Lamprey Watershed Stream Crossing Assessment Summary
Southeastern New Hampshire

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1.0 Introduction

1.1 Project Background

The Lamprey River watershed is found in the counties of Rockingham and Strafford in southeastern New Hampshire (Fig. 1). The watershed has been the subject of a coordinated effort by several agencies and organizations, including the New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Geological Survey (NHGS), to evaluate road-stream crossings. Road-stream crossings, particularly culverts, are very important features in rural and developed watersheds due to flood vulnerability concerns, sediment and woody debris transport, and aquatic organism passage. Undersized or poorly aligned crossings may interrupt these processes, contributing to increased flooding and erosion and infrastructure damages, as well as decreases in fish and wildlife population health. Assessing the condition of structures and whether they allow water, sediment, woody debris, and aquatic organisms to pass through assists in prioritization of structures for replacement. Initial hydraulic models provide a first cut at recommendations for resizing structures.

In early 2016, Fitzgerald Environmental Associates, LLC (FEA) was hired by NHFGD to assess priority crossings in the Lamprey River watershed and evaluate their status for aquatic organism passage, geomorphic compatibility, and hydraulic capacity. The goals of the assessments are described below.

1.2 Project Goals

The overall goal of the project was to assess and prioritizing crossings in the Lamprey River, including all coldwater stream tributaries with wild brook trout populations.

Included with this report are the following:

- Identification of stream-road intersections in the Lamprey River watershed and the assessment status of potential stream crossings at these sites;
- Field assessment data for each structure based on NHGS protocols and including structure condition, invert-roadway relief, crossing slope, etc.;
- Modeling results detailing Aquatic Organism Passage (AOP), Geomorphic Compatibility (GC), and Hydraulic Capacity of each crossing where applicable;
- Community based maps and data tables displaying vulnerability results for each of the models.

2.0 Study Area Description

The Lamprey River watershed is located in southeastern New Hampshire, primarily in the northeastern coastal zone of the mixed wood plains on the Atlantic Coast, which extends from Portland, Maine to New York City along the Atlantic coast and through much of the Hudson River Valley (Fig. 1). The Lamprey River flows from the headwaters in Deerfield and Northwood, NH to the outlet at the Great Bay estuary in Newmarket, NH. The 213.8 square mile watershed intersects the towns of Barrington, Brentwood, Candia, Deerfield, Durham, Epping, Exeter, Fremont, Lee, Newfields, Newmarket, Nottingham, Northwood, Raymond, and Strafford (Fig. 2).

The Lamprey River watershed comprises nine HUC12 subwatersheds: Bean River, Headwaters Lamprey, Little River, Lower Lamprey, Middle Lamprey, North Branch River, North River, Pawtuckaway Pond, Piscassic River (Fig. 2). Elevations in the watershed range from near sea level at the watershed outlet to over 1,100 feet in the headwaters of the northwestern portion of the watershed. Overall, watershed and channel slopes are lower than those found outside of the coastal zone in New Hampshire.

Land cover data for the Lamprey River watershed are summarized in Table 1 (NOAA, 2010). The Lamprey River is a rural watershed, with forests representing the dominant land cover type. Development is low in the Lamprey River study area headwaters and more common in the middle and lower portions of the watershed as it approaches the Great Bays. Agriculture is low throughout much the study area (1-9%) and is mainly present as pasture and hay rather than row crops.

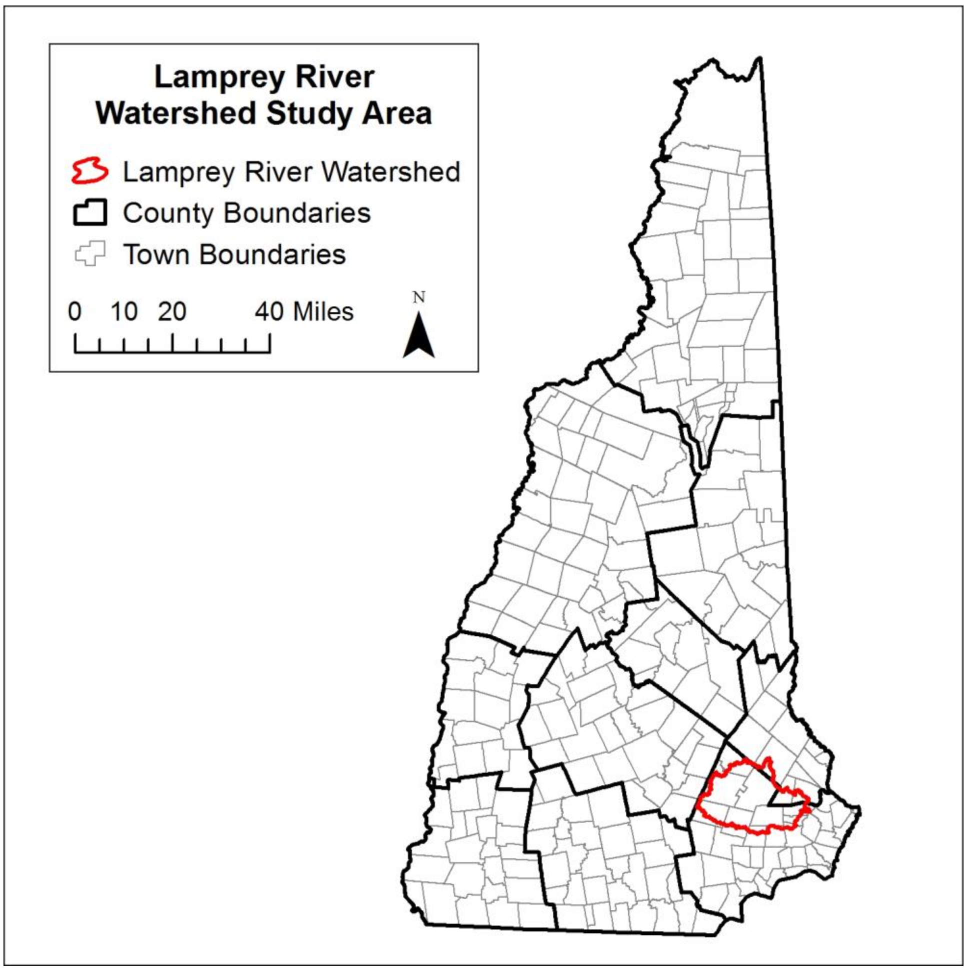

Figure 1: Lamprey River watershed location map

Table 1: Land cover in the Lamprey River watershed and nine subwatersheds

Land Cover/Land Use Type	Little River	Bean River	Headwaters Lamprey River	Pawtuckaway Pond	Lower Lamprey River	North River	North Branch River	Piscassic River	Middle Lamprey River	Entire Lamprey River
Developed	3%	3%	2%	0%	7%	2%	3%	9%	11%	5%
Agriculture	4%	6%	5%	3%	16%	12%	7%	8%	7%	7%
Forest	71%	70%	72%	75%	53%	68%	73%	52%	60%	65%
Open Water	3%	2%	1%	7%	2%	1%	1%	1%	2%	2%
Wetlands	14%	14%	9%	12%	16%	12%	9%	24%	14%	13%
Barren	1%	0%	2%	0%	1%	1%	1%	2%	1%	1%
Grassland & Shrub/Scrub	4%	5%	9%	3%	5%	5%	5%	5%	6%	6%

3.0 Methods

3.1 Crossing Identification

FEA obtained National Hydrography Dataset (NHD) stream flowlines and Department of Transportation (DOT) roads layers from the New Hampshire Geographically Referenced Analysis and Information Transfer System (NH GRANIT) website. To identify potential stream crossings, FEA intersected roads and streams within the Lamprey River study area. FEA identified 510 crossings with the intersects in the Towns of Barrington, Candia, Deerfield, Durham, Epping, Exeter, Fremont, Lee, Newfields, Newmarket, Nottingham, Northwood, and Raymond. A unique ID was assigned to each crossing designated for assessment by FEA by concatenating the numerical Town ID, Road Segment ID, and Stream Segment ID each separated by a hyphen (e.g., 153-41888-141025657).

FEA obtained GIS shapefiles of assessed crossings in the Lamprey River study area from NHGS with the locations of assessed structures and planned assessments for the summer of 2016 (Fig. 2). Of the 510 crossings identified, 237 had been assessed by NHGS prior to the summer of 2016, and 86 had assessments completed or planned by NHGS during the summer of 2016. Of the remaining 187 structures, FEA examined aerial imagery and selected 18 for no assessment in 2016. These included dams (2), sites on larger waterways with bridge crossings unlikely to be barriers to aquatic organisms (5), intersections of class VI roads with a first order stream that were unlikely to have any structure (5), and sites on class VI roads where no there was no maintained road visible in the imagery (6). The number of structures assessed, planned for assessment during the summer of 2016, and not planned for assessment are detailed by subwatershed and town in Table 2.

3.2 Field Assessment

Data Collection

FEA visited all locations identified as stream-road intersections through the GIS analysis. When a structure was present it was assessed following the NH Statewide Asset Data Exchange System (SADES, 2016) data collection protocol for variables with the Department of Environmental Services (DES) tag (2016). Parameters with the Department of Transportation (DOT) tag only where not collected as part of the assessments. In addition to qualitative determinations of parameters including structure condition, measurements of upstream and downstream bankfull widths were collected. A laser-level and receiver were used to measure the vertical distance between the road surface elevation, culvert inlet(s) and outlet(s), and downstream hydraulic control if present. The location of each structure was recorded with a sub-meter GPS and photos of each structure were collected for quality control following the SADES protocol.

Several structures were assessed where there was not enough flow accumulation for a stream channel to exist and were considered drainage structures. FEA collected the parameters that were applicable in this case (ex. structure slope and relief) but did not collect parameters exclusive to stream crossings (ex. bankfull width or bank erosion). In wetland complexes connected by structures, parameters specific to stream channels were also left blank. The models were not run for drainage structures as the criteria being evaluated (i.e., aquatic organism passage) are not applicable in these cases.

Missing Structures

If a structure was not present at the intersect point between the road and NHD layer, we searched the surrounding area for low points and channels to rule out inaccuracies in the NHD accounting for missing structures. Locations with no structures are summarized in Table 3 and included intersections with small first order streams without enough flow accumulation to have warranted a structure, wetland complexes with no clear drainage structure, areas near watershed boundaries where the digital elevation model may have resulted in NHD errors, and at intersections with gravel or unmaintained roads. We noted sites on unmaintained roads where there was a crossing present but no structure (i.e. water flows directly over the road) as well as the locations of storm drains where streams were buried with no distinct inlet or outlet at a road crossing.

3.3 Data Processing

All structure data from field assessments was entered in an access database provided by NHGS. FEA also maintained a shapefile with the locations of all sites visited, including those without structures.

Quality Control

The structures database and photos of each structure were submitted to NHGS for quality control review. FEA responded to all questions and comments received and made any necessary changes to the database identified through the iterative review process. NHGS will maintain a copy of the quality control review documents. The finalized database has been added to the NH Statewide Asset Data Exchange System (SADES).

3.4 Compatibility Screening

NHGS used a Python-based model to determine the AOP and GC of all structures assessed by FEA using the finalized database. AOP is calculated based on the structure outlet invert type, the outlet drop, the presence and depth of a downstream pool, water depth in the structure outlet, number of culverts, inlet obstructions, and sediment in the structure (VTANR, 2009). GC is calculated based on structure width as a percentage of bankfull width measured in the field, sediment continuity (deposition and scour), structure slope compared to channel slope and valley slope breaks, stream approach angle, and erosion and armoring near the structure (VTANR, 2008).

3.5 Hydraulic Modeling

Where applicable, FEA determined the hydraulic capacity of assessed structures using a model developed by Joel and Tom Ballestero through a multi-agency partnership that included the NH Department of Transportation and Southern NH Planning Commission. The model uses a TR-20 runoff model to estimate peak flows for watersheds smaller than one square mile and regional regression equations for larger watersheds (SCS, 1983; Olson, 2014). Reference numbers describing structure inlet conditions were assigned to each culvert and arch based on the inlet shape, headwall and wingwall type, and structure material. Small stone bridges were assigned box culvert reference numbers. FEA used batch processing in USGS StreamStats to generate watersheds, longest flow paths, and channel slopes determined by the 10-85 method corresponding to each structure (USGS, 2012). Watersheds, flowpaths, and channel slopes were manually adjusted where applicable using LiDAR elevation and hillshade information from NH GRANIT to match field observations in which the NHD streamlines flowed contrary to the elevation gradient.

FEA calculated curve numbers for each watershed using SSURGO soils data (NRCS, 2009) and New Hampshire Land Cover Assessment data (UNH, 2001) downloaded from NH GRANIT. Monthly 30-year normal precipitation data were downloaded from the PRISM Climate Group (2012), 24-hour rainfall recurrence intervals for the 2, 10, 25, 50, and 100 year events were obtained from the Northeast Regional Climate Center, and National Wetlands Inventory data were obtained from the US Fish & Wildlife Service (2016). Land cover classes were grouped and missing hydrologic soil group data were assigned per NHGS protocol. FEA used a curve number lookup table provided by NHGS to calculate the average area-weighted curve number for each watershed.

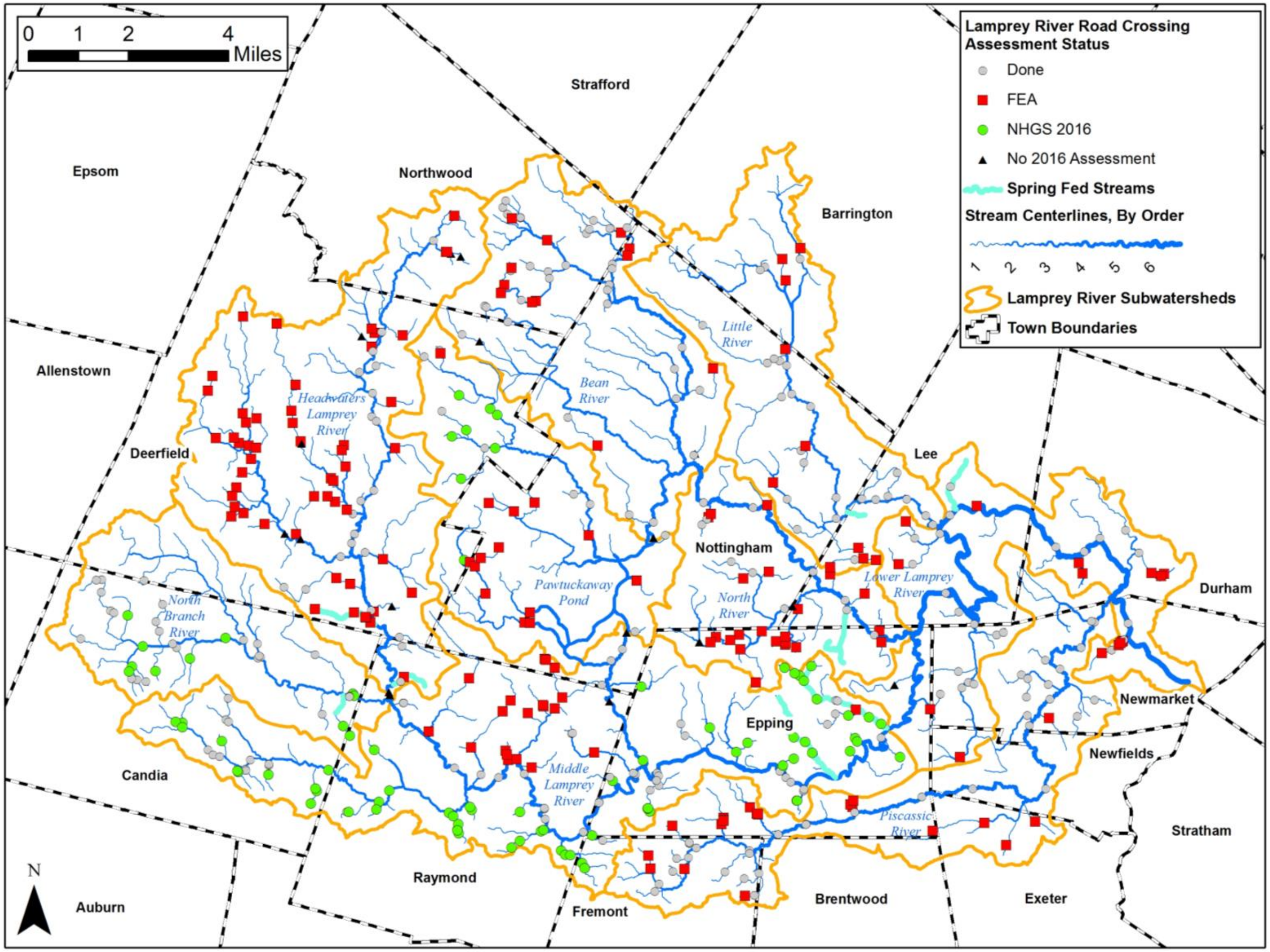

Figure 2: Lamprey River watershed crossings identified in a GIS analysis, by assessing organization.

4.0 Results

4.1 Structure Assessments

FEA visited the 169 crossings identified through our GIS analysis (Fig. 3; Table 2). Three structures on trails were added, two of which were immediately adjacent to other structures we assessed and one downstream of a buried stream outlet. A fourth structure was added where stream braiding resulted in two separate crossings approximately 100 feet along the same road. Of the 126 structures assessed, 6 were bridges, 1 was an arch, and 119 were culverts (94%).

FEA found no structures at 23 road-stream intersections identified through GIS analysis. Two locations were clear crossings with no structures where a class VI road fords the stream. Ten were on trails, class 0 roads, and class VI gravel roads and trails where water may also cross the road during wet periods. Another site ended in a wetland with no outlet in a relatively flat area with abundant wetlands where FEA observed probable inaccuracies in the DEM and NHD. The remaining ten crossings were on first order streams that mainly appeared to lack the flow accumulation necessary to warrant a structure.

In two instances a multilane highway (NH Route 101) was intersected multiple times by the NHD but only had one culvert at each crossing. In this case, duplicate crossing points were eliminated and one point in the center of the multilane divided highway was used. In another instance, an NHD inaccuracy resulted in two intersections in a cul-de-sac while the stream crossed approximately 100 feet away on a single road segment. In this case, the two points were removed and a new intersection with an updated unique ID was created.

Twelve sites were inaccessible due to private roads and property. Three were inaccessible due to gated roads and communities, one site was in a private campground, two were on heavily posted private roads, and six appeared from aerial imagery to be on old unused roads that we were unable to access where they ended in driveways on private property.

FEA maintained a shapefile detailing the assessment status of all crossings. For those crossings with no structure or no access, comments are included detailing why no data were collected.

Table 2: Assessment status of Lamprey River watershed stream crossings identified through GIS analysis prior to summer 2016 field surveys. The number of road-stream intersections for each subwatershed is listed by town, with the number of coldwater stream intersections included in each count listed in parentheses.

Subwatershed	Town	NHGS Done	NHGS 2016	FEA 2016	No 2016 Assessment
Bean River	Deerfield	1			1
	Northwood	35		12	2
Headwaters Lamprey	Deerfield	18 (1)		51 (4)	5
	Northwood	1		3	2
	Raymond	2		2 (2)	2
Little River	Barrington	3		3	
	Lee	8		3	
	Nottingham	14		3	
Lower Lamprey	Durham	5		5	
	Epping			1	1
	Lee	8 (1)		3	
	Newfields			1	
	Newmarket	10		5	
Middle Lamprey	Candia	11	11		
	Epping	23 (2)	32 (8)	1 (1)	
	Fremont	1	3		
	Nottingham	3		3	1
	Raymond	16	21	15	1
North Branch River	Candia	23	10		
	Deerfield	1			
	Raymond		1		
North River	Epping	1		14	2
	Lee	3 (1)		4	1
	Nottingham	7		5	
Pawtuckaway Pond	Deerfield	4	8	1	
	Nottingham	4		13	
Piscassic River	Epping	5		14	
	Exeter			3	
	Fremont	14		4	
	Newfields	2			
	Newmarket	14		1	
	TOTAL:	**237**	**86**	**169**	**18**

Table 3: Summary of locations identified through GIS analysis where no structure was located during field surveys

Location Description	Number of Locations
Class VI Road, Crossing with No Structure (Ford)	2
Trails, Class 0, and Class VI Roads	10
Wetland infiltration in an area with stream line inaccuracies and abundant wetlands	1
First order streams lacking flow accumulation	10

Table 4: Assessment status of 173 Lamprey River watershed road-stream intersections identified through GIS analysis and in field assessments

Assessment Status	Road-Stream Intersections	
	#	%
Structures Assessed	126	73
Duplicate Points	6	3
No Access (Private Roads & Property)	12	7
No Structure	23	13
Storm Drain/Buried Stream	6	3

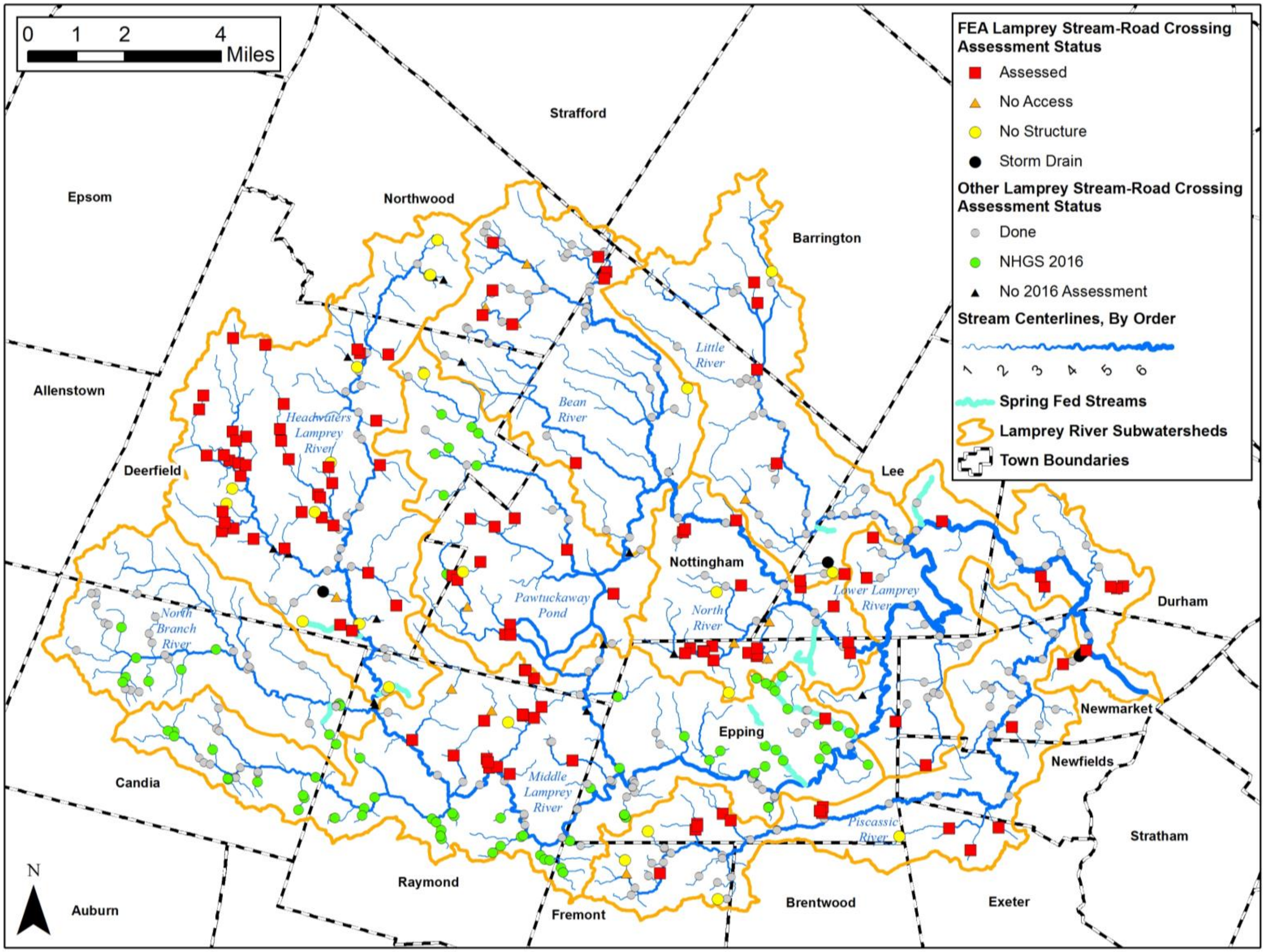

Figure 3: Lamprey River watershed crossing assessment status.

4.2 Compatibility Screening Results

Table 5 summarizes the number and percentage of structures in each category of geomorphic compatibility. Structures receiving no score included those classified as drainage structures (7), structures with a wetland or pond upstream and therefore no bankfull width (14), bridges (6), and arches (1). It is worth noting that several structures in our study area located downstream of wetland areas have low GC scores due to the way bankfull width is evaluated. For example, seven structures had bankfull widths higher than predicted with standard hydraulic geometry curves for New Hampshire, yet they were rated as mostly incompatible due to the presence of wetland areas upstream, which artificially increased the reference width for bankfull.

Table 5: Geomorphic compatibility of assessed structures

Geomorphic Compatibility	Number of Structures	
	#	%
Fully Compatible	4	3
Mostly Compatible	28	22
Partially Compatible	45	36
Mostly Incompatible	21	17
Fully Incompatible	0	0
No Score	28	22

Table 6 summarizes the number and percentage of structures organized by their aquatic organism passage modeling results. Structures receiving no score included bridges and arches (7) and structures with incomplete assessments due to inaccessibility of one side of the culvert and ponding (2).

Table 6: AOP status of assessed structures

Aquatic Organism Passage	Number of Structures	
	#	%
Full AOP	13	10
Reduced AOP	90	71
No AOP Except Adult Salmonids	0	0
No AOP Including Adult Salmonids	14	11
No Score	9	7

4.2 Hydraulic Modeling Results

Table 7 summarizes the overall number and percentage of structures assessed by their capacity in the 2, 10, 25, 50, and 100-year flood events as estimated by the hydraulic model. In Table 8 and Figures 4 through 8, these results are broken out by town. The structures with no results included one structure under inlet control due to a dam at the inlet, structures with incomplete assessments due to inaccessibility of one side of the culvert and inundation (2), and bridges for which the model was not applicable (3).

Table 7: Hydraulic capacity results of all assessed structures

Flood Return Interval	Fail		Transitional		Pass		No Result	
	#	%	#	%	#	%	#	%
2	26	21	8	6	86	68	6	5
10	54	43	22	18	44	35	6	5
25	77	61	10	8	33	26	6	5
50	85	68	8	6	27	21	6	5
100	91	72	8	6	21	17	6	5

Table 8: Hydraulic capacity results of assessed structures by town

Town	Flood Return Interval	Fail		Transitional		Pass		No Result	
		#	%	#	%	#	%	#	%
Barrington	2					2	100		
	10								
	25	2	100	2	100				
	50	2	100						
	100	2	100						
Deerfield	2	6	15	3	8	28	72	2	5
	10	16	41	8	21	13	33	2	5
	25	22	56	3	8	12	31	2	5
	50	25	64	2	5	10	26	2	5
	100	26	67	2	5	9	23	2	5
Durham	2	1	20	1	20	3	60		
	10	2	40	1	20	2	20		
	25	3	60	2	40				
	50	4	80	1	20				
	100	5	100						
Epping	2	7	30	3	13	13	57		
	10	11	48	4	17	8	35		
	25	16	70	1	4	6	26		
	50	17	74	1	4	5	22		
	100	17	74	2	9	4	17		

Town	Flood Return Interval	Fail		Transitional		Pass		No Result	
		#	%	#	%	#	%	#	%
Exeter	2					3	100		
	10			2	67	1	33		
	25	2	67			1	33		
	50	2	67			1	33		
	100	2	67			1	33		
Fremont	2					1	100		
	10					1	100		
	25					1	100		
	50					1	100		
	100					1	100		
Lee	2	3	43	0	0	3	43	1	14
	10	3	43	1	14	2	29	1	14
	25	5	71			1	14	1	14
	50	5	71			1	14	1	14
	100	5	71	1	14			1	14
Newfields	2					1	100		
	10					1	100		
	25					1	100		
	50					1	100		
	100					1	100		
Newmarket	2	1	25	0	0	3	75		
	10	2	50	1	25	1	25		
	25	3	75	1	25				
	50	4	100						
	100	4	100						
Northwood	2	3	60			2	40		
	10	3	60	1	20	1	20		
	25	4	80	1	20				
	50	5	100						
	100	5	100						
Nottingham	2	3	13			18	78	2	9
	10	9	39	1	4	11	48	2	9
	25	12	52	2	9	7	30	2	9
	50	13	57	4	17	4	17	2	9
	100	17	74	1	4	3	13	2	9
Raymond	2	2	15	1	8	9	69	1	8
	10	7	54	1	8	4	31	1	8
	25	8	62			4	31	1	8
	50	8	62			4	31	1	8
	100	8	62	2	15	2	15	1	8

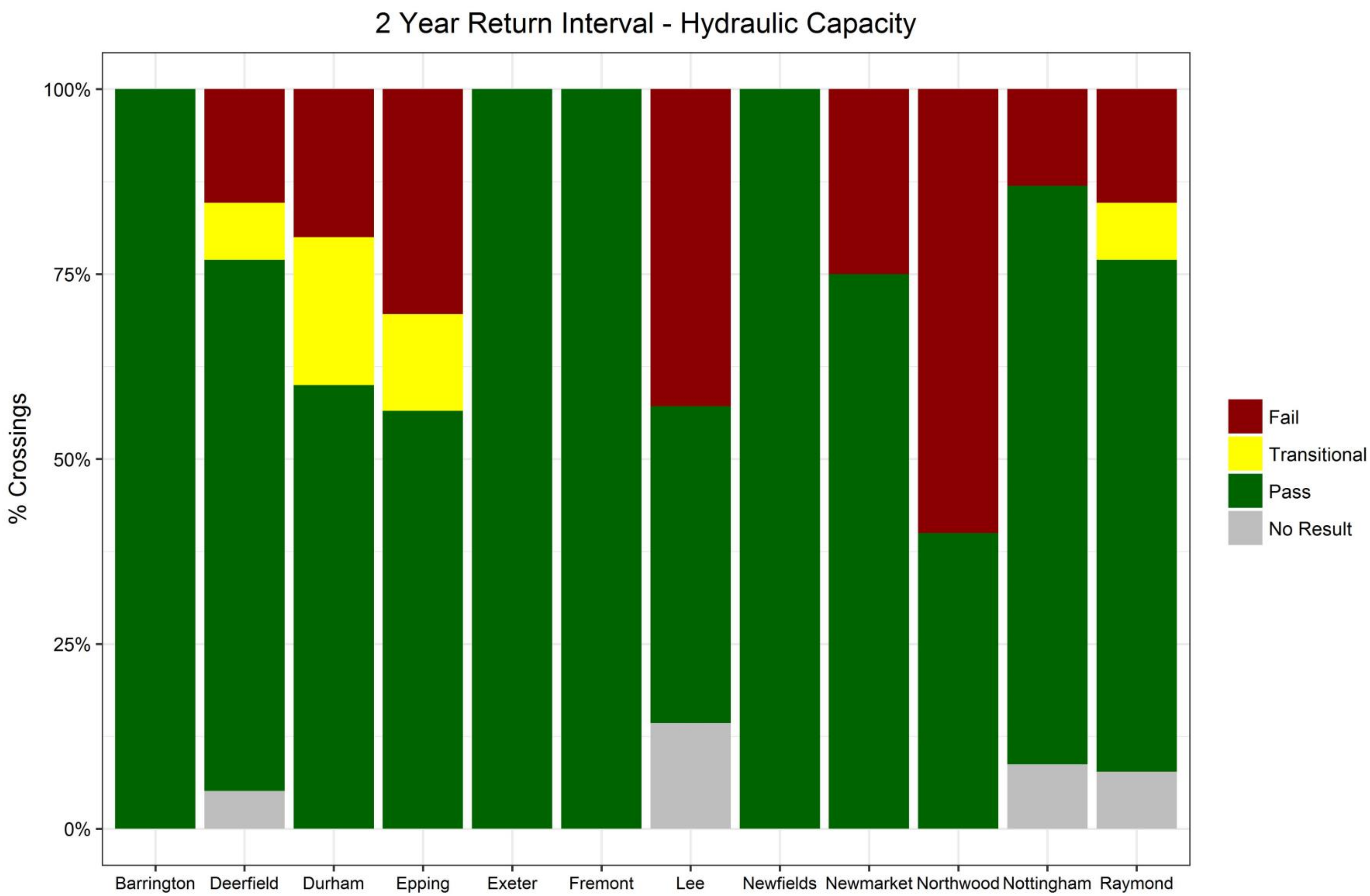

Figure 4: Results of all structures by town for the two-year return interval

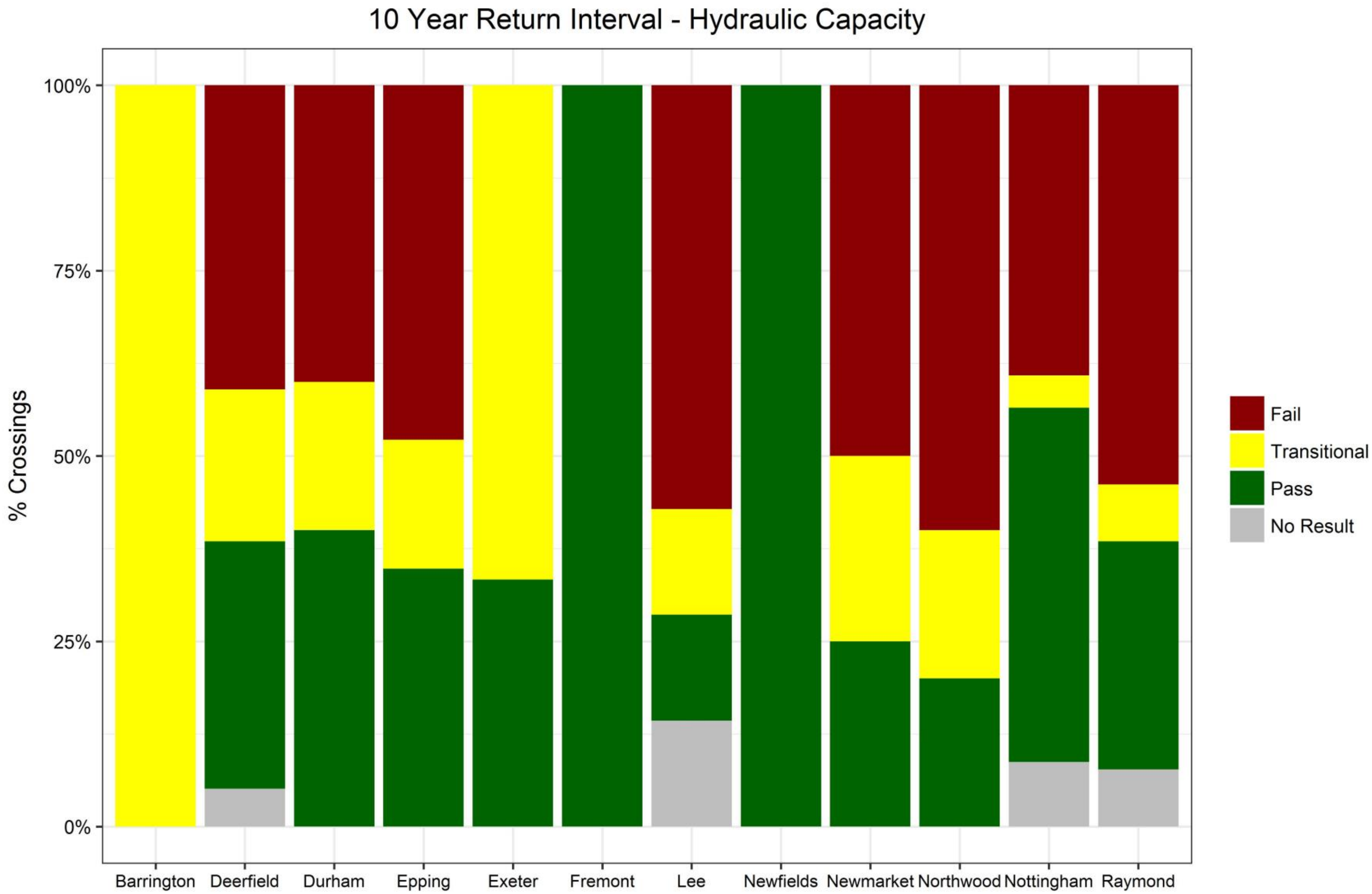

Figure 5: Results of all structures by town for the 10-year return interval

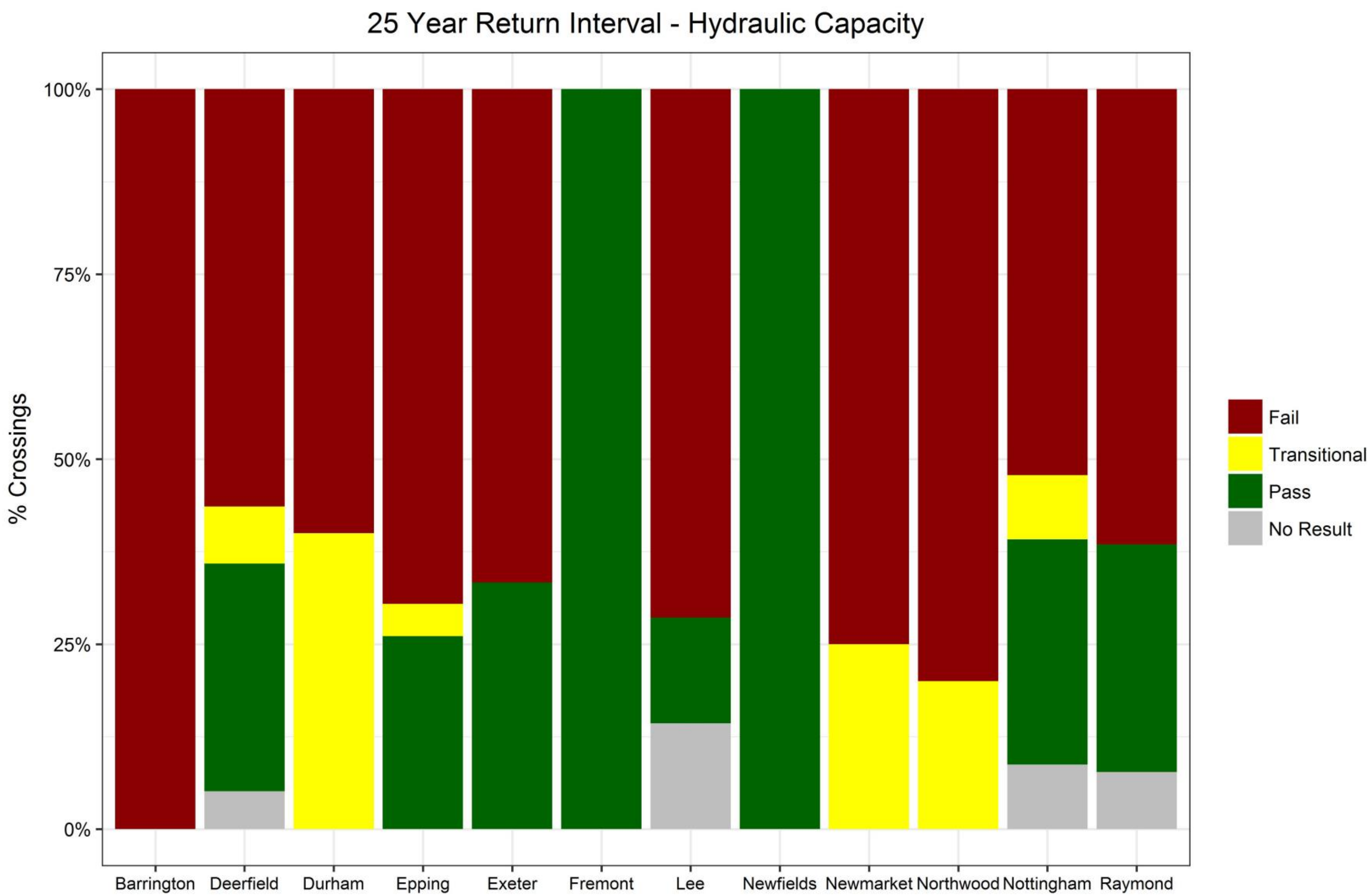

Figure 6: Results of all structures by town for the 25-year return interval

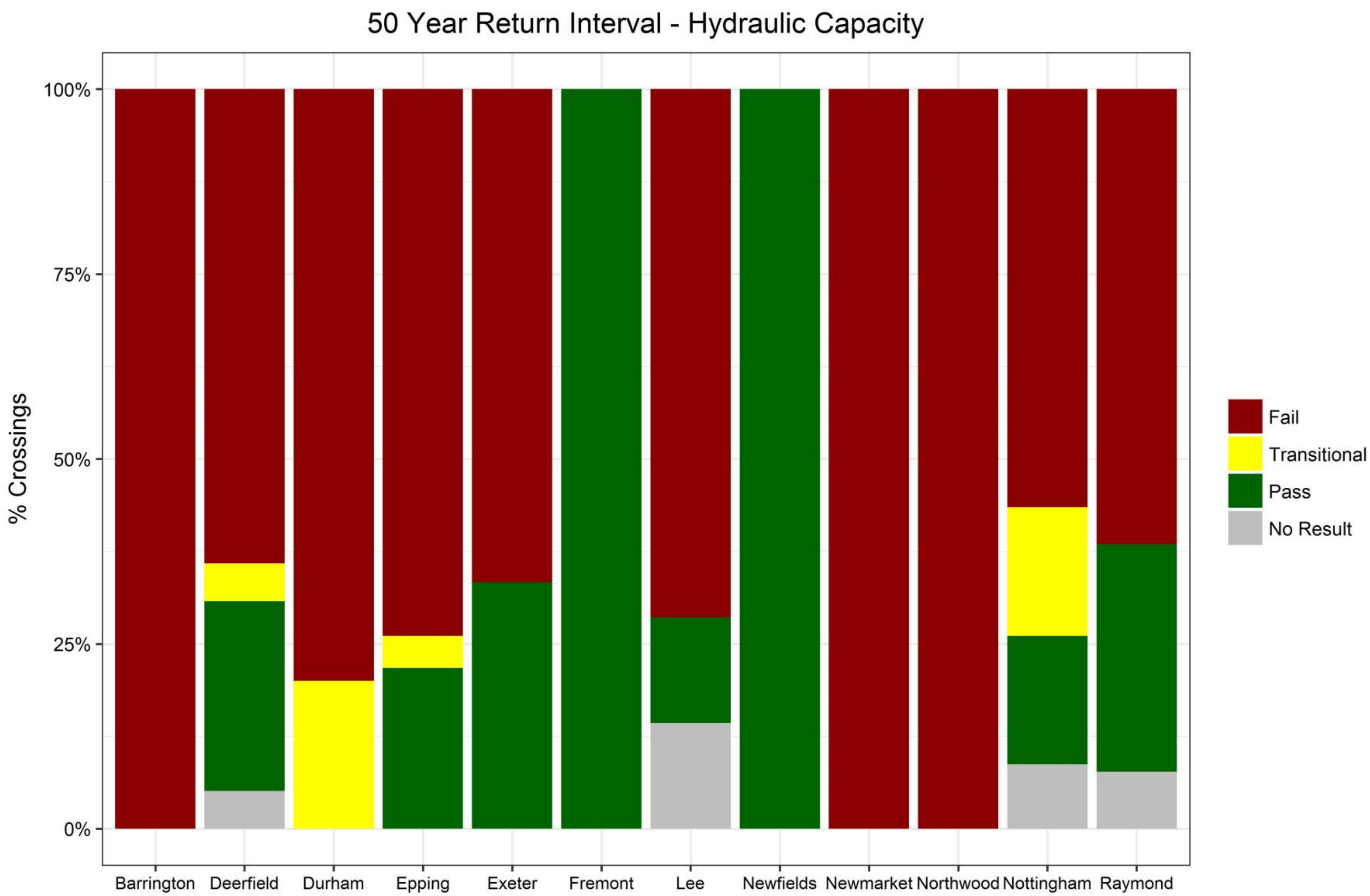

Figure 7: Results of all structures by town for the 50-year return interval

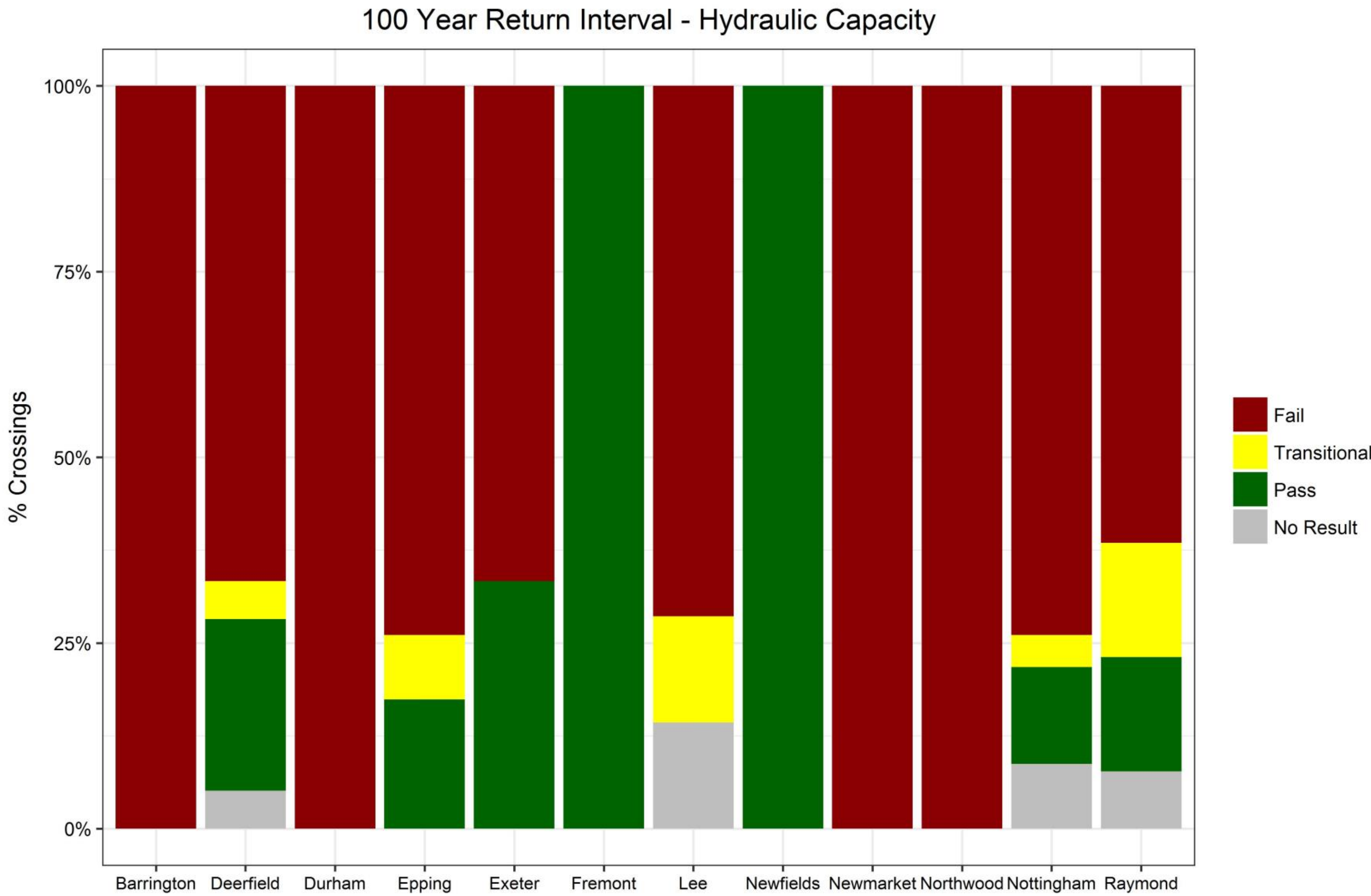

Figure 8: Results of all structures by town for the 100-year return interval

5.0 Discussion

Sixty-eight percent (68%) of the culverts in the Lamprey River watershed assessed by FEA were predicted to have insufficient hydraulic capacity during the 50-year storm event. These findings are similar to those of a previous study in the Piscataquog River watershed, where 73 percent of culverts assessed were predicted to fail in the 50-year storm (TU & SNHPC, 2014). These predicted failure rates may be due in part to the fact that 120 (97%) of the structures with hydraulic capacity results were culverts, which are generally smaller and therefore more likely to be undersized than bridges and arches. Additionally, of the 126 structures assessed, 57 were rusted (14%), eroded (2%), or collapsing (29%), suggesting the presence of older structures built to pass smaller storms.

Of the 91 crossings measured for upstream bankfull width, excluding drainage structures and structures with large ponds or wetland upstream, 13 (14%) were at least 100% of bankfull width and 54 (59%) were 50% or less of bankfull width. These small structures sizes contributed to the finding that only 4 (3%) of the structures assessed were rated as fully compatible with their geomorphic setting.

The results of these screenings may be used to prioritize structures for full hydraulic assessments and possible replacement within the communities drained by the Lamprey River watershed. Final designs for culvert replacement would require more detailed hydraulic modeling. The tables and maps in Appendices A and B will assist in community-based structure prioritization, by providing the GC and AOP screening results as well as the hydraulic capacity modeling results by town. Structures targeted for replacement may include those that are undersized and posing a risk to public infrastructure or reducing the habitat connectivity of aquatic organisms.

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