AASHTOWare Bridge Design & Rating (BrDR) For Research

A Whitepaper based on the NCHRP 15-54 Research – M. Mlynarski

AASHTOWare RADBUG Meeting
July 30-31, 2019
South Lake Tahoe, CA

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AASHTOWare Bridge Design & Rating AASHTO

Using AASHTOWare BrDR For Research

- Brief History/Background
- Methods for using the software
- Conclusions

Using AASHTOWare BrDR For Research

- Brief History/Background
- NCHRP 12-50 – Bridge Software Validation and Guidelines

Using AASHTOWare BrDR For Research

- Brief History/Background
- NCHRP 12-50 – Bridge Software Validation and Guidelines
  - Began right after LRFD Spec Implementation
  - Compared two software packages (PennDOT-BRASS)
  - Developed 12-50 Process (origin of BrDR RTU)

Using AASHTOWare BrDR For Research

- Brief History/Background
- NCHRP 15-28 – CANDE Modernization

Using AASHTOWare BrDR For Research

- Brief History/Background
- NCHRP 15-28 – CANDE Modernization
  - CANDE models soil elements with the culvert structure
  - In use since the 1980's
  - Use of CANDE and modifying for 15-54 was key but won't be discussed for this presentation

Using AASHTOWare BrDR For Research

- Brief History/Background
- NCHRP 12-78 – A comparison of AASHTO Load Rating Methods

Using AASHTOWare BrDR For Research

- Brief History/Background
- NCHRP 12-78 – A comparison of AASHTO Load Rating Methods
  - Intensive use of BrR
  - Collected 18,000+ BrR bridges from the states
  - Created a 1500 bridge – cross section of the NBI
  - 1500 bridge set still used today for regression testing
  - Currently being used for FHWA Truck Platooning study

Using AASHTOWare BrDR For Research

- Brief History/Background
- NCHRP 15-54 – Proposed Modifications to AASHTO Culvert Load Rating Specifications
  - Culvert project
  - Field testing-instrumenting/modeling of culverts
  - Propose specifications
  - Use BrDR to help validate proposed specifications

NCHRP 15-54

Proposed Modifications to AASHTO Culvert Load Rating Specifications

Research Team

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Panel

TIM ARMBRECHT, CHAIR, ILLINOIS DOT

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THOMAS KOCH, NORTH CAROLINA DOT

YI QIU, TEXAS DOT

HOLLY THOMAS

BRAD WAGNER, MICHIGAN DOT

JAMES WITHIAM

WASEEM DEKELBAB, NCHRP

LUBIN GAO, FHWA

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AASHTOWare Bridge Design & Rating

Phases I-III

- Field Testing - Led by Modjeski & Masters
- Develop Test Plan
- Schedule a date
- Instrument
- Load with a known vehicle weight

Phases I-III

- Refine 3D models
- Refine 2D models
- Propose Specs
- Program specs to view effects of change (BrDR) – Regression data From BrR
  - i.e. How do the rating factors change based on the spec change?
  - CALTRANS BrR models

Using AASHTOWare BrDR For Research

- Methods for using the software

How was BrR used?

Using AASHTOWare BrDR For Research

- Methods for using the software
  - Using the software ‘As-Is’
  - Using the regression Data
  - Modifying the software
  - Using a large number of examples already input

Using AASHTOWare BrDR For Research

- Methods for using the software
  - Using the software ‘As-Is’ – Spring Constants
    - Ran culverts without spring constants
    - Ran culverts with proposed spring constants
    - Compare the ratings at varying field depths

Using AASHTOWare BrDR For Research

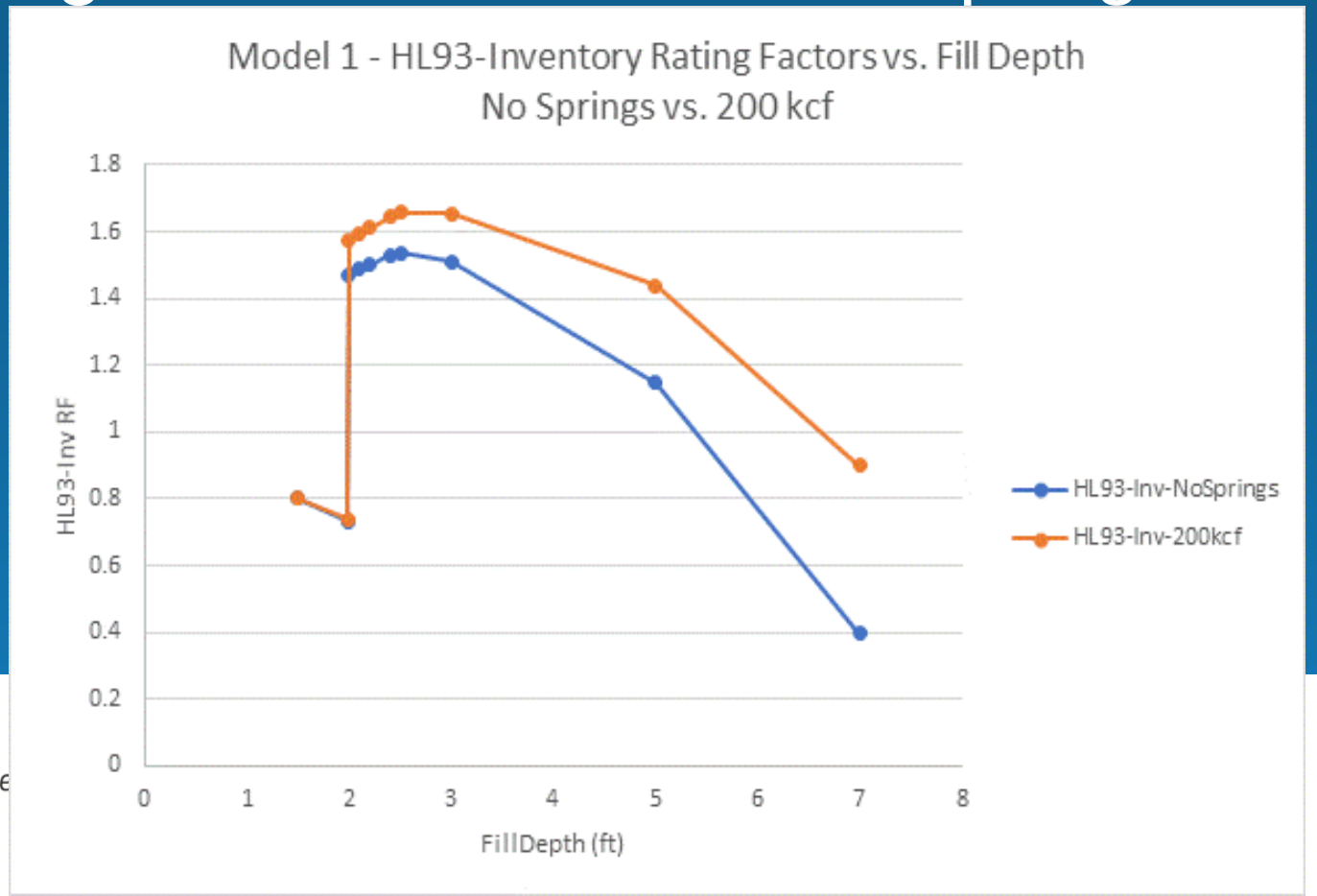
- Methods for using the software
  - Using the software 'As-Is' – Spring Constants

Fill Depth (ft)	Vehicle	HL93-Inv-NoSprings	HL93-Inv-100 kcf Springs	Inv-Ratio*
Model 1				
1.5	HL-93 (US)	0.8	0.802	0.998
1.99	HL-93 (US)	0.733	0.739	0.992
2	HL-93 (US)	1.47	1.541	0.954
2.1	HL-93 (US)	1.486	1.56	0.953
2.5	HL-93 (US)	1.538	1.621	0.949
3	HL-93 (US)	1.509	1.61	0.937
5	HL-93 (US)	1.147	1.376	0.834
7	HL-93 (US)	0.395	0.816	0.484

Less than 1.0 ratio indicates the new rating is greater than the old. As the fill gets deeper, the rating improves

Using AASHTOWare BrDR For Research

- Methods for using the software
  - Using the software 'As-Is' – Spring Constants



MBE – BrDR Bedding Stiffness

- Requires modulus of subgrade reaction (pci)
- Engineering judgement needed
- Values from literature included, for example:

Soil	Range[2] (pci)	Rating Values[3] (pci)
Loose sand	15-60	30
Medium dense sand	35-290	115
Dense sand	230-460	290
Clayey medium dense sand	115-290	200

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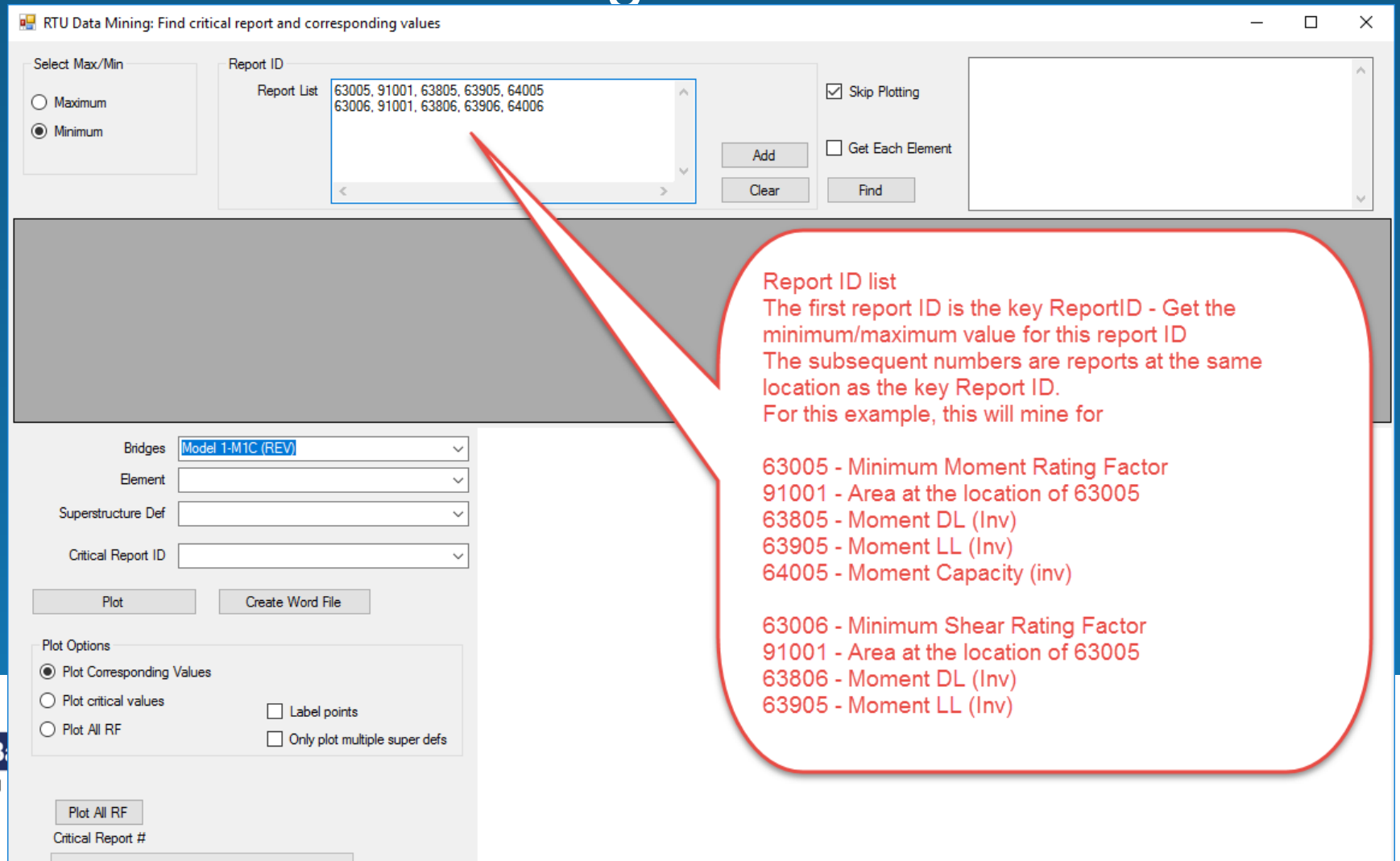
- Methods for using the software
  - Using the regression Data
    - Common use – with RTU utility
    - Using it for other purposes
    - Little Data mining utility written using the BrDR regression data

Using AASHTOWare BrDR For Research

- Methods for using the software



Using AASHTOWare BrDR For Research

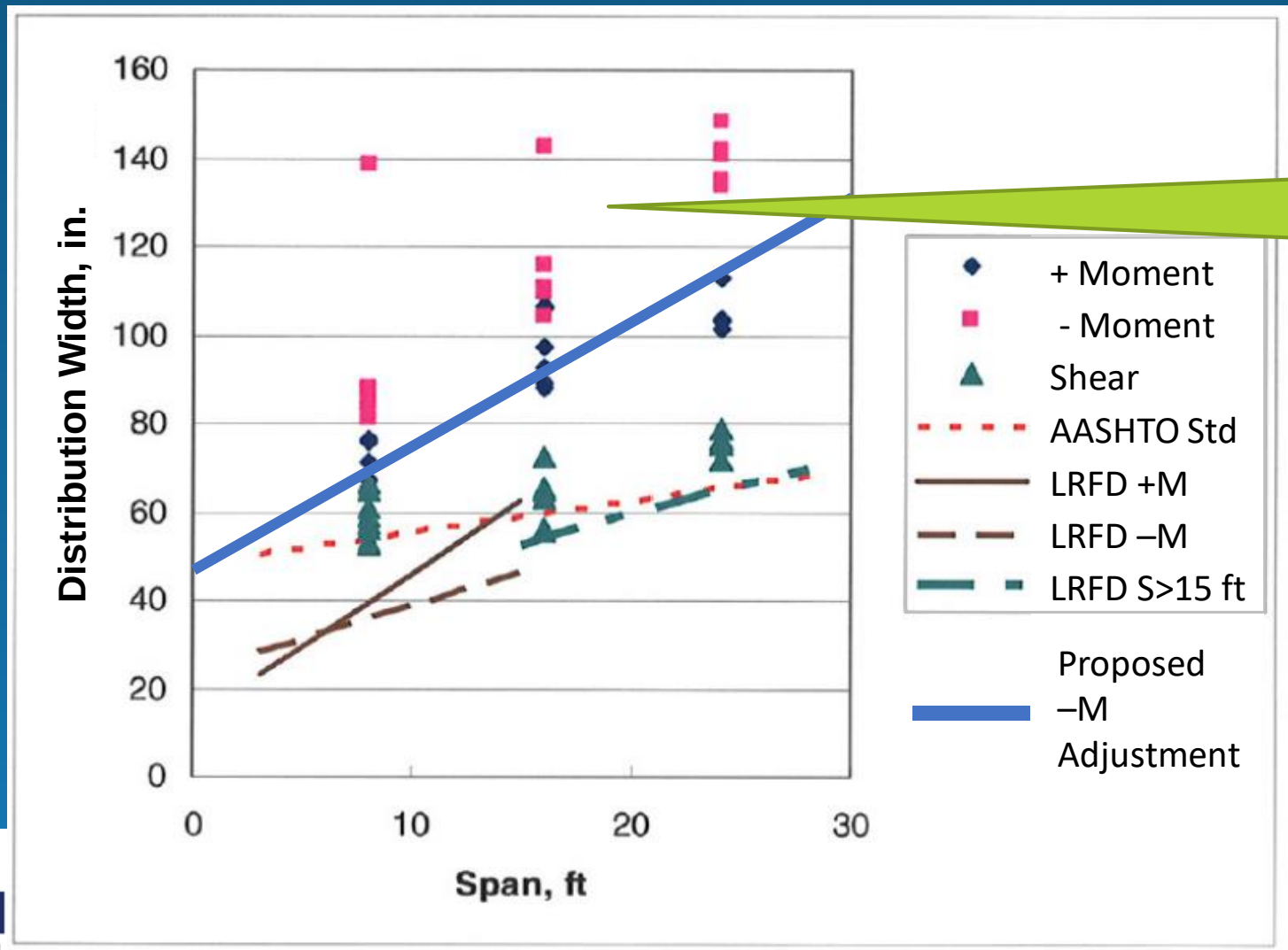
Using AASHTOWare BrDR For Research

- Methods for using the software
  - Other possible uses of regression data
    - Comparing PS shear control options (App B, General…)
    - Changes in RF from one spec to another
    - Producing Graphs/Tables

Using AASHTOWare BrDR For Research

- Methods for using the software
  - Modifying the Software
    - Shear capacity changes
    - Changes to Live Load Surcharge

MBE – R/C Box Culvert Shear



Distribution widths for moments are greater than those for shear

Note: LRFD refers to AASHTO LRFD Bridge Design Specifications, 2nd Edition

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AASHTOWare Bridge Design & Rating

MBE – R/C Box Culvert Shear

Implementation:

$$\varepsilon_s = \frac{\left(\left|\frac{M_{u-mod}}{d_v}\right| + 0.5\, N_u + |V_u|\right)}{E_s A_s} \qquad 5.7.3.4.2\text{-}4$$

$$M_{u-mod} = M_u \frac{96 + 1.44 * Span}{96 + 5.47 * Span}$$

Bridge ID	Fill Depth	Critical Element (Before)	Location (Before)	Critical Element (After)	Location (After)	Shear Inv Rating Factor HL93 (Before)	Shear Inv Rating Factor HL93 (After)	Ratio (before/ after)
CD10x8;10 2002-Rev	1.5	Top Slab 2	0.6025	Top Slab 2	0.6025	1.1099	1.1789	0.9415
CD10x8;10 2002-Rev	1.9	Top Slab 2	0.6025	Top Slab 2	0.6025	1.1066	1.1835	0.9350
CD10x8;10 2010-Rev	1.5	Top Slab 2	0.6925	Top Slab 2	0.6925	1.4619	1.557	0.9389
CD10x8;10 2010-Rev	1.9	Top Slab 2	0.6925	Top Slab 2	0.6925	1.5025	1.5806	0.9506
CD10x8;16 1966-Rev	1.9	Top Slab 1	9.0893	Top Slab 1	9.0893	1.601	1.8908	0.8467
CD10x8;2 1966-Rev	0.5	Top Slab 1	9.3866	Top Slab 1	0.6354	1.0071	1.0407	0.9677
CD10x8;2 1966-Rev	1	Top Slab 1	9.3866	Top Slab 1	0.6354	1.0185	1.1017	0.9245
CD10x8;2 1966-Rev	1.5	Top Slab 1	9.3866	Top Slab 1	9.3866	1.0306	1.0946	0.9415
CD10x8;2 1966-Rev	1.9	Top Slab 1	9.3866	Top Slab 1	9.3866	1.0314	1.0873	0.9486
CD10x8;3 1952-Rev	1.5	Top Slab 1	8.8819	Top Slab 1	8	1.0699	1.3251	0.8074
CD10x8;3 1952-Rev	1.9	Top Slab 1	8.8819	Top Slab 1	8.8819	1.0888	1.3459	0.8090
CD10x8;5 1948-Rev	1	Top Slab 1	8.9271	Top Slab 1	1.1034	1.1191	1.2936	0.8651
CD10x8;5 1948-Rev	1.5	Top Slab 1	8.9271	Top Slab 1	8.9271	1.1443	1.3417	0.8529
CD10x8;5 1948-Rev	1.9	Top Slab 1	8.9271	Top Slab 1	8.9271	1.1661	1.3478	0.8652

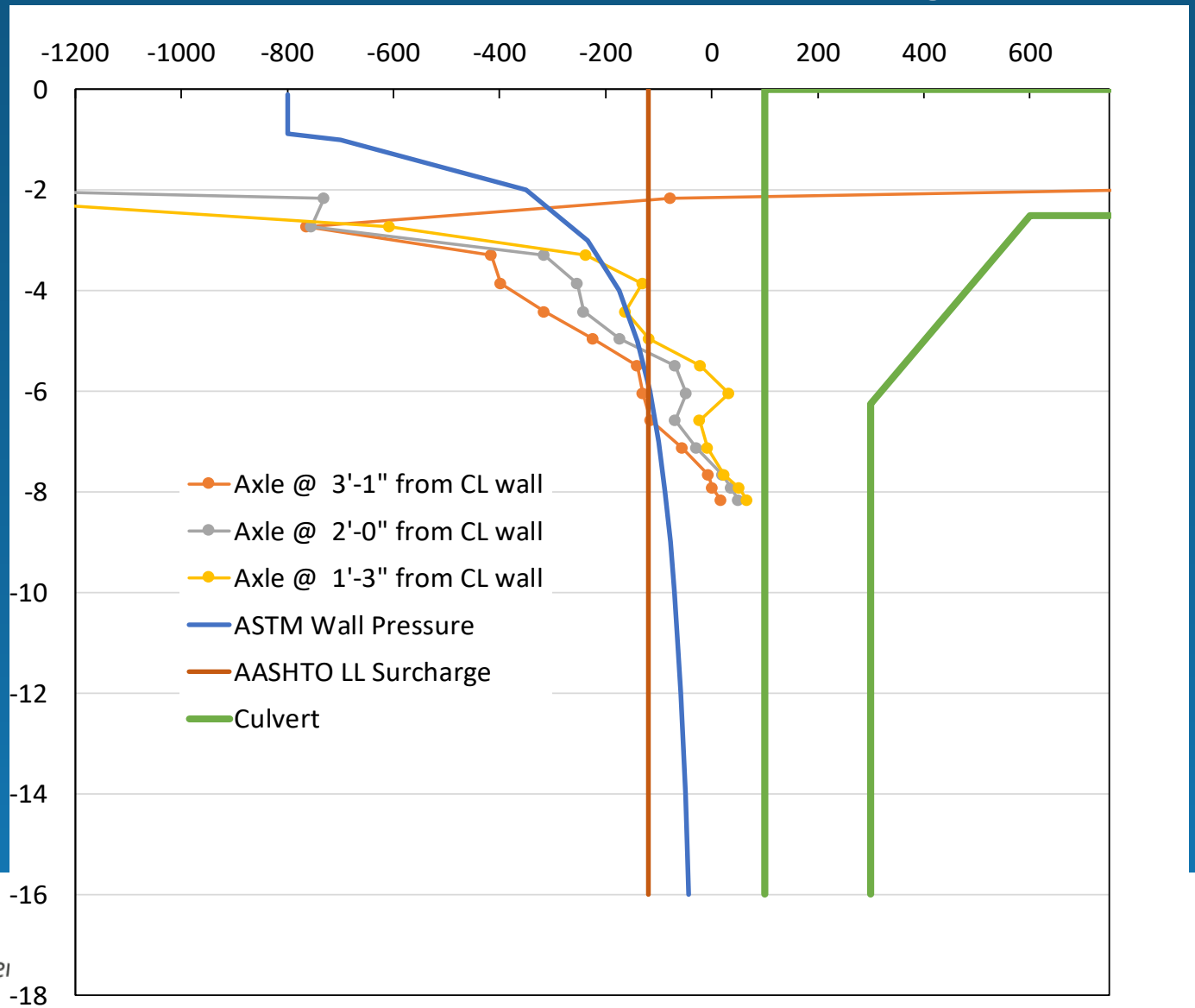
LRFD - Lateral Live Load - Recommendation

- Adopt ASTM approaching wheel load (new Article 3.11.6.4.2)

$$\Delta_p(h_d) = 700/h_d \leq 800 \text{ psf}$$

- Apply to full depth of culverts with less than 2 ft of cover
- Regression Test with current spec (applied evenly along the wall)

Lateral Pressure, psf



LRFD - Lateral Live Load – BrR Regression Test

Culvert	Cover	Inv Rating HL93 (Before)	Inv Rating HL93 (Before)	Inventory Ratio
LS-CD8x8;10 1924-Rev	5 ft Cover	0.919	1.453	0.632485
LS-CD8x8;10 1933-Rev	3.5 ft Cover	1.625	1.739	0.934445
LS-CD8x8;10 1933-Rev	4 ft Cover	1.496	2.119	0.705993
LS-CD10x8;16 1966-Rev	1.9 ft Cover	0.723	0.736	0.982337
LS-CD10x8;16 1966-Rev	2 ft Cover	0.692	0.753	0.918991
LS-CD10x8;16 1966-Rev	2.5 ft Cover	0.549	0.652	0.842025
LS-CD10x8;16 1966-Rev	3 ft Cover	0.401	0.51	0.786275
LS-CD10x8;16 1966-Rev	3.5 ft Cover	0.249	0.337	0.738872
LS-CD10x8;16 1966-Rev	4 ft Cover	0.093	0.134	0.69403
LS-CS10x8;5 1933-Rev	1.5 ft Cover	0.566	0.569	0.994728
LS-CS10x8;5 1933-Rev	1.9 ft Cover	0.456	0.494	0.923077
LS-CS10x8;5 1933-Rev	2 ft Cover	0.429	0.473	0.906977
LS-CS10x8;5 1933-Rev	2.5 ft Cover	0.293	0.35	0.837143
LS-CS10x8;5 1933-Rev	3 ft Cover	0.157	0.203	0.773399
LS-CS10x8;5 1933-Rev	3.5 ft Cover	0.023	0.032	0.71875
LS-CS10x8;10 1933-Rev	7 ft Cover	1.525	1.758	0.867463
LS-CD12x8;9 1948-Rev	1.9 ft Cover	0.427	0.448	0.953125
LS-CD12x8;9 1948-Rev	2 ft Cover	0.399	0.425	

Using AASHTOWare BrDR For Research

- Methods for using the software
  - Using existing BrR data sets from the states
    - 2008 – collected 18,000 BrR bridges from the states
    - 2019 – More than 80,000 BrR bridges have been input
    - Take advantage of this growing, untapped inventory

Using AASHTOWare BrDR For Research

- Conclusions
  - Thanks to AASHTOWare!
  - Continue AASHTO's participation in research
  - Use BrR for parametric/regression studies
  - Review the effects of proposed changes before approval stage of specs