NorthEnd Water Pollution Control Centre
Storage Tank #5

Concrete and Corrosion Assessment

Prepared For: Water & Waste Department – Project Planning and Delivery

Report Written By: Martin Beaudette, E.I.T.

Reviewed by: Leo Mancs, P.Eng

May, 2010

INTRODUCTION

This report has been written following an inspection carried out at the City of Winnipeg's North End Water Pollution Control Centre. At the centre, the interior of Storage Tank #5 was the subject of the evaluation. The purpose of this investigation is to determine the extent of the corrosion and recommend a solution to extend the service life of the structure.

INVESTIGATIVE PROGRAM

Between January 18th and February 10th, Vector carried out the following investigation. A description of each component of the investigation is provided following the outline. The results of this testing are found in the appendices and are discussed in further sections.

1) Conducted a visual and sounding survey of the structure
2) Collected dust samples to determine the concrete's chloride content at various depths and locations
3) Extracted 50mm diameter concrete cores for compression testing from walls, columns, ceiling and floor.
4) Obtained additional 50mm diameter samples next to compression samples to determine the depth of carbonation.
5) Determined the depth of concrete cover provided to the reinforcing steel at various locations of the structure.
6) Obtained corrosion potential measurements throughout the structure to determine corrosion potentials.

Visual Survey

Storage Tank #5's interior structure was visually inspected to determine its general condition. From the visual inspection, the structure was delineated into five (5) Levels.

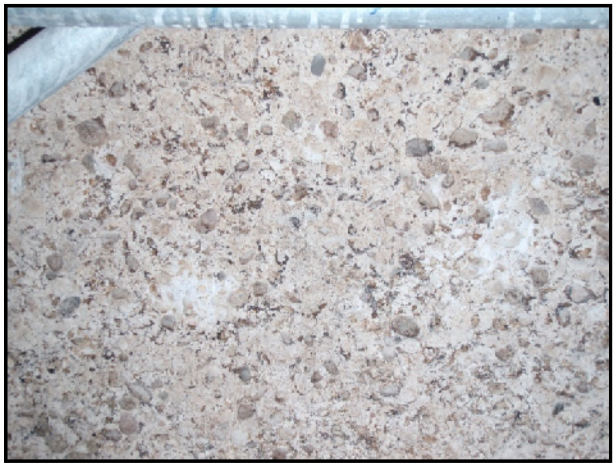
These Levels were labeled from one (1) to five (5) from the floor to ceiling respectively and were observed on the walls as well as the columns. Presented below are photos of the different deterioration levels along with a description and approximate height. The stated height of the level is from the floor of the tank.

1) Level 1 – 0 to 1.2m:
   No loose material, sound concrete

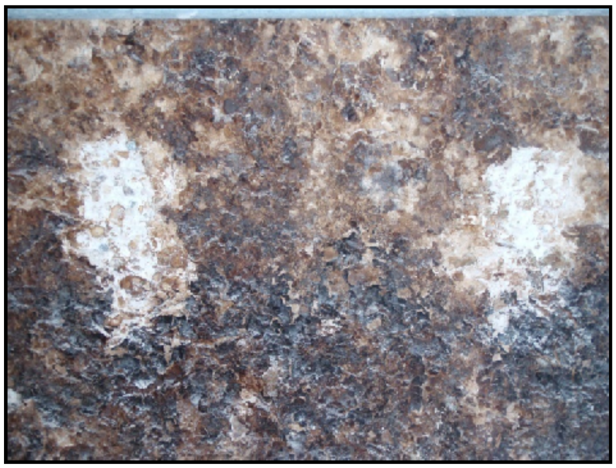
2) Level 2 – 1.2 to 2.7m:
   Deposited material, when scraped away reveals sound concrete, with some loss of fines

3) Level 3 – 2.7 to 3.6m:
   Eroded all surface fines, exposed aggregate finish, but solid substrate

4) Level 4 – 3.6 to 5.7m:
Deterioration increasing with height from eroded surface fines at the bottom to severely decomposed cement paste at the top.



5) Level 5 – 5.7 to 7.9m:
Relatively even deterioration over the height with severely decomposed cement paste throughout. Level is differentiated by dark crusted surface likely from deteriorated coating.



Chloride Content

Dust samples were obtained from multiple locations at the following depths: 1) Outer surface to 25mm depth 2) 25mm to 50mm depth and 3) 50mm to 75mm depth. These sample depths represent depths below the deteriorated concrete; measurements from the surface of the sound concrete. The purpose of the samples is to determine the chloride ion content by weight, expressed as a percentage. The Revised SHRP Chloride Analysis Procedure was followed.

The National Association of Corrosion Engineers (NACE) suggests that a threshold of 0.03% chloride by weight of concrete be followed. If the weight-percent of chlorides fall below this limit, it is assumed that chloride induced corrosion is not present. As the weight-percent increases above this threshold, so does the likelihood of chloride induced corrosion. This is attributed to a loss of the reinforcing steel's protective passive layer.

Compressive Strength

To determine the concrete's compressive strength, 50mm (2") diameter core samples were extracted from site. The samples were load tested to failure following the CSA A23.2-14C standard.

Depth of Carbonation

Carbonation of concrete occurs when the pH of the concrete (normally 11 to 12) drops between 9 and 10. When concrete becomes carbonated, the naturally occurring protective passive oxide film surrounding the outer area of the reinforcement loses its stability and breaks down, allowing corrosion to commence.

To obtain the pH levels of the concrete, 50mm (2") diameter samples were taken near the locations of the compressive strength cores. The cores were fractured in our lab and the freshly exposed concrete was sprayed immediately with a 0.15% solution of phenolphthalein in ethanol. If the solution remained colorless, this indicated that the pH level is less than 10, suggesting that carbonation is present. If the solution turned pinkish in color, the pH is above 10 indicating that carbonation is not present.

Depth of Concrete Cover

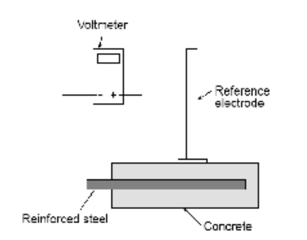
The depth of concrete cover is measured to provide an indication of how much protective concrete covers the reinforcing steel. It also provides a reference point from which a necessary depth to conduct chloride testing can be established. Since a shallower concrete cover leaves the rebar more vulnerable to corrosive agents, it is important that sufficient cover be provided.

The depths of the concrete cover provided were obtained using a Micro Cover meter. The device measures variations in magnetic flux from the embedded rebar and is able to locate the bars with reference to the concrete surface.

Half-Cell Corrosion Potential

The half-cell (reference electrode) is a piece of metal immersed in a solution of its own ions. At these sites, we used a copper rod immersed in a solution of copper sulfate, chemically referred to as Cu-$CuSO_4$

When the half-cell is connected to the embedded reinforcing steel the electrical cell is completed. A voltage is generated since the two different metals (i.e. steel and copper)



are at different positions on the electrochemical series. When the cell is moved along the surface of the concrete, a change in the complete cell occurs due to the different conditions of the rebar surface within the matrix of the concrete.
The test yields a reading on the voltmeter which is referred to as a corrosion potential. Corrosion potentials give an indication of the probability of the occurrence of corrosion activity within the reinforcing steel. A complete description of the testing procedure is outlined in ASTM C 876. Table 1 delineates the interpretation the corrosion potential readings.

Table 1: Corrosion Potential Readings Interpretation

Reading vs. Cu-$CuSO_4$ half-cell	Probability of Corrosion Activity
More positive than -200 mV	Low (< 10% probability of corrosion activity at the time of testing)
-200 to -350 mV	Uncertain (50 % probability of corrosion activity at the time of testing)
More negative than -350 mV	High (> 90% probability of corrosion activity at the time of testing)

It should be noted that these ranges can be affected by many different variables such as moisture content, temperature and resistivity of the concrete. Therefore, consideration should be given not only to the absolute number of the reading but also to large differences between neighboring readings.

TESTING RESULTS

Visual Survey (Appendix A)

The structure was broken out into sections in order to locate of any delaminations as well as mapping the corrosion potentials. This consisted of laying out 3.66m wide sections along the wall with Section 1 starting at the door and moving clockwise around the wall.

A full sounding survey was performed on the floor, finding no delaminations. A full sounding survey was also completed on Levels 1 to 3 on the walls and columns and only a small, 0.1m^2, delamination was located on the wall in Section 7 approximately 2.4m above the floor level. Levels 4 and 5 are similar in deterioration: the expanded layer of decomposed cement paste found in these two layers was thick, as much as 50mm in some places. This type of deterioration is consistent with sulphate attack, common in waste water environments. Therefore, in addition to the sounding survey, we have also investigated the thickness of the softened material and the condition of the concrete beyond the softened material. Four (4) areas were scraped by hand to remove the expanded material in order to complete an additional sounding survey on the concrete underneath. These areas were sections 4, 12, 15 and 20/21.

Section 4

Section 12

Section 15

Section 20/21

In these four (4) sections, no delaminations were found in Levels 4 & 5.

The sounding of the columns happened in much the same way: the bottom three (3) Levels were sounded without any delaminations and the top two (2) consisted as well of the deteriorated concrete. On the columns however, entire levels were not scraped by hand, but 15cm rings were scraped at different heights to determine the deteriorated circumferences of the columns. On average, it was measured that the columns had lost nearly 18mm of concrete surface, ranging from 26mm to 19mm. This includes an additional 6mm of depth which would completely remove the softened concrete and expose the sound substrate below.

Ring Scraped on Column

Chloride Content (Appendix B)

A total of 129 samples were obtained from all different areas of the structure and analyzed in our lab. The test results indicated that the over 85% of the samples tested were higher than the NACE stated corrosion threshold of 0.03%.

Carbonation (Appendix C)

A total of twenty (20) core samples were obtained from different areas of the structure. Seven (7) of the cores showed no signs of carbonation. Of the remaining carbonated cores, six (6) showed carbonation of less than 13mm, five (5) showed carbonation between 13mm and 25mm and two (2) were carbonated above 25mm. Therefore, only reinforcing steel with the shallowest cover would be affected by the carbonation measured.

Compressive Strength (Appendix C)

Twenty cores were extracted from all different elements of the structure. These cores were cut to allow compressive strength testing of the sound concrete, without having the samples compromised by the softened concrete. The average compressive strength of for all the samples was found to be 59 MPa. The average compressive strength of the cores from ceiling, columns, walls and floor were 42.2, 63.8, 62.6 and 54 MPa respectively.

Corrosion Potentials (Appendix D)

Half-Cell Measurements on Ceiling

Corrosion potential readings were obtained from all elements of the structure. Even in Levels 4 and 5 where the softened concrete was preventing obtaining a proper electrolytic connection between the half-cell and the concrete surface, spot scraping was done to expose the sound concrete underneath to perform the test. The results of the corrosion potential testing are outlined in the table below.

Table 2: Corrosion Potential Readings in the Different Ranges

Element	Number of Readings More positive than -200 mV		Number of Readings -200 to -350 mV		Number of Readings More negative than -350 mV	
Ceiling	272	78%	74	21%	2	1%
Columns	238	99%	2	1%	0	0%
Walls	556	98%	12	2%	0	0%
Floor	109	33%	217	66%	4	1%
Total	1175	79%	305	21%	6	0%

Very little of the readings taken were in the active range or the uncertain range, with the exception of the floor. Nearly two thirds of the readings were in the uncertain range, but there too were few readings in the active corrosion range. In general, the readings obtained indicated that only a miniscule amount of active corrosion is present in the reinforcing steel in the concrete structure.

Depth of Concrete Cover

Cover was measured along height of the same reinforcing bar in the scraped sections at the locations for corrosion potential measurements, approximately 1.2m between measurements. Cover depths varied from 27 to 62mm. Cover depths were also noted in many of the columns where it varied due the placement of the reinforcement cage inside the column. On one side the cover was 5-10mm and the other was 40-50mm. Low-cover situations can be critical for carbonated concrete depending on the depth as well as chloride contamination, which decreases with depth.

TESTING CONCLUSION

Laboratory testing of the samples show areas of deep carbonation as well as penetration of chlorides as deep as three (3) inches up to and at times beyond the depth of reinforcing steel. In a normal environment, these two conditions would be sufficient to produce active corrosion of the reinforcing steel. However from the visual survey as well as corrosion potential measurements, corrosion of the reinforcing steel is not attributing to the deterioration of the concrete.

The deterioration is due to sulphuric acid attack of the concrete which is common in waste water environment. Sulphuric acid reacts with the calcium hydroxide to produce gypsum. The formation of gypsum leads to an eventual loss in cohesion as the cementitious calcium compounds are broken down.

Overall there is no significant corrosion or structural issues with the tank structure. Other than the softened or eroded layer, the remaining concrete is in good health. Full structural integrity can be easily restored by rebuilding missing or weak concrete cover.

RECOMMENDATIONS

In order to prevent further concrete deterioration, at a minimum a protective coating or lining system should be applied. The protective system should be able to resist chemical attack, and most specifically resist sulphuric acid.

In conjunction with any selected coating is the question of surface preparation. At a minimum the deteriorated concrete surface should be removed either by high-pressure water, or sand-blasting methods. Surface preparation shall be determined by the selected repair of coating system requirements. Sand blasting creates dry clean-up but creates dusty conditions, water blasting requires wet-cleanup but does not create dusty environment.

Following surface preparation would be the decision to rebuild the concrete section loss due to the sulphate attack. There may also be an inherent difficulty with the application of a coating on a very uneven surface, namely in Level 4 and 5. The deterioration at these Levels will have left a very roughened surface that may not allow a coating to be installed with without defects. There are some coatings that require a smooth surface for proper installation. This concrete replacement can be either hand applied or with mechanical means such as shotcrete or spray applied mortars. It is recommended that the missing concrete is rebuilt to restore the original structural capacity of the concrete and provide a smooth surface for protective coating or lining system.

As an additional measure to extend the life of concrete repairs where patching around reinforcing steel is required, is installing discrete anodes to prevent future corrosion of the reinforcement. Because of the level of chloride contamination of the parent concrete, when surrounding uncontaminated patch material, the difference in the environment around the reinforcing steel will cause a corrosion cell commonly referred to as patch accelerated corrosion or the “halo effect.”

BUDGET

The following budget pricing is prepared for the purpose of showing the order of magnitude that the repair and protection of the digester tank would cost. There are several engineered solutions for protecting the digester tank which can be selected based on the degree of protection they offer.

1.	General Conditions (Mobilization, Ventilation, Lighting, Access etc.)	**$ 100,000 to $ 140,000**
2.	Demolition, Concrete Repair, Resurfacing	**$ 450,000 to $ 550,000**
3.	Coating or Lining Protection	**$ 200,000 to $ 280,000**
	TOTAL	**$ 750,000 - $ 970,000**

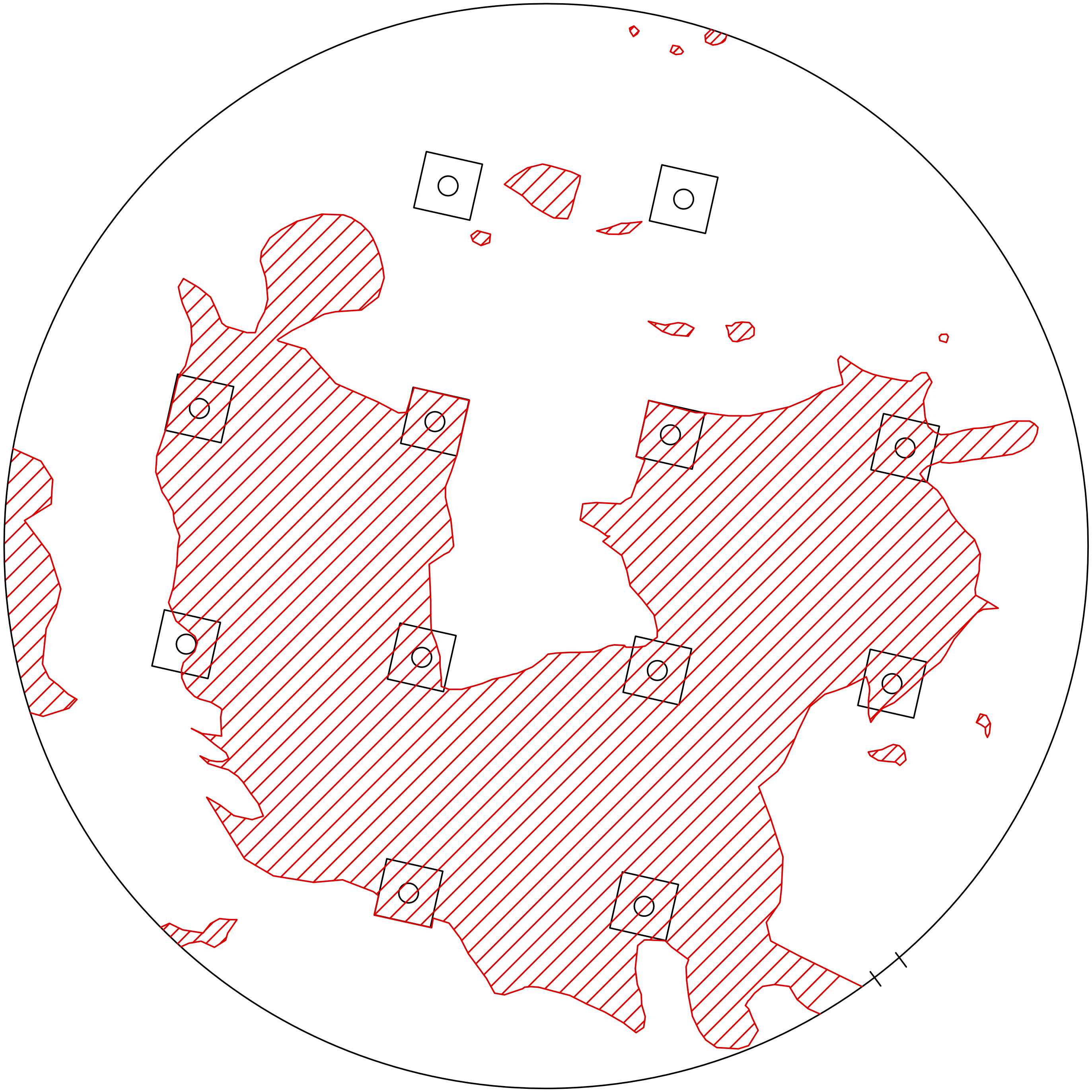
Budget Pricing Breakdown by Structural Elements

TOTAL Ceiling:	5674 ft2	- **$ 185,400 to $ 239,785**
TOTAL Walls:	6943 ft2	- **$ 226,866 to $ 293,413**
TOTAL Columns:	4636 ft2	- **$ 151,484 to $ 195,919**
TOTAL Floor:	5700 ft2	- **$ 186,250 to $ 240,883**
TOTAL:	22953 ft2	

Please note that approximately 37% of the surface areas will require concrete repairs of approximately 1 inches in depth (on average). The balance 63% of surface areas will require resurfacing of approximately 1/8 inches in depth (on average).
Once details of the selected solution are known, the City of Winnipeg can invite qualified installers to submit firm pricing for installation.

APPENDIX A

Visual Survey



VECTOR CORROSION TECHNOLOGIES LTD.

Area of Concrete Deterioration

Digestion Tank #5

Ceiling

Drawn: A.D.J.	Date: MAR 2010

Scraped and Unscraped Level 5

Column with Several Scraped Rings for Circumference Measurements

Scraped Section of Ceiling

Levels 4 and 5, with Scraped Spots for Corrosion Potential Measurements

Column Capital with Scraped Edges

APPENDIX B

Chloride Contents

Vector Corrosion Technologies
474 Dovercourt Drive
Winnipeg, MB R3Y 1G4
www.vector-corrosion.com

Revised SHRP Chloride Analysis Procedure

Vector Corrosion Technologies
474 Dovercourt Drive
Winnipeg, MB R3Y 1G4
204-489-6300

NEWPCC-Digestor #5
Project # 06N10654MB
Attention: Marty Beaudette

Tested by: Myron Henschel

*The accepted threshold range for chloride induced corrosion of the reinforcing steel in concrete is **0.030%** chloride ions by weight of concrete and higher in non-carbonated concrete

Sample ID	Concrete Dust Samples (in.)	mV	%Cl- by Weight of Concrete
Ceiling Sec. 2	0" - 1"	118.5	**0.014**
	1" - 2"	105.5	**0.027**
	2" - 3"	109.4	**0.022**
Ceiling Sec. 5	0" - 1"	89.1	**0.059**
	1" - 2"	95.5	**0.044**
	2" - 3"	95.4	**0.044**
Ceiling Sec. 8	0" - 1"	102.0	**0.032**
	1" - 2"	102.4	**0.031**
	2" - 3"	106.9	**0.025**
Ceiling Sec. 16	0" - 1"	96.4	**0.050**
	1" - 2"	101.6	**0.039**
	2" - 3"	99.2	**0.044**
Ceiling Sec. 17	0" - 1"	91.8	**0.061**
	1" - 2"	94.6	**0.054**
	2" - 3"	95.4	**0.052**
Wall Sec.6 1st Level	0" - 1"	87.6	**0.064**
	1" - 2"	102.8	**0.030**
	2" - 3"	101.4	**0.033**
Wall Sec.12 1st Level	0" - 1"	86.9	**0.066**
	1" - 2"	92.4	**0.051**
	2" - 3"	91.0	**0.054**
Wall Sec.2 2nd Level	0" - 1"	108.8	**0.023**
	1" - 2"	108.3	**0.023**
	2" - 3"	85.3	**0.071**
Wall Sec.17 2nd Level	0" - 1"	92.2	**0.051**
	1" - 2"	91.7	**0.052**
	2" - 3"	96.6	**0.041**

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Sample ID	Concrete Dust Samples (in.)	mV	%Cl- by Weight of Concrete
Wall Sec.4 3rd Level	0" - 1"	81.1	0.086
	1" - 2"	83.7	0.076
	2" - 3"	86.5	0.067
Wall Sec.20 3rd Level	0" - 1"	94.3	0.046
	1" - 2"	92.5	0.050
	2" - 3"	98.8	0.037
Wall Sec. 3 4th Level	0" - 1"	95.0	0.045
	1" - 2"	98.9	0.037
	2" - 3"	100.1	0.035
Wall Sec. 15 4th Level	0" - 1"	87.3	0.064
	1" - 2"	99.6	0.036
	2" - 3"	99.6	0.036
Wall Sec.4 5th Level	0" - 1"	80.1	0.090
	1" - 2"	79.3	0.094
	2" - 3"	80.7	0.088
Wall Sec. 12 5th Level	0" - 1"	100.4	0.034
	1" - 2"	101.9	0.032
	2" - 3"	101.4	0.033
Column 5 1st Level	0" - 1"	93.0	0.049
	1" - 2"	91.8	0.052
	2" - 3"	92.4	0.051
Column 7 1st Level	0" - 1"	88.5	0.061
	1" - 2"	91.1	0.054
	2" - 3"	93.5	0.048
Column 10 1st Level	0" - 1"	91.4	0.053
	1" - 2"	91.9	0.052
	2" - 3"	99.5	0.036
Column 11 1st Level	0" - 1"	91.3	0.053
	1" - 2"	94.8	0.045
	2" - 3"	91.0	0.054

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Sample ID	Concrete Dust Samples (in.)	mV	%Cl- by Weight of Concrete
Column 12 1st Level	0" - 1"	91.5	0.053
	1" - 2"	90.6	0.055
	2" - 3"	93.5	0.048
Column 1 2nd Level	0" - 1"	102.5	0.038
	1" - 2"	98.8	0.045
	2" - 3"	102.0	0.039
Column 4 2nd Level	0" - 1"	108.7	0.028
	1" - 2"	108.0	0.029
	2" - 3"	105.7	0.033
Column 8 2nd Level	0" - 1"	97.5	0.047
	1" - 2"	95.4	0.052
	2" - 3"	100.7	0.041
Column 9 2nd Level	0" - 1"	96.4	0.050
	1" - 2"	100.7	0.041
	2" - 3"	103.3	0.036
Column 12 2nd Level	0" - 1"	107.2	0.030
	1" - 2"	106.6	0.031
	2" - 3"	108.9	0.028
Column 2 3rd Level	0" - 1"	95.0	0.045
	1" - 2"	96.9	0.041
	2" - 3"	96.1	0.042
Column 5 3rd Level	0" - 1"	103.0	0.037
	1" - 2"	102.7	0.037
	2" - 3"	102.4	0.038
Column 6 3rd Level	0" - 1"	103.7	0.036
	1" - 2"	108.5	0.029
	2" - 3"	109.1	0.028
Column 7 3rd Level	0" - 1"	97.2	0.048
	1" - 2"	100.9	0.041
	2" - 3"	102.5	0.038

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Sample ID	Concrete Dust Samples (in.)	mV	%Cl- by Weight of Concrete
Column 3 4th Level	0" - 1"	93.5	0.048
	1" - 2"	94.7	0.045
	2" - 3"	93.3	0.048
Column 6 4th Level	0" - 1"	91.0	0.064
	1" - 2"	103.2	0.037
	2" - 3"	107.4	0.030
Column 8 4th Level	0" - 1"	97.8	0.047
	1" - 2"	96.0	0.051
	2" - 3"	102.7	0.037
Column 11 4th Level	0" - 1"	101.9	0.039
	1" - 2"	107.7	0.030
	2" - 3"	106.8	0.031
Column 12 4th Level	0" - 1"	102.9	0.037
	1" - 2"	110.1	0.026
	2" - 3"	100.7	0.041
Column 1 5th Level	0" - 1"	116.1	0.020
	1" - 2"	108.3	0.029
	2" - 3"	96.1	0.051
Column 2 5th Level	0" - 1"	95.4	0.044
	1" - 2"	97.9	0.039
	2" - 3"	96.1	0.042
Column 3 5th Level	0" - 1"	101.3	0.033
	1" - 2"	91.1	0.054
	2" - 3"	94.1	0.047
Column 4 5th Level	0" - 1"	106.1	0.032
	1" - 2"	98.4	0.046
	2" - 3"	104.7	0.034
Column 9 5th Level	0" - 1"	108.5	0.029
	1" - 2"	105.1	0.033
	2" - 3"	107.7	0.030

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Sample ID	Concrete Dust Samples (in.)	mV	%Cl- by Weight of Concrete
Column 10 5th Level	0" - 1"	103.9	**0.035**
	1" - 2"	104.4	**0.035**
	2" - 3"	105.7	**0.033**
Floor Sec. 3	0" - 1"	94.8	**0.045**
	1" - 2"	94.1	**0.047**
	2" - 3"	93.1	**0.049**
Floor Sec. 15	0" - 1"	93.8	**0.047**
	1" - 2"	97.0	**0.040**
	2" - 3"	97.4	**0.040**
Floor Sec. 17	0" - 1"	91.5	**0.053**
	1" - 2"	91.4	**0.053**
	2" - 3"	91.3	**0.053**

APPENDIX C

Carbonation Testing

VECTOR CORROSION TECHNOLOGIES

innovative solutions for rebar corrosion™

CARBONATION TEST RESULTS

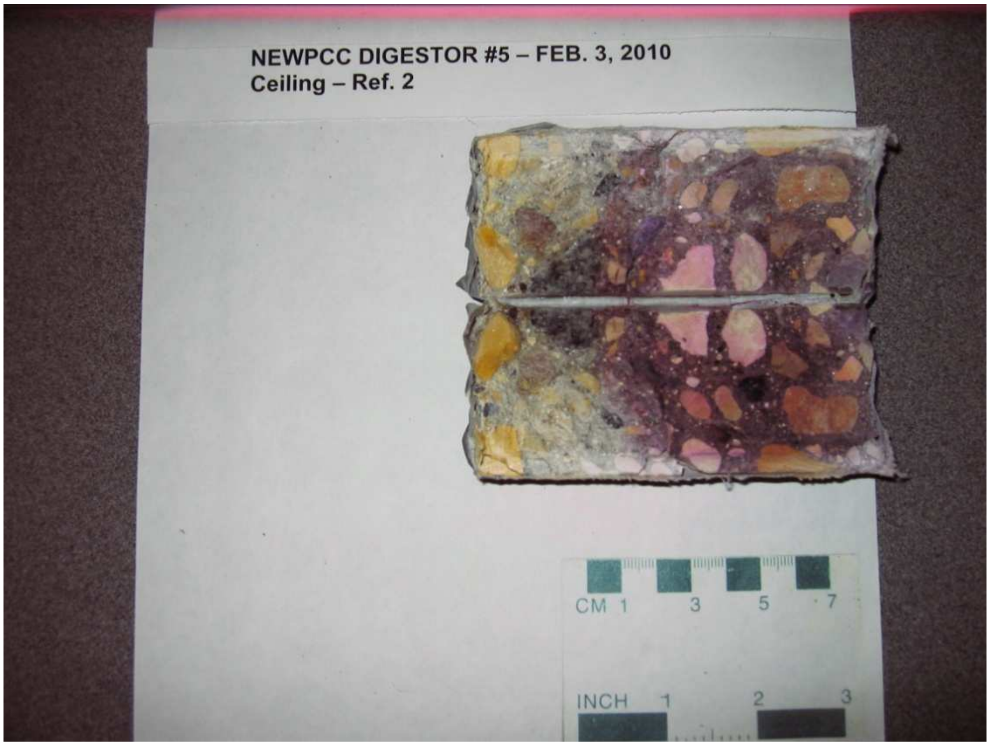
Requested By: Marty Beaudette

Project Number: 06N10654MB

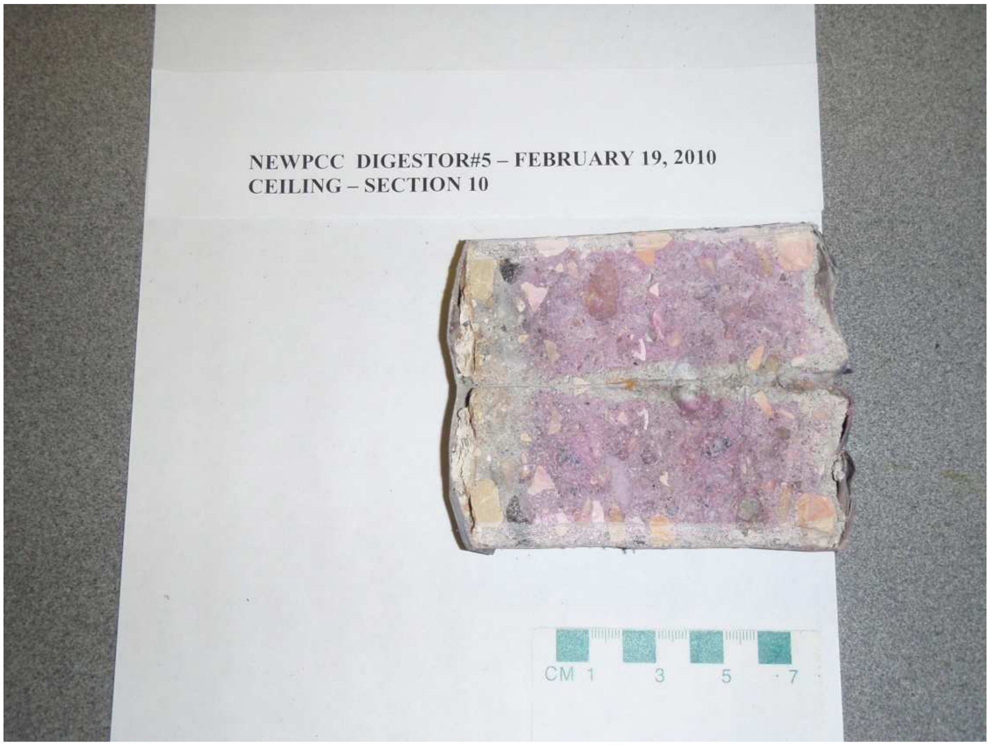
Tested By: Myron Henschel

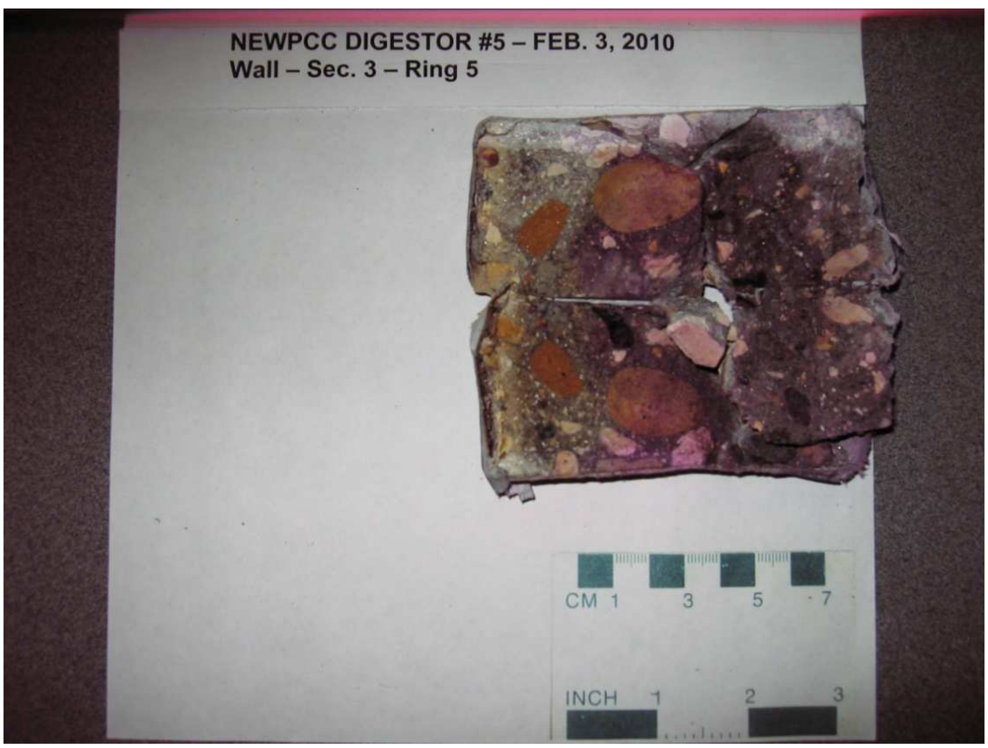
Site and Location: NEWPCC, Winnipeg, MB
Number of Samples: 20 Cores

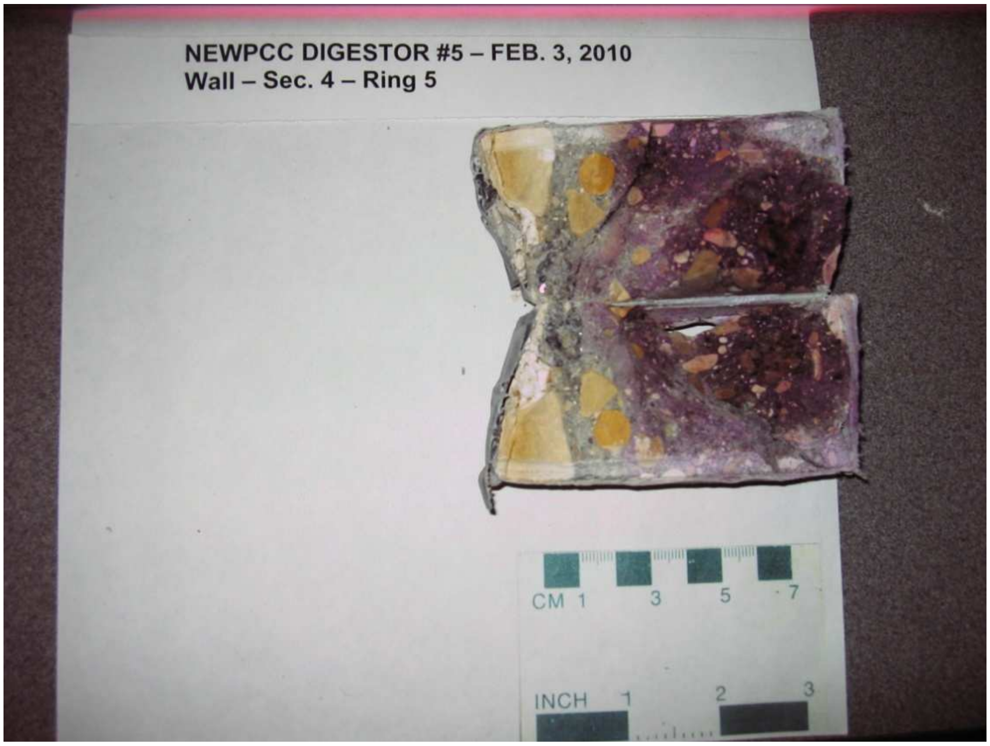
CORE Location/Number	Carbonation Y/N	Top	Bottom
Ceiling - Ref. 2	Y	1 5/16"	0
Ceiling - Sec. 8	N	0	0
Ceiling - Section 10	Y	3/4"	1/4"
Wall - Sec. 2 - Ring 2 @ 5'5"	Y	3/4"	0
Wall - Sec. 3 - Ring 5	Y	1 1/4"	0
Wall - Sec.4 - Ring 5	Y	13/16"	0
Wall - Sec. 10 - 1st Level	N	0	0
Wall - Sec. 12 - Ring 1	N	0	0
Wall - Sec. 12 - Ring 4	N	0	0
Wall - Sec.15 - 4th Level	Y	1/4"	0
Wall - Sec. 17- Ring 1	Y	1/8"	0
Wall - Section 17 3rd Level	Y	3/16"	N
Wall - Sec. 20 - Ring 5	Y	3/16"	0
Column 3 - @ 19'	Y	around steel at 3/4"	0
Column 9 - Ring 1	N	0	0
Column 11 - Ring 2 @ 5'5"	N	0	0
Column 11 5th Level	Y	3/8"	N
Floor - Sec. 6	Y	1/4"	0
Floor - Sec. 10	N	0	0

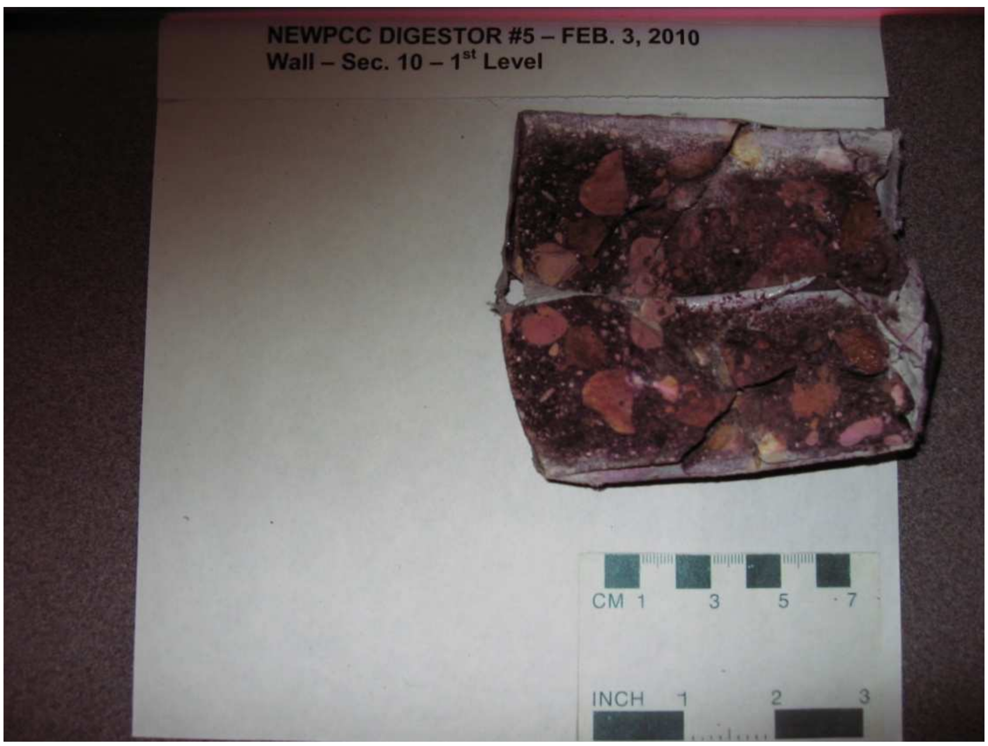

NEWPCC DIGESTOR #5 – FEB. 3, 2010
Ceiling – Ref. 2
CM 1 3 5 7
INCH 1 2 3

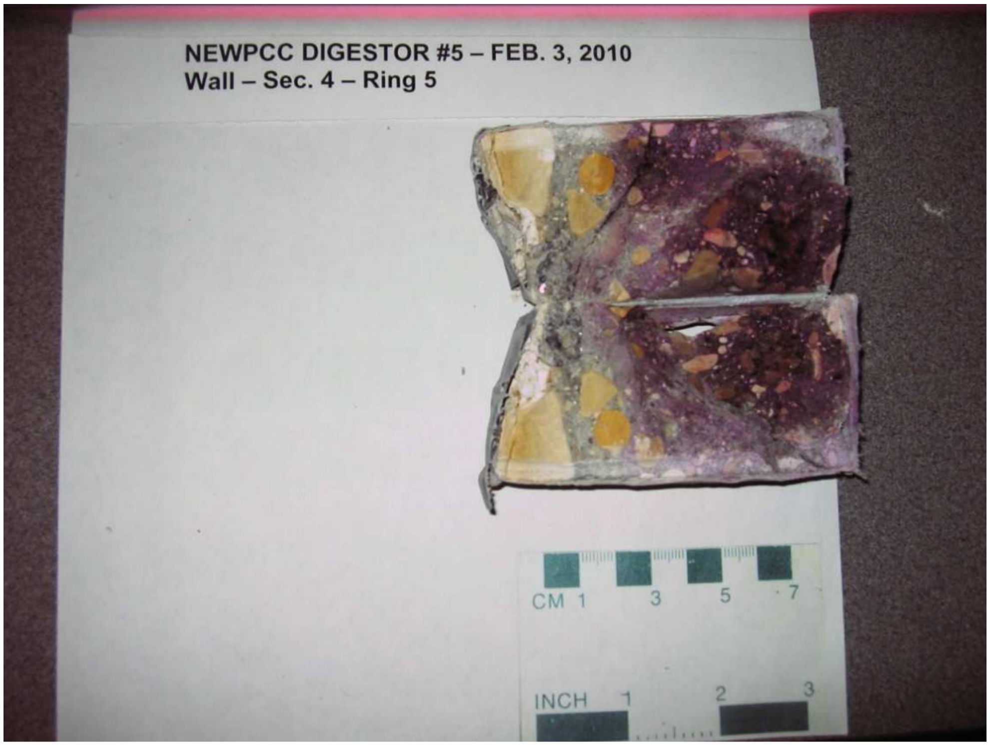

NEWPCC DIGESTOR #5 – FEB. 3, 2010
Ceiling – Sec. 8
CM 1 3 5 7
INCH 1 2 3


NEWPCC DIGESTOR#5 – FEBRUARY 19, 2010
CEILING – SECTION 10
CM 1 3 5 7


NEWPCC DIGESTOR #5 – FEB. 3, 2010
Wall – Sec. 3 – Ring 5
CM 1 3 5 7
INCH 1 2 3


NEWPCC DIGESTOR #5 – FEB. 3, 2010
Wall – Sec. 4 – Ring 5
CM 1 3 5 7
INCH 1 2 3


NEWPCC DIGESTOR #5 – FEB. 3, 2010
Wall – Sec. 10 – 1st Level
CM 1 3 5 7
INCH 1 2 3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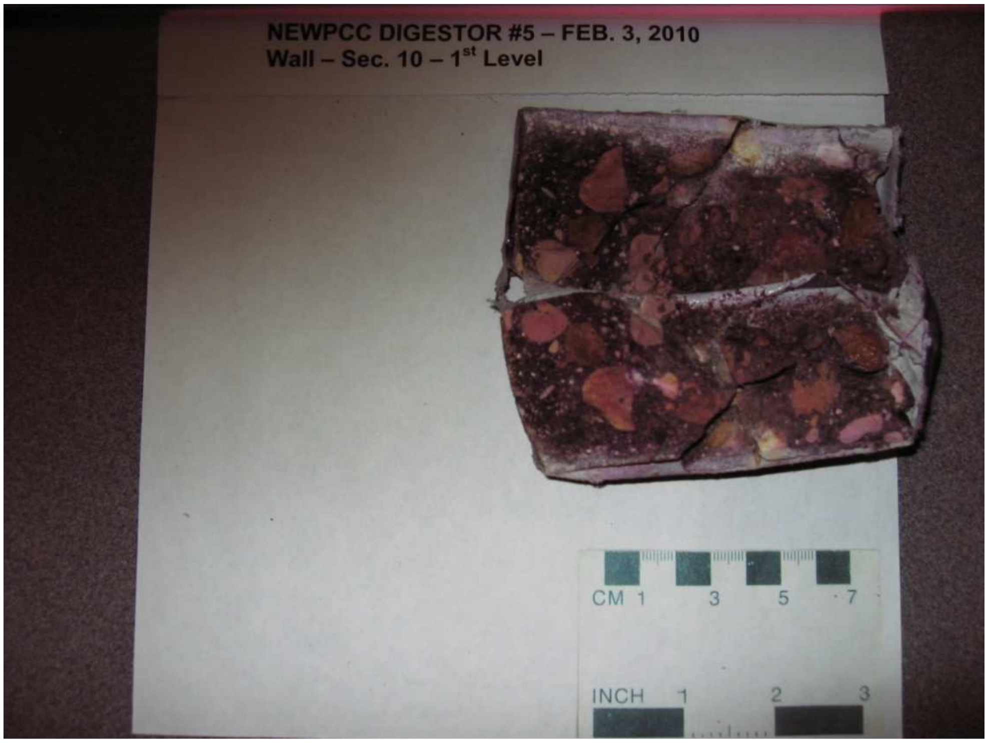
Wall – Sec. 4 – Ring 5
CM 1 3 5 7
INCH 1 2 3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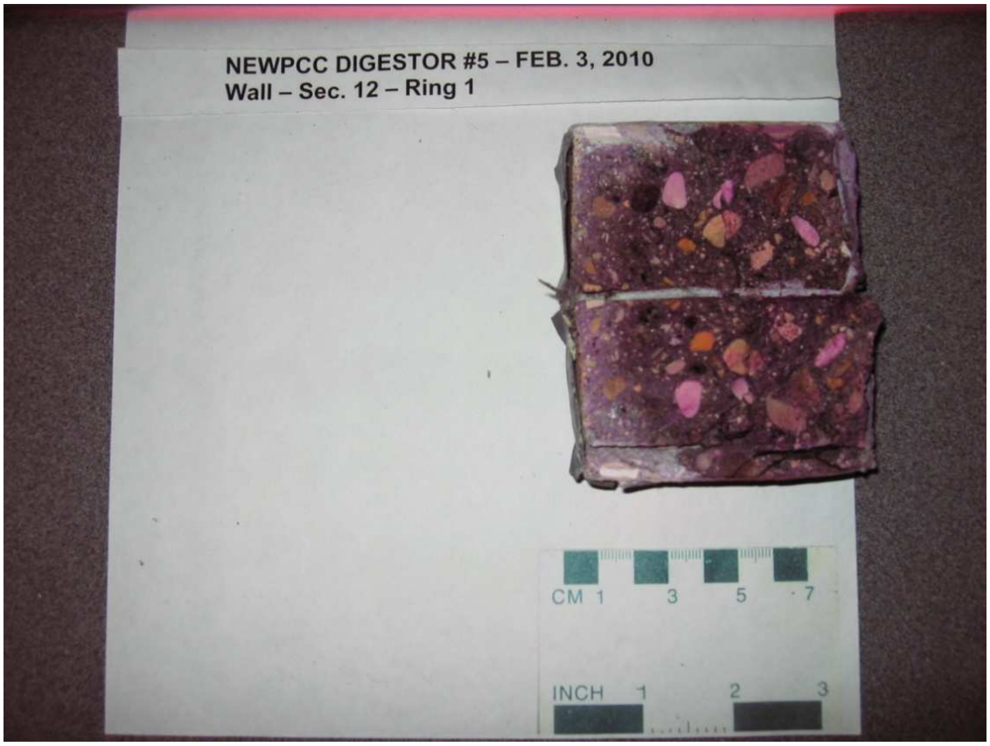
Wall – Sec. 10 – 1st Level
CM 1 3 5 7
INCH 1 2 3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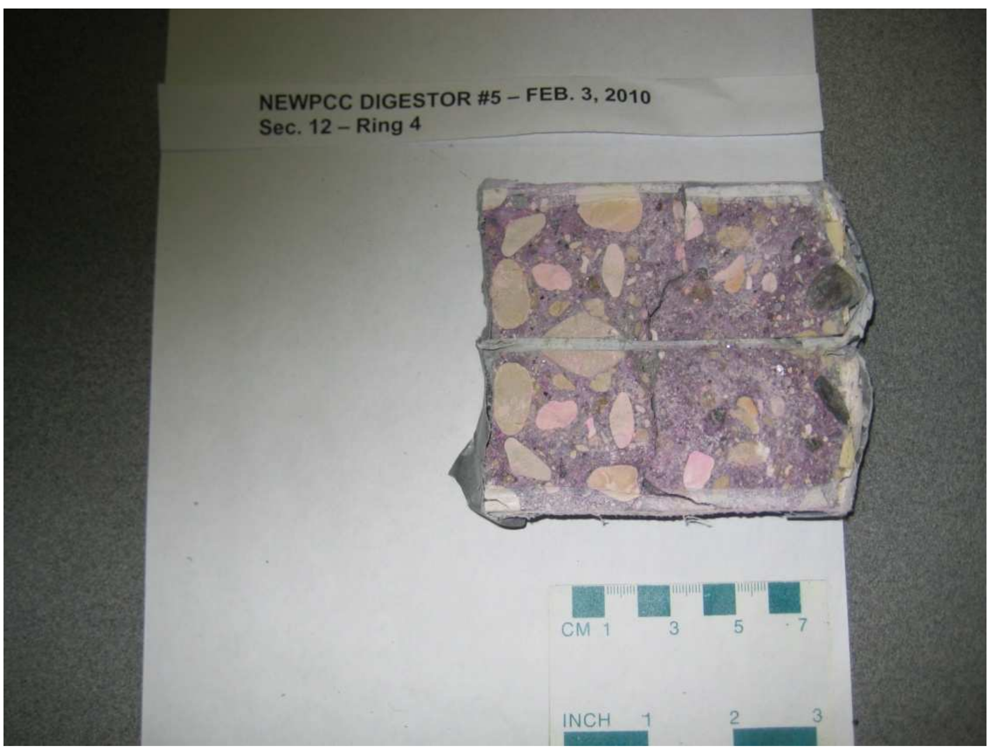
Wall – Sec. 12 – Ring 1
CM 1 3 5 7
INCH 1 2 3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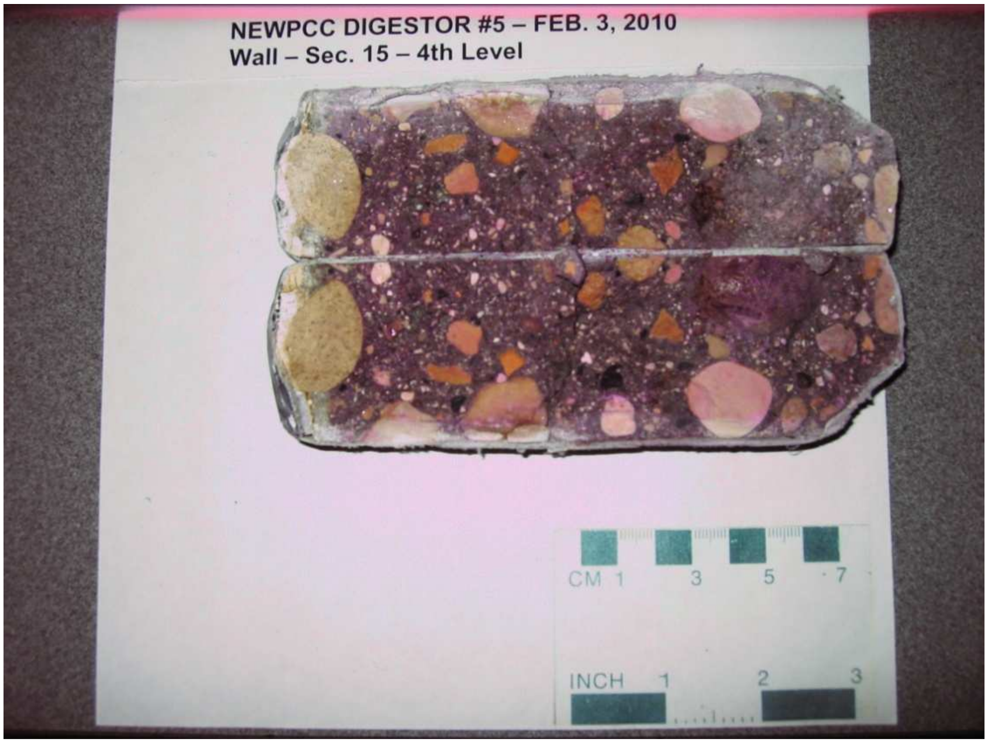
Sec. 12 – Ring 4
CM 1 3 5 7
INCH 1 2 3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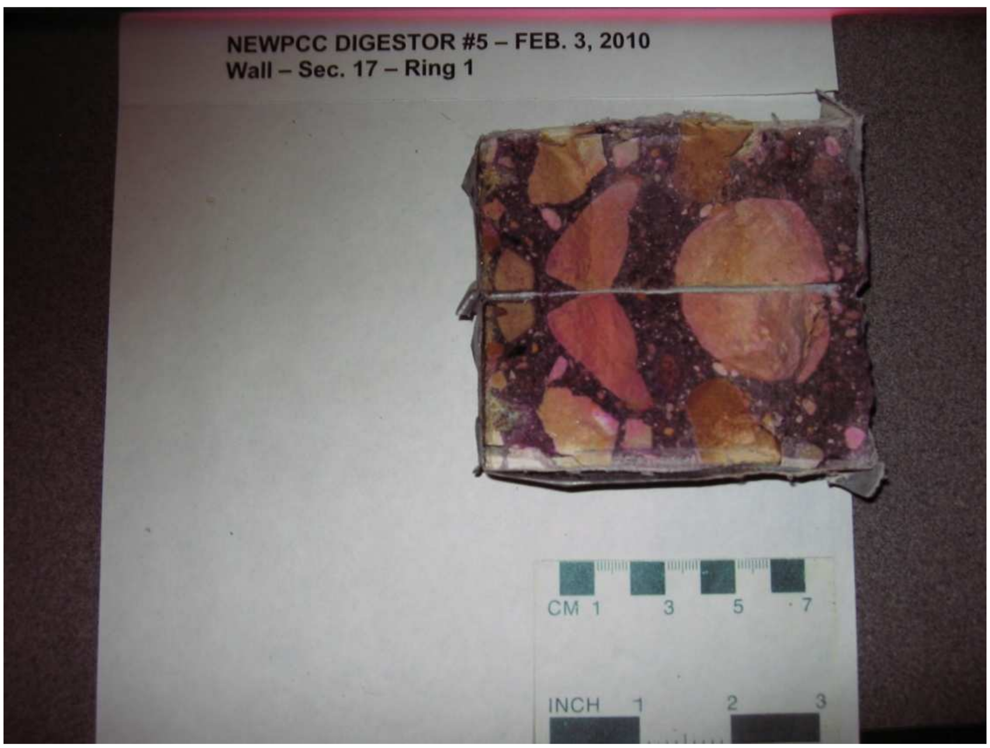
Wall – Sec. 15 – 4th Level
CM 1 3 5 7
INCH 1 2 3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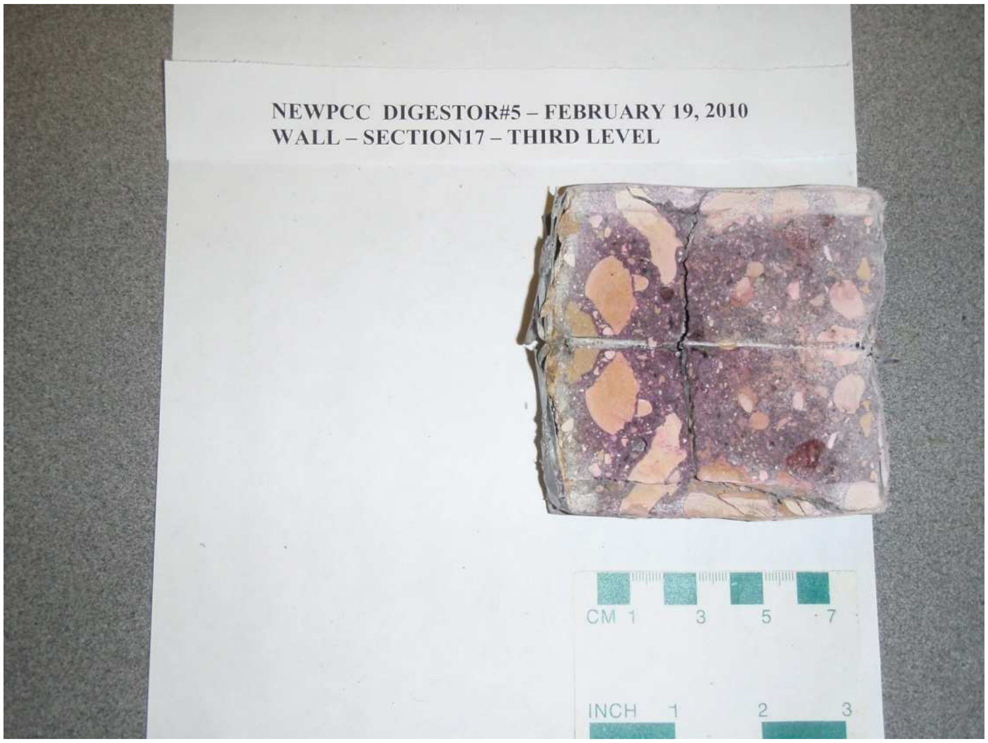
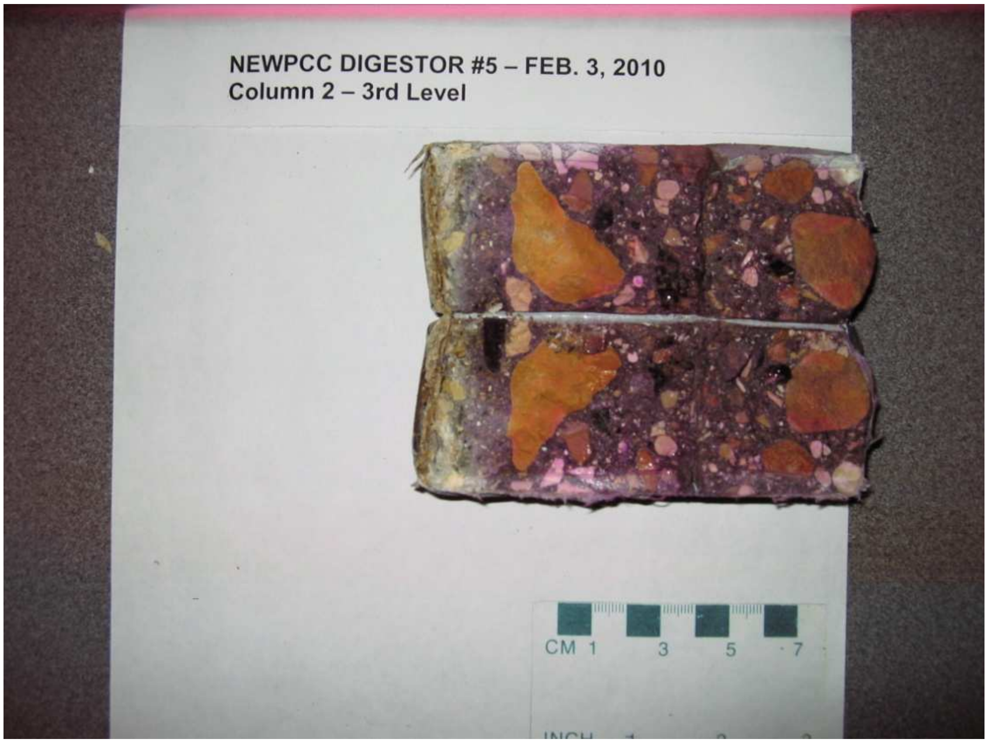
Wall – Sec. 17 – Ring 1
CM 1 3 5 7
INCH 1 2 3

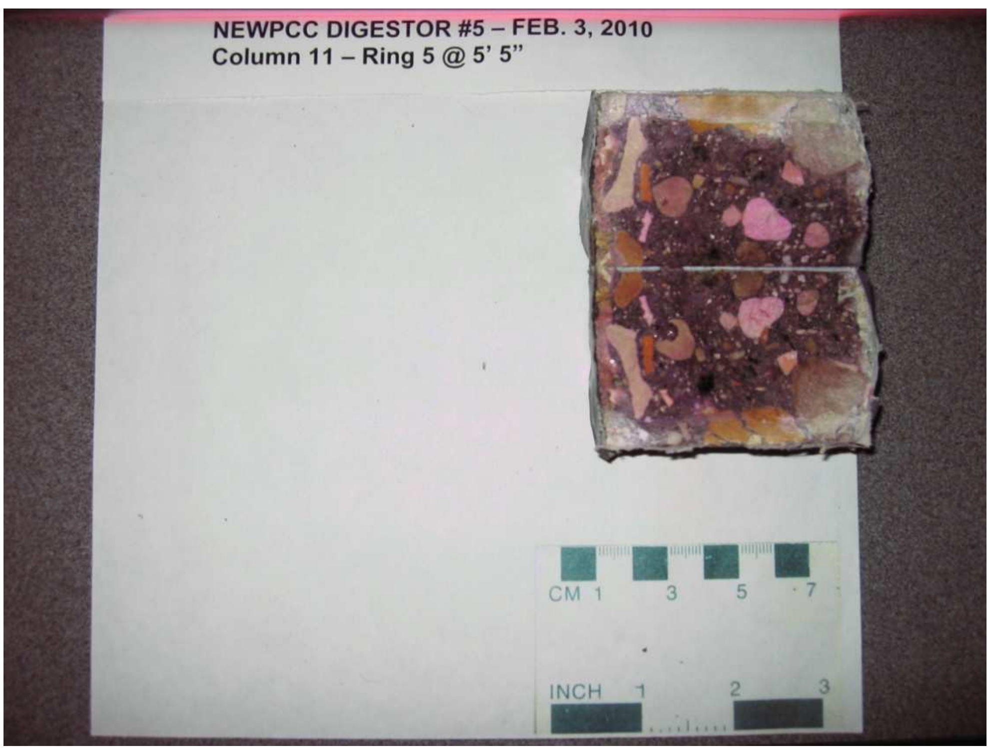

NEWPCC DIGESTOR#5 – FEBRUARY 19, 2010
WALL – SECTION17 – THIRD LEVEL
CM 1 3 5 7
INCH 1 2 3

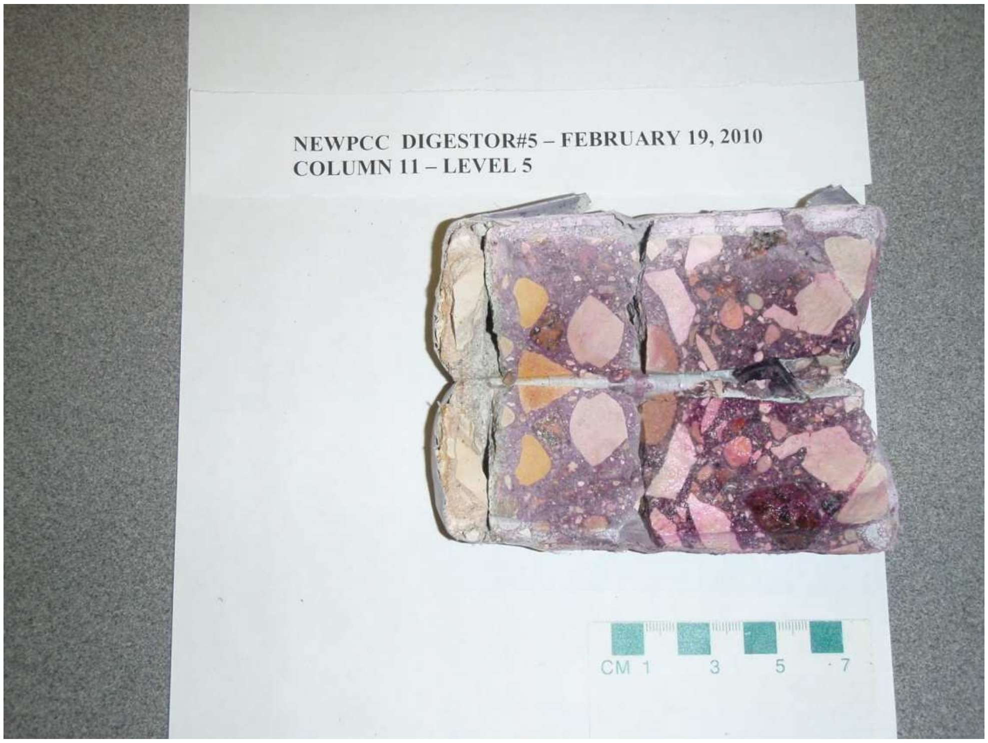

NEWPCC DIGESTOR #5 – FEB. 3, 2010
Wall – Sec. 20 – Ring 5
CM 1 3 5 7
INCH 1 2 3


NEWPCC DIGESTOR #5 – FEB. 3, 2010
Column 2 – 3rd Level
CM 1 3 5 7

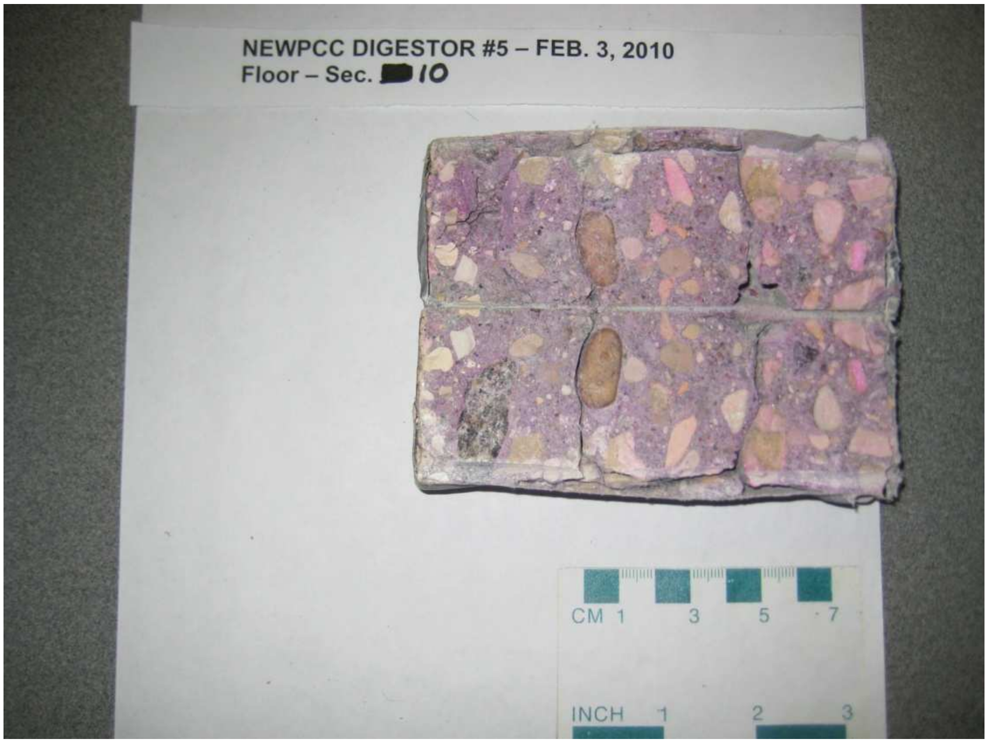

NEWPCC DIGESTOR #5 – FEB. 3, 2010
Column 3 - @ 19'
CM 1 3 5 7
INCH 1 2 3


NEWPCC DIGESTOR #5 – FEB. 3, 2010
Column 9 – Ring 1
CM 1 3 5 7
INCH 1 2 3


NEWPCC DIGESTOR #5 – FEB. 3, 2010
Column 11 – Ring 5 @ 5' 5"
CM 1 3 5 7
INCH 1 2 3


NEWPCC DIGESTOR#5 – FEBRUARY 19, 2010
COLUMN 11 – LEVEL 5
CM 1 3 5 7


NEWPCC DIGESTOR #5 – FEB. 3, 2010
Floor – Sec. 6[redacted]
CM 1 3 5 7
INCH 1 2 3


NEWPCC DIGESTOR #5 – FEB. 3, 2010
Floor – Sec. [redacted]10
CM 1 3 5 7
INCH 1 2 3

APPENDIX D

Compressive Strengths

THE NATIONAL TESTING LABORATORIES LIMITED
Established in 1923

199 Henlow Bay
Winnipeg, MB R3Y 1G4
Phone (204) 488-6999
Fax (204) 488-6947
Email info@nationaltestlabs.com
www.nationaltestlabs.com

Vector Corrosion Technologies
474 Dovercourt Drive
Winnipeg, Manitoba
R3Y 1G4

February 22, 2010

Project: Digestor No. 5 NEWPCC

Attention: Myron Henschel

On February 1 and 19, a total of twenty (20) concrete core samples were submitted to our laboratory for testing. It was reported that the core samples were obtained from Digestor No. 5 at the North End Water Pollution Control Centre (NEWPCC) in Winnipeg. The core samples were tested for compressive strength according to CSA A23.2-14C, Obtaining and Testing Drilled Cores for Compressive Strength. The test results are shown below.

Core No.	Sample Identification	Compressive Strength (MPa)
1	Column 2 - 3rd level	55.3
2	Column 3 - 4th level	68.7
3	Column 9 - 1st level	60.2
4	Column 11 - 2nd level	69.9
5	Ceiling - Section 8	47.1
6	Ceiling - Section 2	56.1
7	Wall - Section 2 - 2nd level	75.0
8	Wall - Section 3 - 3rd level	55.9
9	Wall - Section 4 - 5th level	58.5
10	Wall - Section 10 - 1st level	66.5

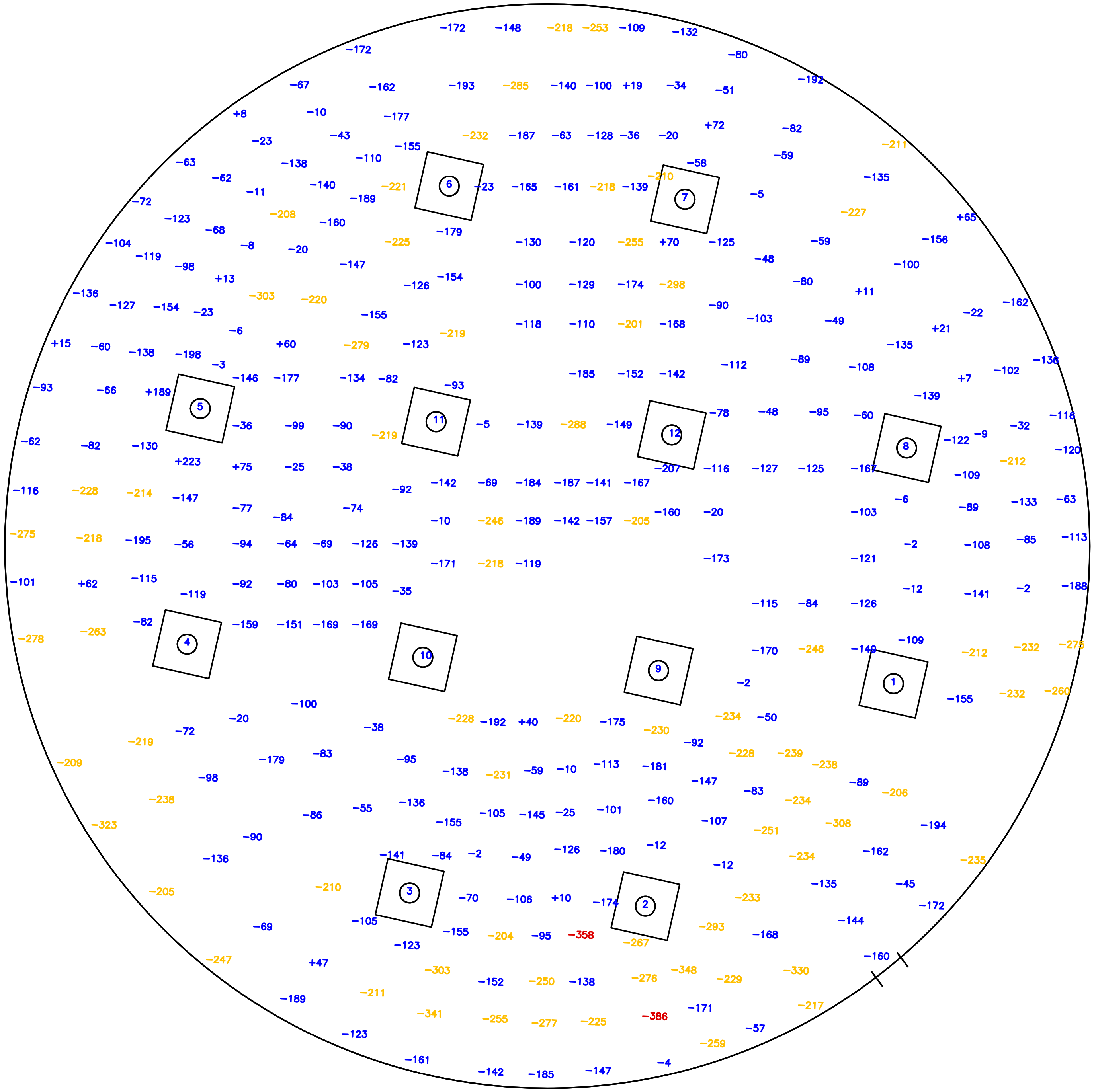
Core No.	Sample Identification	Compressive Strength (MPa)
11	Wall - Section 12 - 1st level	74.0
12	Wall - Section 15 - 4th level	58.3
13	Wall - Section 17 - 2nd level	58.6
14	Wall - Section 20 - 5th level	70.0
15	Floor - Section 6	57.1
16	Floor - Section 10	50.9
17	Wall - Section 12 - 4th level	54.1
18	Ceiling - Section 10	23.4
19	Column 11 - 5th level	65.1
20	Wall - Section 17 - 3rd level	54.9

We appreciate the opportunity to assist you in this project. Please call myself if you have any questions regarding this report.

Jason Thompson, C.E.T.
Manager, Materials Testing Services

APPENDIX D

Half-Cell Measurements



VECTOR CORROSION TECHNOLOGIES LTD.

PLAN NOTES:

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2] IF POTENTIALS OVER AN AREA ARE MORE POSITIVE THAN -200 mV CSE, THERE IS A GREATER THAN 95% PROBABILITY THAT NO REINFORCING STEEL CORROSION IS OCCURRING IN THAT AREA AT THE TIME OF THE MEASUREMENT.

3] IF POTENTIALS OVER AN AREA ARE IN THE RANGE OF -200 TO -350 mV CSE, CORROSION ACTIVITY OF THE REINFORCING STEEL IN THAT AREA IS UNCERTAIN.

4] IF POTENTIALS OVER AN AREA ARE MORE NEGATIVE THAN -350 mV CSE, THERE IS A GREATER THAN 95% PROBABILITY THAT REINFORCING STEEL CORROSION IS OCCURRING IN THAT AREA AT THE TIME OF THE MEASUREMENT.

Half Cell Corrosion Potentials

Digestion Tank #5 Ceiling

Drawn:	A.D.J.	Date:	MAR 2010

Col. 1 S. Face	Col. 1 N. Face	Col. 2 W. Face	Col. 2 E. Face	Col. 3 W. Face	Col. 3 E. Face	Col. 4 S. Face	Col. 4 N. Face	Col. 5 S. Face	Col. 5 N. Face	Col. 6 S. Face	Col. 6 N. Face	Col. 7 W. Face	Col. 7 E. Face
−168	−92	−32	−70	−18	−178							−134	−145
−60	−34	+40	+43	−16	−103	−112	−65	−13	−50	+16	−146	+37	+20
−49	−38	+104	+97	+62	+55	−77	+109	+48	−11	+62	+51	+24	+10
−156	−108	+125	+95	+28	+13	−106	+71	+1	+20	+28	+61	+29	−17
−129	−111	−18	+99	+115	+91	−123	−74	−16	−20	+115	+72	−54	−79
−170	−121	+1	+69	+85	+74	+88	+103	+20	+35	+85	+19	−97	−156
−181	−140	−5	−278	+62	+93	+17	−86	−39	−33	−51	−27	−109	−159
−127	−145	−8	−280	+70	+115	−66	−25	−119	−60	−68	−96	−145	−72
+26	+195	−18	−87	+65	−45	−108	−82	−82	−144	−86	−81	−143	−39
+15	+16	−26	−45	+12	+10	−50	−46	−34	−83	−86	−22	−57	−49

Col. 1 Col. 2 Col. 3 Col. 4 Col. 5 Col. 6 Col. 7

Col. 8 S. Face	Col. 8 N. Face	Col. 9 W. Face	Col. 9 E. Face	Col. 10 W. Face	Col. 10 E. Face	Col. 11 S. Face	Col. 11 N. Face	Col. 12 S. Face	Col. 12 N. Face
		−60	−155	−26	−60	−165	−89	−150	−122
−47	−94	−24	+4	+73	−24	−31	−41	−5	+61
+65	+52	+136	+2	+93	+136	+123	−58	+67	+82
+77	+78	+111	−112	+87	+111	+103	+86	+2	−6
−17	−15	+50	−122	+22	+50	+74	+61	−12	+17
−111	−134	+22	−168	+3	+22	+30	+34	−19	+36
−21	−121	−184	−137	−54	+71	−38	+1	−49	−44
−92	−124	−170	−186	−80	−15	−87	−73	−119	−158
−69	−81	−167	−156	−59	−55	−60	−66	−145	−136
+35	−6	−166	−76	+17	−9	−22	+15	−49	−35

Col. 8 Col. 9 Col. 10 Col. 11 Col. 12

VECTOR

VECTOR CORROSION TECHNOLOGIES LTD.

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Half Cell Corrosion Potentials

Digestion Tank #5 Columns

Drawn: A.D.J. Date: MAR 2010

Zone 1			Zone 2			Zone 3			Zone 4		
			+20	+8	+102	−105	−58	−107	+25	−130	−25
			−25	+34	+78	+83	−26	−56	+38	+26	+17
			+38	+45	+106	+42	+67	−32	+112	+4	+42
		−74	−120	−171	+90	−25	−48	−180	+92	+65	+62
		−7	−25	−20	+57	−25	−32	−180	−54	−20	−30
		+58	−53	+18	+7	+16	−15	−7	−50	−53	−51
−188	−125	−105	−55	−30	−64	−94	−5	−3	+25	−28	−98
−285	−13	+14	+24	−3	−45	−40	0	−100	−18	−93	−58
−225	−125	−99	−100	−140	−140	−115	−82	−96	−80	−18	−28

Zone 5			Zone 6			Zone 7			Zone 8		
−76	−45	−72	+53	+109	+96	+12	+117	−31	−2	−45	−132
+8	+93	+46	+48	−2	+92	+102	+129	+130	+40	−18	−80
+9	+98	−20	−60	+123	−58	+165	+173	+123	+53	−44	−69
+48	+156	+75	+99	+76	+86	−2	+67	−39	−74	−117	−50
−67	+64	+38	−58	−158	−112	+23	+96	+106	+2	+101	+47
−89	+63	+66	+42	−170	−30	+33	+121	+55	+101	−118	−25
−45	−75	−12	0	+50	−60	−8	−71	+40	+54	−250	−75
+7	+88	−28	−44	−110	−137	−50	−130	−94	−180	−37	+90
−72	−63	−105	−65	−65	−53	−13	−40	−90	−2	−32	+54

Zone 9			Zone 10			Zone 11		
−11	−97	+73	+39	+62	+78	+100	+31	+83
+24	−9	−50	−60	−47	−22	+39	+12	+37
+80	+109	−21	−62	+111	+93	+85	+68	+22
+194	+225	+188	+191	+103	+140	+110	+97	+129
+80	+95	+86	+109	+51	+134	+78	−7	+128
−60	−42	−64	−7	−12	+69	+146	+48	+28
−161	−175	−80	−35	−27	+2	+60	+110	+42
−25	−102	−105	−212	−65	−54	−56	+20	−52
−185	−152	−172	−126	−76	−140	−81	−275	−152

Zone 12			Zone 13			Zone 14			Zone 15		
	+78	+76	+6	+53	+49	+79	+15	+18	+15	−61	−49
+59	+85	+68	+78	+1	+20	−20	−54	−54	−20	−90	−80
+44	+76	+80	+89	+98	+25	−13	−8	+41	−106	−39	+24
+31	+68	0	+9	−15	−7	−62	−58	−78	−62	−34	−57
+70	−98	+65	+94	−32	−22	−71	−38	+38	−9	−152	+40
+47	+52	+9	+19	−4	+40	+80	+29	+78	+145	+9	+18
+100	−26	+50	+32	+80	−9	+70	+62	+30	+38	+30	−24
−225	−90	+15	−91	−13	−26	+38	−44	−28	−30	−163	−190
−91	−210	−113	−127	−80	−187	−168	−171	−200	−230	−137	−216

Zone 16			Zone 17			Zone 18			Zone 19		
−42		−51	−6	−76	−31	−10	−30	−66	−82	−35	−23
+155		−99	+15	+24	−28	−26	−25	+37	−30	+3	−25
+13		+68	+88	+116	+58	+95	+63	+39	+45	+42	+37
+28		+199	+29	+22	+40	+51	+80	+78	+35	+61	+131
−33		+39	+114	+65	+97	+76	+56	+45	+3	+13	+112
+29		+15	+41	+139	+96	−14	+100	+122	+75	+48	+124
−33	+30	−50	+18	−218	−22	−282	−57	+3	−110	−80	−7
−66	−27	+60	−48	−86	−120	−202	−49	−101	−218	−29	+32
−198	−225	−240	−281	−245	−210	−194	−99	−176	−250	−8	+36

Zone 20			Zone 21			Zone 22			Zone 23
−83	−66	−199	−57	−200	−258	−59	+12		
+2	−22	+55	+17	−35	+9	−65	+104		
+25	−50	−22	+4	+33	+104	+62	+29		
+29	+3	−87	+115	+34	+95	+56	+172		
+11	+33	+69	+162	+7	+171	+129	+161		
+48	+117	+109	+93	+22	+129	+108	−77		
−129	−108	−110	−91	−170	−135	−36	−7	+31	−15
−188	−140	−99	−99	−221	−183		−81	−215	−140
−189	−45	−75	−155	−85	−158	−116	−134	−73	−28

VECTOR CORROSION TECHNOLOGIES LTD.

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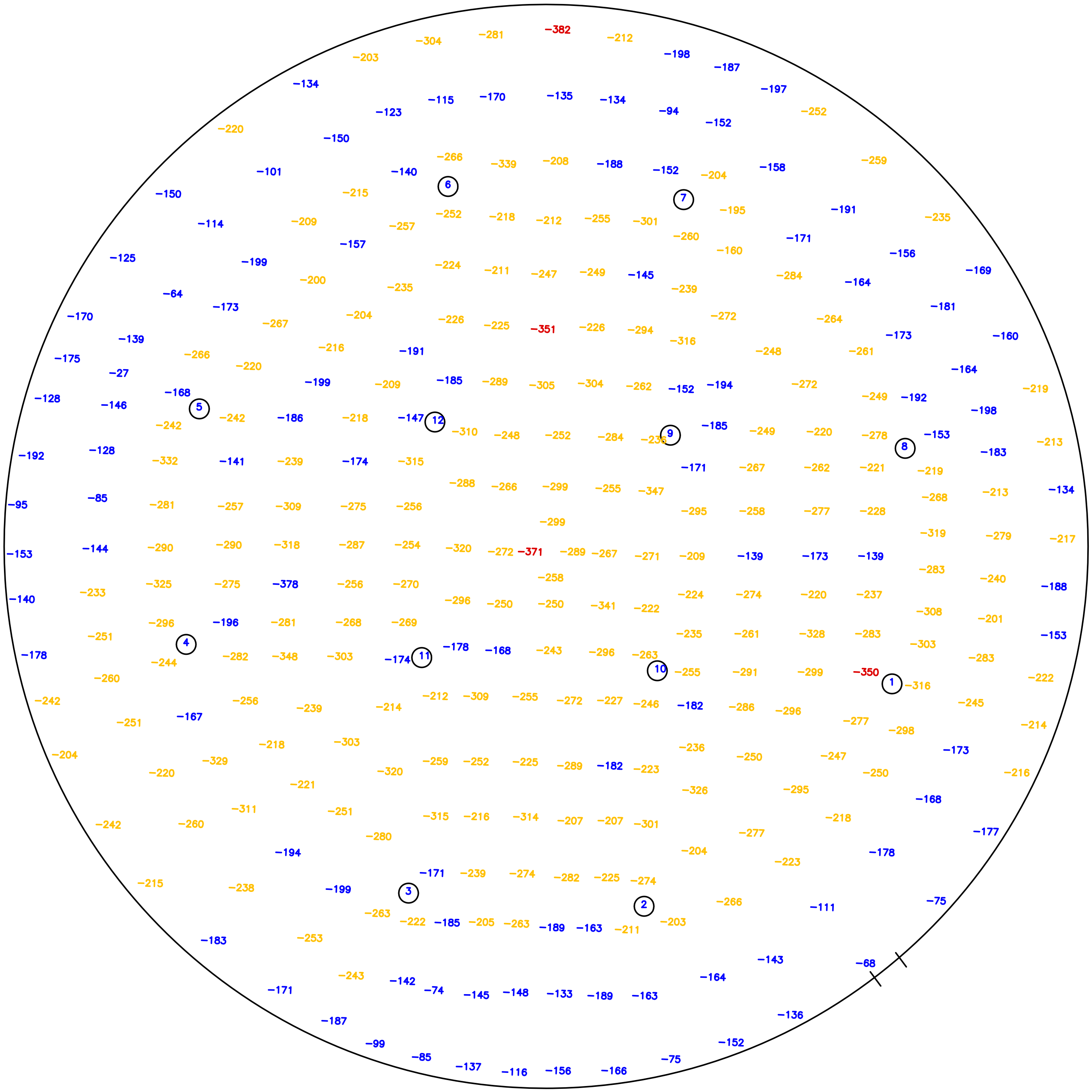
Half Cell
Corrosion Potentials

Digestion Tank #5
Walls

Drawn: A.D.J. Date: MAR 2010



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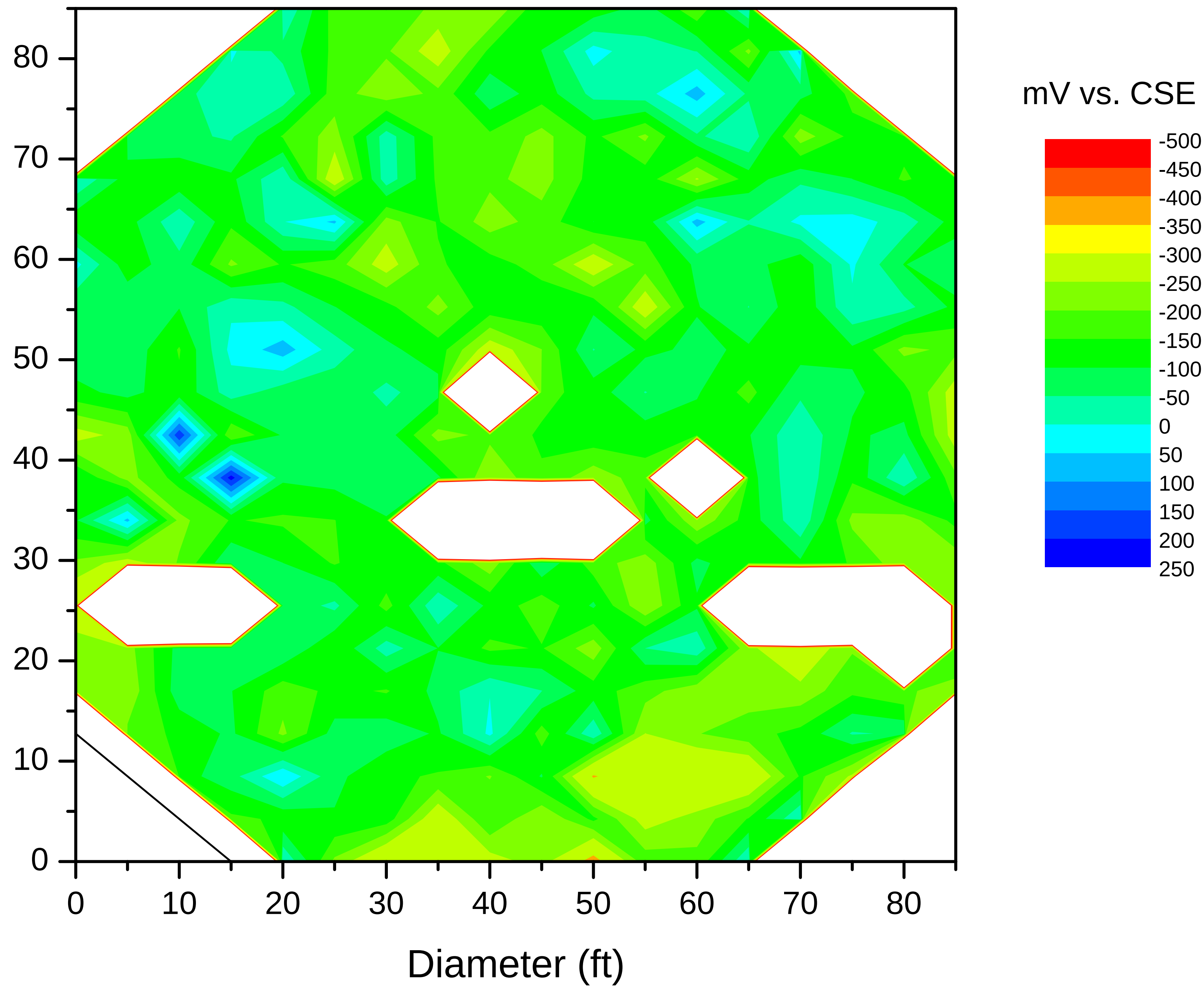
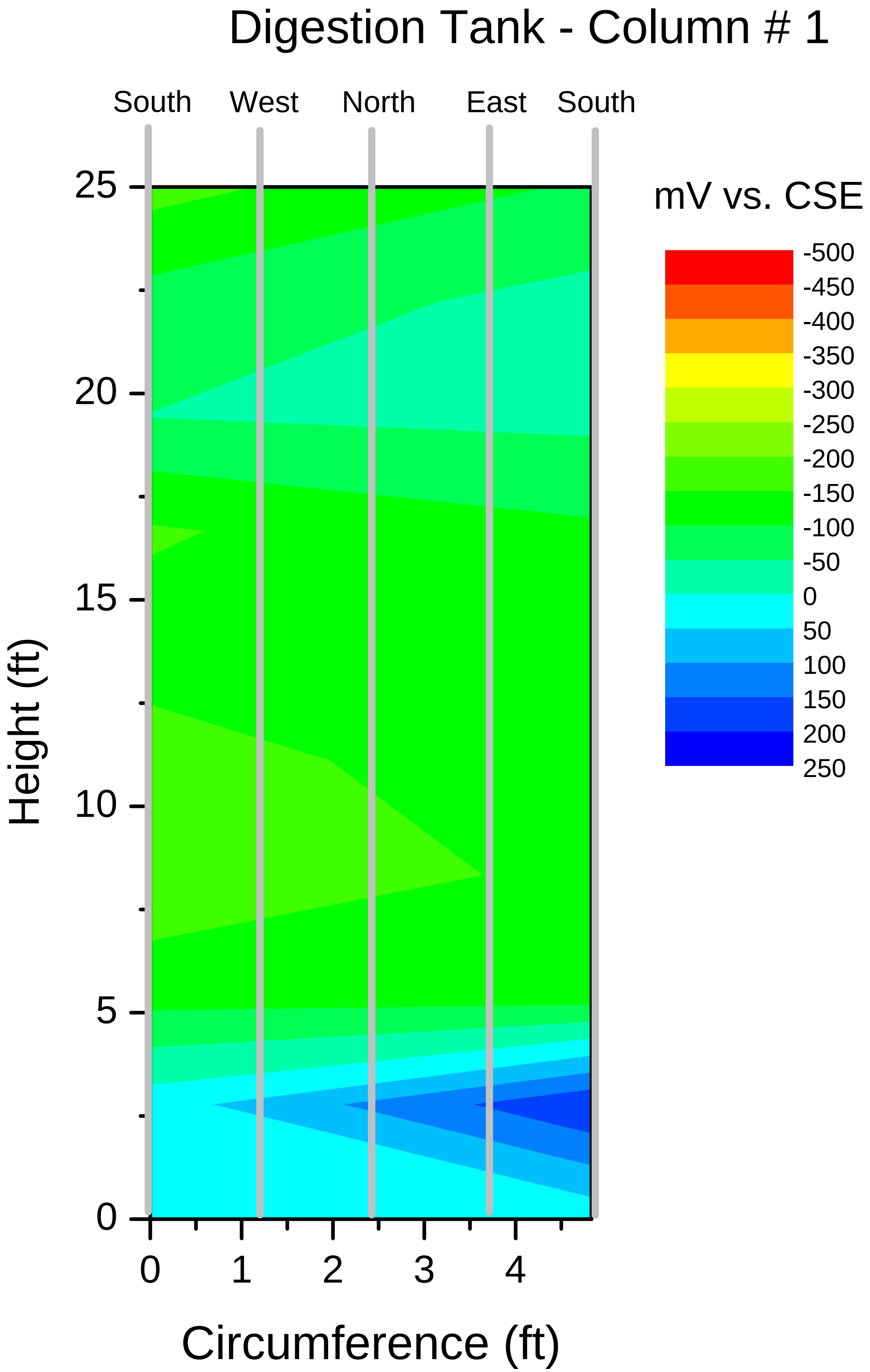
Half Cell
Corrosion Potentials

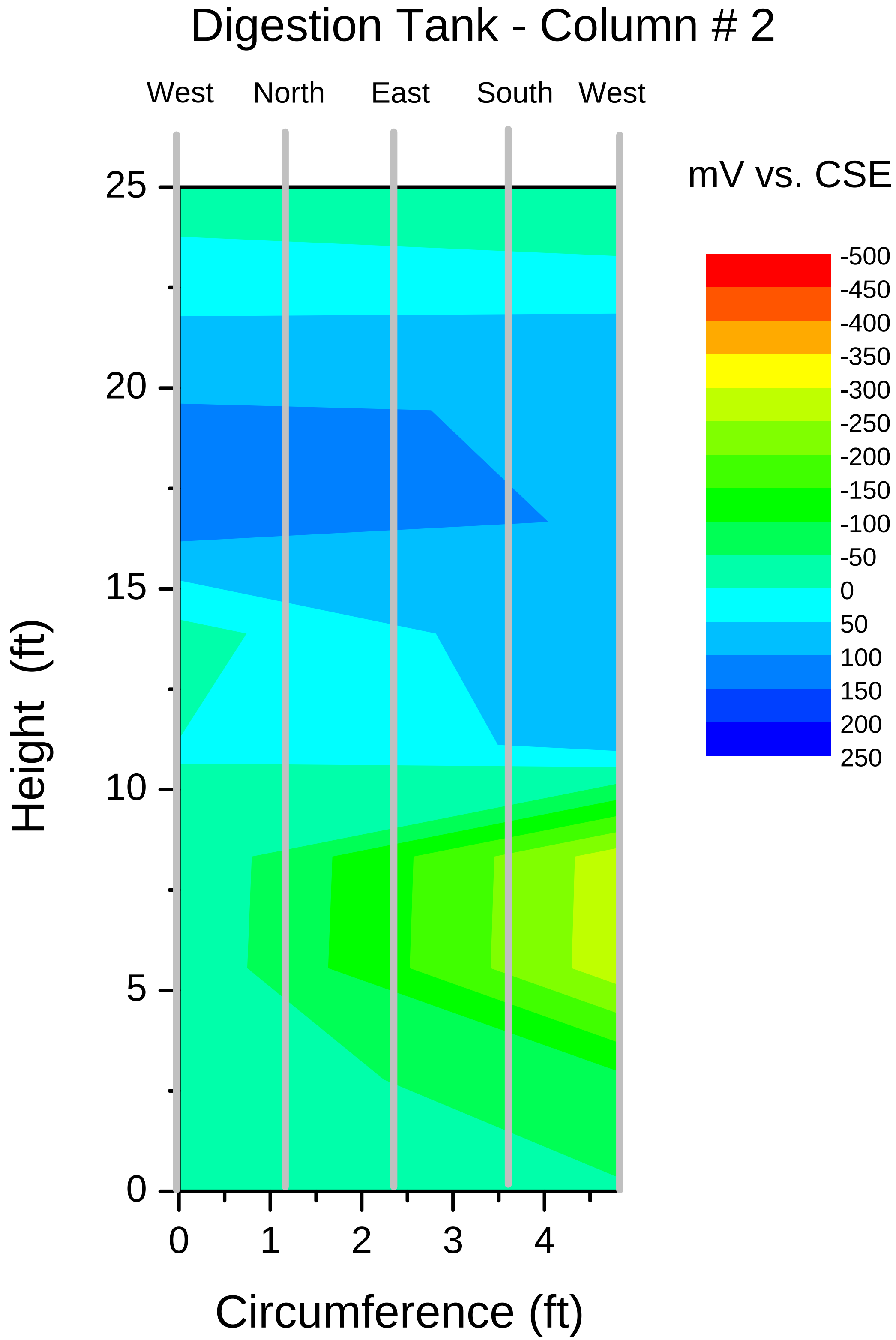
Digestion Tank #5
Floor

Drawn: A.D.J. | Date: MAR 2010

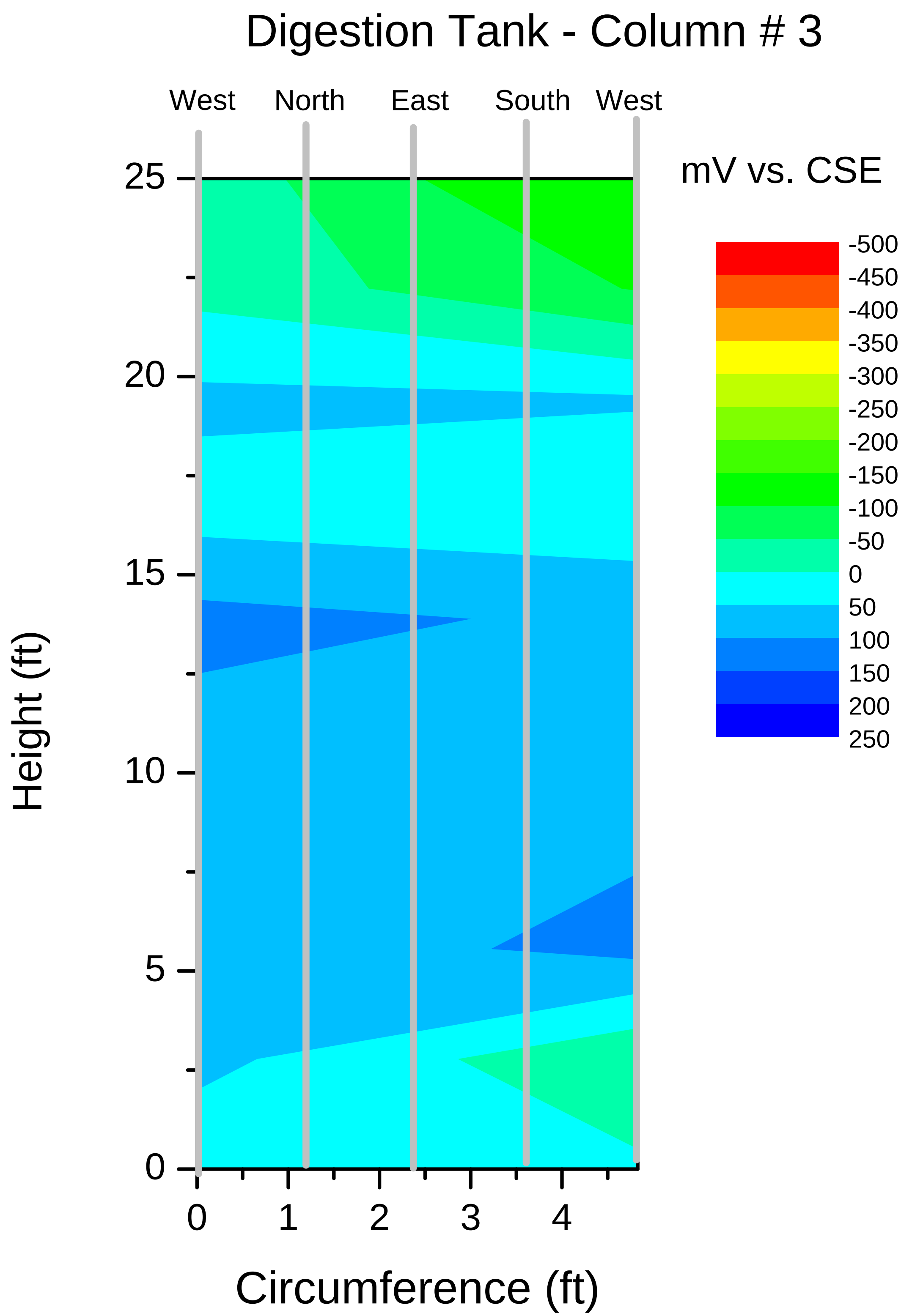
Digestion Tank #5 - Ceiling

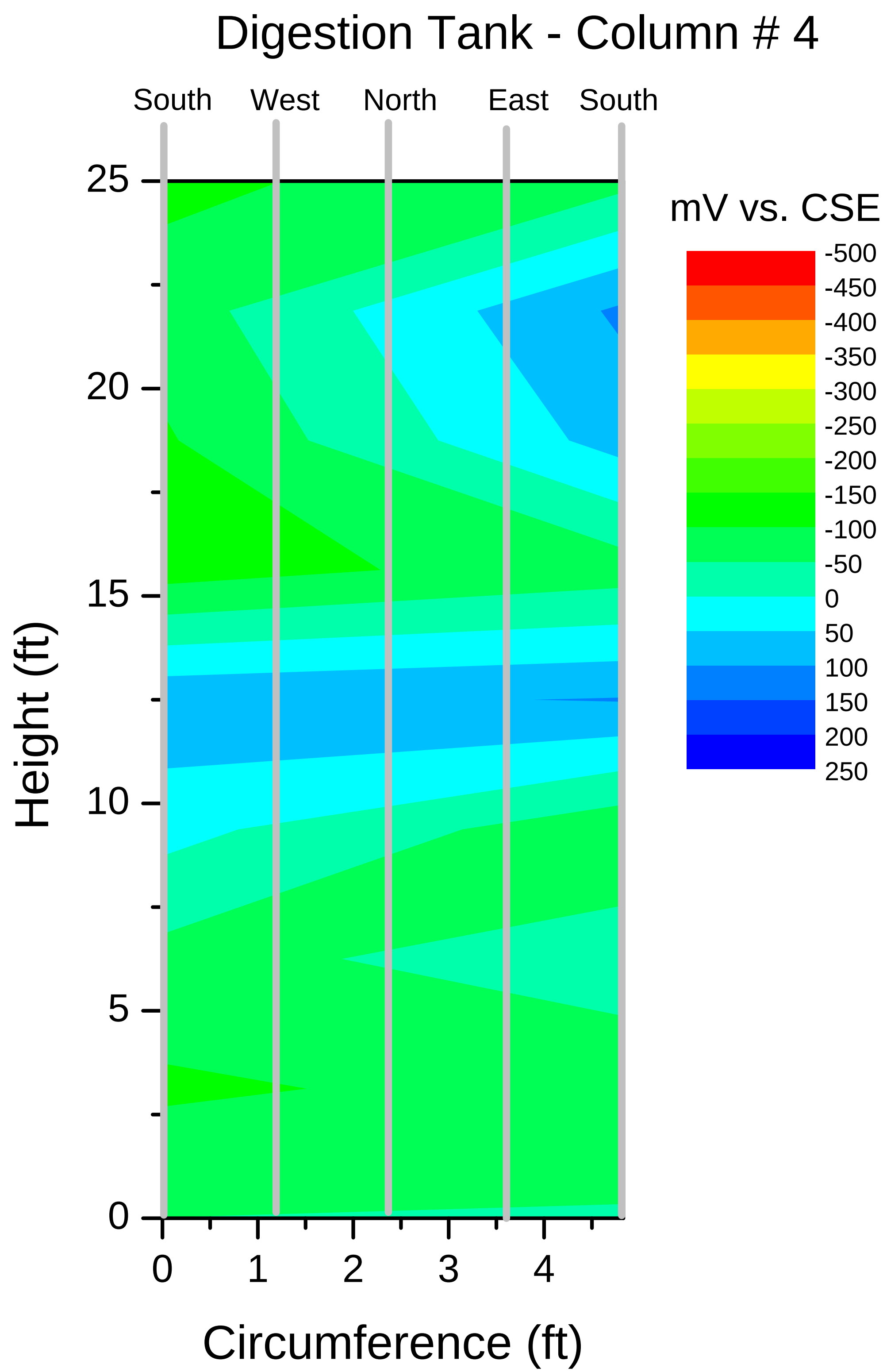



Digestion Tank - Column # 1
South
West
North
East
South
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
25
20
15
10
5
0
Height (ft)
0
1
2
3
4
Circumference (ft)

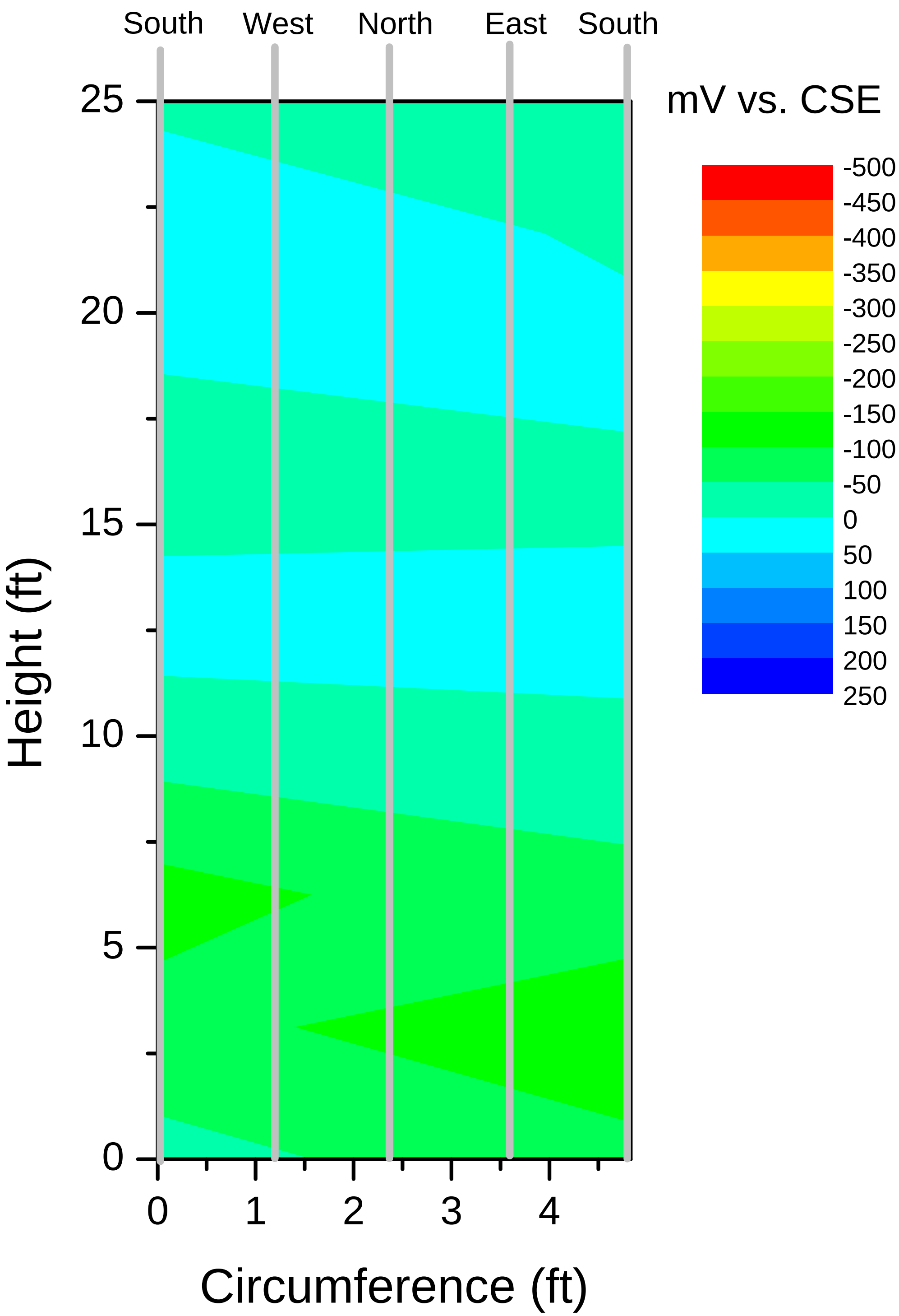


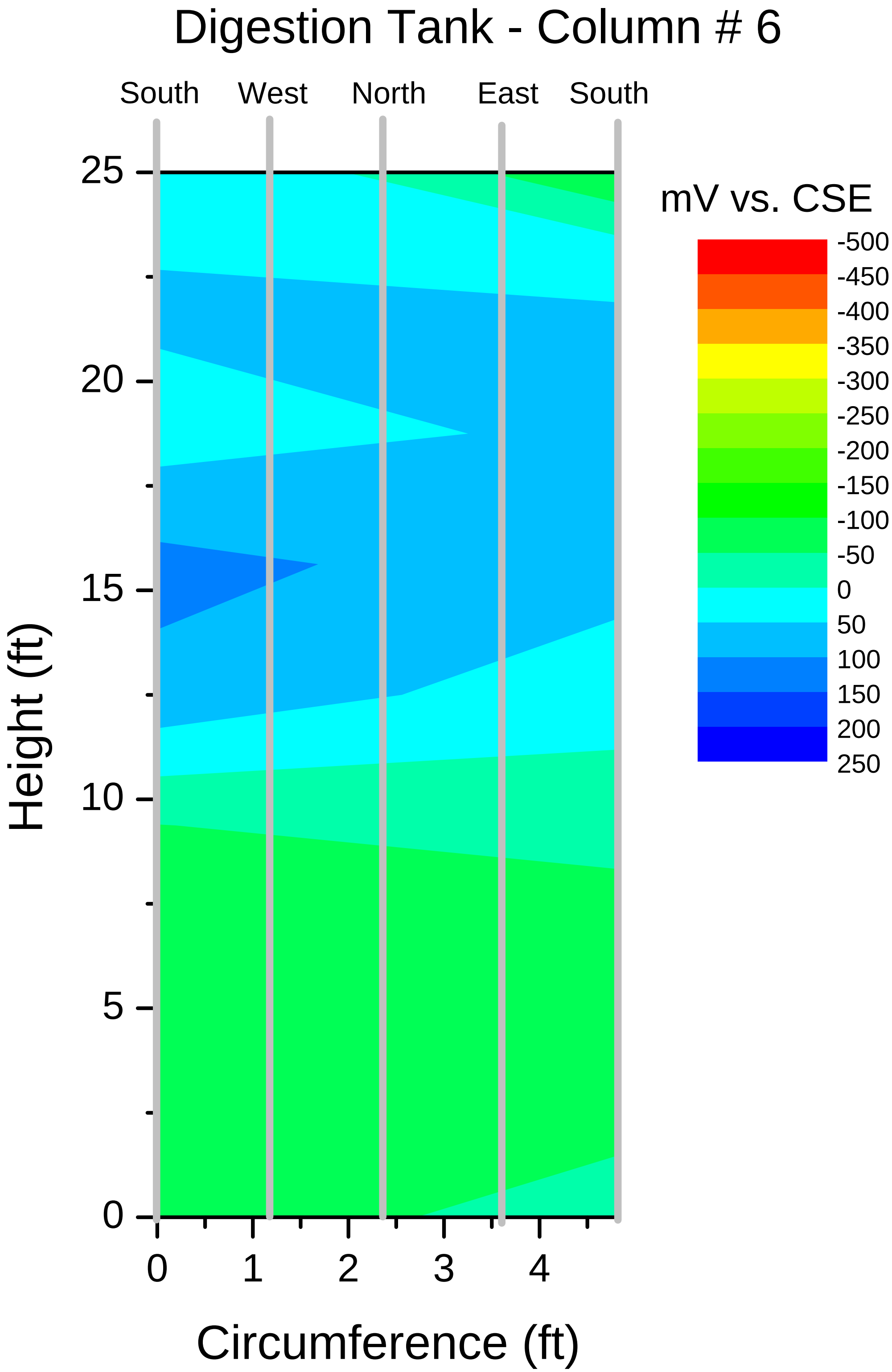
Digestion Tank - Column # 2
West
North
East
South
West
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
25
20
15
10
5
0
Height (ft)
0
1
2
3
4
Circumference (ft)


Digestion Tank - Column # 3
West
North
East
South
West
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
25
20
15
10
5
0
Height (ft)
0
1
2
3
4
Circumference (ft)

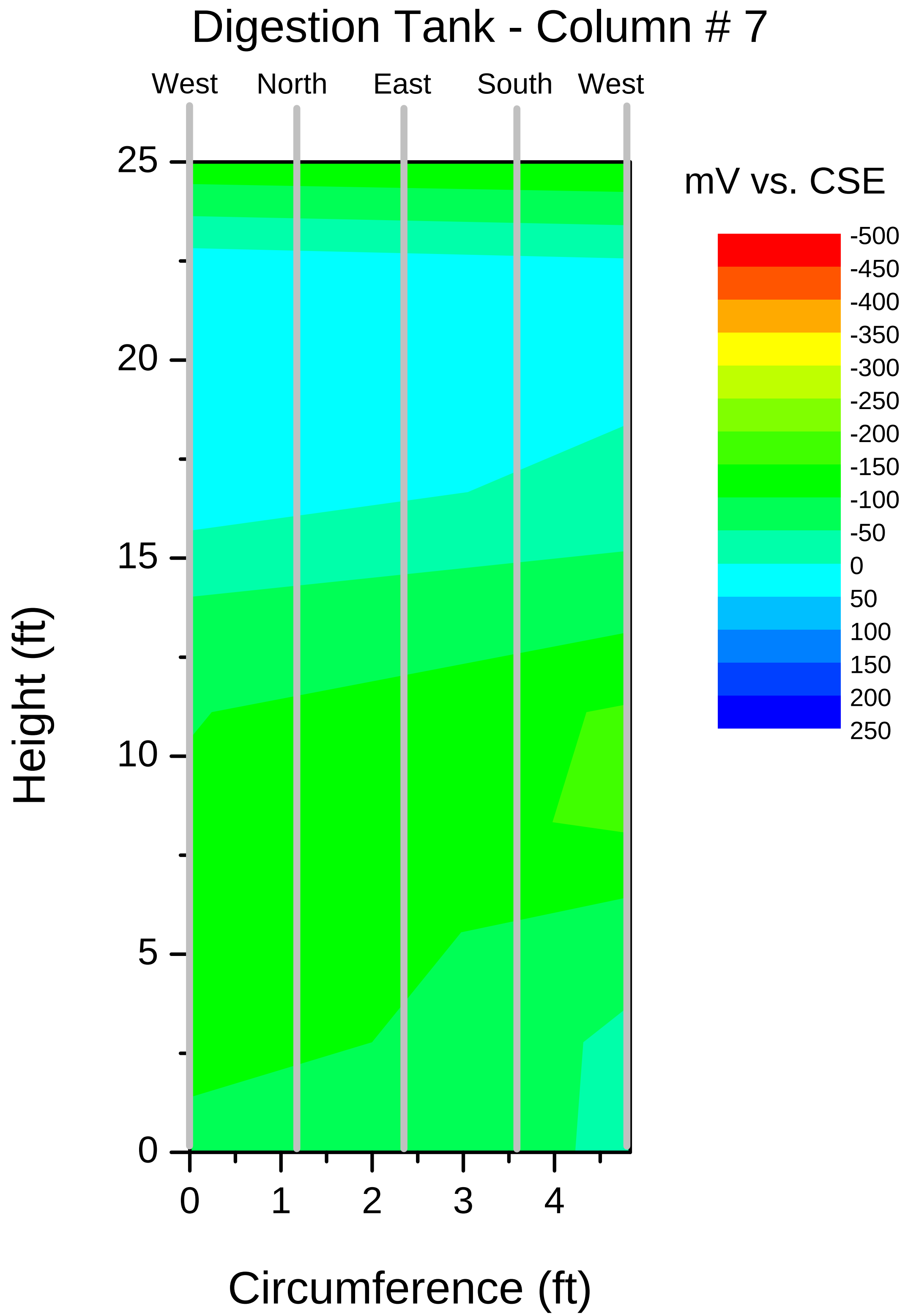

Digestion Tank - Column # 4
South
West
North
East
South
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
Height (ft)
25
20
15
10
5
0
0
1
2
3
4
Circumference (ft)

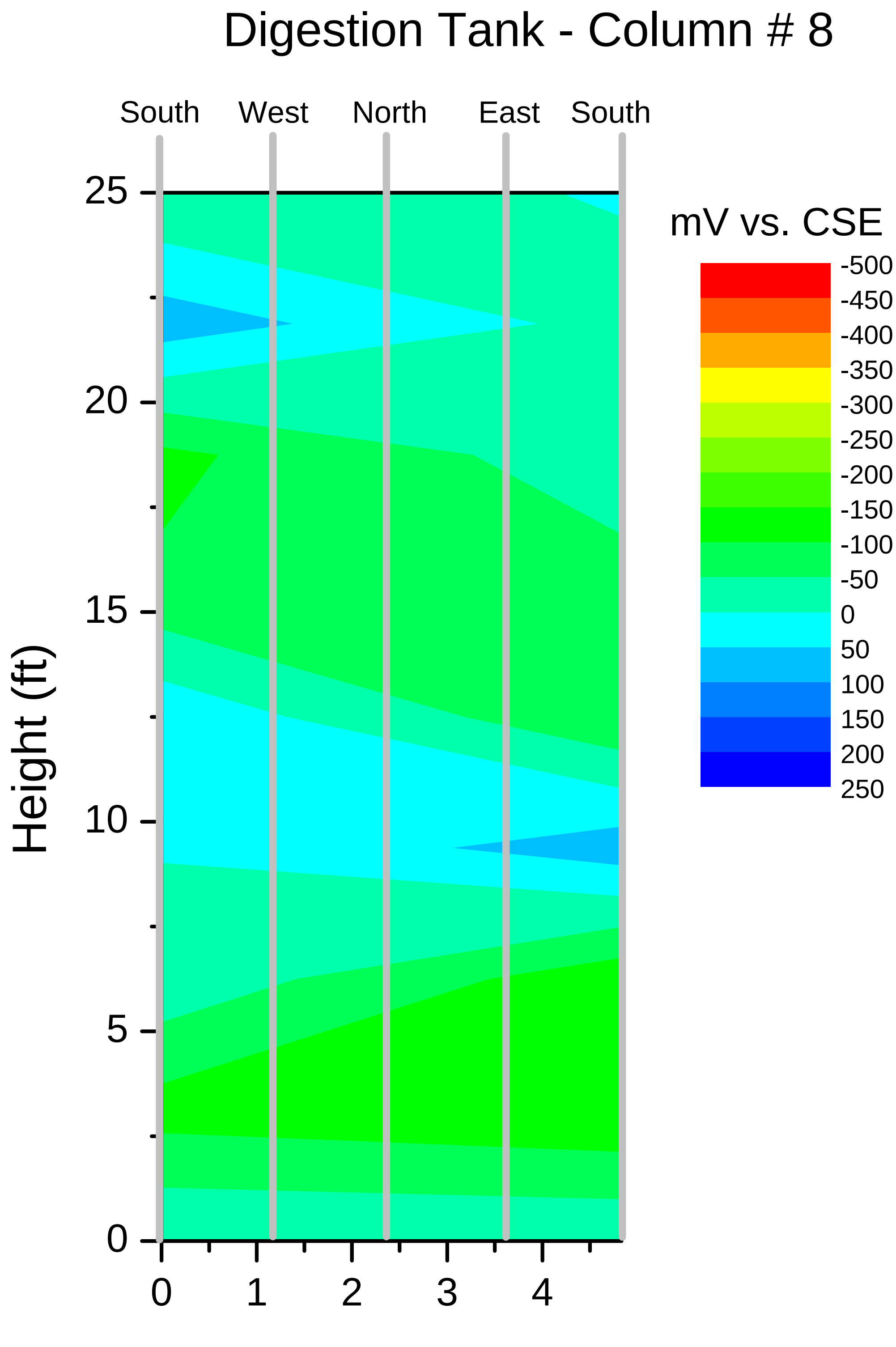
Digestion Tank - Column # 5



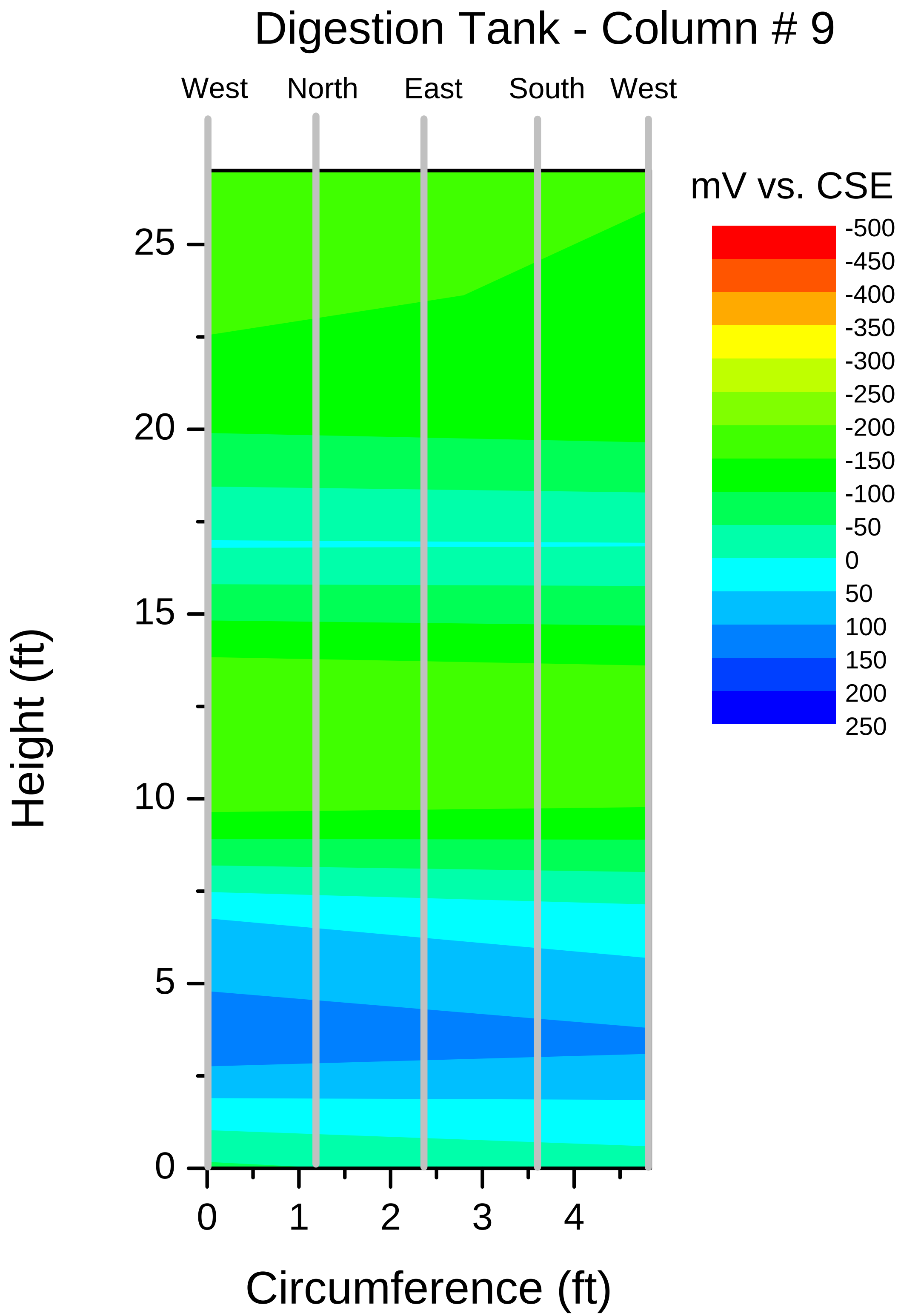


Digestion Tank - Column # 6
South
West
North
East
South
25
20
15
10
5
0
0
1
2
3
4
Height (ft)
Circumference (ft)
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250

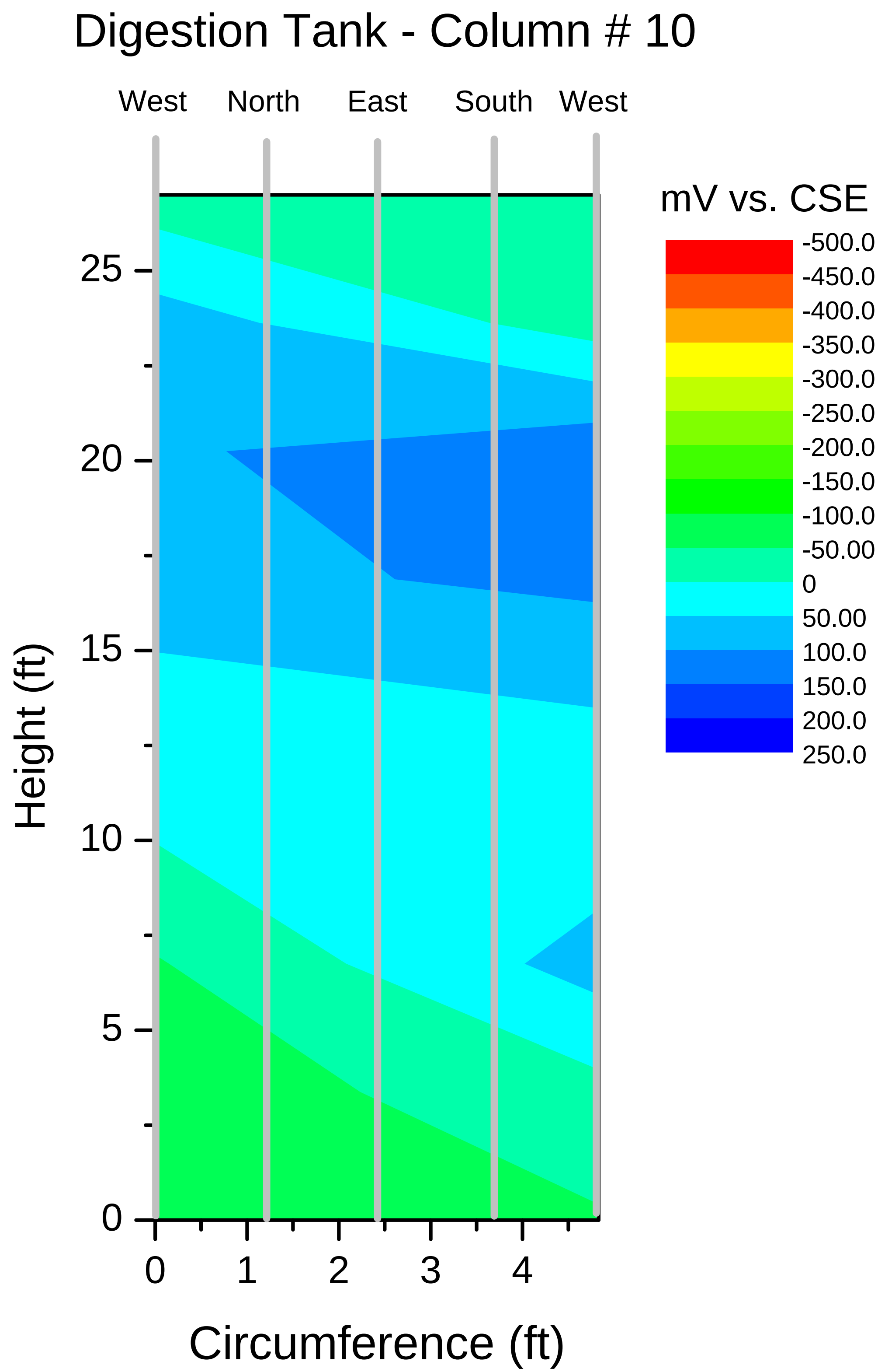

Digestion Tank - Column # 7
West
North
East
South
West
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
Height (ft)
25
20
15
10
5
0
0
1
2
3
4
Circumference (ft)

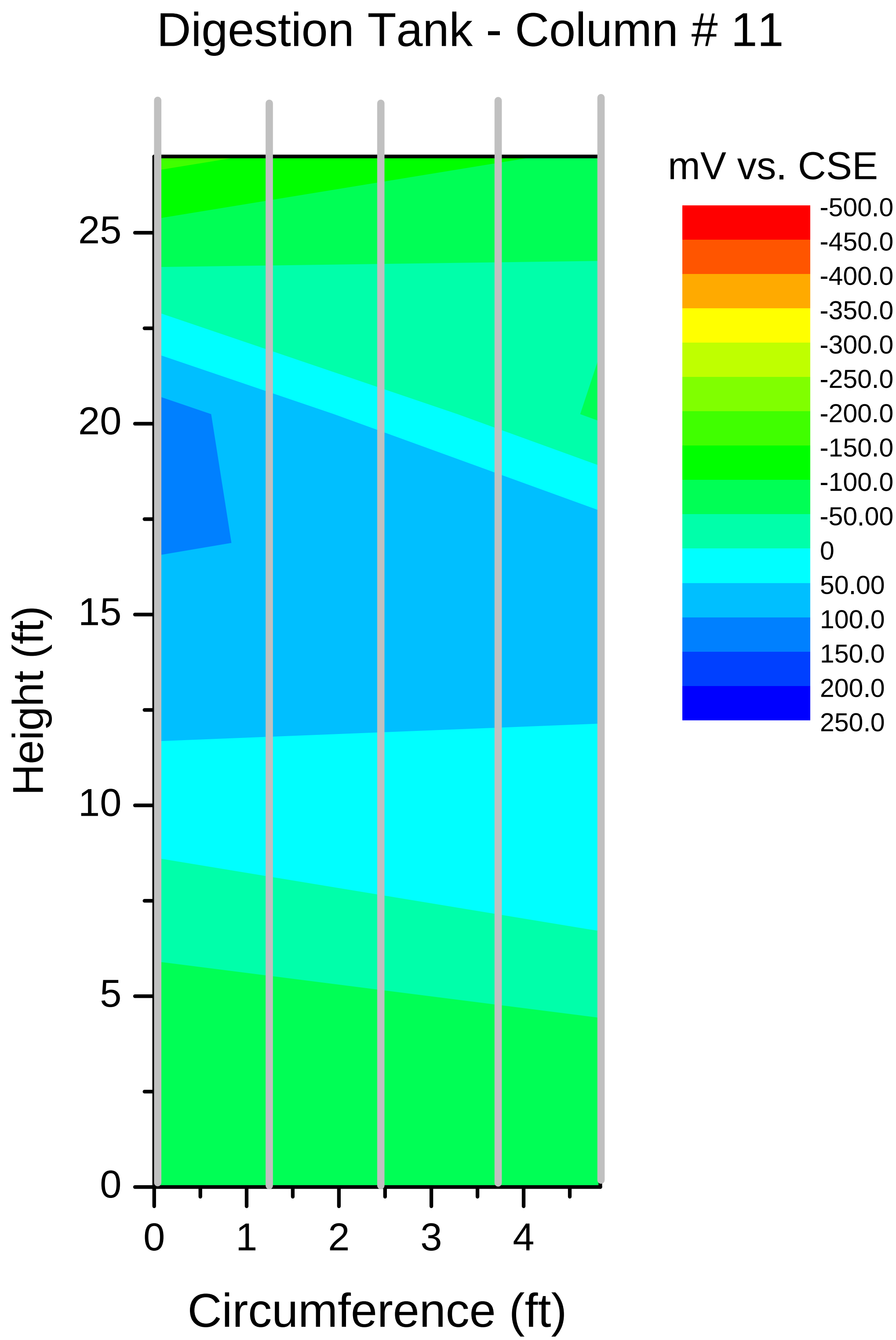


Digestion Tank - Column # 8
South
West
North
East
South
25
20
15
10
5
0
Height (ft)
0
1
2
3
4
Circumference (ft)
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250

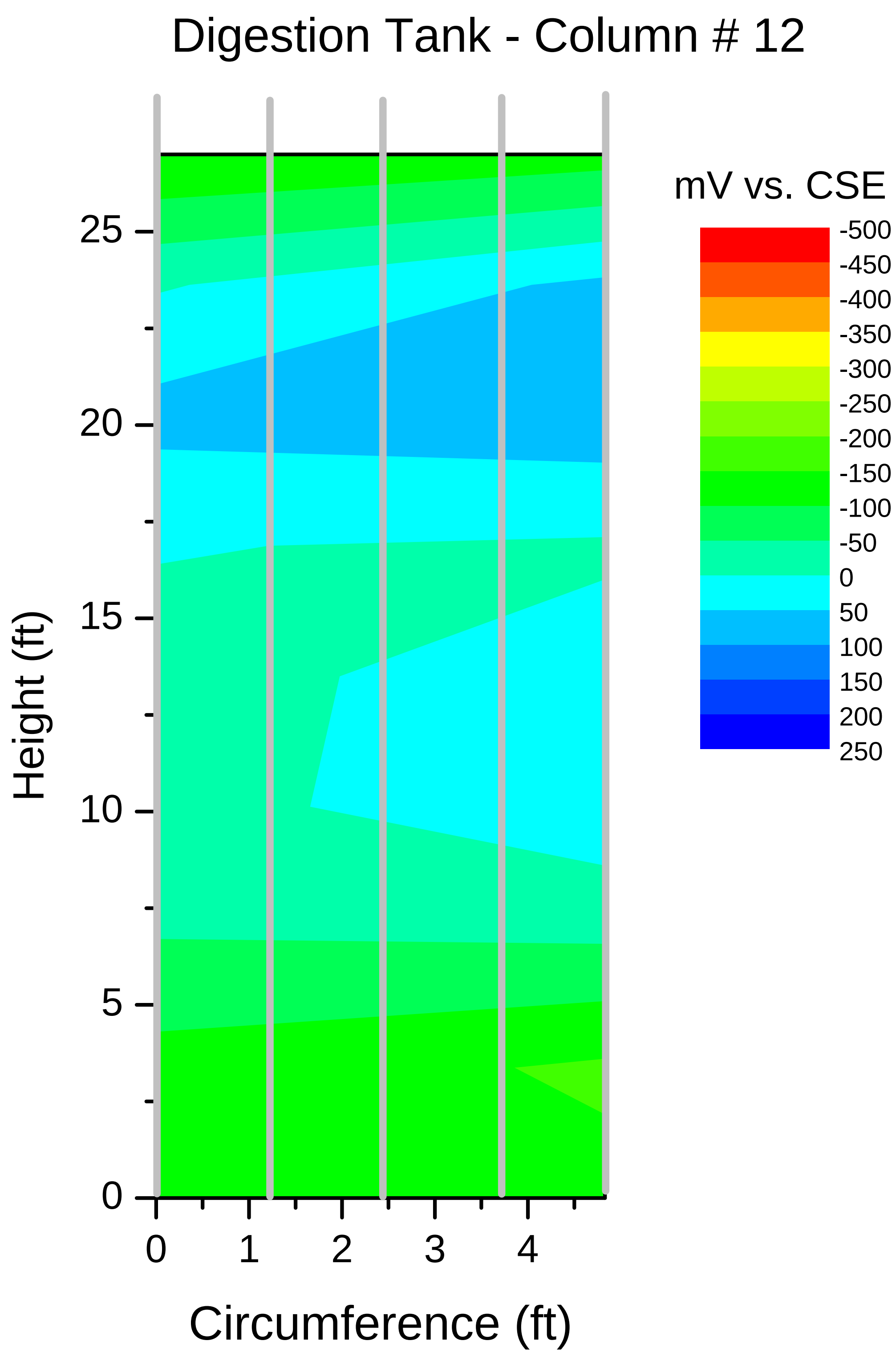


Digestion Tank - Column # 9
West
North
East
South
West
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
Height (ft)
25
20
15
10
5
0
0
1
2
3
4
Circumference (ft)

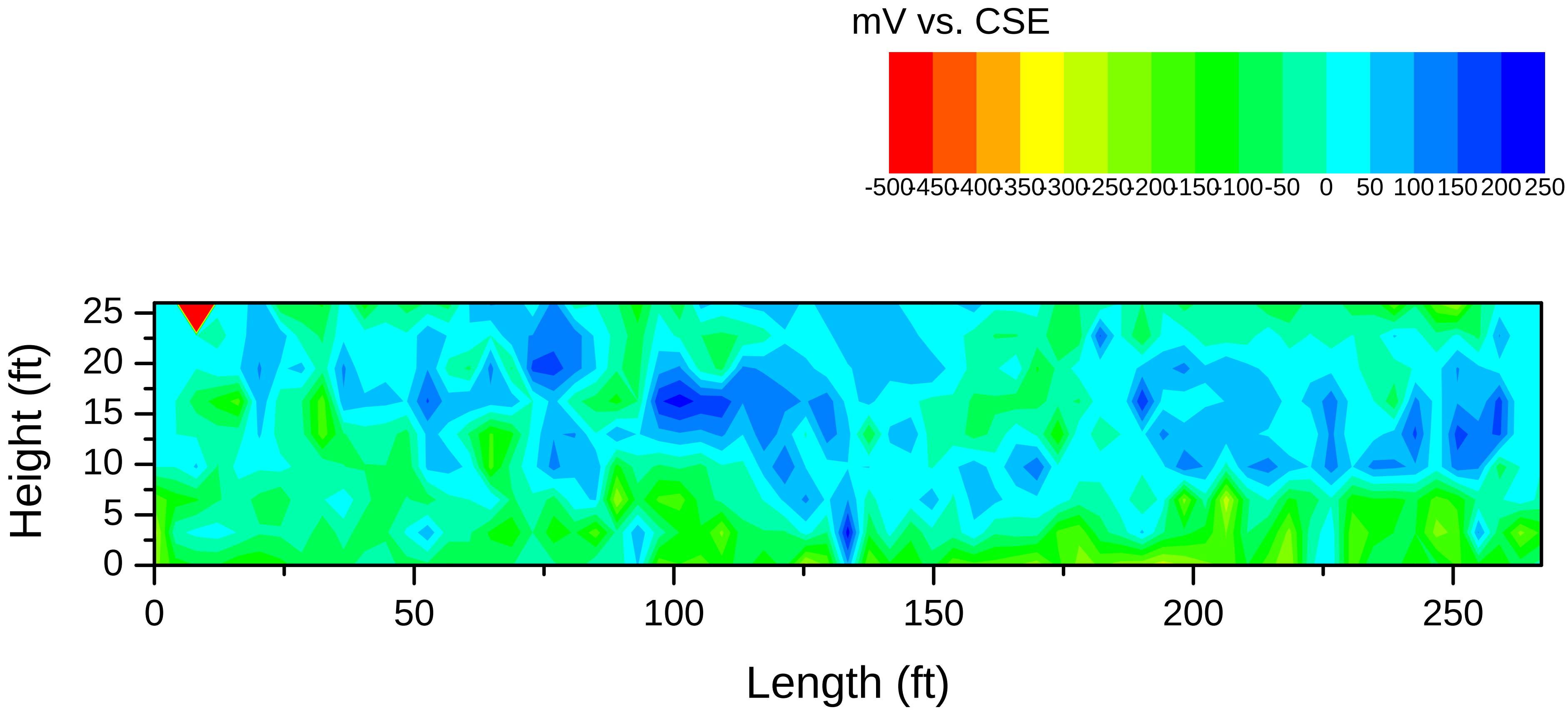

Digestion Tank - Column # 10
West
North
East
South
West
mV vs. CSE
-500.0
-450.0
-400.0
-350.0
-300.0
-250.0
-200.0
-150.0
-100.0
-50.00
0
50.00
100.0
150.0
200.0
250.0
Height (ft)
0
5
10
15
20
25
0
1
2
3
4
Circumference (ft)

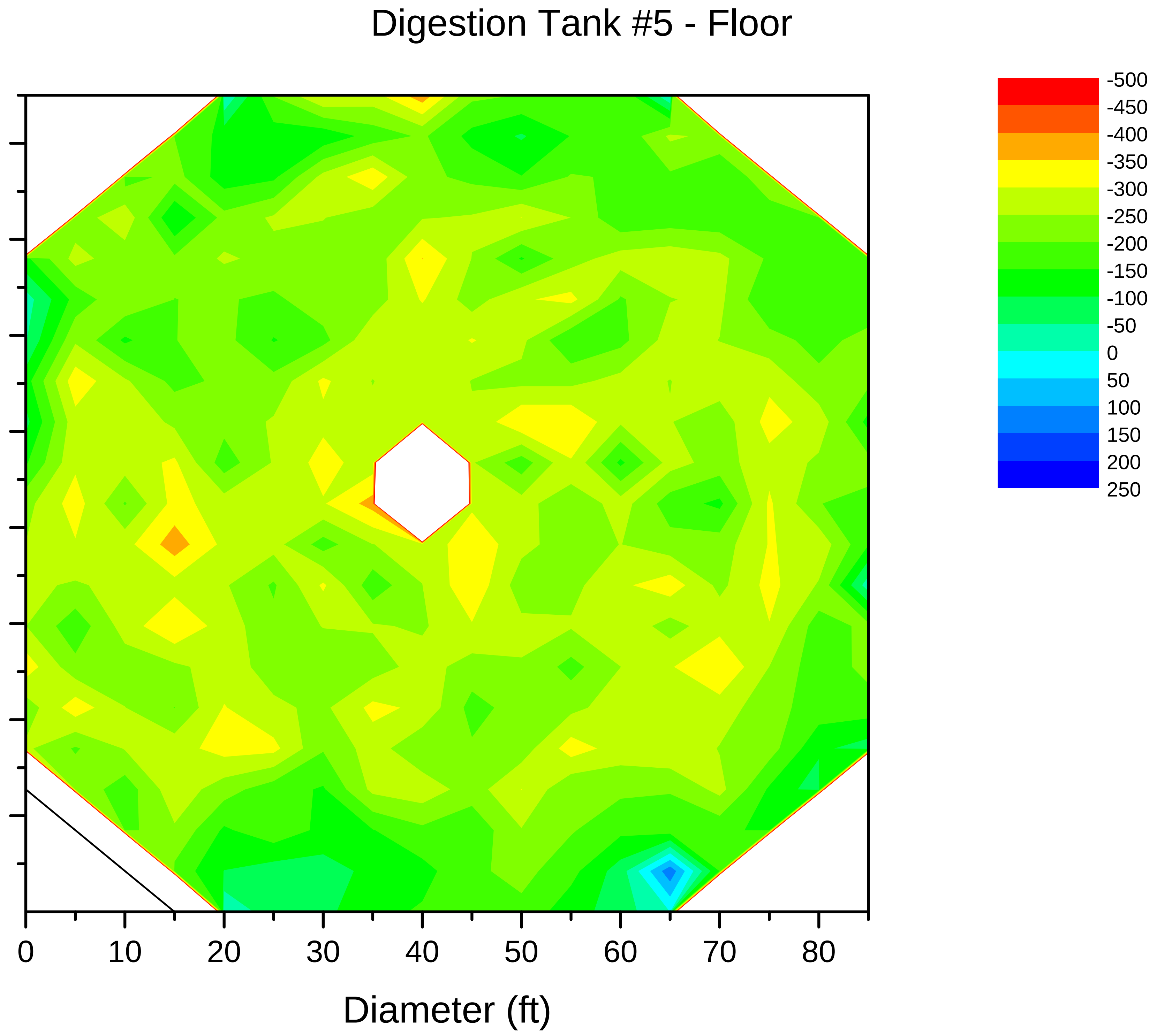


Digestion Tank - Column # 11
mV vs. CSE
-500.0
-450.0
-400.0
-350.0
-300.0
-250.0
-200.0
-150.0
-100.0
-50.00
0
50.00
100.0
150.0
200.0
250.0
Height (ft)
0
5
10
15
20
25
Circumference (ft)
0
1
2
3
4


Digestion Tank - Column # 12
Height (ft)
25
20
15
10
5
0
0
1
2
3
4
Circumference (ft)
mV vs. CSE
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250

Digestion Tank #5 - Wall





Digestion Tank #5 - Floor
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
Diameter (ft)