BARR

the Fargo-Moorhead Diversion Project

Barr Engineering Co.

October 9, 2019

Project partnership agreements (PPA)

- USACE works with local sponsors to plan, design and implement projects
- Partnering with the Corps begins in the budget planning stages – the earlier, the better
- Spend time with your USACE district PMs and decision-makers
- Know your USACE district(s) current priorities and future goals
- Help your USACE district(s) know your needs and see where these intersect with USACE funding

Planning Assistance to States (PAS)

BARR

- 50/50 Federal and non-Federal cost share
- Significant work-in-kind allowed for non-federal match (up to 25%)
- Very broad spectrum of projects are eligible – for planning and studies
- USACE sometimes will have funds that are appropriated that may not be spoken for or fully utilized
- End of fiscal year, there may be additional funding that can be allocated – check with your district office

water studies and planning opportunities

- Water Supply and Demand
- Water Quality
- Environmental Conservation
- Environmental Restoration
- Wetland Evaluation
- Dam Safety/Failure
- Flood Risk Management
- Floodplain Management
- Land Use
- Master Planning
- Brownfields Environmental Assessment
- GIS Development
- Water Conservation
- Flood Preparedness
- Navigation
- Erosion and Sedimentation

BARR

acknowledgments

HMG
Houston-Moore Group

CITY OF
Fargo

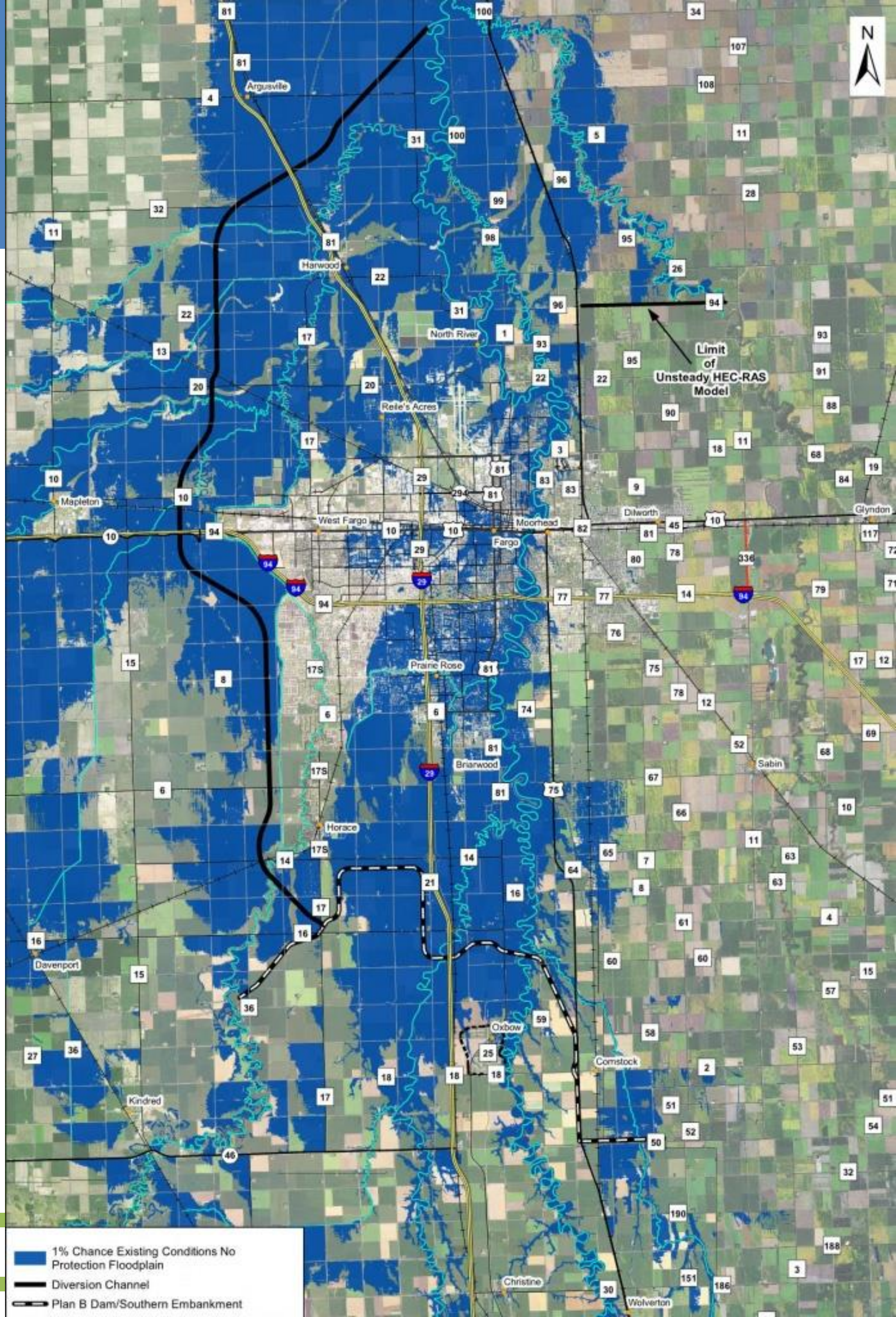
MOORHEAD
MINNESOTA

FLOOD
DIVERSION
AUTHORITY

US Army Corps
of Engineers®

why a project?

The Project will protect approx. 200,000 people from potentially catastrophic flooding

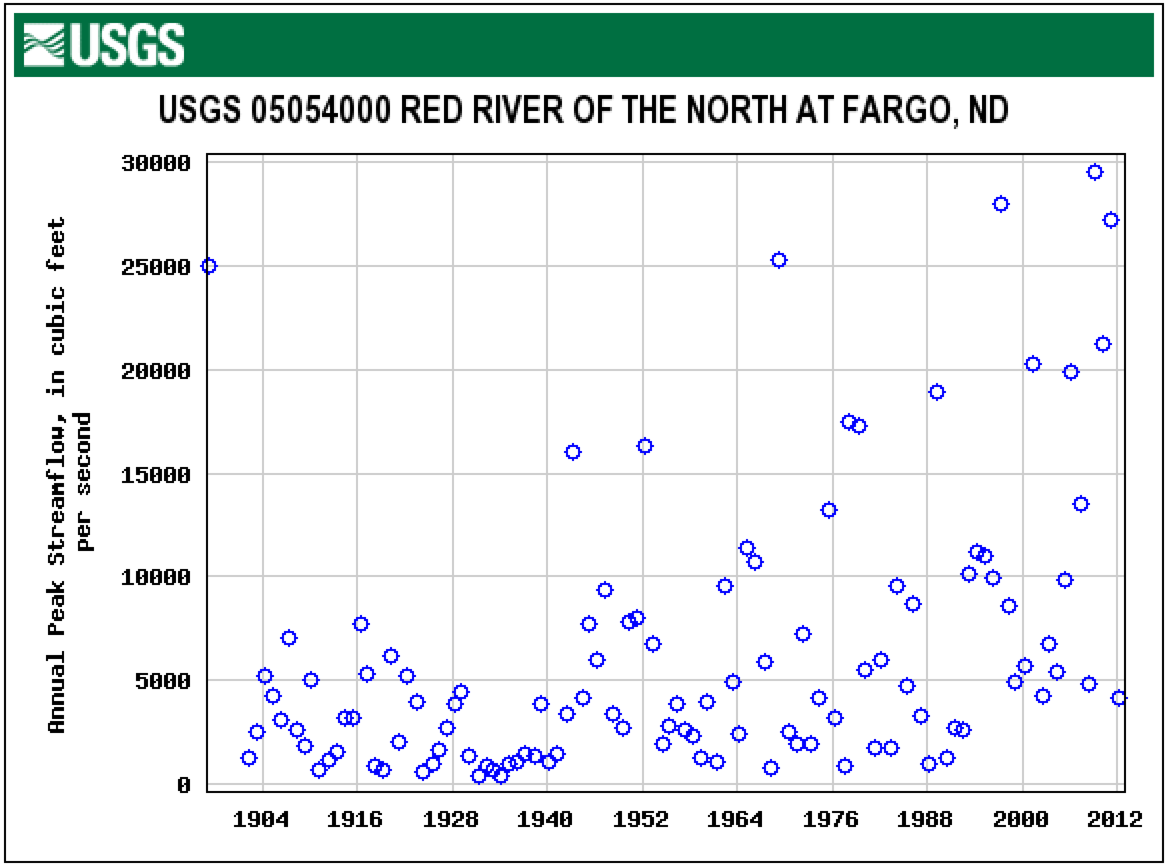


primary design considerations

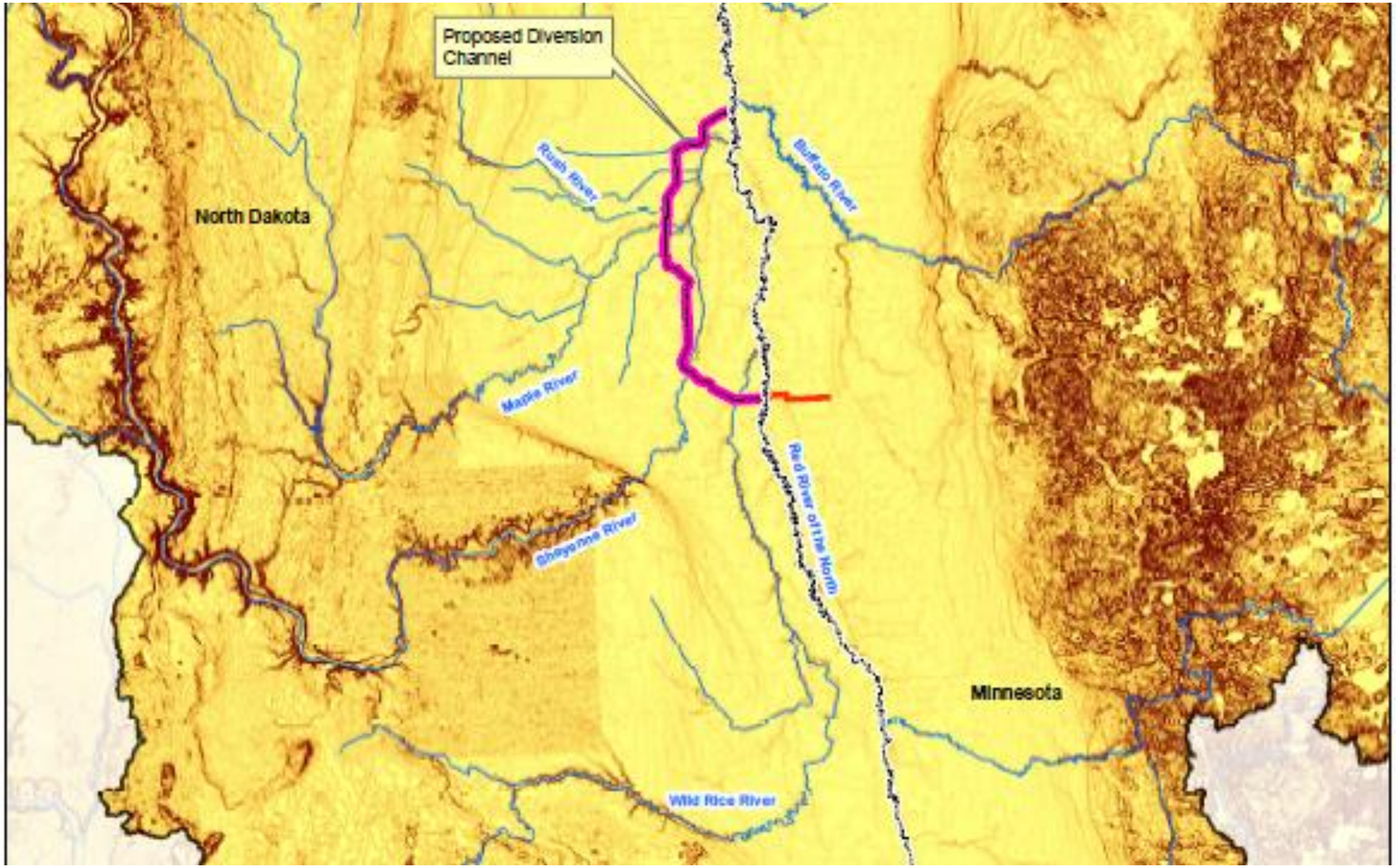
BARR

- Nearly 200,000 people and 70 square miles of infrastructure in the Fargo-Moorhead area
- To provide flood risk reduction for events as large as the 100-yr event in the Red River of the North (RRN)
- To allow for flood fighting efforts up to the 500-yr event in the RRN (or larger)
- To avoid catastrophic failure of the diversion works during most extreme events (SPF, or possibly PMF)
- [To further deal with risk of flooding from ND tributaries]

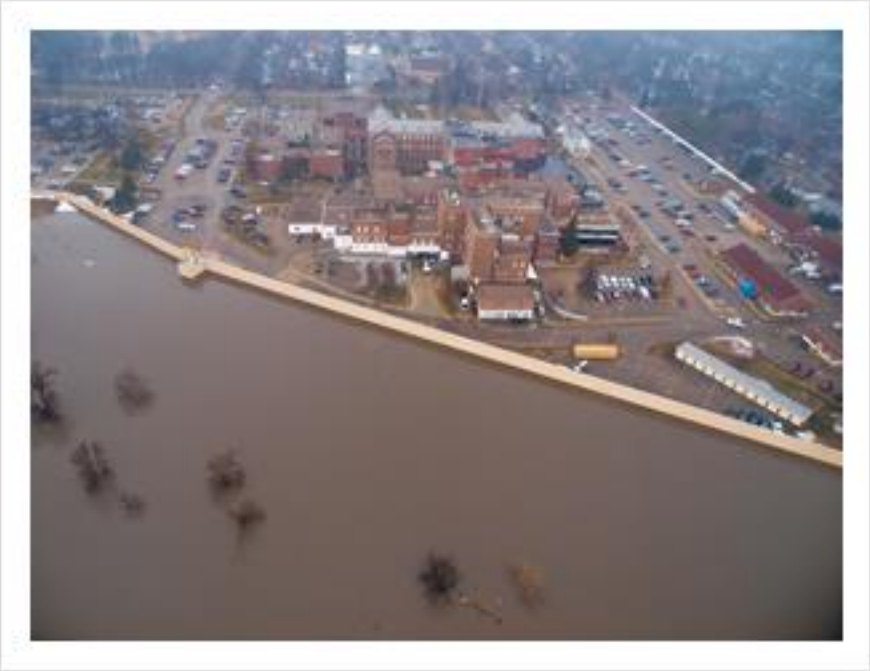
peak flows going up



very flat

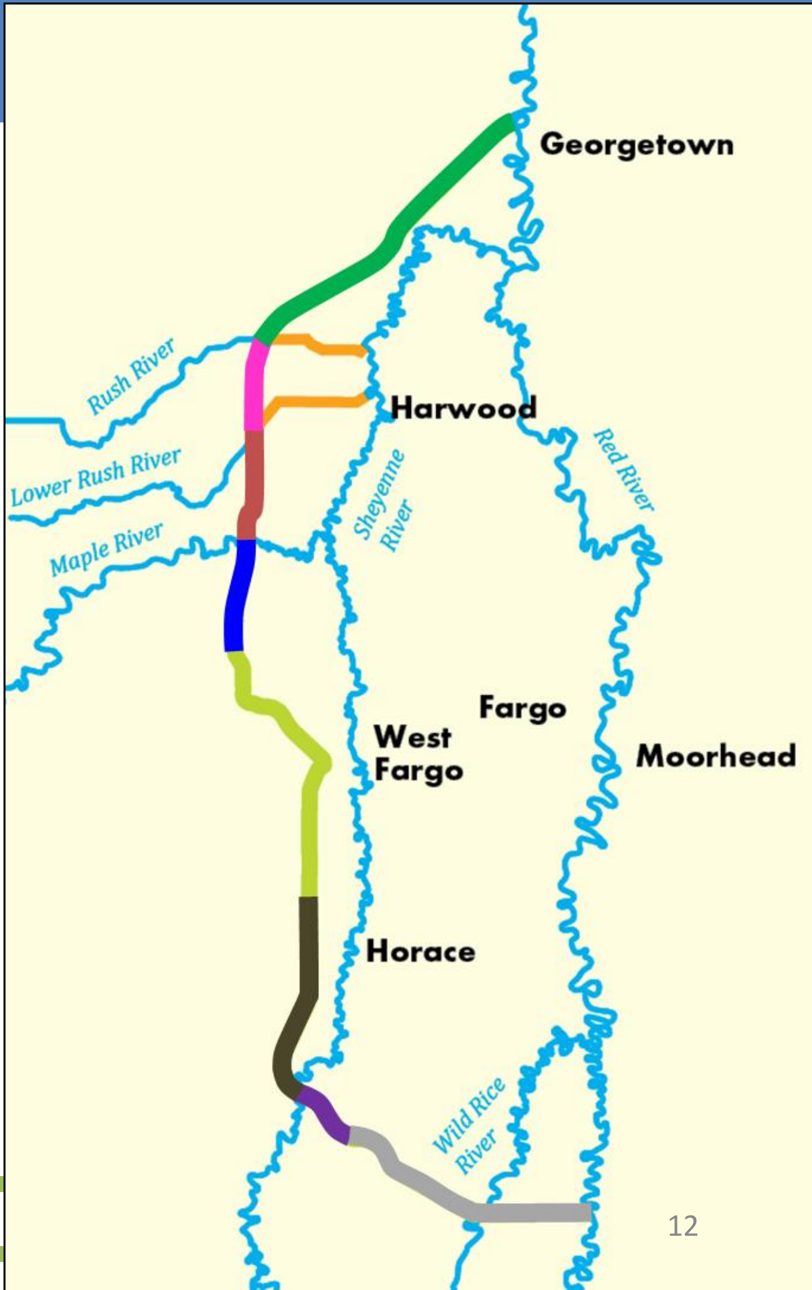

Proposed Diversion Channel
North Dakota
Rush River
Buffalo River
Maple River
Sheyenne River
Red River of the North
Minnesota
Wild Rice River

bad combination



the big picture

- The RRN has exceeded flood stage almost half of the past 120 years
- Successful (barely) flood fight during **flood of record in 2009**
- When it floods, the **floodplain is several miles wide** but flow velocities are relatively low
- Two existing diversions in Sheyenne River in operation since 1992
- **Manitoba Floodway** built in 1968, and expansion completed in 2011



feasibility study and EIS milestones

BARR

- **April 2008:** supplemental reconnaissance report
- mid-2008: start of feasibility study
- May 2009: notice of intent to prepare EIS
- December 2009: alternatives screening document
- June 2010: draft feasibility report and EIS / **several comments about downstream impacts**
- September 2010: **upstream staging** becomes part of the proposed diversion project
- December 2010: notice of intent to prepare SEIS
- July 2011: final EIS is issued
- **April 2012:** Record-of-Decision

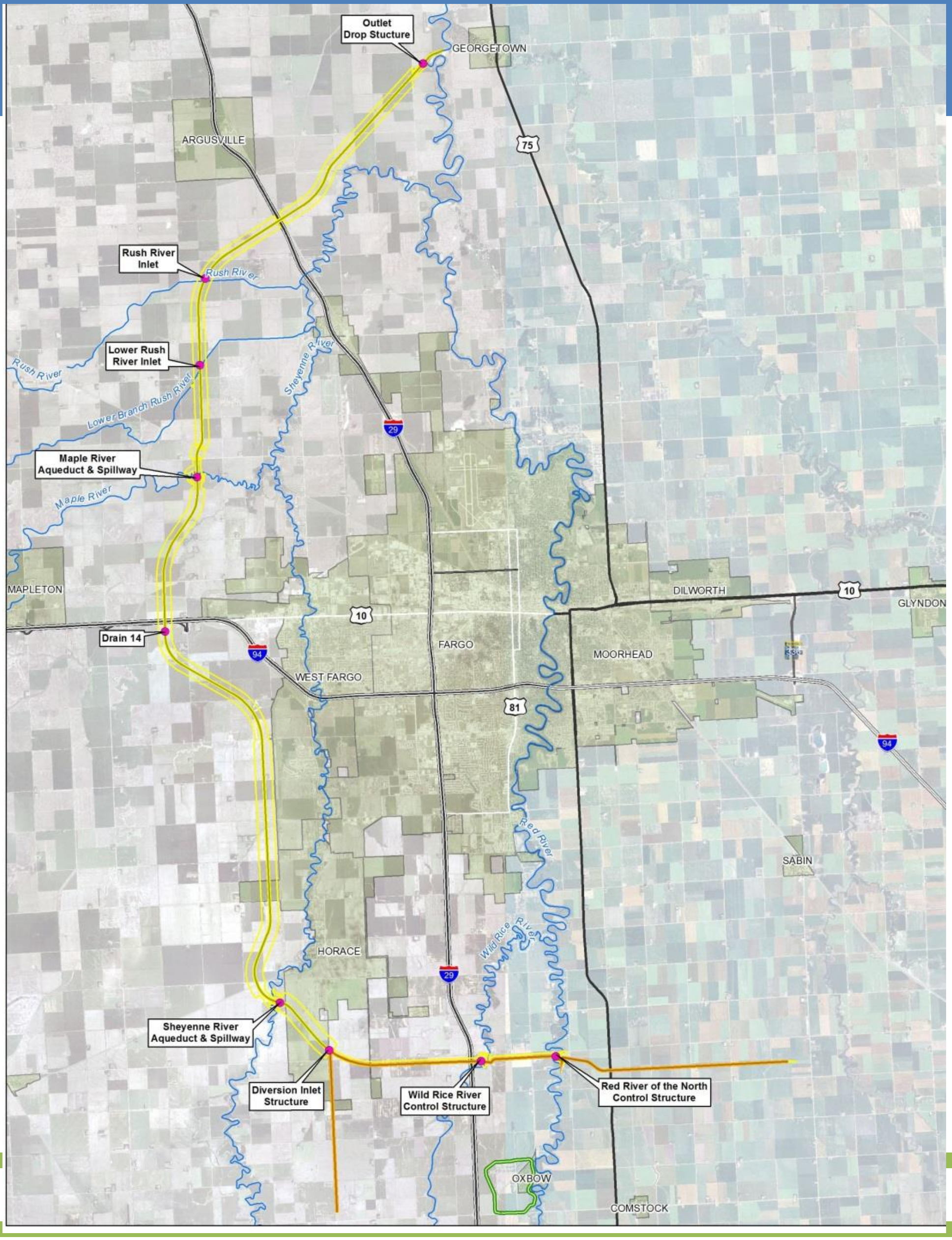
feasibility timeline (simplified)

BARR

- **Phase 1:** 9 diversion alternatives (4 alignments, 3 diversion flows) / report submitted on August 31, 2009 – diversion “competitive” against in-town levees only
- **Phase 2:** 6 diversion alternatives (2 alignments, 4 diversion flows) / report submitted on January 6, 2010 – determination of NED plan, FCP, and LPP (in May 2010)
- **Phase 3:** FCP and LPP / report submitted on August 18, 2010 – significantly greater detail in environmental impacts and cost estimates
- **Phase 4:** LPP with upstream staging / report submitted on April 19, 2011
- **Value engineering:** started in 2011 and still ongoing

main project features

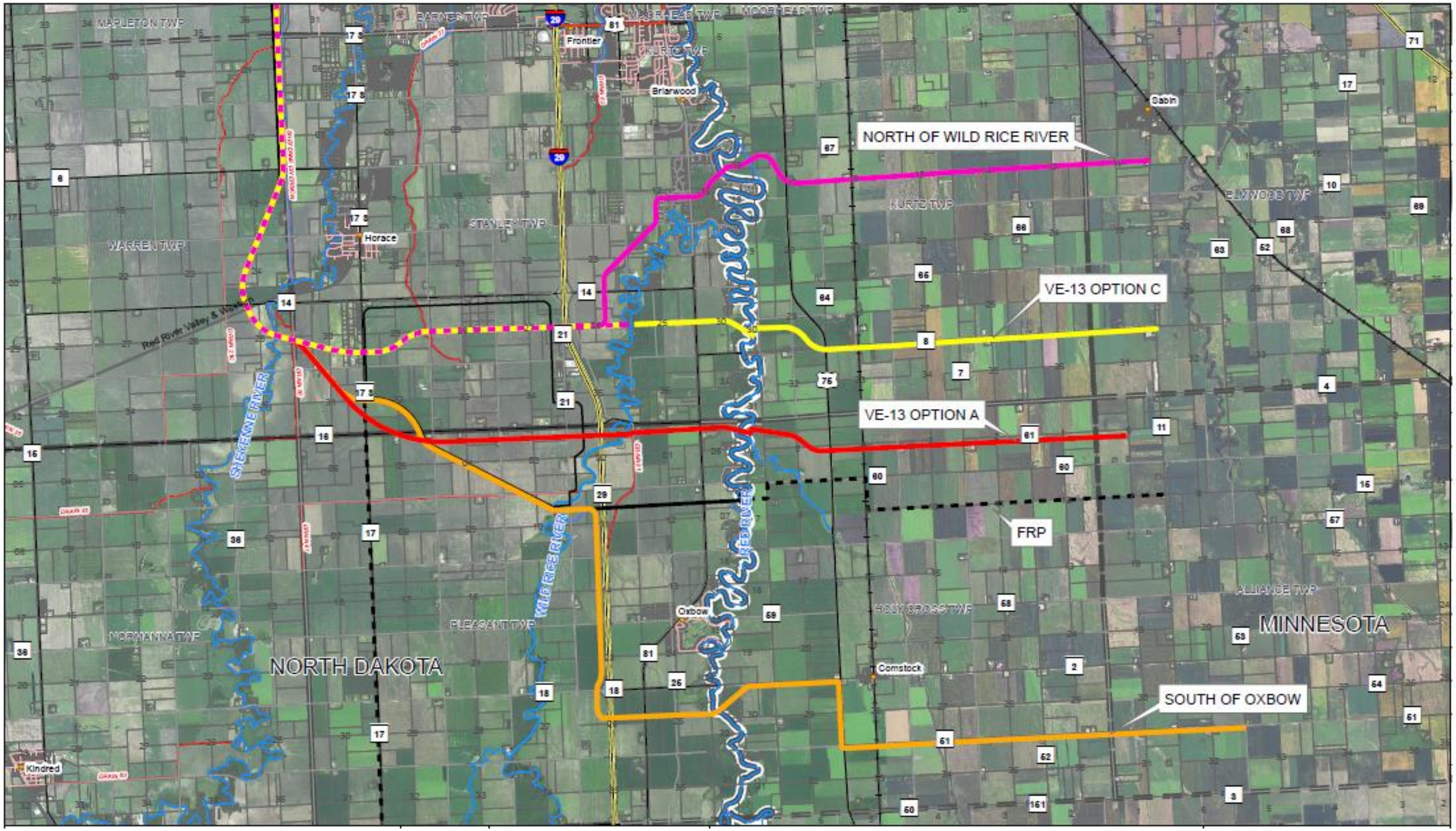
- 35 miles of diversion channel
- Low flow channel
- Staging area
- Control structures (gated) on the RRN and Wild Rice River
- Main diversion inlet (gated)
- Aqueducts and spillways on the Sheyenne River and Maple River
- Rock ramps on the Lower Rush River and Rush River
- Diversion outlet



stakeholders input incorporated in design

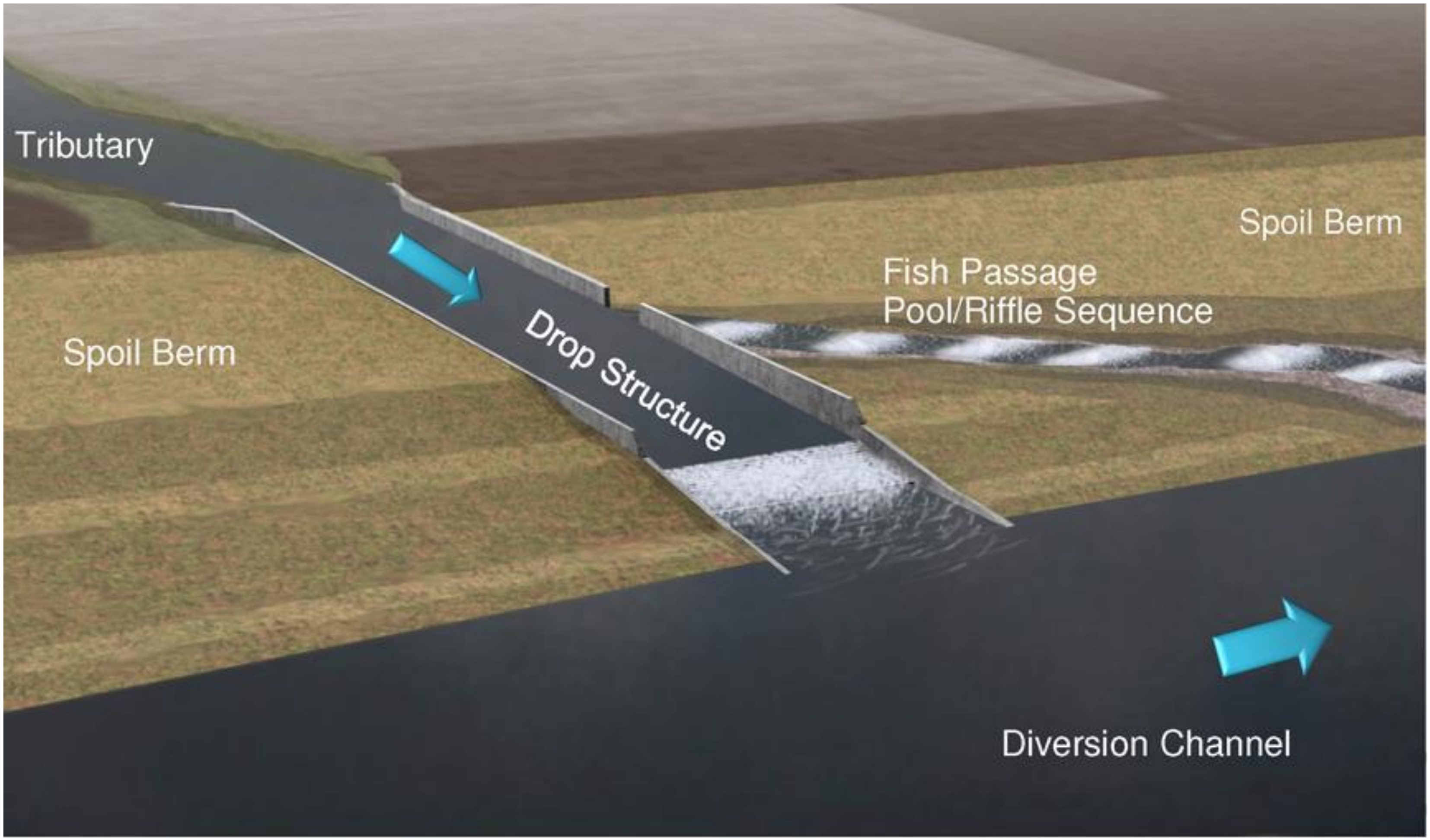
is a fishway still needed?

changes in staging area



Plan B adopted

from two structures for each of the "Rushes"



value engineering started with the feasibility study report

BARR

- “there is an increase of approximately $1.8 Million in the combined cost of the Hydraulic Structures at the Lower Rush River and Rush River from Phase 3 to Phase 4. However, at both locations there is a real opportunity for further evaluating the design of the fishway to operate during all flow conditions, therefore eliminating the need for the very large concrete drop structures that account for a very significant fraction of the total cost (of approximately $35 Million) for the structures at these two sites. Alternatively, the structure at the Lower Rush River could be completely eliminated by routing the flows of this tributary at existing grade along the west side of the diversion channel all the way north to the Rush River, where a single combined drop structure and fish passage could be constructed;”

to just one structure that handles diversion and fish passage

value engineering started with the feasibility study report

- "there is an increase of approximately $20 Million in the cost of the Outlet Structure from Phase 3 to Phase 4, which is mainly driven by the change in feasibility design from the Phase 3 rip rap protection of the downstream 300 feet of the diversion channel to a Phase 4 Ogee-type concrete spillway due to the significant increase in drop between the diversion channel invert at the outlet and the Red River thalweg elevation at that location. However, additional detailed studies could demonstrate that when high flows (driven by either peaks in the Red River of the North or peaks in the ND tributaries) are discharging through this structure, the flows and related water surface elevations in the Red River of the North are also high, so a smaller drop or shorter stilling basin could be justified, in both cases reducing the cost;"

vacationing in Istanbul, Turkey (May 5th, 2011)

BARR

Valens Aqueduct

- Roman aqueduct – 4th century AD, restored by Ottoman Sultans
- Water supply for Byzantium (Constantinople)
- Length of approx. 1 km (3,000 ft) and maximum height of approx. 30 m (100 ft)

why an aqueduct?

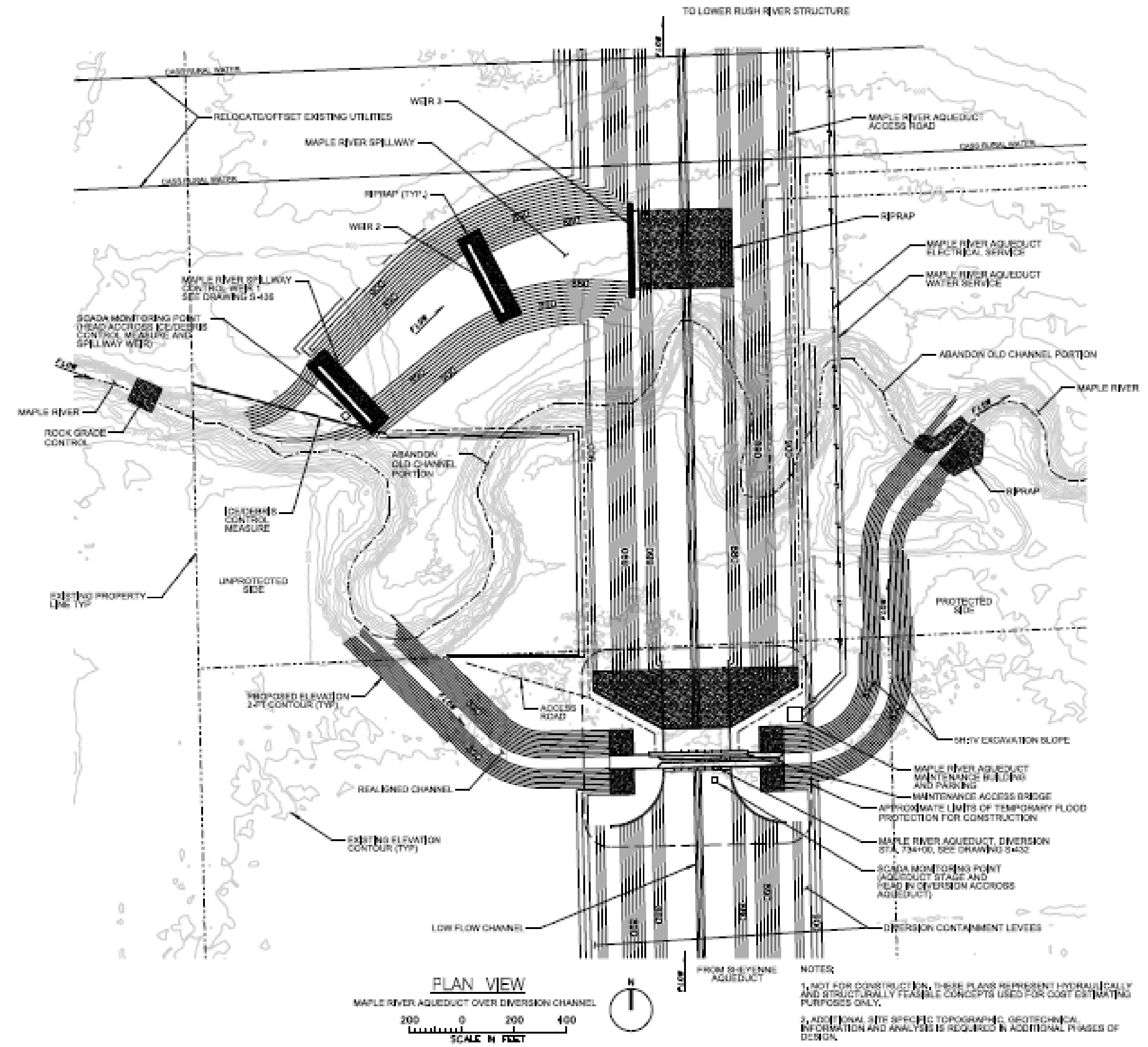
- Because aqueducts have been built and used for over 2,000 years?
- Minimize impact on Existing Conditions **(channel morphology and sediment transport, ice and debris, fish migration and aquatic ecosystems)** when flood damage reduction is not a must
- Significant **elevation differential** between tributary thalweg and Diversion Channel invert
- Flows to pass into flood damage reduction area can be **a few thousand cfs**

previous concepts

- What type of hydraulic structure is needed at the confluence of the Maple River and Diversion Channel to allow some Maple River flow to pass into the flood risk reduction area?
  - Pool with Gates
  - Pass Over
  - Pass Under
- Lots of back and forth with Natural Resources Agencies during six meetings in 2009

doesn't it look pretty (for an engineer)?

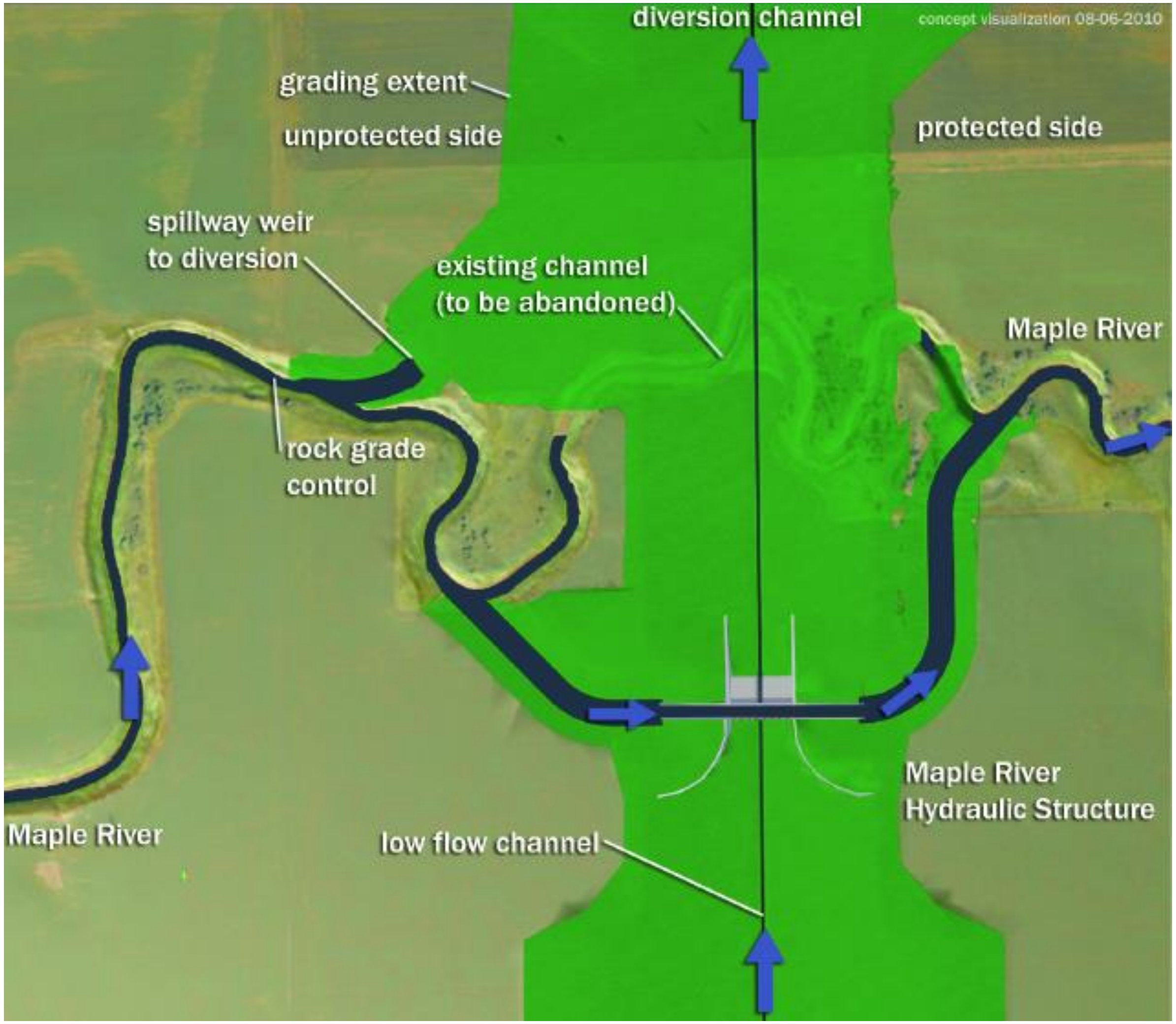
feasibility plan view



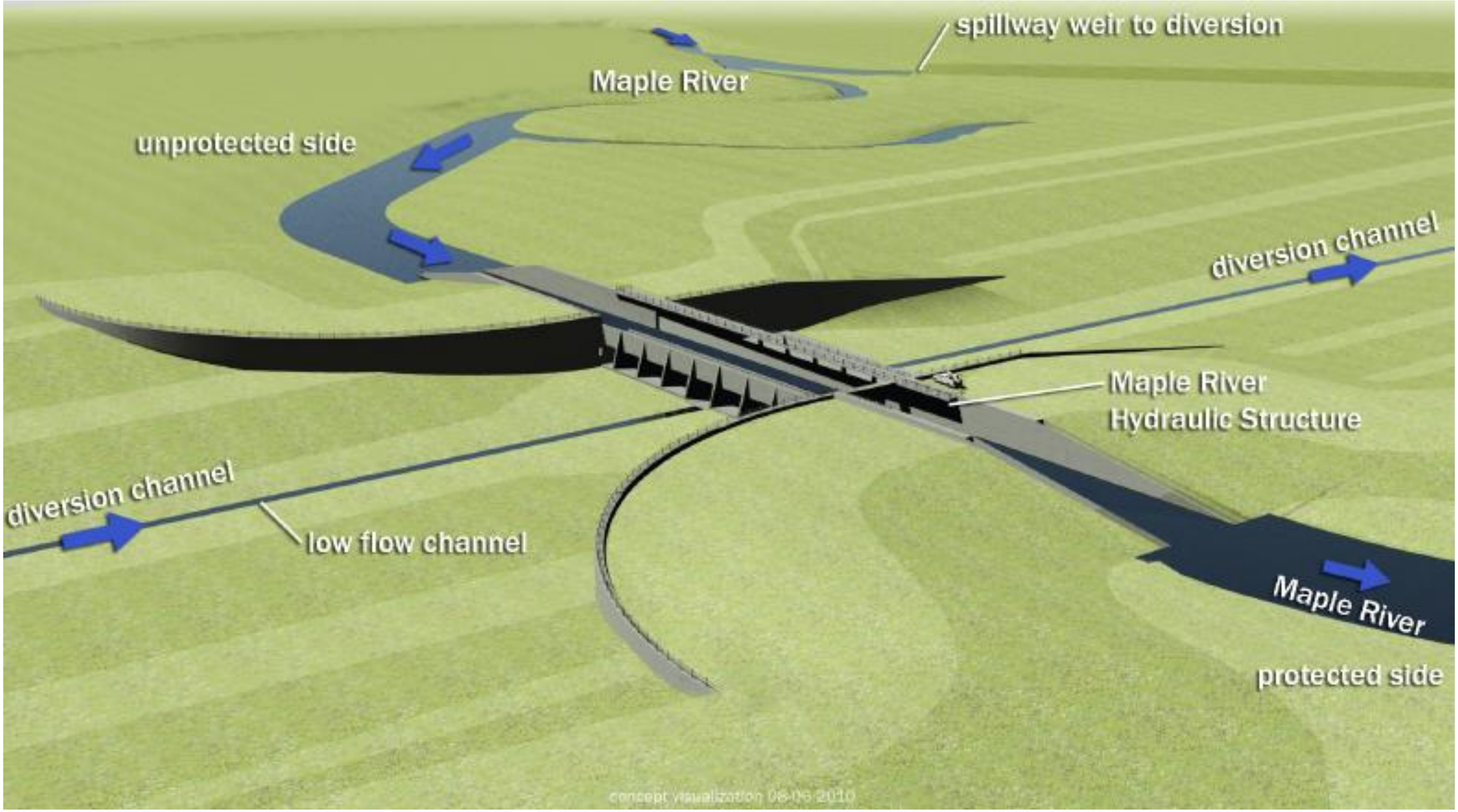
primary hydraulic design considerations for Maple and Sheyenne Structures

- For tributary flows up to the local 2-yr event: all tributary flow through aqueduct
- For tributary flows greater than the local 2-yr event: maximize tributary diversion
- Do not affect WSEL's in floodplain west of tributary structures
- Minimize head losses in Div Ch crossing of aqueduct up to RRN 500-yr event
- If possible, avoid Div Ch overtopping of aqueduct
- Peaks in RRN-coincidental in tribs + Peaks in tribs-coincidental in RRN

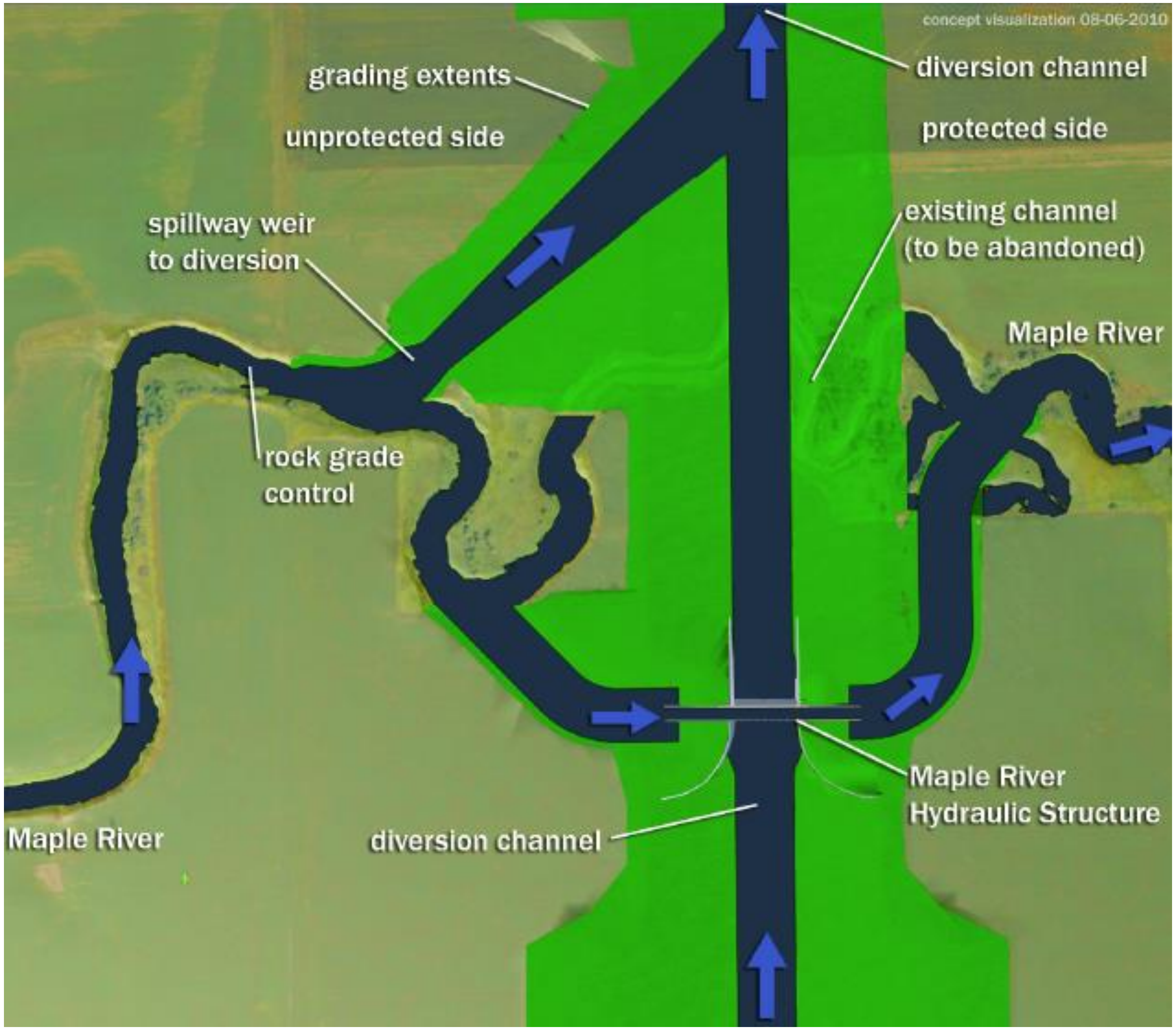
some water in Tributary combined with very little water in Diversion Channel



some water in Tributary combined with very little water in Diversion Channel

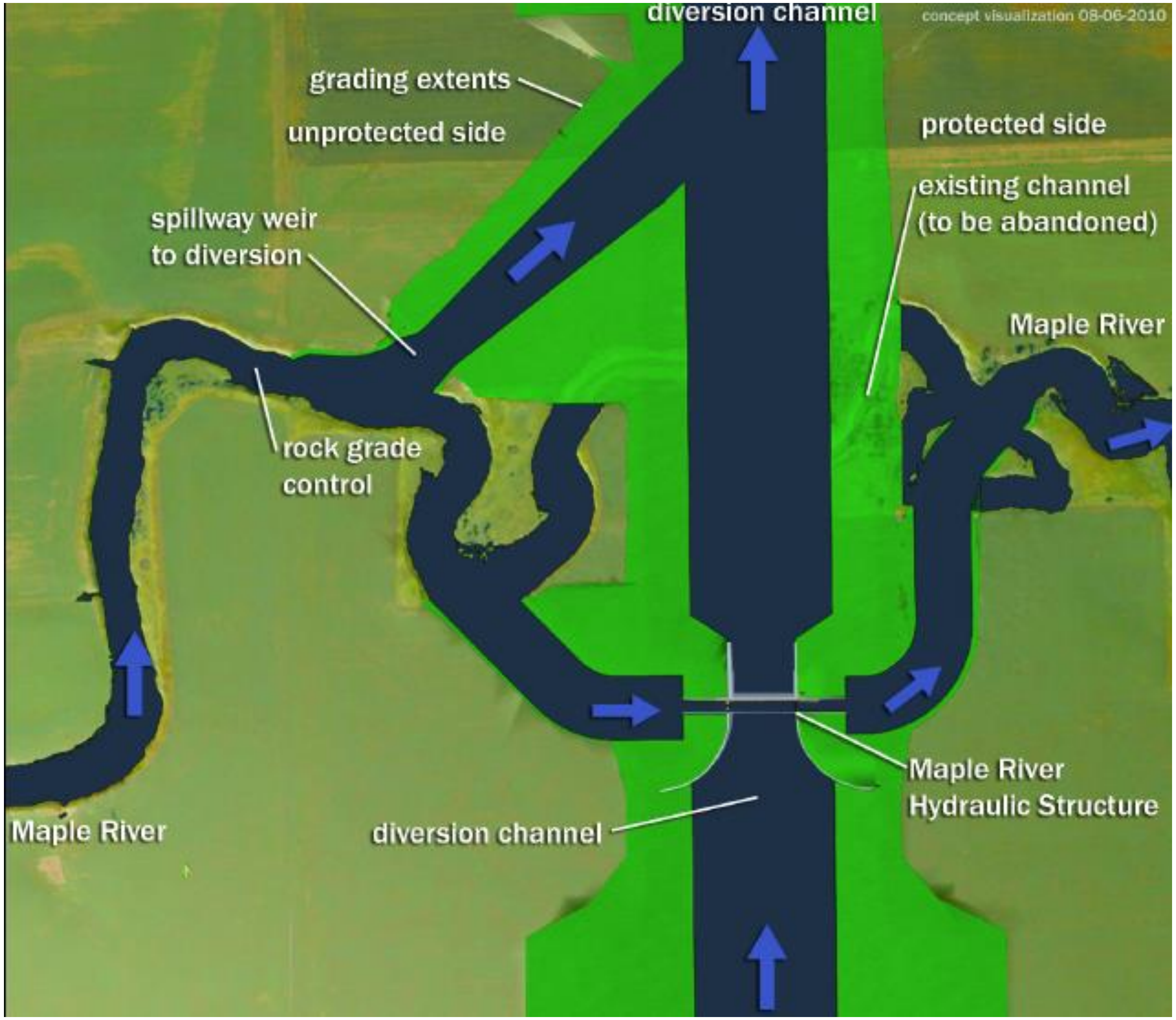


more water in Tributary combined with some water in Diversion Channel



more water in Tributary combined with some water in Diversion Channel

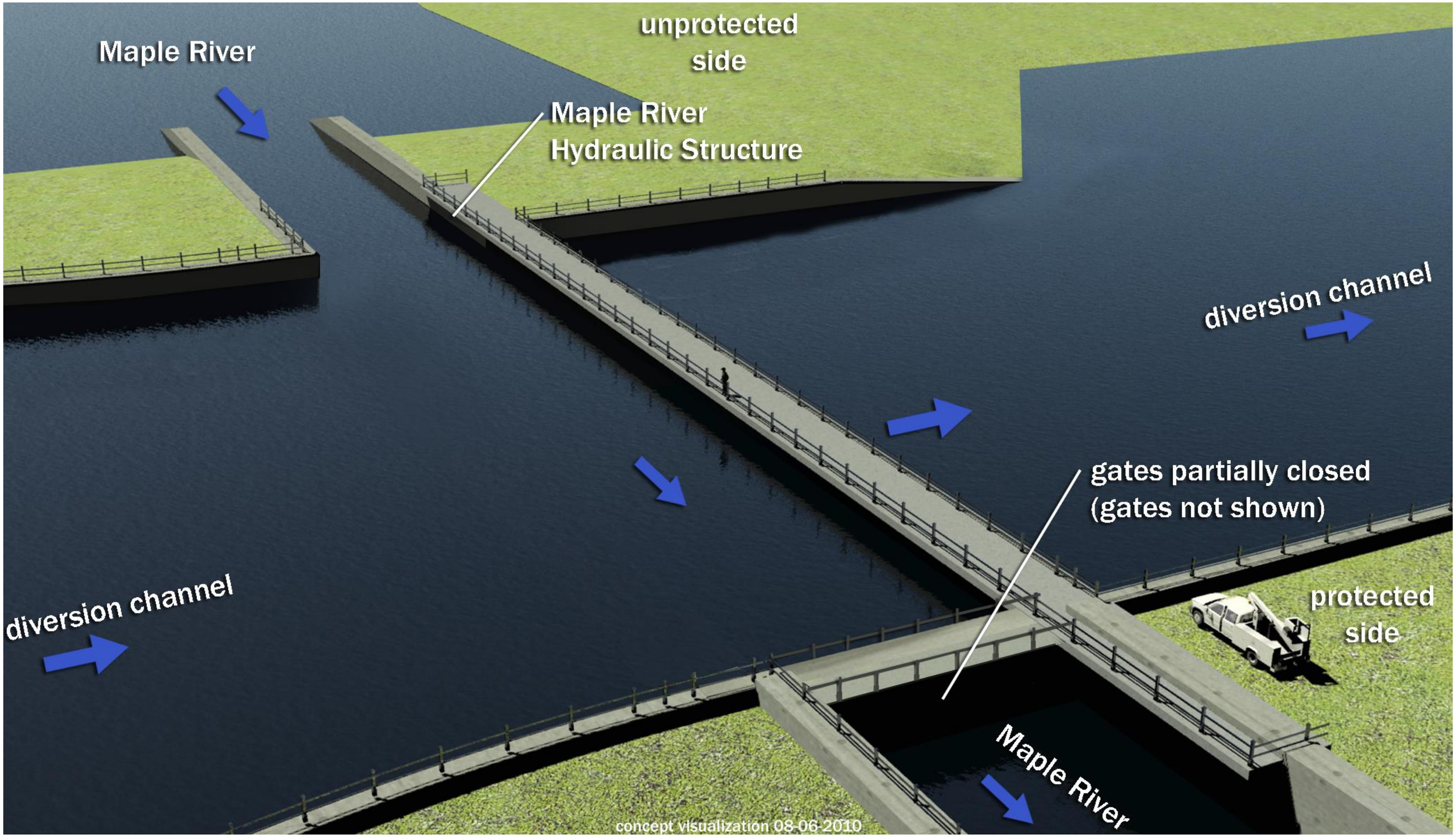
lots of water in Tributary combined with lots of water in Diversion Channel



lots of water in Tributary combined with lots of water in Diversion Channel

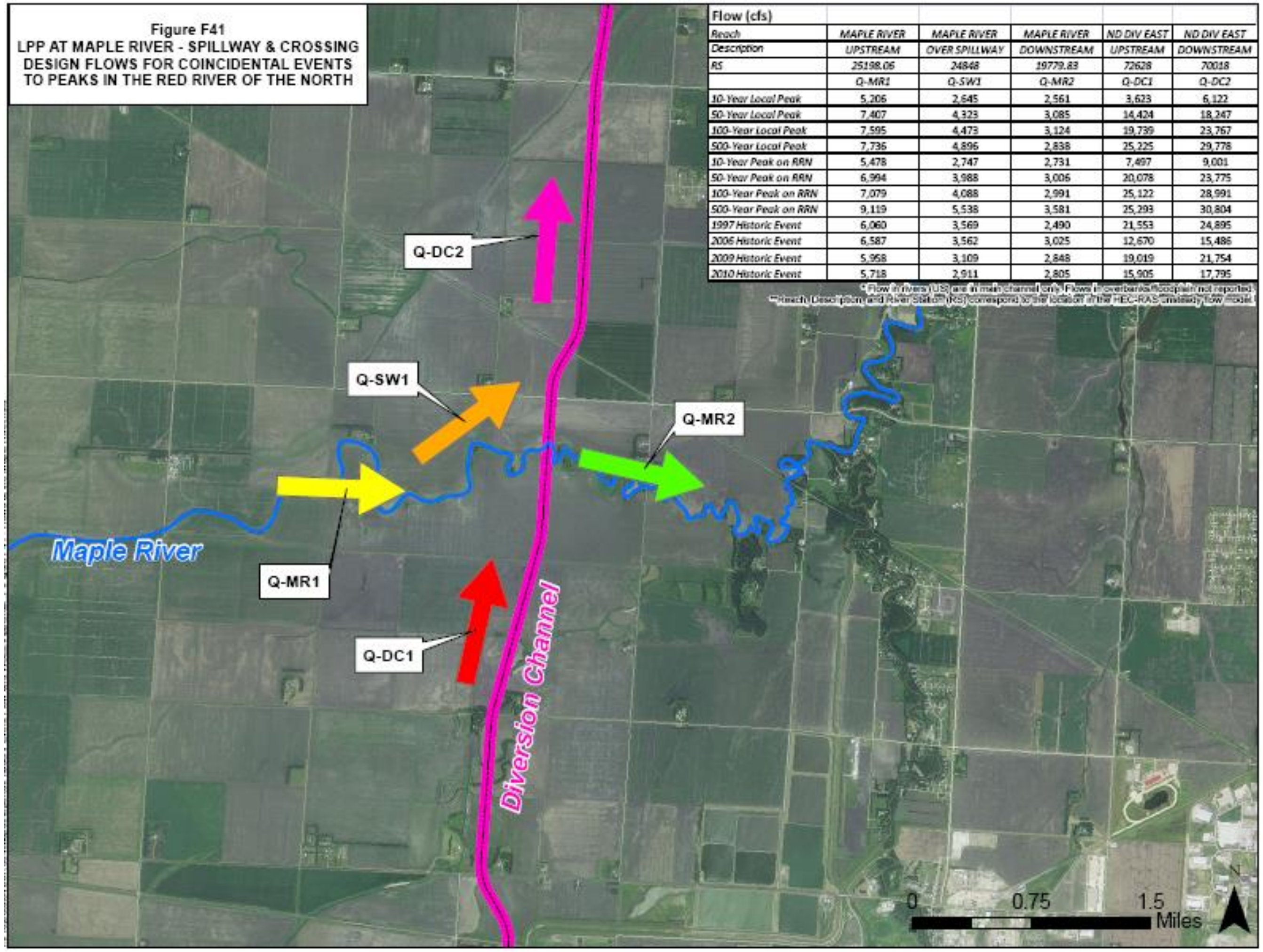
BARR

case evaluated in Phase 3 that did not apply in Phase 4 (but may come back)



where the flows go for different flood events? (Maple River)

Figure F41
LPP AT MAPLE RIVER - SPILLWAY & CROSSING
DESIGN FLOWS FOR COINCIDENTAL EVENTS
TO PEAKS IN THE RED RIVER OF THE NORTH



Flow (cfs)					
Reach	MAPLE RIVER	MAPLE RIVER	MAPLE RIVER	ND DIV EAST	ND DIV EAST
Description	UPSTREAM	OVER SPILLWAY	DOWNSTREAM	UPSTREAM	DOWNSTREAM
RS	25198.06	24848	19779.83	72628	70018
	Q-MR1	Q-SW1	Q-MR2	Q-DC1	Q-DC2
10-Year Local Peak	5,206	2,645	2,561	3,623	6,122
50-Year Local Peak	7,407	4,323	3,085	14,424	18,247
100-Year Local Peak	7,595	4,473	3,124	19,739	23,767
500-Year Local Peak	7,736	4,896	2,838	25,225	29,778
10-Year Peak on RRN	5,478	2,747	2,731	7,497	9,001
50-Year Peak on RRN	6,994	3,988	3,006	20,078	23,775
100-Year Peak on RRN	7,079	4,088	2,991	25,122	28,991
500-Year Peak on RRN	9,119	5,538	3,581	25,293	30,804
1997 Historic Event	6,060	3,569	2,490	21,553	24,895
2006 Historic Event	6,587	3,562	3,025	12,670	15,486
2009 Historic Event	5,958	3,109	2,848	19,019	21,754
2010 Historic Event	5,718	2,911	2,805	15,905	17,795

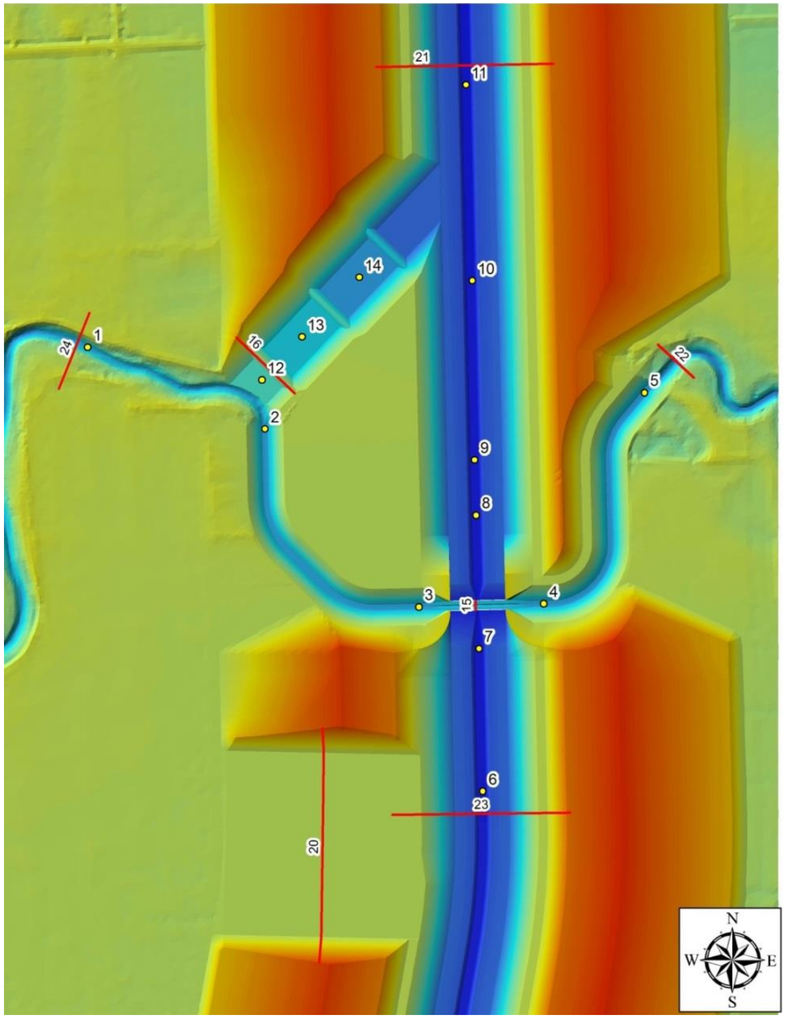
* Flow in rivers (US) are in main channel only. Flows in overbanks/floodplain not reported.
**Reach, Description and River Station (RS) correspond to the location in the HEC-RAS unsteady flow model.

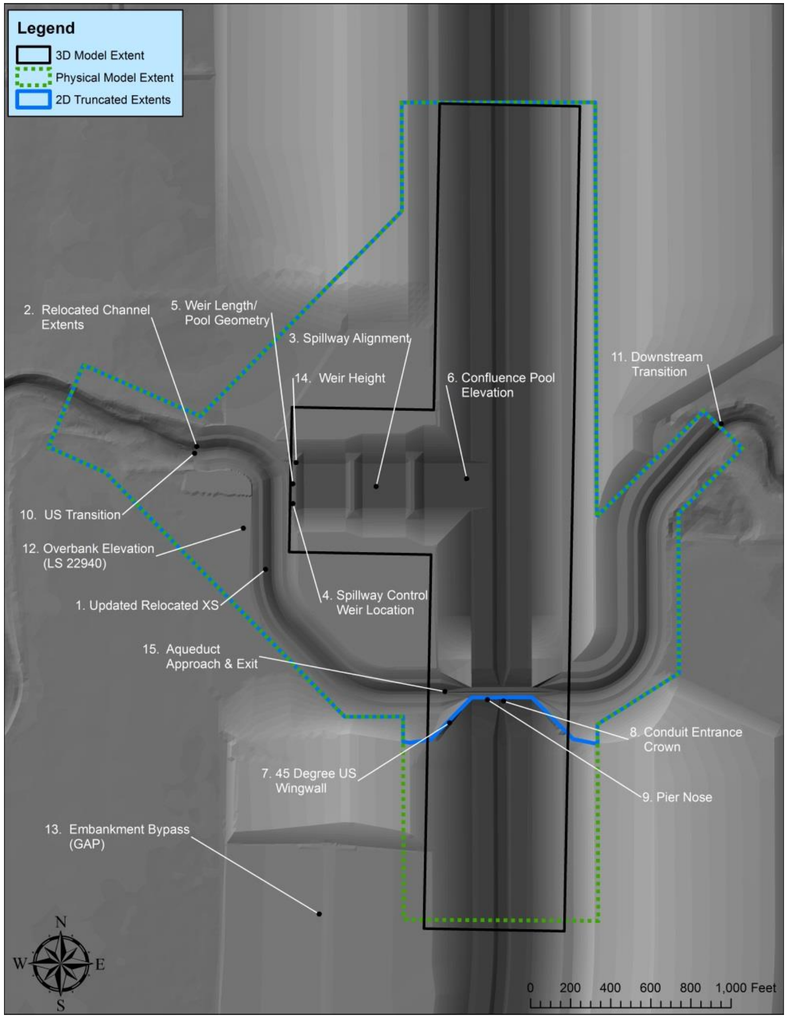
other general design considerations for Maple and Sheyenne Structures

BARR

- **Failure of one component should not lead to failure of entire diversion system**
- Passive (no movable parts) instead of active structures
- **Minimize footprint of diversion features**
- Reduce risk of freezing at critical diversion locations
- Geotechnical and structural design that works with Brenna clays
- Design and construction that accommodates reasonable O&M
- **Cost effective**

design optimization using physical, 2D and 3D flow modeling

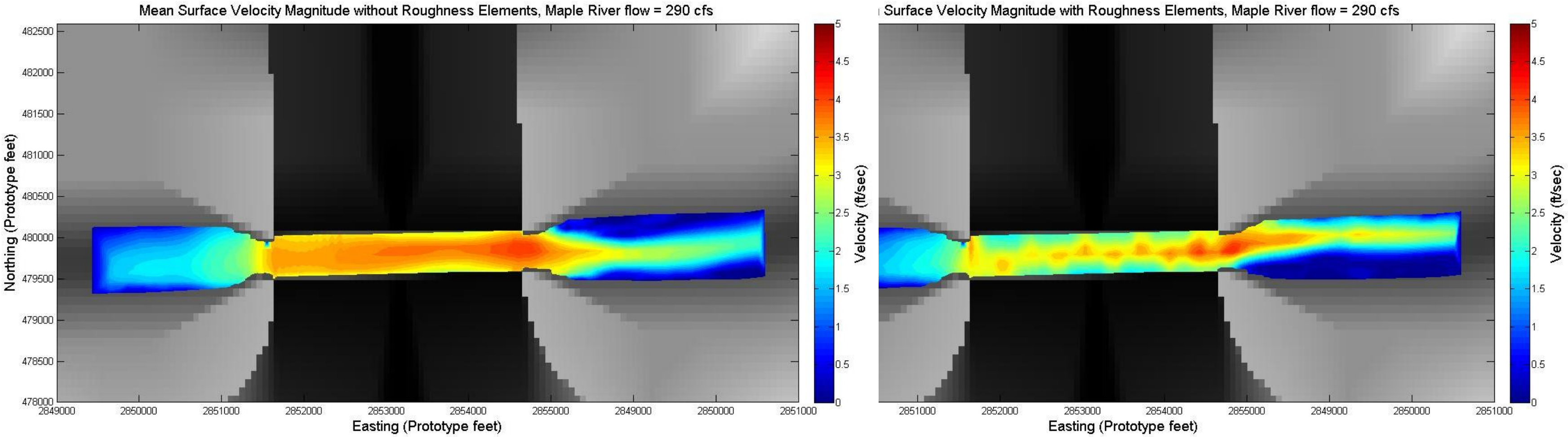


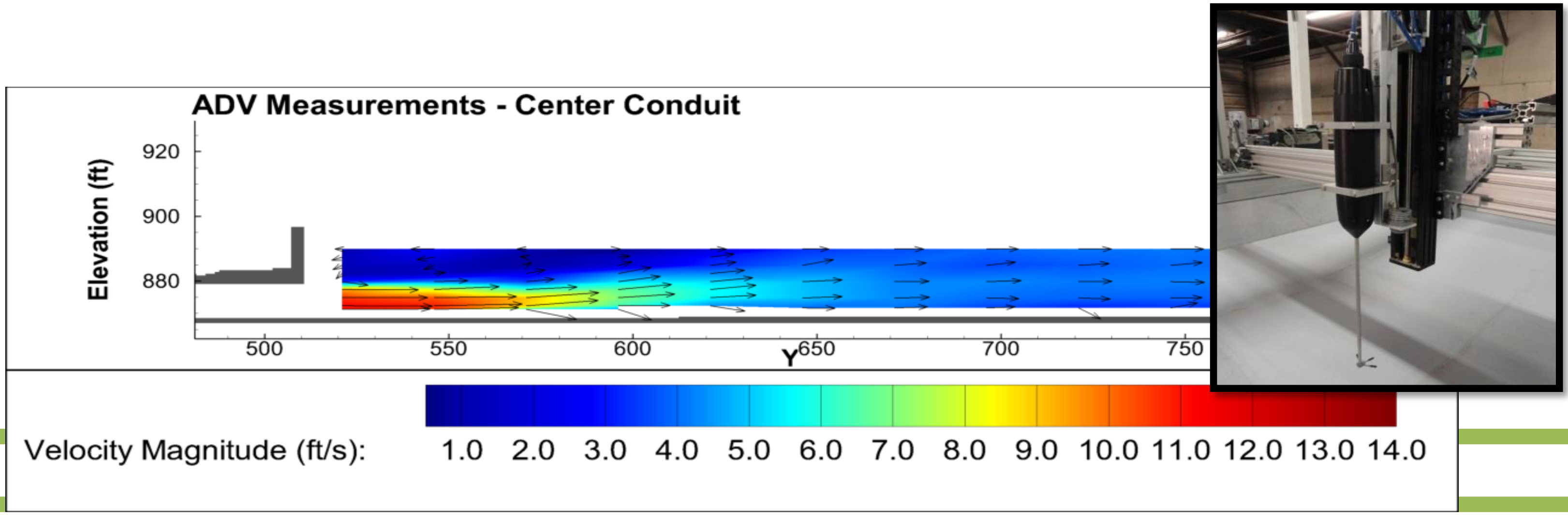


studying ice passage

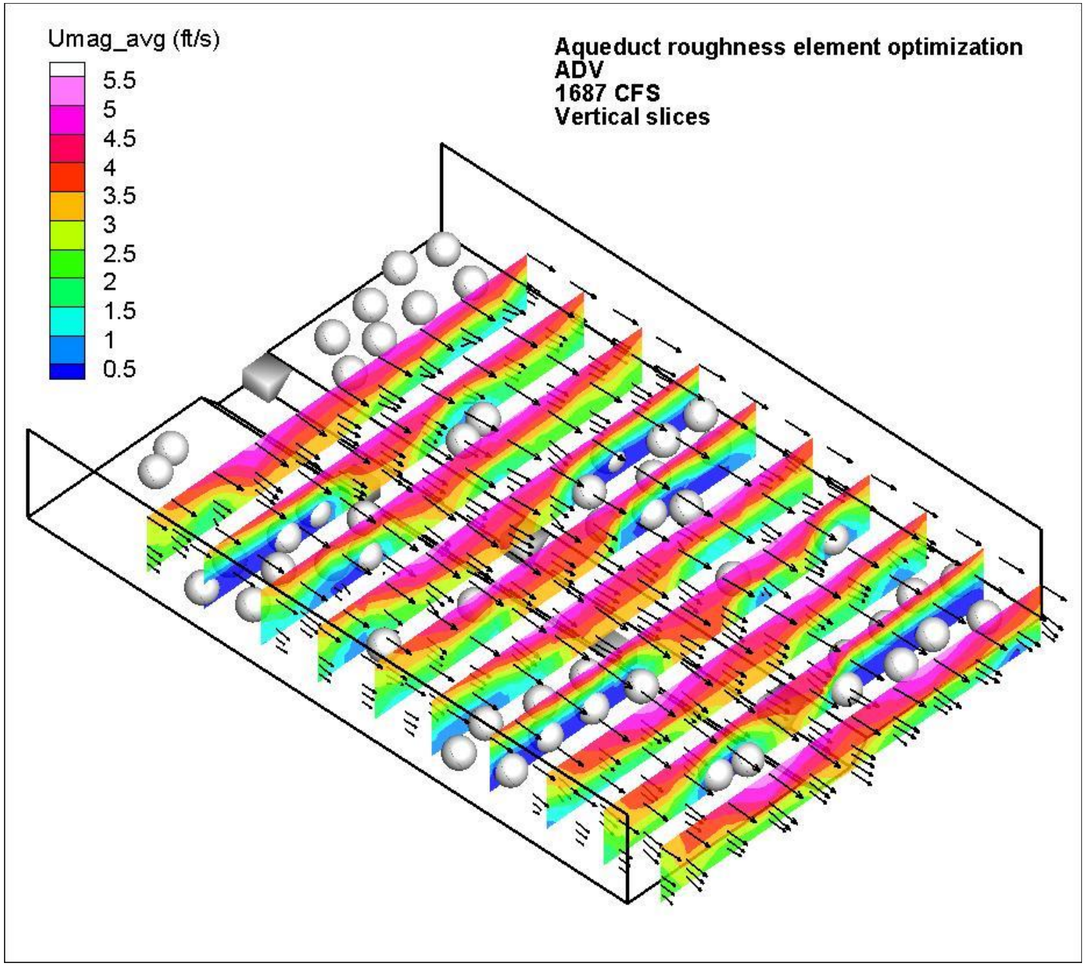
gaining additional insight on transitions, and above all, on head losses

producing high quality data that allows calibration of 2D and 3D flow models

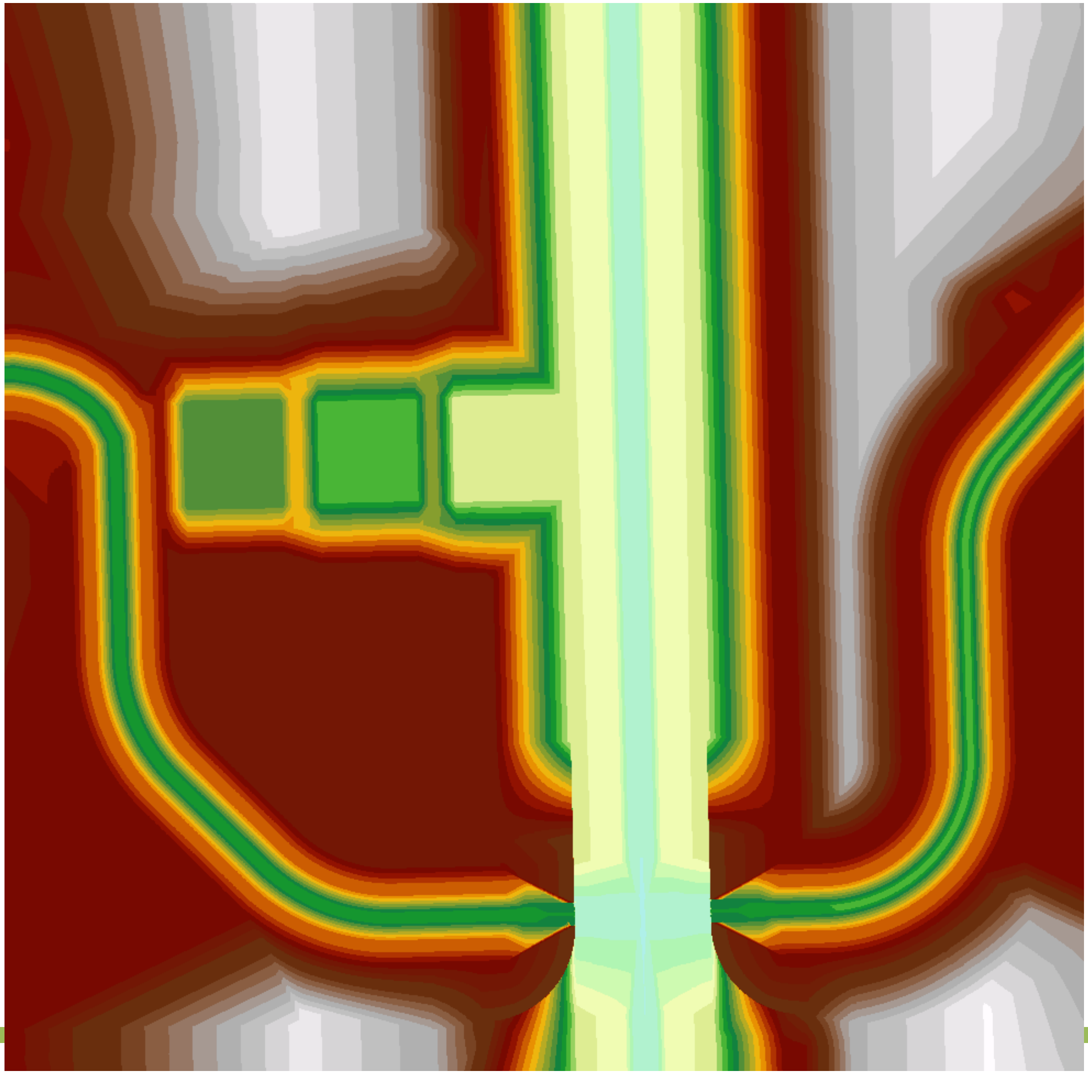




allowing for fish passage while helping with hydraulic performance

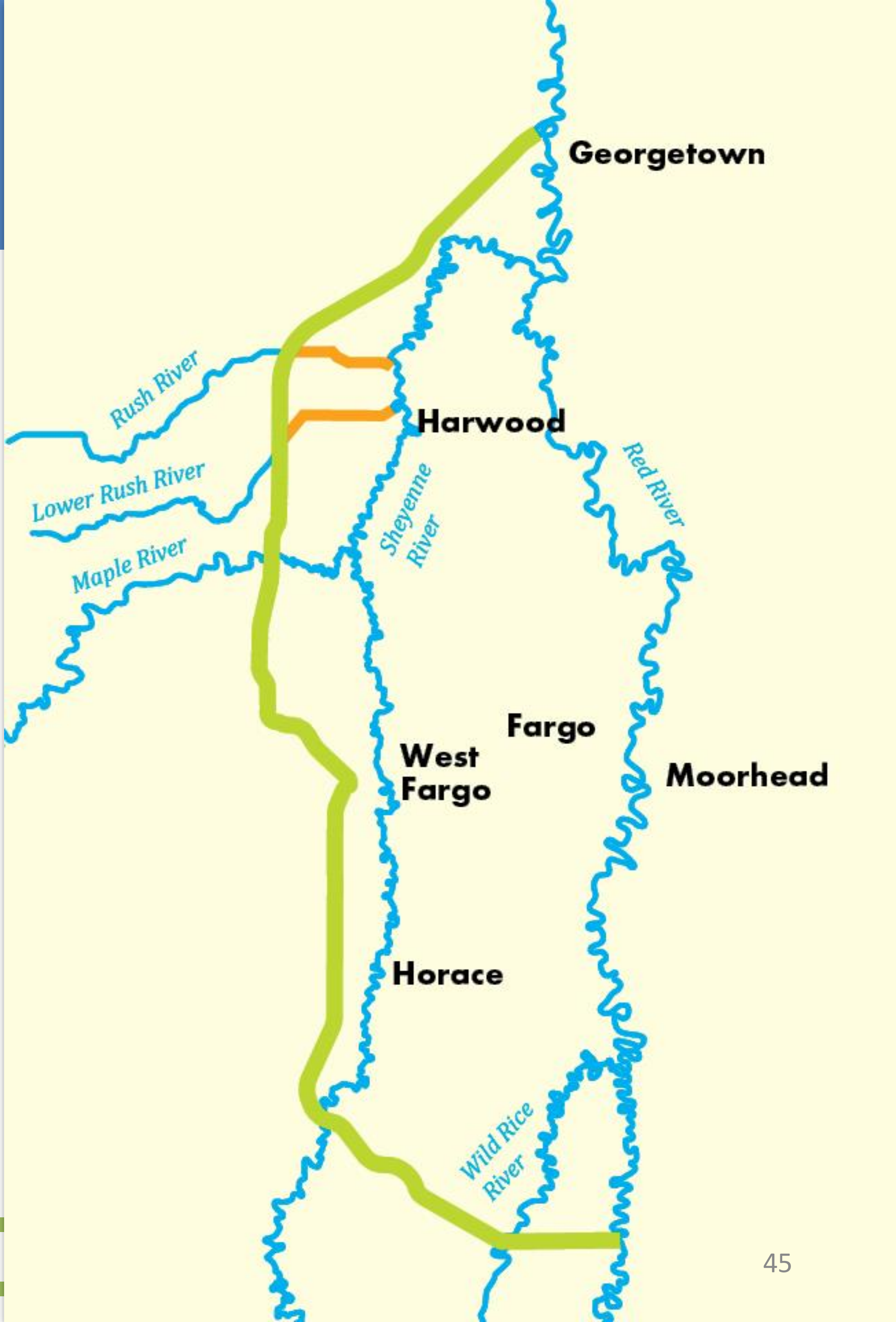


alternative configuration? (more to come in Fargo P3)

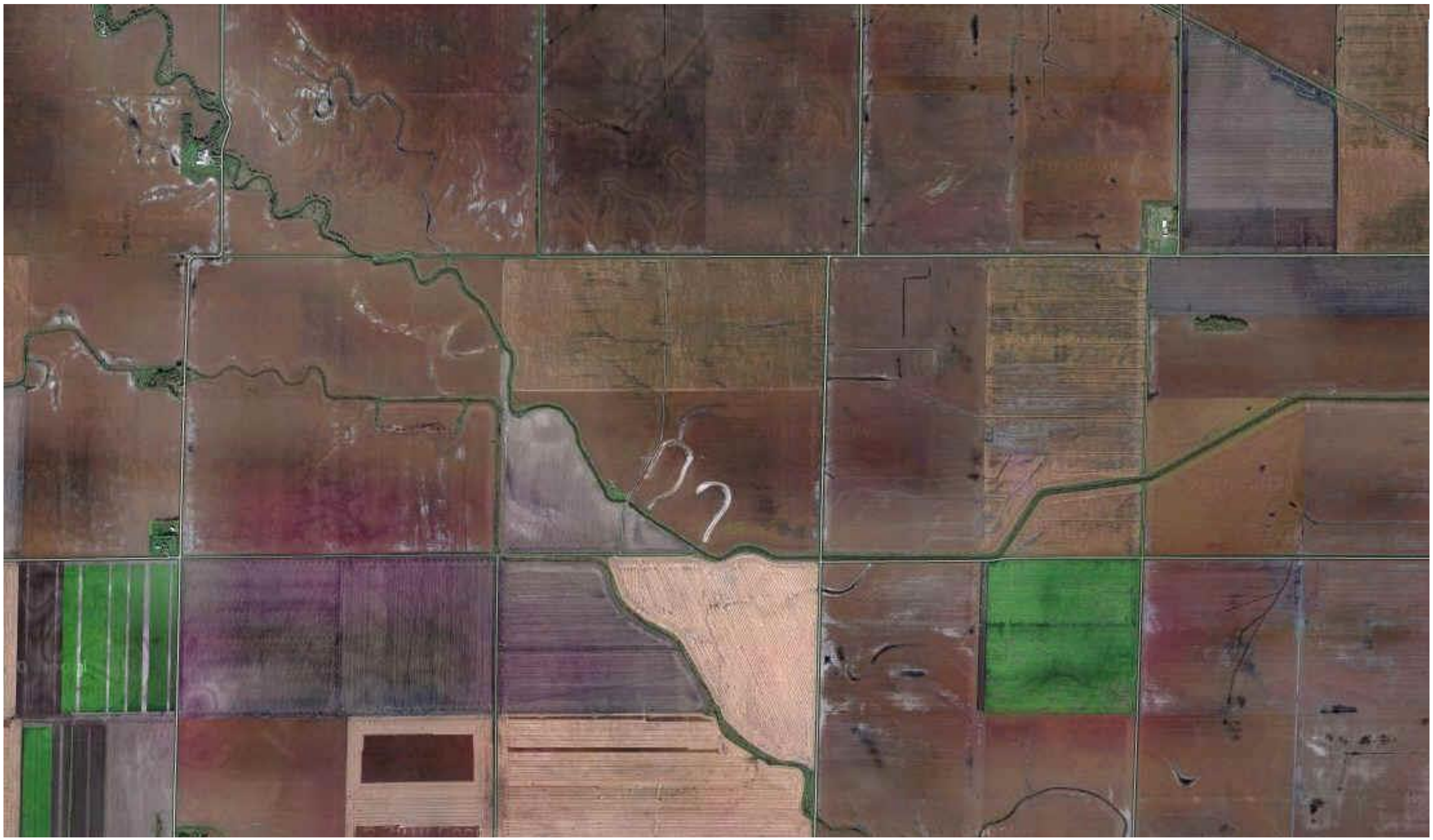


low-flow channel (LFC) overview

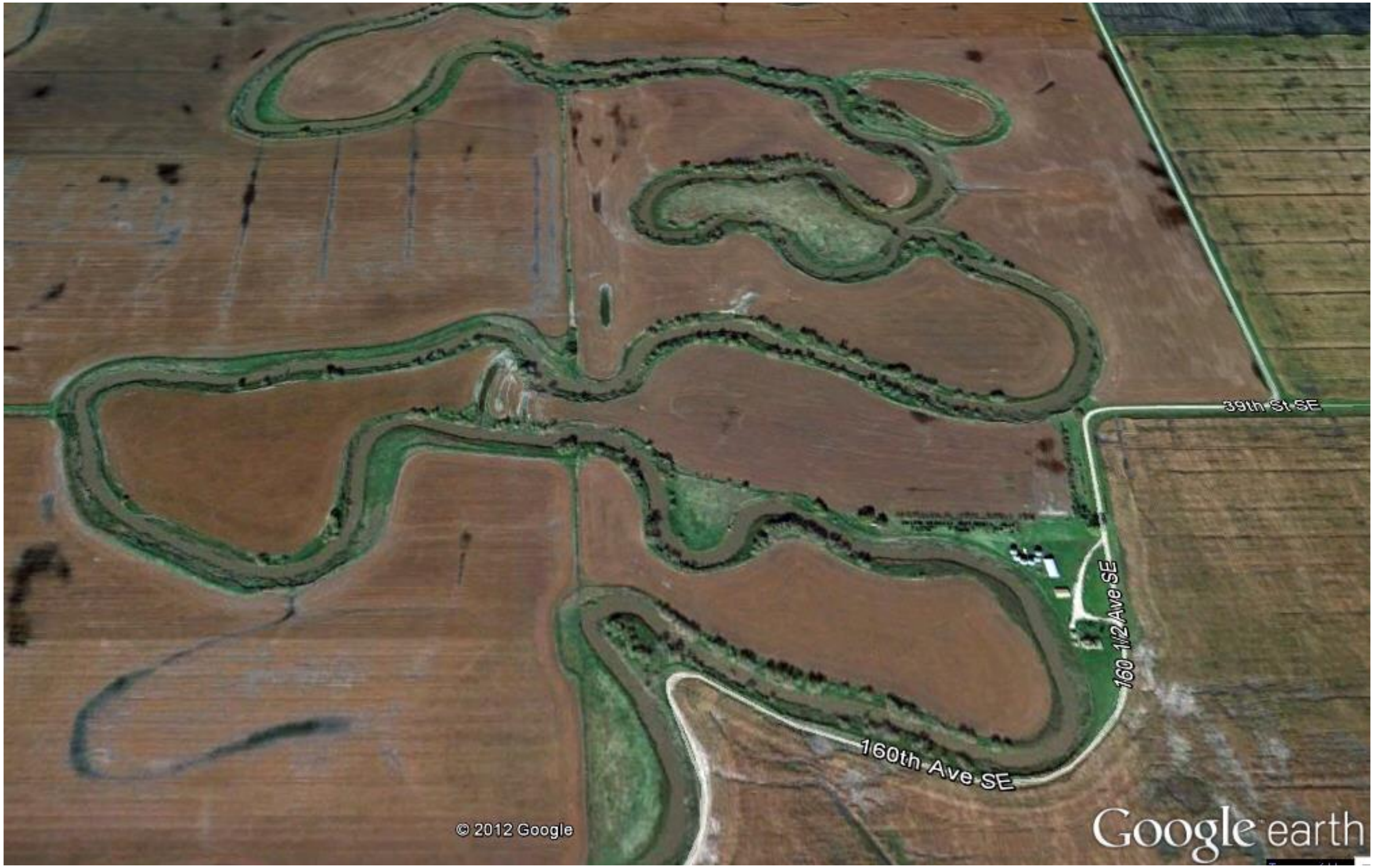
- **Proposed Diversion Channel collects runoff from:**
  - The Rush and Lower Rush Rivers
  - Eleven county and local drainage ditches
  - High flows from the Maple, Sheyenne, Wild Rice, and Red Rivers
- **A meandering Low-Flow Channel is planned for the bottom of the Diversion Channel**
  - The Low-Flow Channel will be sized to convey water and sediment downstream to the Red river



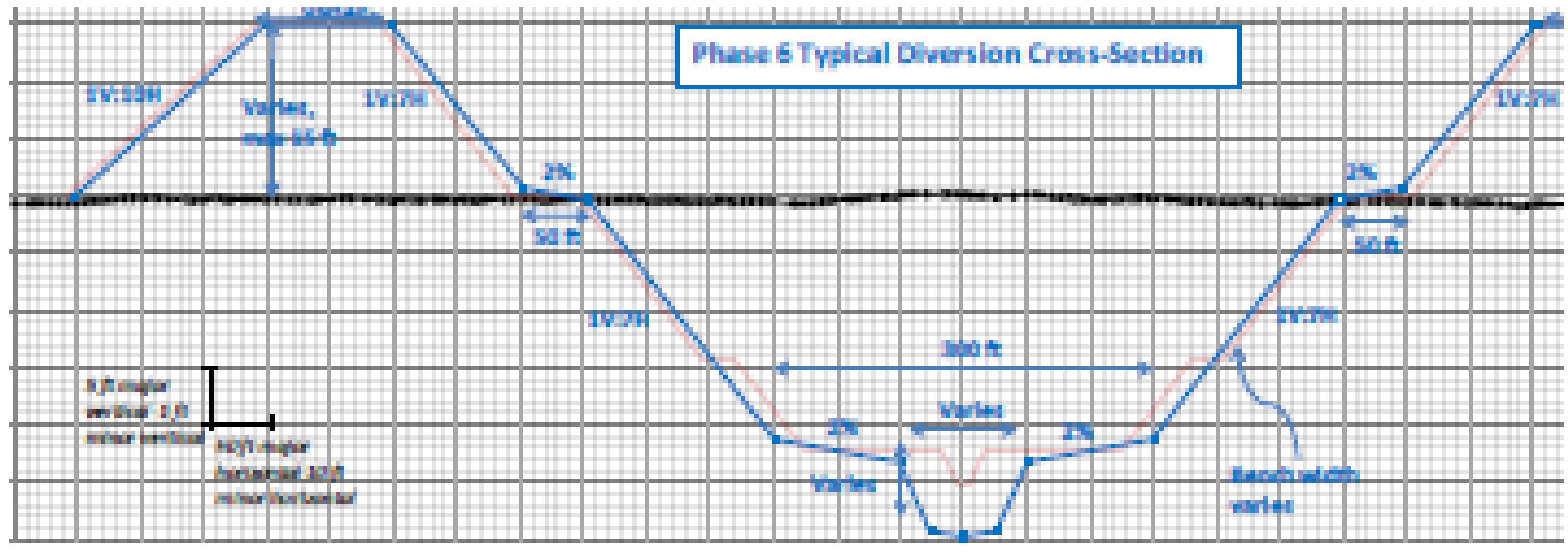
meandering streams and overland flow that were ditched



very sinuous … but does it migrate much?

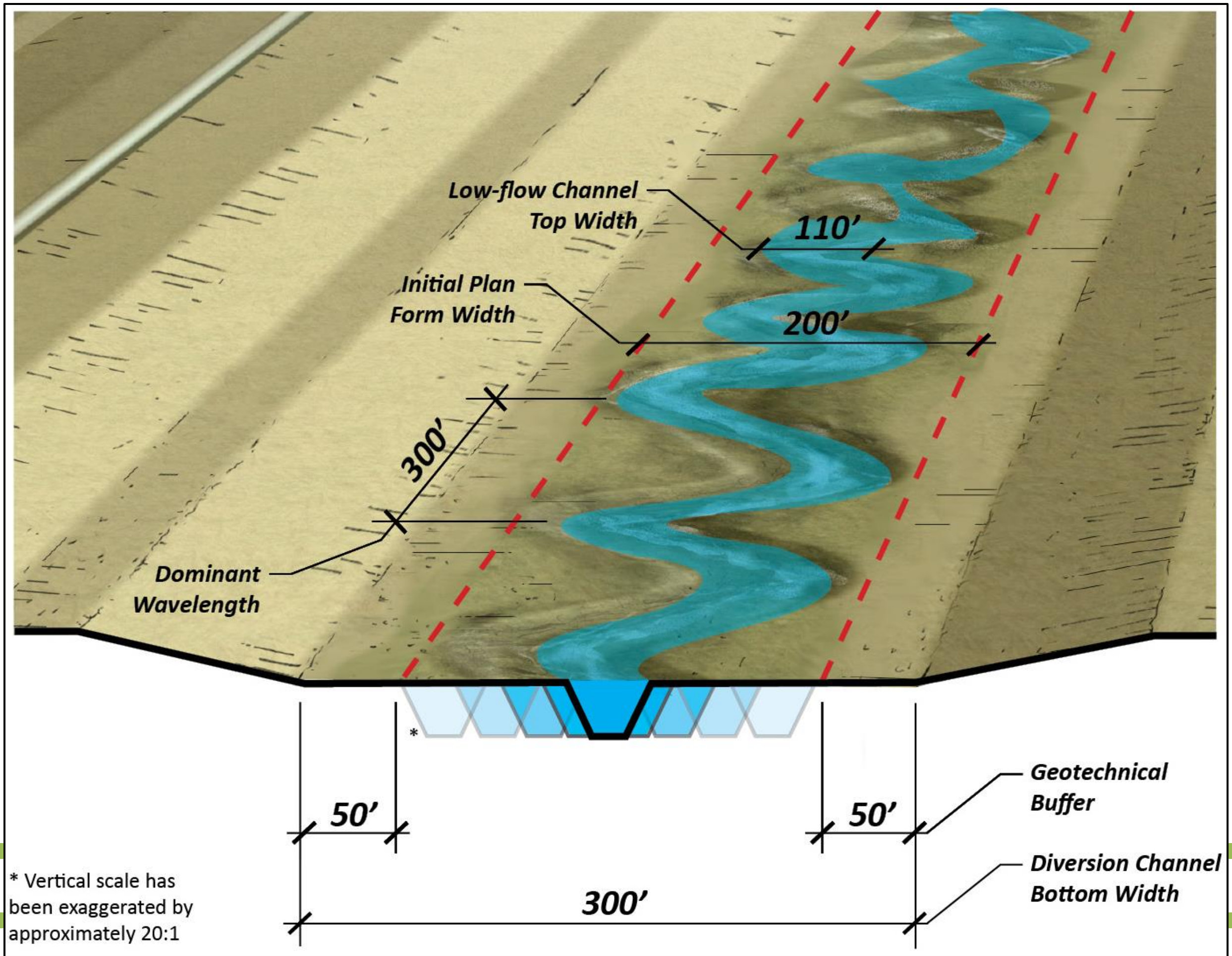


how does it look?

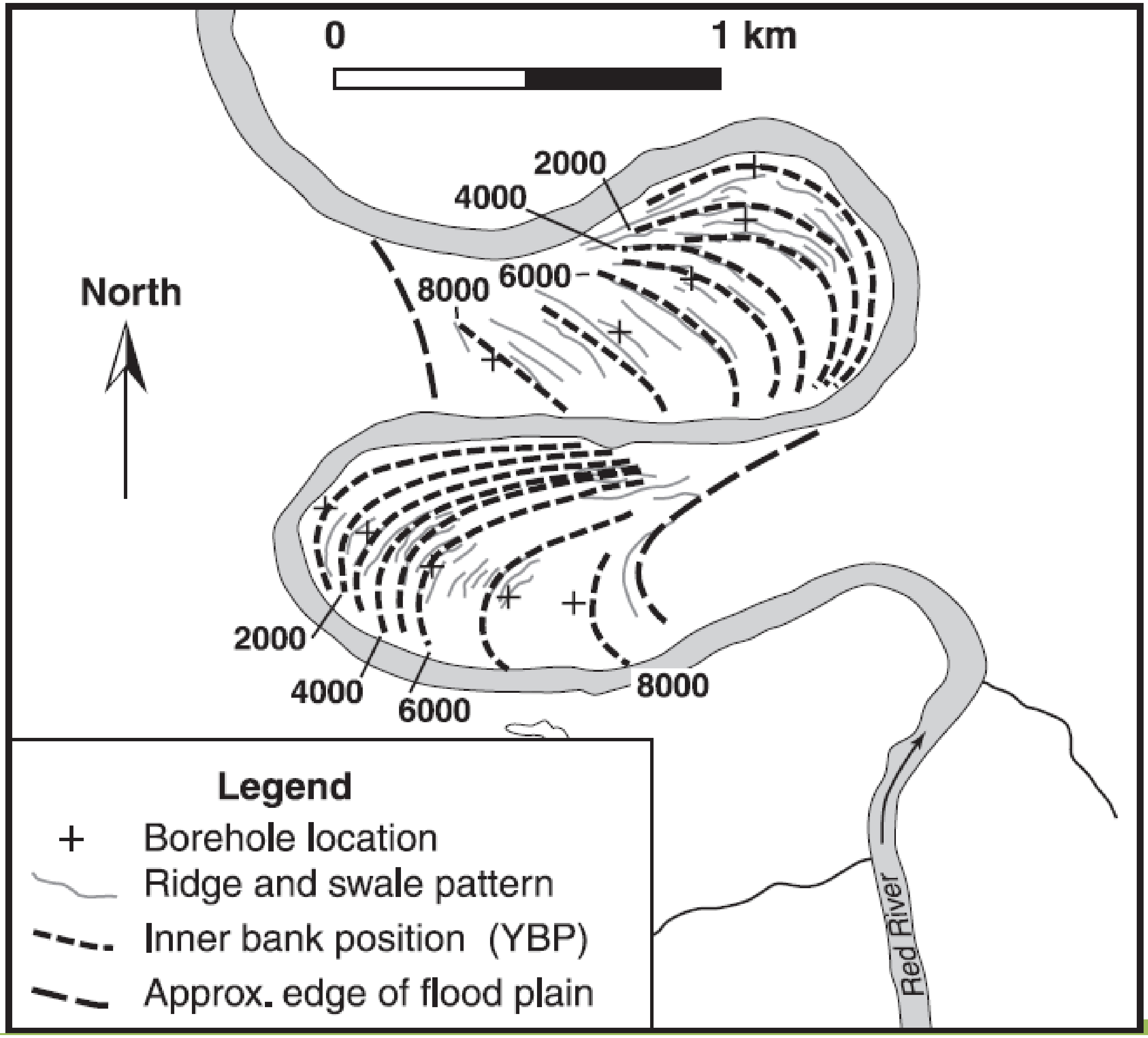


LFC overview

“What is the probability that the LFC will remain within a prescribed meander belt width?”



channel migration rates during Holocene



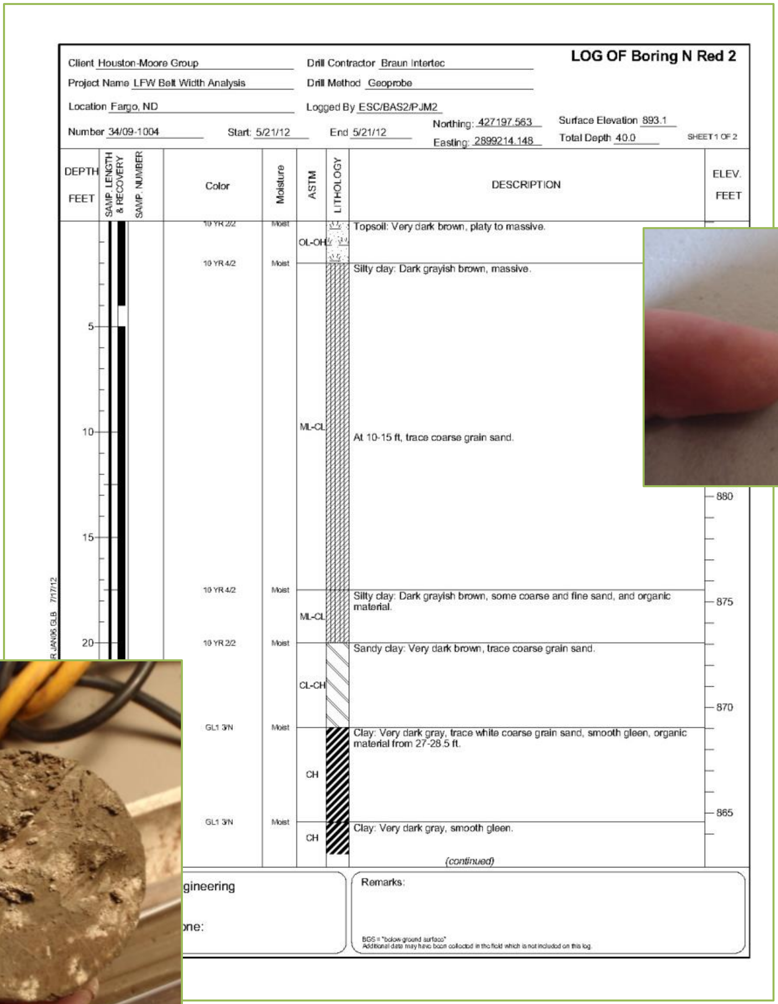
From Brooks, 2003

key questions

- Did channel migration rates decrease significantly around 5,000 years ago?
- How rapidly have the rivers in the study area migrated recently?
- How do differences in the river characteristics affect migration rate?

components of field investigation

BARR



LOG OF Boring N Red 2

Client Houston-Moore Group
Project Name LFW Belt Width Analysis
Location Fargo, ND
Number 34/09-1004 Start: 5/21/12 End 5/21/12

Drill Contractor Braun Intertec
Drill Method Geoprobe
Logged By ESC/BAS2/PJM2
Northing: 427197.563 Easting: 2899214.148
Surface Elevation 893.1 Total Depth 40.0

SHEET 1 OF 2

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Color	Moisture	ASTM	LITHOLOGY	DESCRIPTION	ELEV. FEET
			10 YR 2/2	Moist	OL-OH		Topsoil: Very dark brown, platy to massive.	
5			10 YR 4/2	Moist	ML-CL		Silty clay: Dark grayish brown, massive.	
10							At 10-15 ft, trace coarse grain sand.	
15								880
			10 YR 4/2	Moist	ML-CL		Silty clay: Dark grayish brown, some coarse and fine sand, and organic material.	875
20			10 YR 2/2	Moist	CL-CH		Sandy clay: Very dark brown, trace coarse grain sand.	870
			GL1 3/N	Moist	CH		Clay: Very dark gray, trace white coarse grain sand, smooth gleen, organic material from 27-28.5 ft.	865
			GL1 3/N	Moist	CH		Clay: Very dark gray, smooth gleen.	

(continued)

gineering

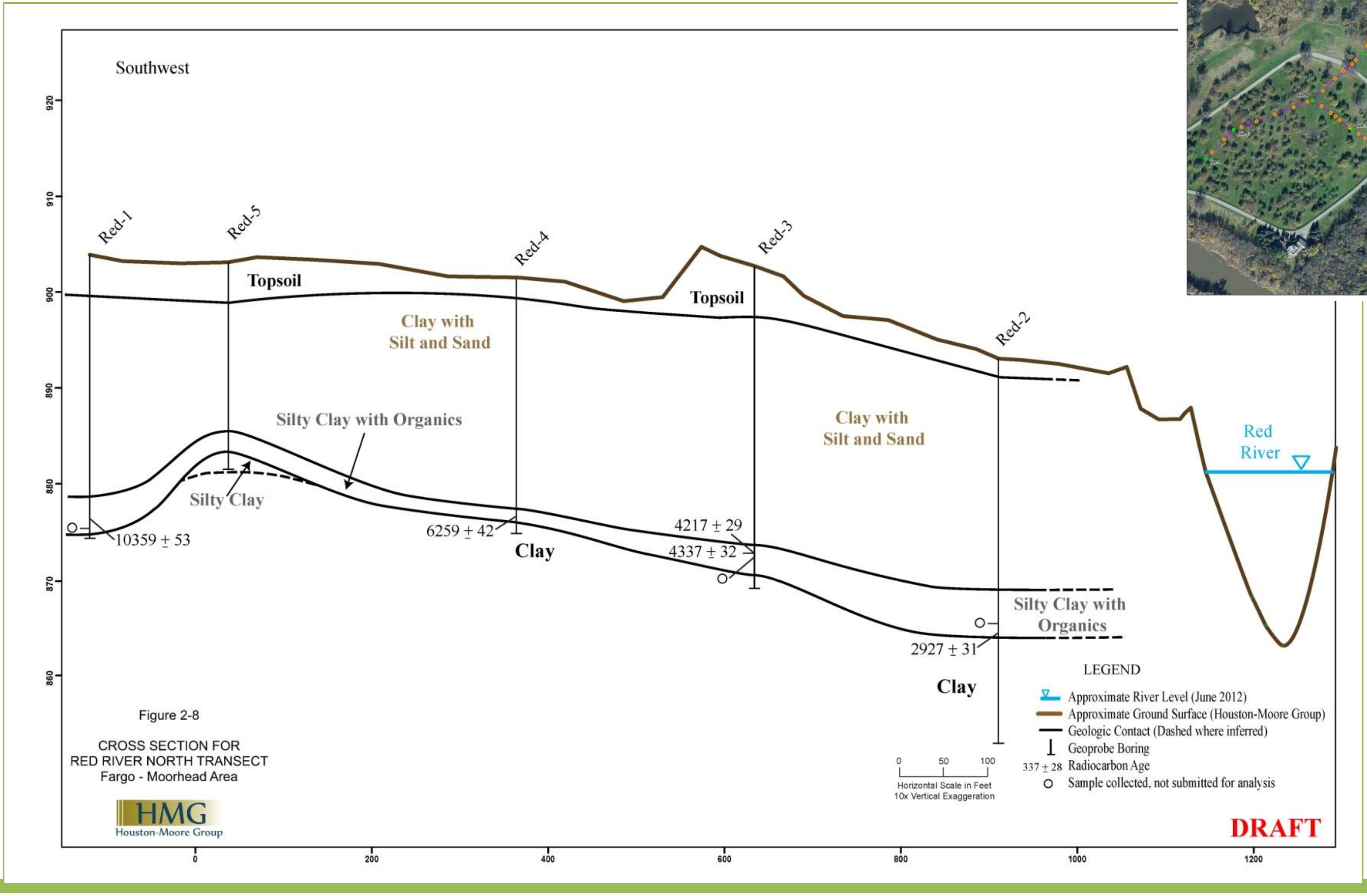
one:

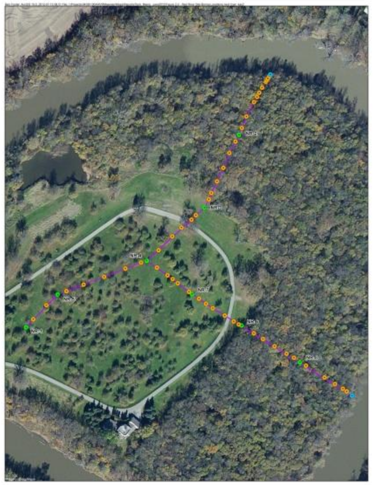
Remarks:

summary of logging and sampling

- 30 to 40 feet of clay with silt (river deposits) overlie dark gray fat clay (Glacial Lake Agassiz deposits)
- Sediments from the Maple and Sheyenne were coarser than from the Red
- Coarser grain sizes and organic matter were concentrated at base of alluvial deposits
- 66 samples of organic matter were collected, 32 were submitted for analysis

RRN: SW-NE Transect

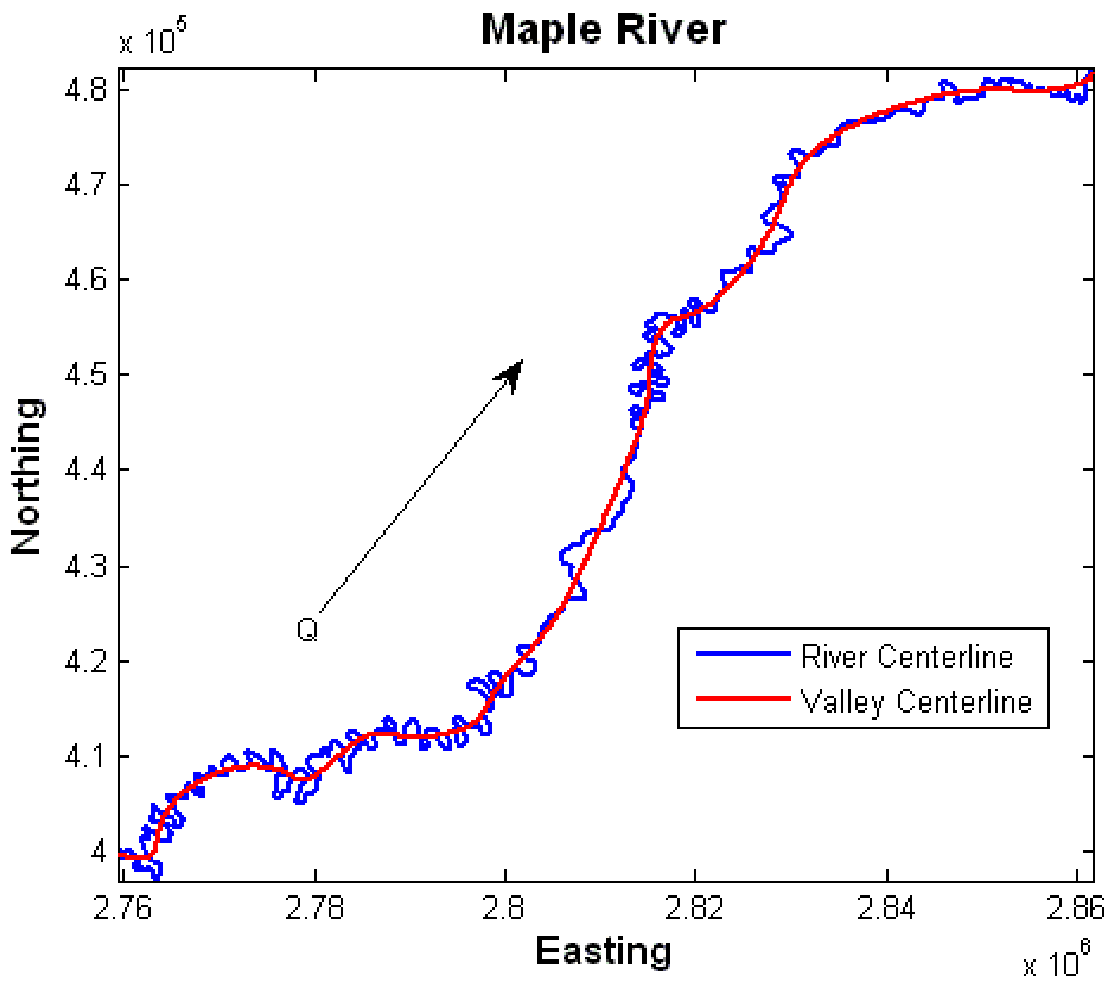




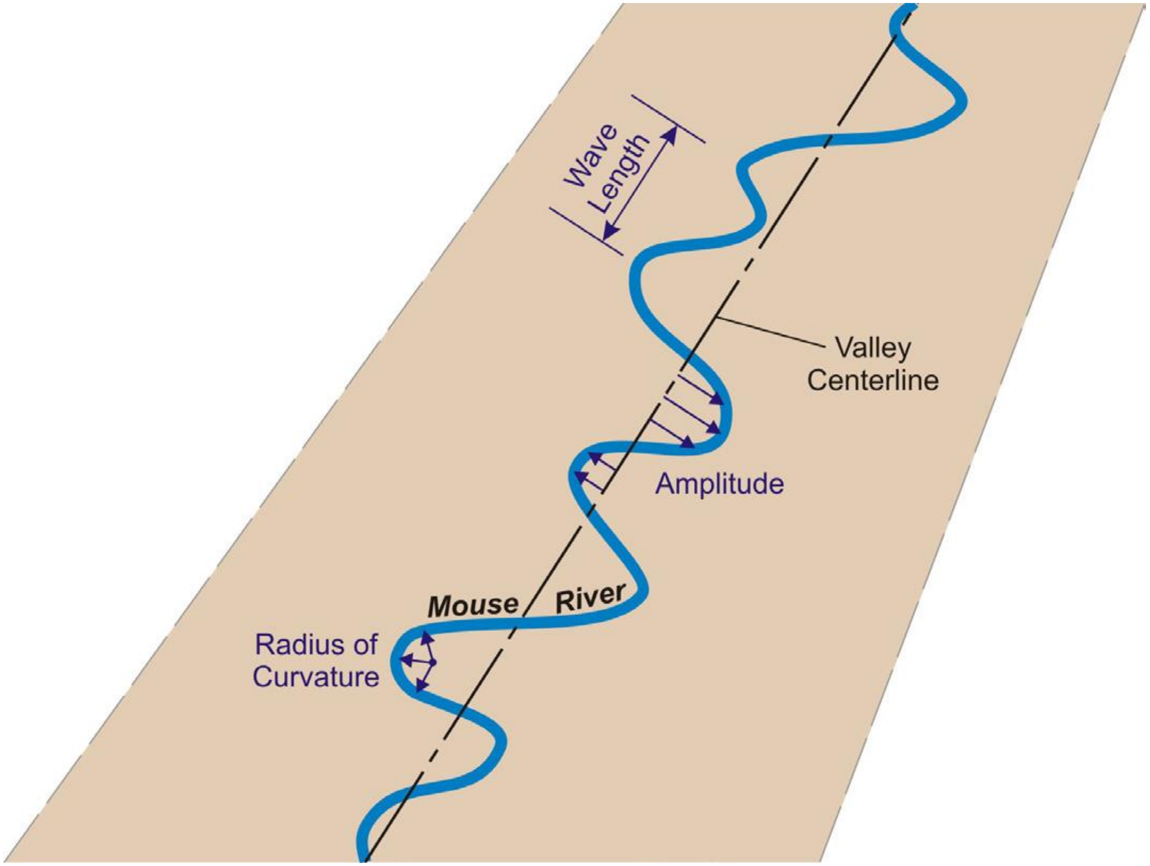
main findings

- Typical migration rate= 0.1 to 0.2 feet/carbon year
- **Migration rates have not changed systematically over the last 10,000 years**
- The results of the field investigation are sufficient to guide design of the LFC: channel migration rates are extremely low, if not negligible
- However, **a comprehensive understanding of how these river systems have evolved during the Holocene (particularly the Sheyenne and Maple Rivers) is incomplete**

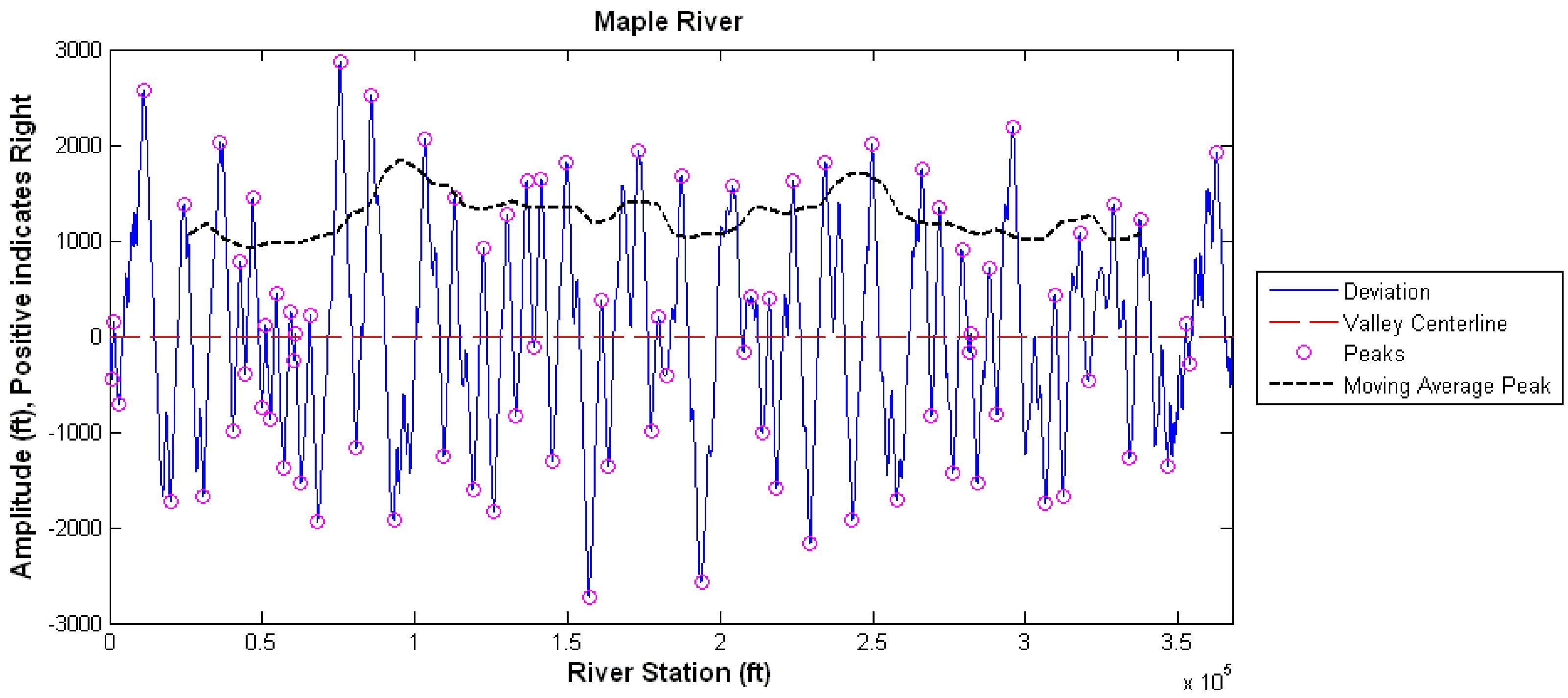
can we learn from the today's "natural" riverine systems?



river planform characteristics

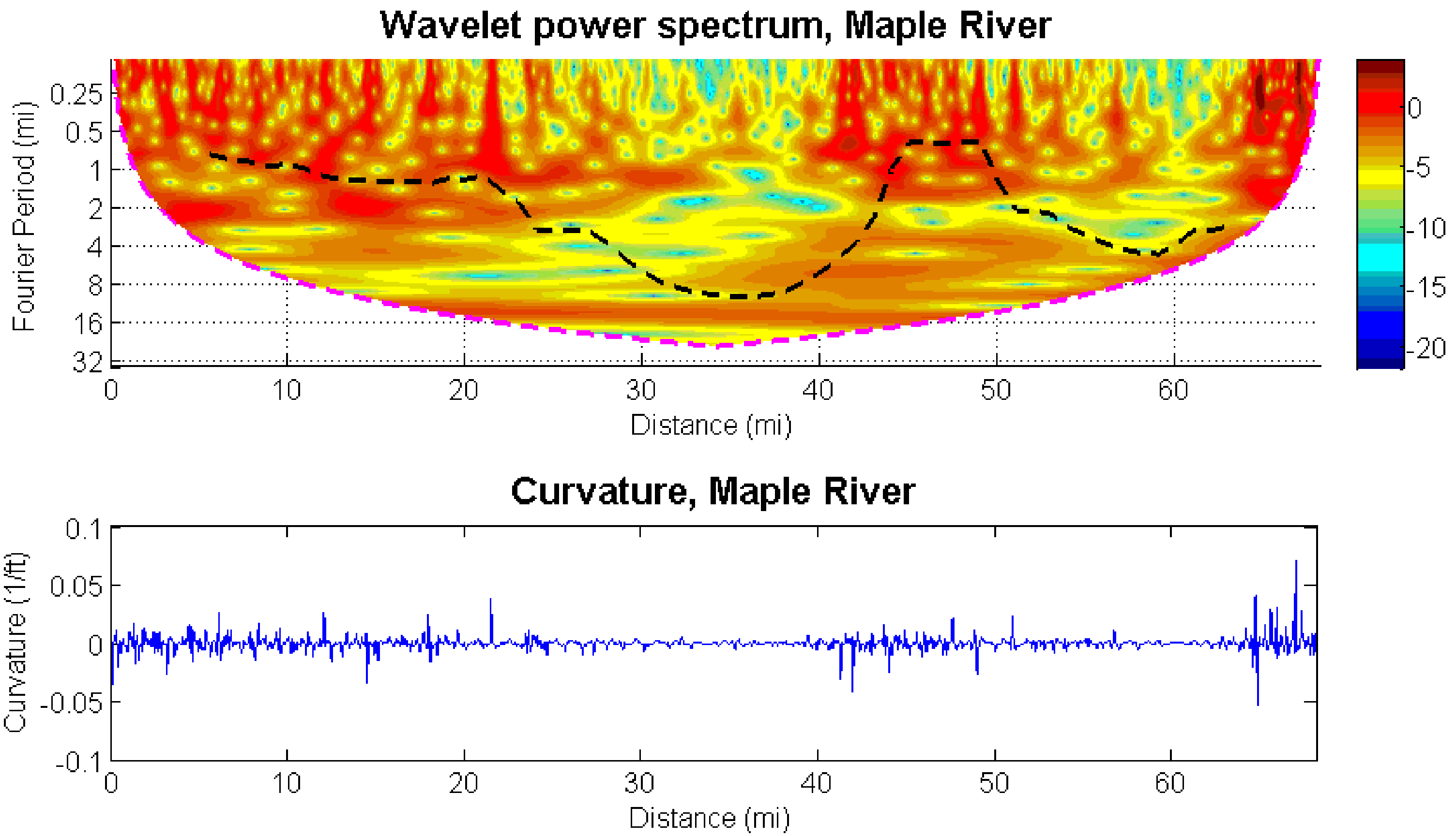


amplitude

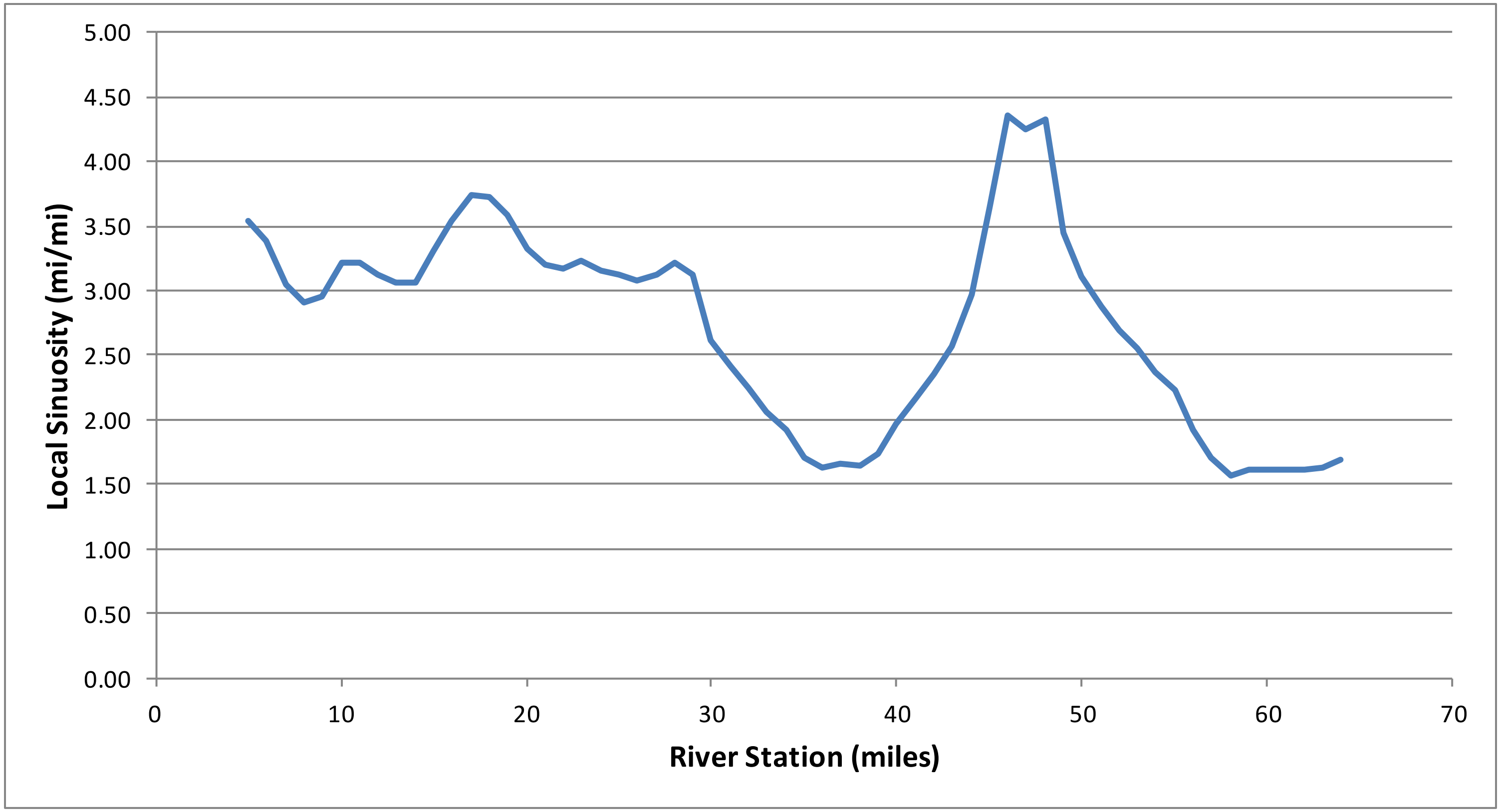


Maple River
Amplitude (ft), Positive indicates Right
River Station (ft)
x 10^5
3000
2000
1000
0
-1000
-2000
-3000
0
0.5
1
1.5
2
2.5
3
3.5
Deviation
Valley Centerline
Peaks
Moving Average Peak

wavelength

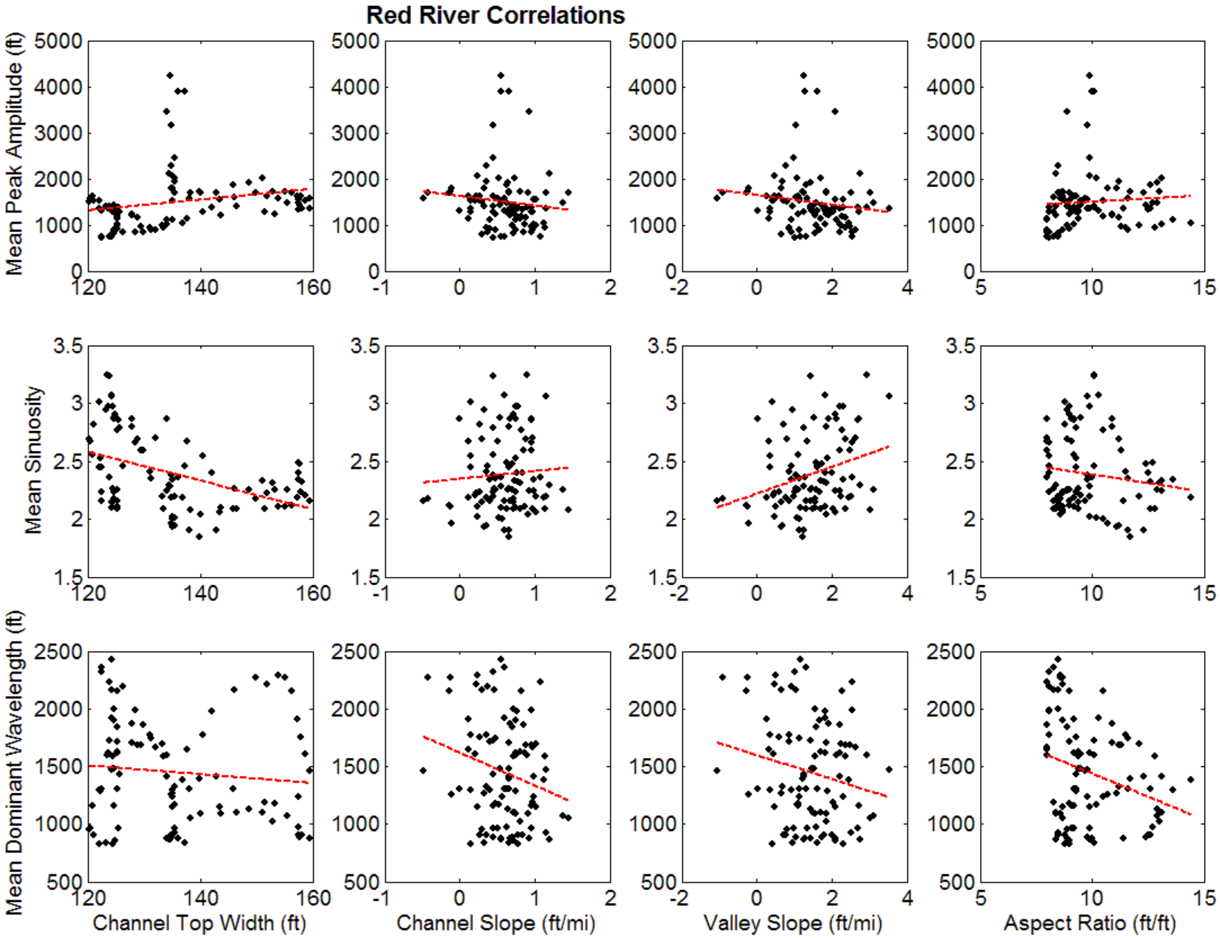

Wavelet power spectrum, Maple River
Fourier Period (mi)
0.25
0.5
1
2
4
8
16
32
0
10
20
30
40
50
60
Distance (mi)
0
-5
-10
-15
-20
Curvature, Maple River
Curvature (1/ft)
0.1
0.05
0
-0.05
-0.1
0
10
20
30
40
50
60
Distance (mi)

sinuosity



Local Sinuosity (mi/mi)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
10
20
30
40
50
60
70
River Station (miles)

Red River of the North (through Fargo)



main findings

- No consistent relationships
- **Possible explanation is that the local systems are not hydraulically driven**
  - Unique soil conditions are more controlling than the hydraulics in this region
  - Possibly the rivers were formed following the last glaciation and have not moved significantly since
  - Potentially, there is no ideal planform to target; instead the design can be driven by engineering constraints

RVR Meander modeling

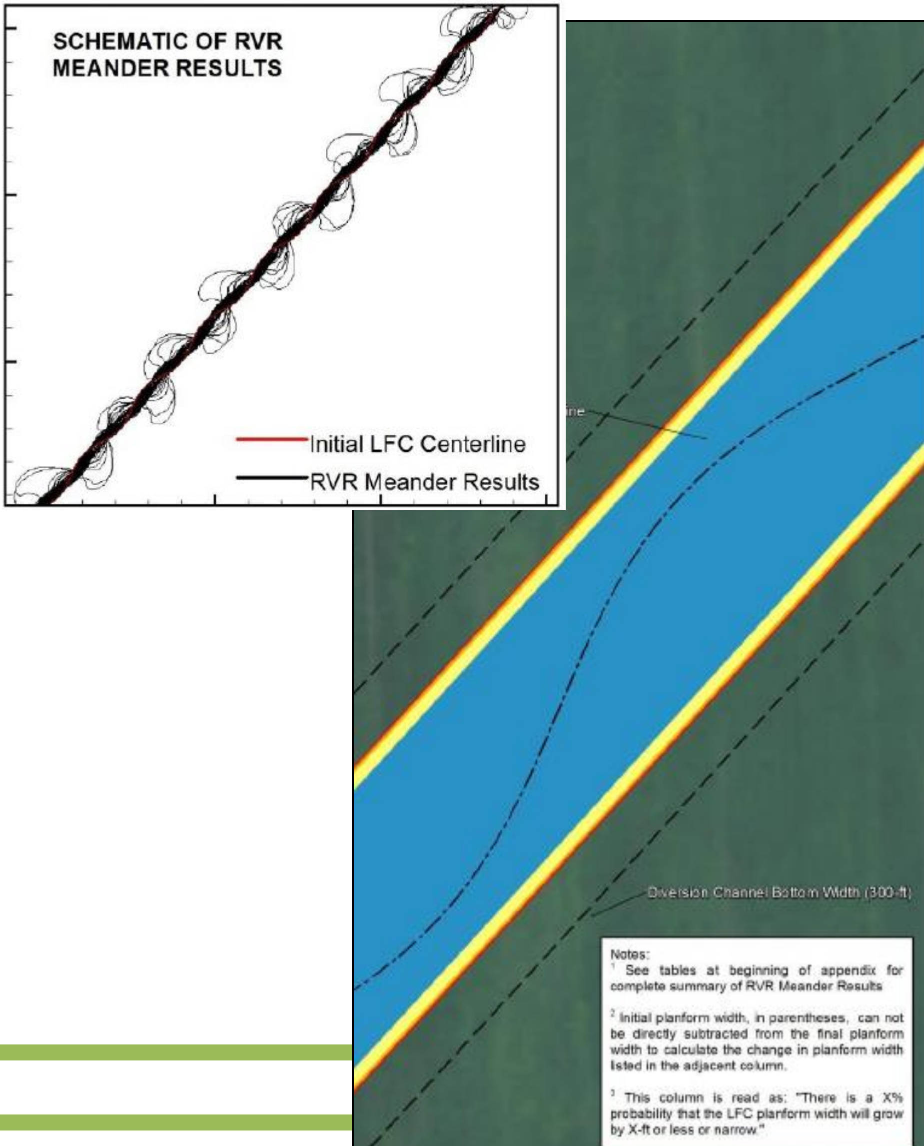
RVR Meander Overview

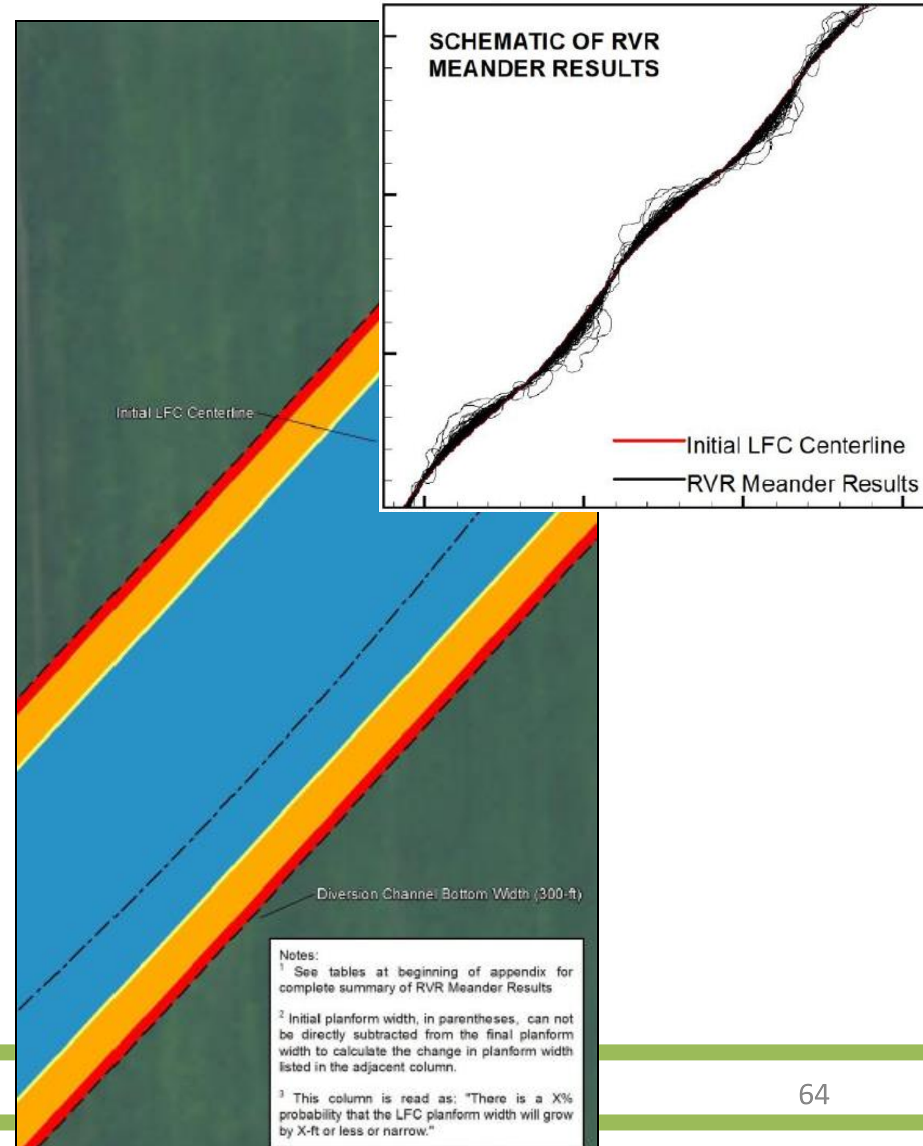
1. **Hydrodynamics** – water surface elevations & velocities
2. **Bed morphodynamics** – transverse bed slope
3. **Bank erosion** – hydraulic erosion as well as mass failure (e.g. cantilever or planar bank failure)

Analysis Methodology

1. **Model Calibration** – Deterministic simulations of rivers near the proposed Diversion Channel
2. **Monte Carlo Analysis** – Probabilistic evaluation of Low-Flow Channel reaches
3. **Summary of Results**

probabilistic evaluation results





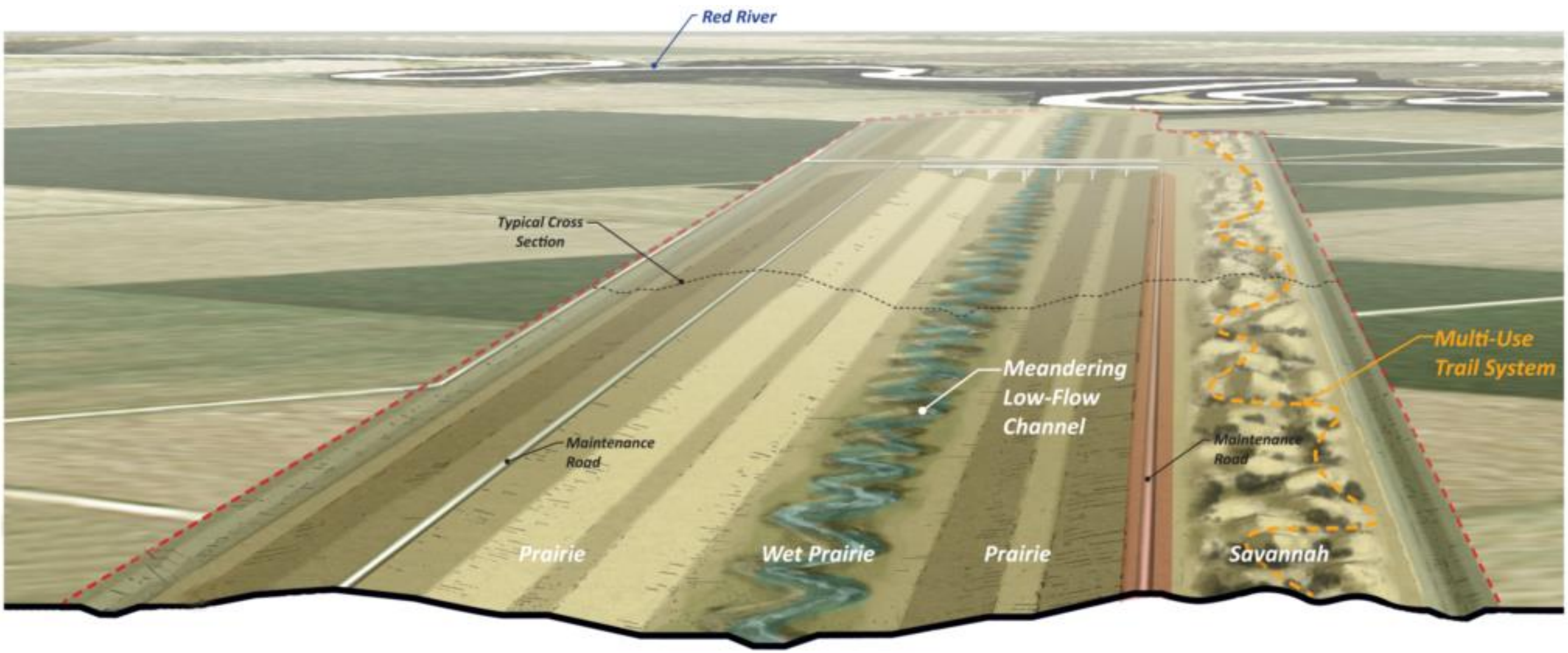
how to use the results?

- RVR Meander model can be applied to non-uniform initial planforms
- The model can be used as a tool by the design team to check the proposed planform for the Low-Flow Channel

methodology proposed

BARR

And used to "verify" Design Reach 1



lessons learned

- Team that effectively plans, decides and communicates
- Who is managing the message to the public and different stakeholders?
- Working for local sponsors allows for some "refreshing independence in professional judgment"
- Value based design charrettes offer an excellent opportunity for "project memory" transfer (how many people read reports?)
- Aggressive schedule forced to make some big assumptions (using "imperfect" information) … which will have to be revisited before final design
- Importance of local knowledge

value engineering – what was the (initial) outcome?

BARR

- A cost savings of $270 million
- FY12 Value Engineering Savings from proposals incorporated into design as a percentage of the FMM Fully Funded Estimate at the initiation of PED is 15%
- The Return on Investment from implemented proposals from the three studies is 971:1
- Additional cost savings opportunities were identified (and some of them have been incorporated later in the process)

- After initial efforts, focus of VE efforts has shifted from cost savings or increased function to reduce risk (e.g., Fargo P3)