Stormwater Master Plan
Town of Sunderland, Vermont

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1.0 Introduction

The Town of Sunderland is situated on the Western slopes of the Green Mountains. The mountains and valleys in most of the Town east of the Route 7 corridor are well forested with very limited roadways and development. Much of the Town drains to the Batten Kill and its tributaries, including the Roaring Branch, Warm Brook, and Lye Brook. These streams mainly begin to the east in high-elevation wetlands in the Green Mountain National Forest, which occupies 75% of the Town. The Town of Sunderland is predominantly forested with areas of low-density residential and agricultural land use. As with most mountain-valley villages of rural Vermont, stormwater concerns are typically related to road washouts and localized erosional areas. Since 1990, the Town of Sunderland has experienced nine moderate floods and one extreme flood, some of which have caused severe damage to private and public land and infrastructure from fluvial erosion and stormwater runoff. The most recent event, Tropical Storm Irene in August 2011, caused widespread damage in southern Vermont, including the Town of Sunderland.

In summer 2016, the Bennington County Regional Commission (BCRC) received a grant from the Vermont Agency of Natural Resources (Ecosystem Restoration Program) to develop a Stormwater Master Plan (SWMP) for the Town of Sunderland. Fitzgerald Environmental Associates, LLC (FEA) was hired by BCRC in the fall of 2016 to develop the plan. The Sunderland SWMP follows the VTANR SWMP guidelines and was developed over the course of 2016 and 2017 through extensive field survey work, interaction with multiple stakeholders in the Town of Sunderland to prioritize projects, and follow-up analysis and design work.

1.1 Project Background

Stormwater runoff is generated any time rain or melting snow runs off the land; stormwater runoff typically increases when the land use has been altered from its natural state. Typically, hardened surfaces such as rooftops and roads are the primary sources of stormwater runoff, however in a rural setting it is important to consider hayfields, pasture, and other developed or agricultural areas that may increase and concentrate runoff. Increased runoff from these areas can exceed the capacity of natural hydrologic systems leading to erosion, flooding, and degradation of downstream receiving water bodies. The network of roads, ditches, and culverts that are found in steep rural settings are important for conveying stormwater and protecting infrastructure. However, these systems concentrate runoff, reduce infiltration, and may lead to areas of erosion and sediment generation.

Stormwater planning efforts in rural areas are most successful when carried out within a context of overarching watershed and stream corridor concerns including transportation infrastructure and maintenance, agricultural land uses, and areas of problematic stream channel erosion. The Roaring Branch/Batten Kill Corridor Plan (FGS, 2007) and Batten Kill, Walloomsac and Hoosic Tactical Basin Plan (VTANR, 2016) summarized stream corridor conflicts and watershed scale stressors and prioritized areas where specific projects and management strategies could reduce erosion conflicts and improve the ecological health of the watersheds. Additional information from high-resolution Light Detection and Ranging (LiDAR) elevation data, a detailed culvert assessment completed with a follow-up in progress by the Bennington County Regional Commission (BCRC), meetings with stakeholders in Sunderland, and field visits to the Town were incorporated into this planning effort to build on past work and identify problem areas associated with stormwater in Sunderland. Best

Management Practices (BMPs) are suggested to mitigate stormwater problem areas contributing to infrastructure vulnerability and degradation of water quality in the watershed.

1.2 Project Goals

The goal of this project was to evaluate developed lands and road corridors in the Town to identify sources of increased stormwater runoff and associated sediments and nutrients discharging to the Batten Kill or its tributaries. The SWMP for Sunderland follows template 3b of the Vermont Stormwater Master Planning Guidelines with a focus on rural roads (VTDEC, 2013). The project tasks were to identify stormwater problem areas throughout the Town, develop one-page summary sheets for approximately 30 projects, complete detailed subwatershed mapping as needed for problem sites, and develop conceptual designs for five (5) high-priority projects.

The Sunderland Town Plan includes encroachment on the river corridor and flood vulnerability as primary concerns for protecting water quality and infrastructure. The Plan lists management and protection of important floodplains and channel meanders, regulations on development in river corridors, low impact development incorporating green stormwater infrastructure, and stream crossing upgrades to reduce water quality impacts and improve infrastructure resiliency (Town of Sunderland, 2015). The Town Highway Department has taken a number of steps to address stormwater runoff and water quality concerns by stabilizing ditches and culvert headers throughout the road network.

This SWMP provides Town officials and stakeholders with a list of high priority stormwater problem areas and conceptual solutions, which will support the development and implementation of future mitigation and restoration projects to improve water quality and reduce stormwater runoff impacts in Sunderland.

2.0 Study Area Description

Sunderland is a 45.6 square mile town located in Bennington County in the southwestern corner of Vermont (Figure 1). Sunderland is bordered by 8 towns (Sandgate, Manchester, Winhall, Stratton, Somerset, Glastenbury, Shaftsbury, and Arlington). The Batten Kill flows through the northwest corner of Sunderland, and most of the Town is drained by tributaries to the Batten Kill, including the Roaring Branch, Warm Brook, and Lye Brook. The Town has a total population of 956 as of the 2010 Census (U.S. Census Bureau, 2011). Land cover data based on imagery from 2011 National Land Cover Dataset (Homer et al., 2015) are summarized in Table 1. The Town of Sunderland is primarily drained by rural watersheds, with forests representing the dominant land cover type. Agricultural lands, primarily as pasture land and hay fields, cover 2.1% of the Town with a majority of the farmlands found along the Sunderland Hill

Figure 1: Town of Sunderland and Batten Kill watershed location map.

Table 1: Land cover in Sunderland.

Land Cover/Land Use Type	% of Town
Agriculture	2.1
Developed	2.7
Forest	83.5
Open Water	0.4
Shrub/Scrub	1.1
Grassland/Herbaceous	0.1
Wetland	9.9

Road corridor. Development is low throughout the Town (1.8%) and is mainly concentrated on the western side of the Route 7 corridor, near the Arlington-Sunderland border. There are 55 miles of roads within the Town, over half of which are Town maintained (Table 2). Kelley Stand Road running from Sunderland into Stratton is a very unique road; it is a Town maintained Class 2 gravel road through the National Forest and most of the road is closed in the winter.

Table 2: Road length by AOT class in Sunderland.

AOT Class	Description	Length (miles)	% of Town Road Length
2	Class 2 Town Highway	15.1	27.6
3	Class 3 Town Highway	13.8	25.2
4	Class 4 Town Highway	1.6	2.9
6	National Forest Highway	3.9	7.1
8	Private Road	9.2	16.8
30	State Highway	2.8	5.1
40, 45	US Highway	8.4	15.3

3.0 Stormwater Management Planning Library

We began our SWMP efforts by gathering and reviewing information and documentation related to stormwater runoff and watershed management in the Town of Sunderland. This section summarizes available documentation and other potential sources of information we explored. Much of this information is from previously completed studies in Sunderland or its associated watersheds, but also includes data sources discussed during a SWMP steering committee meeting on October 20rd, 2016. Other potential sources of data and data gaps are also addressed.

Basin Plan

The Tactical Basin Plan for the Batten Kill, Walloomsac and Hoosic Rivers was prepared by the Vermont Agency of Natural Resources in 2015 (VTANR, 2016). The basin plan catalogs current surface water quality conditions, stressors, and recommended actions for water quality restoration. Sunderland surface waters include Bourn Brook, Lye Brook, and Mill Brook, Batten Kill tributaries which originate in the higher elevations of Sunderland, as well as the Roaring Branch and the Batten Kill mainstem. Overall the water quality in Sunderland is good to excellent based on data collected by VTDEC over the last 10 years.

Ecological Condition

The Basin Plan summarizes streams and waterbodies with notable in ecological significance in the watersheds. The Roaring Branch and Batten Kill are designated by Vermont Department of Fish and Wildlife as Very High Quality spawning and nursery tributaries for trout, and the Batten Kill is designated as a Very High Quality stream for supporting significant wild trout populations. Bourn Pond and Branch Pond are identified as Very High Quality based on Vermont DEC criteria, including wilderness status and the presence of rare species.

Water Quality Stressors

Non-point source pollution from gravel roads is identified as a potential stressor for Sunderland surface waters. Basin-wide restoration recommendations include riparian buffer plantings, agricultural BMP implementation in fields with high erosion risk, and identifying opportunities for dam removals and retrofits.

Roaring Branch/Batten Kill Corridor Plan

Field Geology Services prepared the Roaring Brach/Batten Kill Corridor Plan for the Vermont Department of Environmental Conservation in in 2007 (FGS, 2007). Highlights from the Corridor Plan relevant to recent flooding and stormwater runoff in the watershed are summarized below.

Flood Damage

The Roaring Branch/Batten Kill Phase 2 assessments were conducted prior to Tropical Storm Irene. However, berms constructed in response to flooding in 1973 and older berms that may have been constructed in response to early 20th century flooding were identified in the Corridor Plan. These berms were found along lower reaches of Batten Kill tributaries, such as the Roaring Branch.

Hydrologic and Sediment Regime Stressors

The Corridor Plan includes maps of stressors on the hydrologic and sediment regimes of the Batten Kill and Roaring Branch based on data collected during the Phase 2 Stream Geomorphic Assessments between 2000 and 2005. These maps provide a means for linking the effects of increased stormwater runoff (i.e., gullying, severe channel sedimentation) to known stormwater problem areas in upslope watersheds. The hydrologic regime stressors identified in the Corridor Plan include areas of locally high road densities at the subwatershed level and wetland loss. The sediment regime stressors identified in the Corridor Plan include areas of higher densities of depositional and migration features in the channel such as bar features and flood chutes, identified at the reach-scale.

Overall Stream Stability and Habitat Conditions

A summary of the geomorphic and habitat conditions is provided below in Table 3. Overall the stream conditions are fair to good for those river reaches assessed in more detail in the field. Where the Batten Kill flows through Sunderland, the conditions are fair due to channel alterations and widening with stretches of good conditions where the river has maintained or regained natural meanders. In the lower reaches of Fayville Brook and the Roaring Branch, the conditions are fair mainly due to channel degradation which has resulted in several stream type departures.

VTDEC Hydrologically Connected Road Segment Data

VTDEC created a statewide inventory of roads that are likely to be hydrologically connected to surface waters. The road network was split into 100m segments and then checked for proximity to surface waters and river corridors. Variables including road slope, adjacent hill slope, and soil erodibility were used to create a preliminary "road erosion risk rank". These ranking provide a good starting point for identifying areas of potential sediment generation from erosion of road surfaces and ditches. Road erosion risks are predicted to be low along low-gradient paved roads near Arlington; moderate and high-risk segments become more prevalent along gravel roads in close proximity to streams and in steeper portions of town.

Light Detection and Ranging (LiDAR)

LiDAR data for Bennington County were collected in a series of flights conducted in the Spring of 2012 as part of the VT LiDAR Initiative. Derivations of LiDAR data, such as Digital Elevation Models (DEMs), terrain models, and contours are useful tools for stormwater feature identification and site design. The 2-meter DEM will assist in culvert watershed delineation and the design of stormwater management projects. Terrain models will assist in remote identification of erosion features, such as stormwater gullies.

Table 3. SGA reaches and selected attributes in Sunderland, VT

Stream	Reach	Reference Stream Type	Existing Stream Type	Confinement Type	Habitat Condition	Geomorphic Condition	Notes
Fayville Brook	T2S1S1.02A	B	B	-	-	Good	Bedrock Gorge
	T2S1S1.02B	C	F	Narrow	Fair	Fair	
	T2S1S1.03	C	C	Broad	Good	Fair	
	T2S1S1.04*	C	-	Very Broad	-	-	
Fayville Brook Trib.	T2S1S1S1.01*	C_a	-	Very Broad	-	-	
Roaring Branch	T2.03A	C_b	C	Very Broad	Good	Fair	
	T2.03B	C_b	F	Broad	Good	Fair	
	T2.03C	A_b	A_b	-	-	Good	Bedrock Gorge
	T2.03D	C_b	F_b	Broad	Good	Fair	
	T2.04A	C	F	Very Broad	Good	Fair	
	T2.04B	D_b	D_b	-	-	Fair	Alluvial Fan; Braiding
	T2.04C	D_b	F_b	Very Broad	Fair	Fair	
	T2.05	C_b	C_b	Semi-Confined	Good	Fair	
	T2.06*	B_a	-	Narrow	-	-	
	T2.07*	B	-	Narrow	-	-	
	T2.08*	C_b	-	Very Broad	-	-	
S. Fork Roaring Branch	T2S2.01*	B_a	-	Broad	-	-	
Batten Kill	M05A	E	E	Very Broad	Fair	Fair	
	M05B	E	E	Very Broad	Good	Good	
	M05C	E	E	Very Broad	Fair	Fair	
	M05D	E	E	Very Broad	Good	Good	
	M05E	E	E	Very Broad	Fair	Fair	
	M06	E	E	Broad	Good	Good	
	M07	E	E	Very Broad	Good	Good	
Lye Brook	T3.04*	B_a	-	Broad	-	-	
	T3.05*	C	-	Very Broad	-	-	
	T3.06*	D	-	Very Broad	-	-	
Winhall River	T11.11*	C	-	Broad	-	-	

** Phase 1 assessment only*

Local Data

Town of Sunderland Hazard Mitigation Plan

The Town of Sunderland completed a Hazard Mitigation Plan in 2014. In support of flood and flash flood hazard analyses, the plan catalogues significant flood events in Bennington County between 1996 and 2011. The plan includes a map of flood hazard areas and fluvial erosion hazard zones in Sunderland. Tropical Storm Irene landslide locations as well as road and culvert damages in Sunderland are mapped as well.

Tropical storm Irene (TSI) hit Vermont on August 28th, 2011 and dumped 3-5 inches of rain throughout the state with localized areas receiving totals from 7-11 inches. This rainfall coupled with high antecedent soil moisture conditions produced flooding that approached or exceeded the historic flood of 1927 in many large basins. In Sunderland, damage resulting from Tropical Storm Irene was significant, including three houses lost along Kelley Stand Road, which runs parallel to the Roaring Branch (Figure 2).

Figure 2: Washout along Kelley Stand Road after Tropical Storm Irene. Photo courtesy of BCRC.

Sunderland Culvert Records

The Town of Sunderland completed bridge and culvert inventories in 2009, and a follow-up inventory is currently being conducted by Jim Henderson of Bennington County Regional Commission (BCRC). Data from the 2013 inventory included 277 culverts and 4 bridges. The 2013 inventory included the structure dimensions but is missing several key attributes including overall culvert condition and presence/absence of erosion. The inventory included 57 culverts that have a diameter less than 18 inches, indicating they may be hydraulically undersized depending on the upslope drainage area.

Data Gaps

The watershed library describes the available documents, reports, and datasets that characterize stormwater and flooding concerns within the Town of Sunderland. The geomorphic field data available for the Batten Kill and its tributaries through Sunderland were collected prior to Tropical Storm Irene. A full Phase 2 SGA may not be appropriate for these sections; however, additional data collection for stormwater concerns would be beneficial. Biomonitoring data is relatively sparse for the town and primarily was collected before Tropical Storm Irene. Additional sampling effort in the Batten Kill and smaller streams that may be affected by sedimentation from gravel roads would be helpful for tracking water quality changes over time.

4.0 Stormwater Problem Areas

One of the primary goals of the stormwater master plan is to "develop a comprehensive list of stormwater problems" within the Town. FEA conducted four (4) field tours of the project area and met with Marc Johnston (Town Road Foreman) and with Jim Henderson (BCRC) to identify existing problem areas, evaluate and prioritize sites, and recommend potential solutions.

4.1 Identification of Problem Areas

The initial round of problem area identification began with a desktop exercise scanning the watershed with imagery, NRCS soils data, and high-resolution LiDAR contours and hillshade in a GIS. Meetings with Town officials including tours with the Town Highway Foreman were conducted in the spring of 2017. A detailed watershed tour was conducted on two subsequent field visits by FEA staff to identify the remaining stormwater problem areas. A total of 28 stormwater problem areas were identified and assessed in the field (Figure 3, see detail map in Appendix A and table in Appendix B). We grouped the problem areas into five (5) categories described below.

- **C -** Seven (7) culverts, mainly draining first order and intermittent streams, were analyzed for hydraulic capacity. Runoff volumes for different design storms (e.g., 2-year 24-hour rainfall) were modeled for each crossing using standard rainfall-runoff methods to check for appropriate culvert sizing.
- **DC** - Drainage culvert projects were identified in 2 locations where maintenance practices or stormwater runoff and associated sediment loads at cross-culverts located under Town maintained roads were deemed problematic.
- **RD** – Twelve (12) Roadside ditch projects were identified, typically along steep sections of Town maintained gravel roads. Ditches may convey large volumes of sediment to receiving surface waters, especially if the ditch is eroding, or filling in causing water to run across the road surface.
- **SC** – Three (3) stream crossing projects were identified where a perennial stream crosses under a Town maintained road. These sites were assessed for culvert capacity and for the ease of Aquatic Organism Passage. Runoff volumes for different design storms (e.g., 2-year 24-hour rainfall) were modeled for each project using standard rainfall-runoff methods to check for appropriate culvert sizing.
- **SW –** Four (4) stormwater BMP projects were identified in areas where improved maintenance practices and or the construction of stormwater treatment infrastructure could significantly reduce sediment and nutrient loading to receiving waters.

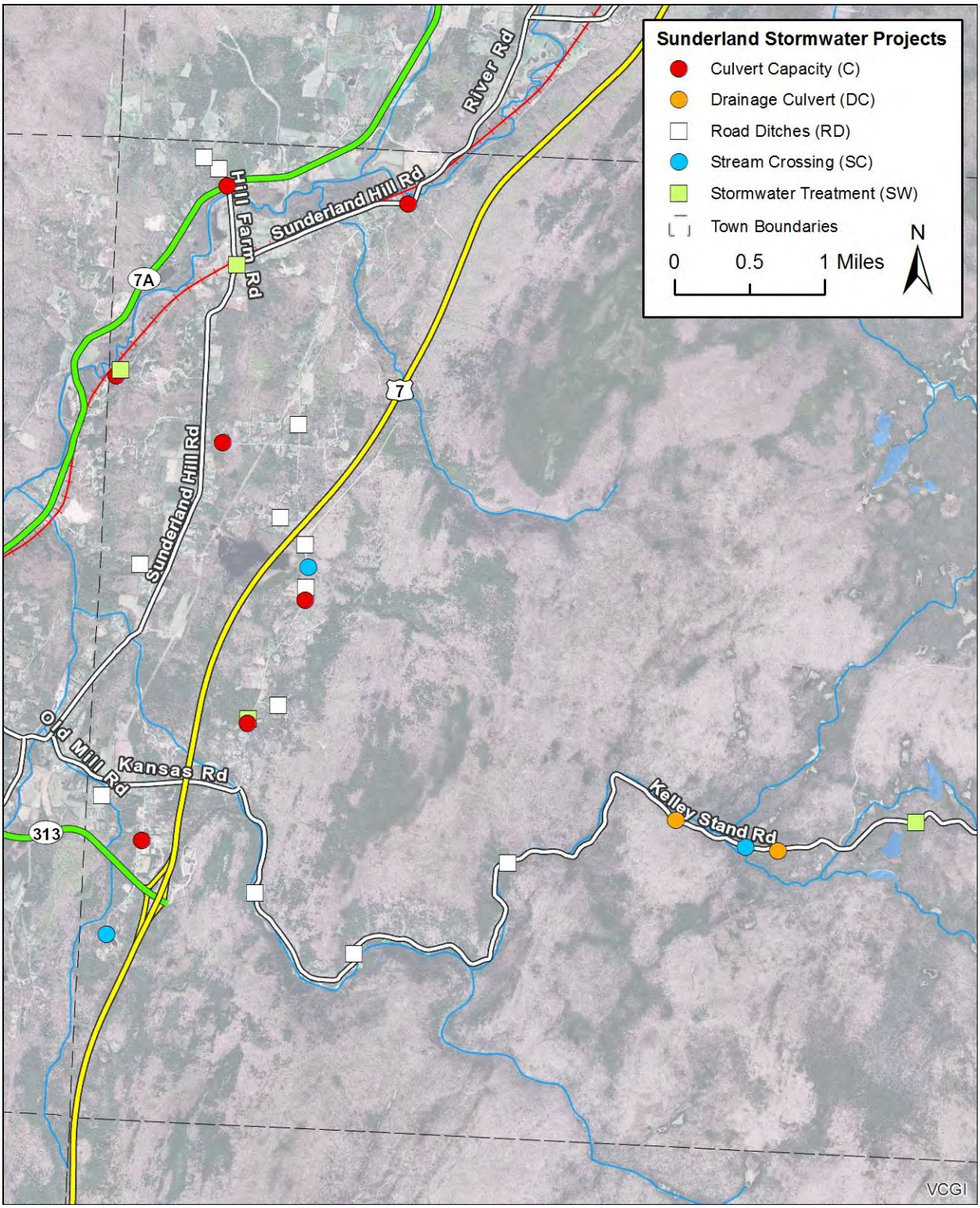

Figure 3: Stormwater problem area overview map, see large map in Appendix A for detail.

4.2 Evaluation and Prioritization of Problem Areas

The 28 projects described in Appendix B were prioritized based on the potential for each project to reduce nutrient and sediment inputs to surface waters, landowner support for the project, operation and maintenance requirements for the project, project cost and constructability, and additional benefits associated with implementation of the project.

GIS-based Site Screening

Using the field data points collected with sub-meter GPS during our watershed tours, we evaluated key characteristics for each site indicating the potential for increased stormwater runoff and pollutant loading, among several other factors described below. These GIS-based observations, along with field-based observations of site characteristics, are summarized in Appendix B in the "problem area description" column.

The following geospatial data were reviewed and evaluated as part of the GIS-based screening:

- **Aerial Photography** – We used the 0.5 m imagery collected for Bennington and Windham counties in 2015 to review the site land cover characteristics (i.e., forest, grass, impervious) and measure the total impervious area in acres draining to the project area as identified in the field.
- **NRCS Soils** – We used the Bennington County Soils data to evaluate the inherent runoff and erosion potential of native soil types (i.e., hydrologic soil group, erodible land class). For project sites with potential for green stormwater infrastructure (GSI), we assessed the general runoff characteristics of the drainage area based on hydrologic soil group (HSG).
- **Parcel Data** – We used the parcel data available through VCGI to scope the limits of potential projects based on approximate parcel boundaries and road right-of-way.
- **VTDEC Hydrologically Collected Road Segment Data –** We used a statewide inventory of road erosion risk and hydrologic connectivity of road segments to prioritize areas of potential sediment loading to visit for field surveys.

Prioritization Metrics

The stormwater problem areas identified during field tours of the study area were assigned several numerical scoring metrics that are weighted to assist in prioritizing each project based on water quality benefits, infrastructure resiliency, project feasibility, maintenance requirements, costs, and any additional benefits. The maximum possible score is 30 and the individual site scores ranged from 10 to 24 (Figure 4). Each category is described below and includes a description of the scoring for each criterion. Final evaluation criteria summarized in the table in Appendix B included the overall prioritization and the following components of the score:

- **Water Quality Benefits (14 points total)**
  - **Nutrient Reduction Effectiveness (4 points)** – Degree of nutrient removal potential with project implementation, this accounts for both the existing nutrient loads and the removal efficiency and capacity of the proposed treatment. Nutrient loading was quantified based on the watershed size, the land cover types, and percent impervious

surfaces, and the effectiveness was based on the treatment efficacy of the potential mitigation options appropriate for the space and location of the treatment area.
    - 0 points – No nutrient source and/or no increased treatment
    - 1 point – Minor nutrient source and/or minor increase in treatment
    - 2 points – Moderate nutrient source with some increase in treatment
    - 3 points – Moderate nutrient source with significant increase in treatment
    - 4 points – Major nutrient source with significant increase in treatment
  - **Sediment Reduction Effectiveness (4 points)** – Degree of sediment removal potential with project implementation, this accounts for both the existing sediment loads and the removal efficiency and capacity of the proposed treatment. Sediment loading was quantified based on the watershed size, the land cover types, and percent impervious surfaces, and the effectiveness was based on the treatment efficacy of the potential mitigation options appropriate for the space and location of the treatment area.
    - 0 points – No sediment source and/or no increased treatment
    - 1 point – Minor sediment source and/or minor increase in treatment
    - 2 points – Moderate sediment source with some increase in treatment
    - 3 points – Moderate sediment source with significant increase in treatment
    - 4 points – Major sediment source with significant increase in treatment
  - **Drainage Area (1 point)** – Approximate drainage area to site is greater than 2 acres
  - **Impervious Drainage (2 points)** – Approximate area of impervious surfaces draining to the site.
    - 0 points – Area of impervious surfaces is less than 0.25 acres
    - 1 point – Area of impervious surfaces is >0.25 acres
    - 2 points – Area of impervious surfaces is >0.5 acres
  - **Connectivity to Surface Waters (2 points)**
    - 0 points – All stormwater infiltrates on site
    - 1 point – Stormwater receives some treatment before reaching receiving waters
    - 2 points – Stormwater receives minimal treatment before reaching receiving waters
    - 3 points – Stormwater drains directly into receiving waters (typically stormwater draining directly into a large wetland is assigned 2 points)
- **Infrastructure Resiliency/Flood Vulnerability (3 points)** – Reduction in flood vulnerability and/or improvement in infrastructure vulnerability associated with project implementation.
    - 0 points – No change in resiliency or vulnerability
    - 1 point – Some improvement in resiliency or reduced vulnerability, especially in smaller floods
    - 2 points – Project will increase resiliency and/or decrease vulnerability across a range of flood magnitudes
    - 3 points – Project will significantly increase resiliency and decrease vulnerability during large flood events

- **Landowner Support (2 points)**
  - 0 points – Project is located on private property, no contact with landowner
  - 1 point – Project is on Town or State property with no contact
  - 2 points – Project has been discussed and is supported by landowner
- **Operation and Maintenance Requirements (2 points)**
  - 0 points – Project will require significant increased maintenance effort
  - 1 point – Project will require some increased maintenance effort
  - 2 points – Project will require no additional maintenance effort
- **Cost and Constructability (6 points)** – This score is based on the overall project cost (low score for high cost) and accounts for additional design, permitting requirements, and implementation considerations, such as site constraints and utilities, prior to project implementation.
- **Additional Benefits (3 points total)** – Description of other project benefits, total score is roughly a count of the number of additional benefits.
  - (1) Chronic Problem Area – The site requires frequent maintenance and/or is an ongoing problem affecting water quality
  - (2) Seasonal Flooding – The site is affected by or contributes to seasonal flooding
  - (3) High Visibility – The site is highly visible and will benefit from aesthetically designed treatment practices
  - (4) Improves BMP Performance – Project implementation will improve the performance of existing stormwater treatment practices that receive runoff from the site
  - (5) Improves Aquatic Organism Passage – Project implementation will improve fish passage through stream crossing structure

Figure 4: The AOP barrier created by a perched 48" culvert along South Road (left) was the lowest scoring projects (SC-2). The extreme erosion along the edges of Barney Orchard Road (right) was the highest scoring project (RD-8).

Hydraulic Analysis

Hydrologic and hydraulic analyses were completed to determine predicted flow volumes and culvert capacity for selected culverts described in the C and SC projects. This process aids in prioritizing potential culvert replacement projects. Culvert drainage areas were delineated using the USGS StreamStats software and contours generated from the LiDAR DEM. Field observations of ditch drainage areas were incorporated into the watershed delineations (drainage areas shown in Appendix A). The dimensions, inlet/outlet configuration, and slope for each culvert were determined in the field using laser surveying equipment. Recurrence interval flow rates were estimated for each culvert using the USGS StreamStats software, which calculates flows based on a statewide regression equation; including drainage area, percentage of wetland cover within the watershed, and total annual precipitation. Culvert capacity was calculated using the Federal Highway Administration HY-8 software. The software calculates headwater depth for each recurrence interval flow and estimates the culvert capacity before the road is overtopped (Table 4). VTrans hydraulic studies were available for the North Road (Cole Brook) and the Dunham Road culverts.

Table 4: Estimated recurrence interval flows and culvert capacity analysis for selected culverts in Sunderland.

		Drainage Area							Discharge (cfs)			
Structure	**Site ID**	**Acres**	**Square Miles**	**Bankfull Width (ft)[1]**	**Culvert Type**	**Culvert Length (ft)**	**Slope (%)**	**Dimensions**	**Q10**	**Q25 (design)**	**Q100 (extreme)**	**Culvert Capacity[2]**
Dunham Road[3]	C-3	355	0.55	10.1	CMP	28	1.0	3' Diameter	65.0	80.0	110.0	41.6
North Road at Cole Brook	SC-1	779	1.22	14.3	CMP	32	6.0	3.5'x5' Squash	202.0	277.0	418.0	115.0
North Road Twin Culverts	C-5	31	0.05	3.5	CPP	36	2.0	1.5' Diameter (2 culverts)	10.6	14.8	23.1	19.0
Sunderland Hill Road	C-2	677	1.06	13.4	CMP	42	4.5	4' Diameter	152.0	209.0	313.0	115.3

[1]Calculated using VTANR hydraulic geometry regressions

[2]Culvert capacity before overtopping road based on HY-8 model

[3]Dunham Road recurrence interval flows are from the VTANR hydraulic study, not StreamStats

4.3 Problem Area Summary Sheets

Problem area summary sheets were developed for each of the 28 projects (Appendix C). The summary sheets include a site map, problem area description, site photographs, a summary of the prioritization categories, and ballpark cost estimates. These sheets were shared with BCRC and Town representatives.

4.4 Project Prioritization and Conceptual Designs

Evan Fitzgerald and Joe Bartlett met with Jim Henderson (BCRC) and Marc Johnston (Sunderland) to review and prioritize the problem areas identified in this document. The following five (5) problem areas were selected for further investigation with conceptual designs provided in Appendix D.

- **C-3:** A small stream crosses under Dunham Road through an undersized culvert. The road washed out in T.S. Irene and severed an important transportation link within the town.
- **RD-1:** A roadside ditch along Bentley Hill Road empties on to the road where a driveway connects to the road without a culvert, significant gully erosion along the road embankment draining directly into a small stream.
- **RD-8:** Extreme ditch erosion along a steep section of Barney Orchard Road is causing significant sediment loading to a small stream.
- **RD-9:** The roadway drainage network along lower Prouty Hill Road is complicated due to a missing driveway culvert, and severe ditch erosion and runoff across the road is causing significant sediment loading to the Fayville Branch.
- **SC-1:** The Cole Brook culvert under North Road is undersized and was the location of significant flooding and roadway damage during T.S. Irene.

5.0 Next Steps

This Stormwater Master Plan represents an extensive effort to identify, describe, and evaluate stormwater problem areas throughout the Town of Sunderland. Many of the problem area descriptions (e.g., drainage culverts and roadside ditches) will aid the Town Highway Department in proactively sizing and constructing these features to avoid future stormwater problems. We provided a preliminary cost estimate and a site rating to aid the Town and other stakeholders in planning and prioritizing restoration efforts.

We recommend that the Town of Sunderland, BCRC and BCCD work together and with VTDEC and VTrans to secure funding for the highest priority projects listed above in Section 4.4 and described in detail in Appendix D. The remaining stormwater problem areas summarized in Section 4.3 and Appendices B and C could be prioritized based on their overall impact and programmed for funding in the future. In addition to addressing the problem areas identified in this document, the Town can take steps to reduce future stormwater problems through planning and zoning regulations as described in the Town Plan (Town of Sunderland, 2015). Many of the problem areas covered in this document are representative of typical issues encountered on gravel roads (i.e., stone lining ditches, culvert sizing, ditch maintenance) in steep watersheds. The recommended practices to address these issues should be applied to future projects to reduce the risk of stormwater runoff conflicts and sediment loading to receiving waters.

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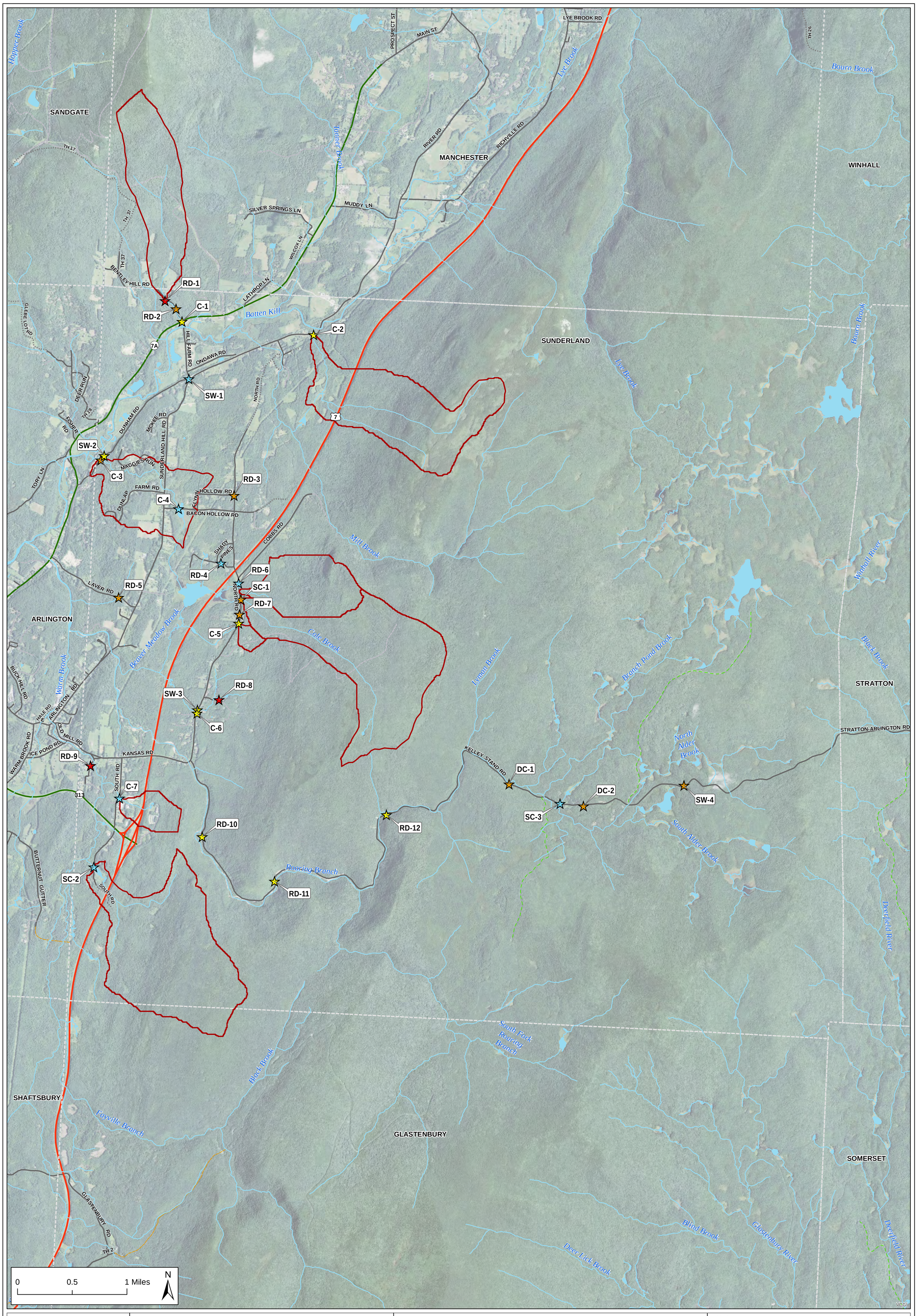
APPENDIX A:

Stormwater Problem Areas
Location Map



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Stormwater Problem Areas

Town of Sunderland

Project Priority (Score)
- Low (10-15)
- Moderate (16-18)
- High (19-21)
- Very High (22+)
- Culvert Drainage Area
- Waterbodies
- Surface Waters
- Town Boundary
- US Highway
- Vermont State Highway
- Town Highway: Class 1-3
- Town Highway: Class 4
- Legal Trail
- State & National Forest Highway
- Other Road Type

Notes
- Stormwater problem areas were identified by FEA in July and August 2017.
- Culvert surveys were completed in August 2017.
- Culvert drainage areas from USGS StreamStats
- NAIP imagery is from 2014.

Map By: JHB
Date: December 20, 2017
Scale: 1:24,000

APPENDIX B:

Problem Area Summary Table and Prioritization Matrix

					Water Quality Benefits												
Project Number	**Project Type**	**Location (Landowner)**	**Problem Area Description**	**BMP Type/Description**	**Nutrient Reduction**	**Sediment Reduction**	**Drainage Area**	**Impervious Drainage**	**Connectivity to Surface Waters**	**Infrastructure Resiliency/ Flood Vulnerability**	**Landowner Support**	**O&M Requirements**	**Cost and Constructability**	**Additional Benefits**	**Additional Benefits Score**	**Total Score**	**Site Photos**
				Maximum Score	**4**	**4**	**1**	**2**	**3**	**3**	**2**	**2**	**6**		**3**	**30**	
C-1	Culvert Replacement	Route 7a (State)	The concrete box culvert under Route 7a is extremely undersized and the abrupt slope decrease causes ongoing sedimentation in the undersized channel and culvert.	Replace the culvert with a larger box culvert (recommend 6ft by 8ft) and consider enlarging the upstream and downstream channel.	0	2	1	2	3	3	1	2	2	1, 2	2	18	756-757
C-2	Culvert Replacement	Sunderland Hill Road (Town)	The existing 4ft culvert is extremely undersized, rusted, and is too short with a very steep embankment and erosion on the inlet side. The steep upstream channel has a high load of coarse sediment.	Replace the culvert with an appropriately sized concrete box culvert (recommend 6ft by 8ft).	0	1	1	2	3	3	2	2	2	1	2	18	199-201
C-3	Culvert Replacement	Dunham Road (Town)	A small stream crosses under Dunham Road through a 36" CMP culvert. The road washed out in TSI and severed an important transportation link within the Town. The channel slope decreases at the culvert leading to sediment deposition. The culvert inlet orientation is at a moderate angle to the channel approach.	Replace the culvert with an appropriately sized concrete box culvert (recommend 4ft by 8ft) and improve the culvert orientation to better match the channel.	1	2	1	0	3	3	2	2	2	1, 2	3	19	770-771, 180
C-4	Culvert Replacement	Bacon Hollow Road (Town)	A 36" CMP culvert under Bacon Hollow Road is fully backwatered due to downstream beaver dams. The culvert is rusted and needs to be replaced. Frequent maintenance is required to keep the outlet channel along the road embankment cleared of beaver dams.	Replace the culvert with a larger structure and consider installation of beaver baffles to reduce flooding risk to road.	0	0	1	0	3	1	2	1	3	1	1	12	779-782
C-5	Culvert Replacement	North Road (Town)	Double 15" CPP under North Road require frequent maintenance to clear sediment, debris, and ice. Culvert slope is low and the inlet is slightly projecting.	Replace with a single larger culvert or concrete box (recommend 24 inch), increase culvert slope if possible to improve conveyance and reduce maintenance requirements.	1	1	1	0	3	2	2	2	3	1	1	16	796-797, 231-233
C-6	Culvert Retrofit/ Replacement	North Road (Town)	36" CMP under North Road is too short for the crossing resulting in a vertical bank on both sides of the road. The road shoulder is eroding and may undermine the edge of the pavement.	Extend the culvert length to allow for a more stable embankment, improve culvert headers on both sides of the road.	1	2	1	0	3	2	2	2	3	0	0	16	801-802
C-7	Culvert Replacement	South Road (Town)	The 24" CMP culvert under South Road near the driveway of the GMP facility is badly rotted and the inlet has collapsed. The embankment is eroding at both the inlet and outlet. The culvert is slightly undersized.	Replace with an appropriately sized culvert (Recommend 3ft).	0	1	1	1	3	2	1	2	3	2	1	15	227-230
DC-1	Culvert Replacement	Kelley Stand Road (Town)	Three 24" CMP cross-culverts are exposed and badly damaged by vehicle and grader traffic. Ditches are filled in and the shoulder is very wet. **Culverts were replaced in 2017.**	Replace the cross-culverts and excavate ditches to ensure sufficient cover over culverts to avoid future damage.	1	2	1	2	3	3	2	2	4	0	0	20	809-812
DC-2	Culvert Replacement	Kelley Stand Road (Town)	A 24" CMP cross culvert is badly damaged by vehicle and grader traffic. The inlet is exposed and crushed. **Culvert was replaced in 2017**	Replace the culvert and ensure sufficient fill over the culvert to prevent future damage, ditch may require some excavation.	1	2	1	1	3	3	2	2	4	0	0	19	815-816
RD-1	Ditch Improvements	Bentley Hill Road (Town)	A driveway located at the stream crossing does not have a culvert, causing the western ditch to spill across the road with major gully erosion at the stream culvert outlet. The ditch should be extended approximately 60ft to minimize the length of culvert.	Install a culvert under the driveway with an outlet directly to the stream at the larger culvert outlet.	2	4	0	2	3	3	1	2	4	1	2	23	187-190, 197
RD-2	Ditch Improvements	Bentley Hill Road (Town)	Significant erosion along the ditches and steep road embankment was observed along the steep stretches of the Road from Rt 7a to the town line. Ditches were typically undersized, shallow, and not stone lined.	Enlarge and stone line the ditches with 6-8" minus in sections less than 10% slope and 12" minus stone in the sections approaching 10% slope. Stabilize gully erosion along the steep road embankment and improve road grading to reduce flow areas directly draining down the embankment. The entire project area is "hydrologically connected".	2	4	1	2	3	2	2	1	3	1	1	21	184-185, 194-195

					Water Quality Benefits												
Project Number	**Project Type**	**Location (Landowner)**	**Problem Area Description**	**BMP Type/Description**	**Nutrient Reduction**	**Sediment Reduction**	**Drainage Area**	**Impervious Drainage**	**Connectivity to Surface Waters**	**Infrastructure Resiliency/ Flood Vulnerability**	**Landowner Support**	**O&M Requirements**	**Cost and Constructability**	**Additional Benefits**	**Additional Benefits Score**	**Total Score**	**Site Photos**
				Maximum Score	**4**	**4**	**1**	**2**	**3**	**3**	**2**	**2**	**6**		**3**	**30**	
RD-3	Ditch Improvements	Flynn Hollow Road (Town)	The ditches along the north side of Flynn Hollow Road and the west side of North Road join and flow through a pipe under North Road. Both ditches are wide and flat and carry a large volume of sediment. Large vehicles turning on to Flynn Hollow repeatedly damage the road shoulder and increase erosion. **Sunderland Highway Department completed this work in 2017.**	Stabilize the ditches and protect the road shoulder from erosion. Consider moving the culvert approximately 10' west to provide a larger turning area.	2	3	1	2	2	1	2	1	5	4	1	20	844-847
RD-4	Ditch Improvements	Shady Pines Road	Short section of road with no ditch along the northern side, moderate gully erosion. Cable lines are shallowly buried in the ditch complicating site improvements. **Sunderland Highway Department completed some site repairs in 2017.**	Install a grassed ditch and driveway culvert.	1	2	0	1	1	1	1	2	4	1	1	14	220-221
RD-5	Ditch Improvements	Laver Road (Town)	The ditch along the north side of the road is undersized and poorly defined with several areas of severe gully erosion. The ditch on the eastern side of the stream crossing is deeply incised and is delivering large volumes of sediment and gravel to the stream channel. **Sunderland Highway Department completed ditch repairs in 2017.**	Excavate and stone line ditches with 6-8" minus stone. Larger rock may be needed in the area east of the culvert inlet where the ditch is badly eroded. Most of the road segments are not "hydrologically connected".	2	4	0	2	3	2	1	2	4	1	1	21	204-218
RD-6	Ditch Improvement	North Road (Town)	West edge of road lacks a ditch and the shoulder is slightly elevated, stopping sheetflow. There is active erosion along the road shoulder, delivering sediment to Beaver Meadow Brook.	Lower the road shoulder and/or install turnouts to allow for sheetflow off or road. Alternatively, install a narrow stone lined ditch with 6-8" minus stone along the edge of pavement.	0	2	0	1	3	1	2	1	5	0	0	15	784-786
RD-7	Ditch Improvement	North Road (Town)	Ditch on both sides of road is poorly defined and is eroding, culvert inlet on east side is very deep and pipe is too short, significant gully erosion at inlet. Tree clearing will be required to establish a ditch along the west side of the road.	Extend the culvert inlet with a cut pipe section and enlarge both ditches and line with 6-8" minus stone.	2	3	0	2	1	2	2	2	4	1	1	19	793-795
RD-8	Ditch Improvements	Barney Orchard Road (Town)	The private road draining to the top of Barney Orchard Road is poorly crowned and lacking appropriate ditches, causing severe erosion and sediment transport to the municipal ditch and turnout. The ditches continuing along the road are undersized and are severely eroded. The large turnout at the bottom of the hill is filled with sediment, reducing effectiveness.	Install a cross-culvert and stabilize ditches on the private road, excavate and stone-line the roadside ditches with 12" minus stone. Stabilize the cross-culvert outlet with large rock. Cleanout the sediment deposits along the stream bank and install a sediment trap.	2	4	1	2	3	2	2	2	3	1, 4	3	24	848-861
RD-9	Ditch Improvements	Prouty Hill Road (Town/ Private)	The driveway for 185 Prouty Hill Rd does not have a culvert, the ditches have a very complicated path to direct flow across the road twice, increasing ditch and road erosion. Both ditches have areas of severe erosion. Check dams and a sediment trap in the lower portion of the east ditch are filled with sediment.	Install a driveway culvert to improve ditch conveyance. Stone line the ditches with 12" minus stone. Increase cleanout frequency for the existing check dams and sediment trap.	2	4	1	2	2	2	1	2	3	1, 4	3	22	824-841
RD-10	Culvert Replacement	Kelley Stand Road (Town)	A recently installed driveway culvert for a trailer parking spot along the road is poorly aligned and is interrupting flow through the ditch. Significant erosion is visible along the road edge and through the ditch.	Reinstall the driveway culvert and stabilize the road edge with rock.	1	3	1	1	2	2	1	2	4	1	1	18	821-823
RD-11	Road Erosion/ Ditch Improvement	Kelley Stand Road (Town)	Runoff along the east side of the road misses a small turnout to the river and is causing significant gully erosion.	Improve the road crown and/or improve the inlet to the upslope turnout to better remove runoff from the road. Stabilize the gully erosion area with larger stone.	1	3	0	1	3	1	2	2	5	0	0	18	803-804
RD-12	Ditch Improvement	Kelley Stand Road (Town)	The ditch along the south side of the road is very steep and eroding, small turnout at bridge traps some sediment.	Construct a stone-lined ditch with 6-8" minus stone.	1	3	1	2	2	1	2	1	4	0	0	17	807-808

					Water Quality Benefits												
Project Number	**Project Type**	**Location (Landowner)**	**Problem Area Description**	**BMP Type/Description**	**Nutrient Reduction**	**Sediment Reduction**	**Drainage Area**	**Impervious Drainage**	**Connectivity to Surface Waters**	**Infrastructure Resiliency/ Flood Vulnerability**	**Landowner Support**	**O&M Requirements**	**Cost and Constructability**	**Additional Benefits**	**Additional Benefits Score**	**Total Score**	**Site Photos**
				Maximum Score	**4**	**4**	**1**	**2**	**3**	**3**	**2**	**2**	**6**		**3**	**30**	
SC-1	Culvert Replacement and Floodplain Reconnection	North Road (Town/ Private)	Cole Brook passes under North Rd through a 48" CMP. This culvert was overtopped in Irene and significant flooding occurred along the road to the north. The upstream channel is deeply incised and has a significantly larger capacity than the culvert.	Replace the culvert with a larger structure (recommend 6ft by 12ft) and assess opportunities for floodplain reconnection upstream through rock/wood structures to reduce channel incision. It may be possible to construct an overflow channel along the east side of North Road to direct floodwaters to the smaller tributary to the north.	1	2	1	1	3	3	2	2	2	1, 2, 5	3	20	787-792, 234-235, 240-244
SC-2	Culvert Retrofit/Replacement	South Road (Town)	New 48" culvert draining the pond is perched approximately 18" and is likely a complete AOP barrier.	Replace the culvert with a concrete box including baffles to form steps and pools throughout culvert to provide fish passage.	0	0	1	0	3	0	1	2	2	5	1	10	222-226
SC-3	Culvert Retrofit/ Replacement	Kelley Stand Road (Town)	Small tributary crosses under Kelley Stand Rd through a 48" CMP that is slightly perched. The culvert is short and the embankments are near vertical with a stacked river rock header that is prone to erosion.	Extend or replace the culvert, Install single piece headers on each side and either replace the culvert at a steep slope to match the channel profile or install a tailwater control structure to address the AOP barrier at the outlet drop.	0	1	1	0	3	2	1	1	2	5	1	12	813-814
SW-1	BMP Installation	Town Garage (Town)	The sand pit and salt shed area drain to a sediment trap along Dunham Rd that that may be undersized given the high sediment load. Erosion along the numerous flow paths is increasing sediment transport to the sediment trap.	Enlarge the sediment trap and provide well defined armored flow paths for runoff to reduce additional erosion.	1	3	0	1	0	0	1	2	5	3	1	14	173-179
SW-2	BMP Opportunity	Dunham Road (Town)	An existing drainage turnout along Dunham Road is delivering large volumes of stormwater and sediment into a large wetland along the Battenkill River floodplain.	Construct a sediment trap that can be easily cleaned from the roadway, stabilize the inlet and outlet of the trap to reduce erosion during large storms.	1	3	0	1	3	0	1	1	5	1, 2	1	16	772-774
SW-3	Ditch Improvement and BMP Opportunity	North Road (Town)	Ditch draining a large portion of North Rd is fairly stable but drains directly in to a stream. There is space for a BMP between the guardrail and the floodplain.	Install check dams in the lower portion of the ditch and install a sediment trap on top of the bank with an armored spillway into the channel.	1	2	1	2	3	1	2	1	4	4	1	18	798-800
SW-4	BMP Opportunity and Ditch Improvement	Kelley Stand Road (Town)	A steep section of road drains to a small turnout along the edge of a wetland on the north side of the road. The ditch shows some active erosion and the turnout is filled with road sediment and with excess material stockpiled during road grading.	Enlarge the ditch and line with 12" minus stone. Install a sediment trap along the edge of the road with a stone lined overflow into the wetland. Ensure that road grading materials are stored in a location that does not drain to the wetland.	1	3	1	2	3	1	2	1	4	1	2	20	817-820

Additional Benefits	
1	Chronic Problem Area
2	Seasonal Flooding
3	High Visibility
4	Improves BMP performance
5	Improves Aquatic Organism

APPENDIX C:

Problem Area Summary Sheets

Project: C-1	**Problem Area Summary**
Date Observed:	8/24/2017
Location:	Route 7a at Bentley Hill
Latitude: **Longitude:**	43.11588 N -73.12075 W
Land Ownership:	State (VTrans)

Site Description: The small stream along Bentley Hill Road flows through a narrow roadside ditch channel before crossing under Route 7a through an extremely undersized concrete box culvert. The channel along Hill Farm Road to the south is also undersized and is filling with sediment.

Photo 1: Steep channel approaching the culvert.

Photo 2: Inlet of the undersized box culvert at Route 7a

BMP Description: Replace the culvert with an appropriately sized concrete box culvert and enlarge the upstream and downstream channels to improve conveyance of floodwaters and sediment transport. Based on an HY-8 culvert sizing analysis, we recommend a 6ft by 8ft box culvert embedded 1ft into the channel bottom.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
8	3	3	2	2	18 **(Moderate)**

Additional Project Benefits Description: Chronic Problem Area, Seasonal Flooding

Project Comments: Moderate priority project due to high cost and difficulty of implementation. **We estimate that this project will cost $150,000 to $250,000.**

Project: C-2	**Problem Area Summary**
Date Observed:	8/24/2017
Location:	Sunderland Hill Road
Latitude: **Longitude:**	43.11424 N -73.09695 W
Land Ownership:	Town

Site Description: The existing 4' culvert is extremely undersized, rusted, and is too short with a very steep embankment and erosion on the inlet side (Photo 1). The steep upstream channel has a high load of coarse sediment (Photo 2).

Photo 1: An undersized culvert under Sunderland Hill Road, with a steep embankment and erosion at the inlet.

Photo 2: Upstream channel with a high coarse sediment load.

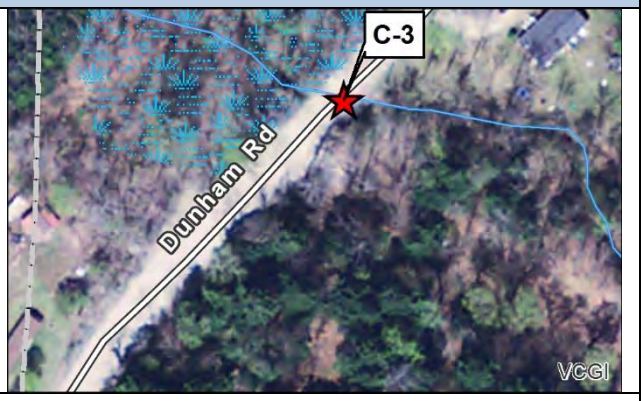
BMP Description: Replace the culvert with an appropriately sized concrete box culvert. Based on an HY-8 culvert sizing analysis, we recommend a 6ft by 8ft box culvert embedded 1ft into the channel bottom.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
7	4	3	2	2	18 **(Moderate)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: Moderate priority project due to improvements to infrastructure resiliency, and additional benefits from fixing a chronic problem area. **We estimate that this project will cost $150,000 to $200,000.**

Project: C-3	**Problem Area Summary**
Date Observed:	7/7/2017 & 8/24/2017
Location:	Dunham Road
Latitude: **Longitude:**	43.09743 N -73.13525 W
Land Ownership:	Town



Site Description: A small stream crosses under Dunham Road through a 36" CMP culvert. The road washed out in TSI and severed an important transportation link within the Town. The channel slope decreases at the culvert leading to sediment deposition. The culvert inlet orientation is at a moderate angle to the channel approach.

Photo 1: A 36" CMP conveys a small stream under Dunham Road.

Photo 2: Dunham road washed out in Tropical Storm Irene.

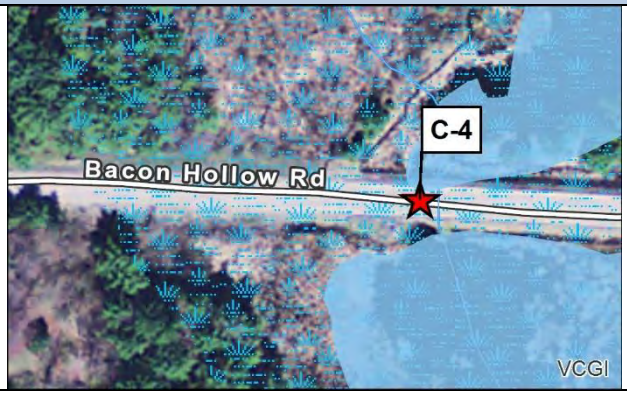
BMP Description: Replace the culvert with an appropriately sized concrete box culvert and improve the culvert orientation to better match the channel. VTrans hydraulic study recommends a 4ft by 8ft culvert embedded 1ft into the channel bottom.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
7	4	3	2	3	19 **(High)**

Additional Project Benefits Description: Chronic Problem Area, Seasonal Flooding

Project Comments: High priority project due to the important transportation link. **We estimate that this project will cost $100,000 to $150,000.**

Project: C-4	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	Bacon Hollow Road
Latitude: **Longitude:**	43.09104 N -73.12114 W
Land Ownership:	Town



Site Description: A 36" CMP culvert under Bacon Hollow Road is fully backwatered due to downstream beaver dams (Photos 1 & 2). The culvert is rusted and needs to be replaced. Frequent maintenance is required to keep the outlet channel along the road embankment cleared of beaver dams.

Photo 1: The culvert under Bacon Hollow Road is backwatered.

Photo 2: Downstream beaver dams backwater the channel.

BMP Description: Replace the culvert with a larger structure and consider installation of beaver baffles to reduce flooding risk to road.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
4	3	1	3	1	12 **(Low)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: Low priority project due to the minor water quality and infrastructure resiliency benefits. **We estimate that this project will cost $20,000 to $30,000.**

Project: C-5	**Problem Area Summary**
Date Observed:	7/7/2017 & 8/24/2017
Location:	North Road
Latitude: **Longitude:**	43.07595 N -73.11014 W
Land Ownership:	Town

Site Description: Double 15" CPP under North Road require frequent maintenance to clear sediment, debris, and ice (Photos 1 & 2). Culvert slope is low and the inlet is slightly projecting.

Photo 1: Double culverts under North Road trap sediment, debris and ice.

Photo 2: Replacing the culverts with a larger culvert or box and increasing the culvert slope would improve conveyance.

BMP Description: Replace with a larger culvert or concrete box, increase culvert slope if possible to improve conveyance and reduce maintenance requirements. Based on an HY-8 culvert sizing analysis, we recommend a 24 inch culvert with an appropriate header.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
6	4	2	3	1	16 **(Moderate)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: Moderate priority project due to the modest maintenance requirements of the implemented project and additional benefits from fixing a chronic problem area. **We estimate this project will cost $4,000 to $8,000.**

Project: C-6	**Problem Area Summary**
Date Observed:	7/7/2017 & 8/24/2017
Location:	North Road
Latitude: **Longitude:**	43.06400 N -73.11754 W
Land Ownership:	Town

Site Description: 36" CMP under North Road is too short for the crossing resulting in a vertical bank on both sides of the road (Photo 1). The road shoulder is eroding and may undermine the edge of the pavement (Photo 2).

Photo 1: A culvert under North Road is too short causing erosion of the road shoulder at the culvert inlet.

Photo 2: Erosion along the road shoulder due to the vertical banks at the culvert outlet.

BMP Description: Extend the culvert length to allow for a more stable embankment, improve culvert headers on both sides of the road.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
7	4	2	3	0	16 **(Moderate)**

Additional Project Benefits Description:

Project Comments: Moderate priority project due to the potential to mitigate direct source of sediment a stream and improvements to infrastructure resiliency. **We estimate that this project will cost $10,000 to $20,000.**

Project: C-7	**Problem Area Summary**
Date Observed:	8/24/2017
Location:	South Road
Latitude: **Longitude:**	43.05265 N -73.13144 W
Land Ownership:	Town

Site Description: The 24" CMP culvert under South Road near the driveway of the GMP facility is badly rotted and the inlet has collapsed (Photo 1). The embankment is eroding at both the inlet and outlet (Photo 2). The culvert is slightly undersized.

Photo 1: Location of a collapsed inlet to a cross culvert under South Road.

Photo 2: Erosion at the outlet of a cross culvert under South Road.

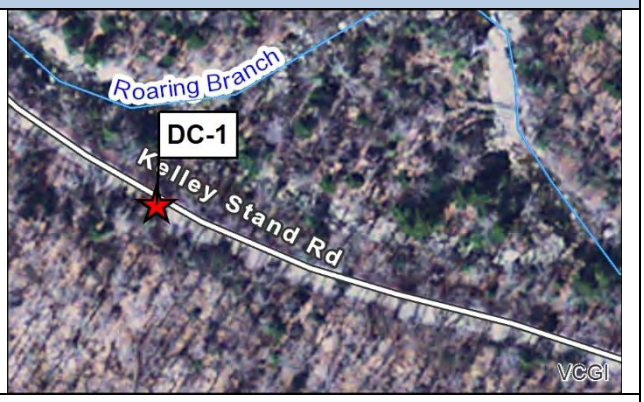
BMP Description: Replace with an appropriately sized culvert. Based on an HY-8 culvert sizing analysis, we recommend a 3ft diameter culvert with an appropriate headwall configuration.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
6	3	2	3	1	15 **(Low)**

Additional Project Benefits Description: Seasonal Flooding

Project Comments: Low priority project due to moderate water quality benefits. **We estimate that this project will cost $5,000 to $10,000.**

Project: DC-1	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	Kelley Stand Road
Latitude: **Longitude:**	43.05491 N -73.06112 W
Land Ownership:	Town



Site Description: Three 24" CMP cross-culverts are exposed and badly damaged by vehicle and grader traffic (Photo 1). Ditches are filled in and the shoulder is very wet (Photo 2). **Culverts were replaced in 2017.**

Photo 1: Exposed and damaged cross culverts on Kelley Stand Road.

Photo 2: Ditches are filled in along a section of Kelley Stand Road.

BMP Description: Replace the cross-culverts and excavate ditches to ensure sufficient cover over culverts to avoid future damage.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
9	4	3	4	0	20 **(High)**

Additional Project Benefits Description:

Project Comments: High priority project due to the potential to mitigate a sediment source to the Roaring Branch and relatively low cost of the project.

Project: DC-2	**Problem Area Summary**

Date Observed:	7/7/2017
Location:	Kelley Stand Road
Latitude: **Longitude:**	43.05205 N -73.04764 W
Land Ownership:	Town

Site Description: A 24" CMP cross culvert is badly damaged by vehicle and grader traffic. The inlet is exposed and crushed, **Sunderland Highway Department completed this work in 2017.**

Photo 1: Location of a damaged cross culvert along Kelley Stand Road.

Photo 2: The culvert inlet is damaged and exposed.

BMP Description: Replace the culvert and ensure sufficient fill over the culvert to prevent future damage, ditch may require some excavation.

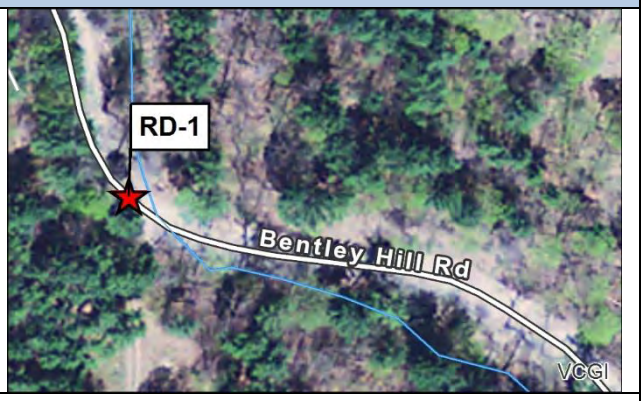
WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
8	4	3	4	0	19 **(High)**

Additional Project Benefits Description:

Project Comments: Moderate priority project due to the potential to mitigate sediment losses and relatively low cost of the project.

Project: RD-1	**Problem Area Summary**

Date Observed:	8/24/2017
Location:	Bentley Hill Road
Latitude: **Longitude:**	43.11859 N -73.12384 W
Land Ownership:	Town



Site Description: A driveway located at the stream crossing does not have a culvert, causing the western ditch to spill across the road with significant rill erosion along the road and gully erosion at the stream culvert outlet (Photos 1 & 2). The ditch should be extended to minimize the length of culvert.

Photo 1: Major gully erosion along Bentley Hill Road.

Photo 2: Sediment deposits at the stream culvert outlet from severe gully erosion along the road.

BMP Description: Extend the west roadside ditch and install a culvert under the driveway with an outlet directly to the stream at the larger culvert outlet.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
11	3	3	4	2	23 **(V. High)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: Very high priority project due to the potential to mitigate a major sediment and nutrient source to a second order stream and improve infrastructure resiliency. **We estimate that this project will cost approximately $10,000.**

Project: RD-2	**Problem Area Summary**

Date Observed:	8/24/2017
Location:	Bentley Hill Road
Latitude: **Longitude:**	43.11753 N -73.12187 W
Land Ownership:	Town

Site Description: Significant erosion along the ditches and steep road embankment was observed along the steep stretches of the Road from Route 7A to the town line (Photo 1). Ditches were typically undersized, shallow, and not stone lined (Photo 2).

Photo 1: Erosion along Bentley Hill Road.

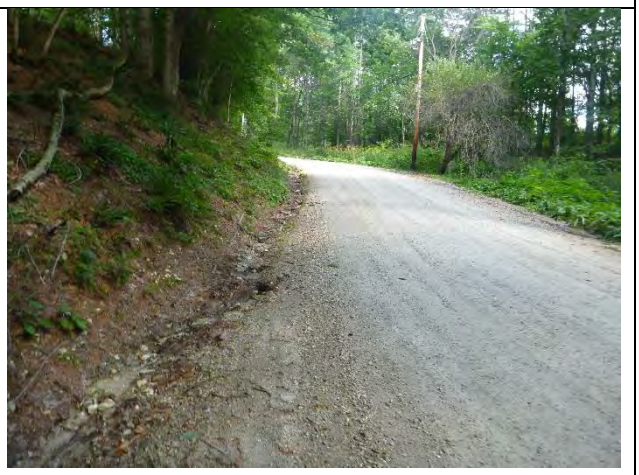


Photo 2: Erosion along Bentley Hill Road, where ditches are shallow and undersized.

BMP Description: Enlarge and stone line the ditches with 6-8" minus in sections less than 10% slope and 12" minus stone in the sections approaching 10% slope. Stabilize gully erosion along the steep road embankment and improve road grading to reduce flow areas directly draining down the embankment. Ditch and road grading extents may approach 800-1,000 feet of roadway length. The entire project area is "hydrologically connected".

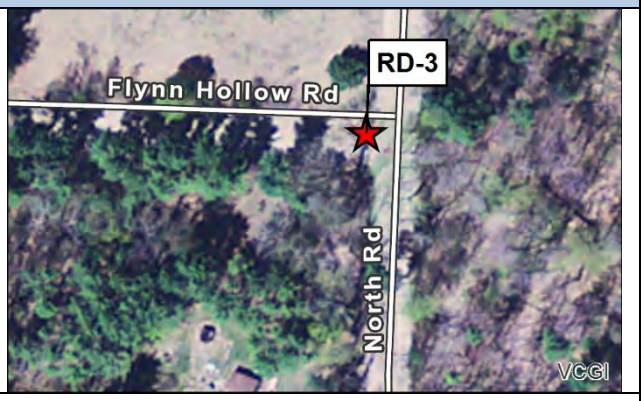
WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
12	3	2	3	1	21 **(High)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: High priority project due to the potential to mitigate a sediment and nutrient source to a second order stream. **We estimate that this project will cost $20,000 to $40,000.**

Project: RD-3	**Problem Area Summary**

Date Observed:	7/7/2017
Location:	Flynn Hollow Road
Latitude: **Longitude:**	43.09286 N -73.11113 W
Land Ownership:	Town



Site Description: The ditches along the north side of Flynn Hollow Road and the west side of North Road join and flow through a pipe under North Road. Both ditches are wide and flat and carry a large volume of sediment (Photos 1 & 2). Large vehicles turning on to Flynn Hollow repeatedly damage the road shoulder and increase erosion. **Sunderland Highway Department completed this work in 2017.**

Photo 1: Ditches along Flynn Hollow Road and North Road carry a large volume of sediment.

Photo 2: Sediment at the inlet of the culvert under Flynn Hollow Road.

BMP Description: Stabilize the ditches and protect the road shoulder from erosion. Consider moving the culvert approximately 10' west to provide a larger turning area.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
10	3	1	5	1	20 **(High)**

Additional Project Benefits Description: Improves BMP Performance

Project Comments: High priority project due to the potential to mitigate sediment and nutrient losses and the relatively low cost of the project.

Project: RD-4	**Problem Area Summary**

Date Observed:	8/24/2017
Location:	Shady Pines Road
Latitude: **Longitude:**	43.08387 N -73.11342 W
Land Ownership:	Town

Site Description: Short section of road with no ditch along the northern side, moderate gully erosion (Photos 1 & 2). Cable lines are shallowly buried in the ditch complicating site improvements. **Sunderland Highway Department completed site repairs in 2017.**

Photo 1: A section of Shady Pines Road has no ditch.

Photo 2: Gully erosion along a section of Shady Pines Road with no ditch.

BMP Description: Install a grassed ditch and driveway culvert.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
5	3	1	4	1	14 **(Low)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: Low priority project due to the relatively low water quality benefits and the additional project implementation requirements to work around the cable line in the ditch.

Project: RD-5	**Problem Area Summary**
Date Observed:	8/24/2017
Location:	Laver Road
Latitude: **Longitude:**	43.07926 N -73.13185 W
Land Ownership:	Town

Site Description: The ditch along the north side of the road is undersized and poorly defined with several areas of severe gully erosion (Photo 1). The ditch on the eastern side of the stream crossing is deeply incised and is delivering large volumes of sediment and gravel to the stream channel (Photo 2). **Sunderland Highway Department completed ditch repairs in 2017.**

Photo 1: Poorly defined ditch with gully erosion along Laver Road.

Photo 2: Incised ditch at the stream crossing is delivering large volumes of sediment and gravel.

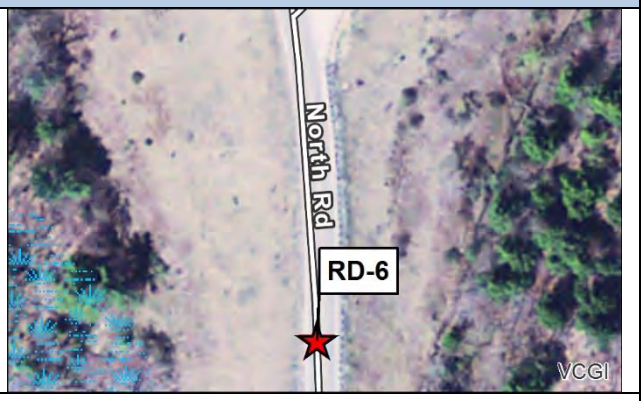
BMP Description: Excavate and stone line ditches with 6-8" minus stone. Larger rock may be needed in the area east of the culvert inlet where the ditch is badly eroded. Most of the road segments are not "hydrologically connected".

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
11	3	2	4	1	21 **(High)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: High priority project due to the potential to mitigate a sediment and nutrient source to a first order stream and relatively low cost of the project.

Project: RD-6	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	North Road
Latitude: **Longitude:**	43.08127 N -73.11078 W
Land Ownership:	Town



Site Description: West edge of road lacks a ditch and the shoulder is slightly elevated, stopping sheetflow. There is active erosion along the road shoulder, delivering sediment to Beaver Meadow Brook.

Photo 1: A section of North Road with no ditch.

Photo 2: A section of North Road with active erosion is a sediment source to Beaver Meadow Book.

BMP Description: Lower the road shoulder and/or install turnouts to allow for sheetflow off or road. Alternatively, install a narrow stone lined ditch with 6-8" minus stone along the edge of pavement.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
6	3	1	5	0	15 **(Low)**

Additional Project Benefits Description:

Project Comments: Low priority project due to the relatively low water quality benefits and low risk of infrastructure damage. **We estimate that this project will cost $2,000 to $5,000.**

Project: RD-7	**Problem Area Summary**

Date Observed:	7/7/2017
Location:	North Road
Latitude: **Longitude:**	43.07712 N -73.10998 W
Land Ownership:	Town

Site Description: Ditch on both sides of road is poorly defined and is eroding, culvert inlet on east side is very deep and pipe is too short, significant gully erosion at inlet (Photos 1 & 2). Tree clearing will be required to establish a ditch along the west side of the road.

Photo 1: Poorly defined and eroding ditch along North Road.

Photo 2: Gully erosion at the inlet to a cross culvert along North Road.

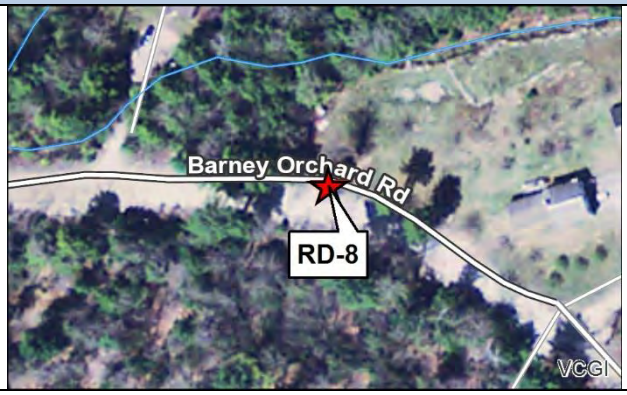
BMP Description: Extend the culvert inlet with a cut pipe section and enlarge both ditches and line with 6-8" minus stone.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
8	4	2	4	1	19 **(High)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: Moderate priority project due to the potential to mitigate sediment and nutrient losses and additional benefits from fixing a chronic problem area. **We estimate that this project will cost $5,000 to $10,000.**

Project: RD-8	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	Barney Orchard Road
Latitude: **Longitude:**	43.06578 N -73.11360 W
Land Ownership:	Town



Site Description: The private road draining to the top of Barney Orchard Road is poorly crowned and lacking appropriate ditches, causing severe erosion and sediment transport to the municipal ditch and turnout. The ditches continuing along the road are undersized and are severely eroded. The large turnout at the bottom of the hill is filled with sediment, reducing effectiveness.

Photo 1: Eroded undersized ditch along Barney Orchard Rd.

Photo 2: Sediment deposits at the bottom of the ditch near a small stream.

BMP Description: Install a cross-culvert and stabilize ditches on the private road, excavate and stone-line the roadside ditches with 12" minus stone. Stabilize the cross-culvert outlet with large rock. Cleanout the sediment deposits along the stream bank and install a sediment trap.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
12	4	2	3	3	24 **(V. High)**

Additional Project Benefits Description: Chronic Problem Area, Improves BMP Performance

Project Comments: Very high priority project due to the potential to mitigate a sediment and nutrient source to a small stream and additional benefits from fixing a chronic problem area and improving BMP performance. **We estimate that this project will cost $20,000 to $30,000.**

Project: RD-9	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	Prouty Hill Road
Latitude: **Longitude:**	43.05694 N -73.13671 W
Land Ownership:	Town

Site Description: The driveway for 185 Prouty Hill Rd does not have a culvert, the ditches have a very complicated path to direct flow across the road twice, increasing ditch and road erosion (Photo 1). Both ditches have areas of severe erosion and are carrying large volumes of sediment (Photo 2). Check dams and a sediment trap in the lower portion of the east ditch are filled with sediment.

Photo 1: Road erosion along Prouty Hill Road.

Photo 2: Check dams and a sediment trap along Prouty Hill road are filled with sediment from ditch and road erosion.

BMP Description: Install a driveway culvert to improve ditch conveyance. Remove three (3) cross-culverts and connect the ditches. Remove the grader berm along the western edge of the road. A culvert is likely needed under the driveway to the west. Line the ditches with 12" minus stone. Increase cleanout frequency for the existing check dams and sediment trap.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
11	3	2	3	3	22 **(V. High)**

Additional Project Benefits Description: Chronic Problem Area, Improves BMP Performance

Project Comments: High priority project due to the ongoing erosion rill and gully erosion issues and the large volumes of sediment being transported to the Fayeville Branch. **We estimate that this project will cost $25,000 to $35,000.**

Project: RD-10	**Problem Area Summary**

Date Observed:	7/7/2017
Location:	Kelley Stand Road
Latitude: **Longitude:**	43.04765 N -73.11644 W
Land Ownership:	Town and Private

Site Description: A recently installed driveway culvert for a trailer parking spot along the road is poorly aligned and is interrupting flow through the ditch (Photo 1). Significant erosion is visible along the road edge and through the ditch (Photo 2).

Photo 1: A recently installed driveway culvert along Kelley Stand Road.

Photo 2: The poorly aligned culvert is interrupting flow and causing erosion along the road and ditch.

BMP Description: Reinstall the driveway culvert and stabilize the road edge with rock.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
8	3	2	4	1	18 **(Moderate)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: Moderate priority project due to the relatively low cost of the project and additional benefits from fixing a chronic problem area. **We estimate that this project will cost less than $5,000.**

Project: RD-11	**Problem Area Summary**

Date Observed:	7/7/2017
Location:	Kelley Stand Road
Latitude: **Longitude:**	43.04182 N -73.10333 W
Land Ownership:	Town

Site Description: Runoff along the east side of the road misses a small turnout to the river and is causing significant gully erosion (Photos 1 & 2). **Sunderland Highway Department completed this work in 2017**.

Photo 1: Gully erosion along Kelley Stand Road.

Photo 2: Erosion along the road delivers sediment to the adjacent river.

BMP Description: Improve the road crown and/or improve the inlet to the upslope turnout to better remove runoff from the road. Stabilize the gully erosion area with larger stone.

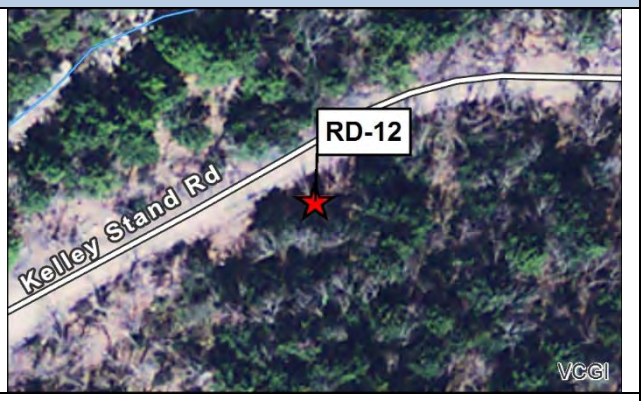
WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
8	4	1	5	0	18 **(Moderate)**

Additional Project Benefits Description:

Project Comments: Moderate priority project due to the potential to mitigate a direct sediment source to the Roaring Branch and the relatively low cost of the project.

Project: RD-12	**Problem Area Summary**

Date Observed:	7/7/2017
Location:	Kelley Stand Road
Latitude: **Longitude:**	43.05072 N -73.08321 W
Land Ownership:	Town



Site Description: The ditch along the south side of the road is very steep and eroding, small turnout at bridge traps some sediment (Photos 1 & 2).

Photo 1: A steep eroding ditch along Kelley Stand Road.

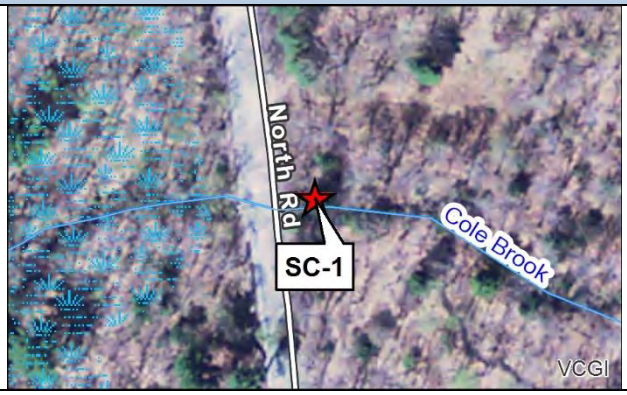
BMP Description: Construct a stone-lined ditch with 6-8" minus stone.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
9	3	1	4	0	17 **(Moderate)**

Additional Project Benefits Description:

Project Comments: Moderate priority project due to the potential to mitigate a sediment source to the Roaring Branch and the relatively low cost of the project. **We estimate that this project will cost approximately $10,000.**

Project: SC-1	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	North Road
Latitude: **Longitude:**	43.07911 N -73.10976 W
Land Ownership:	Town/Private



Site Description: Cole Brook passes under North Road through a 48" CMP (Photo 1). This culvert was overtopped in Irene and significant flooding and damage occurred along the road to the north. The upstream channel is incised and has a significantly larger capacity than the culvert (Photo 2).

Photo 1: An undersized culvert conveys Cole Brook under North Road.

Photo 2: The Cole Brook channel upstream of North Road is deeply incised.

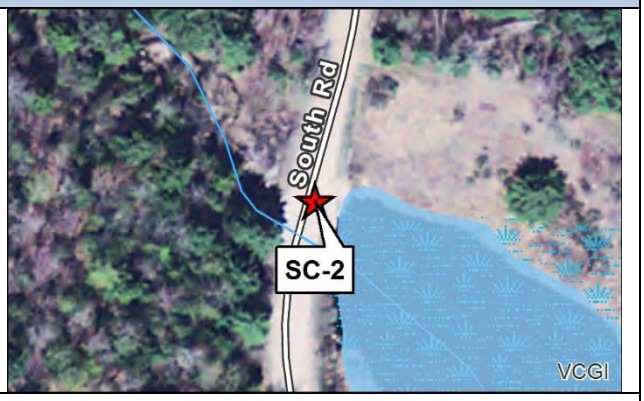
BMP Description: Replace the culvert with a larger structure and assess opportunities for floodplain reconnection upstream through rock/wood structures to reduce channel incision. It may be possible to construct an overflow channel along the east side of North Road to direct floodwaters to the smaller tributary to the north. VTrans hydraulic study recommends 6ftx12ft box culvert, embedded 1ft into the channel bottom.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
8	4	3	2	3	20 **(High)**

Additional Project Benefits Description: Chronic Problem Area, Seasonal Flooding, Improves Aquatic Organism Passage (AOP)

Project Comments: High priority project due to past flooding issues and ongoing channel incision. **We estimate that this project will cost $150,000 to $275,000.**

Project: SC-2	**Problem Area Summary**
Date Observed:	8/24/2017
Location:	South Road
Latitude: **Longitude:**	43.04354 N -73.13598 W
Land Ownership:	Town



Site Description: New 48" culvert draining the pond is perched approximately 18" and is likely a complete AOP barrier (Photos 1 & 2).

Photo 1: The culvert under South Road is perched.

Photo 2: Erosion along the edge of South Road at the culvert outlet.

BMP Description: Based on an HY-8 culvert sizing analysis, we recommend a 5ft by 8ft box culvert embedded 1ft into the channel bottom. Large sediment retention baffles are likely required to maintain material, or provide step-pool formations throughout the steep culvert.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
4	3	0	2	1	10 **(Low)**

Additional Project Benefits Description: Improves Aquatic Organism Passage (AOP)

Project Comments: Low priority project due to no significant water quality benefits aside from improving AOP. **We estimate that culvert replacement will cost $100,000 to $200,000.**

Project: SC-3	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	Kelley Stand Road
Latitude: **Longitude:**	43.05235 N -73.05186 W
Land Ownership:	Town

Site Description: Small tributary crosses under Kelley Stand Rd through a 48" CMP that is slightly perched. The culvert is short, and the embankments are near vertical with a stacked river rock header that is prone to erosion.

Photo 1: A culvert under Kelley Stand Road is short with near vertical embankments.

Photo 2: Vertical embankments at the culvert along Kelley Stand Road are prone to erosion.

BMP Description: Extend or replace the culvert, install single piece headers on each side and either replace the culvert at a steep slope to match the channel profile or install a tailwater control structure to address the AOP barrier at the outlet drop.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
5	2	2	2	1	12 **(Low)**

Additional Project Benefits Description: Improves Aquatic Organism Passage (AOP)

Project Comments: Low priority project due to the moderate cost and difficulty of replacing the structure. **We estimate that this project will cost $5,000 to $15,000.**

Project: SW-1	**Problem Area Summary**
Date Observed:	8/24/2017
Location:	Town Garage
Latitude: **Longitude:**	43.10826 N -73.11943 W
Land Ownership:	Town

Site Description: The sand pit and salt shed area drain to a sediment trap along Dunham Rd that that may be undersized given the high sediment load (Photo 1). Erosion along the numerous flow paths is increasing sediment transport to the sediment trap (Photo 2). We did not observe any evidence of excess sediment loads leaving the site and reaching surface waters.

Photo 1: A sediment trap along Dunham Road that the Town sand pit and salt shed area drains to.

Photo 2: Erosion is overloading the sediment trap.

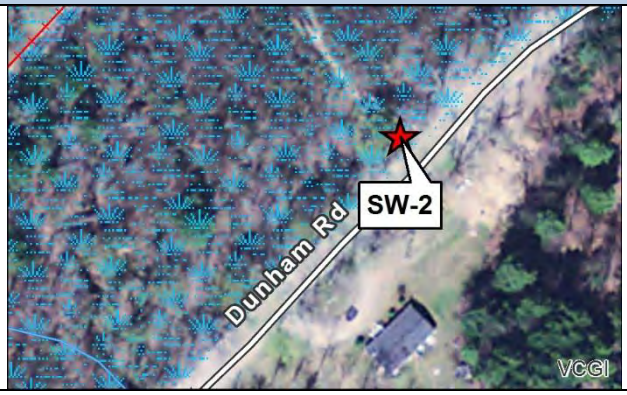
BMP Description: Enlarge the sediment trap and provide well defined armored flow paths for runoff to reduce additional erosion.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
5	3	0	5	1	14 **(Low)**

Additional Project Benefits Description: High Visibility

Project Comments: Low priority project due to the potential to reduce sediment losses, the relatively low cost of the project and additional benefits from implementing a project in an area where it is highly visible. **We estimate that this project will cost $2,000 to $5,000.**

Project: SW-2	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	Dunham Road
Latitude: **Longitude:**	43.09802 N -73.13465 W
Land Ownership:	Town



Site Description: An existing drainage turnout along Dunham Road is delivering large volumes of stormwater and sediment into a large wetland along the Battenkill River floodplain (Photos 1 & 2).

Photo 1: Turnout along Dunham Road.

Photo 2: Sediment and stormwater in a large wetland along the Battenkill River floodplain.

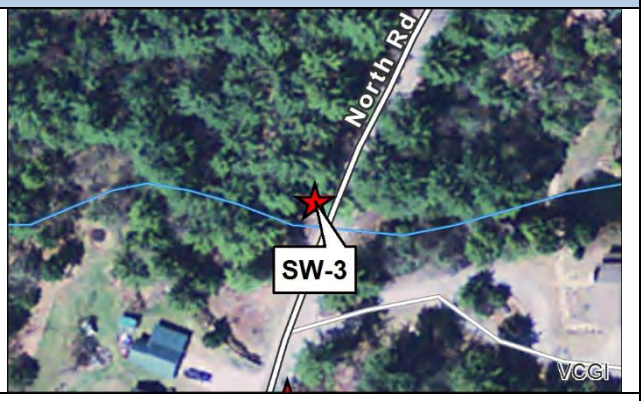
BMP Description: Construct a sediment trap that can be easily cleaned from the roadway, stabilize the inlet and outlet of the trap to reduce erosion during large storms.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
8	2	0	5	1	16 **(Moderate)**

Additional Project Benefits Description: Chronic Problem Area, Seasonal Flooding

Project Comments: Moderate priority project due to the potential to mitigate a sediment an adjacent wetland and additional benefits from fixing a chronic problem area prone to seasonal flooding. **We estimate that this project will cost less than $2,000.**

Project: SW-3	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	North Road
Latitude: **Longitude:**	43.06442 N -73.11747 W
Land Ownership:	Town



Site Description: Ditch draining a large portion of North Rd is fairly stable but drains directly in to a stream with minor gully erosion along the streambank (Photo 1). There is space for a BMP between the guardrail and the floodplain (Photo 2).

Photo 1: A ditch along North Road drains directly into a stream.

Photo 2: There is space for a BMP between the guardrail and floodplain to treat ditch runoff.

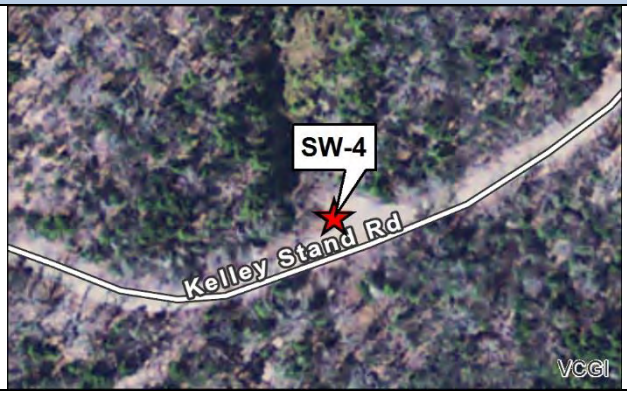
BMP Description: Install check dams in the lower portion of the ditch and install a sediment trap on top of the bank with an armored spillway into the channel.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
9	3	1	4	1	18 **(Moderate)**

Additional Project Benefits Description: Improves BMP Performance

Project Comments: Moderate priority project due to the potential to mitigate a direct sediment source to a second order stream and additional benefits from improving BMP performance. **We estimate that this project will cost $2,000 to $5,000.**

Project: SW-4	**Problem Area Summary**
Date Observed:	7/7/2017
Location:	Kelley Stand Road
Latitude: **Longitude:**	43.05488 N -73.02953 W
Land Ownership:	Town



Site Description: A steep section of road drains to a small turnout along the edge of a wetland on the north side of the road (Photo 1). The ditch shows some active erosion and the turnout is filled with road sediment and with excess material stockpiled during road grading (Photo 2).

Photo 1: A steep section of Kelley Stand Road, with some active erosion in roadside ditches.

Photo 2: The turnout along the edge of a wetland is buried in sediment.

BMP Description: Enlarge the ditch and line with 12" minus stone. Install a sediment trap along the edge of the road with a stone lined overflow into the wetland. Ensure that road grading materials are stored in a location that does not drain to the wetland.

WQ Benefits	Landowner Support and O&M	Infrastructure Resiliency	Cost and Constructability	Additional Benefits	Total Score (Priority)
10	3	1	4	2	20 **(High)**

Additional Project Benefits Description: Chronic Problem Area

Project Comments: High priority project due to the potential to mitigate a sediment source to an adjacent wetland and additional benefits from fixing a chronic problem area. **We estimate that this project will cost $15,000 to $25,000.**

APPENDIX D:

Conceptual Designs

Project C-3, Dunham Road Tributary Culvert Replacement

Existing Conditions

An unnamed first-order tributary draining an approximately 0.3 square mile watershed crosses Dunham Road 400ft northeast of the Arlington town line. The tributary drains a primarily forested watershed with some residential parcels along Dunlap Farm Road. The channel is moderately steep (5-7%) and flows through a narrow valley. The culvert is located at a significant decrease in channel slope as the stream enters the broad Battenkill River valley. The channel takes a sharp bend upstream of the culvert and a moderate bend at the culvert inlet (Figure 1). The top of the culvert at the inlet is less than 0.5ft from the road edge elevation (Figure 2). Downstream of Dunham Road the channel winds through a wide and flat floodplain before crossing under the railroad and entering the floodplain wetlands along the Battenkill River (Figure 3).

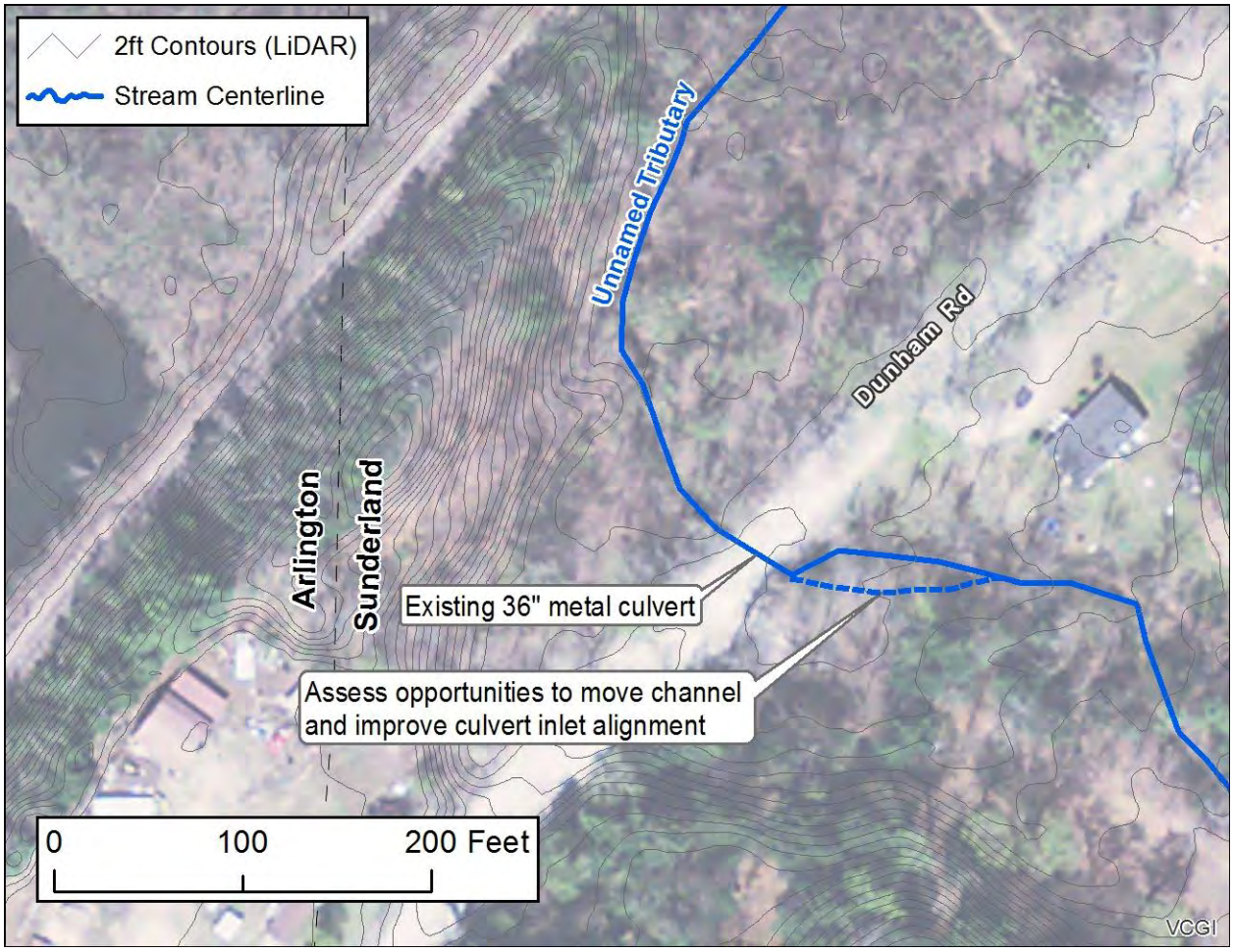


Figure 1: Project location map for the Dunham Road culvert replacement. Conceptual channel alignment shown as dashed line.

Figure 2: Sand and gravel deposition in the channel upstream of the culvert inlet.

Figure 3: Wide and flat channel downstream of the crossing.

Problem Overview

The tributary overtopped the culvert during the T.S. Irene flood of 2011 and washed out Dunham Road.. Dunham Road is a critical alternate transportation route, and damage to the road complicated recovery efforts following T.S. Irene. Total costs to repair the road and reinstall the culvert were approximately $2,000. The change in channel slope and the culvert approach angle are contributing to ongoing deposition of sand and gravel within the channel upstream and downstream of the crossing. Based on conversations with the Town Road Foreman, the culvert regularly overtops in moderate to large storm events.

Culvert Capacity and Sizing Analysis

Existing Conditions

The Vermont Agency of Transportation (VTrans) completed a hydraulic study for the Dunham Road culvert. VTrans compiled the results of several hydrologic methods to estimate design flow rates for recurrence interval storms. The selected flows for the tributary are shown in Table 1.

Table 1: Recurrence interval flows for the Dunham Road culvert

Recurrence Interval (Years)	Flow (cfs)
Q2.33	30
Q10	65
Q25	80
Q50	95
Q100	110

The hydraulic study specifies the 25-year flood as the Town Highway Design Flow and the 100-year flood as the Check Flow. We used the HY-8 software from the Federal Highway Administration to model the existing and proposed culvert capacities. FEA determined the dimensions and profile of the existing culvert using laser survey equipment. The survey assumed a relative roadway elevation of 95.1ft for modeling purposes. Based on the HY-8 analysis, the existing squash culvert has an approximate capacity of 42cfs, well below the 10-year flood (Figure 4).

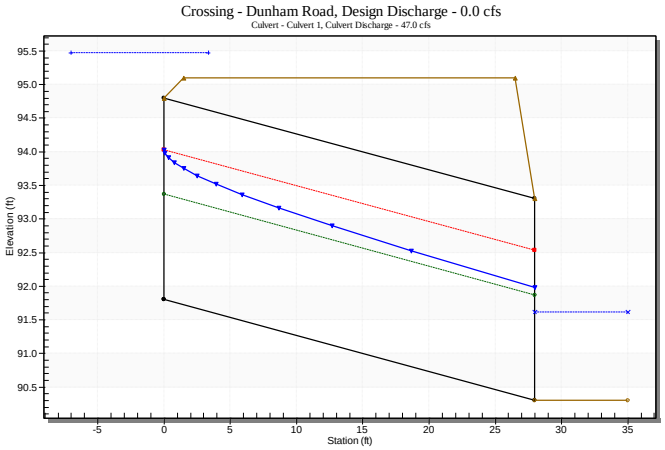


Figure 4: HY-8 plot of the 10-year flow exceeding the existing culvert and overtopping Dunham Road.

Proposed Culvert Replacement

The hydraulic study recommends a 4ft tall by 8ft wide box culvert for a suitable replacement structure. This structure would tie in with the 8ft wide channel upstream of the crossing and is equal to the predicted bankfull channel width based on drainage area. The recommended box culvert includes 6-inch tall sediment retention baffles to ensure that native streambed material is continuous through the culvert. Assuming an additional 6-inches of deposition on top of the baffles, the culvert would have an effective opening of 3ft tall by 8ft wide. The proposed culvert bottom (with sediment retention) would be comparable to the existing culvert. The overall culvert slope will be lower, improving retention of bed material within the culvert and reducing downstream scour. This structure passes the Q25 with approximately 0.5ft of freeboard and does not overtop the road during the Q100. We included the VTrans specified culvert dimensions in the HY-8 model and the predicted water surface elevations were nearly identical to their results (Figures 5 and 6).

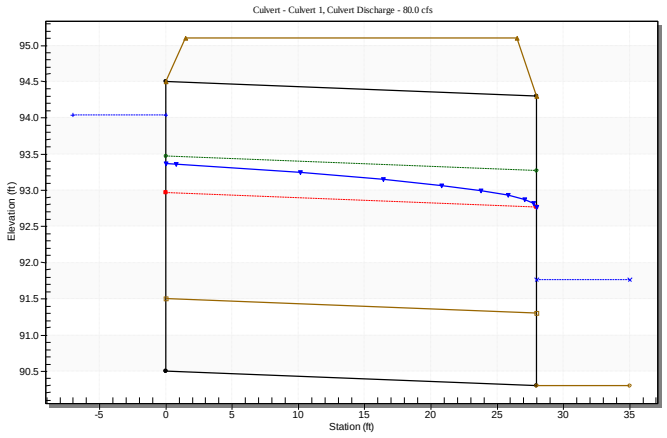


Figure 5: HY-8 plot of the 25-year flow (80cfs) passing through the proposed 3ft by 8ft box culvert.

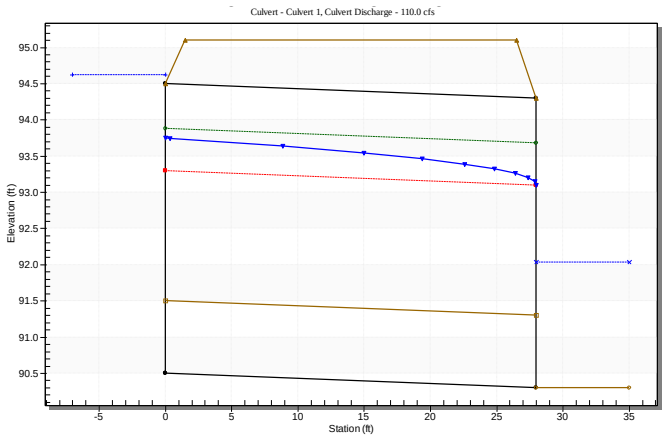


Figure 6: HY-8 plot of the 100-year flow (110cfs) filling the proposed culvert but not overtopping Dunham Road.

Proposed Channel Alignment

The current channel alignment approaching the culvert has two moderate bends. Removing these bends would improve sediment transport though the proposed culvert, reducing maintenance requirements and likely improve sediment transport during large storm events (Figure 1). This effort would require additional site survey and coordination with the private landowner. Improved channel alignment may reduce overbank flooding affecting the house to the north.

Regulatory Requirements

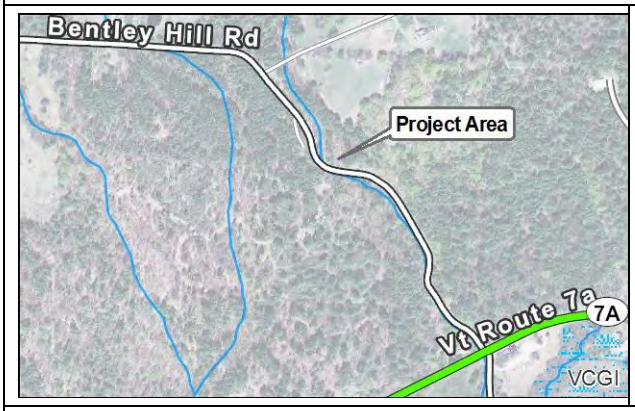
A VTANR stream alterations permit would be required for culvert replacement and channel realignment. Tree clearing associated with the channel alignment will likely need to be coordinated with USACE and other federal agencies (i.e., USFWS) to avoid or minimize impacts on potential habitat for threatened or endangered bat species.

Project Cost Estimate

Additional survey and design work is required for the culvert replacement and for the channel alignment. We estimate that project will cost roughly $100,000 to $150,000 primarily based on the cost of the pre-cast box culvert.

Town: Sunderland	**Road Name:** Bentley Hill Road	**Date Visited:** 10/23/2017

Road Segment IDs: Bentley Hill Road: 7942 and 7943



Existing Conditions

Field Determined Slope: 9-10%

Road Type: Gravel

Conveyance Area/Turnout: 2 Poor

Erosion Types Present: Gully, Rill

Drainage Culverts: Conveyance

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	X	Driveway Culverts (within ROW)	+

Existing Conditions Notes: The ditch along the western side of Bentley Hill Road is undersized and eroding. The ditch ends at a bend in the road approximately 60ft north of the driveway. Runoff spills on to the road and is causing severe gully erosion south of the driveway where it enters the stream near the conveyance culvert outlet. A turnout near the conveyance culvert inlet is unstable.

Photo 1: Severe erosion along Bentley Hill Road at the stream crossing location where the ditch spills onto the road at the private driveway.

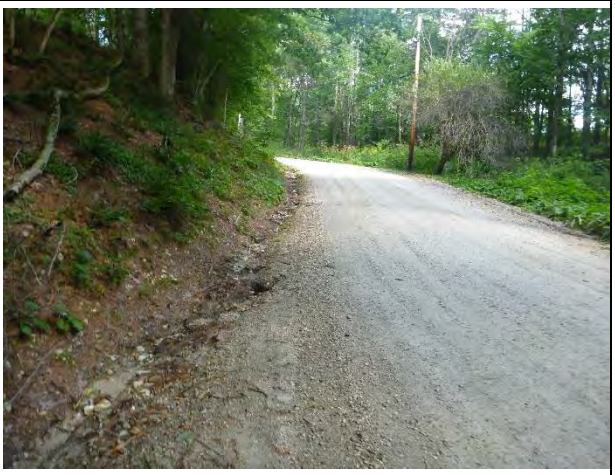


Photo 2: Undersized and eroded ditch along Bentley Hill Road draining to the stream crossing.

Proposed Scope of Work

Roadway/Travel Lane Practices

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

Roadway Drainage Practices

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

Conveyance/Turnout Practices

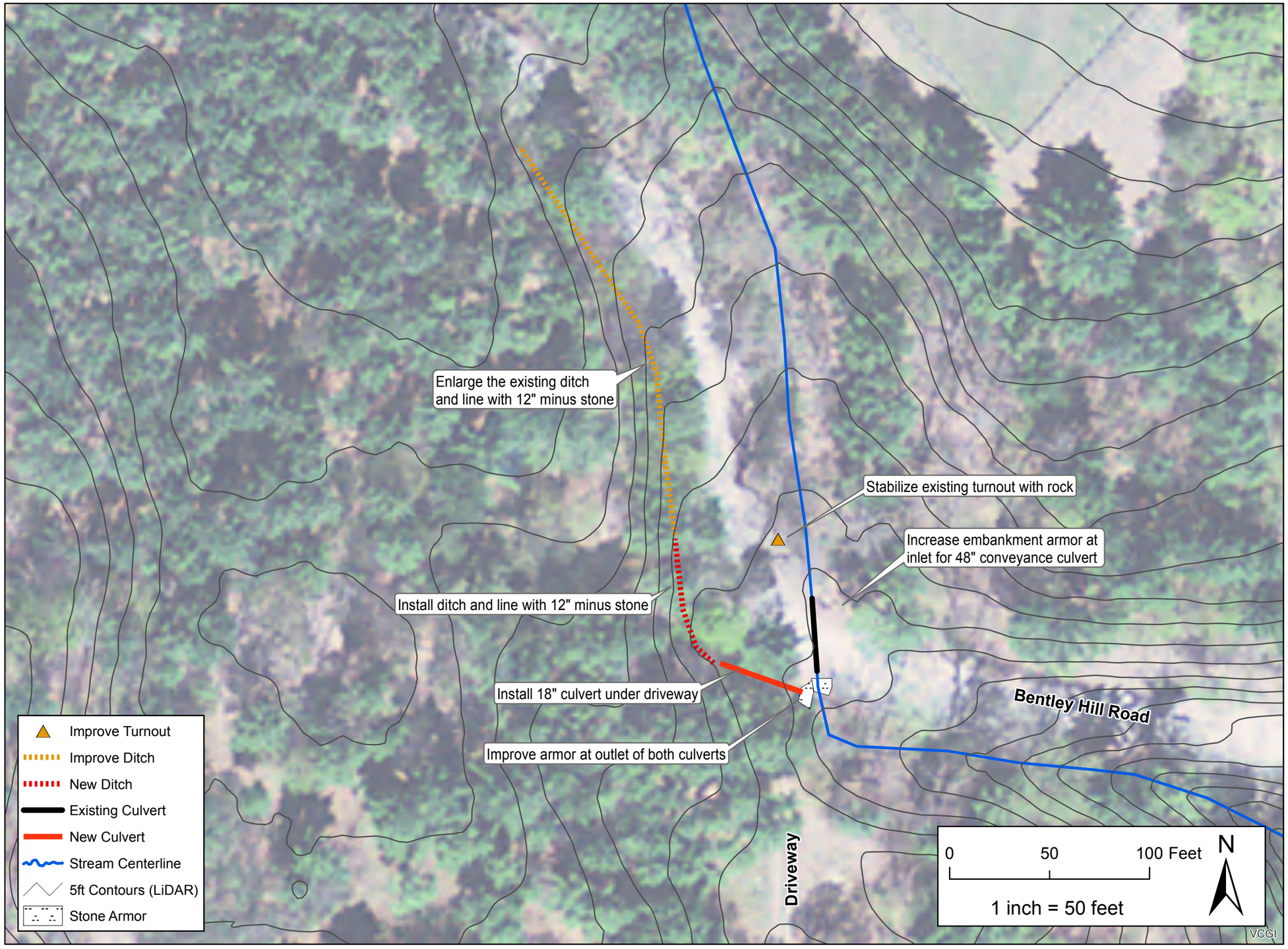
	Install Turnout	**X**	Stabilize/Improve Existing Turnout
	Install/Improve Sediment Trap		Stone Armor on Bank/Slope
	Install Check Dams in Existing Feature		

Culvert Practices

X	New Municipal Culvert		Upgrade Municipal Culvert
	New Driveway Culvert		Upgrade Driveway Culvert
X	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		$ -
Raise Road Grade	Cubic Yard	$ 15		$ -
Remove Grader Berm	Linear Foot	$ 5		$ -
Edge of Road Stabilization/Maintenance	Linear Foot	$ 8		$ -
New Stone-Lined Ditch	Linear Foot	$ 25	60	$ 1,500
New Grass-Lined Ditch	Linear Foot	$ 8		$ -
Side Slope Excavation for New Ditch	Linear Foot	$ 10		$ -
Improve Existing Ditch (Stone)	Linear Foot	$ 20	200	$ 4,000
Improve Existing Ditch (Grass)	Linear Foot	$ 5		$ -
Install/Improve Turnout	Each	$ 200	1	$ 200
Install/Improve Sediment Trap	Each	$ 750		$ -
Install Stone Armor (Bank/Slope)	Cubic Yard	$ 40		$ -
Install Check Dam	Each	$ 40		$ -
New/Upgrade Cross-Culvert (18" to 24")	Each	$ 2,000	1	$ 2,000
New/Upgrade Conveyance Culvert	Each	$ 2,000		$ -
New/Upgrade Driveway Culvert	Each	$ 750		$ -
Install Culvert Headwall/Armor	Each	$ 300	2	$ 600
Remove Sediment/Debris from Culvert	Each	$ 100		$ -
			Total Cost:	**$ 8,300**



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Notes:
Site visit completed on 10/23/2017

Drawn: JHB
Date: 10/31/2017

Concept Design Overview

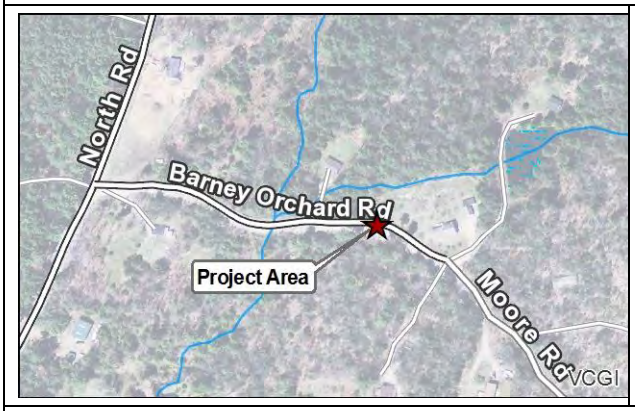
Sunderland Stormwater Master Plan

Bentley Hill Road Site

BENTLEY HILL

Town: Sunderland	**Road Name:** Barney Orchard Road	**Date Visited:** 10/23/2017

Road Segment IDs: Barney Orchard Road: 4646, 4647, 4648



Existing Conditions

Field Determined Slope: 8-12%

Road Type: Gravel

Conveyance Area/Turnout: 1 Good, 1 Filtered

Erosion Types Present: Gully, Rill

Drainage Culverts: Cross

Driveway Culverts: 1

Municipal Road General Permit Standards:

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

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

Existing Conditions Notes: The private road draining to the top of Barney Orchard Road is poorly crowned and is lacking appropriate ditches, causing severe erosion and sediment transport to the municipal ditch and turnout. The ditches along both sides of Barney Orchard Road are undersized and are severely eroded. The large turnout at the bottom of the hill is filled with sediment, reducing effectiveness.

Photo 1: Severe erosion of undersized ditch leading to cross-culvert.

Photo 2: Large turnout to floodplain is filled with road sediment.

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
	Side Slope Excavation for New Ditch		

Conveyance/Turnout Practices

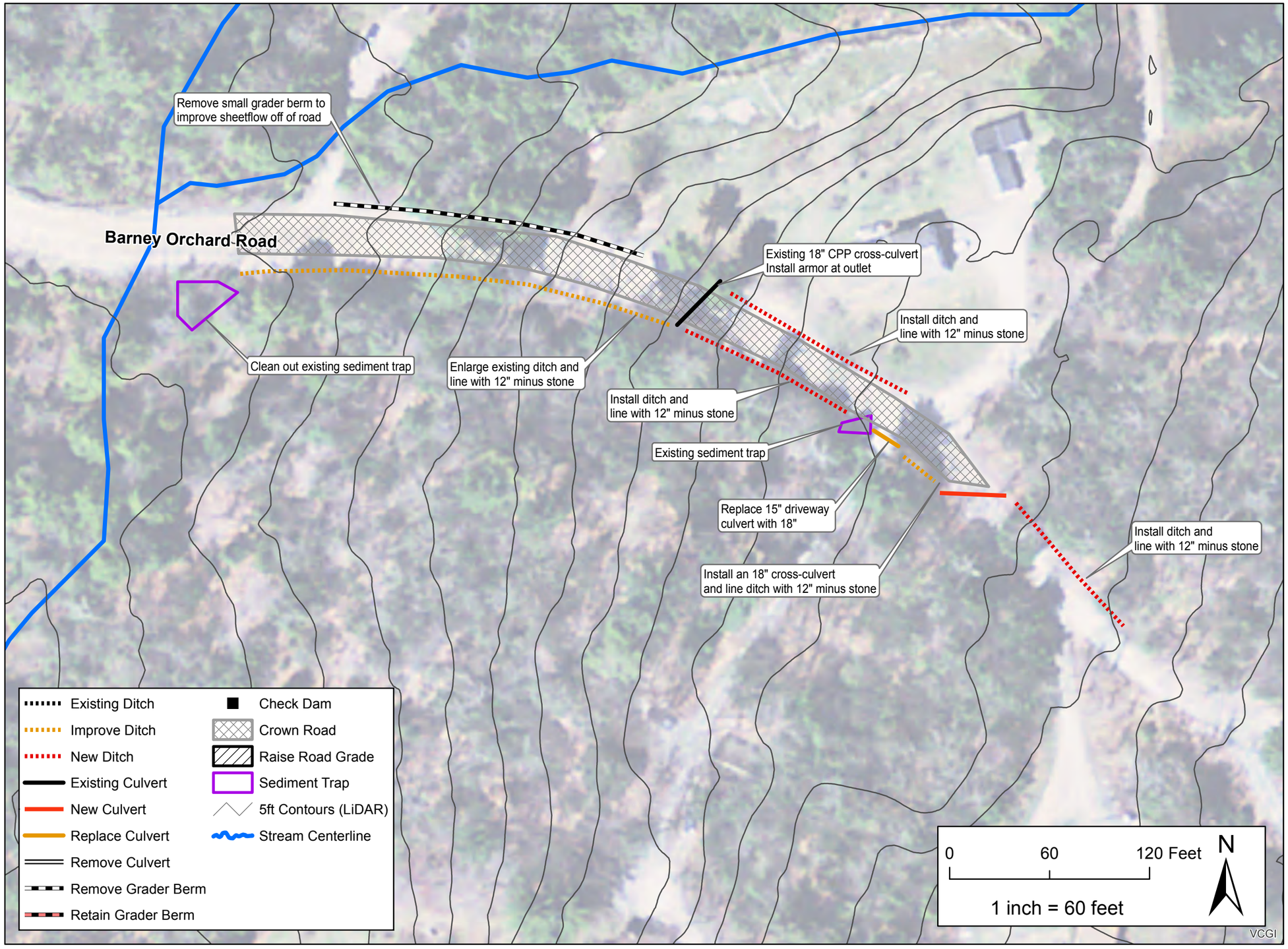
	Install Turnout		Stabilize/Improve Existing Turnout
X	Install/Improve Sediment Trap		Stone Armor on Bank/Slope
	Install Check Dams in Existing Feature		

Culvert Practices

X	New Municipal Culvert		Upgrade Municipal Culvert
	New Driveway Culvert	X	Upgrade Driveway Culvert
X	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	500	$ 2,500
Raise Road Grade	Cubic Yard	$ 15	80	$ 1,200
Remove Grader Berm	Linear Foot	$ 5	180	$ 900
Edge of Road Stabilization/Maintenance	Linear Foot	$ 8		$ -
New Stone-Lined Ditch	Linear Foot	$ 25	330	$ 8,250
New Grass-Lined Ditch	Linear Foot	$ 8		$ -
Side Slope Excavation for New Ditch	Linear Foot	$ 10		$ -
Improve Existing Ditch (Stone)	Linear Foot	$ 20	270	$ 5,400
Improve Existing Ditch (Grass)	Linear Foot	$ 5		$ -
Install/Improve Turnout	Each	$ 200		$ -
Install/Improve Sediment Trap	Each	$ 750	1	$ 750
Install Stone Armor (Bank/Slope)	Cubic Yard	$ 40		$ -
Install Check Dam	Each	$ 40		$ -
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	1	$ 750
Install Culvert Headwall/Armor	Each	$ 300	1	$ 300
Remove Sediment/Debris from Culvert	Each	$ 100		$ -
			Total Cost:	**$ 21,550**



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Notes:
Site visit completed on 10/23/2017

Drawn: JHB
Date: 10/31/2017

Concept Design Overview

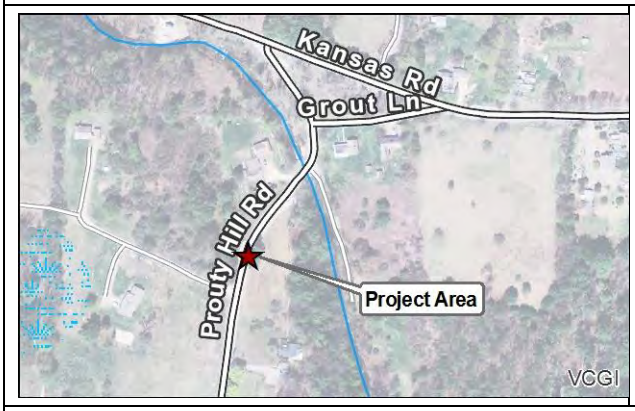
Sunderland Stormwater Master Plan

Barney Orchard Road Site

BARNEY ORCHARD

Town: Sunderland	**Road Name:** Prouty Hill Road	**Date Visited:** 10/23/2017

Road Segment IDs: Prouty Hill Road: 153761, 153762



Existing Conditions

Field Determined Slope: 8-11%

Road Type: Gravel

Conveyance Area/Turnout: 1 Good, 1 Filtered

Erosion Types Present: Gully, Rill

Drainage Culverts: 4 Cross

Driveway Culverts: 1

Municipal Road General Permit Standards:

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

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

Existing Conditions Notes: The driveway for 185 Prouty Hill Road does not have a culvert requiring two cross-culverts with a junction to carry runoff down the road. Small grader berms are increasing rill erosion along the road edges. Ditches have moderate to severe gully erosion. Check dams at the bottom of the east ditch are trapping large volumes of sediment before reaching the sediment basin. The west ditch has a small sediment trap before emptying in to Fayeville Branch.

Photo 1: Location of proposed driveway culvert.

Photo 2: Severe erosion along the road edge where a small grader berm is preventing sheet flow into the ditch.

Proposed Scope of Work

Roadway/Travel Lane Practices

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

Roadway Drainage Practices

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

Conveyance/Turnout Practices

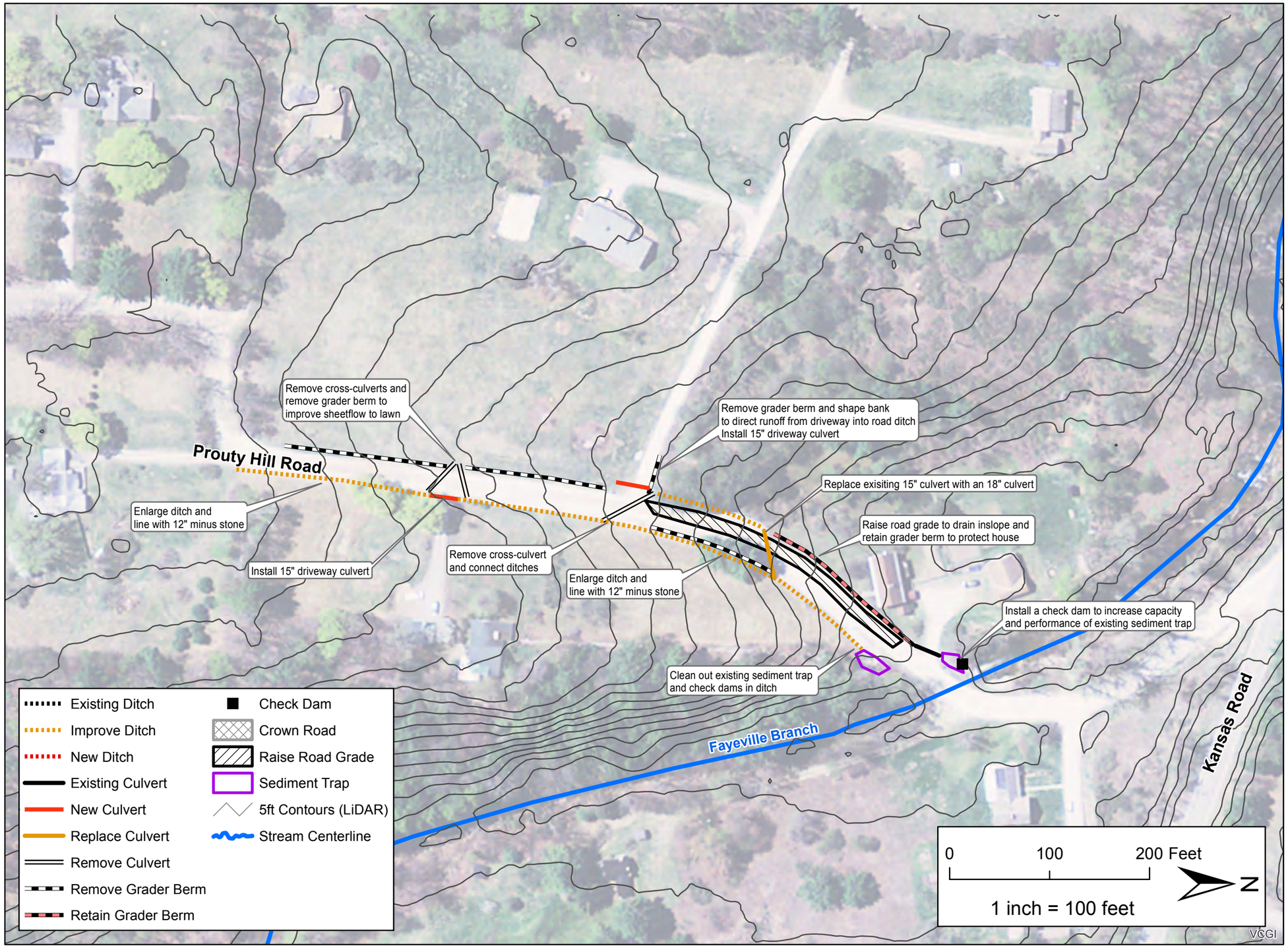
	Install Turnout	X	Stabilize/Improve Existing Turnout
X	Install/Improve Sediment Trap		Stone Armor on Bank/Slope
X	Install Check Dams in Existing Feature		

Culvert Practices

	New Municipal Culvert	X	Upgrade Municipal Culvert
X	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	300	$ 1,500
Raise Road Grade	Cubic Yard	$ 15	150	$ 2,250
Remove Grader Berm	Linear Foot	$ 5	500	$ 2,500
Edge of Road Stabilization/Maintenance	Linear Foot	$ 8		$ -
New Stone-Lined Ditch	Linear Foot	$ 25		$ -
New Grass-Lined Ditch	Linear Foot	$ 8		$ -
Side Slope Excavation for New Ditch	Linear Foot	$ 10		$ -
Improve Existing Ditch (Stone)	Linear Foot	$ 20	750	$15,000
Improve Existing Ditch (Grass)	Linear Foot	$ 5		$ -
Install/Improve Turnout	Each	$ 200		$ -
Install/Improve Sediment Trap	Each	$ 750	2	$ 1,500
Install Stone Armor (Bank/Slope)	Cubic Yard	$ 40		$ -
Install Check Dam	Each	$ 40	1	$ 40
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	2	$ 1,500
Install Culvert Headwall/Armor	Each	$ 300		$ -
Remove Sediment/Debris from Culvert	Each	$ 100		$ -
			Total Cost:	**$25,790**



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Notes: Site visit completed on 10/23/2017

Drawn: JHB
Date: 10/26/2017

Concept Design Overview

Sunderland Stormwater Master Plan

Prouty Hill Road Site

PROUTY HILL

Project SC-1, Cole Brook Culvert Replacement and Flood Resiliency along North Road

Existing Conditions

Cole Brook flows west from a moderately sloped forested watershed, under North Road, and then empties into a wide and gently sloped forested floodplain that transitions to a large beaver marsh on both sides of Route 7. The upstream channel is typically 12ft wide and is moderately incised. The bank heights are typically more than 4ft above the channel bottom and the floodplain benches typically located on both banks are likely only accessed during large floods. The culvert is a 5ft wide by 4ft tall corrugated steel squash that is 32ft long. The culvert is short relative to the road width, requiring very steep embankments that are eroding around the stacked stone headwalls (Figure 1). The culvert outlet is slight perched, reducing aquatic organism passage.

Figure 1: Embankment erosion at the culvert inlet.

Figure 2: Incised channel upstream of the North Road culvert.

Problem Overview

Cole Brook overtopped the culvert during the T.S. Irene flood in 2011 and caused severe damage to North Road. The floodwaters completely washed out the culvert and water spilled over the bank to the north and flowed along the road to the Beaver Meadow Brook crossing approximately 400ft to the north. The washed-out culvert was not damaged and was reset during flood recovery efforts. Total costs to repair the road and reset the culvert were close to $20,000. The T.S. Irene flows likely scoured the upstream channel, decreasing floodplain accessibility during future floods.

Culvert Capacity and Sizing Analysis

<u>Existing Conditions</u>

The Vermont Agency of Transportation (VTrans) completed a hydraulic study for the Cole Brook culvert. VTrans compiled the results of several hydrologic methods to estimate design flow rates for recurrence interval storms. The selected flows for Cole Brook are very similar to flows estimated with the USGS StreamStats program, based on regional flow regression equations (Table 1).

Table 1: Recurrence interval flows for the Cole Brook culvert.

Recurrence Interval (Years)	VTrans Flow (cfs)	StreamStats Flow (cfs)
Q2.33	100	N/A
Q10	220	202
Q25	280	277
Q50	340	343
Q100	400	418
Q500	N/A	627

The hydraulic study specifies the 25-year flood as the Town Highway Design Flow and the 100-year flood as the Check Flow. We used the HY-8 software from the Federal Highway Administration to model the existing and proposed culvert capacities. FEA determined the dimensions and profile of the existing culvert using laser survey equipment. The survey assumed a relative roadway elevation of 100ft for modeling purposes. Based on the HY-8 analysis, the existing squash culvert has an approximate capacity of 110cfs, well below the 10-year flood (Figure 3).

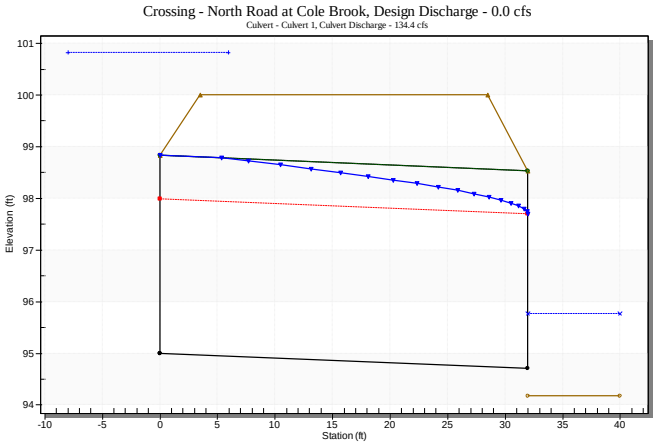


Figure 3: HY-8 plot of the 10-year flow exceeding the existing culvert and overtopping North Road.

Proposed Culvert Replacement

The hydraulic study recommends a 6ft tall by 12ft wide box culvert for a suitable replacement structure. This structure would tie in with the 10-12ft wide channel upstream of the crossing and is only slightly narrower than the predicted bankfull width of 14ft based on drainage area. The recommended box culvert includes 6-inch tall sediment retention baffles to ensure that native streambed material is continuous through the culvert. Assuming an additional 6-inches of deposition on top of the baffles, the culvert would have an effective opening of 5ft tall by 12ft wide. The proposed culvert bottom (with sediment retention) would be approximately 1ft lower than the existing culvert. This structure passes the Q25 with approximately 0.7ft of available capacity and does not overtop the road during the Q100. We included the VTrans specified culvert dimensions in the HY-8 model and the predicted water surface elevations were nearly identical to their results (Figures 4 and 5).

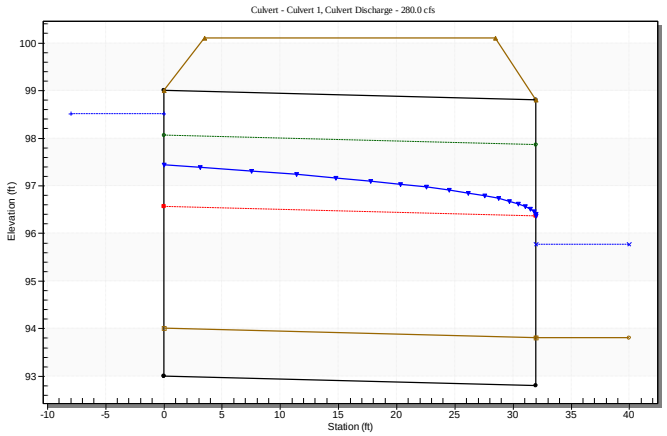


Figure 4: HY-8 plot of the 25-year flow (280cfs) passing through the proposed 6ft by 12ft box culvert.

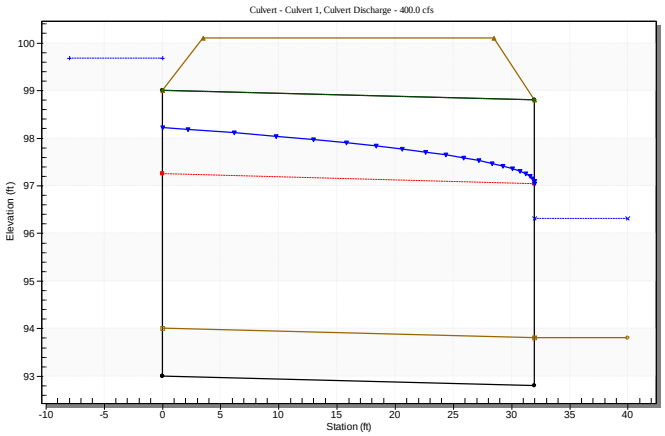


Figure 5: HY-8 plot of the 100-year flow (400cfs) filling the proposed culvert but not overtopping North Road.

Conceptual Overflow Channel

In addition to the culvert replacement, we included a simple flood overflow channel running along North Road to convey excess flows north to the Beaver Meadow Brook culvert (see attached concept design map). Based on the culvert dimensions and a hydraulic analysis using recurrence interval flows from Streamstats and a HY-8 model; the existing culvert has approximately 80cfs of additional capacity during the 100-year flood. The installation of an oversized rock lined ditch could convey approximately 50-60cfs of additional floodwaters during extreme flood events or in the event of sediment or debris accumulation reducing the capacity of the proposed box culvert (Figure 6). Based on the valley and channel setting at the North Road crossing, we feel that sediment and debris accumulation may be an ongoing concern in future floods. The channel slope decreases from approximately 6% to 4% and the channel widens with good floodplain access immediately downstream of the culvert. These factors cause floodwaters to slow down at the crossing, increasing deposition of coarse sediment and debris. The overflow channel would provide additional capacity for floodwaters and would reduce the risk of significant damage to North Road for a relatively low cost.

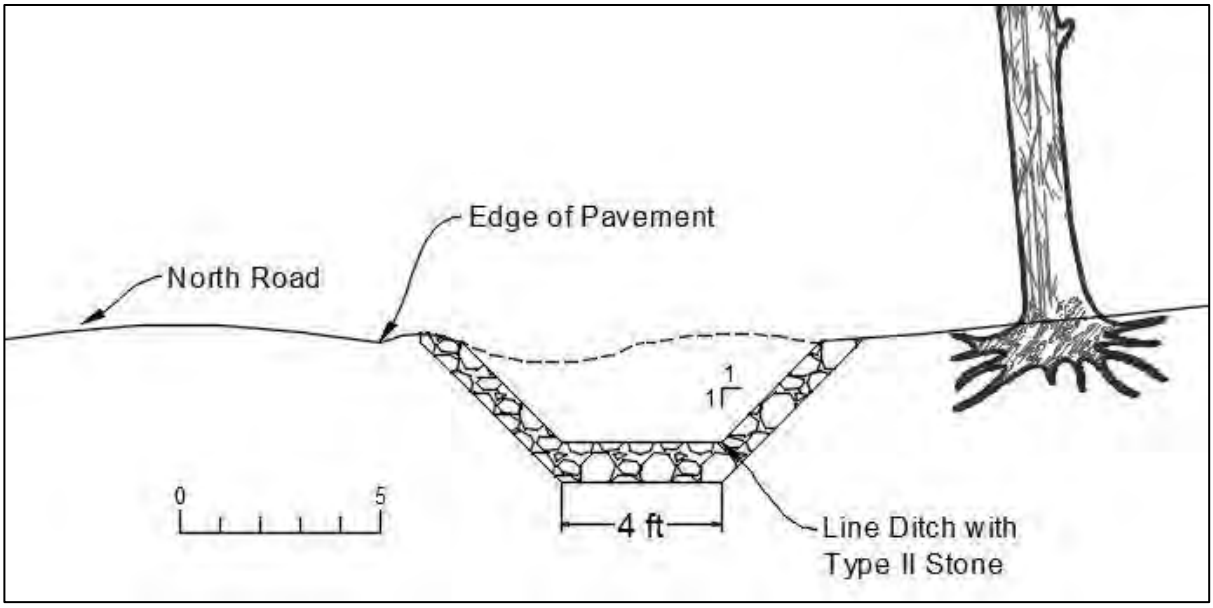


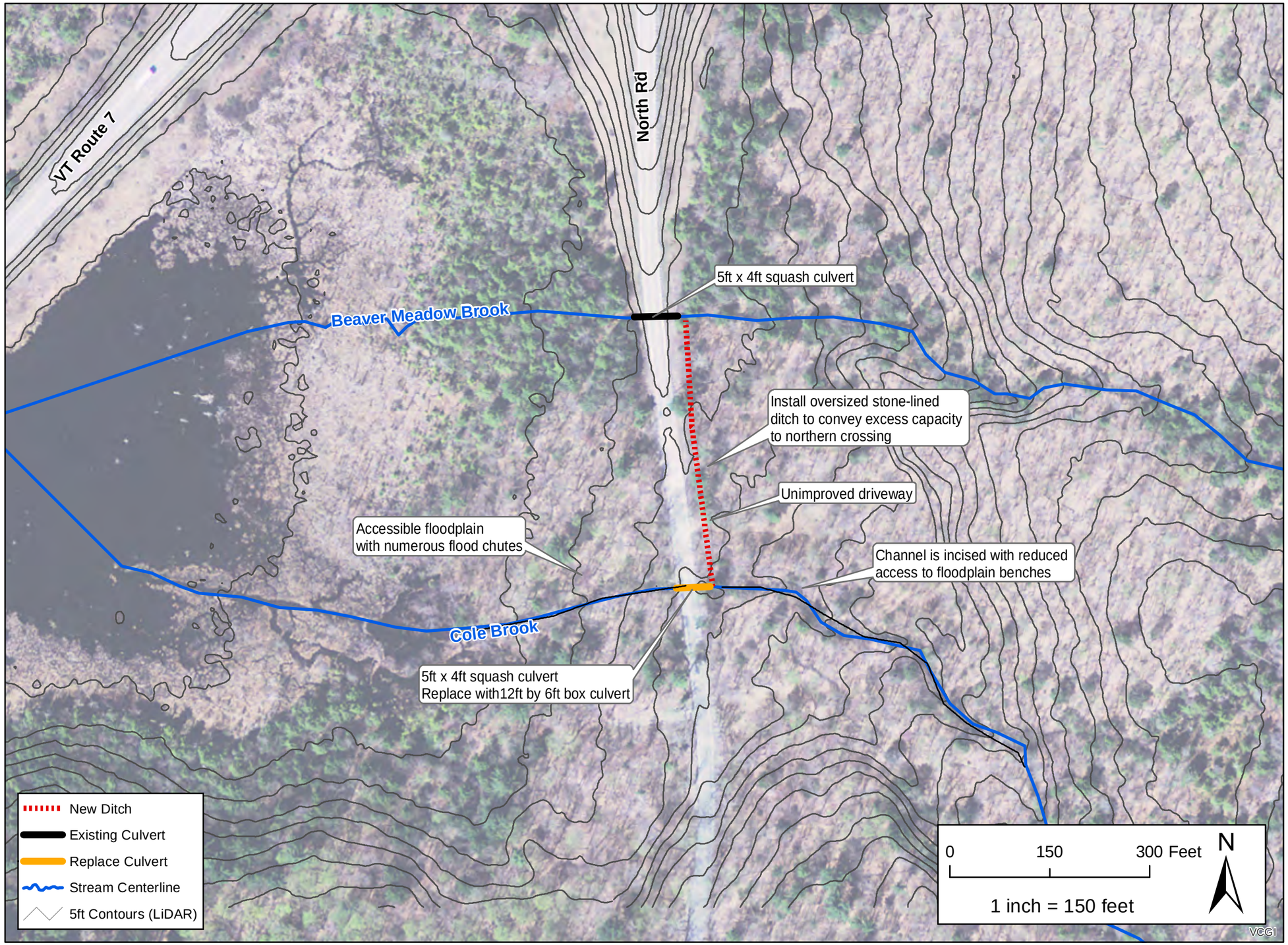
Figure 6: Simplified cross-section sketch of an oversized rock-lined ditch to provide flood relief along North Road. The ditch would be designed to convey approximately 50-60cfs of water with at least 0.5ft of freeboard to the roadway elevation.

Regulatory Requirements

A VTANR stream alterations permit would be required for culvert replacement. Tree clearing associated with the overflow channel will likely 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.

Project Cost Estimate

Additional survey and design work is required for the culvert replacement and for the overflow channel. We estimate that the culvert project will cost roughly $150,00 to $250,000 primarily based on the cost of the pre-cast box culvert. The overflow channel would require approximately 400CY of excavation and 150CY of stone armor (Type II). We estimate that this project would cost approximately $15,000 to $25,000.



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Notes: Site visit completed on 10/23/2017

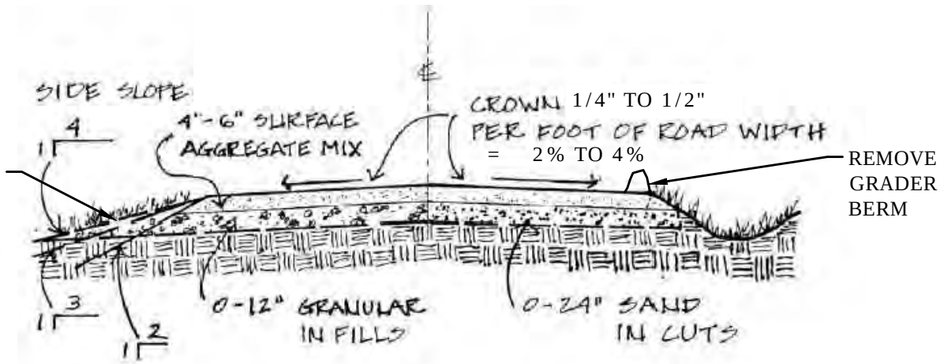
Drawn: JHB
Date: 12/15/2017

Concept Design Overview

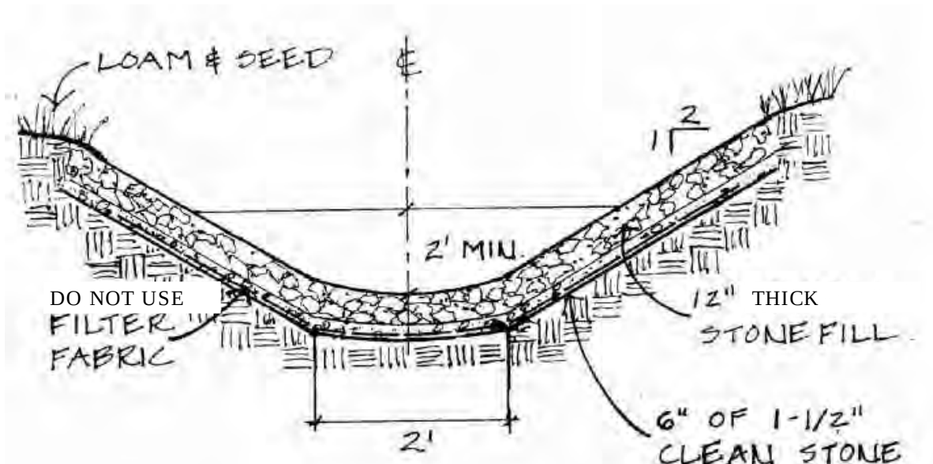
Sunderland Stormwater Master Plan

North Road Site

NORTH ROAD

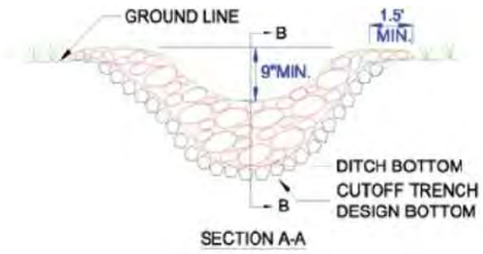


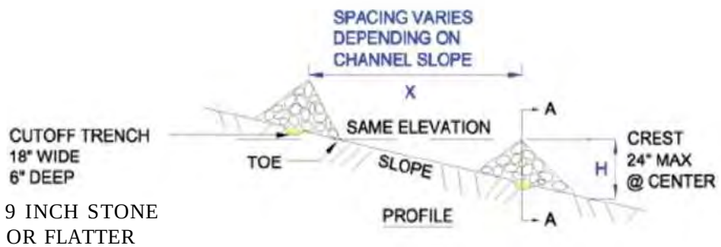
GRAVEL
ROAD CROWN & PROFILE

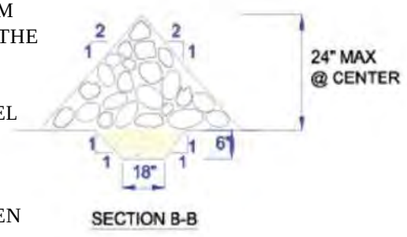


STONE FILL SIZE:
- SLOPES 5% TO 10% USE 6-8 INCH MINUS
- SLOPES MORE THAN 10% USE 12 INCH MINUS

STONE LINED DITCH

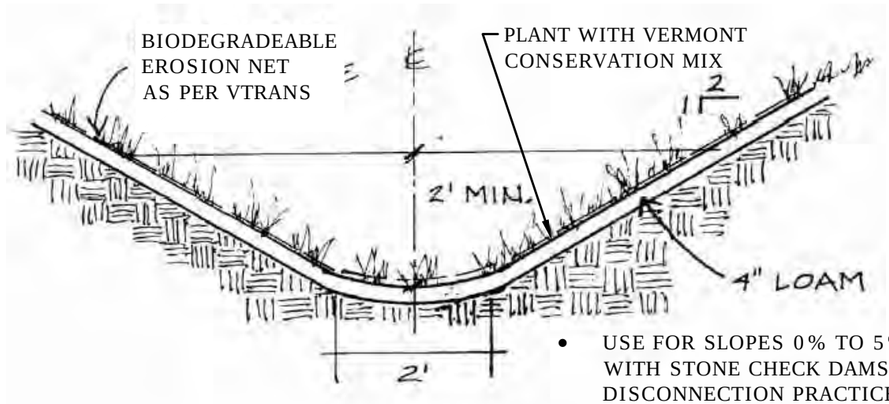






- USE MIX OF 2 TO 9 INCH STONE
- SIDE SLOPES 2:1 OR FLATTER
- SPAN WIDTH OF CHANNEL AND UP SIDES OF BANKS
- SPACE SO THAT THE TOE OF THE UPSTREAM DAM IS THE ELEVATION OF THE CREST OF THE DOWNSTREAM DAM
- PERIODICALLY REMOVE ACCUMULATED SEDIMENT AND DEBRIS TO ALLOW CHANNEL TO DRAIN THROUGH THE STONE AND PREVENT LARGE FLOWS FROM CARRYING SEDIMENT OVER THE DAM
- IF SIGNIFICANT EROSION OCCURS BETWEEN DAMS, A LINER OF STONE SHOULD BE INSTALLED

STONE CHECK DAM



GRASS LINED DITCH

- USE FOR SLOPES 0% TO 5% OR 5% TO 8% WITH STONE CHECK DAMS OR DISCONNECTION PRACTICES EVERY 164 FEET
- NO BARE SOILS ALLOWED
- USE TRAPEZOIDAL OR PARABOLIC CROSS SECTION

REFERENCE NOTE: ADAPTED FROM "VERMONT BETTER BACKROADS MANUAL, CLEAN WATER YOU CAN AFFORD" A PULICATION OF THE NORTHERN VERMONT & GEORGE D. AIKEN RESOURCE CONSERVATION DEVELOPMENT (R C& D) COUNCILS, NOVEMBER 1995, UPDATED 2002, 2009.

STONE CHECK DAM DETAIL FROM STATE OF VERMONT AGENCY OF NATURAL RESOURCES DEPARTMENT OF ENVIRONMENTAL CONSERVATION VERMONT POLLUTION DISCHARGE ELIMINATION SYSTEM (VPDES) GENERAL PERMIT 3-9040 FOR STORMWATER DISCHARGES FROM MUNICIPAL ROADS, FINAL DRAFT.

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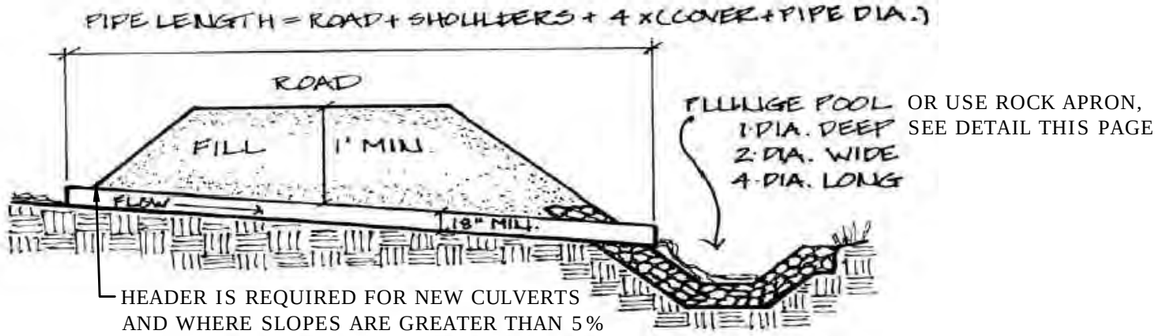
REVISIONS

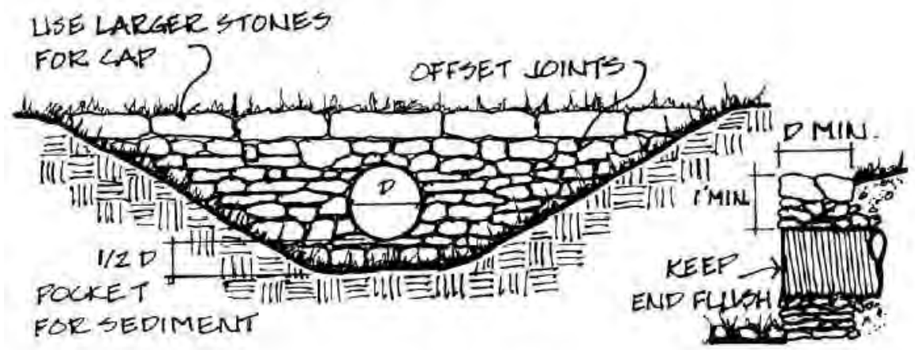
DETAILS - ROAD SECTION
CCRPC ROAD EROSION INVENTORY
CHITTENDEN COUNTY, VERMONT

JCL	JCL	RKS
DESIGNED	DRAWN	CHECKED

SCALE: NOT TO SCALE
DATE: SEPTEMBER 28, 2017
PROJECT NO.: 4294-03
SHEET NO.: D-1



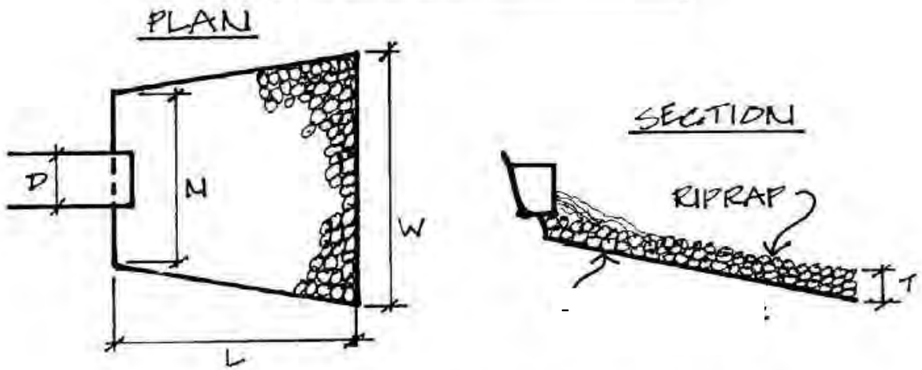
CULVERT PROFILE & CROSS SECTION



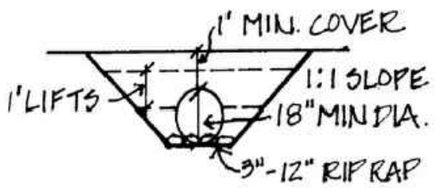
HEADER

Rock Apron Specifications					
Culvert Diameter (D)	Riprap Size	T (in.)	N (ft.)	W (ft.)	L (ft.)
18 inches	(3-12 inch)	18	4.5	14.5	10.0
24 inches	(3-12 inch)	18	6.0	20.0	14.0

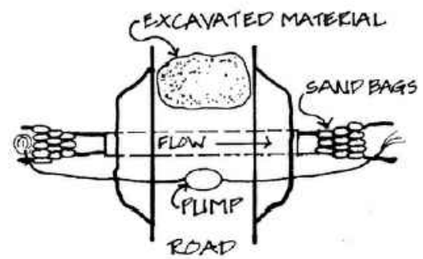
D= diameter of culvert
T= depth of stone in apron
N= width of apron near culvert
W= width at downhill end of apron
L= length of apron



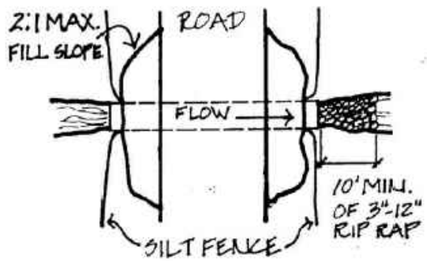
ROCK APRON



CULVERT CROSS SECTION



CULVERT INSTALLATION
FLOW BYPASS



CULVERT PLAN VIEW

REFERENCE NOTE: ADAPTED FROM "VERMONT BETTER BACKROADS MANUAL, CLEAN WATER YOU CAN AFFORD" A PULICATION OF THE NORTHERN VERMONT & GEORGE D. AIKEN RESOURCE CONSERVATION DEVELOPMENT (R C& D) COUNCILS, NOVEMBER 1995, UPDATED 2002, 2009.

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REVISIONS

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CHITTENDEN COUNTY, VERMONT

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SCALE: NOT TO SCALE
DATE: SEPTEMBER 28, 2017
PROJECT NO.: 4294-03
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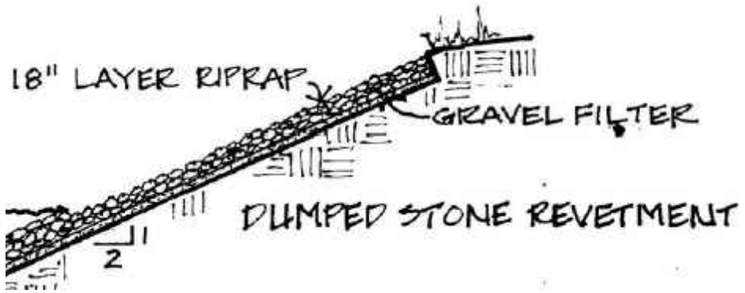
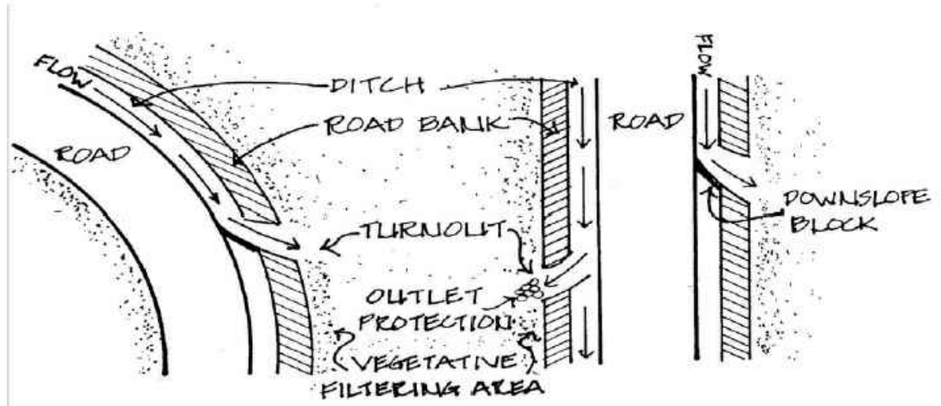


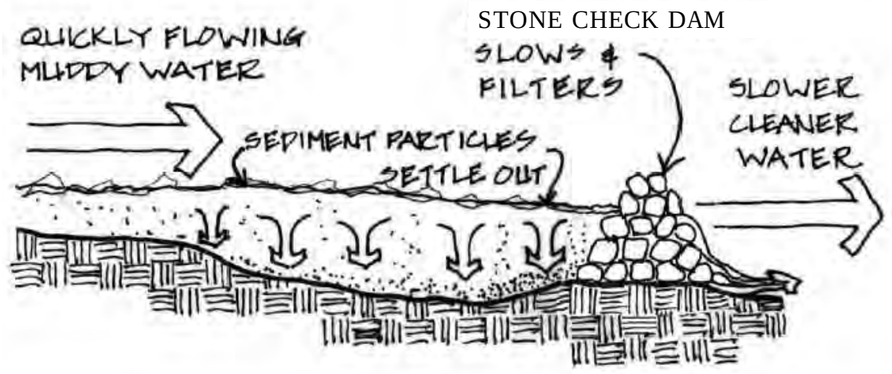
STONE ARMOR (BANK/SLOPE)

- RIRPAP SIZE IS BASED ON QUANTITY AND VELOCITY OF WATER
- ALWAYS CONTACT A STREAM ALTERNATION ENGINEER BEFORE INSTALLING RIPRAP AT A STREAM BANK
- USE ANGULAR STONE
- COVER WITH GRUBBINGS OR TOPSOIL AND SEED. IF ON A STREAM BANK, ONLY APPLY ABOVE ORDINARY HIGH WATER.
- CONSIDER PLANTING WITH ADDITIONAL VEGETATION



TURN-OUT

- AVOID DIRECT OUTLET TO SURFACE WATERS
- STABILIZE OUTLET BASED ON SLOPE:
  - 0% TO 5% STABILIZE WITH GRASS
  - 5% TO 10% STABILIZE WITH 6-8 INCH MINUS STONE
  - GREATER THAN 10% STABILIZE WITH 12 INCH MINUS STONE



SEDIMENT TRAP

- INSPECT ANNUALLY AND AFTER LARGE STORMS
- REMOVE ACCUMULATED SEDIMENT WHEN HALF FULL.

REFERENCE NOTE: ADAPTED FROM "VERMONT BETTER BACKROADS MANUAL, CLEAN WATER YOU CAN AFFORD" A PULICATION OF THE NORTHERN VERMONT & GEORGE D. AIKEN RESOURCE CONSERVATION DEVELOPMENT (R C& D) COUNCILS, NOVEMBER 1995, UPDATED 2002, 2009.

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CHITTENDEN COUNTY, VERMONT

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DESIGNED	DRAWN	CHECKED

SCALE: NOT TO SCALE

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PROJECT NO.: 4294-03

SHEET NO.: D-3