Shane Marshall | Construction Management

Pegula Ice Arena

Advisor: Raymond Sowers

Building Information

Location: Pennsylvania State University | University Park

Function: Division 1 Hockey | Community Rink

Size: 227,000 SF
Three Stories
Height = 65 ft. above grade

LEED: Gold Potential

Construction Information

Schedule: First Puck Drop – PSU vs. Army | October 11, 2013
Start | February, 2012
End | September, 2013

Delivery Method: CM at Risk

Cost: Project | $102 M
Construction | $89 M

Contract: Guaranteed Maximum Price

Structure: Moment & Braced Frame
Precast Stadia

Mechanical: 12 Air Handling Units

Project Team Members

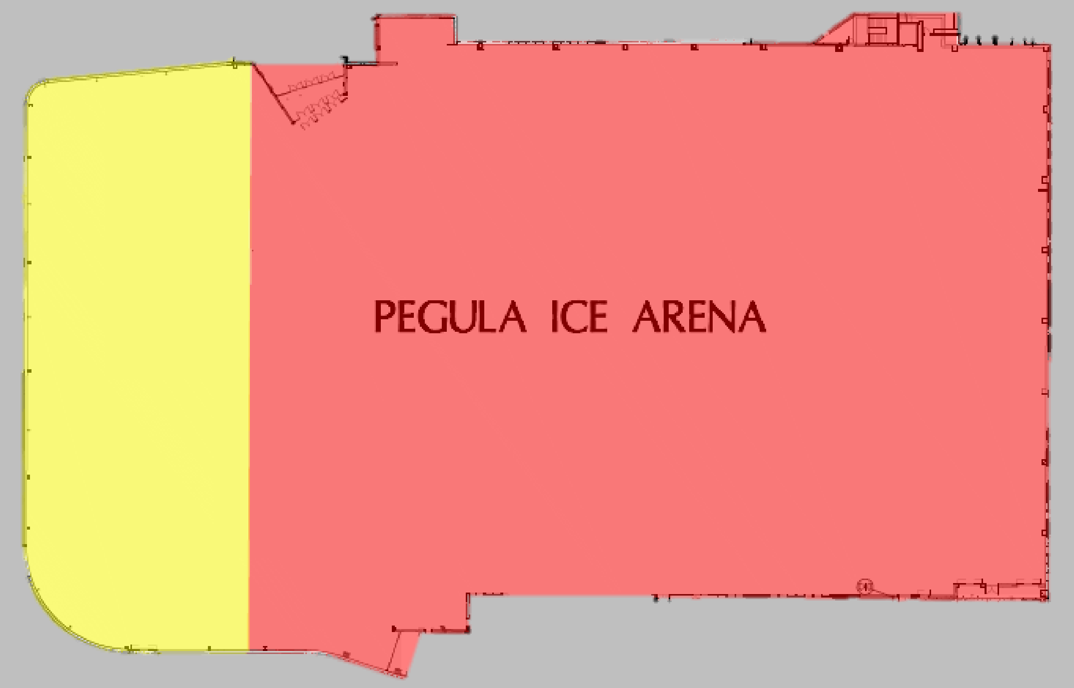
CRAWFORD

Mortenson construction

PENN STATE

Community Rink
Sequence off Critical Path

Main Rink vs. Community Rink



Main Rink

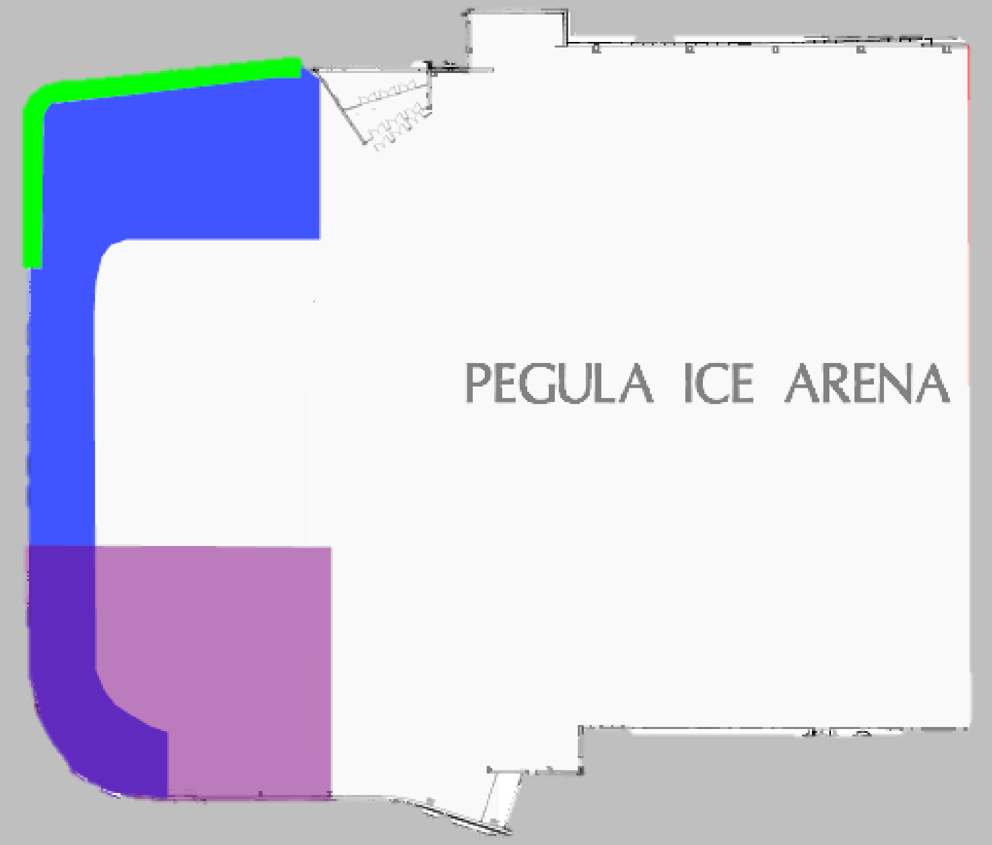
Community Rink

Community Rink Critical Path Items

Foundation Wall

Underground MEP & SOG

Structural Steel



Key Points from Schedule 1

- Community Rink line items (foundation wall, underground MEP & SOG, and structural steel) lie on the critical path
- Finishes have the potential to be expedited

New Schedule

- Backward logic applied to removed community rink schedule line items.
- Exterior CMU along west portion of building now controls community rink.
  - Structural steel (NW) finish-start relationship with exterior CMU.
- 17 days of float are available for the community rink.

Crane

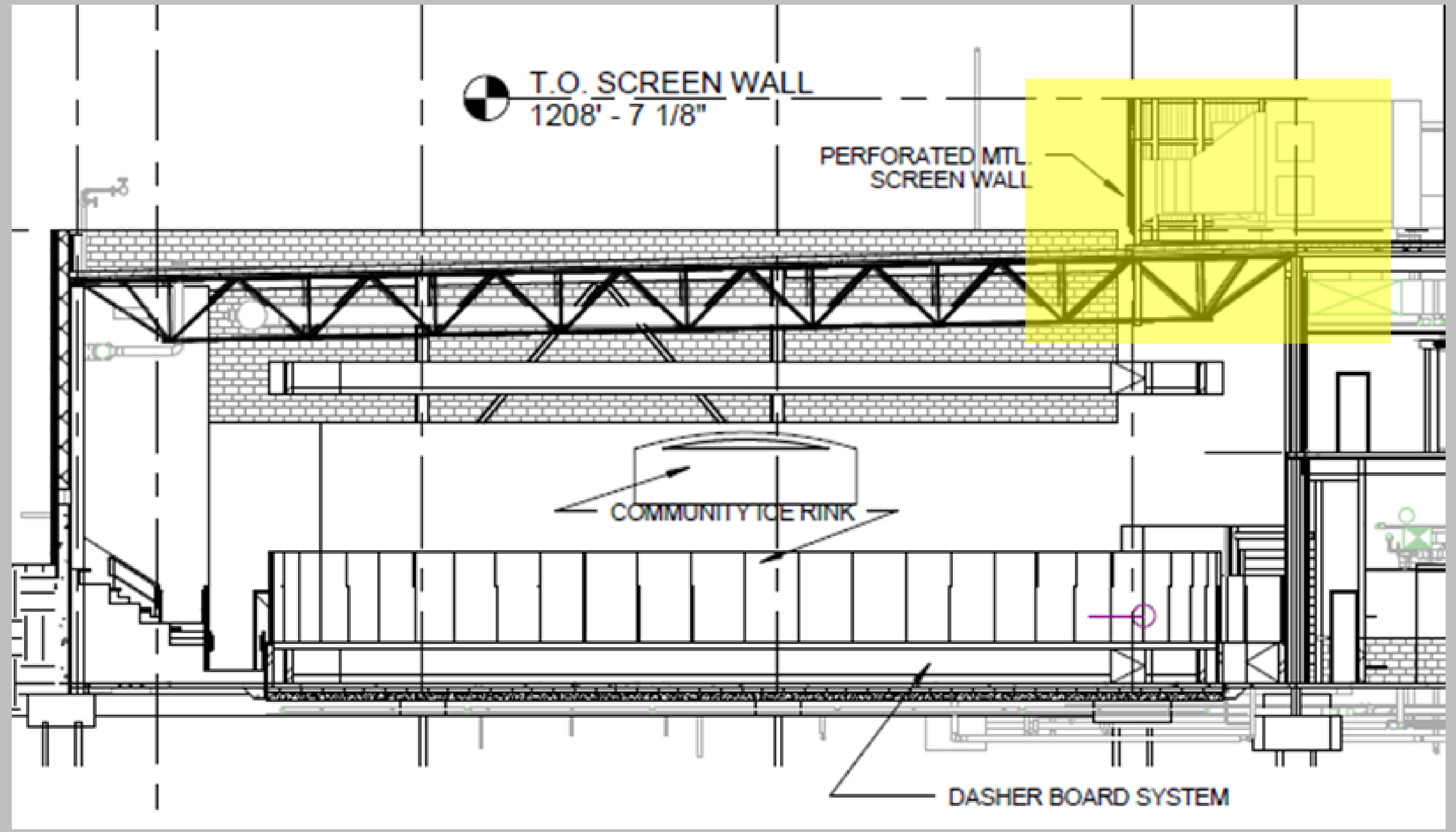
Crane Driven Activities			
	Original Schedule	New Schedule	
Start Date	7/16/2012	7/16/2012	Total Days Saved
Finish Date	10/26/2012	10/3/2012	
Actual Days	103	80	23
Working Days	75	58	17

* There are not actually 17 days of crane reduction.

Finishes

Finish Work Driven Activities (FRP SW #9 Ends)			
	Original Schedule	New Schedule	
Start Date	5/18/2012	5/18/2012	
Finish Date	11/6/2012	10/15/2012	Total Days Gained
Actual Days	174	151	22
Working Days	123	107	16

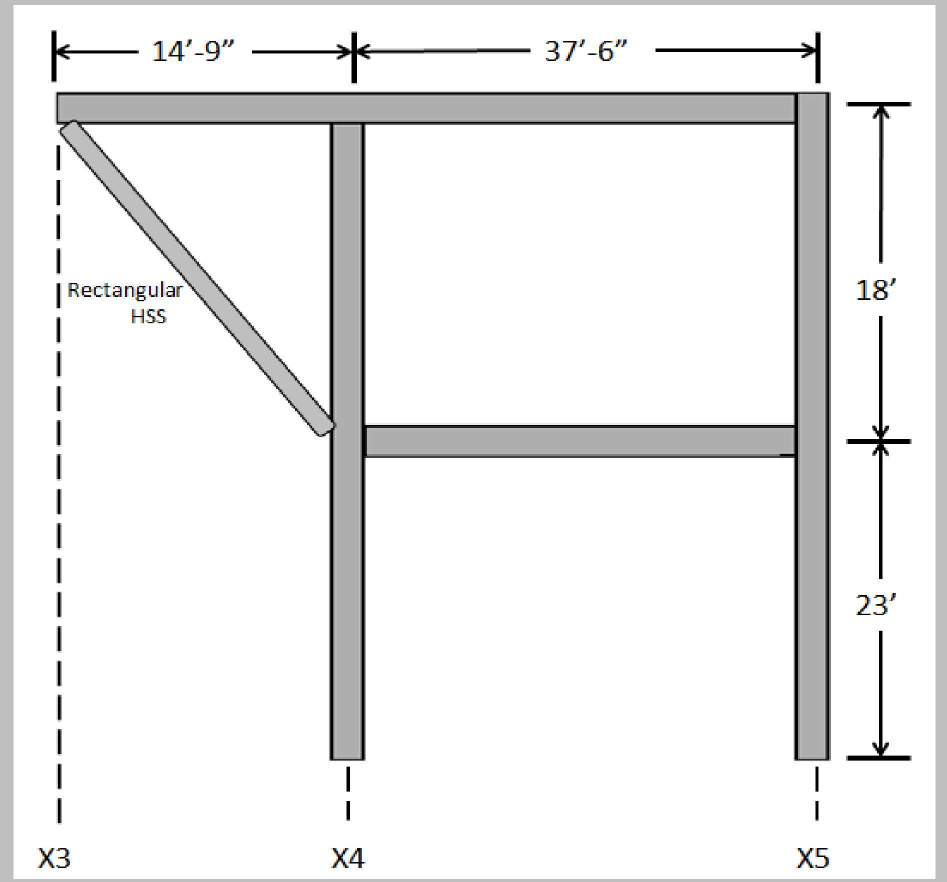
Mechanical Units



Key Point

Mechanical units rest over main rink and community rink

Proposed Structural Design



Load Calculations

Community Roof

- DL = 3.6psf TPO + 5psf beam self-weight = 8.6psf
- LL = 20psf (roof load)
- SL = 30psf
- W_u = 1.2(8.6) +1.6(20) + 0.5(30) = 57.3psf
- Point Load = 57.3psf * 47.5' * 26'(worst case scenario) = 70.766kip

Cantilevered Section Top Girder (Gridlines X3 to X4)

- DL = 75psf (concrete slab) + 24psf (AHU weight) + 10psf girder self-weight = 109psf
- LL = 20psf (roof load)
- SL = 30psf
- W_u = 1.2(109) +1.6(20) + 0.5(30) = 180psf
- Distributed Load = 180psf * 26' = 4.68kip/ft

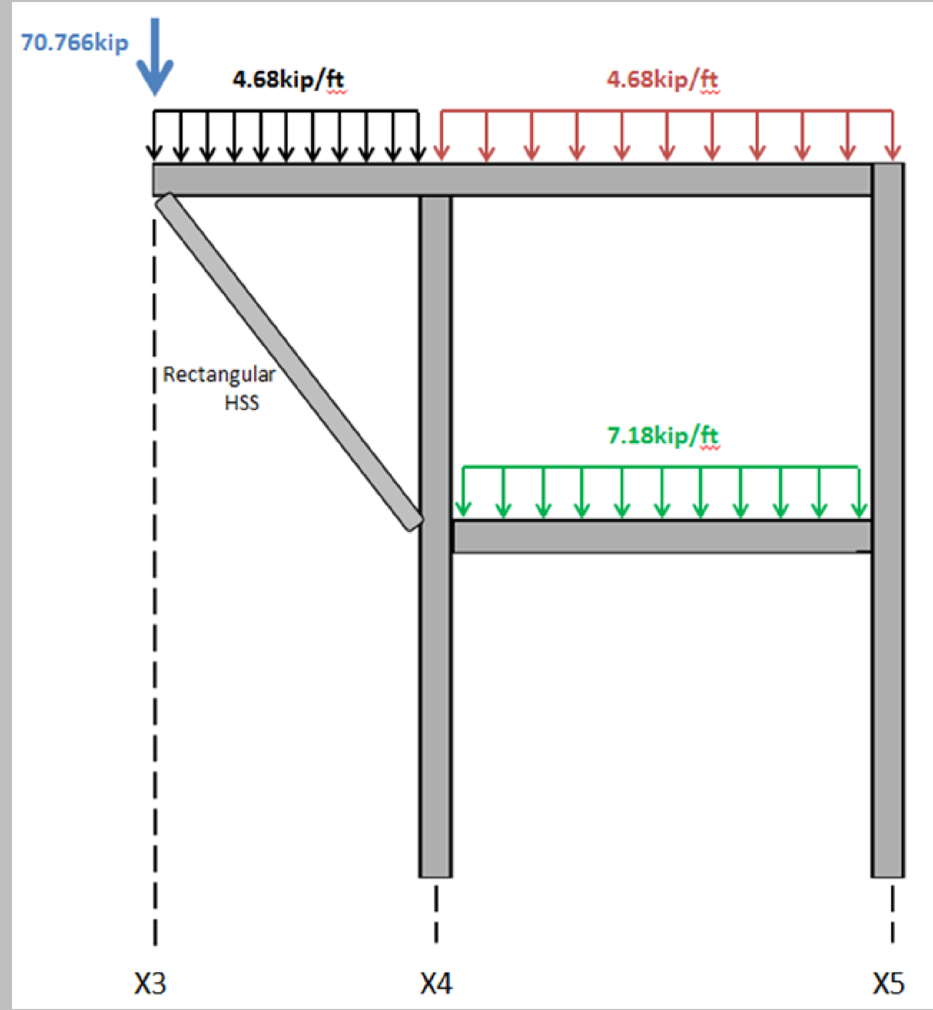
Top Girder (Gridlines X4 to X5)

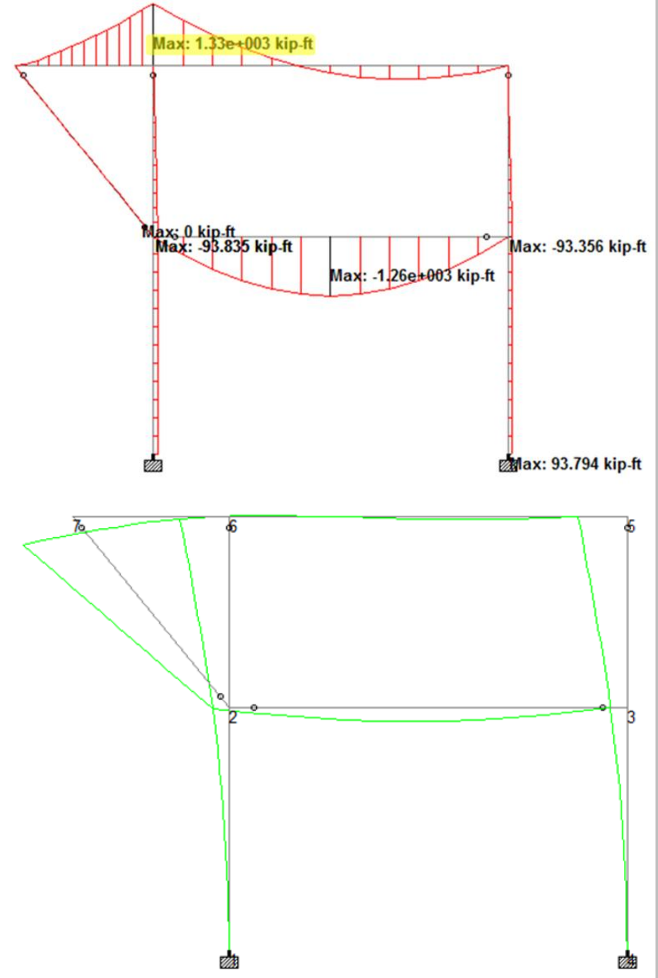
- DL = 75psf (concrete slab) + 24psf (AHU weight) + 10psf girder self-weight = 109psf
- LL = 20psf (roof load)
- SL = 30psf
- W_u = 1.2(109) +1.6(20) + 0.5(30) = 180psf
- Distributed Load = 180psf * 26' = 4.68kip/ft

Bottom Girder (Gridlines X4 to X5)

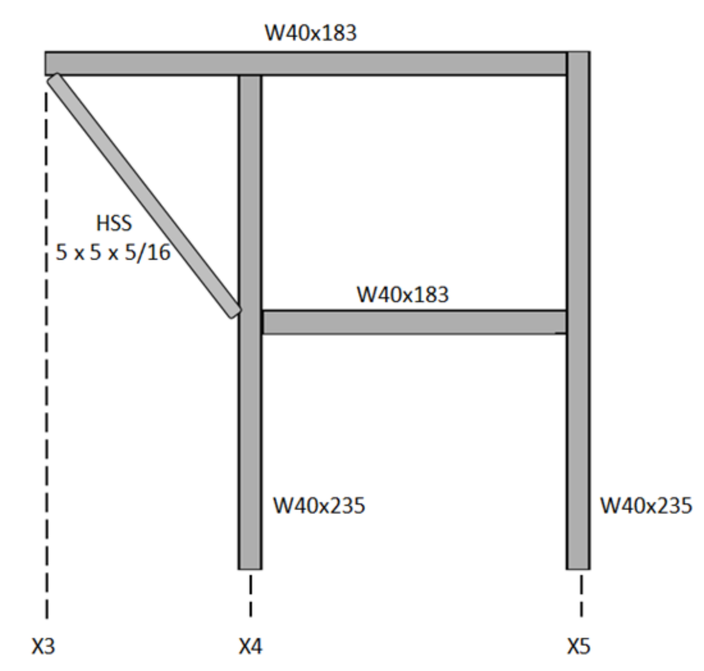
- DL = 75psf (concrete slab) + 10psf girder self-weight = 85psf
- LL = 100psf (corridor)
- W_u = 1.2(85) +1.6(100) = 262psf
- Distributed Load = 262psf * 27.4' (worst case scenario) = 7.183kip/ft

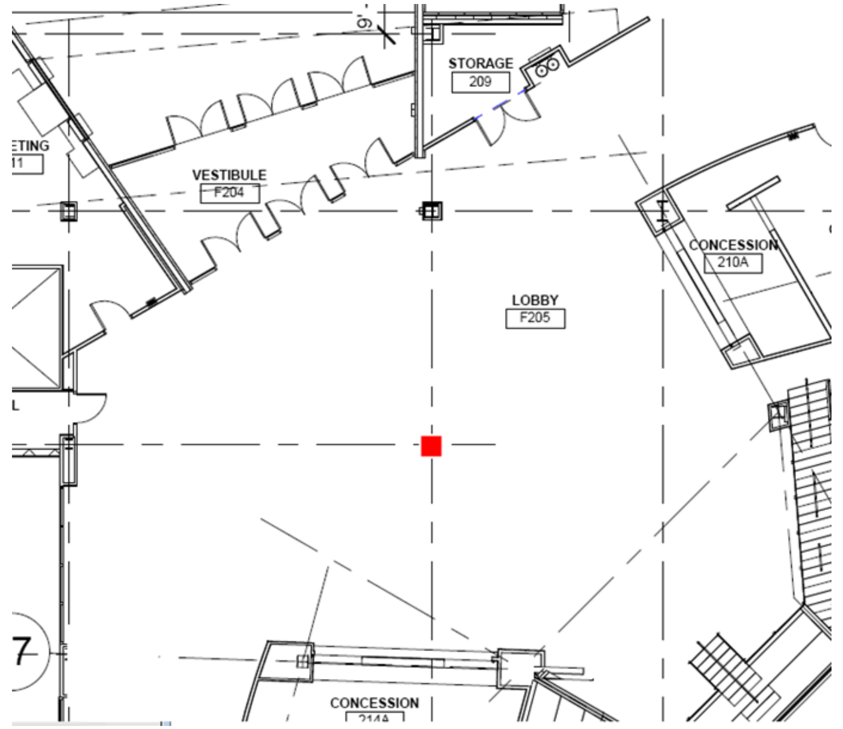
Structural Loads



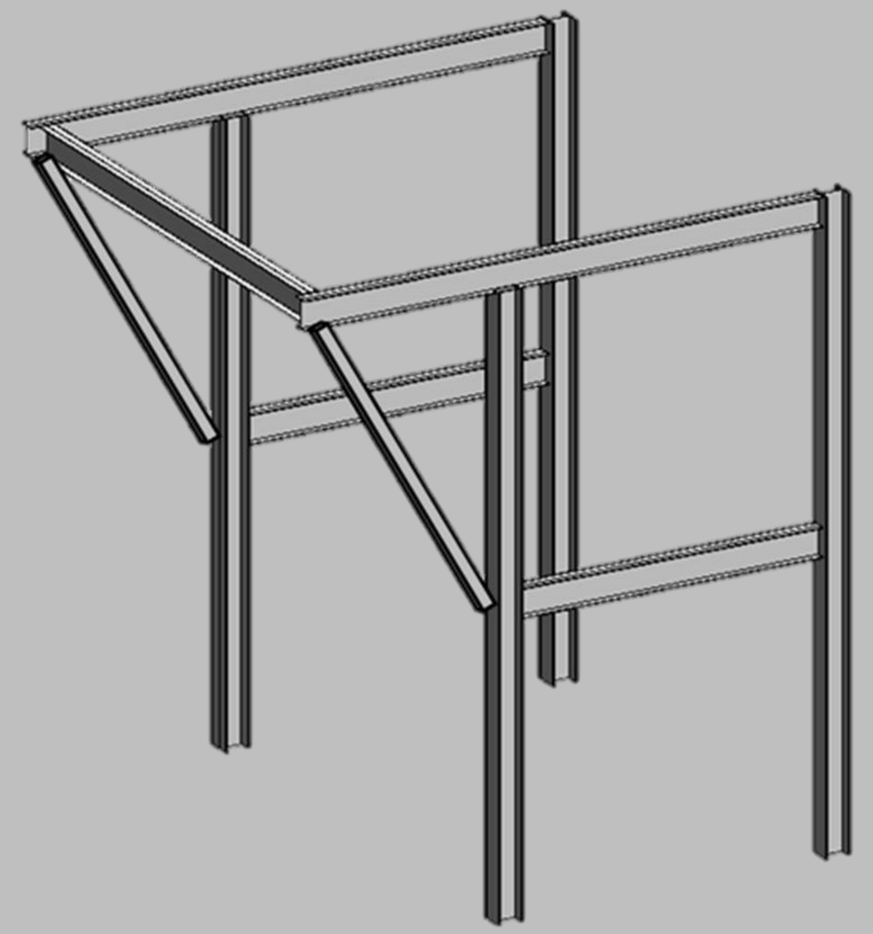


Structural Member Results





Structural Figure



Advantages

- Finishes can begin more quickly ahead of the current schedule which will result in the project finishing three weeks ahead of schedule.
- Allows more float on community rink activities. Specifically mechanical room has much more time to get underground work finished.
- Decrease in general conditions
    - Employee Costs: $91,500
    - Miscellaneous Costs: $8,175
    - Total Costs: $99,675

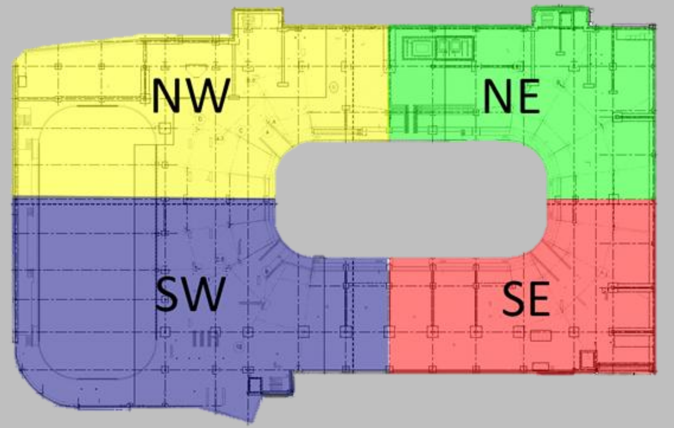
Disadvantages

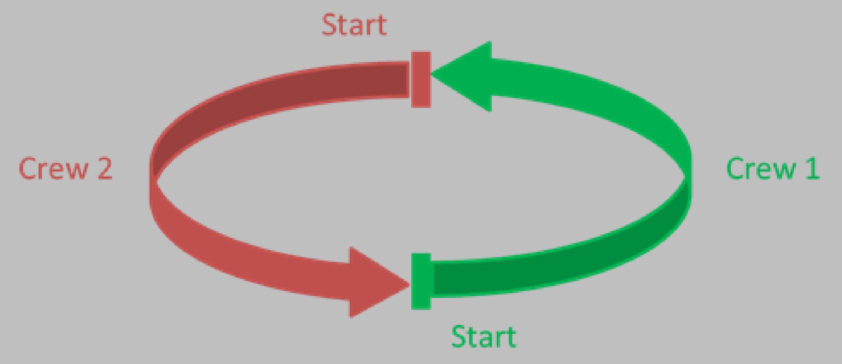
- Significant increase in size of steel columns and girders.
- Additional cost in steel. ($361,748)
- Potential foundation upgrades.
- Minimal crane time saving.
- Significant aesthetic disruption at student entrance.

Analysis 1 Conclusion

Building Sequence

Schedule

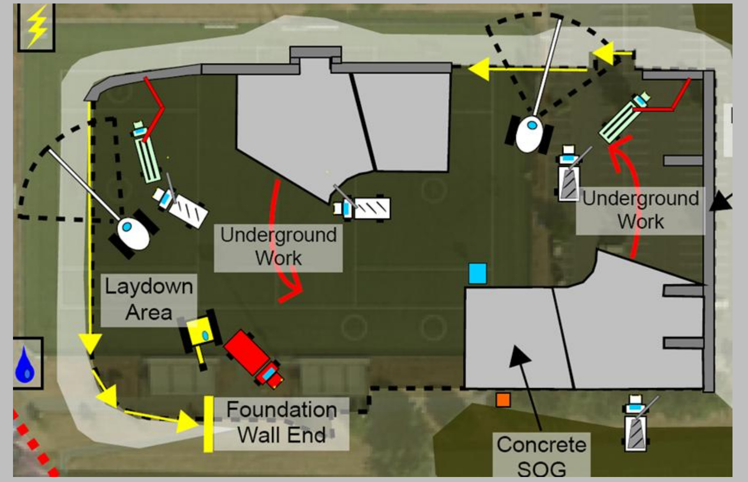




	Base Summary Schedule	Two Crews Summary Schedule
Start	January 26, 2012	January 26, 2012
Finish	September 17, 2013	March 8, 2013

	Base Summary Schedule	Excavation, Concrete, Steel Two Crews
Start	January 26, 2012	January 26, 2012
Finish	September 17, 2013	August 23, 2013

Logistics



Excavation:

Twice the amount of heavy machinery

Traffic flow on the site and at the site entrance

Foundation and Concrete:

Tight working conditions

Lack of maneuverability to working spaces

Logistics

Steel:

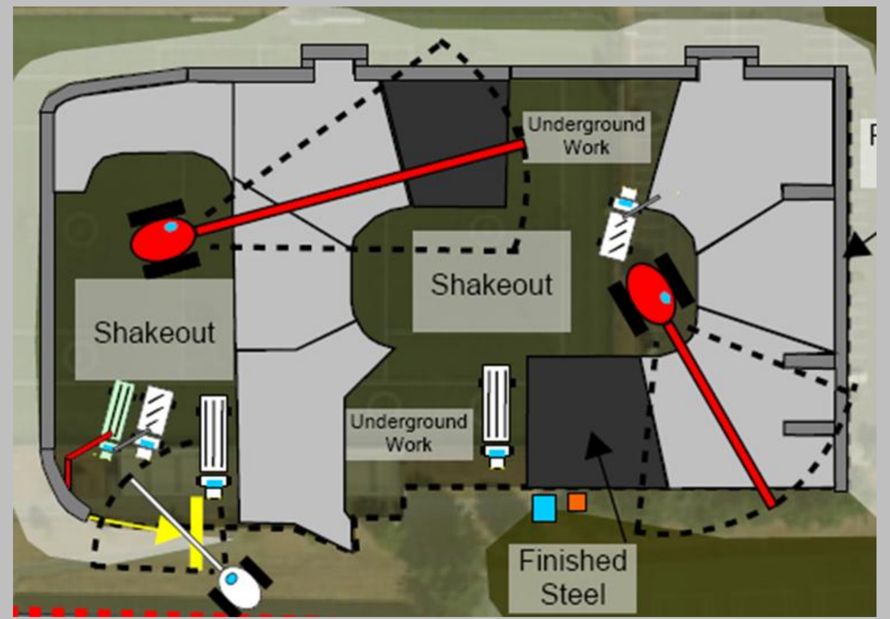
Tight working conditions

Lack of maneuverability for steel deliveries

Little to no shakeout area

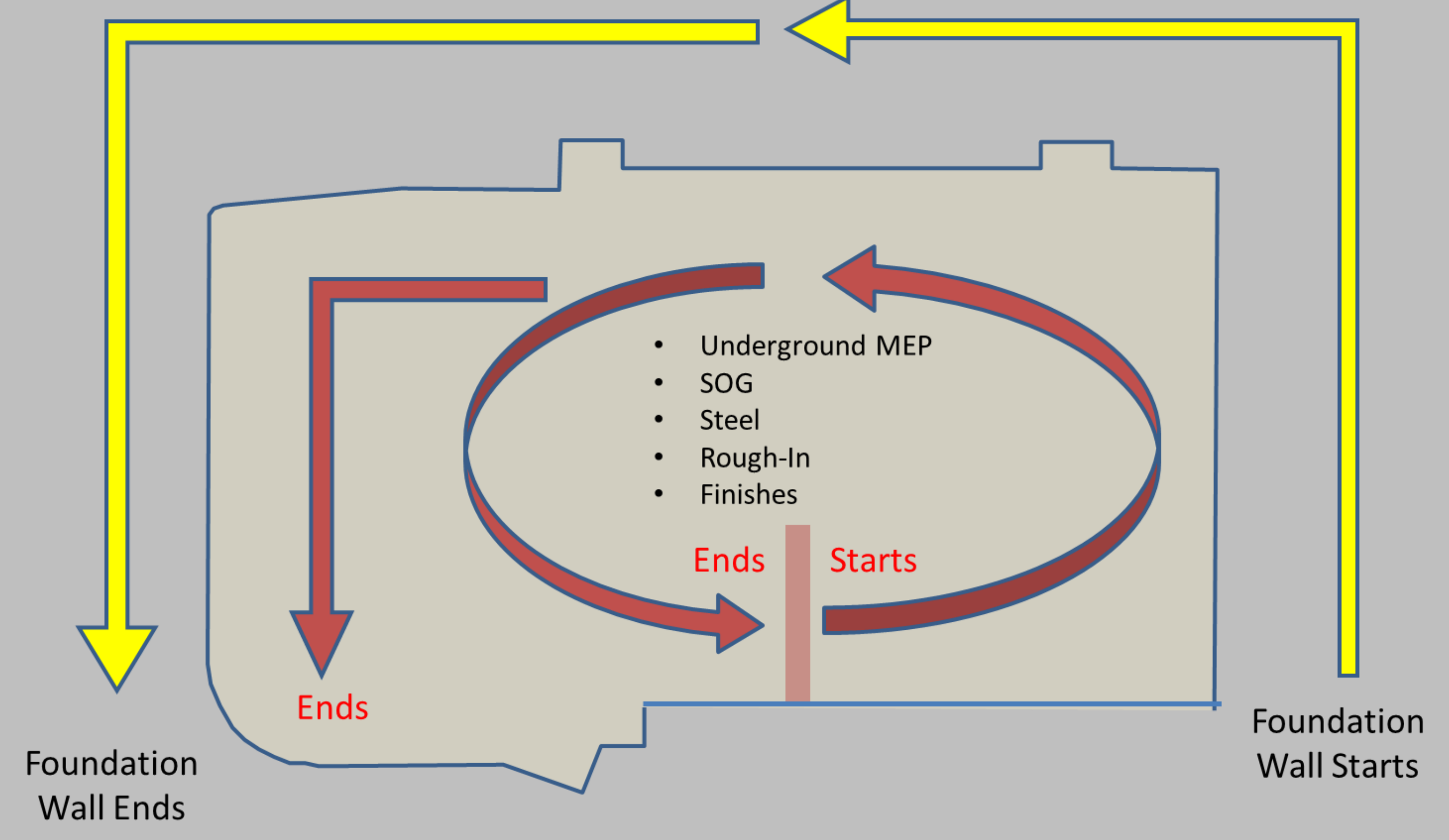
Second crane has potential to boom out over public buildings and pathways

Cranes have potential to collide

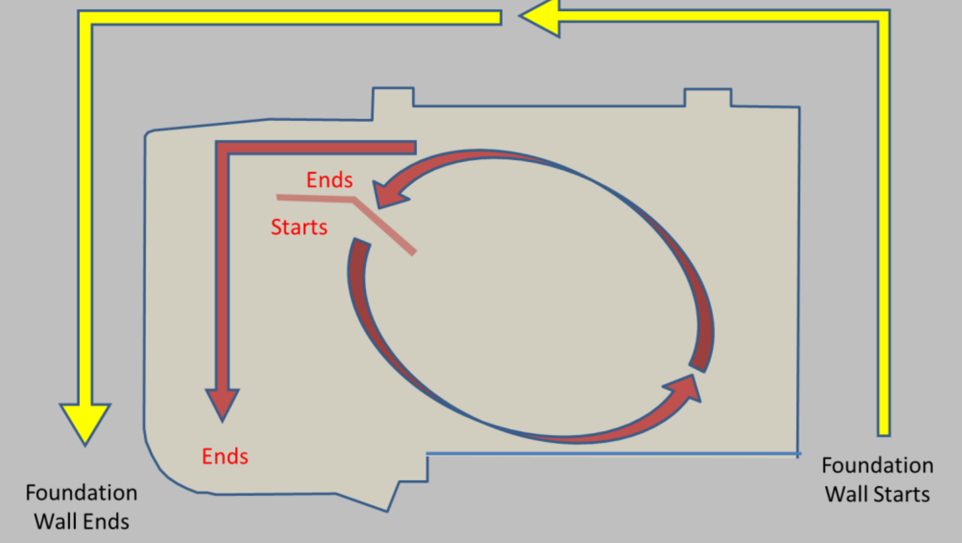


Two Crews

Original Sequence

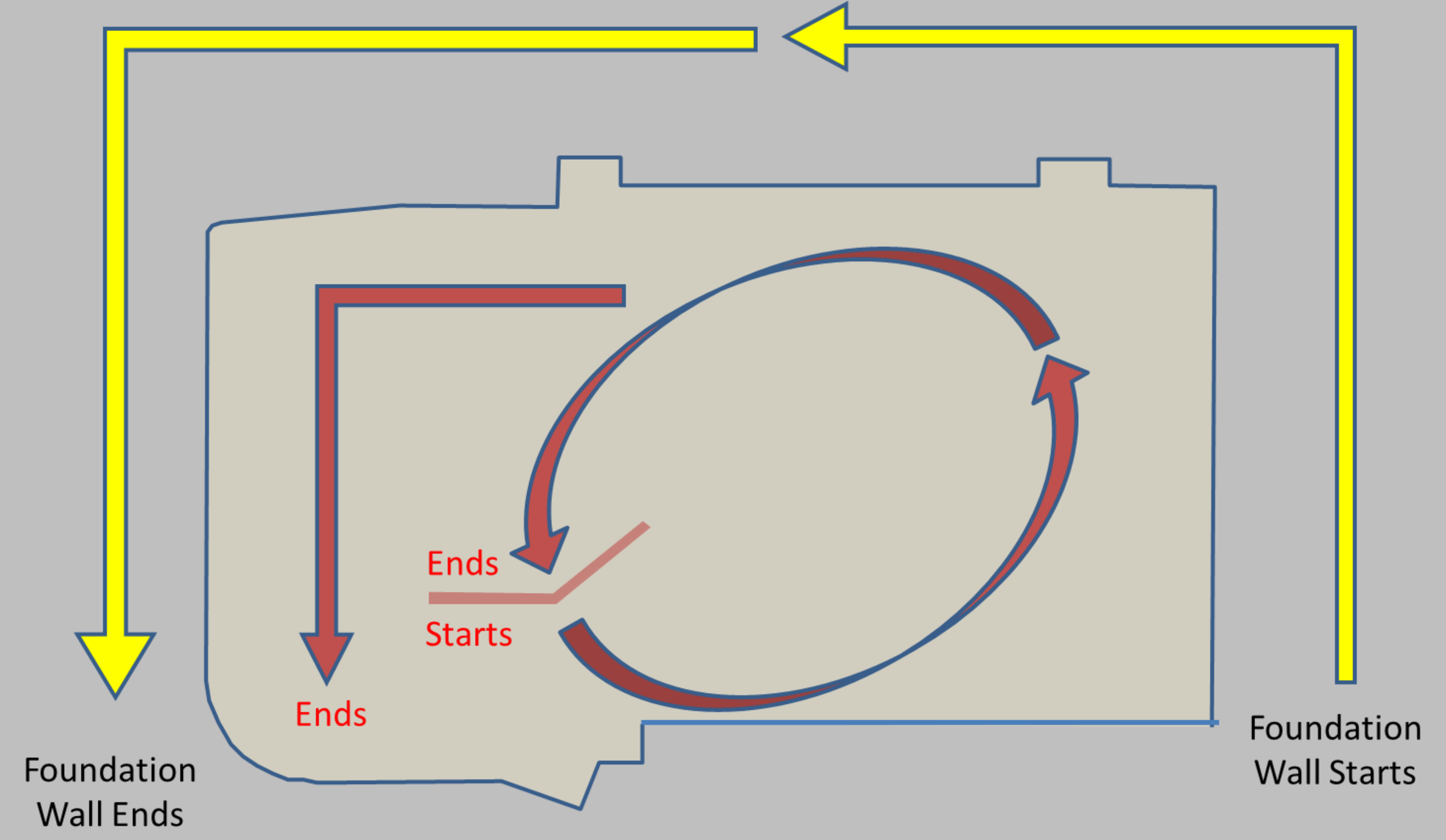


Proposed Sequence



Task Name	Different Project Start Point		
	Duration	Start	Finish
Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12
Mobilization	6 days	Fri 1/27/12	Fri 2/3/12
Excavation - Bottom of SOG	51 days	Mon 2/13/12	Mon 4/23/12
Excavation - Foundations	41 days	Tue 3/27/12	Tue 5/22/12
Foundation Concrete	43 days	Tue 3/27/12	Thu 5/24/12
Underground MEP / SOG Concrete	60 days	Fri 3/16/12	Fri 6/29/12

Proposed Sequence



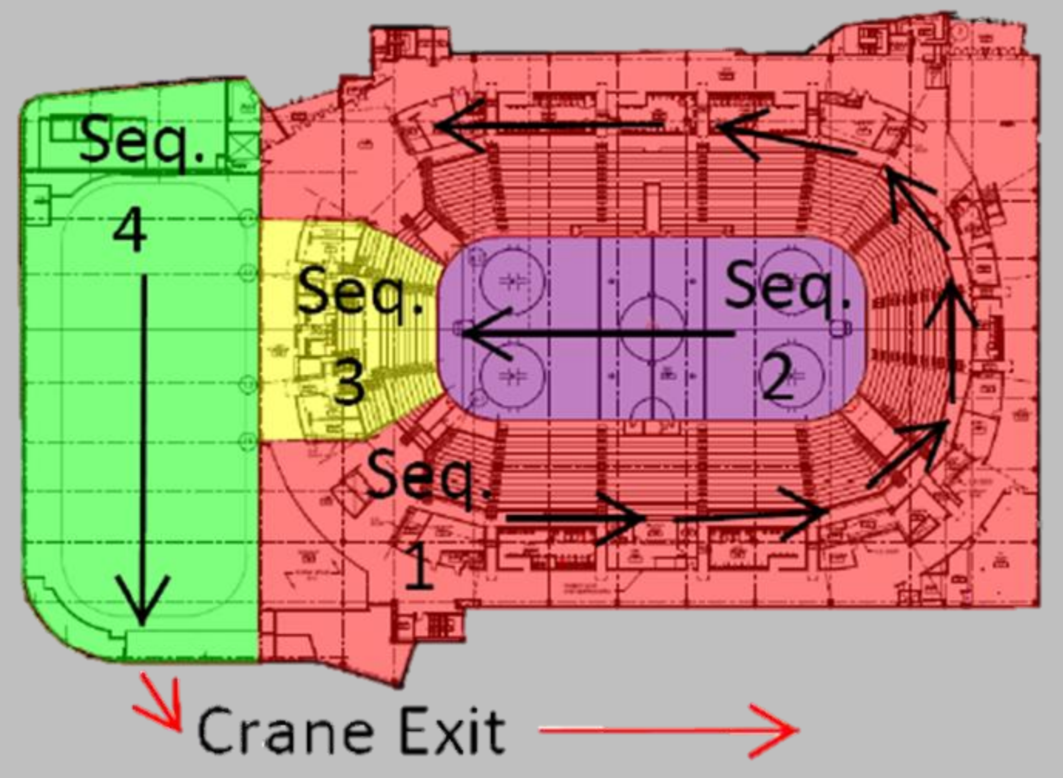
2 weeks of schedule reduction!!!

Start Location
Project Introduction
Analysis 1 Community Rink
Analysis 1 Structural Breadth
Analysis 2 Building Sequence
Analysis 3 Building Enclosure
Analysis 3 Architectural Breadth
Analysis 4 Geotech Investigation

Two Crews

Logistical Challenges

Crane Sequence



Work at Sequence 3

Advantages vs. Disadvantages

Advantages

- Rough-In and Finishes can begin more quickly (2 weeks of schedule reduction)
- Roof enclosure has less chance to be "snowed out"
- Potential alternative crane logistics
- Potential for no SOG comeback pours

Disadvantage

- Most difficult sequence of steel / precast would be installed blind
- Potential for increased crane time and additional cost

Building Enclosure

Current Enclosure

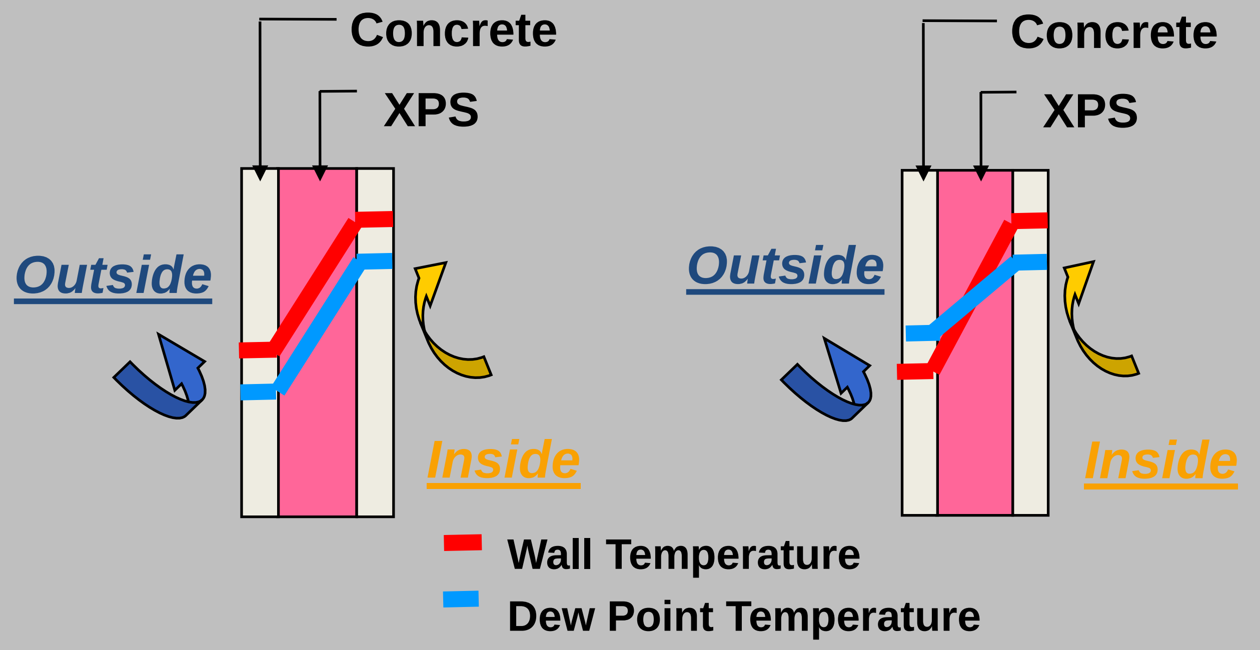
Proposed Wall System

HIGH CONCRETE GROUP

NO air/vapor barrier?

CarbonCast Insulated
Architectural Cladding

Vapor Barrier Issue

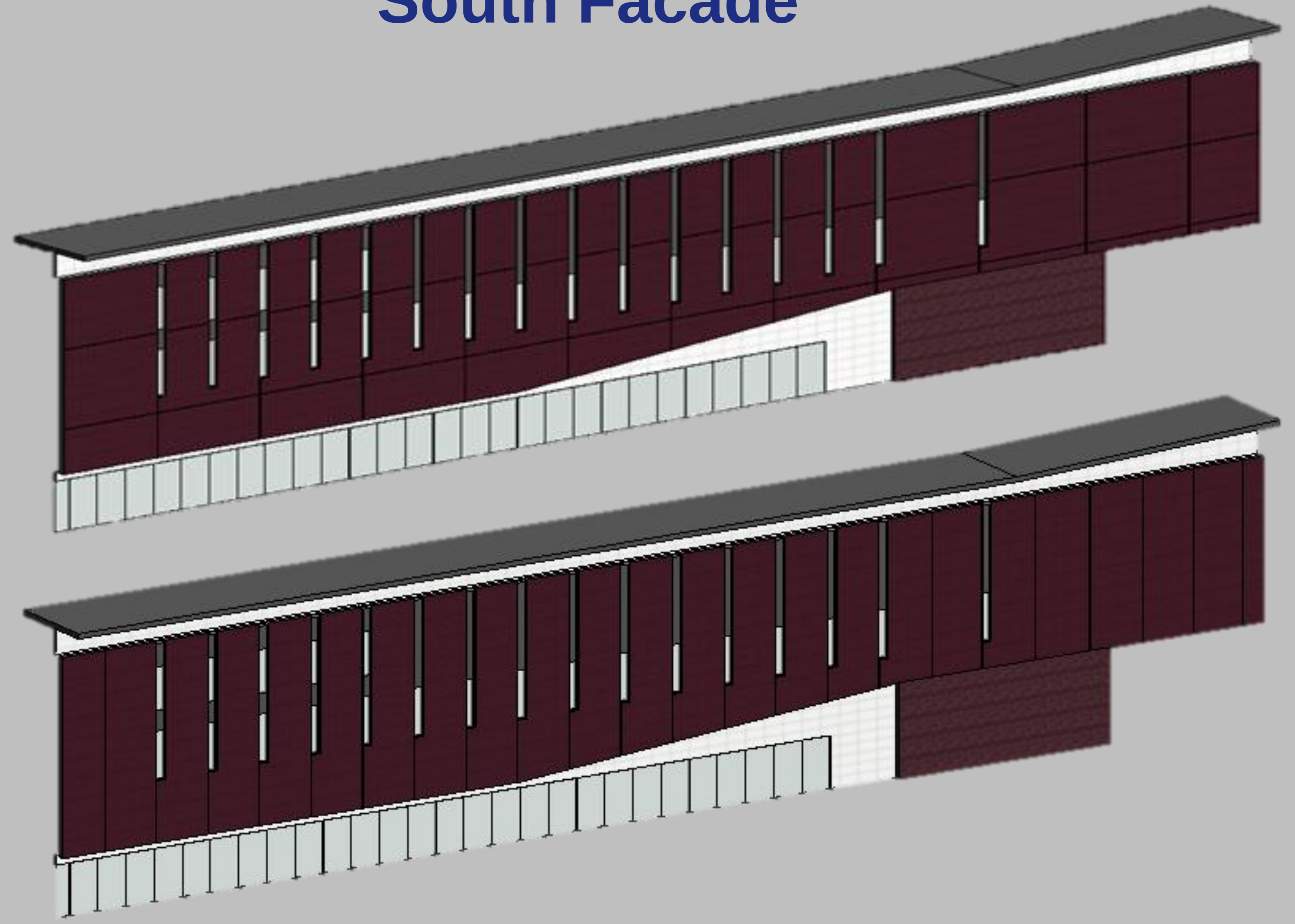


Plot the temperature lines & examine for locations where actual temperature falls below dewpoint temperature…

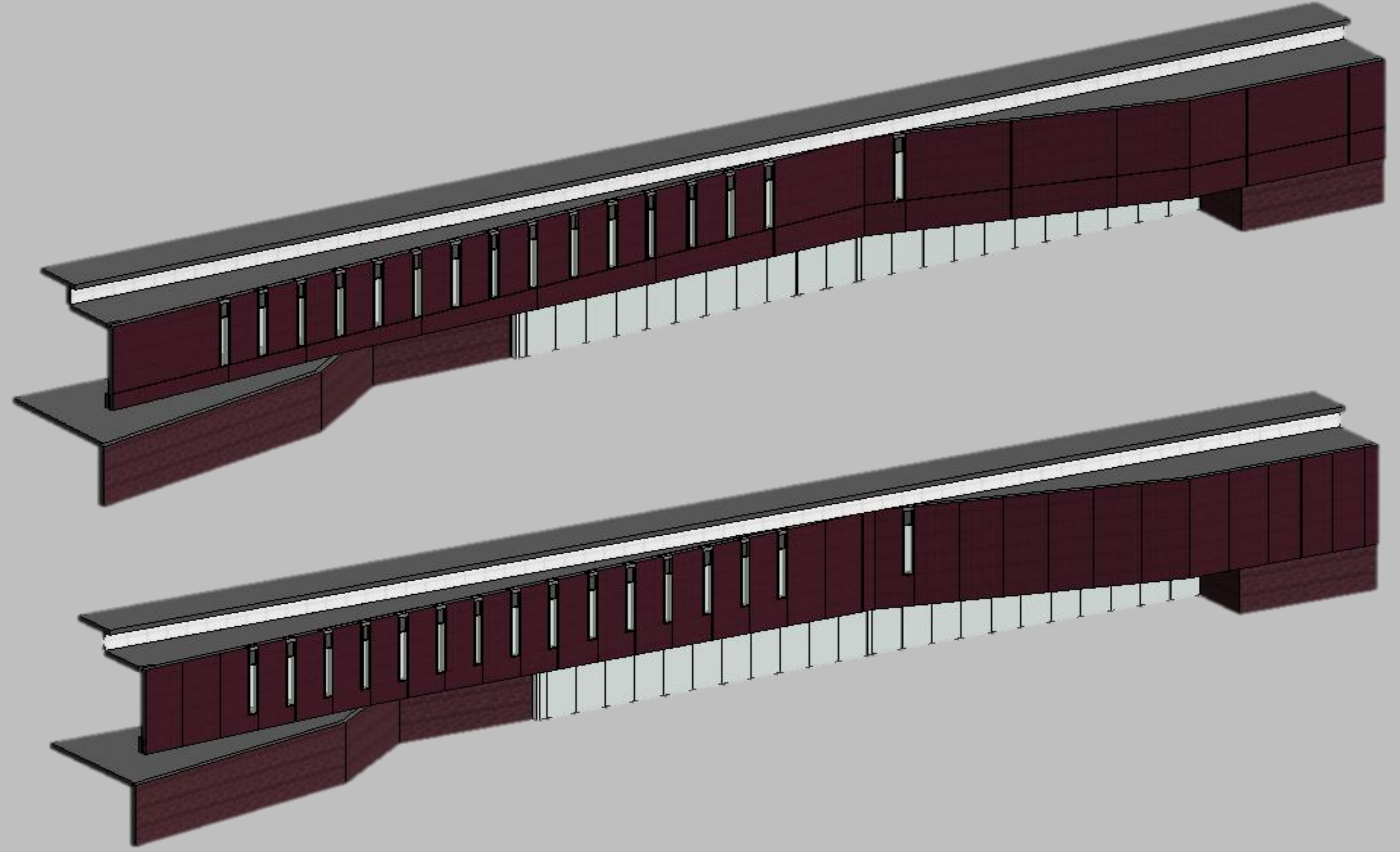
That indicates a location for potential condensation

Panels

South Facade



North Facade



Façade Design

Project Introduction

Analysis 1 Community Rink

Analysis 1 Structural Breadth

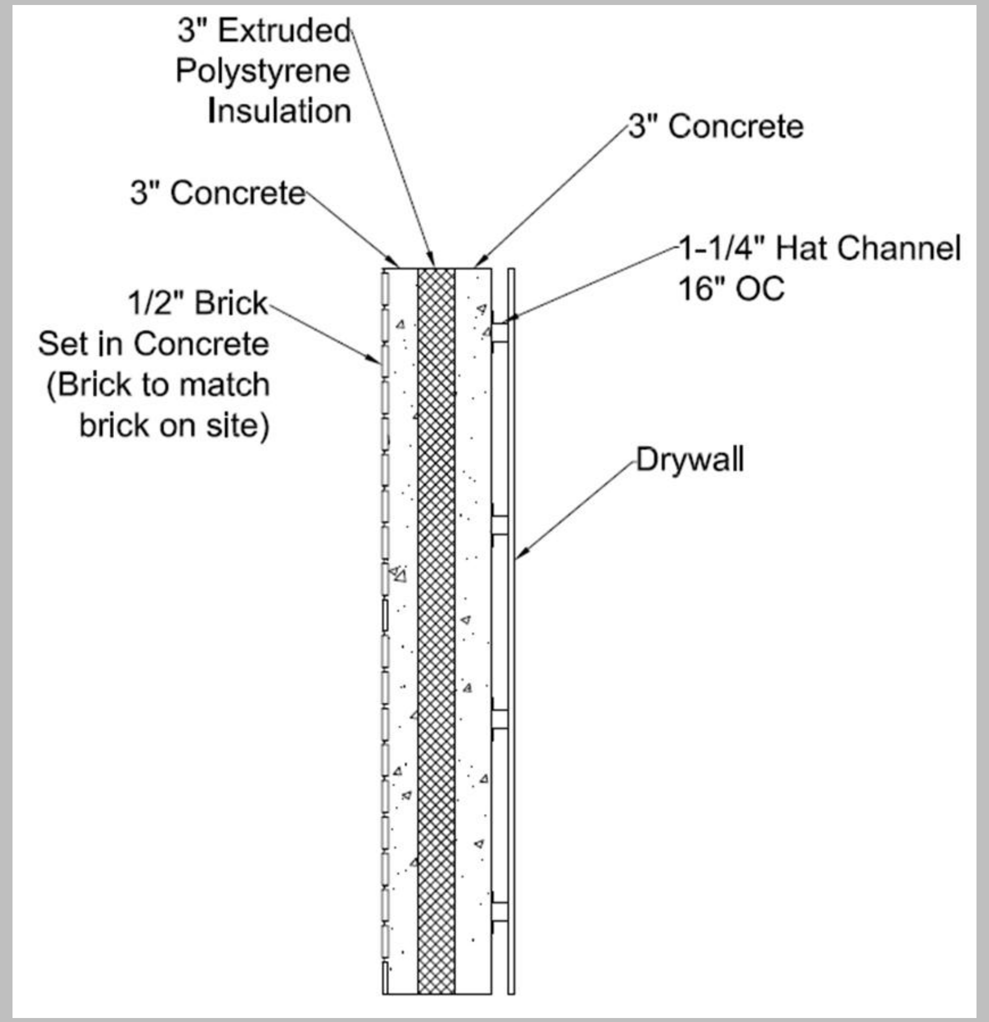
Analysis 2 Building Sequence

Analysis 3 Building Enclosure

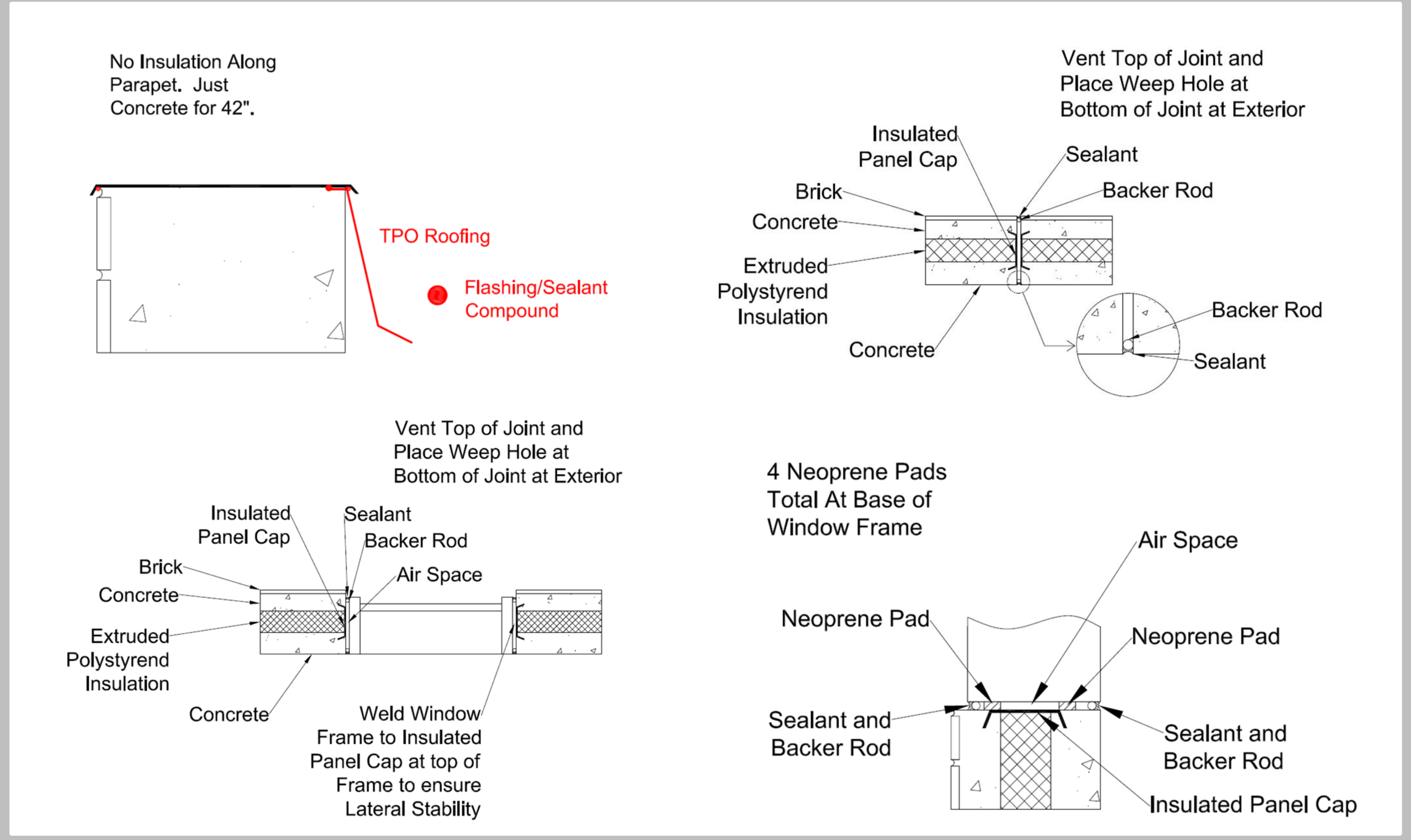
Analysis 3 Architectural Breadth

Analysis 4 Geotech Investigation

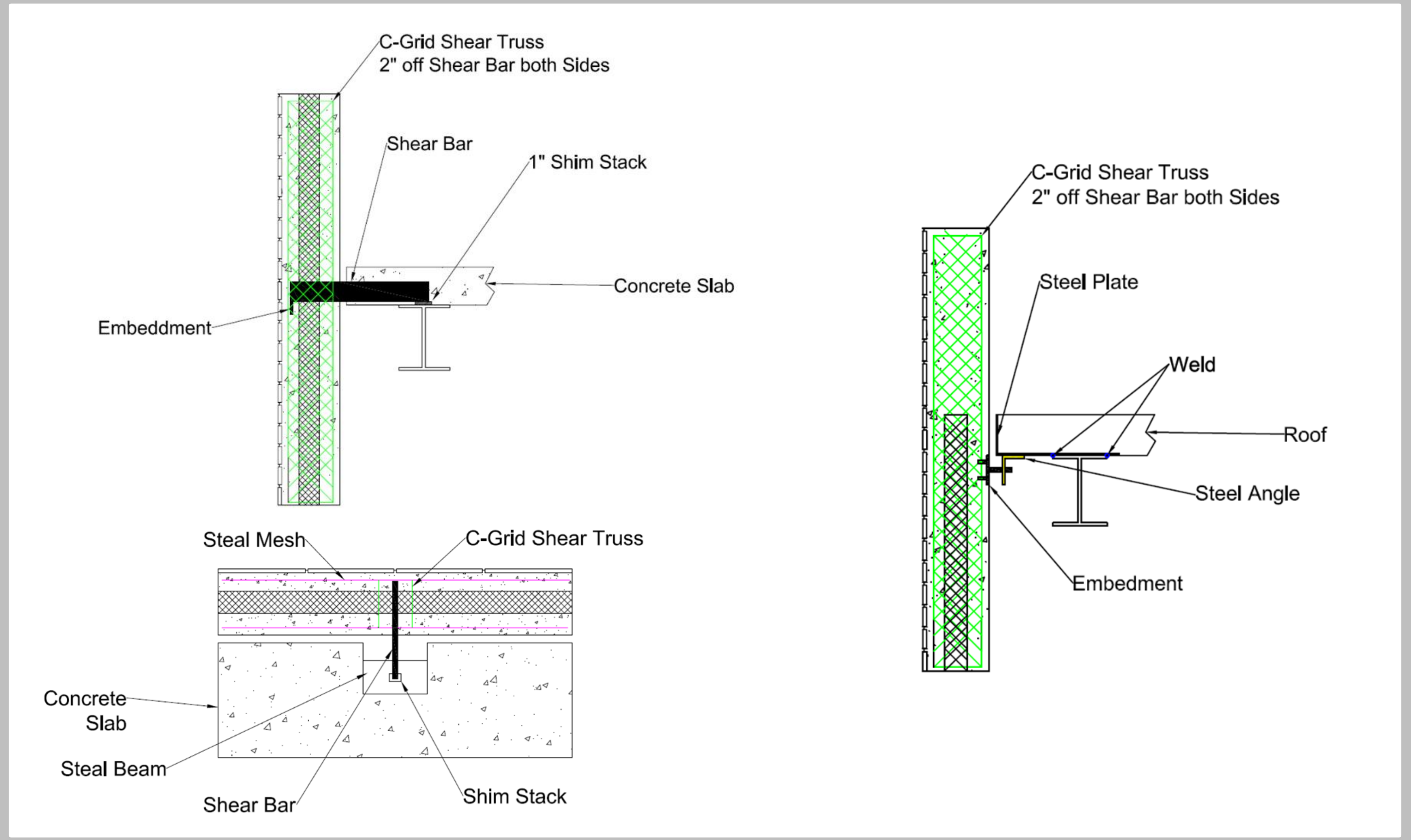
Enclosure Section



Construction Drawings



Structural Drawings



Drawing Details

Project Introduction | Analysis 1 Community Rink | Analysis 1 Structural Breadth | Analysis 2 Building Sequence | Analysis 3 Building Enclosure | ***Analysis 3 Architectural Breadth*** | Analysis 4 Geotech Investigation

Weight

Original System
- Panels (Studs, sheathing, Vapor Barrier) = 8 psf
- Insulation = 5 psf
- Brick = 42 psf
- **Total =55 psf**

New System
- 6” Concrete and Thin Brick = 75 psf
- Insulation = 5 psf
- **Total = 80 psf**

Schedule

Original System
- 54 Working Days
- Start Date: December 2012
- Finish Date: February 2013

New System
- Per RS Means, based on average square foot, 3 panels can be erected per day. There are 57 panels total
- 57/3 = 19 Working Days
- Start Date: August 2012
- Finish Date: September 2012

Cost

Original System
- Panels (Studs, Sheathing, Vapor Barrier, Insulation) = $495,000
- Scaffold Temporary Heating = $30,000
- Brick = $9.00 sf x 12,973 sf = $116,757
- **Total = $641,757 | $49.47 sf**

New System
- 6” Precast Concrete = $44.84 sf x 12,973 sf = $581,709
- Insulation Panel (3”) = $1.60 sf x 12,973 sf = $20,757
- Thin Brick façade, modular, red= $8.75 sf x 12,973 = $113,514
- Cost increase of crane = $50,000
- Adjustment Factor (admixtures, large panels/shipping, additional structural support to accommodate additional weight) = 1.1
- **Total = $842,578 | $64.95 sf**

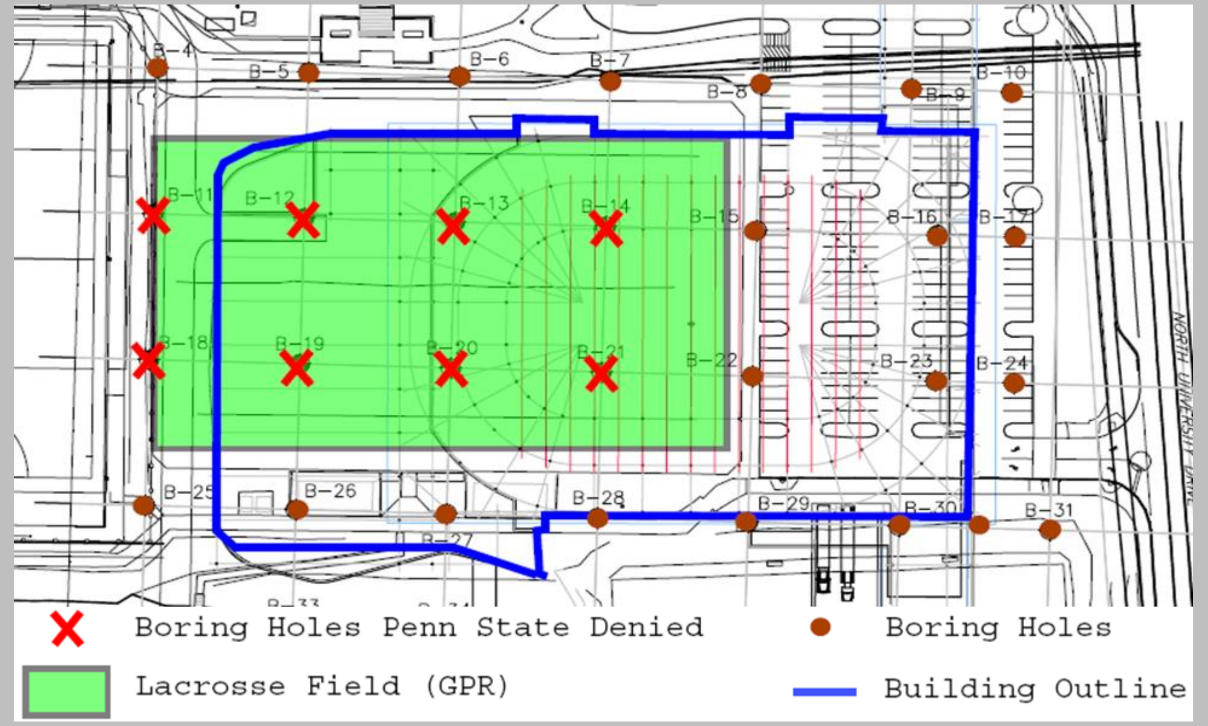
New vs. Original System

Advantage	Disadvantage	Disadvantage
Safety	**Masonry activities are expedited; however, overall schedule duration does not change since finishes cannot begin any earlier.**	**Cost Increase of over $200, 000**

Analysis 3 Conclusion

Geotechnical Investigation

Pegula Geotechnical Investigation



Boring Cost Analysis

Geotechnical Estimate (Boring)

System	Amount	Unit	Material	Labor	Equipment	Total	Total Incl O and P	Cost
Borings, initial field stake out & determination of elevations	1	Day		705	78.5	783.5	1150	$1,150
Drawings showing boring details	1	Day		310		310	390	$390
Report and recommendations from P.E.	1	Day		720		720	900	$900
Mobilization and demobilization	1	Day		209	246	455	590	$590
Borings in earth, with samples, 2-1/2" diameter	567	L.F.	22	15.05	17.7	54.75	66.5	$37,706

Total: $40,736

Advantages vs. Disadvantages

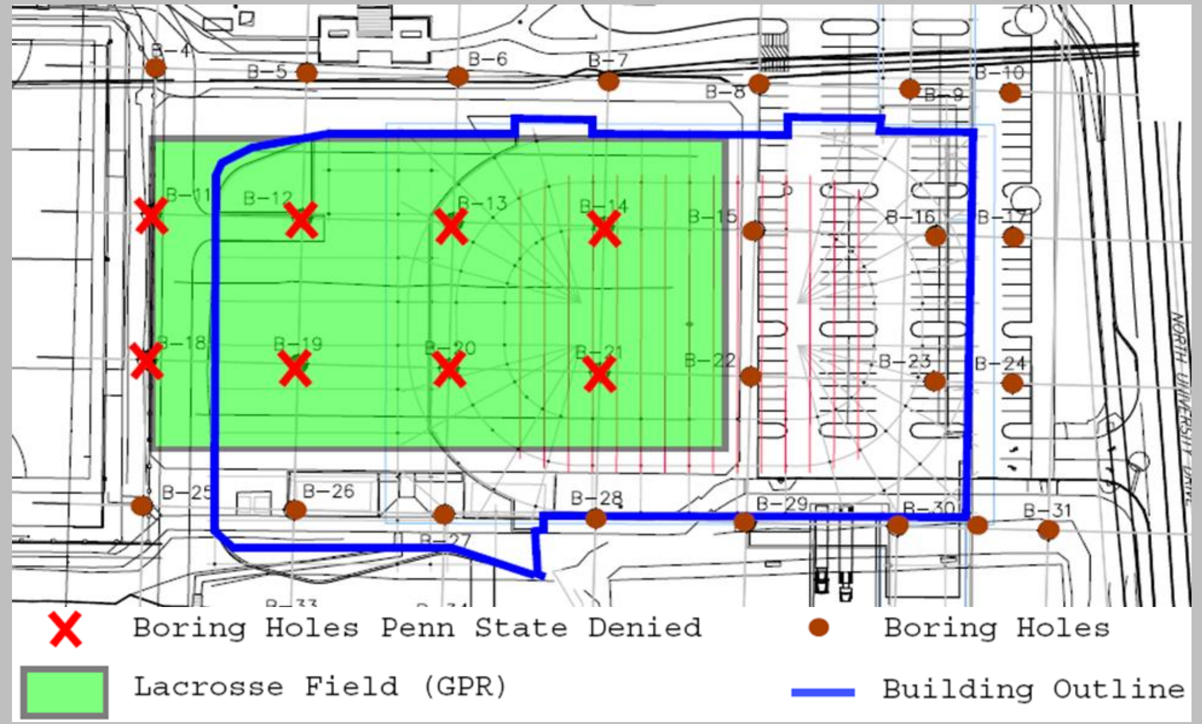
Advantages

- Accurate, Proven, Consistent
- Reliable in identifying soil type
- Reliable in identifying ground water

Disadvantage

- Expensive
- Identifies material and water through destruction (turf example)

Pegula Geotechnical Investigation



GPR Cost Analysis

THG GEOPHYSICS

$1,000 - $2,000

Advantages vs. Disadvantages

Advantages

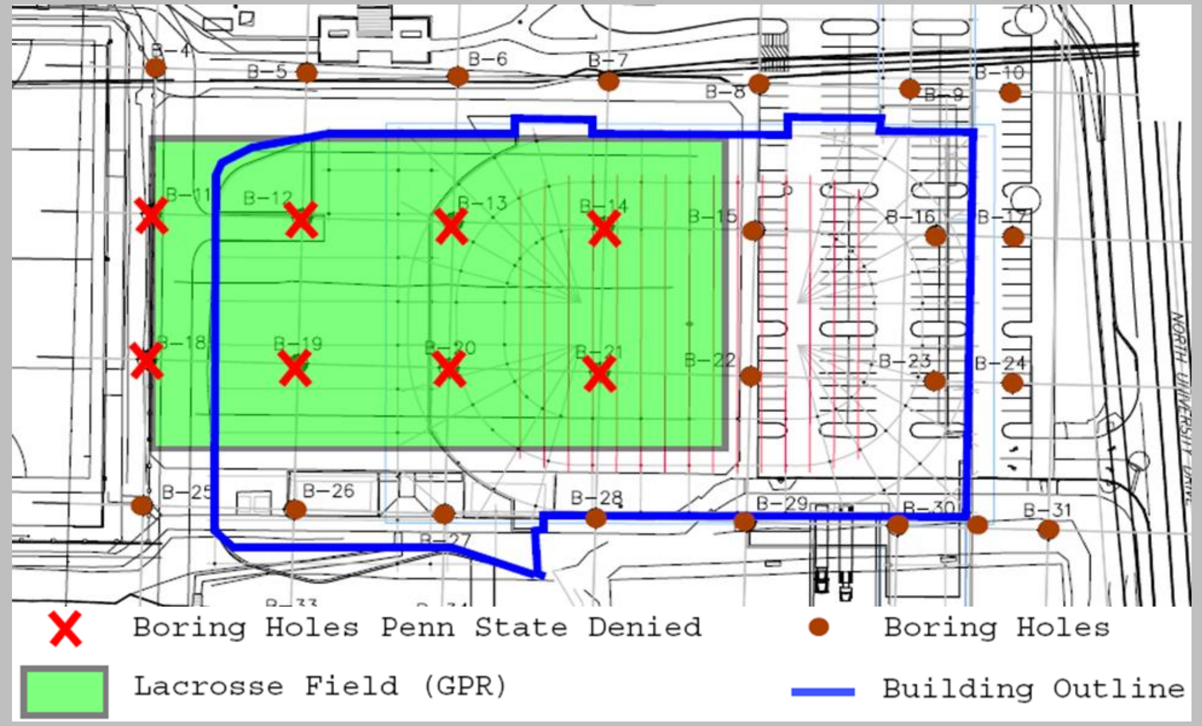
- Fast and instant
- Inexpensive
- Environmentally friendly
- Noninvasive
- Can detect utility lines
- Can be used inside (reinforcement in slabs)

Disadvantage

- NOT efficient and accurate
- Does NOT work well through clay
- Does NOT reach great depths
- Does NOT detect a water table

Ground Penetrating Radar

Pegula Geotechnical Investigation



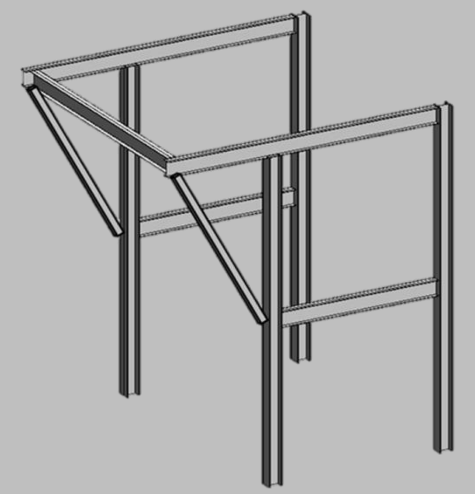
Boring vs. GPR

Boring vs. GPR

Boring		GPR
✓	Soil	
✓	Ground Water	
	Cost	✓
✓	Depth	
	Invasiveness	✓
	Environment	✓

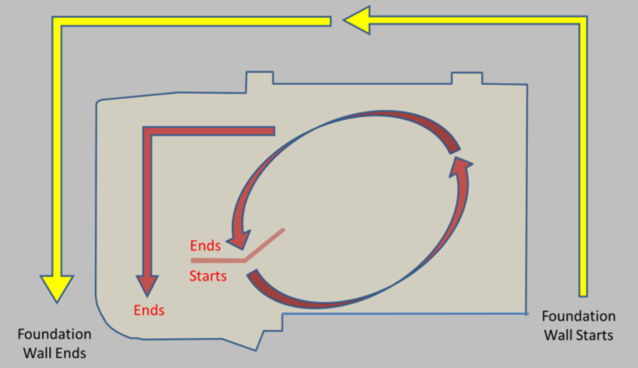
Analysis 4 Conclusion

Recommendations



Analysis 1: Community Rink

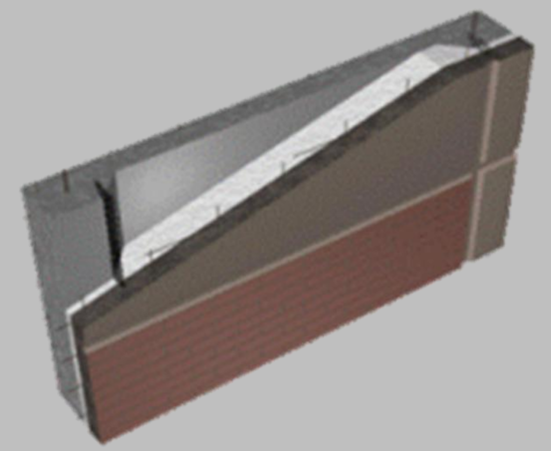
Benefit to Owner: NO
Benefit to Architect: NO
Benefit to CM: YES



Analysis 2: Project Sequence

Benefit to Owner: YES
Benefit to Architect: --
Benefit to CM: YES

Recommendations



Analysis 3: Building Enclosure

Benefit to Owner: NO
Benefit to Architect: --
Benefit to CM: YES

Analysis 4: Geotechnical Investigation

	Boring	GPR
Benefit to Owner:	YES/NO	YES/NO
Benefit to Architect:	--	--
Benefit to CM:	YES	NO

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Robert Holland (Architectural Advisor)

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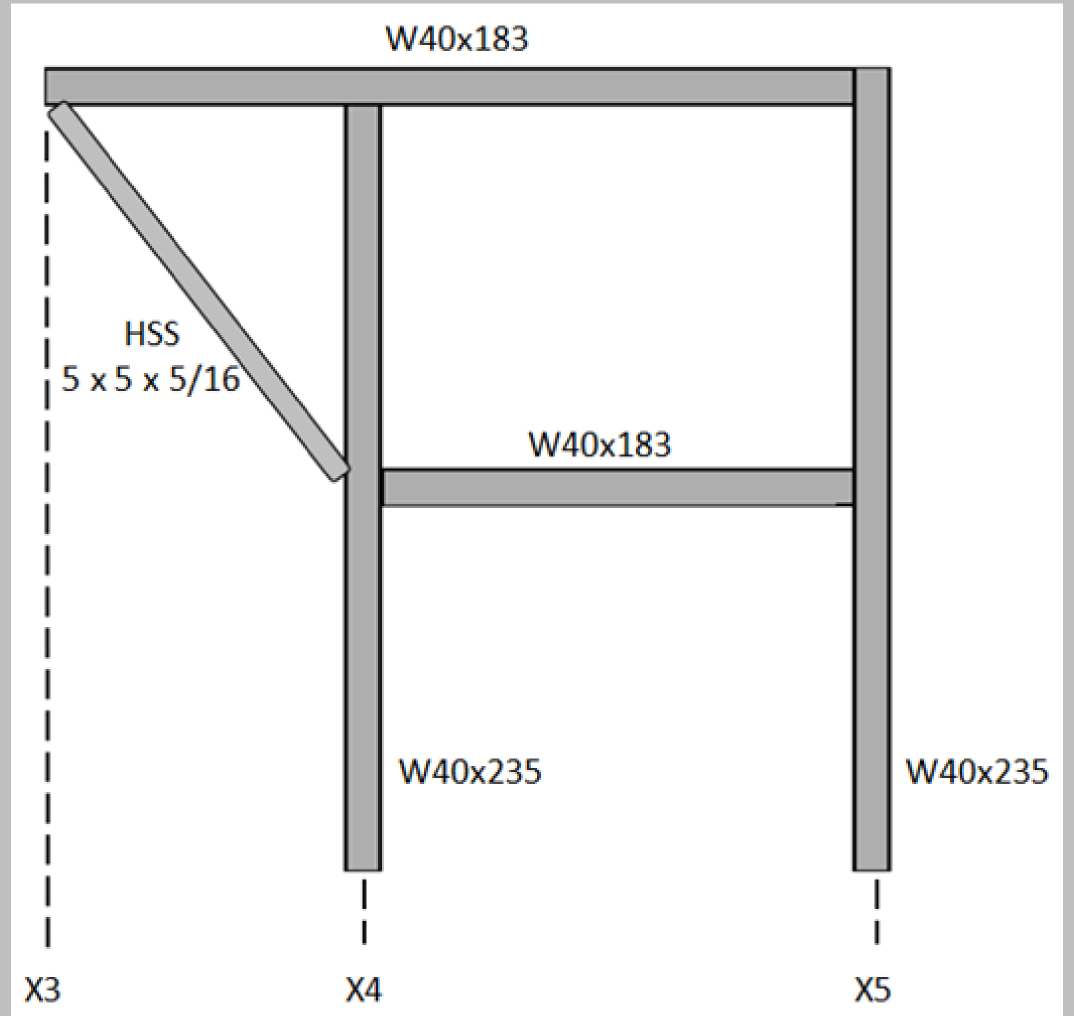
Jeffrey Angstadt (VP of Operations) of Foreman Program and Construction Managers

PACE Industry Members

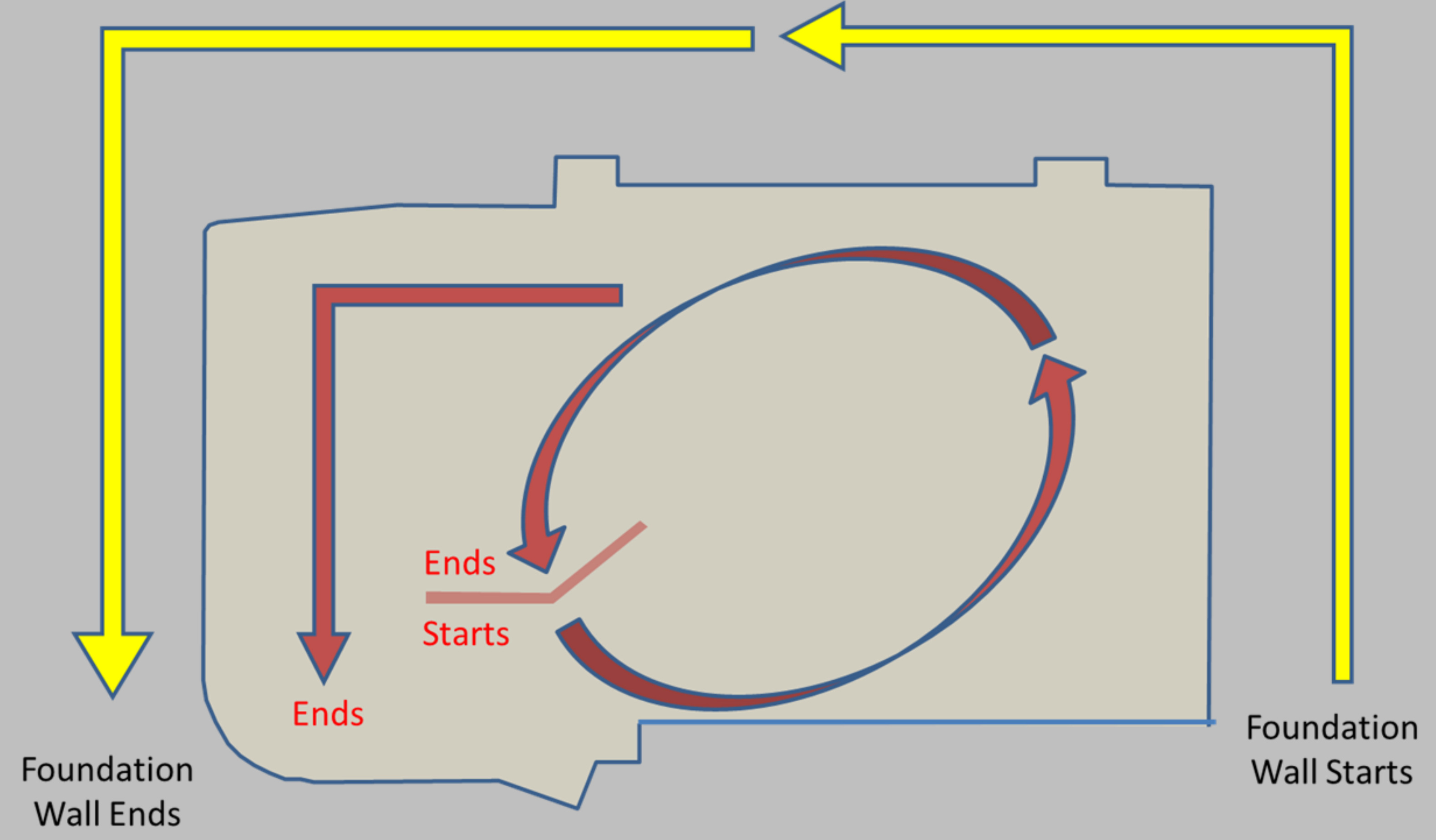
Family & Friends

Questions?

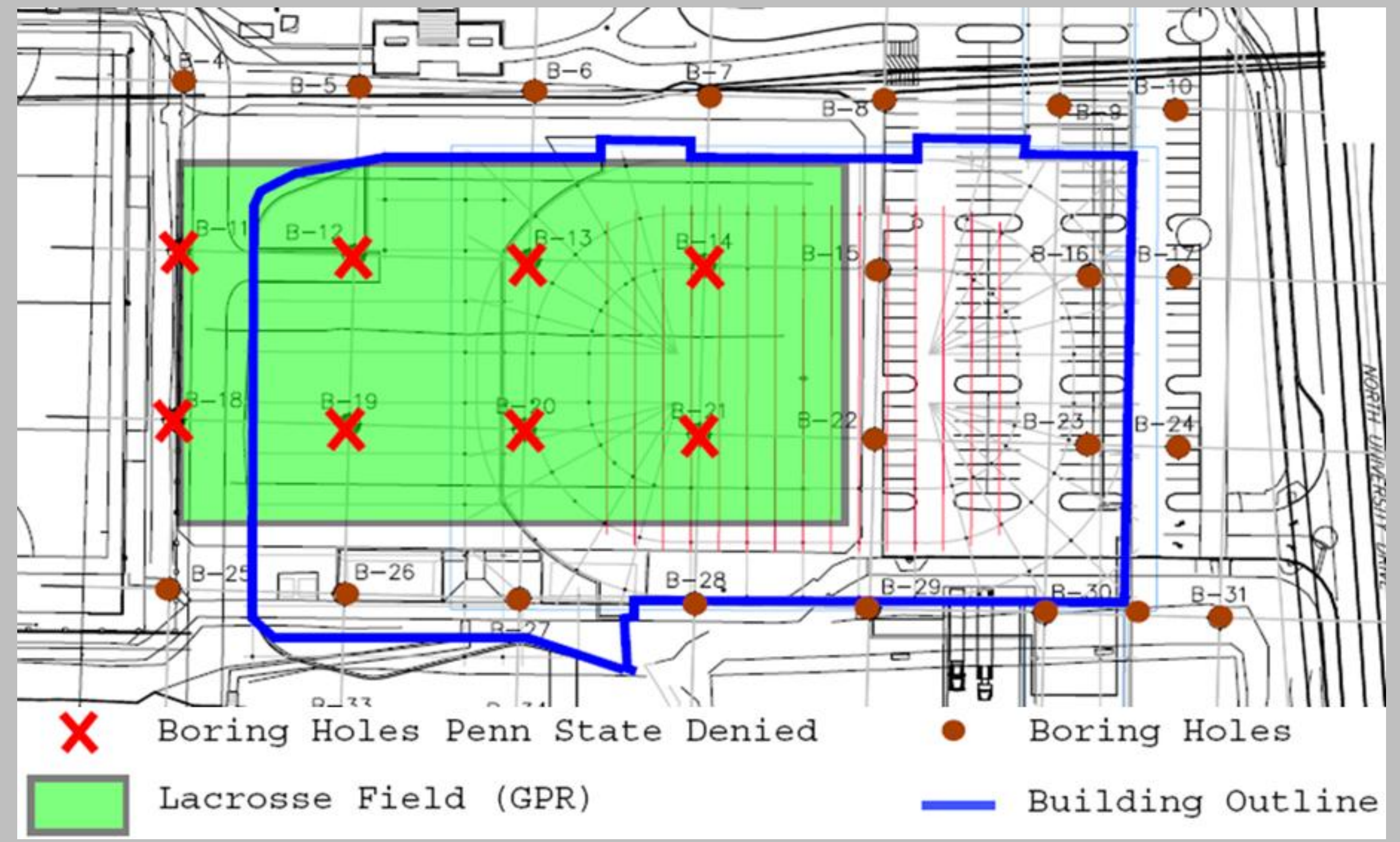
Analysis 1



Analysis 2



Analysis 4



Conductivity values are found in lecture notes 6 of AE 542 (pg 58-61)						$\Delta T_i = \frac{R_i}{\sum R_i}(T_{int} - T_{ext})$		Permeability values are found in Straube and Brunett, 2005			$\Delta P_w = \frac{R_{vi}}{\sum R_{vi}}(P_{int} - P_{ext})$			
	k=Ct	Given	C=k/t	R=5.678R_{SI}	R_{SI}=1/C			Material Property	M=μ/t	R_v=1/M				RH=P_w/P_{ws}*100
Layer material	Conductivity (k)	Thickness (t)	Conductance (C)	Resistance (R)	Resistance (R_{SI})	Δtemp (Δt)	temp (t)	Permeability (μ)	Vapor Permeance (M)	Vapor Resistance (R_v)	ΔVapor Pressure (ΔP_w)	Vapor Pressure (P_w)	Saturated Vapor Pressure (Pw,sat)	Relative Humidity (RH)
Units	[W/m*K]	[m]	[W/m^2*K]		[m2*K/W]	[°C]	[°C]	[ng/Pa*s*m]	[ng/Pa*s*m^2]	[Pa*s*m^2/ng]	[Pa]	[Pa]	[Pa]	(%)
Interior Temp							23.89					1179.84	2949.60	40.00
Interior film	N/A	N/A	8.30	0.68	0.12	-0.47		N/A	15000.00	0.000067	-3.65			
							24.36					1183.49	3033.45	39.01
Drywall	0.16	0.01	12.31	0.46	0.08	-0.32		25.00	1923.08	0.000520	-28.49			
							24.67					1211.98	3091.17	39.21
Air Space	N/A	0.03	N/A	0.97	0.17	-0.66		175.00	7000.00	0.000143	-7.83			
							25.33					1219.81	3215.02	37.94
Concrete	1.80	0.08	24.00	0.24	0.04	-0.16		5.00	66.67	0.015000	-821.85			
							25.49					2041.66	3246.03	62.90
Insulation XPS	0.03	0.08	0.38	15.14	2.67	-10.34		2.00	25.00	0.040000	-2191.60			
							35.83					4233.26	5858.78	72.25
Concrete	1.80	0.08	24.00	0.24	0.04	-0.16		5.00	66.67	0.015000	-821.85			
							36.00					5055.11	5910.97	85.52
Exterior film	N/A	N/A	34.00	0.17	0.03	-0.11		N/A	75000.00	0.000013	-0.73			
Exterior Temp							36.11					5055.84	5948.05	85.00
		R_{SI} Total			3.15				R_v Total	0.07				
		R Total		17.89						ΔP_w Total	-3876.00			
	U=1/R	Overall co-eff. Of heat (U)			**0.32**									

Summer

Interior

T=23.89°C=301K RH= 40 percent

$$P_{WS} = 1000 * e^{[52.58 - \frac{6790.5}{T} - 5.028\ln(T)]}$$

P_{ws}= 2949.600858

$$P_W = RH * P_{WS}$$

P_w= 1179.840343

Exterior

T=36.11°C=258K RH= 85 percent

$$P_{WS} = 1000 * e^{[52.58 - \frac{6790.5}{T} - 5.028\ln(T)]}$$

P_{ws}= 5948.045099

$$P_W = RH * P_{WS}$$

P_w= 5055.838334

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