HYDROLOGIC & HYDRAULIC ANALYSIS OF LOWER JEWETT BROOK

Laconia, New Hampshire

Prepared for:

City of Laconia, NH
and
U.S. Army Corps of Engineers

Prepared by:

DuBois & King inc.

August 2011

D&K#: 120490

Hydrologic and Hydraulic Analysis of
Lower Jewett Brook

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TABLE OF CONTENTS

ATTACHMENTS

1.0 EXECUTIVE SUMMARY

Not included with draft report

2.0 INTRODUCTION

This report presents DuBois & King's (D&K) hydrologic and hydraulic (H&H) analysis of the lower Jewett Brook in Laconia, New Hampshire. The study reach extends from upstream of the Union Avenue bridge down to the mouth of Jewett Brook at the Winnipesaukee River, a distance of approximately 1200 feet. A site location map and photographs are located in Attachment A.

Moving from upstream to downstream in the study area, the brook is spanned by the Union Street Bridge, two building access ramps, a restored mill building, the Davis Place Bridge, and finally a pedestrian bridge. Each structure, particularly the upstream Union Street bridge have been observed to restrict high flows and contribute to flooding. There is also significant accumulation of sediment within the channel that reduces the capacity. There have been public calls for expanding one or more of the crossings and for dredging the accumulated sediment in order to reduce the frequency of flooding.

The objectives of this study are to evaluate the hydraulic factors that have led to repeated out-of-bank flood events in the lower Jewett Brook and to evaluate potential measures that may decrease the frequency of flooding. The results of this study, along with the results of a concurrent geomorphic assessment of the brook and watershed, will be used as the basis for a Jewett Brook Watershed Plan.

This project is funded by the U.S. Army Corps of Engineers, New England District. The local sponsor is the City of Laconia, New Hampshire.

3.0 BACKGROUND

3.1 Setting

The Jewett Brook watershed is 5.4 square miles at its mouth (the confluence with the Winnipesaukee River). At Union Street bridge (near the upper end of the study reach) the watershed area is marginally smaller at approximately 5.3 square miles. The main channel slope within the watershed is 144 feet per mile, or 2.7%, based on the USGS topographic map. The channel slope within the study reach is considerably flatter at approximately 37 ft per mile or 0.7%.

From the Union Street bridge to the outlet of the Davis Place bridge, the channel has a concrete bottom, though it is largely concealed by deposited sediment. Concrete and vertical stone walls form the banks of the channel in this reach. Channel width ranges from 18 to 24 feet. A primary flow channel approximately six feet wide has naturally developed through the deposited sediment within the upper half of the study area.

There is extensive development including buildings, roads, and parking lots on both sides of the brook from the Union Street bridge to the outlet of the Davis Place bridge (the upper half of the study area). Below the Davis Place bridge, the overbanks are relatively undeveloped.

3.2 Flood History and Damages

Out of bank flooding has been a recurring problem in the Lower Jewett Brook. Typically, water is reported to first exit the channel on the upstream side of the Union Street bridge. When it does, floodwaters inundate the intersection of Union Street and Davis Place and then generally flow down Davis Place (to the left of the Normandeau Square Building) where they rejoin the brook on the downstream side of the Davis Place Bridge.

Photographic evidence of flooding at this location dates back to at least 1936 (see Attachment A). Anecdotal reports indicate that the frequency of flooding has increased in recent years. Flooding was reported at the site four times in 2007, for instance (see April 16, 2007 photos Attachment A). However, there has been no effort to date to discern whether there has in fact been an increase in flood frequency or whether that increase is due simply to precipitation patterns or to physical changes at the site.

There are a large number of commercial and residential structures that experience flooding when the Jewett Brook overflows its banks in the vicinity of Union Avenue and Winter Street. The structures at the Union Avenue and Winter Street intersection and the structures along Davis Place road will experience flooding.

4.0 FIELD DATA COLLECTION

D&K conducted a limited topographic survey of the study area on October 2010. The primary intent of the survey was to collect information for use in hydraulic modeling. Additional information was collected to facilitate preparation of a basemap of the portion of the study area where channel modifications have been proposed. The basemap with cross section locations is included in Attachment A.

The survey was tied to the City of Laconia's bench marks that are tied to the horizontal datum NAD83 feet and vertical datum NAVD88 feet. The survey was also tied to a benchmark used in the 1980 Flood Insurance Study for the City of Laconia.

5.0 HYDROLOGY

The watershed is a steeply sloped basin that consists of wooded areas, open lands and commercial and residential development. The total contributing drainage area is about 5.4 square miles at the mouth. A map showing the watershed is included in Attachment A. The main channel slope within the watershed is 144 feet per mile, or 2.7%, based on the USGS topographic map. The channel slope within the study reach is approximately 37 ft per mile or 0.7%.

Peak river discharges at the bridge site were obtained from the FEMA Flood Insurance Study for the City of Laconia dated February 1980. The results are presented in Table 1.

Table 1. Summary of Peak Discharges

Location	Drainage Area (square miles)	Peak Discharges (cfs)			
		10-year	50-yr	100-year	500-year
Jewett Brook at its mouth	5.4	394	970	1190	2500

The computed values were checked for reasonableness against a plot of USGS-computed 50-year and 100-year flow at gaged sites located in New Hampshire and the surrounding States (Attachment B). The estimated discharges were deemed reasonable based on this comparison, and thus used for this analysis without modification.

6.0 EXISTING CONDITIONS HYDRAULICS

6.1 Model Setup

Hydraulic analysis for both existing and proposed conditions was performed using the HEC-RAS computer program. HEC-RAS calculates water surface profiles for steady gradually varied flow in natural or man-made channels. HEC-RAS has the capacity to model various obstructions such as bridges, culverts, weirs and other structures. The program computes a wide range of hydraulic variables for each peak discharge simulated including water surface elevation, velocity, and shear stress.

For this analysis, the starting water surface elevation at the downstream limit of the model was based on the slope of the channel (normal depth analysis) as used in the FEMA Flood Insurance Study. The slope of Jewett Brook at its mouth is 0.0028 ft/ft or 15 ft/mile.

Cross section geometry used in the model was based on field survey obtained in October 2010. Manning's “n” values (hydraulic roughness of the river channel and its overbanks) were assigned to the channel and overbanks on the basis of field observations and standard reference material. The “n” values of the streambed and overbanks were 0.03 and 0.04, respectively.

Within the 1200-foot long study reach there are six crossings over the channel (total bridge length of 281 feet). Approximately 520 feet of the reach has a rectangular section with concrete bed and concrete or steel sheeting side walls

All six crossings are included in the existing conditions HEC-RAS model. The Normandeau Square Building and the downstream Davis Place Bridge were modeled as a single bridge. The existing bridge configurations are summarized in Table 2.

Table 2. Summary of Existing Bridge / Channel Crossing Configurations

Crossing	Ped Bridge	Normandeau Square Bldg and Davis Place Rd Bridge	Downstream Bldg Access / Ped Bridge	Upstream Bldg Access / Ped Bridge	Union Ave Bridge
River Station	RS 427	RS 732	RS 779	RS 998	RS 1108
Structure Type	Pedestrian Bridge	Auto bridge and abutting mill building	Pedestrian Bridge	Pedestrian Bridge	Auto Bridge
Bridge Length (ft)	30	135	20	26	70
Hydraulic Width (ft)	20	20 DS [1,2] 12.5 US [1]	24	22	21 DS 17.8 US
Vertical Opening (ft)	5.8	4.4 DS 5.0 US	5.2	4.2	2.9
Waterway Opening (sq ft)	112.4	80 DS 125 US	138.8	106.7	54.7
Streambed Elev. (ft)	489.7	492.0	492.7	494.3	494.8
Available Head (ft) [3]	8.0	8.0	8.8	6.7	5.3
Elev. of Low Chord (ft)	495.8	495.6 DS 497.0 US	499.9 [4] 498.0 [4]	499.4	497.7
Top of Road Elev. (ft)	497.7	497.4 DS 500.0 US	501.5	501.0	500.1

[1] DS = downstream bridge opening dimension, US = Upstream bridge opening dimension
[2] US side two openings with 3-ft pier
[3] Vertical distance from streambed to top of road.
[4] Suspended utility conduits. Actual structure low chord is higher.

6.2 Existing Conditions Results

The following bullets summarize the significant results of the existing conditions hydraulic analysis. Table 3 summarizes the results at each of the five crossings for the 10, 50, and 100-year flows. Flood profiles and copy of the HEC-RAS summary output for existing and proposed conditions are included in Attachment C.

- The Union Avenue Bridge at the upstream end of the modeled reach is the limiting hydraulic control point. This is not surprising given that the waterway opening of the bridge is approximately 50% of the downstream crossings and has the lowest available head (Table 2). The capacity of the Union Avenue Bridge prior to overtopping the road is approximately 450 cfs, which is only marginally (15%) higher than the 10-year flow.

- Between the Union Street Bridge and the Normandeau Square Building, the capacity before overtopping is approximately 700 cfs. The channel opening under the building, not the two pedestrian bridges, is the hydraulic control in this reach.

Table 3. Results of Existing Conditions Hydraulic Analysis

	Ped Bridge	Normandeau Square Bldg and Davis Place Rd Bridge	Downstream Bldg Access / Ped Bridge	Upstream Bldg Access / Ped Bridge	Union Ave Bridge
10-Year (Q10 = 394 cfs)					
Water Surface Elevation (ft)	493.4	495.7	495.6	498.0	499.4
Headspace below low chord (ft)	2.4	1.3	3.4	1.4	-1.7
Water over Road?	No	No	No	No	No
Bridge Velocity (fps)	8.7	5.7	6.4	5.2	6.5
Channel Flow (cfs) [1]	394	394	394	394	394
Overbank Flow (cfs)	0	0	0	0	0
50-Year (Q50 = 970 cfs)					
Water Surface Elevation (ft)	496.4	499.2	499.2	499.8	501.3
Headspace below low chord (ft)	-0.6	-2.2	-0.2	-0.4	-3.5
Water over Road?	Yes, approach road	No	No	No	Yes
Bridge Velocity (fps)	6.0	8.0	4.1	5.5	5.8
Channel Flow (cfs) [1]	657	749	749	749	749
Overbank Flow (cfs)	313	221	221	221	221
100-Year (Q100 = 1190 cfs)					
Water Surface Elevation (ft)	496.4	500.2	500.3	500.6	501.4
Headspace below low chord (ft)	-0.6	-3.2	-1.3	-1.2	-3.6
Water over Road?	Yes, approach road	No	No	No	Yes
Bridge Velocity (fps)	6.2	7.1	3.8	5.2	4.8
Channel Flow (cfs) [1]	680	892	892	892	892
Overbank Flow (cfs)	510	298	298	298	298

[1] If channel flow is less than the total flow (e.g., less than 970cfs for the Q50), then water has spilled into the overbank and flooded the intersection of Union Avenue and Davis Place.

7.0 PROPOSED CONDITIONS HYDRAULICS

Two channel modification scenarios – channel dredging and additional culvert under Union Avenue – were considered.

7.1 Model Setup

Channel Dredging

There is deposited sediment in the channel from the Union Avenue Bridge through the Normandeau Building. The depth of sediment ranges from zero where a pilot channel has naturally formed up to approximately 2 feet.

The hydraulic analysis of the dredging proposal assumed that the sediment was removed down to the existing concrete invert of the channel from the Union Avenue Bridge through the Normandeau Building. In effect, the capacity of the channel at the time of construction was assumed to be restored.

Larger Union Avenue Bridge

Since the existing conditions results demonstrated that the Union Avenue Bridge is the controlling point in the system, it is logical to consider increasing the capacity under Union Avenue. This might be accomplished by a wider bridge, a taller bridge, or additional parallel culverts. From constructability and cost perspectives, each has pros and cons. From a hydraulic standpoint they are similar; each increases the flow capacity under the road before overtopping occurs.

The hydraulic analysis of this alternative assumes the existing bridge opening is widened by 10 feet. In practice, it might be more cost effective to add a parallel culvert to the right (looking downstream) of the existing bridge, but from a hydraulics standpoint the results would be similar.

7.2 Proposed Conditions Results

Channel Dredging

Dredging sediment out of the channel from the Union Avenue Bridge down to the Normandau Building increases the capacity of the channel and would reduce the frequency of flooding. Flood profiles included in Attachment C. With dredged conditions, the capacity at the Union Street Bridge increases 60% from 450 cfs to 720 cfs. Whereas flows only marginally above the 10-year event pass under existing conditions, flows just above the 25 year event can pass under dredged conditions. Even with improved hydraulic capacity due to dredging, the Union Avenue bridge remains the limiting hydraulic point in the system, which suggests that a dredging operation limited to the bridge and a relatively short distance downstream might be as effective at reducing road overtopping as an operation that dredged all the way to the Normandeau Building.

Larger Union Avenue Bridge

Widening the Union Avenue Bridge by 10 feet (or installing a parallel box culvert with similar dimensions) increase the capacity of the channel and reduce the frequency of overtopping. The improvement is marginal, however: flow capacity increases 20% from 450 cfs to 540 cfs. While this is an improvement, Union Avenue still would not be able to pass even the 25-year storm event, and it would remain the limiting hydraulic point in the system.

8.0 DISCUSSION

8.1 Existing Conditions

Under existing conditions, flows above approximately the 10-year level exceed the capacity of the Union Avenue Bridge and spill toward and down Davis Place. The downstream channel between Union Avenue and the Normandeau Building has additional capacity, but it goes unused because water can't get under Union Avenue.

Current hydraulic capacity guidelines for municipal bridges suggest that the 50-year flow should be able to pass with a foot of headspace (i.e., clearance between water surface and bottom of bridge). At this particular site, that guideline is likely not achievable. Without significantly raising the roadway on either side of the bridge to get a taller opening (which is problematic at best given the adjacent buildings and intersections), even a brand new larger bridge would likely fall short of current hydraulic capacity guidelines. This is not uncommon at sites with very flat bridge approaches. That said, overtopping during approximately the 10-year event is generally considered unacceptable for a major municipal road.

8.2 Dredging

The hydraulic analysis presented here demonstrates that dredging to remove accumulated sediment in the channel from the Union Avenue Bridge to the Normandeau Building would reduce the frequency of flooding. The improvement would still leave the bridge far short of the hydraulic capacity typically desired for a new bridge, but it is nonetheless a significant improvement and one that could be done for relatively little cost.

The movement of sediment from upstream to downstream is a natural process in even the most stable and undisturbed stream channels. Depending on location within a stream network, channels may be marked by sediment production (typically high in a watershed), sediment transport (typically middle of watersheds), or sediment deposition (typically low in watersheds). On a watershed scale, channel modifications such as retaining walls, berms, undersized or poorly designed crossings, and removal of riparian vegetation tend to cause channel instability and exacerbate the production of sediment and delivery to downstream locations.

At this project site, the stream channel has transitioned to a markedly flatter channel than exists upstream, and the resulting low velocities mean the site is clearly a depositional zone. Thus, dredging should be seen as a temporary solution because new sediment from upstream can be expected to replace the removed material.

Dredging would require a permit from the NH Department of Environmental Services. Issues that would likely need to be addressed include the frequency at which dredging would need to be repeated and whether the upstream sediment supply could be reduced toward natural background levels. The Geomorphic Assessment of the Jewett Brook Watershed presented separately from this Hydrologic and Hydraulic Analysis provides information to help address both those issues.

8.3 Larger Union Avenue Bridge

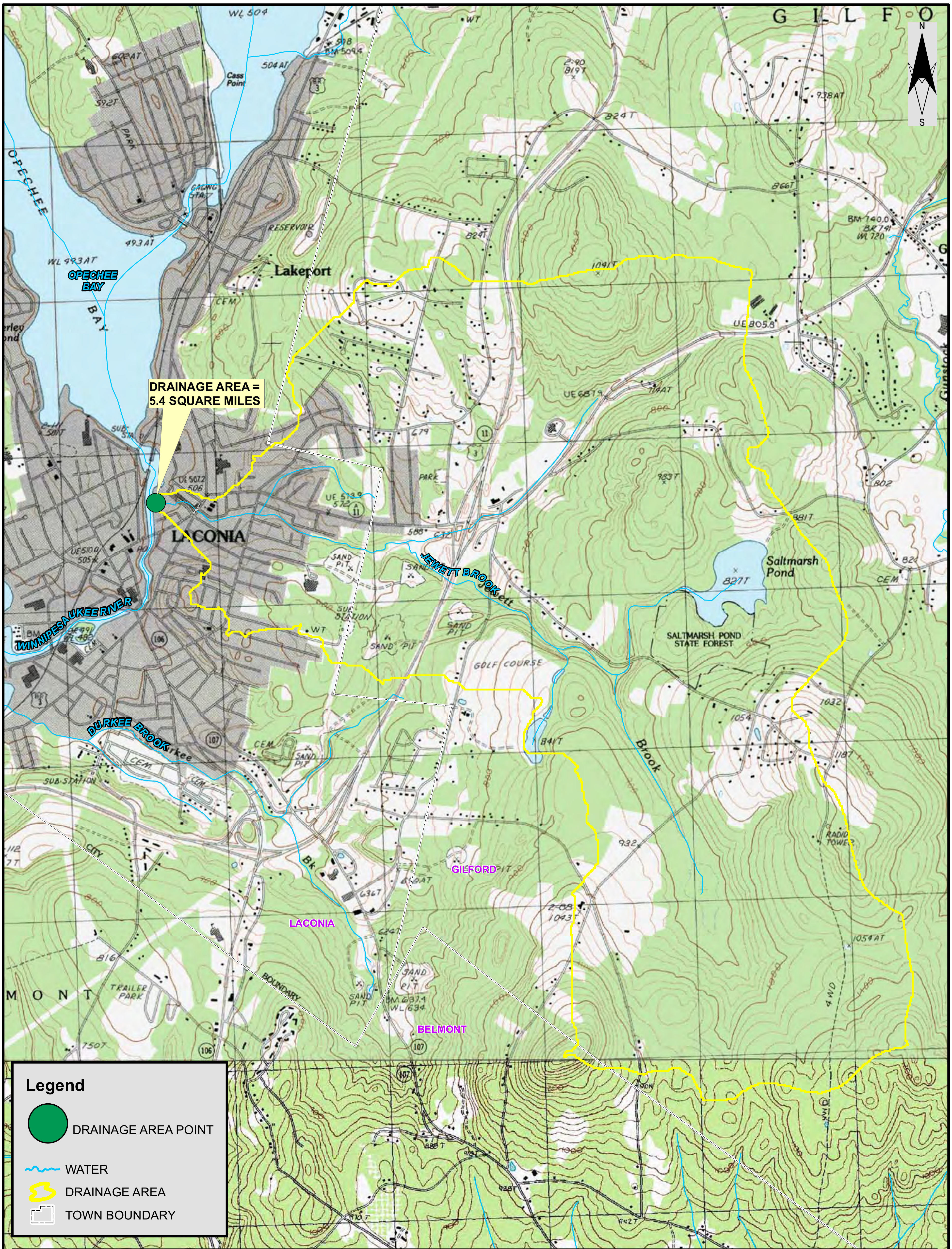
The hydraulic analysis presented here demonstrates that a 50% increase in the waterway opening (i.e., widening from approximately 18 feet to 28 feet) at the Union Avenue bridge results in only a 20% increase in flow capacity. The marginal increase is due in large part to the backwater on the downstream side of the bridge; the water simply has nowhere to go.

Increasing the capacity under Union Avenue could be done with a newer, wider bridge, though that would be a relatively expensive undertaking. Installation of a parallel box culvert to the right of the bridge (looking downstream) would likely be more cost effective. Grading at the inlet and outlet of the wider bridge or parallel culvert would be required. In many locations, increased bridge capacity can be achieved by increasing the height of the opening rather than the width. Such an approach requires raising the roadway approaches to the bridge. In a developed location such as this with buildings and intersections immediately adjacent, raising the approaches would be a very involved and expensive undertaking.

9.0 RECOMMENDATIONS

Based on the data and information presented in this report, we offer the following recommendations:

- Recognize that this location with its relatively wide flat floodplain, low roadway approaches, and flat channel slope is inherently prone to flooding.
- Consider dredging from the Union Avenue Bridge down to the Normandeau Building as a cost-effective method to significantly increase flow capacity and reduce the frequency of overtopping of Union Avenue.
- Recognize that dredging will provide only temporary relief and must be repeated to remove newly-deposited sediment.
- Develop and implement a plan to reduce the sediment supply by protecting and restoring the upstream channel and surrounding watershed.



REFERENCE:
THE ABOVE USGS QUAD (BELMONT-1987), WATER, AND TOWN BOUNDARY GIS DATA WAS OBTAINED FROM NEW HAMPSHIRE GEOGRAPHICALLY REFERENCED ANALYSIS AND INFORMATION TRANSFER SYSTEM (NH GRANIT) WEB SITE. THE ABOVE USGS QUAD (LACONIA-1987) WAS OBTAINED FROM THE TERRAIN NAVIGATOR PRO BY AMPTECH. PLEASE NOTE THIS DATA IS FOR INFORMATIONAL PURPOSES ONLY. IT IS NOT MEANT FOR DESIGN, LEGAL, OR ANY OTHER USES. THERE ARE NO GUARANTEES ABOUT ITS ACCURACY. DuBOIS & KING, INC. ASSUMES NO RESPONSIBILITY FOR ANY DECISION MADE OR ANY ACTIONS TAKEN BY THE USER BASED UPON INFORMATION OBTAINED FROM THE

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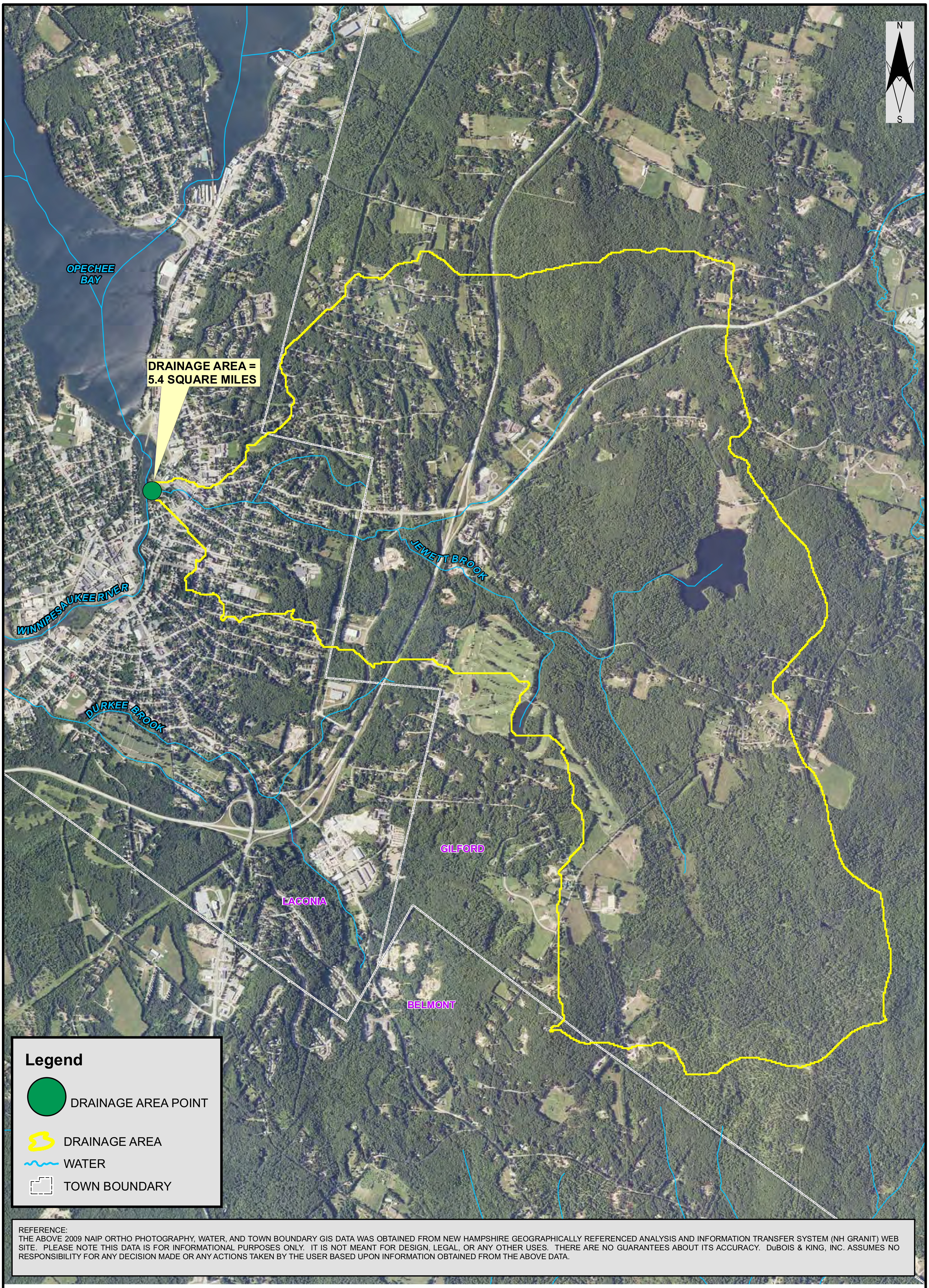
WATERSHED TOPOGRAPHIC MAP

JEWETT BROOK
WATERSHED ASSESSMENT
LACONIA, NH
BELKNAP COUNTY

DRAWN BY: DPM	DATE: 11-18-10
CHECKED BY:	PROJECT NO: 120490
PROJ. ENG: CJK	FIGURE NO:
SCALE: 0 1,000 2,000 4,000 Feet	



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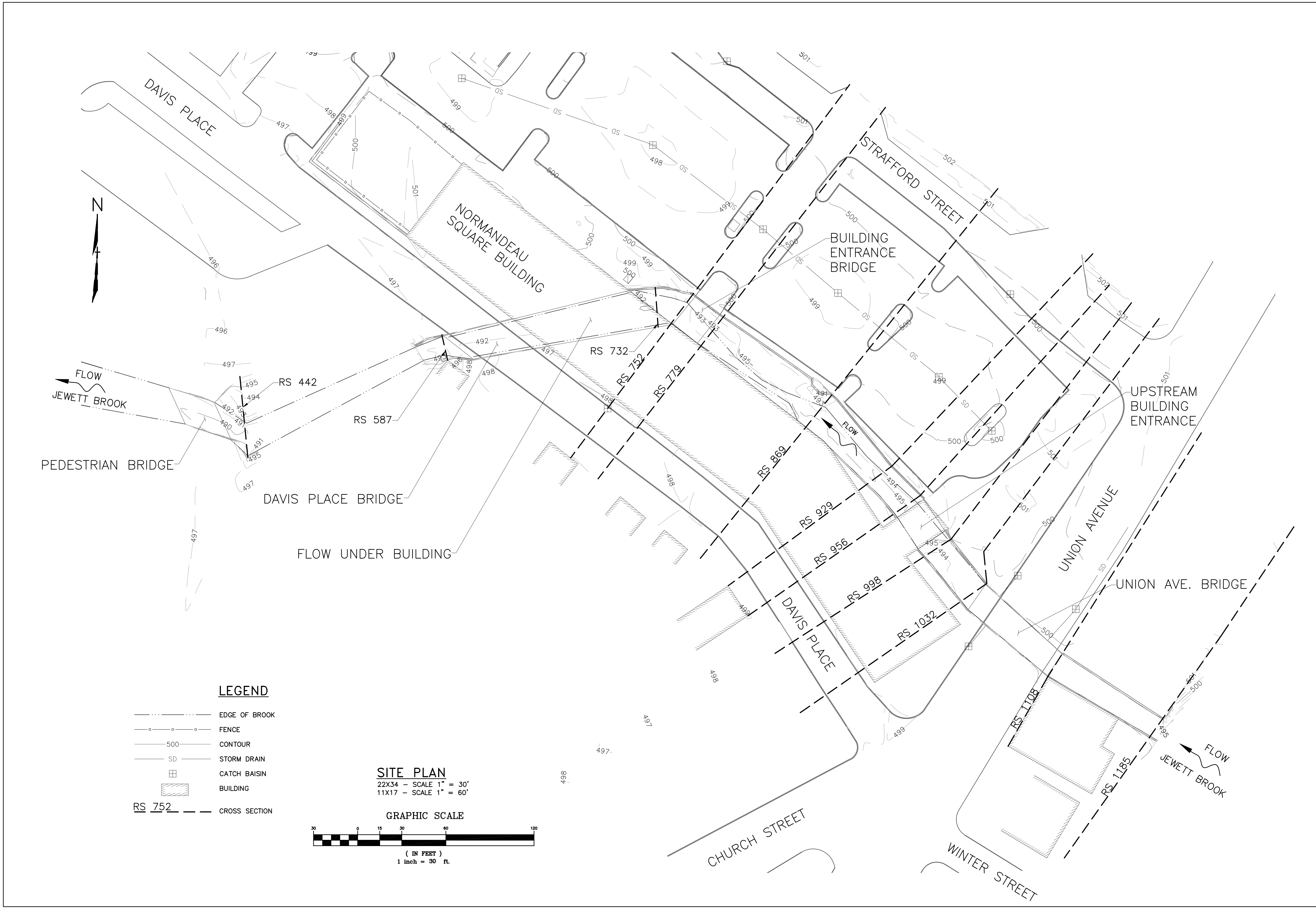
WATERSHED ORTHOGRAPHIC MAP

JEWETT BROOK
WATERSHED ASSESSMENT
LACONIA, NH
BELKNAP COUNTY

DRAWN BY: DPM	DATE: 11-18-10
CHECKED BY:	PROJECT NO: 120490
PROJ. ENG: CJK	FIGURE NO:
SCALE: 0 1,000 2,000 4,000 Feet	



ENGINEER

NO.	DATE	REVISIONS	BY	CK'D

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JEWETT BROOK
LACONIA, NH - BECKNAP COUNTY
CITY OF LACONIA, NEW HAMPSHIRE

SITE PLAN

PROJECT NO: 120490
DESIGNED BY: CJK
DRAWN BY: ZDC
DATE: NOV. 2010
CHECKED BY: CJK
DRAWING NO:
SHEET 1 OF 1

NOT FOR CONSTRUCTION

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Jewett Brook – Access/pedestrian (RS 427) road bridge downstream of Davis Place Road, view looking west.

Jewett Brook – Davis Place road view looking toward Access/pedestrian bridge downstream of Davis Place bridge. View of right overbank (looking downstream).

Jewett Brook – Davis Place road view looking westerly. Outlet of the Davis Place road bridge at the guardrail in the photograph. Davis Place road bridge connects to the Normandin Square building bridge structure at the new concrete on the sidewalk at the building in the photograph.

Jewett Brook – Davis Place road view looking west. Outlet of the Davis Place road bridge at the guardrail in the photograph. Home at 32 Davis Place.

Jewett Brook – Davis Place road view looking at outlet (RS 587).

Jewett Brook – View looking upstream at the outlet of Davis Place bridge (RS 587).

Jewett Brook – Davis Place road looking easterly toward Union Ave.

Jewett Brook – Davis Place road looking west from Union Ave.

Jewett Brook – View looking westerly along Davis Place road from Davis Place bridge.

Jewett Brook – View looking along the north side of the Normandin Square building at 22 Stafford Street toward Union Ave.

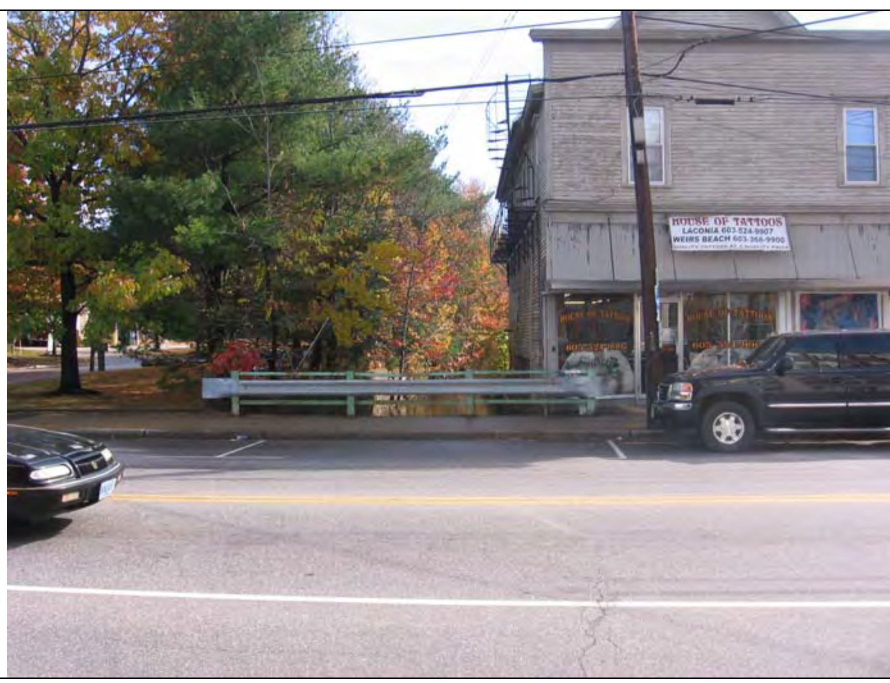
Jewett Brook – View looking at the entrance to the bridge that conveys Jewett Brook under the Normandin Square Building at 22 Stafford Street (RS 732).

Jewett Brook – View looking through the entrance to the bridge that conveys Jewett Brook under the Normandin Square Building at 22 Stafford Street (RS 732).

Jewett Brook – View looking downstream at Jewett Brook along the Normandin Square building at pedestrian bridge No.1 (RS 779)

Jewett Brook – View looking upstream along the north side of the Normandin Square building toward Union Ave at pedestrian bridge No.2 (RS 998).

Jewett Brook - Union Ave view looking toward intersection of Union Ave, Davis Place, Winter Street and Church Street. The outlet of the Union Ave bridge is at the guardrail in the photograph.



Jewett Brook – Jewett Brook flows under the Union Ave bridge; entrance to the bridge at guardrail in photograph.

Jewett Brook – Entrance to the Union Ave bridge (RS 1108)

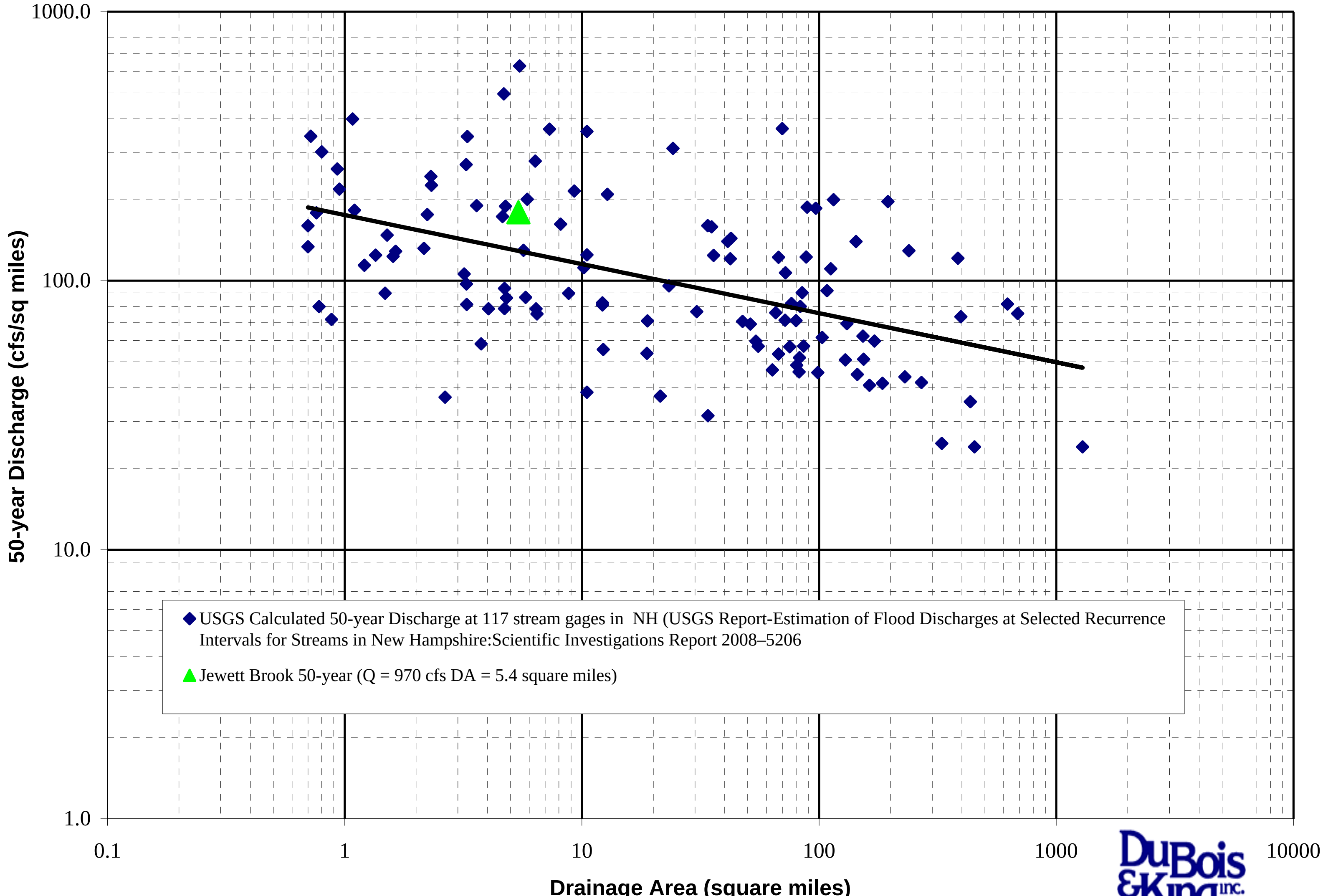
Jewett Brook - Photo from the intersection of Strafford and Union Ave toward bank parking lot (right overbank of Jewett Brook). RS 1108

Jewett Brook – Outlet of Davis Place bridge

Jewett Brook – Unknown residential area

Figure 2 - Jewett Brook flooding in the area of Casino Square, as seen from Court Street looking toward the intersection of Church Street, Davis Place, Union Avenue, and Winter Street, 1936.

Jewett Brook - Regional Analysis
Laconia, NH - Belknap County
50-Year Computed Peak Discharges For New Hampshire



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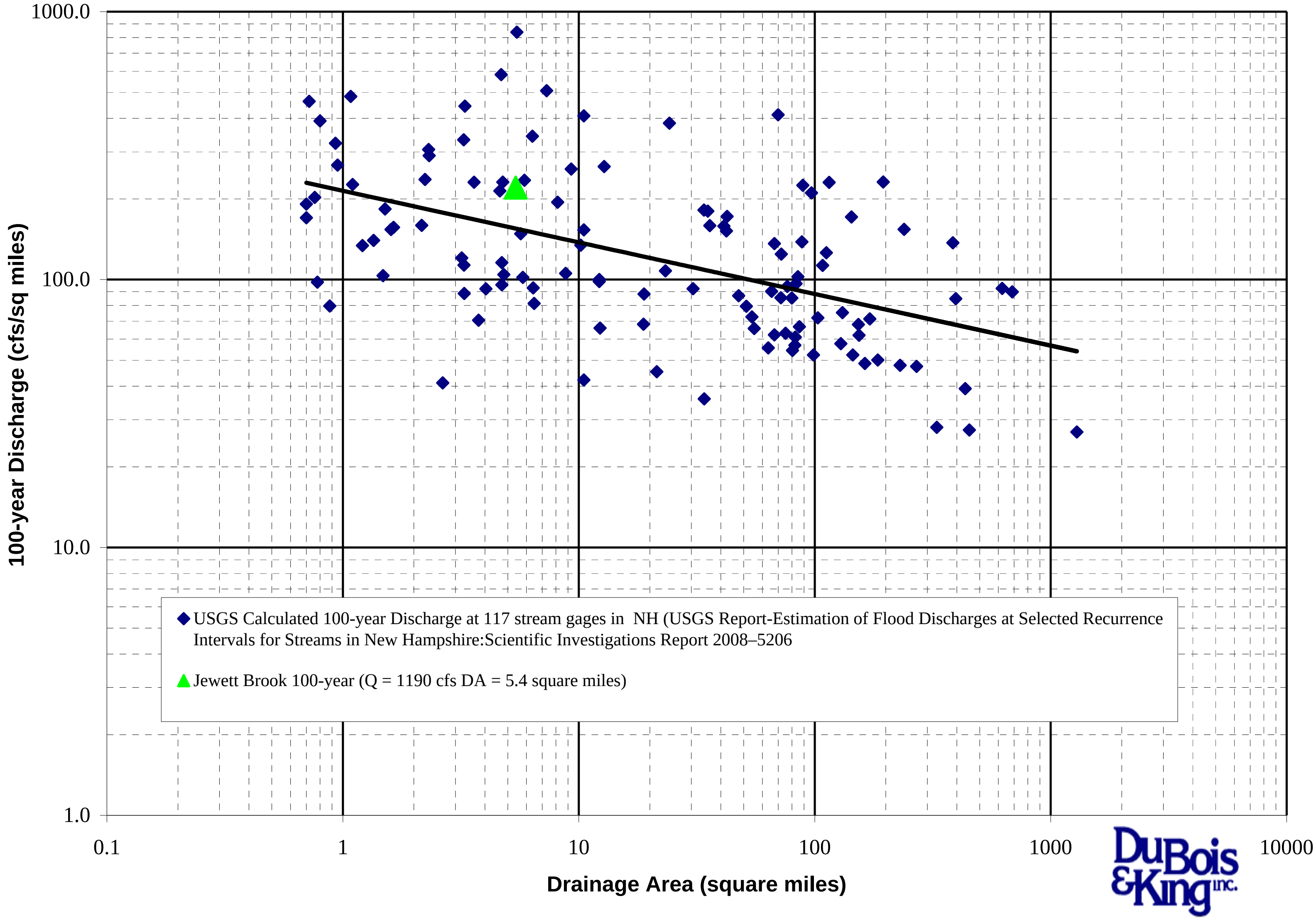
Jewett Brook - Regional Analysis
Laconia, NH - Belknap County
100-Year Computed Peak Discharges For New Hampshire



Jewett Brook
DA = 5.4sq miles
Wbf = 28.5 ft
Dbf = 2.0 ft
Abf = 57.3 sq ft

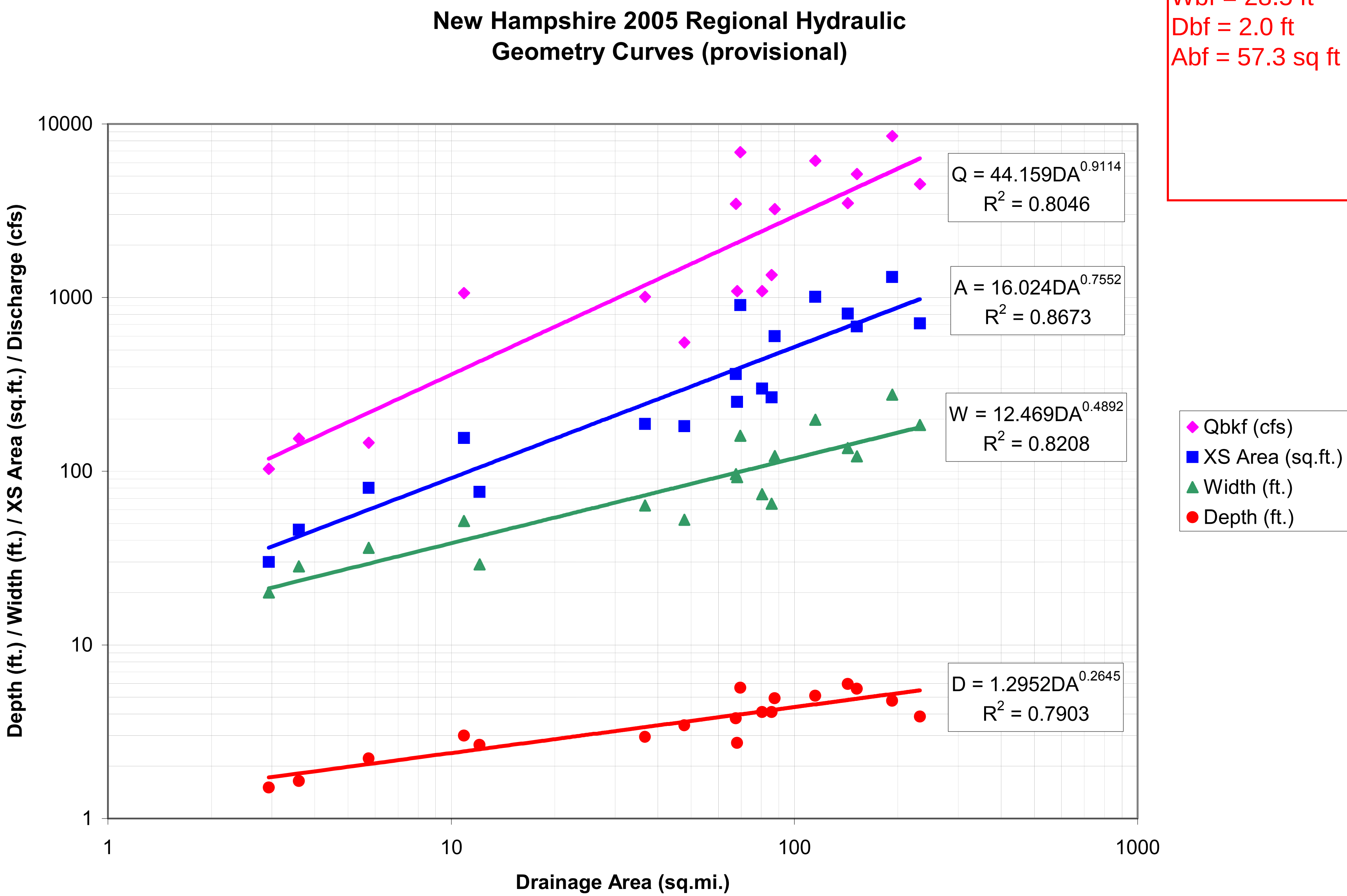
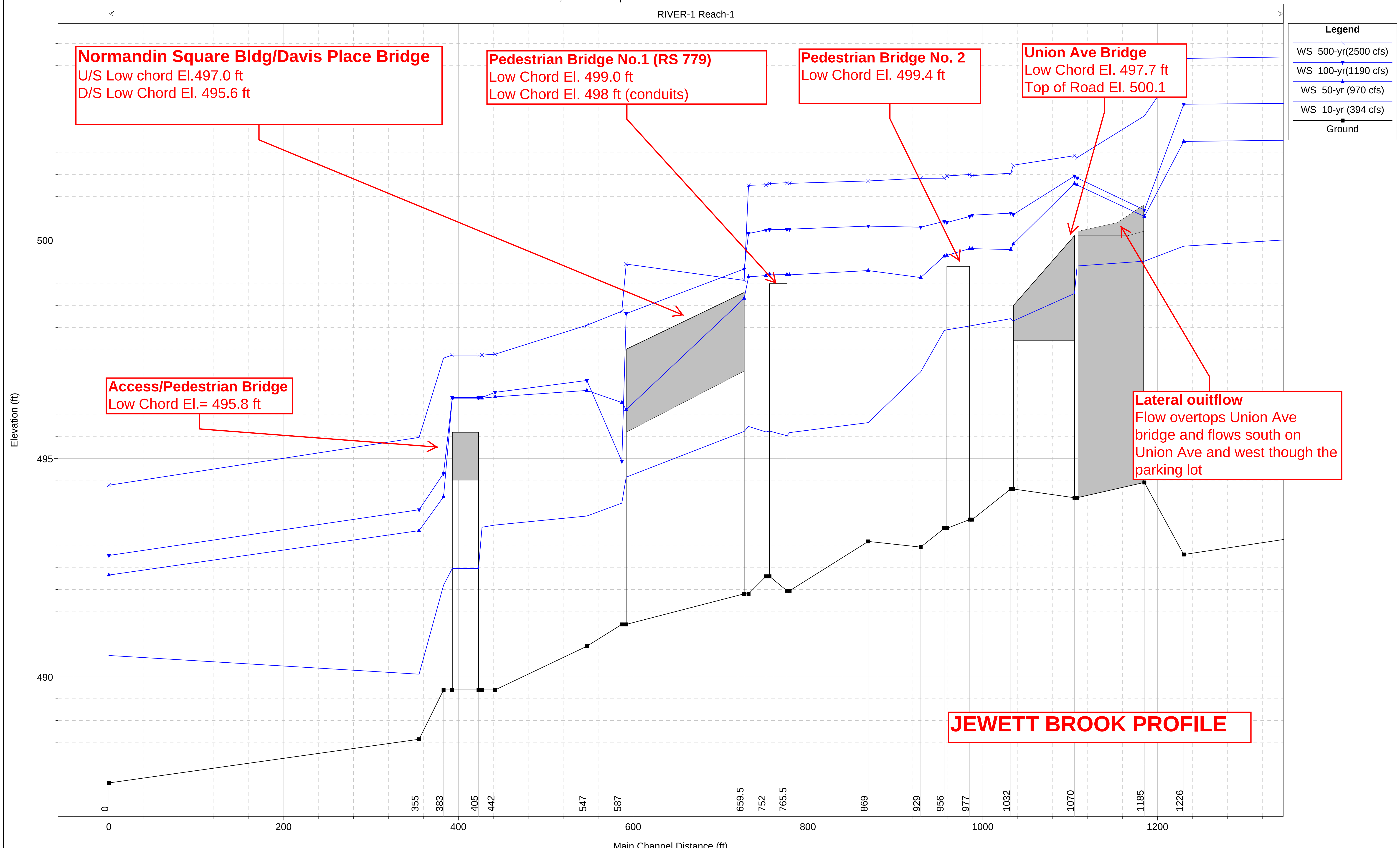


Figure 2.4: Provisional regional hydrualic geometry curves for the State of New Hampshire (Source: The New Hampshire Stream Team, 2005).

Jewett Brook - Laconia, New Hampshire Plan: Jewett Brook Oct 2010 Exist Cond 11/10/2010



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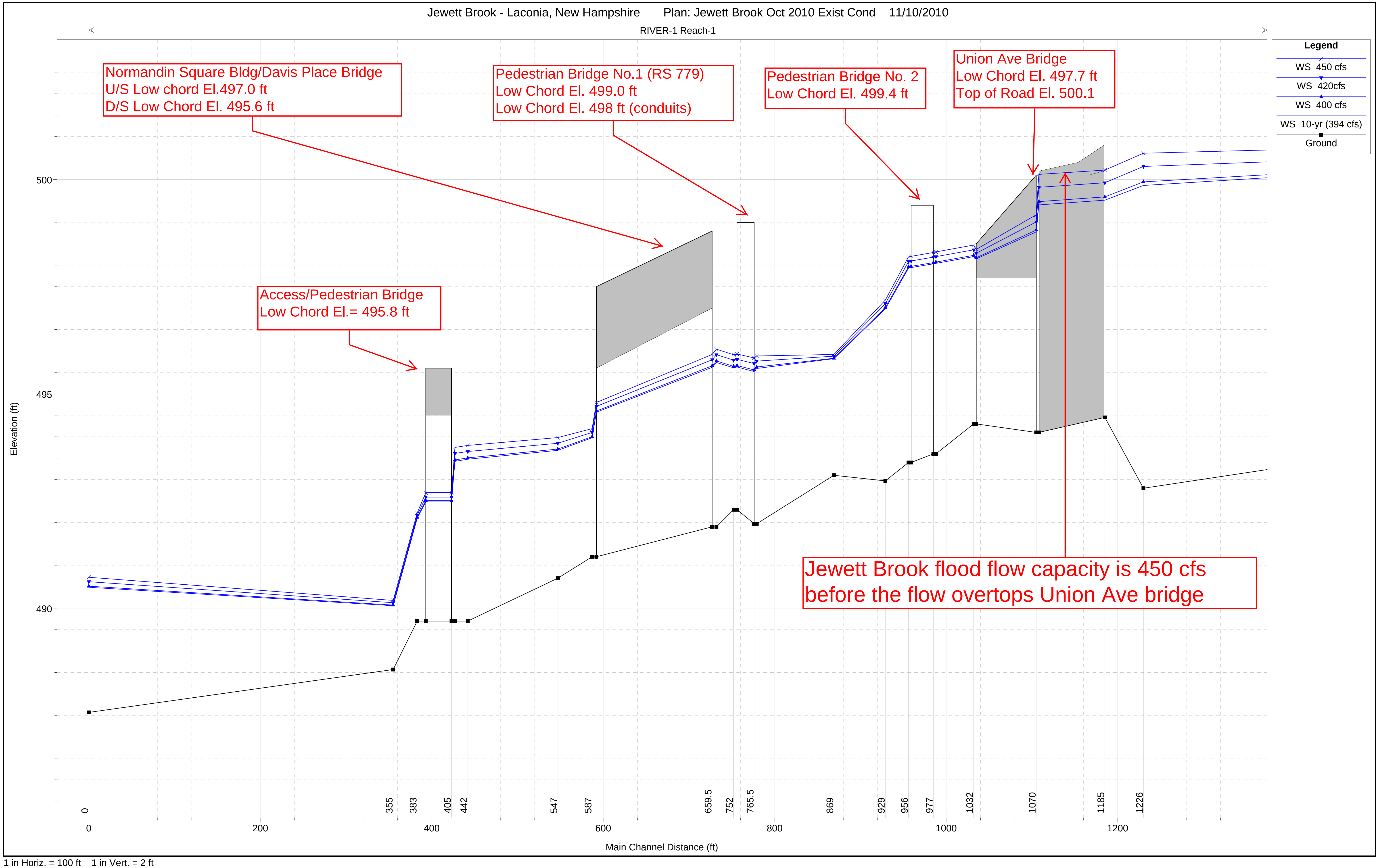
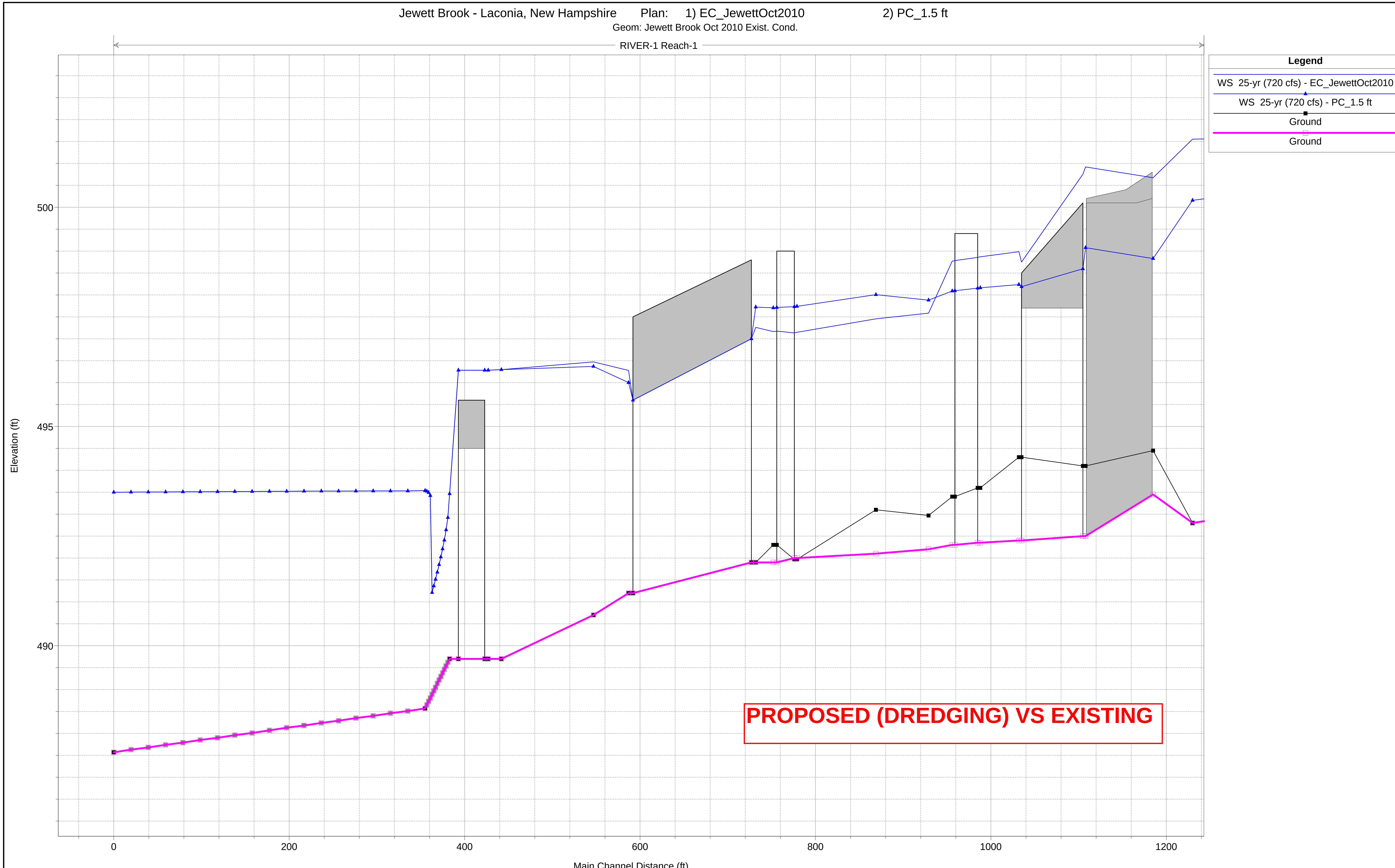
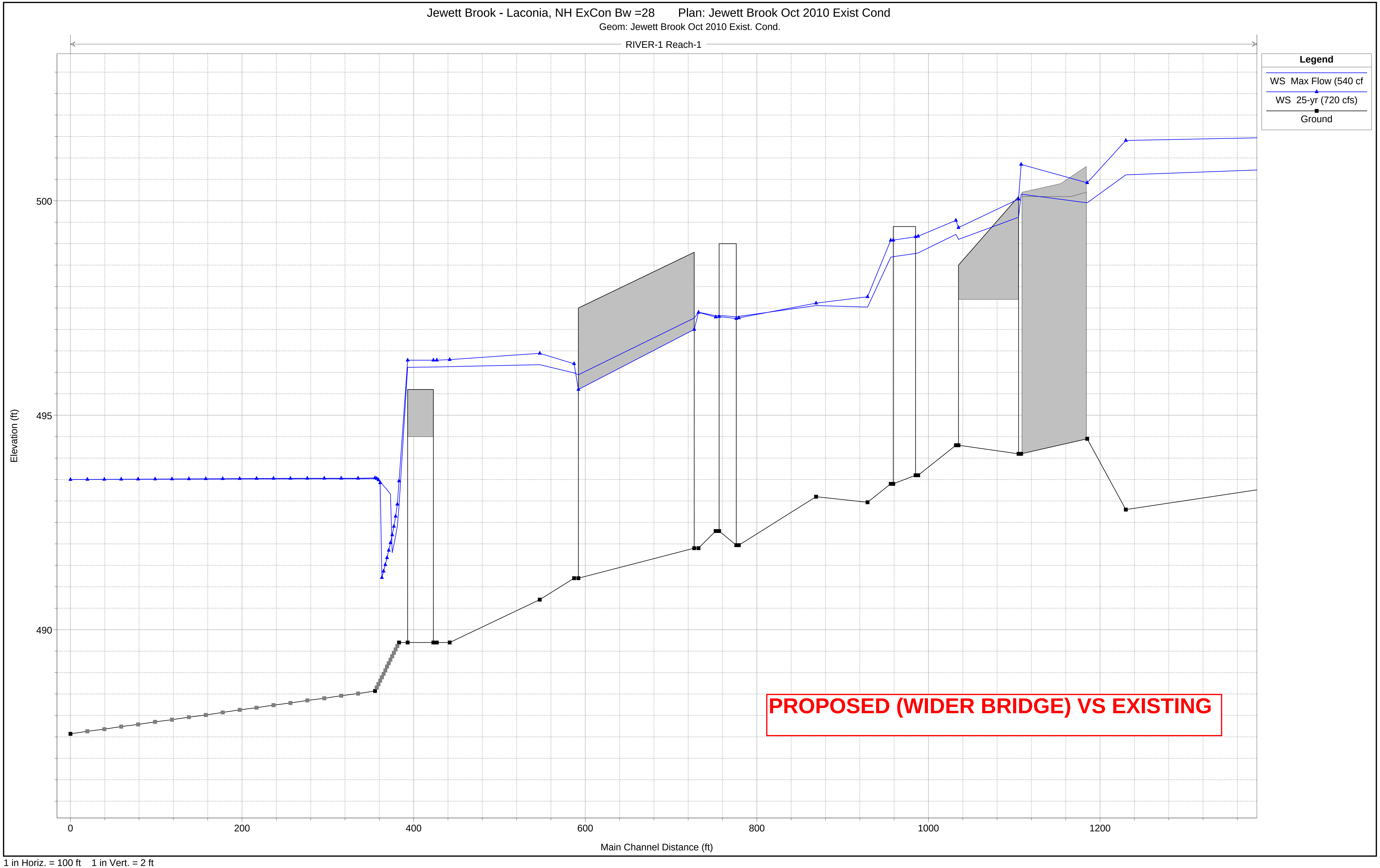

Jewett Brook - Laconia, New Hampshire Plan: Jewett Brook Oct 2010 Exist Cond 11/10/2010
RIVER-1 Reach-1
Legend
WS 450 cfs
WS 420cfs
WS 400 cfs
WS 10-yr (394 cfs)
Ground
Normandin Square Bldg/Davis Place Bridge
U/S Low chord El.497.0 ft
D/S Low Chord El. 495.6 ft
Pedestrian Bridge No.1 (RS 779)
Low Chord El. 499.0 ft
Low Chord El. 498 ft (conduits)
Pedestrian Bridge No. 2
Low Chord El. 499.4 ft
Union Ave Bridge
Low Chord El. 497.7 ft
Top of Road El. 500.1
Access/Pedestrian Bridge
Low Chord El.= 495.8 ft
Jewett Brook flood flow capacity is 450 cfs
before the flow overtops Union Ave bridge
Elevation (ft)
500
495
490
0
355
383
405
442
547
587
659.5
752
765.5
869
929
956
977
1032
1070
1185
1226
0
200
400
600
800
1000
1200
Main Channel Distance (ft)
1 in Horiz. = 100 ft 1 in Vert. = 2 ft



1 in Horiz. = 100 ft 1 in Vert. = 2 ft


Jewett Brook - Laconia, NH ExCon Bw =28 Plan: Jewett Brook Oct 2010 Exist Cond
Geom: Jewett Brook Oct 2010 Exist. Cond.
RIVER-1 Reach-1
Legend
WS Max Flow (540 cf
WS 25-yr (720 cfs)
Ground
Elevation (ft)
500
495
490
0
200
400
600
800
1000
1200
Main Channel Distance (ft)
PROPOSED (WIDER BRIDGE) VS EXISTING
1 in Horiz. = 100 ft 1 in Vert. = 2 ft