VERMONT

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SUBJECT: Lyndon 091-3(53) pin #19A189
Lyndon, I-91 Br 96-3N and 96-3S, over unnamed tributary to Passumpsic River
Site location: 1.2 miles north of Exit 24, MM 141.30
Coordinates: 44.570978, -72.039018

This memo presents hydraulic design requirements of culverts Br 96-3N and 96-3S at the crossing of Interstate 91 and an unnamed tributary to Passumpsic River. The VTrans Hydraulics unit used methods described in 2015 VTrans Hydraulics Manual to preform hydraulic analyses of the structures.

Table 1 presents the existing culvert characteristics. Tables 2 and 3 show the physical characteristics of the drainage basin and design flows. We used USGS Regression Equation Method to calculate the design flow rates, see section 4.7 in the VTrans Hydraulics Manual. The design flow rate for Interstate 91 is the 1% AEP.

Table 1. Existing Culvert Characteristics

Name	Material/Shape	Dimensions	Length (ft)	Upstream Invert (ft)	Downstream Invert (ft)	Slope (%)
96-3N	CMP/Vertical Ellipse	8.25-ft span x 9.25-ft height	366	790.13	769.42	5.67
96-3S	CMP/Vertical Ellipse	8.25-ft span x 9.25-ft height	310	768.55	750.01	6.00

Table 2. Drainage Basin Characteristics

Drainage Area	2.75 square miles
Land Cover	Forested
Percent Water Bodies and Wetlands	2.49%
Average Mean Annual Precipitation	43.4 in/yr

Table 3. Design Flow Rates

Annual Return Probability (%)	Flow Rate (cfs)
43	110
10	200
4	260
2	320
1 – Design	380
0.5 – Check	440

Proposed Structure Design Specifications

VTrans Hydraulics unit performed a preliminary hydraulic analysis using the Federal Highway Administration (FHWA) tool HY-8 and Aquevo's Surface-water Modeling System (SMS)/ SRH-2D to evaluate the performance of existing and proposed structures at the 1% design event and the 0.5% check event. Table 4 presents the proposed structure types and dimensions.

On 5/19/21, we met with Vermont Agency of Natural Resources (ANR) at the site. ANR will require a minimum replacement structure span of 20-feet to span bankfull width (BFW). Table 5 presents the minimum span for any new replacement structure.

Table 6 presents the preliminary model results and minimum culvert hydraulic requirements from the VTrans Hydraulics Manual (See section 6.5.2 Culvert Design Limitations). ANR will not require a natural channel to provide aquatic organism passage (AOP) through the structure due to a natural barrier directly upstream of the 96-3N inlet. However, a closed bottom structure shall be buried and filled to the top of the streambed with VTrans E-stone that provides an immobile structure bed. Roughening up the interior surface will allow for acceptable velocities at the outlets and prevent excessive erosion. Bed retention sills need to be added to the bottom of the structure. Sills must be 12 inches high across the full width of the structure and be buried so the top of the sills will not be visible. Sills need to be spaced no more than 8 feet apart throughout the structure with one sill placed at both the inlet and the outlet.

Table 7 presents the model results and minimum bridge hydraulic requirements from the VTrans Hydraulics Manual (See section 6.5.1 Bridge Design Limitations). Ledge is visible in the main channel and assumed to be shallow. For this reason, we did not perform a preliminary scour analysis. The bottom of abutment footings should be at least 6 feet below the channel bottom, or to ledge. An updated/detailed scour analysis will need to be performed during the final hydraulics phase.

See Table 8 and attached white paper for stone fill size considerations.

Table 4. Proposed Minimum Replacement Specifications

Name	Type	Minimum Dimensions
96N-3N	4-sided Box	20-ft span by 8-ft clear height
96N-3S	4-sided Box	20-ft span by 8-ft clear height
96N-3N	3-sided Bridge or Rigid Frame	20-ft span by 8-ft clear height
96N-3S	3-sided Bridge or Rigid Frame	20-ft span by 8-ft clear height

Table 5. Minimum Span Requirements

Structure	ANR Bankfull width (ft)*	Bankfull width (ft)**	Minimum Span (ft)
96N-3N	20.4	20	20
96N-3S	20.4	20	20

*Determined using the ANR BFW regression equation based on a drainage area of this size
**Field measured BFW

Table 6. Hydraulic Requirements and Performance for a Box Type Structure

Structure	Clear Height (ft)	Embedment Depth (ft)	VTrans E-Stone Type/ D50 (in)	Headwater Elevation at 1% AEP (ft)*	Headwater depth (ft)	HW/D**	Average Velocity at 1% AEP (fps)	Maximum Applied Shear Stress (psf)
96N-3N	8	3	III/ 24	796.5	6.4	0.8	9.0	9.2
96N-3S	8	3	III/ 24	772.6	4.0	0.5	9.8	8.5

*Headwater elevations taken 20 ft upstream of each structure (Using SMS/SRH-2D results)
**Allowable headwater to depth ratio is less than or equal to 0.8 at the design event frequency (due to the slope transition at the 96N-3N inlet and potential debris concerns – see manual section 6.4.2.1 Allowable Headwater and Backwater)

Table 7. Hydraulic Requirements and Performance for a Bridge Type Structure

Structure	Minimum Low Chord Elevation (ft)	Clear Height	VTrans E-Stone Fill Type/ D50 (in)	Headwater Elevation (ft) at 1% AEP	Freeboard (ft)*	Minimum Footing Depth (ft)	Average Velocity at 1% AEP (fps)	Maximum Applied Shear Stress (psf)
96-3N	798.13	8	Type III/ 24	796.5	1.6	6 or to ledge	9.0	9.2
96-3S	776.55	8	Type III/ 24	772.5	4.0	6 or to ledge	9.8	8.5

*Provide a minimum of 1.0 ft of freeboard during the design event

Table 8. E-Stone Design Specifications

E-Stone Type	D50 (in)	Allowable Shear Stress for an immobile streambed (psf)*	Approximate Stone fill Manning's n value	Embedment depth (ft)
I	12	4.4	0.046	1.5
II	18	8.0	0.053	2
III	24	10.6	0.060	3
IV	36	15.9	0.071	4

*Allowable shear stress for an immobile bed during the design storm (1% AEP) determined using methodology used in HEC-26 chapter 7.6.1.1 and chapter 7.9.2

This memo presents the preliminary hydraulic design completed by VTrans. Other structures could change hydraulic calculations and still meet VTrans Hydraulic Manual standards. If another alternative is considered, it

will need to be accounted for during the final hydraulics phase and coordinated with ANR.

The VTrans hydraulics unit inquired with ANR rivers program regarding using a dual cell structure. We agreed this option would be a reasonable option for this site if both spans total the 20 ft width minimum. If this option is preferable to the design build team, additional modeling will be necessary to confirm VTrans Hydraulics Manual standards are still met.