Br. 196.6 Hydraulic Modeling (Bismarck, ND)

June 10, 2019

BNSF RAILWAY

Hydraulic Modeling Summary

- **Case A** - BNSF Preferred Design WITHOUT Existing Bridge - Tracks positioned on existing alignment and 30' north:
  - Yields a no-rise in base flood elevation.
  - No structures impacted by base flood.

- **Case B** – New bridge with tracks positioned 80' and 105' north of existing bridge WITH existing bridge, and every other new "wet" pier aligned with an existing pier:
  - Yields a base flood elevation rise of 0.02'.
  - Rise extends eight miles upstream and impacts approximately 500 structures.

- **Case C** - BNSF Preferred Design WITH Existing Bridge - Tracks positioned on existing alignment and 30' north of existing bridge, and all new piers offset from existing piers:
  - Yields a base flood elevation rise of 0.03'.
  - Rise extends ten miles upstream and impacts approximately 550 structures.

Cost and R/W Implications

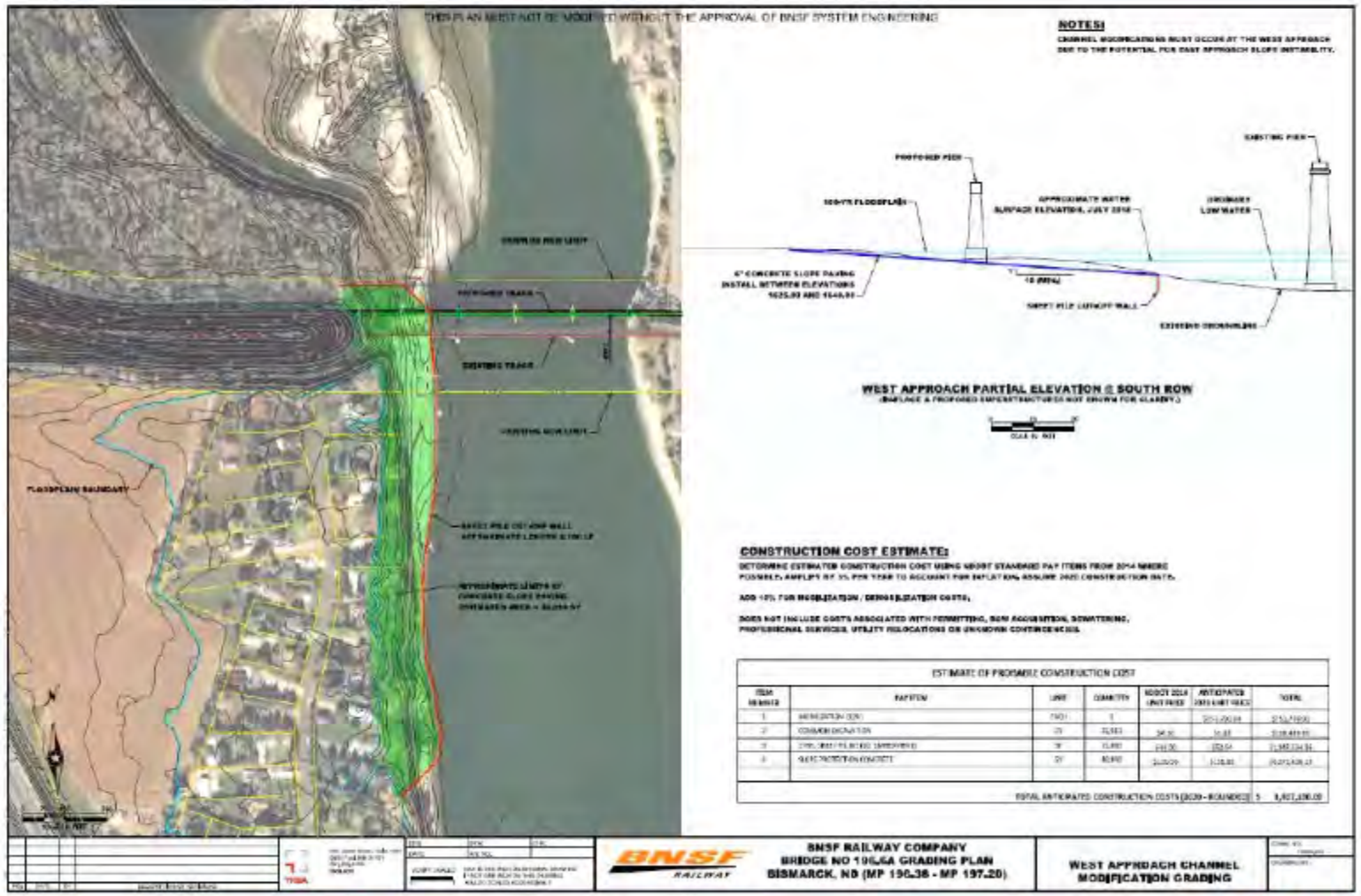
- **Case A** - BNSF Preferred Design with no rise in base flood elevation:
  - Provides baseline cost for comparison to Cases B and C.
  - All work is within BNSF R/W.

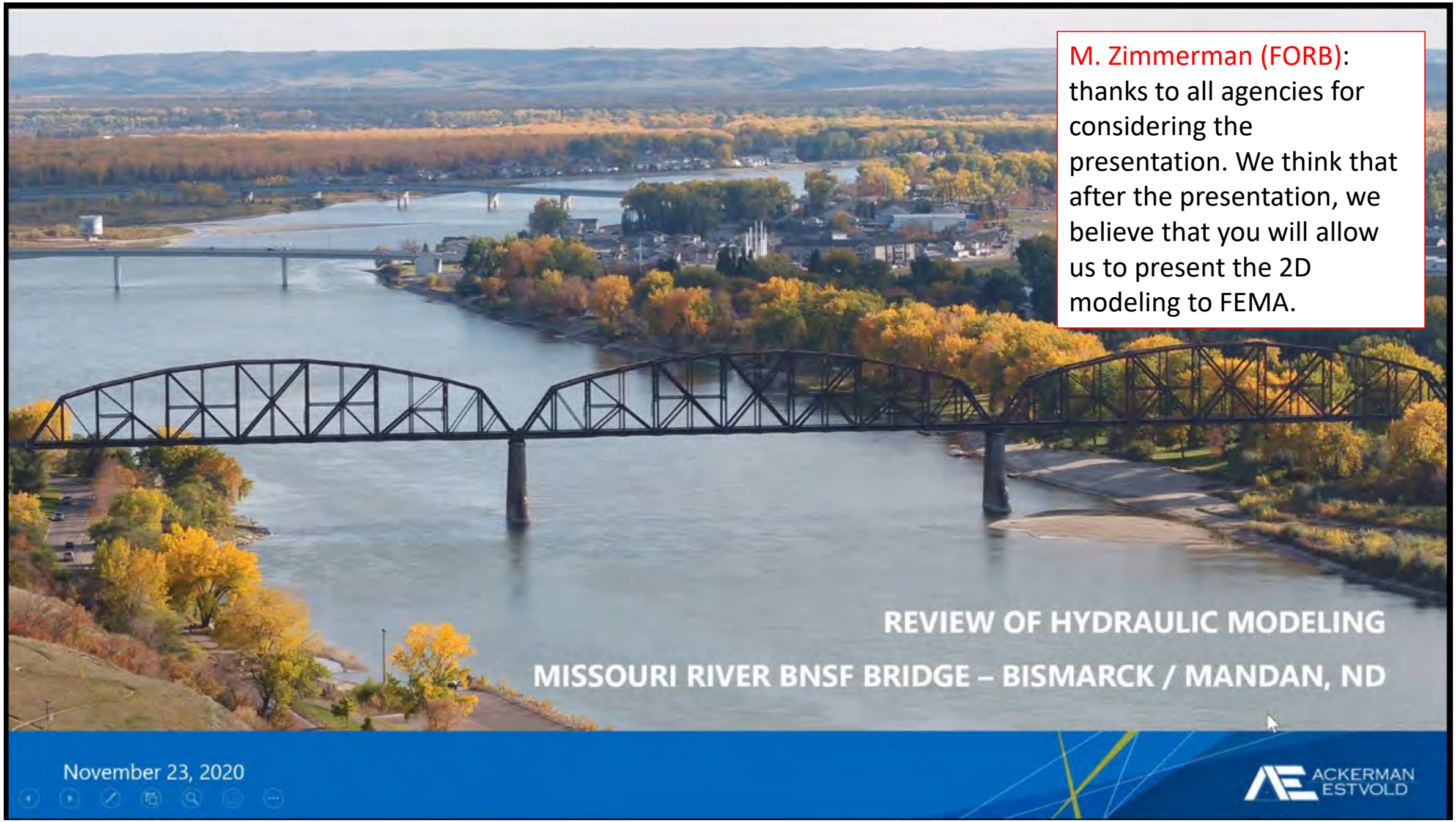
- **Case B** - Base flood elevation rise of 0.02':
  - Requires a cost premium of $32M compared to Case A:
    - $23.7M to construct modified bridge design.
    - $8.4M to achieve a no-rise base flood elevation rise. (See slide #4)
  - Requires significant work outside of BNSF R/W.

- **Case C** - Base flood elevation rise of 0.03':
  - Requires an added premium cost, in excess of the $8.4M, to achieve a no-rise base flood elevation rise.
  - Work to achieve no-rise base flood extends further off BNSF R/W than required for Case B.

M. Herzog (BNSF): BNSF has only submitted the proposed action for CLOMR review. BNSF does not believe that the proposed culvert mitigation would be sufficient and would result in both performance and maintenance issues during winter months.

Case B Mitigation – Base Flood Elevation Rise 0.02’





M. Zimmerman (FORB): thanks to all agencies for considering the presentation. We think that after the presentation, we believe that you will allow us to present the 2D modeling to FEMA.

OUTLINE OF OBSERVATIONS

- Review of Conditional Letter of Map Revision (CLOMR) Submittal to FEMA
- Review of BNSF Concept 3 – Existing Bridge Remains / New Bridge 42.5 Feet Upstream
- BNSF Concept 3 Impact Mitigation
- Alternative Hydraulic Modeling Approach (2-Dimensional Modeling)

Review of Conditional Letter of Map Revision (CLOMR) to FEMA

- CLOMR computations based on HEC-RAS model used by FEMA for Flood Insurance Study
- Appears to be two submittals:
  - Submittal 1 - indicated 0.02-foot rise with 64 structures impacted
  - Submittal 2 - compares BNSF preferred option to existing conditions to indicate 'no rise'
- Notable difference is in how bridge losses are computed (1 – Energy Equation; 2 – Yarnell Equation)
- Submittal 2 uses **Yarnell K=1.15 for Existing Bridge** and K=1.05 for BNSF Preferred Option
  - This means that the model treats the preferred option as a more hydraulically efficient option than the existing option (lower K values indicate lower friction losses)

R. Ackerman (AE): Believes that Yarnell coefficient for existing structure may be too high and warrants discussion if 1D modeling is the only way through.

Review of Conditional Letter of Map Revision (CLOMR) to FEMA

Because the BNSF Preferred Option has more blockage, the only way the Yarnell method will show "no rise" is to choose Yarnell coefficients where with the coefficient for the existing bridge is higher (less efficient) than the Preferred Option.

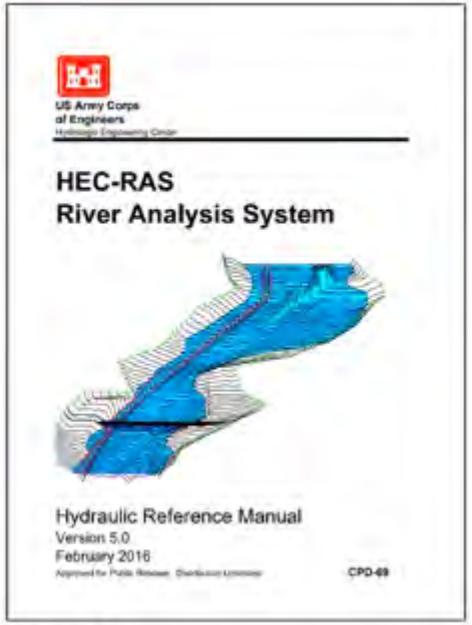


Table 5-4

Yarnell's pier coefficient, K, for various pier shapes

Chapter 5– Modeling Bridges

Pier Shape	Yarnell K Coefficient
Semi-circular nose and tail	0.90
Twin-cylinder piers with connecting diaphragm	0.95
Twin-cylinder piers without diaphragm	1.05
90 degree triangular nose and tail	1.05
Square nose and tail	1.25
Ten pile trestle bent	2.50

R. Ackerman (AE): Yarnell coefficient for existing structure should be between 0.90 and 1.05.

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Review of BNSF Concept 3 – Existing Bridge Remains / New Bridge 42.5 Feet Upstream

- Possible compromise solution
- Able to accept two new tracks
- Results in 0.03-ft upstream rise based on One-Dimensional HEC-RAS model
- Increased construction cost and schedule

Concept 3: 200ft Spans, Piers 42.5ft Upstream

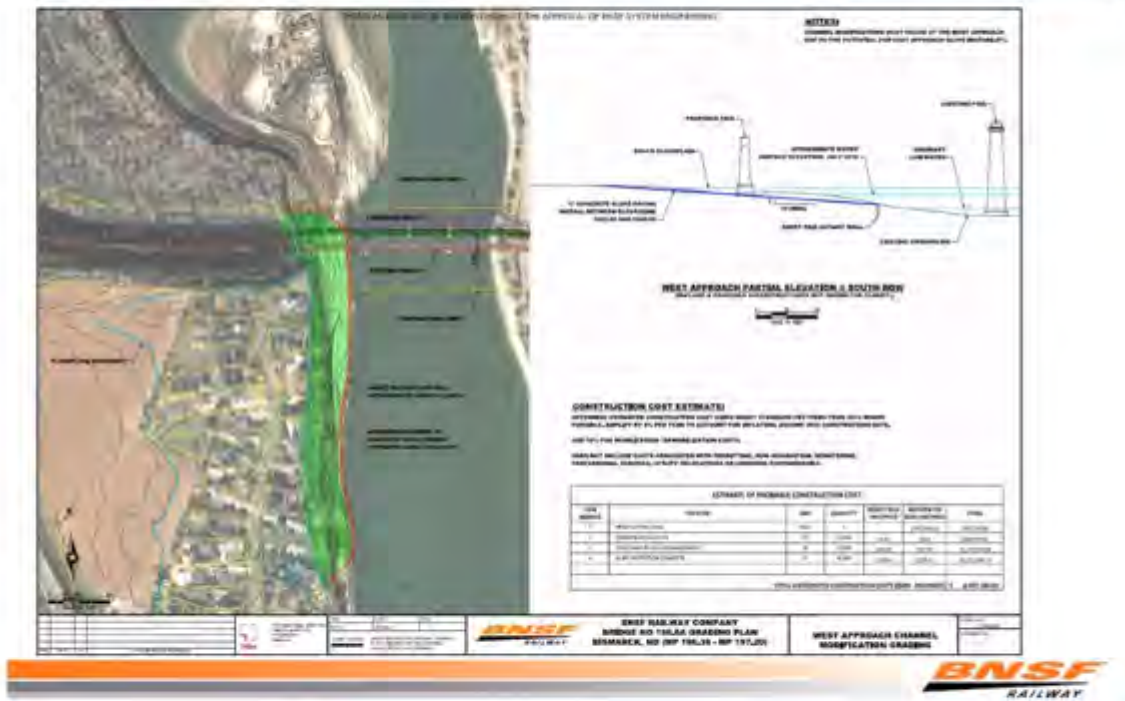
R. Ackerman (AE): 1D modelling concurs with BNSF conclusion of a rise for Concept 3.

BNSF Concept 3 Impact Mitigation – BNSF Mitigation Concept

R. Ackerman (AE): Mitigation proposed for 0.02 ft rise, not 0.03. Not believed to be either socially or environmentally palatable.

- Reduce water surface profile to eliminate modeled rise
- BNSF evaluated solution to pave ¼ to ½ mile of beach to mitigate 0.02' rise
- ~$8.4 M Cost
- More expensive to mitigate 0.03' rise
- Likely socially and environmentally unacceptable

Case B Mitigation – Base Flood Elevation Rise 0.02'



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BNSF Concept 3 Impact Mitigation – Alternative Mitigation Concept

- Results Based on One-Dimensional HEC-RAS Model
  - Reduce water surface profile to eliminate modeled rise
  - Provide three 12-ft relief culverts through Interstate 94 embankment
  - Cost $5M to $10M
  - Enhance floodplain hydraulics
  - Provide wildlife passage across I-94 corridor
  - Possibly affect 1 structure – increase BFE less than 1/2-inch on posts of deck/boat dock

R. Ackerman (AE): Three 12-ft culverts would address 0.03 ft of rise.

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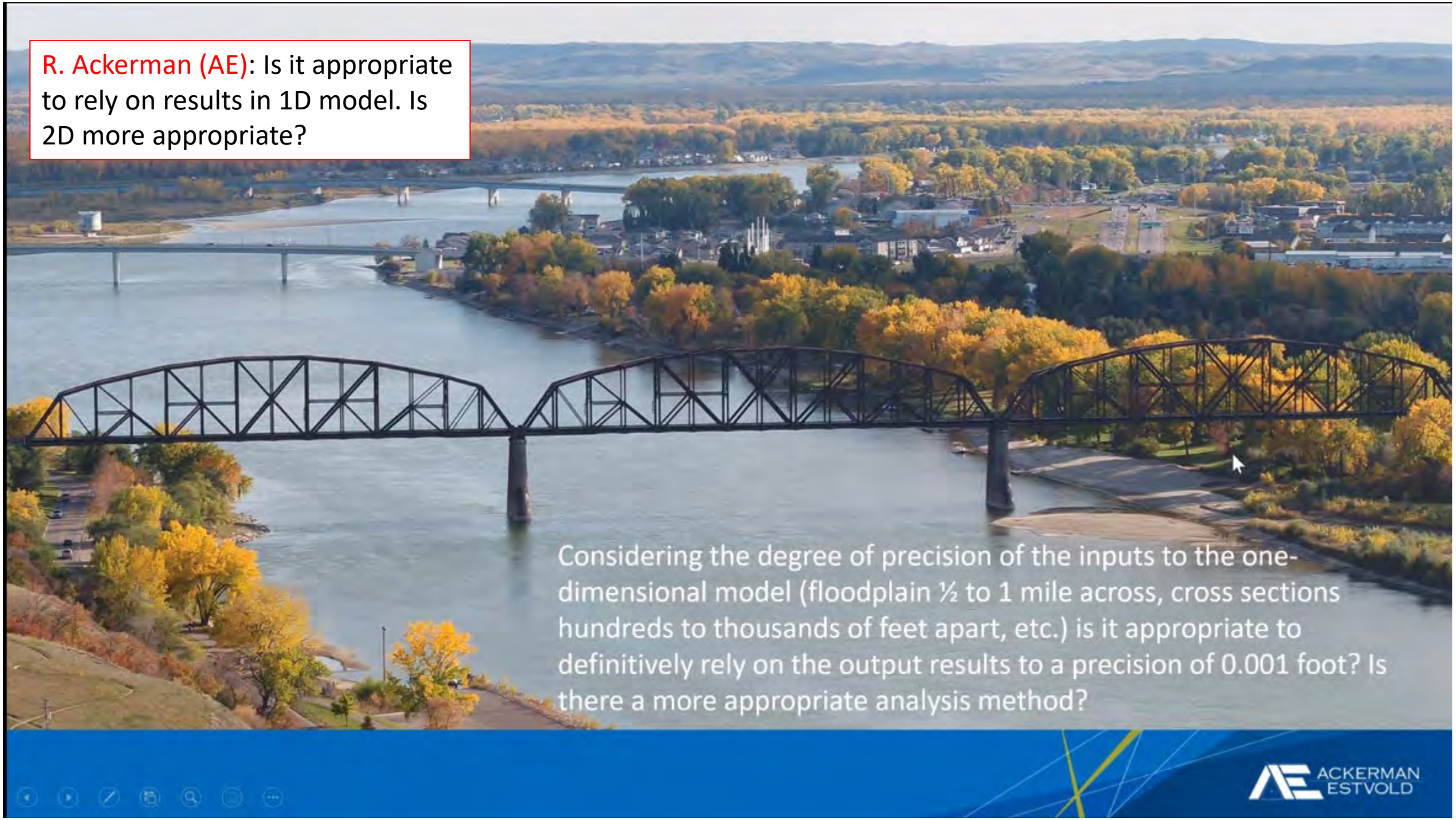
R. Ackerman (AE): Is it appropriate to rely on results in 1D model. Is 2D more appropriate?



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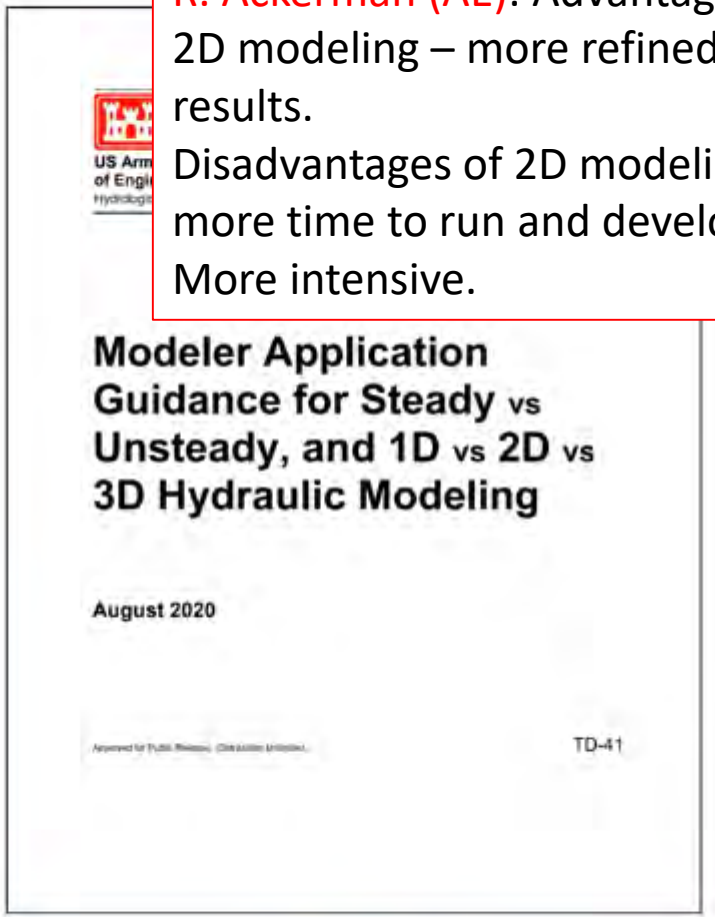
Alternative Hydraulic Modeling Approach (2-Dimensional Modeling)

2D Modeling Advantages:

- The flow path of the water, for all events, does not have to be known to develop the model. However, the extent of the flooding does need to be correctly defined.
- The direction of the flow can change during the event. Water can move in any direction, based on energy and momentum of the flow.
- Velocity, momentum, and the direction of the flow are more accurately accounted for with 2D modeling. This accountability is especially true for flow going over roads, levees, barriers, structures, around bends, and at flow junctions/splits. Additionally, 2D models can be used to analyze eddy zones within the flow field. Around bends, 2D models produce accurate water surface elevations, but velocity distributions might be erroneous due to the existence of helical flow.
- Energy and force losses due to contractions and expansions, etc. are directly accounted for, and do not require empirical coefficients, increased roughness, or user defined ineffective flow areas.
- The mapping of the inundated area, as well as velocities, and flood hazards (depth x velocity) is more accurate.
- Detailed modeling of hydraulic structures, in a full 2D modeling approach, can provide more insight into the flow distribution approaching, going through, and coming out of a structure.

R. Ackerman (AE): Advantages of 2D modeling – more refined results.
Disadvantages of 2D modeling – more time to run and develop. More intensive.


US Army Corps of Engineers
Hydrologic

Modeler Application Guidance for Steady vs Unsteady, and 1D vs 2D vs 3D Hydraulic Modeling

August 2020

TD-41

Alternative Hydraulic Modeling Approach (2-Dimensional Modeling)

Existing Bridge and New Bridge 42.5-feet Upstream - Two-Dimensional Modeling

R. Ackerman (AE): 2D results show with no mitigation in place, proposed action (new bridge upstream) would increase flood elevation by 0.003 ft.

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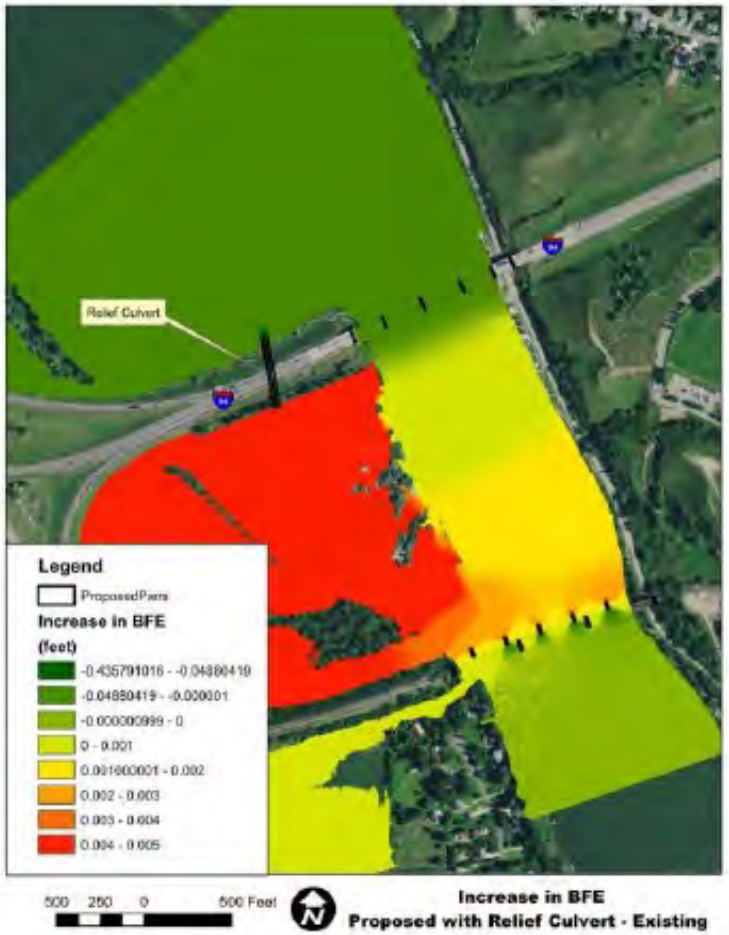
Alternative Hydraulic Modeling Approach (2-Dimensional Modeling)

- Relief culverts allow flow on the west floodplain and mitigates rise upstream of Interstate 94

Alternative Hydraulic Modeling Approach (2-Dimensional Modeling)

- A single relief culvert mitigates rise upstream of Interstate 94

R. Ackerman (AE): Could mitigate rise shown in 2D modeling with one 12-ft relief culvert.



CONCLUSIONS

Based on One-Dimensional HEC-RAS Modeling:

- The BNSF proposed option, when using the one-dimensional HEC-RAS model, seems to mitigate rise through increasing the K-factor for the existing bridge above published values. If a K-factor is used between the values published for a pier with rounded ends and a pier with triangular ends, the modeled rise is 0.01 foot.
- The FORB preferred option, when using the one-dimensional HEC-RAS model, indicates a rise of 0.03 feet, potentially affecting 552 structures already located within the 100-year floodplain.
- Relief culverts through the Interstate 94 embankment can mitigate the rise. Based on the one-dimensional model, three 12-foot diameter culverts can be installed to mitigate the upstream rise and additional evaluation would be necessary at the river boat structure.

R. Ackerman (AE): Would FEMA accept 2D modeling? What is the precision and threshold needed to demonstrate no rise? If rounding to nearest 0.01, then 0.003 is 0.00. Based on 2D results, both BNSF and option 3 would be permissible and decision would rely on other impacts (cultural, environmental, etc.) Floodplain considerations were being used to discount Concept 3. FORB disagrees with that position.

- FEMA has not yet indicated if a two-dimensional model would be accepted. They indicated that the local floodplain administrators (Bismarck/Mandan/Burleigh/Morton) should be consulted.
- What is the precision and threshold utilized by the local floodplain administrators to determine 'no rise'?
  - For example, some jurisdictions require modeling results to be displayed to the nearest 0.001 foot, but the difference between two scenarios (existing vs. proposed) is to be rounded to the nearest 0.01 foot. Essentially, if a modeled rise is less than 0.005 feet, the interpretation is 'no rise'.
- If a two-dimensional model is utilized for comparison purposes and the final proposed configuration would seem to indicate 'no rise', the floodplain permitting considerations would seem to be independent of the final decision. In other words, both the FORB Option and the BNSF Option would be permittable. Other considerations (cost, schedule, impacts to cultural resources, impacts to natural resources, etc.) would be used to inform the ultimate decision.

Discussion (1)

- B. Ehreth (Bismarck): Has FORB contacted DOT regarding impacts to their embankment? – Mark: No, waiting to see if 2D modeling would be acceptable first.
  - M. Zimmerman (FORB): Not yet, waiting to see if 2D modeling would be acceptable first.
- S. Ouradnik (Mandan): Have you taken into account ice dams in modeling?
  - R. Ackerman (AE): not yet, currently just comparing existing versus proposed conditions.

B. Ehreth (Bismarck): CLORM is proposal for an action to occur within special flood hazard area. Floodplain development permit – issued by local floodplain administrators. Project would require floodplain development permit from both Bismarck and Mandan. Community acknowledgement form – reviewed and possibly signed by local floodplain administrators. Community acknowledgement form initiates CLOMR review process. Notifies applicant of other required permits.

Key Terms

- **Conditional Letter of Map Revision (CLOMR)** – Is FEMA's comment on a proposed project that would, upon construction, affect the hydrologic or hydraulic characteristics of a flooding source and thus result in the modification of the existing regulatory floodway, the effective Base Flood Elevation (BFE), or the Special Flood Hazard Area (100 – year floodplain)
- **Floodplain Development Permit** – A permit required by Bismarck and Mandan Floodplain ordinance and issued before construction or development begins within the 100 year floodplain (Special Flood Hazard Area) or regulatory floodway.
- **Community Acknowledgement Form** – A form required to be signed by the official responsible for local floodplain management. In part this form acknowledges the intent to pursue a CLOMR and puts the applicant on notice that they will need to obtain all necessary local, state, and federal permits.

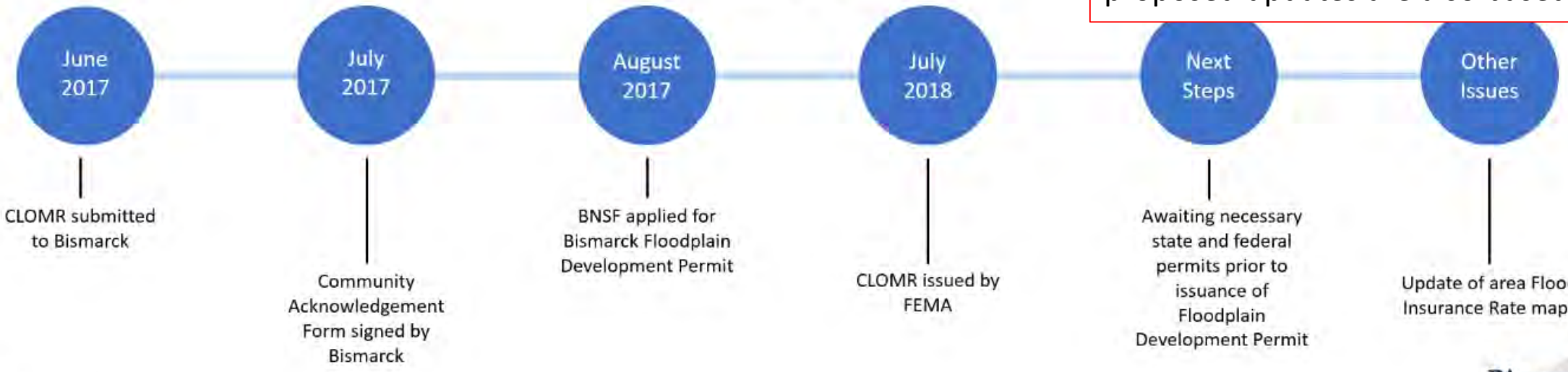
Bismarck

B. Ehreth (Bismarck): Brady –local floodplain administrator (Bismarck). Shawn – local floodplain administrator (Mandan). Floodplain development permit still pending on both Bismarck and Mandan side. Other state/federal permits required in hand first, including USCG bridge permit. Will not issue floodplain development permit until other permits are issued. Related work in area right now - FIRM risk maps are being updated as we speak. Timing with new FIRM rate maps needs to be considered. Existing CLOMR approved by FEMA is included in FIRM updates. Existing FIRM rate maps are based on 1D and proposed updates are also based on 1D modeling.

Status of FEMA and Local Review

- Local Flood Plain Administrators
  - Bismarck – Brady Blaskowski
  - Mandan – Shawn Ouradnik

Bismarck Timeline



Bismarck

Discussion (2)

- G. Heiser (ND State Water Commission): Sovereign Lands permit – will not process permit until there is a final project to review. This includes leaving or removing existing structure and any necessary mitigation. May cause permit do-loop/circular argument.
- B. Ehreth (Bismarck): USCG may be waiting as well. May be in circular logic.
- S. Sugarman (USCG): USCG needs things to be done for us to move forward as well. Is there reasonable assurance that we can get regarding acceptance of alternative? When can we move forward and consider it a reasonable alternative? Usually we don't wait for floodplain development permit to issue our permit.
  - B. Ehreth (USCG): crux of one of the questions that FORB/Ackerman is also asking. Based on our interpretation, question is "can multiple CLOMRs be considered? And then up to local entities to flush it out"? Yes, multiple CLORMs can be considered and does not necessarily need to be submitted by BNSF.
  - M. Brady (FEMA): yes multiple CLOMRs can be considered at one time for the same area. BNSF has considered CLOMR for Case A. If another entity wants to submit CLOMR for their proposal, they can submit a CLOMR. Does not need to be BNSF. Can have multiple CLOMRs considered.

Discussion (3)

- B. Ehreth (Bismarck): Ultimately the flooplain permit issued by Bismarck/Mandan would be for one deemed appropriate. This is unusual situation.
  - M. Brady (FEMA): Permit would identify which CLOMR being selected invalidating other CLOMRs.
- S. Sugarman (USCG): 1 year from CLOMR submitted to approved. Can be expedited?
  - M. Brady (FEMA): CLOMR process begins when submittal is sent to FEMA. Case number recorded, fee paid, then applicant is reviewed. FEMA has 90 days to complete CLOMR. Most always, additional data request sent to applicant within 90 days. Applicant then has 90 days to respond. Process continues until sufficient information received to issue CLOMR. Never seen one processed without additional data requests.
  - D. Kaitala (BNSF): Took BNSF just over a year for their CLOMR to be approved.

Discussion (4)

- B. Ehreth (Bismarck): Speaking only for Bismarck, but Mandan has their own process. Would appreciate it if Mandan would speak up if they disagree with anything.
  - S. Ouradnik (Mandan): Agrees with Bismarck thus far.
- B. Ehreth (Bismarck): – acceptance of 2D vs 1D model. Bismarck would have concerns with 2D model given increased complexity and cost to applicants. If 1D model used to develop FIRM, need to sync up with river-side FIRM. Any future development in the area would then need to use 2D model. Can't flip back and forth between 1D and 2D. Could create complications for Bismarck and other future applicants. 2D model in that area could take some properties out of special flood hazard area or add them in. Concerning to Bismarck. As Bismarck understands it, justification for why 1D model is inappropriate to use. Can't be "well it results in a different answer". Need justification for inappropriateness of 1D model.

Discussion (5)

- S. Ouradnik (Mandan) – they agree with Bismarck that 2D may not be appropriate in this situation. 2D could make things more difficult in the future.
- B. Ehreth (Bismarck): List of other questions from FORB/Ackerman) - Precision of threshold for no-rise. If impact in thousandth of a foot either rounded up or down. Example, 0.003 can be rounded down to 0.00, if 0.005 or greater, rounded up to 0.01.
  - M. Brady (FEMA): This is correct. Round beyond 0.01 position. Interpreted by FEMA to mean 0.00 feet. Community has the option to say that no rise beyond 0.000 position is unacceptable. Federal minimum is 0.00 feet.
- S. Wefald (FORB): Would FORB still have the opportunity to submit a CLOMR for 1D study to FEMA?
  - B. Ehreth (Bismarck): Yes but Bismarck/Mandan would need to work through how that decision would be made. Not a lot of projects where alternative CLOMR proposals have been submitted. But yes, it can be submitted using 1D model.

Discussion (6)

- S. Sugarman (USCG): What about Yarnell coefficient?
  - B. Ehreth (Bismarck): Would open that discussion up to Ryan or others to captured correctly.
  - R. Ackerman (AE): We felt that the coefficient used for Yarnell was outside of published values. Sensitivity study done on Yarnell and if set to 1.0 (between published values) the BNSF proposed action would result in 0.01 ft rise in 1D model.
  - B. Ehreth (Bismarck): Then that rise would need to be mitigated for.
  - R. Ackerman (AE): Proposed mitigation to shine light on the fact that other mitigations are possible. They did not believe that array of mitigation options were all fully addressed.
  - M. Herzog (BNSF): Yarnell coefficient used was transparent with FEMA through data request process.
  - B. Ehreth (Bismarck): Confident that FEMA was thorough in their analysis of materials submitted.

Discussion (7)

- R. Ackerman (AE): Further to Yarnell, first submittal used energy equation to compute loss through the bridges resulting in 0.02 ft rise. Kicked back by FEMA. Second submittal changed energy loss method to Yarnell, existing bridge coefficient set to 1.15, and preferred option set at 1.05. Model treats preferred option as more hydraulically efficient than existing structure. No rise for proposed action possible because treating existing piers as "more rough" than replacement bridge would be. Hydraulic reference manual by USACE with 0.90 – 1.05 range based on pier geometry. 0.90 would be more appropriate. BNSF bridge has a relatively wide nose with potential to act as a square nose but do not believe 1.15 is appropriate. Coefficient of 1.0 shows rise in proposed action (0.01 foot).
- S. Sugarman (USCG): FORB would have to use the same coefficients that BNSF used?
  - B. Ehreth (Bismrck): A CLOMR once issued is not rescinded. If disagreement on assumptions, an alternative CLOMR would need to be submitted with appropriate mitigation measures in place.
  - M. Brady (FEMA): FEMA issued CLOMR used Yarnell process as discussed. FEMA felt that it was reasonable. If FORB wants to submit new CLOMR with different value, that is their choice. They would need to go through the process and demonstrate why a different value should be used. Similar for 2D. Community has to be willing to accept 2D model for that reach. Would cause increased costs for community. Would be more expensive going forward. FEMA has to be provided sufficient justification regarding why 2D model is better for this project. Burden on applicant to demonstrate why 2D model is better. Even if possible, final decision goes back to the community.

Discussion(8)

- M. Herzog (BNSF): Would Adam Nies of Houston comment on Yarnell coefficient?
  - A. Nies (Houston Engineering): Appreciate the in depth look from Ackerman. As we went back and forth with FEMA contractor for review, considered width, rough granite blocks, degree of radius for round vs square nose. Various pier cross sections, part of it is round, part of it is ice nose. All of this was worked through with FEMA to develop most justifiable coefficient. Acknowledges at some point, best judgement is involved. Applied same Yarnell coefficient to alternatives for comparison as well.
- L. Ackerman (ND State Water Commission): What is the basis of 2D mesh for river channel?
  - R. Ackerman (AE): Interpolated based on one dimensional cross sections.
- S. Sugarman (USCG): Would application include mitigation factors? Would that CLOMR application contain other agency responsibilities?
  - M. Brady (FEMA): Content of CLOMR would need to include mitigation plan if there is a rise. Needs to demonstrate how rise is addressed. A CLOMR is a proposal, not a guarantee that a community will accept the proposal/project with that CLOMR. Community has option to accept or add contingencies, etc.
  - B. Ehreth (Bismarck): Community acknowledgement form would need to be signed, and both Bismark and Mandan have concerns with 2D model.

Discussion (9)

- G. Heiser (ND State Water Commission): Has the potential for ice jamming been evaluated? Intuitively, we can say that leaving both bridges in place would increase risk of ice jamming. How might that be modeled to identify the risks? Can it be mitigated? If so, how? This issue is a key consideration to sovereign lands permit.
- S. Sugarman (USCG): If FORB submits a CLOMR and that is ultimately used, can that accepted CLOMR be used by BNSF for development permit? It is a different entity submitting CLOMR for project, but project is used by BNSF.
  - B. Ehreth (Bismrck): Interesting question. Ultimately, it will come down to local floodplain administrators feel most accurately represents the proposed construction.
  - B. Blaskowski (Bismarck): CLOMR is a plan. Doesn't matter who submits that plan. BNSF permit would be to entity completing construction, regardless of who submits CLOMR.