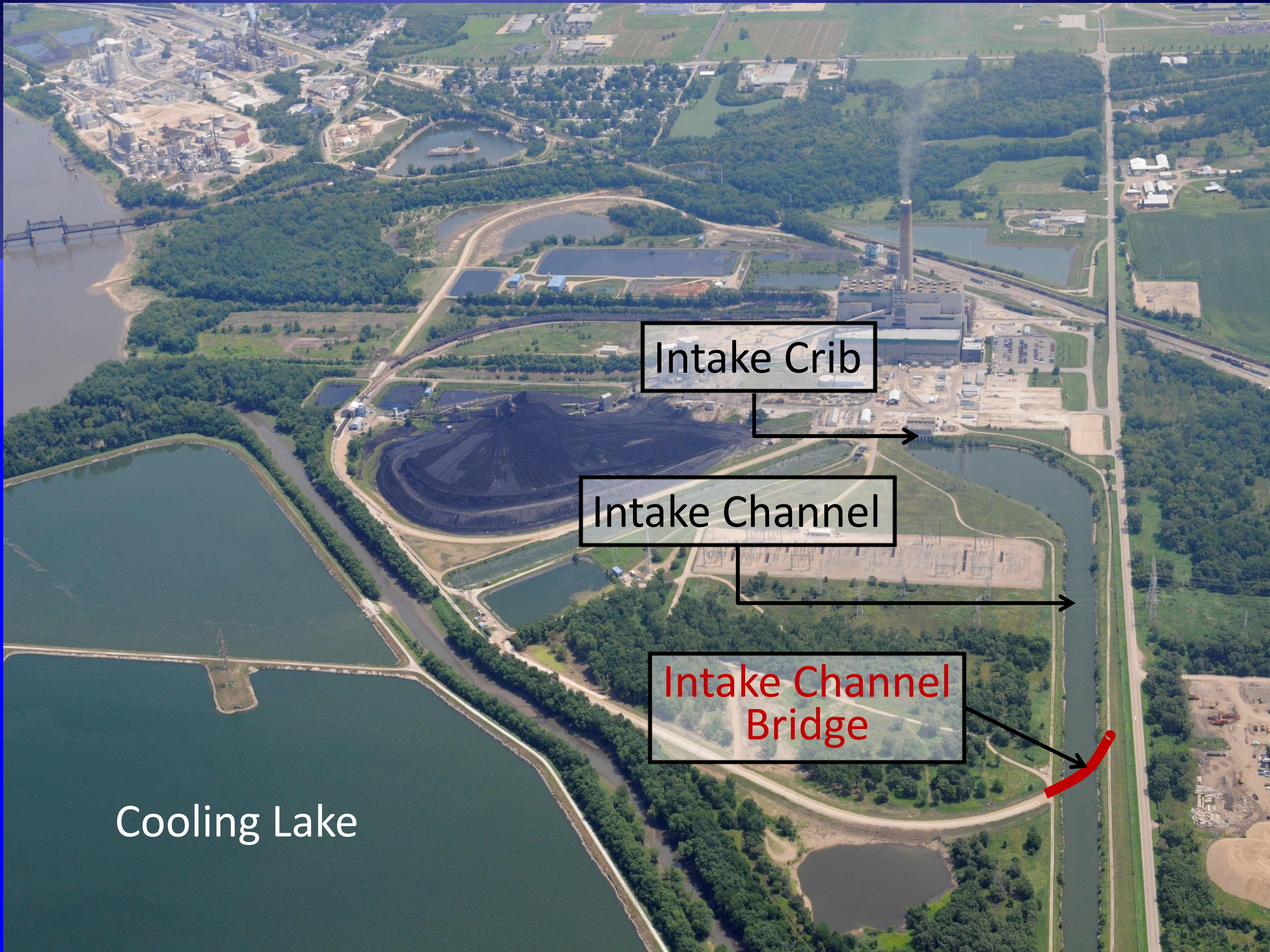
Adam D. James, P.E., CFM
Eric Y. Chow, P.E., CFM

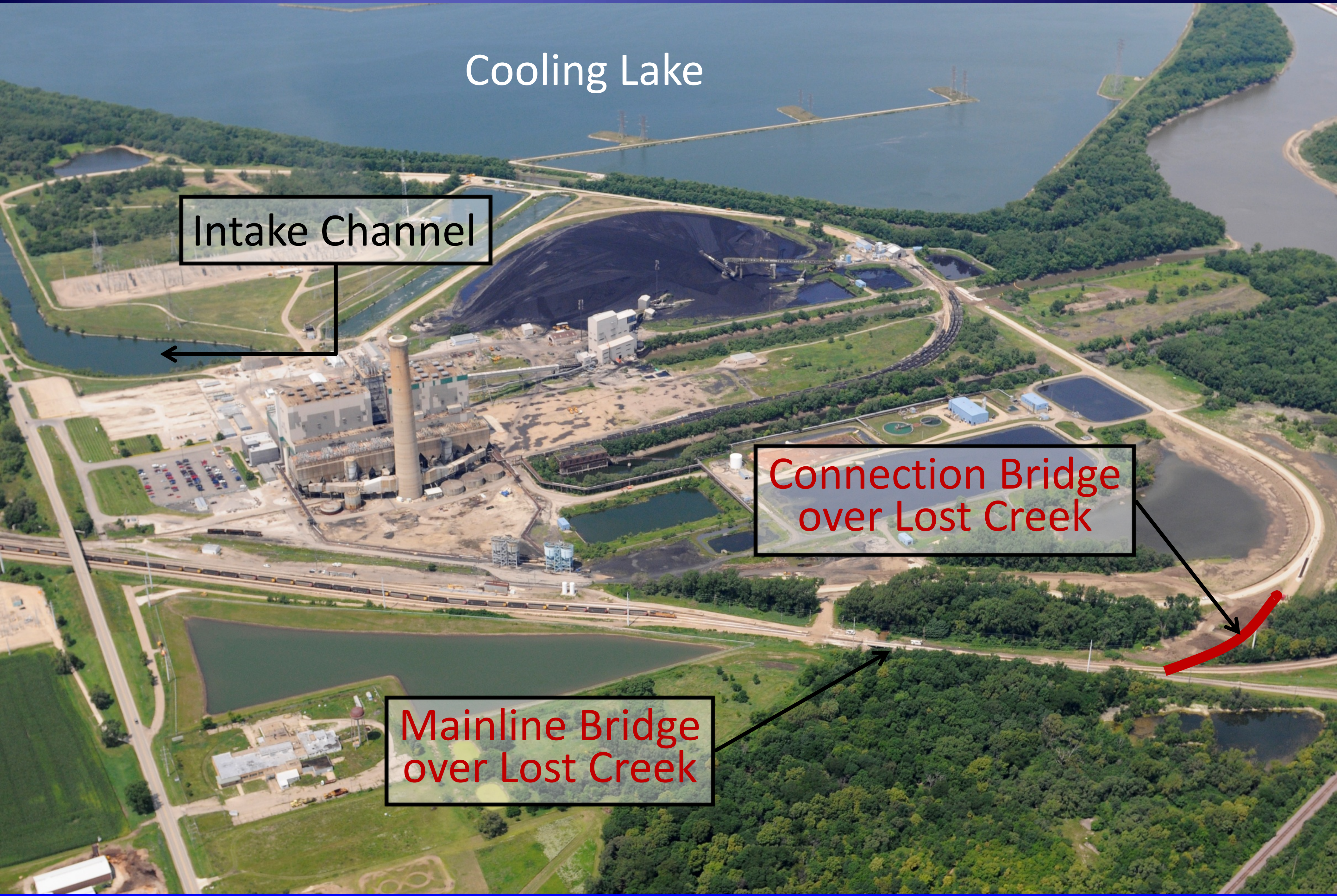
MODELING A ZERO SLOPE CHANNEL IN HEC-RAS; APPLICATION OF IDNR REGULATIONS TO CONCURRENT / CONTINGENT RAILROAD BRIDGE PERMITTING

PATRICK ENGINEERING

Background

- As part of upgrades to a coal-fired power plant, two new rail spurs were constructed:
  - One over an intake channel that conveys cooling water to the plant
  - One over Lost Creek


Intake Crib
Intake Channel
Intake Channel
Bridge
Cooling Lake


Cooling Lake
Intake Channel
Connection Bridge over Lost Creek
Mainline Bridge over Lost Creek

Modeling the Zero Slope Intake Channel

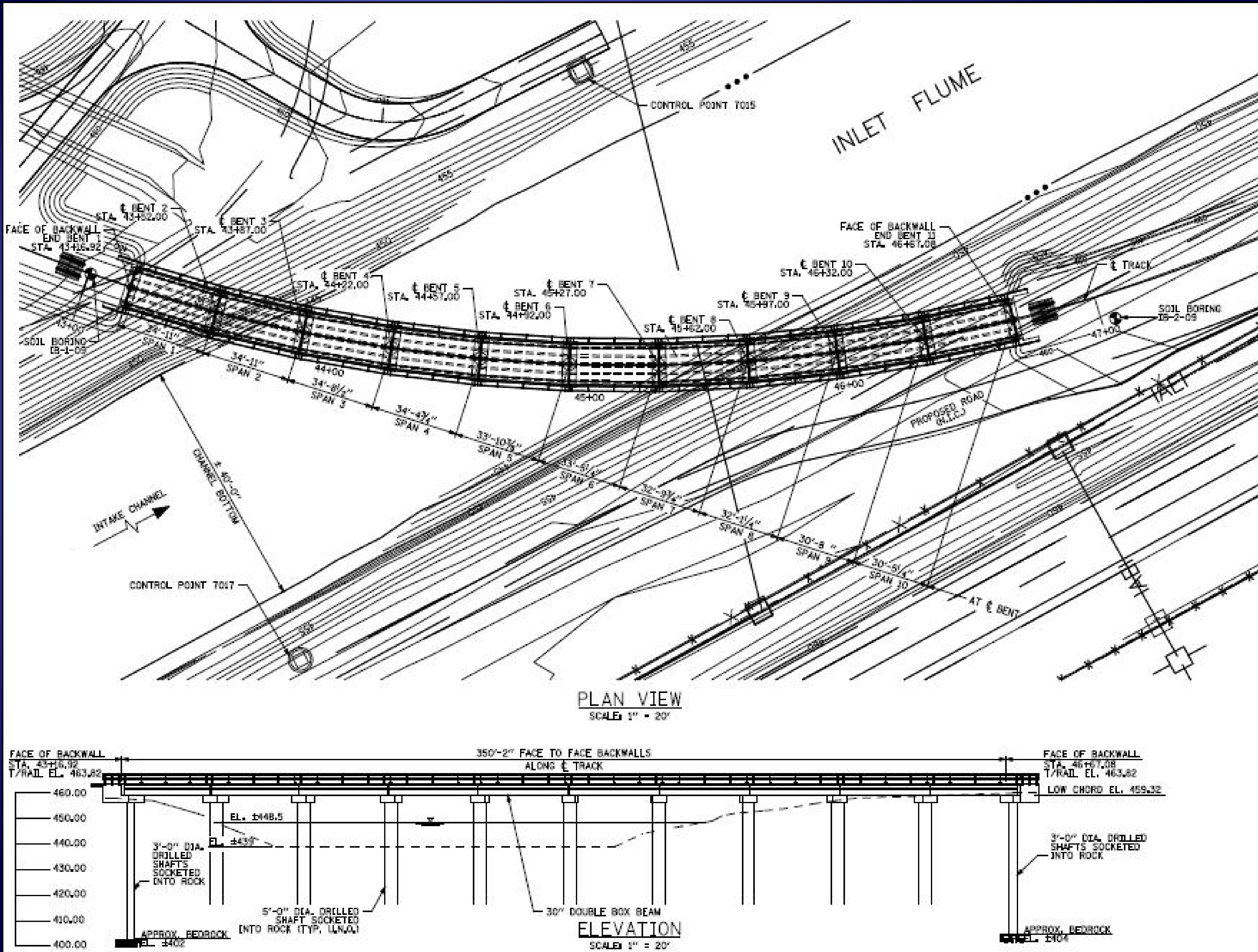
- HEC-RAS used to determine hydraulic impacts of proposed intake channel bridge
- Since channel bottom has zero slope, slope required to convey peak flow was calculated using Manning's equation.
  - $Q = 1.486 / n * A * R^{2/3} * S^{1/2}$
- Channel geometry was known from design plans
- Water surface elevation/depth at bridge location known from survey
- Peak flow taken from information on pumps in crib house

PATRICK ENGINEERING

Model Calibration

- Water surface data at cooling lake and intake crib was provided by plant operator for various pumping rates (discharges)
- Using theoretical channel slope from Manning's equation, drop in water surface between cooling lake and intake crib was estimated
- For peak flow, observed elevation differences from plant records correlated well with predicted drop
- Therefore method employed to back calculate theoretical channel slope proved valid
- Slope calculated using Manning's was then used in HEC-RAS to calculate head created by proposed bridge

PATRICK ENGINEERING

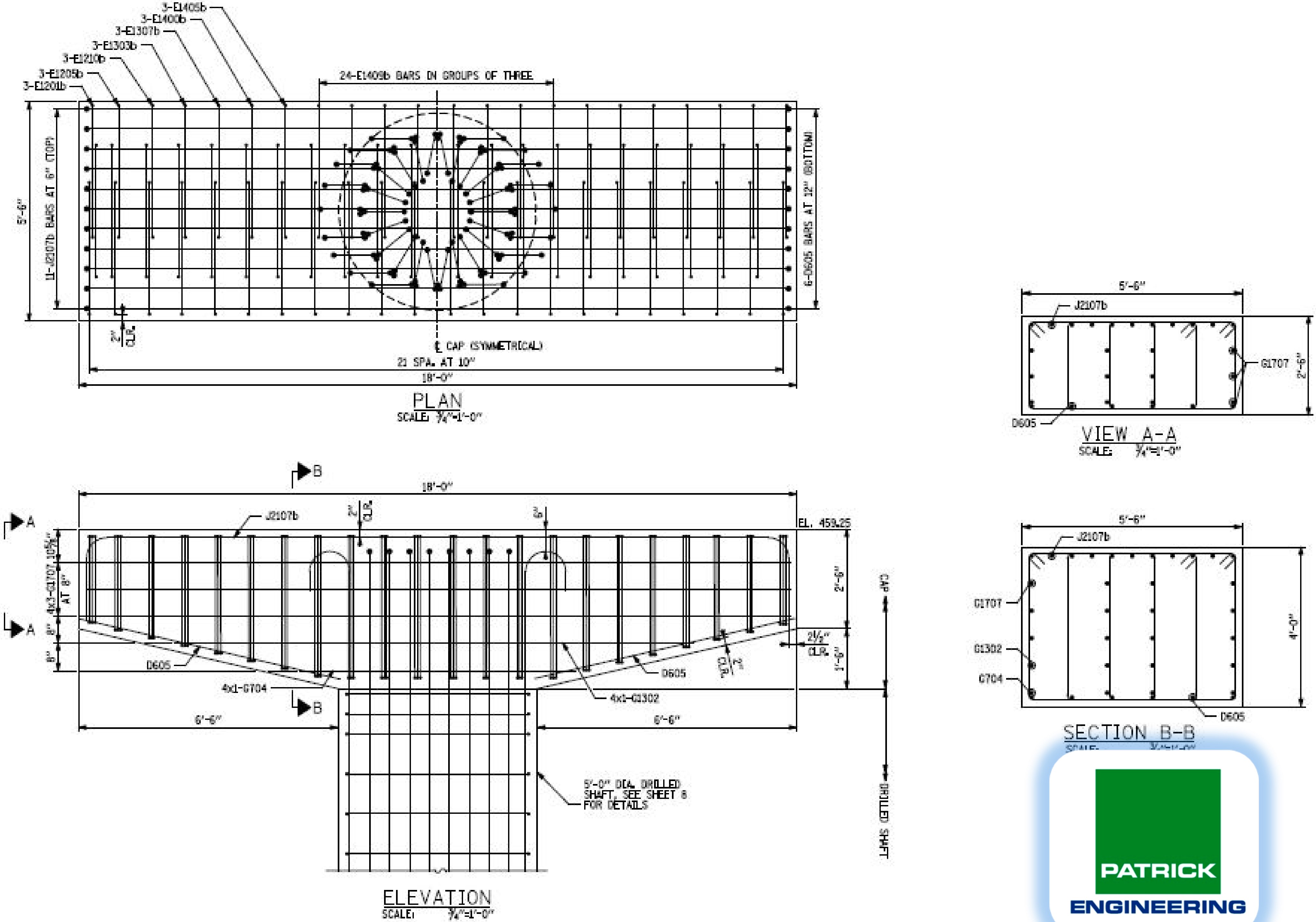


INLET FLUME
CONTROL POINT 7015
FACE OF BACKWALL
END BENT 1
STA. 43+16.92
℄ BENT 2
STA. 43+52.00
℄ BENT 3
STA. 43+87.00
℄ BENT 4
STA. 44+22.00
℄ BENT 5
STA. 44+57.00
℄ BENT 6
STA. 44+92.00
℄ BENT 7
STA. 45+27.00
℄ BENT 8
STA. 45+62.00
℄ BENT 9
STA. 45+97.00
℄ BENT 10
STA. 46+32.00
FACE OF BACKWALL
END BENT 11
STA. 46+67.08
℄ TRACK
SOIL BORING
B-2-09
SOIL BORING
B-1-09
SPAN 1
34'-11"
SPAN 2
34'-8¼"
SPAN 3
34'-4¾"
SPAN 4
33'-10¾"
SPAN 5
33'-5¼"
SPAN 6
32'-9¾"
SPAN 7
32'-1¼"
SPAN 8
30'-8"
SPAN 9
30'-5¼"
SPAN 10
AT ℄ BENT
44+00
45+00
46+00
47+00
PROPOSED ROAD (N.I.C.)
± 40'-0" CHANNEL BOTTOM
INTAKE CHANNEL
CONTROL POINT 7017
PLAN VIEW
SCALE: 1" = 20'
FACE OF BACKWALL
STA. 43+16.92
T/RAIL EL. 463.82
350'-2" FACE TO FACE BACKWALLS
ALONG ℄ TRACK
FACE OF BACKWALL
STA. 46+67.08
T/RAIL EL. 463.82
LOW CHORD EL. 459.32
460.00
450.00
440.00
430.00
420.00
410.00
400.00
EL. ±448.5
EL. ±439
3'-0" DIA. DRILLED SHAFTS SOCKETED INTO ROCK
3'-0" DIA. DRILLED SHAFTS SOCKETED INTO ROCK
5'-0" DIA. DRILLED SHAFT SOCKETED INTO ROCK (TYP. U.N.O.)
30" DOUBLE BOX BEAM
APPROX. BEDROCK EL. ±402
APPROX. BEDROCK EL. ±404
ELEVATION
SCALE: 1" = 20'

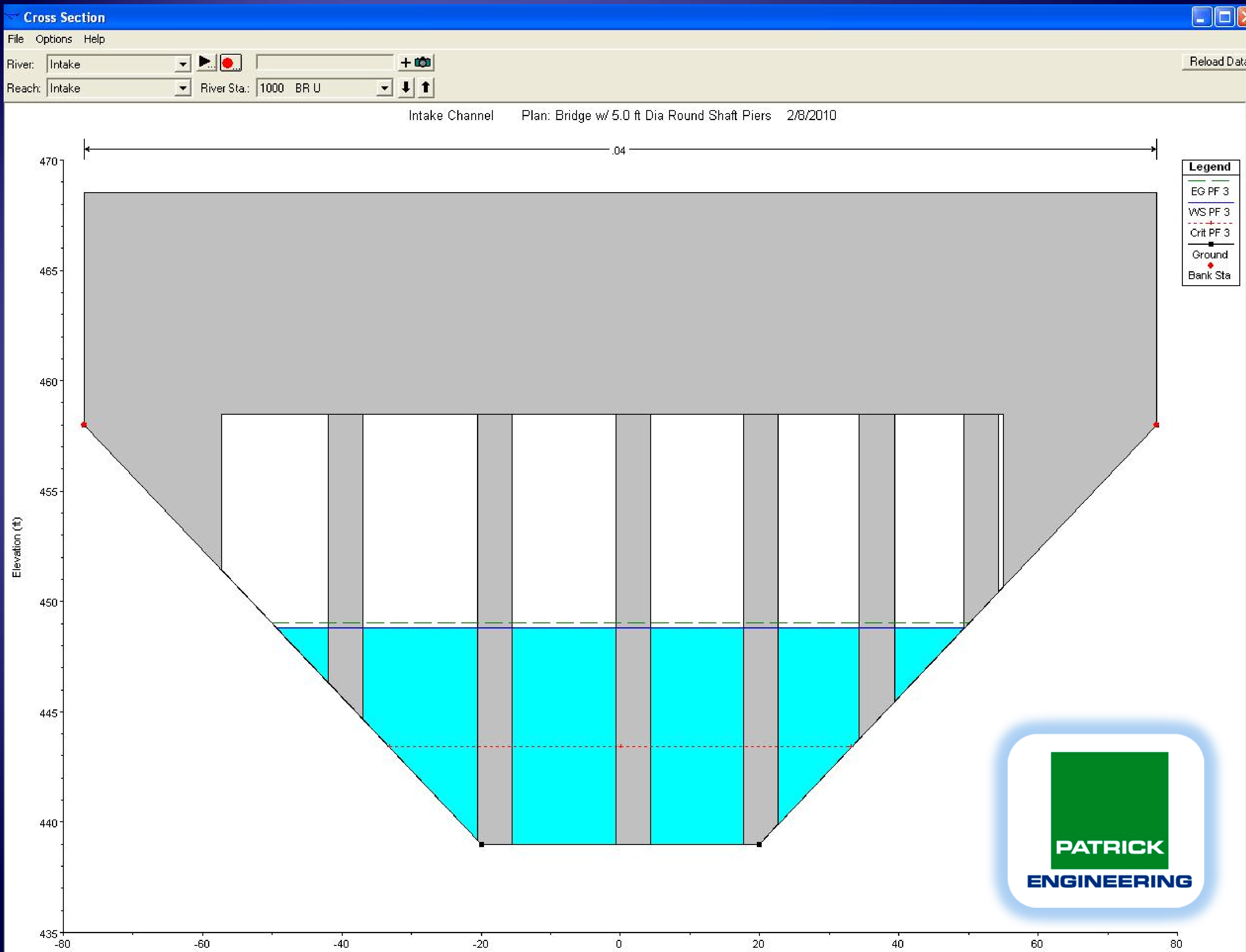
Modeling the Skewed Bridge

- Since bridge is skewed to channel, contemplated whether to skew bridge and adjacent sections. This approach did not seem correct given trapezoidal channel geometry
- Also considered turning cross sections at bridge to be parallel/tangent to bridge but results were very suspect
- Eventually piers designed to have single round shaft so bridge modeled as perpendicular to channel, but pier projection used to establish pier stations

PATRICK ENGINEERING



PATRICK ENGINEERING



Cross Section
File Options Help
River: Intake
Reach: Intake
River Sta.: 1000 BR U
Reload Data
Intake Channel Plan: Bridge w/ 5.0 ft Dia Round Shaft Piers 2/8/2010
.04
Legend
EG PF 3
WS PF 3
Crit PF 3
Ground
Bank Sta
Elevation (ft)
470
465
460
455
450
445
440
435
-80
-60
-40
-20
0
20
40
60
80
PATRICK
ENGINEERING

Intake Channel

Looking Upstream from Near Crib House

Suction Induced Flow

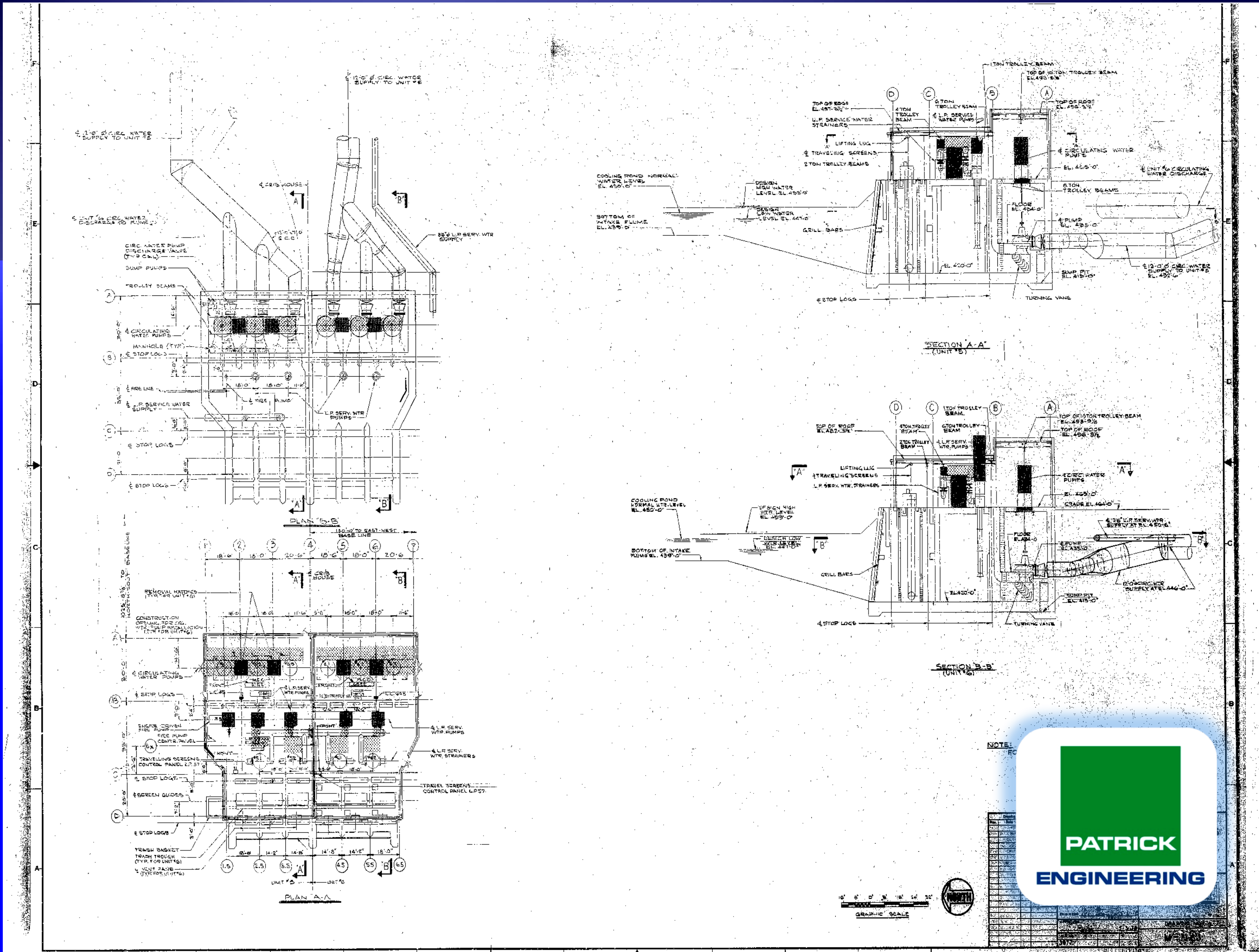
- Since flow in channel is actually suction induced (by pumps at the downstream end of channel), head created by bridge actually represents lowering of water at downstream end of channel /crib house

PATRICK ENGINEERING

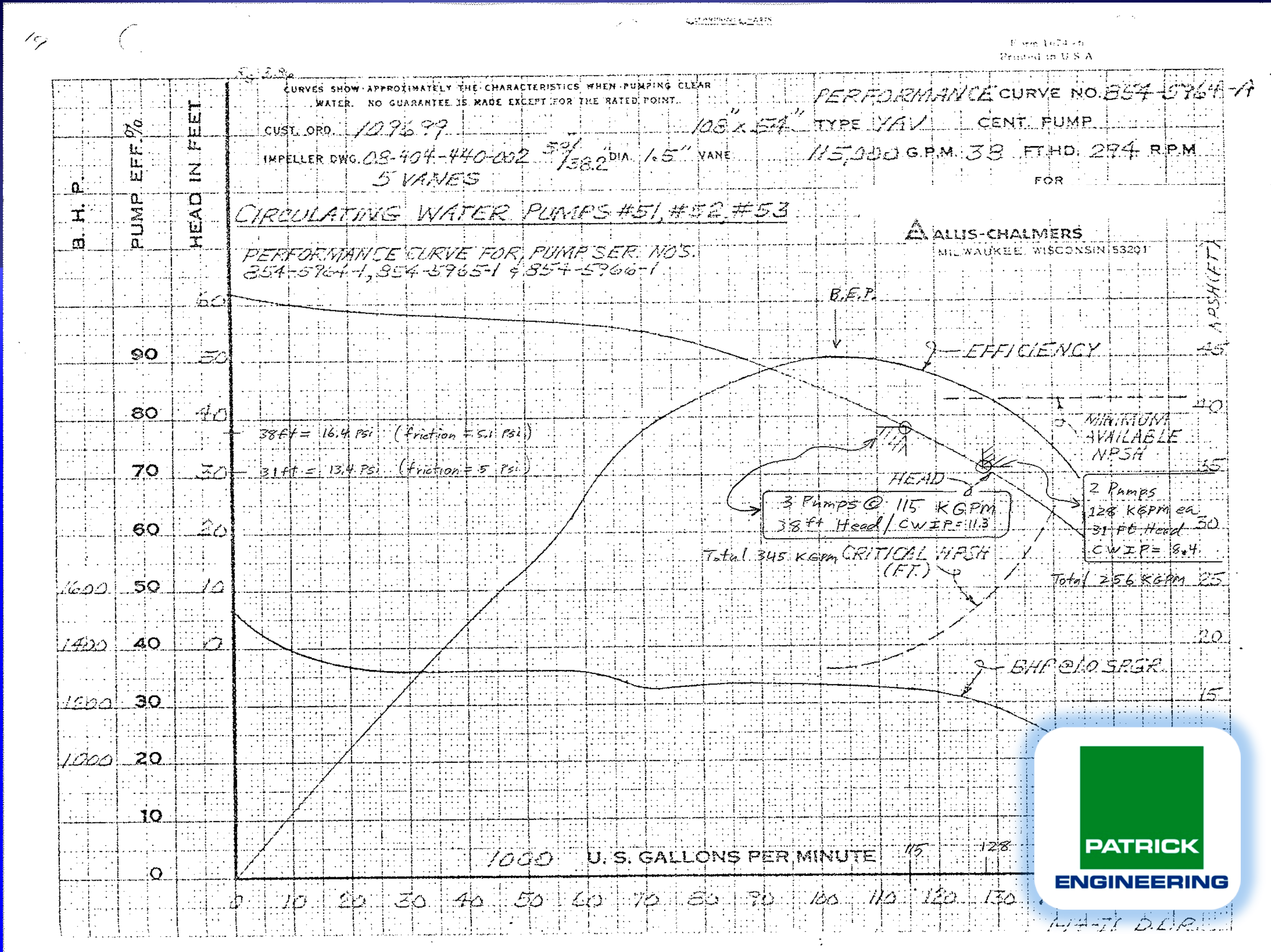
Effects on Pumps

- Effects on Net Positive Suction Head (NPSH) and associated margin ratios were calculated to ensure risk of cavitation not significantly increased
  - $NPSH = P_{atm/}\gamma - P_{vapor}/\gamma + \Delta Z - h_{fs}$
  - NPSH Margin Ratio = $NPSH_A$ / $NPSH_R$
- Lower water surface elevation meant reduction in submergence, therefore submergence checked
- Reduced water depth translated to increase in static head, corresponding reductions in discharges from pumps estimated from pump curves
- This information provided to plant operators to assess economic impacts of reduced pumping rates

PATRICK ENGINEERING

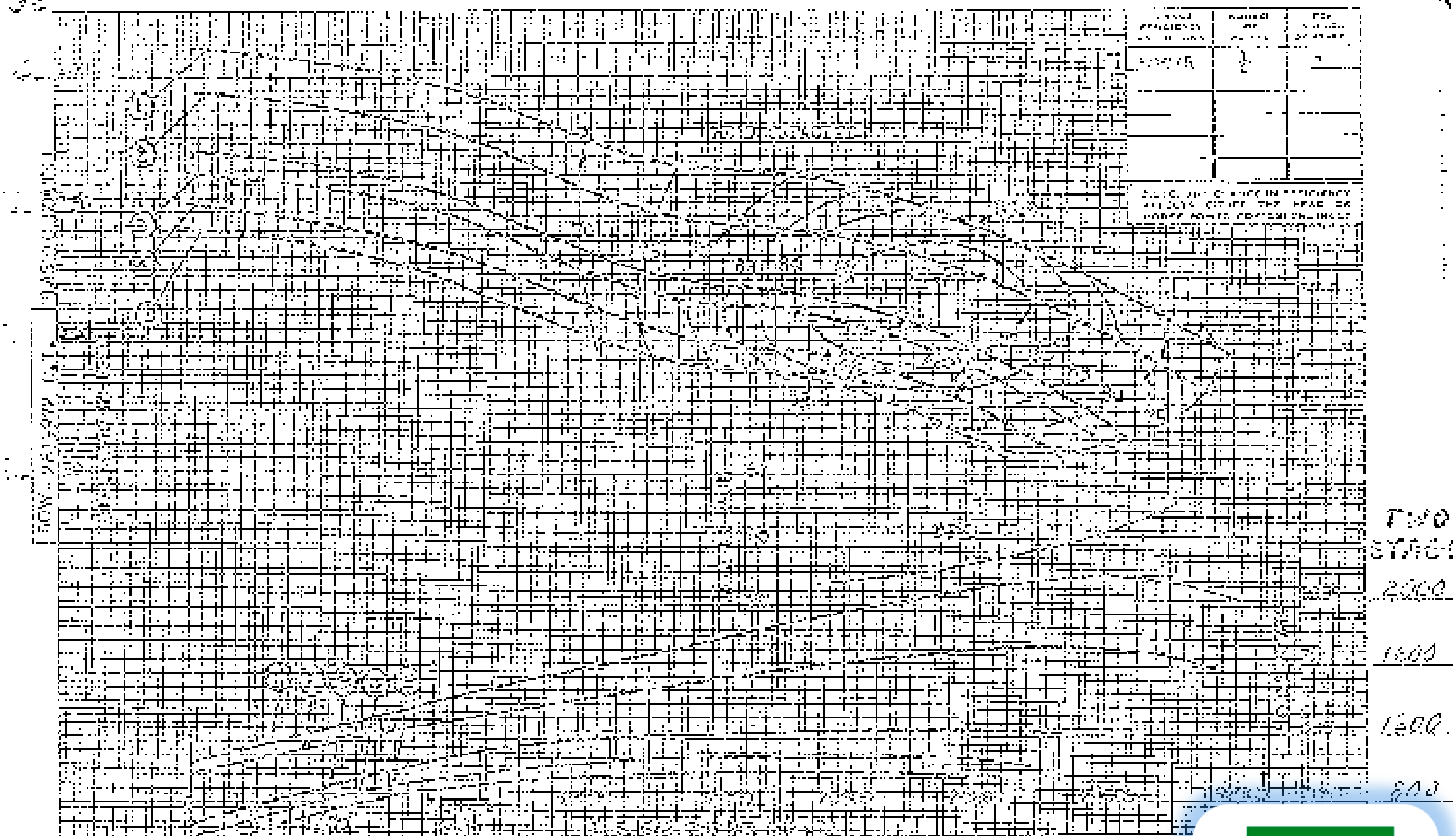


PATRICK
ENGINEERING



CURVES SHOW APPROXIMATELY THE CHARACTERISTICS WHEN PUMPING CLEAR WATER. NO GUARANTEE IS MADE EXCEPT FOR THE RATED POINT.
PERFORMANCE CURVE NO. 854-5764-A
CUST. ORD. 109699
108" x 54" TYPE YAV CENT. PUMP
IMPELLER DWG. 08-404-440-002
DIA. 1.5" VANE
115,000 G.P.M. 38 FT. HD. 294 R.P.M.
FOR
5 VANES
CIRCULATING WATER PUMPS #51, #52, #53
ALLIS-CHALMERS
MILWAUKEE, WISCONSIN 53201
PERFORMANCE CURVE FOR PUMP SER. NO'S.
854-5964-1, 854-5965-1 & 854-5966-1
B. H. P.
PUMP EFF. %
HEAD IN FEET
B.E.P.
EFFICIENCY
MINIMUM AVAILABLE NPSH
38 ft = 16.4 psi (friction = 5.1 psi)
31 ft = 13.4 psi (friction = 5 psi)
HEAD
3 Pumps @ 115 KGPM
38 ft Head / CWIP = 11.3
2 Pumps
128 KGPM ea
31 Ft Head
CWIP = 8.4
Total 345 KGPM
CRITICAL NPSH (FT.)
Total 256 KGPM
BHP @ 1.0 SP.GR.
U. S. GALLONS PER MINUTE
1000
NPSH (FT)

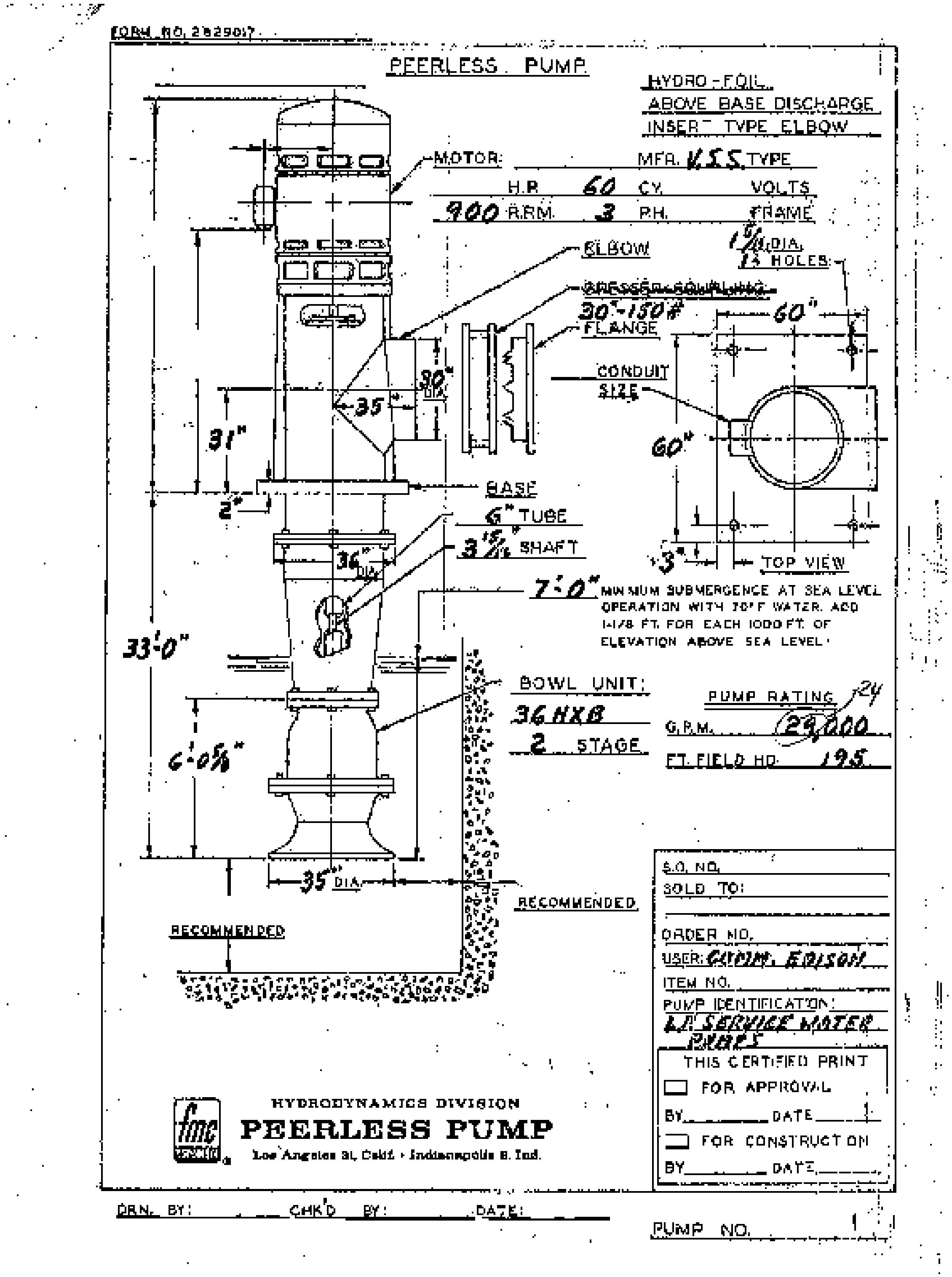
COMMONWEALTH EDISON LR SERVICE WATER PUMPS
CAPACITY 24,000 GPM HEAD 192 FT EFF 86% SEP 1976



CURVE NO.	IMPELLER NO.	IMPELLER DIA.	TAKEN FROM
1	2620660	27-7/16 x 28-13/16	36722
2	2620664	26-5/32 x 27-23/32	36756
3	2620664	24-7/32 x 25-13/16	36765
4	2620664	23-7/32 x 24-13/16	36655

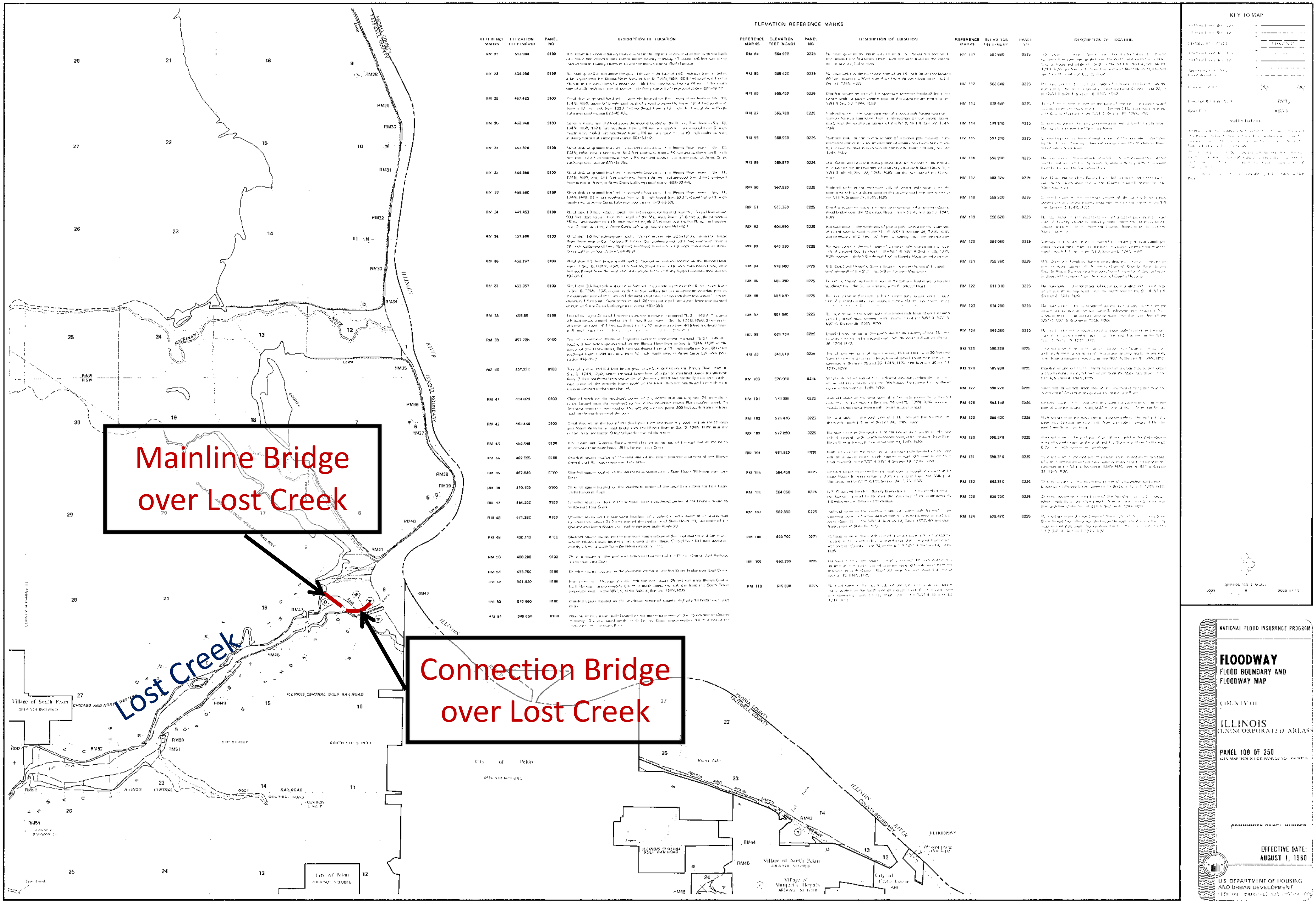
PEERLESS PUMP

PATRICK ENGINEERING

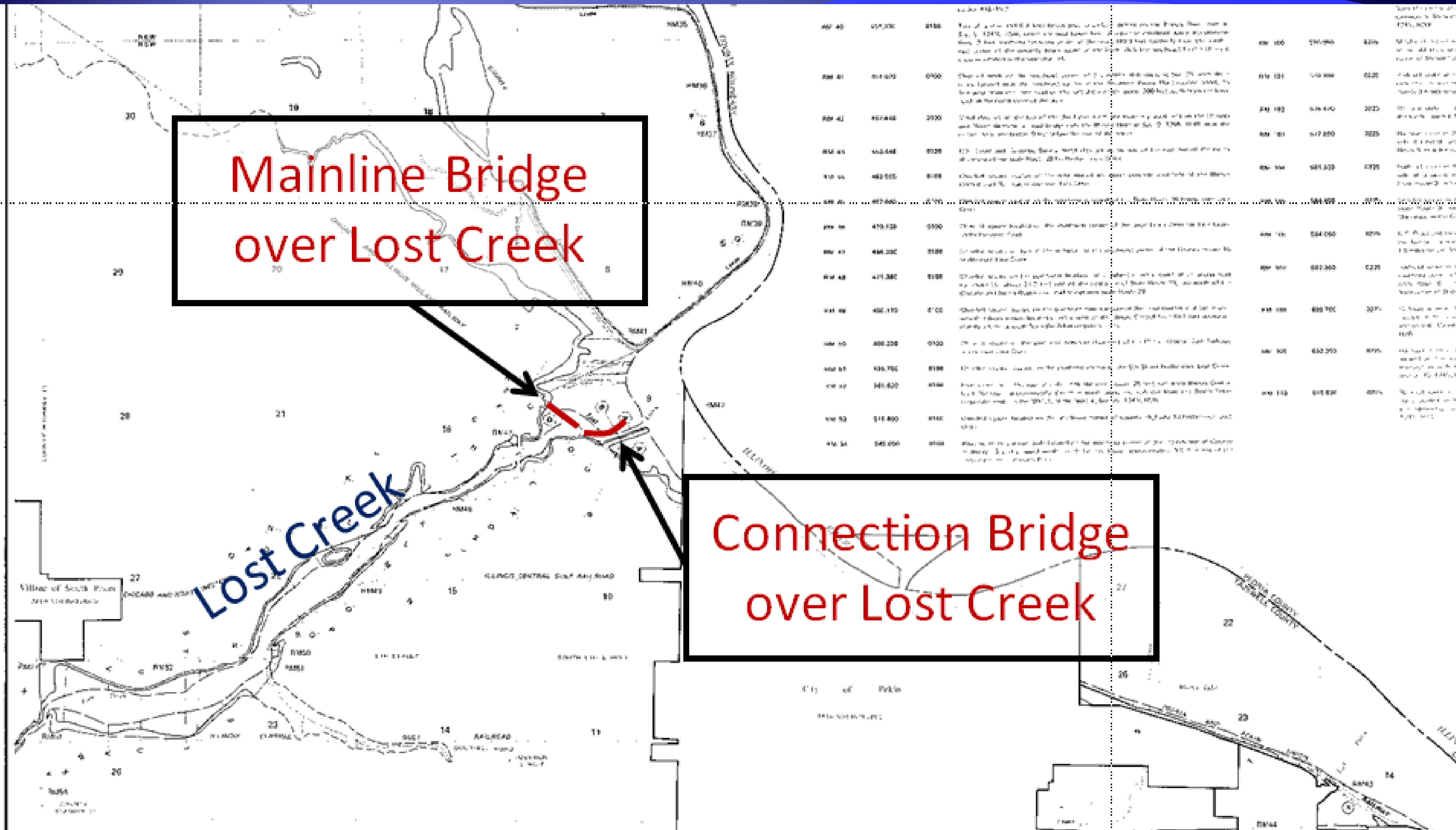


PATRICK ENGINEERING

Lost Creek Bridges



Mainline Bridge over Lost Creek
Connection Bridge over Lost Creek
Lost Creek
ELEVATION REFERENCE MARKS
KEY TO MAP
NATIONAL FLOOD INSURANCE PROGRAM
FLOODWAY
FLOOD BOUNDARY AND FLOODWAY MAP
COUNTY OF
ILLINOIS
PANEL 100 OF 250
EFFECTIVE DATE: AUGUST 1, 1980
U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT



Mainline Bridge
over Lost Creek
Connection Bridge
over Lost Creek
Lost Creek

The Lost Creek Bridge

- New bridge over Lost Creek 900’ downstream of existing, restrictive mainline railroad bridge.
- IDNR Part 3700 Rules Applied (Increase up to 1.0’ at structure and 0.5’ 1000’ upstream).
- Additionally IDNR would not allow any additional created head upstream of the existing mainline railroad bridge resulting from construction of a new bridge.

PATRICK ENGINEERING

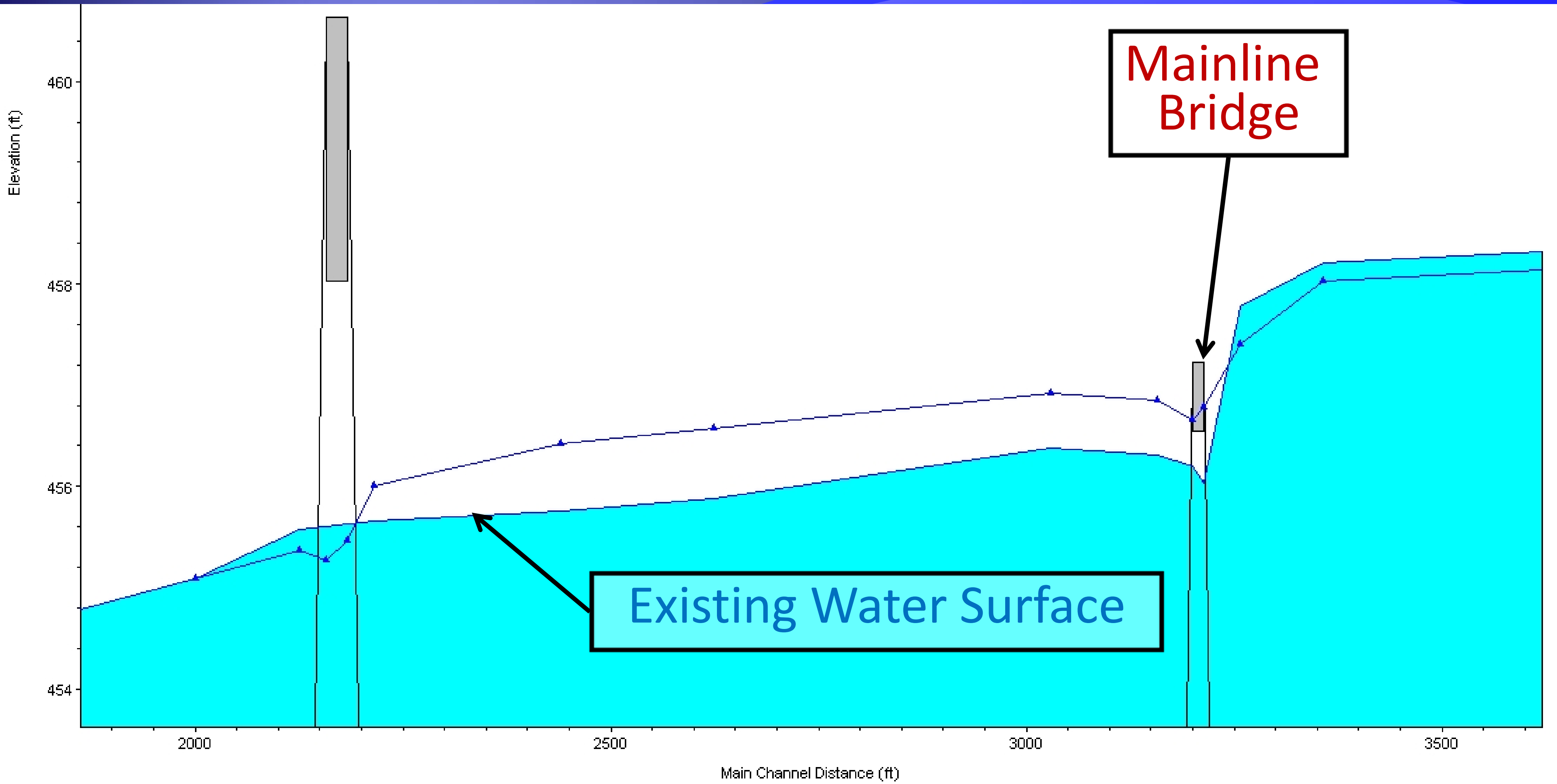
Old Mainline Bridge

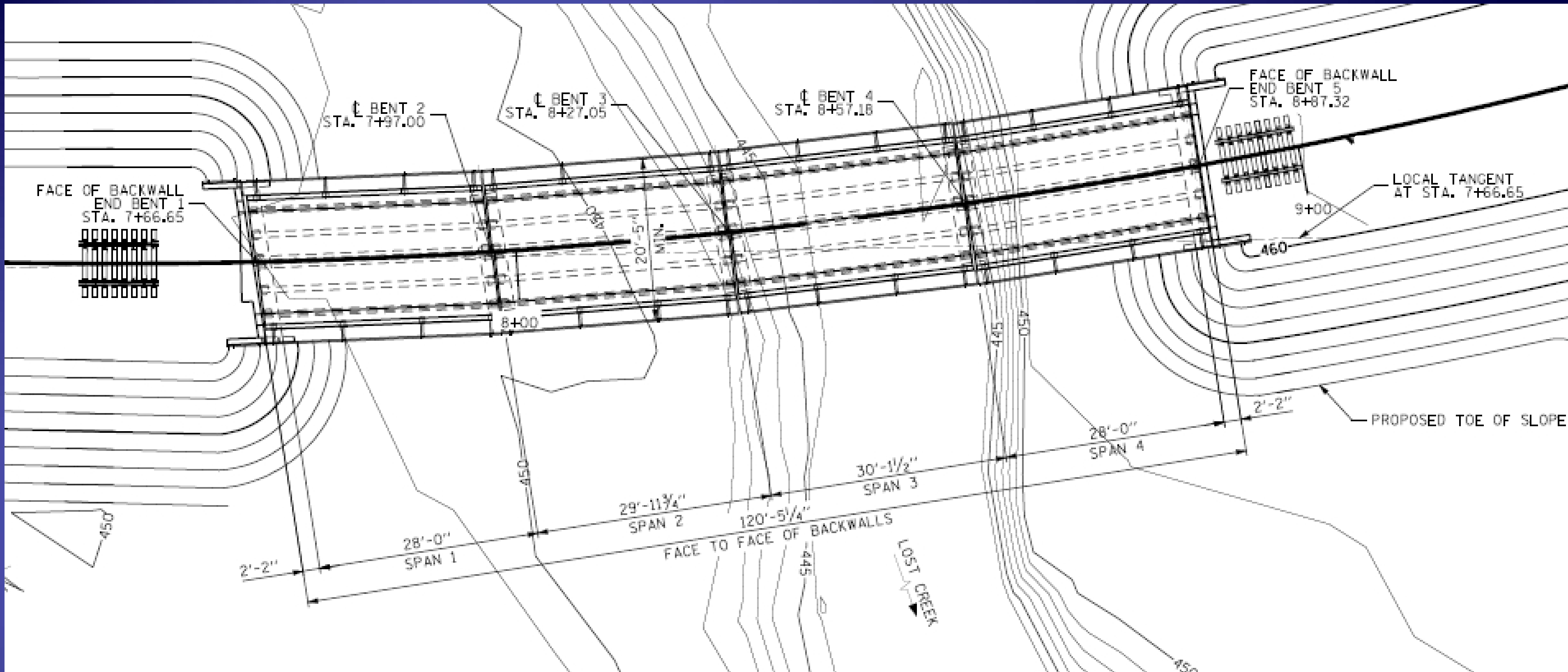
Additional Complications

- The owner of the existing mainline railroad bridge was planning on replacing their bridge.
- Under the 3700 Rules, existing mainline bridge could be replaced with a structure just as restrictive as the existing bridge. The existing bridge was "using up" all of our client's allowable created head and as a result they effectively could not construct a new bridge.

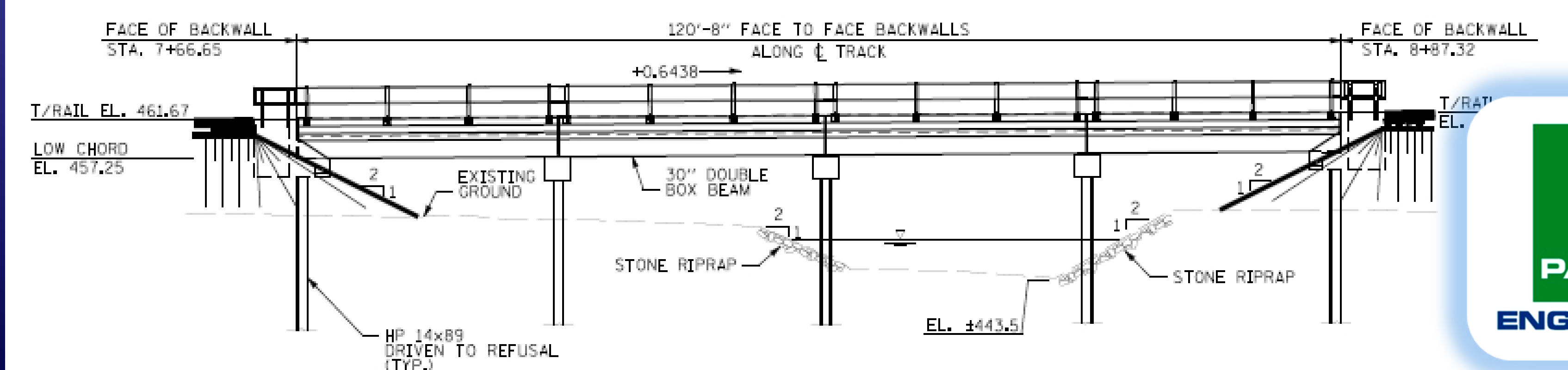
Section 3700.70 Special Provisions for Bridges and Culverts
b) General Standards for Bridge and Culvert Reconstruction
A bridge or culvert reconstruction project which would meet the following provisions will be permissible. A reconstruction project which would not meet these provisions must comply with the general standards for new bridges and culverts.
1) **The reconstruction (including approach roads) shall be no more restrictive to normal and flood flows than the existing bridge or culvert crossing**; and

- The new bridge is slightly skewed: Pier projections were modeled in HEC-RAS.


Mainline Bridge
Existing Water Surface
Elevation (ft)
460
458
456
454
2000
2500
3000
3500
Main Channel Distance (ft)

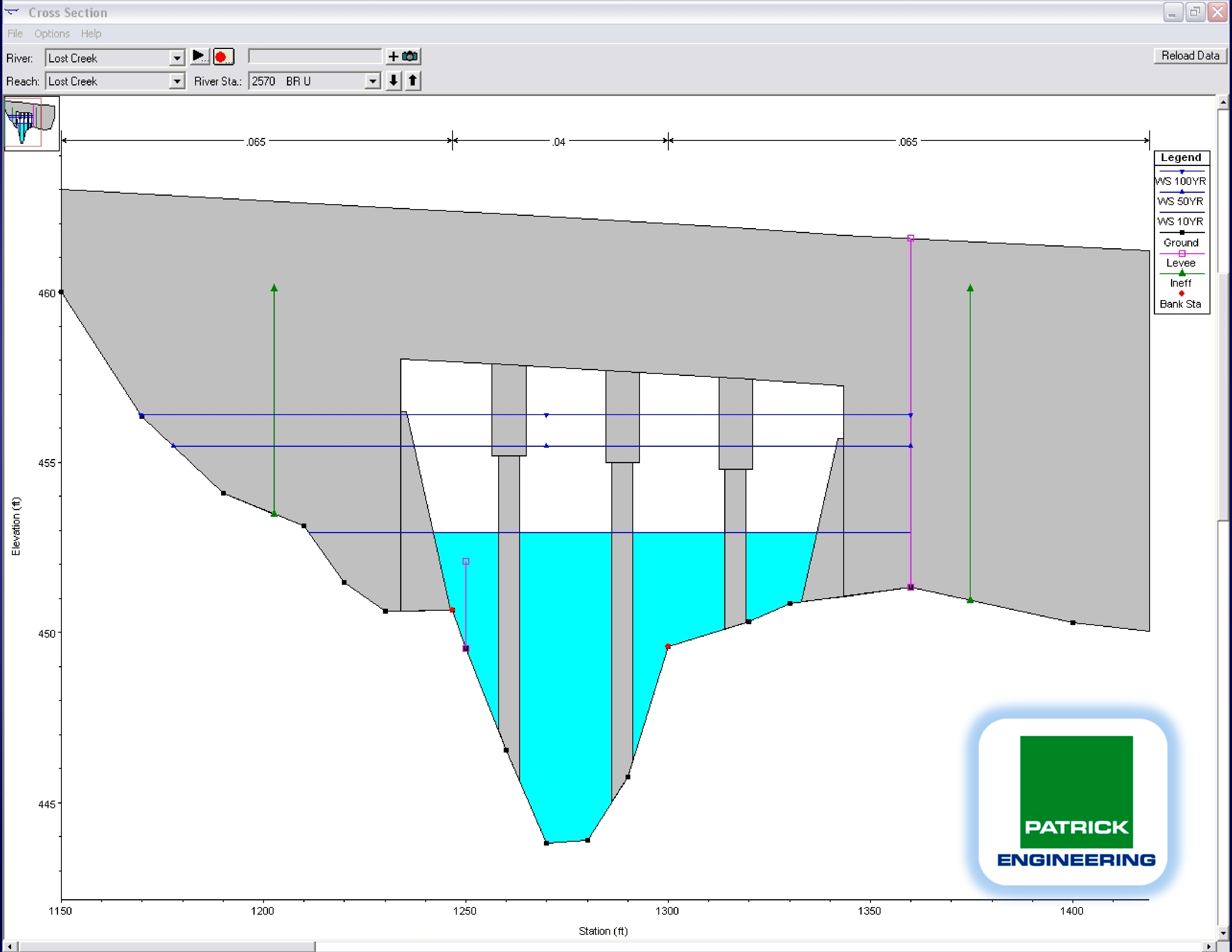


PLAN
SCALE: 1" = 10'-0"

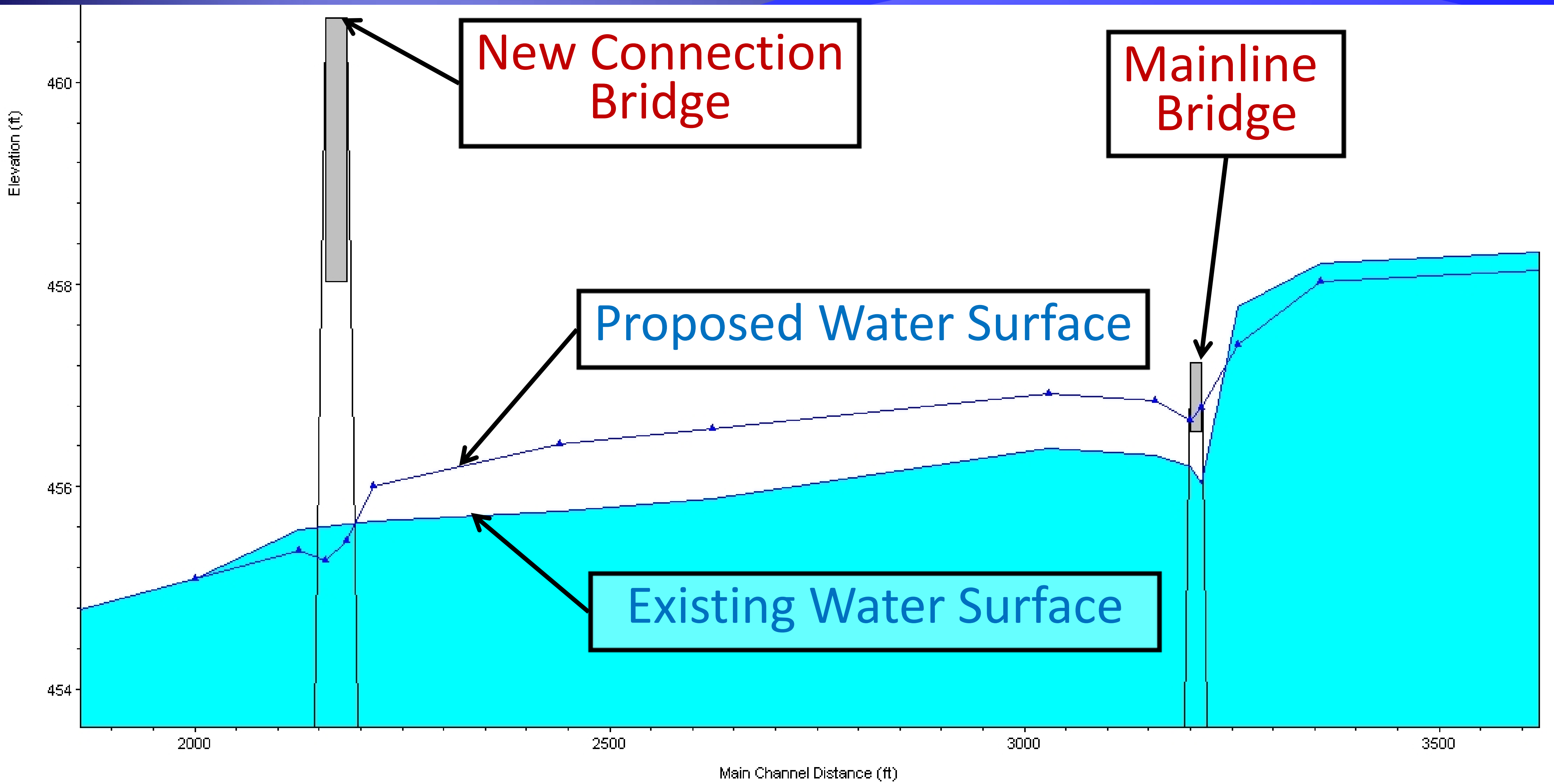


ELEVATION
SCALE: 1" = 10'-0"

PATRICK ENGINEERING



Cross Section
File Options Help
River: Lost Creek
Reach: Lost Creek
River Sta.: 2570 BR U
Reload Data
.065
.04
.065
Legend
WS 100YR
WS 50YR
WS 10YR
Ground
Levee
Ineff
Bank Sta
Elevation (ft)
460
455
450
445
1150
1200
1250
1300
1350
1400
Station (ft)
PATRICK ENGINEERING


New Connection Bridge
Mainline Bridge
Proposed Water Surface
Existing Water Surface
Elevation (ft)
460
458
456
454
2000
2500
3000
3500
Main Channel Distance (ft)

Success

- Unique opportunity:
  - Modifying the railroad's replacement bridge to make it less restrictive
  - Permitting the two bridges in tandem for no net increased flood elevations upstream of the existing bridge
- Patrick sized two bridges using an independent HEC-RAS model constructed from surveyed cross sections and flood insurance study discharges
- Successfully permitted the bridges with IDNR and both bridges were constructed in the second half of 2009

PATRICK ENGINEERING

New Mainline Bridge

PATRICK ENGINEERING

New Connection Bridge

Questions?

PATRICK
ENGINEERING