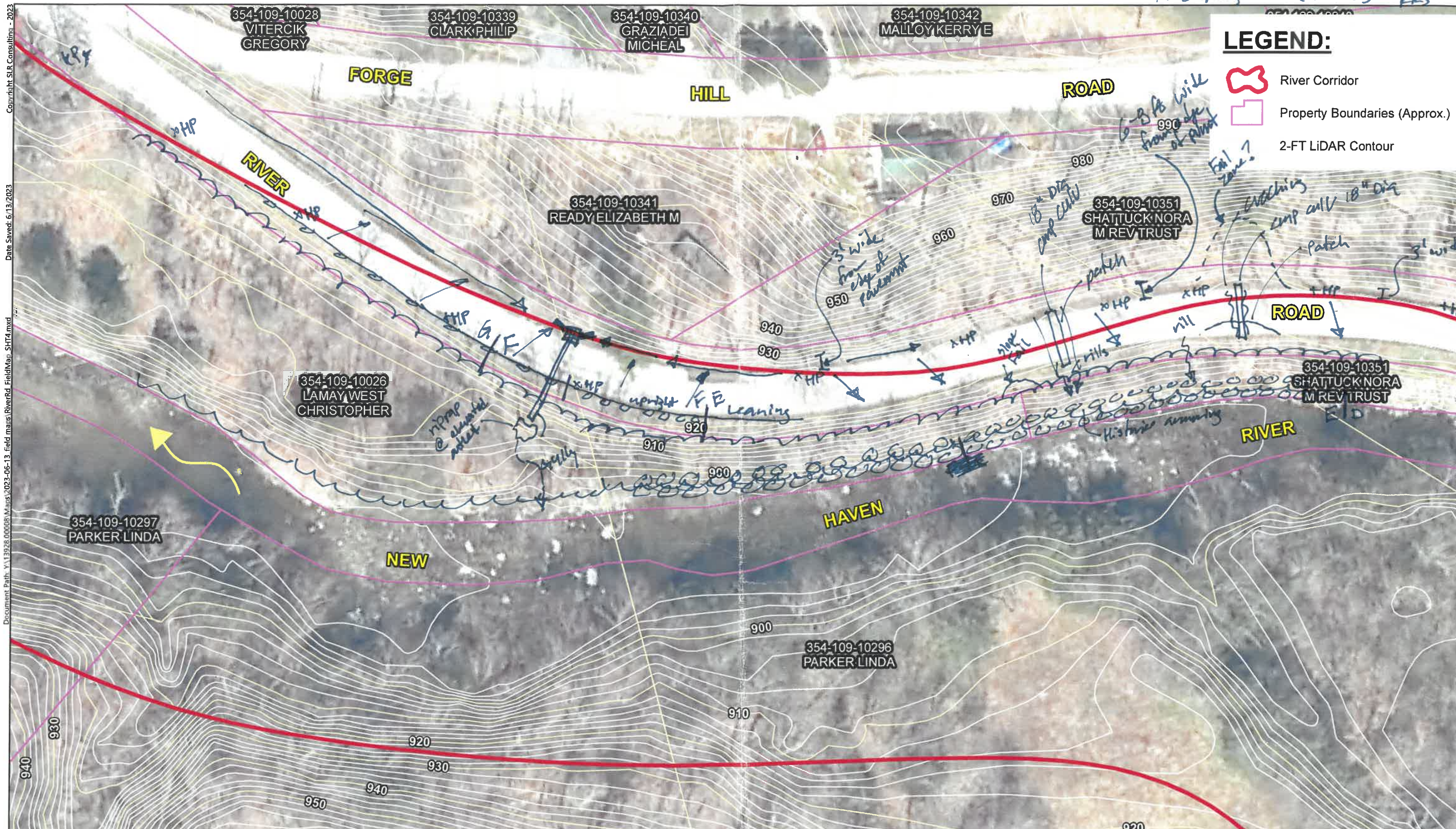
802.882.8335

Field Notes Jan 14 2023 p. 3




SHEET 4 - EXISTING CONDITIONS

RIVER ROAD STABILIZATION PROJECT
TOWN OF LINCOLN, VERMONT

0 25 50
Feet
1 in = 50 feet

N

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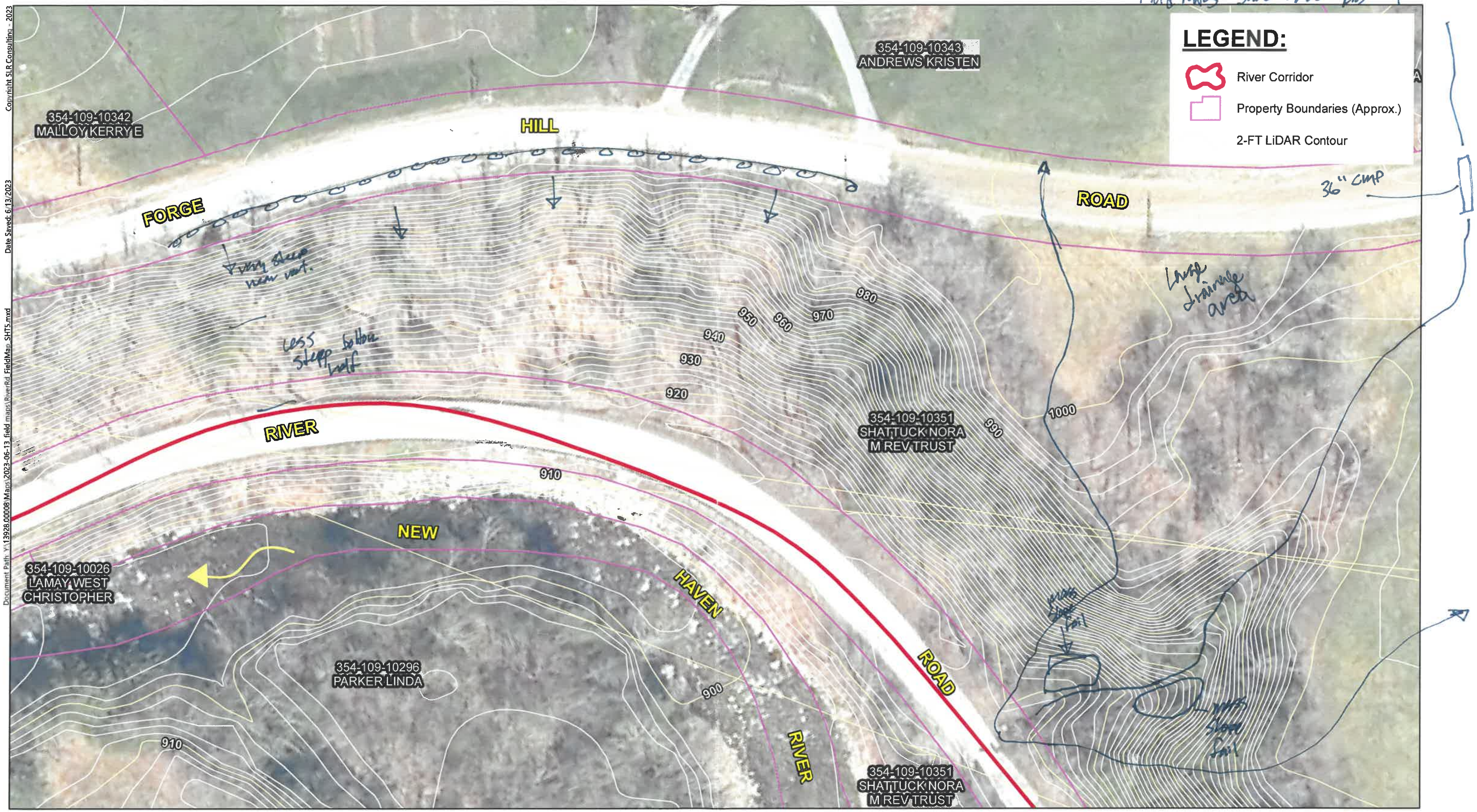
Field Notes – June 14 2023 BMC RMS p.4




SHEET 5 - EXISTING CONDITIONS

RIVER ROAD STABILIZATION PROJECT
TOWN OF LINCOLN, VERMONT

0 25 50 Feet
1 in = 50 feet

N

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Field Notes - June 14 2023 EMC RKS p.5



Date Saved: 6/13/2023

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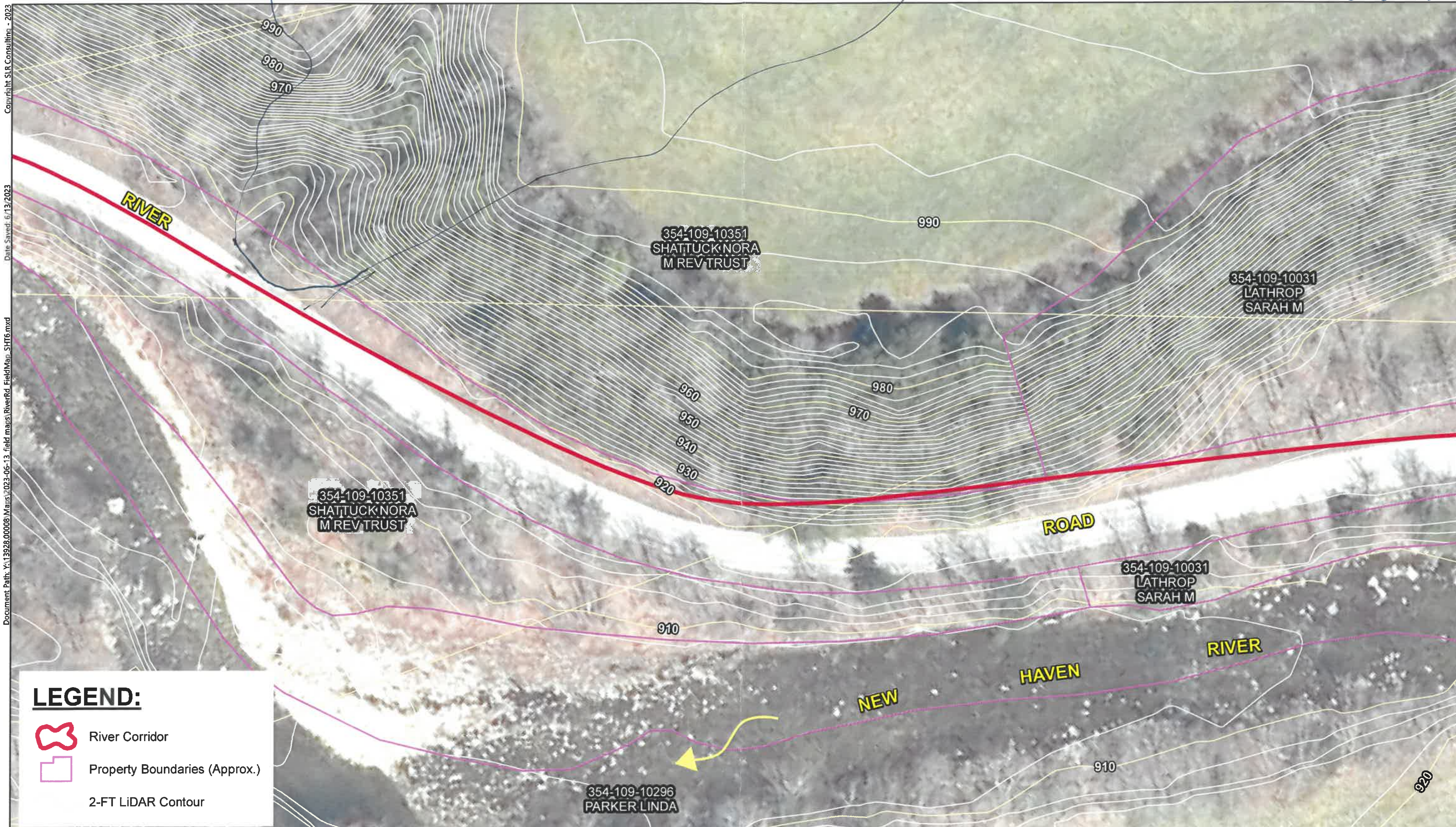


SHEET 6 - EXISTING CONDITIONS

RIVER ROAD STABILIZATION PROJECT
TOWN OF LINCOLN, VERMONT

0 25 50
Feet
1 in = 50 feet

N

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# APPENDIX C – CONCEPTUAL DESIGN PLANS

Drawing: W:\CADDESIGN\13928.00008-DE\CAD\RR-TITLE.DWG Layout Tab:11X17-TITLE

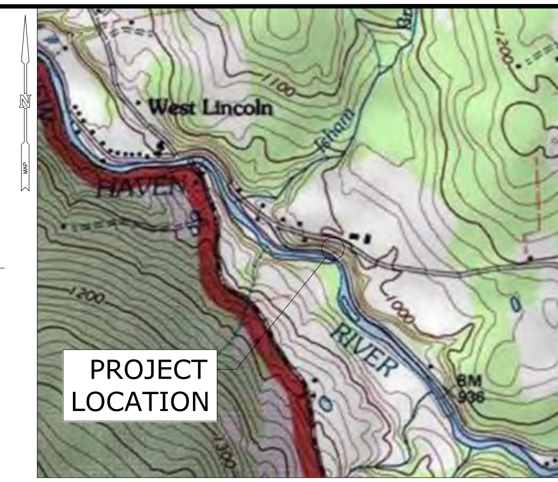
# RIVER ROAD STABILIZATION

## RIVER ROAD
## LINCOLN, VERMONT

CONCEPT DESIGN
AUGUST 31, 2023

**PROJECT SITE VICINITY MAP:**

0' 250' 500'
0 1/2" 1"
SCALE 1" = 500'




**LOCATION MAP:**

0' 1000' 2000'
0 1/2" 1"
SCALE 1" = 2000'

**PREPARED FOR:**

ADDISON COUNTY REGIONAL PLANNING COMMISSION
14 SEMINARY STREET
MIDDLEBURY, VERMONT 05753

**LIST OF DRAWINGS:**

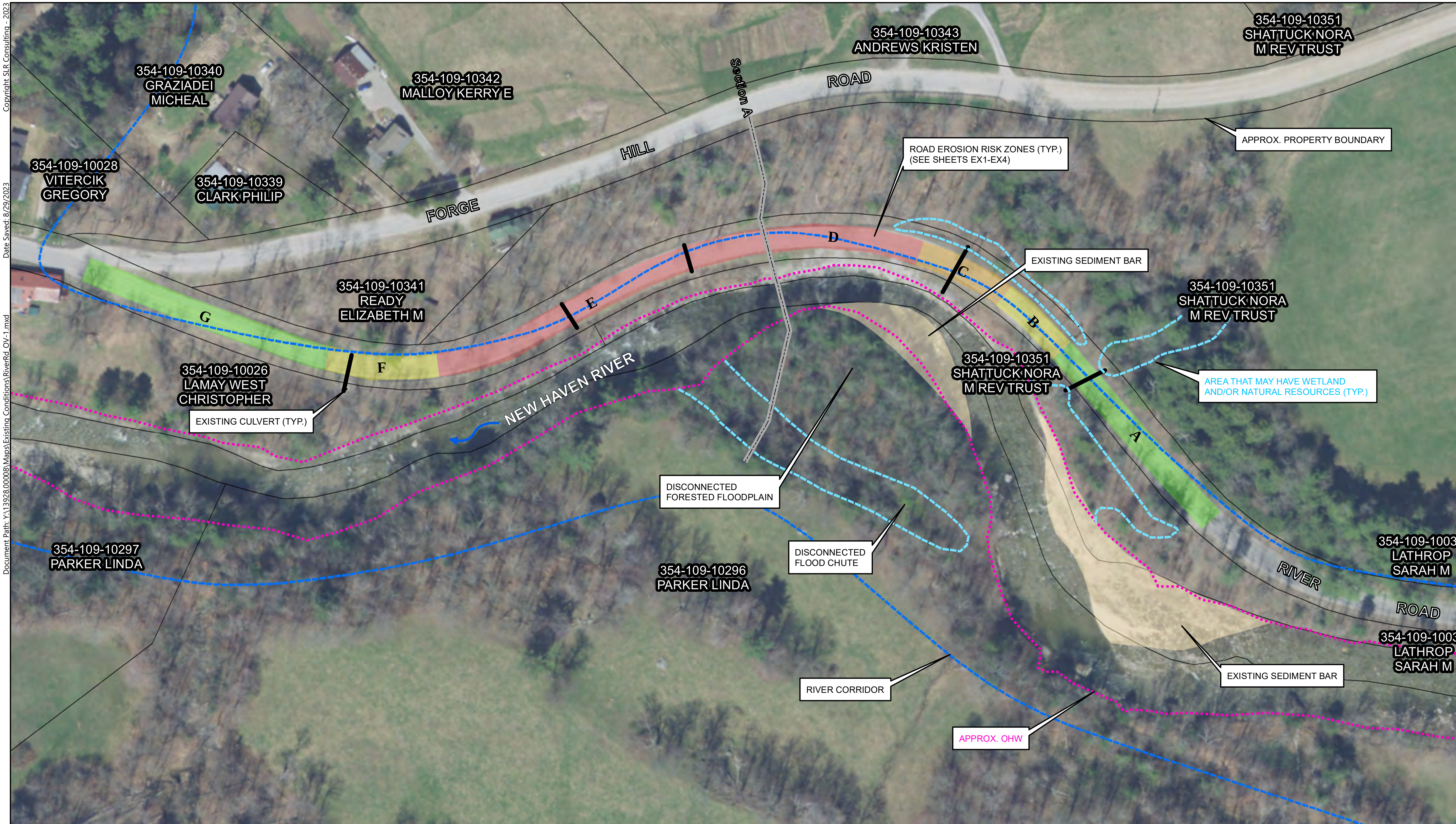


**PREPARED BY:**


SLR
1 SOUTH MAIN STREET
WATERBURY, VT 05676
802.882.8335
SLRCONSULTING.COM


811
Know what's **below.**
**Call** before you dig.
www.cbyd.com

Plotted by: ERICHARDS On this date: Thu, 2023 August 31 - 9:45am






# SHEET OV-1: OVERVIEW MAP

RIVER ROAD STABILIZATION
TOWN OF LINCOLN, VT

0 25 50 100
Feet

1 in = 100 feet
AUGUST 31, 2023

N

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1 SOUTH MAIN ST
WATERBURY, VT 05676
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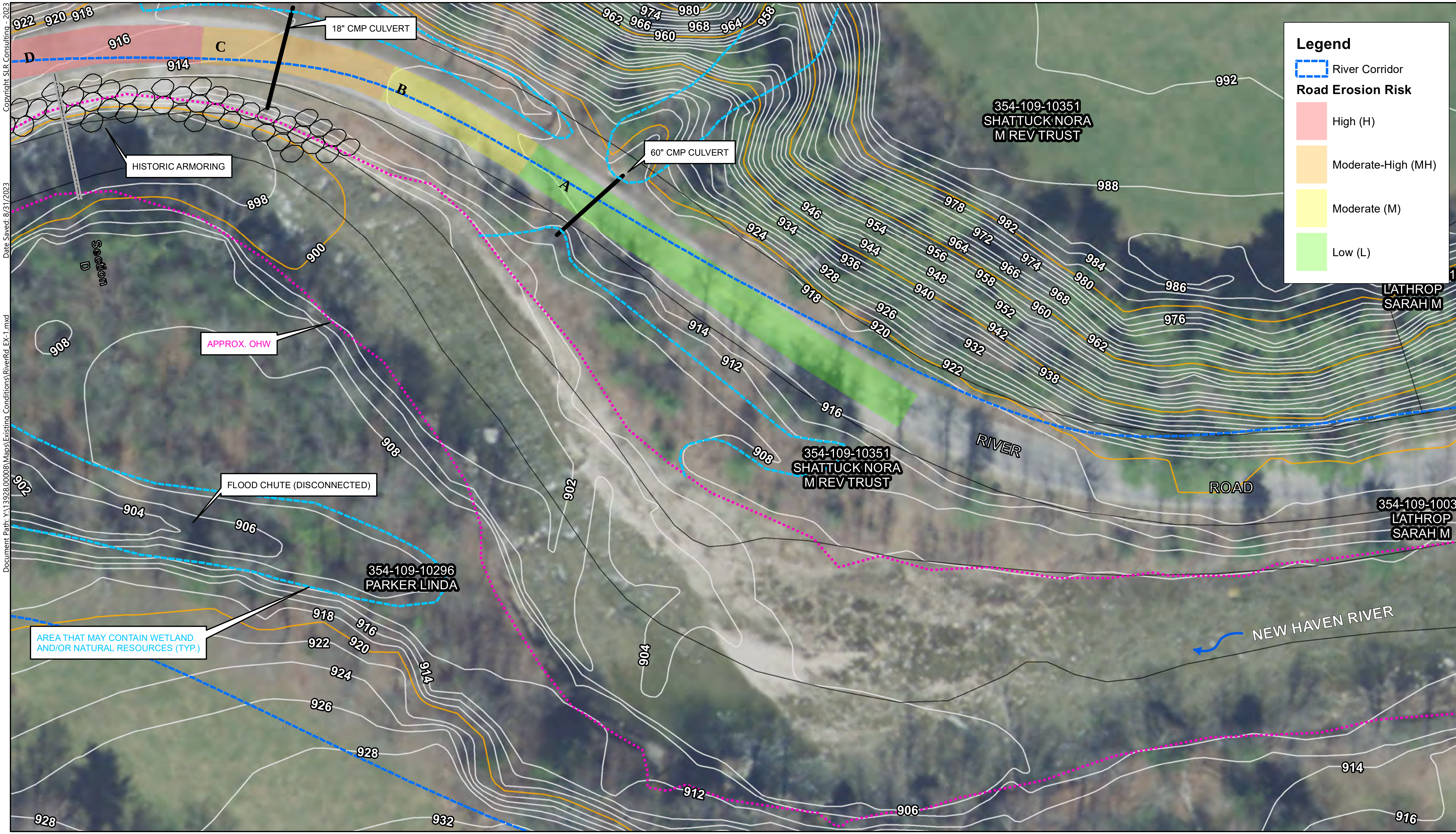


# SHEET EX-1: EXISTING CONDITIONS

RIVER ROAD STABILIZATION
TOWN OF LINCOLN, VT

0 5 10 20 30 40 50
Feet
1 in = 50 feet
AUGUST 31, 2023

N

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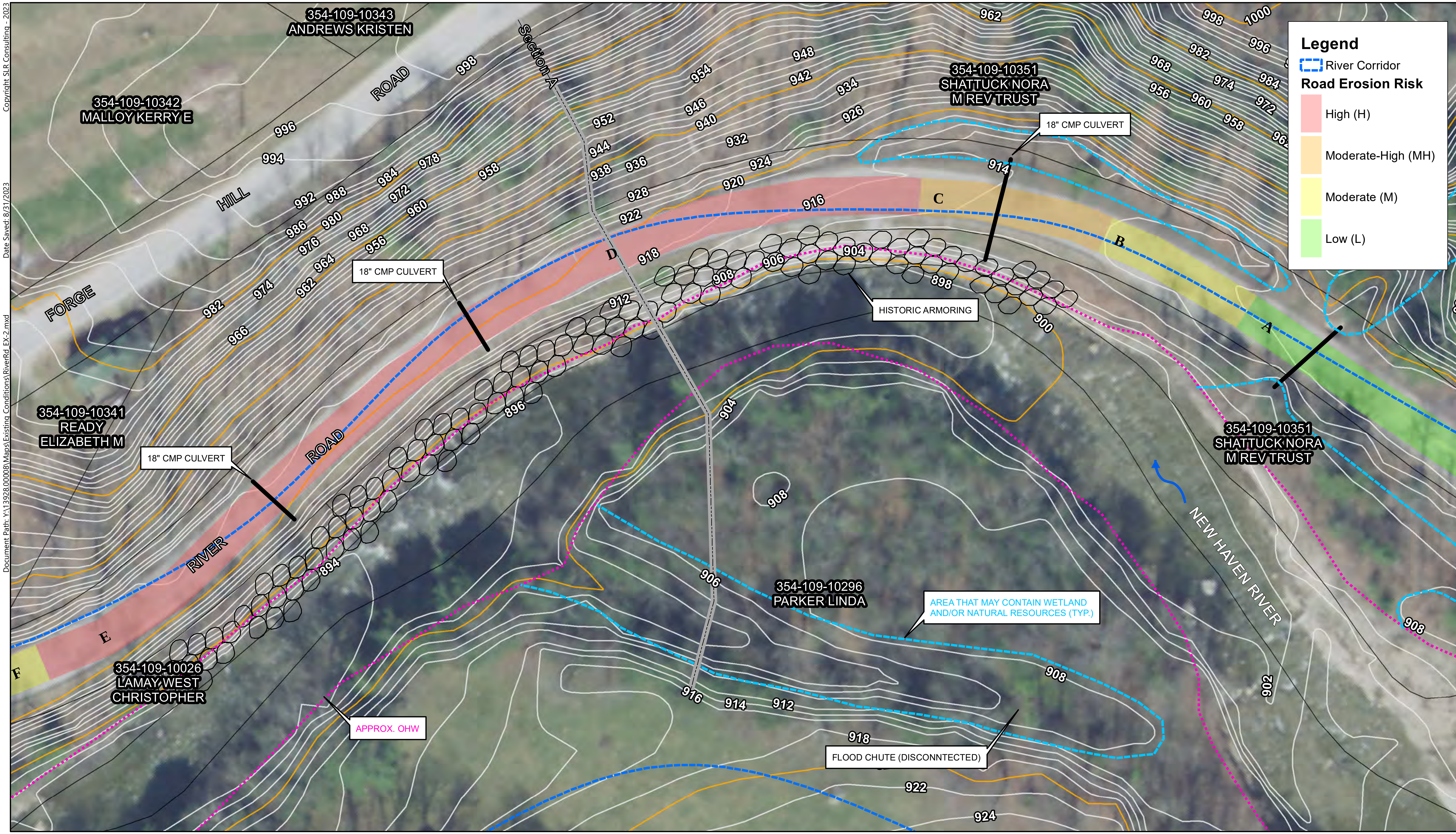


# SHEET EX-2: EXISTING CONDITIONS

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TOWN OF LINCOLN, VT

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Feet
1 in = 50 feet
AUGUST 31, 2023

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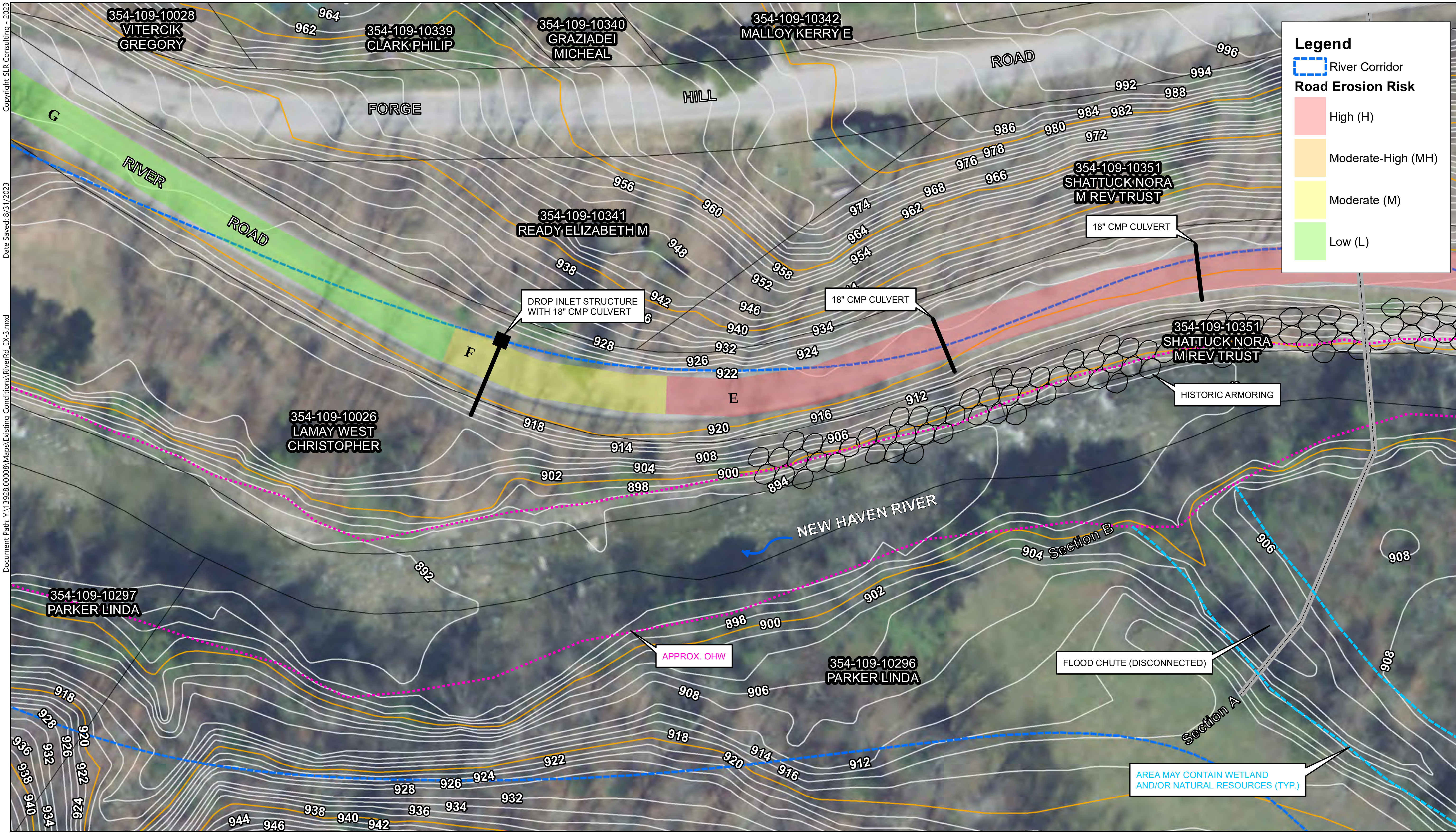


# SHEET EX-3: EXISTING CONDITIONS

RIVER ROAD STABILIZATION
TOWN OF LINCOLN, VT

1 in = 50 feet
AUGUST 31, 2023

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Date Saved: 8/31/2023
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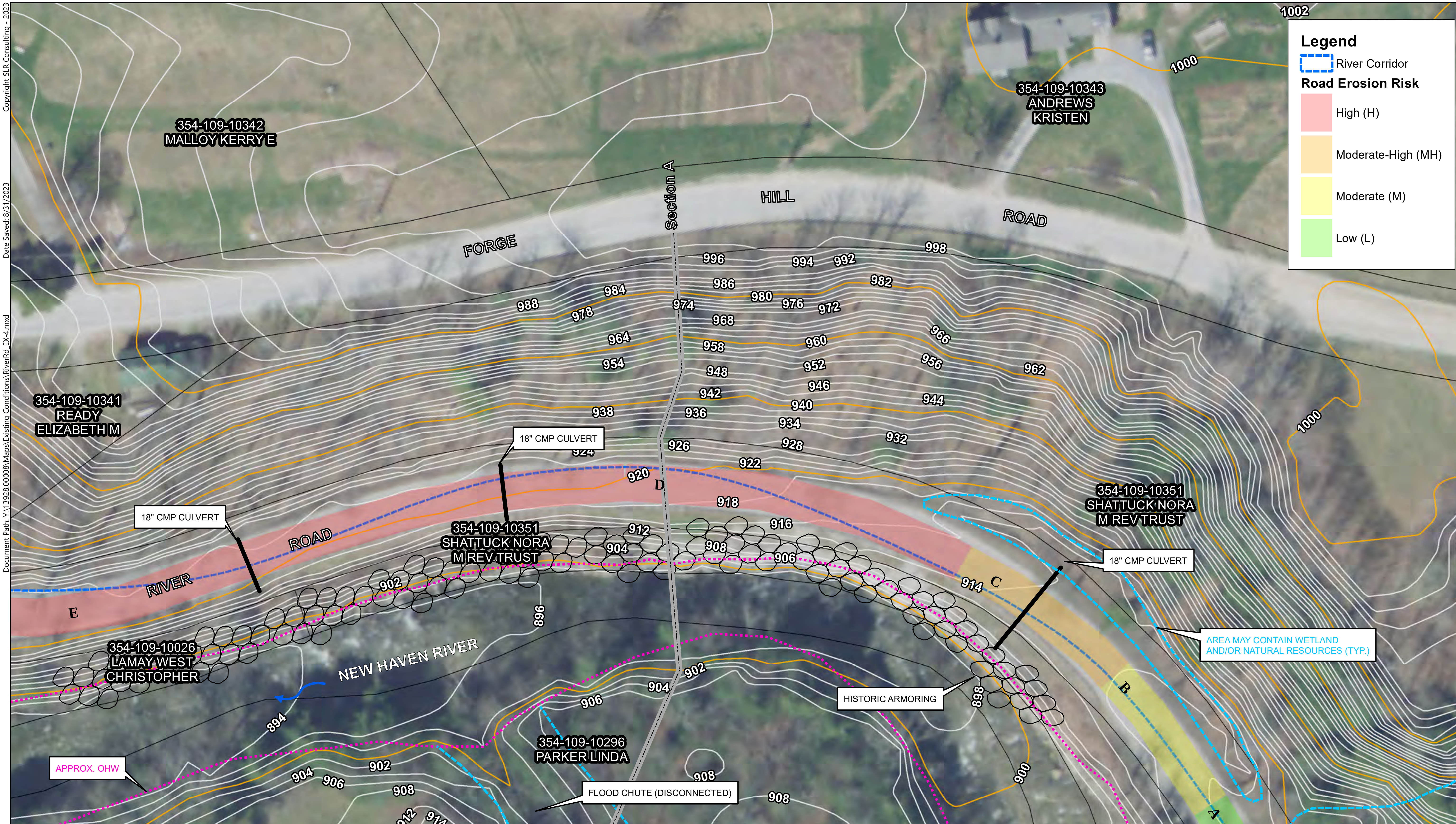


# SHEET EX-4: EXISTING CONDITIONS

RIVER ROAD STABILIZATION

TOWN OF LINCOLN, VT

0 5 10 20 30 40 50
Feet

1 in = 50 feet

AUGUST 31, 2023

N

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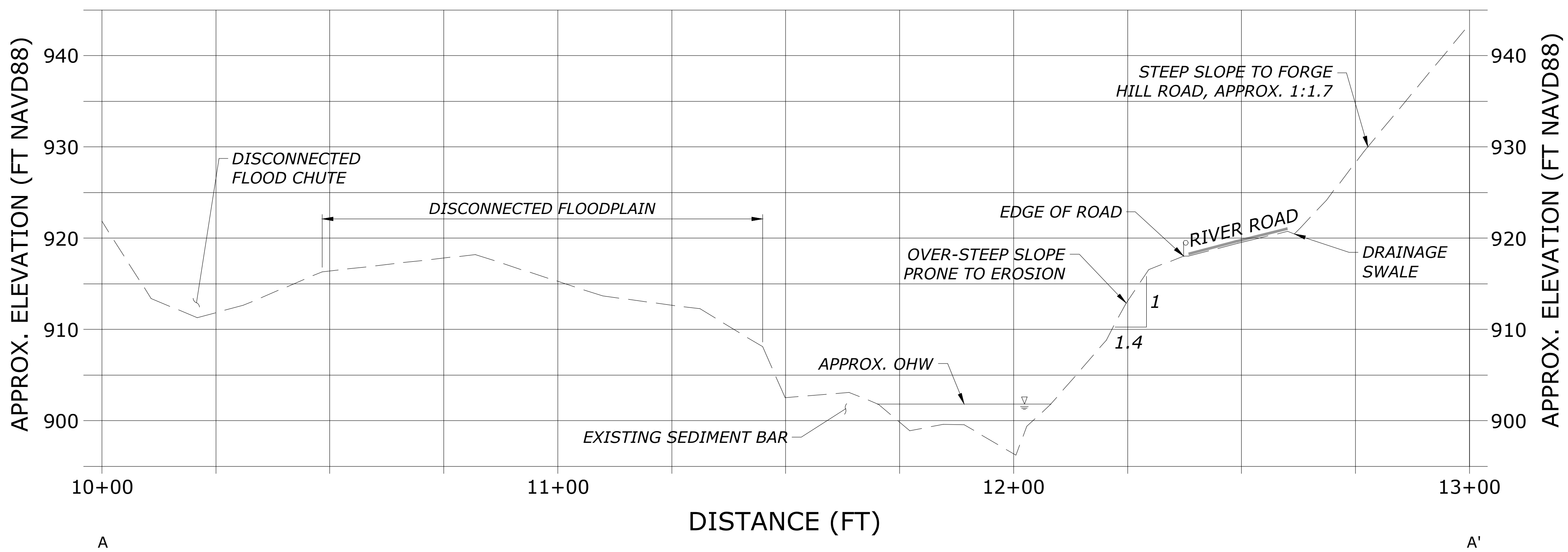
1 SOUTH MAIN ST
WATERBURY, VT 05676
802.882.8335




CROSS SECTION VIEW (LOOKING DOWNSTREAM) - SECTION R-R'

FIGURE 1 - LOOKING DOWNSTREAM

FIGURE 2 - LOOKING UPSTREAM

SLR
99 REALTY DRIVE
CHESHIRE, CT 06410
203.271.1773
SLRCONSULTING.COM

REVISIONS

TYPICAL SECTION - SECTION A

RIVER ROAD STABILIZATION
PROJECT NAME 2

RIVER ROAD
LINCOLN, VERMONT

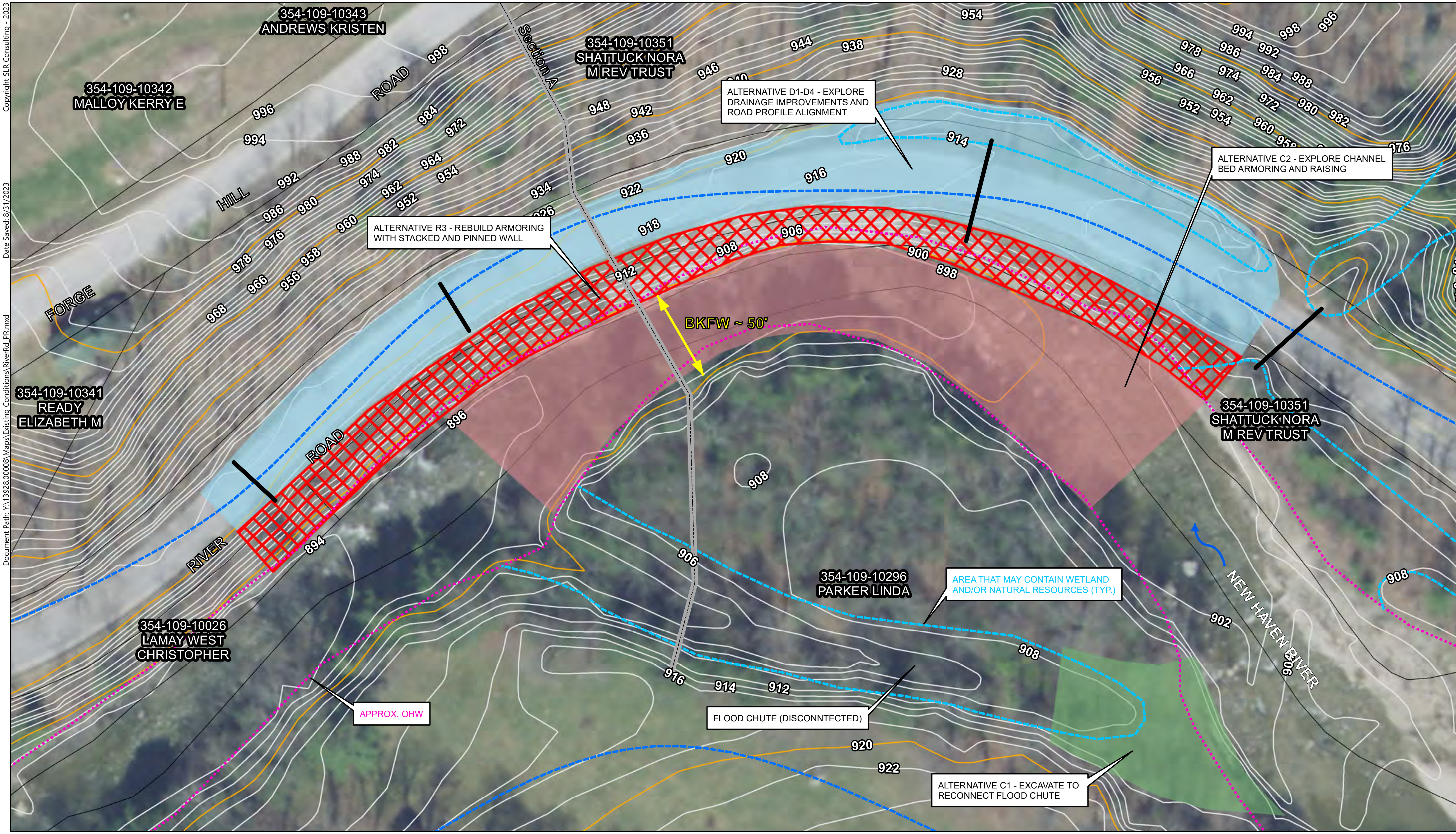
| DESIGNED | DRAWN | CHECKED |
|---|---|---|
| -- | EMR | -- |

SCALE: AS NOTED

DATE: AUGUST 31, 2023

PROJECT NO.: 13928.00008

SHEET NO.: XS-1




## SHEET PR-1: PROPOSED CONDITIONS

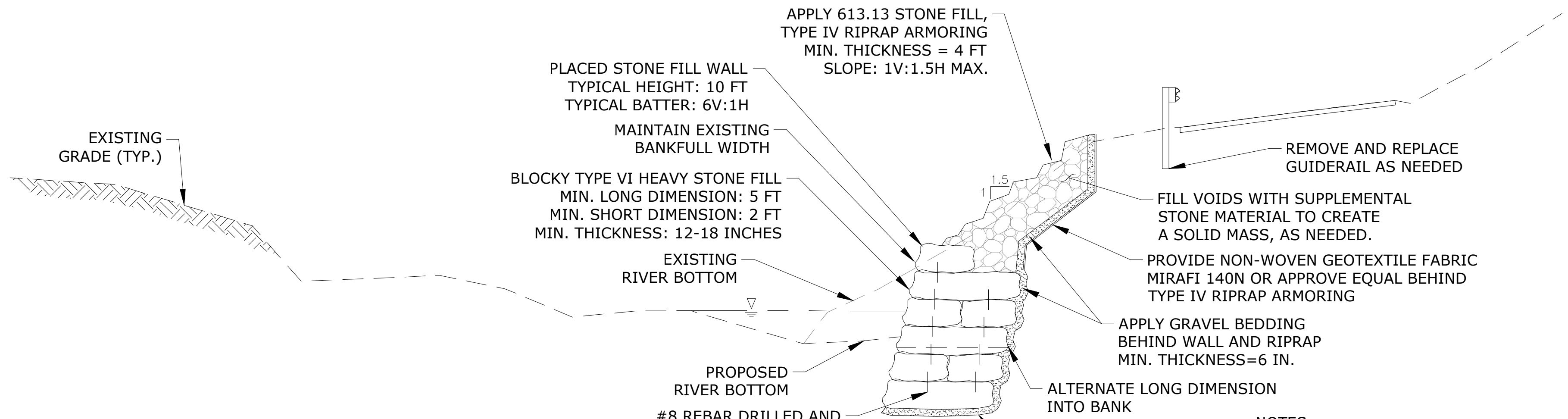
RIVER ROAD STABILIZATION
TOWN OF LINCOLN, VT

0 5 10 20 30 40 50
Feet

1 in = 50 feet
AUGUST 31, 2023

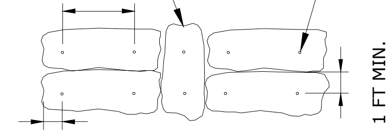
N

SLR
1 SOUTH MAIN ST
WATERBURY, VT 05676
802.882.8335




SECTION VIEW

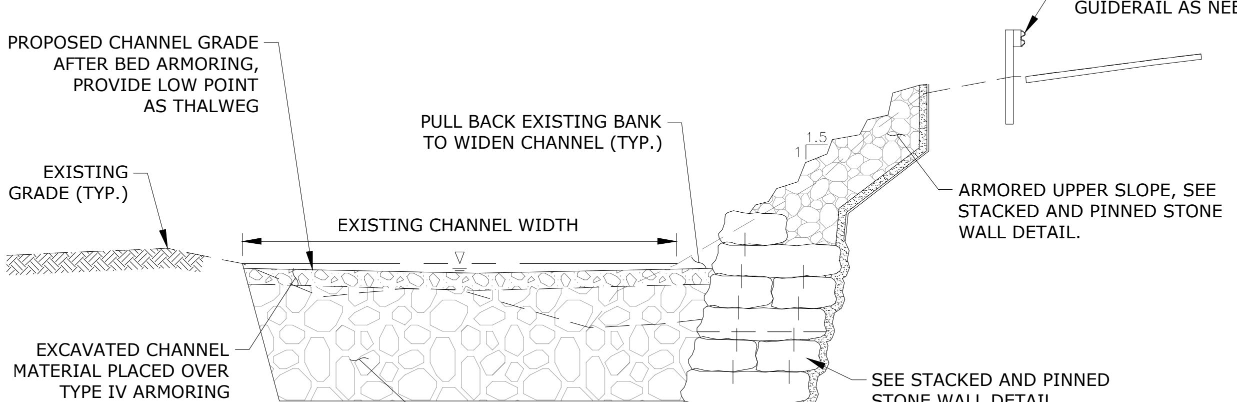
NOTES:
1. LOCATIONS OF DOWELS ARE FOR GUIDANCE ONLY. CONTRACTOR TO SUBMIT PLAN FOR APPROVAL BY PROJECT ENGINEER.
2. A NON-SHRINK GROUT SHALL BE USED IN THE PLACING OF DOWELS AND APPROVED BY THE ENGINEER.
3. DRILLING AND GROUTING DOWELS SHALL INCLUDE DRILLING 2 FOOT MINIMUM INTO THE LEDGE.
4. NUMBER OF LAYERS OF PLACED STONE FILL WALL TO DEPEND ON THICKNESS OF STONE.




# STACKED AND PINNED STONE WALL

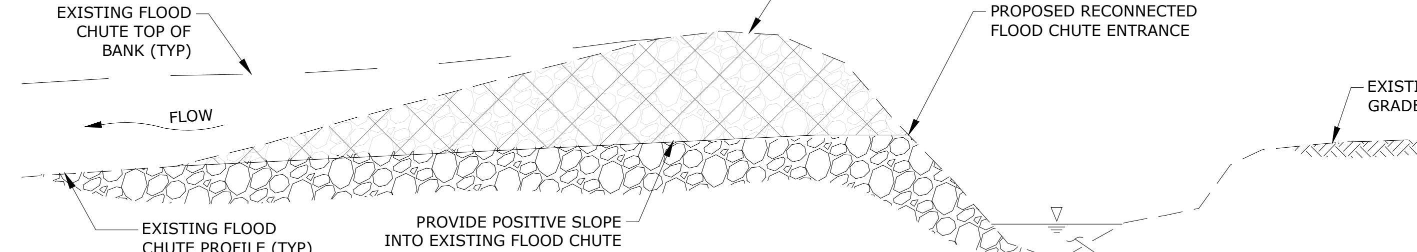
NOT TO SCALE

PLAN VIEW




# TYPICAL CHANNEL BED ARMORING

NOT TO SCALE




# TYPICAL FLOOD CHUTE RECONNECTION

NOT TO SCALE

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WATERBURY, VT 05676
802.882.8335
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REVISIONS

DETAILS
RIVER ROAD STABILIZATION
RIVER ROAD
LINCOLN, VERMONT

| BMC | EMR | --- |
|---|---|---|
| DESIGNED | DRAWN | CHECKED |

SCALE: AS NOTED
DATE: AUGUST 31, 2023
PROJECT NO.: 13928.00008
SHEET NO.: DET-1