2014

Earthquake Resistant Parking Structure

Cylor Morgan
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Capstone

The three areas of emphasis for my Bachelors of Integrated Studies degree consist of Construction Management Technology (CMT), Geographic Information Systems (GIS), and Geology (GEO). All of these areas are useful and compliment the direction I want to take my future career. I chose Construction Management Technology as one of my areas of emphasis because I am a very hands-on person and enjoy planning, scheduling and building things. I have always been hands-on and excel at leading people in the right direction to get the job done. I am currently employed in the industrial construction industry and have been involved in a few construction internships as well. I have since started to see the different sides of construction from the design, schedule, logistics, and management areas that the construction industry has to offer. I chose Geology as one of the legs of my BIS degree because it has always been an interest of mine. I have always been interested in the change in morphology that can occur when geologic events happen. I enjoy knowing why the surface of the earth looks the way it does and what caused these geologic formations to appear. With the way things are going in the world, having knowledge in the area of geology can give me a solid base for great jobs. With the United States, as well as the rest of the World, relying on petroleum products more and more it will be a sustainable future for my career. I chose my third area Geographic Information Systems because of what I was planning on doing with my professional life. Having knowledge about geology and the construction industry it seemed like a good fit. By being able to use GIS to see an overview of my other two areas of emphasis it will allow me to bridge the gap between the two. Having the capability of utilizing images of areas where future construction would be taking place is a good skill to have. Being able to use GIS software to

map the area of construction or determine what the terrain is going to be like without leaving the office will be a great asset for many companies. This area will allow me to make more informed decisions when estimating the cost of projects. Using maps and imaging allows me to show useful information to myself the client and also other employees.

For my capstone project I feel like I have come up with a great way to showcase these three areas into one project by designing an earthquake resistant parking structure that will mimic the Northeast parking lot on WSU's campus. The parking structure I am going to design will be roughly 140,000 square feet and add an extra 367 parking spaces. The idea behind this project is to pull together all areas of the construction design aspect, as well as mapping out fault areas that are prevalent around the Wasatch front and Weber State's campus, and understanding the stresses an earthquake will impose on the ground and structures near the event areas.

The CMT classes I have taken a Weber State have allowed me to think critically and put the ideas about designing structures into a visual copy. Being able to understand construction blueprints and the order that things need to be constructed is critical to making the process go smooth and efficient. These classes have also taught me what materials are best to make a structure last through the years. With the knowledge I have gained through this program I will be able to design the structure and complete the material takeoffs necessary.

My GEO classes have opened my eyes to what is going on around me. While taking these classes I learned a lot about how geology changes over time. Understanding the movement of the Earth's plates and what this movement does to the surface of the earth is a

skill I have utilized in contemplating my design. By knowing how an earthquake will affect the ground and buildings it allows me to better understand the stresses the building must endure. By having knowledge in this area I can use my skills in GIS to get a bird's eye view of what is going on around the area I have chosen for the construction of my parking structure. Using images of the faults very near to the proposed construction site will help me make my case to the client that the danger is a real one. These two areas of study are very useful on their own, but extremely useful when they are paired together. Having the capabilities to map out the fault lines and foresee the hazards will allow me to build a safer structure that can maintain its integrity in these types of ground moving events. Having an understanding of what will most likely happen around my construction area during an earthquake will give me a great advantage of making a safe structure.

When I began thinking about this project I wanted to understand the history and mechanics of the earthquakes that have happened along the Wasatch Fault. I want to determine the frequency of the events and the sizes that this fault area has produced. Understanding what has happened in the past will give a good insight into what will likely happen in the future. First, I began with the mechanics of earthquakes and why they are so damaging to buildings. "There are slow and powerful surface waves that cause the majority of earthquake damage - Love waves, which move horizontally, and Rayleigh waves, which move vertically. There are also two types of body waves that travel underground - P waves and S waves. P-waves, or primary waves, that travel at 3 miles (5 km) per second, stretching and squeezing rocks laterally. S-waves, or secondary waves, move from side to side at about 2 miles (3 km) a second."(ThinkQuest, ThinkQuest Contest, Educational Contest, Internet Contest, Students,

Teachers. "ThinkQuest : Library." *ThinkQuest*. Oracle Foundation, n.d. Web. 27 Feb. 2014.) How damaging these forces are to the structures on the surface depends not only on the magnitude of the event, but also the height and weight of the building along with the composition of the ground under and surrounding it. Weber County is located atop ancient Lake Bonneville, which is made up of very weak ancient lake bottom soils. The area is also has a high water table coupled with a high earthquake danger. The liquefaction associated with an earthquake would more than likely cause the majority of the damage. Historically the ground rupturing faults are not as common, but definitely possible. If the structure is built on bedrock or very solid ground there will likely be less damage to the structure. The harder more solid earth will not transfer as much movement into the structure. On the other hand if the composition of the soils below and around the structure is more of a sandy or muddy composition this can cause liquefaction. Liquefaction occurs when the soils starts to behave as a liquid, this allows the surface of the earth to behave more violently and cause a greater amount of damage to structures. Due to the fact that a vast majority of Utah's population lives on ground that has the potential to behave this way it is a large problem. Most of the development along the Wasatch Fault was built on alluvial fans and the sandy bottom of Lake Bonneville therefore liquefaction is a real danger to the structural integrity of those developments. The area that this proposed parking structure will be constructed is directly to the West of the Wasatch Fault. The Wasatch Fault is a normal fault that runs from Malad City, Idaho, to Fayette, Utah, a span of 240 miles. The fault is broken down into ten segments that can move independently as well as interacting with one another.

The size and weight of a building greatly effects how it reacts during an earthquake. I am going to make this structure short and low to the ground so that it will be less influenced by the

movement that an earthquake produces. By not having any cladding on the structure it will reduce and or eliminate the risk of falling objects during an event. The parking structure I have designed will mimic the existing parking lot. When planning the parking structure I wanted to make it safe if an earthquake were to hit. This has allowed me to brain storm about ways that the structure could serve a very useful purpose and be safe if a catastrophic event were to happen. When designing the parking structure I wanted it to have useful but limited movement without being structurally compromised. I also designed this structure with somewhat independent sections. By doing this it will allow the structure to move more fluidly when the earth below begins to shift. I want the driving surface of the structure to act like that of a dock used on lakes, which will minimize the damage to the objects on the surface. Almost all of the structure is to be constructed from steel I-Beams, although it is relatively heavy I feel that it will have a better chance of remaining structurally sound over other materials. One of the most important features that I have added to this structure is the base. I researched and thought about how I could make this be stable every day and also remain stable in the event of an earthquake. One technique to minimize the effects of an earthquake is called base isolation. I made the decision that the footings on this structure will be a four by four foot wide by two inch thick steel plate. This plate will have five semicircle indentations that will house five heavily greased ball bearings. This thicker plate attached to the structural columns will sit on an eight by eight foot steel plate that has a one inch thick wall that will extend above grade level, essentially making an open box. This is needed to hold back the ground and allow the columns to move freely without obstruction as well as keep the steel plates relatively clean of debris. When making a box like this there will need to be small holes drilled in the bottom to allow

water to escape so it doesn't cause numerous small ponds to develop. In case of an event this design will allow the building to be more flexible than a standard construction practice. I believe by allowing the structure to move it will greatly decrease the damage to the structure. This type of technique has been researched in many places and has used many different materials such as two Teflon plates one attached to the structure and the other sitting on the earth. I feel that for this application and with how many columns are needed it would be more cost effective to just use the steel and ball bearing approach. I have also come up with a way that the building will be able to rebound and be pulled back to the center of the larger plate. Each footing will be fitted with two very large laminated rubber isolators that will pull the structure smoothly back to the center of the bottom plate. These rubber isolators have been tested on two story houses in Japan by Ichijo USA Co., Ltd., although they took a different approach. When they did the testing they used fewer rubber isolators and had them placed independently of the sliding base isolator plates. My design will be more robust due to the greater weight and overall size of this structure. The two rubber isolators will be place 90 degrees apart so that each leg will be pulled very close to center of the bottom plates when moved in any direction. By using this technique of base isolation and rebound I think this will greatly diminish/eliminate the resonance throughout the structure.

During the construction of the elevated parking lot there will need to be a vast amount of excavation so the large steel boxes will fit firmly in the earth. Each of the boxes will extend above grade so that nothing will roll or fall into the box. Also each box will be covered with a grating and rubber covering that will be strong enough to keep people, trash and most water out, but will not interfere with the movement needed in an earthquake. Due to the size of this

structure I believe that the footing boxes and footings should be field fabricated. Every structural column will need to be cut to a custom length to make the parking surface level. This coupled with the amount of excavation required will be a smooth and steady workflow, and keep large uncovered excavations to a minimum. With the overall size of the structure I am planning on having the horizontal supports beams shop fabricated. Having the horizontal structural supports shop fabricated will cut down on the amount of time needed to install each piece which reduces labor costs. Having the ability to ship materials in sequence will keep the work quick and orderly.

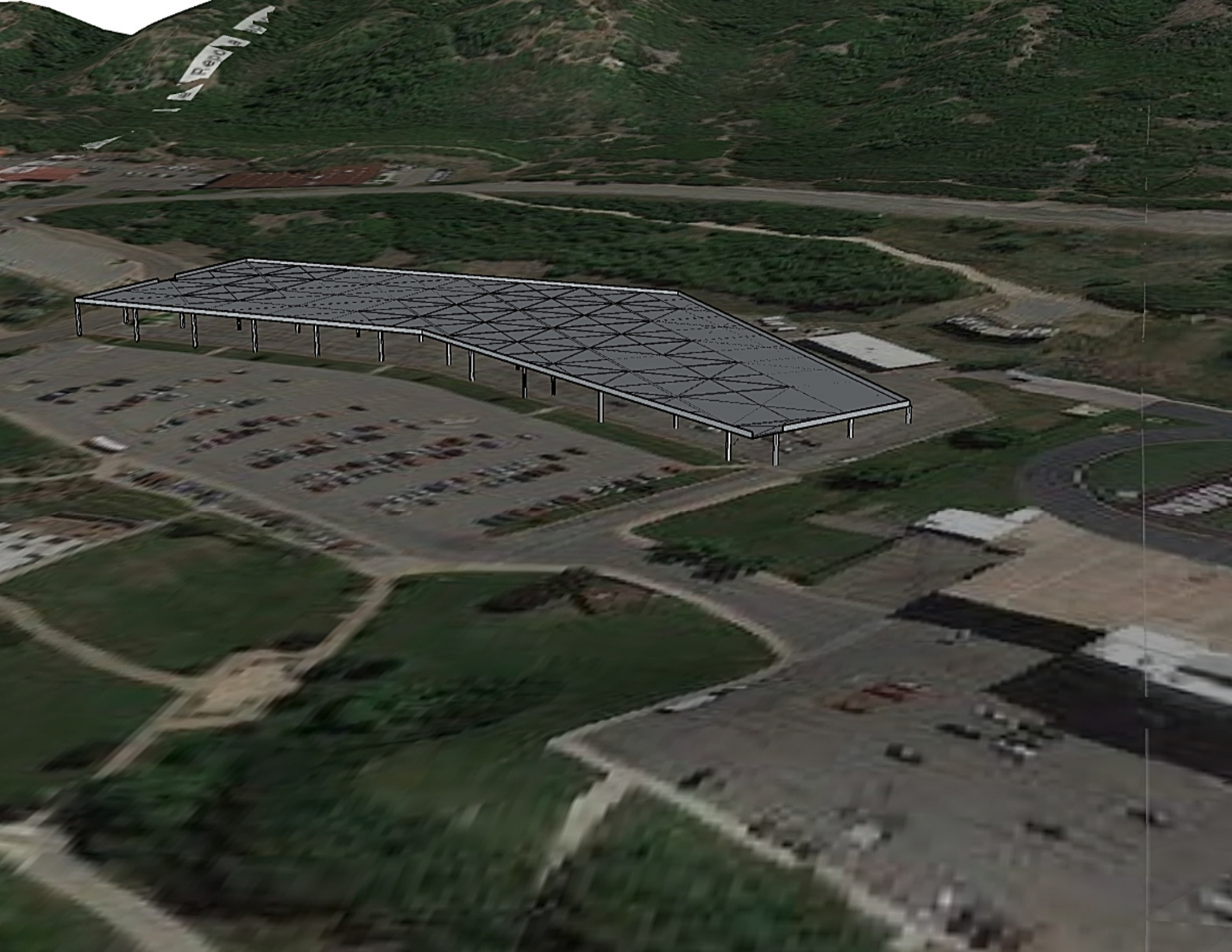
When looking at the "Fault Map" around the area of the proposed building you can see that there are many faults in close proximity. Having the capabilities to show the proximity of the hazards in the area is a great tool. For this project, I wanted to portray to the owner given how close and imminent the hazard is the cost of this construction is going to be more expensive, but a good investment. Showing the maps of the eminent danger in the area will further make my case for the necessary cost of the construction. The majority of the faults are running in a North South direction. This is due to the fact that the main Wasatch Fault is doing the same. When looking at the fault map you can see that in the event of an earthquake the ground under the structure will be shifted to the West. A majority of the faults closest to campus are dated at less than 15,000 years old according to USGS. "On the Holocene fault on which a magnitude 6.5 (approximate) or larger earthquake occurs. On average, these earthquakes may occur once every 120 years on various faults in the Wasatch Front region; once every 350 years somewhere along the central part of the Wasatch fault (between Brigham City and Nephi); once every 2,000 years at any specific locality along the central Wasatch fault;

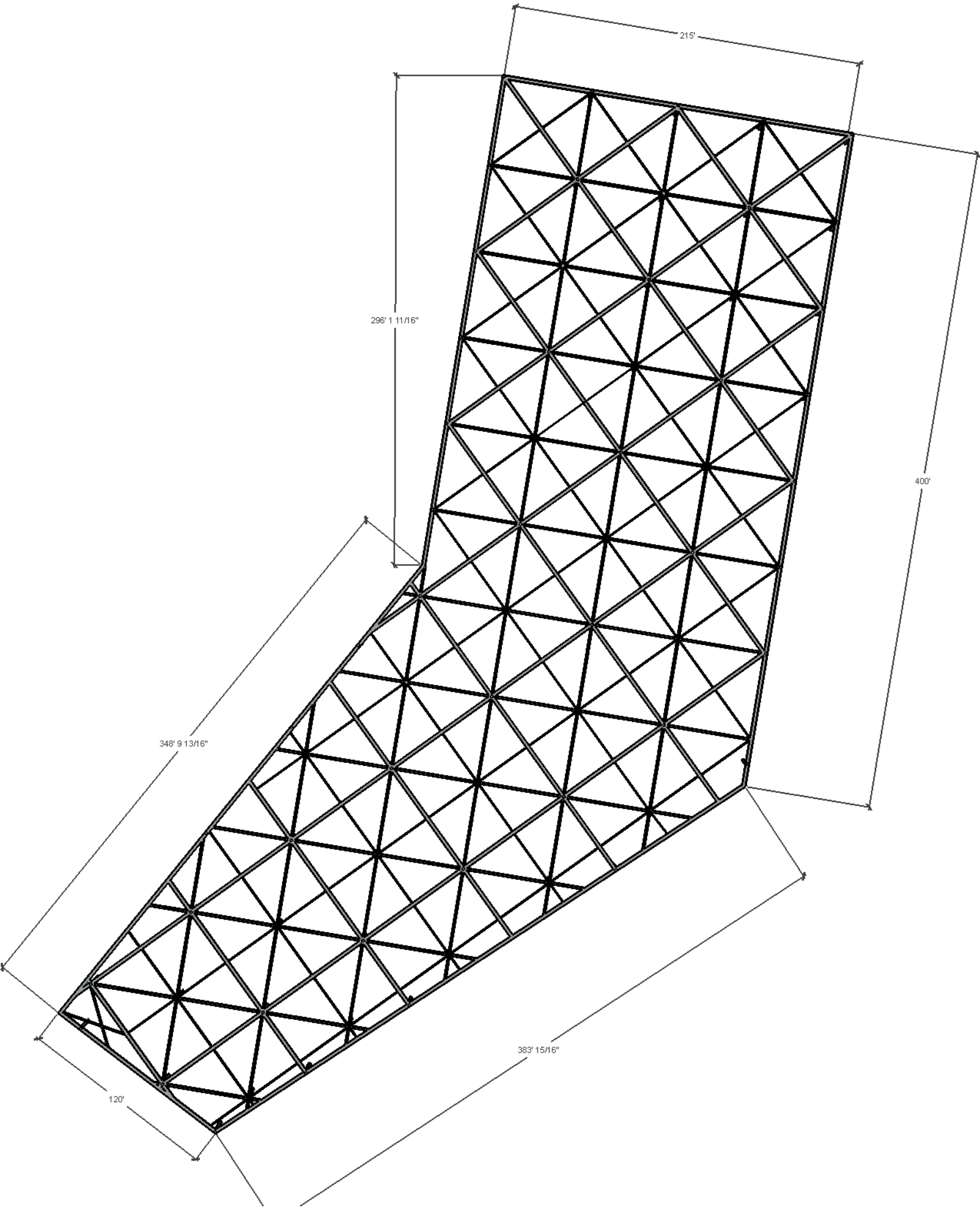
and once every 5,000 to 20,000 years or more on other Holocene faults in the state." ("Earthquake Faults." *Utah Geological Survey*. Utah Geological Survey, 2013. Web. 12 Feb. 2014.) . The Weber segment is historically one of the most active segments of the Wasatch Fault which puts the Ogden area at a greater risk for an earthquake. Two major earthquakes have occurred in Ogden in the last 120 years, both being a Richter scale magnitude of 5-5.5 one happening in 1894 and the next in 1962. "For any individual segment of the central portion of the fault, the "average recurrence interval" is longer - about every 1,200 to 2,600 years. In comparison, each of the distal segments have recurrence intervals of about 10,000 years or more, (recurrence intervals are long-term averages)." (Sandra N. Eldredge. *The Wasatch Fault*. N.p.: Sandra N. Eldredge, 1996. Print.). The Brigham City segment of the Wasatch Fault is also very close to the proposed construction area and in the past has been very active. When looking at the information provided in "The Wasatch Fault" this segment is overdue to produce a large damaging earthquake at any time. The movement of the ground during a normal fault rupture is mostly vertical and the downhill side will lose elevation and the uphill side will gain it.

In conclusion this project uses all three of my areas of emphasis to produce a finished product. I was capable of using my geology knowledge to understand the hazards an earthquake will produce. I used my GIS skills to produce and understand maps that will show the owner how close the dangers really are. I was also able to use my CMT background to brainstorm and make an earthquake resistant structure and put together a construction schedule. As mentioned before my BIS degree goes right in line with where I want to take my future career.

Citations:

- Sandra N. Eldredge. *The Wasatch Fault*. N.p.: Sandra N. Eldredge, 1996. Print.
- "Earthquake Faults." *Utah Geological Survey*. Utah Geological Survey, 2013. Web. 12 Feb. 2014.
- ThinkQuest, ThinkQuest Contest, Educational Contest, Internet Contest, Students, Teachers. "ThinkQuest : Library." *ThinkQuest*. Oracle Foundation, n.d. Web. 27 Feb. 2014.

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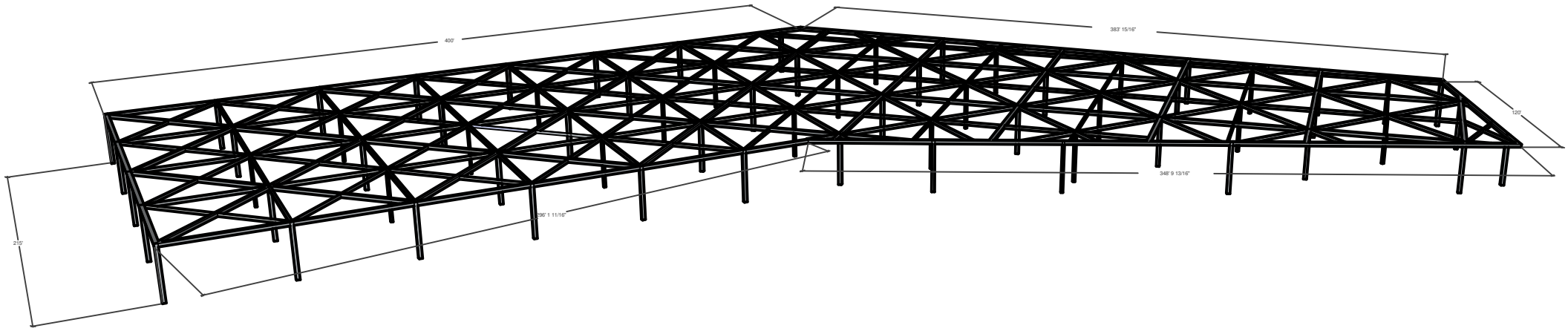
400'
348' 9 13/16"
383' 15/16"
120'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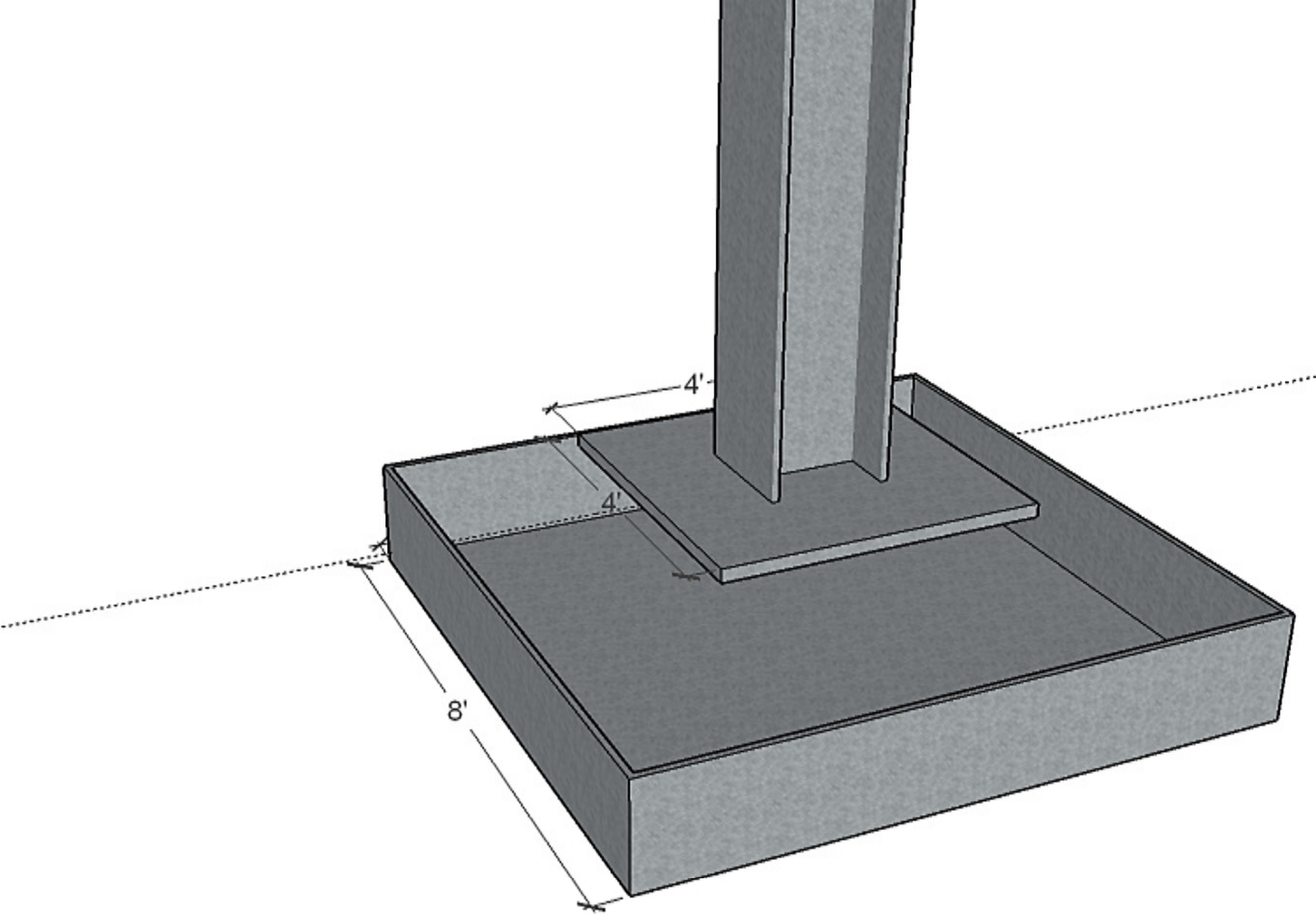
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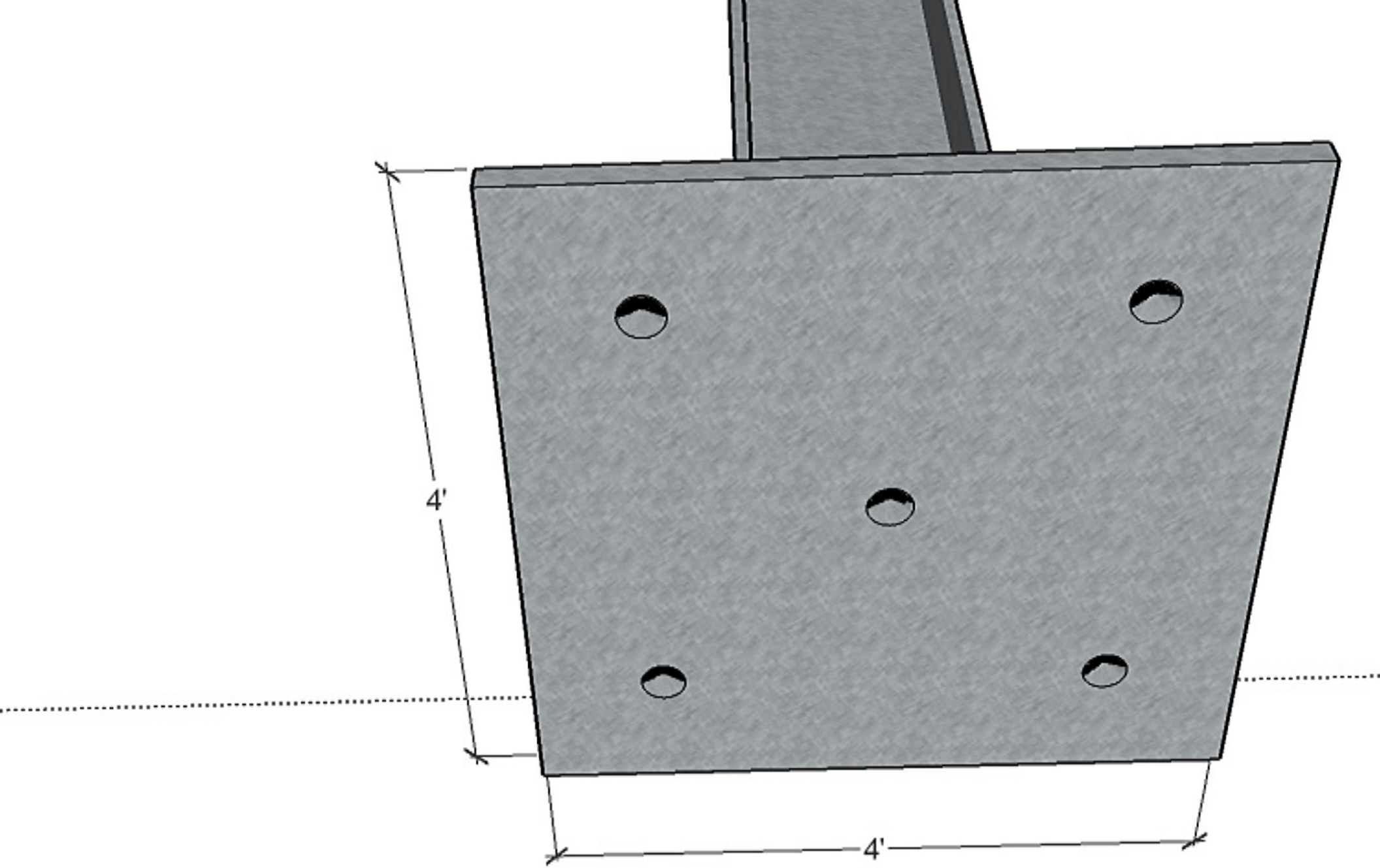

4'
4'

Fault Map

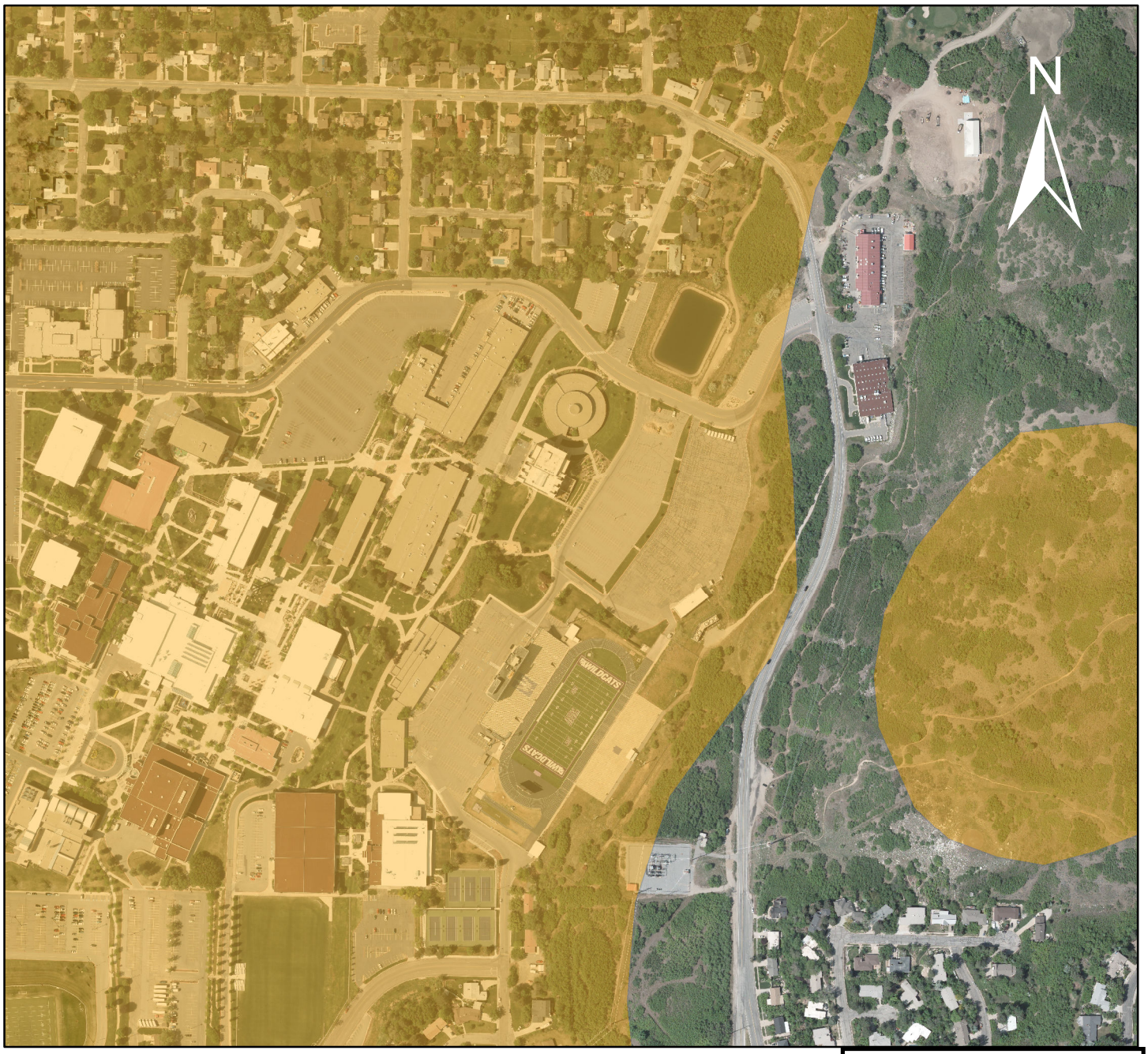
This map is to show how close the faults are to the construction site. As you will notice there are numerous faults that are running very close to WSU's campus. This close proximity to the faults makes the added cost of construction necessary.

Legend

Faults

Projected Coordinate System: NAD_1983_UTM_Zone_12N
Geographic Coordinate System: GCS_North_American_1983

Landslide Areas



Legend

Landslides_Areas

0 0.05 0.1 0.2 Miles

Project name	Capstone Estimate Ogden Utah 84403
Estimator	Cylor Morgan
Labor rate table	Wy/NM/Ks98
Report format	Sorted by 'Group phase/Phase' 'Detail' summary

Item		Description	Takeoff Qty		Labor Unit Cost	Material Unit Cost	Subcontract Unit Cost	Equipment Unit Cost	Other Unit Cost	Total Unit Cost
1000		***GEN CONDITIONS***								
1070		**PER-DEM**								
	65	Per Diem @ $65 Per Day	40.00	each	-	-	-	-	4,290.00	4,290.00
1200		**Project Utility**								
conp		Construction Power	1.00	lsum	0.00	500.00	-	-		500.00
1625		**RENTAL TOOLS & EQUIPMENT**								
	0002	1/2 or 3/4 ton Pickup Truck	4.00	mnth	-	-	-	1,200.00	-	1,200.00
	0002	1/2 or 3/4 ton Pickup Truck	4.00	mnth	-	-	-	1,200.00	-	1,200.00
	0004	Office Trailer	4.00	mnth	-	-		400.00	-	400.00
	0011	Conex Box	4.00	mnth	-	-		400.00	-	400.00
	0021	35 Ton RT Crane(picker rental)	4.00	mnth	-	800.00		4,800.00	-	5,600.00
	0021	35 Ton RT Crane(picker rental)	3.00	mnth	-	800.00		4,800.00	-	5,600.00
	0021	35 Ton RT Crane(picker rental)	3.00	mnth	-	800.00		4,800.00	-	5,600.00
	0025	40'-45' Man Lift	3.00	mnth	-	400.00		1,500.00	-	1,900.00
	0025	40'-45' Man Lift	3.00	mnth	-	400.00		1,500.00	-	1,900.00
	0036	Compactors - Hand Operated	4.00	mnth	-	125.00		800.00	-	925.00
	0066	20 CY Dump Truck	3.00	mnth	-			1,500.00	-	1,500.00
	0067	Small Ditcher	8.00	week	-			750.00	-	750.00
	0073	Track Hoe 55-65K	4.00	mnth	-	1,440.00		4,300.00	-	5,740.00
	0073	Track Hoe 55-65K	4.00	mnth	-	1,440.00		4,300.00	-	5,740.00
	0073	Track Hoe 55-65K	4.00	mnth	-	1,440.00		4,300.00	-	5,740.00
1700		**SUPPORT FACILITIES**								
	20	Dumpster Haul & Fee 20 Cuyd	2.00	each	-	-	150.00	-	-	150.00
john		Porta John	4.00	mnth	-	-	125.00	-	-	125.00
john		Porta John	4.00	mnth	-	-	125.00	-	-	125.00
2000		***SITEWORK***								
2220		**MACH. EXCAVATE & BACKFILL**								
exca		Excavation & Backfill	1,793.00	cuyd	7.52	0.001	-		-	7.521
5000		***STEEL***								
5128		**STRUCT SHAPES**								
p124		W12 x 65 Structural Beam	6,454.00	lnft	-	49.211	-	-	-	49.211
s 61		W 8 x 35 Structural Beam	4,488.00	lnft	-	24.71	-	-	-	24.71

Item	Description	Takeoff Qty		Labor Unit Cost	Material Unit Cost	Subcontract Unit Cost	Equipment Unit Cost	Other Unit Cost	Total Unit Cost
5128	**STRUCT SHAPES**								
s 81	W 5 x 19 Structural Beam	3,672.00	lnft	-	17.06	-	-	-	17.06
5500	**METAL FABRICATION ONLY**								
fabs	Field Fabricate Heavy Steel	50,000.00	lbs	0.32	0.00	-	0.144	-	0.46
fabs	Field Fabricate Heavy Steel	2,500.00	lbs	0.32	0.00	-	0.144	-	0.46
fabs	Field Fabricate Heavy Steel	2,500.00	lbs	0.32	0.00	-	0.144	-	0.46
sfab	Shop Fabricate Heavy Steel	500,000.00	lbs	0.27	0.03	-	0.144	-	0.444
5510	**METAL INSTALL/ ERECT ONLY**								
ferw	Field Erect/Weld Structural Steel	646,358.00	lbs	0.112	0.001	-	0.051	-	0.164
5540	**STEEL PLATE**								
pl80	1" A36 STEEL PLATE	163,925.00	sqft	1.60	16.69	-	-	-	18.29

13000 BUILDINGS

13001	**PRE-ENGINEERED STRUCTURES**								
shk1	Red Iron Shakeout	10.00	each	5,000.00	0.001	-	-	-	5,000.001
13008	**LINER PANEL**								
lnr1	Liner Panel	138,197.00	sqft	0.56	0.001	-	-	-	0.561

16000 ELECTRICAL

16500	**LIGHTING**								
fixt	Light Fixtures	90.00	each	45.00	0.10	-		-	45.10
16605	**ELECTRICALTERMINATIONS**								
inst	Instrument and Lighting	90.00	each	7.50	0.60	-	-	-	8.10
16650	**ELECTRICAL-TEST&RING OUT**								
ring	Circuit Testing and Ringout	90.00	each	30.00	0.01	-	-	-	30.01
16660	**ELECTRICAL HEAT TRACE**								
cabl	Heat Trace Cable	10,000.00	lnft	1.80	0.01	-	-	-	1.81
kits	Power and End Termination Kits	50.00	each	30.00	0.10	-	-	-	30.10
pwr	Heat Trace Power Kit	5.00	each	40.50	55.00	-	-	-	95.50
16710	**CONDUIT & FITTINGS (AG)**								
rg03	1" Rigid Conduit	2,000.00	lnft	7.20	0.01	-	-	-	7.21
rg06	2" Rigid Conduit	1,000.00	lnft	9.00	0.01	-	-	-	9.01

Estimate Totals

Description	Amount	Totals	Hours	Rate
Labor	678,398		41,008.046 hrs	
Material	3,271,406			
Subcontract	1,300			
Equipment	248,114		18,683.346 hrs	
Other	171,600			
	4,370,818	**4,370,818**		
UTAH LABOR BURDEN	122,112			18.000 %
50 HOUR WEEK-OVERTIME %	74,624			11.000 %
50 HR WEEK-BURDEN ON OVERTIME	13,432			18.000 %
	210,168	**4,580,986**		
Total		***4,580,986***		

Description	Takeoff Qty		Order Qty		Unit Price	Amount
Elect. Mat. Abvgrnd						
1" EMT Conduit	2,000.00	lnft	20.00	C	1.00	20.00
2" Rigid Conduit	1,000.00	lnft	10.00	C	1.00	10.00
						30.00
Electrical Material						
Instrument and Lighting	90.00	each	90.00	each	0.60	54.00
						54.00
Heat Trace Materials						
Heat Trace Cable	10,000.00	lnft	10,000.00	lnft	0.01	100.00
Heat Trace Controls	5.00	each	5.00	each	55.00	275.00
Power and End Termination Kits	50.00	each	50.00	each	0.10	5.00
						380.00
Lighting Material						
Light Fixtures	90.00	each	90.00	each	0.10	9.00
						9.00
Steel-Structural						
2 1/2" x 2 1/2" x 1/2" Angles	163,925.00	sqft	6,694,697.000	lbs	0.41	2,735,323.00
W12 x 65 Structural Beam	6,454.00	lnft	342,062.000	lbs	0.93	317,605.00
W 8 x 35 Structural Beam	4,488.00	lnft	77,418.00	lbs	1.432	110,892.00
W 5 x 19 Structural Beam	3,672.00	lnft	84,456.000	lbs	0.742	62,646.00
						3,226,466.00
**** unassigned ****						
Construction Power	1.00	lsum	1.00	lsum	500.000	500.00
35 Ton RT Crane(picker rental)	4.00	mnth	4.00	mnth	800.00	3,200.00
35 Ton RT Crane(picker rental)	3.00	mnth	3.00	mnth	800.00	2,400.00
35 Ton RT Crane(picker rental)	3.00	mnth	3.00	mnth	800.00	2,400.00
40'-45' Man Lift	3.00	mnth	3.00	mnth	400.00	1,200.00
40'-45' Man Lift	3.00	mnth	3.00	mnth	400.00	1,200.00
Compactors - Hand Operated	4.00	mnth	4.00	mnth	125.00	500.00
20 CY Dump Truck	3.00	mnth	3.00	mnth		
Small Ditcher	8.00	week	8.00	week		
Track Hoe 55-65K	4.00	mnth	4.00	mnth	1,440.00	5,760.00
Track Hoe 55-65K	4.00	mnth	4.00	mnth	1,440.00	5,760.00
Track Hoe 55-65K	4.00	mnth	4.00	mnth	1,440.00	5,760.00
Excavation & Backfill	1,793.00	cuyd	1,793.00	cuyd	0.001	1.79
Field Fabricate Heavy Steel	50,000.00	lbs	50,000.00	lbs		0.00
Field Fabricate Heavy Steel	2,500.00	lbs	2,500.00	lbs		0.00
Field Fabricate Heavy Steel	2,500.00	lbs	2,500.00	lbs		0.00
Shop Fabricate Heavy Steel	500,000.00	lbs	500,000.00	lbs	0.03	15,000.00
Field Erect/Weld Structural Steel	646,358.00	lbs	646,358.00	lbs	0.001	646.36
Red Iron Shakeout	2.00	each	2.00	each	0.001	
Liner Panel	138,197.00	sqft	138,197.00	sqft	0.001	138.20
Circuit Testing and Ringout	90.00	each	90.00	each	0.01	0.90
						44,467.25
Grand Total						***3,271,406.25***