

## Appendix 1: Site Descriptions

**Table 1.** Site locations

Site Name (ID)	Longitude	Latitude	Elevation (m)	Town
I-89 North (1)	-73.1862	44.5515	43.9	Colchester
I-89 North (2)	-73.1756	44.5793	44.0	Colchester
I-89 South (3)	-73.1927	44.5182	65.1	Colchester
Young (10)	-73.1959	44.5004	68.0	Colchester
Elm (11)	-73.1974	44.4945	47.3	Winooski
Corduroy (13)	-73.0891	44.4896	127.2	Essex
Vale (15)	-73.0870	44.4906	134.9	Essex
Milo White (16)	-72.9650	44.4392	295.3	Jericho
I-89 Middlesex (28)	-72.7051	44.3153	152.3	Middlesex
Maple Run (30)	-72.7071	44.5234	452.9	Stowe
Maple Run (31)	-72.7097	44.5241	457.2	Stowe
Clay Hill (32)	-72.6778	44.6384	157.5	Johnson
Clay Hill (33)	-72.6770	44.6418	180.5	Johnson

**Table 2.** Site types and survey dates

Site Name (ID)	Site type <sup>1</sup>	Treatment installation date	Pipe Diameter (inches)	Pipe Material	Survey Begin Date	Number of Surveys
I-89 North (1)	Treatment	10/27/20	18	Metal	5/14/ 2020	4
I-89 North (2)	Control		36	Metal	10/25/2019	5
I-89 South (3)	Treatment	10/30/20	18	Metal	10/21/ 2019	5
Young (10)	Control		12	Metal	10/4/2019	8
Elm (11)	Treatment	11/23/20		Metal	10/3/2019	8
Corduroy (13)	Control		15		10/10/2019	5
Vale (15)	Control		15	Metal	9/27/2019	4
Milo White (16)	Treatment	6/12/20	24	Metal	5/12/2020	5
I-89 Middlesex (28)	Control		18	Concrete	5/12/2020	5
Maple Run (30)	Treatment	9/25/20		Metal	10/2/2019	6
Maple Run (31)	Control			Metal	10/2/2019	5
Clay Hill (32)	Treatment	9/30/20	18	Metal	5/8/2020	4
Clay Hill (33)	Control		18	Metal	5/8/2020	4

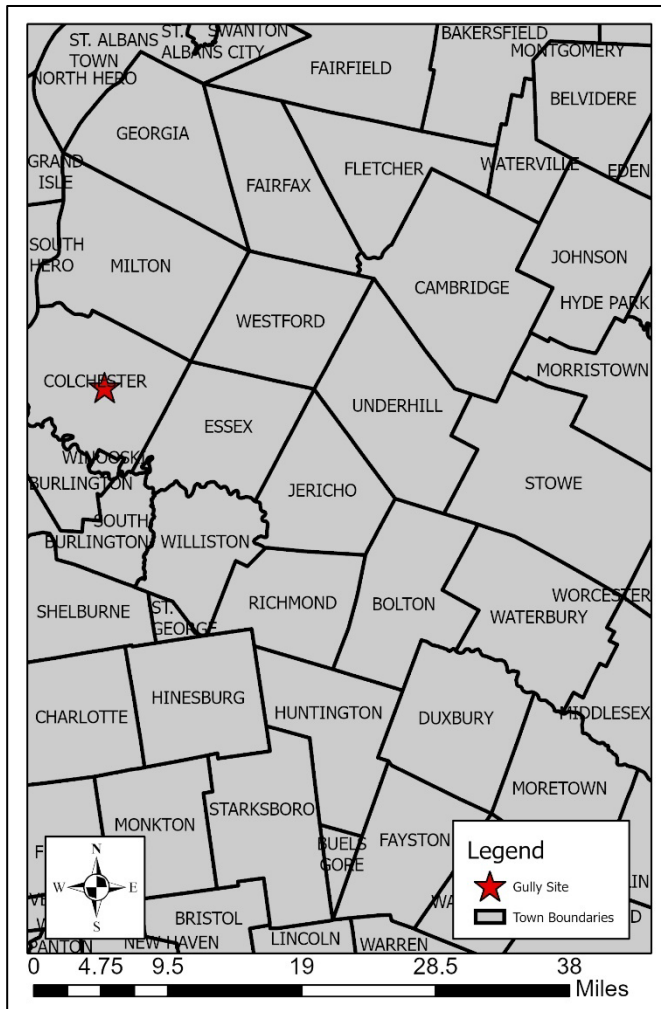
<sup>1</sup> Per project design, sites were designated as reference or “control” sites or as “treatment” sites where erosion mitigation projects would be installed. For treatment sites, approximate dates of installation of erosion mitigation work are given, based on email notifications by contacts on the project Technical Advisory Committee.

**Table 3.** Dimensions of gullies at each site and length of erosion mitigation at the treatment sites.

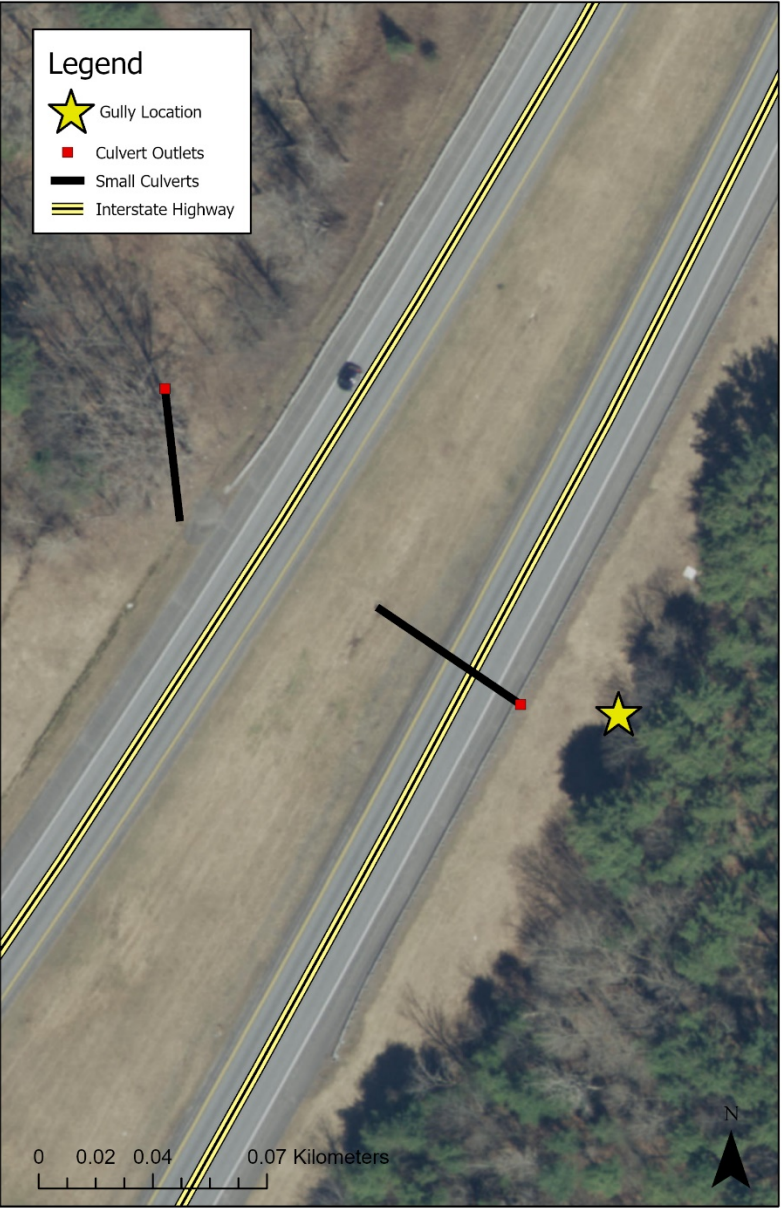
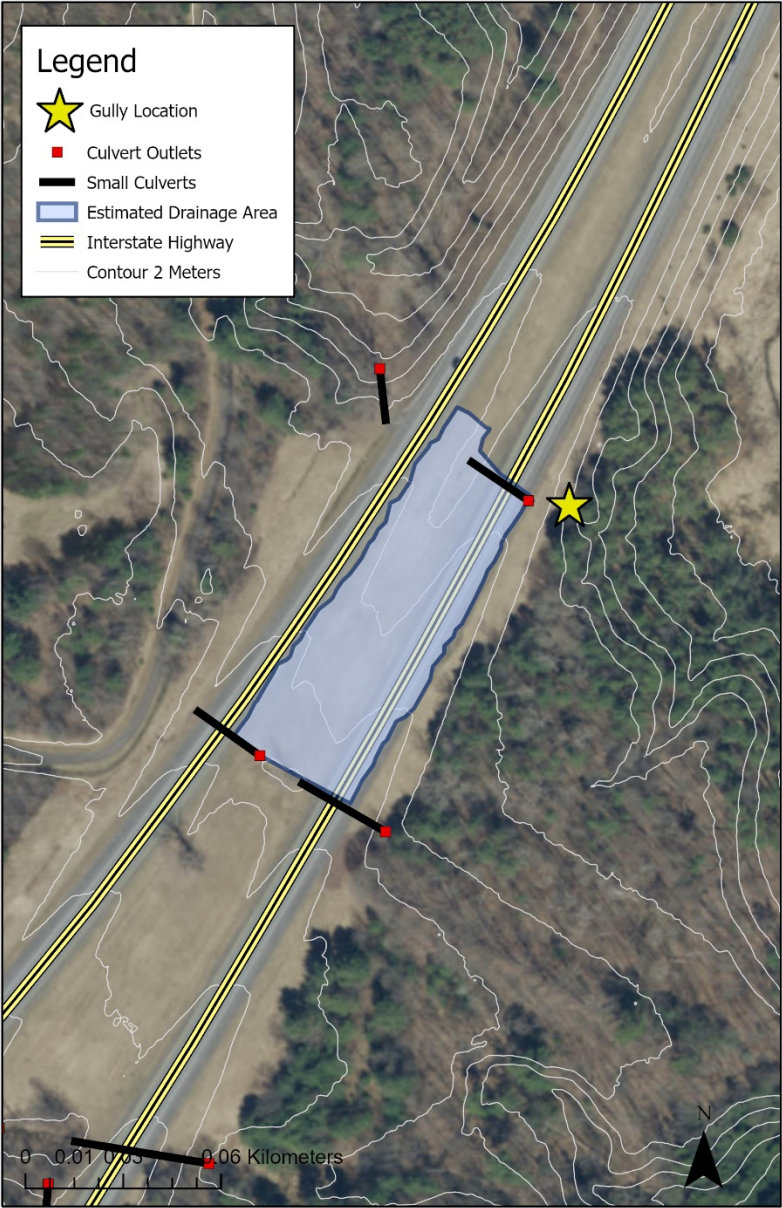
<b>Site Name (ID)</b>	<b>Length (m)</b>	<b>Maximum Width (m)</b>	<b>Maximum Depth (m)</b>	<b>Width Depth Ratio</b>	<b>Length of Treatment Installed (m)</b>
I-89 North (1)	29.9	3.9	1.7	2.3	15.7
I-89 North (2)	44.8	5.1	1.8	2.8	--
I-89 South (3)	46.0	5.5	2.1	2.6	46.0
Young (10)	23.4	5.7	2.1	2.7	--
Elm (11)	25.5	7.0	3.7	1.9	25.5
Corduroy (13)	30.4	8.0	1.9	4.2	--
Vale (15)	10.1	5.0	1.9	2.6	--
Milo White (16)	30.8	4.7	1.3	3.6	7.7
I-89 Middlesex (28)	30.3	1.5	0.7	2.1	--
Maple Run (30)	27.3	3.0	0.5	6.0	3.5
Maple Run (31)	47.2	5.0	1.5	3.3	--
Clay Hill (32)	7.9	2.0	0.5	4.0	12.9
Clay Hill (33)	9.2	5.1	1.5	3.4	--

## I-89 NORTH (1)

This gully at the north direction on Interstate 89 is located at mile marker 95.05 north in the town of Colchester, Vermont. This road is a one lane Interstate Highway that is maintained by the Vermont Agency of Transportation District 5. The culvert monitored is part of the Small Culvert Inventory database with an ID of 50194. The culvert was a metal material and 18 inches in diameter and 73 feet in length. The system type of the culvert is a single pipe. The drainage area for this culvert was estimated to be 4,352 meters<sup>2</sup> (derived from 0.7-meter DEM). The road length draining to this culvert was estimated at 154.4 meters and an average width of 17.5 meters. The slope steepness at outlet was estimated as 31.2% (derived from 10-meter DEM). The soil type at the culvert outlet is Belgrade and Eldridge with a soil texture of coarse silt loam. Repeated surveys on this site took place from May 14<sup>th</sup>, 2020 to May 12, 2021 with a total of 4 surveys. Erosion mitigation was installed late October 2020.



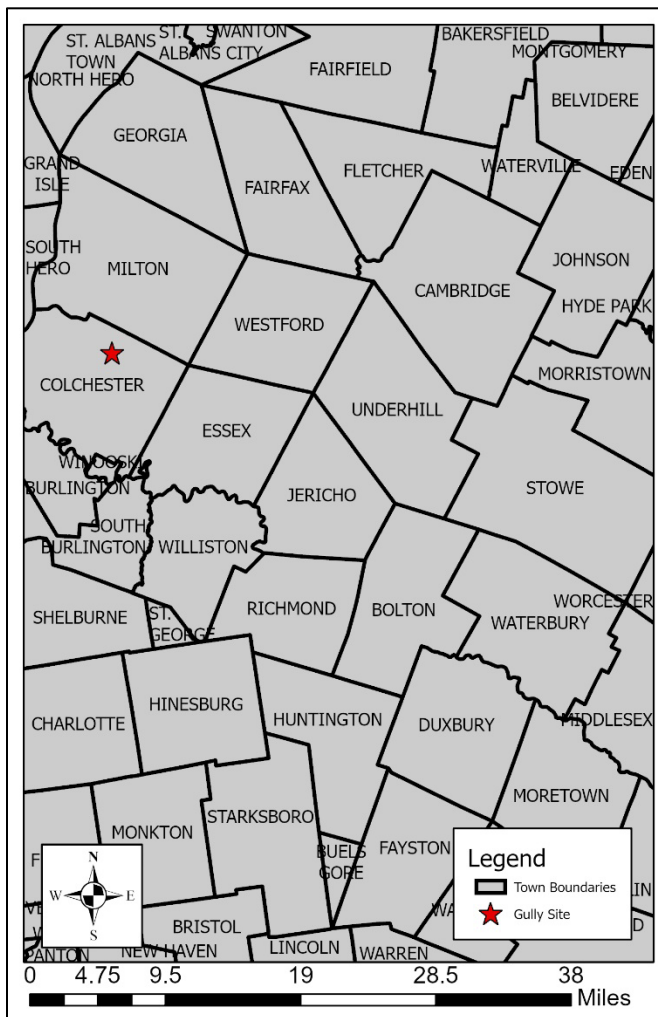




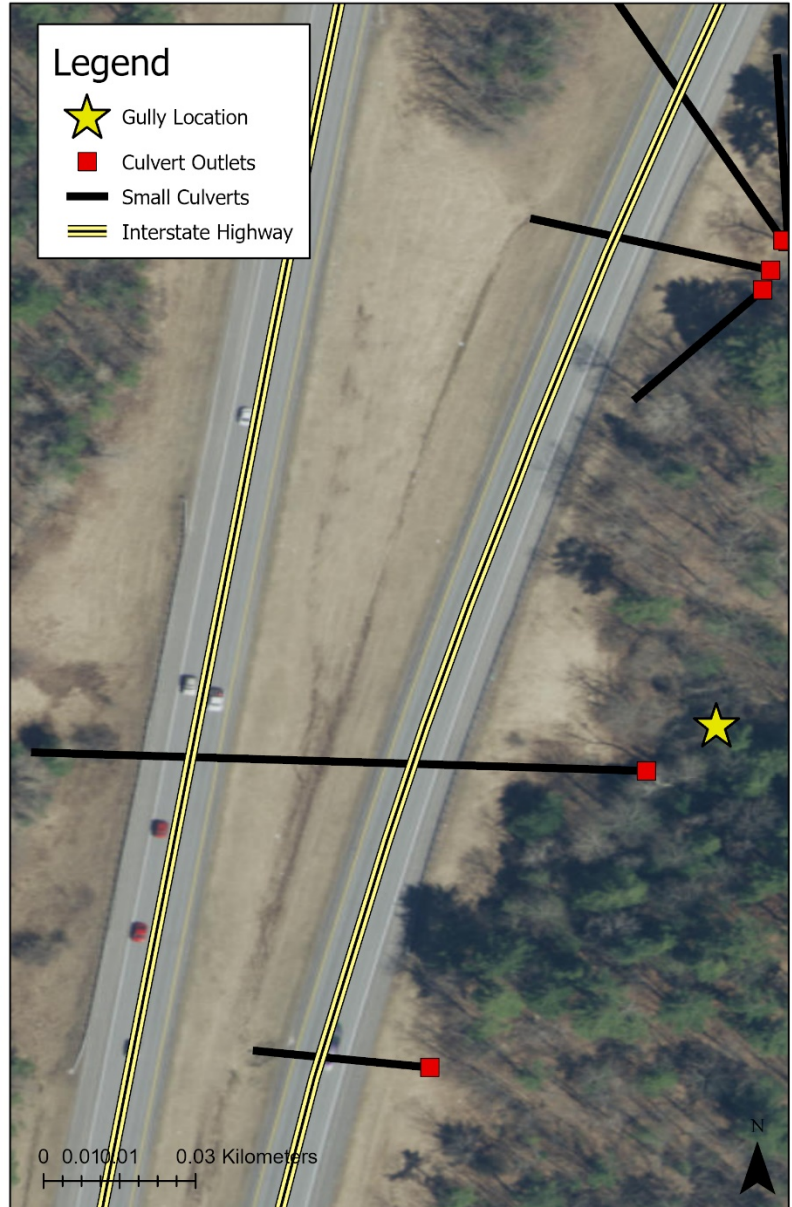
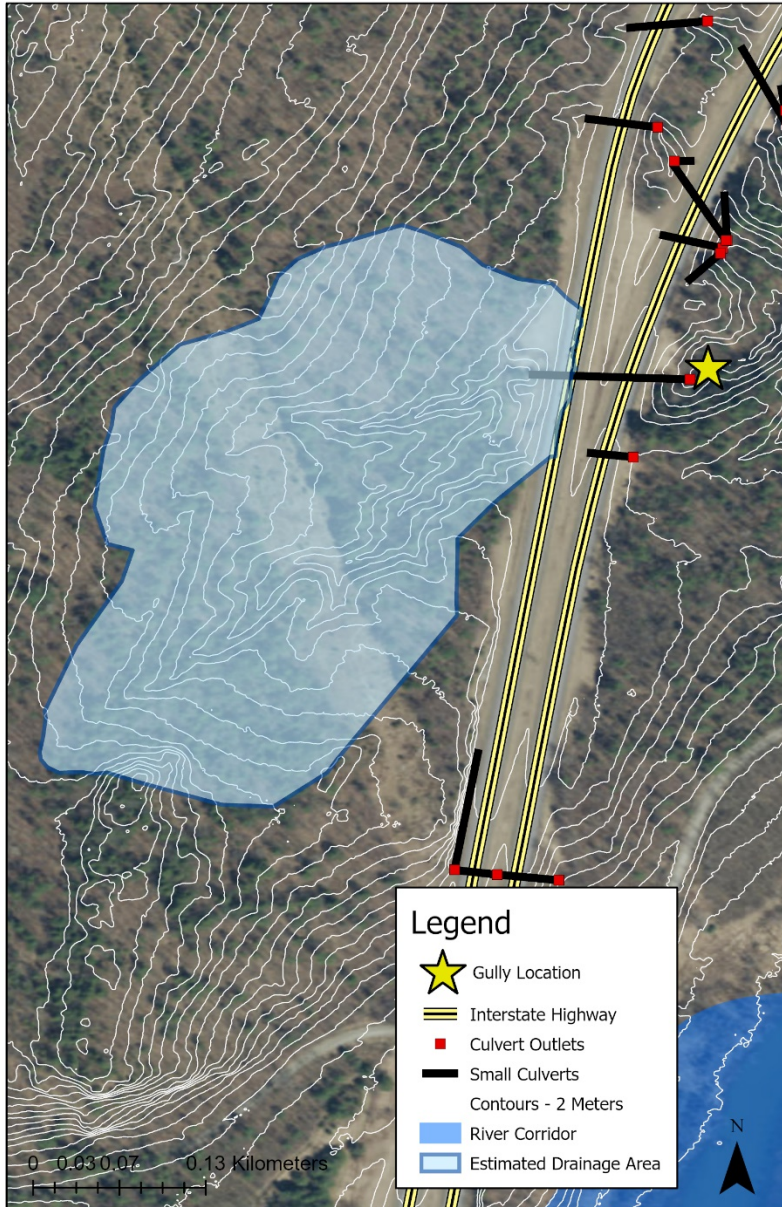


## I-89 NORTH (2)

This gully is at the north direction on Interstate 89 and is located at mile marker 97.05 north in the town of Colchester, Vermont. This road is a one lane Interstate Highway that is maintained by the Vermont Agency of Transportation District 5. The culvert monitored is part of the Small Culvert Inventory database with an ID of 58013. The culvert was a metal material and 36 inches in diameter and 285 feet in length. The system type of the culvert is a single pipe. The drainage area for this culvert was estimated to be 78,077 meters<sup>2</sup> (derived from 0.7-meter DEM). The road length draining to this culvert was estimated at 322.8 meters and an average width of 17.5 meters. The slope steepness at outlet was estimated as 7.7% (derived from 10-meter DEM). The soil type at the culvert outlet is Terrace Escarpments with a soil texture of silty clay. Repeated surveys on this site took place from October 25<sup>th</sup>, 2019 to May 12, 2021 with a total of 5 surveys. Erosion mitigation was not installed at this site.



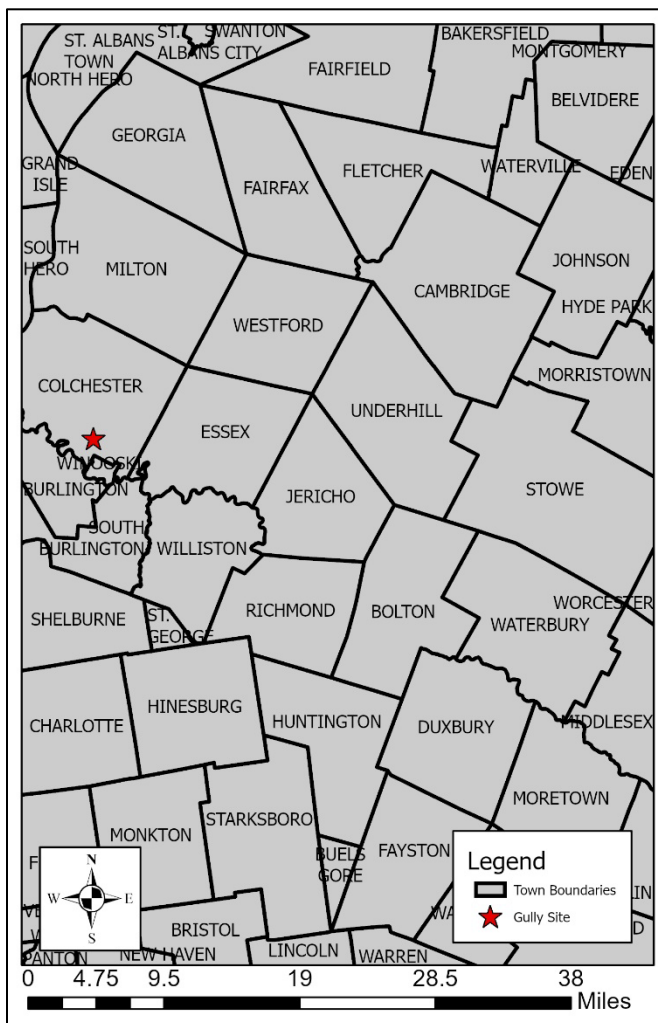




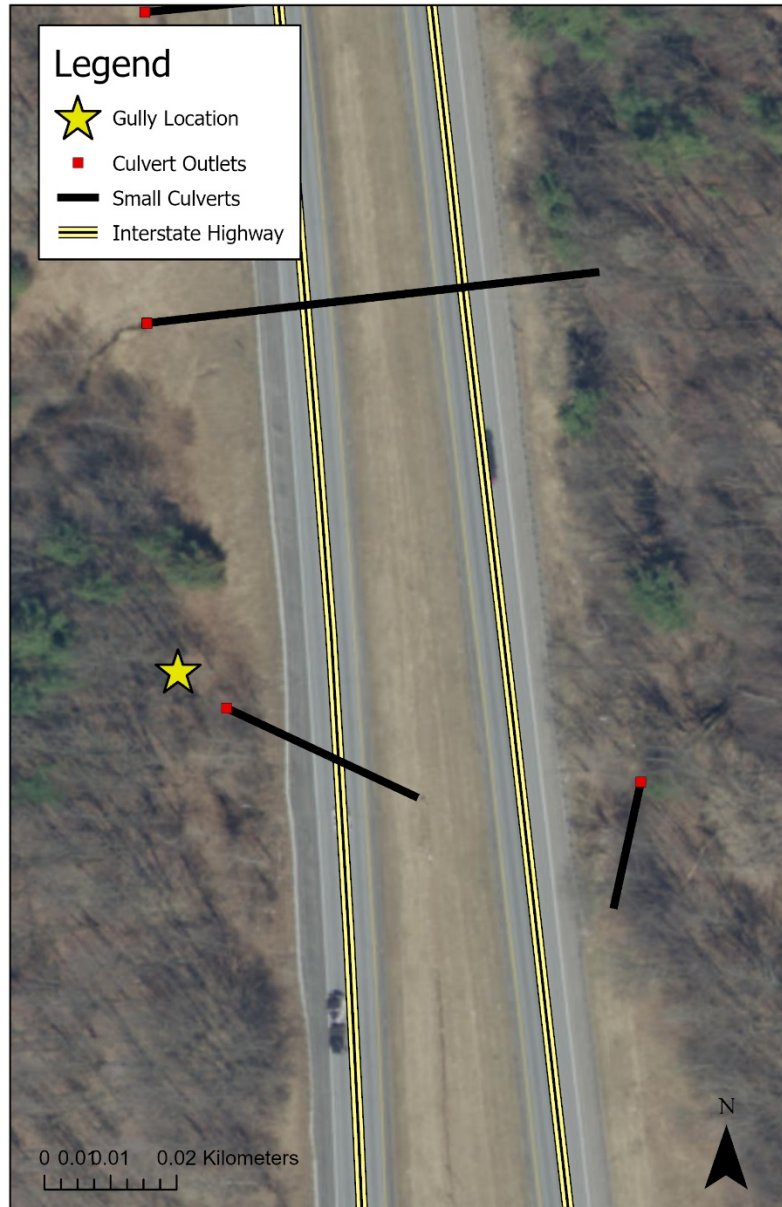
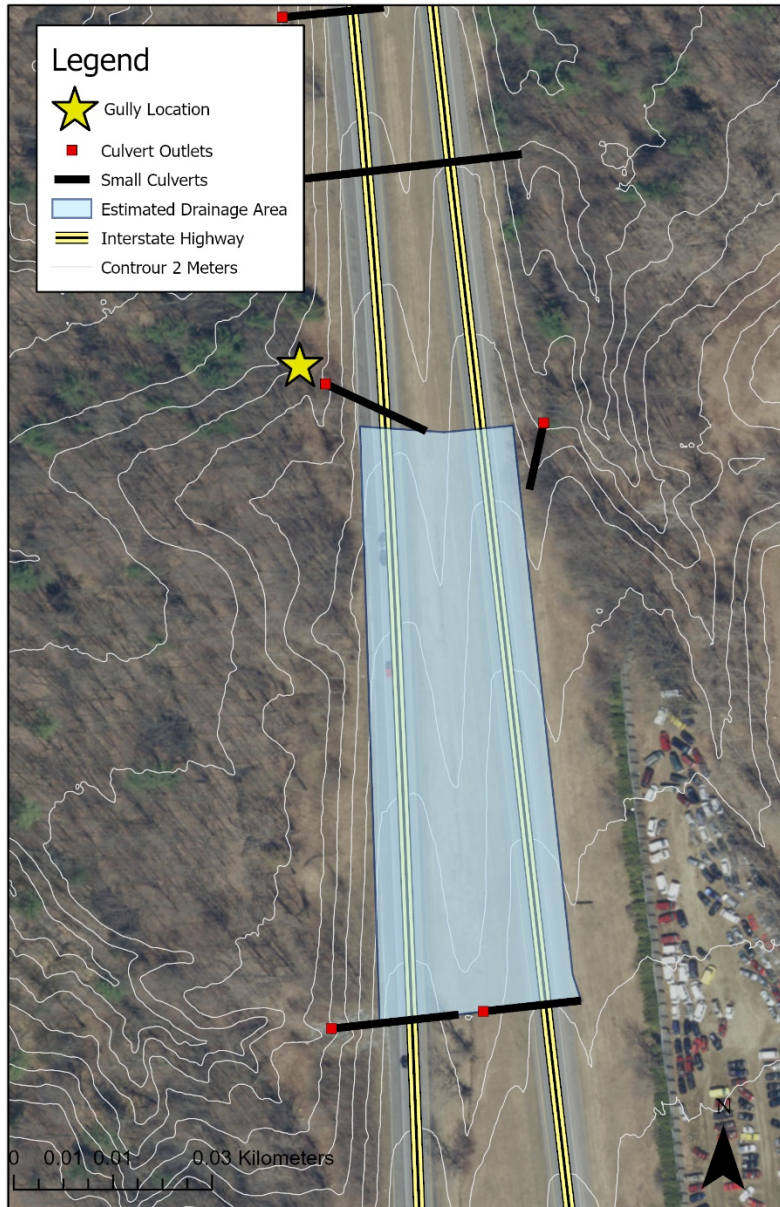


### I-89 SOUTH (3)

This gully is at the south direction on Interstate 89 and is located at mile marker 92.4 south in the town of Colchester, Vermont. This road is a one lane Interstate Highway that is maintained by the Vermont Agency of Transportation District 5. The culvert monitored is part of the Small Culvert Inventory database with an ID of 50151. The culvert was a metal material and 18 inches in diameter and 105 feet in length. The system type of the culvert is a closed system. The drainage area for this culvert was estimated to be 8,458 meters<sup>2</sup> (derived from 0.7-meter DEM). The road length draining to this culvert was estimated at 168.5 meters and an average width of 17.5 meters. The slope steepness at outlet was estimated as 24.4% (derived from 10-meter DEM). The soil type at the culvert outlet is Adam and Windsor with a soil texture of loamy sand. Repeated surveys on this site took place from October 21<sup>st</sup>, 2019 to May 12, 2021 with a total of 5 surveys. Erosion mitigation was installed late October 2020.



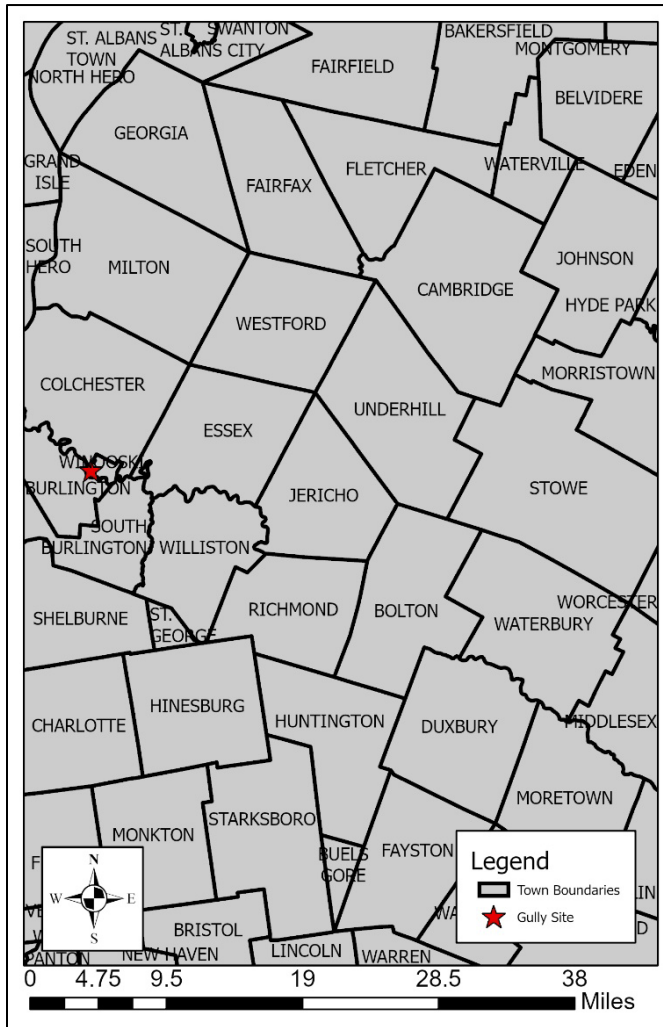




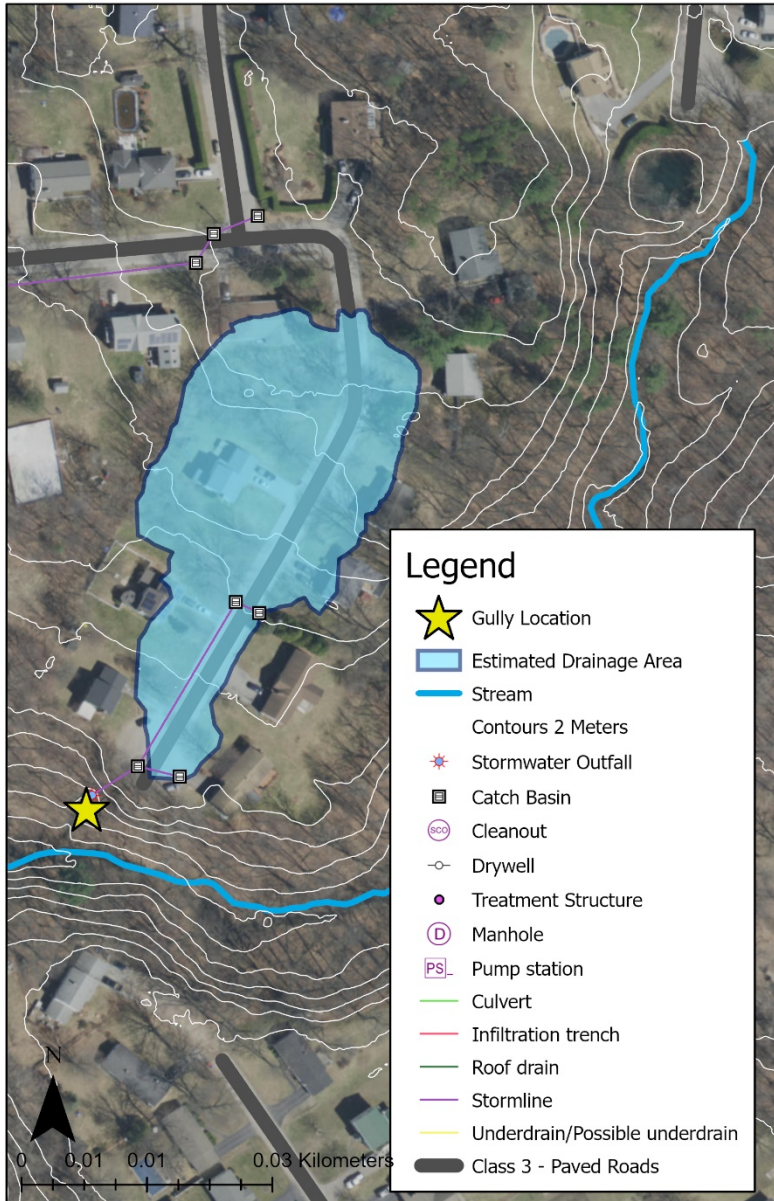


## YOUNG STREET (10)

This gully is located at the end of Young Street in the town of Colchester, Vermont. This road is a class 3 paved road that is residential. The culvert monitored is part of the town of Colchester culvert database. The culvert was a metal material and 12 inches in diameter and 52 feet in length. The system type of the culvert is a closed drainage system. The drainage area for this culvert was estimated to be 6,428 meters<sup>2</sup> (derived from 0.7-meter DEM). The road length draining to this culvert was estimated at 56.5 meters and an average width of 11.8 meters. The slope steepness at outlet was estimated as 35.9% (derived from 10-meter DEM). The soil type at the culvert outlet is Adam and Windsor with a soil texture of loamy sand. Repeated surveys on this site took place from October 4<sup>th</sup>, 2019 to May 11, 2021 with a total of 7 surveys. Erosion mitigation was not installed at this site.



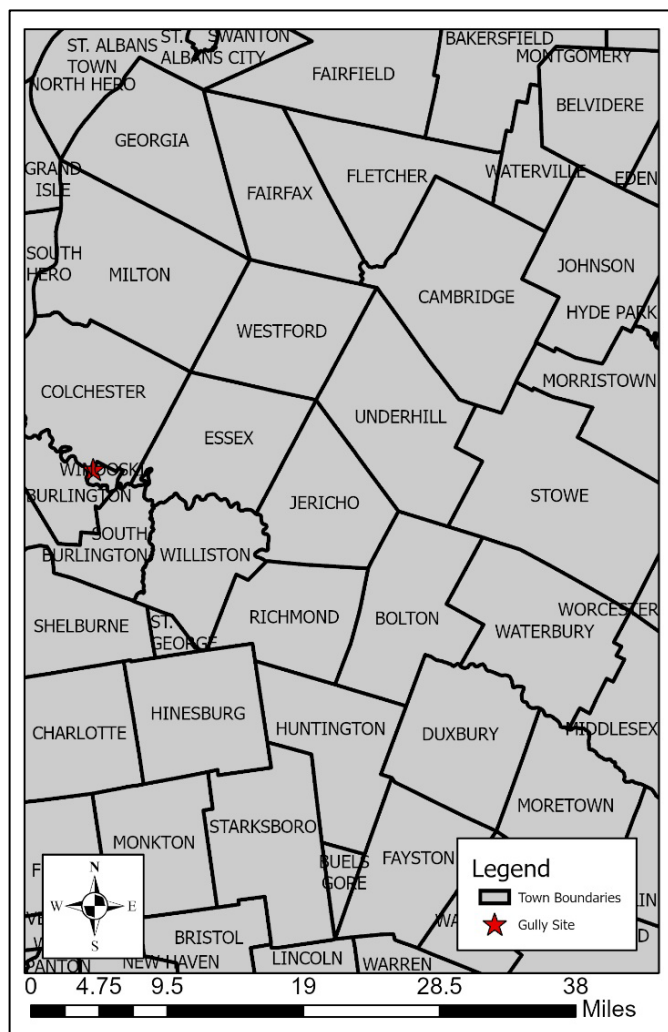




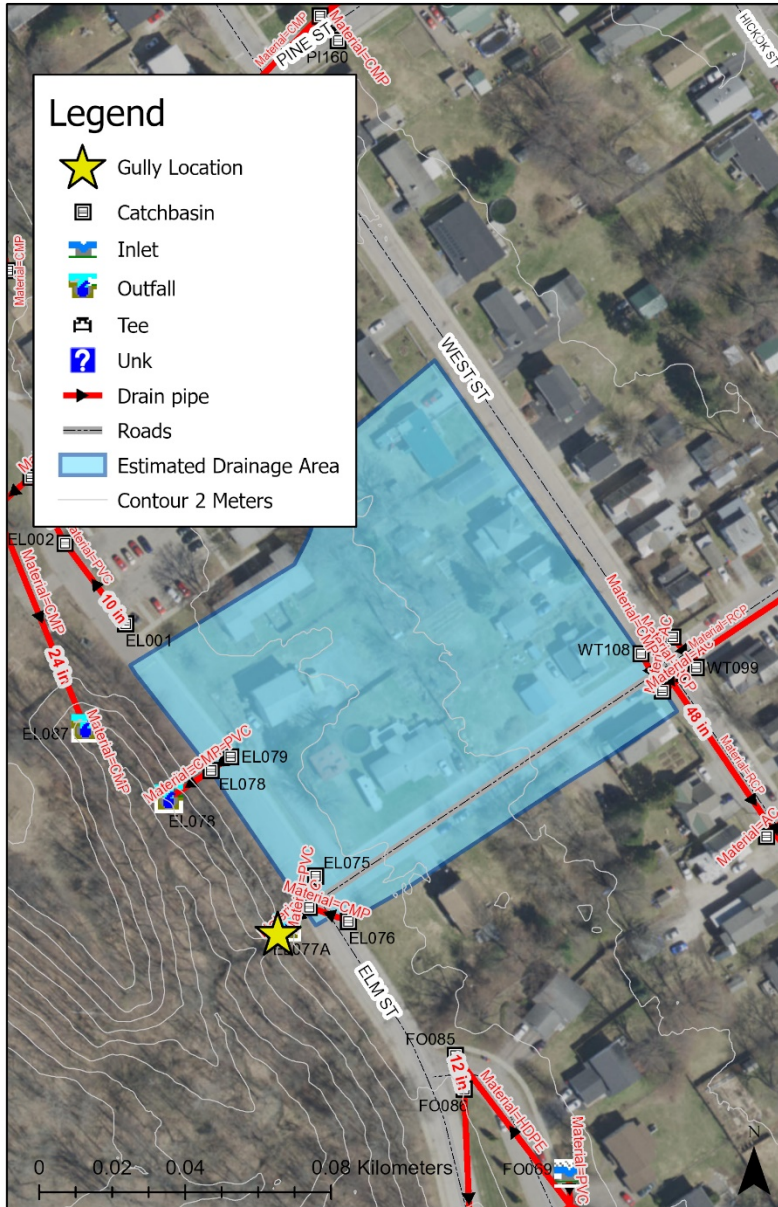


## ELM STREET (11)

This gully is located at the intersection of Elm Street and Forrest Street in the town of Winooski, Vermont, and drains a closed system. The gully was specifically located just behind the “River Works” sign. This road is a class 3 paved road that is residential. The culvert monitored is part of the town of Winooski culvert database. The culvert was a metal material, and the diameter and length of the culvert is unknown (not visible at the ground surface). The drainage area for this culvert was estimated to be 11,574 meters<sup>2</sup>. The road length draining to this culvert was estimated at 201 meters and an average width of 6.5 meters. The slope steepness at outlet was estimated as 36.2% (derived from 10-meter DEM). The soil type at the culvert outlet is Colton and Stetson with a soil texture of loamy sand. Repeated surveys on this site took place from October 3<sup>rd</sup>, 2019 to May 11, 2021 with a total of 7 surveys. Erosion mitigation was installed at this site in November 2020.

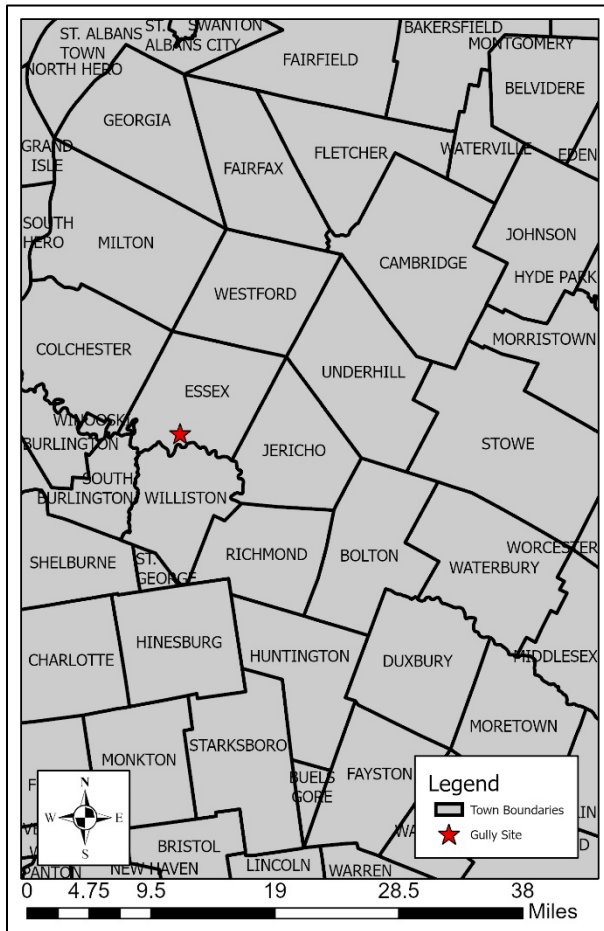




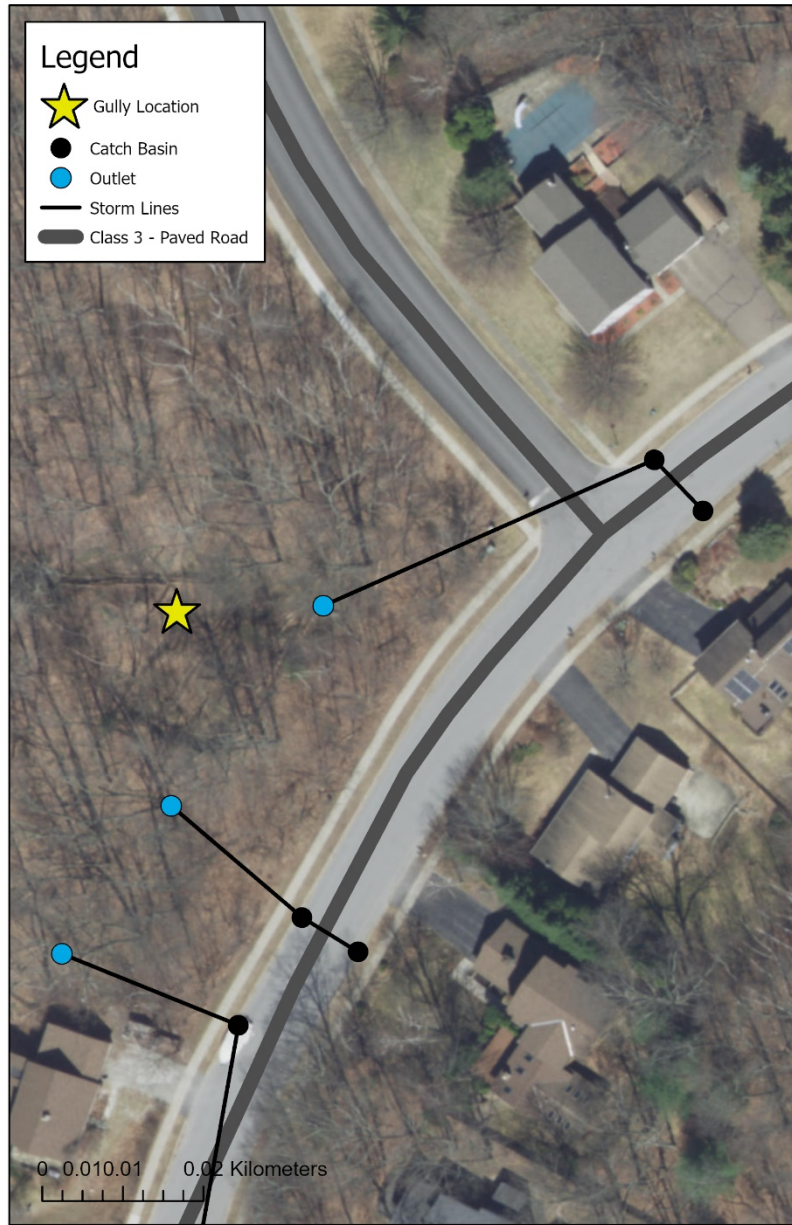
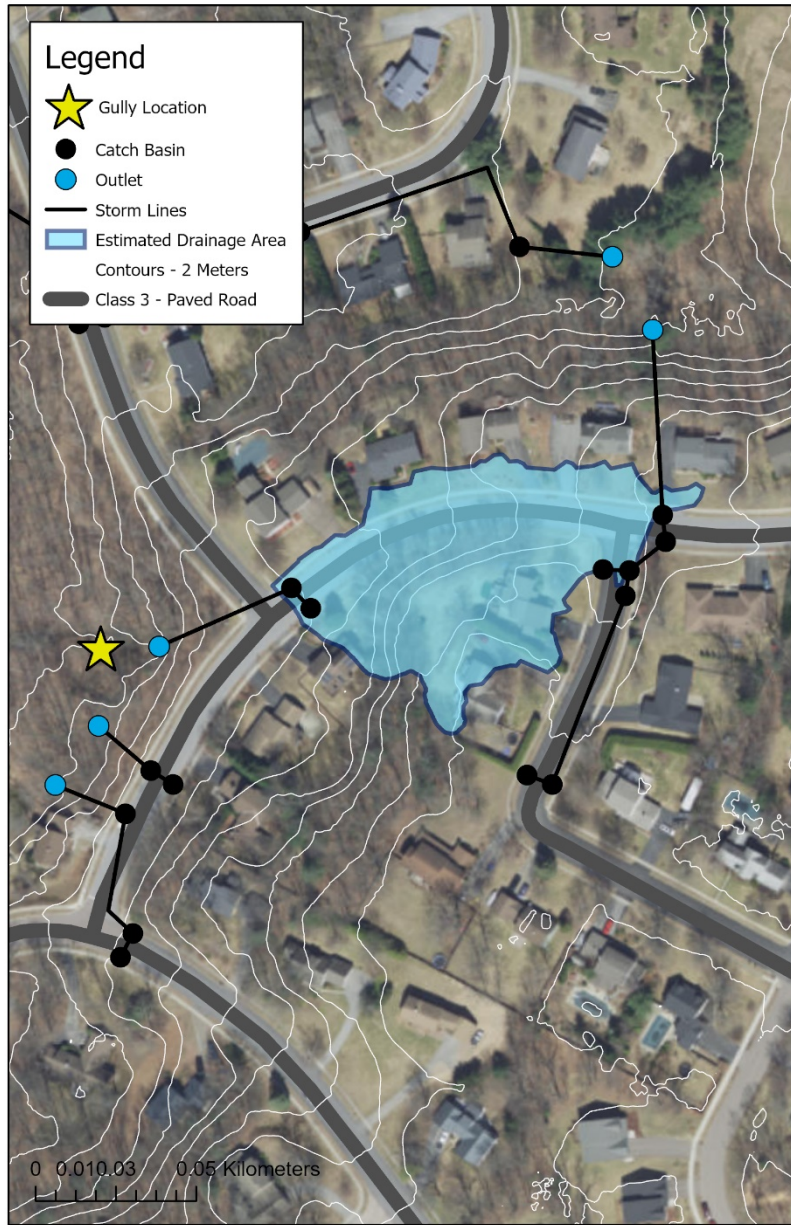


## CORDUROY ROAD (13)

This gully is in a valley between Corduroy Road, Brickyard Road, and Briar Lane in the town of Essex, Vermont. The access to this gully is specifically on Brickyard Road, near the intersection of Corduroy Road. This road is a class 3 paved road that is residential. The culvert monitored is part of the town of Essex culvert database. The culvert diameter is 15 inches and is a closed drainage system. The drainage area for this culvert was estimated to be 5,768 meters<sup>2</sup>. The road length draining to this culvert was estimated at 127 meters and an average width of 9.2 meters. The slope steepness at outlet was estimated as 29.5% (derived from 10-meter DEM). The soil type at the culvert outlet is Duane and Deerfield with a soil texture of loamy sand. Repeated surveys on this site took place from October 10<sup>th</sup>, 2019 to May 11, 2021 with a total of 5 surveys. Erosion mitigation was installed at this site by the Village of Essex Junction before July 2019 when this study was initiated.



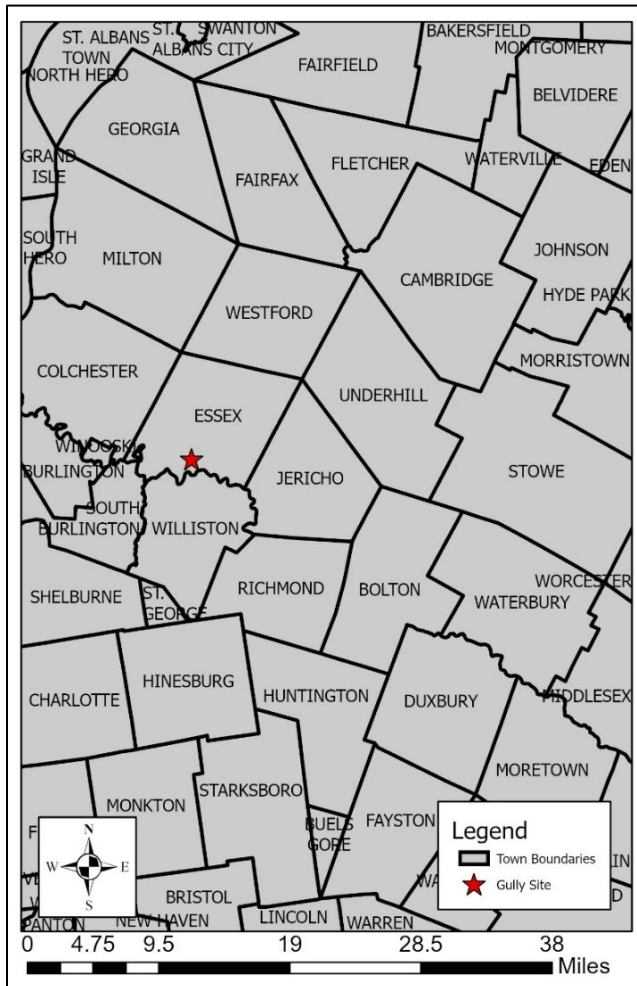


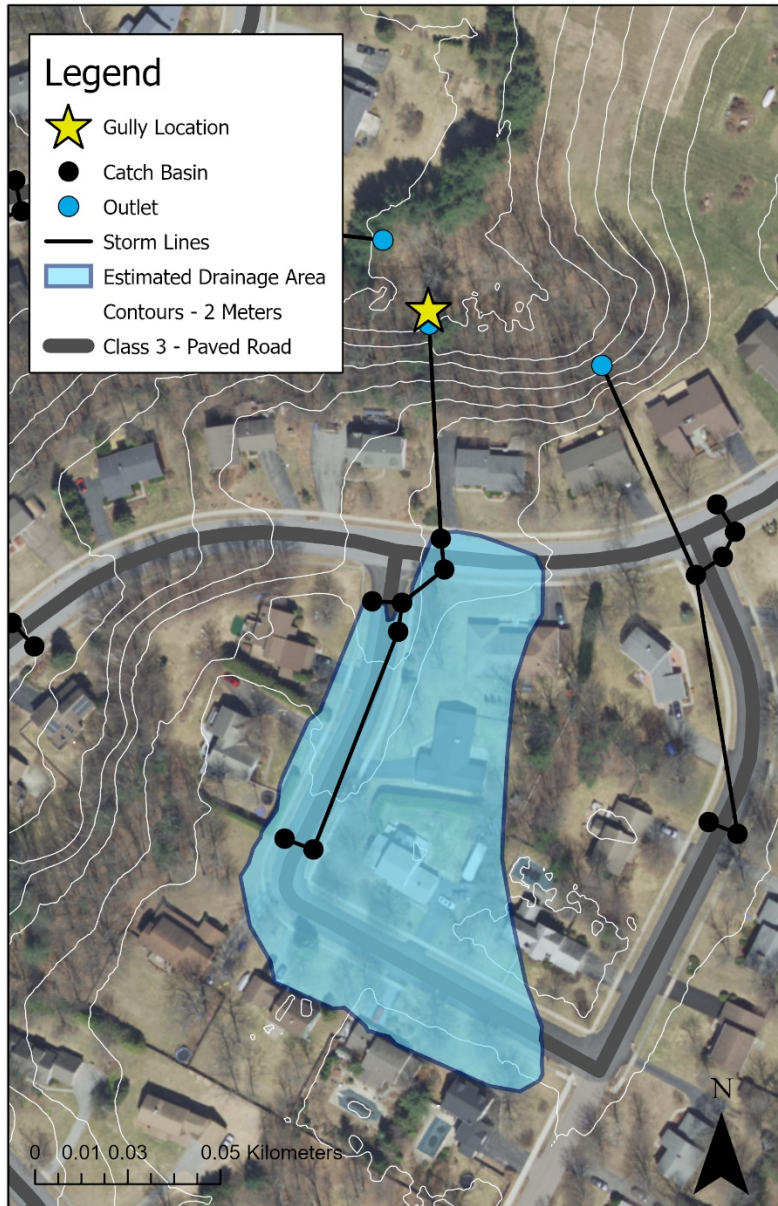




## VALE DRIVE (15)

This gully is located between Vale Drive and Corduroy Road in the town of Essex, Vermont. The access to this gully was specifically on Vale Drive where field technicians had landowner permission to access gully behind their house. This road is a class 3 paved road that is residential. The culvert monitored is part of the town of Essex culvert database. The culvert diameter is 15 inches and is a closed drainage system. The drainage area for this culvert was estimated to be 7,910 meters<sup>2</sup>. The road length draining to this culvert was estimated at 212.9 meters and an average width of 9.2 meters. The slope steepness at outlet was estimated as 35.2% (derived from 10-meter DEM). The soil type at the culvert outlet is Agawam with a soil texture of fine sandy loam. Repeated surveys on this site took place from September 27<sup>th</sup>, 2019 to September 9<sup>th</sup>, 2020 with a total of 4 surveys. Due to landowner restrictions, surveying at this was terminated after September 9<sup>th</sup>, 2020. Erosion mitigation was not installed at this site.

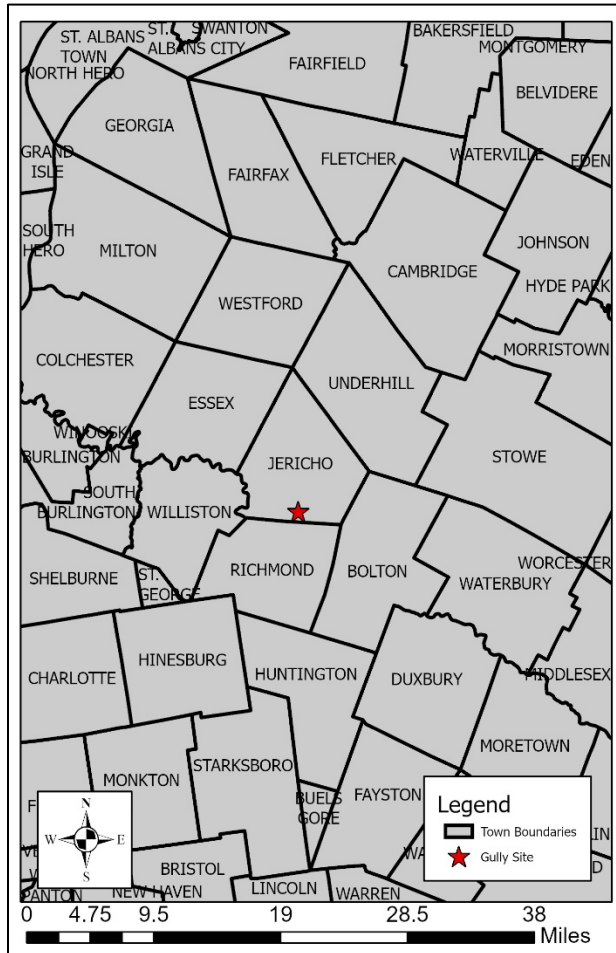




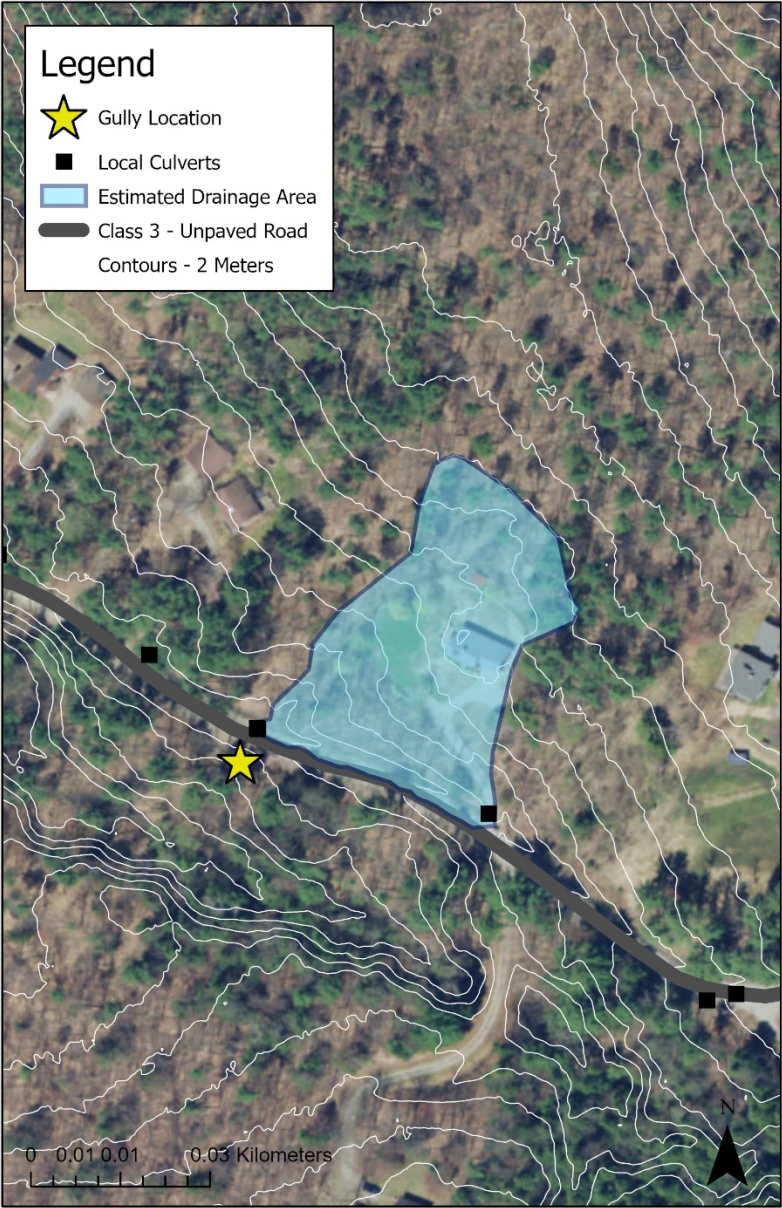


## MILO WHITE ROAD (16)

This gully is located off Milo White Road in the town of Jericho, Vermont. This road is a class 3 unpaved road that is residential. Specifically, the gully is located 1.12 kilometers from the intersection of Brown's Trace Road on the right. The culvert monitored is part of the town of VTCulverts database. The culvert diameter is 24 inches and 35 feet in length. This culvert is a single pipe part of an open drainage network. The drainage area for this culvert was estimated to be 6,147 meters<sup>2</sup>. The road length draining to this culvert was estimated at 169.2 meters and an average width of 9.5 meters. The slope steepness at outlet was estimated as 13.7% (derived from 10-meter DEM). The soil type at the culvert outlet is Peru with a soil texture of fine sandy loam. Repeated surveys on this site took place from May 12<sup>th</sup>, 2020 to May 13, 2021 with a total of 5 surveys. Erosion mitigation was installed at this site in early July 2020.



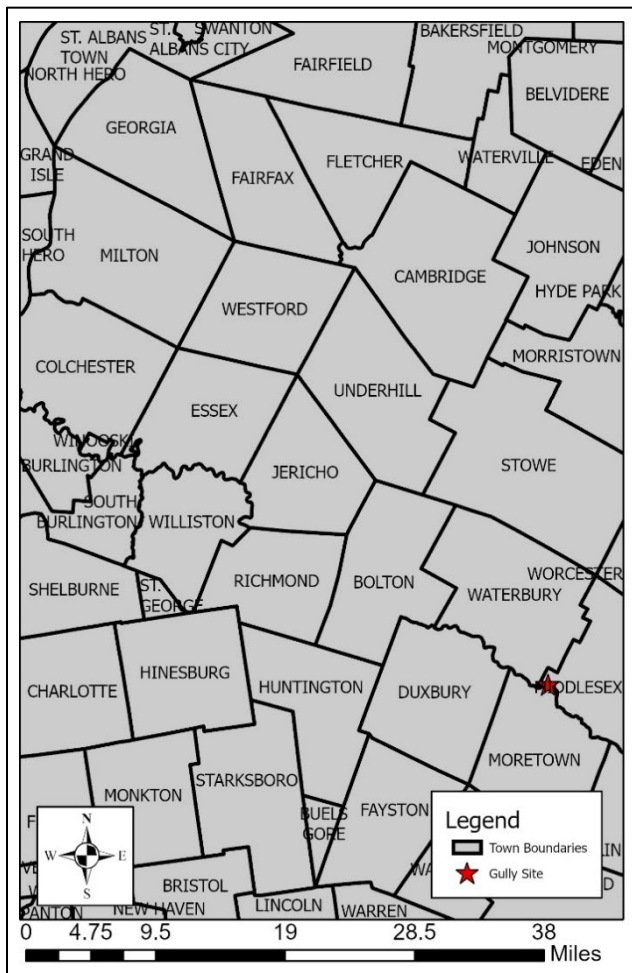


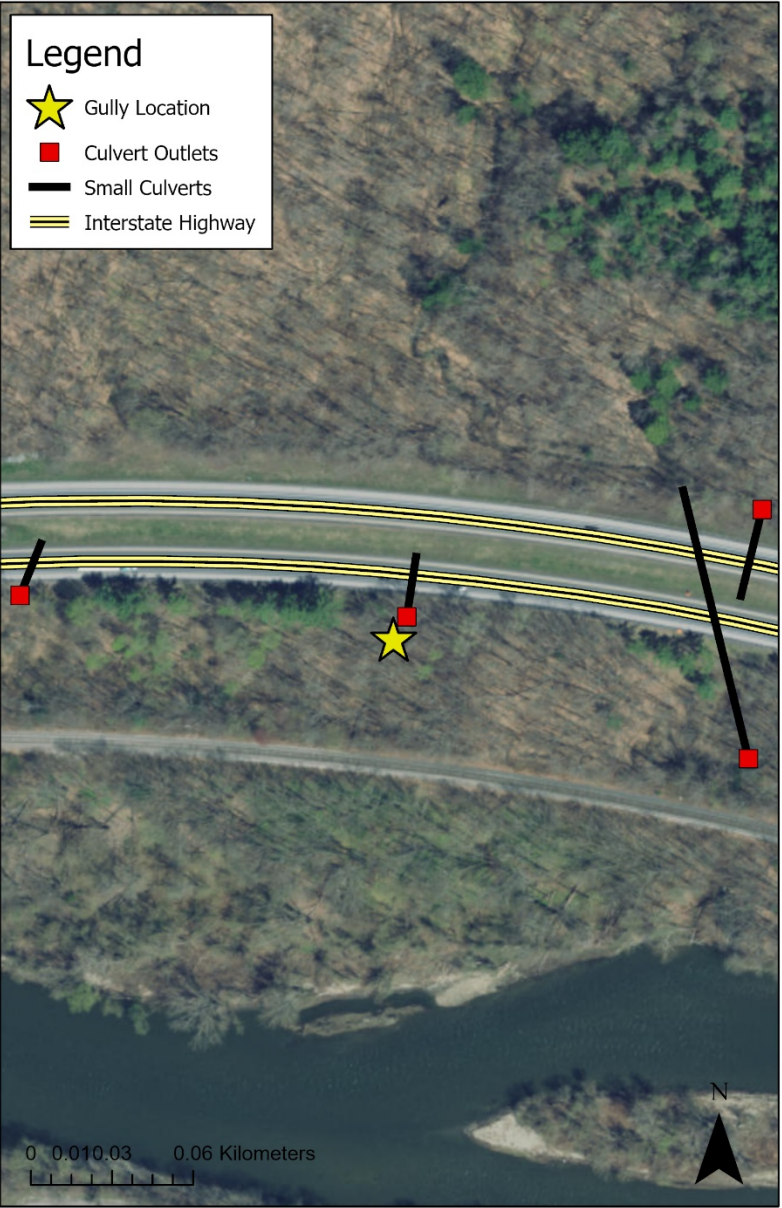
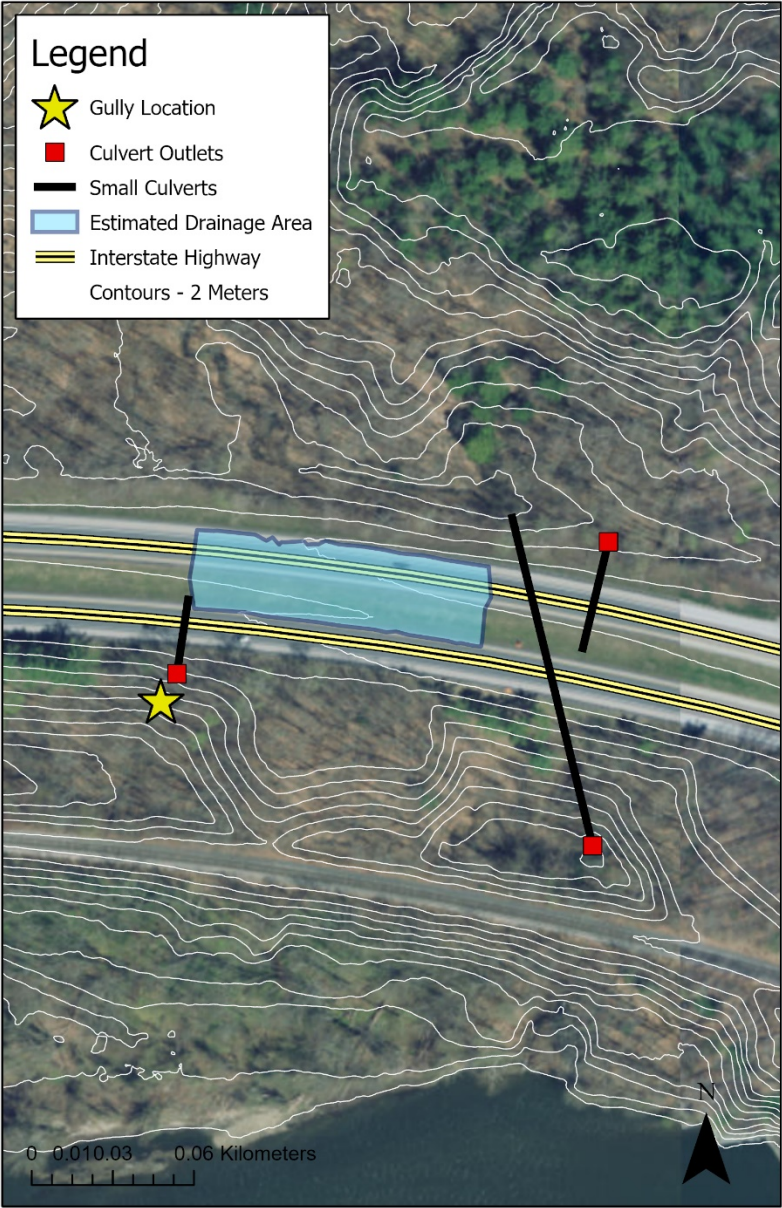




## I-89 MIDDLESEX

This gully is at the south direction on Interstate 89 and is located 5.7 kilometers past the Montpelier on ramp in the town of Middlesex, Vermont. This road is a one lane Interstate Highway that is maintained by the Vermont Agency of Transportation District 5. The culvert monitored is part of the Small Culvert Inventory database with an ID of 60855. The culvert was a concrete material and 18 inches in diameter and 79 feet in length. The system type of the culvert is a single pipe. The drainage area for this culvert was estimated to be 2,164 meters<sup>2</sup> (derived from 0.7-meter DEM). The road length draining to this culvert was estimated at 90.9 meters and an average width of 14 meters. The slope steepness at outlet was estimated as 48.1% (derived from 10-meter DEM). The soil type at the culvert outlet is Tunbridge-Lyman Complex with a soil texture of fine sandy loam. Repeated surveys on this site took place from May 12<sup>th</sup>, 2020 to May 13, 2021 with a total of 5 surveys. Erosion mitigation was not installed at this site.

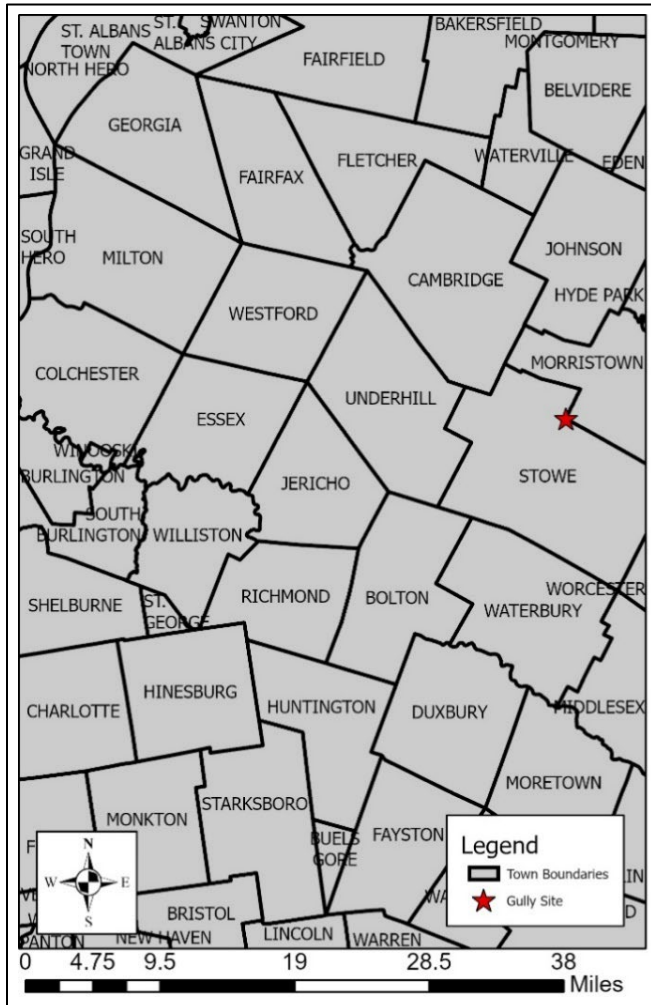




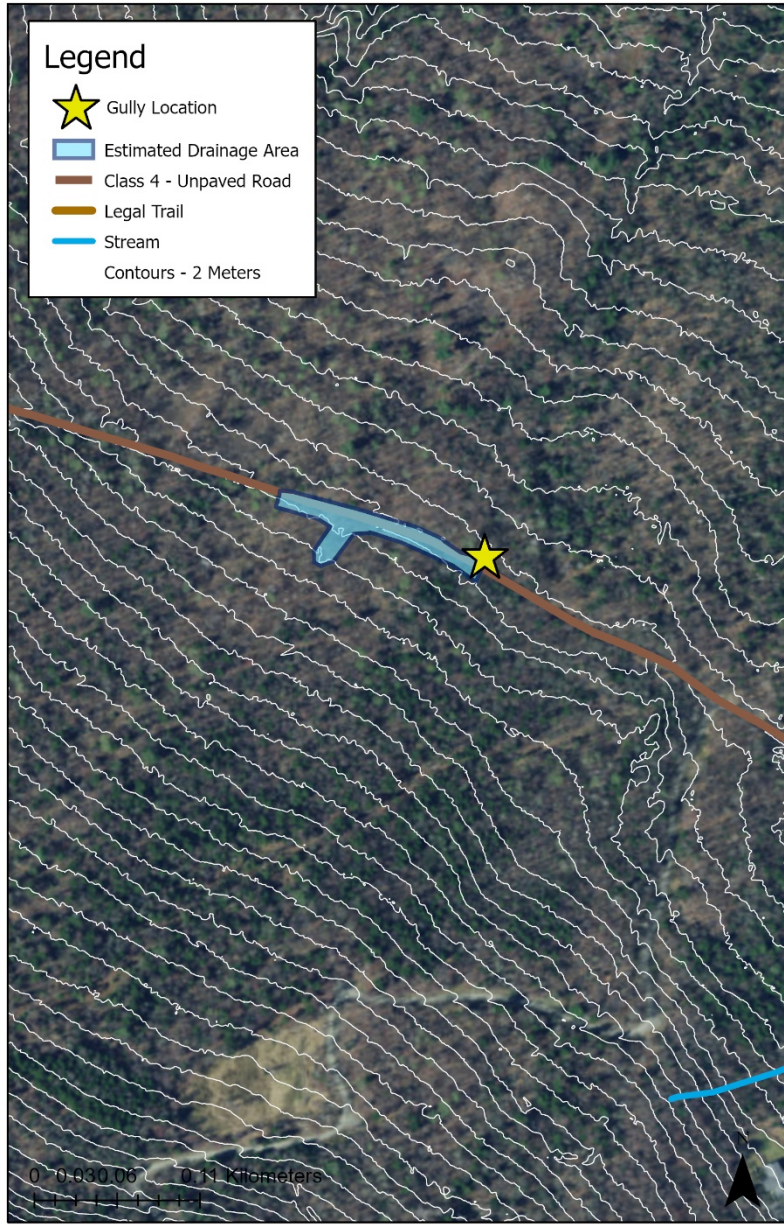


## MAPLE RUN LANE (30)

This gully is located off Maple Run Lane in the town of Stowe, Vermont. This road is a class 4 unpaved road and located 0.18 kilometers from a pull off on Maple Run Lane (access to site is on foot). The culvert monitored is not part of any database. This culvert is a single pipe part of an open drainage network. The drainage area for this culvert was estimated to be 2,294 meters<sup>2</sup>. The road length draining to this culvert was estimated at 145.3 meters and an average width of 4.5 meters. The slope steepness at outlet was estimated as 7.7% (derived from 10-meter DEM). The soil type at the culvert outlet is Berkshire with a soil texture of fine sandy loam. Repeated surveys on this site took place from November 2<sup>nd</sup>, 2019 to May 17, 2021 with a total of 6 surveys. Erosion mitigation was installed at this site in October 2020.



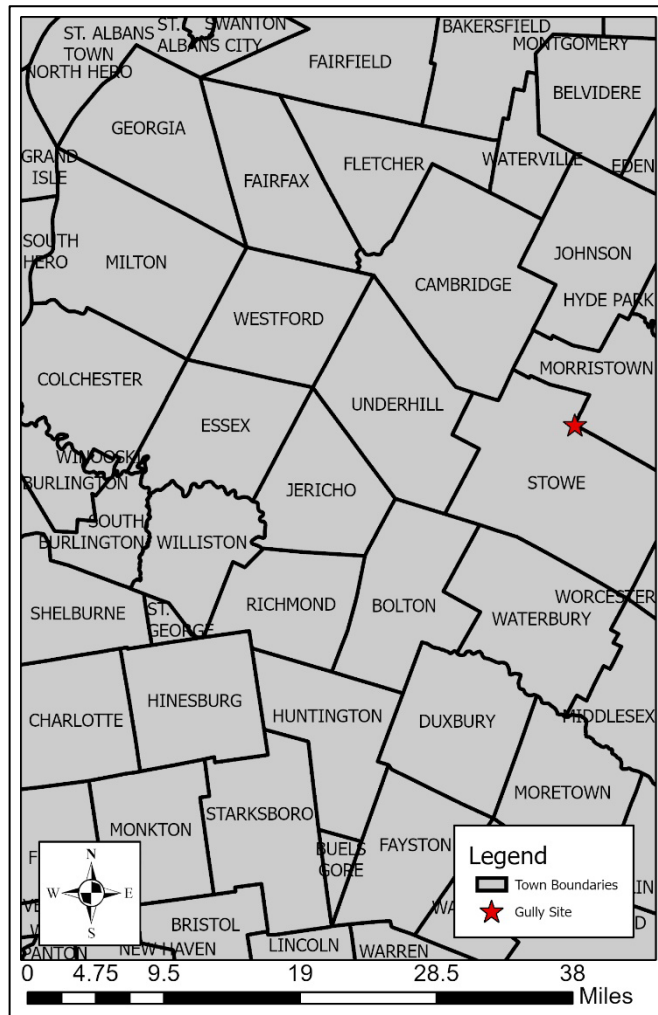




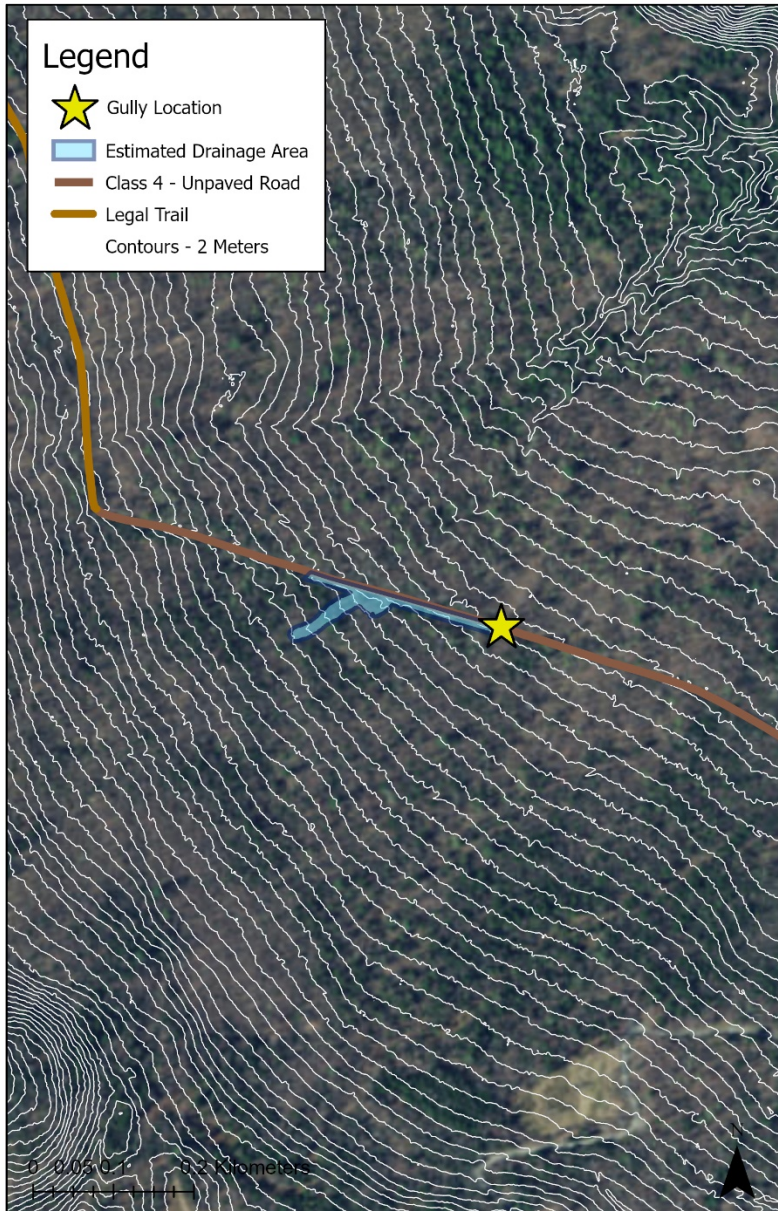


## MAPLE RUN LANE (31)

This gully is located off Maple Run Lane in the town of Stowe, Vermont. This road is a class 4 unpaved road and located 0.40 kilometers from a pull off on Maple Run Lane (access to site is on foot). The culvert monitored is not part of any database. This culvert is a single pipe part of an open drainage network. The drainage area for this culvert was estimated to be 2,698 meters<sup>2</sup>. The road length draining to this culvert was estimated at 180.6 meters and an average width of 4.5 meters. The slope steepness at outlet was estimated as 7.5% (derived from 10-meter DEM). The soil type at the culvert outlet is Berkshire with a soil texture of fine sandy loam. Repeated surveys on this site took place from November 2<sup>nd</sup>, 2019 to May 17, 2021 with a total of 5 surveys. Erosion mitigation was not installed at this site.



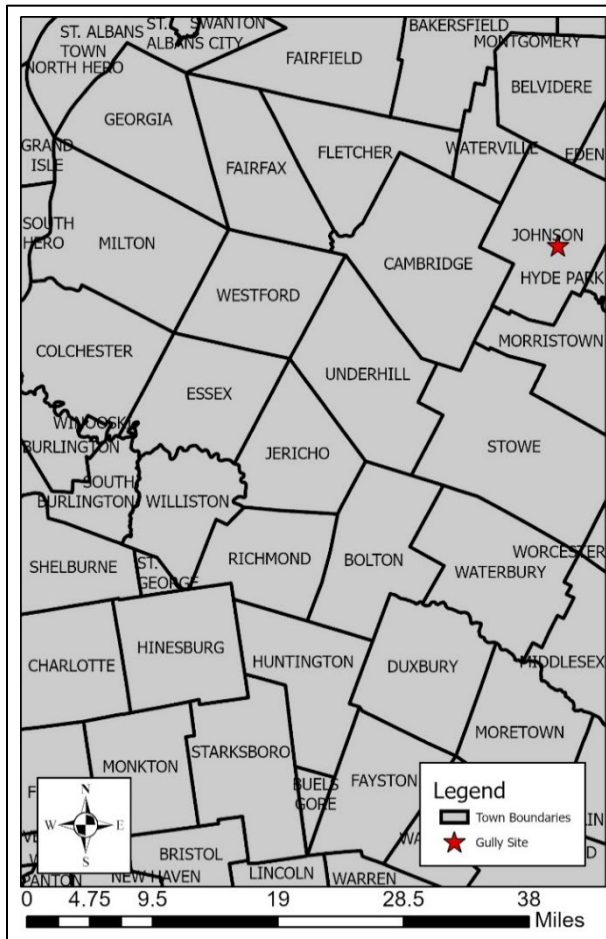




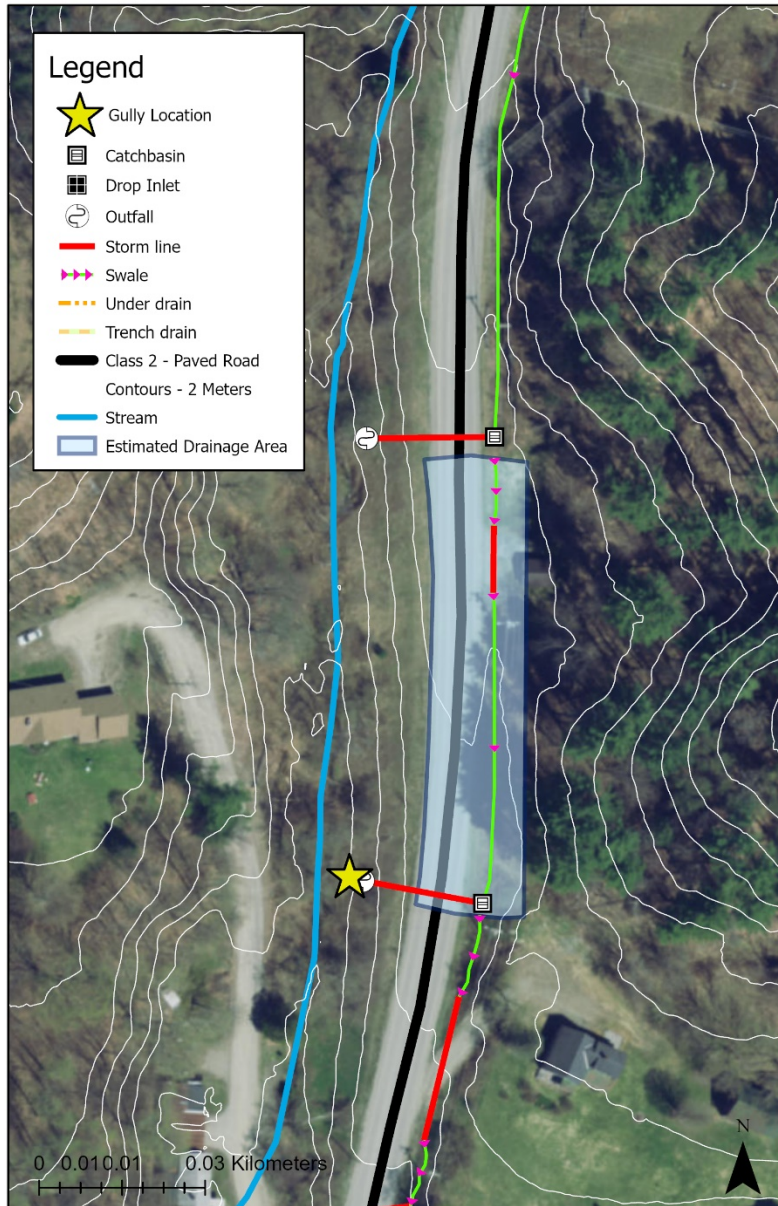


## CLAY HILL ROAD (32)

This gully is located off Clay Hill Road in the town of Johnson, Vermont. This road is a class 3 paved road and located on the left 0.4 kilometers from the intersection of Lower Main Street and Pearl Street (Pearl Street turns into Clay Hill Road at the intersection of School Street). The culvert monitored is part of the town of an Agency of Natural Resources database that included supplementary information on the drainage and hydrologic network. The metal culvert diameter is 18 inches in width and 60 feet in length. This culvert is a single pipe part of an open drainage network. The drainage area for this culvert was estimated to be 1,490 meters<sup>2</sup>. The road length draining to this culvert was estimated at 79.7 meters and an average width of 7.8 meters. The slope steepness at outlet was estimated as 14.7% (derived from 10-meter DEM). The soil type at the culvert outlet is Salmon Variant with a soil texture of very fine sandy loam. Repeated surveys on this site took place from May 8<sup>th</sup>, 2020 to May 18, 2021 with a total of 4 surveys. Erosion mitigation was installed at this site in October 2020.



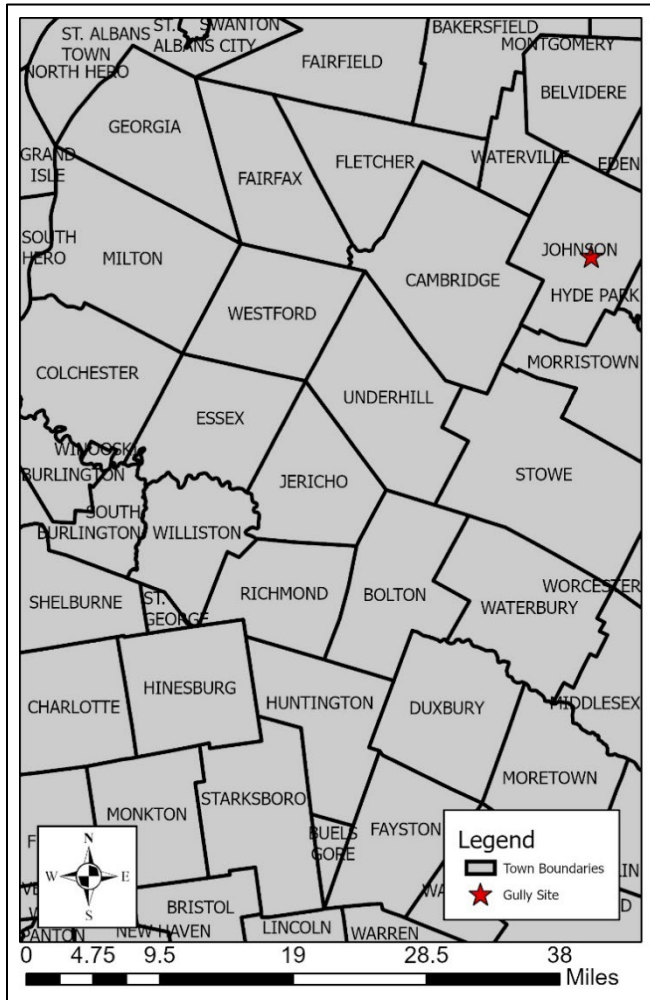




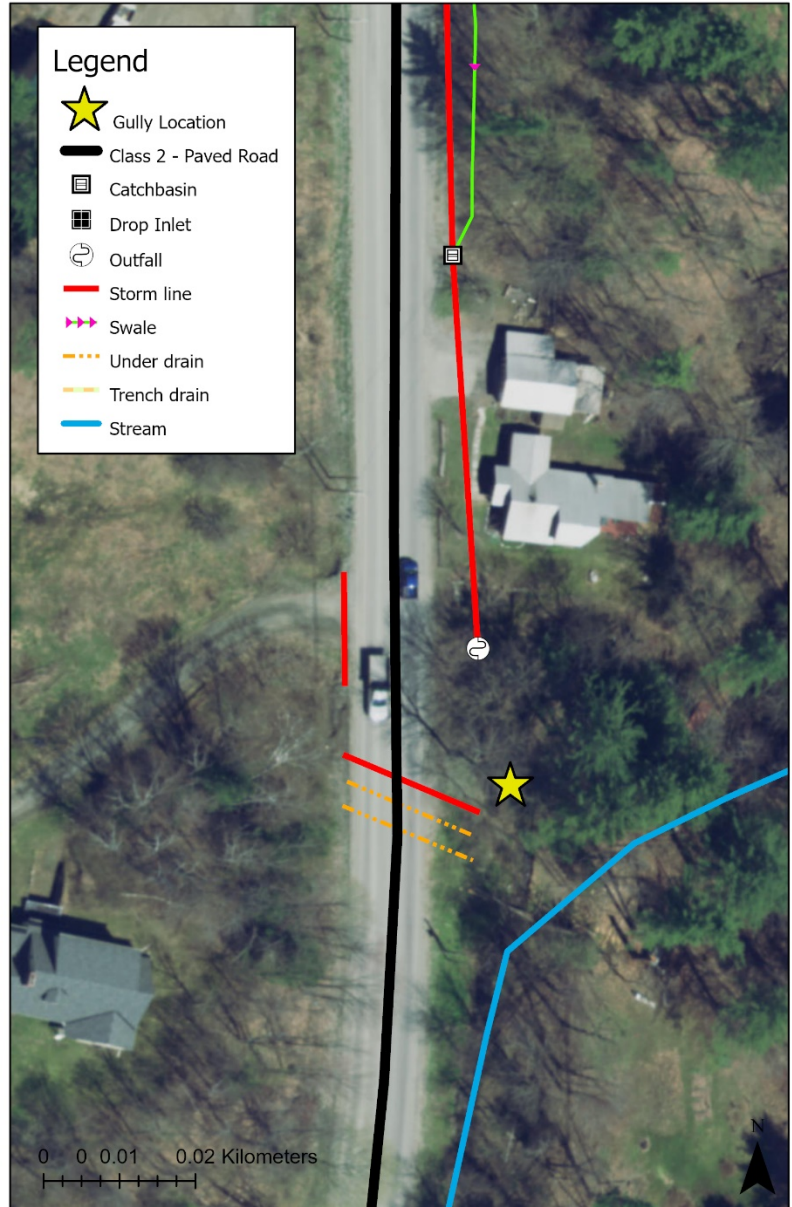
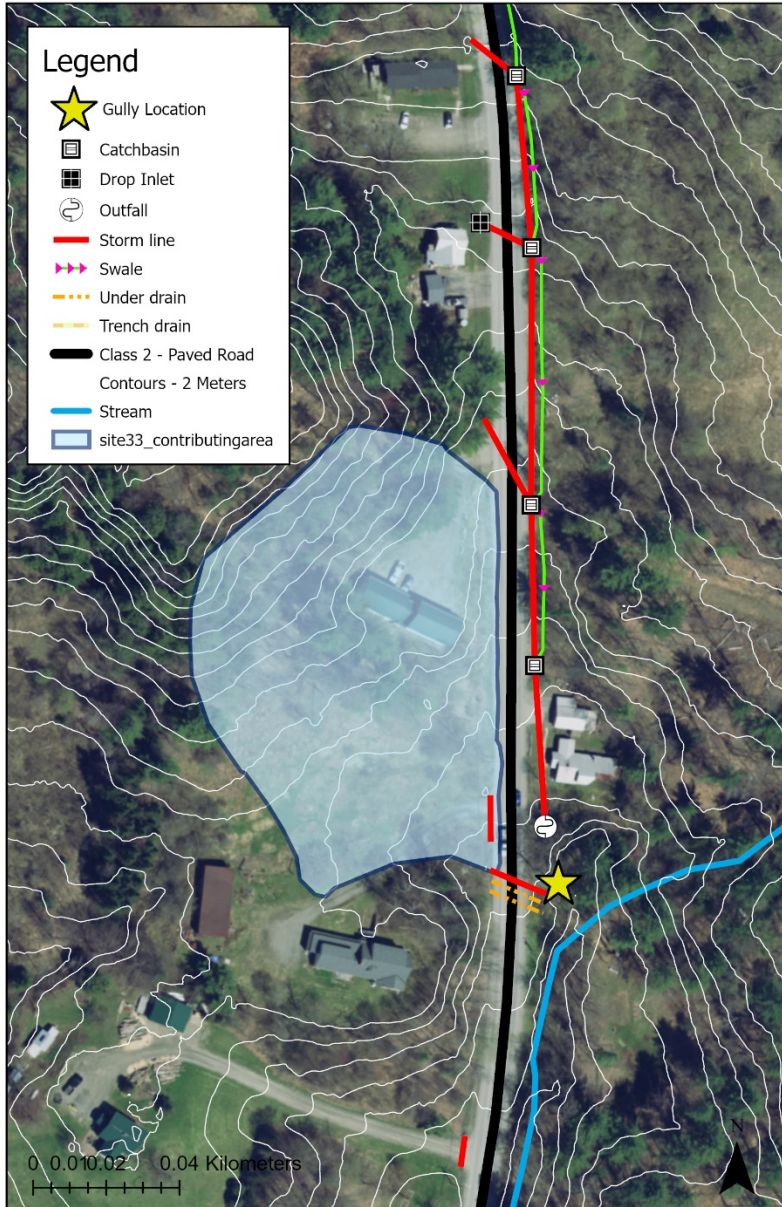


## CLAY HILL ROAD (33)

This is located off Clay Hill Road in the town of Johnson, Vermont. This road is a class 3 paved road and located on the right 0.77 kilometers from the intersection of Lower Main Street and Pearl Street (Pearl Street turns into Clay Hill Road at the intersection of School Street). The culvert monitored is part of the town of an Agency of Natural Resources database that included supplementary information on the drainage and hydrologic network. The metal culvert is 18 inches in diameter and 48 feet in length. This culvert is a single pipe part of an open drainage network. The drainage area for this culvert was estimated to be 8,341 meters<sup>2</sup>. The road length draining to this culvert was estimated at 103.8 meters and an average width of 7.8 meters. The slope steepness at outlet was estimated as 20.8% (derived from 10-meter DEM). The soil type at the culvert outlet is Salmon Variant with a soil texture of very fine sandy loam. Repeated surveys on this site took place from May 8<sup>th</sup>, 2020 to May 18, 2021 with a total of 4 surveys. Erosion mitigation was not installed at this site.



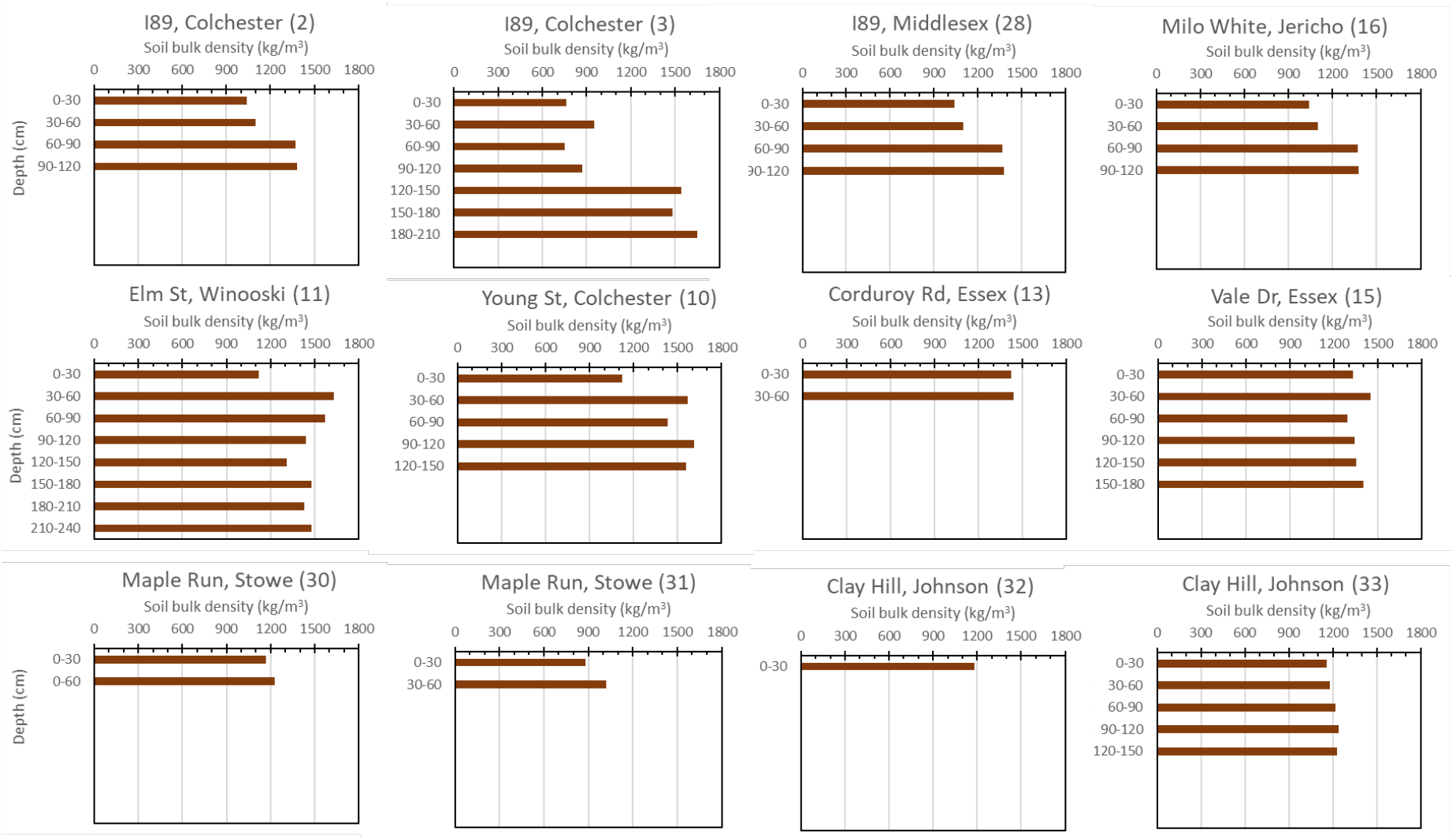






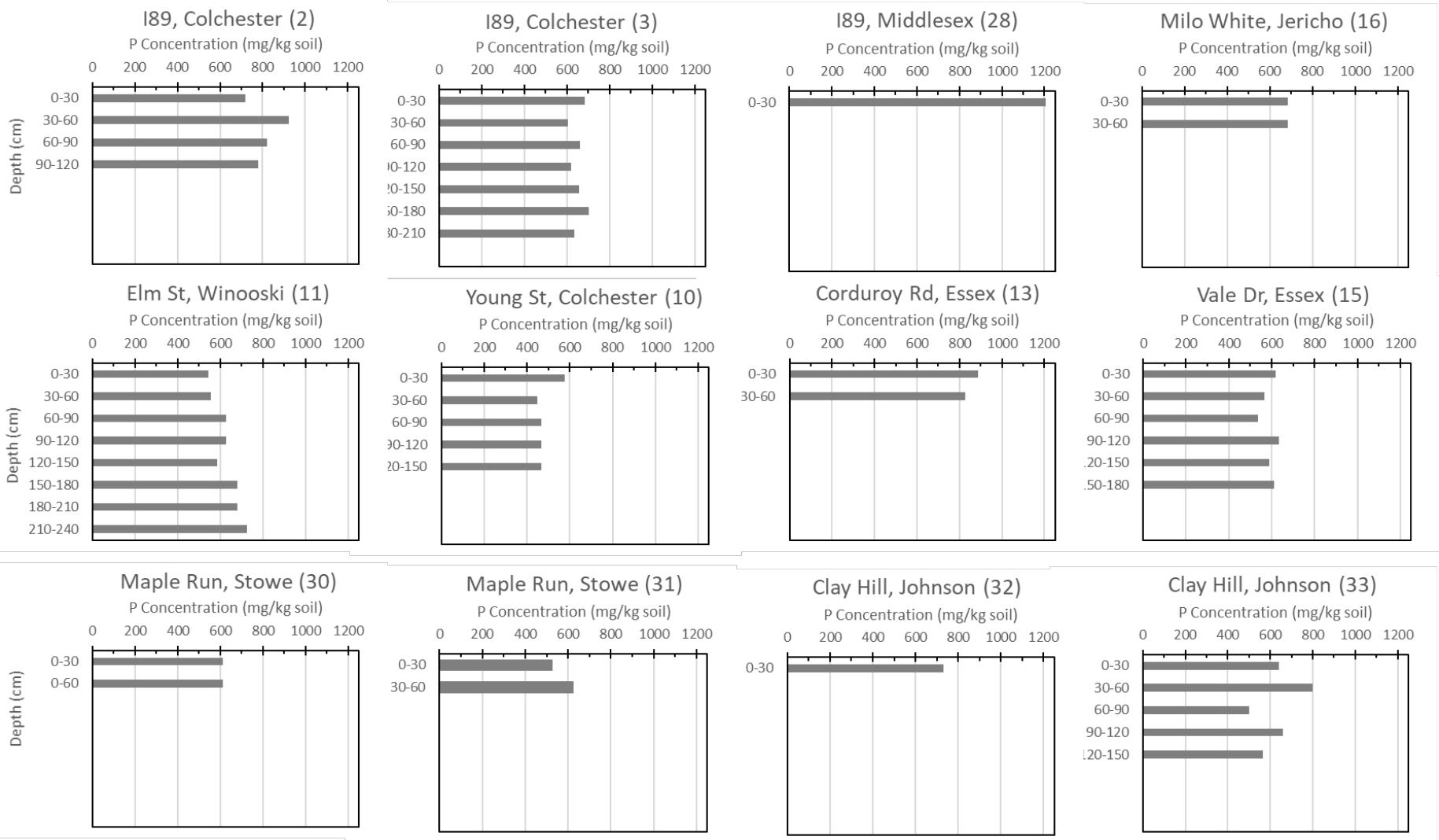
## Appendix 2: Soil bulk density and phosphorus concentrations from sampled gullies

## A. Soil Bulk Density





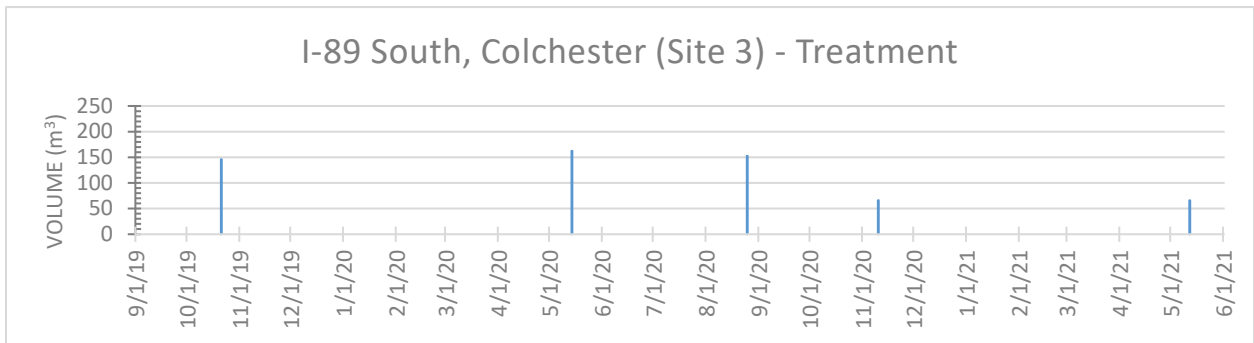
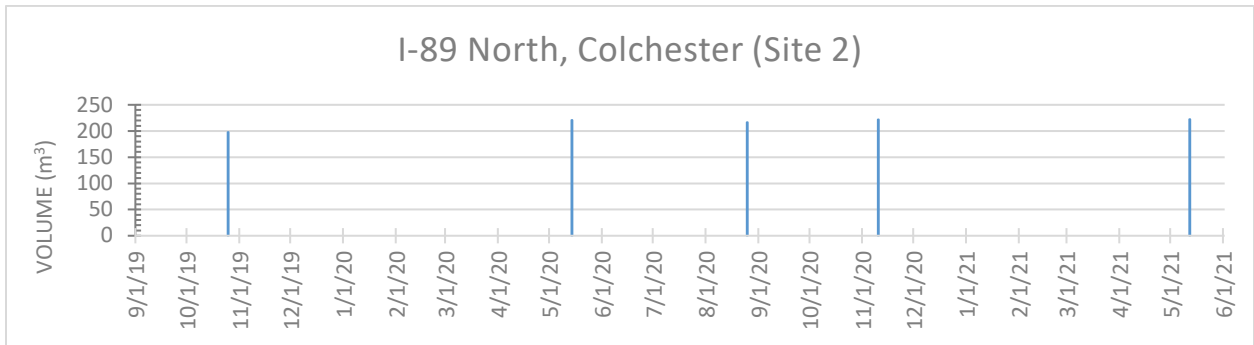
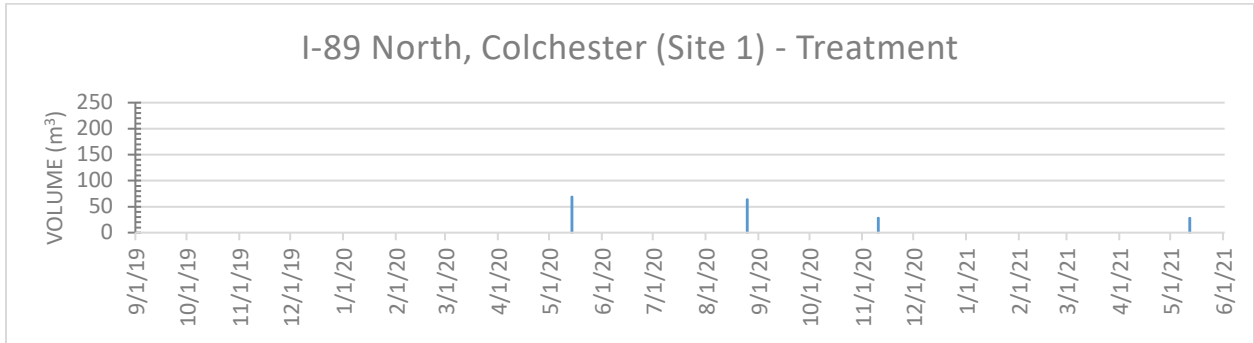
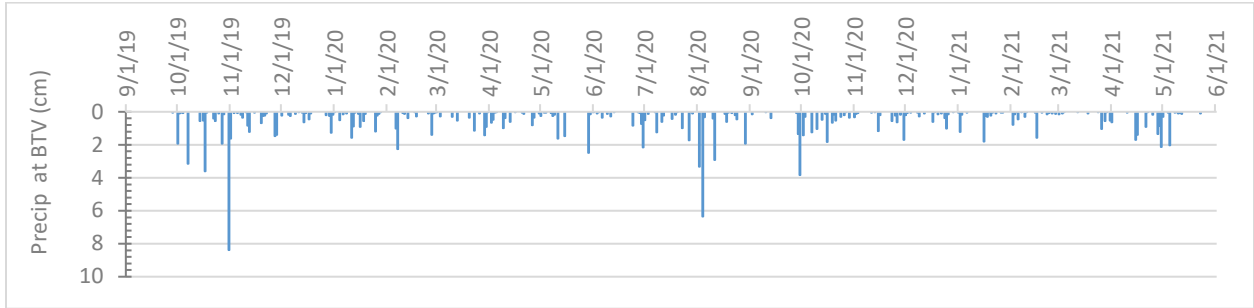
**B. Phosphorus Concentration**

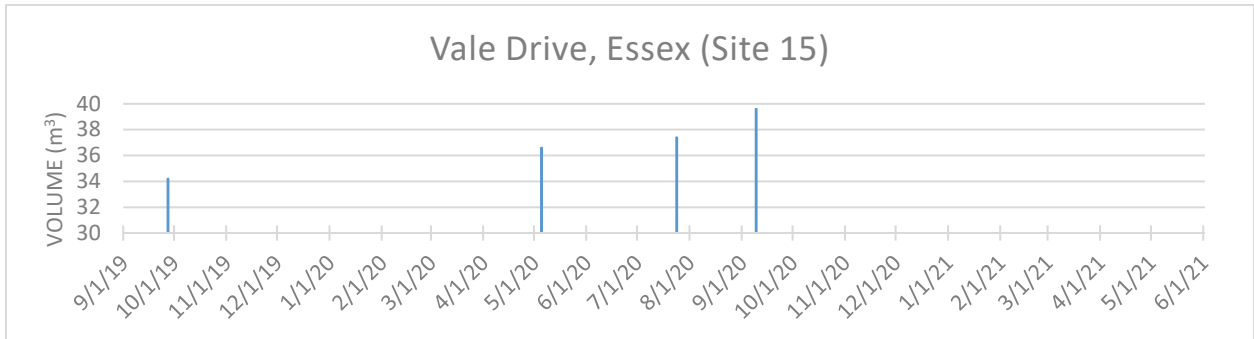
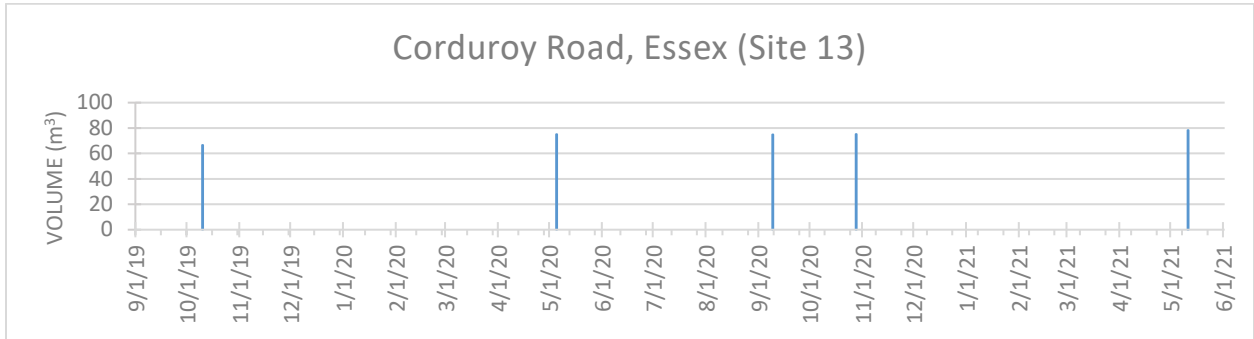
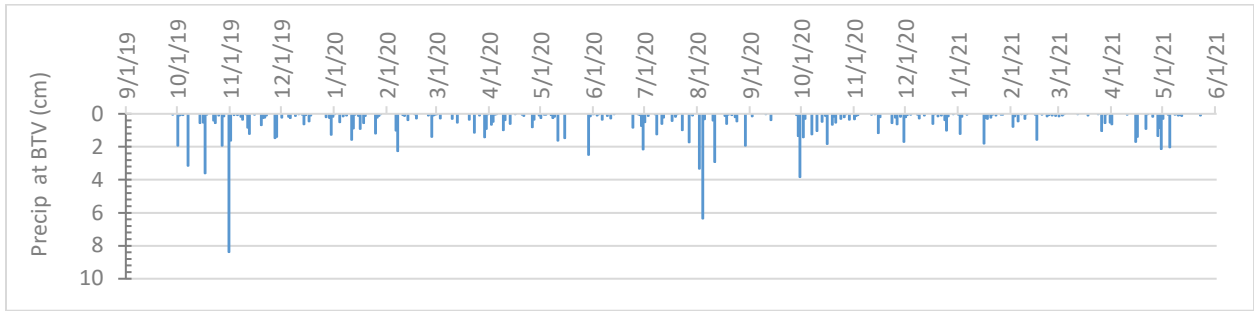


## Appendix 3: Time series plots of gully volumes

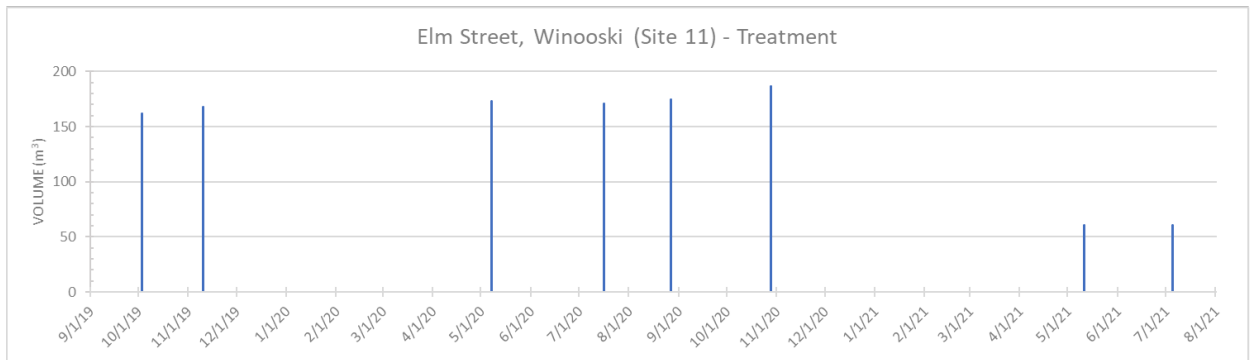
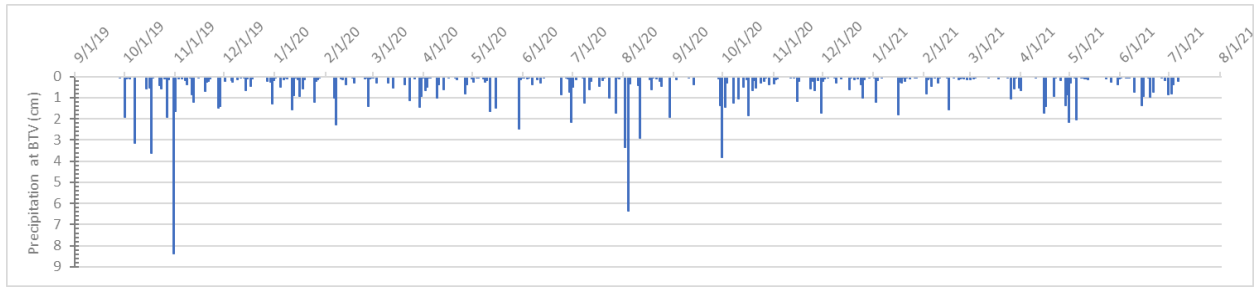
Note: Plots presented in this Appendix are for data collected over the term of this project. Precipitation data are daily totals for Burlington International Airport (BTV) and Morrisville Airport (MVL). Y-axis scales for precipitation and gully volume differ among plots displayed. Site pairs are plotted on common y-axis scale to aid in visual comparison of gully volumes.

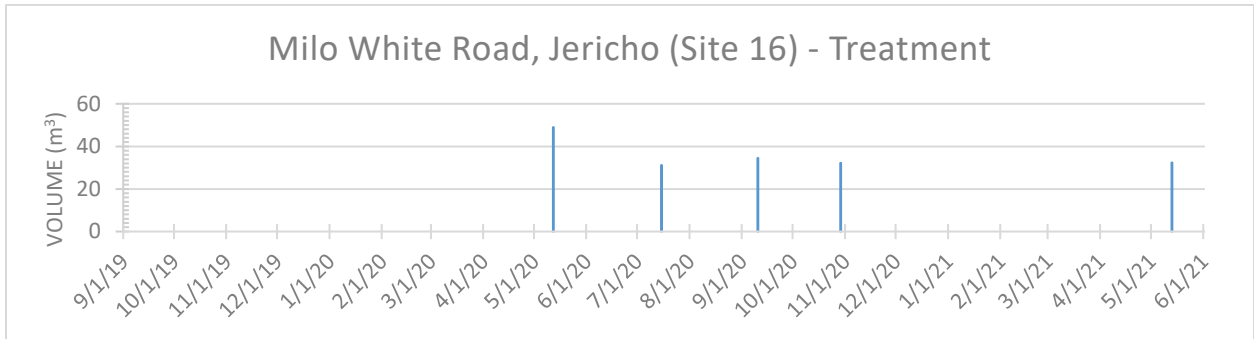
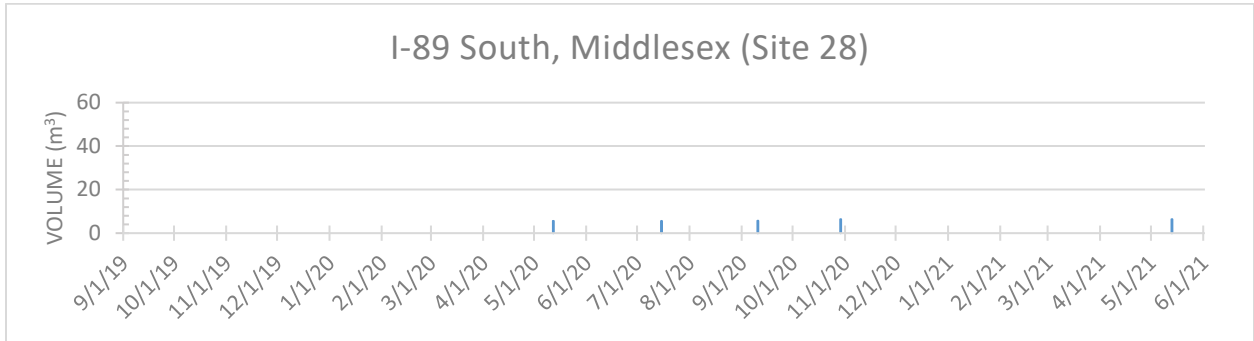
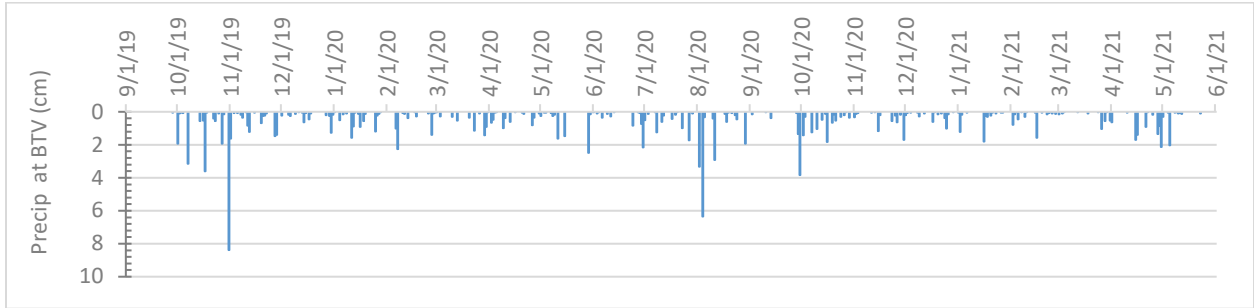




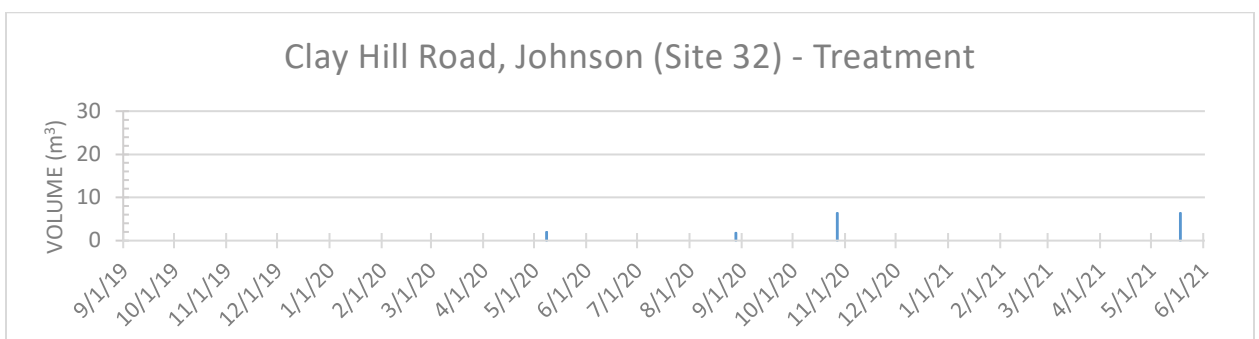
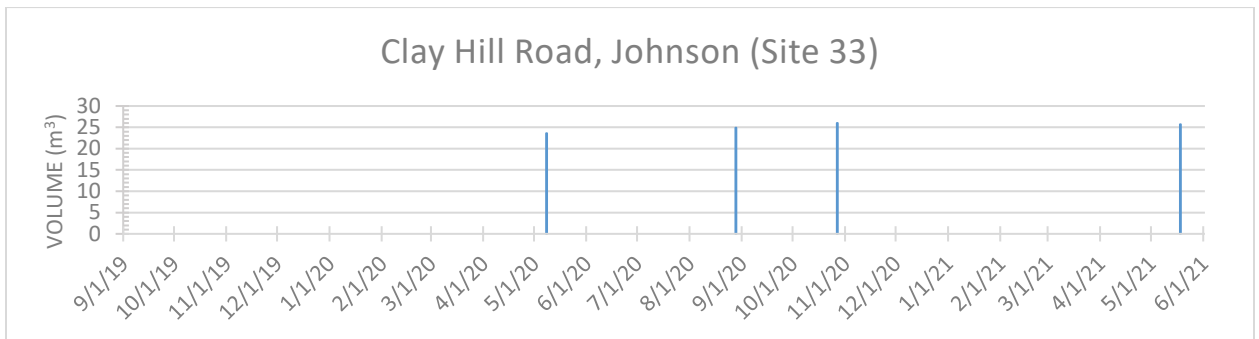
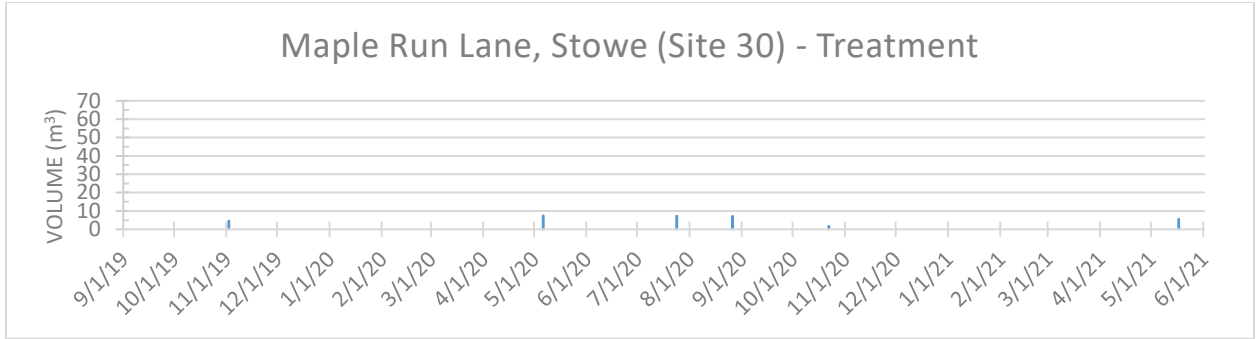
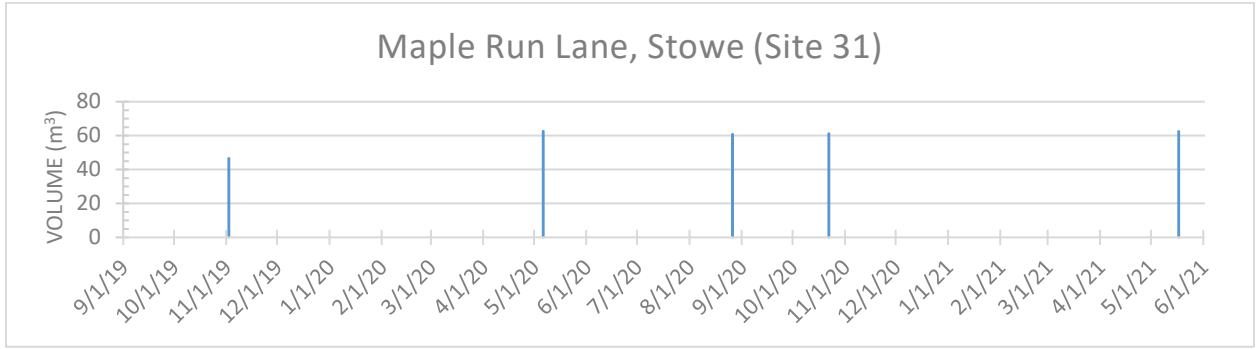
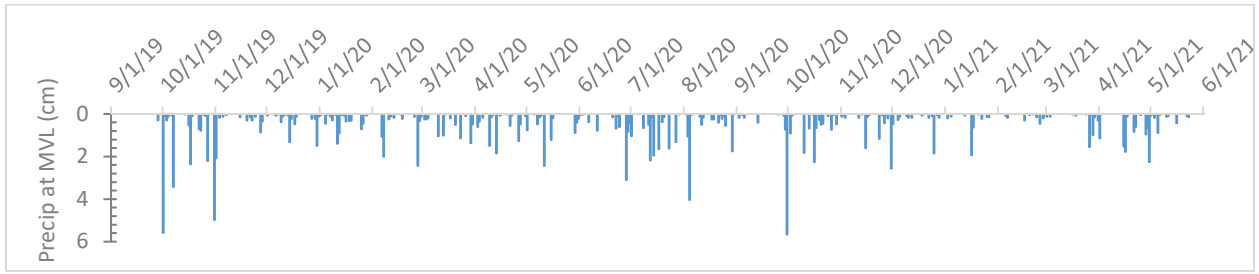










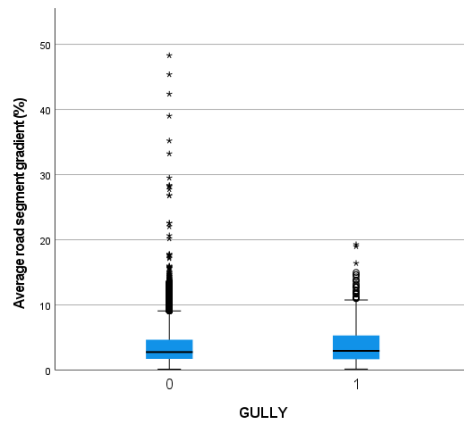
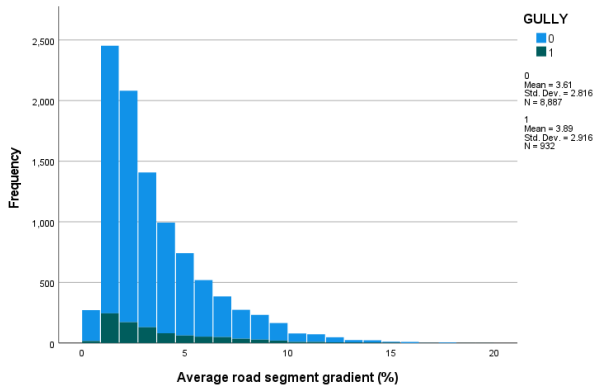
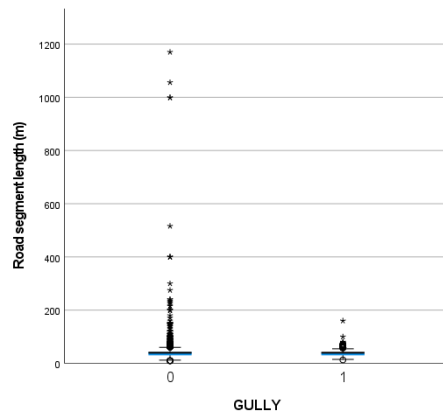
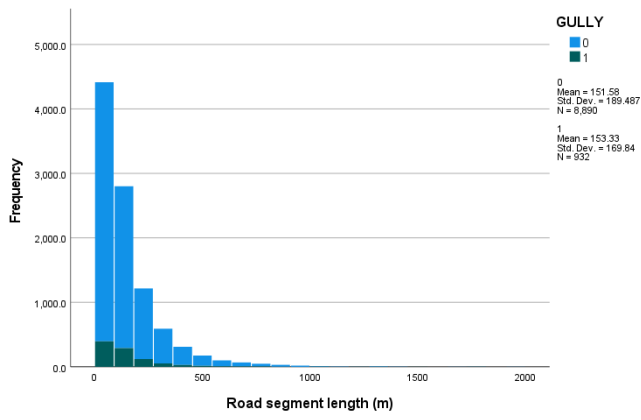
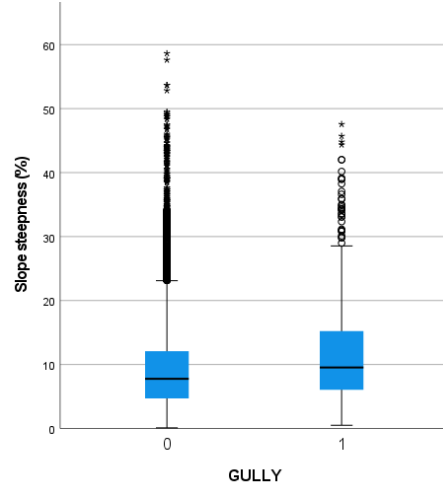
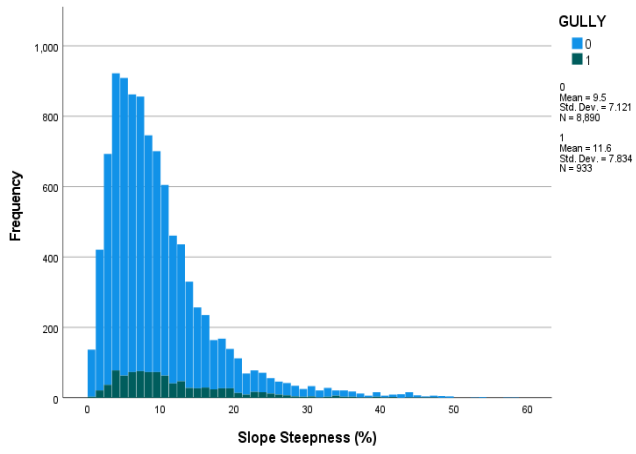


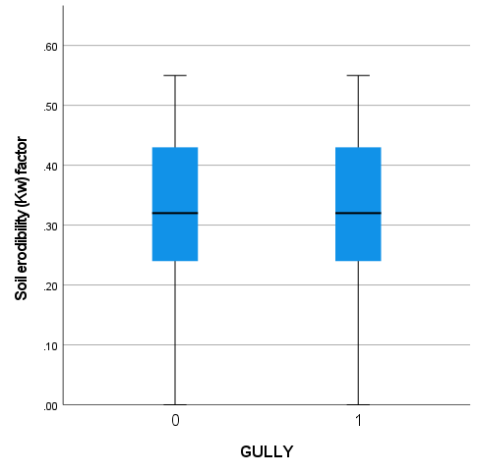
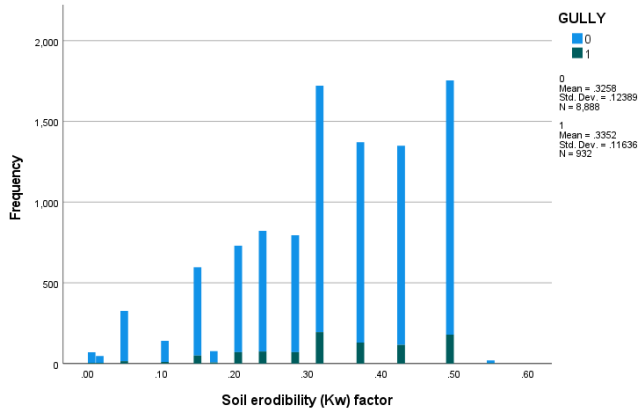
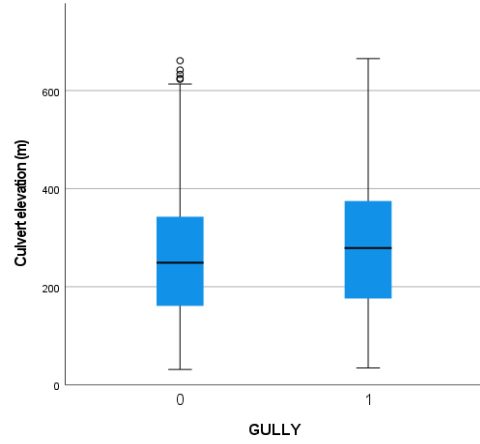
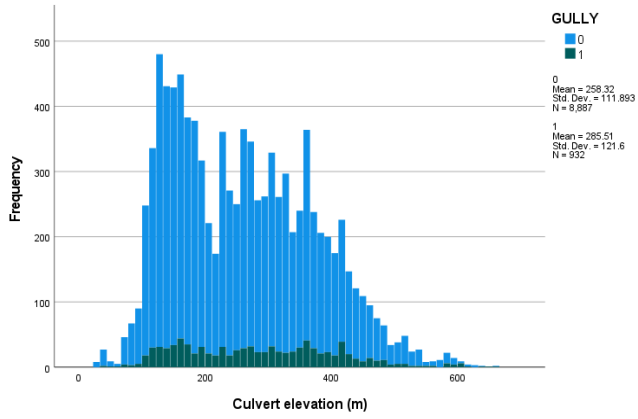
## Appendix 4: Airborne Lidar Data Visualizations and Statistical Analyses

This appendix contains plots for the dataset of gullies identified on airborne lidar data. The graphs on the following pages visualize gully occurrence against the set of continuous variables assessed (in both histogram form and as error bar plots). Tables summarize counts of culverts with (gully = 1) and without (gully = 0) against categorical explanatory variables.

Note to TAC: This appendix could be supplemented, by request of TAC members, to include additional data plots exploring bivariate relationships. We did not find statistically significant relationships between gully volume or volume change over time and explanatory variables assessed. Visualizations of these plots may be of interest to TAC members to see where expected associations fail to emerge in the dataset.









### GULLY \* Parent\_Code Crosstabulation

Count

		Parent_Code		Total
		1	2	
GULLY	0	2069	6644	8713
	1	207	708	915
Total		2276	7352	9628

### GULLY \* HSG\_Code Crosstabulation

Count

		HSG_Code		Total
		1	2	
GULLY	0	1913	6742	8655
	1	209	706	915
Total		2122	7448	9570

### GULLY \* River\_200m Crosstabulation

Count

		River_200m		Total
		0	1	
GULLY	0	6185	2705	8890
	1	634	299	933
Total		6819	3004	9823

### GULLY \* Impacted\_Irene Crosstabulation

Count

		Impacted_Irene		Total
		0	1	
GULLY	0	6401	2489	8890
	1	642	291	933
Total		7043	2780	9823

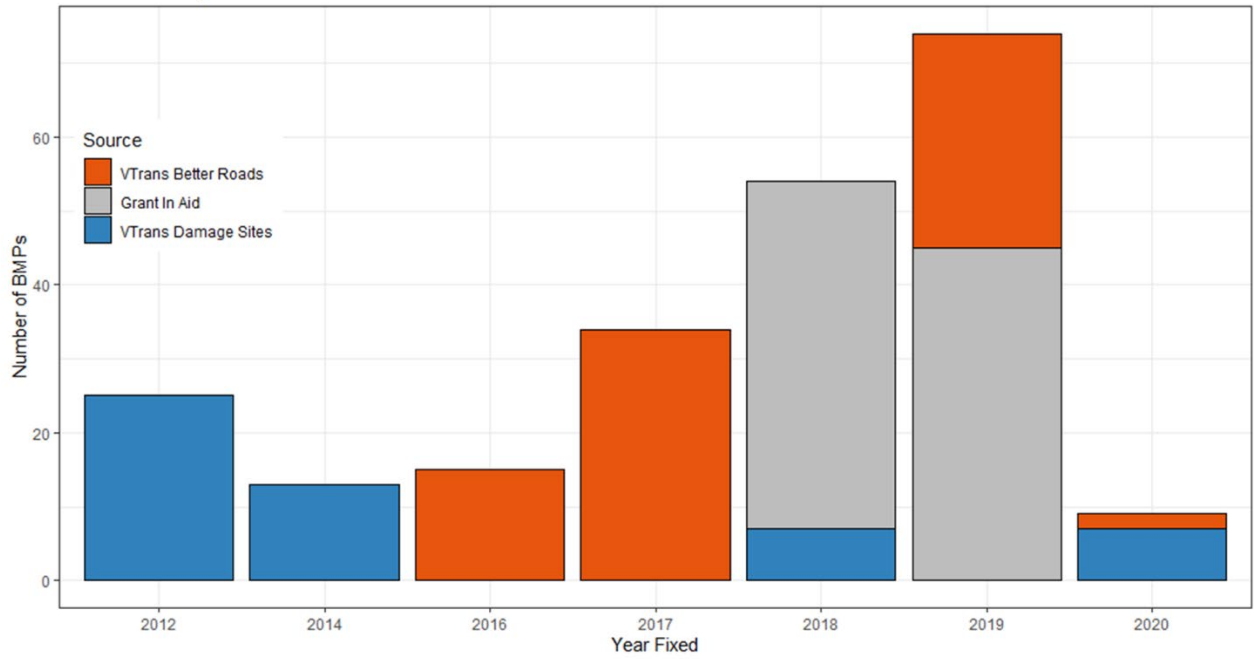
## Appendix 5: Retrospective Analysis

This appendix contains plots for the retrospective assessment dataset. Each observation is an assessment of an erosion mitigation installation (or “best management practice, BMP”), drawn from the VTRANS Direct Damage Inspection Reports (DDIR), Better Roads, and Grants in Aid databases provided by members of our Technical Advisory Committee and their collaborators.

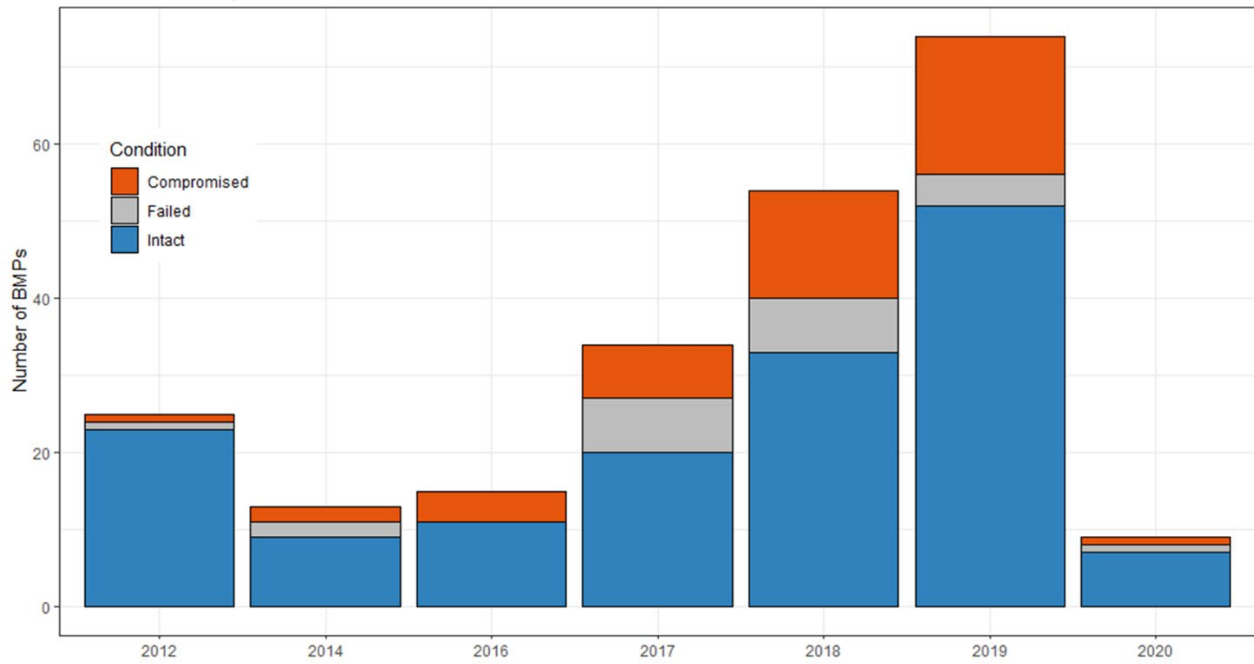
The graphs on the following pages visualize the sites assessed against variables of interest, including year practice was installed, assessed condition of the practice, age of practice (assumed to be 2020 minus year recorded in the database), and slope steepness on which the erosion remediation project (or BMP) was installed.



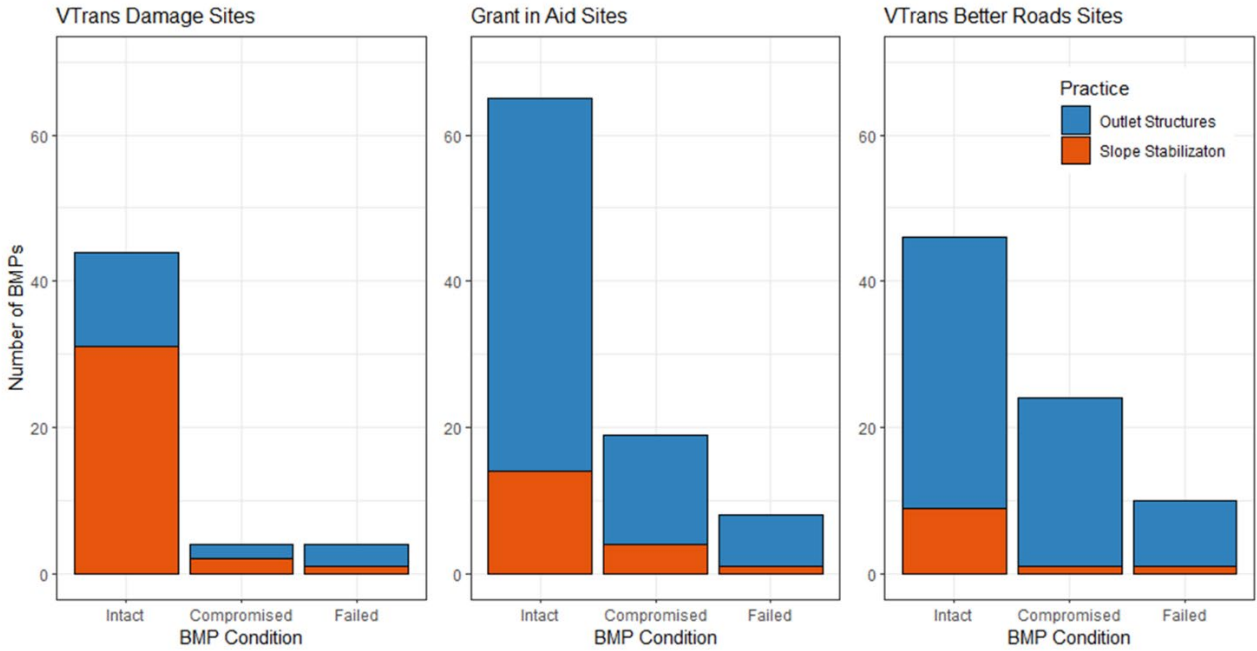
Source of Site by Year Fixed



Condition of BMP by Year Fixed



Condition of BMP Assessed by Site Source



Condition of BMP Assessed by Age of Project

