

Stormwater Master Plan for the Town of Ludlow Vermont

FINAL REPORT

June 24, 2021



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1.0 Introduction

In 2019 the Southern Windsor County Regional Planning Commission, now the Mount Ascutney Regional Commission (MARC) obtained grant funding from the Vermont Agency of Natural Resources (VTANR) Ecosystem Restoration Program (ERP) to develop a Stormwater Master Plan (SWMP) for the Town of Ludlow. In consultation with the Town, MARC hired Fitzgerald Environmental Associates, LLC (FEA) and project partner Dufresne Group Consulting Engineers (DG) in the summer of 2020 to develop the plan. This final SWMP report for the Town of Ludlow represents significant efforts and collaborations over the last year between the Town, FEA, DG, MARC, VTANR, the Lake Rescue Association (LRA) and other partners, including private landowners and business owners, interested in mitigating stormwater and improving water quality.

1.1 Stormwater Master Planning

Stormwater runoff is caused by precipitation, both in the form of rain or melting snow/ice, that is not infiltrated into the ground, absorbed by wetlands, or otherwise intercepted by plants. Human alteration of our landscapes in the form of impervious surfaces (i.e., pavement, rooftops) and compaction of soils disrupts natural hydrology and causes increased stormwater runoff. Increased stormwater runoff leads to higher magnitude flood flows and greater erosive power in stream channels, increased delivery of sediment, nutrients, and other pollutants to waterways, and increased flooding conflicts with improved properties downstream. Increased stormwater runoff is directly linked to the quality of water in our streams, rivers, ponds, and lakes that we depend on for drinking water, healthy fisheries, and recreation.

Stormwater master plans can prevent problems from happening either by mitigating impacts before they create problems or by avoiding the creation of problems; in other words, prevention is cheaper than restoration. If we are to avoid the high cost of restoring degraded surface waters, we must better manage stormwater runoff before waters become impaired. Plans are developed with public involvement and comment and should be as comprehensive as possible in listing all known problems. Plans are based on a prioritized list of projects or a strategic approach and are therefore more likely to succeed than a reactionary approach that addresses problems as they arise. Historically almost all Vermont municipalities have responded to stormwater runoff or drainage problems the latter way, and frequently during an emergency or after a structural failure has occurred. Stormwater management plans contain important information about preserving natural features and functions of a watershed and provide a list of evaluated alternatives such as using traditional pipe (gray) infrastructure versus green stormwater infrastructure.

1.2 Project and Town Background

The Town of Ludlow (Population 1,963) has dense residential and commercial development within the Village area and Okemo Mountain Resort. Commercial areas extend outside of Village following Route 103 and Route 100 to a lesser extent. The Black River is an important feature flowing the center of the Village. Lake Rescue is located in the northern portion of the Town and is a significant recreational area. A Town Road Erosion Inventory completed by SWCRPC (MARC) in 2017 found that over 50% of the hydrologically connected road segments within the Town were not in compliance with standards in the VTDEC Municipal Roads General Permit (MRGP). These findings suggest that runoff from Town roads is a significant concern for water quality.



1.3 Project Goals and Objectives

The primary goals of this planning effort are to better manage stormwater runoff to reduce sediment and nutrient pollution in the Black River and to reduce peak flood elevations in and around the Village Center, and to reduce sediment loading to Lake Rescue from erosion along gravel roads. The primary objectives of this SWMP are to:

- Identify opportunities to incorporate stormwater treatment and/or outfall stabilization at the outfalls of existing closed stormwater conveyance systems.
- Identify opportunities to incorporate green stormwater infrastructure within Ludlow Village.
- Identify opportunities to improve stormwater management in areas with active erosion and/or poor conveyances.

Project prioritization followed the Unified Scoring Metrics recently developed by VTDEC (2018a). Conceptual design plans (30% design) were prepared for 12 high-priority projects. Phosphorus loading and removal estimates were provided for each project to assist the Town with prioritization for meeting water quality goals.

2.0 Study Area Description

Ludlow is a 35.7 square mile town located in Windsor County in Southern Vermont. The 0.6 square mile village center spans the Black River. As of the 2010 census, Ludlow has a total population of 1,963 people, with 811 people living in the village center (U.S. Census Bureau, 2011). The Town's area is primarily forested and is 10.1% developed (Table 1). The Okemo Mountain Ski Resort is located within the Town and constitutes a large developed area. Ludlow is bordered by 5 Vermont towns (Mount Holly, Plymouth, Cavendish, Chester, and Andover). Most of the roads in Ludlow are municipal and private, with 10.8% of the Town's road length on Vermont State Roads (Table 2).

The Village of Ludlow lies within the Black River Watershed, which drains into the Connecticut River to the East. Lake Rescue is north of the Village center in Ludlow and constitutes another focus area for this stormwater master plan.

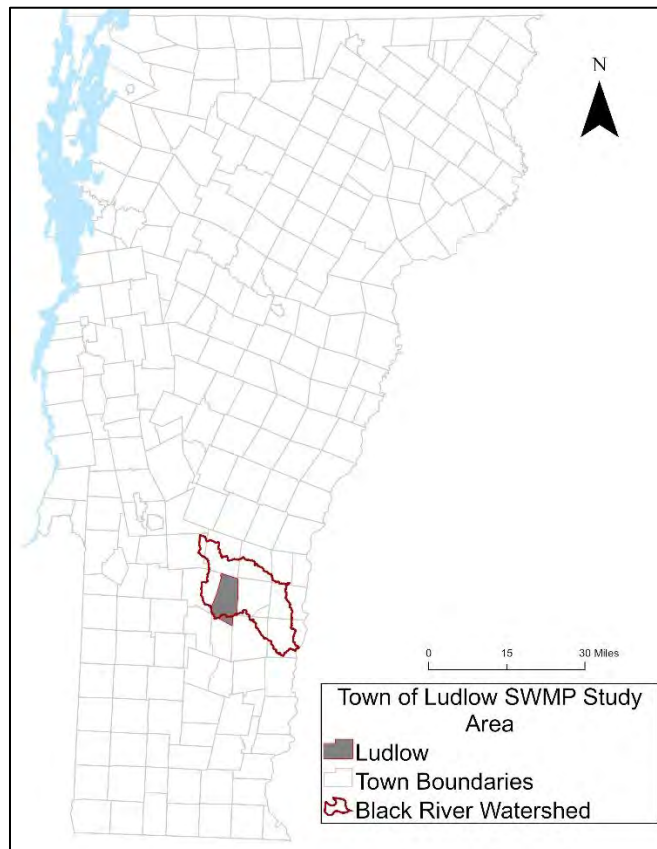


Figure 1: Town of Ludlow and Black River Basin Location Map



Table 1: Land cover in Ludlow (Homer et al., 2015)

Landcover/Landuse Type	% of Town
Agriculture	7.5
Barren	0.7
Developed	10.1
Forest	75.3
Open Water	1.2
Shrub/Scrub	2.3
Grassland/Herbaceous	2.2
Wetland	0.8

Table 2: Road length by AOT Class in Ludlow (VTrans, 2017)

AOT Class	Description	Length (miles)	% of Town Road Length (excluding discontinued)
1	Class 1 Town Highway	2.32	2.1
2	Class 2 Town Highway	9.46	8.4
3	Class 3 Town Highway	49.52	44.1
4	Class 4 Town Highway	3.61	3.2
5	State Forest Highway	2.00	1.8
7	Legal Trail	-	-
8 & 9	Private Road	33.24	29.6
30	Vermont State Highway	12.15	10.8
40	US Highway	-	-
96	Discontinued Road	0.43	-

Soil mapping for the Town shows that well drained soils are primarily located at lower elevations along the Black River and heavier soils (Hydrogroup C and D) are most common at higher elevations (Table 3). Most of the Village is mapped as unrated soils (Urban Land – Colton Croghan complex). The concentrated development along Route 103 and Route 100 is primarily associated with unrated soils and well drained soils. Okemo Mountain Resort is generally mapped as C-type soils (somewhat poorly drained).

Table 3: Summary of town-wide and developed lands soil drainage

Soil Hydrogroup	Town of Ludlow(acres)	Developed Lands (acres)
A	2,193	553
B	5,237	449
C	9,009	531
D	5,382	455
Not Rated	459	267
Total	22,279	2,255



3.0 Stormwater Management Planning Library

3.1 Mapping Data

VTDEC Municipal Roads Program

A Road Erosion Inventory (REI) for the Town of Ludlow was conducted by the Southern Windsor County Regional Planning Commission (SWCRPC) in 2017. The REI was developed for municipalities to fulfill requirements of the VTDEC Municipal Roads General Permit (MRGP). In this inventory, roads are divided into 100-meter (328 ft) segments with unique identification numbers. The segments deemed hydrologically connected to surface waters are assessed in the field and given a road erosion score. This score is determined from characteristics of the roadway and of the stormwater drainage features associated with it (crown, berm, ditch, conveyance stability, culverts, etc). Each segment is classified as “Fully Meets”, “Partially Meets”, or “Does Not Meet”, to reflect the current level of conformance with the MRGP standards. Of the 760 hydrologically connected segments inventoried in Ludlow, 152 (20%) did not meet MRGP standards and 256 (34%) partially met MRGP standards ([link](#)). Roads in the Town with segments that did not meet or partially met MRGP standards included South Hill Road, Lovejoy Brook Road, Smokeshire Road, and Commonwealth Avenue, among others. The MRGP specifies a timeline for bringing all road segments up to standards. High priority segments identified in the REI are potentially important opportunities to reduce erosion and sediment loading to receiving waters.

Light Detection and Ranging (LiDAR)

LiDAR returns for Ludlow were collected in a series of flights conducted during 2016 as part of the VT LiDAR Initiative. The data meet the National Digital Elevation Program Quality Level 2 specifications for accuracy satisfactory for generation of a 0.7-meter Digital Elevation Model (DEM) and 1-foot contours. 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 0.7-meter DEM can assist in culvert watershed delineation and the design of stormwater management projects. Terrain models can assist in remote identification of erosion features, such as stormwater gullies.

Municipal Bridge and Culvert Data

Culvert and bridge data collected by the Southern Windsor County Regional Planning Commission (SWCRPC) for Town roads in Ludlow are available online (<https://vtculverts.org/>). The dataset includes the structure dimensions and overall conditions but does not include the presence/absence of erosion. While most culverts were rated as good or excellent, a few were rated as poor or fair.

Village of Ludlow Stormwater Infrastructure Mapping Project

This dataset was produced by the Vermont Agency of Natural Resources (VTANR) in 2016. The Stormwater Mapping Project documents the connectivity of stormwater infrastructure on private and public land within the Town of Ludlow. The data show the paths of stormwater from different areas of impervious surface (Figure 2). The associated report identifies eight high priority sites for improvement, and points to another five sites of moderate priority. Eleven potential retrofit projects were identified in this study.



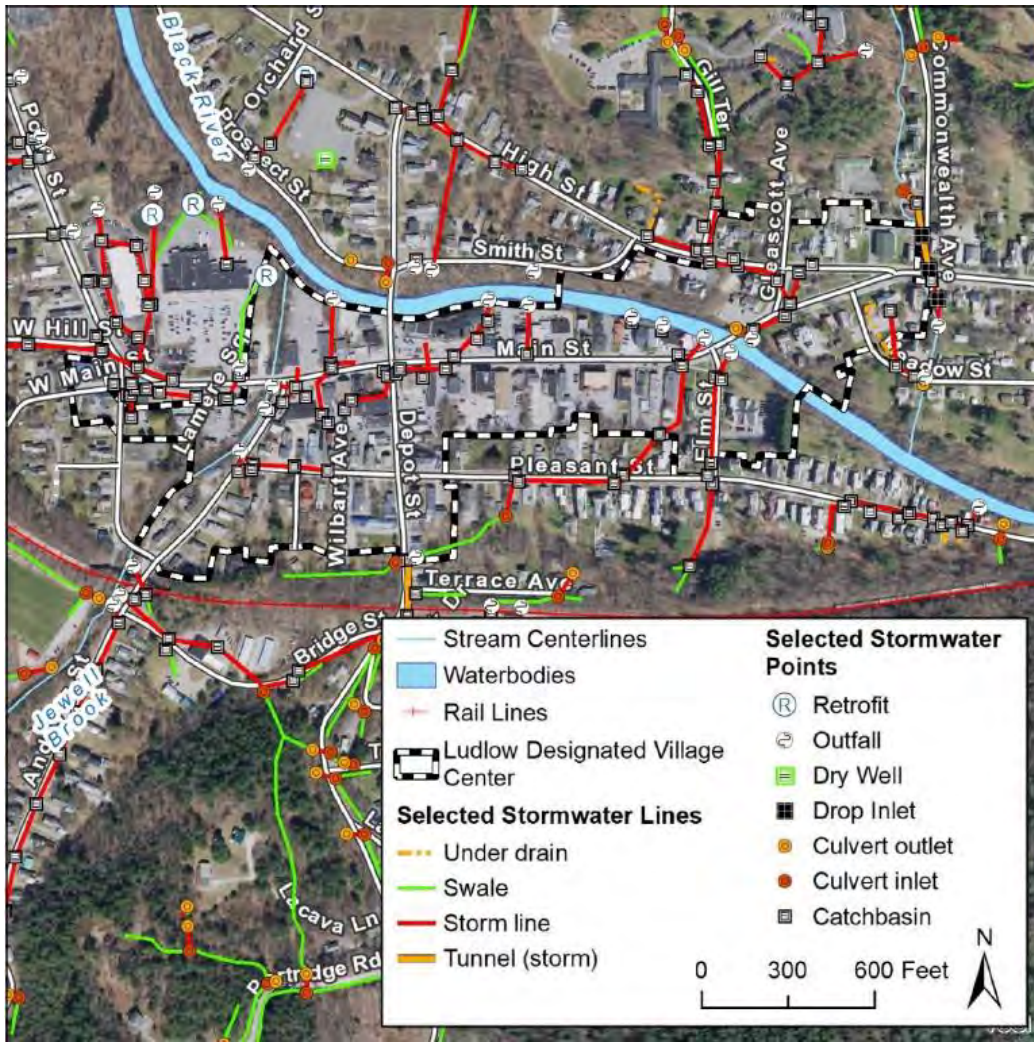


Figure 2: Ludlow Stormwater Infrastructure Map

Natural Resources Conservation Service (NRCS) Soils Survey

The NRCS soil survey dataset is valuable for stormwater master planning (websoilsurvey.sc.egov.usda.gov). As part of our initial scoping, we will screen problem areas based on the NRCS hydrologic soil groupings (HSG). The HSGs indicate the infiltration potential of the native soil type, which is useful for identifying areas of excessive runoff potential (e.g., HSG D-type) or good infiltration (e.g., HSG A-type) where stormwater infiltration practices should be explored.

Flood Hazard Mapping

The FEMA DFIRM flood hazard dataset categorizes areas based on flooding potential. This dataset can inform planning on where high flow volumes will occur during major storm events. This dataset can also be used to inform BMP designs and location. BMPs proposed for areas upgradient of areas that are at high risk of flooding may have the potential to reduce downstream flooding and erosion issues. Project prioritization was informed by flood hazard potentials to mitigate flood damage within the Village center.

River Corridor Mapping

River corridor maps were produced by the Vermont Agency of Natural Resources. These data display both the river channel and the active corridor through which a river can be expected to meander over time. This mapping can inform stormwater mitigation efforts by indicating where rivers and streams might flow during flood events. This dataset also identifies areas where the river channel has been altered or confined. These problem areas are often prone to erosion and flooding.

3.2 Watershed Planning

Basin 10 Tactical Basin Plan

The Tactical Basin Plan for Basin 10 was prepared by the Vermont Agency of Natural Resources in 2018. Basin 10 includes the Black River, the Ottauquechee River and the adjacent portion of the Connecticut river and related tributaries. This Basin plan catalogs current surface water quality conditions, stressors, and recommended actions for water quality restoration. Basin 10 consists of 2 major watersheds: the Ottauquechee River Watershed and the Black River Watershed. Both rivers' mouths join the Connecticut River in North Hartland and Hoyt's Landing respectively. Roughly 80% of the basin is forested, with about 10% agriculture and 6.7% developed. The Black River is the focus of this plan. Its mainstem is 40 miles long and drains 202 square miles of Vermont. The Black River is most heavily impacted by pollution from sediment, nutrients, *E. coli*, combined sewers, oils, metals, urban runoff, and flow alteration from flood control dams in North Springfield. The Tactical Basin Plan prioritizes river corridor protection, stormwater treatments, dam removal, and flood modelling and mitigation for the Black River. Since the last Basin 10 tactical plan was completed in 2012, 37 clean water projects have been implemented. The Tactical Basin Plan draws focus to a number of potential projects for the Black River. These include: Restoration of Natural Flows, Hazard Mitigation, Flood Resiliency, Habitat Restoration, Water Quality Improvement, Shoreland Protection/Restoration, Wetland Restoration, and Stormwater Management (pollution and volume reduction).

Basin 10 IDDE Report

The Illicit Discharge Detection and Elimination (IDDE) report for Basin 10 was produced by Stone Environmental for VTDEC in 2019. The study investigated discharges in 11 towns. Researchers collected water samples at outfalls and junctions in stormwater systems and tested them for chemical and biological pollutants. Based on surveys in 2017, the study confirmed one illicit discharge location in Ludlow and identified 8 locations with suspected illicit discharges. Any sites where stormwater and wastewater may be comingling are high priorities for the SWMP.

Black River Watershed Water Quality/Aquatic Habitat Assessment Report

This report on water quality in the Black River watershed was produced in June 2016 by VTANR and VTDEC. The study included monitoring for biological contaminants and *E. coli* as well as physical condition monitoring and identification of hazardous waste sites and old landfills. The study identified stressors of all these types in Ludlow. The most common stressors in Ludlow were hazardous waste sites. The biological health of the river for macroinvertebrates was generally good to excellent, however, a number of sites need to be resampled or sampled for the first time. Roughly half of the sites included in the report



were above standards for E. coli levels. Impaired sites from this study could make good improvement sites under the SWMP.

Phase 2 Stream Geomorphic Assessment (SGA) of the Black River Corridor

The SWCRPC conducted a Phase 2 Stream Geomorphic Assessment (SGA) of selected reaches on the Black River mainstem and its tributaries in 2007. Major problems in these reaches included human-caused channel and valley constriction. Channel straightening, berming, and stream bank armoring have all brought the Black River channel away from its natural geomorphology and caused increased risk of damage and erosion during high flow events. Habitat conditions in these reaches were generally fair. Some other general information about each reach is summarized in Table 4. The locations of these reaches are shown in Figure 3.

Table 4: Summary of Phase 2 Reaches in Ludlow

Stream	Reach	Existing Stream Type	Confinement Type	Habitat Condition	Geomorphic Condition
Black River	M37B	-	Narrow	Good	Fair
	M36A	C	Broad	Fair	Good
	M36B	Cc	Broad	-	-
	M35	Bc	Semi-Confined	Fair	Good
	M34	F	Semi-Confined	Fair	Fair
	M33A	C	Broad	Fair	Fair
	M33B	F	Narrow	Fair	Good
	M32A	Bc	Semi-Confined	Fair	Fair
	M32B	C	Narrow	Fair	Fair
	M32C	Bc	Broad	Fair	Fair
	M40	C	Broad	Fair	Fair
Tributary 4	M36T4.01	F	Broad	Fair	Fair



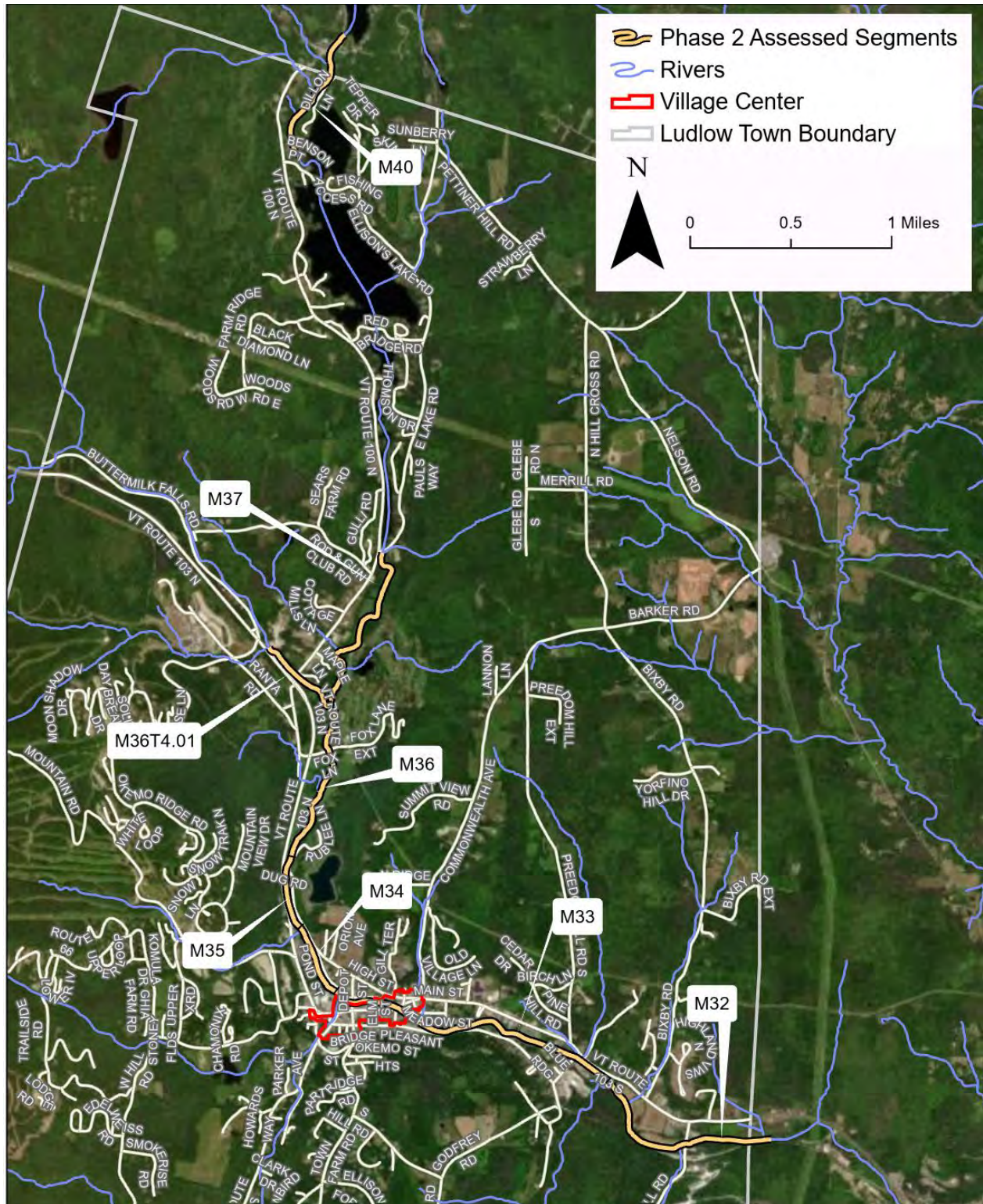


Figure 3: Map of Phase 2 Reaches in Ludlow



3.3 Town Planning and Permitting

Lake Rescue Atlas of Stormwater Outfalls

A series of maps prepared by the Lake Rescue Association (LRA) shows municipal and private stormwater infrastructure around the perimeter of the lake. The maps show the locations of drop inlets, road segments, catch basins, and outfalls. Information about individual features' drainage areas is included for some entries. This map helped identify project sites around the Lake Rescue area.

Ludlow Municipal Plan

The Ludlow Municipal Plan was adopted by the Town in October 2019 and was developed by the Ludlow Planning Commission with assistance from SWCRPC. This plan aims to guide future growth and development of land, public services, and facilities, and to protect the environment. One of the main goals for the municipal plan is to “protect and preserve scenic and historic features, open spaces, and improve the quality of air, water, wildlife, and land resources.” Ludlow expects to bring all municipal road segments up to Municipal Roads General Permit (MRGP) standards by the end of 2036. The plan prioritized Green Stormwater Infrastructure (GSI) and Low Impact Development solutions to achieve this goal. The Town is susceptible to flooding and experienced severe flood damage during Hurricane Irene in 2011 which caused \$2.6 million in damages within the Town. FEMA flood hazard mapping will be used to inform project selection to address flood risk and minimize damage. The Village center's stormwater is drained through a closed system and includes areas in need of improvements at catchments and outlets.

Ludlow Zoning and Flood Hazard Regulations

This document was completed and implemented by the Town of Ludlow in 2014. The purpose of these regulations is to promote the development of the Town in a way that minimizes potential damages from future flood events. It limits development in flood hazard areas such as floodplains, river corridors, and wetlands. These guidelines helped informed site selection for the SWMP.

Existing Project Applications

Lake Rescue Watershed

As a response to flood damage from Tropical Storm Irene and chronic impairment of water quality, the Town of Ludlow identified four project areas to improve the water quality of Lake Rescue in 2012. These areas are the Buffalo Brook Watershed, the Money Brook Watershed, Pingree Fields, and Patch Brook Road. None of these areas fall within the Town of Ludlow, but all are part of the watershed that feeds into Lake Rescue. These projects aim to address landslides and river corridor constriction and alteration among other issues. Two of the project areas listed above have been addressed with the implementation of projects funded by VTDEC. These are 1) stream crossings, trail drainage work, and trail maintenance in the Buffalo Brook watershed on the State-owned Coolidge Lands, and 2) restoration of the alluvial fan of Money Brook on Pingree Flats to attenuate sediment before it enters the Black River. By prioritizing proper forest management and healthy river corridors upstream of the lake, the LRA its partners (State, Town, etc) can reduce stressors to the water quality.



Lake Rescue Better Backroads Sites

The Town of Ludlow has identified five (5) areas around Lake Rescue that are suitable for Better Backroads funding to make erosion and water quality improvements. The stream crossing on East Lake Road near Archibald Lane needs bank stabilization and culvert repair. This project is the highest priority and has been selected for the Better Backroads grant. The stream crossing from the intersection of East Lake Road and Ellison's Lake Road needs stream stabilization in the main channel and three small tributaries. This site is their next highest priority and has a serious sediment deposition problem. Both sides of Ellison's Lake Road near Badee Inn need swales or ditches and potentially a new cross culvert. Tepper Drive and Scott's Landing both need ditch stabilization. Finally, the intersection of Ellison's Lake Road and Fishing Access Road need ditch stabilization as they are regularly clogged by eroded sediment.

3.4 Data Gaps

The data sources and information describing stormwater and watershed management in the Town of Ludlow are thorough and primarily up to date. The stormwater infrastructure mapping was completed in 2015 there may have been important updates to the drainage systems within the Village in recent years.

4.0 Stormwater Problem Areas

One of the primary objectives of the SWMP is to "develop a comprehensive list of stormwater problems" within the Town of Ludlow. FEA and DG completed a total of five (5) field tours of the project area and hosted several meetings with Town, VTANR, LRA, and MARC staff 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 the identification of stormwater related projects using a desktop exercise scanning the watershed with aerial imagery, NRCS soils data, Town stormwater infrastructure mapping, contour data, and road erosion inventory results in GIS. Potential project areas were identified and mapped for review during site visits. The priority assessment areas identified in the project scope were the focus of the field assessment effort. The priority areas are listed below (abbreviations are shown in parentheses):

- LT: Ludlow Town/Village (42 projects)
- LR: Lake Rescue (6 projects)
- OK: Okemo Mountain Resort (7 projects)

A total of 55 stormwater problem areas were identified and assessed in the field (see map in Appendix A and table in Appendix B). We grouped the problem areas into four (4) project categories described below.

- **Green Stormwater Infrastructure (GS) Installation/Retrofit** – Opportunity to reduce sediment and nutrient loads through the installation of a new stormwater best management practice (BMP). Sites where nutrient and sediment reductions could be improved through the retrofit of existing stormwater BMPs.
- **Road Erosion Mitigation** – Areas of high sediment and nutrient loading due to road, embankment, and ditch erosion.
- **Gully Stabilization** – Areas of severe erosion from concentrated stormwater runoff.



- **Stream Restoration/Culvert Replacement** – Problem areas where stream bank or bed erosion is a significant nutrient and sediment source, or where undersized culverts are exacerbating erosion issues.

4.2 Evaluation and Prioritization of Problem Areas

The 55 projects described in the master project table (Appendix B) were prioritized based on the potential for each project to improve water quality, reduce environmental impact, project feasibility, and co-benefits. Estimated project cost and the phosphorus removal efficiency (\$/lb of P) were included. We followed the Unified Scoring Prioritization for Stormwater Master Plans document developed by VTDEC (VTDEC, 2018a), with an adjustment to the phosphorus loading and phosphorus reduction criteria. This method includes a total of 19 criteria divided into 3 categories. The final score is expressed as a percent of the total score, with slightly different criteria applied to road drainage projects. Total scores were out of a maximum of 50 points (Table 5). Two scoring categories are not applicable to road erosion/road drainage projects, which had a maximum score of 44 points. The projects in Appendix B ranged from a low score of 15 to 42 points (Figure 4).



Figure 4: Project LT-04 had the highest score (42 out of 50). The project is located on a Town owned parking lot that is leased by Okemo Mountain Resort (blue lot). A large portion of the gravel parking lot drains to a deep catch basin structure which is directly connected to a stream to the north. Large gully and rill erosion features were observed along concentrated flow paths across the parking area. The opportunity to treat a large volume of water and a very high sediment/nutrient load while on Town property produced the highest score for any of our stormwater master planning projects to date.



Table 5: Unified scoring prioritization for stormwater master plans, developed by VTANR (VTDEC, 2018a).

Criteria	Proposed Weight	Max points
Water Quality/Environmental impact		
Sediment reduction (using STP calculator for sediment) (not yet developed)	0-4 (natural groupings within the range of sediment reductions for proposed projects for a specific plan. 0=very low reduction, 4= very high sediment reduction)	4
Phosphorus/nutrient reduction (using STP Calculator)	0-4 (natural groupings within the range of phosphorus reductions for proposed projects for a specific plan. 0=very low p reduction, 4= very high P reduction)	4
Impervious area managed	1-4 (natural groupings within the range of impervious surface managed for proposed projects for a specific plan. More impervious treated gets more points)	4
Percent of Water Quality & Channel Protection Volume treated*	0-3 (0= no WQ treated, 1= ½ WQV treated, 2=meeting WQV, 3=meets WQV and CPV). Do not apply to road projects.	3
Percent of Recharge criteria met *	0-3 (0= no infiltration, 1 =infiltrates less than recharge volume, 2= meets full recharge, 3= exceeds recharge 1.5 times or more) Do not apply to road projects.	3
Streambank or other gully erosion mitigation	0-2 (calculate volume= Length x avg. width x avg. depth, use natural groupings to divide volume into 3 categories)	2
Green infrastructure opportunity	0-1 (0=no, 1=yes)	1
* WQV, CPV and Recharge criteria as outlined in 2017 Vermont Stormwater Management Manual		
Total Water Quality Score (out of 21, or 15 if road project)		
Feasibility Criteria		
Public land or Private Landowner support	0-3 (3=public land, 2=willing private land owner, 0=unwilling or unknown willingness of private landowner)	3
Project and Permitting complexity (number of permits required)	0-2 (2= simple permitting, 0= complex permitting-potential denial)	2
Infrastructure conflicts	1 (Y= 0, N=1)	1
Total Estimated Project Cost)	Enter engineering estimate+ construction estimate (no points)	
Project efficiency (\$/lbs. of P removed)	1-12 (Use natural grouping of \$/lbs. removed)	12
Ease of O&M and ease of access for O&M	0-2 (based on municipal input on what is easiest to maintain, 0=high maintenance, 2=easy maintenance)	2
Total Feasibility Score (out of 20)		
Other considerations/Co-benefits (0=doesn't address concern, 1=addresses concern)		
Educational benefits and or Recreational benefits	1	1
Natural habitat creation/protection	1	1
Infrastructure improvement (culvert replacement)	1	1
Outfall erosion control	1	1
Connected to receiving water	3=all runoff infiltrates on site, 2= runoff receives some treatment before reaching receiving water. 1=runoff drains via infrastructure directly to receiving water with no erosion or additional pollutant loading, 0 =runoff drains directly to receiving water	3
Flood mitigation (known problem)	1	1
Existing local concerns	1	1
Total Co-benefits Score (out of 9)		
Overall Score (out of 50 or 44)		



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 the project prioritization table (Appendix B).

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

- **Subwatershed Mapping** – The contributing drainage area to each problem area was mapped based on field observations and 2-foot contours derived from the 0.7 2014/2015 LiDAR elevation surface.
- **Aerial Photography** – We used the 0.3 m imagery collected for Windsor County in 2016 to review the site land cover characteristics (i.e., forest, grass, impervious).
- **Impervious Surfaces Data** – We used the 2016 statewide high-resolution impervious surfaces data layer developed by the UVM Spatial Analysis Lab.
- **Stormwater Infrastructure** – We used the Stormwater Infrastructure Mapping Project data collected in 2015 with detailed mapping of stormwater infrastructure throughout the Town.
- **NRCS Soils** – We used the Windsor 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.

4.3 Unified Matrix Evaluation and Prioritization of Problem Areas

The 34 projects that could be assessed for a GSI treatment volume or erosion volume are described in the Unified Prioritization Project Table (Appendix B). These projects were prioritized based on the potential for each project to improve water quality, reduce environmental impact, project feasibility, and co-benefits. Estimated project cost and the phosphorus removal efficiency (\$/lb of P) were included. We followed the Unified Scoring Prioritization for Stormwater Master Plans document developed by VTDEC, with an adjustment to the phosphorus loading and phosphorus reduction criteria (VTDEC, 2018). This method includes a total of 19 criteria divided into 3 categories. The final score is expressed as a percent of the total score, with slightly different criteria applied to road drainage projects. **It is important to note that the phosphorus loading estimates for the unified scoring system have only been developed for the Lake Champlain Basin.** VTANR has not yet released a timeline for developing nutrient loading calculations for the Connecticut River basin. Phosphorus loading rates are highly variable between lake segments. We selected the loading rates for the “Winooski River” lake segment, as these rates are roughly in the median range for phosphorus loading from pervious and impervious surfaces.

We anticipate that stormwater management efforts in the Connecticut River basin will consider nitrogen removal to be as important as phosphorus. VTANR has not yet developed guidance for calculating nitrogen



loading rates or nitrogen removal efficiencies for stormwater treatment practices. We are evaluating options for estimating these loads and removal rates for our high priority projects that are selected for concept design development. Most stormwater treatment practices have similar removal efficiencies for nitrogen and phosphorus, therefore the information used for project prioritization should remain applicable if the focus of stormwater treatment shifts towards nitrogen in the Connecticut River Basin.

Phosphorus Loads from Sediment

Land cover-based phosphorus loading estimates account for generalized assumptions of sediment mobilization; however, we believe that phosphorus loading from active erosion areas may be underestimated for some of the stormwater problem areas. Other project types such as stream bank restoration or gully stabilization do not fit into the VTDEC Unified Scoring framework. We followed the VTDEC Standard Operating Procedure (SOP) for tracking and accounting of phosphorus associated with the Municipal Roads General Permit (MRGP) to estimate phosphorus loading and reduction associated with road improvements and erosion stabilization (VTDEC 2020).

For estimating the overall phosphorus loading and phosphorus reduction associated with excess sediment mobilization and stabilization, we used methods and loading rates established for the stabilization of roadside gully erosion in the VTDEC SOP. We estimate annual soil loss (in cubic feet) based on our best professional estimate of the age and volume of erosion features. We apply a 43.38 kg/ft³ sediment bulk density to volume of erosion and 0.000396 kg (P)/ kg sediment (TSS), the equivalent of an annual loading rate of 0.017 kg (P)/ft³ and 0.037 kg (P)/ft³ (VTDEC 2020).

BMP Unit Costs and Adjustment Factors

BMP unit costs (2016 \$) and adjustment factors were derived from recent stormwater master plans completed by Watershed Consulting Associates (2018). These numbers were primarily based on research completed by the Charles River Watershed Association and the Center for Watershed Protection (EPA, 2016), as well as updates based on actual construction costs in Vermont (Table 6). The unit cost estimates include an 8% total inflation adjustment for 2017-2020 based on the Consumer Price Indicator Inflation Calculator. Unit construction costs for road drainage projects were based on the estimates provided in the Road Erosion Site Prioritization and Remediation Project Summary (Fitzgerald Environmental Associates and Milone and MacBroom, Inc., 2017). Additional multipliers for site type (Table 7) and level of permitting and engineering required (Table 8) are also shown below.



Table 6: BMP Unit Costs (\$)

BMP Type	Cost/ft ³ Treatment Volume
Constructed Wetland	9.49
Dry Pond	4.87
Grass Conveyance Swale	4.32
Rain Garden (no underdrain)	16.72
Rain Garden (with underdrain)	16.72
Subsurface Infiltration	6.76
Surface Infiltration	6.75
Wet Pond	7.35

Table 7: Site Type Cost Adjustment

Site Type	Cost Multiplier
Existing BMP retrofit	0.25
New BMP in undeveloped area	1.00
New BMP in partially developed area	1.50
New BMP in developed area	2.00

Table 8: Permitting and Engineer (P&E) Cost Adjustment

Level of P&E Required	Cost Multiplier
None	1.00
Low	1.20
Moderate	1.25
High	1.35

4.3 Non-Unified Evaluation and Prioritization of Problem Areas

Areas identified during field tours of the study area where the primary project recommendation was not stormwater treatment infrastructure (e.g., road erosion stabilization, gully stabilization, and undersized culvert replacements) were assigned several numerical scoring metrics that are weighted to assist in prioritizing each project based on water quality benefits, project feasibility, maintenance requirements, costs, and any additional benefits. The maximum possible score is 30 and the individual site scores ranged



from 10 to 19. Each category is described below and includes a description of the scoring for each criterion. Final evaluation criteria summarized in the Non-Unified Prioritization Project Table (Appendix B) are described below:

- **Water Quality Benefits (15 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 (3 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 0.25-0.5 acres
 - 2 points – Area of impervious surfaces is 0.5-1.0 acres
 - 3 points – Area of impervious surfaces is >1.0 acres
 - **Connectivity to Surface Waters (3 points)**
 - 0 points – All stormwater infiltrates on site
 - 1 point – Stormwater receives some treatment before reaching receiving waters
 - 2 points – Stormwater drains into drainage infrastructure that directly outlets to receiving waters (assumes no erosion or additional pollutant loading to discharge point)
 - 3 points – Stormwater drains directly into receiving waters (typically stormwater draining directly into a large wetland is assigned 2 points)



- **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 (5 points total)** – Description of other project benefits, total score is roughly a count of the number of additional benefits. Additional benefits considered in the prioritization are as follows:
 - **(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) Educational** – The site provides an opportunity to educate the public about stormwater treatment practices
 - **(4) High Visibility** – The site is highly visible and will benefit from aesthetically designed treatment practices
 - **(5) Infrastructure Conflicts** – The stormwater problem area is increasing erosion or inundation vulnerability of adjacent infrastructure (i.e. roads, buildings, etc.)
 - **(6) Drains to Connected Stormwater Infrastructure** – The site drains into a larger stormwater conveyance system that is less likely to receive downstream treatment
 - **(7) Reduces Thermal Pollution** – Project implementation will reduce the risk of thermal loading from runoff to receiving surface waters
 - **(8) Improves BMP Performance** – Project implementation will improve the performance of existing stormwater treatment practices that receive runoff from the site
 - **(9) Peak Flow Reduction** – Project implementation will significantly reduce stormwater peak flows leaving the site
 - **(10) Enhances Lakeshore Natural Communities** – Project implementation will promote a native vegetated lakeshore buffer and/or provide wildlife habitat along the lakeshore

4.4 Problem Area Summary Sheets

Problem area summary sheets were developed for 18 of the high and moderate priority project sites, and are provided in Appendix C. These sites were selected based on the prioritization categories shown in the Problem Area Table in Appendix B, and from input from project stakeholders during several meetings and field tours. Problem areas and prioritization strategies were discussed and refined with input from Town of Ludlow, MARC, and VTANR staff. The one-page summary sheets found in Appendix C include a site map and description, site photographs, and prioritization categories.



4.5 Conceptual Designs

FEA and DG hosted a meeting with the Town, MARC, and VTANR in February 2021 to discuss project prioritization and selection of 12 projects for conceptual design development. The consensus from this meeting was to focus concept designs on projects that would address flooding and erosion issues in the Black River valley and erosion and water quality concerns for Lake Rescue. Twelve (12) projects were selected at this meeting for concept designs. FEA and DG developed 30% conceptual designs and preliminary cost estimates for these 12 projects. Concept designs include:

- A site plan with contours, existing stormwater infrastructure, and proposed design elements
- Where relevant, hydrologic and hydraulic modeling data of the contributing drainage area and proposed BMP sizing and design specifications
- Typical details for proposed practices
- A preliminary cost opinion

The projects selected for 30% conceptual design were:

1. **Project LR-01 – Tepper Drive and Scotts Landing:** Steep private roads lack ditches and carry sediment into a town-maintained ditch before flowing through a cross-culvert and discharging to Lake Rescue.
2. **Project LR-06 – Red Bridge Road:** Ditch along north/east side of Red Bridge Road spills across road at bend with moderate erosion, runoff continues along road to lake with moderate erosion down foot path to canoe/kayak access. Private landowner (Sperzel) is supportive of water quality projects.
3. **Project LT-02 – Mountain Road (Blue Lot):** Driveway from upper lot associated with LT-4 has gully erosion leading down to the road. Runoff comes down ramp instead of through the ditch and then follows mountain road down. Limited space for treatment around edges of parking lot.
4. **Project LT-04 – Mountain Road (Blue Lot):** Catch basin directly connected to perennial stream drains a very large gravel parking lot (Town owned). Numerous gully and rill erosion features along concentrated flow paths through parking lot. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 50.
5. **Project LT-06 – West Hill Recreation Area:** Existing stormwater treatment system along parking lot does not receive any runoff due to grading. Green space north of parking lot receives runoff from portion of parking lot, gravel road, and the building. Existing site provides minimal treatment along gentle grassed slope to reservoir.
6. **Project LT-09 – Town Garage:** Sheet Erosion off portion of parking lot flows to grassed area. Some erosion along edge of steep driveway from concentrated flow of parking lot. Buried electric nearby. Border of A/Unrated soils. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 51.
7. **Project LT-30 – Gill Terrace:** Outfall from stormline draining a portion of the retirement complex is causing severe gully erosion down a steep slope to a stream.



8. **Project LT-34 – Deeplawn Court:** Catch basin adjacent to Elementary School playground drains parking lot and swale from LD-11.
9. **Project LT-36 – High School:** High school roof drains into combined sewer. This is the last remaining combined sewer connection in the Town.
10. **Project LT-37 – Ludlow Community Center:** Large portion of school complex drains to storm line with adjacent green spaces around the Community Center.
11. **Project LT-38 – Ludlow Community Center:** Two catch basins on either side of gravel road leading up to community center and thrift store. Erosion along both sides of road.
12. **Project LT-41 – Orchard Street:** Runoff from the steep driveway into the cemetery crosses High St and flows to a drop inlet that is mostly filled, discharging to a grassed swale. The swale drains to another drop inlet that is the top of a long stormline to the river. A neighbor said that soils were very well drained. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 27

5.0 Next Steps

This stormwater master plan represents an extensive effort to identify, describe, and evaluate stormwater issues affecting water quality and localized flooding in the Town of Ludlow. For each project recommendation, we provided a preliminary cost estimate and nutrient/sediment treatment estimates to MARC and Town representatives in planning and prioritizing project implementation. The problem area descriptions for Town roads (e.g., roadside ditches) will aid the Town Highway Department in proactively stabilizing and maintaining these features to avoid future stormwater problems, and to come into compliance with the VTANR Municipal Roads General Permit.

We recommend that MARC continues to work with the Town and VTDEC to secure funding for the high priority projects described in Appendices B, C, and D. Landowner outreach should be completed for all projects that are not on Town land or right-of-way. The BMP installation/retrofit opportunities identified in the Unified Prioritization Matrix represent a potential phosphorus load reduction of approximately 150lb/year. Based on our review and preliminary designs and our experience with previous SWMP efforts, we feel that the projects listed in Appendix D should be considered for further development and implementation.



6.0 References

- Clean Water Initiative Program, Watershed Management Division, Vermont Department of Environmental Conservation, April, 2016. Town of Ludlow Stormwater Infrastructure Mapping Project
- Fitzgerald Environmental Associates and Milone and MacBroom. 2017. Road Erosion Site Prioritization and Remediation Project Summary. Memo prepared for the Chittenden County Regional Planning Commission. Dated December 27, 2017.
- Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, [Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information](#). *Photogrammetric Engineering and Remote Sensing*, v. 81, no. 5, p. 345-354
- Ludlow Planning Commission, 2018. Village of Ludlow, Vermont: Zoning and Flood Hazard Regulations (Amended)
- Ludlow Planning Commission, 2019. Municipal Plan for the Town and Village of Ludlow, Vermont
- Stone Environmental, Inc., January, 2019. Detecting and Eliminating Illicit Discharges in Basin 10: Final Report
- Watershed Management Division, Vermont Agency of Natural Resources, 2016. Black River Watershed Updated Water Quality/Aquatic Habitat Assessment Report
- Watershed Management Division, Vermont Agency of Natural Resources, 2018. Black and Ottauquechee River and adjacent Connecticut River & Tributaries Tactical Basin Plan
- Watershed Consulting Associates, LLC. 2018. Stormwater Master Plan for the Town of Berlin, Vermont. Prepared for the Central Vermont Regional Planning Commission. Final Report, January 17, 2018.

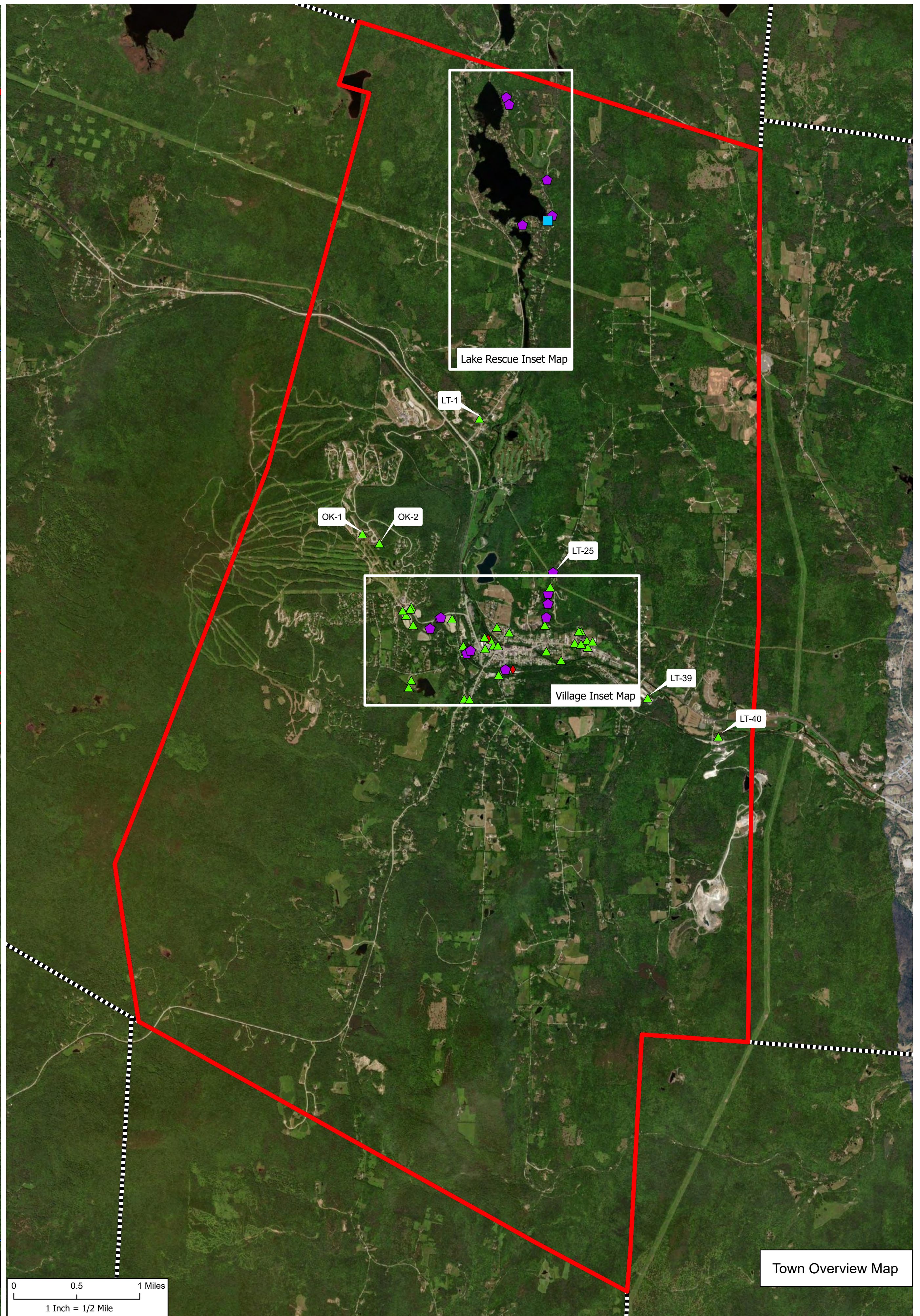


APPENDIX A

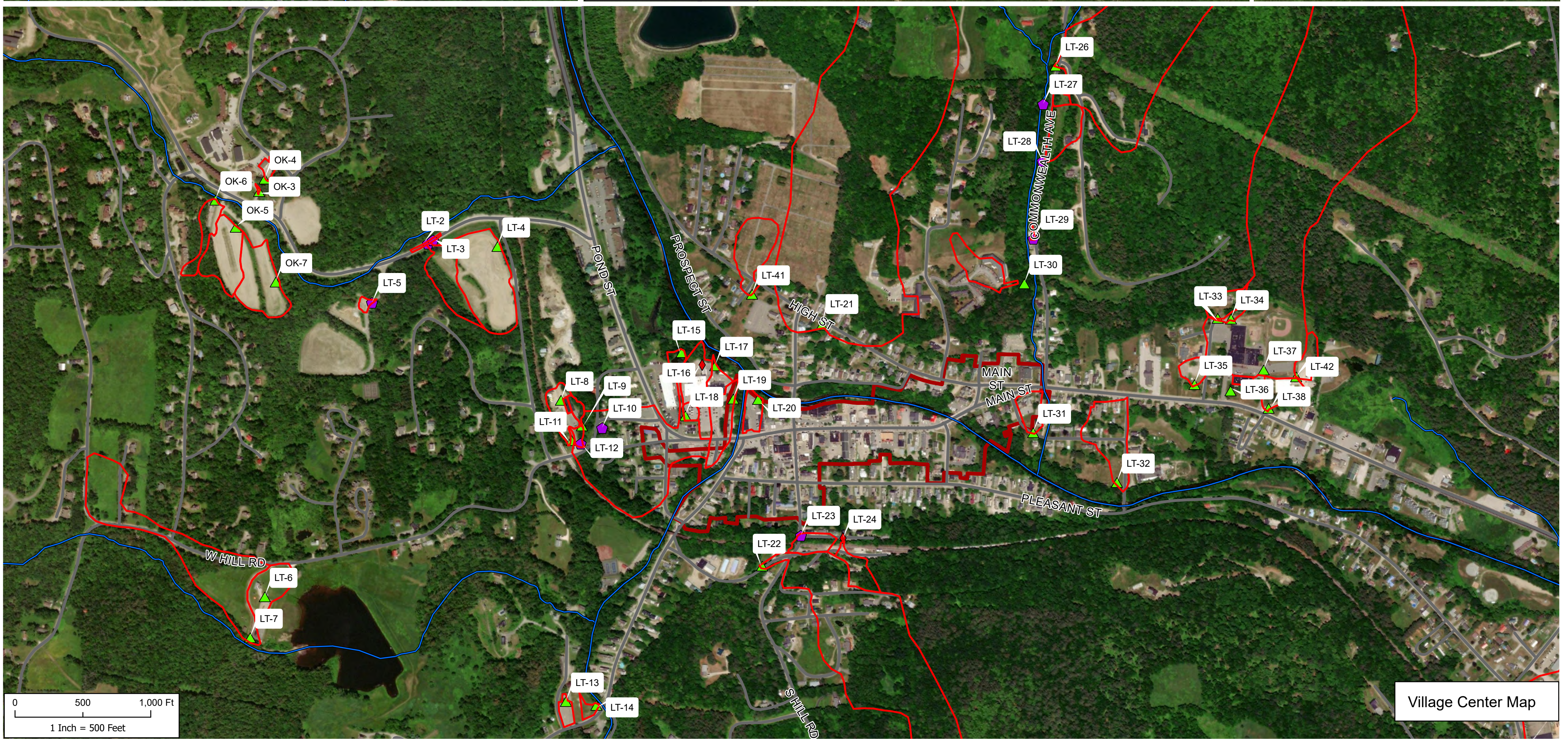
Project Location Map (24"x36")



Lake Rescue Map



Town Overview Map

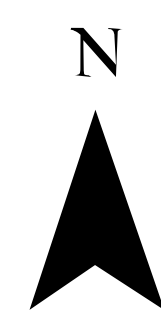


Village Center Map

Proposed Project Type

- Stormwater BMP New/Retrofit
- Gully Stabilization
- Road Erosion Mitigation
- Stream Restoration/Culvert Replacement
- Surface Waters

- Roads
- Town Boundaries
- Village Center
- Ludlow
- Drainage Areas



Notes

Project locations and suggestions based on site visits by FEA in August and September, 2020
 Map By: FCP
 Date: January 28, 2021

APPENDIX B

Project Prioritization Tables (11"x17")

Stormwater Master Plan - Town of Ludlow
Unified Prioritization Project Table
May 19, 2021

Project ID	Project Type	Location	Description	Preliminary Recommendations	Total Acreage	Impervious Acreage	% Impervious	P Load (lb/yr)	WQv (cf)	BMP Type	BMP Volume (cf)	BMP P Reduction (lb/yr)	Erosion P Reduction (lb/yr)	Total P Reduction (lb/yr)	Gully Mitigation	Landowner	Project/Permitting Complexity	Infrastructure Conflicts	Total Cost	Project Efficiency \$/lb	Ease of O&M	Co-Benefits Sum	Total Score	Possible	Final Score %
LR-6	GSI	Red Bridge Road	Ditch along north/east side of Red Bridge Road spills across road at bend with moderate erosion, runoff continues along road to lake with moderate erosion down foot path to canoe/kayak access. Private landowner (Sperzel) is supportive of water quality projects	Improve ditch and install cross culvert at Sperzel driveway. Room for a sediment trap and small infiltration feature with some tree clearing. A soils	0.88	0.17	19%	0.78	710	Surface Infiltration	250	0.59	0.185	0.78	1	2	0	1	\$ 15,000	\$ 19,255	1	5	23	50	46%
LT-01	GSI	VTRANS facility on Route 100	Large grass swale/depression draining to a single catch basin that is directly connected to receiving water. Large drainage area including garage rooftop area and paved/gravel parking lot. North side of property drains to existing swale to catch basin. Steep slopes adjacent to swale. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 66	Install a large infiltration feature in grass area south of parking lot with an overflow to the existing catch basin. May need to line the downhill side. Enhance existing swale along north side.	4.68	1.61	34%	5.51	6,103	Subsurface Infiltration	6,200	5.23	0	5.23	0	3	2	1	\$ 52,400	\$ 10,019	2	4	35	50	70%
LT-04	GSI	Witalec Rd - Blue Lot	Catch basin directly connected to perennial stream drains a very large gravel parking lot (Town owned). Numerous gully and rill erosion features along concentrated flow paths through parking lot. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 50	Adjust grading and stabilize flow paths to direct runoff to a new infiltration feature near the existing catch basin. Surface or subsurface infiltration are feasible.	5.66	4.95	87%	12.53	17,201	Surface Infiltration	17,200	12.18	18.5	30.68	2	3	2	1	\$ 145,100	\$ 4,730	1	4	42	50	84%
LT-06	GSI	West Hill Recreation Area	Existing stormwater treatment system along parking lot does not receive any runoff due to grading. Green space north of parking lot receives runoff from portion of parking lot, gravel road, and building	Direct drainage into a rain garden or bioretention swale	0.93	0.37	40%	1.39	1,378	Rain Garden (no underdrain)	800	0.57	0.037	0.61	0	3	2	1	\$ 16,000	\$ 26,273	1	4	22	50	44%
LT-07	GSI	West Hill Recreation Area	Wetland swale getting at least half of basketball area	Improve/ upsize wetland swale according to drainage area	9.38	1.54	16%	7.77	6,728	Constructed Wetland	600	1.01	0	1.01	0	3	0	1	\$ 3,600	\$ 3,571	1	2	27	50	54%
LT-09	GSI	Town Garage	Sheet Erosion off of portion of parking lot flows to grassed area. Some erosion along edge of steep driveway from concentrated flow of parking lot. Buried electric nearby. Border of A/Unrated soils. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 51	Install a collection swale and infiltration basin	0.32	0.17	52%	0.49	604	Surface Infiltration	600	0.48	0.185	0.66	1	3	2	0	\$ 7,600	\$ 11,513	1	3	28	50	56%
LT-11	GSI	Town Garage	Outfall in lawn drains to train tracks then into a depression with no connection to surface water. Space for a larger feature but likely less opportunity for water quality improvement.	Infiltration basin or bioretention feature	1.31	1.03	78%	2.66	3,587	Surface Infiltration	1,500	2.13	0	2.13	0	3	2	0	\$ 12,700	\$ 5,957	1	2	29	50	58%
LT-13	GSI	Parker Ave	Filled in catchbasin presumably connected to culvert under house. Drains abandoned parking lot	Install dry well and/or remove pavement to allow for infiltration	0.43	0.38	90%	0.97	1,333	Subsurface Infiltration	600	0.85	0.185	1.03	0	0	2	1	\$ 5,100	\$ 4,936	1	3	28	50	56%
LT-14	GSI	Andover St.	Bad fill behind new wall has a big sinkhole gully. Runoff is from a smaller portion of road. Needs repair and is contributing sediment to jewel brook. Approx 30' long 3' deep 4' wide. Talked to property maintenance guy, it's the site of an old woolen mill with a big dye storage tank underground. Planned for condo/hotel but stalled.	Redirect system to empty lot and treat underground	0.28	0.13	48%	0.40	487	Subsurface Infiltration	400	0.37	0.74	1.11	2	0	0	0	\$ 19,000	\$ 17,065	1	5	25	50	50%
LT-15	GSI	Benson's Chevrolet	Existing wet pond with no stabilized outlet resulting in erosion into wetland. Drains all of subwatershed 46, gully erosion where water overflows pond. VTANR Stormwater Infrastructure Mapping Project High priority project subwatershed 46	Use existing wet pond as a forebay and make a new wet pond or gravel wetland, could also take portion of runoff from LT-16 (1 acre).	12.98	7.00	54%	20.74	25,225	Wet Pond	15,000	8.51	0.37	8.88	2	0	0	0	\$ 111,700	\$ 12,580	1	5	27	50	54%
LT-17	GSI	Behind Shaws on Main St.	Low point along back of parking area, catchbasin leading to outfall directly into black river. Sufficient room for a project	Install a Rain Garden to collect sheetflow	0.62	0.54	86%	1.36	1,867	Rain Garden (no underdrain)	500	0.99	0	0.99	0	0	0	1	\$ 15,700	\$ 15,918	1	3	19	50	38%
LT-18	GSI	Shaws front parking lot on Main St.	Corner of parking lot with poor drainage	Install dry well in pavement	0.31	0.31	100%	0.75	1,056	Subsurface Infiltration	800	0.72	0	0.72	0	0	2	0	\$ 13,000	\$ 18,027	1	3	19	50	38%
LT-19	GSI	Shaws front parking lot on Main St.	Buried culvert, eroding/filled swale along edge of parking lot. Large drainage area with minimal catch basins. Culvert under main street from Lamere Square is almost completely filled. Fire hydrant and likely other utilities. Possibly river corridor conflicts. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 44	Repair Swale and add another, Add forebay and bioretention feature, likely in adjacent lawn. Soils are unrated	1.88	1.49	79%	3.85	5,196	Rain Garden (no underdrain)	2,000	2.70	0.185	2.88	0	0	0	0	\$ 83,600	\$ 28,995	1	3	18	50	36%
LT-20	GSI	Municipal Parking lot on Main St.	Municipal parking lot low point drains into the river	Stabilize swales along parking lot, add rain garden in the corner to treat water before it enters the river, soils are unrated	0.82	0.67	83%	1.73	2,351	Rain Garden (no underdrain)	1000	1.28	0	1.28	0	3	0	1	\$ 31,300	\$ 24,502	1	4	22	50	44%
LT-21	GSI	High Street	Stormline with a large drainage area passes through an empty private lot. High Street has recent catchbasin and stormline upgrades, but no treatment.	Opportunity for a large underground infiltration feature. Flow split would be required at the final catch basin, or new catch basin. Would likely require an inline pre-treatment device (swirl separator). Pipe elevations surveyed and water elevation can't be raised in drainage network. Soils are unrated but neighbor says well drained	64.02	5.33	8%	42.93	29,045	Subsurface Infiltration	10,000	27.71	0	27.71	0	0	2	0	\$ 192,500	\$ 6,947	1	6	31	50	62%
LT-22	GSI	Bridge Street	Empty private lot with adjacent stormline system draining large steep area	Add a flow split in existing CB or in a new CB, install large underground infiltration. Would likely require an inline pre-treatment device (swirl separator).	21.15	2.52	12%	15.67	12,082	Subsurface Infiltration	5000	8.28	0	8.28	0	0	2	1	\$ 136,000	\$ 16,418	1	3	26	50	52%

Stormwater Master Plan - Town of Ludlow
Unified Prioritization Project Table
May 19, 2021

Project ID	Project Type	Location	Description	Preliminary Recommendations	Total Acreage	Impervious Acreage	% Impervious	P Load (lb/yr)	WQv (cf)	BMP Type	BMP Volume (cf)	BMP P Reduction (lb/yr)	Erosion P Reduction (lb/yr)	Total P Reduction (lb/yr)	Gully Mitigation	Landowner	Project/Permitting Complexity	Infrastructure Conflicts	Total Cost	Project Efficiency \$/lb	Ease of O&M	Co-Benefits Sum	Total Score	Possible	Final Score %
LT-30	GSI	Behind Retirement home on Gill Terrace	Outfall from stormline draining a portion of the retirement complex is causing severe gully erosion down a steep slope to a stream. Avg 4x2, max 8x5, length:120.	Treat runoff with subsurface infiltration feature, stabilize outlet erosion. Gully is likely too steep to access with equipment.	1.81	0.80	44%	2.48	2,938	Subsurface Infiltration	3000	2.39	2.22	4.61	2	0	2	1	\$ 50,500	\$ 10,965	1	5	36	50	72%
LT-31	GSI	Meadow St	Open Lot adjacent to stormwater system	Could redirect across road to open lot for surface treatment. Soils are unrated, private property	1.02	0.57	56%	1.62	2,031	Surface Infiltration	1000	1.24	0	1.24	0	0	0	1	\$ 43,900	\$ 35,539	1	3	16	50	32%
LT-32	GSI	Mill St	Empty lot next to stormwater system and surface flow, area was inundated in Irene, possible FEMA buyout	Subsurface infiltration system, would require floodproofing. Unrated soils	3.30	1.21	37%	4.04	4,566	Subsurface Infiltration	2000	2.92	0	2.92	0	0	0	1	\$ 52,000	\$ 17,823	1	3	21	50	42%
LT-33	GSI	Deeplawn Ct. Elementary school parking lot	Two gravel driveways on steep slopes drain into swale at corner of school parking lot, moderate erosion along driveways	Room for a small rain garden along edge of parking lot, need to design for excess sediment	1.16	0.35	30%	1.28	1,351	Rain Garden (no underdrain)	200	0.56	0.185	0.75	1	0	2	1	\$ 8,400	\$ 11,206	1	4	25	50	50%
LT-34	GSI	Deeplawn Ct. Elementary school parking lot	Catch basin drains parking lot and swale from LD-11. Electric overhead	Room for a small rain garden in the swale and around the catch basin. Overflow into the CB	1.41	0.41	29%	1.52	1,605	Rain Garden (no underdrain)	300	0.77	0.185	0.96	0	3	2	0	\$ 9,000	\$ 9,424	1	4	27	50	54%
LT-35	GSI	Empty lot on Deeplawn Ct.	Field with water pooling from gravel parking lot. Plenty of room. Soils are unrated but appear well drained. Minimal connection to surface water. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 2	Infiltration basin	0.72	0.51	71%	1.36	1,797	Surface Infiltration	1,200	1.16	0	1.16	0	0	2	1	\$ 9,700	\$ 8,386	1	0	24	50	48%
LT-36	GSI	Black River High School	High school roof drains into combined sewer. This is the only remaining combined sewer connection in the Town.	Redirect roof drains to back or east side of building to new underground infiltration. Overflow could be connected to existing storm line	0.21	0.21	100%	0.52	726	Subsurface Infiltration	800	0.48	0	0.48	0	3	2	0	\$ 28,100	\$ 58,771	2	4	22	50	44%
LT-37	GSI	Main St behind Elementary School	Large portion of school complex drains to storm line with adjacent green spaces.	Install an underground infiltration system. Several potential areas, likely not room for full WQv. Unrated soils.	9.26	3.97	43%	12.45	14,651	Subsurface Infiltration	10,000	9.44	0	9.44	0	3	1	0	\$ 250,000	\$ 26,489	1	5	28	50	56%
LT-38	GSI	Driveway for community center/ thrift store	Two catch basins on either side of gravel road leading up to community center and thrift store. Erosion along both sides of road.	Add infiltrating swale along road and rain garden in the green space to the north, unrated soils	1.16	0.66	57%	1.87	2,367	Surface Infiltration	1,600	1.58	0.185	1.77	1	3	2	0	\$ 19,400	\$ 10,967	1	4	30	50	60%
LT-39	GSI	LaValley Building Supply Parking Lot	Very large drainage area to a channel through the LaValley Building Supply parking lot. Room for wetland treatment benches along channel in 3 areas. large sediment load from parking area. Stream is mapped as perennial. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 13	Install floodplain benches and potentially an outlet control structure to create a wetland treatment system. Three separate areas along channel could be modified. Smaller footprint may be more feasible (2,000sqft)	50.67	8.99	18%	43.27	38,564	Constructed Wetland	6,000	8.48	0.37	8.85	1	2	0	1	\$ 102,500	\$ 11,581	1	3	27	50	54%
LT-40	GSI	E Hill Rd	Swale is partially filled in and has reduced function. Fills with water and overflows into river. Erosion from gravel lot above is adding a significant sediment load. Dry hydrant and industrial water withdrawal are next to swale.	Regrade uphill gravel road to divert runoff into swale. Improve swale and install check dams to provide pre-treatment. Widen infiltration area and install stable overflow to river. B soils	2.42	1.15	48%	4.06	4,194	Surface Infiltration	2500	3.14	0.74	3.88	2	0	0	0	\$ 12,500	\$ 3,223	0	5	33	50	66%
LT-41	GSI	Orchard St at High St	Runoff from the steep driveway into the cemetery crosses High St and flows to a drop inlet that is mostly filled, discharging to a grassed swale. The swale drains to another drop inlet that is the top of a long stormline to the river. A neighbor said that soils were very well drained. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 27	Install a new catch basin and cross-culvert at the east side of the cemetery driveway, replace the shallow DI with a catch basin, install an infiltrating bioretention feature along the grassed swale with overflow to the existing drop inlet.	5.52	1.77	32%	3.25	7,100	Surface Infiltration	3000	2.68	0.037	2.72	0	2	2	1	\$ 18,100	\$ 6,662	2	4	34	50	68%
LT-42	GSI	Parking Area for community center/thrift store	Gravel parking lot drains to a grass swale to catch basin	Install an infiltrating swale or rain garden using the CB as overflow	0.81	0.31	38%	0.79	1,160	Surface Infiltration	800	0.84	0.037	0.87	0	3	2	0	\$ 6,500	\$ 7,446	1	3	28	50	56%
OK-1	GSI	Harrison Ln at property management building	Swale gets runoff from steep gravel road with gully erosion. Winterplace permit 3718-9010 (No actual treatment specified)	Stabilize swale and add infiltration basin in green space behind building	1.62	1.03	64%	2.84	3,670	Surface Infiltration	1,200	2.00	0.185	2.19	1	0	2	1	\$ 12,700	\$ 5,807	0	3	27	50	54%
OK-3	GSI	Mountain Rd	Small area of paved parking lot draining along curb	add a curb cut that diverts water into adjacent green space where you could put a rain garden	0.02	0.02	100%	0.05	70	Surface Infiltration	50	0.04	0	0.04	0	0	2	0	\$ 800	\$ 18,182	1	1	16	50	32%
OK-4	GSI	Okemo Ridge Rd and Spaulding Farm Rd	Minor erosion in small gravel parking lot. More erosion along the edge of the parking lot. Drains directly into a small stream. Included in retrofits planned for General Permit 3125-9015.1. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 58	Add grass swale along parking lot and small wetland in the corner	0.32	0.31	98%	0.77	1,073	Constructed Wetland	500	0.29	0.074	0.36	1	0	0	1	\$ 8,900	\$ 24,722	1	3	15	50	30%

Stormwater Master Plan - Town of Ludlow
 Unified Prioritization Project Table
 May 19, 2021

Project ID	Project Type	Location	Description	Preliminary Recommendations	Total Acreage	Impervious Acreage	% Impervious	P Load (lb/yr)	WQv (cf)	BMP Type	BMP Volume (cf)	BMP P Reduction (lb/yr)	Erosion P Reduction (lb/yr)	Total P Reduction (lb/yr)	Gully Mitigation	Landowner	Project/Permitting Complexity	Infrastructure Conflicts	Total Cost	Project Efficiency \$/lb	Ease of O&M	Co-Benefits Sum	Total Score	Possible	Final Score %
OK-5	GSI	Mountain Rd. Parking lot	Large, 2-tier parking lot with gravel. Could use multiple projects. Catchbasin draining upper lot leads to gully (5x4x25ft) into stream. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 56	Install a large underground infiltration in upper lot area, need to verify water table on steep slope. Unrated soils	3.35	2.70	81%	6.97	9,429	Subsurface Infiltration	5,000	4.88	1.11	5.99	2	0	0	0	\$ 68,400	\$ 11,411	1	6	33	50	66%
OK-7	GSI	Mountain Rd Parking lot	Ditches along the west and east sides of gravel lot collect runoff, eroded swale through parking lot to catchbasin with outlet to stream. Drains southern section of OK-5 lower lot. Gully through lot into CB that outlets into stream. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 56	Install surface infiltration feature using CB as overflow, or potential for a large underground system is sufficient soil depth. Unrated soils	2.26	2.01	89%	5.07	6,976	Surface Infiltration	5000	4.40	1.11	5.51	1	0	0	0	\$ 68,300	\$ 12,396	1	6	33	50	66%

Stormwater Master Plan - Town of Ludlow
Non-Unified Prioritization Project Table
February 3, 2021

Additional Benefits Codes	CPA	SF	E	IC	SW	BMP	HV	TH	PF	L
	Chronic Problem Area	Seasonal Flooding	Educational	Infrastructure Conflicts	Drains to Connected Stormwater Infrastructure	Improves Existing BMP Performance	High Visibility	Reduces Thermal Pollution	Peak Flow Reduction	Enhance Lakeshore Natural Communities

Project ID	Project Type	Location	Description	Preliminary Recommendations	Water Quality Benefits					Landowner Support	O&M Requirements	Cost and Constructability	Additional Benefits	Additional Benefits Score	Total Score	Cost Estimate	Priority
					Nutrient Reduction	Sediment Reduction	Drainage Area	Impervious Drainage	Connectivity to Surface Waters								
					4	4	1	3	3	2	2	6		5	30		
LT-02	Road Erosion Mitigation	Mountain Rd	Driveway from upper lot associated with LT-4 has gully erosion leading down to the road. Runoff comes down ramp instead of through the ditch and then follows mountain road down. Limited space for enhanced treatment. Town property	Stabilize driveway and reinforce ditch, may be room for a small sediment trap or check dams	2	2	1	3	2	1	1	3	CPA, IC, SW, HV	4	19	5-20k	Medium
LT-03	Road Erosion Mitigation	Mountain Rd	Gully along side of the road leading right into stream.	Add series of turnouts or a ditch	1	1	0	0	3	1	1	4	CPA, IC, HV	3	14	1-5k	Medium
LT-05	Road Erosion Mitigation	Mountain Rd.	Major sediment runoff into woods, minimal hydro connection	Install a rock lined ditch and sediment trap	1	2	0	0	0	0	1	4	CPA, IC	2	10	1-5k	Low
LT-08	Road Erosion Mitigation	Town Garage	West side of garage roof drips down into dirt and dirty pavement	Extend grass area next to building to catch roof runoff for infiltration, or install gravel splash pad	1	2	0	0	1	1	2	5	CPA	1	13	<1k	Low
LT-10	Road Erosion Mitigation	West hill Road and Bowker Road	Concentrated flow along very steep paved road causing moderate erosion along edge of pavement, no ditch and no opportunity for sheet flow off of road. Runoff enters DI.	Repair road and install stone lined ditch.	1	1	1	2	1	1	2	4	CPA, IC, SW, HV	4	17	1-5k	Medium
LT-12	Road Erosion Mitigation	Town Garage	Eroding swale draining into LT-15 system, runoff would be treated upslope with the LT-09 project	Install rock lined ditch to road	1	1	0	1	1	1	2	4	CPA, SW	2	13	1-5k	Low
LT-16	Gully Stabilization	Behind Shaws on Main St.	Large gully off corner of parking lot. Erosion is threatening edge of pavement. VTANR Stormwater Infrastructure Mapping Project - High priority project subwatershed 45	Stabilize gully, some flow along edge of parking lot could be directed to LT-15	3	3	1	3	2	0	2	3	CPA, IC	2	19	5-20k	High
LT-23	Road Erosion Mitigation	Depot St. and Terrace Ave	Catchbasins at this intersection are not receiving much runoff due to poor placement and road grade, excess runoff continues down road, potentially overloading drainage infrastructure	Replace Catchbasins and adjust road grade to direct more runoff into the system	0	1	1	2	1	1	2	2	CPA, SF, IC, SW, HV	4	14	20-50k	Low
LT-24	Gully Stabilization	Terrace Ave	Small gully from outfall up slope. Water enters filled-in roadside swale	Stabilize outfall clean out swale	1	1	0	1	0	1	2	4	SF, IC	2	12	1-5k	Low
LT-25	Road Erosion Mitigation	Commonwealth Ave and N Ridge Rd	Culvert crossing north ridge rd is clogged. Erosion on gravel road surface is deposited down the ditch along commonwealth .	Replace and upsize existing culvert, repair eroded road surface	1	2	1	2	1	1	2	4	CPA, IC	2	16	1-5k	Medium
LT-26	Gully Stabilization	Commonwealth Ave and Old Village Ln	Unmapped cross culvert with long(120') gully leading down to the stream. Sediment deposition the whole way. Most of the active erosion at the bottom near the stream.	Stabilize outfall and channel to stream	4	4	1	3	3	0	1	2	CPA	1	19	20-50k	High
LT-27	Road Erosion Mitigation	Commonwealth Ave	24" cross culvert perched with erosion above and below. Deposited sediment nearly reaches stream. Gully: 3x2x25 feet.	Stabilize Outfall	1	1	0	0	2	1	2	4	CPA, IC	2	13	1-5k	Low
LT-28	Road Erosion Mitigation	Commonwealth Ave	Cross culvert with 24" and 8" pipe with mild erosion at outlet. Steep grade and little space for improvement. Sediment from runoff 30' downhill.	Install turnout below and stabilize outlet	2	2	0	0	2	1	1	3	CPA, IC	2	13	5-20k	Low
LT-29	Road Erosion Mitigation	Commonwealth Ave	Turnout from road not collecting all runoff, small gully going under raised building	Improve Turnout and ditch	1	1	0	0	2	0	1	4	CPA, IC	2	11	1-5k	Low
OK-2	Road Erosion Mitigation	White Loop	Small basin with no storage. Green area in traffic circle already treats water. Outlet is perched but well-armored. Surface flow is eroding bank at the pipe	Stabilize eroding areas	1	1	0	2	0	0	1	4	BMP	1	10	1-5k	Low
OK-6	Gully Stabilization	Mountain Rd parking lot	Same parking lot as OK-5, different drainage area causing a gully at the lot entrance that leads directly into the stream	Install grassed swale and stabilize steep conveyance to stream. Potential to install catchbasin and divert runoff to OK-5 system if there is sufficient capacity	2	3	0	2	3	0	2	3	CPA, IC, HV	3	18	5-20k	High
LR-1	Road Erosion Mitigation	Corner of Norman Dr. and Tepper Dr.	Steep private roads lack ditches and carry sediment into town-maintained ditch before flowing through a cross-culvert and discharging to Lake.	Install proper ditches, cross-culverts, and turnouts. Consider installing small sediment basin near boat storage area.	3	4	1	1	2	1	2	2	CPA, IC, HV	3	19	20-50k	High
LR-2	Road Erosion Mitigation	Corner of Norman Dr. and Ellison's Lake Rd	Unstable road swale leads to town-maintained ditch before flowing through a cross-culvert and discharging to Lake.	Consider check dams in ditch and small sediment trap prior to town cross-culvert.	2	3	1	1	3	1	1	3	CPA, IC	2	17	5-20k	High




Stormwater Master Plan - Town of Ludlow
Non-Unified Prioritization Project Table
February 3, 2021

Additional Benefits Codes	CPA	SF	E	IC	SW	BMP	HV	TH	PF	L
	Chronic Problem Area	Seasonal Flooding	Educational	Infrastructure Conflicts	Drains to Connected Stormwater Infrastructure	Improves Existing BMP Performance	High Visibility	Reduces Thermal Pollution	Peak Flow Reduction	Enhance Lakeshore Natural Communities

Project ID	Project Type	Location	Description	Preliminary Recommendations	Water Quality Benefits					Landowner Support	O&M Requirements	Cost and Constructability	Additional Benefits	Additional Benefits Score	Total Score	Cost Estimate	Priority
					Nutrient Reduction	Sediment Reduction	Drainage Area	Impervious Drainage	Connectivity to Surface Waters								
					4	4	1	3	3	2	2	6		5	30		
LR-3	Road Erosion Mitigation	Ellison's Lake Rd	Multiple steep road segments do not meet MRGP standards and discharge to stream flowing into the lake.	Evaluate areas for improved ditching and turnouts to reduce sediment load to stream.	2	3	1	1	3	1	1	2	CPA, IC	2	16	20-50k	Medium
LR-4	Road Erosion Mitigation	Corner of Ellison's Lake Rd and Archibald Ln	Town ditch networks lead to a 36" cross-culvert and an armored channel discharging to the Lake.	Evaluate areas for improved ditching and sediment traps to reduce sediment load to stream.	2	2	1	0	3	1	1	2	CPA, IC	2	14	20-50k	Low
LR-5	Stream Restoration/Culvert Replacement	Ellison's Lake Rd	Steep ephemeral/intermittent channel leading to lake carries high bedload during floods and clogs driveway culvert near lake.	Look for opportunities to reconnect channel to floodplain downstream of Ellison's Lake Road. Consider upsizing culvert on private drive or making a stream ford.	2	3	1	1	3	1	1	2	CPA, SF, IC	3	17	20-50k	Medium

APPENDIX C

Problem Area Summary Sheets
(8.5"x11")

Project: LT-1		Problem Area Summary				
Location	VTRANS Facility on Route 100					
Land Ownership	VT Highway Dept.					
BMP Type	Surface Infiltration, Swale Enhancement					
Drainage Area/Impervious	4.68/1.61 acres					
% Impervious	34%					
Estimated Project Cost	\$ 52,400					
P Efficiency (\$/lb removed)	\$ 10,019					
Project Priority	High					
<p>Site Description: Large grass swale/depression draining to a single catch basin that is directly connected to receiving water. Large drainage area including garage rooftop area and paved/gravel parking lot. North side of property drains to existing swale to catch basin. Steep slopes adjacent to swale.</p>						
						
<p>Photo 1: Swale from the north entering the catch basin.</p>		<p>Photo 2: Large depression where a feature could be installed.</p>				
<p>BMP Description: Install a large infiltration feature in the grassy depression south of the parking lot (photo 2) with an overflow into the existing catch basin. Enhance the existing swale (photo 1) to infiltrate runoff.</p>						
BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
6,200	5.51*	5.23**	Low	100/45	Sheet	Low
<p>Feasibility Comments: VTrans ownership will simplify maintenance. Site is open and easily accessible. Design considerations for Steep slope to road adjacent to site.</p>						
<p>Other Considerations/Benefits: This project would treat a large drainage area with over an acre of impervious including paved and gravel.</p>						

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-4		Problem Area Summary
Location	Witalec Rd. Okemo Blue Lot	
Land Ownership	Town of Ludlow	
BMP Type	Surface Infiltration	
Drainage Area/Impervious	5.66/4.95 acres	
% Impervious	87%	
Estimated Project Cost	\$ 145,100	
P Efficiency (\$/lb removed)	\$ 4,730	
Project Priority	High	

Site Description: Catch basin directly connected to perennial stream drains a very large gravel parking lot (Town owned). Numerous gully and rill erosion features along concentrated flow paths through parking lot.



Photo 1: The large parking lot as seen from the location of the catch basin.

Photo 2: Rill and gully erosion into the catch basin (location marked by FEA personnel)

BMP Description: Adjust grading and stabilize flow paths to direct runoff to a new infiltration feature near the existing catch basin. Surface or subsurface infiltration are feasible.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
17,200	12.53*	30.68**	High	100/41	Gully, Rill	Mod

Feasibility Comments: Town owned land. Likely sufficient room for surface infiltration feature, which would simplify maintenance and reduce costs.

Other Considerations/Benefits: The system drains directly into a stream and has a very high sediment/nutrient load, project would represent a significant water quality improvement.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-6		Problem Area Summary
Location	West Hill Rd. West Hill Recreation Area	
Land Ownership	Town of Ludlow	
BMP Type	Rain Garden	
Drainage Area/Impervious	1.89/0.43 acres	
% Impervious	23%	
Estimated Project Cost	\$ 16,000	
P Efficiency (\$/lb removed)	\$ 23,680	
Project Priority	Medium	

Site Description: Existing stormwater treatment system along parking lot does not receive any runoff due to grading. Green space north of parking lot receives runoff from portion of parking lot, gravel road, and building



Photo 1: Open space along runoff flow path suitable for rain garden installation.



Photo 2: Swale along east side of parking lot that does not receive runoff due to poor site grading

BMP Description: Direct drainage into a rain garden or bioretention swale

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
800	1.8*	0.68	Low	46/11	None	Mod

Feasibility Comments: Town property and open space could make this project very feasible.

Other Considerations/Benefits: Potential educational benefits for installing a BMP in a public park.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-9		Problem Area Summary
Location	West Hill Rd. Town Garage	
Land Ownership	Town of Ludlow	
BMP Type	Surface Infiltration	
Drainage Area/Impervious	0.32/0.17 acres	
% Impervious	52%	
Estimated Project Cost	\$ 7,600	
P Efficiency (\$/lb removed)	\$ 11,513	
Project Priority	High	

Site Description: Sheet Erosion off of portion of parking lot flows to grassed area. Some erosion along edge of steep driveway from concentrated flow of parking lot. Buried electric nearby. Border of A/Unrated soils



Photo 1: Sediment deposition at low point of the parking lot where water runs off. Ineffective catch basin in the top right corner.



Photo 2: Minor rill erosion alongside buried utilities.

BMP Description: Install a collection swale and infiltration basin

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
600	0.49*	0.66**	Med	100/42	Rill	Mod


Feasibility Comments: Many utilities are present on the site, snow storage concerns.

Other Considerations/Benefits: Project is located on Town property, easy maintenance.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-15		Problem Area Summary
Location	Benson's Chevrolet	
Land Ownership	Benson's Chevrolet	
BMP Type	Wet Pond or Constructed Wetland	
Drainage Area/Impervious	12.98/6.13 acres	
% Impervious	47%	
Estimated Project Cost	\$ 111,700	
P Efficiency (\$/lb removed)	\$ 12,580	
Project Priority	Medium	

Site Description: Existing wet pond with no outlet infrastructure. Drains all of subwatershed 46, gully erosion where water overflows pond



Photo 1: Low point of the existing wet pond's rim where water spills over. **Photo 2:** Existing wet pond from above.

BMP Description: Use existing wet pond as a forebay and make a new wet pond or gravel wetland, could also take portion of runoff from LT-16 (1 acre).

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
15,000	20.74*	8.88**	Med	59/29	Gully	Mod

Feasibility Comments: River corridor is mapped throughout this area. Multiple private landowners. New feature would require tree clearing.

Other Considerations/Benefits: There is potential to tie runoff from LT-16 into this retrofit and address both of their drainage areas with one large treatment feature.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-16		Problem Area Summary
Location	Main St. behind Shaws	
Land Ownership	Shaws Super Markets Inc.	
BMP Type	Gully Stabilization	
Drainage Area/Impervious	2.58/2.07 acres	
% Impervious	80%	
Estimated Project Cost	\$ 20,000	
P Efficiency (\$/lb removed)	\$ 3,000 (approx.)	
Project Priority	High	

Site Description: The Shaws parking lot and rooftop drain to the corner of the lot through swales and overland flow and into a large gully that leads directly into the Black River.



Photo 1: Rill erosion in swale along the side of the parking lot. **Photo 2:** Severe erosion near gully head

BMP Description: Stabilize gully, some flow along edge of parking lot could be directed to LT-15

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
N/A	7*	7**	High	N/A	Gully, Rill	Low

Feasibility Comments: The project may be within the river corridor and could require additional permitting. The berm that separates this project from LT-15 is made up of fill and could be easy to reshape or remove.

Other Considerations/Benefits: Addressing this large gully that leads directly into the river would have a substantial water quality benefit.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-20		Problem Area Summary
Location	Main St. Municipal Parking Lot	
Land Ownership	Bailey Holdings LLC.	
BMP Type	Rain Garden	
Drainage Area/Impervious	0.82/0.67 acres	
% Impervious	83%	
Estimated Project Cost	\$ 31,300	
P Efficiency (\$/lb removed)	\$ 24,502	
Project Priority	Medium	

Site Description: The low point of the municipal parking lot drains directly into the river.



Photo 1: Municipal parking lot with minor sediment deposition.



Photo 2: The low point in the corner of the lot. All drainage from the lot drains over this area.

BMP Description: Stabilize and enhance the swales along the sides of the parking lot. Install a rain garden in the corner to treat the water before it enters the river.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
1,000	1.73*	1.28	Low	43/16	None	Mod

Feasibility Comments: The project may fall in the river corridor and could require additional permitting.

Other Considerations/Benefits: The public location of this project could provide educational benefits to people visiting the town.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-21		Problem Area Summary
Location	High St.	
Land Ownership	Private	
BMP Type	Subsurface Infiltration	
Drainage Area/Impervious	64.02/5.33 acres	
% Impervious	8%	
Estimated Project Cost	\$ 192,500	
P Efficiency (\$/lb removed)	\$ 6,947	
Project Priority	High	

Site Description: Stormline with a large drainage area passes through an empty private lot. High Street has recent catch basin and stormline upgrades, but no treatment.



Photo 1: Catch basin next to empty lot.



Photo 2: Road draining to catch basin

BMP Description: Opportunity for a large underground infiltration feature. Flow split would be required at the final catch basin, or new catch basin. Would likely require an inline pre-treatment device (swirl separator). Pipe elevations surveyed and water elevation can't be raised in drainage network. Soils are unrated but neighbor says well drained.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
10,000	42.93*	27.71	Low	34/8	None	Mod

Feasibility Comments: Project is dependent on landowner permission. Pipe inverts are deep, requiring the infiltration area to be deep. Soils are unrated.

Other Considerations/Benefits: Opportunity to treat runoff from a large drainage area that is currently directly discharging to river.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-30		Problem Area Summary
Location	Gill Terrace, Behind Retirement Home	
Land Ownership	Private	
BMP Type	Subsurface Infiltration, Gully Stabilization	
Drainage Area/Impervious	1.81/0.80 acres	
% Impervious	44%	
Estimated Project Cost	\$ 50,500	
P Efficiency (\$/lb removed)	\$ 10,965	
Project Priority	High	

Site Description: Outfall from stormline draining a portion of the retirement complex is causing severe gully erosion down a steep slope to a stream.



Photo 1: Erosion at the head of the gully.



Photo 2: Sediment deposition at the outlet of the culvert.

BMP Description: Treat runoff with subsurface infiltration feature, stabilize outlet erosion. Gully is likely too steep to access with equipment.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
3,000	2.48*	4.61**	High	100/44	Gully	Mod

Feasibility Comments: Stabilizing the entire gully length will be difficult due to the steep, wooded slope.

Other Considerations/Benefits:

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-36		Problem Area Summary
Location	Black River High School	
Land Ownership	Public	
BMP Type	Subsurface Infiltration	
Drainage Area/Impervious	0.21/0.21 acres	
% Impervious	100%	
Estimated Project Cost	\$ 17,700	
P Efficiency (\$/lb removed)	\$ 37,020	
Project Priority	Medium	

Site Description: High school roof drains into combined sewer. This is the only remaining combined sewer connection in the Town.



Photo 1: Open space in front of school suitable for subsurface infiltration



Photo 2: Open space in front of school suitable for subsurface infiltration

BMP Description: Redirect roof drains to back or east side of building to new underground infiltration. Overflow could be connected to existing storm line

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
800	0.52*	0.48	None	110/44	None	Low

Feasibility Comments: School property with multiple options suitable for infiltration. Project is supported by the Town wastewater manager.

Other Considerations/Benefits: Implementation would remove that last known combined sewer connection.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-37		Problem Area Summary
Location	Main St. in School Parking Lot	
Land Ownership	Ludlow School District	
BMP Type	Underground Infiltration Chamber	
Drainage Area/Impervious	51.7/4.9 acres	
% Impervious	9%	
Estimated Project Cost	\$ 295,600	
P Efficiency (\$/lb removed)	\$ 14,461	
Project Priority	High	

Site Description: Large portion of school complex drains to storm line with adjacent green spaces.



Photo 1: Catch basin tied into the system.



Photo 2: Green space above pipe where underground infiltration could be installed.

BMP Description: Install an underground infiltration system. Several potential areas, likely not room for full WQv. Unrated soils.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
12,500	35.83*	20.44	Low	50/12	None	Mod

Feasibility Comments: Project will likely require multiple tiers, or to be reduced to a relatively small portion of WQv

Other Considerations/Benefits: Location at the school could provide educational benefits.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-38		Problem Area Summary
Location	Community Center	
Land Ownership	Public	
BMP Type	Rain Garden	
Drainage Area/Impervious	1.3/0.80 acres	
% Impervious	61%	
Estimated Project Cost	\$ 24,300	
P Efficiency (\$/lb removed)	\$ 11,662	
Project Priority	Medium	

Site Description: Two catch basins on either side of gravel road leading up to community center and thrift store. Erosion along both sides of road.



Photo 1: Open space adjacent to tank for larger bioretention feature with overflow to catch basin

Photo 2: Erosion and sediment deposition along road in front of community center

BMP Description: Add infiltrating swale along road and rain garden in the green space to the north, unrated soils

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
2,000	2.22*	2.08**	Mod	70/25	Rill	Mod

Feasibility Comments: Town property with sufficient space along road for swale and rain garden.

Other Considerations/Benefits: Highly visible project with potential for educational opportunities.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources



Project: LT-39		Problem Area Summary
Location	Pleasant St. Ext. LaValley Building Supply	
Land Ownership	Private	
BMP Type	Constructed Wetlands	
Drainage Area/Impervious	50.67/8.99 acres	
% Impervious	18%	
Estimated Project Cost	\$ 102,500	
P Efficiency (\$/lb removed)	\$ 11,581	
Project Priority	Medium	

Site Description: Very large drainage area to a channel through the LaValley Building Supply parking lot. Room for wetland treatment benches along channel in 3 areas. large sediment load from parking area. Stream is mapped as perennial



Photo 1: Swale in the middle of the large gravel parking lot. Rill erosion visible in the bottom of the photo.



Photo 2: Sheet erosion off gravel parking lot into one of the swales.

BMP Description: Install floodplain benches and potentially an outlet control structure to create a wetland treatment system. Three separate areas along channel could be modified.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
6,000	43.27*	8.85**	Med	16/4	Rill	Mod

Feasibility Comments: Discussed the project with property manager, who was supportive. Smaller project using 1 or 2 of the cells may be easier to implement.

Other Considerations/Benefits:

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-40		Problem Area Summary
Location	East Hill Rd.	
Land Ownership	Private	
BMP Type	Surface Infiltration, Swale Enhancement	
Drainage Area/Impervious	2.42/1.15 acres	
% Impervious	48%	
Estimated Project Cost	\$ 12,500	
P Efficiency (\$/lb removed)	\$ 3,223	
Project Priority	Medium	

Site Description: Swale is partially filled in and has reduced function. Fills with water and overflows into river. Erosion from gravel lot above is adding a significant sediment load. Dry hydrant and industrial water withdrawal are next to swale.



Photo 1: Sediment deposition in the swale.

Photo 2: Eroding corner of the gravel road.

BMP Description: Regrade uphill gravel road to divert runoff into swale. Improve swale and install check dams to provide pre-treatment. Widen infiltration area and install stable overflow to river. B soils

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
2,500	4.06*	3.88**	High	60/24	Gully, Rill	High

Feasibility Comments: Project may lie in the river corridor requiring additional permitting. A dry hydrant is in the general area and may need to be avoided.

Other Considerations/Benefits: Treating this area would address a significant sediment source close to the river for a substantial water quality benefit.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LT-41		Problem Area Summary
Location	Orchard St.	
Land Ownership	Annunciation Catholic Church	
BMP Type	Surface Infiltration	
Drainage Area/Impervious	2.63/0.32 acres	
% Impervious	12%	
Estimated Project Cost	\$ 9,200	
P Efficiency (\$/lb removed)	\$ 11,581	
Project Priority	Medium	

Site Description: Runoff from the steep driveway into the cemetery crosses High St and flows to a drop inlet that is mostly filled, discharging to a grassed swale. The swale drains to another drop inlet that is the top of a long stormline to the river. A neighbor said that soils were very well drained.



Photo 1: Drop inlet and grass swale where project will be installed.



Photo 2: Existing drop inlet, some runoff likely bypasses the DI due to poor grading.

BMP Description: Install a new catch basin and cross-culvert at the east side of the cemetery driveway, replace the shallow DI with a catch basin, install an infiltrating bioretention feature along the grassed swale with overflow to the existing drop inlet.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
800	1.98*	1.69**	Low	53/35	None	Low

Feasibility Comments: Installation of a new catch basin would increase the size of the drainage area being treated and improve drainage along High Street.

Other Considerations/Benefits: Potential educational benefit for a project on church property.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: OK-5		Problem Area Summary
Location	Mountain Rd. Okemo Upper Parking Lot	
Land Ownership	Okemo Mtn. LLC.	
BMP Type	Underground Infiltration	
Drainage Area/Impervious	3.35/2.7 acres	
% Impervious	81%	
Estimated Project Cost	\$ 68,400	
P Efficiency (\$/lb removed)	\$ 11,411	
Project Priority	High	

Site Description: Large, 2-tier parking lot with gravel. Could use multiple projects. Catch basin draining upper lot leads to gully (5x4x25ft) into stream. May be included in planned updates under 3125-9015.1



Photo 1: Catch basin in upper lot where treatment feature will be located.



Photo 2: Outfall from the system with gully erosion into stream.

BMP Description: Install a large underground infiltration in upper lot area, need to verify water table on steep slope. Unrated soils

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
5,000	6.97*	5.99**	Mod	53/23	Gully, Rill	Mod

Feasibility Comments: Nearby swales were observed with standing water. The water table must be analyzed in the area before initial designs. OMR may have other stormwater treatment plans for this area.

Other Considerations/Benefits: Treatment here would greatly reduce the amount of water and sediment entering the system which also drains the lower lot. Another similar project should be considered at the catch basin in the lower lot.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LR-1		Problem Area Summary
Location	Corner of Norman Dr. and Tepper Dr.	
Land Ownership	Private	
BMP Type	Road Erosion Mitigation	
Drainage Area/Impervious	12.77/0.85 acres	
% Impervious	7%	
Estimated Project Cost	\$ 40,000	
P Efficiency (\$/lb removed)	\$ 10,000	
Project Priority	High	

Site Description: Steep private roads lack ditches and carry sediment into town-maintained ditch before flowing through a cross-culvert and discharging to Lake. Estimated 50cf of sediment per year from road and ditch erosion.



Photo 1: Outfall into eroding gully that leads to lake. **Photo 2:** Existing gully/flow path into lake.

BMP Description: Upgrade ditches, cross culverts and turnouts. Install small sediment basin near outlet into lake.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
N/A	4.0*	4.0**	High	N/A	Gully	Low


Feasibility Comments: Private land ownership and steep, forested slopes may make work off the ROW difficult.

Other Considerations/Benefits: Addressing this direct sediment source into the lake would have a substantial water quality benefit.

*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



Project: LR-6		Problem Area Summary
Location	Red Bridge Road	
Land Ownership	Private	
BMP Type	Road Erosion Mitigation	
Drainage Area/Impervious	0.88/0.17 acres	
% Impervious	19%	
Estimated Project Cost	\$ 3,000	
P Efficiency (\$/lb removed)	\$ 3,851	
Project Priority	Medium	

Site Description: Ditch along north/east side of Red Bridge Road spills across road at bend with moderate erosion, runoff continues along road to lake with moderate erosion down foot path to canoe/kayak access. Private landowner (Sperzel) is supportive of water quality projects.



Photo 1: Open space along runoff flow path suitable for rain garden installation.



Photo 2: Swale along east side of parking lot that does not receive runoff due to poor site grading

BMP Description: Room for a sediment trap and small infiltration feature with some tree clearing. Type A soils with good infiltration rate. Coordination with private landowner needed.

BMP Volume (cf)	P Load (lbs)	P Reduction (lbs)	Sed Reduction	%WQv/CPv	Gully/Erosion	Maintenance
250	0.78*	0.78**	Mod	35/17	None	Mod

Feasibility Comments: Town property and open space could make this project very feasible.

Other Considerations/Benefits: Potential educational benefits for installing a BMP in a popular boating area.

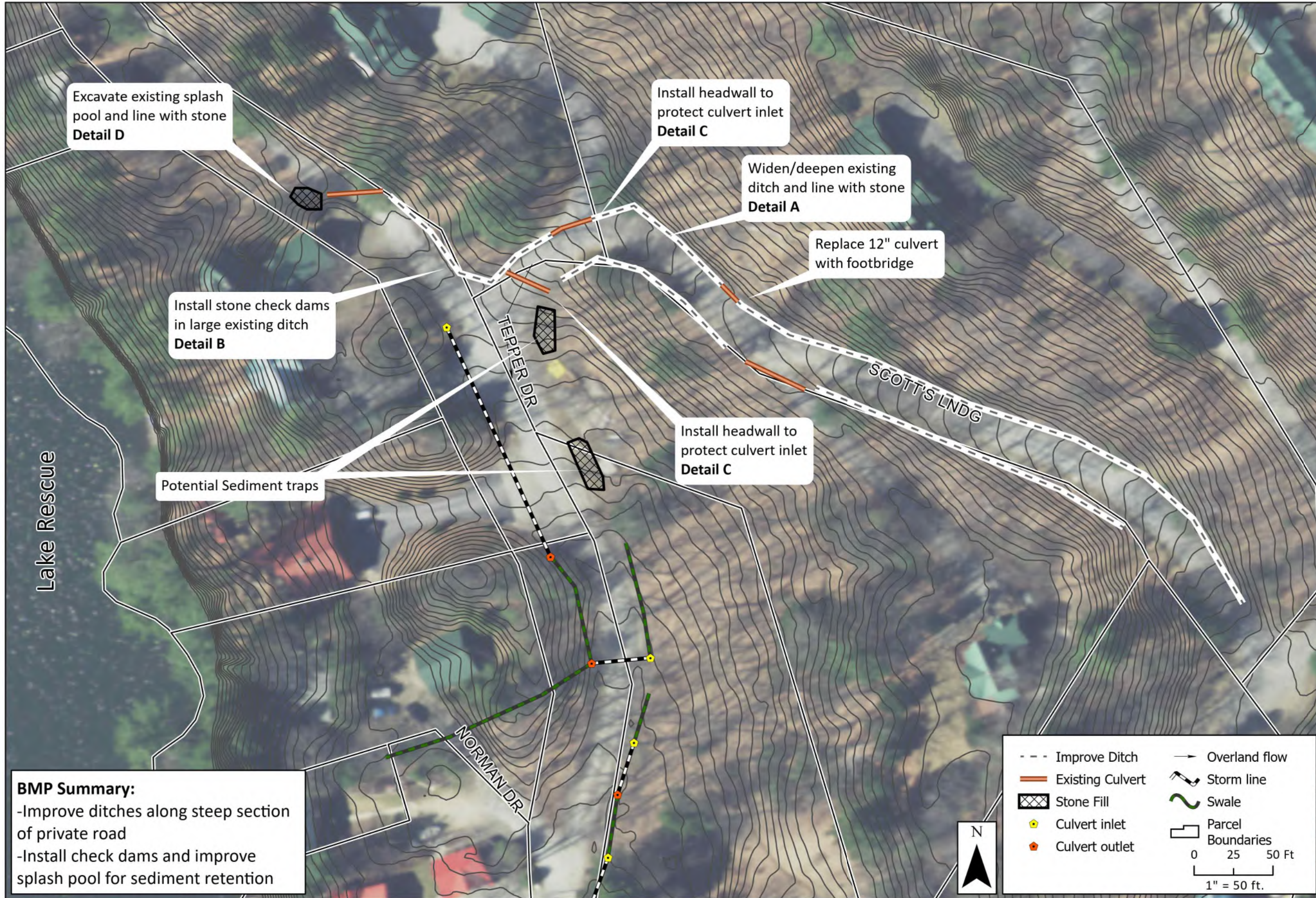
*P load (annual) is estimated from land cover values for each lake segment.

**Estimates include additional P loading from erosion or other sources.



APPENDIX D

**30% Conceptual Designs
(11"x17")**



BMP Summary:
 -Improve ditches along steep section of private road
 -Install check dams and improve splash pool for sediment retention

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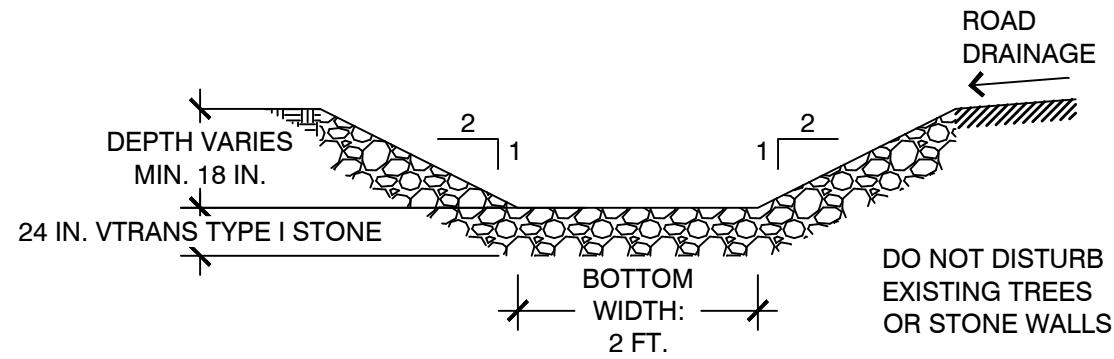
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Notes:
 -Depth to groundwater and soil infiltration must be verified prior to construction
 -Contours based on 0.7-M LIDAR DEM
 -Project locations and drainage areas based on field visits by FEA during summer and fall of 2020

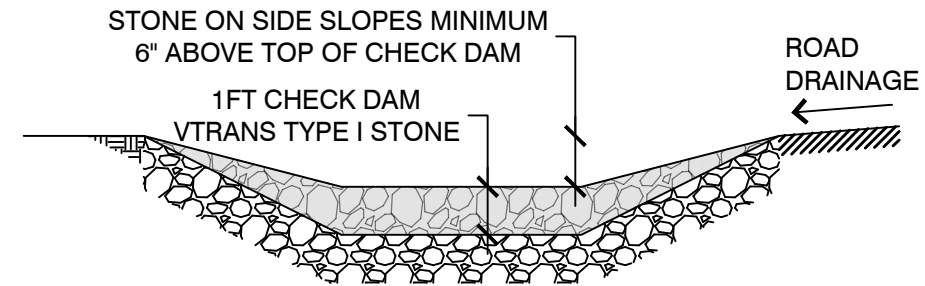
30% Conceptual Design
Project LR-01
Ludlow SWMP

FCP	JHB
Drawn	Checked
1" = 60 ft.	
Scale	
4/14/2021	
Date	
Project LR-01	
Sheet 1	
SHEET NO.	

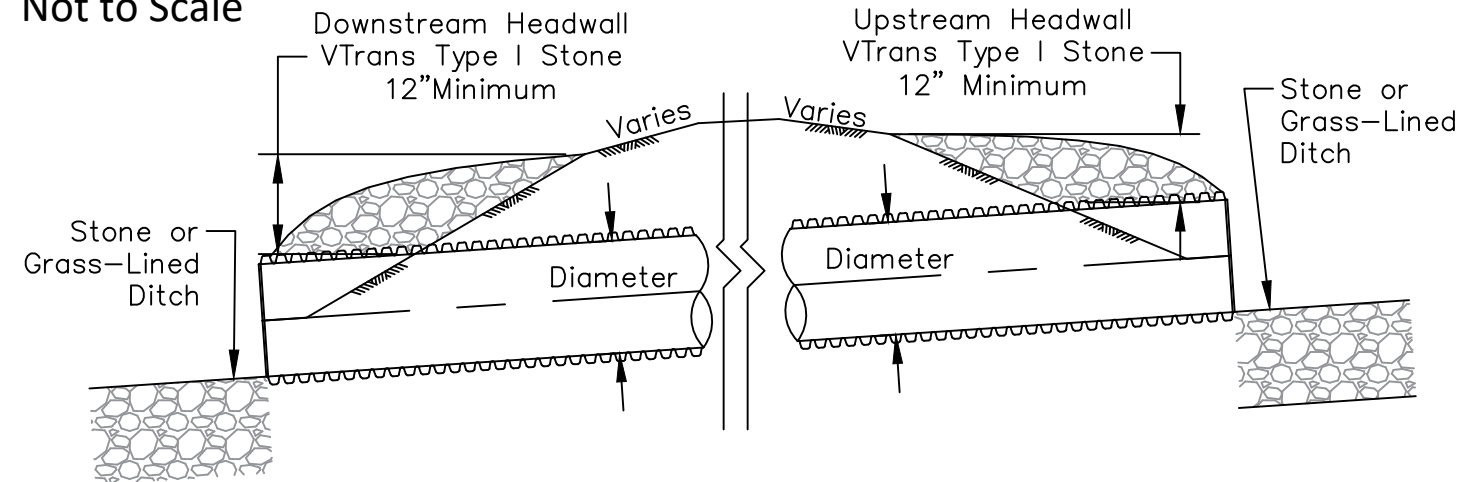
Detail A: Stone Lined Ditch Typical Detail
Not to Scale



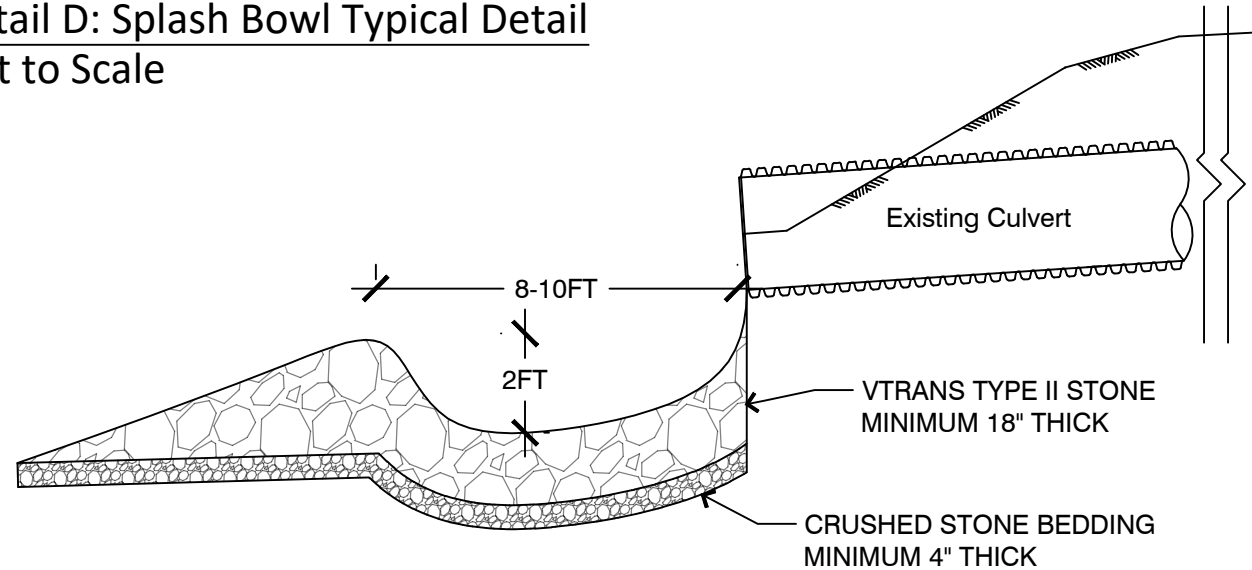
Detail B: Check Dam Typical Detail
Not to Scale



Detail C: Culvert Headwall Typical Detail
Not to Scale



Detail D: Splash Bowl Typical Detail
Not to Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Price	Cost
Mobilization/Demobilization	1	LS	\$ 1,500	\$ 1,500
Common Excavation	15	CY	\$ 25	\$ 375
Trucking	15	CY	\$ 20	\$ 300
Improve Stone Lined Ditch	1000	LF	\$ 20	\$ 20,000
Stone (8" minus)	15	CY	\$ 40	\$ 600
Stone (3/4" crushed)	5	CY	\$ 40	\$ 200
Stone Check Dam	3	EA	\$ 100	\$ 300
Install Footbridge	1	LS	\$ 500	\$ 500
Misc. Erosion Control	1	LS	\$ 1,000	\$ 1,000
Final Design & Permitting				\$ 2,000
Construction Oversight				\$ 1,000
			Subtotal	\$ 27,775
			Contingency (20%)	\$ 5,560
			Total	\$ 33,335

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30% Conceptual Design
Project LR-1
Ludlow SWMP

EHB DRAWN JHB CHECKED

SCALE: As Shown

DATE: 4/21/2021

PROJECT LR-1
SHEET 2

SHEET NO.



BMP Summary:
 -Existing road ditch is undersized and eroding with poor drainage at northern driveway
 -Existing lake access is eroded

New Culvert/ Pipe	Parcel Boundaries
New Stone-Lined Ditch	2-Foot Contours
Forebay	Proposed Surface Infiltration
Stone Fill	

0 20 40 Ft
1" = 40 ft.

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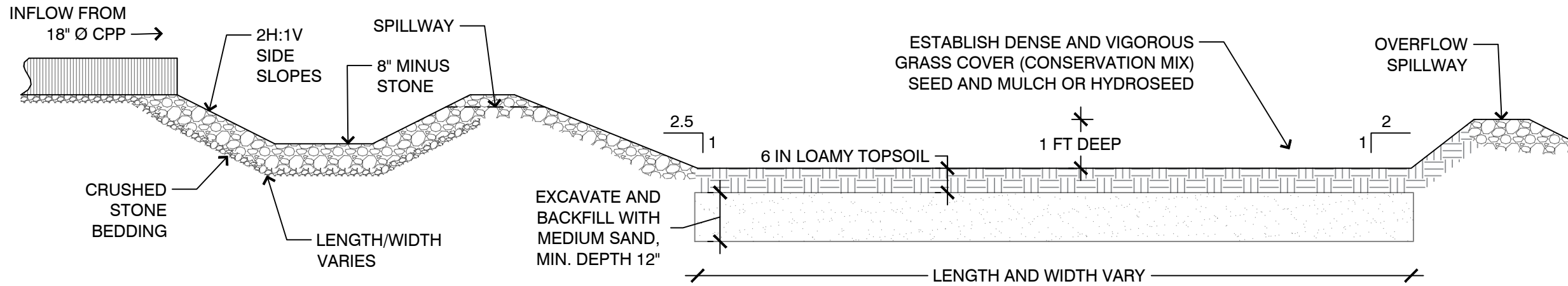
Notes:
 -Depth to groundwater and soil infiltration must be verified prior to construction
 -Contours based on 0.7-M LIDAR DEM
 -Project locations and drainage areas based on field visits by FEA during summer and fall of 2020

30% Conceptual Design
Project LR-06
Ludlow SWMP

FCP	JHB
Drawn	Checked
1" = 40 ft.	
Scale	
4/13/2021	
Date	
Project LR-06	
Sheet 1	
SHEET NO.	

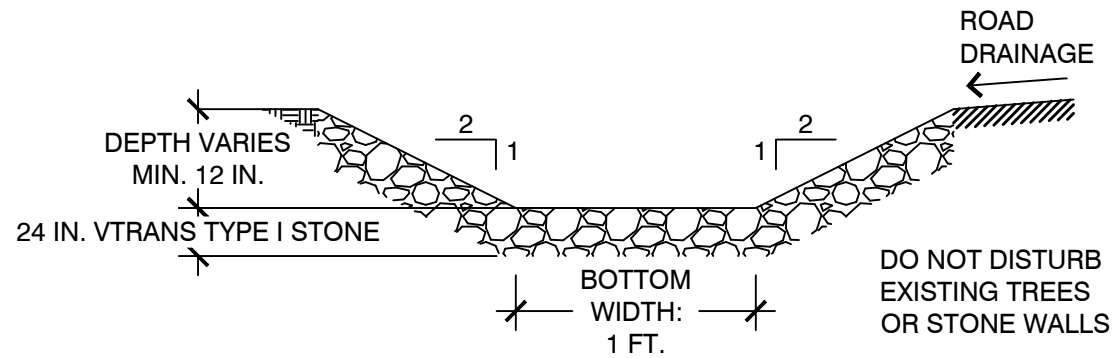
Detail A: Infiltration Feature with Sediment Forebay Typical Profile

Not to Scale



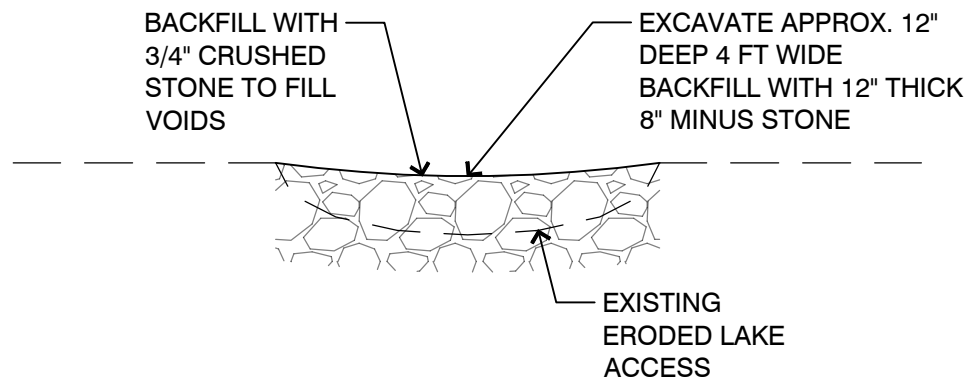
Detail B: Stone Lined Ditch Typical Section

Not to Scale



Detail C: Stone Armored Lake Access

Not to Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Price	Cost
Mobilization/Demobilization	1	LS	\$ 1,000	\$ 1,000
Common Excavation and Soil Amendment	20	CY	\$ 25	\$ 500
Trucking	20	CY	\$ 20	\$ 400
Topsoil/Compost	5	CY	\$ 50	\$ 250
Stone Lined Ditch	330	LF	\$ 25	\$ 8,250
Stone (8" minus)	25	CY	\$ 40	\$ 1,000
Stone (3/4" crushed)	10	CY	\$ 40	\$ 400
Laborer	8	HR	\$ 40	\$ 320
Misc. Erosion Control	1	LS	\$ 1,000	\$ 1,000
18" Cross Culvert	1	LS	\$ 2,000	\$ 2,000
Final Design & Permitting				\$ 3,000
Construction Oversight				\$ 1,000
Subtotal			\$	19,120
Contingency (20%)			\$	3,820
Total			\$	22,940



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30% Conceptual Design
Project LR-06
Ludlow SWMP

EHB DRAWN JHB CHECKED

SCALE: As Shown

DATE: 4/21/2021

PROJECT LR-06
SHEET 2

SHEET NO.



BMP Summary:
 -Drainage Area: 2.4 acres, 51% Impervious
 -Install grass and stone swales/ditches
 -Install sediment traps

Improve existing ditches and line with stone
Detail A

Install shallow stone swale - drivable
Detail B

Stone lined sediment traps
Detail C

Grassed conveyance swales
Detail D

Proposed Conveyance Swale	2-Foot Contours
Improve Ditch	Overland flow
Stabilized Flow Path	Storm line
Culvert inlet	Stream
Culvert outlet	Swale
	Parcel Boundaries

0 25 50 Ft
1" = 50 ft.

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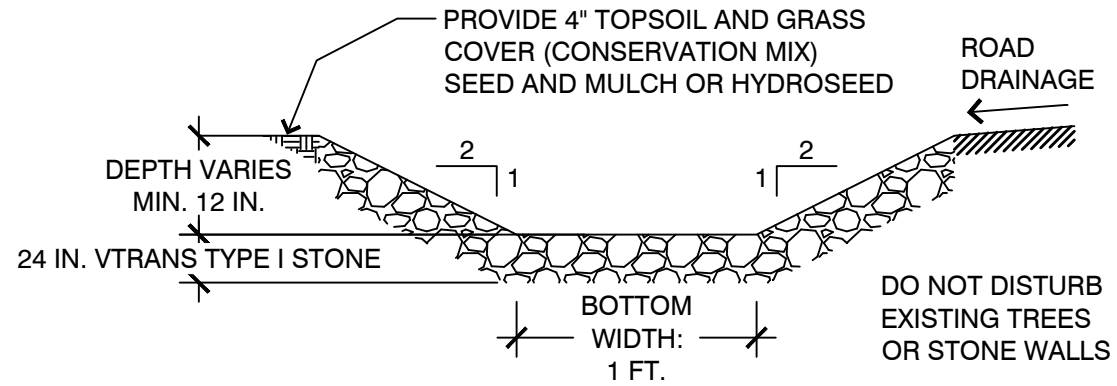
Notes:
 -Depth to groundwater and soil infiltration must be verified prior to construction
 -Contours based on 0.7-M LIDAR DEM
 -Project locations and drainage areas based on field visits by FEA during summer and fall of 2020

30% Conceptual Design
Project LT-02
Ludlow SWMP

FCP	JHB
Drawn	Checked
1" = 50 ft.	
Scale	
4/13/2021	
Date	
Project LT-02	
Sheet 1	
SHEET NO.	

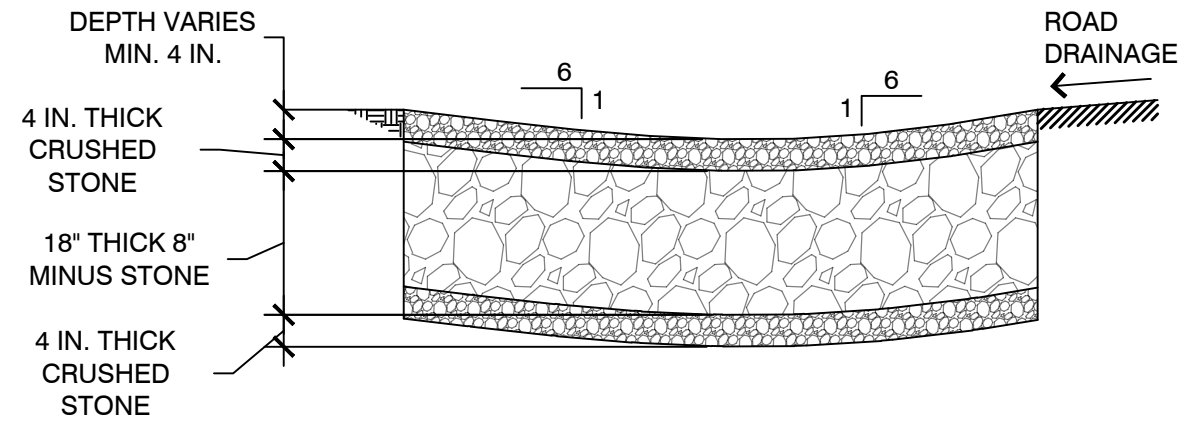
Detail A: Stone Lined Ditch Typical Detail

Not to Scale



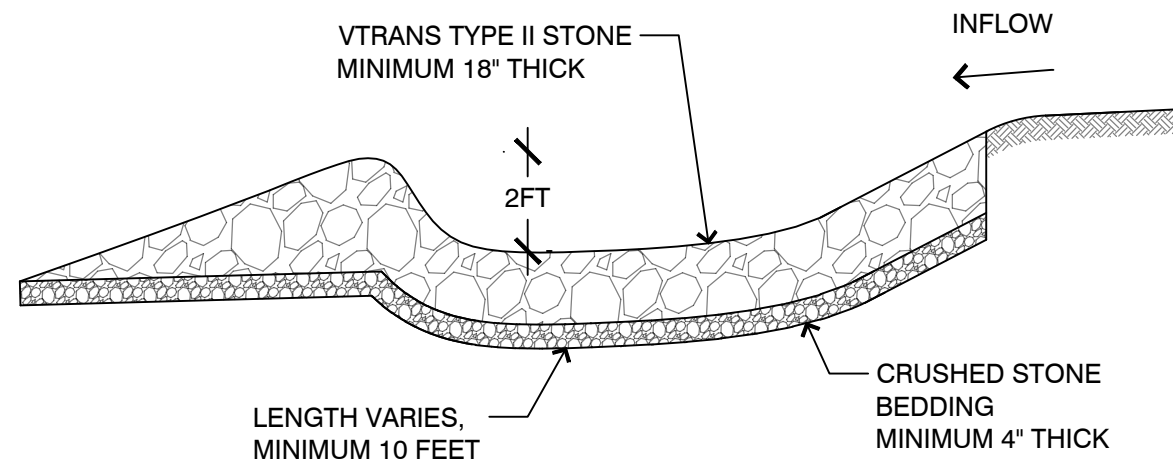
Detail B: Drivable Stone Lined Ditch Typical Detail

Not to Scale



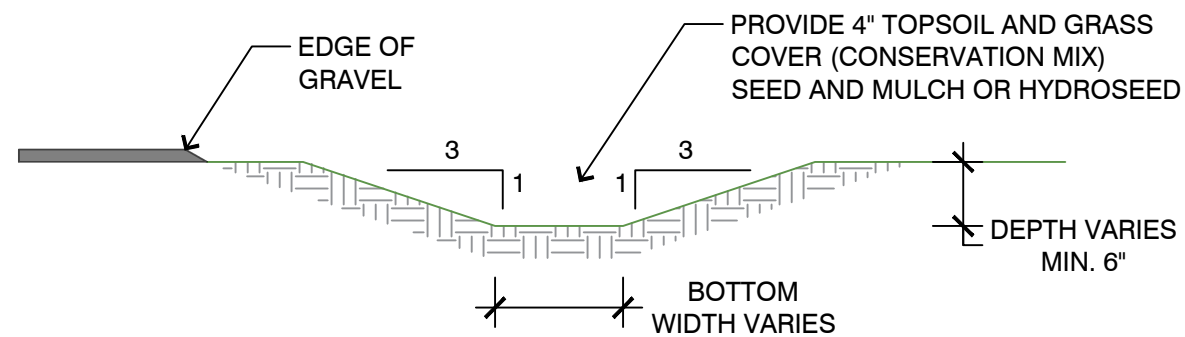
Detail C: Sediment Trap Typical Detail

Not to Scale



Detail D: Grass Conveyance Swale Typical Detail

Not to Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Price	Cost
Mobilization/Demobilization	1	LS	\$ 2,000	\$ 2,000
Common Excavation	75	CY	\$ 25	\$ 1,875
Trucking	75	CY	\$ 20	\$ 1,500
Improve Stone Lined Ditch	220	LF	\$ 20	\$ 4,400
Stone (8" minus)	75	CY	\$ 40	\$ 3,000
Stone (3/4" crushed)	20	CY	\$ 40	\$ 800
Grass Conveyance Swale	450	LF	\$ 10	\$ 4,500
Misc. Erosion Control	1	LS	\$ 1,000	\$ 1,000
Final Design & Permitting				\$ 2,000
Construction Oversight				\$ 1,000
			Subtotal	\$ 22,075
			Contingency (20%)	\$ 4,420
			Total	\$ 26,495



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30% Conceptual Design
Project LT-02

Ludlow SWMP

EHB
DRAWN

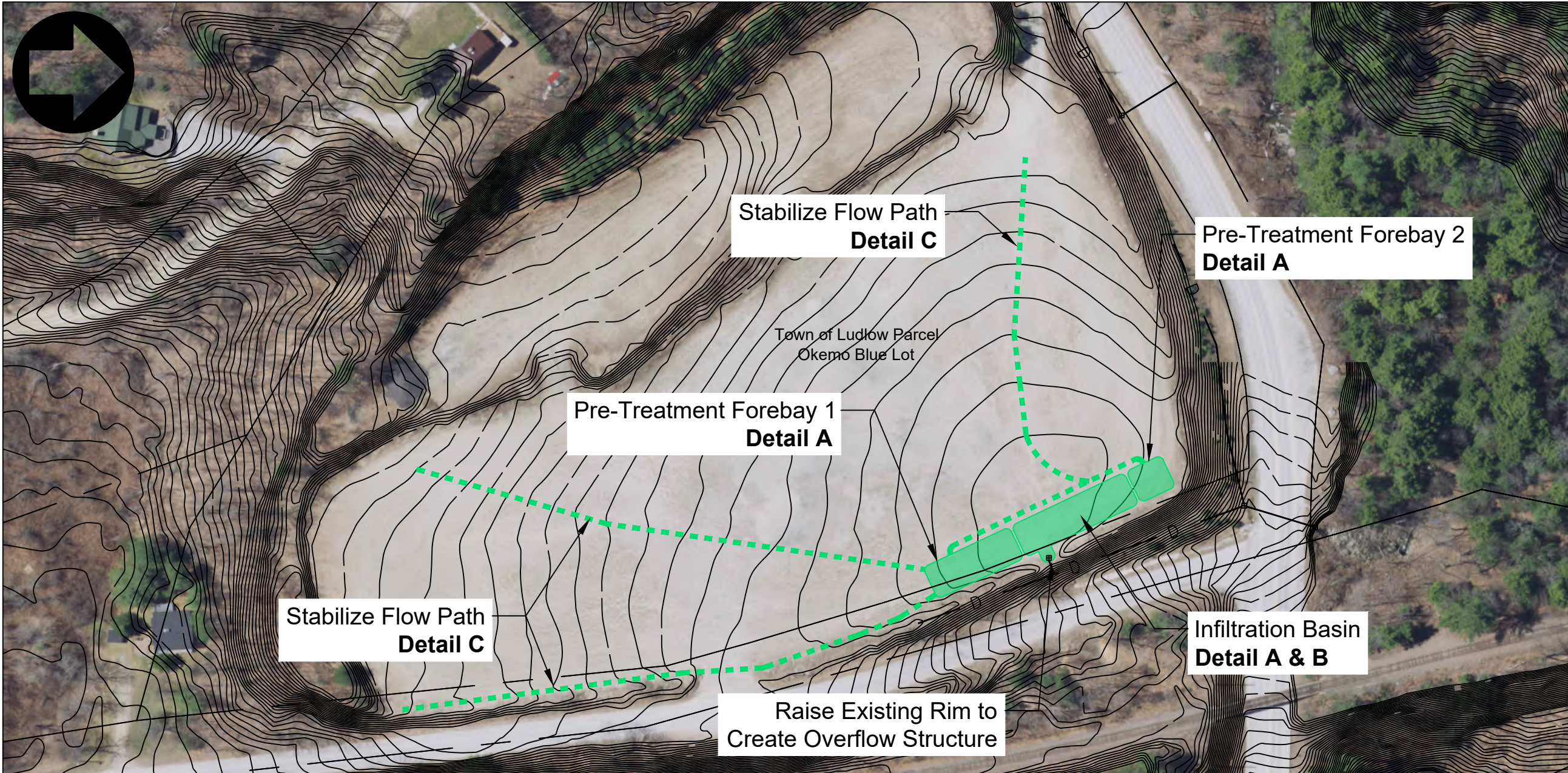
JHB
CHECKED

As Shown
SCALE

4/21/2021
DATE

PROJECT LT-02
SHEET 2

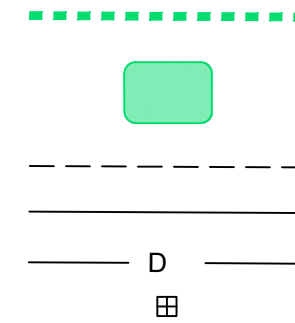
SHEET NO.



BMP Summary:

- Drainage Area: 5.66 acres, 82% impervious
- Pretreatment provided by grassed forebays
- Infiltration basin with maximum depth of 3 feet
- Maximum 24-hour drain time.
- Overflow to existing catch basin.
- Storage Volume: 16,200 cubic feet

Stabilized Flow Path/Swale
 Proposed Infiltration
 2 Foot Contours
 Parcel Line
 Existing Storm Drain
 Existing Catch Basin



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**30% Conceptual Design
 Project LT-4 - Plan
 Ludlow SWMP**

MCB DRAWN	CMH CHECKED
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SCALE 1"=100'

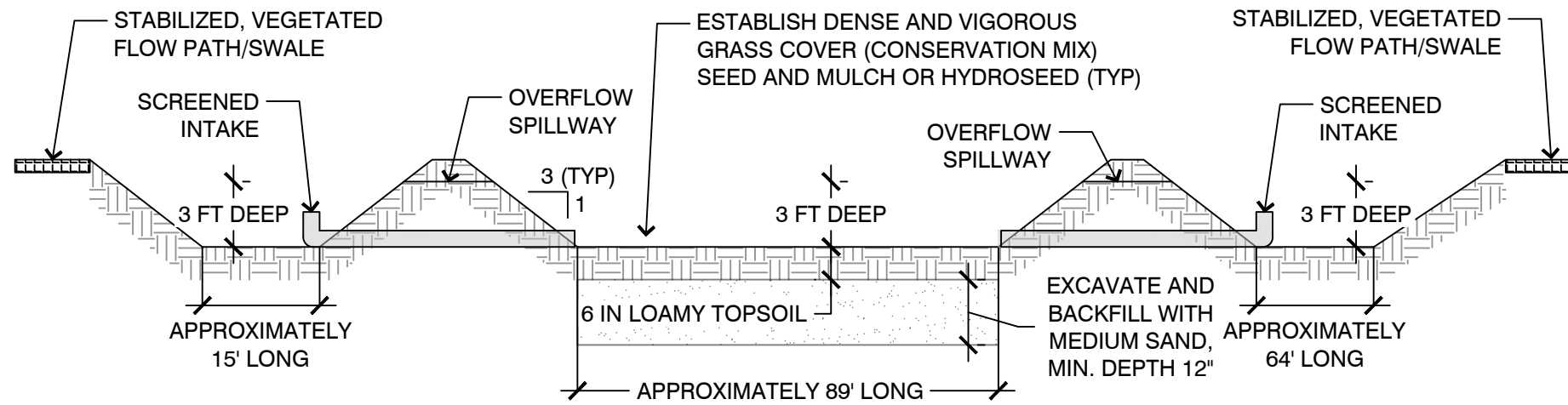
DATE 4/20/2021

PROJECT LT-04
SHEET 1

SHEET NO.

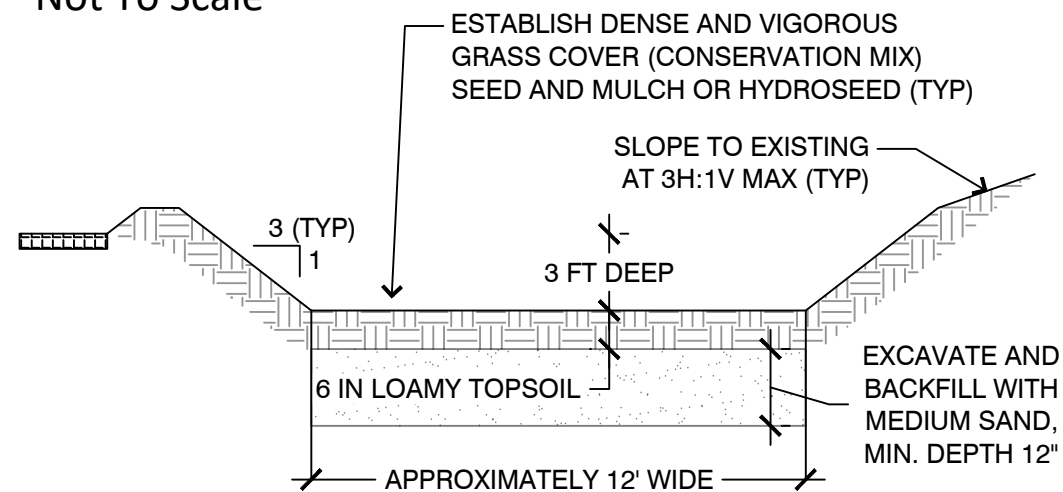
Detail A: Infiltration Feature Typical Profile

Not to Scale



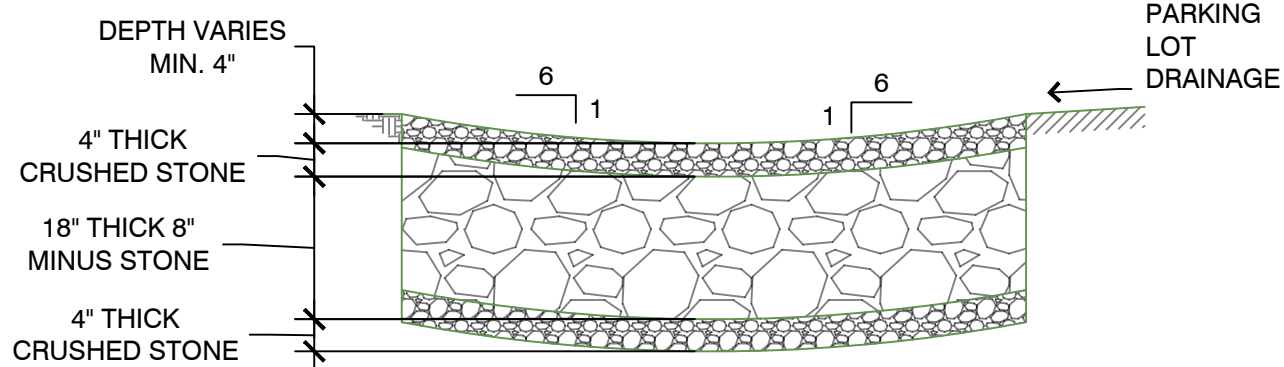
Detail B: Infiltration Feature Typical Section

Not To Scale



Detail C: Stabilized Flow Path Typical Section

Not To Scale



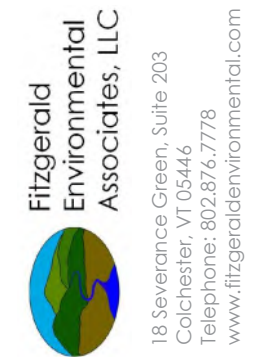
Note:

- Infiltration rate shall be verified during final design. Infiltration rate shall be a minimum of 1.5 inches per hour.

Preliminary Cost Opinion

Item	Quantity	Unit	Unit Cost	Item Total
Common Excavation	485	CY	\$25.00	\$12,125
Berm Construction	20	CY	\$15.00	\$300
Infiltration Sand	40	CY	\$40.00	\$1,600
Flow Path Stabilization	1,420	LF	\$20.00	\$28,400
Pipe	45	LF	\$45.00	\$2,025
Structure Adjustment	1	EA	\$1,000.00	\$1,000
Erosion Control	1	LS	\$2,000.00	\$2,000
Restoration	1	LS	\$2,000.00	\$2,000
Mobilization/Demobilization	1	LS	\$5,550.00	\$5,550
Final Design & Permitting				\$7,000
Construction Oversight				\$4,000

Construction Subtotal: \$66,000.00
 Contingency (20%): \$13,000.00
Total: \$79,000.00



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30% Conceptual Design
Project LT-4 - Details
Ludlow SWMP

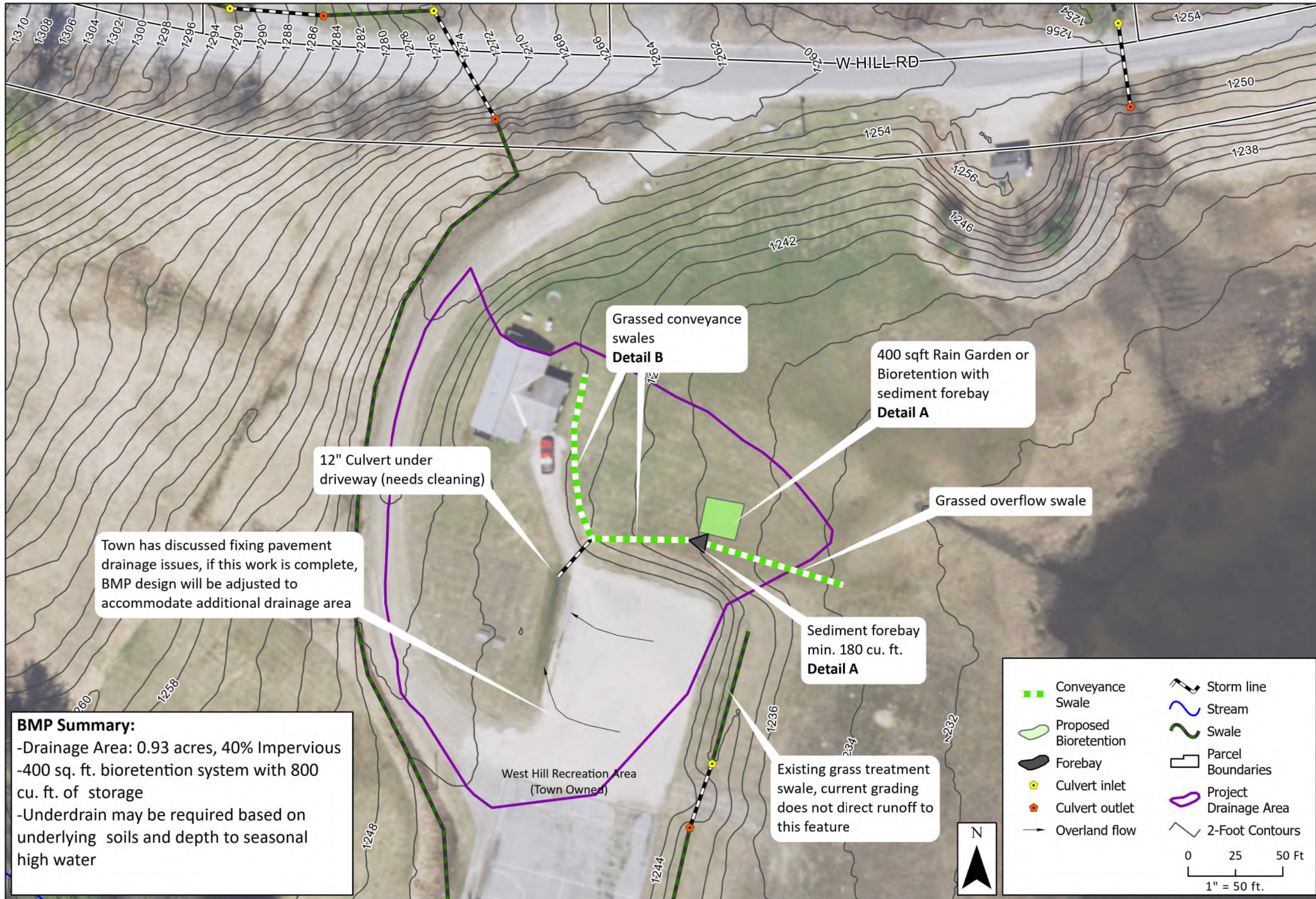
MCB CMH
 DRAWN CHECKED

As Shown
 SCALE

4/20/2021
 DATE

PROJECT LT-04
SHEET 2

SHEET NO.



BMP Summary:
 -Drainage Area: 0.93 acres, 40% Impervious
 -400 sq. ft. bioretention system with 800 cu. ft. of storage
 -Underdrain may be required based on underlying soils and depth to seasonal high water

Town has discussed fixing pavement drainage issues, if this work is complete, BMP design will be adjusted to accommodate additional drainage area

12" Culvert under driveway (needs cleaning)

Grassed conveyance swales
Detail B

400 sqft Rain Garden or Bioretention with sediment forebay
Detail A

Grassed overflow swale

Sediment forebay min. 180 cu. ft.
Detail A

Existing grass treatment swale, current grading does not direct runoff to this feature

Conveyance Swale	Storm line
Proposed Bioretention	Stream
Forebay	Swale
Culvert inlet	Parcel Boundaries
Culvert outlet	Project Drainage Area
Overland flow	2-Foot Contours

0 25 50 Ft
 1" = 50 ft.

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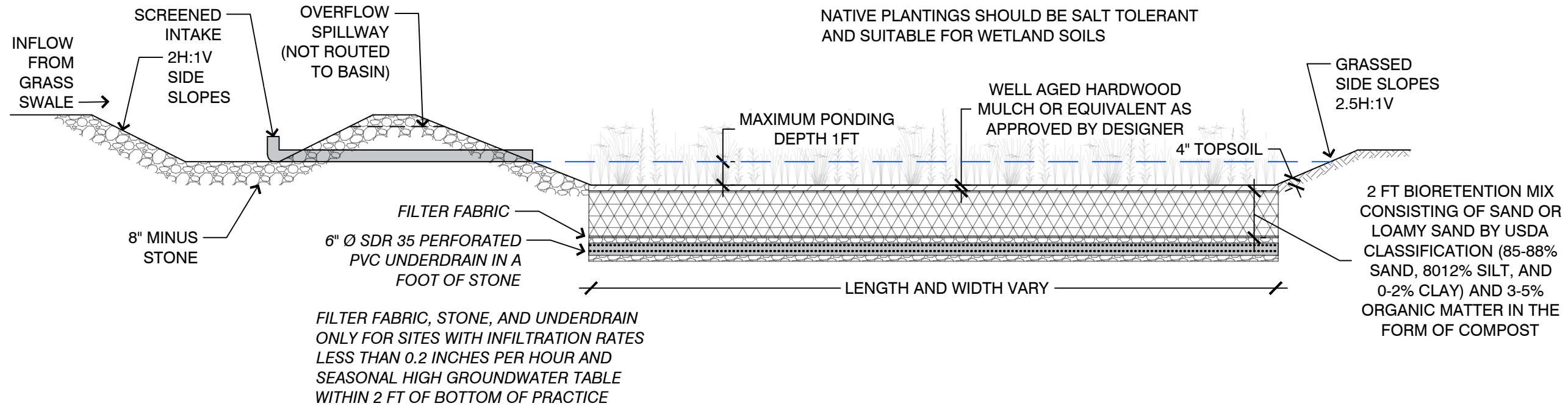
Notes:
 -Depth to groundwater and soil infiltration must be verified prior to construction
 -Contours based on 0.7-M LIDAR DEM
 -Project locations and drainage areas based on field visits by FEA during summer and fall of 2020

30% Conceptual Design
Project LT-06
Ludlow SWMP

FCP	JHB
Drawn	Checked
1" = 50 ft.	
Scale	4/13/2021
Date	Project LT-06
Sheet 1	
SHEET NO.	

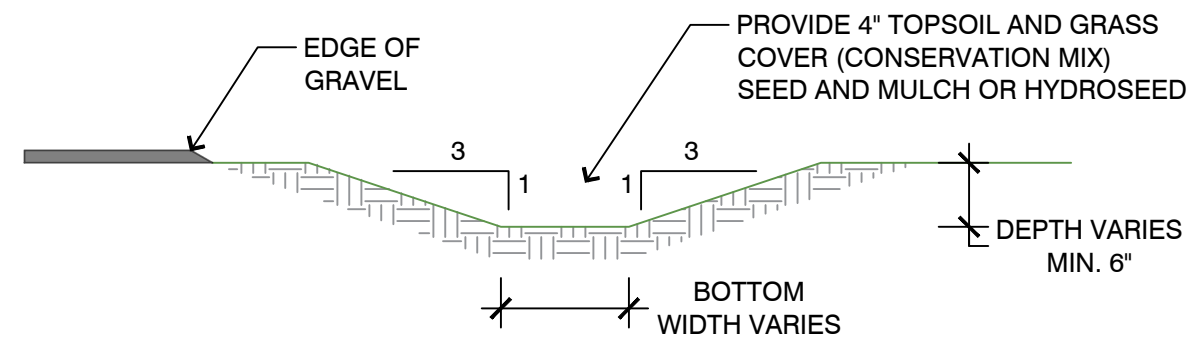
Detail A: Rain Garden or Bioretention Feature with Sediment Forebay Typical Profile

Not to Scale



Detail B: Grass Conveyance Swale Typical Section

Not To Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Price	Cost
Mobilization/Demobilization	1	LS	\$ 1,000	\$ 1,000
Common Excavation and Soil Amendment	50	CY	\$ 25	\$ 1,250
Trucking	50	CY	\$ 20	\$ 1,000
Topsoil/Compost	10	CY	\$ 50	\$ 500
Bioretention Media	20	CY	\$ 50	\$ 1,000
Grass Swale	250	LF	\$ 10	\$ 2,500
Stone (8" minus)	10	CY	\$ 40	\$ 400
Plantings	20	EA	\$ 15	\$ 300
Laborer	16	HR	\$ 40	\$ 640
Misc. Erosion Control	1	LS	\$ 2,000	\$ 2,000
Culvert Cleanout	1	LS	\$ 500	\$ 500
Final Design & Permitting			\$	\$ 3,000
Construction Oversight			\$	\$ 2,000
			Subtotal	\$ 16,090
			Contingency (20%)	\$ 3,220
			Total	\$ 19,310

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30% Conceptual Design
Project LT-06

Ludlow SWMP

EHB
DRAWN

JHB
CHECKED

As Shown

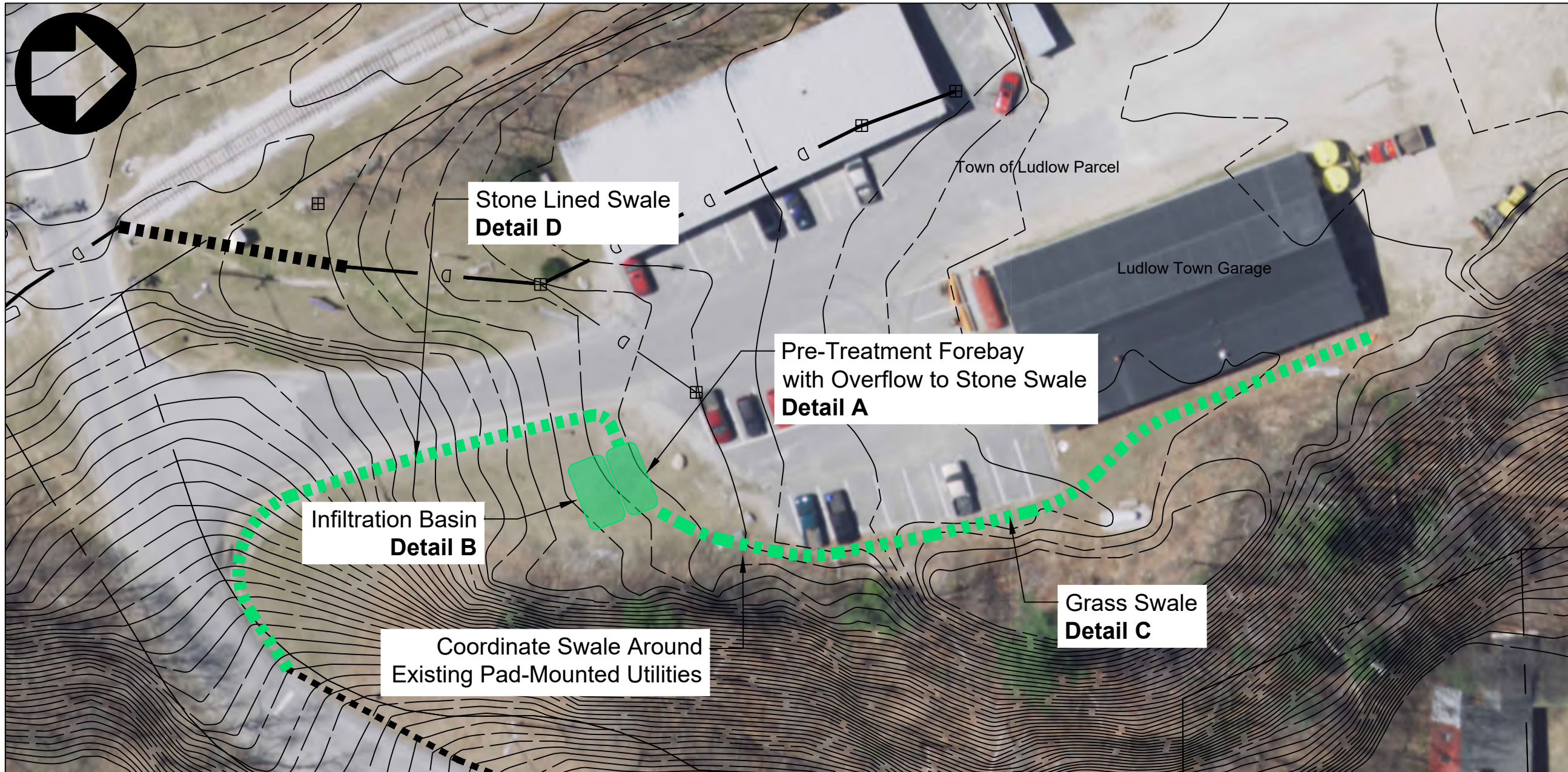
SCALE

4/21/2021

DATE

PROJECT LT-06
SHEET 2

SHEET NO.



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**30% Conceptual Design
 Project LT-9 - Plan
 Ludlow SWMP**

MCB DRAWN | CMH CHECKED

SCALE: 1"=40'

DATE: 4/20/2021

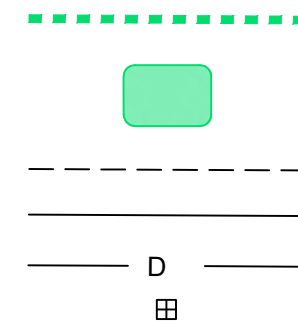
PROJECT LT-09
SHEET 1

SHEET NO.

BMP Summary:

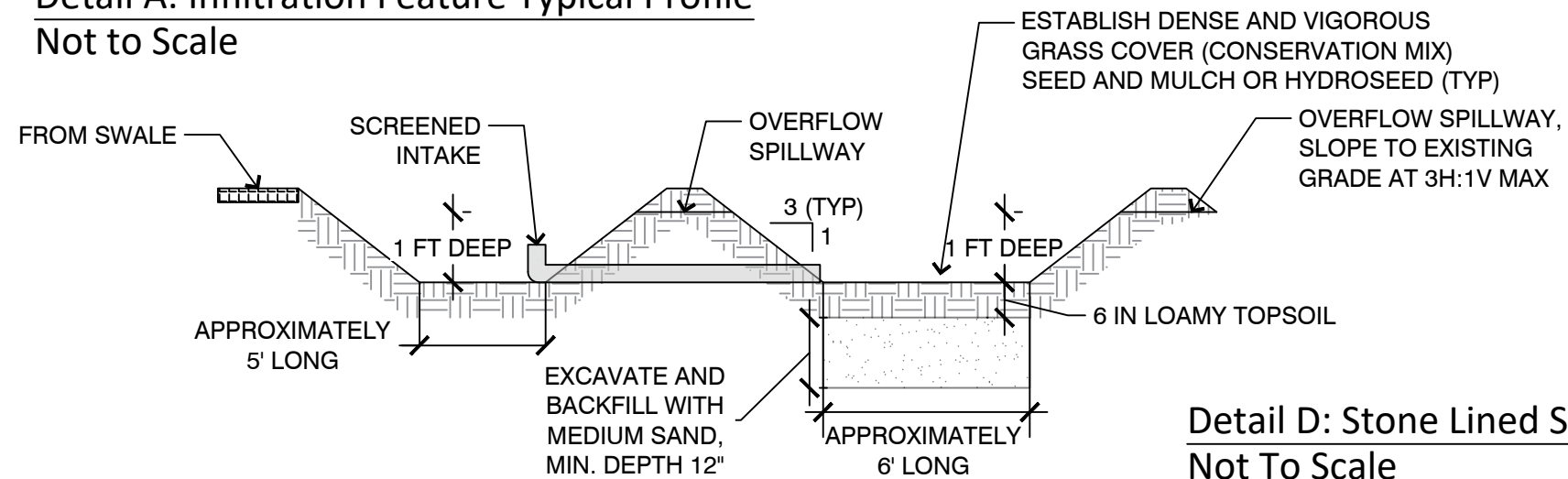
- Drainage Area: 0.32 acres, 53% impervious
- Pretreatment provided by grassed forebay
- Infiltration basin with maximum depth of 1 foot
- Maximum 24-hour drain time.
- Overflow to existing grass and paved swales.
- Storage Volume: 690 cubic feet

Grass/Stone Swale
 Proposed Infiltration
 2 Foot Contours
 Parcel Line
 Existing Storm Drain
 Existing Catch Basin



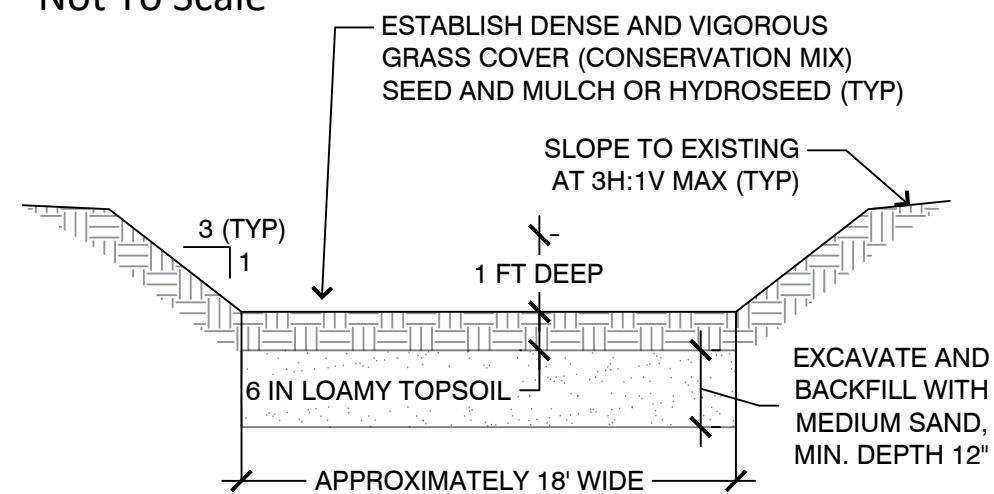
Detail A: Infiltration Feature Typical Profile

Not to Scale



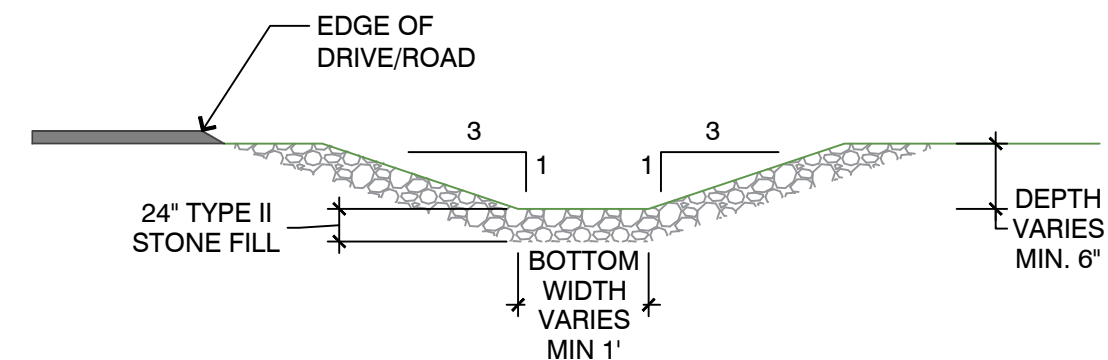
Detail B: Infiltration Feature Typical Section

Not To Scale



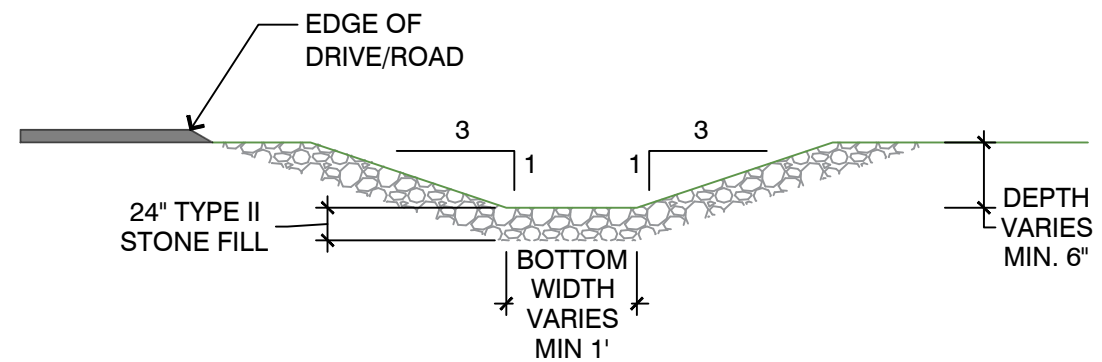
Detail C: Grass Conveyance Swale Typical Section

Not To Scale



Detail D: Stone Lined Swale Typical Section

Not To Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Cost	Item Total
Common Excavation	20	CY	\$25.00	\$500
Berm Construction	10	CY	\$15.00	\$150
Infiltration Sand	5	CY	\$40.00	\$200
Grass Swale Earthwork	265	LF	\$10.00	\$2,650
Stone Lined Swale	190	LF	\$20.00	\$3,800
Pipe	8	LF	\$45.00	\$360
Erosion Control	1	LS	\$1,000.00	\$1,000
Restoration	1	LS	\$1,000.00	\$1,000
Mobilization/Demobilization	1	LS	\$1,340.00	\$1,340
Final Design & Permitting				\$3,000
Construction Oversight				\$2,000
Construction Subtotal:				\$16,000
Contingency (20%):				\$3,000
Total:				\$19,000



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30% Conceptual Design
 Project LT-9 - Details

Ludlow SWMP

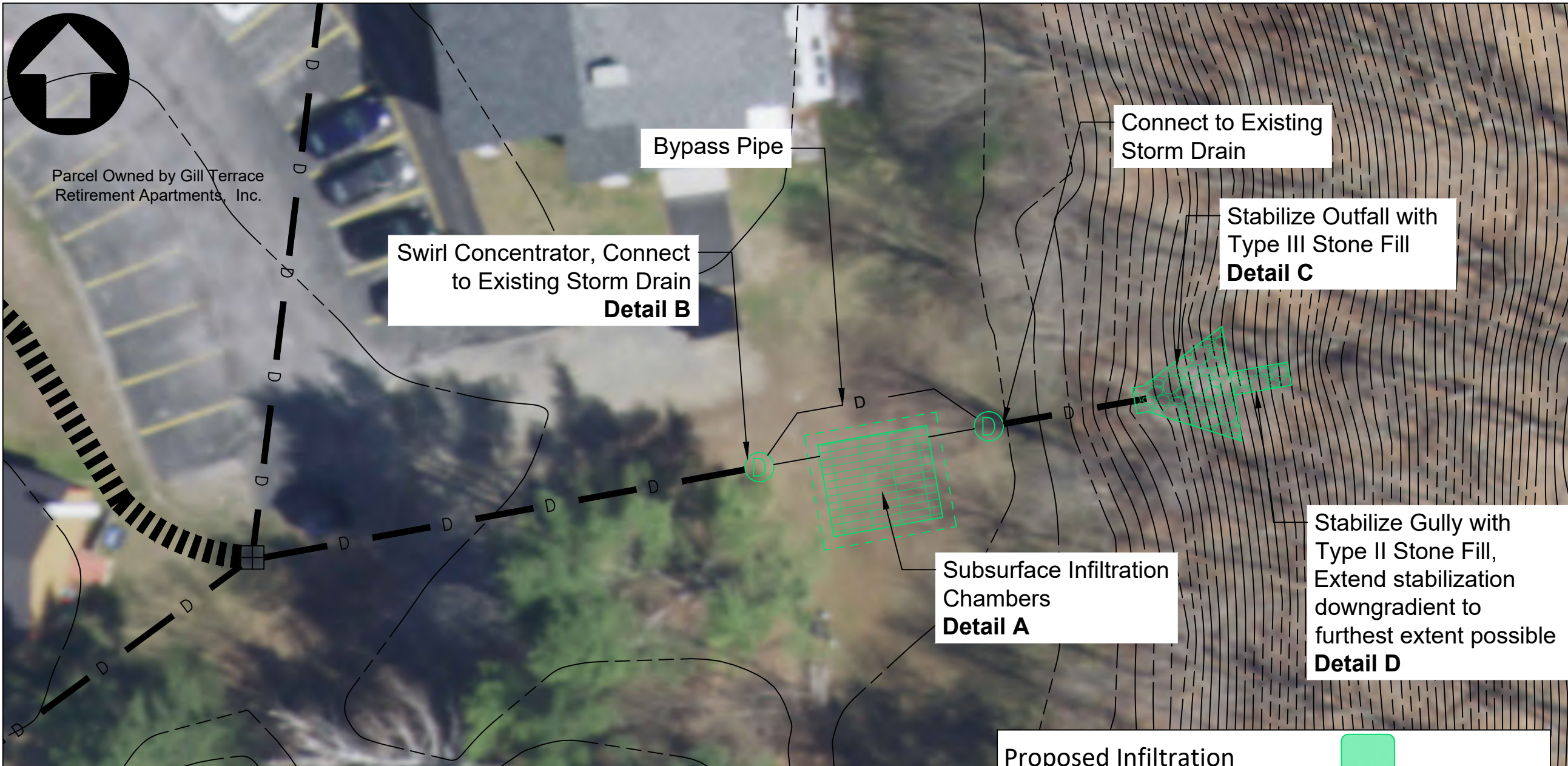
MCB DRAWN CMH CHECKED

SCALE As Shown

DATE 4/20/2021

SHEET NO.

PROJECT LT-09
SHEET 2



BMP Summary:

- Drainage Area: 1.81 acres, 44% impervious
- Pretreatment provided by swirl separator.
- Infiltration chambers with depth to bottom of practice of 6 feet.
- Maximum 24-hour drain time.
- Overflow to existing storm drain.
- Storage Volume: 3,000 cubic feet

Proposed Infiltration	
Proposed Drain Manhole	
Proposed Subsurface Infiltration Chambers	
Proposed Rip Rap	
2 Foot Contours	
Parcel Line	
Existing Storm Drain	
Existing Catch Basin	

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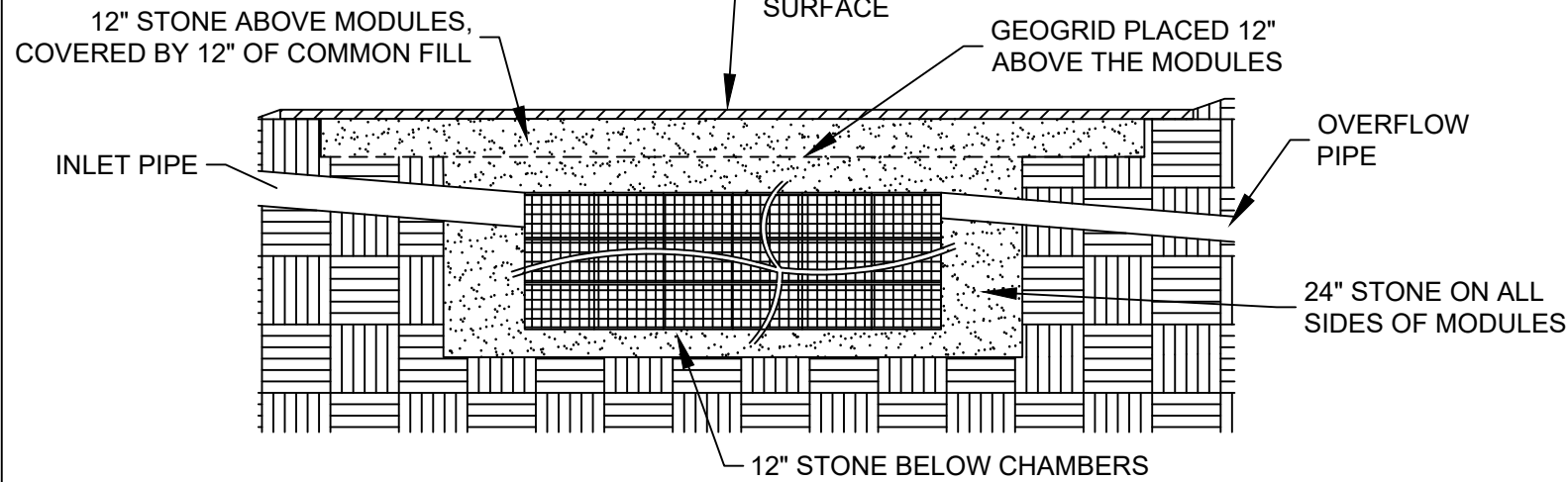
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30% Conceptual Design
Project LT-30 - Plan
Ludlow SWMP

MCB DRAWN	CMH CHECKED
SCALE 1"=20'	
DATE 4/20/2021	
PROJECT LT-30 SHEET 1	
SHEET NO.	

Detail A: Infiltration Feature Typical Profile

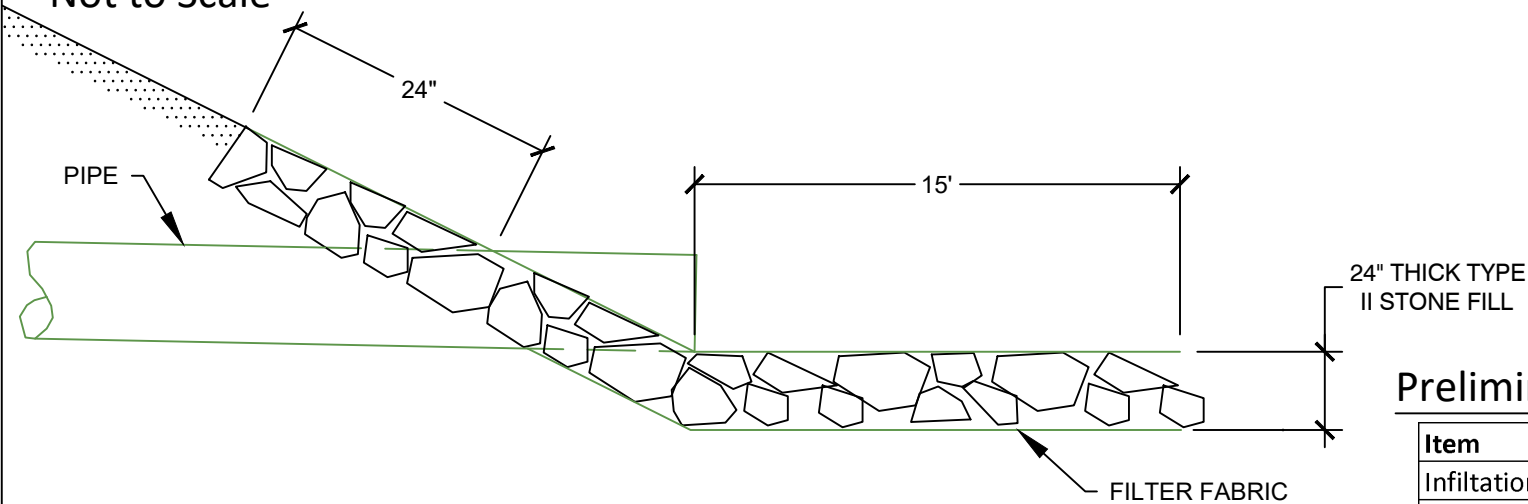
Not to Scale



Note: Chamber depth and footprint are dependent on filtration rates and shall be sized to ensure full dewatering in 24 hours.

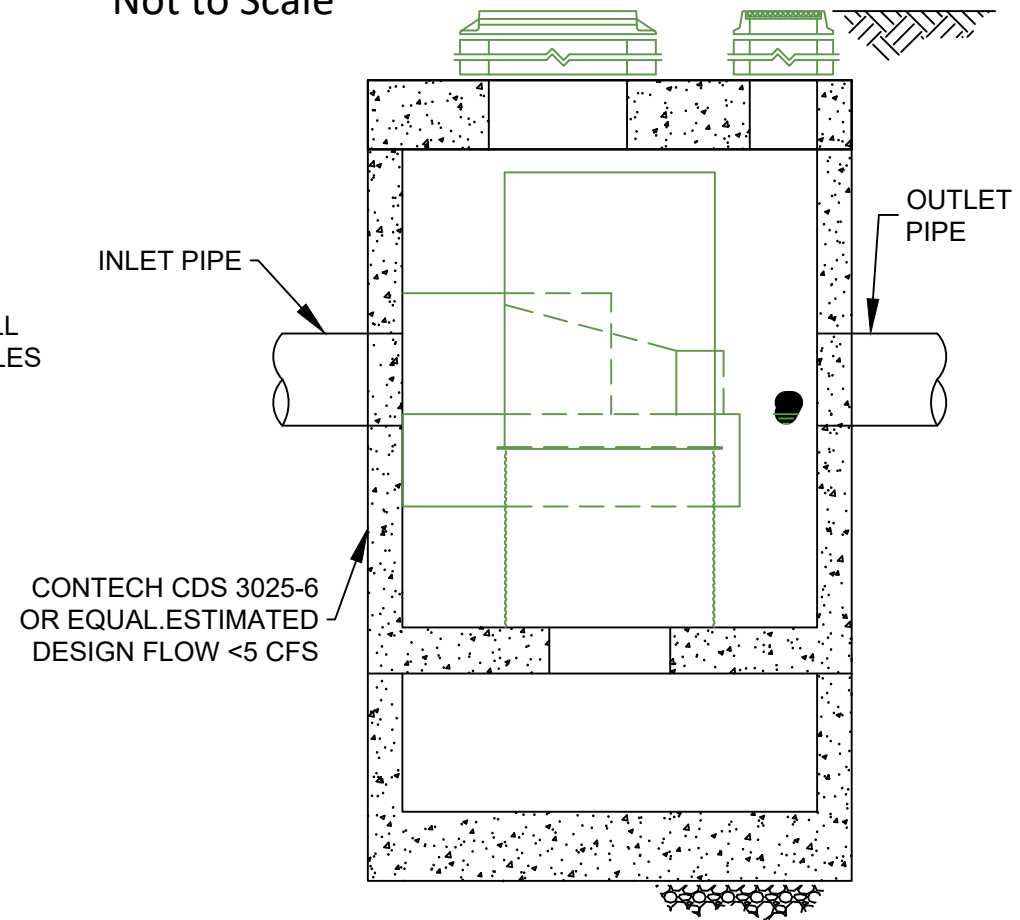
Detail B: Outfall Stabilization

Not to Scale



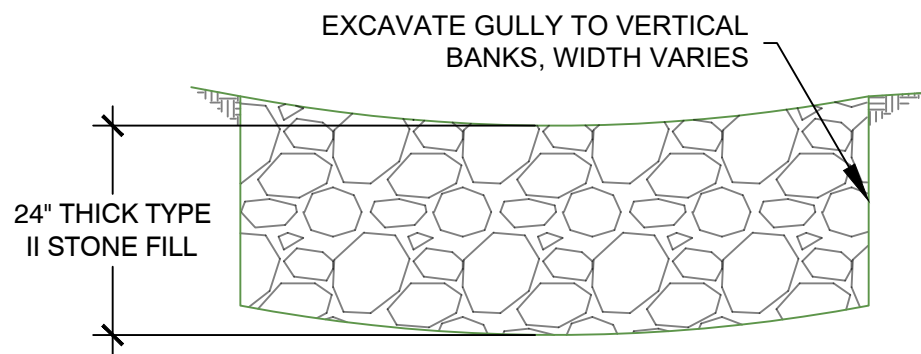
Detail B: Pre-Treatment Swirl Separator

Not to Scale



Detail D: Gully Stabilization

Not to Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Cost	Item Total
Infiltration Chamber System	1	LS	\$15,000.00	\$15,000
Hydrodynamic Separator	1	EA	\$30,000.00	\$30,000
PVC Manhole	1	EA	\$2,500.00	\$2,500
Pipe (15")	70	LF	\$55.00	\$3,850
Common Excavation	14	CY	\$25.00	\$350
Stone Fill (Type II/III)	20	CY	\$75.00	\$1,500
Erosion Control	1	LS	\$3,000.00	\$3,000
Restoration	1	LS	\$1,000.00	\$1,000
Mobilization/Demobilization	1	LS	\$7,800.00	\$7,800
Final Design & Permitting				\$7,000
Construction Oversight				\$4,000

Construction Subtotal: \$76,000
 Contingency (20%): \$15,000
Total: \$91,000

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**30% Conceptual Design
 Project LT-30 - Details
 Ludlow SWMP**

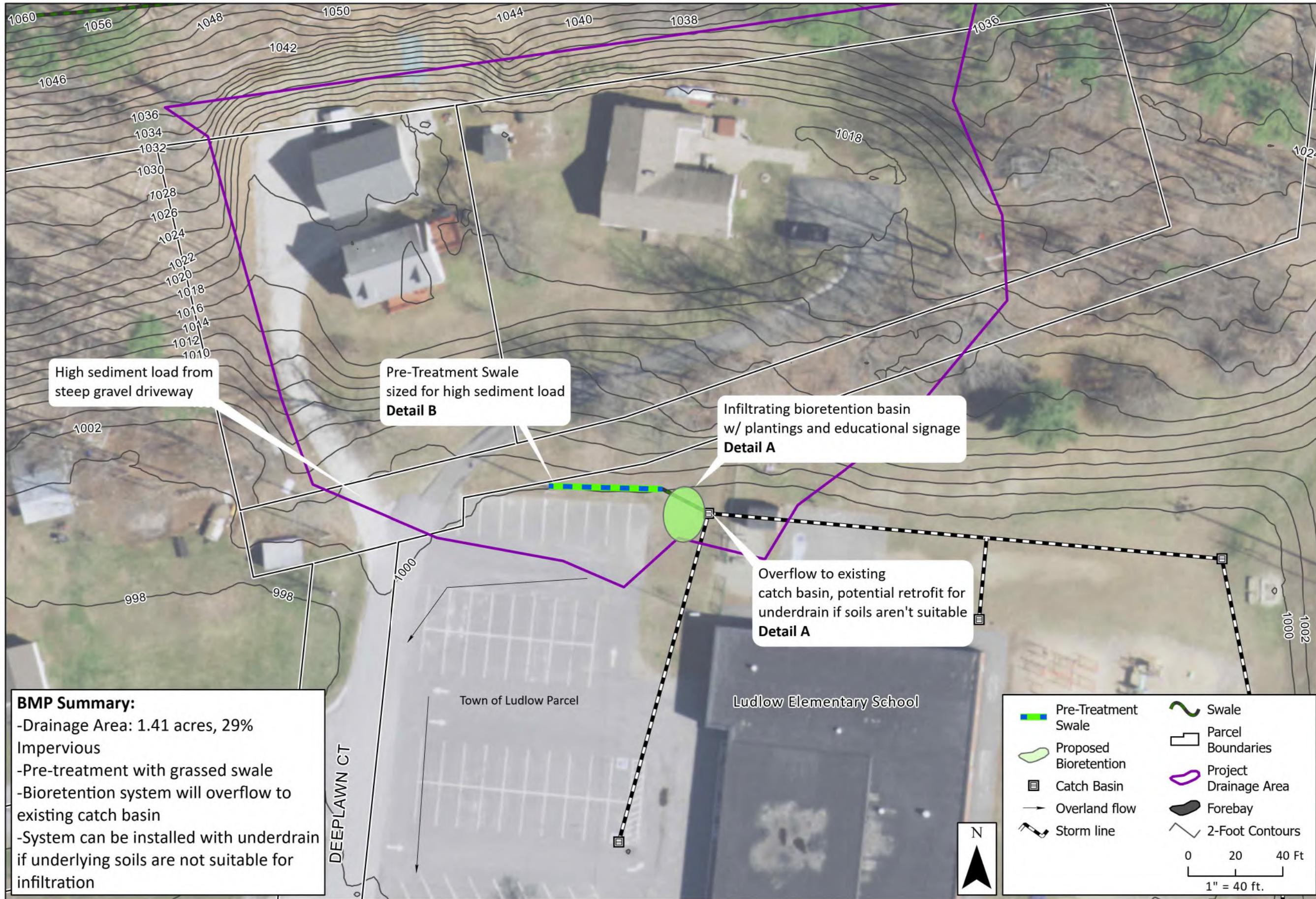
MCB DRAWN CMH CHECKED

SCALE: As Shown

DATE: 4/20/2021

PROJECT LT-30
SHEET 2

SHEET NO.



High sediment load from steep gravel driveway

Pre-Treatment Swale sized for high sediment load
Detail B

Infiltrating bioretention basin w/ plantings and educational signage
Detail A

Overflow to existing catch basin, potential retrofit for underdrain if soils aren't suitable
Detail A

BMP Summary:
 -Drainage Area: 1.41 acres, 29% Impervious
 -Pre-treatment with grassed swale
 -Bioretention system will overflow to existing catch basin
 -System can be installed with underdrain if underlying soils are not suitable for infiltration

Pre-Treatment Swale	Swale
Proposed Bioretention	Parcel Boundaries
Catch Basin	Project Drainage Area
Overland flow	Forebay
Storm line	2-Foot Contours

0 20 40 Ft
1" = 40 ft.

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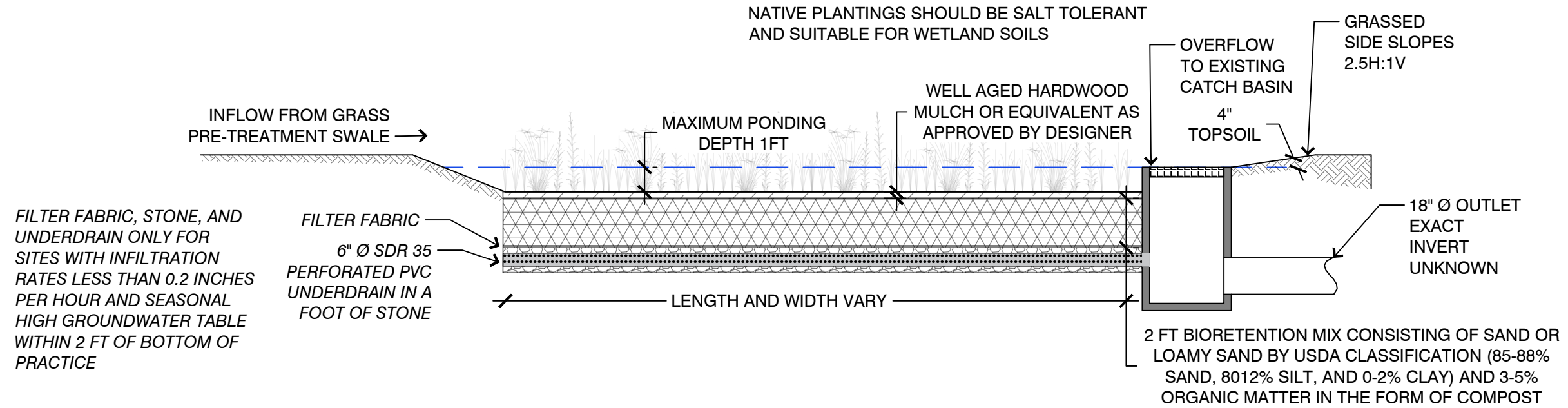
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Notes:
 -Depth to groundwater and soil infiltration must be verified prior to construction
 -Contours based on 0.7-M LIDAR DEM
 -Project locations and drainage areas based on field visits by FEA during summer and fall of 2020

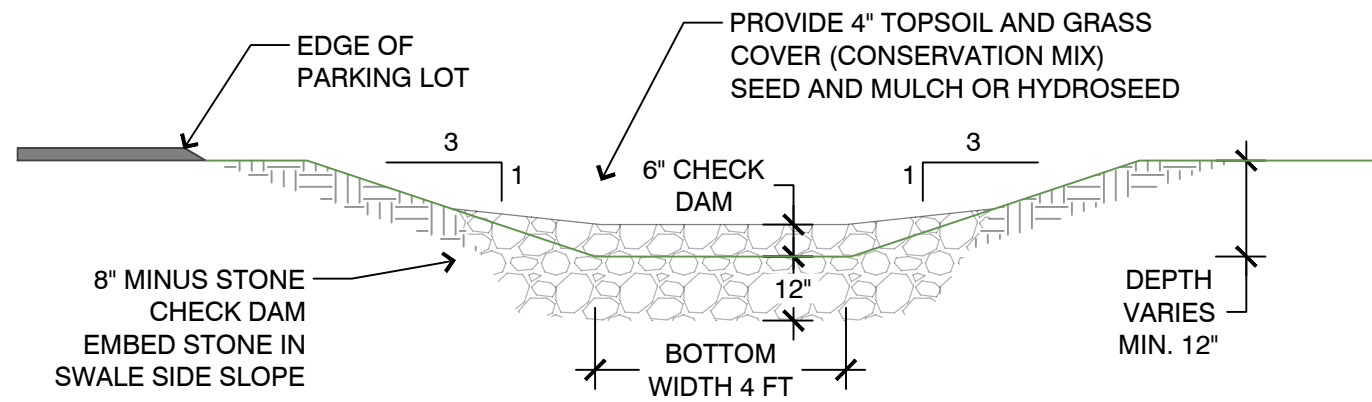
30% Conceptual Design
Project LT-34
Ludlow SWMP

FCP	JHB
Drawn	Checked
1" = 40 ft.	
Scale	
4/8/2021	
Date	
Project LT-34	
Sheet 1	
SHEET NO.	

Detail A: Rain Garden or Bioretention Feature Typical Profile
 Not to Scale



Detail B: Grass Pre-Treatment Swale with Stone Check Dam Typical Section
 Not To Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Price	Cost
Mobilization/Demobilization	1	LS	\$ 1,000	\$ 1,000
Common Excavation	75	CY	\$ 25	\$ 1,875
Trucking	75	CY	\$ 20	\$ 1,500
Topsoil/Compost	10	CY	\$ 50	\$ 500
Bioretention Media	20	CY	\$ 50	\$ 1,000
Stone Check Dam	2	EA	\$ 100	\$ 200
Plantings	20	EA	\$ 15	\$ 300
Laborer	16	HR	\$ 40	\$ 640
Misc. Erosion Control	1	LS	\$ 1,000	\$ 1,000
Final Design & Permitting				\$ 2,000
Construction Oversight				\$ 2,000
			Subtotal	\$ 12,015
			Contingency (20%)	\$ 2,400
			Total	\$ 14,415

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30% Conceptual Design
Project LT-34
Ludlow SWMP

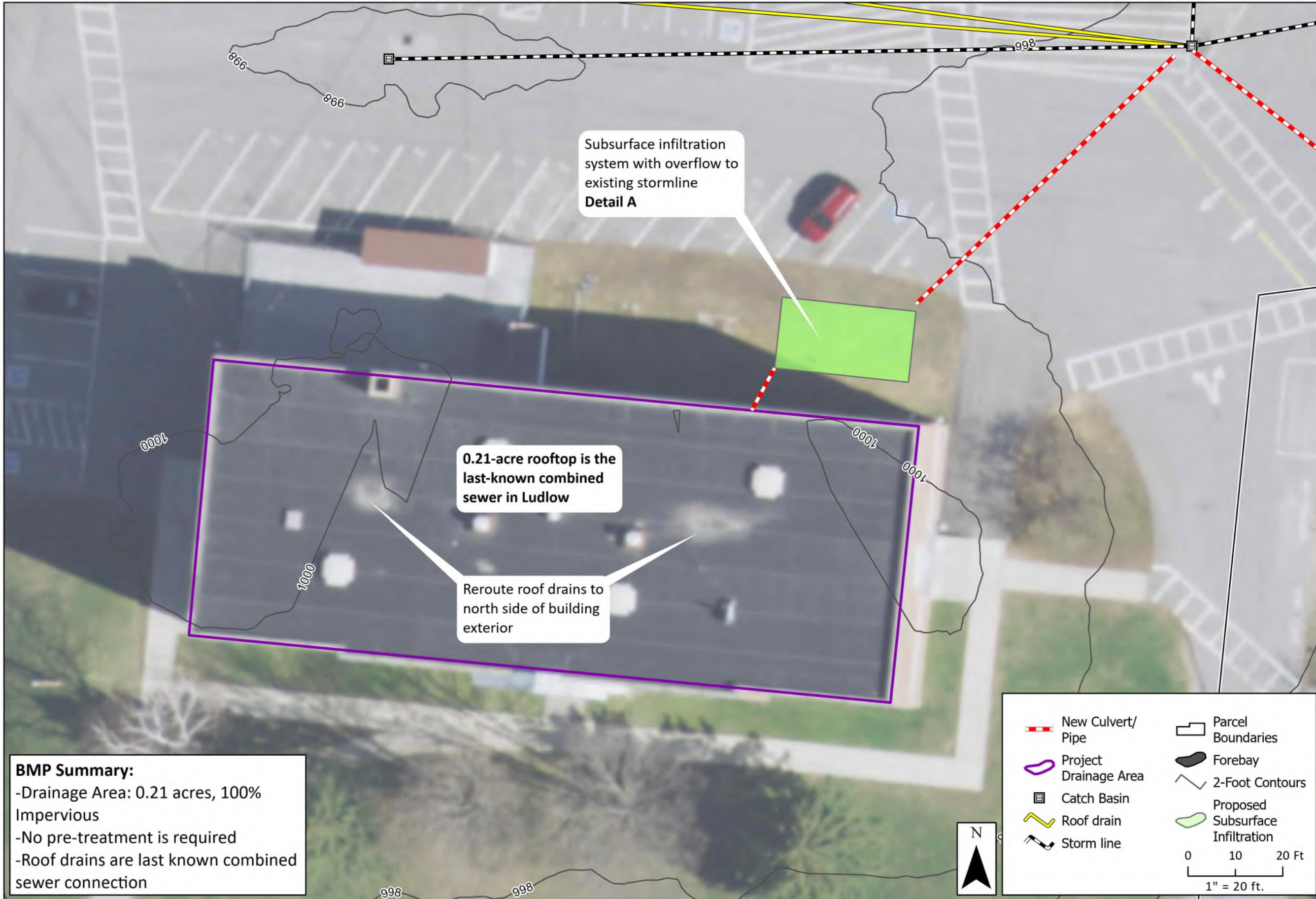
EHB DRAWN JHB CHECKED

SCALE As Shown

DATE 4/21/2021

PROJECT LT-34
SHEET 2

SHEET NO.



Subsurface infiltration system with overflow to existing stormline
Detail A

0.21-acre rooftop is the last-known combined sewer in Ludlow

Reroute roof drains to north side of building exterior

BMP Summary:
 -Drainage Area: 0.21 acres, 100% Impervious
 -No pre-treatment is required
 -Roof drains are last known combined sewer connection

New Culvert/ Pipe	Parcel Boundaries
Project Drainage Area	Forebay
Catch Basin	2-Foot Contours
Roof drain	Proposed Subsurface Infiltration
Storm line	

0 10 20 Ft
1" = 20 ft.

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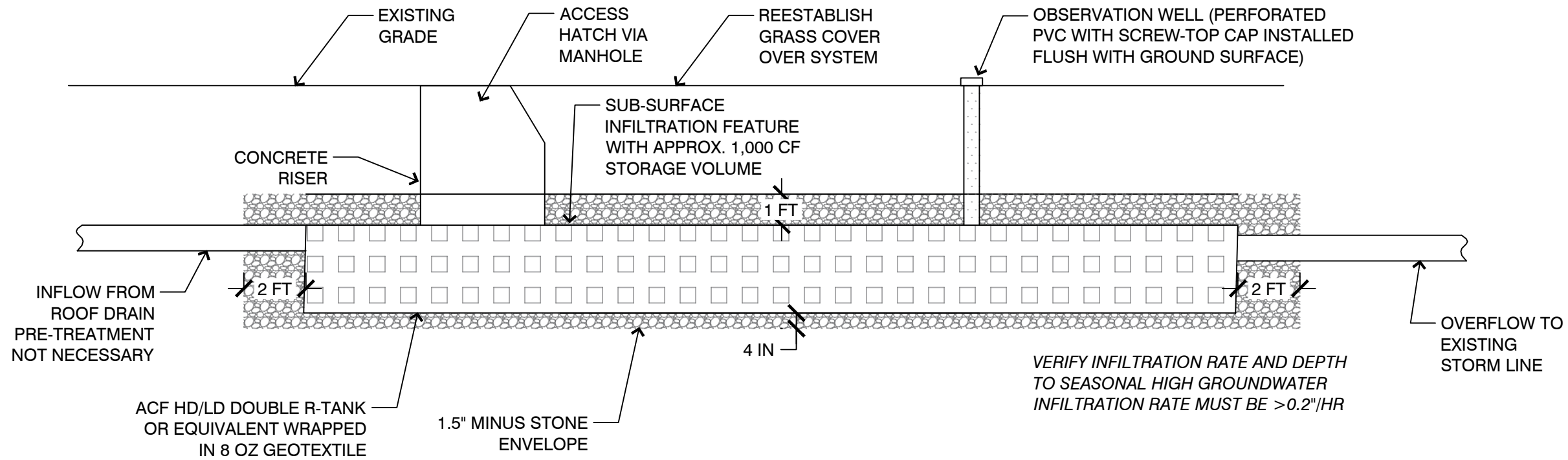
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Notes:
 -Depth to groundwater and soil infiltration must be verified prior to construction
 -Contours based on 0.7-M LIDAR DEM
 -Project locations and drainage areas based on field visits by FEA during summer and fall of 2020

30% Conceptual Design
Project LT-36
Ludlow SWMP

FCP	JHB
Drawn	Checked
1" = 20 ft.	
Scale	4/13/2021
Date	Project LT-36
Sheet 1	
SHEET NO.	

Detail A: Subsurface Infiltration Feature Typical Profile
 Not to Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Price	Cost
Mobilization/Demobilization	1	LS	\$ 1,000	\$ 1,000
Infiltration Chamber System	1	LS	\$ 12,000	\$ 12,000
Precast Concrete Manhole (4' dia.)	1	EA	\$ 3,000	\$ 3,000
Roof Drain Routing	1	LS	\$ 5,000	\$ 3,000
12" HDPE Storm Drain	75	LF	\$ 65	\$ 4,875
Misc. Erosion Control	1	LS	\$ 1,000	\$ 1,000
Final Design & Permitting				\$ 5,000
Construction Oversight				\$ 2,000
Subtotal				\$ 31,875
Contingency (20%)				\$ 6,380
Total				\$ 38,255

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30% Conceptual Design
Project LT-36
Ludlow SWMP

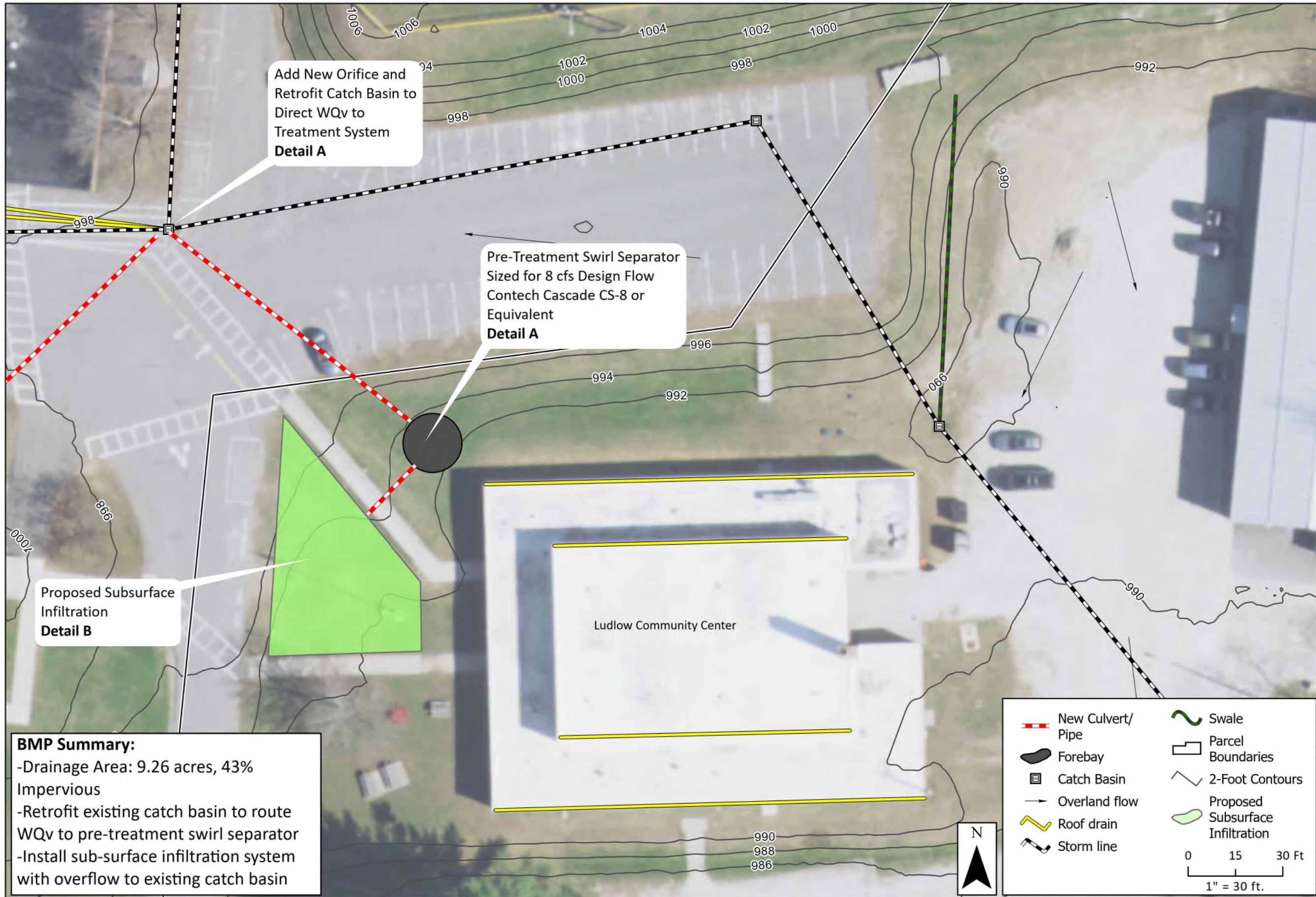
EHB DRAWN JHB CHECKED

SCALE: As Shown

DATE: 4/21/2021

PROJECT LT-36
SHEET 2

SHEET NO.



BMP Summary:
 -Drainage Area: 9.26 acres, 43% Impervious
 -Retrofit existing catch basin to route WQv to pre-treatment swirl separator
 -Install sub-surface infiltration system with overflow to existing catch basin

Add New Orifice and Retrofit Catch Basin to Direct WQv to Treatment System
Detail A

Pre-Treatment Swirl Separator Sized for 8 cfs Design Flow
 Contech Cascade CS-8 or Equivalent
Detail A

Proposed Subsurface Infiltration
Detail B

New Culvert/ Pipe	Swale
Forebay	Parcel Boundaries
Catch Basin	2-Foot Contours
Overland flow	Proposed Subsurface Infiltration
Roof drain	
Storm line	

0 15 30 Ft
 1" = 30 ft.

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Notes:

- Depth to groundwater and soil infiltration must be verified prior to construction
- Contours based on 0.7-M LIDAR DEM
- Project locations and drainage areas based on field visits by FEA during summer and fall of 2020

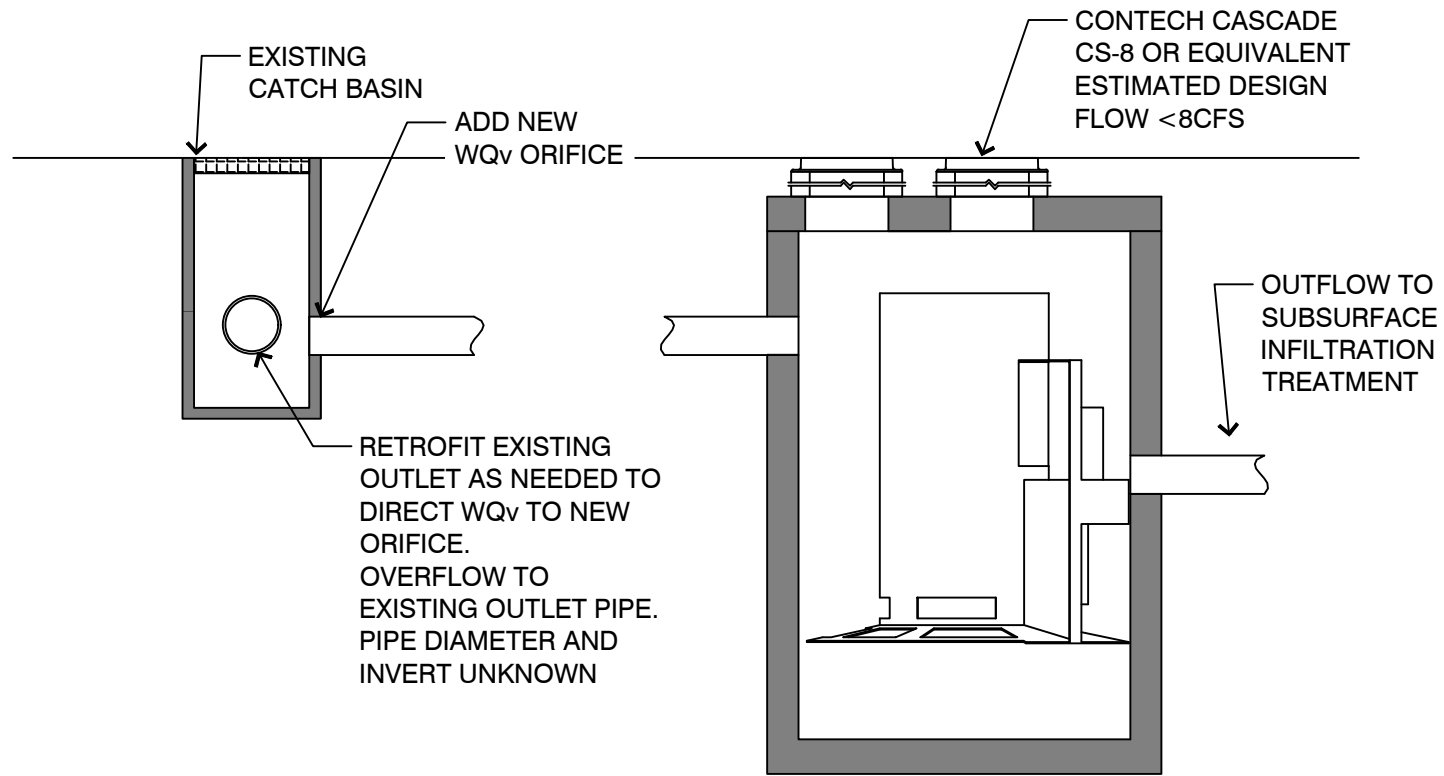
30% Conceptual Design
Project LT-37

Ludlow SWMP

FCP	JHB
Drawn	Checked
1" = 30 ft.	
Scale	
4/13/2021	
Date	
Project LT-37	
Sheet 1	

SHEET NO.

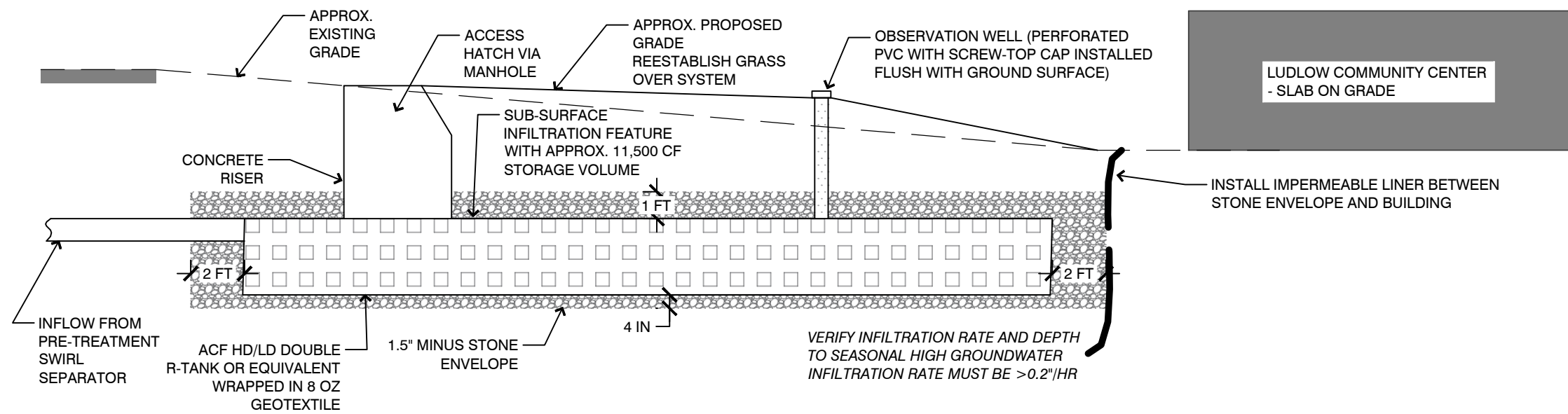
Detail A: Pre-Treatment Swirl Separator
Not to Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Price	Cost
Mobilization/Demobilization	1	LS	\$ 1,000	\$ 4,000
Infiltration Chamber System	1	LS	\$ 90,000	\$ 90,000
Contech CS-8 Pre-treatment	1	EA	\$ 50,000	\$ 50,000
Utilities/Infrastructure Relocation	1	LS	\$ 5,000	\$ 3,000
12" HDPE Storm Drain	220	LF	\$ 65	\$ 14,300
Misc. Erosion Control	1	LS	\$ 2,000	\$ 2,000
Final Design & Permitting				\$ 8,000
Construction Oversight				\$ 4,000
Subtotal				\$ 175,300
Contingency (20%)				\$ 35,060
Total				\$ 210,360

Detail B: Subsurface Infiltration Typical Profile
Not to Scale



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30% Conceptual Design
Project LT-37
Ludlow SWMP

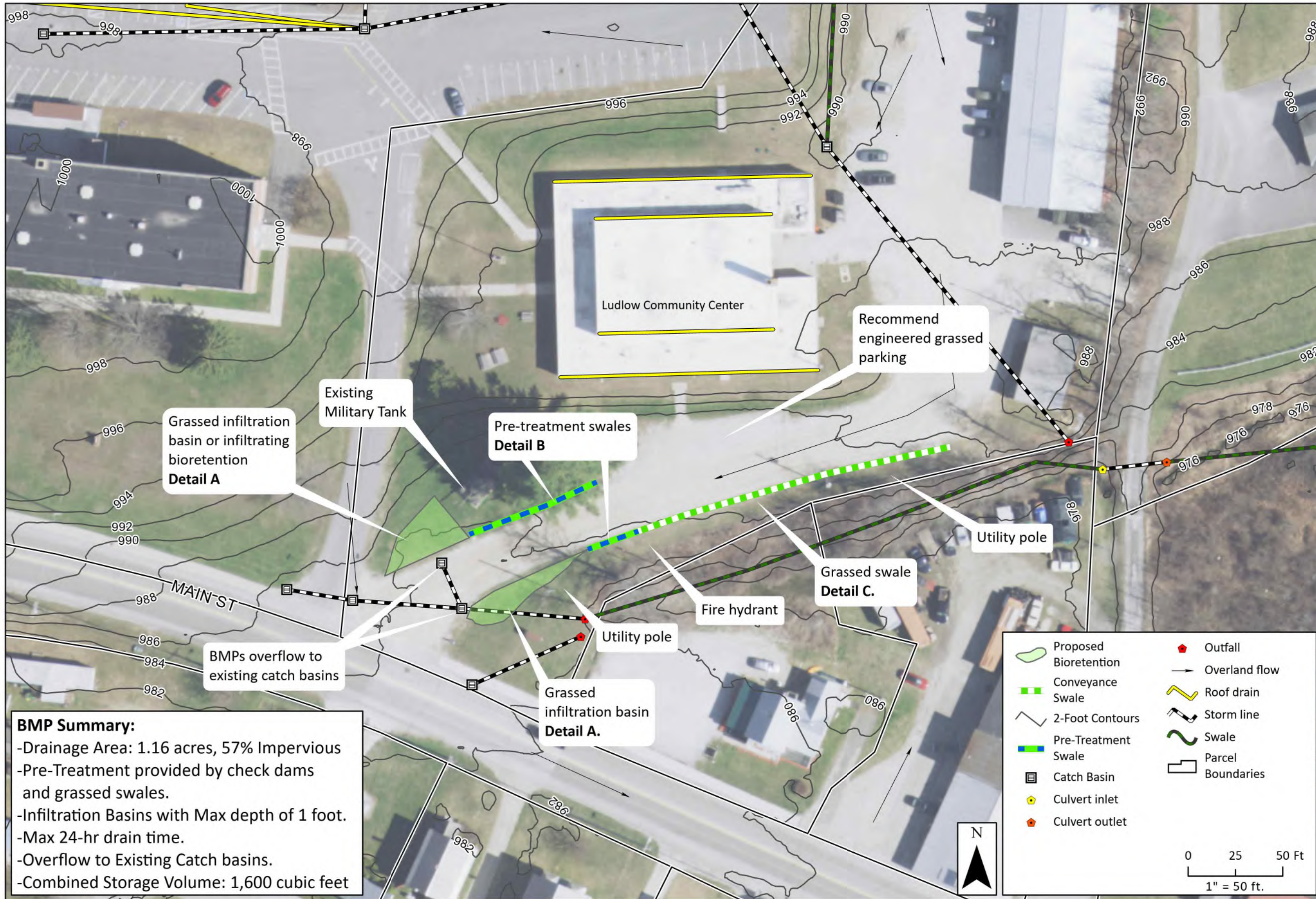
EHB DRAWN | JHB CHECKED

As Shown
SCALE

4/21/2021
DATE

PROJECT LT-37
SHEET 2

SHEET NO.



BMP Summary:

- Drainage Area: 1.16 acres, 57% Impervious
- Pre-Treatment provided by check dams and grassed swales.
- Infiltration Basins with Max depth of 1 foot.
- Max 24-hr drain time.
- Overflow to Existing Catch basins.
- Combined Storage Volume: 1,600 cubic feet

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Notes:

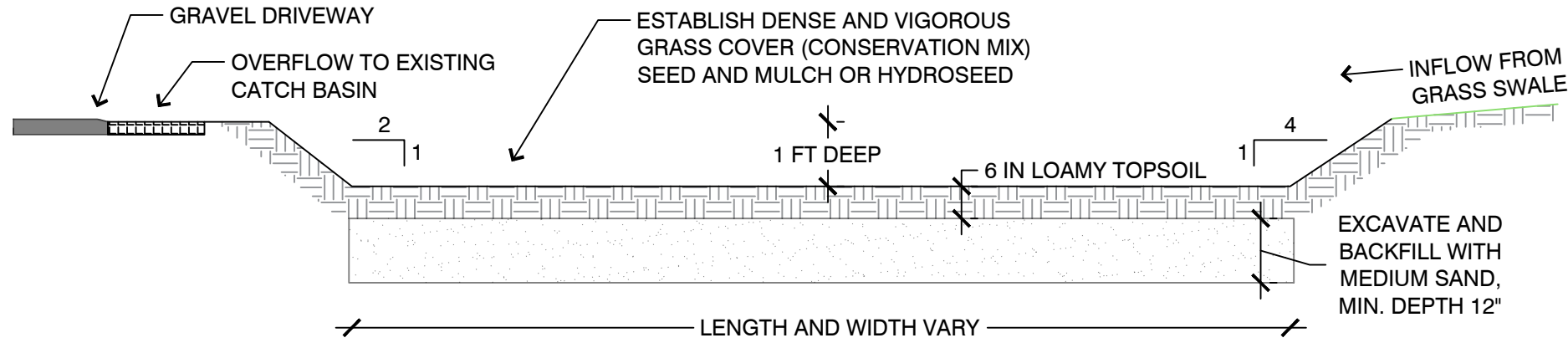
- Depth to groundwater and soil infiltration must be verified prior to construction
- Contours based on 0.7-M LIDAR DEM
- Project locations and drainage areas based on field visits by FEA during summer and fall of 2020

30% Conceptual Design
Project LT-38
Ludlow SWMP

FCP	JHB
Drawn	Checked
1" = 50 ft.	
Scale	
4/13/2021	
Date	
Project LT-38	
Sheet 1	
SHEET NO.	

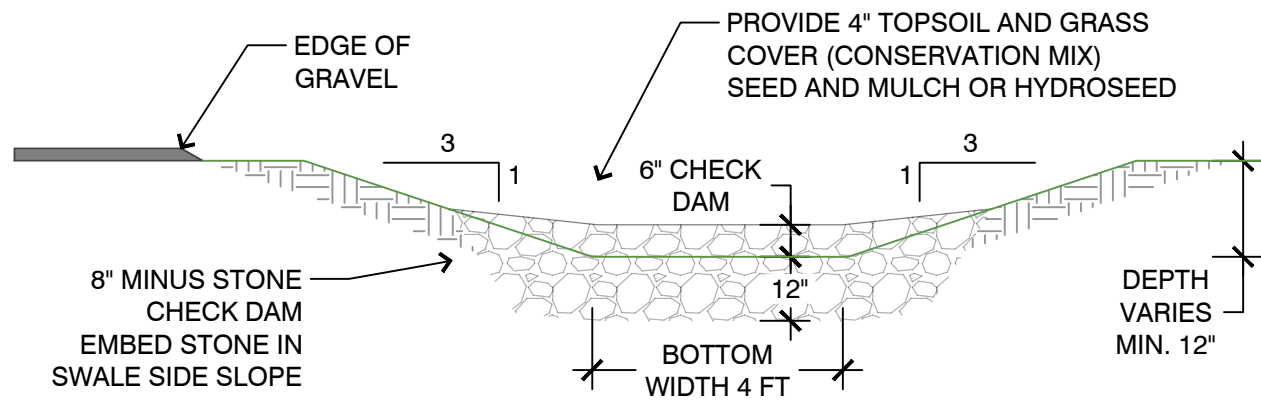
Detail A: Infiltration Feature Typical Profile

Not to Scale



Detail B: Grass Pre-Treatment Swale with Stone Check Dams Typical Section

Not To Scale

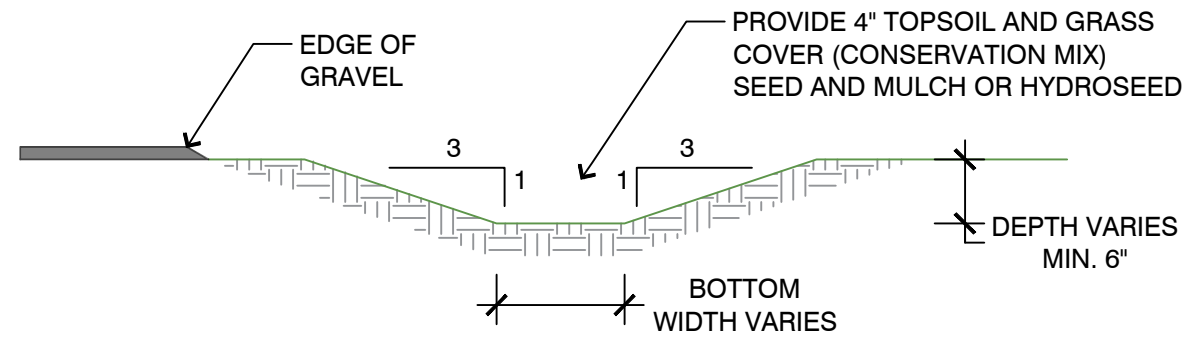


Preliminary Cost Opinion

Item	Quantity	Unit	Unit Price	Cost
Mobilization/Demobilization	1	LS	\$ 1,000	\$ 1,000
Common Excavation and Soil Amendment	200	CY	\$ 25	\$ 5,000
Trucking	200	CY	\$ 20	\$ 4,000
Topsoil/Compost	15	CY	\$ 50	\$ 750
Infiltration Sand	40	CY	\$ 40	\$ 1,600
Grass Swale	250	LF	\$ 10	\$ 2,500
Stone Check Dams	6	EA	\$ 100	\$ 600
Plantings	0	EA	\$ 15	\$ -
Laborer	16	HR	\$ 40	\$ 640
Misc. Erosion Control	1	LS	\$ 2,000	\$ 2,000
Final Design & Permitting				\$ 3,000
Construction Oversight				\$ 2,000
			Subtotal	\$ 23,090
			Contingency (20%)	\$ 4,620
			Total	\$ 27,710

Detail C: Grass Conveyance Swale Typical Section

Not To Scale



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**30% Conceptual Design
 Project LT-38
 Ludlow SWMP**

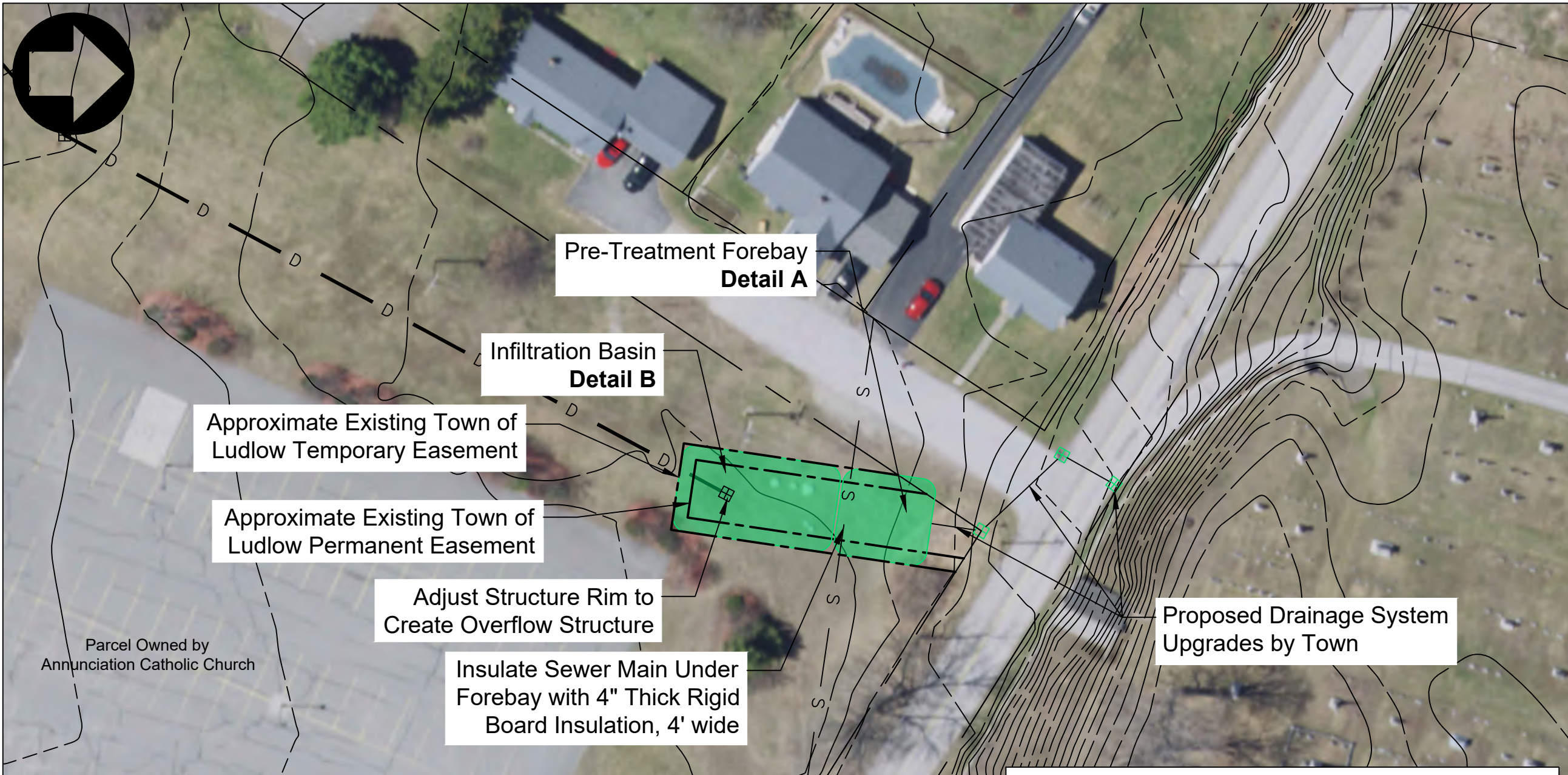
EHB DRAWN JHB CHECKED

SCALE: As Shown

DATE: 4/21/2021

PROJECT LT-38
SHEET 2

SHEET NO.



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**30% Conceptual Design
 Project LT-41 - Plan
 Ludlow SWMP**

MCB DRAWN	CMH CHECKED
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SCALE 1"=40'

DATE 4/20/2021

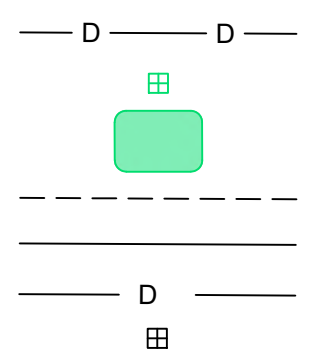
PROJECT LT-41
SHEET 1

SHEET NO.

BMP Summary:

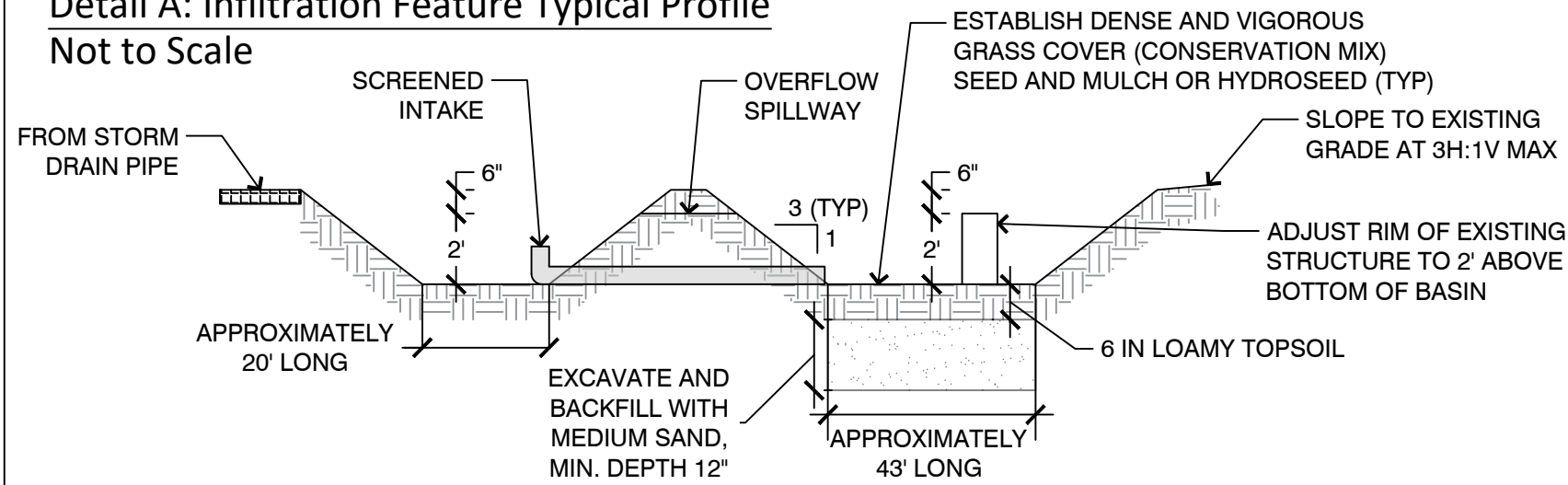
- Drainage Area: 5.52 acres, 32% impervious
- Pretreatment provided by grassed forebay
- Infiltration basin with maximum depth of 2 feet
- Basin and forebay to be located within existing easement.
- Maximum 24-hour drain time.
- Overflow to existing catch basin.
- Storage Volume: 6,860 cubic feet

Proposed Storm Drain
 Proposed Catch Basin
 Proposed Infiltration
 2 Foot Contours
 Parcel Line
 Existing Storm Drain
 Existing Catch Basin



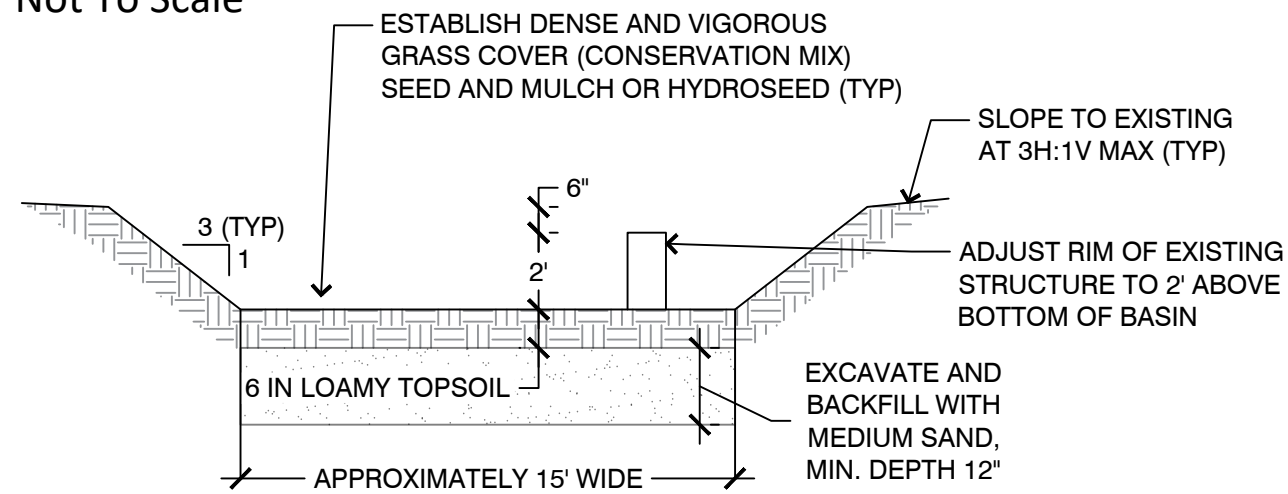
Detail A: Infiltration Feature Typical Profile

Not to Scale



Detail B: Infiltration Feature Typical Section

Not To Scale



Preliminary Cost Opinion

Item	Quantity	Unit	Unit Cost	Item Total
Common Excavation	180	CY	\$25.00	\$4,500
Infiltration Sand	30	CY	\$40.00	\$1,200
Pipe	16	LF	\$45.00	\$720
Sewer Main Insulation	120	SF	\$4.00	\$480
Structure Adjustment	1	EA	\$1,000.00	\$1,000
Erosion Control	1	LS	\$1,000.00	\$1,000
Restoration	1	LS	\$2,000.00	\$2,000
Mobilization/Demobilization	1	LS	\$1,100.00	\$1,100
Final Design & Permitting				\$3,000
Construction Oversight				\$1,000

Construction Subtotal: \$12,000
 Contingency (20%): \$2,000
Total: \$14,000

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**30% Conceptual Design
 Project LT-41 - Details
 Ludlow SWMP**

MCB DRAWN CMH CHECKED

As Shown
 SCALE

4/20/2021
 DATE

PROJECT LT-41
SHEET 2

SHEET NO.