Progress Report 2

(For the Period Covering 12/01/2009 to 03/08/2010)

Time Dependent Load Response of Flexible Pipe Subjected to Sustained Loading

FDOT Contract No. BDK75 977-21

UF Contract No. 82153

FDOT Project Manager:	Rick Renna, P.E.
UF Principal Investigator:	David Bloomquist, P.E.
Co-Principal Investigator:	Timothy McGrath, P.E.
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Date of Submittal: April 1, 2010

1. Work Accomplished This Quarter

   This quarter, preparation work continued on the FDOT Soil Box to complete it for the proposed testing program. This involved numerous tasks, ranging from ordering new materials, machining parts for the project, to doing research on a number of different testing techniques. Specifically, the following was accomplished this quarter:

   a. Discussion and selection of an appropriate method for sealing the interface between the pipe end and the soil box wall.

   b. Discussion and selection of an appropriate method for avoiding differential settlement of the load plates.

   c. Discussion and selection of locations for earth pressure cells within the soil box.

   d. Discussion and selection of a system for measuring pipe displacement/deflection.

   e. Revision of load plate and lift bag configuration to achieve the most uniform pressure distribution and to avoid eccentric loading.

   f. Fabrication of the sealing system for the interface between pipe end and soil box wall.

   g. Machining of one of the soil box porthole covers to allow for proper threading of all instrumentation wires into and out of the box.

   h. Selection of a system to interface with the machined soil box porthole cover and instrumentation wiring.

   i. New test pipes were delivered to the University of Florida Coastal Lab.

   j. New load plates and lift bags were delivered to the Coastal Lab.

   k. Spiral ribbed flexible pipes were outfitted with a circular metal strip around the inside perimeter to provide for better seal which would work with the selected sealing system.

   l. Flexible pipes with circular corrugations had the corrugation filed back so as to be able to adequately interface with selected sealing system.

   m. Field visit to accurately document all inside dimensions of the soil box for purposes of producing detailed AutoCAD drawings.

n. Numerous visits to the Lab to photograph newly delivered materials, newly machined parts, and project progress in general.

o. Literature review.

p. Continued discussion on instrumentation to be used during the testing.

A discussion of the completed activities follows.

a. Discussion and selection of an appropriate method for sealing the interface between the pipe end and the soil box wall.

There were many possibilities discussed for the selection of a seal between the pipe ends and the sides of the soil box. Among the considerations in the selection process were the following: the side walls of the soil box are not completely vertical; the solution must provide for adequate free movement on both ends of the pipe, so that the pipe ends do not drag on the side of the soil box; and that all the pipes have either spiral or circular corrugations, making it difficult for any elastic type material to completely wrap around the outside pipe edge.

Along with the other concepts discussed in Progress Report 1, here are three more concepts.

The first concept, which is detailed on Pages C-13 and C-14 of the Appendix, involved using inflatable tubes around the pipe perimeter. The idea was to wrap a two inch wide PVC strip around the outside of the pipe end. Then, the tubes would be laid on the PVC strip, deflated. A secondary two inch wide PVC strip, with a larger diameter than the first, would then serve as an outer casing for the tubes so that the inflated size would be limited. This would be performed on both ends of the pipe, and then the assembly would be lowered into the tank, after which time the tubes would be inflated.

Ultimately, this option brought up concerns of cost feasibility because of the custom nature of most of the parts that would need to be used. Also, the pressure that the tubes would need to be inflated to in order to provide adequate seal would have been so much that the pipe would effectively be fixed at both ends. This would have interfered with the dynamics of the test, not allowing the pipe to move freely along its entire length.

Details for the second concept can be found on Pages C-15 and C-16 of the Appendix. This concept is what was discussed as "Idea Three" in Progress Report 1. This concept makes use of a wall flange bolted onto the wall of the soil box. A rubber membrane is then wrapped around the protruding part of the flange. The other end of the membrane is then wrapped around the pipe end. Spirally corrugated pipes have the membrane wrapped around a metal strip that was machined to the inside pipe perimeter, extending slightly beyond the pipe end. For the pipes with circular corrugations, the rubber membrane wraps around a portion of the pipe where the corrugation has been filed back about two inches. Pictures for the modified pipe ends for both types of corrugations are found in Sections k and l.

As discussed in Progress Report 1, as long as the rubber membrane is between the range of soft to medium soft, this option would allow the pipe to move freely along its entire length. Moreover, the rubber membrane will be fabricated to be slightly wider than needed. Therefore, when the load is applied from above and movement of the pipe begins, there will not automatically be any pulling of the membrane, since there is some “slack” built into it. This concept was also selected because of its cost effectiveness, with only the rubber membrane needing to be purchased from an outside vendor.

The third concept was only briefly discussed, but nonetheless was an option to consider. The idea was to create a square Styrofoam block with a hole cut through the center, the hole being the size of the diameter of the pipe. The Styrofoam would then be pressed on to the pipe end on both sides, and the assembly would then be lowered into the soil box. As with the first concept, this was eventually ruled out because the Styrofoam would have to be so stiff, that it too would make the pipe ends fixed to the soil box walls.

b. Discussion and selection of an appropriate method for avoiding differential settlement of the load plates.

This particular issue with the project has proved somewhat difficult to find a solution to. Along with what will be discussed in Section e for the location of the load plates and lift bags, the decision was made that there would need to be some sort of material between the top of the lightly compacted fill and the bottom of the load plates. Among many considerations, the best solution involves a chain link type material that will be laid over the top of the backfill. This material will be strong, but at the same time, it will be able to deflect differentially. This deflection, however, is going to be limited by the strength of the material. This way, a load plate completely over the fill will not dangerously affect the performance of the load plate next to it, whose center is directly over the centerline of a pipe. A geotextile sheet would also provide similar tensile strength while still being able to deflect. This specific part of the project is still being investigated.

c. Discussion and selection of locations for earth pressure load cells within the soil box.

As mentioned in Progress Report 1, only 18 earth pressure cells are necessary for the soil box being tested with two pipes. The earth pressure cells that will be used can be seen in Figure 1 below. Pages C-1 through C-10 of the Appendix provide numerous views and details of the locations for the earth pressure cells. Pages C-1 through C-5 detail the locations with for the tests with the 24 inch diameter pipes, while Pages C-6 through C-10 detail the locations with for the tests with the 36 inch diameter pipes. This setup represents the best layout of pressure cells to be able to obtain the most variety of data.

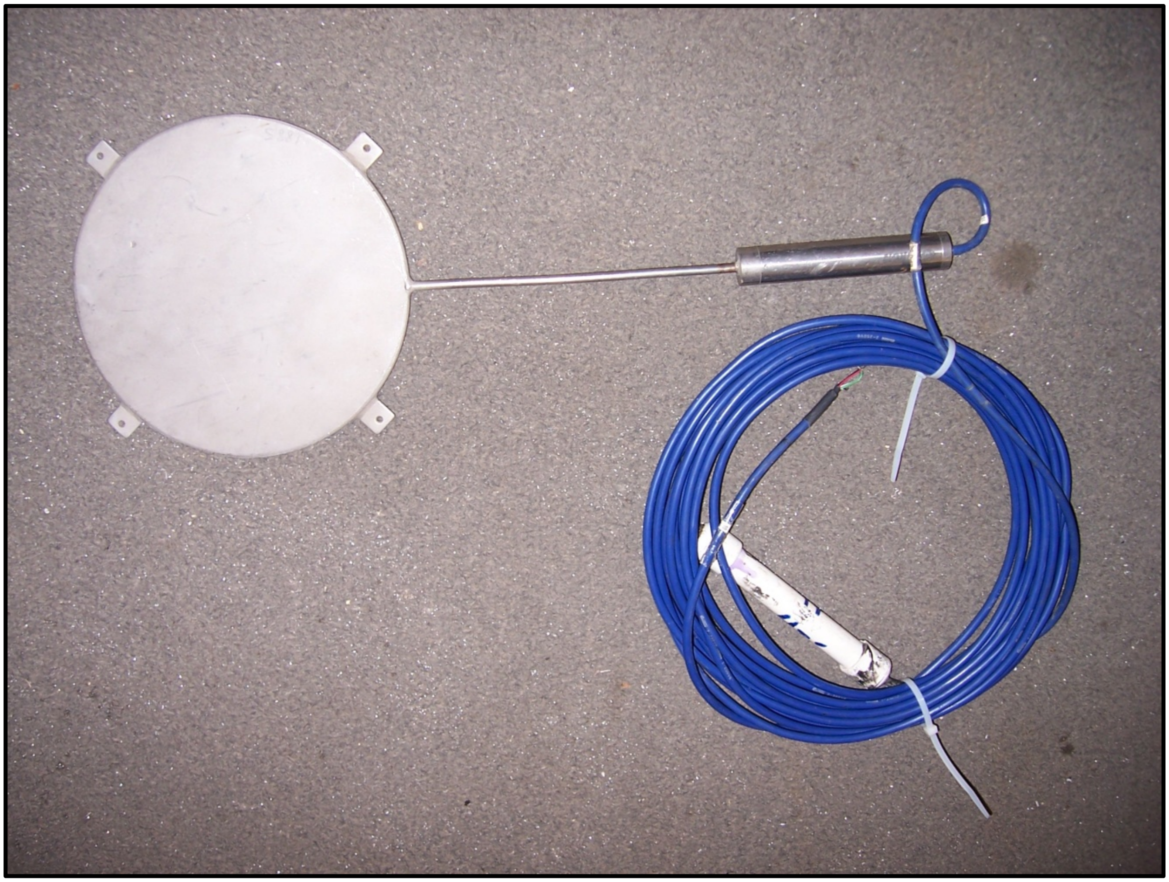

Figure 1: Earth Pressure Cell.

d. Discussion and selection of system for measuring pipe displacement/deflection.

Progress Report 1 discussed this particular project issue under the heading, “Pipe Deflection Measurement.” Whereas it was initially thought that a laser system would be cost prohibitive, an industry contact offered to provide the University with a track-mounted laser which had a 360 degree spinning mirror, as well as camera. The pieces of equipment needed, along with the software and other data logging equipment, was going to be provided free of charge. The simple trolley with rotating LVDT mounted on a track was superseded by this option, mainly because the laser option would end up not using any additional project funds. However, less than one week before the end of this quarter. The industry contact informed the University of the unavailability of the equipment that had been promised. This was an unfortunate setback, but a solution was quickly discovered.

On another FDOT/UF project, a laser had been used for the purposes of displacement measurement. That project has since been brought to a close, and the laser was unused over at the FDOT State Materials Office. Daniel Pitocchi, the Soils and Foundation Lab Manager over at the SMO, was kind enough to provide us with the laser. Due to the fact that this was obtained nearly at the end of the quarter, a mounting system for the laser has yet to be fabricated. A more detailed discussion of the mounting system will take place in Progress Report 3, covering the next quarter.

The laser being used, shown in Figure 2 below, has a start of measuring range equal to 200 mm, or 7.9 inches, and an end of measuring range of 950 mm, or 37.4 inches. This means that the target can be no closer than 7.9 inches, and no farther away than 37.4 inches. The mounting system currently being developed takes into account these maximum and minimum limits. The laser's resolution is 50 micrometers, or about 0.002 inches. This is more than accurate for the tests that will be performed.

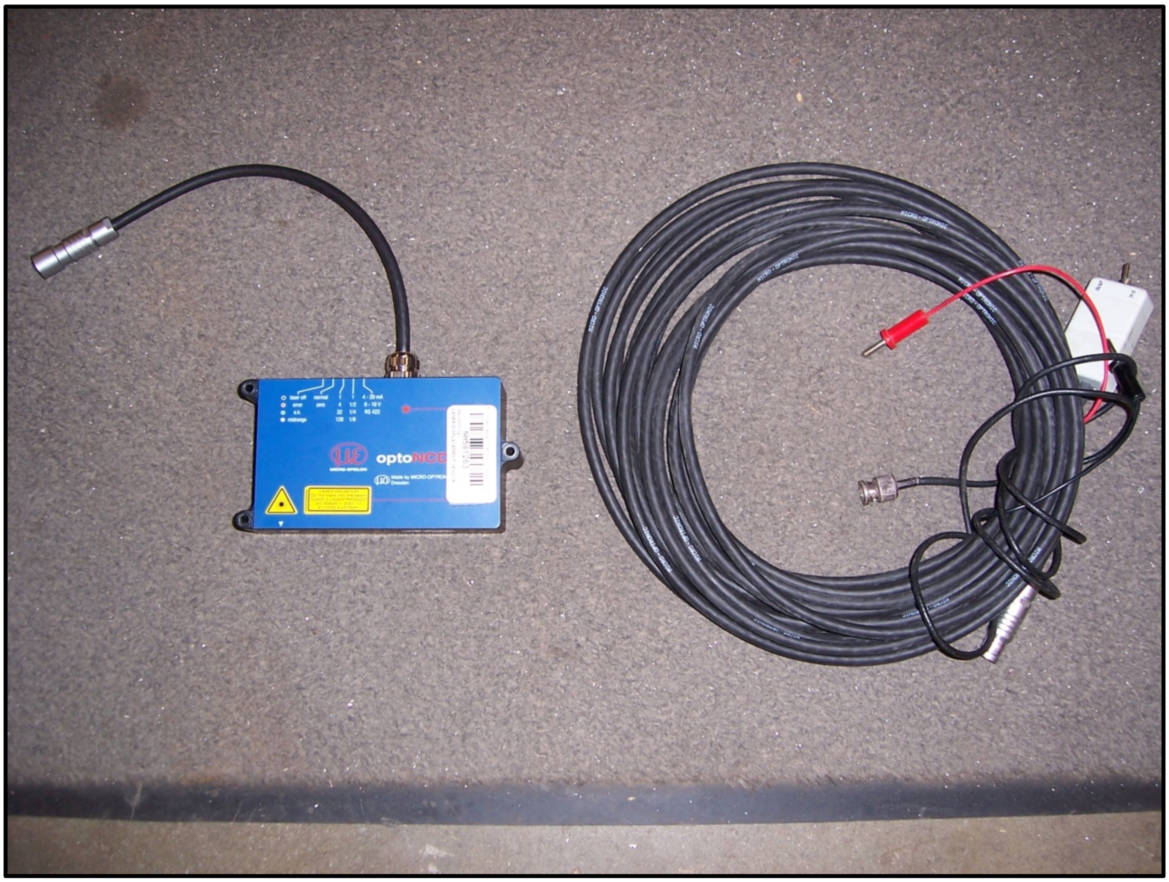

Figure 2: Micro-Epsilon Laser Displacement Sensor and cabling.

e. Revision of load plate and lift bag configuration to achieve the most uniform pressure distribution and to avoid eccentric loading.

Initially, the uniform loading of the soil box was going to take place with the use of eight, five foot square load plates. Each load plate would have a 42 inch square lift bag on top of it. However, this setup did not provide for optimal testing conditions because the plates were located in such a manner that the joint between two plates was over the centerline of the pipe. This issue would cause extreme tilting of the plates once the loading began.

Instead, the decision was made to use six of the five foot square plates towards the inside of the box, and four smaller plates towards the outside. Four new lift bags with smaller dimensions had to be ordered to accommodate this new design. Details of this layout are found on Pages C-11 and C-12 of the Appendix. With this setup, the load plates are either directly over the fill, or directly over the centerline of the pipe. The tilting settlement is therefore eliminated, and the issue of differential settlement of the plates will be dealt with as discussed in Section b.

f. Fabrication of sealing system for interface between pipe end and soil box wall.

This issue was discussed in detail in Section a. Figure 3 below demonstrates what the completed wall flange looks like when bolted onto the soil box side wall.

Figure 3: Completed wall flange for sealing system.

g. Machining of one of the soil box porthole covers to allow for proper threading of all instrumentation wires out of the soil box.

Due to the large amount of instrumentation equipment being used for this project, careful attention was taken to ensure proper organization of all wiring. All instrumentation wiring will exit through the center porthole on the East side of the soil box. This porthole cover was machined, as shown in Figure 4 below, to allow for proper exit of all instrumentation wiring.

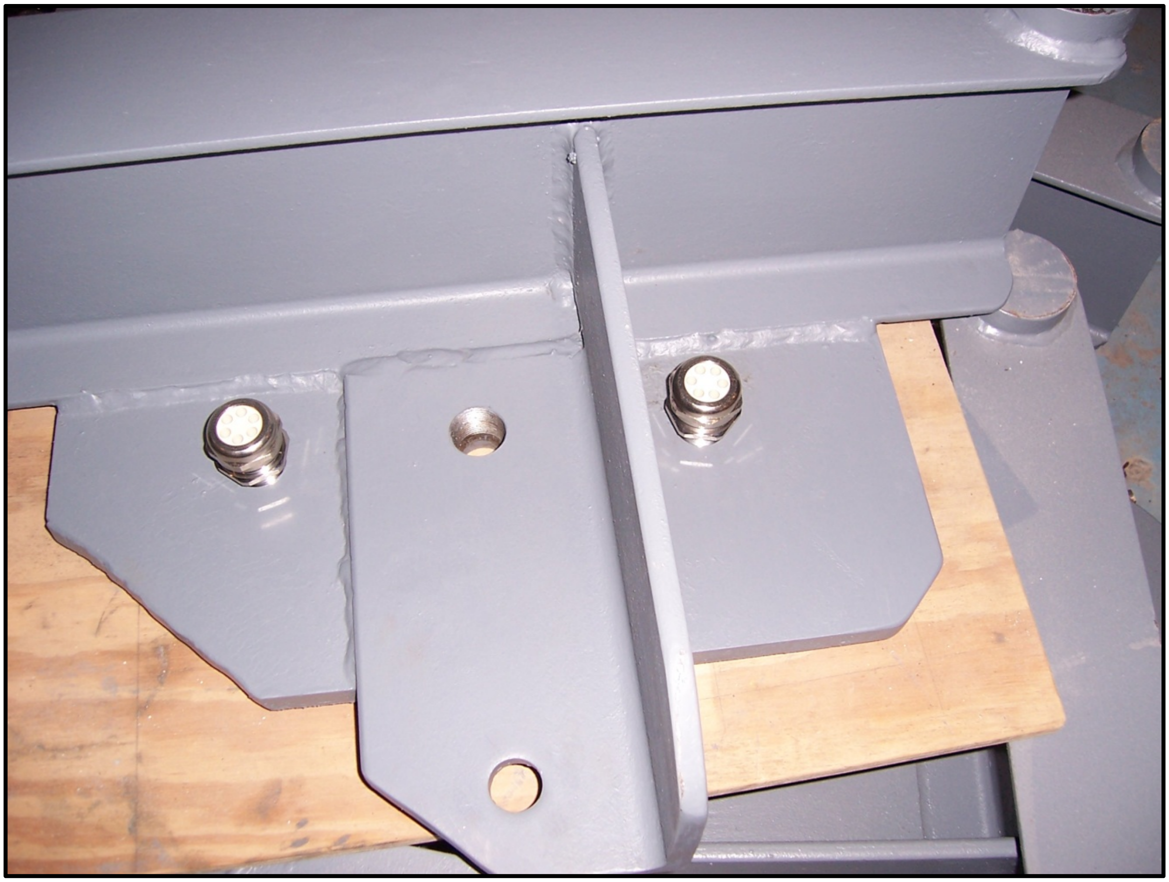

Figure 4: Machined porthole cover.

h. Selection of system to interface with machined soil box porthole cover and instrumentation wiring.

Figure 5 below shows what the instrumentation wiring will be guided through so there is no chance of wires being cut or improperly handled. These “knobs” are screwed into the threaded holes that were machined on the soil box porthole cover.

Figure 5: Instrumentation wiring guide.

i. New pipes were delivered to the University of Florida Coastal Lab.

In the first quarter of this project, the Coastal Lab received 24 inch and 36 inch diameters of the M294 HDPE pipes. During this last quarter, the Lab received the 24 inch and 36 inch diameters of the Steel pipes, 36 inch diameter F949 PVC pipes, and 36 inch diameter Aluminum pipes. These all can be seen in the Figure below.

Figure 6: Other pipes to be used for testing.

j. New load plates and lift bags were delivered to the University of Florida Coastal Lab.

During this quarter, the load plates were ordered and delivered to the Coastal Lab. The change in number and layout of load plates and lift bags was made prior to the ordering of the plates, so no additional plates were necessary. However, the layout design modification did come after the eight large lift bags were ordered and delivered. As discussed in Section e, four smaller lift bags had to be ordered. The loads plates and lift bags can be seen in the Figures below. The lift bags were delivered along with all the necessary connectivity equipment, including regulators, valves, and hoses. These are seen in the Figures below. In regards to the valve stem with eight valves, seen below in Figure 11, this stem will be modified to include ten valves, each connecting to a separate lift bag. Also, each valve will have a regulator. This will provide for control of the pressure and rate of inflation of each of the ten lift bags.

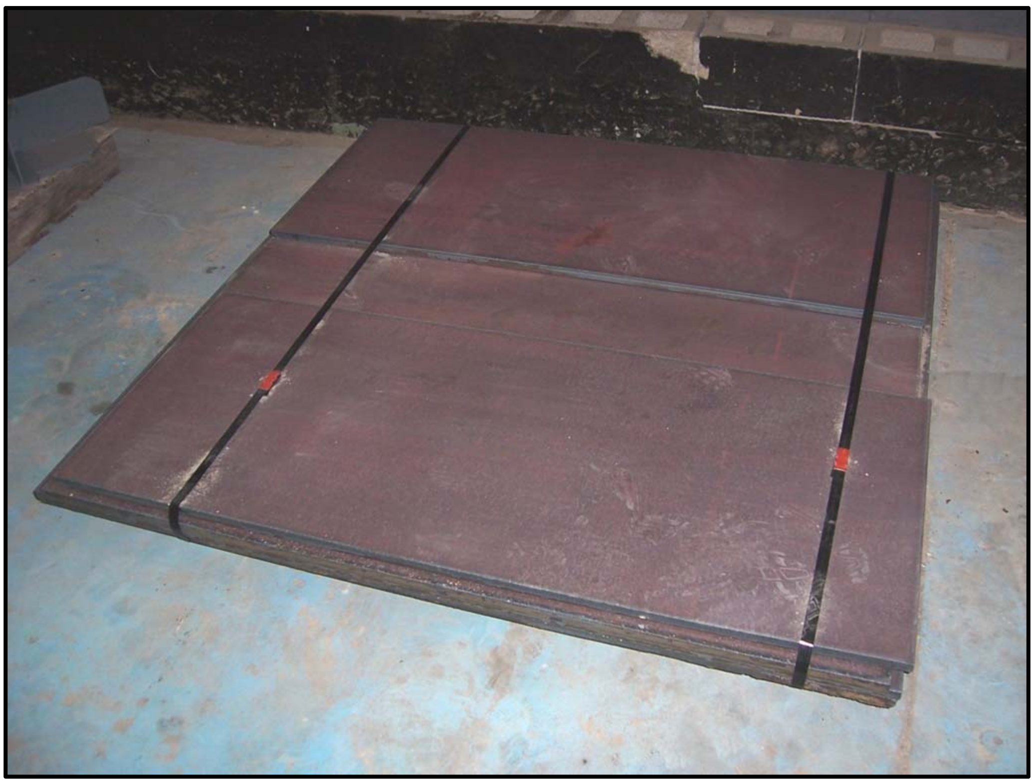

Figure 7: Load Plates.

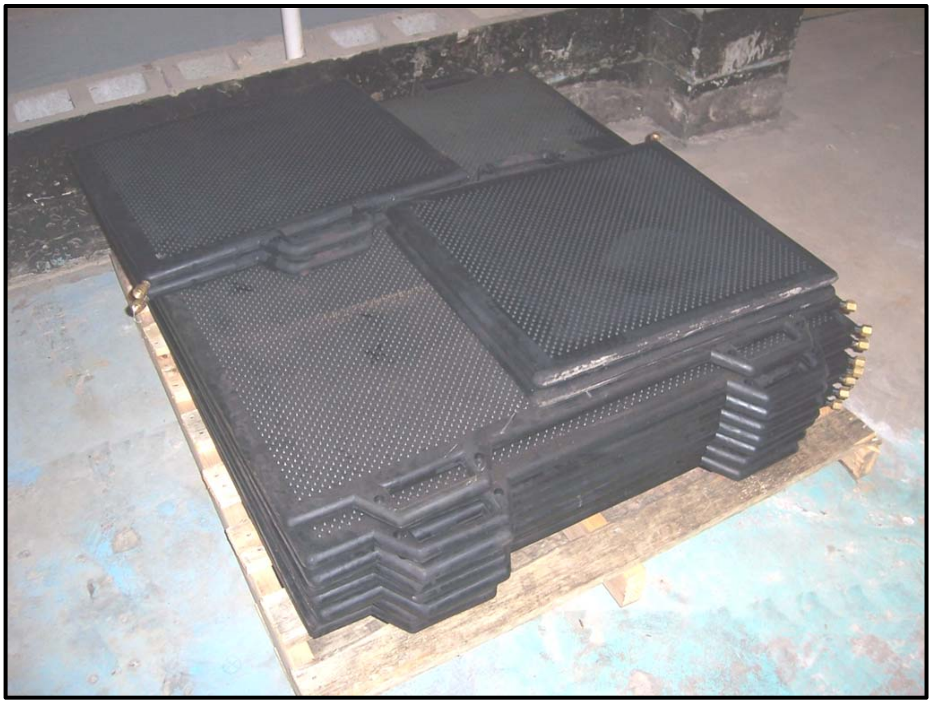

Figure 8: Lift Bags.

Figure 9: Regulator.

Figure 10: Air Hoses.

Figure 11: Valve stem.

k. Spiral ribbed flexible pipes were outfitted with a circular metal strip around the inside perimeter to provide for better seal which would work with selected sealing system.

In order for the pipes to properly interface with the sealing system discussed in Section a, the spirally corrugated pipes needed to have a strip of metal welded to the inside perimeter. This slight modification can be seen below in Figure 12 for the Aluminum pipes. The same modification is being performed on the Steel pipes.

Figure 12: Metal strip welded onto spirally corrugated pipes.

l. Flexible pipes with circular corrugations had the corrugating filed back to be able to adequately interface with selected sealing system.

For the pipes with circular corrugations, no additional metal strip was added. Instead, the corrugation was filed back. See figures below for M294 HDPE and F949 PVC pipes.

Figure 13: Filed back corrugation on M294 HDPE pipe.

Figure 14: Filed back corrugation on F949 PVC pipe.

m. Field visit to accurately document all inside dimensions of the soil box for purposes of producing detailed AutoCAD drawings.

In order for all AutoCAD drawings to accurately reflect the inside condition of the soil box, exact dimensions were taken with the use of a tape measure. All measurements were made to the nearest 1/8 of an inch. The AutoCAD drawings are all dimensioned to the nearest 1 inch for ease of viewing.

n. Numerous visits to University of Florida Coastal Lab to photograph newly delivered materials, newly machined parts, and project progress in general.

Each week, pictures are taken of all the new steps that have progressed. This process will continue throughout the duration of the project.

o. Literature review.

The following articles have been collected and are being reviewed. Literature review will continue throughout the duration of the project.

Abolmaali, Ali. "Experimental Verification of CUES Laser Profiler Deformation Analysis Results." Arlington, TX: University of Texas, 2008. Print.

Moser, A.P. Buried Pipe Design. Second Edition. New York, NY: McGraw-Hill, 2001. Print.

Motahari, Ardavan, and Jorge Forteza. "Accuracy of Laser Profiling of Flexible Pipes Using CUES System." Arlington, TX: University of Texas, 2008. Print.

Palmer, Michael. "Results of Full-Scale Test on 16-inch HDPE Pipe." 2005. Web. 25 Jan 2010.

p. Continued discussion on instrumentation to be used during the testing periods.

There is continued discussion on instrumentation that will be used in combination with the laser system for measuring displacement. It is very important to be able to know the horizontal distance along the pipe when a measurement is taken. This way, the process can be standardized amongst all the tests. Most likely, this will be accomplished with the use of a string potentiometer.

All the instrumentation will be connected to the same data logger. All data will therefore be recorded in one convenient location, containing the elapsed time, pipe deflection measurement, horizontal distance measurement, and earth pressure cell readings.

2. Activities Planned for Next Quarter

The first test has yet to be performed. It is anticipated that a full test will begin during the next quarter. Although Progress Report 1 indicated that Tasks 2a and 3a would be completed by now, the instrumentation setup has taken longer than anticipated. This is mainly due to the unexpected change with the laser system and deflection measurement. Once this system is fully designed and fabricated, the project schedule will be back on track.

Triaxial test data will be obtained from the FDOT SMO for the A-2-4 soil that will be used for this project. Nuclear density tests will also be performed as soil is added to the box to ensure that the soil is being compacted to the correct level.

3. Activities Beyond the Next Quarter

Once a successful test has taken place, the process becomes somewhat repetitious. The idea has been to make sure that everything is standardized prior to the running of any tests. This way, testing methods do not change from one test to another.

4. Summary of Requested Modifications

No changes or modifications are requested.

5. Project Schedule

A table of tasks to be completed with current status is provided on the next page.

FLORIDA DEPARTMENT OF TRANSPORTATION
RESEARCH CENTER

PROJECT SCHEDULE

Project Title	Time Dependent Load Response of Flexible Pipe Subjected to Sustained Loading					
FDOT Project No.	BDK75 977-21	FY	2009/10	Months	Dec-March	
Research Agency	University of Florida					
Principal Investigator	Dr. David Bloomquist, Dr. Timothy McGrath					

RESEARCH TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	ESTIMATED % COMPLETION
Task 1 Install Visqueen Sheeting/Purchase Lift Bags	■																								5
Task 2a Install Bedding Material/Earth Pressure Cells		■																							7
Task 3a Install Two 36" HDPE Pipes/Backfill/Flooding			■																						4
Task 4a Fill Box/Install Pressure Cells/Lift Bags				■																					10
Task 5 Conduct Triaxial/1D Compression Tests	■	■																							4
Task 6 Finalize Design/Construction of LVDT Profiler	■	■																							3
Task 7 Conduct Staged Load Tests on Dual 36" HDPE Pipe					■	■																			6
Task 8A Repeat Tests on Single Pipes w/ Trench Boxes							■	■	■	■	■														10
Task 8B Repeat Test Series on 36" Corrugated Steel Pipe												■	■												8
Task 8C Repeat Test Series on 36" Corrugated Aluminum Pipe														■	■										8
Task 8D Repeat Test Series on 36" PVC Pipe																■	■								8
Task 8E Repeat Test Series on 24" HDPE Pipe																		■	■						8
Task 8F Repeat Test Series on 24" Corrugated Steel Pipe																				■	■				8
Task 9 Perform FEM modeling						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			10
Task 10 Preparation of Final Report						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1
																									100%
Overall % Complete Projected	4%	8%	12%	16%	20%	24%	28%	32%	36%	40%	44%	48%	52%	56%	60%	64%	68%	72%	76%	80%	85%	90%	95%	100%	
Overall % Complete Actual	4%	5.50%																							

FIG. A -- OVERALL PROJECT SCHEDULE

Appendix

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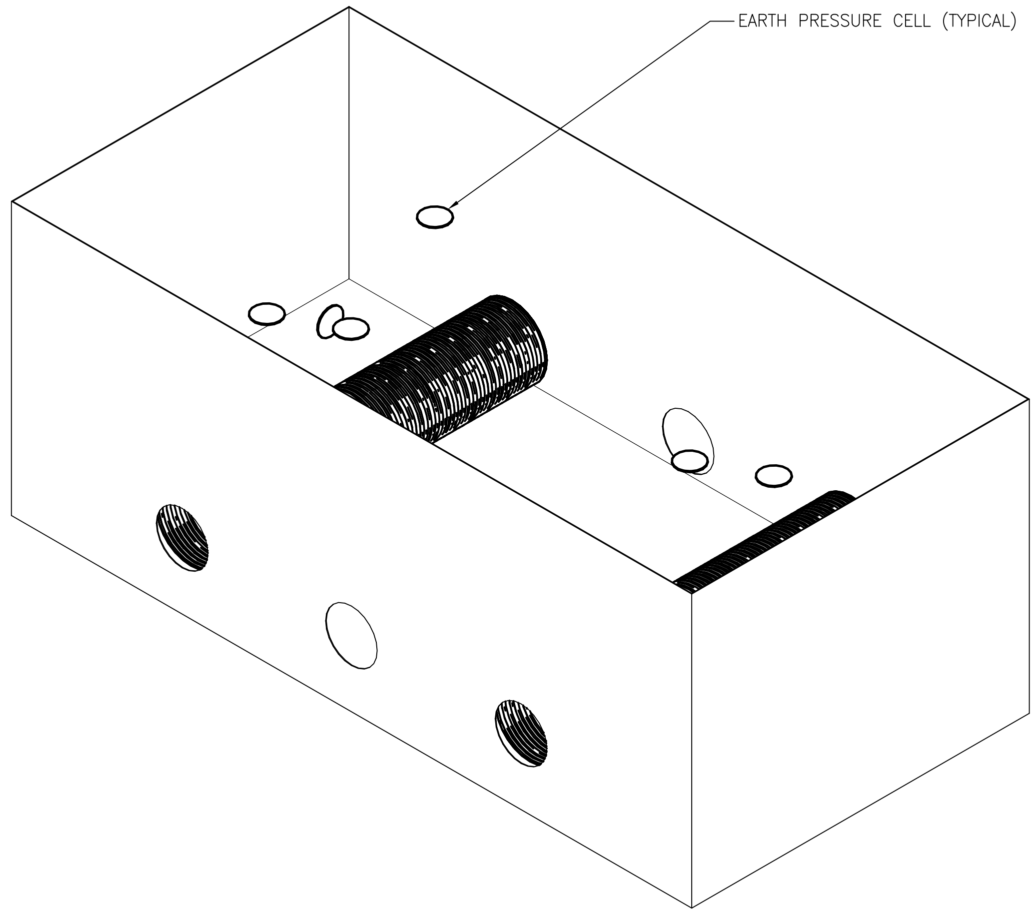

SOIL BOX ISOMETRIC VIEW WITH 24 INCH DIAMETER PIPES

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP–KP	
PROJECT #:	BDK75 977–21	DATE:	04–01–2010
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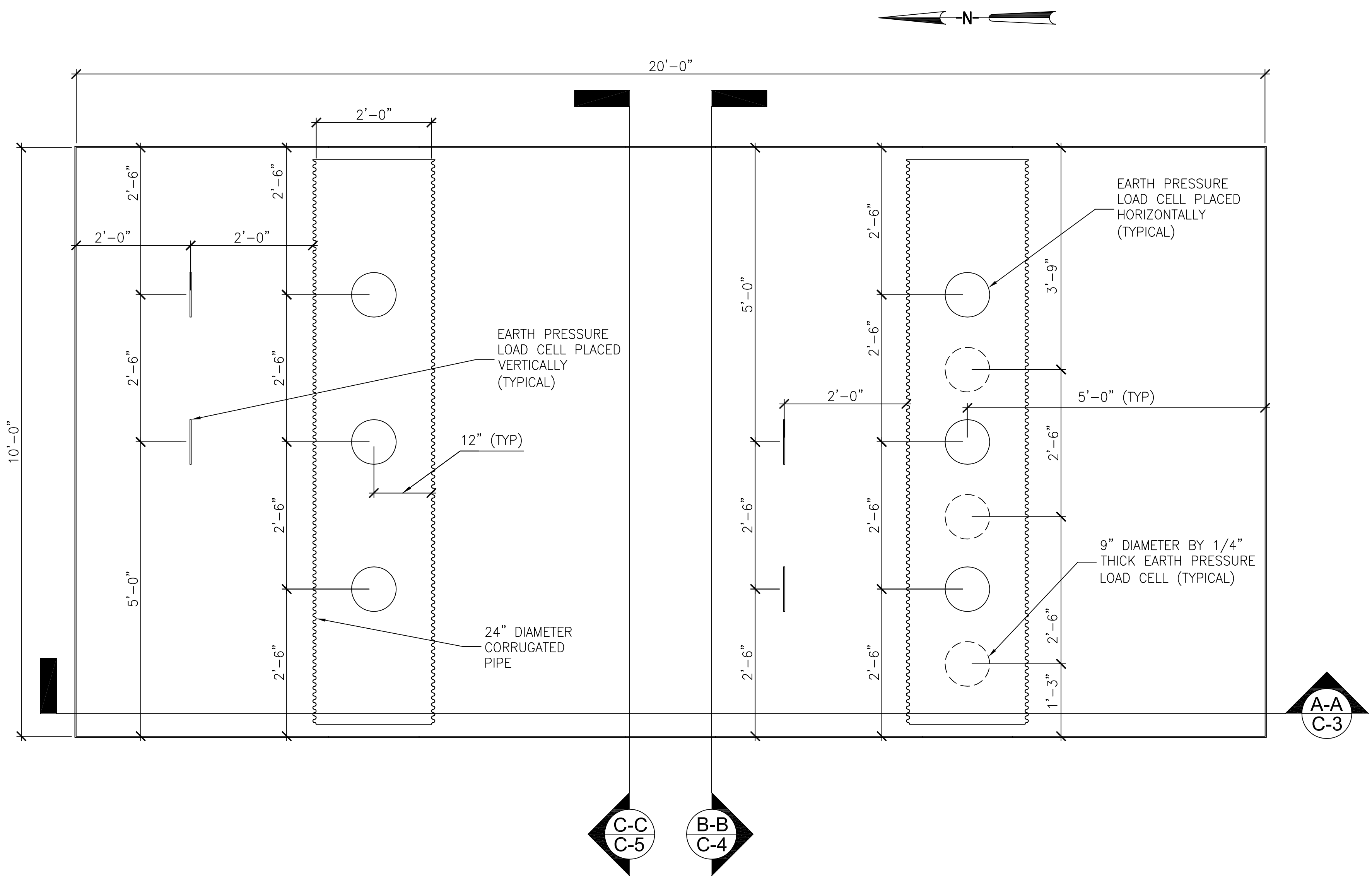

SOIL BOX PLAN VIEW WITH 24 INCH DIAMETER PIPES

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DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP–KP	
PROJECT #:	BDK75 977–21	DATE:	04–01–2010
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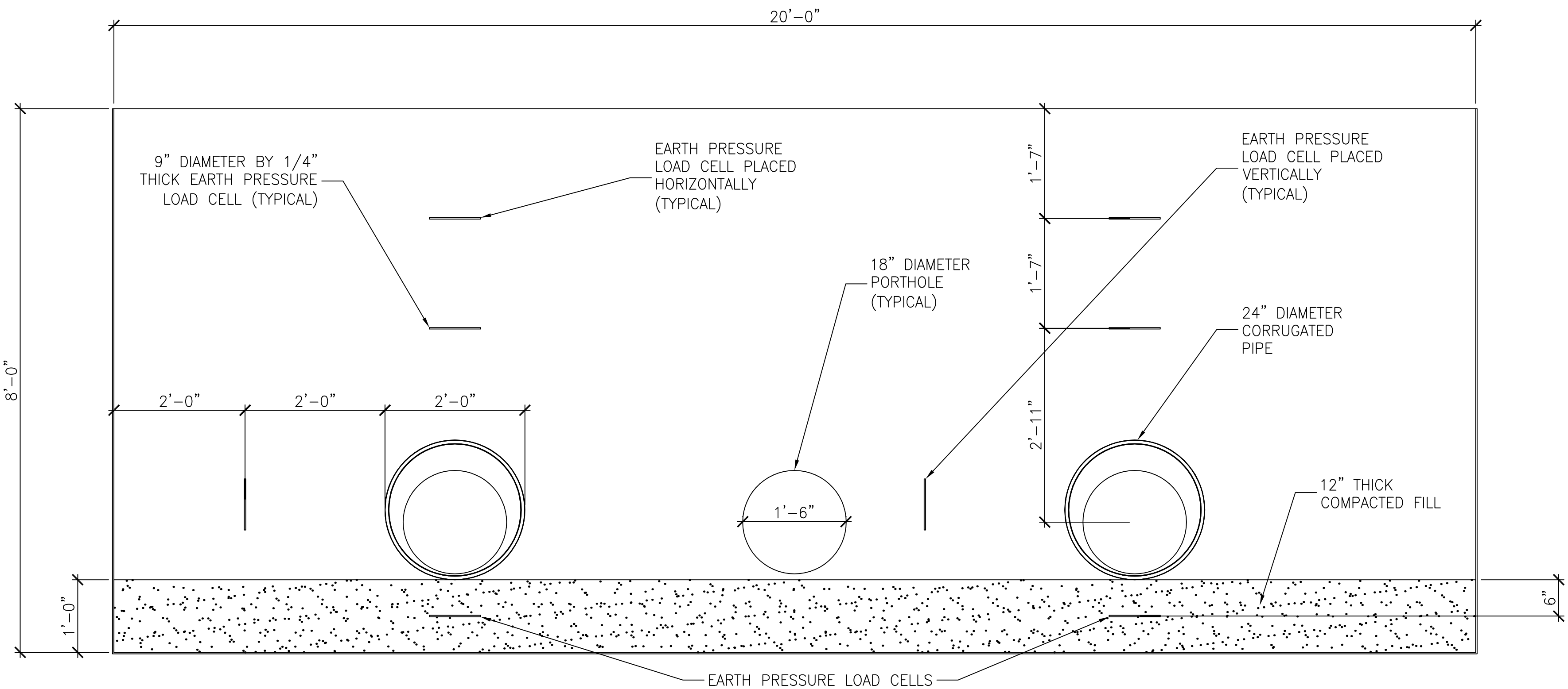

SOIL BOX PROFILE VIEW
SECTION A-A

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DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
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PROJECT #:	BDK75 977-21	DATE:	04-01-2010
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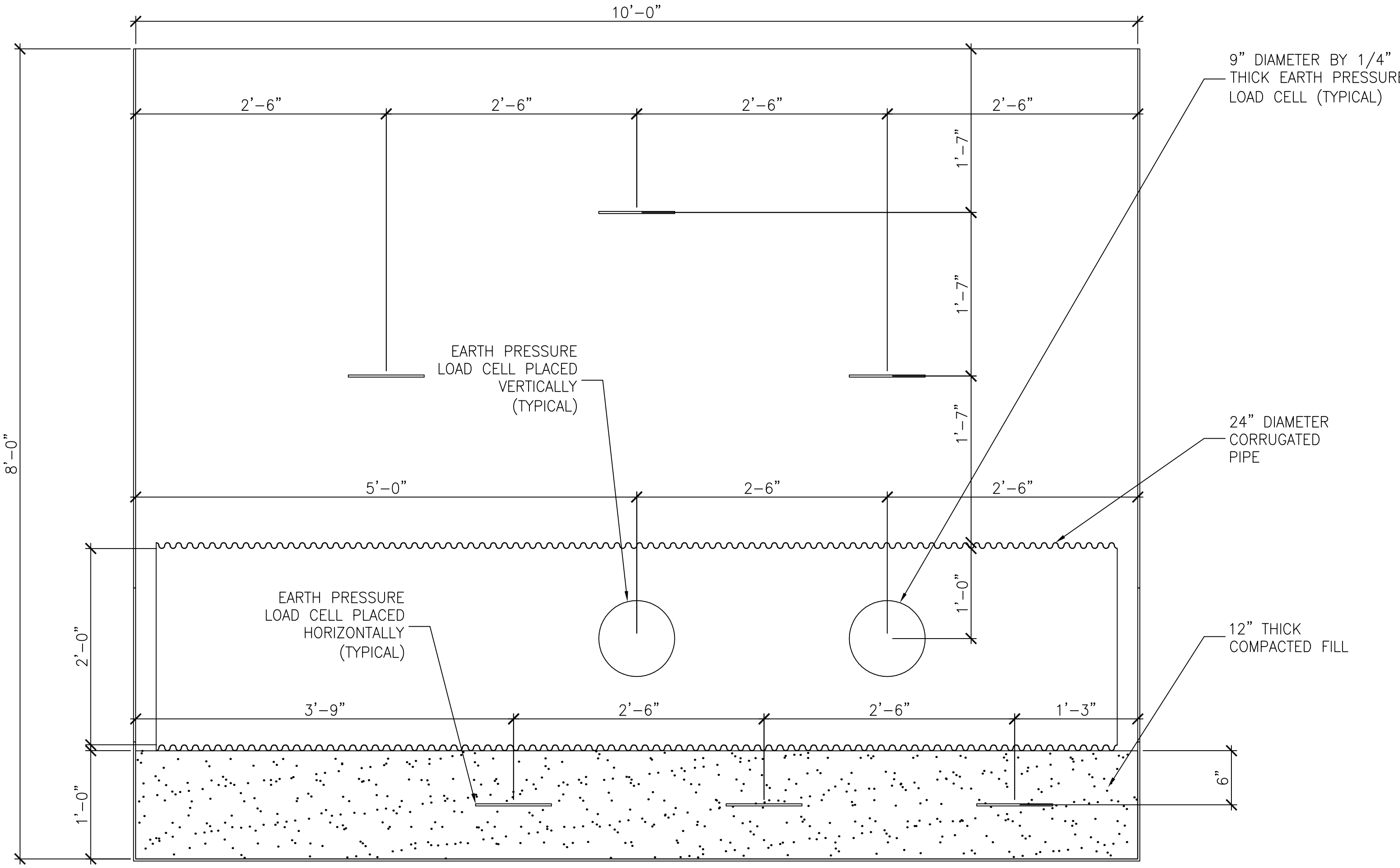

SOIL BOX PROFILE VIEW
SECTION B-B

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
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PROJECT #:	BDK75 977-21	DATE:	04-01-2010
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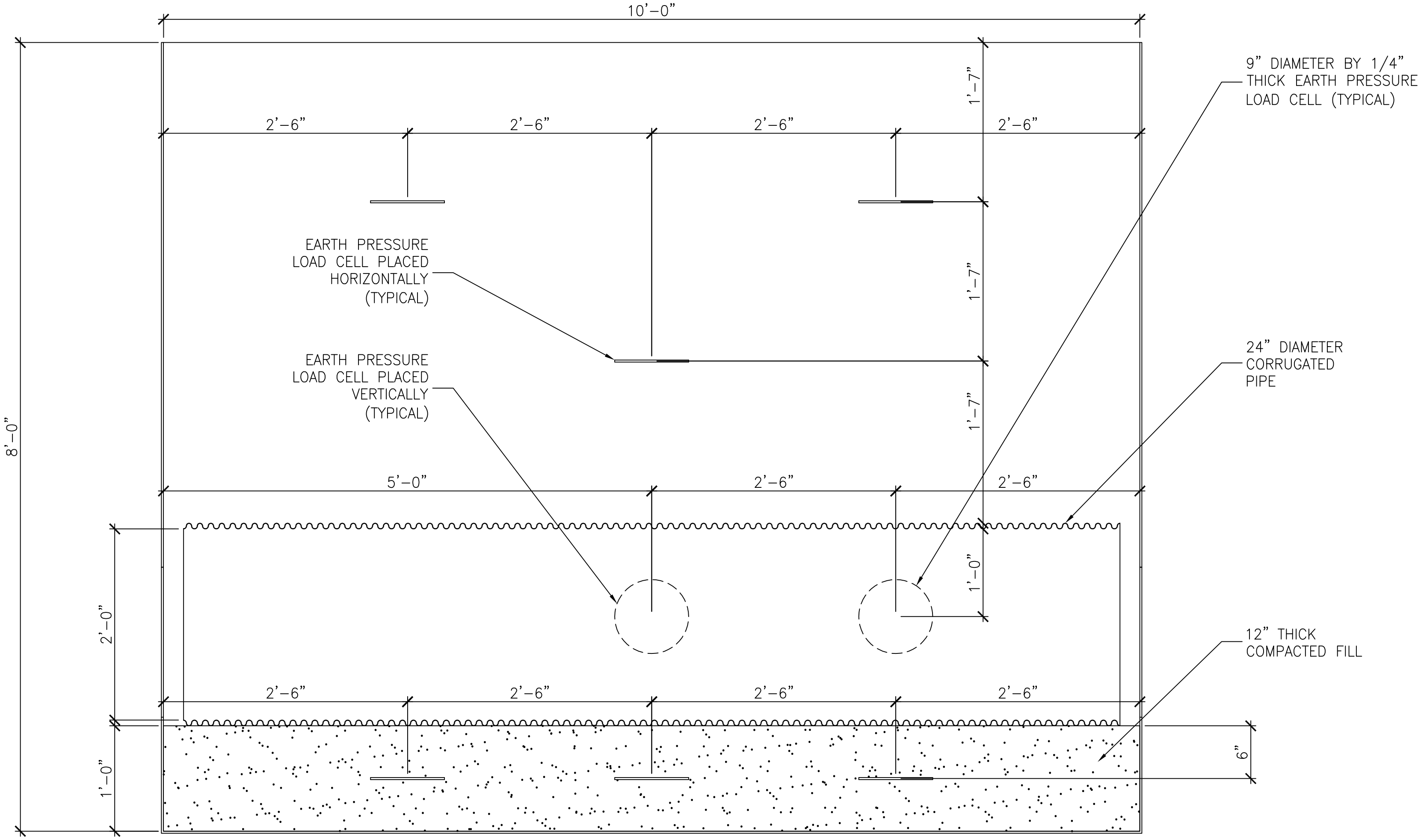

SOIL BOX PROFILE VIEW
SECTION C-C

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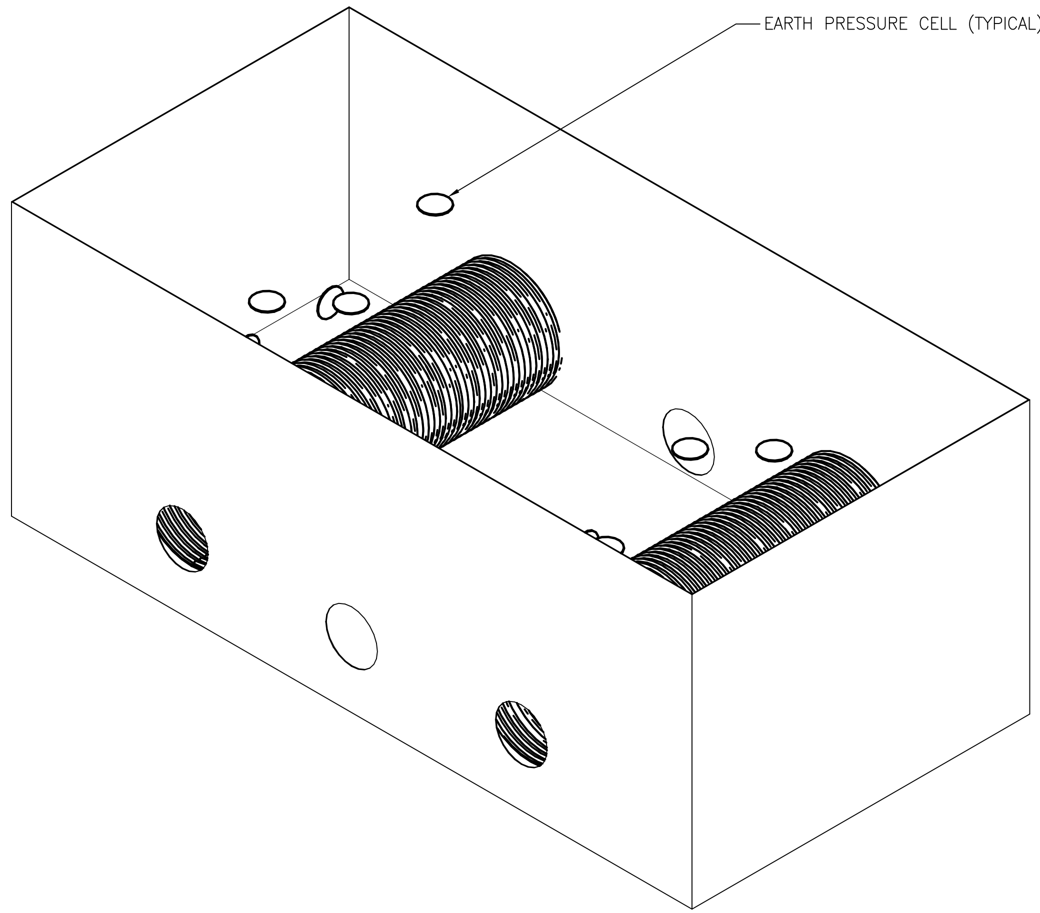

SOIL BOX ISOMETRIC VIEW WITH 36 INCH DIAMETER PIPES

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DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP–KP	
PROJECT #:	BDK75 977–21	DATE:	04–01–2010
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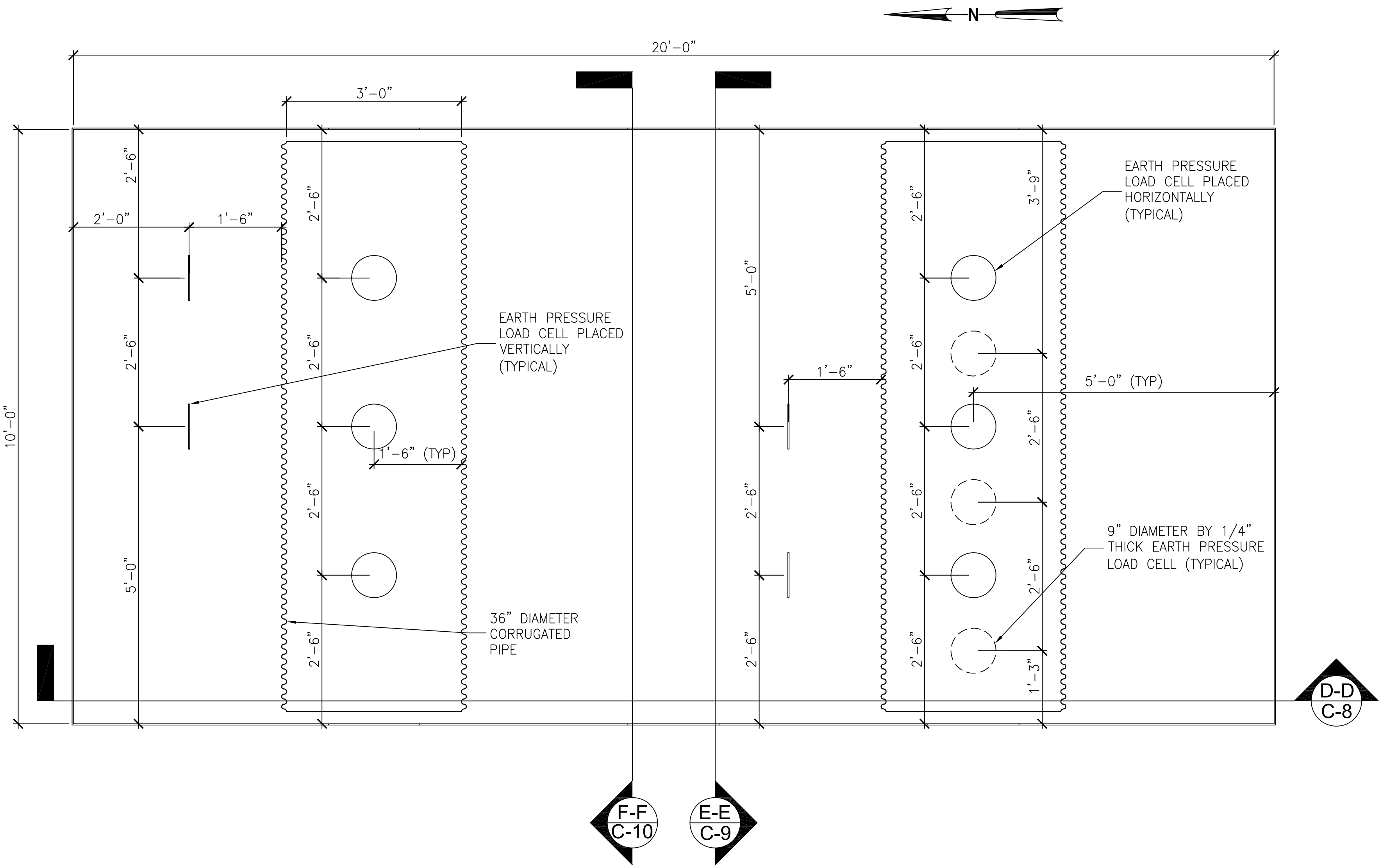

SOIL BOX PLAN VIEW WITH 36 INCH DIAMETER PIPES

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FDOT SOIL BOX PROJECT			
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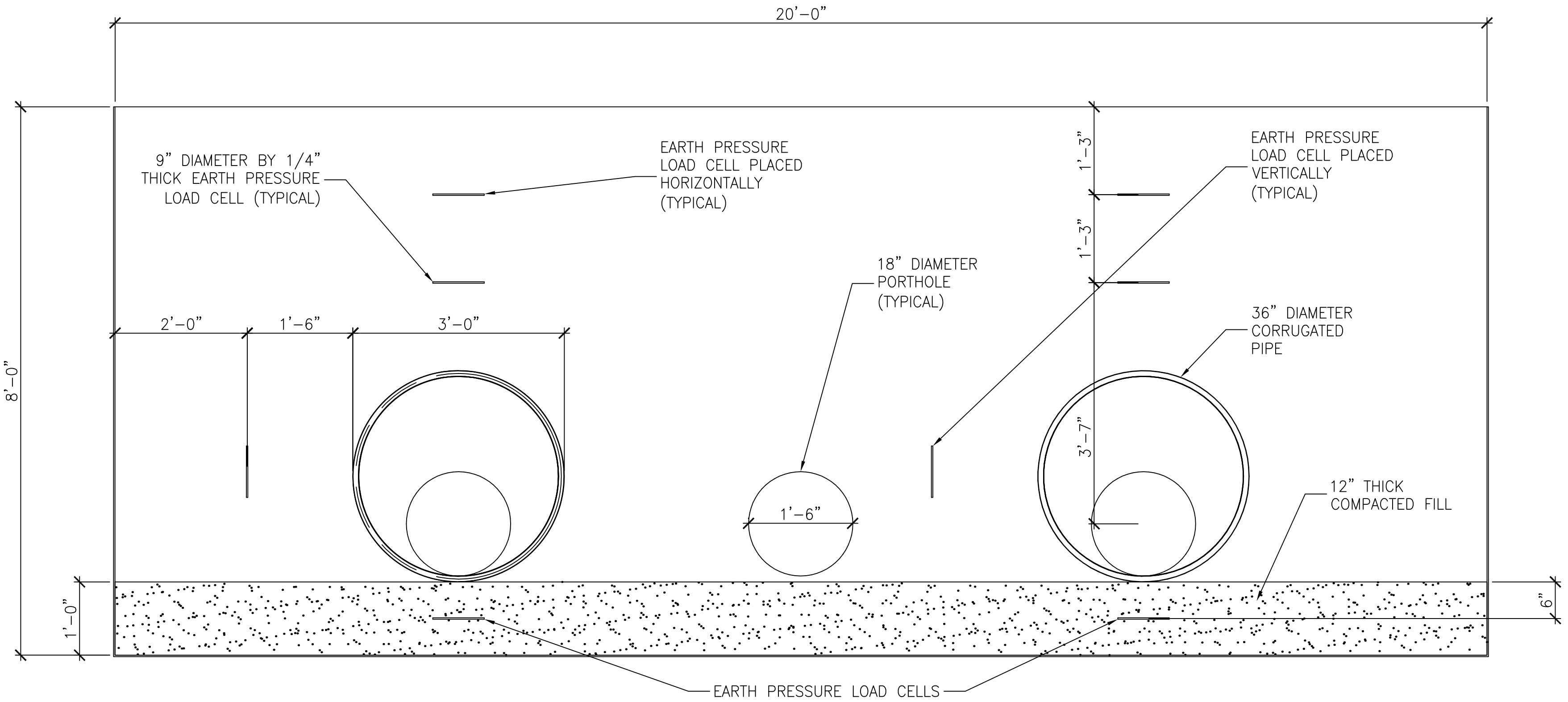

SOIL BOX PROFILE VIEW
SECTION D-D

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DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
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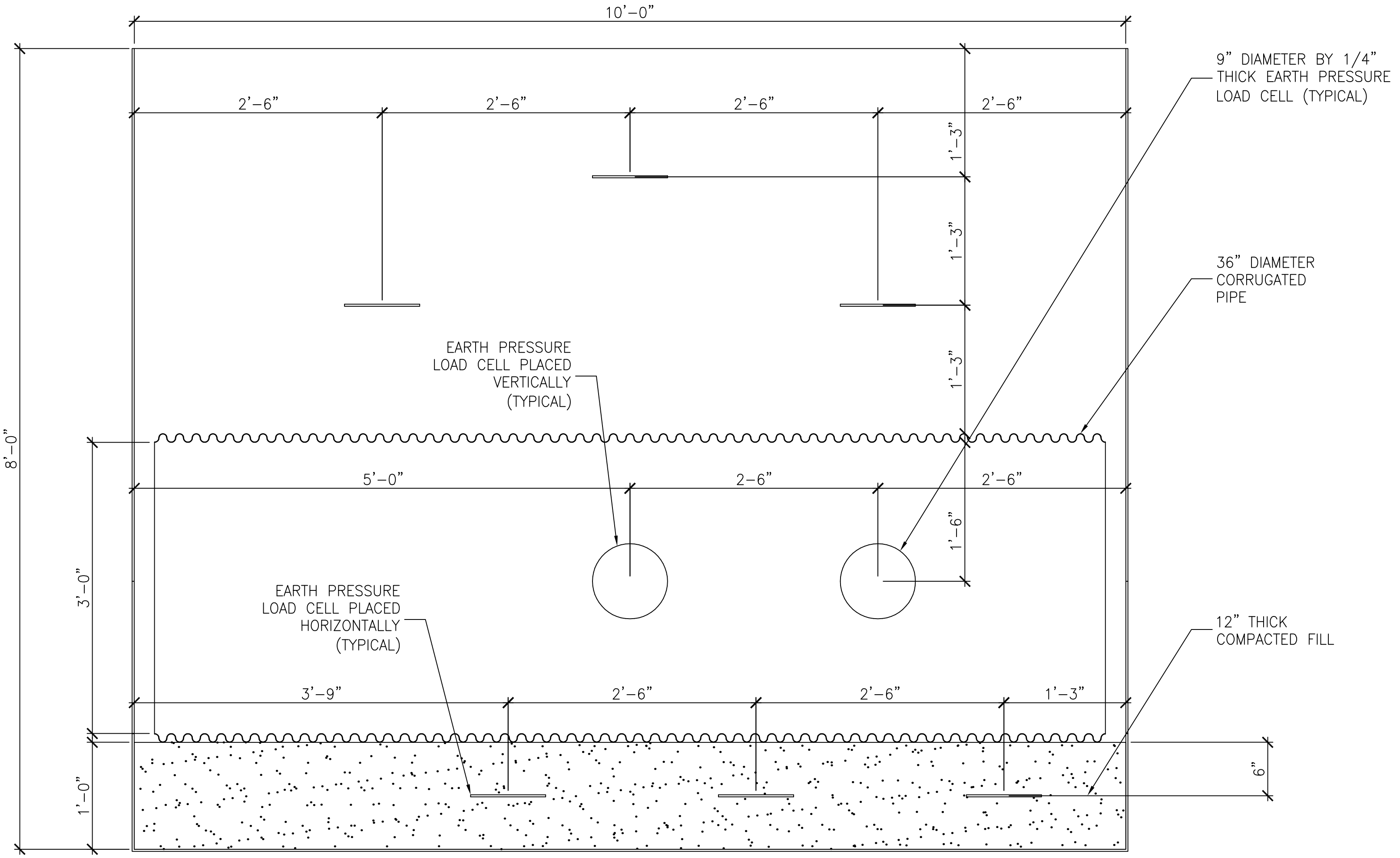

SOIL BOX PROFILE VIEW
SECTION E-E

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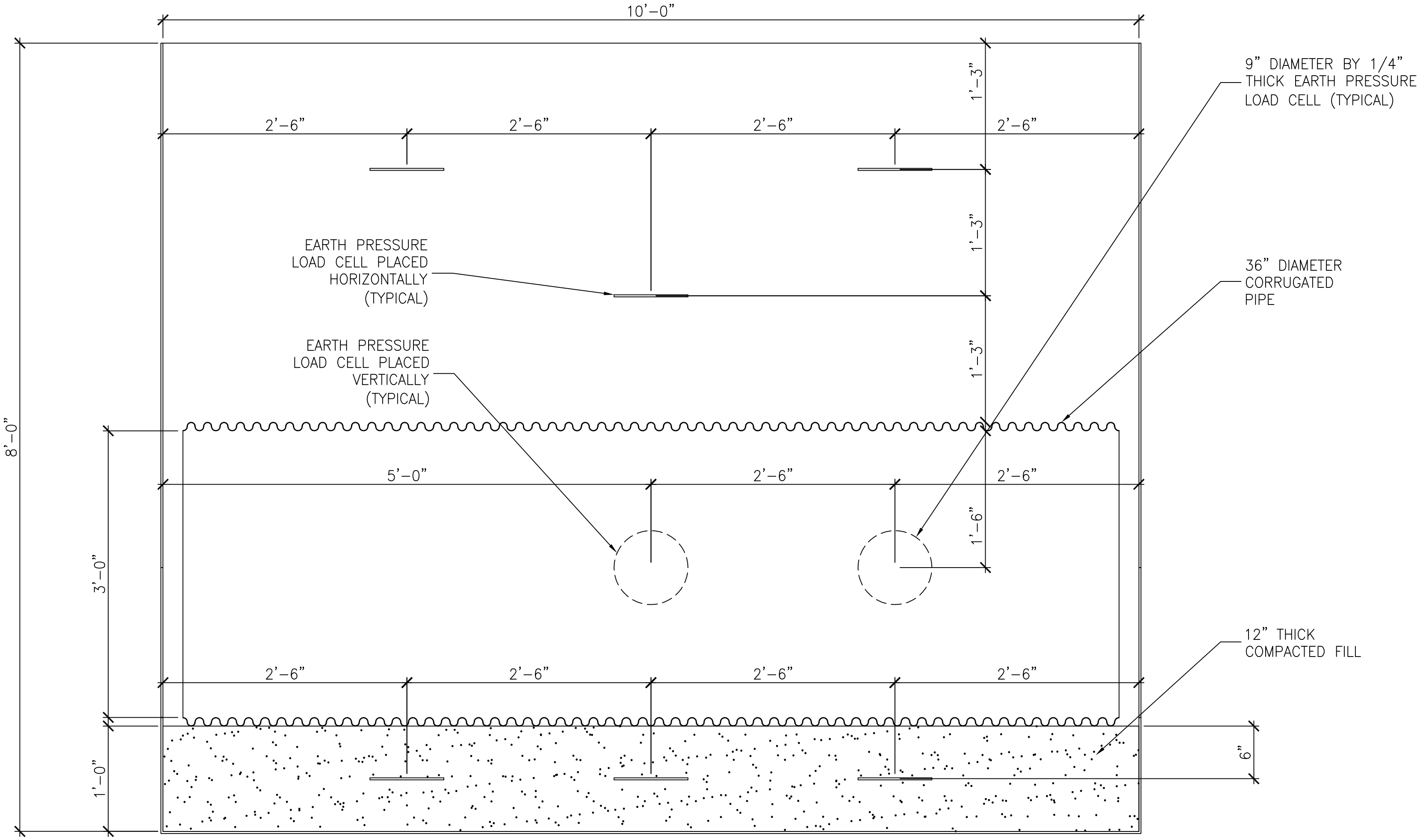

SOIL BOX PROFILE VIEW
SECTION F-F

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	04-01-2010
SCALE:	1:20	PAGE:	C-10 OF C-16

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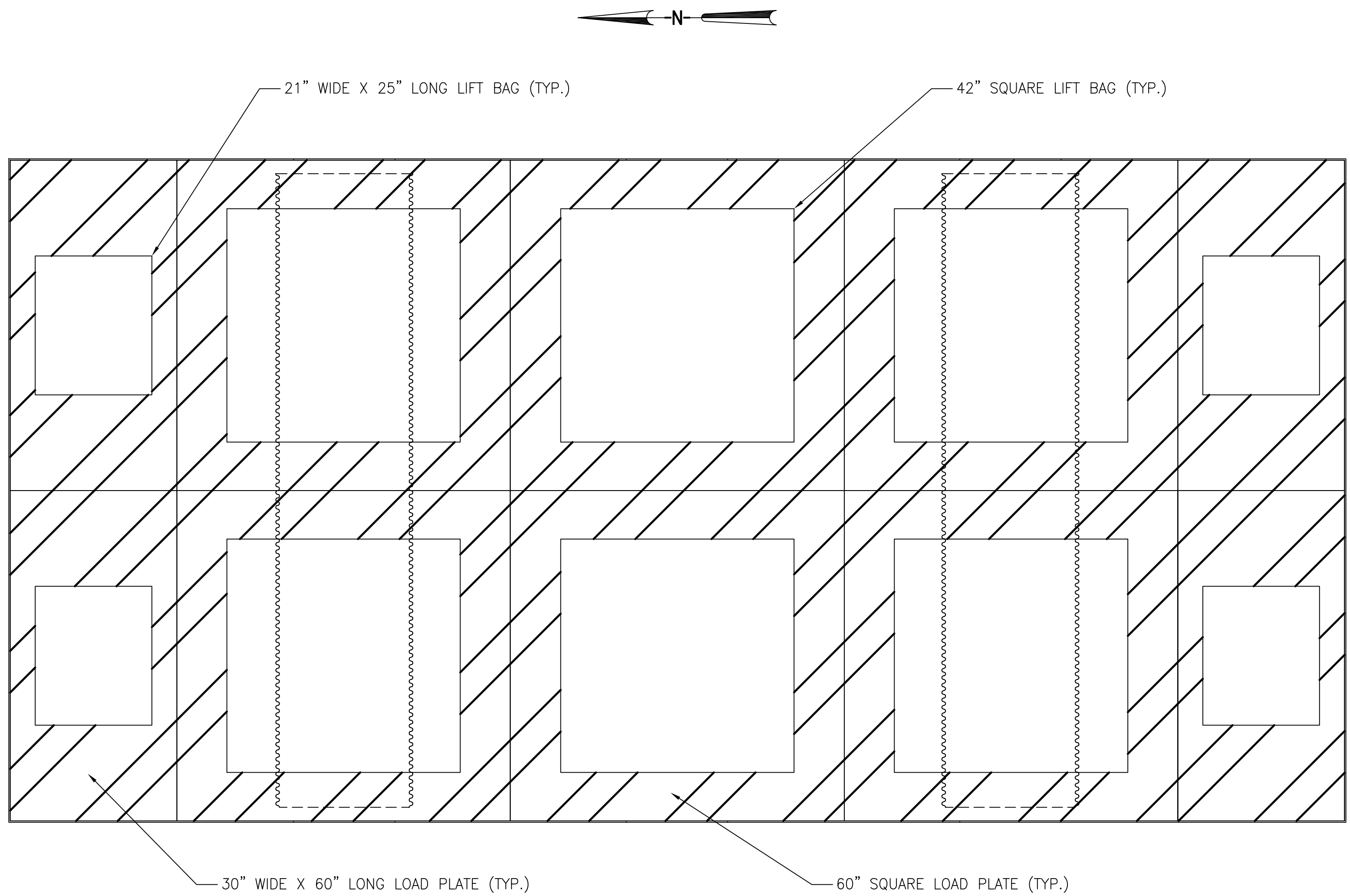

SOIL BOX PLAN VIEW
WITH LOAD PLATES AND LIFT BAGS
(24 INCH DIAMETER PIPES)

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	04-01-2010
SCALE:	1:30	PAGE:	C-11 OF C-16

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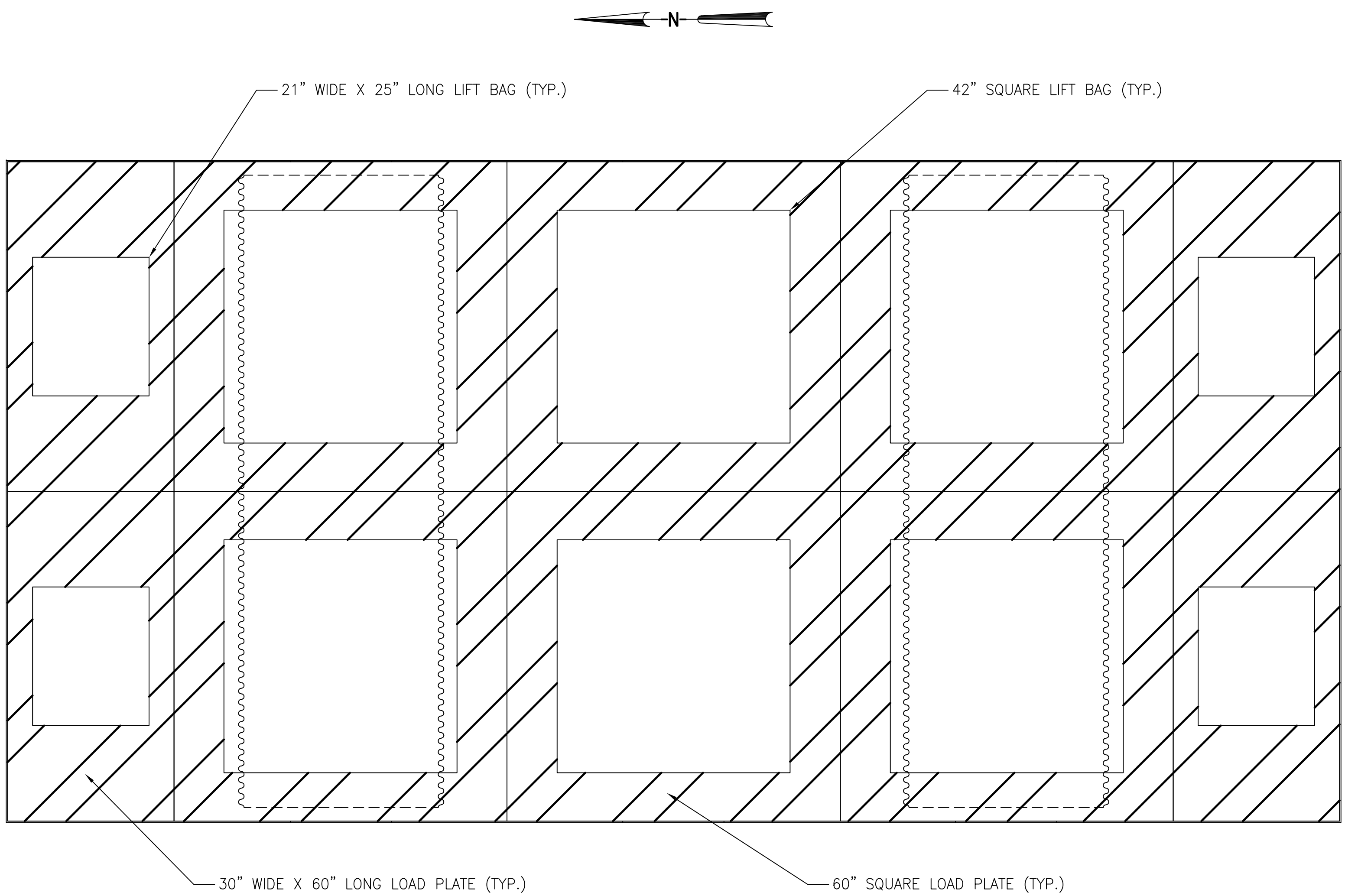
PLOTTED: 3/31/2010 10:44 PM



SOIL BOX PLAN VIEW WITH LOAD PLATES AND LIFT BAGS (36 INCH DIAMETER PIPES)

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	04-01-2010
SCALE:	1:30	PAGE:	C-12 OF C-16

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PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT

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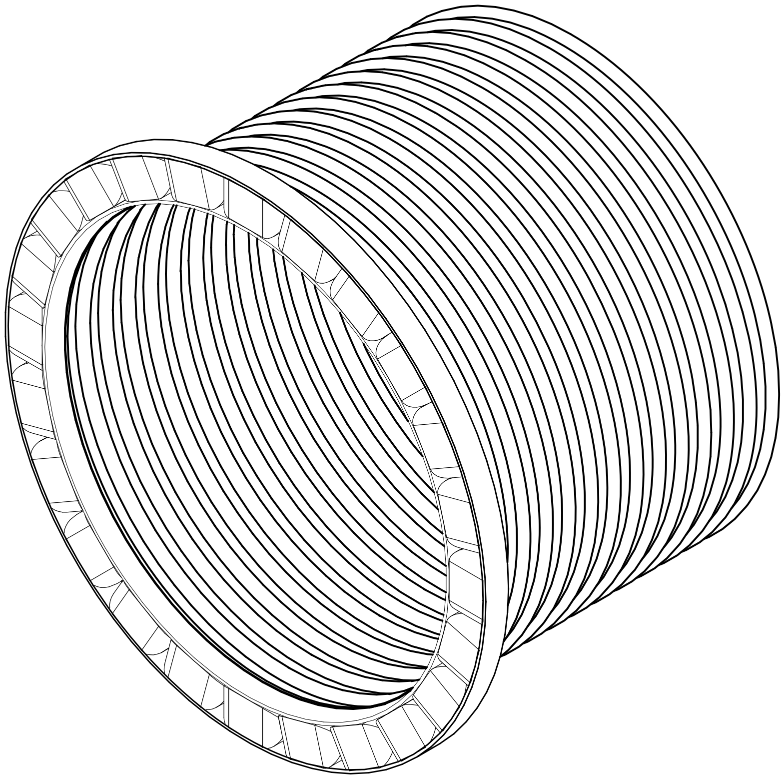
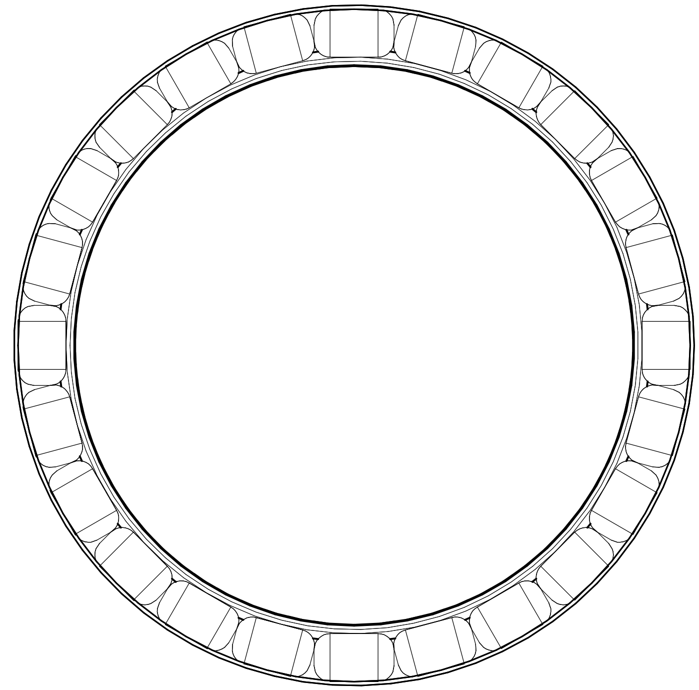


SEAL CONCEPT #1
ISOMETRIC VIEW



SEAL CONCEPT #1
FRONT VIEW

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	04-01-2010
SCALE:	1" = 1'-0"	PAGE:	C-13 OF C-16

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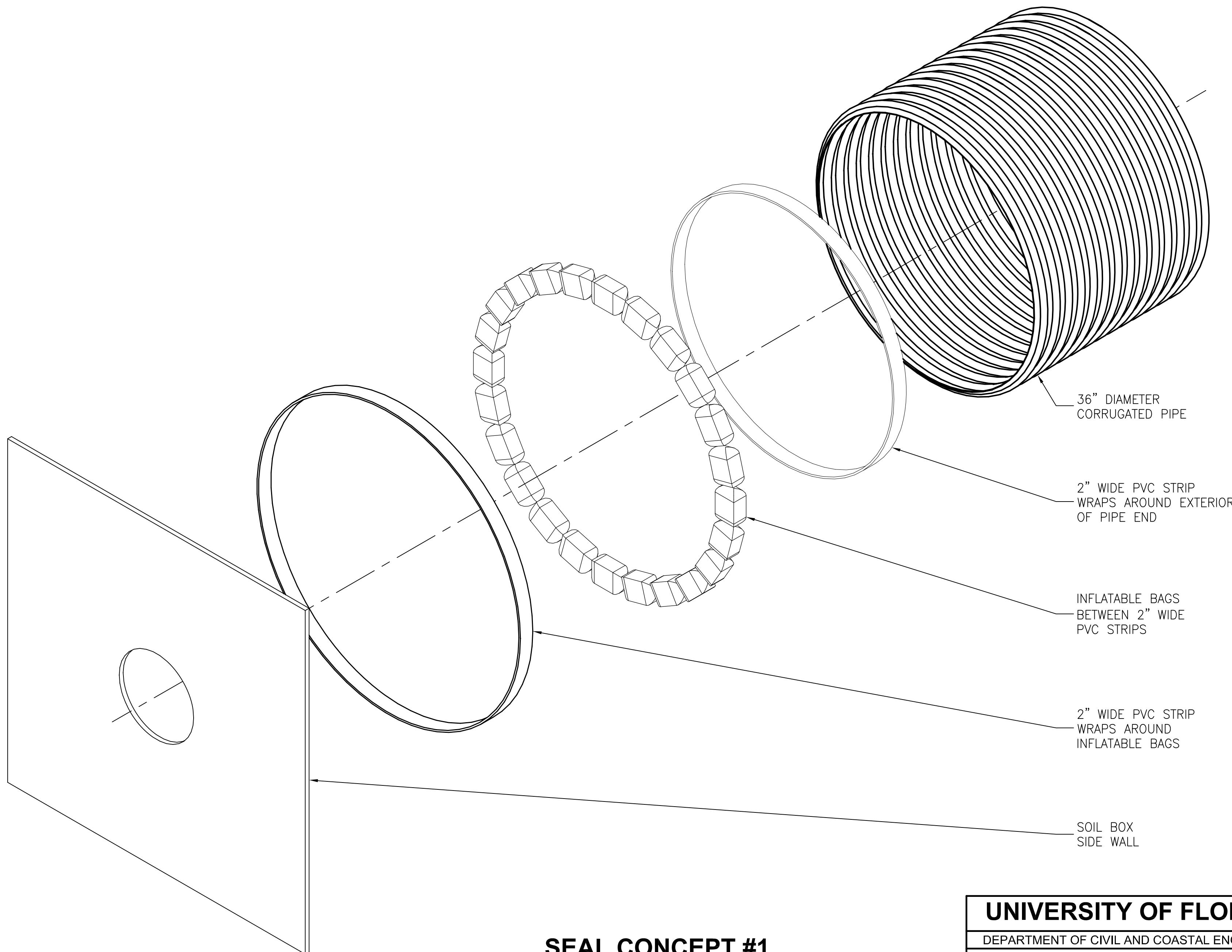

SEAL CONCEPT #1
EXPLODED VIEW

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	04-01-2010
SCALE:	3/4" = 1'-0"	PAGE:	C-14 OF C-16

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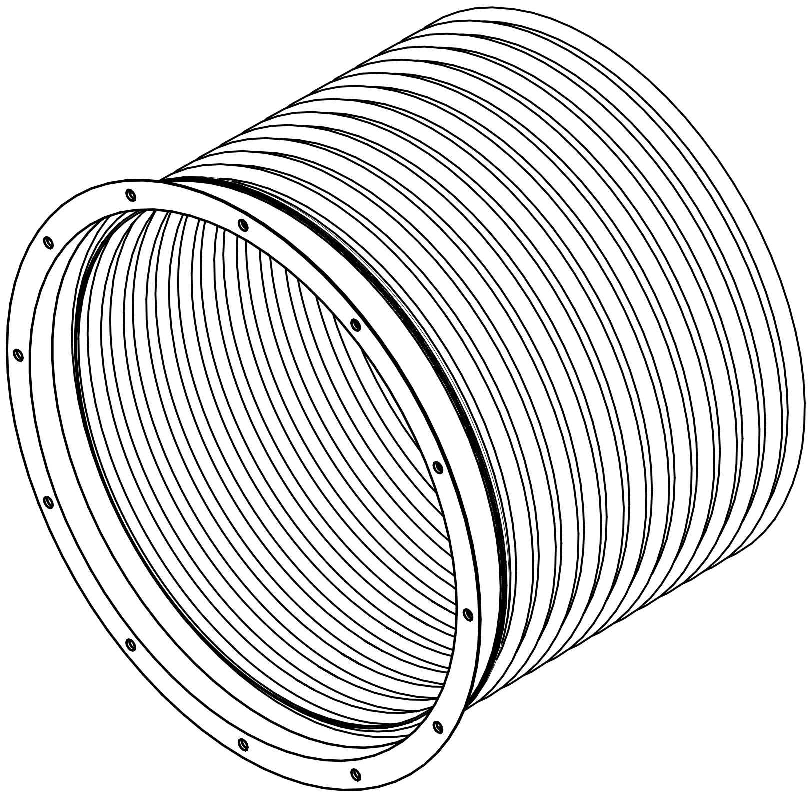
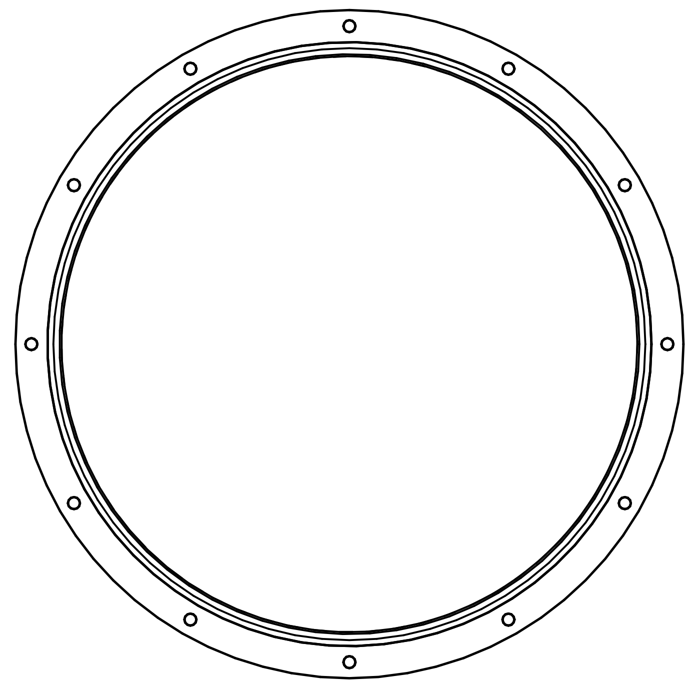


SEAL CONCEPT #2
ISOMETRIC VIEW



SEAL CONCEPT #2
FRONT VIEW

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	04-01-2010
SCALE:	1" = 1'-0"	PAGE:	C-15 OF C-16

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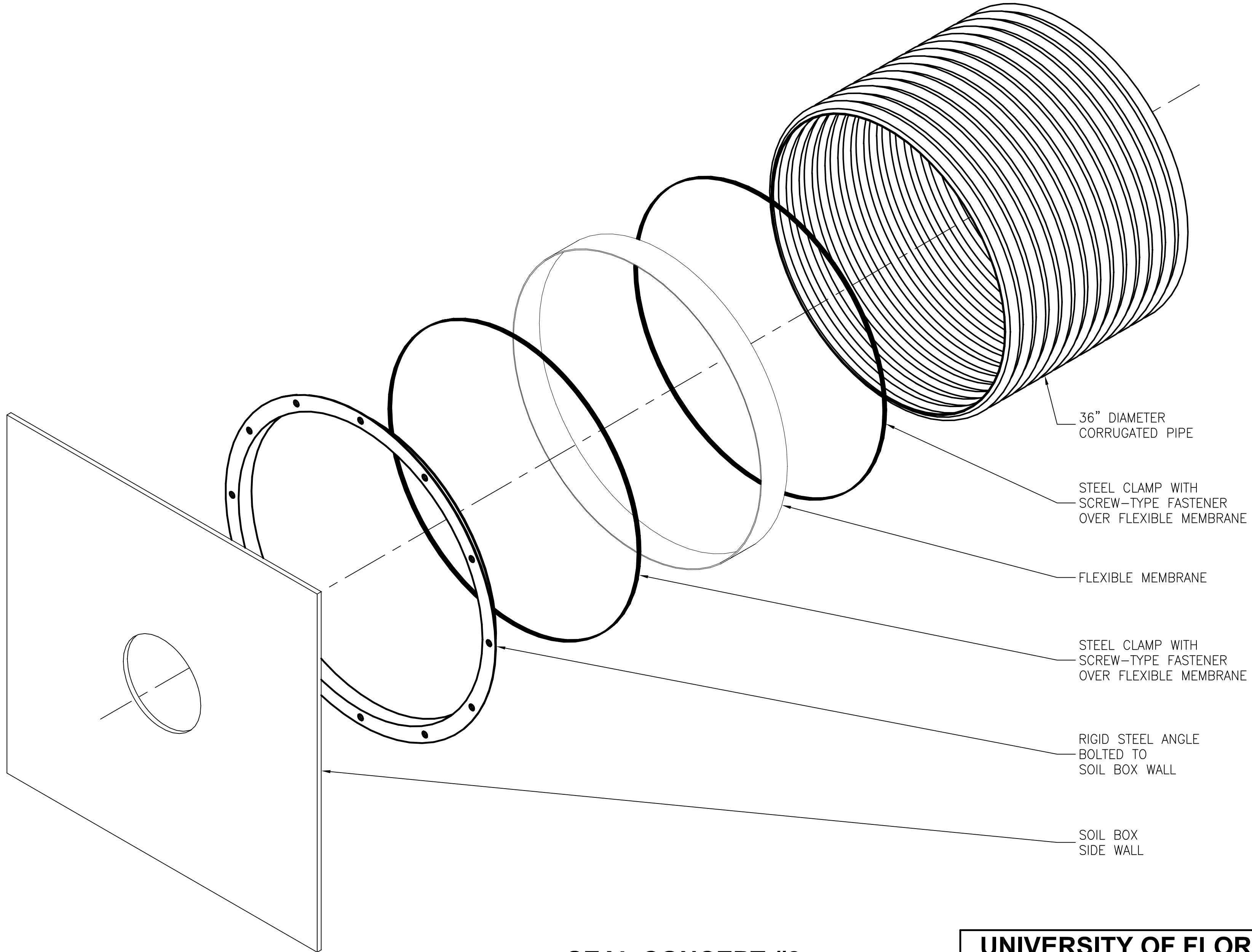

SEAL CONCEPT #2
EXPLODED VIEW

UNIVERSITY OF FLORIDA			
DEPARTMENT OF CIVIL AND COASTAL ENGINEERING			
FDOT SOIL BOX PROJECT			
DESIGNED BY:	D. BLOOMQUIST, P.E.	DRAWN BY: JP-KP	
PROJECT #:	BDK75 977-21	DATE:	04-01-2010
SCALE:	3/4" = 1'-0"	PAGE:	C-16 OF C-16

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