Box Culvert Design and Case Studies

Steve Smart
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Precast Structures

Fundamentals

Precast Structures: Fundamentals

American Concrete Pipe Association

Pipe

ASTM C76

4 Sided Box

ASTM C1577

3 Sided Box

ASTM C1504

Precast Structures: Fundamentals

American Concrete Pipe Association

Round

Elliptical

Arch

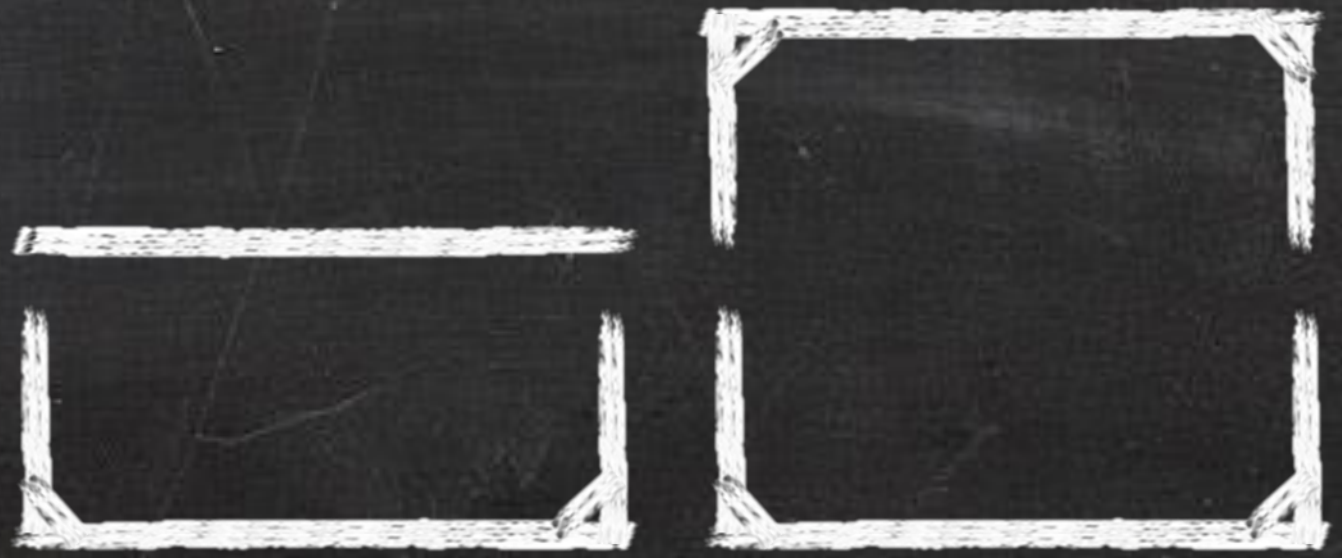
Precast Structures: Fundamentals

American Concrete Pipe Association

Monolithic

Box Culvert

4 Sided Box



Segmented

Clamshell

Splitbox Culvert

Precast Structures: Fundamentals

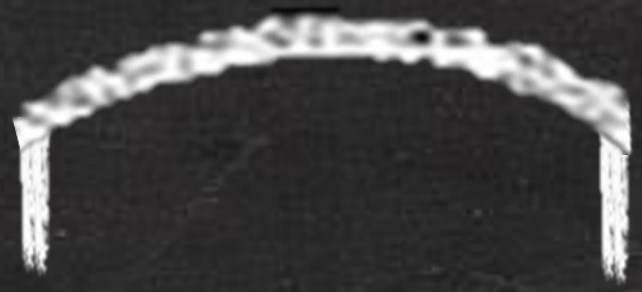
American Concrete Pipe Association

3 Sided Box

3 Sided Bridge
Flat Top Bridge
Concrete Frame

HySpan

3 Sided Bridge

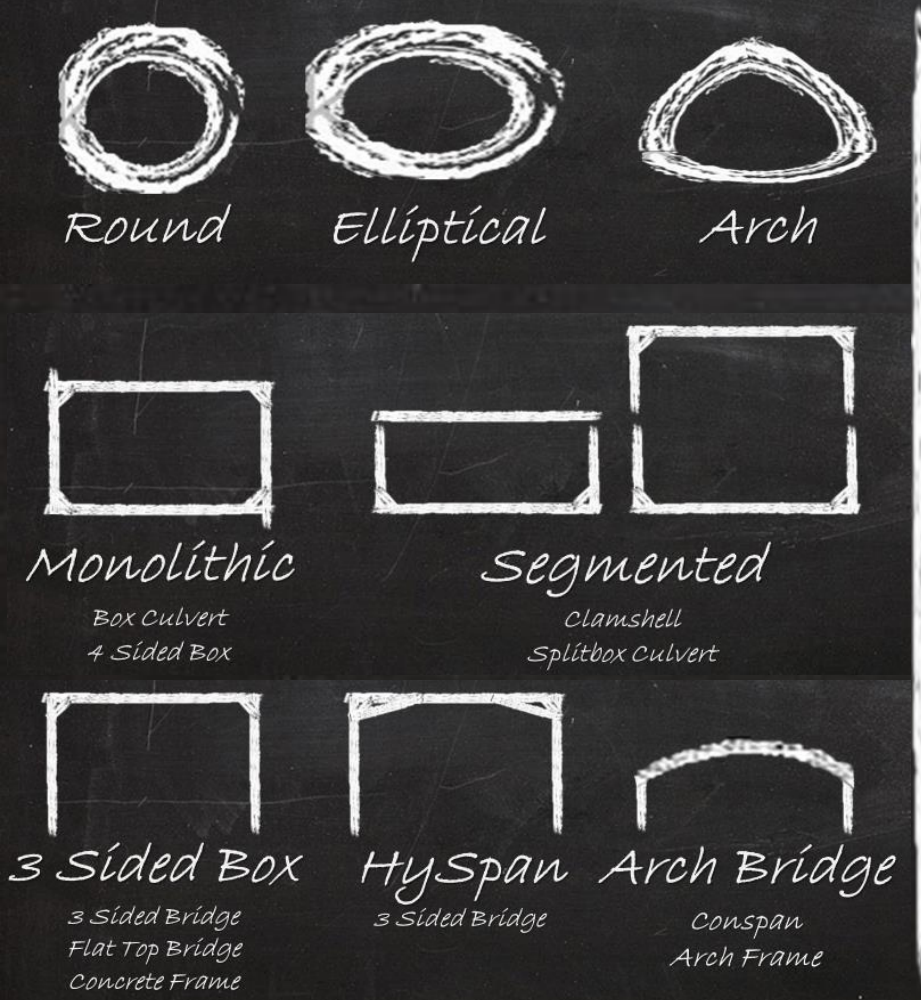


Arch Bridge

Arch Frame

Precast Structures: Fundamentals

American Concrete Pipe Association



Precast

vs

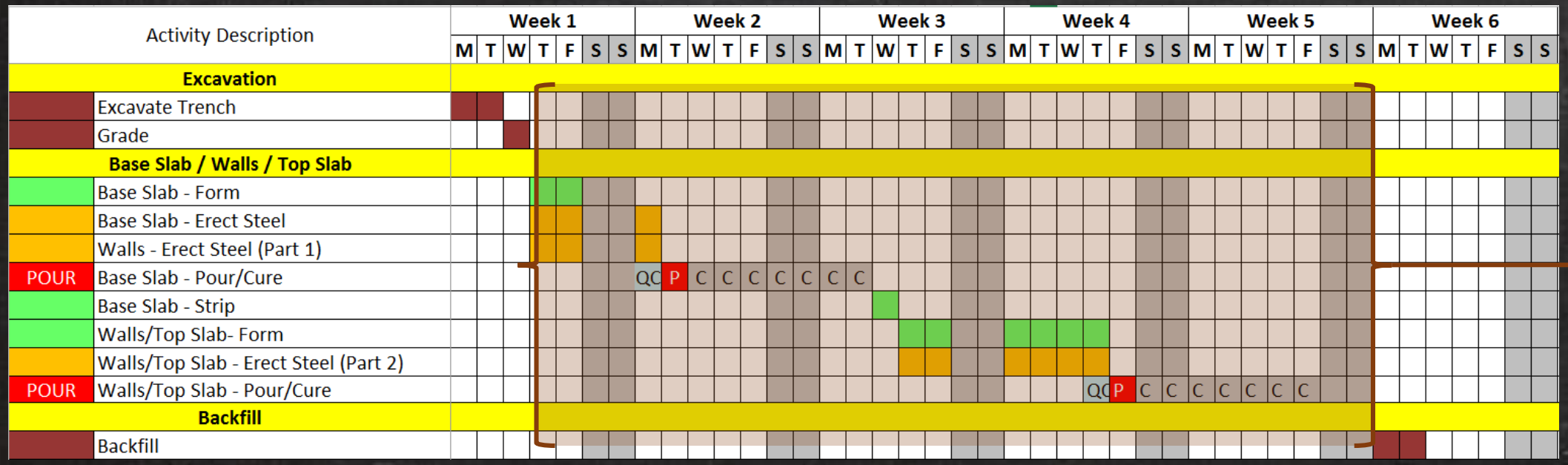
Cast-in-Place

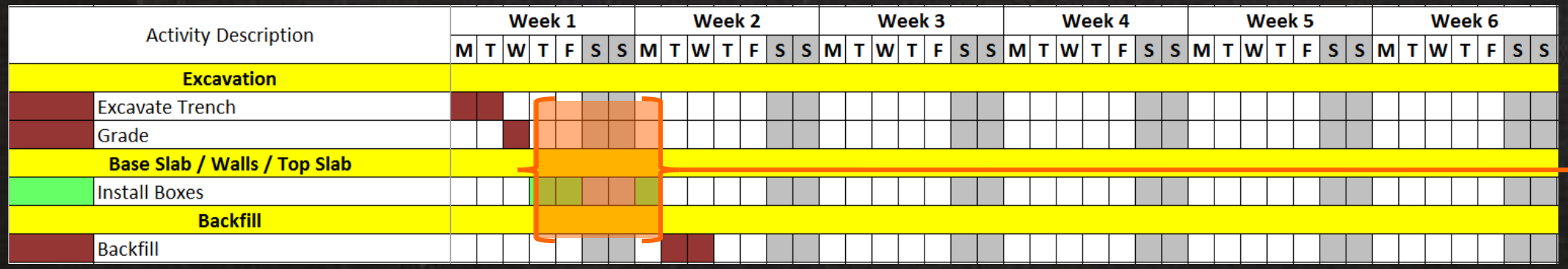
Precast Structures:

Precast vs Cast-in-Place

Precast Structures:

Precast vs Cast-in-Place





Precast Structures:

Precast	Vs	Cast-in-Place
• Products are fully cured before delivery		• Must reach 7 day strengths before stripping
• Backfill immediately		• Backfill only after reaching strengths
• Structure removed from critical path		• Form/steel/pour/cure/strip fully within critical path
• Cured in a controlled environment		• Pours are weather dependent
• In-plant QC		• Job site QC
• Decreased Traffic Risk		• Fabrication & Public safety concerns
• Accelerated project completion		• Standard completion times

Precast Structures:

Precast vs Cast-in-Place

Precast Structures:

Precast Vs Cast-in-Place

- Inspection
- Dimensions
- Reinforcement
- Climate
- Water/Cement Ratio

Precast Structures:

Precast Vs Cast-in-Place

- Agency approved in-plant Quality Control

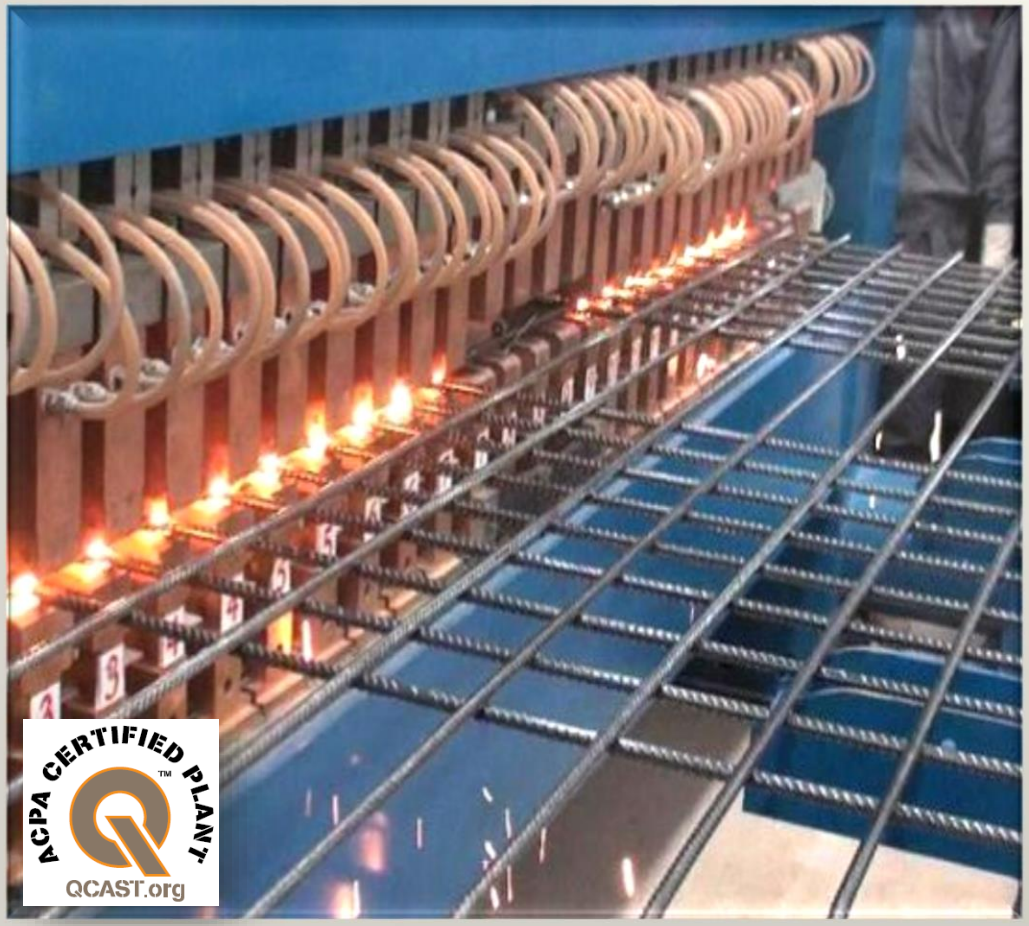
Precast Structures:

Precast Vs Cast-in-Place

- Consistent dimension tolerance

Precast Structures:

Precast vs Cast-in-Place



- Consistent engineered welded wire mesh – 65ksi min

Precast Structures:

Precast vs Cast-in-Place

- Weather resilient construction

Precast Structures:

Precast vs Cast-in-Place

- Consistent water/cement ratio

Precast Structures:

Precast Vs Cast-in-Place

Cast-in-place 8' Section of 8x8:

- 9.5"x8"x9.5" = 2.01 tons/ft

Precast 8' section of 8x8:

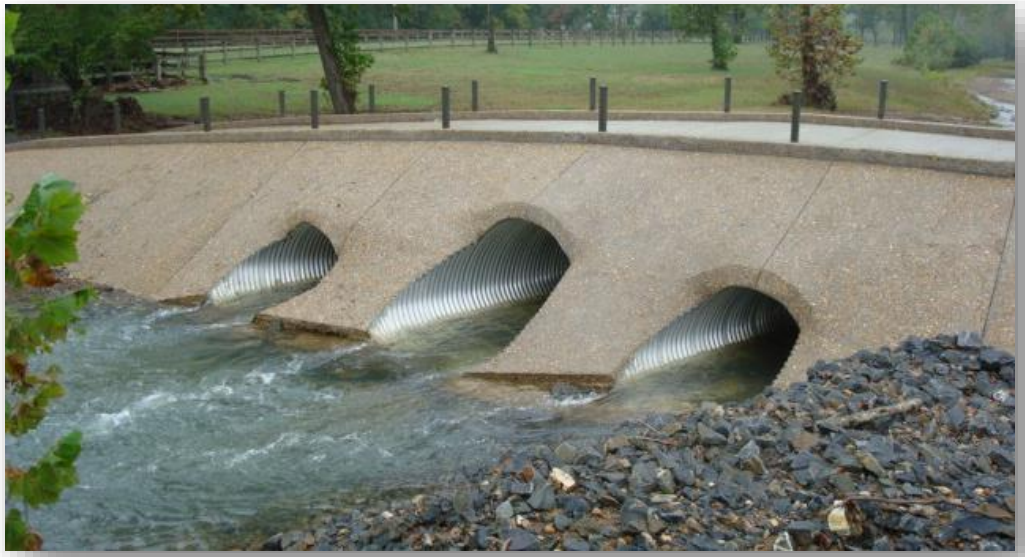
- 8"x8"x8" = 1.8 tons/ft

Special Design Precast 8' Section of 8x8:

- 8"x7"x7" = 1.63 tons/ft

Why Box Culverts?

- Improved hydraulic capacity
- Accelerated Construction
- Minimal cover requirements
- Resiliency of precast infrastructure
- Elimination of weather sensitivity



Why Box Culverts?

- Basic Box (C1577): 3x2 up to 12x12
- Custom sizes
- Multi-barrels
- Deep fill (up to 300 ft)
- Large Boxes

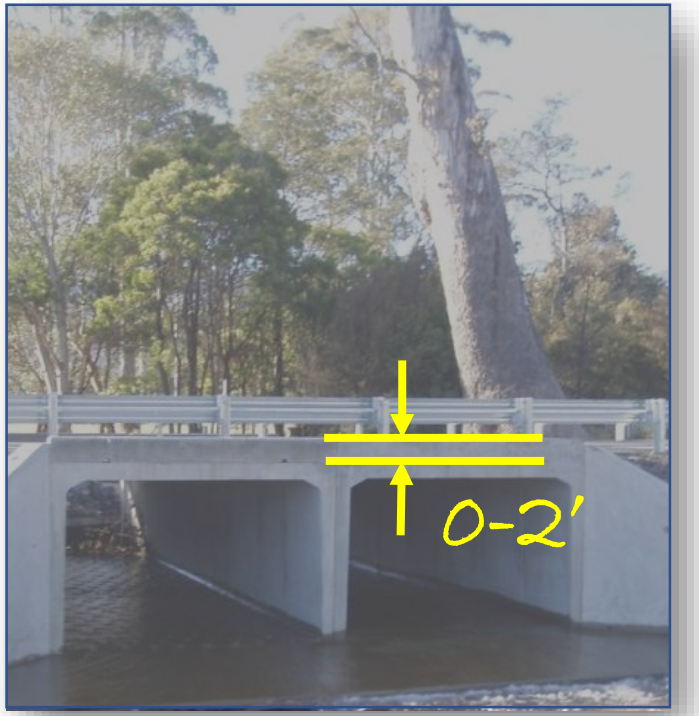
RCB Installation types:

Embankment

Trench

Jacked

Cover: 0-2’



AASHTO: M273
ASTM: C850

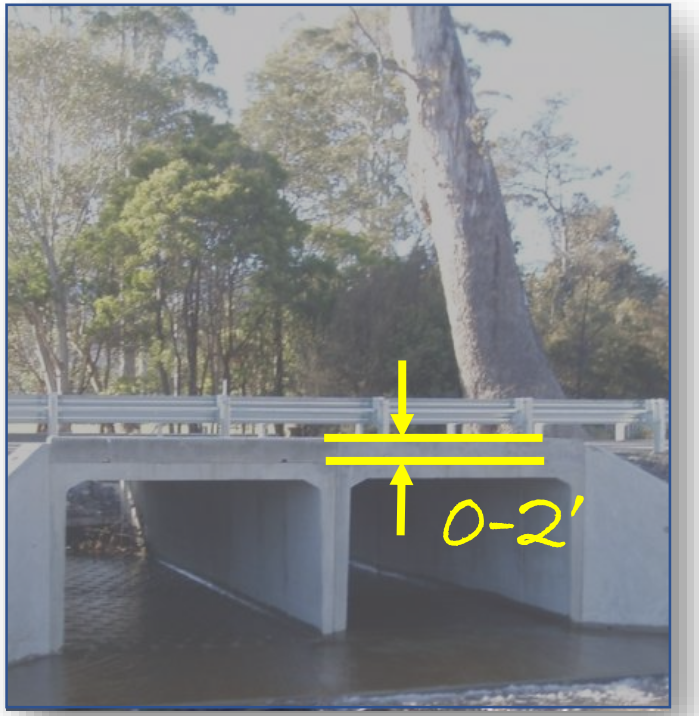
Cover: 2’+

AASHTO M259
ASTM C789

ASTM: C1433 (1999)

LRFD → ASTM: **C1577 (2005)**

Cover: 0-2’



AASHTO: M273

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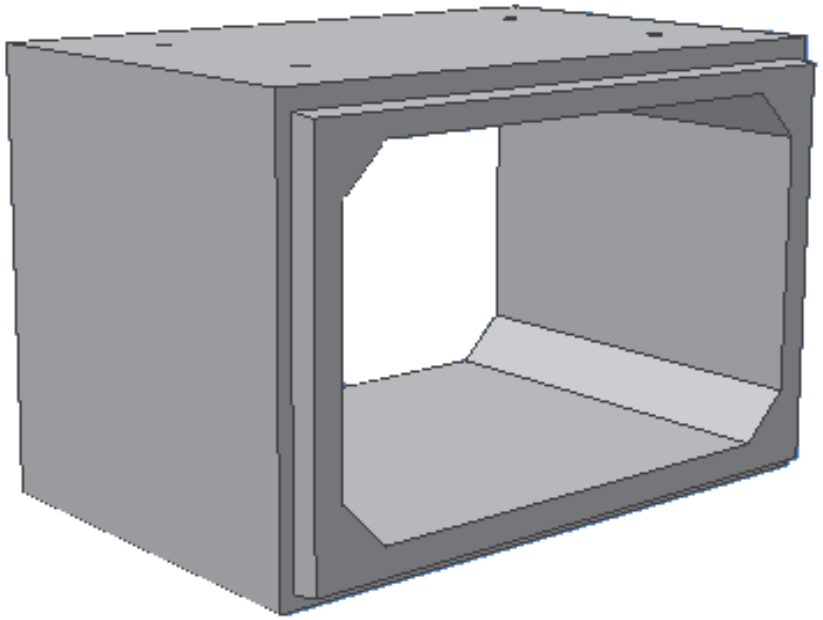
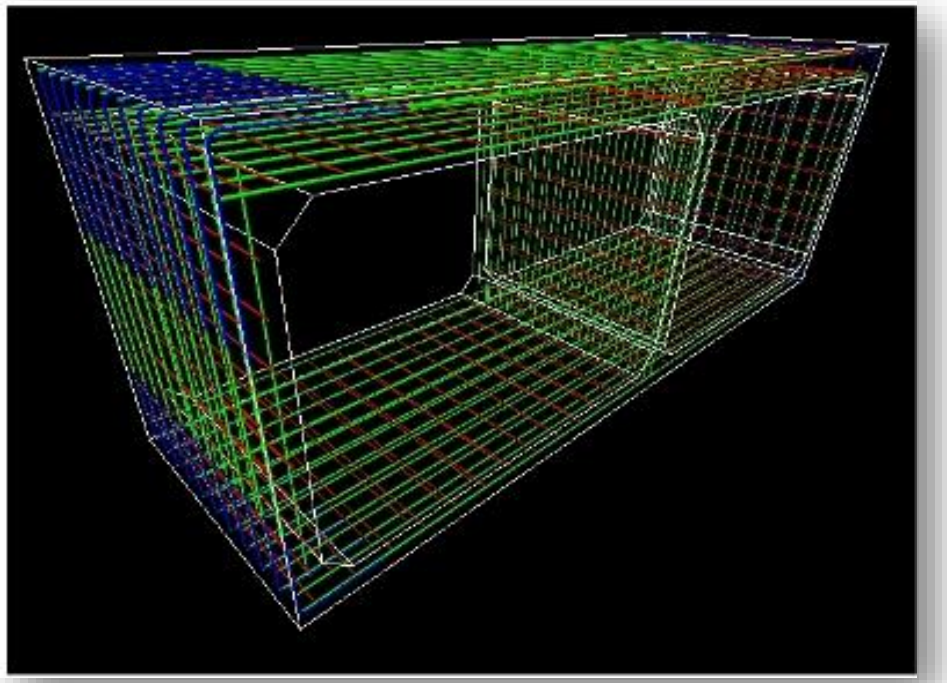
BOXCAR OR ET CULVERT





- AASHTO / ASTM C1577 DESIGN
- 3D WIREFRAME GENERATION
- LOAD RATINGS PER C1577 & SECTION 12

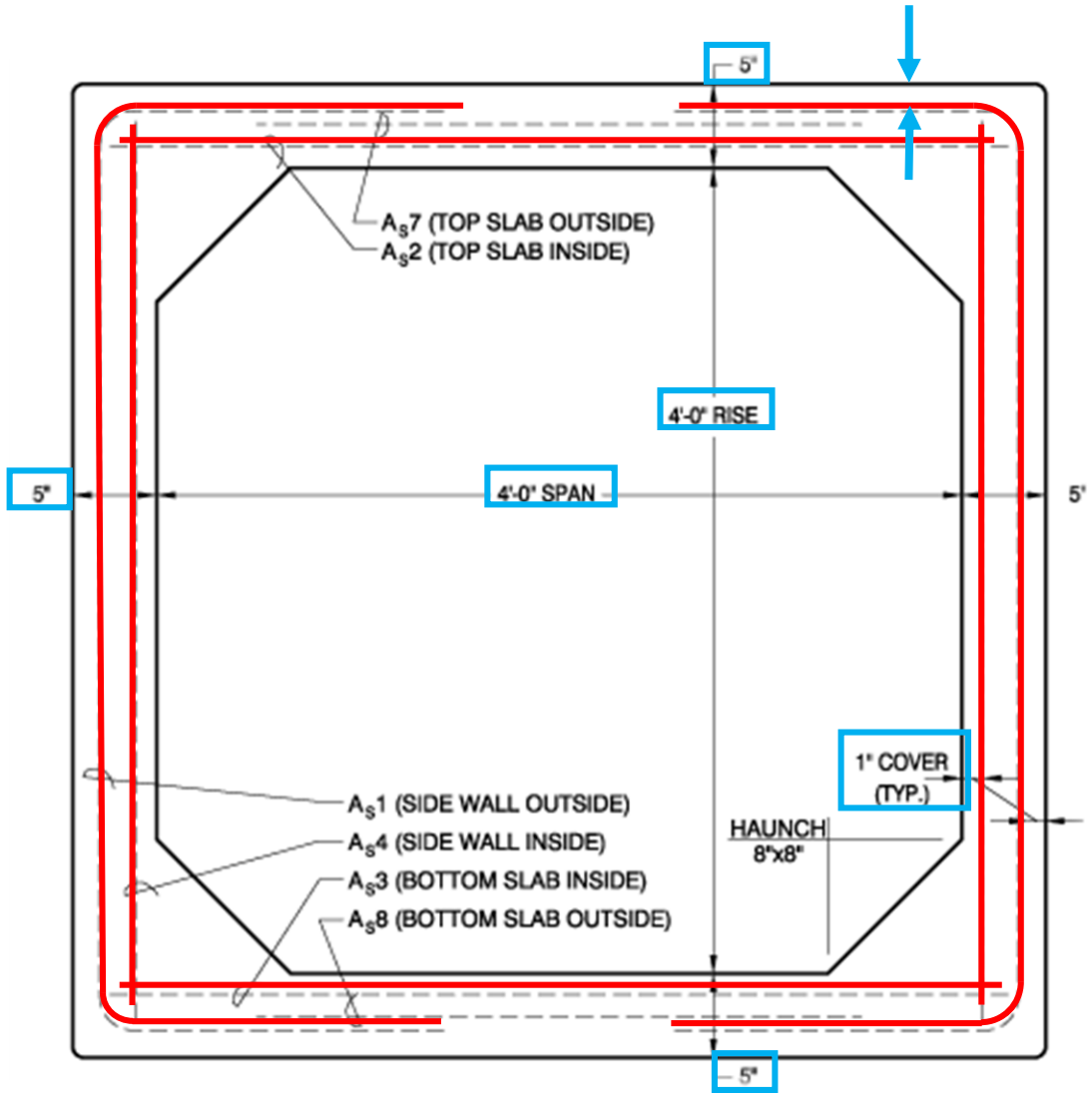
ASTM C1577

- Single cell precast monolithic boxes
- Standard sizes up to 12x12
- HL-93 Live Loading
- 5,000 psi Compressive Strength Concrete
- Design Tables:

	4 ft by 4 ft by 5 in.							
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.²/ft							
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.18	0.33	0.20	0.12	0.18	0.18	0.14	
2<3	0.12	0.26	0.23	0.12				38
3-5	0.12	0.18	0.18	0.12				38
10	0.12	0.15	0.15	0.12				38
15	0.12	0.19	0.20	0.12				38
20	0.12	0.25	0.25	0.12				38
25	0.14	0.31	0.31	0.12				38
30	0.17	0.37	0.37	0.12				38

Tabular designs in C1577 were prepared according to AASHTO LRFD Bridge Design Specifications

Example: C1577: 4'x4'x5" – 3'-5' Cover



- 4' Span, 4' Rise, 5" Walls
- 5" Top and Bottom Slab
- 1" Cover on reinforcing
- 5000 psi Concrete

- As1 – 0.12 (Side Wall Outside)
- As2 – 0.18 (Top Slab Inside)
- As3 – 0.18 (Bottom Slab Inside)
- As4 – 0.12 (Side Wall Inside)

Example: C1577: 4'x4'x5" – 0'-2" Cover

Design Earth Cover, ft	4 ft by 4 ft by 5 in. Circumferential Reinforcement Areas, in.²/ft							
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.18	0.33	0.20	0.12	0.18	0.18	0.14	
2<3	0.12	0.26	0.23	0.12				38
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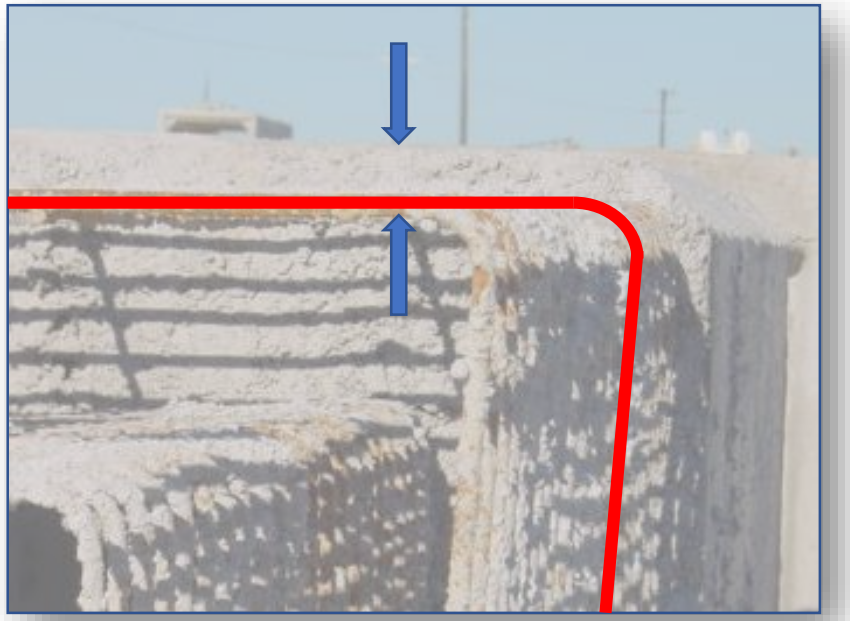
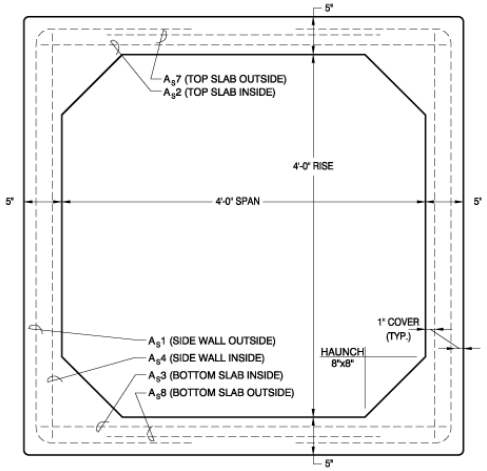
10	0.12	0.15	0.15	0.12				38
15	0.12	0.19	0.20	0.12				38
20	0.12	0.25	0.25	0.12				38
25	0.14	0.31	0.31	0.12				38
30	0.17	0.37	0.37	0.12				38

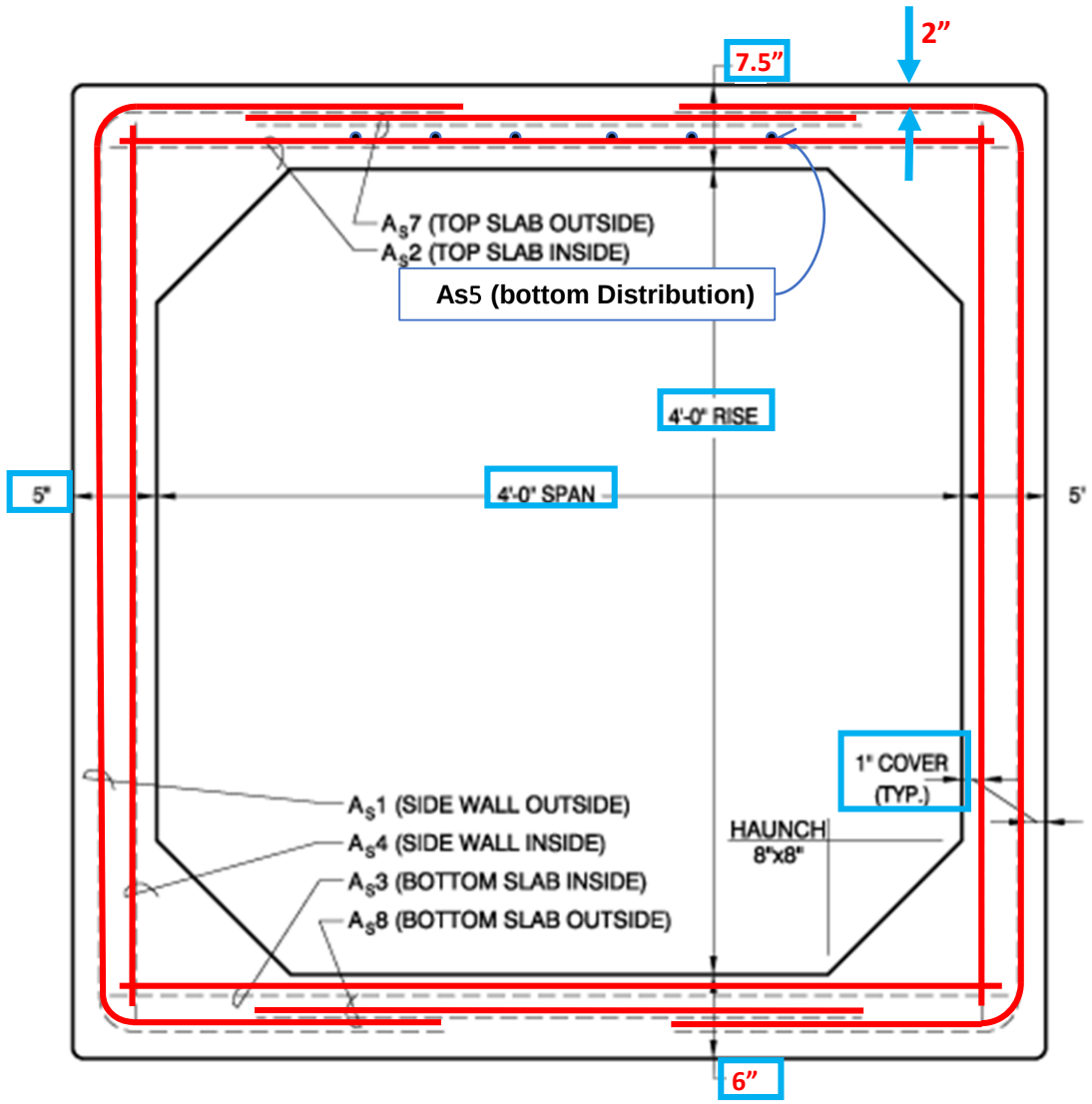
[A] Top slab 7.5 in., bottom slab 6 in.





- 4x4x5 Box
  - 0-2' of Cover:
    - 5" Walls
    - Top slab increases to 7.5"
    - Bottom slab increases to 6"
    - As5, As7 & As8 Required
    - 2" Cover over As7

Example: C1577: 4'x4'x5" – 0'-2" Cover



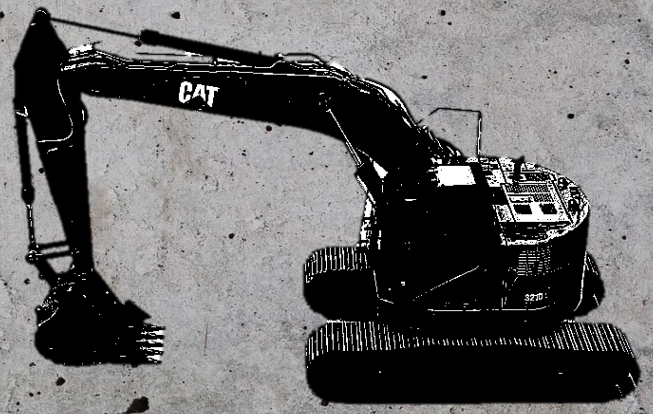
- 4' Span, 4' Rise, 5" Walls
- 7.5" Top Slab
- 6" Bottom Slab
- 2" Cover On Top Slab Top Layer
- 1" Cover on Other Reinforcing
- 5000 psi Concrete

- As1 – 0.18 (Side Wall Outside)
- As2 – 0.33 (Top Slab Inside)
- As3 – 0.20 (Bottom Slab Inside)
- As4 – 0.12 (Side Wall Inside)

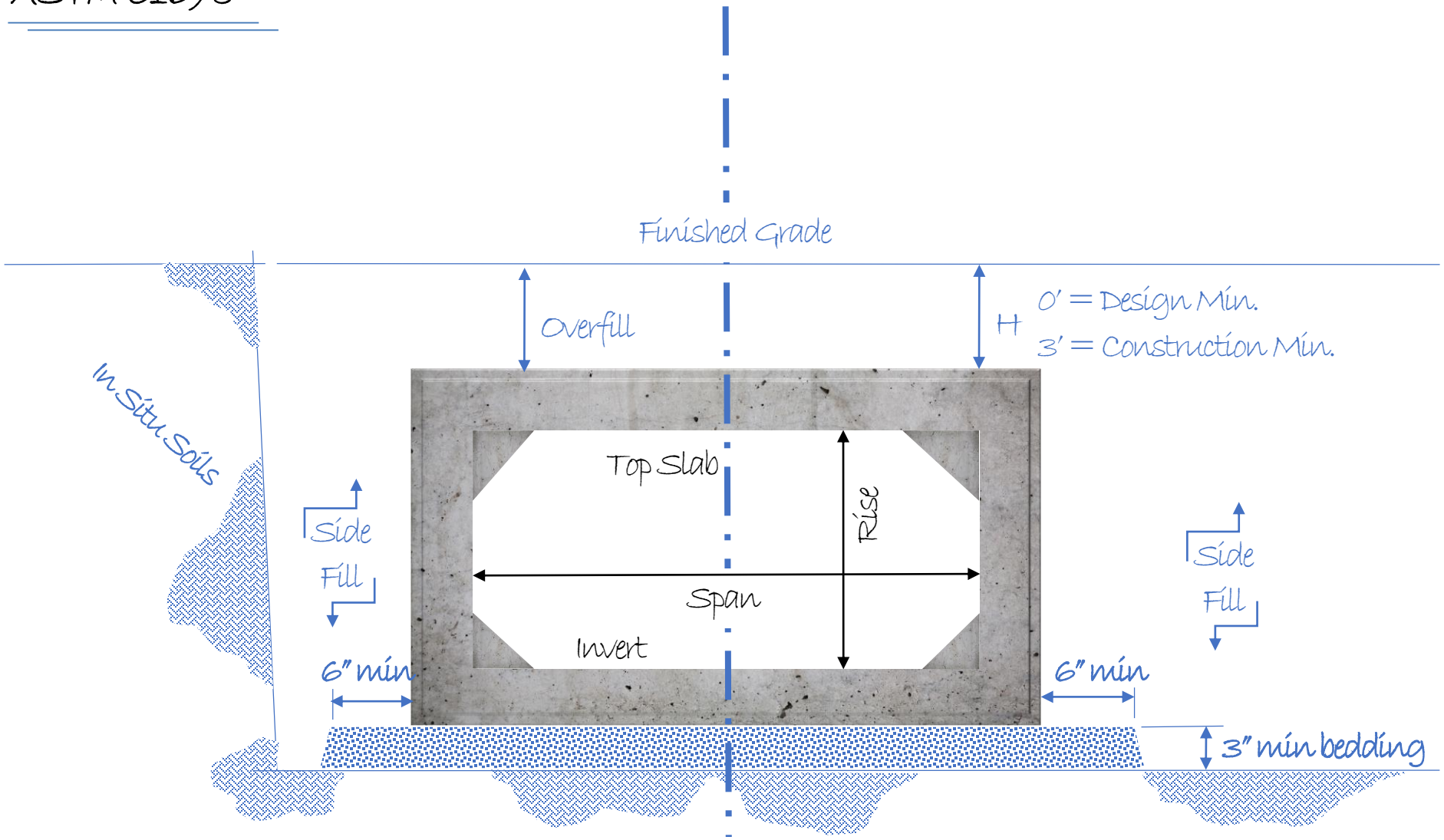
- As5 – 0.18 (Top Slab Inside Distribution)
- As7 – 0.18 (Top Slab Outside)
- As8 – 0.14 (Bottom Slab outside)

…shall contain sufficient longitudinal wires extending through the box section to maintain the shape and position of the reinforcement.

Installation



ASTM C1675



Foundation

TRENCH | **EMBANKMENT**

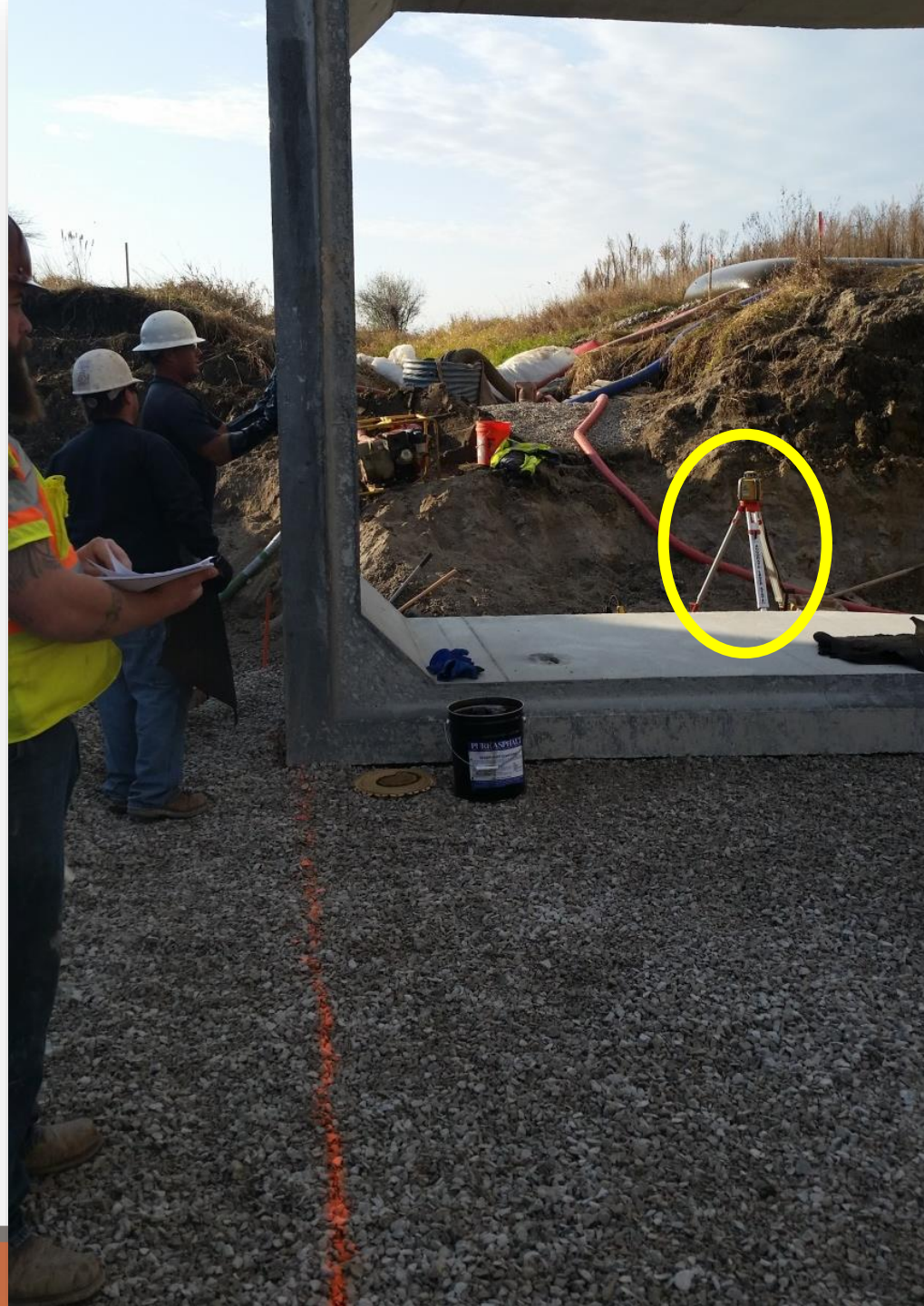
Culvert Loading

- Earth
- Live
- Construction

Unless designed for construction loading, RCB backfill should be placed 3’ above top of box to accommodate construction loads.

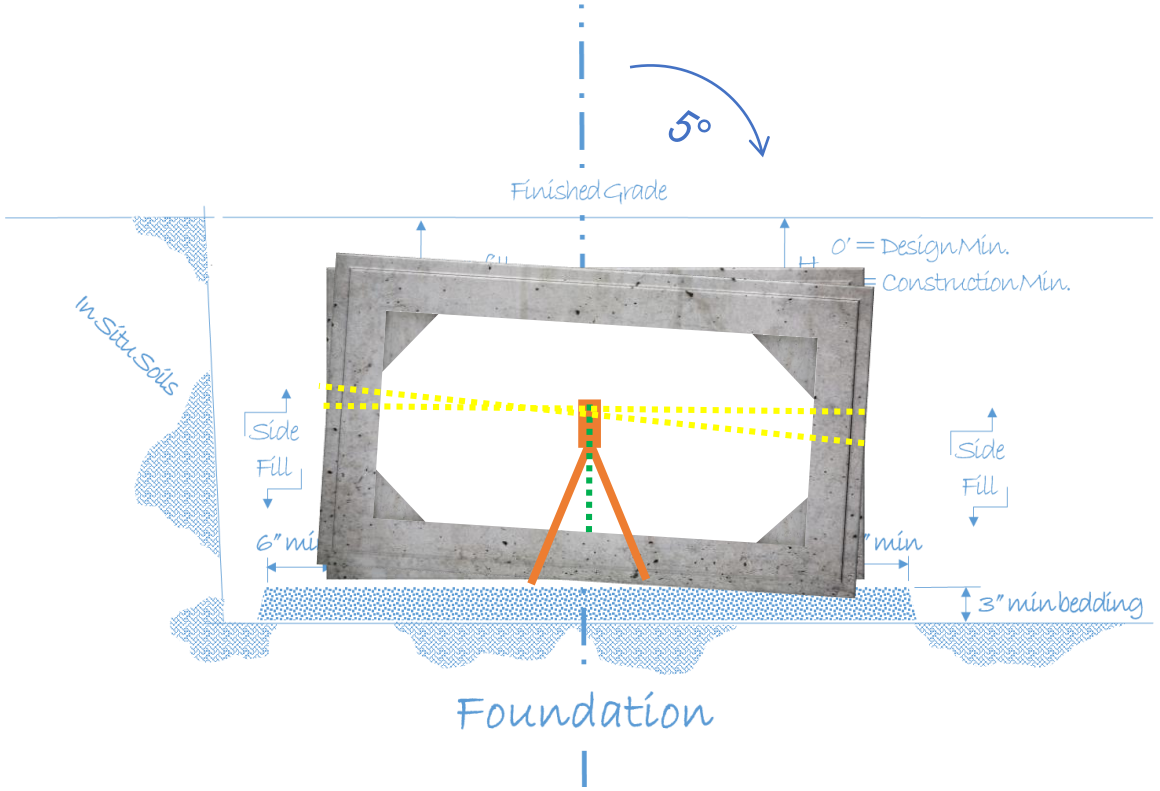
Bedding:

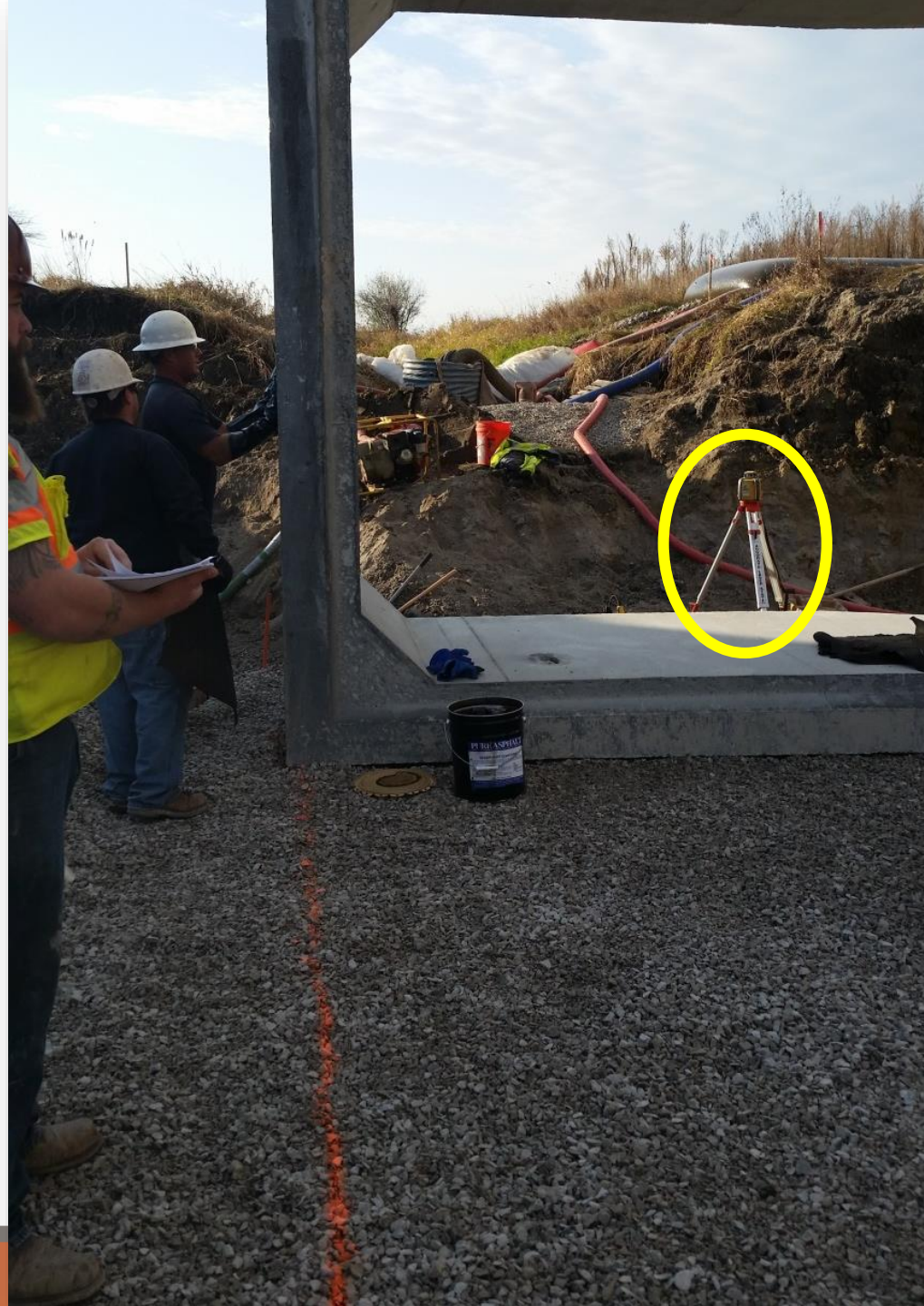
Check line and grade frequently and evenly



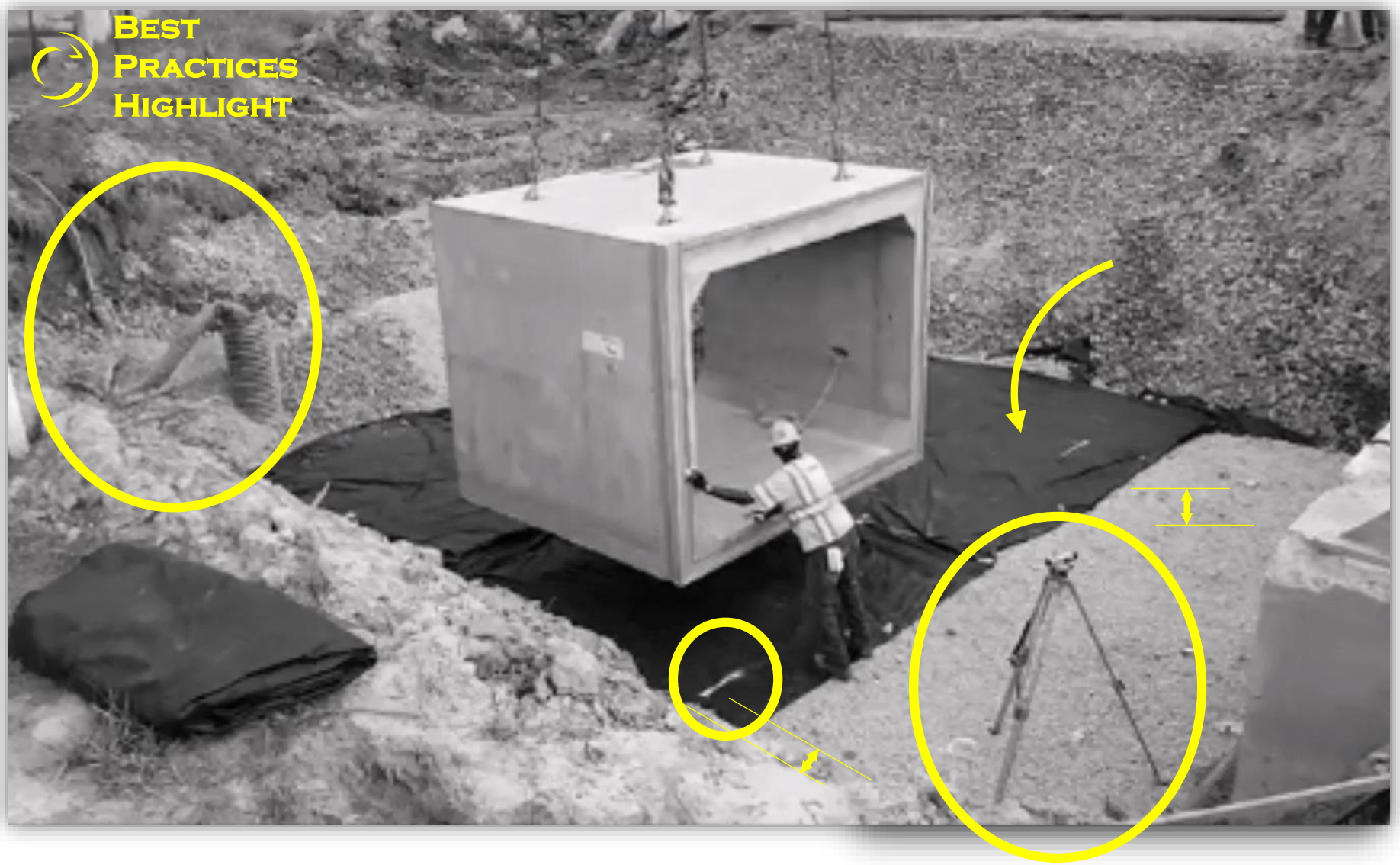
Bedding:

Check line and grade frequently and evenly





Bedding: Bedding is key to a smooth installation!



Installation Best Practices

- Scheduling & Unloading = Project Efficiency
- Divert drainage
- Establish a good, level grade
  - Use fine to medium material
  - Leveling course should be 3” (min)

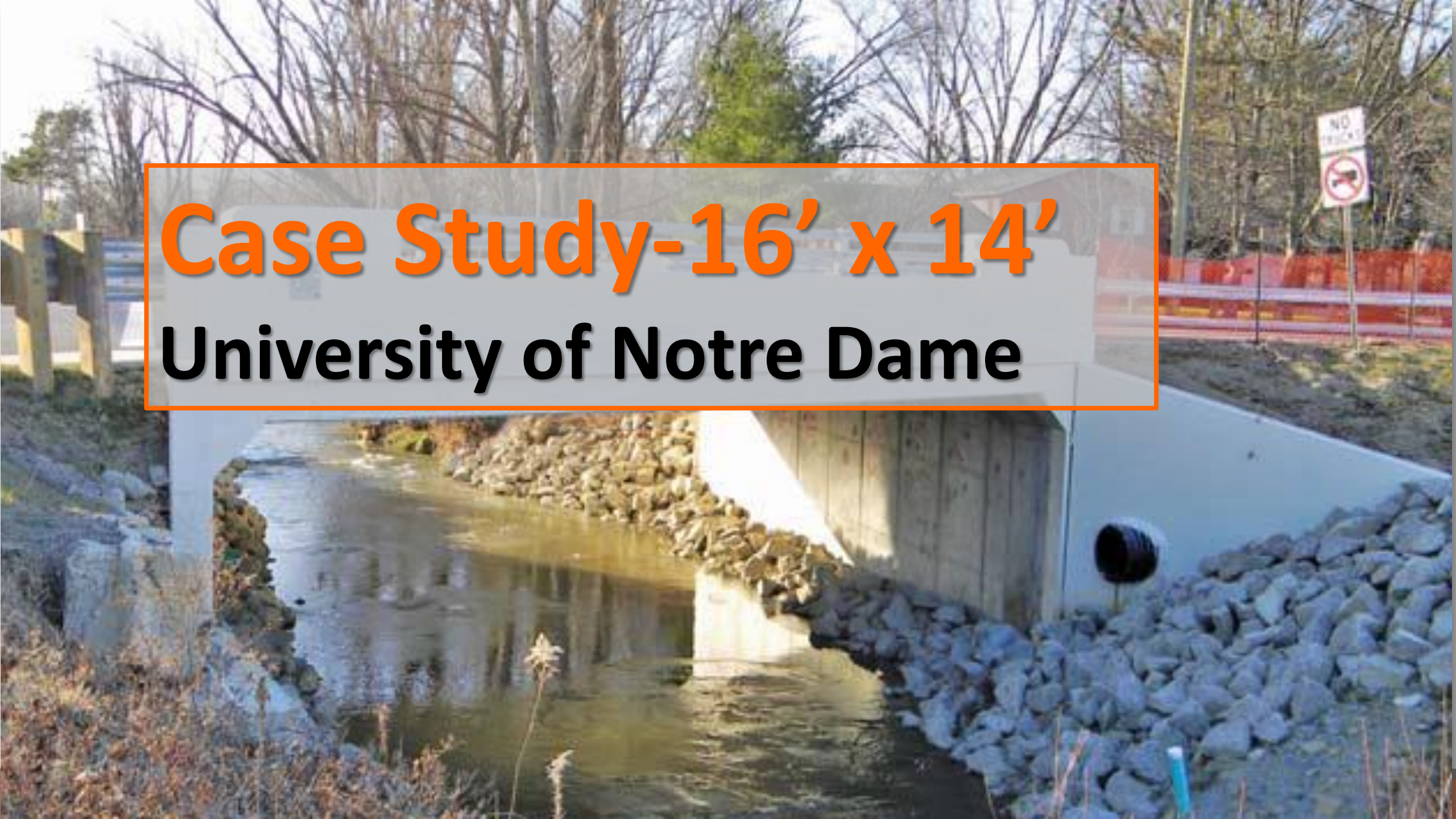
Installation Best Practices

- ❑ Install 1st & 2nd boxes accurately
- ❑ Place joint materials
- ❑ Properly align prior to pushing home
- ❑ Keep weight of box off bedding
- ❑ Pull home with winches or dozer

American Concrete Pipe Association

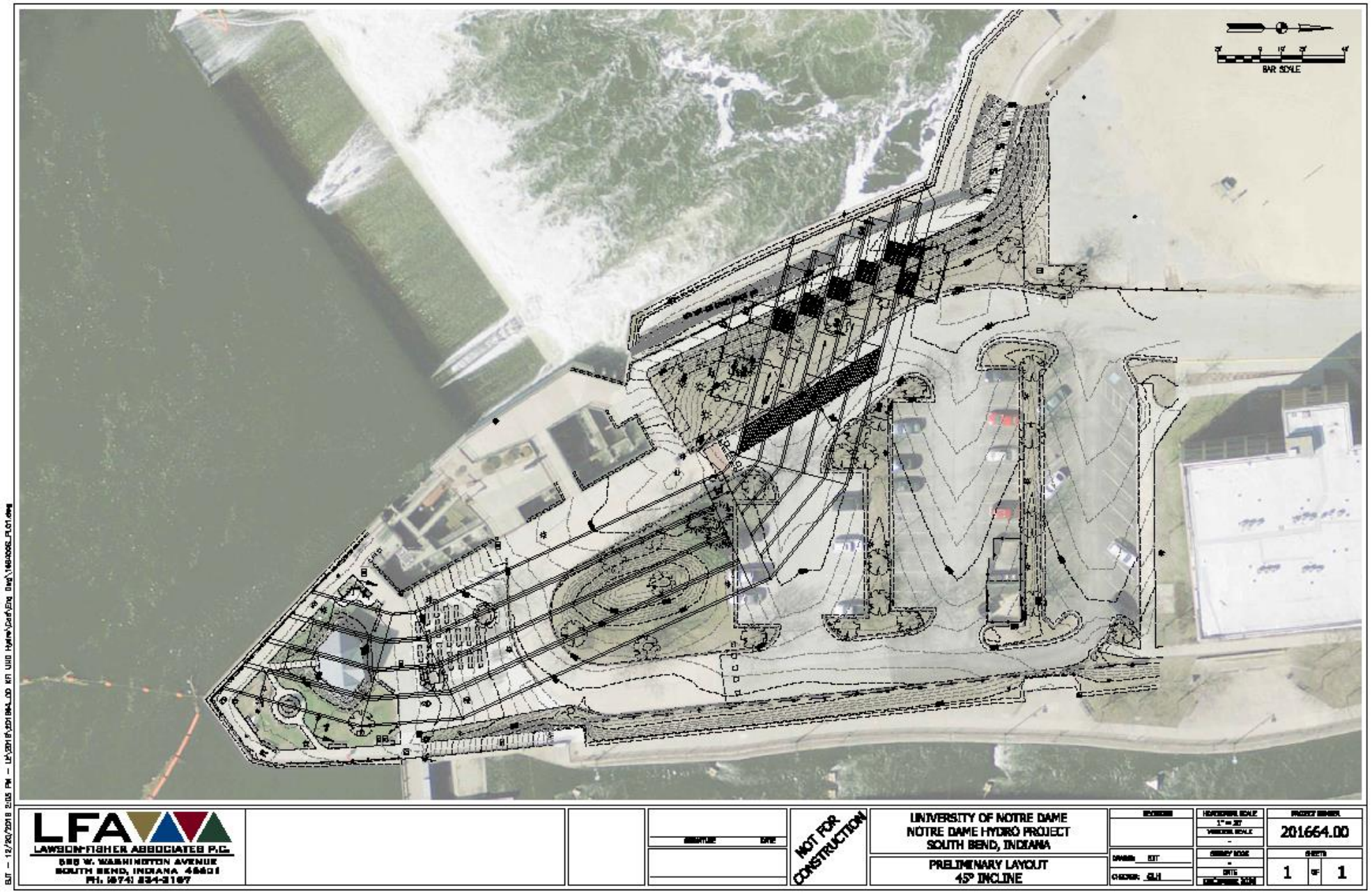
American Concrete Pipe Association

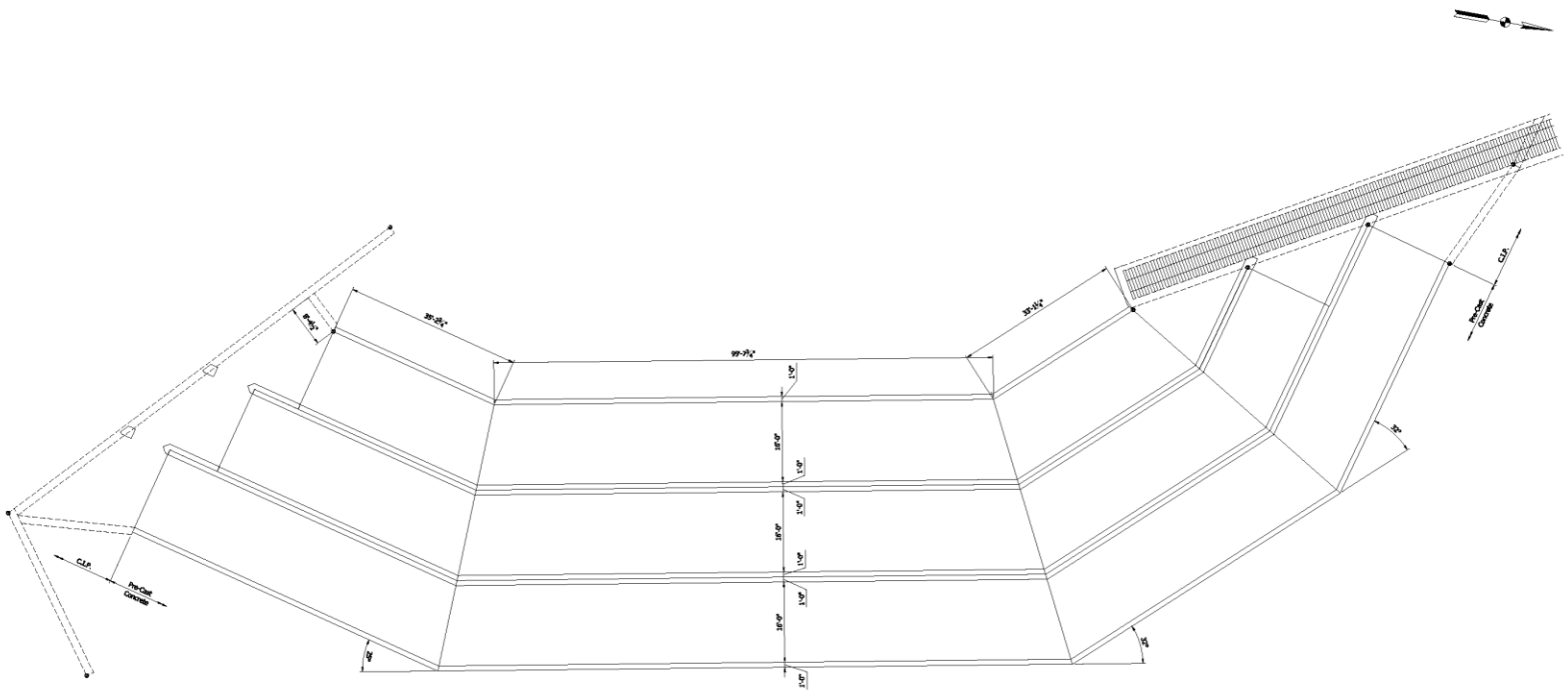
Case Studies



Case Study-16’ x 14’

University of Notre Dame


BAR SCALE
LFA
LAWSON-FISHER ASSOCIATES P.C.
580 W. WASHINGTON AVENUE
SOUTH BEND, INDIANA 46601
PH. (574) 234-3167
NOT FOR CONSTRUCTION
UNIVERSITY OF NOTRE DAME
NOTRE DAME HYDRO PROJECT
SOUTH BEND, INDIANA
PRELIMINARY LAYOUT
45° INCLINE
201664.00
1 OF 1



NOTES:

1. Precast box wall thicknesses are approximate and shall be designed by manufacturer.

PRECAST BOXES - GENERAL PLAN

Scale: 1/8" = 1'-0"

0 2 4 8 16'

BAR SCALE

FOR REFERENCE ONLY
NOT FOR CONSTRUCTION

No.	Date	By	Revision
-	-	-	-
0	09-19-17	BWJ	75% REVIEW SET
D	09-08-17	BWJ	OWNER REVIEW
B	09-08-17	BWJ	OWNER REVIEW
A	09-8-17	BWJ	OWNER REVIEW

UNIVERSITY OF NOTRE DAME

Kerges-Faulconbridge,Inc.
Engineers
6100 SOUTH YORK ROAD WEST
ST. PAUL, MINNESOTA 55110
Ph: (651) 291-0000
Fx: (651) 291-0878
Email: info@kfengineers

LFA
LAWSON-FISHER ASSOCIATES P.C.
3325 N. WASHINGTON AVENUE
SOUTH BEND, INDIANA 46201
PH. (574) 233-0187

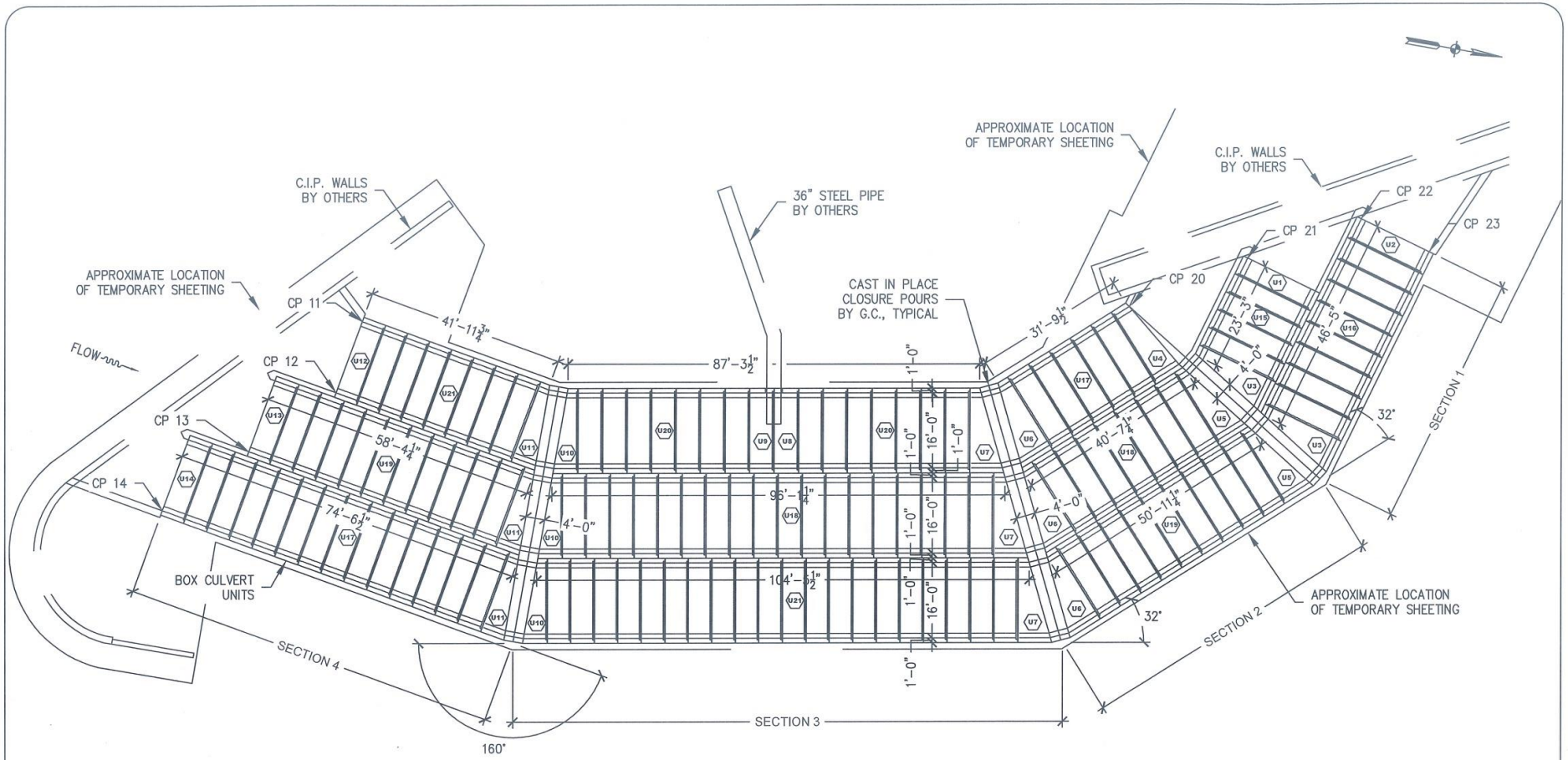
Project Title: SOUTH BEND DAM HYDROELECTRIC PROJECT UNIVERSITY OF NOTRE DAME SOUTH BEND, INDIANA

Sheet Title: PRECAST CONCRETE BOX GENERAL PLAN

Date: 09-19-17
Drawn By: BIT
Checked By: SLH
Project No.: 16-280.02
DWG. Scale: As Noted
Sheet Size: 36x42

Revision Number:

Sheet Number: STR-4301



1/2 OVERALL STRUCTURE PLAN
1" = 20'-0"

Box span - 16'-0"
Box rise - 14'-0"

Date: 28 June 2018
Job no.: SPC-18-3015
Scale: 1"=20'-0"
Created by: ARW
Checked by: ZSS

HYDROELECTRIC PROJECT
UNIVERSITY OF NOTRE DAME
RIETH-RILEY CONSTRUCTION

St. Joseph County, Indiana

Overall Plan

S1.0

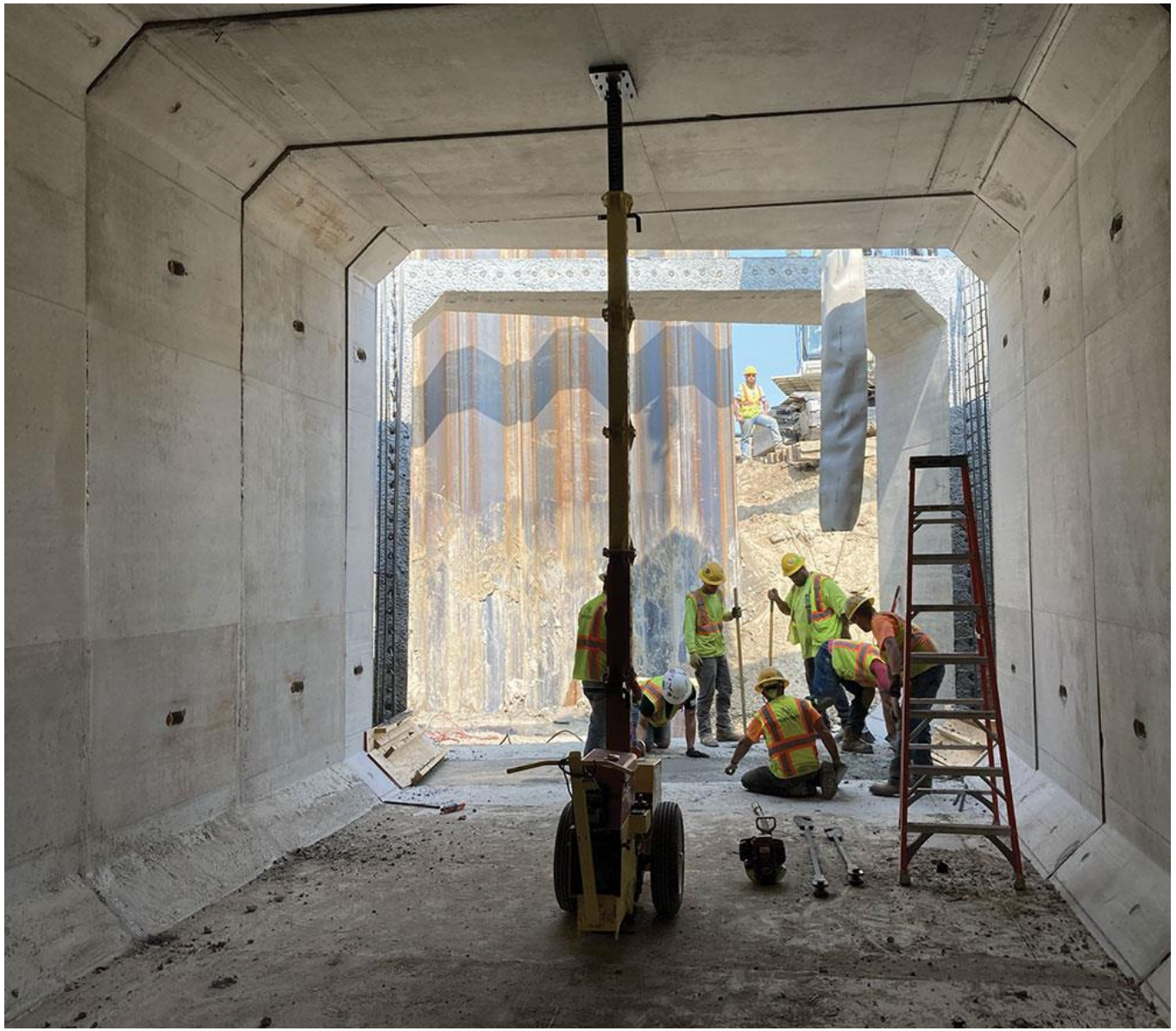
Sanders
Pre-Cast Concrete Systems, Inc.

6051 South Indianapolis Road
Whitestown, IN 46075-9527
(317) 769-5503 office
(317) 769-3712 fax
(800) 769-5503 toll free
www.sanderscompanies.com

Rieth-Riley Construction South Bend Group

ALL CRANE RENTAL
800-232-4100
www.allcrane.com

U 15-3



AM General
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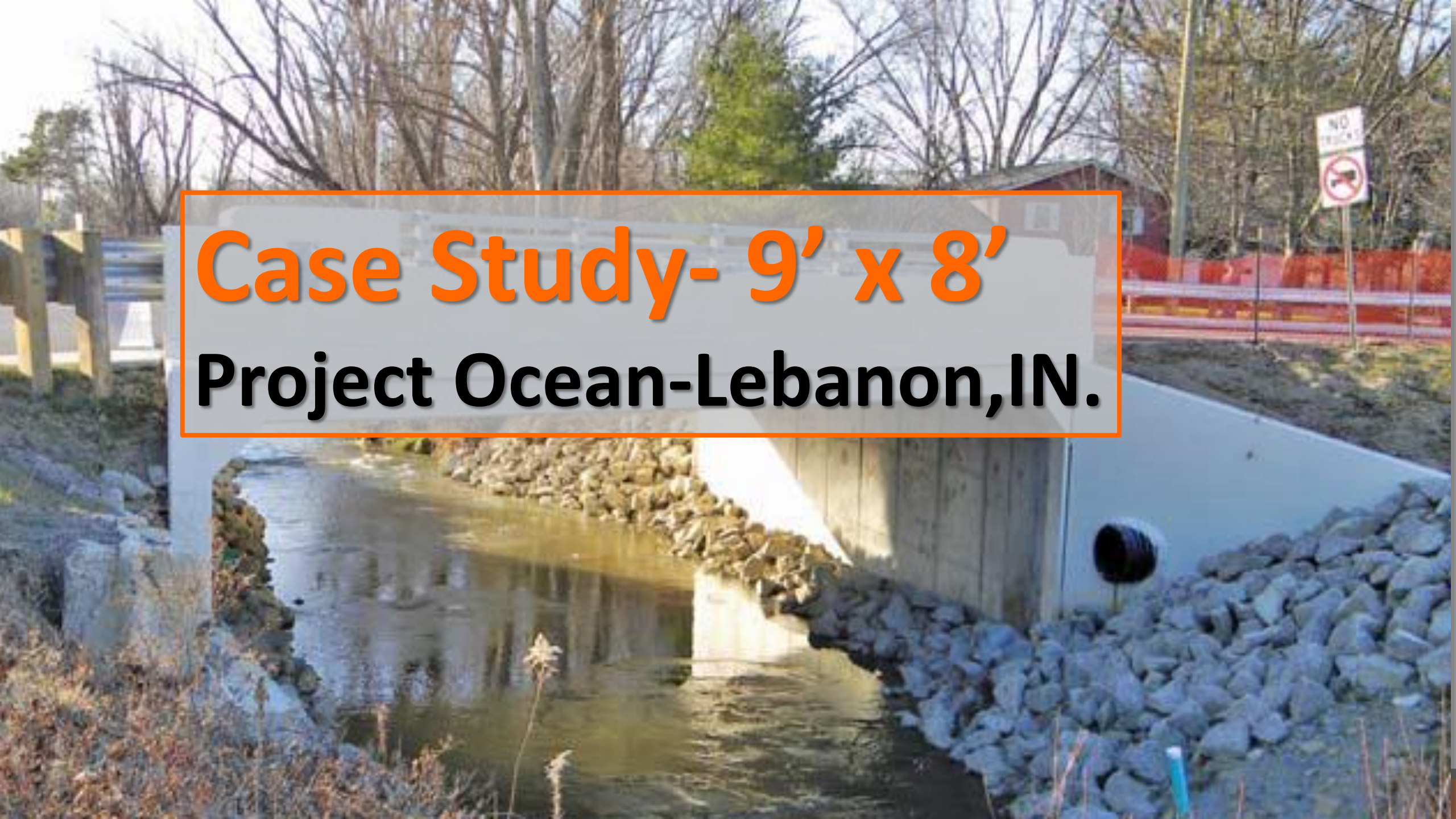


Case Study- 9’ x 8’

Project Ocean-Lebanon,IN.

FCL BUILDERS

FCL Builders has reviewed for general conformance with design, contract documents and verification of products required, adjacent construction work and coordination of information. The review is cursory and in no way relieves the Subcontractor of responsibility for field dimensions, accuracy and compliance with the plans, specifications (manual) and code requirements. No work shall commence, or materials released for order without Architects/Engineer Review being issued.

- [x] REVIEWED
- [ ] REVIEWED AS NOTED
- [ ] REJECTED, RESUBMIT

Project # SD Smith 18032
Date 4-3-19
By Walt Sabbath

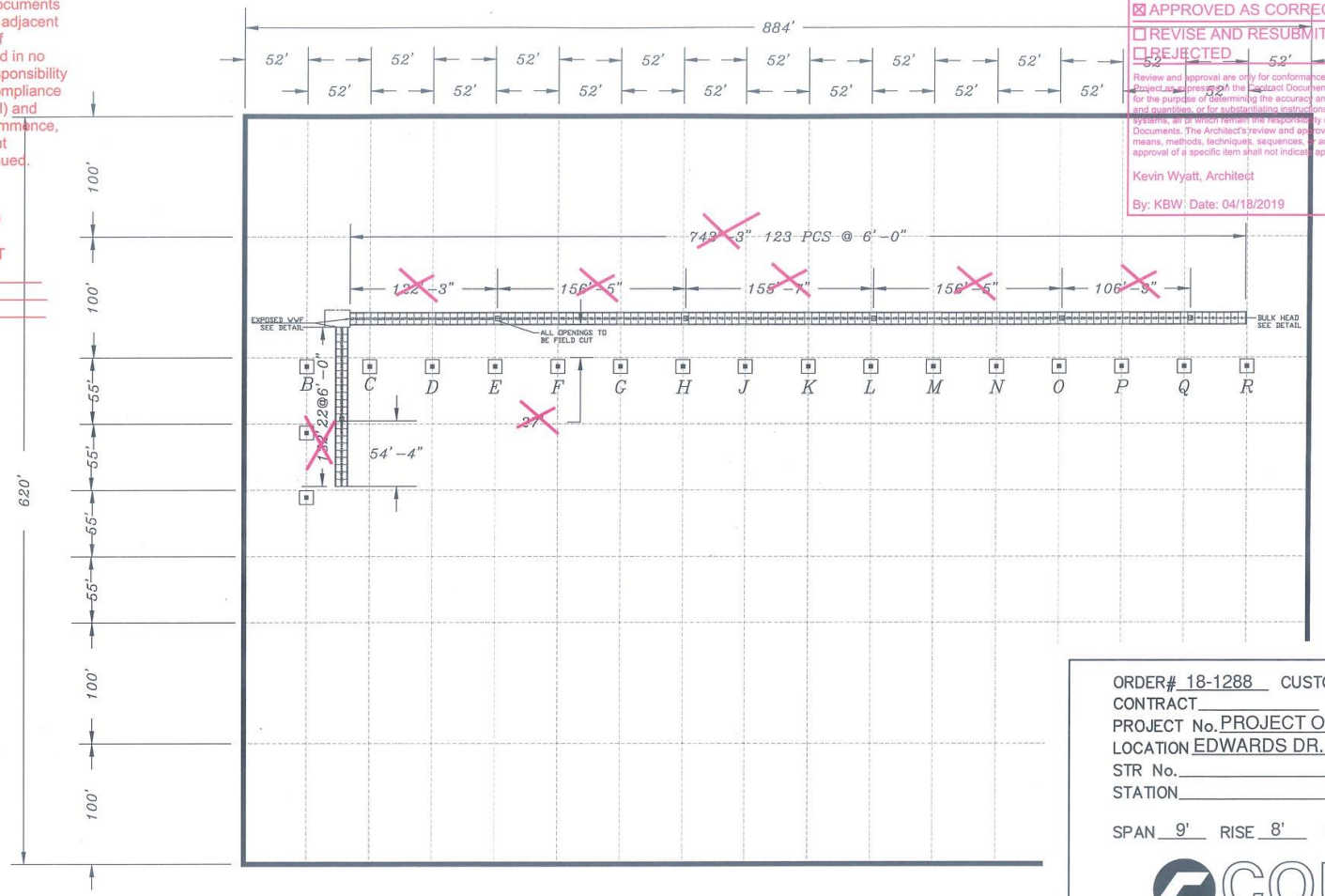
Kevin Wyatt Architect

- ☐ APPROVED
- ☒ APPROVED AS CORRECTED — Fabrication / installation may be undertaken. Approval does not authorize changes in Contract Sum or Contract Time.
- ☐ REVISE AND RESUBMIT
- ☐ REJECTED — Fabrication / installation MAY NOT be undertaken. In resubmitting, limit corrections to the items marked.

Review and approval are only for conformance with the information given and the design concept of the Project as expressed in the Contract Documents. Review and approval of submittals are not conducted for the purpose of determining the accuracy and completeness of other details, such as dimensions and quantities, or for substantiating instructions for the installation or performance of equipment or systems, all of which remain the responsibility of the Contractor as required by the Contract Documents. The Architect's review and approval SHALL NOT constitute approval of any construction means, methods, techniques, sequences, or any safety precautions or procedures. The Architect's approval of a specific item shall not indicate approval of an assembly of which the item is a component.

Kevin Wyatt, Architect

By: KBW Date: 04/18/2019

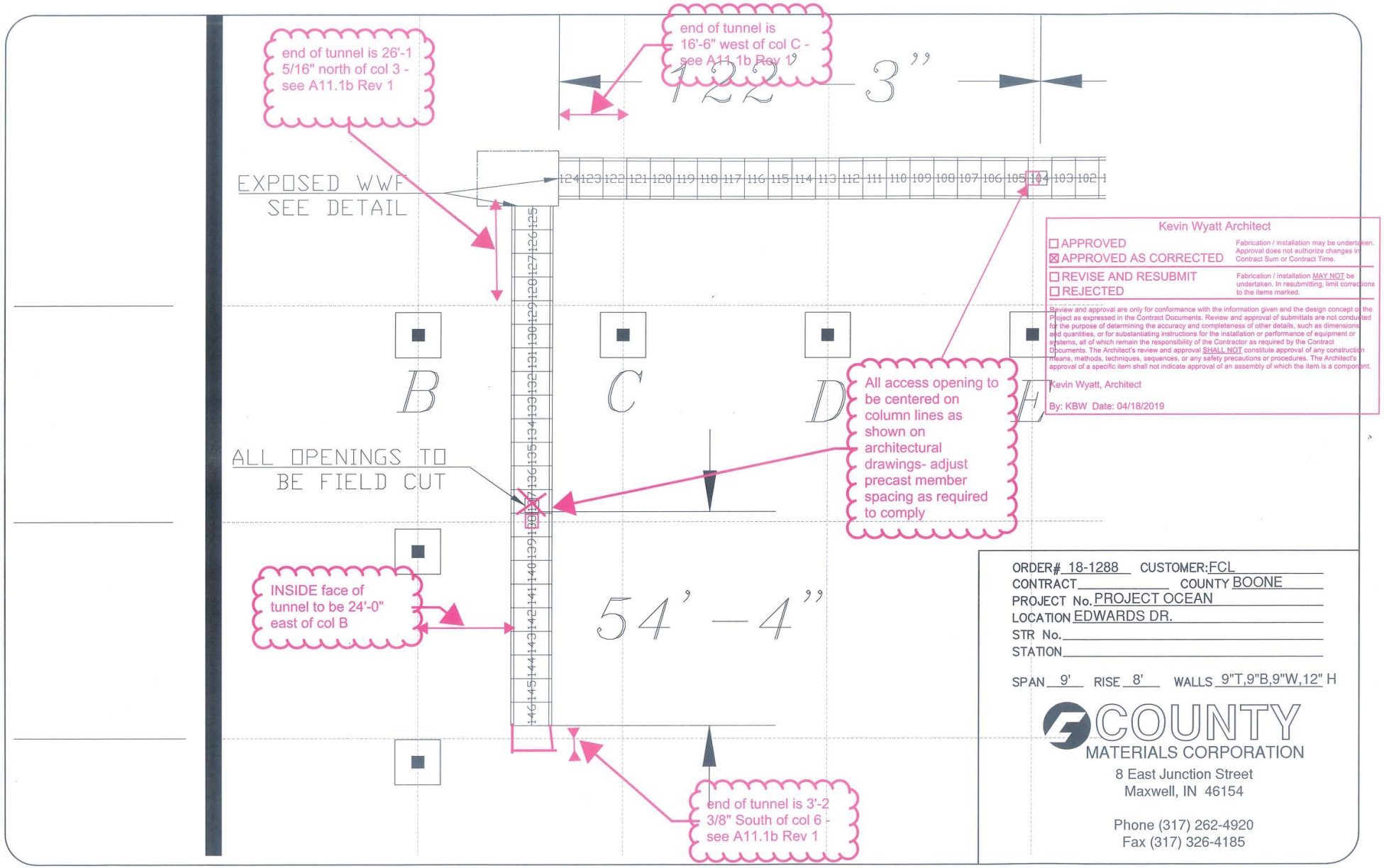


ORDER# 18-1288 CUSTOMER: FCL
CONTRACT _____ COUNTY BOONE
PROJECT No. PROJECT OCEAN
LOCATION EDWARDS DR.
STR No. _____
STATION _____

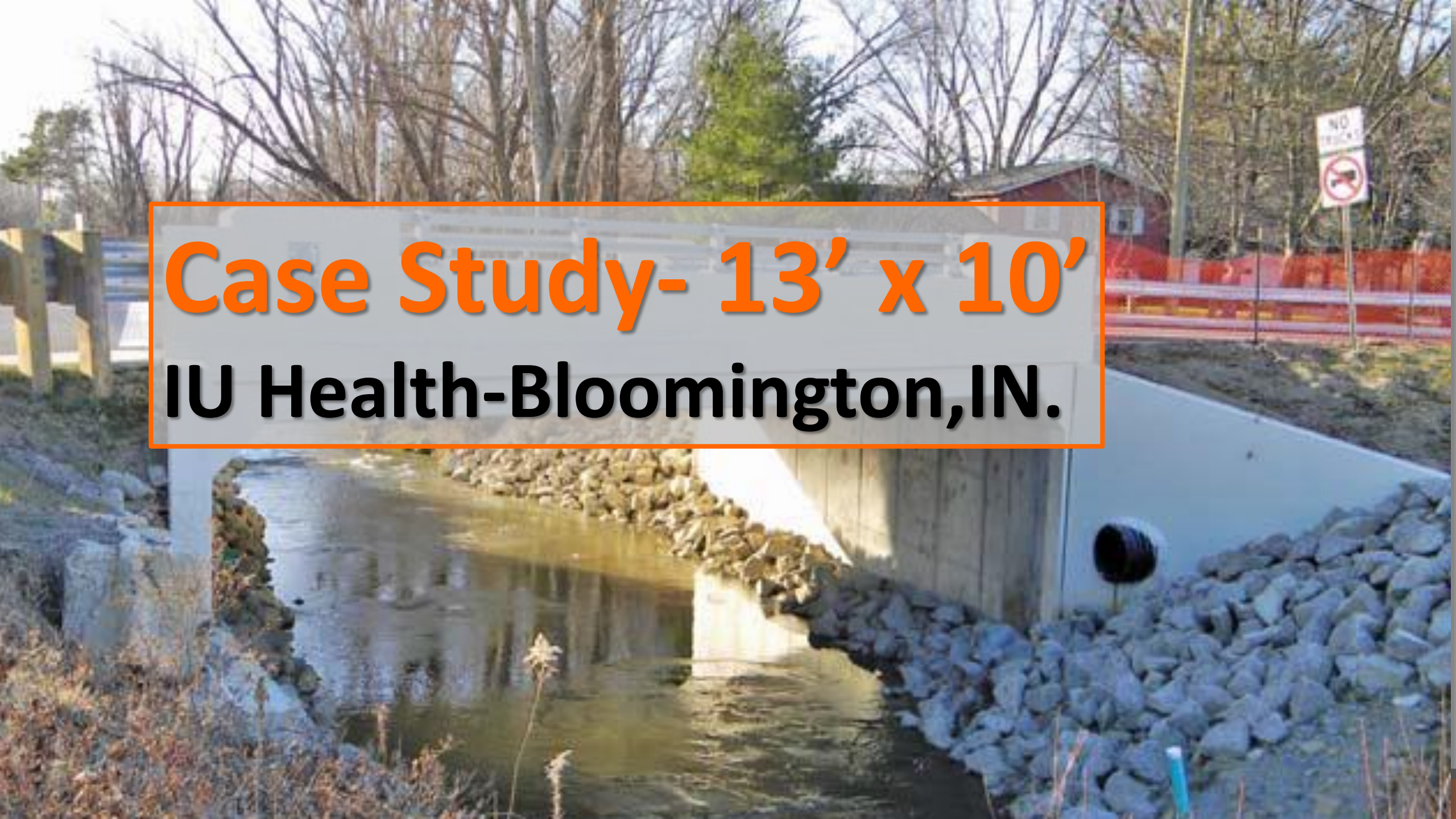
SPAN 9' RISE 8' WALLS 9"T,9"B,9"W,12" H

COUNTY MATERIALS CORPORATION
8 East Junction Street
Maxwell, IN 46154

Phone (317) 262-4920
Fax (317) 326-4185


end of tunnel is 26'-1 5/16" north of col 3 - see A11.1b Rev 1
end of tunnel is 16'-6" west of col C - see A11.1b Rev 1
122' - 3"
EXPOSED WWF SEE DETAIL
B
C
D
E
ALL OPENINGS TO BE FIELD CUT
All access opening to be centered on column lines as shown on architectural drawings- adjust precast member spacing as required to comply
INSIDE face of tunnel to be 24'-0" east of col B
54' - 4"
end of tunnel is 3'-2 3/8" South of col 6 - see A11.1b Rev 1
Kevin Wyatt Architect
☐ APPROVED
☒ APPROVED AS CORRECTED
Fabrication / installation may be undertaken. Approval does not authorize changes in Contract Sum or Contract Time.
☐ REVISE AND RESUBMIT
☐ REJECTED
Fabrication / installation MAY NOT be undertaken. In resubmitting, limit corrections to the items marked.
Review and approval are only for conformance with the information given and the design concept of the Project as expressed in the Contract Documents. Review and approval of submittals are not conducted for the purpose of determining the accuracy and completeness of other details, such as dimensions and quantities, or for substantiating instructions for the installation or performance of equipment or systems, all of which remain the responsibility of the Contractor as required by the Contract Documents. The Architect's review and approval SHALL NOT constitute approval of any construction means, methods, techniques, sequences, or any safety precautions or procedures. The Architect's approval of a specific item shall not indicate approval of an assembly of which the item is a component.
Kevin Wyatt, Architect
By: KBW Date: 04/18/2019
ORDER# 18-1288 CUSTOMER: FCL
CONTRACT COUNTY BOONE
PROJECT No. PROJECT OCEAN
LOCATION EDWARDS DR.
STR No.
STATION
SPAN 9' RISE 8' WALLS 9"T,9"B,9"W,12" H
COUNTY
MATERIALS CORPORATION
8 East Junction Street
Maxwell, IN 46154
Phone (317) 262-4920
Fax (317) 326-4185

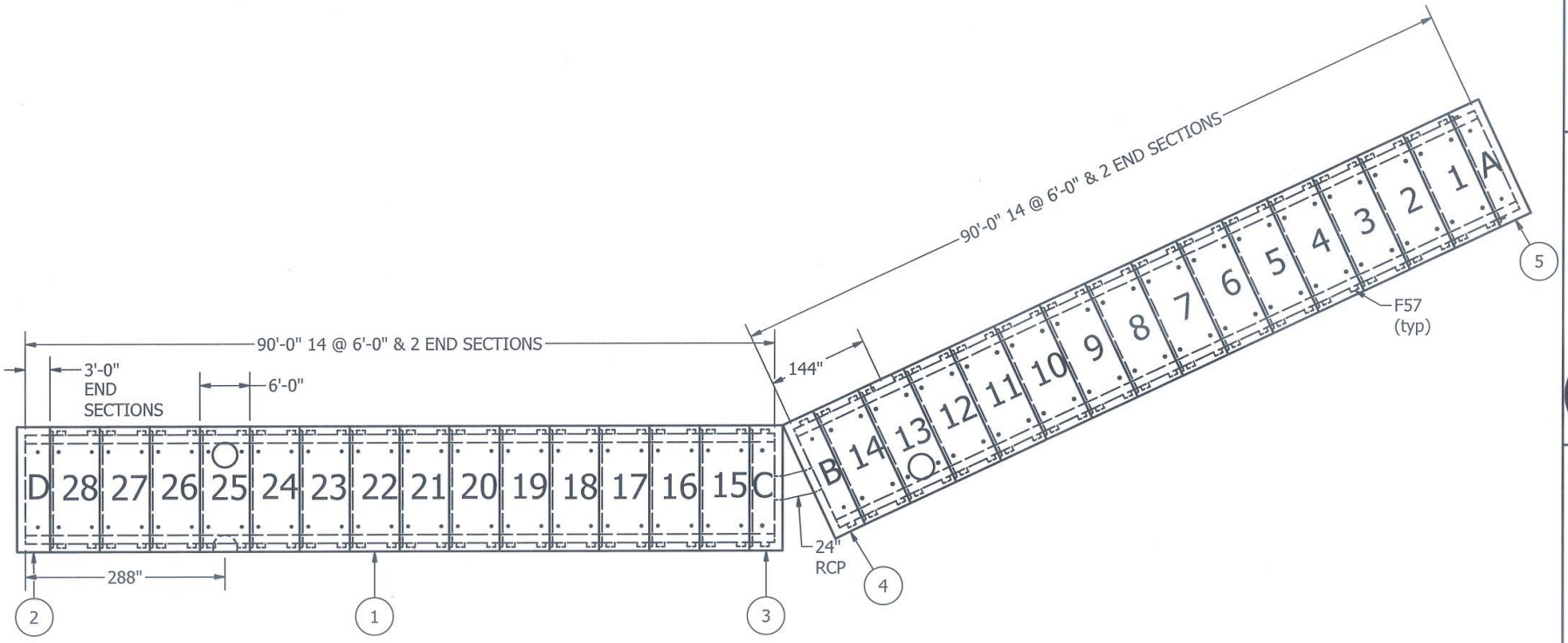
CAT
COUNTY



Case Study- 13’ x 10’

IU Health-Bloomington,IN.

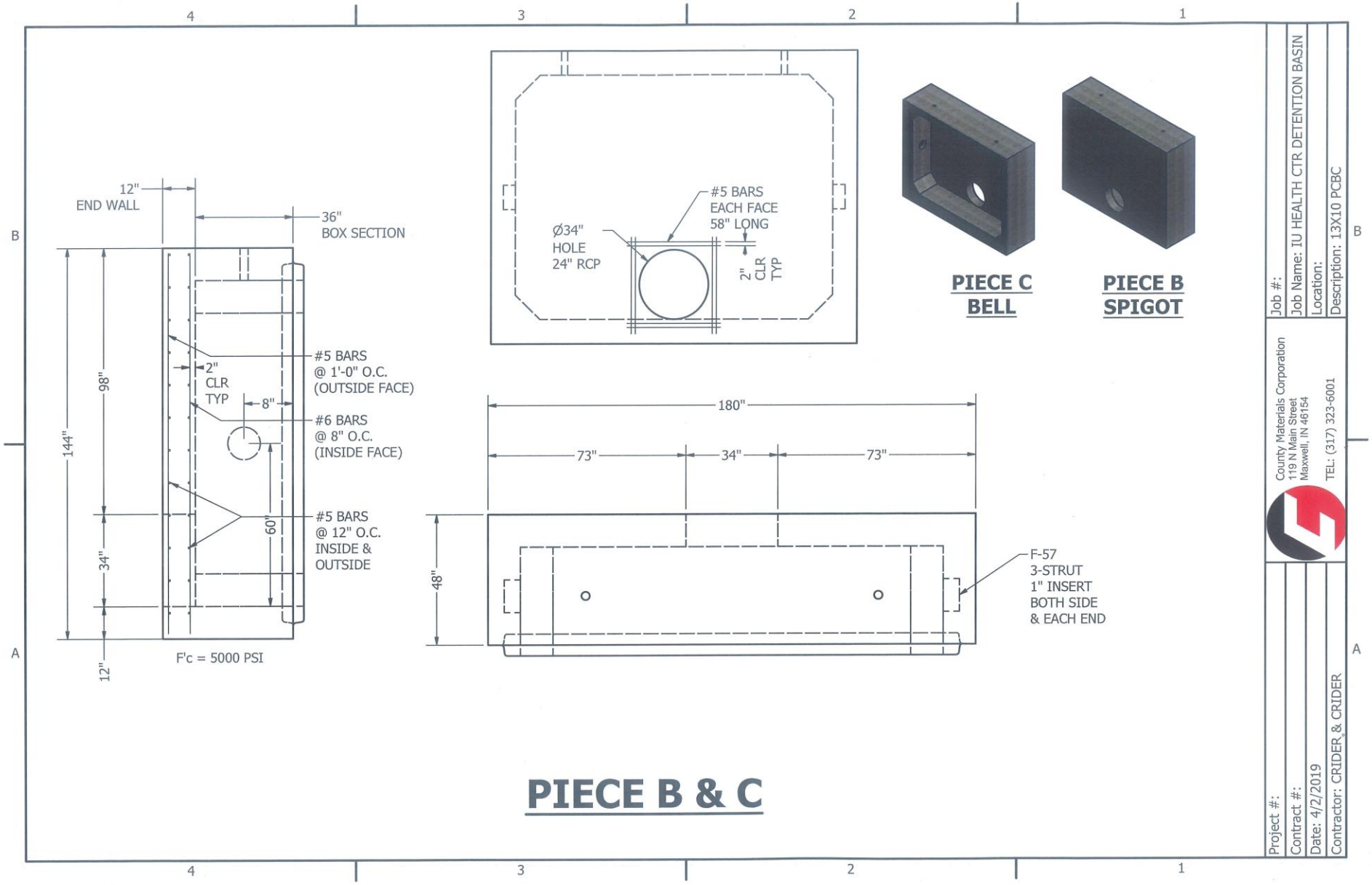
PARTS LIST			
ITEM	QTY	PART NUMBER	MASS #
1	28	PCBC-6'0'-13'x10'-12,12,12,12-SPIGOTxBELL-N	46623
2	1	PCBC-3'0'-13'x10'-12,12,12,12-SPIGOTxFLAT-N Piece D	51783
3	1	PCBC-3'0'-13'x10'-12,12,12,12-SPIGOTxBELL-B Piece C	48113
5	1	PCBC-3'0'-13'x10'-12,12,12,12-SPIGOTxBELL-Piece A	49163
4	1	PCBC-3'0'-13'x10'-12,12,12,12-SPIGOTxBELL-N Piece B	50717



Job #:
Job Name: IU HEALTH CTR DETENTION BASIN
Location:
Description: 13X10 PCBC

County Materials Corporation
119 N Main Street
Maxwell, IN 46154
TEL: (317) 323-6001

Project #:
Contract #:
Date: 4/2/2019
Contractor: CRIDER & CRIDER


12"
END WALL
36"
BOX SECTION
#5 BARS
@ 1'-0" O.C.
(OUTSIDE FACE)
2"
CLR
TYP
8"
#6 BARS
@ 8" O.C.
(INSIDE FACE)
#5 BARS
@ 12" O.C.
INSIDE &
OUTSIDE
144"
98"
60"
34"
12"
F'c = 5000 PSI
#5 BARS
EACH FACE
58" LONG
Ø34"
HOLE
24" RCP
2"
CLR
TYP
PIECE C
BELL
PIECE B
SPIGOT
180"
73"
34"
73"
48"
F-57
3-STRUT
1" INSERT
BOTH SIDE
& EACH END
PIECE B & C
Job #:
Job Name: IU HEALTH CTR DETENTION BASIN
Location:
Description: 13X10 PCBC
County Materials Corporation
119 N Main Street
Maxwell, IN 46154
TEL: (317) 323-6001
Project #:
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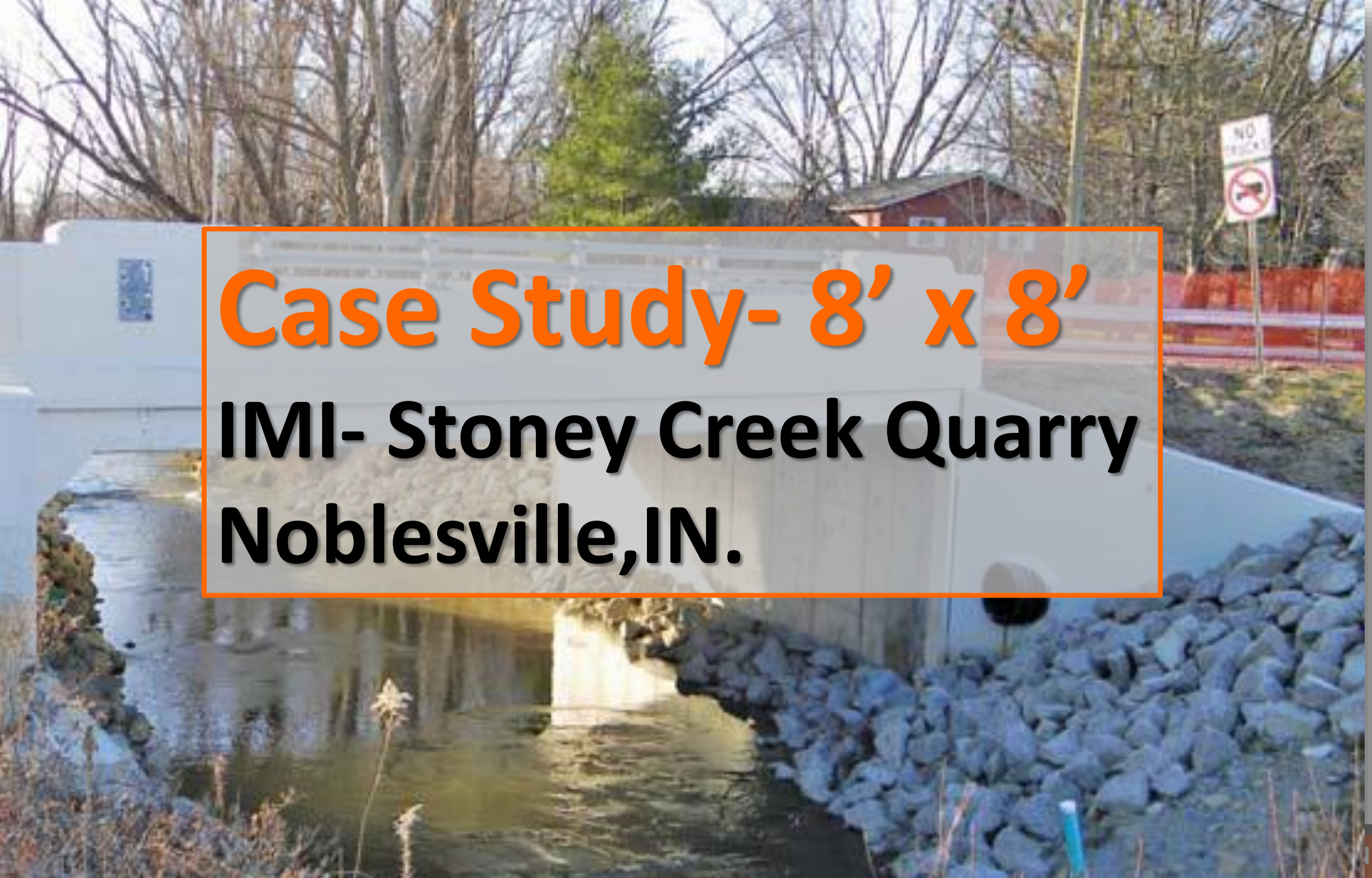
CAT



Case Study- 8’ x 8’

IMI- Stoney Creek Quarry
Noblesville,IN.

PRECAST REINFORCED CONCRETE FOUR SIDED BOX STRUCTURE

COUNTY MATERIALS CORPORATION

INDEX OF SHEETS

SHEET NUMBER	DESCRIPTION
1	TITLE AND INDEX OF SHEETS
2	STRUCTURE PLAN
3	CULVERT REINFORCEMENT
4-6	BOX CULVERT UNITS
7-8	DETAILS

IMI - STONEY CREEK QUARRY

SR 38/32

NOBLESVILLE, IN

THESE DRAWINGS CONTAIN PROPRIETARY INFORMATION WHICH MUST NOT BE TRANSMITTED TO ANY PERSON OR FIRM NOT INVOLVED WITH THIS PROJECT EXCEPT BY WRITTEN PERMISSION OF COUNTY MATERIALS CORPORATION

TOMMY NICHOLSON REGISTERED No. PE 11120281 STATE OF INDIANA PROFESSIONAL ENGINEER

DECEMBER 20, 2018

DATE	ISSUE / REVISIONS
12-XX-2018	ISSUED FOR CONSTRUCTION

RECOMMENDED FOR APPROVAL: _____ DESIGN ENGINEER DATE

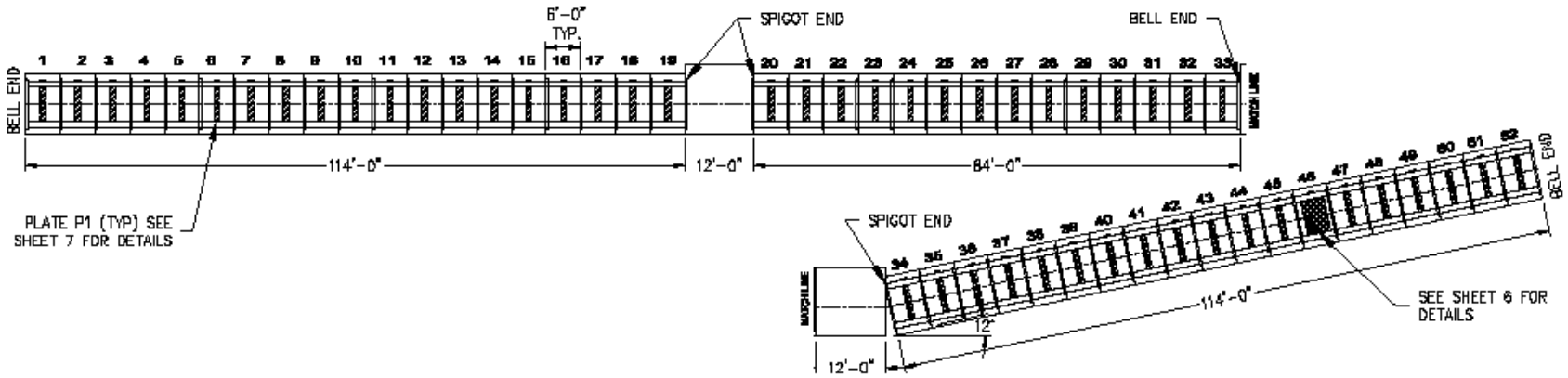
DESIGNED: ARW DRAWN: ARW

CHECKED: SS CHECKED: SS

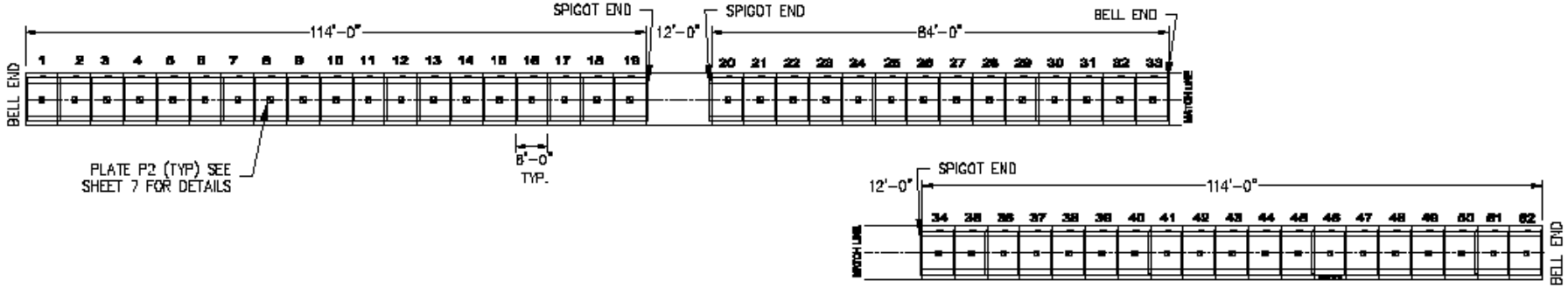
TITLE AND INDEX OF SHEETS

COUNTY MATERIALS CORPORATION
119 N. Main Street
Maxwell, IN. 46154
Ofc. (317) 323-6000
Fax (877) 249-1374

STRUCTURE NO.:	8' x 8'
--	BOX CULVERT
DESIGNATION NO.:	STRUCTURE:
IMI - STONEY CREEK QUARRY	NOBLESVILLE, IN
ROUTE:	SPC JOB NO.:
SR 38/32	18-1080
COUNTY:	SCALE:
HAMILTON	1" = 10'-0"
PROJECT NO.:	SHEET:
----	1 OF 8



1/2 STRUCTURE ELEVATION
1" = 20'-0"



2/2 STRUCTURE PLAN
1" = 20'-0"

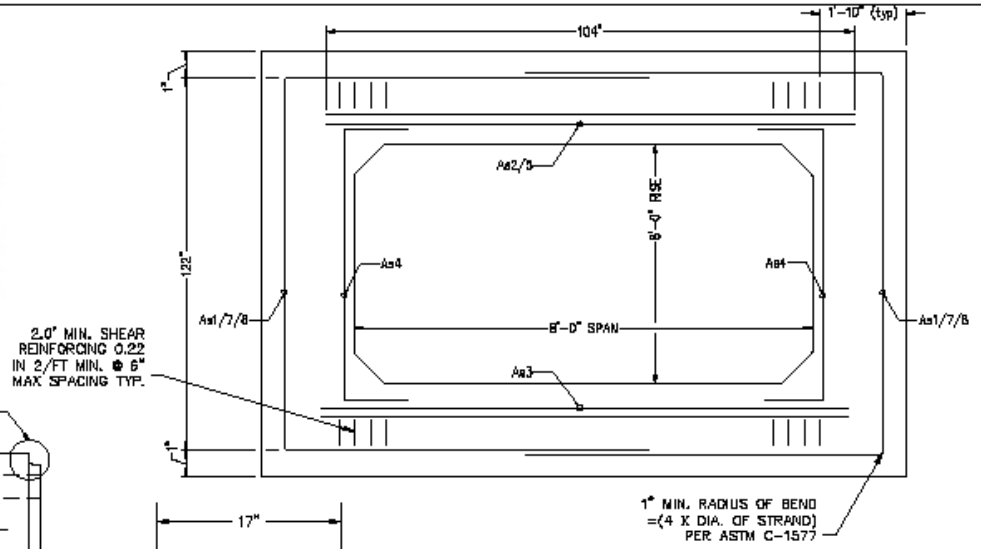
TOMMY NICHOLSON
REGISTERED
No. PE 11100281
STATE OF
INDIANA
PROFESSIONAL ENGINEER

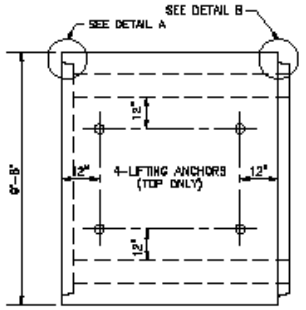
DECEMBER 20, 2018

RECOMMENDED FOR APPROVAL: DESIGN ENGINEER DATE		STRUCTURE PLAN	STRUCTURE NO.: – / 8' x 8' BOX CULVERT
DESIGNED: ARW	DRAWN: ARW	COUNTY 110 N. Main Street Marwell, IN. 46154 Ofc. (317) 323-6000 Fax (877) 249-1374	DESIGNATION NO.: STRUCTURE / IMI - STONEY CREEK QUARRY NOBLESVILLE, IN
CHECKED: SS	CHECKED: SS		ROUTE: SPC JOB NO.: / 88 3602 18-1086
			COUNTY: SCALE: / HAMILTON 1" = 20'-0"
			PROJECT NO.: SHEET: / 2 OF 8

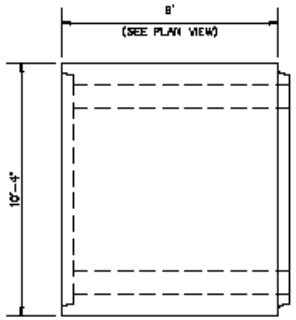
TOMMY NICHOLSON
REGISTERED
No. PE 11100261
STATE OF INDIANA
PROFESSIONAL ENGINEER

DECEMBER 20, 2018

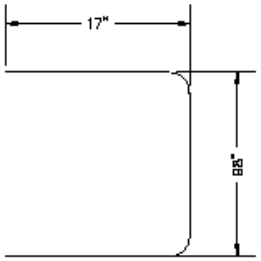




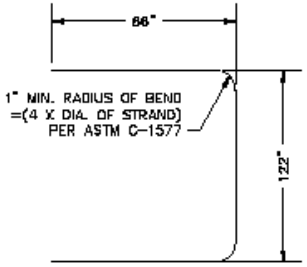
PLAN



ELEVATION

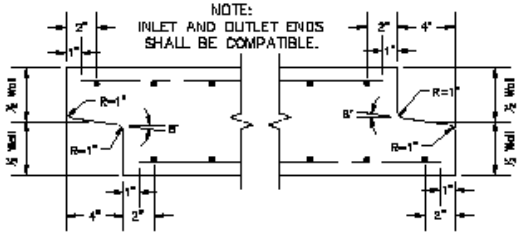


As4



As1/7/8

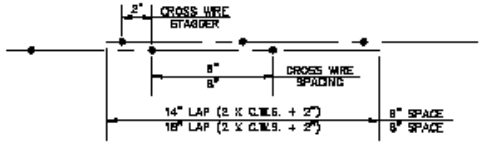
NOTE:
INLET AND OUTLET ENDS SHALL BE COMPATIBLE.



DETAIL A
TYP. INLET END

DETAIL B
TYP. OUTLET END

JOINT DETAIL



TYPICAL LAP

GENERAL NOTES:

PRECAST CONCRETE BOX SECTIONS SHALL CONFORM TO THE APPLICABLE REQUIREMENTS OF THE INDIANA DOT SPECIFICATIONS FOR PRECAST REINFORCED CONCRETE BOX CULVERTS SECTION 714, ASTM DESIGNATION C-1577 AND IN THE THE DETAILS SHOWN ON THIS DRAWING.

THE DESIGN CONFORMS TO HL-93 LOADING IN ACCORDANCE WITH CURRENT AASHTO LOAD AND RESISTANCE DESIGN (LRFD) SPECIFICATIONS FOR HIGHWAY BRIDGES. 35 PSF FOR F.W.S. INCLUDED.

MINIMUM 28 DAY CONCRETE STRENGTH SHALL BE 6500 PSI.

REINFORCEMENT SHALL BE WELDED WIRE FABRIC CONFORMING TO AASHTO M55 (ASTM A 1064) SMOOTH OR (ASTM A 496) DEFORMED WIRE.

THE JOINTS OF THE PRECAST BOX SECTIONS SHALL BE SEALED IN ACCORDANCE WITH THE INDOT STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION.

REQUIRED STEEL AREAS:

As1	.48	As5	N/A	Cover	81'-0"
As2	1.68	As7	N/A	"M" Dim	-- min.
As3	1.68	As8	N/A	Skew	0"
As4	.48			Epoxy	NO

ACTUAL FURNISHED WWF:

As1	2	x	8	-	D8.0	x	D4.0	= .48
As2	2	x	6	-	D14.0	x	D6.0	= .84(2)pieces=1.68
As3	2	x	6	-	D14.0	x	D6.0	= .84(2)pieces=1.68
As4	2	x	6	-	D8.0	x	D4.0	= .48
As7	2	x	6	-	D8.0	x	D4.0	= .48
As8	2	x	8	-	D8.0	x	D4.0	= .48

CONTRACT 18-1086 COUNTY HAMILTON
PROJECT No. STONEY CREEK QUARRY
CONTRACTOR IMI
LOCATION SR 38 /32 NOBLESVILLE, IN

STIRRUPS ARE REQUIRED IN SIDES, TOP, AND BOTTOM

SPAN 8' RISE 8'
TOP 14' BOTTOM 14' WALLS 10"
HAUNCH 12"

RECOMMENDED FOR APPROVAL: DESIGN ENGINEER DATE		CULVERT REINFORCEMENT	
DESIGNED: ARW	DRAWN: ARW	COUNTY	119 N. Main Street Maxwell, IN. 46154 Ofc. (317) 323-6000 Fax (877) 249-1374
CHECKED: SS	CHECKED: SS		

STRUCTURE NO.: –	8' x 8' BOX CULVERT
DESIGNATION NO.: IMI - STONEY CREEK QUARRY	STRUCTURE: NOBLESVILLE, IN
ROUTE: SR 38/32	SPC JOB NO.: 18-1086
COUNTY: HAMILTON	SCALE: 1" = 10'-0"
PROJECT NO.: ----	SHEET: 3 OF 8

CAT
374F L

Will You Be Able to Use This Information?

Donald E. McNutt, pe
Great Lakes Region Engineer
American Concrete Pipe Assoc
dmcnutt@concretepipe.org