MINNESOTA DEPARTMENT OF TRANSPORTATION

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2008 MnROAD Phase II Construction Report

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16. Abstract (Limit: 250 words)

This report documents substantial work for MnROAD Phase II Construction, which began in 2007 and continued in 2008. Funding sources for the construction and research have come from many partners both locally and nationally. New test cells consisted of both new construction and rehabilitation techniques representing both national and regional interests. Funding for this phase of MnROAD is $10.9 million, which covers construction, research, instrumentation, and administration costs.

The core research areas that guided Phase II Construction are mechanistic design, innovative construction, preventive maintenance, recycled materials, pavement rehabilitation, surface characteristics, and other non-pavement research.

The purpose of this report is to provide details on the MnROAD construction that was completed during the 2008 construction season. It features projects that involved the reconstruction of Cells 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, and 23 on MnROAD's Mainline section and Cells 24, 39, 53, 85, 86, 87, 88, and 89 on MnROAD's Low Volume Road section. The new test cells included various asphalt and concrete pavement materials as well as various aggregate base materials.

This report documents the research projects and objectives, pavement structural and mix designs for each cell, instrumentation plan, field construction activities, material sampling, and laboratory test results.

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EXECUTIVE SUMMARY

This report documents the MnROAD Phase II Construction project in 2008, which was brought about by a partnership with the Transportation Engineering and Road Research Alliance (TERRA). TERRA is a research governance structure formed in 2004 to foster a comprehensive road research program, and brings together government, industry, and academia in a dynamic partnership to advance innovations in road engineering and construction. Its mission is to develop, sustain, and communicate a comprehensive program of research on pavement, materials, and related transportation engineering challenges, including issues related to cold climates. One of TERRA's main focus areas is to expand the utilization of the MnROAD test facility. In addition to MnROAD, TERRA works with researchers and facilities at the University of Minnesota and across the world. TERRA has broadened the use of the MnROAD research facility and helped guide future research in Minnesota. These efforts are built around our core research areas which are the design guide, innovative construction, preventative maintenance, recycled materials, rehabilitation, surface characteristics, and continued support of non-pavement research at the MnROAD facility.

The purpose of this report is to provide details on the MnROAD construction that was completed during the 2008 construction season. It features projects that involved the reconstruction of 16 cells on the MnROAD Mainline and 8 cells on the MnROAD Low Volume Road. Also reconstructed were the inside and outside shoulders and the transition areas to the mainline cells. The new test cells included various asphalt and concrete pavement materials as well as various aggregate base materials. Test cells consisted of both new construction and rehabilitation techniques representing both national and regional interests.

Funding sources for the construction and research have come from many partners both locally and nationally. Funding for this phase of MnROAD is $10.9 million, which covers construction, research, instrumentation, and administration costs.

Progressive Contractors, Inc. was awarded the prime construction contract, and they performed all of the grading and concrete paving work. Hardrives, Inc. was the bituminous paving subcontractor. The Mn/DOT Construction office in Golden Valley provided inspection and administration of the construction contract. Construction activities began in late April 2008 and were complete in early November 2008. Traffic was opened on the Low Volume Road in December 2008 and on the Mainline in February 2009.

Researchers performed a multitude of material tests on the aggregate, concrete, and asphalt materials in both the field and the laboratory. The purpose was to fully characterize all of the pavement materials used in the test cells. Many of the tests were performed by Mn/DOT staff, and others were hired out to various consultants. In addition, the standard QA testing was performed by Mn/DOT inspectors for each of the materials according to construction specifications.

Measuring the response of pavement structures to traffic and environmental loadings has been a

key component of the MnROAD facility, accomplished predominantly through the use of electronic instrumentation. For Phase II construction we invested almost $900,000 on instrumentation and the associated infrastructure. The report includes tables describing the sensors and infrastructure as well as several plots showing the specific instrumentation layout in each cell.

During construction, MnROAD staff made several determinations about construction processes. They include:

1. The most important lesson learned during this construction season is to require earlier construction end dates for the contract. This contract originally specified an end of construction as October 15th, which was extended due to unforeseen delays. However, this late date also made it difficult to finish construction, all punch list items, and initial monitoring measurements before the ground froze and the construction season ended. The construction end should be specified earlier to remedy this problem.
2. Researchers also learned not to add clay borrow over an existing clay subgrade. The base on several cells was soft and it was difficult to support construction traffic over the clay on clay areas.
3. Researchers also learned the importance of maintaining oversight over all partnership projects to ensure consistency between cells and projects. This is especially true when some research elements are not included in a construction contract.
4. Several materials and/or designs in the construction plans were not feasible. This reminded researchers that both design and constructability need to be balanced during a project.
5. Mn/DOT and the plant and paving crews successfully built our first porous asphalt and pervious concrete paving jobs together. It took several false starts and practice runs before settling on the proper techniques.
6. Open lines of communication between researchers, field inspectors, and contractors (and countless other key players) are essential in constructing a research project that meets everyone’s needs.

CHAPTER 1—INTRODUCATION

MnRoad Facility

The Minnesota Department of Transportation (Mn/DOT) constructed the Minnesota Road Research Project (MnROAD) between 1990 and 1993. MnROAD is located 40 miles northwest of Minneapolis/St. Paul and is an extensive pavement research facility consisting of two separate roadway segments originally containing 40 distinct test cells. Each MnROAD test cell is approximately 500 feet long. Subgrade, aggregate base, and surface materials as well as roadbed structure and drainage methods vary from cell to cell. All data presented herein, as well as historical sampling, testing, and construction information, can be found in the MnROAD database and in various publications. Layout and designs used for the Mainline and Low Volume Road are shown in Appendix A. Additional information on MnROAD can also be found on its web site at http://www.dot.state.mn.us/mnroad/index.html.

Mainline

The MnROAD Mainline is a 3.5-mile 2-lane interstate roadway carrying “live” traffic. The Mainline consists of both 5-year and 10-year pavement designs. The 5-year cells were completed in 1992 and the 10-year cells were completed in 1993. Originally, a total of 23 cells were constructed consisting of 14 hot mix asphalt (HMA) cells and 9 Portland cement concrete (PCC) test cells. Superpave and whitetopping cells were added in 1997 and 2004. Maintenance activities have also been done periodically to investigate the effectiveness of crack sealing and microsurfacing.

Traffic on the Mainline comes from the traveling public on westbound I-94. Typically the Mainline is closed for three days per month and the traffic is rerouted to the original interstate highway to allow MnROAD researchers the ability to safely collect data and record test cell performance. The traffic volume has increased dramatically since the test facility first opened, from an estimated 14,000 vehicles per day in 1994 to over 28,000 vehicles per day today with 13% trucks. The Mainline equivalent single axle loads (ESALs) are determined from two weigh-in-motion (WIM) devices located at MnROAD.

Low Volume Road

Parallel and adjacent to the Mainline is the Low Volume Road (LVR). The LVR is a 2-lane, 2 ½-mile closed loop that contains 20 test cells. Traffic on the LVR is restricted to a MnROAD operated vehicle, which is an 18-wheel, 5-axle, tractor/trailer with one loading configuration. The “legal” load configuration has a gross vehicle weight of 80 kips (80K configuration). The truck travels on the inside lane of the LVR loop 5 days per week. The outside lane does not have traffic on it to study the environmental effects on pavement performance.

Several pavement sections on the Low Volume Road have been reconstructed since 1993 due to early failures or new research projects. Maintenance activities, including microsurfacing and crack sealing, have been performed over time as needs arose.

Project Background

MnROAD test cells have been designed around the active studies that are being developed through its partners. They include both new construction and rehabilitation, and the research represents both national and regional interests. The 2008 Construction is complete on (8) LVR and (16) ML Test Cells, which are supporting the active studies.

Reconstruction of MnROAD (Phase-II) began in 2007 and continued into 2008. Funding sources for the construction and research have come from many partners as shown in Figure 1 and Table 1 below. Funding for this phase of MnROAD is $10.9 million, which covers construction, research, instrumentation, and administration costs.

Figure 1 shows the cost of the Phase II project, and how Mn/DOT funds are being used along with others.

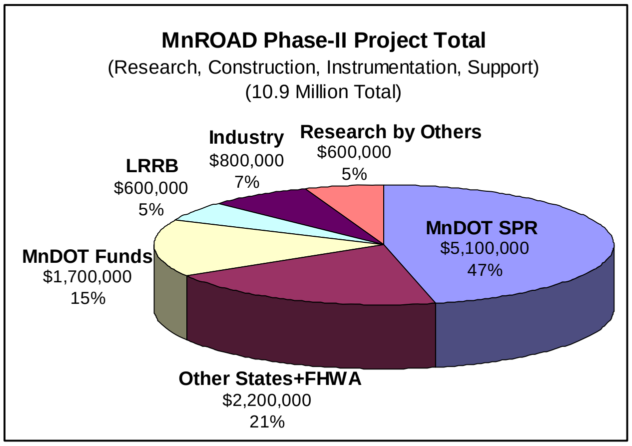


Figure 1. Phase II Funding Totals

MnROAD partnered with the Transportation Engineering and Road Research Alliance (TERRA) to deliver Phase II. TERRA is a research governance structure formed in 2004 to foster a comprehensive road research program, and brings together government, industry, and academia in a dynamic partnership to advance innovations in road engineering and construction. Its mission is to develop, sustain, and communicate a comprehensive program of research on pavement, materials, and related transportation engineering challenges, including issues related to cold climates.

One of TERRA's main focus areas is to expand the utilization of the MnROAD test facility. In addition to MnROAD, TERRA works with researchers and facilities at the University of Minnesota and across the world. TERRA has broadened the use of the MnROAD research facility and helped guide future research in Minnesota. These efforts are built around our core research areas which are the design guide, innovative construction, preventative maintenance, recycled materials, rehabilitation, surface characteristics, and continued support of non-pavement research at the MnROAD facility.

Each of the core research areas are outlined below:

Mechanistic Design – The MEPDG pavement design guide requires extensive field calibration and validation in all climates. There will be continued development of models, particularly for cold climates.

- Low Temperature Cracking
- Design and Construction of Composite Pavements & SHRP-II Composite Pavement Studies (2009)
- Investigation of Polyphosphoric Acid Modified Asphalt (2007)

Innovative Construction – Implement technology and methods for bound and unbound materials.

- Pervious Concrete "Overlay" & New Designs for HMA and PCC for Cold Regions (3 Studies)
- Intelligent Compaction of Bound and Unbound Materials
- High Performance Concrete Pavements

Preventive Maintenance – Improve techniques to maintain our current pavement investments.

- Optimal Timing of Preventive Maintenance for Addressing Environmental Aging
- Effects of Implements of Husbandry "Farm Equipment" on Pavement Performance (2007)

Recycled Materials – Study the effective use of recycled materials throughout the pavement structure including the use of taconite aggregates.

- Recycled Unbound Pavement Materials
- Highway Base Material Stabilized With High Carbon Fly Ash (2007)
- Taconite Aggregates in Pavement Applications
- Recycled Asphalt Pavements

Rehabilitation – Improving pavement rehabilitation techniques for both Hot Mix Asphalt and Portland Cement Concrete pavements. Examine new materials, methods, and processes. Develop and refine techniques for seasonal material classification and performance. Develop and refine techniques for cost effective pavement rehabilitation.

- Whitetopping Design
- Unbonded Concrete Overlay
- Full-Depth Reclamation Stabilized with Engineered Emulsion

Surface Characteristics – Evaluate and develop construction techniques and materials for smooth, quiet, durable, and skid-resistant pavements.

- PCC Surface Characteristics – Rehabilitation
- PCC and HMA Surface Characteristics – New Construction (2 Studies)

Non-Pavement Research – Continued support of research in intelligent transportation systems. Make the MnROAD facility available for groups to develop new products or systems. Other partners for the Phase II research are listed in Table 1.

Table 1. MnROAD Phase II Research Partners

MnROAD Partners	Research Study Effort
CA , MI, MN, OH, TX, WI	Recycled Unbound Pavement Materials (TPF-5(129))
CT, IA, ID, MN, ND, NY, WI, LRRB	Investigation of Low Temperature Cracking in Asphalt Pavements - Phase II (TPF-5(132))
MN, LRRB, IL, IA, PNAAW	Effects of Implements of Husbandry "Farm Equipment" on Pavement Performance (TPF-5(148))
CA, MN, WA, FHWA, LRRB TRB, U of MN, ARA	Composite Pavement Systems (TPF-5(149)) SHRP-II Composite Pavement Study (2009)
MD, MN, OH, TX, LRRB	Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in HMA Pavements (TPF-5(153))
MS, MN, MO, NY, PA, TX	Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements (TPF-5(165))
MN, TX, IGGA, ACPA, FHWA, Diamond Surfacing Inc.	PCC Surface Characteristics – Rehabilitation (TPF-5(134))
LRRB, Mn/DOT, FHWA	HMA Surface Characteristics Related to Ride, Texture, Friction, Noise, Durability PCC Surface Characteristics – Construction
Bloom Consultants, U of WI, Washington State University, MPCA, US Department of Energy	Field Investigation of Highway Base Material Stabilized with High Carbon Fly Ash
SemMaterials	Full-Depth Reclamation Study
CTRE, ACPA, ARA	*Pervious Concrete Mix Design for Wearing Course Applications*
LRRB	Permeable (HMA) Pavement Performance in Cold Regions Pervious Concrete Pavement Study
Innophos, Marathon, Paragon, ICL, MTE, WRI, FHWA, Dupont	MnROAD Field Investigation of Polyphosphoric Acid Modified Asphalt
Mn/DOT	Investigation of High Performance (60 Year Design) Concrete Pavement, Concrete Pavement Thickness Optimization for High Volume Roads
CPAM, ACPA	Performance of Thin Unbonded Concrete Overlays on High Volume Roads
NRRI	Use of Taconite Aggregate in Pavement Applications
LRRB	Recycled Asphalt Pavements

Project Prioritization

TERRA's goals will be achieved through a combination of pooled fund research projects, single state research projects, industry sponsored research, Local Road Research Board sponsored projects, and studies conducted by Mn/DOT staff. Specific cells will be constructed to support the initial study and as many potential follow-up studies as possible. In the case of partner studies, Mn/DOT may not be as involved in the study, but always requires that any data be included in the MnROAD database.

TERRA originally sought dedicated federal funding for the reconstruction of MnROAD and research priorities. This funding approach was not successful in 2005 or 2006. Early in the fall of 2006, Mn/DOT identified unspent Federal State Planning and Research (SPR) funds as an alternate source of funding for MnROAD reconstruction and other research initiatives. Because of the Mn/DOT and FHWA requirements to qualify for SPR funds, a unique process was developed for TERRA to evaluate the priorities for MnROAD reconstruction. The "2008 MnROAD Reconstruction Selection Process" is a one-time process and not the general TERRA process for selecting research priorities.

The 2008 MnROAD Reconstruction Selection Process is shown in Figure 2, built upon the original research ideas developed and prioritized by the TERRA Research Committee. The Research committee created a list of 120 total research ideas, of which 44 were rated as both MnROAD compatible and a high priority. This list was used to solicit twelve pooled fund projects for some of the research to accompany reconstruction. In addition to pooled fund projects, partnerships were developed on specific topics of interest (some outside of the original list), along with projects initiated by Mn/DOT.

Since the SPR funding includes specific federal funds allocated to Mn/DOT, the Office of Research Services and the local FHWA Division Office make decisions concerning eligibility of individual projects for these funds. A final review of the total MnROAD Phase II reconstruction plan was made by the TERRA Research Committee.

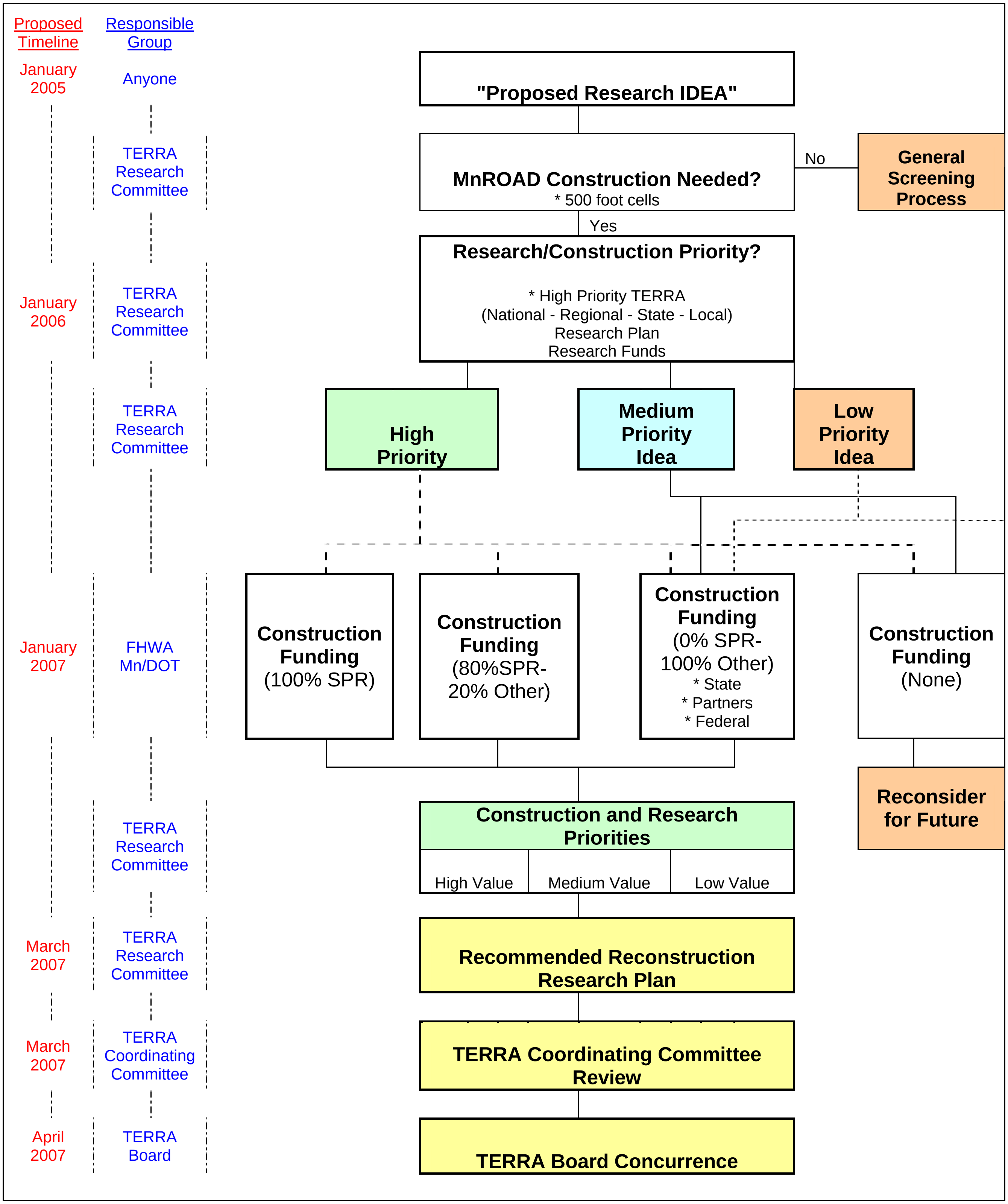


Figure 2. MnROAD Reconstruction Selection Process

CHAPTER 2 – CONSTRUCTION DETAILS

The purpose of this report is to provide details on the 2008 MnROAD reconstruction of 16 Mainline cells (Cells 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23) and 8 Low Volume Road cells (Cells 24, 39, 53, and 85 – 89). Because of space limitations several 500-ft cells were split into smaller subcells (i.e., Cell 5 was split into Cells 105, 205, 305, and 405 – each about 125 ft long). Also reconstructed were the inside and outside shoulders and the transition areas to the mainline cells.

Nineteen research studies directed the reconstruction for 2008:

1. Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements (Whitetopping)
2. Recycled Unbound Pavement Materials
3. Investigation of Low Temperature Cracking in Asphalt Pavements - Phase II
4. HMA Surface Characteristics related to Ride, Texture, Friction, Noise, Durability
5. Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in HMA Pavements
6. Design and Construction Guidelines for Thermally Insulated Concrete Pavements
7. Incorporation of Roofing Shingles into HMA Mixes
8. Warm Mix Asphalt
9. Use of Taconite Aggregates in Pavement Applications
10. Investigation of High Performance (60 Year Design) Concrete Pavement
11. Unbonded Concrete Overlay
12. Permeable (HMA) Pavement Performance in Cold Regions
13. Pervious Concrete Overlay
14. Pervious Concrete Pavement Study (Full Depth)
15. PCC Surface Characteristics - Construction
16. Concrete Pavement Optimization – Determining the Lower Threshold of Slab Thickness for High Volume Roads
17. Intelligent Compaction Research (not part of the PCI’s construction contract)
18. Full Depth Reclamation with Engineered Emulsion (not part of the PCI’s construction contract)
19. PCC Surface Characteristics - Rehabilitation (not part of the PCI’s construction contract)

Table 2. Cell Descriptions for 2008 Construction Season

New Cell	Original Cell	Roadway	Description
2, 3, 4	2, 3, 4	Mainline	FDR with Engineered Emulsion
105, 205, 305, 405	5		Unbonded Concrete Overlay , PCC Surface Characteristics
106, 206	6		Composite Pavement (new HMA over new PCC) , 4.75 mm Taconite HMA
7, 8, 9	7, 8, 9		PCC Surface Characteristics - Rehabilitation
113, 213, 313, 413, 513	13		Thin Concrete (5” to 6.5” thick), PCC Surface Characteristics
114, 214, 314, 414, 514, 614, 714, 814, 914	14		Whitetopping (6” PCC over variable depth HMA), PCC Surface Characteristics
15	15		3” Warm Mix Asphalt Overlay
16, 17, 18, 19	16, 17, 18, 19		Recycled Unbound Base Experiment
20, 21, 22	20, 21, 22		Low Temperature Cracking Study (Fractionated RAP)
23	23		Taconite Railroad Ballast, Warm Mix Asphalt
Shoulders, transition areas	Shoulders, transition areas, 50, 51		Incorporation of Roofing Shingles into HMA Mixes
24	24	Low Volume Road	HMA Aging Study, Warm Mix Asphalt Control
39	39		Pervious Concrete Overlay
53	53		60-Year Concrete, PCC Surface Characteristics
85, 86, 87, 88, 89	25, 26		Pervious PCC & Porous HMA Pavement Performance in Cold Regions

The boundaries of each cell included in the studies outlined above are described in Table 3.

Table 3. Cell Boundaries

Cell	Road	Cell Description	Starting Station	Ending Station	Cell Length	Design Life
2	Mainline	FDR + EE	110840	111400	560	5 years
3		FDR + EE	111400	111985	585	5 years
4		FDR + EE	111985	112580	595	5 years
105		Unbonded PCC Overlay	112580	112758	178	5 years
205		Unbonded PCC Overlay	112758	112893	135	5 years
305		Unbonded PCC Overlay	112893	113043	150	5 years
405		Unbonded PCC Overlay	113043	113163	120	5 years
106		Composite Pavement	113173	113440	267	5 years
206		Composite Pavement	113440	113710	270	5 years
513		Thin Concrete	118345	118434	89	5 years
113		Thin Concrete	118434	118530	96	5 years
213		Thin Concrete	118530	118650	120	5 years
313		Thin Concrete	118650	118770	120	5 years
413		Thin Concrete	118770	118890	120	5 years
114		Whitetopping	118890	118989	99	5 years
214		Whitetopping	118989	119013	24	5 years
314		Whitetopping	119013	119151	138	5 years
414		Whitetopping	119151	119181	30	5 years
514		Whitetopping	119181	119217	36	5 years
614		Whitetopping	119217	119325	108	5 years
714		Whitetopping	119325	119343	18	5 years
814		Whitetopping	119343	119367	24	5 years
914		Whitetopping	119367	119421	54	5 years
15		WMA Overlay	119445	120018	573	5 years
16		Recycled Unbound Base + WMA	120018	120590	572	5 years
17		Recycled Unbound Base + WMA	120590	121150	560	5 years
18		Recycled Unbound Base + WMA	121150	121720	570	5 years
19		Recycled Unbound Base + WMA	121720	122280	560	5 years
20		Low Temperature Cracking/RAP	122280	122850	570	5 years
21		Low Temperature Cracking/RAP	122850	123435	585	5 years
22		Low Temperature Cracking/RAP	123435	124015	580	5 years
23		WMA on Taconite RR Ballast	124015	124585	570	5 years
24	Low Volume Road	WMA Control/Aging Study	15800	16350	550	5 years
39		Pervious PCC Overlay	9690	10230	540	5 years
53		60-Year Concrete	21085	21200	115	5 years
85		Pervious PCC on Sand	16368	16594	226	5 years
86		Porous HMA on Sand	16594	16820	226	5 years
87		Superpave on Sand/Clay	16820	17046	226	5 years
88		Porous HMA on Clay	17046	17272	226	5 years
89		Pervious PCC on Clay	17272	17498	226	5 years

The objective and construction process for each study is outlined in more detail below.

Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements (Cell 14 – Consists of Subcells 114, 214, 314, 414, 514, 614, 714, 814, and 914)

Thin (TCOAP) and ultra-thin (UTCOAP) concrete overlays of existing asphalt pavement (also known as whitetopping) are pavement rehabilitation options that have been increasing in popularity in the US over the past 15 years. The recent International Conference on Best Practices for Ultra-thin and Thin Whitetopping (April 2005) demonstrated that many states now have experience with at least a couple of completed COAP projects. The recently completed NCHRP Synthesis 338 on Thin and Ultra-thin Whitetopping also shows the use of this product is currently of great interest to the transportation community.

The one area of deficiency in the application of TCOAP and UTCOAP (TWT and UTW whitetopping) is the lack of a unified national design guide. The results from this MnROAD study and other accelerated loading facilities (ex. FHWA) can now be utilized to develop a unified comprehensive mechanistic-empirical based design method for thin and ultra-thin concrete overlays of existing asphalt pavement. This study provided an opportunity to utilize early performance data from a thin concrete overlay of a distressed full-depth asphalt pavement. Initial whitetopping test sections built at MnROAD in 1997 and 2004 consisted of HMA layers in good condition, and the new cells built in 2008 had significant amounts of transverse and longitudinal cracking in the asphalt pavement.

Construction

Cells in this study are constructed of 6” PCC over 5-8” HMA over a clay subgrade. Typical sections are shown in Figure 3 and joint layouts are shown in Table 4. Profile milling of the HMA surface on this Cell 14 was conducted on May 8th. PCI milled 6” deep on the west end and tapered to 3” deep on the west end. This provided researchers a consistent PCC surface over a variable depth HMA to determine how much asphalt needed to remain in place in order to construct a long-lasting pavement. The cell itself was overlaid on October 10th. All shoulder work was completed by late October, and topsoil grading finished November 3rd.

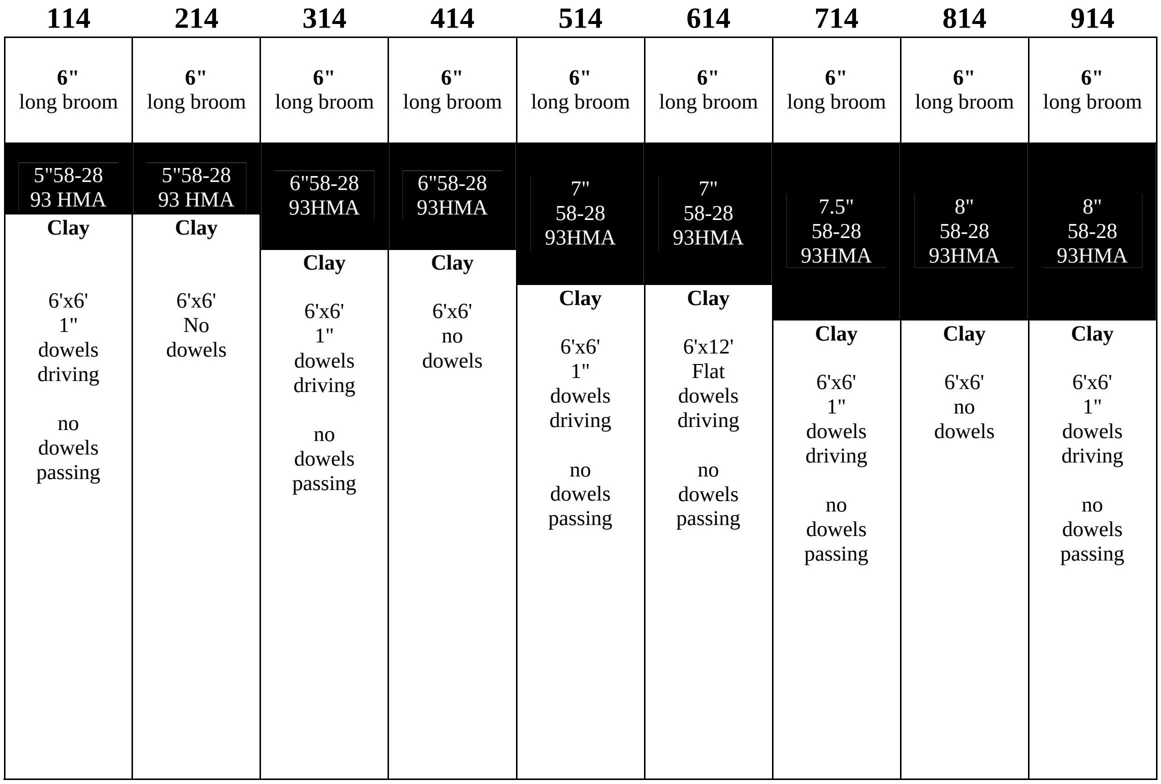


Figure 3. Typical Sections for Cell 14

Table 4. Design Parameters for Cell 14

Cell	HMA Thickness	PCC Thickness	Panel Size	Dowel Condition	
				Driving Lane	Passing Lane
114	5”	6”	6’x 6’	1”	None
214	5”	6”	6’x 6’	None	None
314	6”	6”	6’x 6’	1”	None
414	6”	6”	6’x 6’	None	None
514	7”	6”	6’x 6’	1”	None
614	7”	6”	6’x 12’	Flat plate dowels	None
714	7.5”	6”	6’x 6’	1”	None
814	8”	6”	6’x 6’	None	None
914	8”	6”	6’x 6’	1”	None

Recycled Unbound Pavement Materials (Cells 16-19)

Minnesota has had a long history of using recycled materials in pavement construction. Recycled materials have been used in all layers of the pavement, from the surface down to the unbound supporting layers. Mn/DOT's current Class 7 specification (Spec 3138) allows salvaged or recycled HMA, PCC, and glass to be used as part of the granular base materials. However, their material properties (strength, stiffness, unsaturated properties, etc.) are not well understood. Under the current design procedures, Class 7 materials are assigned the same empirical properties as a typical Class 5 (gravel) material. New mechanistic-empirical design procedures require more detailed material properties in order to accurately predict pavement performance.

The objective of this study was to monitor the performance of several test cells (numbers 16-19) constructed using recycled materials in the granular base layers, including blended with virgin materials and 100% recycled asphalt and concrete pavement materials. The material properties were monitored during construction and throughout the pavement life in order to determine their effects on pavement performance. The properties will be used to verify mechanistic-empirical design inputs, especially their variation with changing seasons and moisture regimes.

Construction

This study was part of a larger set of eight cells (numbers 16-23) that all have the same 5" of asphalt wearing course, although the asphalt mixtures changed for three of the cells. The first three of these cells are built on 12" of recycled base course material over 12" of C1ass 3, over 7" of select granular. Each has a clay subgrade. The recycled base materials include 100% recycled PCC on Cell 16, a mixture of 50% recycled PCC and 50% Class 5 on Cell 17, and 100% RAP on Cell 18. It was important for the aggregate bases of these three cells to have very similar gradations. This took some work, but was eventually accomplished. Cell 19 is has the same overall section, but the base is Class 5 aggregate used as the control section for this study.

For this study, the researchers at the University of Wisconsin installed lysimeters to measure movement of water through the base in each section. To this end, a pan lysimeter was installed in each cell to monitor the quantity of water percolating from the pavement and the concentration of trace elements in the leachate.

The lysimeter is 10 ft wide, 10 ft long, and 3 inches deep and is lined with 1.5-mm-thick linear low density polyethylene geomembrane. The base of the lysimeter was overlaid by a geocomposite drainage layer (geonet sandwiched between two non-woven geotextiles) in order to freely drain the water and to keep aggregate particles from clogging the system. MnROAD staff excavated a hole at the top of the Class 3 layer in each cell. The lysimeter was installed, and a drainage pipe was also installed off to the shoulder. The recycled aggregate base material was placed in each lysimeter and compacted prior to adding the remainder of the base layer in each cell.

University of Wisconsin researchers will conduct the environmental monitoring for this project. It consists of monitoring the volume of water draining from the pavement and concentrations of trace elements in the leachate. Water collected in the drainage layer will be plumbed to a 30-gallon insulated polyethylene collection tank buried adjacent to the roadway. The leachate will be removed periodically with a submersible pump, and the volume of water in the tanks will be recorded. A complete chemical analysis will be conducted to determine the leachate's pH, Eh, and electrical conductivity, and the samples will be filtered, preserved, and analyzed. Samples will be collected each month for the first quarter following construction and at least once quarterly thereafter for the duration of the project. Following the collection of leachate the collection tanks will be totally pumped out after each sampling event and the quantity of water recorded.

Cell 19 is unusual in that it contains multiple strain and moisture gauges; a mini instrumentation rodeo of sorts in that we will perform direct comparisons of different brands and types of sensors. Figure 4 shows the typical section for each cell in this study.

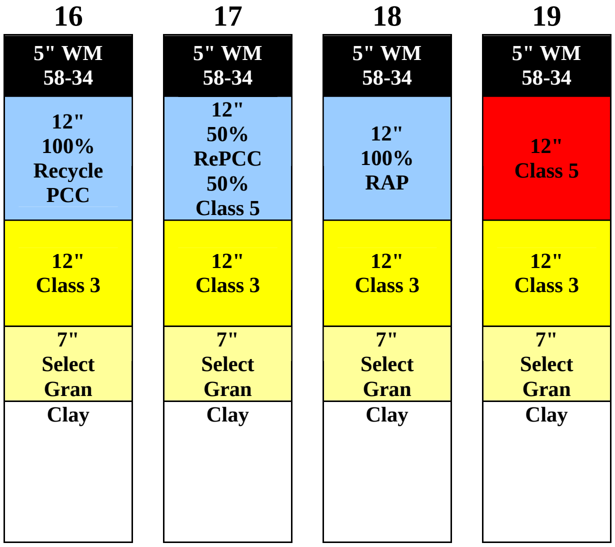


Figure 4. Typical Section for Cells 16-19

The contractor began milling Cells 16-19 May 7, removing all HMA material to 8" deep. Milling was complete by early June. The Class 3 aggregate material removed from Cells 16-19 was salvaged and reused in Cells 16-23. Clay subgrade material was also salvaged and reused on Cells 6 and 13.

The subcut was complete in late June, and the IC roller was used to measure compaction on several layers: subgrade, select granular, subbase and aggregate base. The IC measurements were followed up with FWD, LWD, and DCP testing for all materials. Aggregate base layers were constructed in late August and early September, and the cells paved September 15th.

The plans called for the select granular materials to have a minimum 15% passing the #200 sieve. PCI planned to accomplish this by reclaiming the HMA and aggregate base from Cells 21-23. An initial gradation of the stockpiled material to be used for these cells showed 100% passing the 1" sieve, and 3.3% passing the No. 200. Additional fine material was needed to get to 15-20% material passing the No. 200 sieve. However, after discussion with researchers and field staff, MnROAD staff decided to use select granular “as is” without dirtying it up. PCI miscalculated their materials needs, and the final select granular material was a blend of 50% reclaimed material and 50% salvaged class 3. This blend has approximately 8% passing the No. 200 sieve.

See the following three plots for gradation curves of select granular, Class 3 aggregate subbase, and Class 7/5 aggregate base materials, respectively.

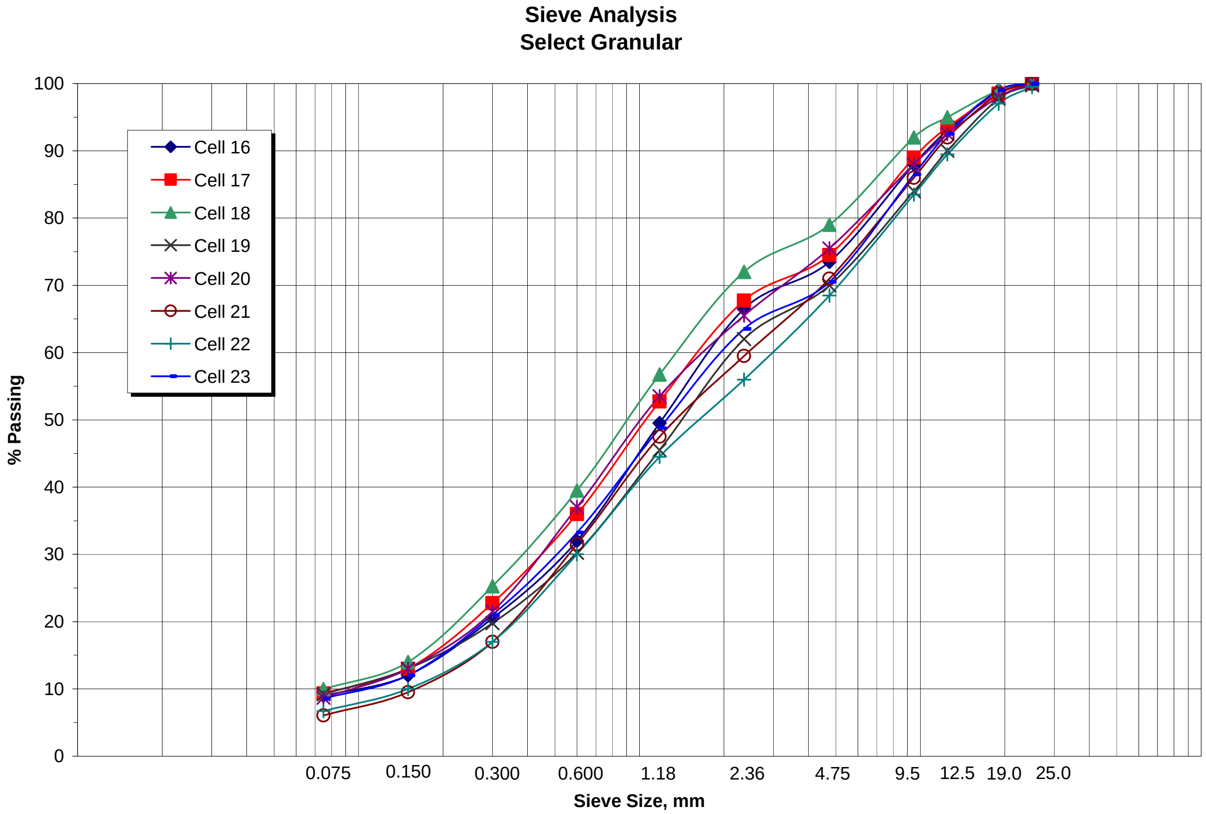


Figure 5. Gradation Data for Select Granular on Cells 16-23

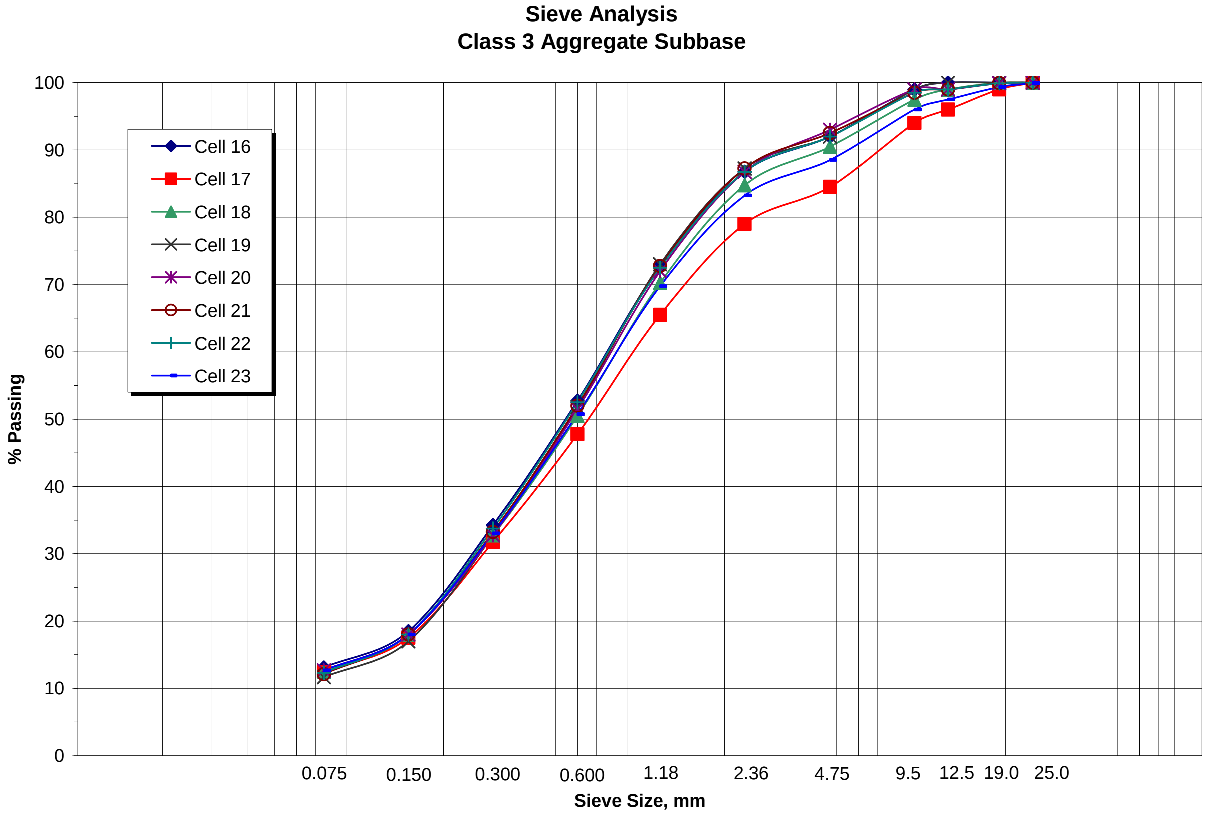


Figure 6. Gradation Data for Class 3 on Cells 16-23

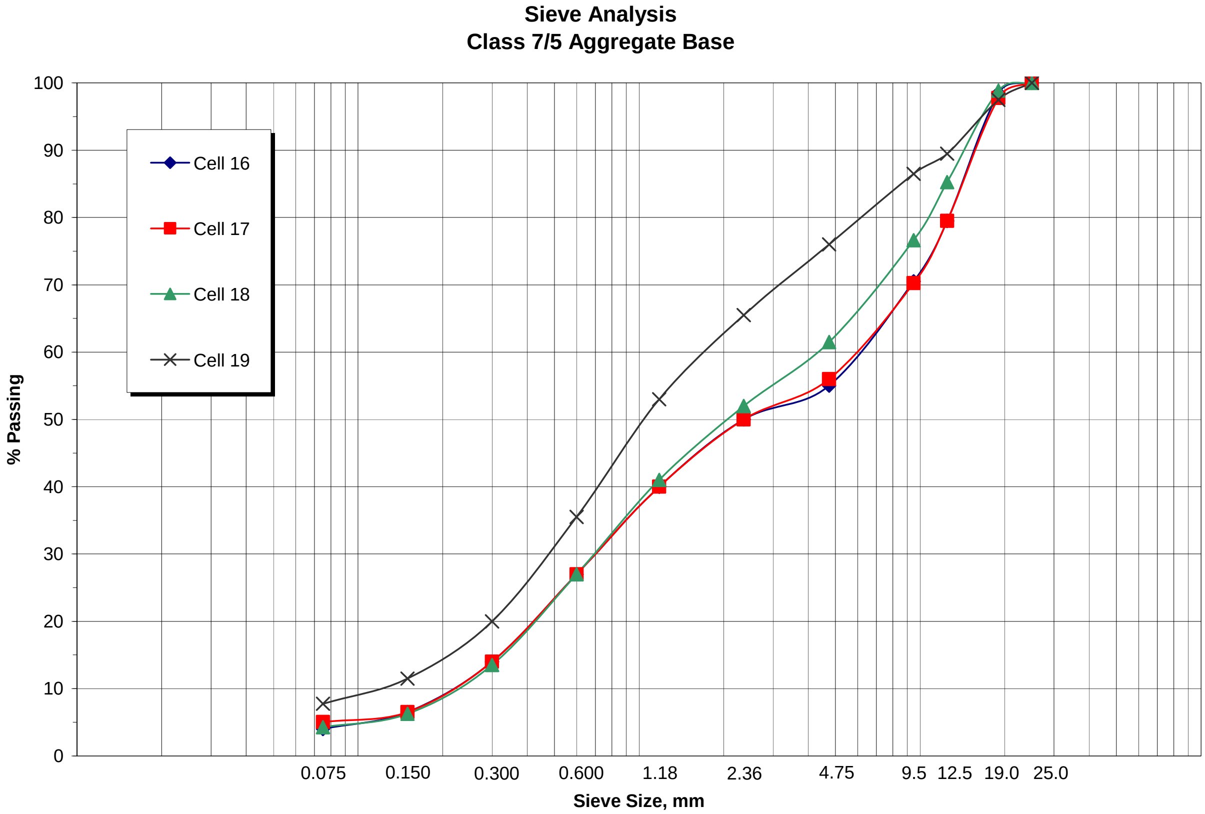


Figure 7. Gradation Data for Class 7 (Cells 16-18) and Class 5 (Cell 19)

Investigation of Low Temperature Cracking in Asphalt Pavements - Phase II (Cells 20, 21, 22)

Low temperature cracking is the most prevalent distress found in asphalt pavements built in cold weather climates. As the temperature drops the restrained pavement tries to shrink. The tensile stresses build up to a critical point at which a crack is formed. The current Superpave specification attempts to address this issue by specifying a limiting low temperature for the asphalt binder. The specification does a reasonable job predicting performance of conventional asphalt cements, but this does not hold true for polymer-modified asphalt binders that are manufactured to reach very cold temperature grades needed in cold climates. Currently the low temperature specification considers only the asphalt binder. Specifications must be developed for the asphalt mixture as well. It is very important to understand the mechanism of crack initiation and propagation. Thermal cracks can be initiated by traffic loading or cycles of temperature changes and then propagated by a large drop in temperature.

The main objective of this study was to validate the laboratory test procedures, models, and pavement design procedures that came out of Phase I of this study. This will be accomplished by monitoring new test sections at MnROAD that contain an assortment of asphalt binder grades and mixture types. Phase I was aimed at developing a fracture mechanics-based specification for a better selection of asphalt binders and mixtures with respect to their resistance to crack formation and propagation. This fracture mechanics approach will also be used to investigate the detrimental effects of aging and moisture on the fracture resistance of asphalt materials.

Construction

This study was also part of a larger set of eight cells (numbers 16-23) that all have the same 5” of asphalt wearing course, although the PG grade varies. This set of three cells are all built on 12” of Class 5 over 12” of class 3 over 7” of select granular. Cell 20 incorporates a 30% non-fractionated RAP material in the HMA mixture. Cells 21 and 22 are built on a mixture with 30% fractionated RAP split on the ¼” screen. Cells 20 and 21 have a PG grade of 58-28 and Cell 22 has a PG grade of 58-34. Figure 8 shows the typical section for each cell in this study.

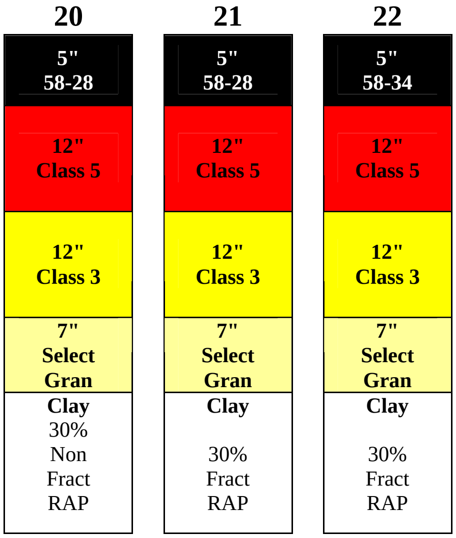


Figure 8. Typical Sections for Cells 20-22

Milling on Cells 20-21 began May 7th and continued into June. The aggregate base materials were subcut the first and second weeks of June. These cells were also used in the Intelligent Compaction specification verification study, and were rolled with the IC roller on both the passing and driving lanes. Each IC test roller pass was followed by testing with the FWD, LWD, and DCP. After the clay subgrade was tested with the IC roller, select granular was placed beginning June 17th and 18th. Sensor conduits were installed, and the IC roller was again used to test the compaction of the select granular layer. Class 3 and 5 aggregate base was placed in late June, and these materials were also tested using the IC roller and subsequent verification tests.

Table 5. Fractionated RAP Asphalt Mixtures

Cell	Mn/DOT Mix Type[1]	Description	PG Grade	RAP
20	SPWEB440B	wear	58-28	30% non-fractionated
20	SPNWB430B	non-wear	58-28	30% non-fractionated
21	SPWEB440B Special	wear	58-28	30% fractionated
21	SPNWB430B Special	non-wear	58-28	30% fractionated
22	SPWEB440C Special 1	wear	58-34	30% fractionated
22	SPNWB430C Special 1	non-wear	58-34	30% fractionated

[1] See Mn/DOT Specification 2360 for a description of mixture designations: http://www.dot.state.mn.us/pre-letting/prov/order/2360-2350-combined.pdf

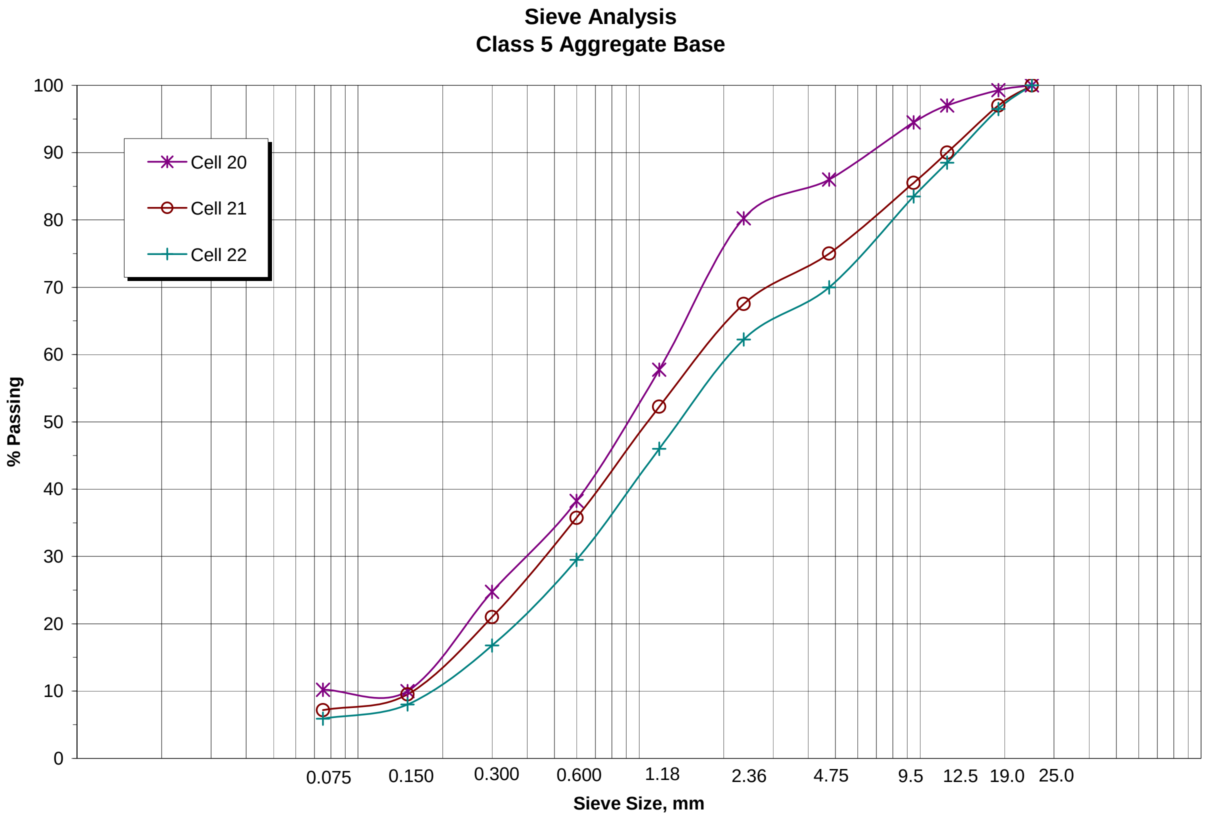


Figure 9. Class 5 Aggregate Base Gradations for Cells 20-22

HMA Surface Characteristics related to Ride, Texture, Friction, Noise, Durability (Cells 86, 87, 88 on the LVR, and Cells 2, 3, 4, 6, 19 on the Mainline)

Increased attention has been paid recently to hot mix asphalt pavement surface characteristics. In addition to structural capacity and durability, it is now desirable to design pavements to meet noise, texture, friction, and ride requirements. Noise (both interior and roadside) is at the forefront of the minds of both pavement designers and the traveling public. Many studies are currently underway around the US and in Europe to address noise and these other issues.

This research project followed two tracks:

1. Construction of new HMA pavements using porous HMA, 4.75-mm Superpave mix , and Novachip specifically for the purpose of reducing the noise while maintaining other important surface characteristics.
2. Monitoring all the new test cells built at MnROAD for their noise, texture, friction, and ride characteristics.

Cells 2 and 3 on mainline each were constructed using a 1” Novachip surface over 2” of level 4 Superpave with a PG grade 64-34. Each was constructed over 6” of full depth reclaimed surface course treated with and engineered emulsion. Cell 4 had 3” of the same Superpave mix as in Cells 2 and 3 over 8” treated FDR. Cell 19 was another standard Superpave mixture (PG 58-34) over gravel base material. Cell 6 is a 4.75 mm Superpave mix composed of taconite aggregates and a PG 64-34 binder.

Cells 86 and 88 on the low volume road were constructed of 5” pervious HMA with PG 70-28 binder. Cell 87 is a control level 3 Superpave mix with PG 58-28 binder. See Table 6 for a summary of each mix.

Table 6. Asphalt Mix Designs

Cell	Surface Mix Type[1]	Description	PG Grade	RAP
2, 3	Novachip		64-34	None
4	SPWEB440F	Level 4 Superpave	64-34	None
6	SPWEB440F Special	4.75 mm Taconite HMA	64-34	None
19	SPWEB440C Special	Warm Asphalt Wear Course	58-34	20%
86	SPWEB440H Special 1	Porous Asphalt	70-28	None
87	SPWEB340B	Level 3 Superpave	58-28	30%
88	SPWEB440H Special 1	Porous Asphalt	70-28	None

[1] See Mn/DOT Specification 2360 for a description of mixture designations: http://www.dot.state.mn.us/pre-letting/prov/order/2360-2350-combined.pdf

Construction

Figure 10 shows the typical section for each cell in this study. Descriptions of the construction of each cell can be found in the appropriate sections in this chapter. The HMA Surface Characteristics study incorporated HMA mixes into other research projects

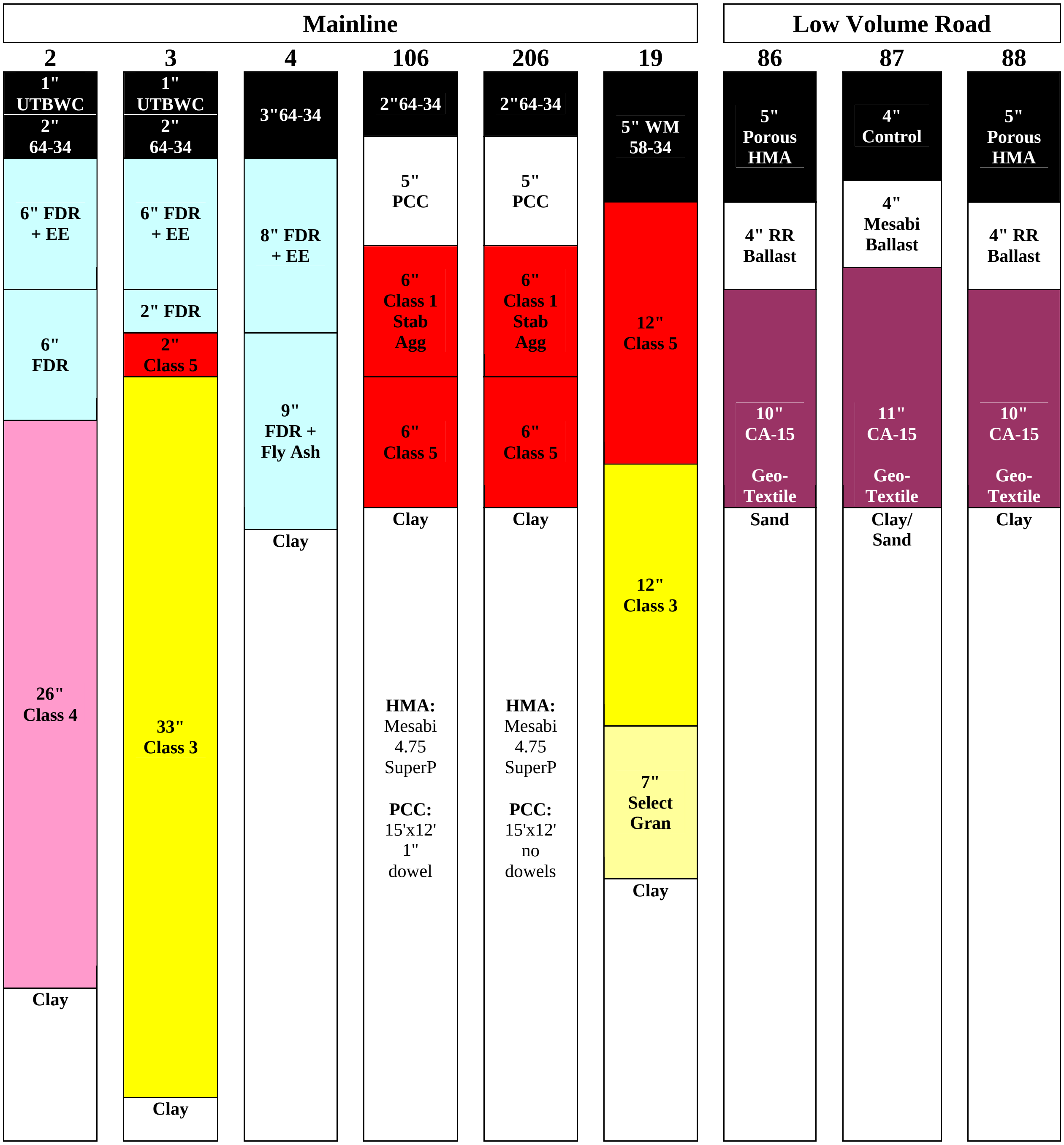


Figure 10. Typical Sections for HMA Surface Characteristic Study

Incorporation of Roofing Shingles into HMA Mixes (Mainline Shoulders and Transition Areas)

For the past few decades highway departments have been cooperating with the paving industry and local solid waste environmental groups to incorporate both manufactured shingle scrap (MSS) and, more recently, tear-off shingle scrap (TOSS) into asphalt pavement structures. Since the completion of a number of projects, several concerns have arisen, including:

1. Increasing landfill disposal, construction and asphalt binder costs make the use of TOSS and MSS more attractive.
2. Mn/DOT shingle specification presently allows a 5% replacement for the RAP allowed in HMA mixes. Field performance of RAS mixes indicates too little new asphalt binder is being added to the mixes (premature failures).
3. The use of RAS can lead to brittle mixes. Although use of soft virgin asphalt binder or softening agent can be used to counteract the RAS stiffness problem not much research has been done on the effect of softening agent or amounts of softer binder that can be added to maximize the use of RAS in the mixes.

In this study, a matrix of mixes using Tear-Off Scrap shingles (TOSS), Manufacturer Waste recycled shingles (MWS) and Recycled Asphalt Pavement (RAP) was analyzed for asphalt binder and mixture properties. Recovered asphalt and shingle binder were tested for high and low temperature properties, and stripping and thermal cracking characteristics determined on laboratory and production recycled asphalt shingles (RAS) HMA specimens. The study will attempt to determine the contribution of RAS and RAP binder to final binder properties, as well as minimum and maximum asphalt content and recycled material limits for quality RAS HMA mixes.

In addition, a survey of the field performance of RAS/RAP mixtures used in Minnesota was conducted to help verify laboratory evaluation. A portion of this work was conducted by placing two shingle mixes on the mainline shoulders and transition areas.

Construction

Early in the project, Hardrives contacted Mn/DOT with a proposal to substitute the shoulder mix using conventional RAP with two shingle mixtures. The East transition area and outside shoulders on Cells 15-23 were paved with a mix containing 5% tear-off shingles. The West transition area and both shoulders on Cells 5, 6, 13, and 14 were paved with a mix containing 5% manufactured waste shingles. Neither mix incorporated any other RAP, and each included PG 58-28 binder.

The shoulders on Cells 15-23 were paved with relative ease, as there were no obstacles to the paver. However, paving the outside shoulders on Cells 5, 6, 13, and 14 was more challenging. This was primarily due to LVDT boxes, maturity meter sensors, and other instrumentation present. Some hand work and special protective measures were required to complete the paving. The inside 4’ shoulder on Cells 5, 6, 13, and 14 was paved with a shouldering machine.

Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in HMA Pavements (Cell 24)

A major objective for any transportation agency pavement management system is to select the appropriate alternative for rehabilitation and maintenance. Users need to understand how preventive maintenance improves the performance of the existing pavements, to develop new techniques, and to determine the optimal timing for the application of these treatments.

The progression of the asphalt pavement surface condition is mostly related to the aging characteristics of the asphalt binder and to the evolution of the mechanical properties of the binder with aging. An ongoing project at the University of Minnesota investigates several issues related to the application of surface treatments, including environmental (climatic) modeling and mixture and binder testing to determine when preventive maintenance activities should be done. The results of this study should lead to recommended guidelines on the timing and value of preventive maintenance applications to HMA pavements.

The goal of this study was to determine the proper timing of preventive maintenance treatments in order to optimize life cycle costs and pavement performance. Environmental aging of the asphalt binder in the underlying pavement is not well understood, and this project sought to better understand the aging mechanism and how it can be reduced through pavement preservation. A portion of this study will be conducted on Cell 24. Fog or chip seals will be placed on the pavement in 100-ft subsections in successive years according to Figure 12. The mix doubles as the warm mix asphalt control section containing PG 58-34 binder without the warm mix additive.

Construction

Cell 24 was constructed with 3 inches of HMA, built on a class 6 aggregate base and sand subgrade. Milling of the existing bituminous surface for this section began on June 24th. Final grading occurred in early October, and the cell was paved October 16th. A fog seal was placed on a 100-foot subsection in late October with CSS-1 emulsion because it was too late in the season to obtain CRS-2P for a chip seal.

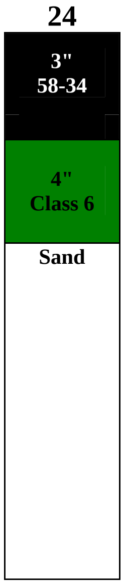


Figure 11. Cell 24 Pavement Structure

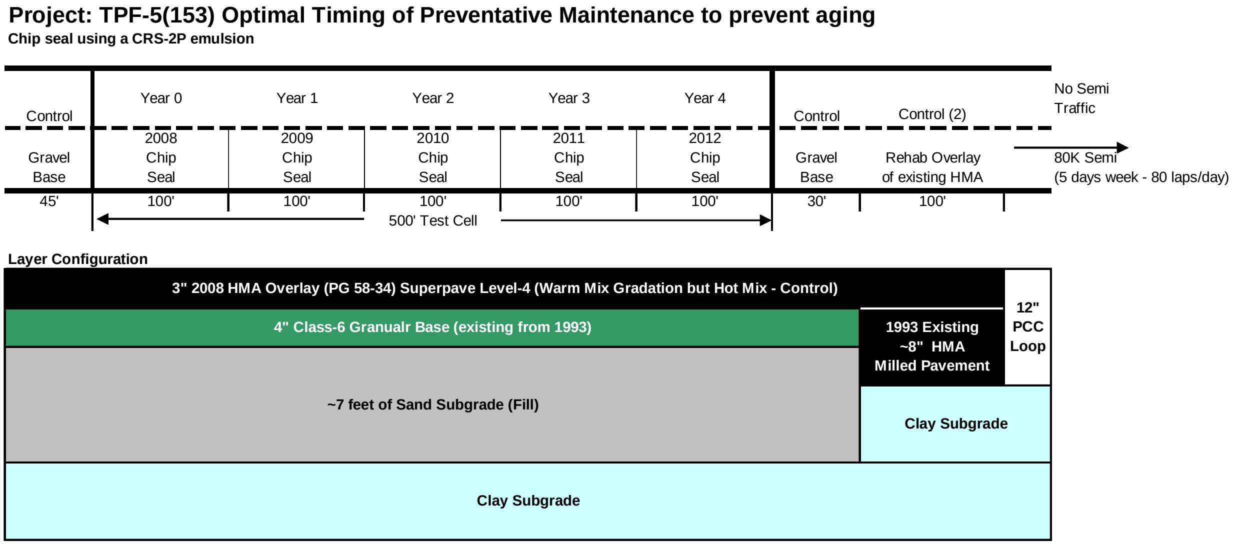


Figure 12. Cell 24 Preventive Maintenance Plan

PCC Surface Characteristics - Rehabilitation (Cells 7, 8, and 9)

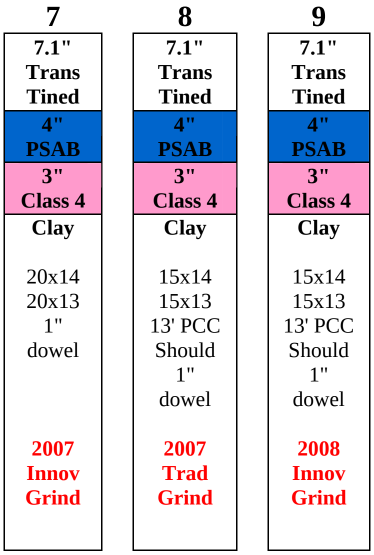
People desire smooth, quiet, and safe pavements. To encourage smooth pavements, the effects of other important pavement performance parameters on ride must be quantified, including texture, noise, and friction. An understanding of the interaction of texture and ride is still very rudimentary. In 2002 the Mn/DOT Concrete Engineering Unit and the Concrete Pavers Association of Minnesota created a test section on TH 212 at Bird Island to study the effects of texture and joints in pavement smoothness. The results showed that profile index was affected by texture and joints. However, data is so far insufficient to define a global correlation between texture values and their effect on ride, and the results obtained for the effects of joints on ride were not conclusive because of unanticipated construction issues.

At the same time, one option is for rehabilitating Portland cement concrete pavements without the need to restore structural capacity is to diamond grind the surface. This process removes much of the pavement roughness and restores texture and friction. Many variables play into the grinding operation, such as blade spacing, depth of cut, kerf configuration, etc. These parameters affect and govern the preponderant frequencies that cause noise when such frequencies are not randomized. Power spectrum density analysis of results obtained in the Bird Island Test section as well as profilometer-generated roughness showed that diamond grinding did improve the ride. The resulting texture and noise were not measured until 2005 when the FHWA PSC study team measured the site. Minor changes in the geometry of diamond grinding equipment tremendously affect the friction and noise performance, but the optimum geometry is still unknown.

The research for this project was conducted as a multi-state pooled fund project. Texas and Federal Highway Administration are participating in the project. Research findings will enable Mn/DOT to specify friction, ride, and texture ranges of values that will optimize quietness, ride, texture and friction in program delivery. It will reduce the incidence of uncomfortable ride, hydroplaning, and obnoxious whines. The average road user will benefit from the results of this study. Research outcomes will facilitate a family of curves and algorithms that will address the optimization for giving good friction.

Construction

The innovative grinding techniques used at MnROAD were developed at Purdue University and brought to MnROAD for field validation. This work included "proof testing" on Cell 37 with both traditional and innovative grinding before grinding the Mainline test sections. Concrete on Cells 7 and 8 were ground in 2007. Details are outlined in the construction report for that construction season (see www.dot.state.mn.us/materials/researchdocs/ReportDiamondGrinding.pdf). The contractor returned to the project and used a new and improved technique to grind Cell 9 on October 8th. Figure 14 shows the diamond grinding on Cell 9. Also note that Cell 5 was diamond ground on November 5th, 2009, because the surface texture on the newly-constructed pavement did not meet the minimum requirements.



7	8	9
7.1" Trans Tined	7.1" Trans Tined	7.1" Trans Tined
4" PSAB	4" PSAB	4" PSAB
3" Class 4	3" Class 4	3" Class 4
Clay 20x14 20x13 1" dowel 2007 Innov Grind	Clay 15x14 15x13 13' PCC Should 1" dowel 2007 Trad Grind	Clay 15x14 15x13 13' PCC Should 1" dowel 2008 Innov Grind

Figure 13. Typical Sections on Cells 7-9

Figure 14. Cell 9 Diamond Grinding

Warm Mix Asphalt (Cells 15, 16, 17, 18, 19, 23, 24)

The Warm Mix Asphalt (WMA) study at MnROAD initiated from the desire of Mn/DOT researchers to demonstrate the potential benefits of WMA to other Mn/DOT staff. By placing WMA at MnROAD, the results of the study will be disseminated to a wider audience of city and county engineers, consultants, contractors, and researchers throughout Minnesota and the entire country. Many environmental, health, and construction-related benefits are realized by the use of WMA, and MnROAD staff are most interested in its potential for better low temperature cracking performance. Thermal cracking is the predominant mode of distress of HMA pavements in Minnesota, and the study hypothesizes that the reduced level of oxidation at the mix plant will lead to better long-term pavement performance. Other performance measures such as rutting, fatigue cracking, top down cracking, and ride will be monitored.

The WMA was placed on six test cells on the MnROAD Mainline. The mix was a level 4 Superpave (3-10 million ESALs) with PG 58-34 binder and 20% RAP. Five cells consist of 5" WMA (3" wear, 2" non-wear) over 12" recycled aggregate base, 12" aggregate subbase, 7" select granular, over a clay subgrade. A single asphalt mixture was needed to cover all five cells for a recycled aggregate base pooled fund study, on Cells 16-19 and 23. The sixth cell (Cell 15) consisted of a 3" WMA overlay of an existing HMA pavement, which represents a "typical" rehabilitation strategy in Minnesota. A control cell for WMA on the Low Volume Road (Cell 24) was also included in the study. The control mix has same mix design as the WMA but produced at typical HMA temperatures without the additive. Results of the study will include the performance of WMA vs. HMA under traffic and environmental loading conditions.

Construction

During construction, Hardrives chose the Evotherm 3G product because of its ease of use. This product is a chemical-based additive that does not use any water but still promotes coating at lower temperatures. Mathy Construction mixed the WMA additive directly into the binder at the terminal, and they shipped the ready-made binder to Hardrives in a tanker, where it was hooked up directly to the drum for mixing.

Operations at both the plant and the paver ran smoothly. The HMA plant simply had to turn down the temperature on the burner to roughly 50°F lower than normal HMA temperatures. Plant personnel noticed fewer fumes and emissions from the warm mix as well as lower burner fuel consumption. Likewise, the paver and roller operators noticed fewer fumes and emissions during paving. Density was achieved with less compactive effort than normal. The only concern was that the new mat was still slightly soft the following morning. At MnROAD this was fine, but it could pose problems in a typical mill-and-overlay situation where it was expected to open up to traffic quickly after paving.

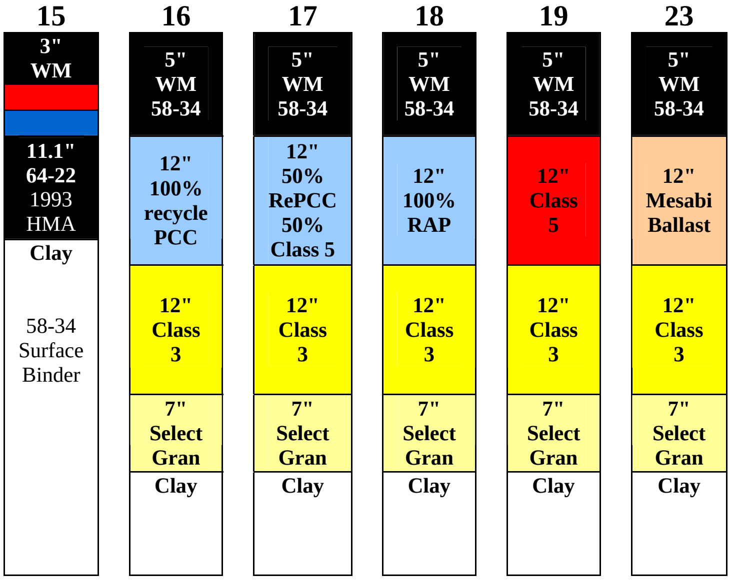


Figure 15. Typical Sections for Cells 15-19, 23

Cell 15 was overlaid September 15th, with no prep work prior to paving other WMA cells at the same time.

Use of Taconite Aggregates in Pavement Applications (Cells 6, 23)

Expansion and maintenance of roadway infrastructure creates a demand for high quality paving aggregates, which are becoming more scarce in many parts of the country. Taconite industry waste rock and tailings are a potential new source of virgin paving aggregates. Currently there is limited information available for implementing these products in construction design specifications.

In 2004 Mn/DOT began a partnership with the Minnesota Department of Natural Resources in order to evaluate Mesabi Select aggregates for use in asphalt mixtures. Part of this evaluation included construction of a Superpave Traffic Level 2 mixture composed of Mesabi aggregates on the MnROAD Low Volume Road. A follow-up project with the Natural Resources Research Institute at the University of Minnesota at Duluth included continued monitoring of this LVR test cell (along with a concrete cell also constructed with taconite aggregates), support for new construction using taconite aggregates, and other maintenance treatment trials.

The main goal of this coordinated research effort was to determine if taconite aggregates can be practically used in pavement construction projects. The issues involve both engineering/ material properties and economics/logistics of transportation. Several questions that need to be answered include:

- Can taconite aggregates be used (either exclusively or in combination with other aggregates) in the production of “typical” HMA and PCC mixtures?

- What engineering properties (texture, friction, strength, etc.) of the aggregates can be used to our advantage to build premium pavements? Possibilities include SMA, Novachip, microsurfacing, or quiet pavements.
- What are the differences (size, shape, texture, mineralogy, etc.) between each taconite aggregate source? All taconite aggregates are not the same.
- What is the quality of the bond between taconite aggregates and asphalt binder (HMA) or paste (PCC)? Work on surface energy conducted at Texas A & M may be applicable here.
- Should payment schedules be adjusted because of the increased bulk specific gravity (G_{sb}) of the taconite?

One cell on the Mainline (Cell 6, which is broken into subcells 106 and 206) was constructed to investigate the performance of a fine aggregate asphalt mixture using a blend of two Taconite Tailing aggregates and a locally manufactured sand. Fine mixtures, such as 4.75-mm HMAs, have recently received attention due to their potential for surface course and thin lift applications. It was placed as a surface layer on a new concrete section, making a composite pavement test section. The evaluation included the performance of the taconite HMA overlay, its surface characteristics for noise, ride and friction, and as a composite pavement (warp, curl, reflective cracking).

The other application of taconite aggregates was the use of railroad ballast material as an aggregate base under an asphalt pavement on Cell 23 on the Mainline.

Construction

All taconite aggregates were delivered by RailMate trailers, which are pulled first by train and then by truck. NRRI arranged for the ballast to be delivered to the MnROAD stockpile area in two shipments. They also had the two tailings products delivered directly to the Hardrives plant in Becker.

Cell 6 was built over a clay subgrade that became very soft during construction. It was difficult to obtain compaction over this soft clay subgrade. This soft clay was removed, and class 5 aggregate base was installed in its place, followed by 6" of stabilizing aggregate. Five inches of concrete pavement was then placed, followed by 2" of HMA on October 30, 2008. The surface layer consisted of a taconite HMA mixture. Removals for this cell began April 28th and continued all the way into July. The class 5 aggregate base was placed and tested with the intelligent compaction (IC) roller in mid September.

Cell 23 is built using 12" of Mesabi ballast over 12" of class 3 aggregate base, as shown in Figure 16. It is paved with 5" of warm mix asphalt. Milling on Cell 23 began May 7. It was subcut on June 23rd and Georolls for the cell arrived the same day. The subcut was tested using the IC roller, FWD, LWD, and DCP testing. There was one soft spot on Cell 23 by the driveway entrance ramp that was repaired. Conduit was placed shortly after that. The IC roller again tested the select granular material, and class 3 aggregate. Fabric was placed between the class 3 aggregate base and taconite ballast on Sept. 8th and 9th, followed by the ballast. The ballast was pushed into place by a dozer and rolled vigorously to "seat" the aggregate. Researchers later discovered that this compactive effort actually fractured many of the particles in the lower part of the layer. The cell was paved September 15th. The HMA quantities on the bottom lift overran by about 30% due to loss into the voids in the ballast. Figure 17 shows the taconite ballast placed and being rolled.

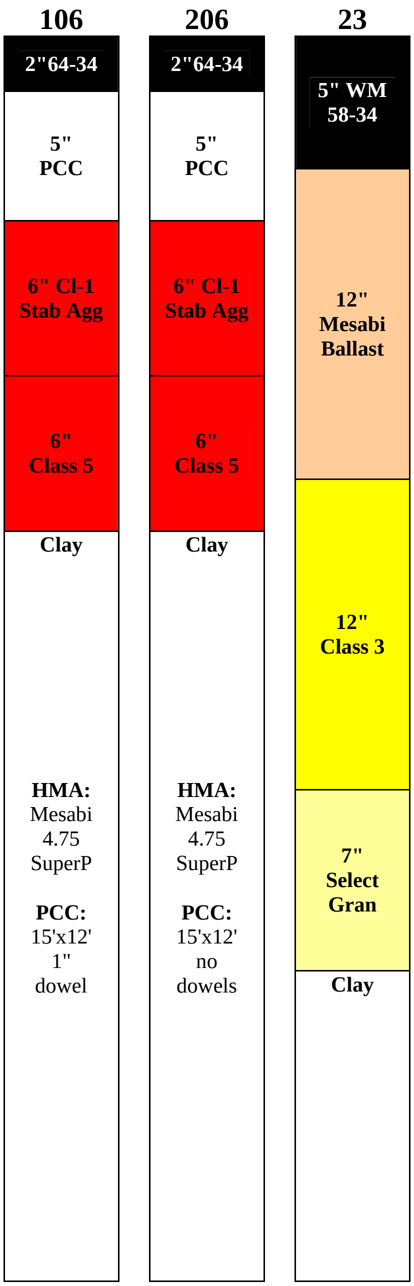


Figure 16. Typical Sections of Cells Using Taconite Aggregates

Figure 17. Cell 23 Taconite Railroad Ballast

Investigation of High Performance (60-Year Design) Concrete Pavement (Cell 53)

Due to increased traffic congestion and reduced highway construction budgets, emphasis is now being placed on designing and constructing longer life pavements. For concrete pavements, the new goal for urban high volume highways in Minnesota is toward a 60-year design life. Using the current Mn/DOT design guide for concrete pavement design (based on 1986 AASHTO Design Guide), Mn/DOT is now constructing what is believed to be 60-year design concrete pavements. However, during the design process, both the traffic prediction and service life of the concrete pavement is being extrapolated far beyond the available charts in the current design method. This research will strive to improve Mn/DOT's concrete pavement design method by measuring and characterizing the actual stresses and strains experienced by the 60-year design pavements currently being built in Minnesota.

This study had the following objectives:

- Construct a 60-year design concrete pavement test section on the Low Volume Road. Early planning discussions included constructing half of the test cell during the day, and the other half at night, to understand the effect of built-in curl on the long-term behavior of 60-year design concrete pavements. The cell was built entirely during the day.
- Construct thin concrete shoulders without any steel reinforcement to demonstrate the feasibility of this pavement type for shoulders.
- Instrument the test cell to measure the stresses, strains, and deflections experienced by a thick 60-year design concrete pavement (similar to what is currently being built throughout the Metro area) and compare it to thinner traditional designs.
- Develop improved performance prediction models that can be incorporated into the current Mn/DOT concrete pavement design method, or the new MEPDG when it is adopted.

Construction

Cell 53 consists of a 12” transverse broom PCC finish with 1.5” stainless steel dowels over 5” of class 5 aggregate base and 36” of select granular salvaged from Cell 25. The subgrade section was modified during construction to avoid MnROAD power & communication cables. PCI cut straight down from the outside shoulder and ran a 1% cross slope on the subgrade all the way to the inside ditch. This cell also has 3” PCC shoulders. Removals began April 28th along with existing concrete breakup. The concrete wasn’t actually removed until September 8th, and the cell subcut was completed September 11th, 2008. Grading took place after that, and the section was paved October 16th. The shoulder work was completed after that, with completion in late October.

Figure 18 shows the typical section of Cell 53, and Figure 19 shows instrumentation and dowel bars laid out before concrete paving.

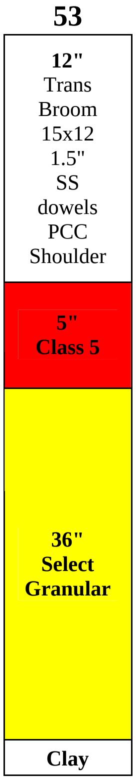


Figure 18. Cell 53 Typical Section

Figure 19. Cell 53 Sensor and Dowel Bar Layout

Unbonded Concrete Overlay (Cell 5: 105, 205, 305, 405)

An unbonded overlay, or unbonded concrete resurfacing, is a rehabilitation method that is typically used to restore the ride and structural capacity of an older distressed concrete pavement. The behavior of this complex system is currently not well understood, and consequently the design of unbonded concrete overlays has traditionally been conservative, usually consisting of a 7-8” thick concrete layer placed over a 1.0-1.5” thick bituminous stress relief interlayer. The bituminous interlayer serves two important functions in the pavement system: stress relief and cushioning. The interlayer relaxes built-up stresses from the underlying concrete pavement caused by the movements of joints, cracks, and other discontinuities, thus retarding or preventing the onset of reflective cracking in the upper layer, which is a critical distress mechanism of pavement overlays. The interlayer is not a “bond breaker” per se, as it should provide a sufficient amount of friction to facilitate joint formation in the upper concrete layer and in the case of thin unbonded resurfacings facilitate the transmission of loads from the upper concrete layer to the underlying concrete to provide structural support. The interlayer provides cushioning that helps to lessen the damage done to curled and warped concrete slabs as they are loaded by heavy vehicles. Permeable asphalt stabilized stress relief course (PASSRC) has come to be accepted as Mn/DOT’s standard interlayer in unbonded concrete overlays.

Recent Mn/DOT unbonded concrete overlay projects were built with the aim of increasing structural capacity over concrete in good condition. We have always been faced with the challenge of placing pavements with unskewed joints over pavements with skewed joints because of the perceived tendency for the skewed joints to forcibly reflect upwards. To address this scenario, the study will create controlled and measurable joint deterioration by demolishing select joints in the existing substrate. This will be overlaid with a bond breaker and by an unbonded overlay.

The study objectives were as follows:

- Create distressed joints at predetermined locations by eliminating load transfer.
- Construct very thin (4”) and a thin (5”) unbonded concrete overlay on MnROAD test Cell 5.
- Collect and analyze sensor measurements including maturity, dynamic and environmental strain, displacement, slab warp and curl, joint load transfer efficiency, joint faulting, and water flow through the pavement layers.
- Frequently (at least seasonally) monitor surface distress and ride quality of the test cell for a 5-year period.
- Conduct 1, 3, and 5-year performance surveys and prepare, publish, and present research reports and papers based on the findings.
- Recommend changes to Mn/DOT standard specifications, special provisions, manuals, and other implementation pathways.

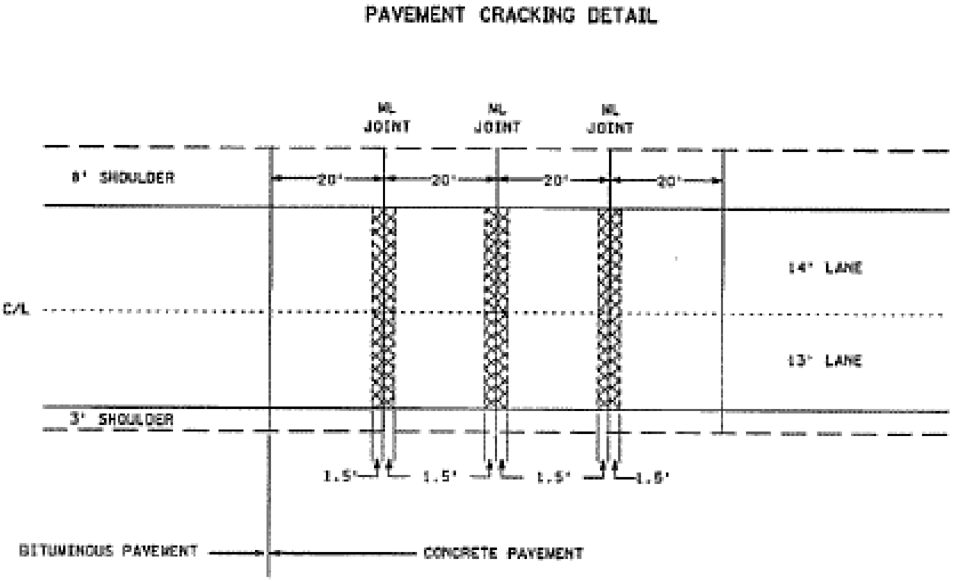
Construction

The existing pavement in Cell 5 was constructed in 1993 and consisted of 7.1” of PCC placed over 3” class 4 aggregate base over 27” class 3 aggregate subbase over a clay subgrade. This pavement had 20’ long (1’ skew) by 13’(passing lane) or 14’ (driving lane) wide panels and bituminous shoulders. The longitudinal joints were reinforced and sealed with bituminous hot pour sealant. The transverse joints had 1” dowels and were sealed with neoprene sealant.

Cell 5 was overlaid with an experimental thin unbonded concrete resurfacing treatment. This experimental design consisted of slab thicknesses of either 4” or 5” and panels that were 15’ long (no skew) by 13’ (passing lane) or 14’ (driving lane) wide. The bituminous shoulders were reconstructed during this project as well. The longitudinal joints were reinforced but not sealed. The transverse joints were neither doweled (due to the thin pavement thickness) nor sealed. The interlayer consisted of 1” PASSRC.

Cell 5 consists of four distinct subcells that were designed to experimentally isolate the effect of thickness (4” and 5”) and joint condition (distressed or intact) on performance (see Figure 22). Prior to construction, eight of the existing joints in two of the subcells were distressed with a “Road Warrior” guillotine pavement breaker at a rate of 4 drops at each joint location, with 4 passes to cover the entire 27’ wide joint (see Figures 20 and 21). Conduits for the electronic sensors were installed on July 21, and the overlay was paved on October 8th. 126 lineal feet of horizontal strip/wick drains (1” high x 12” wide) spaced at 100’ intervals was placed on each side of the cell under the HMA shoulders and class 5 aggregate base, with the purpose of draining the PASSRC layer.

Figure 20. Guillotine Pavement Breaker



CRACKING PLAN
1125+80 TO 1127+30 INDUCED CRACKING AT JOINTS (8 JOINTS)
1127+30 TO 1128+95 NO CRACKING-CONTROL SECTION (8 JOINTS + 2 TRANSITION)
1128+95 TO 1130+45 INDUCED CRACKING AT JOINTS (8 JOINTS)
1130+45 TO 1131+72.5 NO CRACKING-CONTROL SECTION (6 JOINTS)

NOTE: NO CRACKING ADJACENT TO BITUMINOUS PAVEMENT. CRACKING SHALL BE BE PERFORMED ON MAINLINE (27' WIDTH) ONLY.

Figure 21. Pavement Cracking Detail

After paving was complete, MnROAD staff measured low texture and friction numbers, and longitudinal tining could not achieve sufficient friction. The cell was diamond ground to achieve sufficient friction, and the cost was split cost 50/50 between the contractor and MnROAD. This work was done November 5th.

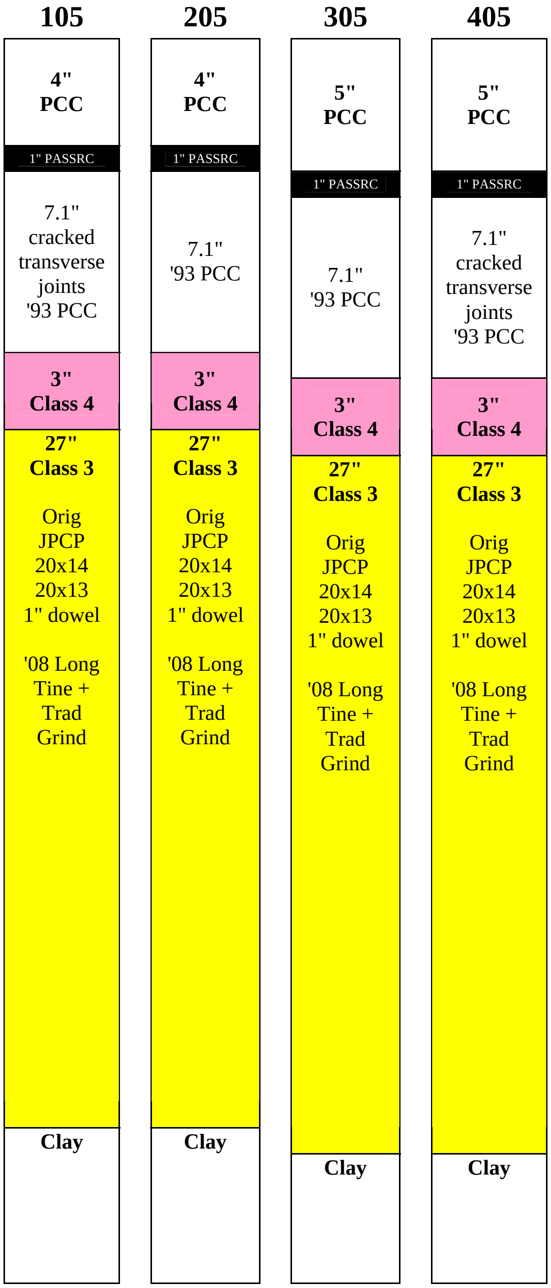


Figure 22. Cell 5 Typical Sections

Design and Construction Guidelines for Thermally Insulated Concrete Pavements (Cells 106, 206)

Thermally insulated concrete pavements (TICP) consist of a concrete pavement structure (jointed or continuously reinforced) covered by an asphalt layer during construction (before opening to traffic) or soon after construction to address ride quality or surface characteristic issues. Thin asphalt overlays of the existing concrete pavement encompass many of the same ideas as TICPs, and they were considered in this pooled fund study.

TICPs combine the structural longevity of PCC pavements with the serviceability of HMA pavements. One of the perceived benefits of TICPs is the simplification of the PCC design and construction through a thinner PCC layer, simplified finishing, and simplified joint formation techniques.

The main objective of the proposed research was to develop design and construction guidelines for thermally insulated concrete pavements (TICP), i.e. composite thin HMA overlays of new or structurally sound existing PCC pavements. A secondary objective was to develop recommendations for feasibility analysis of newly constructed TICP or thin overlays of the existing concrete pavements. These objectives will be accomplished by collecting field performance data and evaluating the influence of design, material properties, and construction on the performance of TICP.

Construction

The typical section for Cells 106 and 206 were shown in Figure 16. Removals for this cell began April 28th and continued all the way into July. The class 5 aggregate base was placed and tested with the IC roller in mid September. As noted earlier, Cell 6 was built over a clay subgrade that became very soft during construction due to heavy rains after the base was placed. It was difficult to obtain compaction over this soft clay subgrade. This soft clay was removed, because it was felt that a poor subgrade should not be the potential cause for failure for this study. Rather, composite pavement is the topic being addressed in the study. Class 5 aggregate base was installed in place of the clay, followed by 6” of class 1 stabilizing aggregate. 5” of concrete pavement was then placed, textured, and cured for about three weeks before the 2” taconite HMA surface was paved on October 30th.

Panel size and layout for this study are shown in Table 7.

Table 7. Joint and Dowel Layouts for Cell 6

Cell Number	Joint Spacing	Joint Layout	Dowel Conditions
106	15’	Perpendicular	1” in both lanes
206	15’	Perpendicular	No dowels

Permeable (HMA) Pavement Performance in Cold Regions (Cells 86-88)

Porous asphalt pavement is an emerging technology in pavement design especially because of the potential benefits of managing runoff through the pavement rather than through a storm water system. Recently, the Capitol Region Watershed District began requiring a higher level of water quality and quantity control, such as reducing 1” of rainfall runoff on any project disturbing over 1 acre of land. This type of pavement may offer an effective means of managing storm water runoff with the potential to reduce or eliminate the need for water detention structures. However, prior research on porous asphalt in the seasonally diverse Midwest climate is lacking.

Traditional roadways generate storm water runoff, requiring secondary treatment systems such as detention ponds. Porous asphalt roadways combine access needs with effective storm water treatment. This technology will also improve safety by reducing water spray and ice formation, reducing deicing needs, and minimizing the need for additional land dedicated to storm water management.

The objectives of this research were to evaluate the durability, hydrologic characteristics, and environmental effects of porous asphalt pavement when used on a low volume roadway in a cold climate.

Construction

Cells 86 and 88 were constructed with a pervious HMA surface, and control Cell 87 was paved with dense-graded Superpave. All are constructed using open-graded (high porosity) aggregates as a base material (to collect surface water runoff), and all sections included a Type V geotextile fabric (to separate the base and subgrade layers), vertical plastic barriers (to prevent water from flowing into or out of the pavement from the sides), and transverse drains to capture surface runoff. The only difference between the cells is that Cell 86 contains a sand subgrade, and Cell 88 contains a clay subgrade.

Grading on these cells began June 25th. After instrumentation work was completed in early August, the cells were subcut. Researchers and PCI personnel placed clear plastic sheeting vertically 4’ deep around all four sides of each cell to isolate the water flowing through the pavement structure without escaping laterally. The Geotextile fabric was placed September 15th, and subcuts backfilled with CA-15 the week after. The CA-15 showed instability on Cells 85 to 89, so Meridian ballast was hauled in to use in the top 4 inches. Cell 87 was constructed using 4 inches of taconite ballast that leftover from Cell 23. This material was graded in early October, curb and gutter was placed October 1st, and paving of Cells 86-88 was completed on October 15th.

The contractor experienced trouble at the plant and paver while paving these cells. The aggregates came to the HMA plant directly off the wash plant from the quarry. The material would not veil in the drum and almost started the baghouse on fire. The plant operator decided to run each of the aggregate materials through the plant separately to dry them before mixing. When that was finished the asphalt binder line was cooled off and plugged. These issues were finally resolved and mix production resumed. At MnROAD the cells were paved 8” thick to obtain the 5” final layer thickness after compaction, and the contractor waited about 5 hours to roll until the mix temperature was below 100^{o}F. Then they rolled the mat once or twice to make it smooth, but no more so as to retain the desired porosity. This was a learning experience for Mn/DOT and contractor personnel alike.

Figure 23 shows the typical section for Cells 86-88. Figure 24 shows the permeable asphalt wearing course during paving operations.

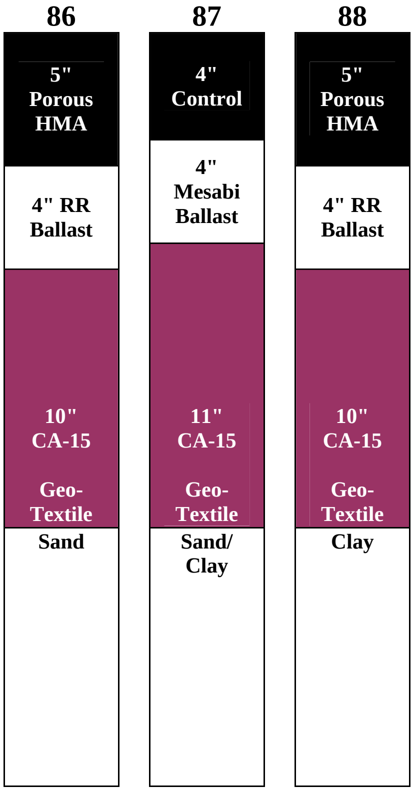


Figure 23. Typical Sections for Cells 86-88

Figure 24. Porous Asphalt Pavement Construction

After paving was complete MnROAD staff constructed transverse drains to capture the surface water runoff in each cell, including the non-pervious control Cell 87. Saw cuts were made approximately 2’ wide, and the pavement was removed down to the ballast. Steel reinforcement was tied in the trenches to support the drains. Wood forms were fabricated and laid in the trench. Concrete was poured to create the drain, and a PVC pipe ran from the centerline to a collection tank in the inside ditch. Four drains were built in the fall, with the remaining two to be built in spring 2009.

Pervious Concrete Pavement Study (Cells 85, 89)

The reduction of pervious surfaces has been an issue of concern with the construction of bound pavement surfacing. Some Cities in the Metro area have been forced to improvise methods of minimizing storm water intrusion from developments that are in proximity to wetlands or some trout streams. Run-off from impervious surfaces has been known to distort the thermal balance of streams when extreme temperatures precede heavy rains. In solving this problem some communities have made various attempts to encourage some infiltration by constructing pervious concrete on porous bases. While their understanding of the performance of pervious concrete in Northern climates is still rudimentary, Mn/DOT and the Aggregate Ready Mix Association of Minnesota provide leadership in this technology. The partnership resulted in the construction of a pervious concrete pavement in a parking lot in MnROAD in 2005 and pervious sidewalks on site the following year.

Ordinarily storm water run-off necessitates expensive design and construction of storm water structures that include detention or infiltration ponds. Intuitively, there is a huge saving in cost if the paved surface is pervious and conducts the storm water directly to the ground. The pervious concrete design provides this benefit. Normal concrete is impervious and may contain entrained air up to 7.5% as in high performance concrete. The entrained air is discontinuous in normal concrete; permeability is infinitesimal compared to the rate of flooding or ponding or run-off on the pavement surface. Pervious concrete is made up of gap-graded aggregate linked by cement paste, systematically placed to allow for contiguous voids or cavities that allow for free passage of water.

Because of limited funding, the pervious concrete initiative of 2005 on a MnROAD parking lot was completed on a small scale. The instrumentation is skeletal and detached from the omnibus MnROAD data collection system and the technology at that time was rudimentary. In order to adequately evaluate pervious concrete in this climate, a test section with a proper mix design and instrumentation on the MnROAD Low Volume Road was needed. This will also provide an operations research advantage as the porosity and infiltration can be monitored over time and standard measurable traffic loads and environmental effects can be measured. This study will provide validation of the mix design recommendations in the lab based on a previous Iowa study. It will also validate pervious concrete pavements as a tool for local communities to fulfil the environmental requirements of the Clean Water Act and as a pavement noise attenuation tool in the kit.

Construction

Both Cells 85 and 89 were originally designed as 7” of pervious PCC over 12” of CA-15 over

Type V geotextile fabric. Cell 85 is over a sand subgrade, and Cell 89 is on a clay subgrade. Construction progressed similar to that in Cells 86-88. A plastic barrier, geotextile fabric, and transverse drains (see Figure 26) were installed. The CA-15 showed instability on both cells, so Meridian ballast was used in the top 4 inches. This material was graded in early October, and paving was complete later in October. The concrete mixture was soft the next day, but it stiffened up later in the week. Joints were cut at a 10' spacing, and no steel dowels or tie bars were included in the pavement.

Figure 25 shows the typical section for both cells.

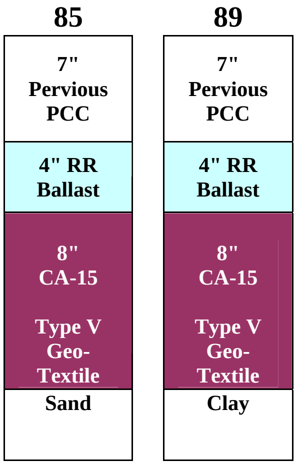


Figure 25. Typical Sections for Cells 85, 89

Figure 26. Transverse Drains in Cells 85-89

Pervious Concrete Overlay (Cell 39)

Pervious concrete has great potential to reduce roadway noise, improve splash and spray, and improve friction as a surface wearing course. A pervious concrete mix design for a surface wearing course must meet the criteria of adequate strength and durability under site-specific loading and environmental conditions. To date, two key issues that have impeded the use of pervious concrete in the United States are that compressive strengths of pervious concrete have been lower than necessary for required applications and the freeze-thaw durability of pervious concrete has been suspect.

The objectives of the integrated research study include finding optimal pervious concrete mix designs for wearing course sections in pavement applications. Information needed for the wearing course sections must address the issues of noise and skid resistance, assuming adequate strength and durability are developed. The constructability issues are also very critical. It is of paramount importance for the research to determine techniques for construction that utilizes existing pavement equipment. At present the construction of pervious concrete sections is quite labor intensive. The use of pervious concrete as a wearing course entails construction of a concrete overlay in rehabilitation efforts. In new construction two-lift construction is a possibility.

Construction

Cell 39 consists of a 4” pervious PCC overlay over the existing 6.5” of 20’ x 12’ PCC with 1” dowels. That material was placed over 5” of Class 5 and a clay subgrade. Sensor retrofits and subsequent patching for Cell 39 were conducted May 8th and 9th. Notches were milled into the concrete on either end September 12th to accommodate bituminous tapers, and the concrete overlay was placed October 17th. PCI matched the joints in the overlay with those of the underlying layer. The concrete was placed one lane at a time and finished with a roller screed. This screed was out-of-round, as evidenced by regular humps in the pavement causing a rough ride.

Figure 27. Sensor Retrofits Installed on Cell 39

This cell was designed and built with a class 5 aggregate shoulder. Shortly after construction, it was noticed that the water that drained through the pervious concrete overlay got to the aggregate shoulder and just sat there because the aggregate was, for all practical purposes, impervious. MnROAD operations staff corrected the problem by building French drains along the shoulders. We trenched about 6” wide and 4” deep along the entire length (both lanes) of the overlay. We removed the class 5 material from the trench, sometimes taking great effort to get it “uncaked” from the sides of the pavement. We backfilled the trenches with an open graded concrete aggregate that would drain the water, cutting transverse outlet drains through the shoulder approximately every 100 ft.

Concrete Pavement Optimization – Determining the Lower Threshold of Slab Thickness for High Volume Roads (Cell 13 – Consists of Subcells 113 to 513)

The thicknesses of today’s concrete pavements in Minnesota are a result of many years of empirical research and design. Due to uncertainty with traffic predictions and material performance, these designs tend to be conservative, resulting in very few concrete pavements failing due to fatigue cracking under traffic loading. Many of the designs are actually based on extrapolation of original AASHO Road Test data, which was based on a limited set of traffic loadings, subgrade type, and environmental exposure (2 years). Work has been done recently to evaluate and calibrate the new mechanistic empirical pavement design guide (MEPDG), but datasets have been limited to thicker pavements. To improve the calibration of new mechanistic-empirical concrete pavement design methods, data is needed to fully develop the distress and life prediction models of thinner, more optimized and economical pavements.

The primary objective of this research study is to develop better distress and life prediction models for more optimized (thinner) concrete pavements. Secondary objectives include understanding the behavior of these pavements with regards to maturity, slab warp and curl, thermal expansion, and repair techniques. These objectives will be accomplished through extensive testing of materials during construction, as well as the application of interstate traffic, conducting extensive seasonal load response testing, and monitoring the field performance of an instrumented variable thickness concrete pavement test cell. New MnROAD concrete test cells were built with slab design thicknesses of 5, 5.5, 6 and 6.5 inches. All other design variables were fixed, except for some panel length sizes and dowel bar types in the 5-inch thick subsections. For those subsections, flat rectangular dowel bars were installed into seven of the twelve transverse joints, and will be monitored for load transfer performance.

Construction

Cell 13 is constructed as 5, 5.5, 6 and 6.5 inches of PCC over 5" of class 5 aggregate base on a variable depth clay subgrade. Removals began April 28th and the concrete broken and removed in June and early July. The subcut was completed and the IC roller used on the clay subgrade August 21st. Figure 28 shows the construction of Cell 13.

Figure 28. Paving Cell 13

Like Cell 6, construction of this cell also included hauling in additional clay to raise the grade. This clay borrow became very soft during construction. It was difficult to obtain compaction over this soft clay subgrade. After some construction traffic traveled over the initial class 5 base material, it was decided to remove the soft clay layer. Class 5 aggregate base was installed in its place, followed by 6" of class 1 stabilizing aggregate. Materials for Cell 13 were graded September 15th and paved October 10.

Measurements taken after construction revealed that portions of the cell, which were designed as a thin concrete experiment, were paved significantly thicker than the design thickness. As such, certain research objectives are being reexamined to utilize the thicker as-built sections. Table 8 shows the as-built concrete thickness for each subcell after construction.

Table 8. Cell 13 As-Built Concrete Thickness

Cell	Core Sample ID	Approx Offset from CL	Location (Between Jts)	Avg Depth from T2 Device (in)	As-built Depth (in)	Avg Depth Driving Lane OWP (in)	Avg Depth Centerline (in)	Avg Depth Passing Lane OWP (in)	Overall as-built Average Depth (in)	Design Depth (in)	Difference between as-built depth versus Design Depth (in)
513	513A	-11	4101-4102		6.13	6.13					
513	513B	-1	4101-4102		5.88		5.88				
513	513C	3	4101-4102		5.50		5.50				
513	513D	11	4101-4102		6.25			6.25			
513	513E	-10	4102-4103		6.00	6.00					
513	513F	-11	4103-4104		6.50	6.50					
513	513G	-1	4103-4104		5.88		5.88				
513	513H	2	4103-4104		5.63		5.63				
513	513J	11	4103-4104		5.88			5.88			
513	513K	-10	4106-4107		6.00	6.00					
513	513L	1	4106-4107		5.50		5.50				
513	513M	11	4106-4107		5.63			5.63			
						6.16	5.68	5.92	**5.90**	**5**	**0.90**
113	113A	-11	4108-4109	**5.75**	**5.50**	5.50					
113	113B	-1	4108-4109		5.00		5.00				
113	113C	11	4108-4109		5.50			5.50			
113	113D	-11	4111-4112		5.75	5.75					
113	113E	-1	4111-4112		5.25		5.25				
113	113F	11	4111-4112		6.00			6.00			
113	113G	-11	4113-4114		5.88	5.88					
113	113H	1	4113-4114		5.38		5.38				
113	113J	11	4113-4114		6.38			6.38			
						5.71	5.21	5.96	**5.63**	**5**	**0.63**
			Combined Cells 513 and 113			5.97	5.50	5.94	**5.78**	**5**	**0.78**
213	213A	-11	4115-4116		6.00	6.00					
213	213B	2	4115-4116		5.13		5.13				
213	213C	11	4116-4117		6.25			6.25			
213	213D	-2	4116-4117		5.88		5.88				
213	213E	-10	4118-4119	**6.46**	**6.25**	6.25					
213	213F	1	4118-4119		6.00		6.00				
213	213G	11	4118-4119		6.25			6.25			
213	213H	-11	4120-4121		6.25	6.25					
213	213J	-1	4120-4121		5.50		5.50				
213	213K	11	4120-4121		6.13			6.13			
						6.17	5.63	6.21	**5.96**	**5.5**	**0.46**
313	313A	-11	4123-4124		6.25	6.25					
313	313B	-1	4123-4124		6.25		6.25				
313	313C	11	4123-4124		6.38			6.38			
313	313D	-11	4127-4128		6.50	6.50					
313	313E	1	4127-4128		6.13		6.13				
313	313F	11	4127-4128		6.13			6.13			
313	313G	-10	4128-4129	**5.99**	**5.88**	5.88					
						6.21	6.19	6.26	**6.22**	**6**	**0.22**
413	413A	-11	4131-4132		6.63	6.63					
413	413B	1	4131-4132		6.13		6.13				
413	413C	11	4131-4132		6.38			6.38			
413	413D	-11	4133-4134		6.38	6.38					
413	413E	11	4133-4134		6.63			6.63			
413	413F	-10	4135-4136	**6.47**	**6.38**	6.38					
413	413G	1	4135-4136		6.38		6.38				
413	413H	11	4135-4136		6.50			6.50			
						6.46	6.26	6.50	**6.43**	**6.5**	**-0.07**

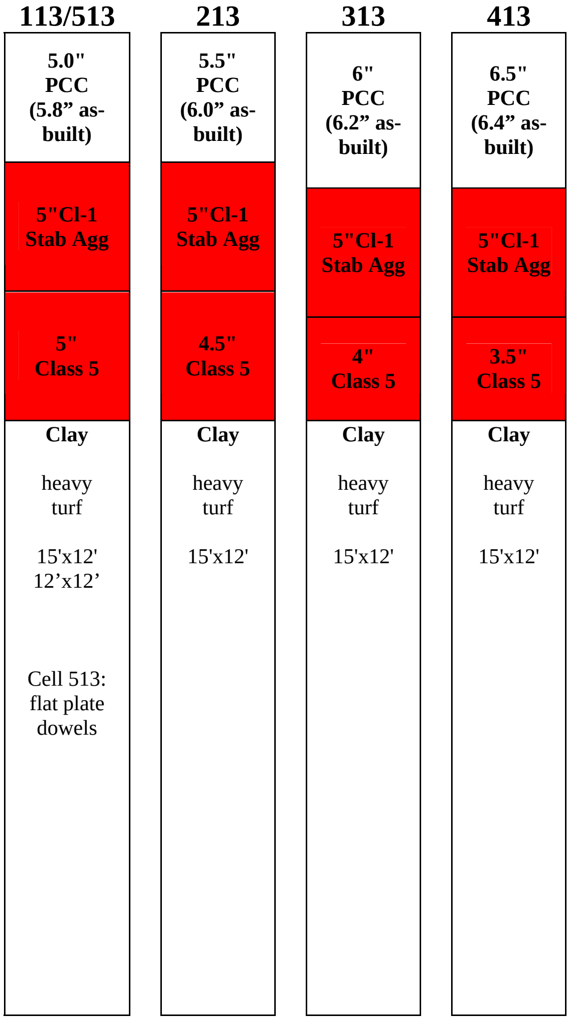


Figure 29. Typical Sections for Cell 13

Table 9. Joint Layout and Dowel Conditions for Cell 13

Cell	Panel Size	Dowel Condition	
		Driving Lane	Passing Lane
113	15’x12’, 12’x12’	1” round	1” round
213	15’x12’	1” round	1” round
313	15’x12’	1” round	1” round
413	15’x12’	1” round	1” round
513	15’x12’, 12’x12’	Flat plate dowels	Flat plate dowels

PCC Surface Characteristics - Construction (Cells 5, 13, 14, 53, 39, 85, 89)

Smooth, quiet, and safe pavements are desirable. To encourage the construction of smooth pavements, other important pavement performance parameters on ride should be quantified. These parameters include texture, noise, and friction. An understanding of the interaction of texture and ride is still very rudimentary. In 2002 the Mn/DOT Concrete Engineering Unit and the Concrete Pavers Association of Minnesota created a test section on TH 212 at Bird Island to study the effects of texture and joints in pavement smoothness. The results showed texture and joints affected the profile index. However, data is so far insufficient to define a global correlation between texture values and their effect on ride, and the results obtained for the effects of joints on ride were not conclusive because of unanticipated construction issues.

Research findings from this study will enable Mn/DOT to specify friction, ride, and texture ranges of values that will optimize quietness, ride, texture and friction in program delivery. Research outcomes will facilitate a family of curves and algorithms that will address the optimization for giving good friction, which unfortunately was interpreted by profilometers as pavement roughness as well as noise and friction. Researchers also hope to predict noise level based on the grinding techniques. The project will provide data for optimization of pavement quietness, friction, texture, and ride.

Construction

Details on test cell construction can be found in the appropriate sections in this chapter. The PCC Surface Characteristics study incorporated various surface textures into other research projects. Table 10 outlines the concrete surface textures for the cells in this study.

Table 10. Concrete Surface Textures

Texture/ Finishing	Cell	Performance Specification
Longitudinal Tining	5	To be achieved with a rake or other device that will imprint sufficient texture as would guarantee an MTD of 1.2 to 1.5mm behind the paver. The tining spacing shall be 1/2 inch from groove to groove and shall be parallel to the direction of travel. The tining depth and spacing shall be chosen to ensure sufficient friction but shall in no case be less than ¼” in depth. *Note: This texture changed to diamond grinding after testing the initial longitudinal tining.*
Longitudinal Astro -Turf / Hessian Drag	6 (before HMA overlay), 13	Minimum of 1.2 mm Spot mean texture depth (MTD) behind the paver. Uniformity of 1.2 to 1.5 is the desired setting. The texturing will not proceed until the engineer certifies that texture lies within this range. This shall be maintained by the acceptable bristle density and uniform distributed load (UDL) achieved with a metal chain. Aggregate shall not be accepted, as UDL The surface should be void of scrapings unless the contractor guarantees that subsequent removal of the scrapings shall not result in tearing of the surface.
Longitudinal Broom Drag	14	Minimum of 1.2 mm (MTD) Spot tests behind the paver. Uniformity of 1.2 to 1.5 is the desired setting. The texturing will not proceed until the engineer certifies that texture lies within this range. This shall be maintained by the acceptable bristle density and uniform distributed load (UDL) achieved with a metal chain. Aggregate shall not be accepted as UDL The surface should be void of scrapings unless the contractor guarantees that subsequent removal of the scrapings shall not affect result in tearing of the surface.
Transverse Broom/Turf	53	Minimum of 1.2 mm Spot mean texture depth (MTD) behind the paver. Uniformity of 1.2 to 1.5 is the desired setting. The texturing will not proceed until the engineer certifies that texture and geometry lie within this range. This shall be maintained by the acceptable bristle density and uniform distributed load (UDL) achieved with a metal chain. Aggregate shall not be accepted, as UDL The surface should be void of scrapings unless the contractor guarantees that subsequent removal of the scrapings shall not result in tearing of the surface.
Pervious Concrete	85, 89	Porosity shall be 15 to 18 % and void ratio shall be 18 to 21%. The surface shall be void of laitance or slurry and should guarantee uniform porosity through the depth of the concrete. The matrix should be resistant to undesirable raveling and weathering. This shall be established during the trial mixing process. Unit weight may not exceed 135 pcf unless if by improved practice or otherwise, contactor achieves desired porosity while attaining 7-day flexural strength of 300psi.
Porous Overlay	39	Specified by Others. Consists of 4 “ porous overlay on existing concrete primarily for a noise attenuation Study.

Intelligent Compaction Research (Conducted on Cells 2-4, 6, 13, 16-23)

Road authorities across Minnesota spend millions of dollars each year on the construction of pavement structures. Unfortunately, the quality control and quality assurance (QC/QA) testing used during pavement construction currently has little connection to the material properties used during mechanistic pavement design.

In order to more efficiently design and construct these pavements, the Federal Highway Administration (FHWA), Local Road Research Board (LRRB) and Mn/DOT have invested significant resources to develop and advance the use of non-destructive testing devices (e.g., Light Weight Deflectometer [LWD], Intelligent Compaction [IC], Dynamic Cone Penetrometer [DCP]) aimed at assessing in situ design-related pavement parameters. Figure 30 shows the LWD and DCP on site at MnROAD, and Figure 31 shows the intelligent compaction roller.

Researchers conducted LWD, IC, Falling Weight Deflectometer (FWD), moisture, nuclear gauge and gradation tests on various layers and cells for this project. The objective of this implementation project was to obtain data for further refinement/development of QC/QA specifications and procedures, enhancement of material property based compaction requirements, development of statistically based requirements and tests, and further development of the link between mechanistic-empirical pavement design and construction.

Figure 30. LWD and DCP Field Testing

Figure 31. Caterpillar CS-563 Intelligent Compaction Roller

Construction

This project was intended to verify some of the work that was done in the 2008 to determine specifications and compaction methods using the IC roller. Caterpillar donated the roller for the entire summer, so that, as sections became available for testing, they could be rolled. This step was not part of the construction process; researchers ran the roller to map each layer after it had passed the QA testing requirements. MnROAD staff will hire a consultant to organize and analyze the data.

Full Depth Reclamation with Engineered Emulsion (Cells 2, 3, 4)

This project was conducted by SemMaterials on Cells 2-4 as a special partnership research project to determine the optimal percentage blend of HMA and aggregate base for full depth reclamation with engineered emulsion. The three blends of HMA and aggregate base were constructed at 50/50 (Cell 2), 75/25 (Cell 3), and 100/0 (Cell 4). Researchers also evaluated how to best rehabilitate full depth HMA on clay pavements.

Construction

This project included reclaiming 12” on Cell 2 (6” HMA + 6” aggregate base) and 8” on Cell 3 (6” HMA + 2” aggregate base) and treating the top 6” of reclaimed asphalt with an engineered emulsion. On Cell 4 the top 8” of HMA was milled and set aside for later use. The subgrade was then stabilized using Class C fly ash spread with a vane feeder truck, which was then reclaimed along with the bottom 1” of HMA and 8” of clay to arrive at a fly ash content of 16%. Water was added to attain a moisture content of 16%. A DCP test indicated increased strength in the stabilized subgrade on Cell 4 after two days hydration. Hardrives compacted the reclaimed layer on Cells 2 and 3. The top 6” of material was pushed to the side and the bottom portion of the material was compacted. The material was then pushed back to proper grade. Millings were pushed back into place on Cell 4. Two inches of class 5 was added to the outside shoulder on

Cells 2-4 to be reclaimed with 2" HMA later.

Instrumentation was installed, including pressure cells at the bottom of non-stabilized reclaimed layers on Cells 2-3, placed just into fly ash as stabilized subgrade on Cell 4.

Midstate Reclamation and Hardrives performed full depth reclamation stabilized with the engineered emulsion. This was done by dry mixing the shoulder about 4" deep. Midstate then stabilized Cells 2-4 and the outside shoulder. The design emulsion contents were measured as:

- Cell 2 – 4.0%
- Cell 3 – 3.0%
- Cell 4 – 0.5% (0.75% actual due to limitations of the construction equipment)
- Shoulders – 4.5%

Later, the IC roller measured very stiff layers on Cell 3 with the 75% HMA +25% aggregate blend, which were verified by the FWD. This was after the engineered emulsion stabilization. Strain, temperature, moisture, and pressure gauges were installed in Cells 2-4 and the surface was paved with 2" Superpave on September 17th. The Novachip (Cells 2 & 3) and Superpave (Cell 4) mixes were paved on October 29th. Shoulder work continued and was completed on October 29th. This included grading the backslopes and placing microsurfacing along the outside shoulder with a Mn/DOT MiniMac machine to fill in the lane-shoulder drop-off.

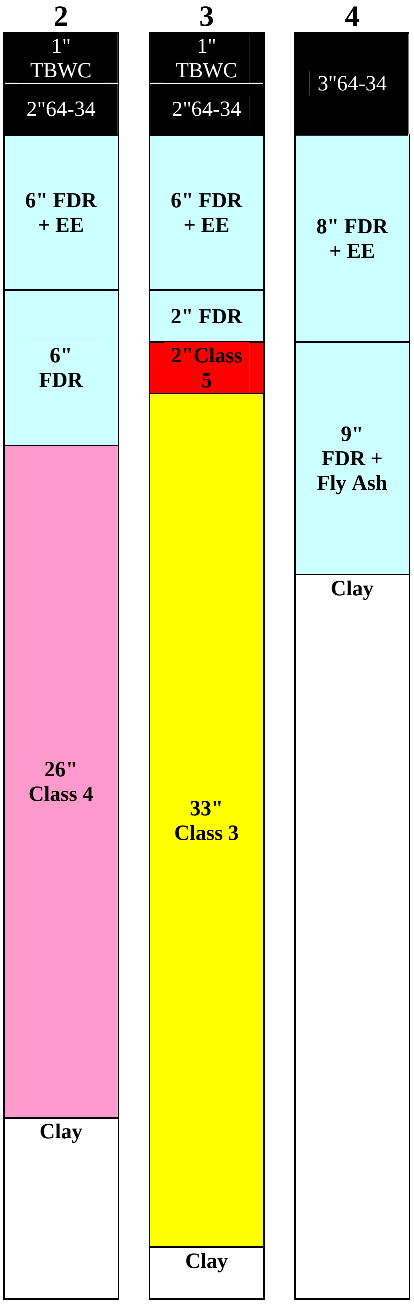


Figure 32. Typical Sections for Cells 2-4

Construction Season Progress

The project was assigned SP Number 8680-157, and let on January 25, 2008. Seven local contractors submitted bids, and Progressive Contractors, Inc. (PCI) was awarded the contract based on their low bid of $2,092,828.30. The contract award date was February 12, 2008, and the contract number was S08003.

April

Construction on this project began April 21, 2008. PCI was awarded the contract for approximately $2.1 million dollars. Bill Hines served as the project manager from PCI, and Golden Valley field staff was in charge of construction administration. A pre-construction meeting was held April 16th in Golden Valley. Mn/DOT Golden Valley, MnROAD, PCI and representatives from the subcontractors attended. The subcontractors for this project included Hardrives Inc., Safety Signs, Aggregate Industries and Doucette's Landscaping and Contracting.

Work began with the installation of silt fence, however rain kept work to a minimum during the first week of construction. Concrete breaking was scheduled to begin on April 28th in Cell 5, along with removals in other mainline Cells.

No work was done the week of April 28th because of weather. A meeting was held to discuss erosion control, traffic control, sublet requests, schedules, material supply and specs. The decision was made to remove Cell 11 (PCC Subgrade Drag / Tie Bar Design) from plans due to a delay in partnership funding.

May

During the third week of construction, PCI began milling on Mainline and Mainline shoulders. Shoulder millings were stockpiled for future use, and excess mainline millings were also sold off-site at $6/ton. Other millings produced were used by Hardrives as RAP on the project. Forensic cores along transverse cracks were taken to investigate performance of PSAB vs. conventional aggregate base. A panel in LVR Cell 39 was removed to allow for instrumentation for porous overlay and GPS positioning system validation.

During the week of May 12th, the contractor was off site. MnROAD staff calibrated and installed sensors and inventoried forensic cores.

During the month of May, MnROAD staff installed conduit and handholes for instrumentation, and prepared sensors, including vibrating wire strain gauges and vibrating wire pressure cells for concrete test sections which measure strain in a PCC slab due to material shrinkage and environmental forces over time. In addition, ECH20-TE sensors were validated prior to installation and used to measure moisture content in base and subgrade materials. MnROAD staff also installed sensor conduit in Cell 5 and Cell 39.

Aggregate samples were obtained from two sources: Ispat taconite tailings and microsurfacing aggregate for use in the 4.75-mm Superpave mix on Cell 6.

June

Work did not resume on the project until the first week of June, when PCI began grinding Cells 21-23. The materials were blended and approved for later use as Select Granular, as gradations showed 100% passing 1" and 3.3% passing #200. The material amounted to about half of the required select granular, so the contractor blended excess salvaged Class 3 aggregate base off the mainline HMA cells to produce the total amount of materials needed.

Grading continued throughout the third week in June, as PCI subcut clay on two cells and prepped subgrade on Cells 20-22. That week, the Road Warrior pavement breaker was used to break concrete on Cells 6, 13 and 53 prior to removal, and to provide cracking on select joints on Cell 5. MnROAD staff mapped and installed conduit and risers on Cells 5, 15, 20, 21 and 22. Decagon moisture sensors were tested and thermocouple trees were constructed. Thermocouples were installed on Cell 15, and Premier (a separate electrical contractor) installed conduit and handholes and BD closures on Cells 5, 6, 13, 14.

Figure 33. Concrete after Breakup by Road Warrior

Figure 34. Removals on Cells 21-23

Several research projects were conducted or implemented in late June. Minnesota State University at Mankato conducted an implementation project for a new test rolling regime at MnROAD, and there was a demonstration of a prototype ultrasonic sensing device by Geoprobe. The University of Minnesota developed a GPS based system for one of the MnROAD trucks for high precision vehicle tracking, and Transtec performed tests for a pavement surface characteristics pooled fund study.

During the last week of June, PCI subcut 19.5” of clay from Cell 23 and backhauled Class 5 aggregate base material to Cells 20-22. They placed select granular in Cells 19 & 23 and excavated/salvaged Class 3 from Cells 16 & 17 and hauled it to Cells 19 & 23. They also placed select granular in Cell 16. After PCI was finished with each layer, researchers again came in to test with the IC roller, FWD, LWD, DCP, nuclear gauge, and sand cone. Samples of all the grading materials were also taken to the Maplewood Lab for testing.

This last week of June, Hardrives also milled the HMA on Cells 24 & 25, and millings were reused as the RAP in the new HMA cells. MnROAD staff completed installation of conduit and risers on Cells 23 and 19. QC testing of Decagon moisture sensor continued.

July

The remaining Low Volume Road Cells 25 and 26 and West Transition on the Mainline were milled the first week of July. Millings were all hauled to the stockpile area to be blended and reused as Class 7 base material in Cell 18 (this was not successful – the millings failed to meet the required Class 7 gradation). The granular layers completed earlier were tested with the IC roller, FWD, LWD, DCP, and nuclear gauge, and grading samples were taken for testing.

During the second week of July, PCI removed concrete from mainline Cells 6 and 13. MnROAD Staff installed moisture gauges in Class 5 aggregate base on Cells 20-22.

SemMaterials worked on Cells 2-4 the week of July 14th on a special partnership research project to determine the optimal percentage blend of HMA and aggregate base for full depth reclamation with engineered emulsion. They also evaluated how to best rehabilitate full depth HMA on clay pavements. FDR work progressed as described in an earlier section.

Figure 35. Reclaiming and Compacting Cell 2

Conduit and thermocouple trees were installed in Cell 14 prior to the thin concrete overlay. Strain, temperature, moisture, and pressure gauges were installed in Cells 2-4. The last week of July, PCI cut the final grade on Select Granular layer on Cell 16. Data was collected with the IC and FWD, but weather did not permit other tests. Later, the IC roller measured very stiff layers on Cell 3 with the 75% HMA +25% aggregate blend, which were verified by the FWD.

Figure 36. Asphalt Emulsion Application to Reclaimed Material

August

PCI resumed grading on Mainline and salvaging Class 3 aggregate subbase from Cell 17 and placing it on Cell 16. After exposing the subgrade on Cell 17, PCI added select granular from the stockpile and Class 3 salvaged from Cell 18. They also subcut Cells 6 and 13 to clay. MnROAD crews installed conduit and risers on Cells 16 and 17. They also installed pressure gauges at the top of the Class 3 layer on Cells 16 and 19.

MnROAD staff assisted with the testing and preparation for pooled fund project TPF-5(148), “The Effects of Implements of Husbandry "Farm Equipment" on Pavement Performance. They installed LVDTs and horizontal clip gauges to Cell 54 in order to measure PCC joint opening under loading by heavy farm vehicles. They also performed FWD testing on the Farm Loop.

September

PCI constructed the aggregate bases on Cells 16, 17 and 18, which consist of various recycled materials. For these cells, it was important for all of the class 7 mixtures to be very similar. It took some effort to get the proper gradation.

They hauled Class 5 to Cells 6, 13, and 19, and completed final grading on Cells 20-22 in preparation for paving. PCI also cut Cell 26 to the clay subgrade in preparation for constructing the pervious HMA and PCC cells, and graded the Class 3 layer on Cell 23 in preparation for laying the taconite ballast. MnROAD staff sampled the CA-15 for use as an aggregate base in Cells 85-89 and accepted the material based on the gradation and percent crushing. Researchers ran IC, LWD, and DCP tests on several of the granular layers as time allowed. A thermocouple & moisture tree was installed in Cell 17. Five such trees were installed in Cell 19, which included five different technologies for measuring moisture content (Campbell CS 616, TDR, Decagon 5TE, moisture block, and an experimental TDR strip from Ohio University).

University of Wisconsin researchers worked on the recycled unbound base project in September, installing lysimeters on Cells 16-19. In each cell, they cut a 10 ft square hole into the top of the Class 3 aggregate subbase about 4” deep. Then, they placed three layers of fabric and a drain out to a collection tank in the ditch, and backfilled and compacted the appropriate recycled base material.

Hardrives paved the 2” non wear lifts on Cells 20-22 for the RAP project. Four asphalt strain gauges (two longitudinal and two transverse) were placed at the bottom of this layer in each cell.

PCI graded the entire second week of September. They began by adding class 5 aggregate to the shoulders on Cells 20-22, and hauled the 100% RAP material to Cell 18 as an aggregate base as well as the taconite ballast material to Cell 23. PCI also fine-graded Cells 16-19 to prepare them for next week’s paving. PCI spent the remainder of the week grading on the Low Volume Road. They removed the concrete pavement and subcut the existing material from Cell 53. Once the bottom of the clay subgrade was graded, they began hauling sand salvaged from Cells 85-87 to Cell 53 as select granular material. PCI also cut to the clay subgrade on Cells 87-89.

Figure 37. Installation of Moisture and Temperature Gauges in Cell 23

Hardrives paved the wearing course on Cells 20-22, and loose mix samples were taken for MnROAD, Federal Highway Administration, and the National Center for Asphalt Technology (NCAT). Samples of asphalt binder, RAP, and aggregate were also taken for further laboratory studies. One pallet of mix samples from Cells 20-22 was delivered to the University of Minnesota for both their Low Temperature Cracking Phase II project and their contract to perform low temperature fracture tests on all the MnROAD HMA mixes for material characterization. Samples were also set aside for Ohio University and the Texas Transportation Institute to perform additional tests.

PCI also milled the bituminous shoulders on Cell 39. Researchers finished using the intelligent compaction roller on the base materials in Cells 17, 18, and 23.

The third week of September, PCI hauled stabilizing aggregate to Cells 6 and 13. They continued grading these two cells throughout the week, fine grading with a trimmer to prepare for concrete paving. The rest of the week was spent working on Cells 85-89. They backfilled the trenches along the plastic liner around each cell and began hauling CA-15 aggregate for the base material. PCI also rolled out geotextile as a separator fabric before placing the CA-15. They left the CA-15 4” low on all cells and made up the difference with railroad ballast from Martin Marietta.

Prior to backfilling, MnROAD staff placed a plastic liner in Cells 85-89 to provide a 4’ tall vertical barrier around all 4 sides of each cell, preventing the flow of groundwater into or out of each cell. They also installed instrumentation in Cells 53, 39, 14, and all of the HMA cells (16-19 & 23).

Figure 38. Geotextile and CA-15 Base in Cells 85-89

In late September, MnROAD staff installed dynamic pressure gauges on Cells 85-89 prior to the CA-15 being placed, as well as instrumentation on Cells 5, 6, 13, 14, 39, and 53 in preparation for concrete paving. The gauges installed include thermocouples, Decagon 5TE's, vibrating wires, water blocks, and dynamic strain gauges, among others. The University of Wisconsin researchers returned to install the collection tanks for the lysimeters in Cells 16-19.

Figure 39. Instrumentation in Cell 53

PCI paved one lane of the 60-year concrete on Cell 53 the last week of September, as well as one lane of the porous concrete overlay on Cell 39. They also placed curb on Cells 85-89. American Engineering and Testing ran compressive strength, flexural strength, permeability, and freeze-thaw durability tests in their local laboratories on samples of each of the concrete mixtures.

Samples were also sent to the University of Pittsburgh to perform coefficient of thermal expansion tests.

October

The PCI grading crew spent the first week of October finish grading on Cell 24 and backfilling behind the curbs on Cells 85-89. Cells 5, 6, 13, and 14 were paved with a slip form paver. PCI then applied different surface textures (longitudinal tining, Astroturf drag, and broom drag) to the concrete to accommodate a surface characteristics research project. Dowel baskets were also laid out in accordance with the research plans. The dowel bar plan included traditional 1” epoxy coated dowels as well as some flat plate dowels placed in the thin concrete sections. The panel sizes also varied (6, 12, and 15 ft). The contractor also did some cleanup grading work on Cells 2-4. A crew from Diamond Surfacing Inc. provided diamond grinding on Cell 9 for the PCC Surface Characteristic Study. Researchers from the University of Michigan were on site this week to do proof testing on their newly developed high speed laser profiling system.

During the second week of October, PCI placed aggregate base on the shoulders on Cells 5 & 6 after 7-day flexural strength tests showed that the concrete on those cells gained sufficient strength. SemMaterials staff returned to the site to assess the grading work done along the shoulders on Cells 2-4.

PCI also paved the outside lane of Cell 53 (60-year concrete) and the inside lane of Cell 39 (pervious concrete overlay). Staff from the CP Tech Center at Iowa State University observed the paving. Hardrives paved the porous asphalt on Cells 86-88, along with the warm mix asphalt control mix (no WMA additive) on Cell 24. Thermocouple trees and asphalt strain gauges were installed in Cells 24, 86, and 88. Early-age concrete performance was tested including curl and warp measurements using a homemade Portable Automatic Laser Profile System (PALPS), joint opening, texture, and other measurements.

Figure 40. Porous HMA Paving Over Railroad Ballast

The third week of October, PCI grading crews added Class 5 aggregate shouldering material to Cells 5, 6, 13, 14, 39, and 53. They also added wick drains to Cell 5, which are designed to drain the water from the PASSRC layer to the shoulder. PCI placed the pervious concrete on Cells 85 and 89, as well as the 3" concrete shoulders on Cell 53. MnROAD staff installed vibrating wires, thermocouples, maturity meters, pressure cells, water marks, and other gauges in Cells 85 and 89.

Hardrives paved the 4.75-mm taconite mixture on Cell 6 and the shoulders along the Mainline concrete cells (Cells 5, 6, 13, and 14) using a mix containing 5% manufactured waste shingles the last week of October. They finished by paving the ramps on each end of the 4" pervious concrete overlay on Cell 39. Finally, Hardrives placed a pseudo-fog seal (a thick layer of CSS-1H emulsion) on a 100-ft section of Cell 24 to support our HMA Aging study. MnROAD staff collected sample buckets of HMA from Cell 6 and the shoulders, as well as 56 buckets of mix to ship to the University of California to perform a complete fatigue testing regime. Final clean-up including turf establishment, striping, and grinding Cell 5 (to obtain adequate surface characteristics) was completed by November 5th.

Figure 41. Cell 85 Pervious Concrete Still Soft after 24 Hours

Traffic opened on the Low Volume Road loop in early December 2008. The Mainline section opened to traffic in early February 2009 after researchers collected baseline monitoring data on each cell.

Table 11. 2008 HMA & PCC Paving Dates

Date	Cell Number	Description
5-Sep-08	20, 21, 22	Fractionated RAP non-wear
10-Sep-08	20, 21, 22	Fractionated RAP wear
16-Sep-08	16, 17, 18, 19, 23	WMA non-wear
17-Sep-08	15, 16, 17, 18, 19, 23	WMA wear
	2, 3, 4	Superpave
18-Sep-08	15, 16, 17, 18, 19, 23	WMA wear
19-Sep-08	5	PASSRC
	15, 16, 17, 18, 19, 20, 21, 22, 23	Outside Shoulder - TOSS Shingles
29-Sep-08	2, 3	Novachip
	4	Superpave
	53	60-year PCC - Inside Lane
30-Sep-08	West Transition	MW Shingles
1-Oct-08	East Transition	TOSS Shingles
	39	Pervious PCC Overlay - Outside Lane
	85-89	Concrete Curb & Gutter
2-Oct-08	East Transition	TOSS Shingles
8-Oct-08	5	Unbonded PCC Overlay
9-Oct-08	6	Composite Pavement
10-Oct-08	13, 14	Thin Concrete, Whitetopping
15-Oct-08	86, 87, 88	Porous HMA & Superpave
16-Oct-08	53	60-year PCC - Outside Lane
17-Oct-08	39	Pervious PCC Overlay - Inside Lane
20-Oct-08	85, 89	Pervious PCC - Outside Lane
21-Oct-08	53	60-year PCC - OL & IL Shoulders
24-Oct-08	24	WMA Control
	85, 89	Pervious PCC - Inside Lane
30-Oct-08	6	4.75 mm Taconite HMA
	5, 6, 13, 14	Inside & Outside Shoulders - MW Shingles
	39	HMA Ramps to Pervious PCC Overlay

CHAPTER 3 – SAMPLING AND TESTING

Material Sampling and Testing

One of the major activities during MnROAD Phase II reconstruction is to fully characterize each of the pavement materials used in the test sections. Some of this work was performed by Mn/DOT, but much of it was conducted by our research partners. MnROAD executed several individual testing contracts to cover work during the 2008 construction season. These contracts are summarized in Table 12. The tables and graphs on the following pages depict the sampling and testing plans on unbound, asphalt, and concrete materials as well as select test results on these materials. The full collection of test data is stored in the MnROAD database.

Pavement Performance Monitoring

MnROAD staff regularly monitor Mainline, Low Volume Road, and Farm Loop test sections to track the changes in pavement performance over time. Many types of measurements of structural and functional performance are made at certain intervals throughout the year. Other tests are performed on an as-needed basis.

The adopted monitoring schedule for MnROAD Phase II is given in Table 13. Initial and ongoing tests will be performed on each cell as outlined in the table. Table 14 is an example of a detailed monitoring plan for March 2009.

Table 12. Construction Testing Contracts

Research Partner	Description of Work
Professional Engineering Services, Ltd. (PES)	**Intelligent Compaction Verification Testing w/ LWD and DCP** PES was on site as needed to perform LWD and DCP testing of those cells compacted with the IC roller. They collected data that will be used to further verify the IC compaction specifications and correlations that were developed by MnROAD staff.
CNA Consulting Engineers (CNA)	**Intelligent Compaction Data Analysis** The objective of this research is to obtain data for further refinement/development of QC/QA specifications and procedures, enhancement of material property based compaction requirements, development of statistically based requirements and tests, and further development of the link between mechanistic-empirical pavement design and construction. CNA will clearly detail the field and laboratory test results and an engineering analyses of the tests performed. A summary and analysis of the following tests results shall be completed: • Intelligent Compaction • Light Weight Deflectometer • Dynamic Cone Penetrometer • Falling Weight Deflectometer • Nuclear Gauge • Moisture Testing • Proctor • Hydrometer • Atterberg Limits • Gradation
University of Minnesota	**Asphalt Binder and Mixture Fracture Testing** The objective of this project is to collect laboratory test data on the low temperature fracture properties of asphalt binders and mixtures used in the 2008 MnROAD reconstruction project. In-depth analysis will not be a part of this project; instead it will be accomplished in a concurrent project sponsored by Mn/DOT. This project involves laboratory testing on 12 asphalt mixtures and 9 asphalt binders from MnROAD.
American Engineering and Testing (AET)	**Concrete Sampling and Testing** AET completed all of the sampling and testing for Cells 5, 6, 13, 14, 85, 89, 53, and 39. This includes aggregate quality and slump, temperature, and unit weight of fresh concrete. They also performed compression and flexural testing, freeze/thaw durability, permeability, and trial mix verification.
Texas Transportation Institute (TTI)	**HMA High Temperature Performance Testing** TTI performed rutting and cracking HMA performance tests (Hamburg wheel tracker and overlay tester) on 17 different mixtures from MnROAD.
Ohio University	**HMA Low Temperature Performance Testing** Ohio University performed HMA low temperature cracking performance (ABCD) tests on all mixtures and binders from the project.
Mn/DOT Maplewood Lab	**Aggregate Base, Subgrade, Asphalt Mixture, and Asphalt Binder Testing** MnROAD staff collected hundreds of samples throughout the season on various pavement materials. Material characterization testing was performed in the Aggregate, Soils & Cement, Trial Mix, Chemical, and Metro Bituminous Laboratories in Maplewood.

Table 13. Overall Monitoring Activities and Schedule

MnROAD Monitoring Activities and Schedule - 2009

Update: 2/27/09

Measurement		Cells	Frequency	Tests/Lane/ Cell	Lead	Month												Comments
						J	F	M	A	M	J	J	A	S	O	N	D	
Aging Samples	Cores	All	1 / year	2 / lane/ cell	Burnham					▨	🟩		▨					Cores taken to monitor aging of HMA mix and PCC joint condition.
Curl & Warp	PALPS	Special	2 / year	Hourly Tests	Burnham				Opt	▨			▨		Opt			ALPS Data collected to support Mich Tech study - Detailed measurements taken over several periods thoughtout the day and seasons.
Distress Survey	Regular	All	2 / year	1 Survey	Worel				🟩	▨			▨	🟩				Modified LTPP Survey on all cells
	Pervious Cells	Pervious	4 / year	1 Survey				🟩	🟩	▨		🟩	▨	🟩				
Dynamic Load Testing	Truck / FWD	All	5 / year	Variable	Burnham	▧		🟩	🟩	▨		🟩	▨		🟩			Dynamic load testing of sensors. Loading from MnROAD truck and FWD.
Joint Faulting/ Shoulder Dropoff	Faultmeter	PCC	3 / year	Variable	Burnham				🟩	▨		🟩	▨		🟩			Mn/DOT modified Georgia Faultmeter measurements.
	Faultmeter	PCC	3 / year	1 midpanel edge/100'	Burnham				🟩	▨		🟩	▨		🟩			Use of the Georgia Faultmeter per modified LTPP protocol
Friction	KJ Law	All	2 / year	1 test Cell/Surface	Fischer			🟩		▨	🟩		▨	🟩		🟩		KJ Law profiler used – one test per lane per cell using both smooth and ribbed tire - collected by Mn/DOT pavements office for MnROAD.
	Grip Tester	All	4 / year	1 test Cell/Surface	S. Olson			🟩		▨	🟩		▨	🟩		🟩		Borrowed equipment.
	Dynamic Friction Tester	Select	2 / year	1 test / 25'	Wood			🟩		▨			▨	🟩				New equipment being acquired.
Falling Weight Deflectometer	FWD - PCC Cells	PCC	7 / year	Variable	Worel	▧		🟩	🟩	▨	No Jts	No Jts	▨	🟩	🟩			MnROAD has 2 Dynatest falling weight deflectometers and Mn/DOT also has 2. HMA testing includes both lanes roughly every 100' at marked points. PCC testing includes 5 point a panel and 5 panels a lane for both lanes. Testing schedule varies thoughout the year – multilple tests per year.
	FWD - HMA Cells	HMA	8 / year	1 test / 100' (multiple offsets)	Worel		🟩	🟩	🟩	▨	🟩	🟩	▨	🟩	🟩	🟩		
	Relative Calibration		4 / year		Worel		🟩		🟩	▨		🟩	▨		🟩			
	Reference Calibration		1 / year		Worel	▧				▨			▨					
HMA Rutting	ALPS	HMA	2 / year	10 points	Strommen				🟩	▨			▨	🟩				Advanced Laser Profile System (ALPS) every 50 feet. Used to characterize ruts, faults, cupping, lane/shoulder drop-off.
Noise	OBSI	All	4 / year	1 run	S. Olson			🟩		▨		🟩	▨		🟩	🟩		On Board Sound Intensity (OBSI) measurements will be conducted with a Mn/DOT owned system.
Piezometer	Piezometer	Pervious	4 / year	2 / Cell	Herndon	▧			🟩	▨		🟩	▨		🟩			Monitoring well measurements.
Permeability	Perveometer	Pervious	4 / year	1 test / 25'	Rohne			🟩	🟩	▨		🟩	▨		🟩			Test permeability of pervious/porous test cells.
Ride Quality	Pathways	All	3 / year	1 run	Pavements			🟩		▨		🟩	▨			🟩		Pavement Management office collects ride data summaries using using Pathways equipment.
	LISA	All	4 / year	10 runs	Pantelis			🟩		▨	🟩		▨	🟩		🟩		Mn/DOT owned lightweight Profiler. IRI and ERD files developed for each lane and cell.
Sound Absorption	Sound absorption device	PCC/Pervious	2 / year	2 / lane/ cell	S. Olson				🟩	▨		🟩	▨					Sound absorbtion measurements.
Surface Texture	Sand Patch	Select	4 / year	1 test / 25'	S. Olson/ Wood			🟩	🟩	▨		🟩	▨		🟩			Two locations per cell per lane unless part of a surface characteristics study which will increase the number of points to 5/points a cell (use FWD testing panels)
	Texture Meter	Select	4 / year	1 test / 50'	S. Olson			🟩	🟩	▨		🟩	▨		🟩			One location per cell per lane unless part of a surface characteristics study which will increase the number of points to 5/points a cell (Use FWD testing panels)

Table 14. Example Monitoring Activities and Assignments - March 2009

MnROAD Monitoring Activities and Assignments **Early March 2009**

Key: ▨ = Do not test for this cell ☐ = Test this cell and initial when complete **Update: 3/12/2009**

Tester 1	Doug Pat	Pavements	Steve	John P.	Bev	Bev	Ben	Ryan	Jack	Pavements	John P.	Steve	Steve	Steve
Tester 2	Chavonne			Tom W.	Pavements	Pavements					Steve	Tom W.		John P.
Cell	Dynamic Load Testing - Mainline	FRICTION - KJ LAW	FRICTION - GRIP TESTER	Dynamic Friction Tester	FWD Routine	FWD Sensor Testing	DISTRESS SURVEY	PERMEABILITY - PERVEOMETER	WATER LEVEL - PIEZOMETER	RIDE QUALITY - PATHWAYS	RIDE QUALITY - LISA	SURFACE TEXTURE - SAND PATCH	SURFACE TEXTURE - TEXTURE METER	NOISE - OBSI
1	▨					▨		▨	▨			▨	▨	
2					▨			▨	▨			▨	▨	
3					▨			▨	▨					
4					▨			▨	▨					
5	▨			▨		▨	▨	▨	▨			▨	▨	
105		▨	▨	▨	▨			▨	▨	▨	▨			▨
205		▨	▨	▨	▨			▨	▨	▨	▨			▨
305		▨	▨	▨	▨			▨	▨	▨	▨			▨
405		▨	▨	▨	▨			▨	▨	▨	▨			▨
6	▨					▨	▨	▨	▨			▨	▨	
106		▨	▨	▨	▨			▨	▨	▨	▨			▨
206		▨	▨	▨	▨			▨	▨	▨	▨			▨
7	▨			▨		▨		▨	▨					
8	▨			▨		▨		▨	▨					
9	▨			▨		▨		▨	▨					
60	▨			▨		▨		▨	▨			▨	▨	
61	▨			▨		▨		▨	▨			▨	▨	
62	▨			▨		▨		▨	▨			▨	▨	
63	▨			▨		▨		▨	▨			▨	▨	
96	▨			▨		▨		▨	▨			▨	▨	
97	▨			▨		▨		▨	▨			▨	▨	
92	▨			▨		▨		▨	▨			▨	▨	
10	▨			▨		▨		▨	▨			▨	▨	
11	▨			▨		▨		▨	▨			▨	▨	
12	▨			▨		▨		▨	▨			▨	▨	
13	▨			▨		▨	▨	▨	▨			▨	▨	
113		▨	▨	▨				▨	▨	▨	▨			▨
213		▨	▨	▨				▨	▨	▨	▨			▨
313		▨	▨	▨				▨	▨	▨	▨			▨
413	▨	▨	▨	▨		▨		▨	▨	▨	▨			▨
14	▨			▨		▨	▨	▨	▨			▨	▨	
114		▨	▨	▨	▨			▨	▨	▨	▨			▨
214		▨	▨	▨	▨			▨	▨	▨	▨			▨
814		▨	▨	▨	▨			▨	▨	▨	▨			▨
914		▨	▨	▨	▨			▨	▨	▨	▨			▨
15	▨					▨		▨	▨			▨	▨	
16					▨			▨	▨			▨	▨	
17						▨		▨	▨			▨	▨	
18						▨		▨	▨			▨	▨	
19					▨			▨	▨					
20						▨		▨	▨			▨	▨	
21						▨		▨	▨			▨	▨	
22					▨			▨	▨					
23					▨			▨	▨			▨	▨	
24					▨			▨	▨					
85	▨					▨								
86	▨				▨									
87	▨				▨				▨					
88	▨				▨									
89	▨					▨								
27	▨					▨		▨	▨			▨	▨	
28	▨					▨		▨	▨			▨	▨	
77						▨		▨	▨			▨	▨	
78						▨		▨	▨			▨	▨	
79						▨		▨	▨			▨	▨	
31	▨					▨		▨	▨			▨	▨	
32				▨		▨		▨	▨			▨	▨	
52				▨		▨		▨	▨			▨	▨	
53				▨				▨	▨					
54	▨			▨		▨		▨	▨			▨	▨	▨
33						▨		▨	▨			▨	▨	
34						▨		▨	▨			▨	▨	
35						▨		▨	▨			▨	▨	
36	▨			▨		▨		▨	▨			▨	▨	
37	▨			▨		▨		▨	▨			▨	▨	
38	▨			▨		▨		▨	▨			▨	▨	
39	▨			▨		▨			▨					
40	▨			▨		▨		▨	▨			▨	▨	▨
41	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨
42	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨
43	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨
44	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨
45	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨
46	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨	▨	▨	▨
83	Farm study	▨	▨	▨	▨	Farm study		▨	▨	▨	▨	▨	▨	▨
84	Farm study	▨	▨	▨	▨	Farm study		▨	▨	▨	▨	▨	▨	▨
64	▨	▨	▨	▨	▨				▨	▨	▨	▨	▨	▨

Table 15. Sampling and Testing Plan for Grading and Base Materials

		LAB						FIELD					
	Who? Mn/DOT (M) or Consultant (C)	**M**	**M**	**M**	**M**	**C**	**M**	**C**	**C**	**M**	**M**	**C**	**CAT**
Cell	**Material**	**Gradation**	**Proctor**	**Hydrometer**	**Atterberg Limits**	**Resilient Modulus (consult)**	**Resilient Modulus (optimum)**	**DCP**	**LWD**	**FWD**	**Moisture**	**Nuclear Density**	**IC**
2	Clay Subgrade	X	X	X	X		**X**						
	Class 4 Sp	X	X				**X**						
	FDR (HMA + Cl 4)	X	X				**X**	10	10	20	10	10	
3	Clay Subgrade	X	X	X	X		X						
	Class 3 Sp	X	X				**X**						
	Class 5 Sp	X	X				**X**						
	FDR (HMA + Cl 5)	X	X				**X**	10	10	20	10	10	
4	Clay Subgrade	X	X	X	X		X						
	FDR + Clay	X	X	X	X		**X**	10	10	20	10	10	
	FDR (HMA)	X	X				**X**	10	10	20	10	10	
6	Clay Subgrade	X	X	X	X		**X**	10	10	20	10	10	
	Clay Borrow	X	X	X	X		**X**	10	10	20	10	10	
	Class 5	X	X				**X**	10	10	20	10	10	
13	Clay Subgrade	X	X	X	X		**X**	10	10	20	10	10	
	Clay Borrow	X	X	X	X		**X**	10	10	20	10	10	
	Class 5	X	X				**X**	10	10	20	10	10	
16	Clay Subgrade	X	X	X	X		**X**	10	10	20	10	10	X
	Select Granular	X	X				**X**	10	10	20	10	10	X
	Class 3 Sp	X	X				**X**	10	10	20	10	10	X
	Class 7 Sp	X	X				**X**	10	10	20	10	10	X
17	Clay Subgrade	X	X	X	X		X	10	10	20	10	10	X
	Select Granular	X	X				X	10	10	20	10	10	X
	Class 3 Sp	X	X				X	10	10	20	10	10	X
	Class 7 Sp	X	X				**X**	10	10	20	10	10	X
18	Clay Subgrade	X	X	X	X		X	10	10	20	10	10	X
	Select Granular	X	X				X	10	10	20	10	10	X
	Class 3 Sp	X	X				X	10	10	20	10	10	X
	Class 7 Sp	X	X				**X**	10	10	20	10	10	X
19	Clay Subgrade	X	X	X	X		**X**	10	10	20	10	10	X
	Select Granular	X	X				**X**	10	10	20	10	10	X
	Class 3 Sp	X	X				**X**	10	10	20	10	10	X
	Class 5 Sp	X	X				**X**	10	10	20	10	10	X
20	Clay Subgrade	X	X	X	X		X	10	10	20	10	10	X
	Select Granular	X	X				X	10	10	20	10	10	X
	Class 3 Sp	X	X				X	10	10	20	10	10	X
	Class 5 Sp	X	X				X	10	10	20	10	10	X
21	Clay Subgrade	X	X	X	X		X	10	10	20	10	10	X
	Select Granular	X	X				X	10	10	20	10	10	X
	Class 3 Sp	X	X				X	10	10	20	10	10	X
	Class 5 Sp	X	X				**X**	10	10	20	10	10	X
22	Clay Subgrade	X	X	X	X		X	10	10	20	10	10	X
	Select Granular	X	X				X	10	10	20	10	10	X
	Class 3 Sp	X	X				X	10	10	20	10	10	X
	Class 5 Sp	X	X				X	10	10	20	10	10	X
23	Clay Subgrade	X	X	X	X		**X**	10	10	20	10	10	X
	Select Granular	X	X				**X**	10	10	20	10	10	X
	Class 3 Sp	X	X				**X**	10	10	20	10	10	X
	Taconite Ballast	X	X				**X**	10	10	20	10	10	X
53	Clay Subgrade	X	X	X	X		**X**	8	8	16	8	8	
	Select Granular	X	X				**X**	8	8	16	8	8	
	Class 5	X	X				**X**	8	8	16	8	8	
85	Sand Subgrade	X	X				**X**	8	8	16	8	8	X
	CA-15	X	X				**X**	8	8	16	8	8	X
86	Sand Subgrade	X	X				**X**	8	8	16	8	8	X
	CA-15	X	X				X	8	8	16	8	8	X
87	Clay Subgrade	X	X	X	X		X	8	8	16	8	8	X
	Sand Subgrade	X	X				X	8	8	16	8	8	X
	CA-15	X	X				X	8	8	16	8	8	X
88	Clay Subgrade	X	X	X	X		**X**	8	8	16	8	8	X
	CA-15	X	X				X	8	8	16	8	8	X
89	Clay Subgrade	X	X	X	X		**X**	8	8	16	8	8	X
	CA-15	X	X				**X**	8	8	16	8	8	X
	TOTAL	62	62	20	20		62	532	532	1064	532	532	43
	x2	124	124	40	40		124						

**** Gradation, Proctor, hydrometer, and Atterberg Limit tests are all x2 locations per material per cell**

**** Note particular LWD, DCP, moisture, nuclear density testing regimes from Grading & Base Office**

**** Plan on all Mr testing done at Mn/DOT soils lab - red bold X's will be tested, other X's collected (will be tested only if needed)**

Table 16. Concrete Sampling and Testing Plan

		Aggregate Quality	Rheological			Compression Sampling, Testing, and Reporting				Flexural Sampling, Testing, and Reporting				Freeze Thaw Durability		Permeability	COTE		Trial Mixing
Cell	**Structural Design**	**Sampling, Transport, Testing, & Reporting**	**Slump**	**Temp**	**Unit Weight**	**1-DAY COMP**	**3-DAY COMP**	**7-DAY COMP**	**28-DAY COMP**	**1-DAY FLEX**	**3-DAY FLEX**	**7-DAY FLEX**	**28-DAY FLEX**	**F-T Sampling Prisms**	**F-T ASTM 666 Testing and Reporting**	**Permeability Sampling, Testing, & Reporting (1, 3, 7, 14, 28, 56, 90 Days) 5 cylinders per mix type**	**Cylinder Sampling & Transport**	**Testing & Reporting**	**Includes Batching, Flex/Comp/ Durability/Permeability, Reporting, Final Mix Design**
5	Unbonded Concrete Overlay	1	11	11	11	3	3	3	3	2	2	2	2	6	6	1	5	5	1
6	Composite Pavement		10	10	10	3	3	3	3	2	2	2	2				5	5	
13	Thin Concrete		11	11	11	3	3	3	3	2	2	2	2				5	5	
14	Whitetopping		12	12	12	3	3	3	3	2	2	2	2				5	5	
85	Pervious PCC Pavement	1	7	7	7	3	3	3	3	2	2	2	2	6	6	1	5	5	1
89	Pervious PCC Pavement		7	7	7	3	3	3	3	2	2	2	2				5	5	
53	60-Year PCC Pavement	1	7	7	7	3	3	3	3	2	2	2	2	6	6	1	5	5	1
39	Pervious PCC Overlay	1	8	8	8	3	3	3	3	2	2	2	2	6	6	1	5	5	1
	Total Tests	4	73	73	73	24	24	24	24	16	16	16	16	24	24	4	40	40	4

** Assuming American Engineering Testing (AET) will do **ALL** sampling, testing, & reporting

** w/c ratio, air content, and other QC tests will be run at the plant under normal Mn/DOT procedures

Table 17. Asphalt Sampling and Testing Plan

		HMA Performance Tests								Asphalt Binder Tests						"Typical" QA Tests							
	Who? Mn/DOT (M) or Consultant (C)	M	M	C	C	C	C	M	C	M	M	M	C	C	M	M	M	M	M	M	M	M	M
Cell	Mix Type	APA Rutting	Dynamic Modulus	SCB or DCT Fracture	IDT Creep & Strength	TTI Overlay Tester &Wet Hamburg	ABCD Mix Test	Moisture Sensitivity	Lab Permeability	Neat PG Grade	Neat MSCR	Neat Master Curve	Neat DENT Fracture	ABCD Binder	Extracted Master Curve	Gradation	Coarse Angularity	Fine Angularity	Coarse Gsb	Fine Gsb	Mix Voids (Lab)	Field Density	AC %
2	Novachip	X	X	X	X	X	X	X								X	X	X	X	X	X	X	X
	SPWEB440F	X	X	X	X	X	X	X								X					X	X	X
3	Novachip															X					X	X	X
	SPWEB440F															X					X	X	X
4	Novachip									X	X	X	X	X	X	X					X	X	X
	SPWEB440F															X					X	X	X
5	PASSRC			X	X	X	X	X	X	X			X	X		X	X		X		X	X	X
6	SPWEB440F Special	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X		X	X	X	X
15	SPWEB440C Special															X					X	X	X
16	SPWEB440C Special	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SPNWB430C Special	X	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X
17	SPWEB440C Special															X					X	X	X
	SPNWB430C Special															X					X	X	X
18	SPWEB440C Special															X					X	X	X
	SPNWB430C Special															X					X	X	X
19	SPWEB440C Special															X					X	X	X
	SPNWB430C Special															X					X	X	X
20	SPWEB440B	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SPNWB430B	X	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X
21	SPWEB440B Special	X	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X
	SPNWB430B Special	X	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X
22	SPWEB440C Special 1	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SPNWB430C Special 1	X	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X
23	SPWEB440C Special															X					X	X	X
	SPNWB430C Special															X					X	X	X
86	SPWEB440F Special 1	X	X	X	X	X	X	X	X						X	X	X	X	X	X	X	X	X
87	SPWEB340B	X	X	X	X	X		X	X							X	X	X	X	X	X	X	X
88	SPWEB440F Special 1															X					X	X	X
*	Standard RAP pile									X		X	X		X	X	X	X	X	X			X
*	Coarse RAP pile									X		X	X		X	X	X		X				X
*	Fine RAP pile									X		X	X		X	X		X		X			X
	TOTAL	**14**	**14**	**15**	**15**	**15**	**14**	**15**	**3**	**9**	**5**	**8**	**9**	**6**	**15**	**32**	**15**	**15**	**15**	**15**	**29**	**29**	**32**

Table 18. Stockpile Samples

Contractor or Mn/DOT forces hauled 1 stockpile (about 8 tons) of each material (when available) to bins in the MnROAD Stockpile Area.		
Material	**Application**	**Cells**
MnROAD Millings	HMA aggregate	15-20, 23
Taconite Ballast	Agg Base	23
Select Granular	Agg Subbase	16-23
Class 5 Special	Agg Base	original cells
MinTac Taconite Tailings	HMA aggregate	6
Ispat Tailings	HMA aggregate	6
Loken Manufactured Sand	HMA aggregate	6, 87
Martin Marietta SC 1/2" Washed Chips (Granite)	HMA aggregate	15-23, shoulders
Martin Marietta SC 3/4" Unwashed (Granite)	HMA aggregate	2-4, 86, 88, shoulders
Martin Marietta SC CA-50 (Granite)	HMA aggregate	2-4, 86, 88
Martin Marietta SC Washed Sand (Granite)	HMA aggregate	2-4, 15-23, shoulders
Vonco II BA Sand	HMA aggregate	2-4, 87, shoulders
Shingles (Tear Offs)	HMA aggregate	shoulders
Shingles (Manufactured Scrap)	HMA aggregate	shoulders
MnROAD Crushed Millings	HMA aggregate	15-20, 23
Fiber Stabilizer (for Porous HMA)	HMA aggregate	86, 88

Table 19. Proctor Data for Class 3 Material

Cell	Opt. Moisture (%)	Max Density (pcf)
3	9.4	128.6
16	9.3	127.4
17	9.1	130.1
18	9.1	129.6
19	9.6	127.6
20	9.1	129.0
21	9.3	128.9
22	9.4	128.5
23	8.9	129.4

Table 20. Proctor Data for Class 5 Material

Cell	Opt. Moisture (%)	Max Density (pcf)
3	7.5	131.7
6	9.6	124.7
13	10.2	125.5
19	9.1	128.3
20	9.3	129.2
21	8.9	129.3
22	10.3	128.1

Table 21. Proctor Data for Class 7 Material

Cell	Material	Opt. Moisture (%)	Max Density (pcf)
16	Class 7 (100% PCC)	11.7	118.0
17	Class 7 (50-50 PCC-Class 5)	10.4	123.2
18	Class 7 (100% RAP)	6.7	124.4

Table 22. Proctor Data for Sand Subgrade and Select Granular

Cell	Material	Opt. Moisture (%)	Max Density (pcf)
85	Sand Subgrade	9.4	120.1
86	Sand Subgrade	8.0	115.4
87	Sand Subgrade	9.2	125.2
53	Select Granular	9.8	121.7
16	Select Granular	8.1	131.5
17	Select Granular	8.1	130.6
18	Select Granular	7.9	130.1
19	Select Granular	7.7	131.4
20	Select Granular	8.5	129.6
21	Select Granular	8.3	129.2
22	Select Granular	8.4	128.6
23	Select Granular	7.6	131.4

Table 23. Material Properties for Clay Subgrade Materials

Cell	Optimum Moisture	Max Density	Liquid Limit	Plastic Limit	Plasticity Index	R-Value
4	12.1	120.0	26.7	18.1	8.5	31.5
6	14.3	115.2	29.6	18.9	10.7	21.3
13	13.3	117.2	28.6	19.9	8.7	19.9
16	13.6	117.1	30.5	19.3	11.2	25.8
17	14.9	113.5	33.8	20.8	13.0	18.9
18	13.9	114.2	33.8	20.5	13.3	20.9
19	15.6	112.1	29.8	21.9	8.0	28.2
20	15.2	113.2	30.3	15.5	14.8	22.9
21	16.4	108.9	32.6	18.1	14.5	25.4
22	15.7	112.6	30.9	18.5	12.4	23.0
23	16.5	109.7	34.1	20.5	13.7	18.5
53	15.4	111.4	32.1	18.8	13.3	25.0
87	11.1	123.3	22.1	18.0	4.1	32.5
88	10.2	124.7	26.5	25.8	0.7	30.5
89	10.7	123.0	27.5	24.5	3.0	28.4

Table 24. Average Density and Air Void Results for HMA Cores

Cell	Description	% Density	Air Voids
6	4.75 mm taconite	93.1	6.9
15-19, 23	WMA non wear	93.4	6.6
15-19, 23	WMA wear	92.0	8.0
20	RAP non wear	95.6	4.4
20	RAP wear	92.5	7.5
21	frac RAP non wear	95.0	5.0
21	frac RAP wear	92.3	7.7
22	frac RAP non wear	95.4	4.6
22	frac RAP wear	93.6	6.4
24	WMA control	91.4	8.6
87	porous control	93.2	6.8
88	porous HMA	82.0	18.0
15-23	Tear Off Shingles	92.4	7.6
5, 6, 13, 14	Mfr Wst Shingles	91.4	8.6

Table 25. Concrete Coefficient of Thermal Expansion

Cell	Average CTE (10^{-6} in/in/^{O}F)	Std. Dev.
5	5.4	0.09
6	5.3	0.04
13	5.3	0.04
39	4.8	0.16
53	5.3	0
85	4.8	0.07
89	4.9	0.12

Table 26. Rapid Chloride Ion Permeability Test Results (ASTM C 1202)

Cell	Coulombs	Milliamps
5	2040	116.1

Note: The pervious nature of the concrete in Cells 39, 85, and 89 did not allow the test to provide accurate results.

Table 27. Freeze-Thaw Durability Test Results (ASTM C 666)

Cell	Relative Dynamic Modulus, %	Dilation %	Weight Loss %	Durability Factor
5	95	0.04	0.35	95
6	94	0.04	0.38	94
39	Failed at 83 Cycles			15
39	Failed at 100 Cycles			19
53	95	0.04	0.32	95
85	Failed at 228 Cycles			44
85	Failed at 127 Cycles			24
89	Failed at 117 Cycles			23

Table 28. Concrete Flexural Strength Summary

Average Flexural Strength @ 1 Day(psi)					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trail Batch					
5	2	490	N/A	490	490
6					
13-14					
39 Inside Lane					
39 Outside Lane	1	90	N/A	90	90
53 Inside Lane	1	280	N/A	280	280
53 Outside Lane					
85 Inside Lane					
85 Outside Lane					
89 Inside Lane					
89 Outside Lane					

Average Flexural Strength @ 3 Days(psi)					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trail Batch					
5	2	565	N/A	560	570
6					
13-14					
39 Inside Lane					
39 Outside Lane	1	360	N/A	360	360
53 Inside Lane	1	580	N/A	580	580
53 Outside Lane					
85 Inside Lane	2	295	N/A	310	280
85 Outside Lane	2	440	N/A	460	420
89 Inside Lane	2	435	N/A	460	410
89 Outside Lane	2	330	N/A	350	310

Average Flexural Strength @ 4 Days(psi)

Cell	Number of Specimens	Average Strength	Standard Deviation	High	Low
Trail Batch					
5					
6					
13-14					
39 Inside Lane	2	380	N/A	390	370
39 Outside Lane					
53 Inside Lane					
53 Outside Lane					
85 Inside Lane					
85 Outside Lane					
89 Inside Lane					
89 Outside Lane					

Average Flexural Strength @ 7 Days(psi)

Cell	Number of Specimens	Average Strength	Standard Deviation	High	Low
Trail Batch					
5	4	620	26.3	640	580
6					
13-14					
39 Inside Lane	2	575	N/A	590	570
39 Outside Lane	2	400	N/A	410	390
53 Inside Lane	2	760	N/A	790	730
53 Outside Lane	1	710	N/A	710	710
85 Inside Lane	2	320	N/A	320	320
85 Outside Lane	2	450	N/A	480	420
89 Inside Lane	2	425	N/A	450	400
89 Outside Lane	2	390	N/A	400	380

Average Flexural Strength @ 28 Days(psi)					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trail Batch					
5	4	930	87.3	1010	830
6					
13-14					
39 Inside Lane	2	855	N/A	890	820
39 Outside Lane	2	465	N/A	470	460
53 Inside Lane	2	1115	N/A	1150	1080
53 Outside Lane					
85 Inside Lane	2	325	N/A	330	320
85 Outside Lane	2	490	N/A	520	460
89 Inside Lane	2	490	N/A	520	450
89 Outside Lane	2	440	N/A	460	410

Average Flexural Strength @ 47 Days(psi)					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trail Batch					
5					
6					
13-14					
39 Inside Lane					
39 Outside Lane					
53 Inside Lane					
53 Outside Lane	2	885	N/A	930	840
85 Inside Lane					
85 Outside Lane					
89 Inside Lane					
89 Outside Lane					

Table 29. Concrete Compressive Strength Summary

Average Compressive Strength @ 3 Days(psi)					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trial Batch	1	2700	N/A		
5	4	2550	194	2830	2390
6	1	3750	N/A		
13-14	1	3210	N/A		
39 Inside Lane					
39 Outside Lane	2	1355	N/A	1410	1300
53 Inside Lane	2	3250	N/A	3270	3230
85 Inside Lane	2	3110	N/A	3190	3020
85 Outside Lane	2	3280	N/A	3470	3080
89 Inside Lane	2	3070	N/A	3210	2930
89 Outside Lane	2	2270	N/A	2370	2160

Average Compressive Strength @ 5 Days(psi)					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trial Batch					
5					
6					
13-14					
39 Inside Lane	2	2550	N/A	2570	2530
39 Outside Lane					
53 Inside Lane					
85 Inside Lane					
85 Outside Lane					
89 Inside Lane					
89 Outside Lane					

Average Compressive Strength @ 7 Days(psi)					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trial Batch	1	4280	N/A		
5	4	3760	191	4040	3620
6	1	4320	N/A		
13-14	1	3850	N/A		
39 Inside Lane	2	2915	N/A	2990	2840
39 Outside Lane	2	2395	N/A	2400	2390
53 Inside Lane	2	4445	N/A	4470	4420
85 Inside Lane	2	3220	N/A	3230	3200
85 Outside Lane	2	4160	N/A	4270	4040
89 Inside Lane	2	3410	N/A	3460	3350
89 Outside Lane	2	3120	N/A	3160	3070

Average Compressive Strength @ 21 Days(psi):					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trial Batch					
5	4	4530	67	4600	4470
6					
13-14					
39 Inside Lane	2	4255	N/A	4380	4130
39 Outside Lane	2	3020	N/A	3120	2920
53 Inside Lane	2	5465	N/A	5560	5370
85 Inside Lane	2	3450	N/A	3560	3340
85 Outside Lane	2	5005	N/A	5060	4950
89 Inside Lane	2	4130	N/A	4160	4090
89 Outside Lane	2	3520	N/A	3610	3430

Average Compressive Strength @ 28 Days(psi):					
Cell	**Number of Specimens**	**Average Strength**	**Standard Deviation**	**High**	**Low**
Trial Batch					
5	4	5200	85	5300	5100
6	2	5670	N/A	5750	5580
13-14	2	5030	N/A	5130	4920
39 Inside Lane	2	4750	N/A	4780	4720
39 Outside Lane	2	4020	N/A	4060	3980
53 Inside Lane	2	5895	N/A	5950	5840
85 Inside Lane	2	3850	N/A	3880	3810
85 Outside Lane	2	5200	N/A	5240	5150
89 Inside Lane	2	4290	N/A	4330	4240
89 Outside Lane	2	4250	N/A	4300	4200

CHAPTER 4 – INSTRUMENTATION

Measuring the response of pavement structures to traffic and environmental loadings has been a key component of the MnROAD facility. These measurements have been accomplished predominantly through the use of electronic instrumentation. Over 8500 sensors were installed during the initial construction at MnROAD. For Phase II construction we invested almost $900,000 on instrumentation and the associated infrastructure. The following three tables describe the sensors and infrastructure and where they were installed. Following the tables, several plots show the instrumentation layout in each cell.

Table 30. Sensors Installed During 2008 Season

Description	Model	# of Gauges
Moisture Content of Unbound Materials (MC)	Decagon 5TE	152
Moisture Content of Bound/ Unbound Materials (MC)	Davis Irrometer 200 SS-60	58
Moisture Content of Unbound Materials (MC)	Campbell TDR	16
Moisture Content of Unbound Materials (MC)	Strip TDR	1
Temperature Tree, TC_{16}	Omega / MnROAD	22
Temperature Tree, TC_8	Omega / MnROAD	14
Concrete Pavement Maturity (IK)	IntelliRock	72
Static Strain (Vibrating Wire, VW)	Geokon 4200	182
Static Strain (Vibrating Wire, VG)	Geokon 4202	8
Static Horizontal Displacement (Horizontal Clip Gauges, HC)	Tokyo Sokki PI-5S-50/150	50
Dynamic Strain (CE)	Tokyo Sokki PML-60	279
Dynamic Displacement (LVDT)	Schaevitz GSHAR 750-250	51
Static Normal Pressure (PT)	Geokon 4800	6
Dynamic Normal Pressure (PG)	Geokon 3500	42
Dynamic Strain of HMA (LE or TE or AS)	CTL Group CTL-152	84
Dynamic Strain of HMA (LE or TE or AS)	Dynatest PAST-II AC	7
Dynamic Displacement of Unbound Materials	CTL	10

Table 31. Infrastructure Installed During 2008 Season

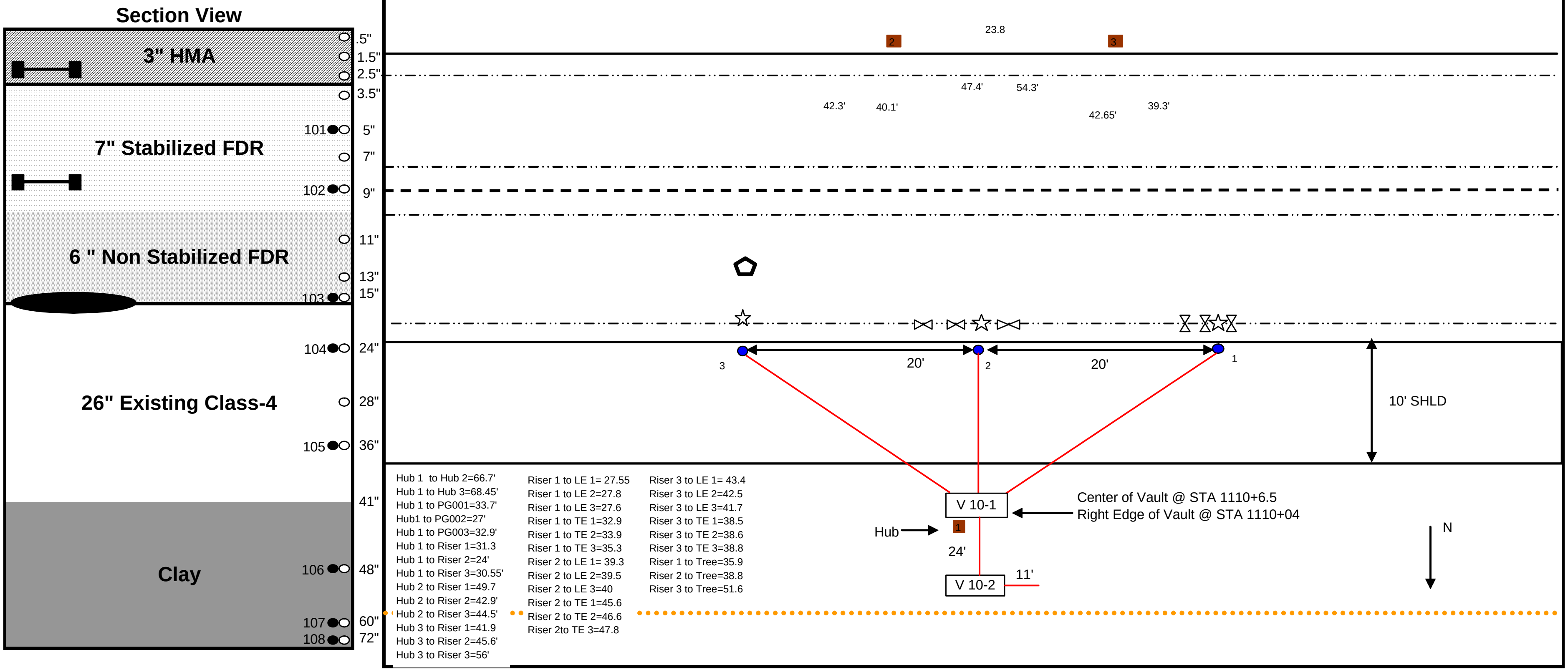
Description	Model	Total #
Control Cabinets and Foundations	NEMA 334	6
Power Pedestals		5
BD 4 Pedestals	Charles Pedlock BD-4	13
PE Hand Holes w/ rings and covers		14
0.625" Invar Rods (12 feet long)		32
Static Sensor Datalogger	Campbell CR 1000	22
Multiplexor	Campbell AM16/32A	1
Time-Domain Reflectometry	Campbell TDR100	3

Table 32. Instrumentation by Cel

	Sensor Description																							
Cell	**PG**	**TE**	**LE**	**TC**	**EC**	**DYN-LE**	**WM Tree**	**TDR strip**	**CS 616**	**LSIM**	**Loop**	**SGC**	**AS**	**CE**	**DT**	**IV**	**HC**	**IK**	**VG**	**WM**	**VW**	**XG**	**XV**	**PT**
2		6	6	16	8																			
3		6	6	16	8																			
4		6	6	16	8																			
105														12	2	1								
205				24										15	4	3	4	6			16		16	
305				16										15	4	3	4	6			16		16	
405														12	2	1								
106				49									1	18	6	4	4			10	16		16	4
206				16									2	9	6	4	4	6			16		16	2
113				16										19	7	5	6	6	2	12	16	3	16	2
213				8										10										
313				8										19	4	3	6	6						
114														16	2	1	4	6	2		16			
214				8										4	2	1	4				4			
814				24										4	3	1	4				4			
914														16	2	1	4				8			
15				16																				
16	3	3	3	16	8							2												
17	3	3	3	16	8							2												
18	3	3	3	16	8							2												
19	3	3	3	16	8	3	1	1	1			2												
20	2	2	2	16	8																			
21	2	2	2	16	8																			
22	2	2	2	16	8																			
23	2	2	2	16	8																			
24				16																				
39				8										18							16			
53				24										19	6	4	6	10	3	12	16	3	16	
85	2			8							1							8			16			
86	2	2	2	16	8					1	1													
88	2	2	2	16	8					1	1													
89	2			8							1							9			16			

MnROAD Instumentation Summary for Full Depth Reclaimation Experiment

Cell	2
Project	8680-157



Hub 1 to Hub 2=66.7'
Hub 1 to Hub 3=68.45'
Hub 1 to PG001=33.7'
Hub1 to PG002=27'
Hub 1 to PG003=32.9'
Hub 1 to Riser 1=31.3
Hub 1 to Riser 2=24'
Hub 1 to Riser 3=30.55'
Hub 2 to Riser 1=49.7
Hub 2 to Riser 2=42.9'
Hub 2 to Riser 3=44.5'
Hub 3 to Riser 1=41.9
Hub 3 to Riser 2=45.6'
Hub 3 to Riser 3=56'

Riser 1 to LE 1= 27.55
Riser 1 to LE 2=27.8
Riser 1 to LE 3=27.6
Riser 1 to TE 1=32.9
Riser 1 to TE 2=33.9
Riser 1 to TE 3=35.3
Riser 2 to LE 1= 39.3
Riser 2 to LE 2=39.5
Riser 2 to LE 3=40
Riser 2 to TE 1=45.6
Riser 2 to TE 2=46.6
Riser 2to TE 3=47.8

Riser 3 to LE 1= 43.4
Riser 3 to LE 2=42.5
Riser 3 to LE 3=41.7
Riser 3 to TE 1=38.5
Riser 3 to TE 2=38.6
Riser 3 to TE 3=38.8
Riser 1 to Tree=35.9
Riser 2 to Tree=38.8
Riser 3 to Tree=51.6

Sensor Requirement

Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Decagon ECH_2O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	6	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	6	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	3	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

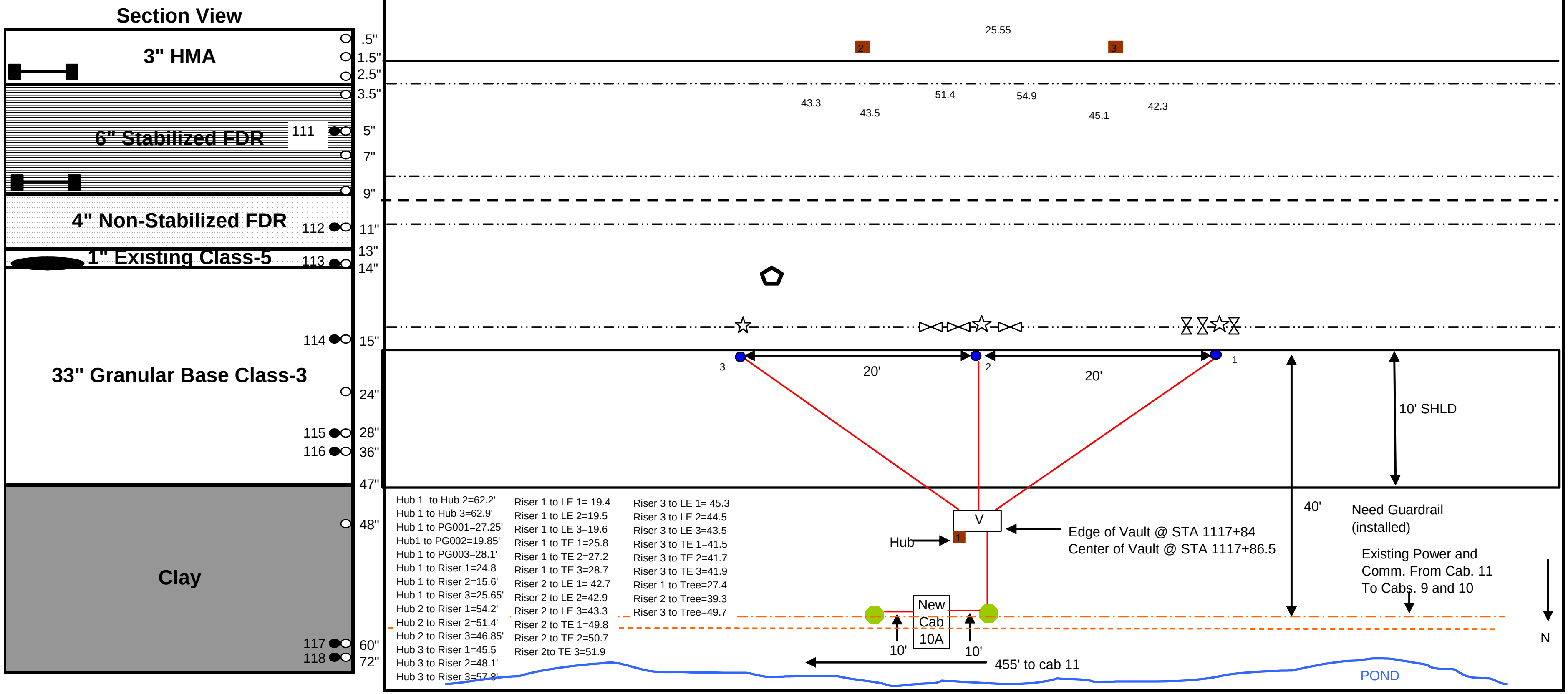
Cab 10

Legend			
●	Risers	−··−··	Wheelpath (9.5' offset from CL)
▬ ▬ ▬	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧖	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor		
●	Handhole		

Figure 42. Instrumentation for Cell 2

MnROAD Instumentation Summary for Full Depth Reclaimation Experiment

Cell	3
Project	8680-157



Sensor Requirement

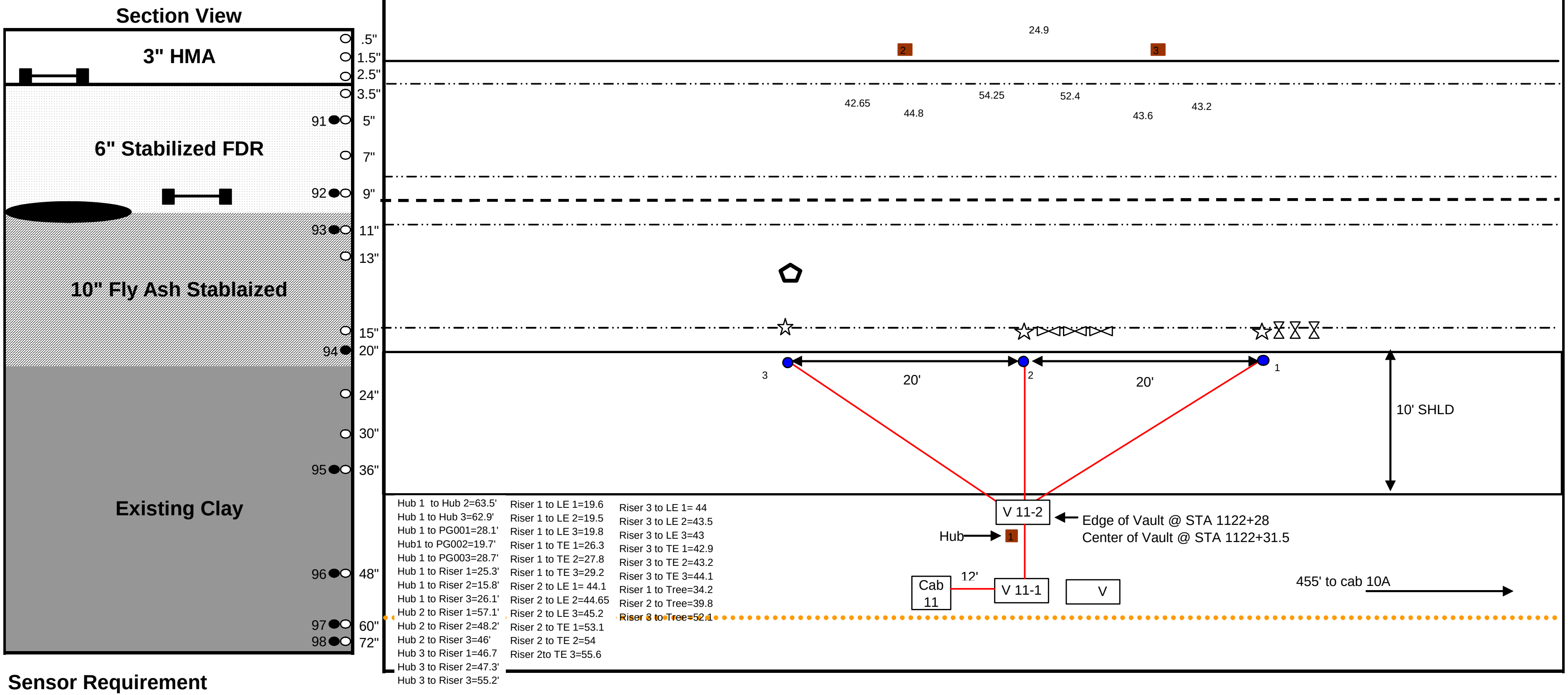
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	6	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	6	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	3	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

Legend			
●	Risers	—··—··	Wheelpath (9.5' offset from CL)
— — —	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	——	Conduit
⧖	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor		
●	Handhole		

Figure 43. Instrumentation for Cell 3

MnROAD Instumentation Summary for Full Depth Reclamation Experiment

Cell	4
Project	8680-157



Sensor Requirement

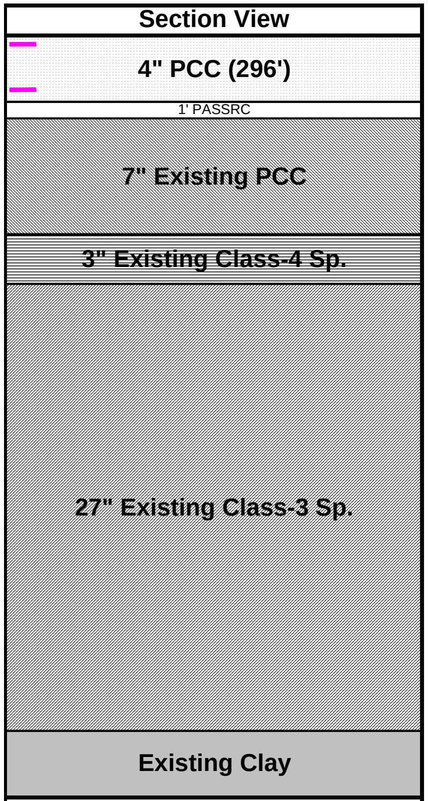
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture	Measures volmetric moisture content, temperature, electric conductivity
TE	6	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	6	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	3	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

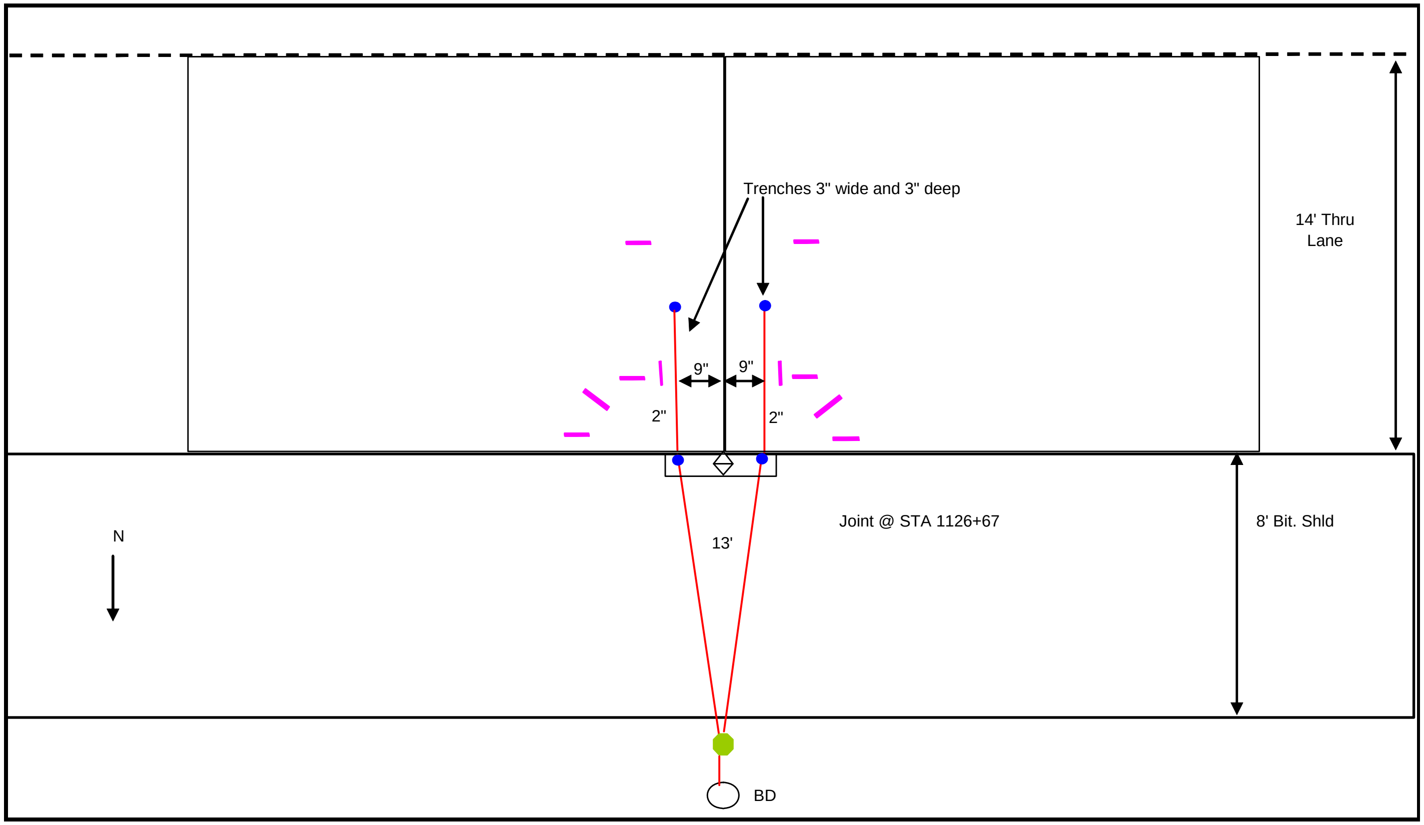
Legend			
●	Risers	−··−	Wheelpath (9.5' offset from CL)
− − −	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor		
●	Handhole		

Figure 44. Instrumentation for Cell 4

MnROAD Instumentation Summary For PCC Overlay Experiment

Cell	5 - 105
Project	8680-157





Sensor Requirement

Code	Number	Sensor	Description
CE	16	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	0	Vibrating Wire Strain Gauge	Static (Environmental) Strain
DT	2	LVDT	Linear Variable Displacement Transducer (LVDT), Vertical Displacement of the Panel at the Joint
IV	1	Invar Rod	Static Reference Point for Vertical Measurement

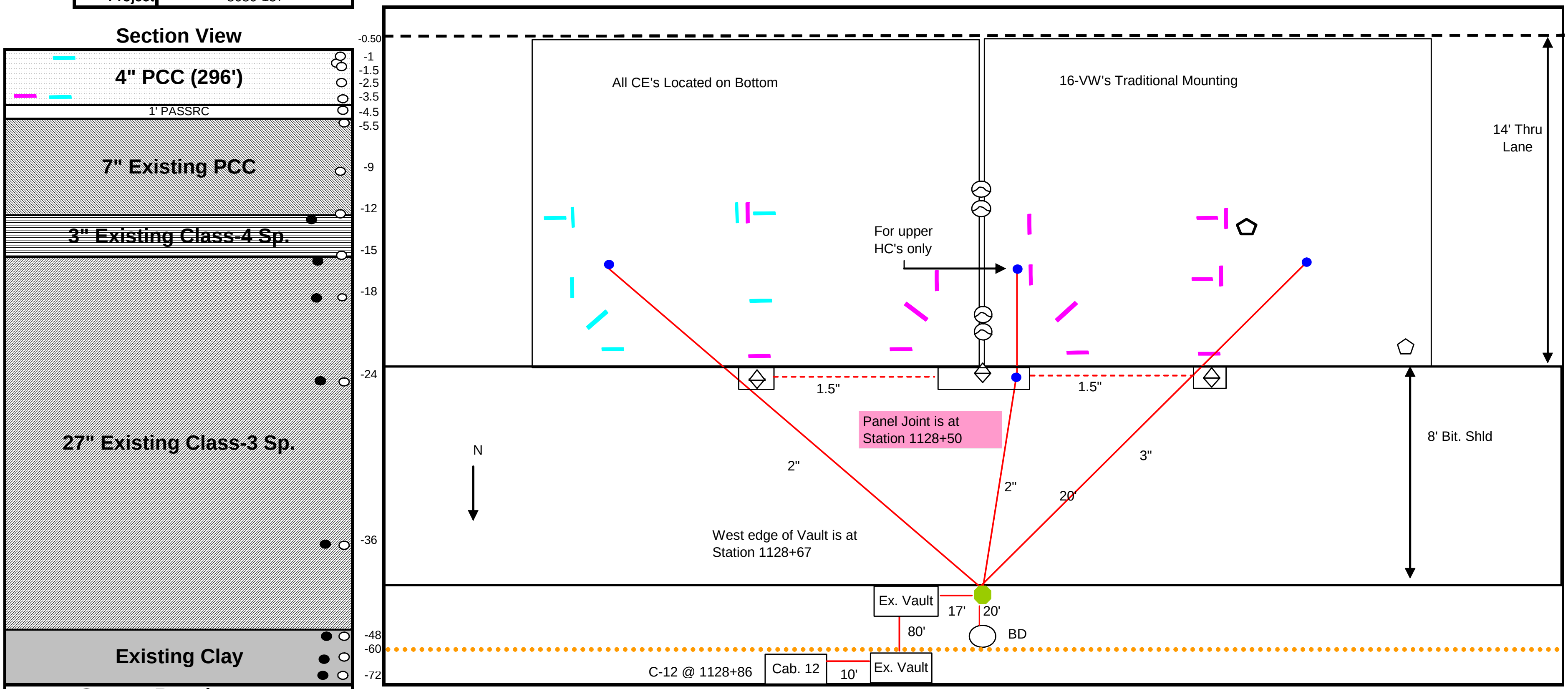
Legend

●	Risers	⟠	DT
– – –	Centerline	••••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	▬	CE sensor
●	Handhole	▬	VW Sensors

Figure 45. Instrumentation for Cell 105

MnROAD Instumentation Summary For PCC Overlay Experiment

Cell	5 - 205
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
CE	15	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain
IK	9	Maturity	Maturity Sticks
TC_8	1	Thermocouple	Eight-Pair Thermocouple Wire Tree W/O Moisture Tree
TC_{16}	1	Thermocouple	Sixteen-Pair Thermocouple Wire Tree W/ Moisture Tree
HC	4	Strain Gauge	Horizontal Clip Gauge, Longitudinal Strain Across Transverse Joints
DT	4	LVDT	Linear Variable Displacement Transducer, Vertical Panel Displacement
EC	8		

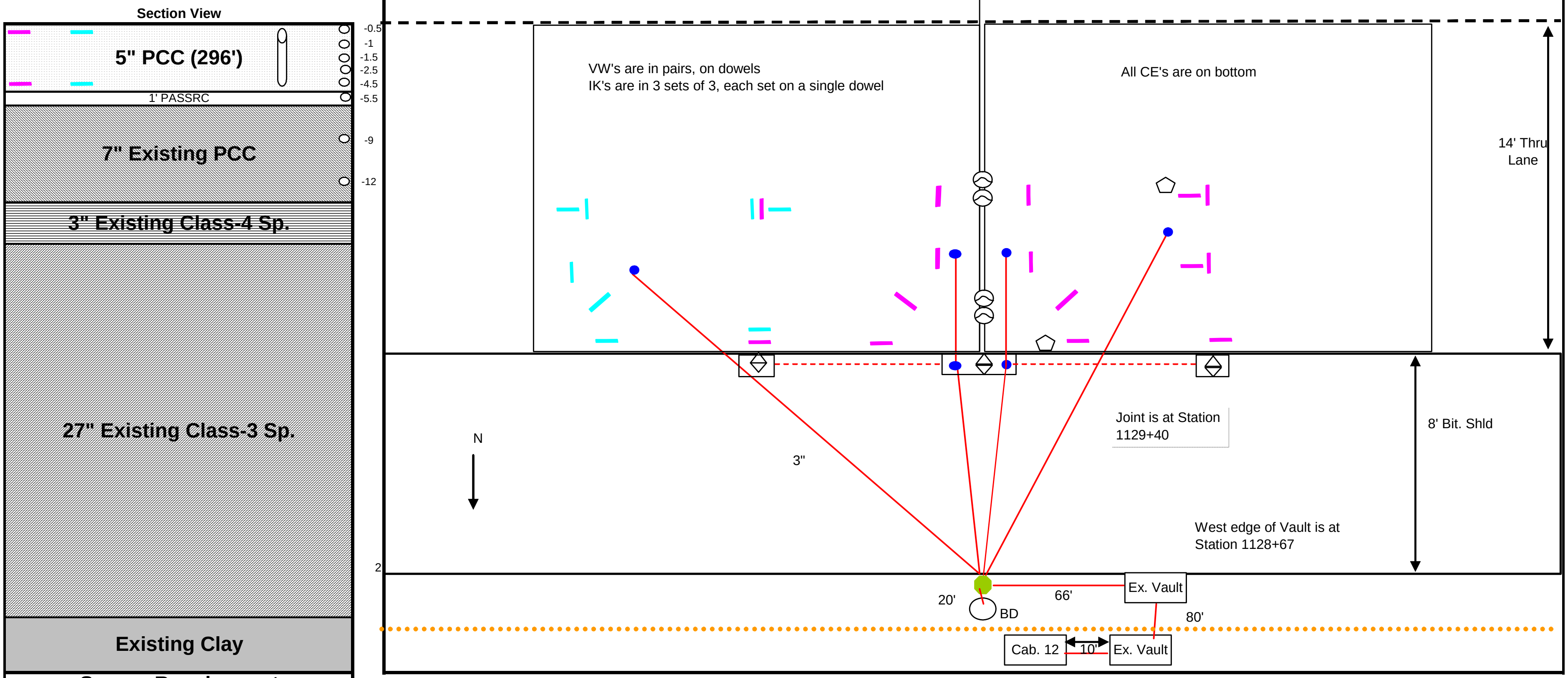
Legend

●	Risers	◈	DT
- - -	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
╳	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠ / ⬟	TC or **TC/ M** Sensor Tree	⌷	IK
●	Handhole	▬	CE sensor
		▬	VW Sensors

Figure 46. Instrumentation for Cell 205

MnROAD Instumentation Summary For PCC Overlay Experiment

Cell	5 - 305
Project	8680-157



VW's are in pairs, on dowels
IK's are in 3 sets of 3, each set on a single dowel

All CE's are on bottom

Joint is at Station 1129+40

West edge of Vault is at Station 1128+67

Sensor Requirement

Code	Number	Sensor	Description
CE	16	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain(Longitudinal and Transverse)
IK	9	Maturity	3-Sensor Maturity Sticks
TC_8	2	Thermocouple	Eight-Pair Thermocouple Wire Tree W/O Moisture Tree
HC	4	Strain Gauge	Horizontal Clip Gauge, Longitudinal Strain Across Transverse Joints
DT	4	LVDT	Linear Variable Displacement Transducer, Vertical Panel Displacement

Legend

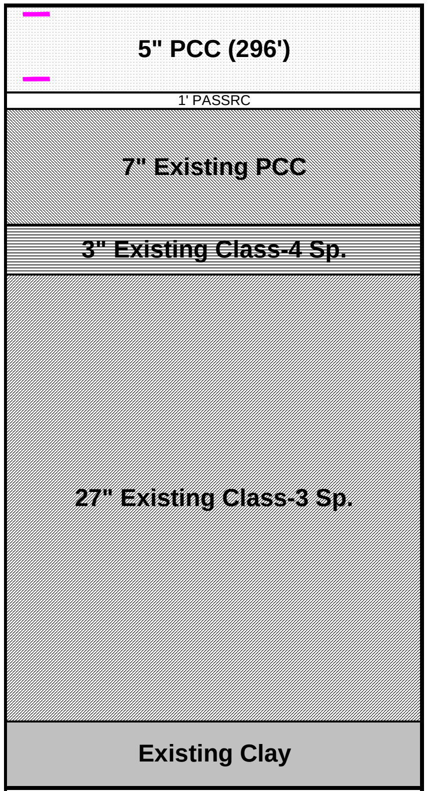
●	Risers	⬘	DT
▬ ▬ ▬	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧖	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC Sensor Tree	⌸	IK
●	Handhole	▬	CE sensor
		▬	VW Sensors

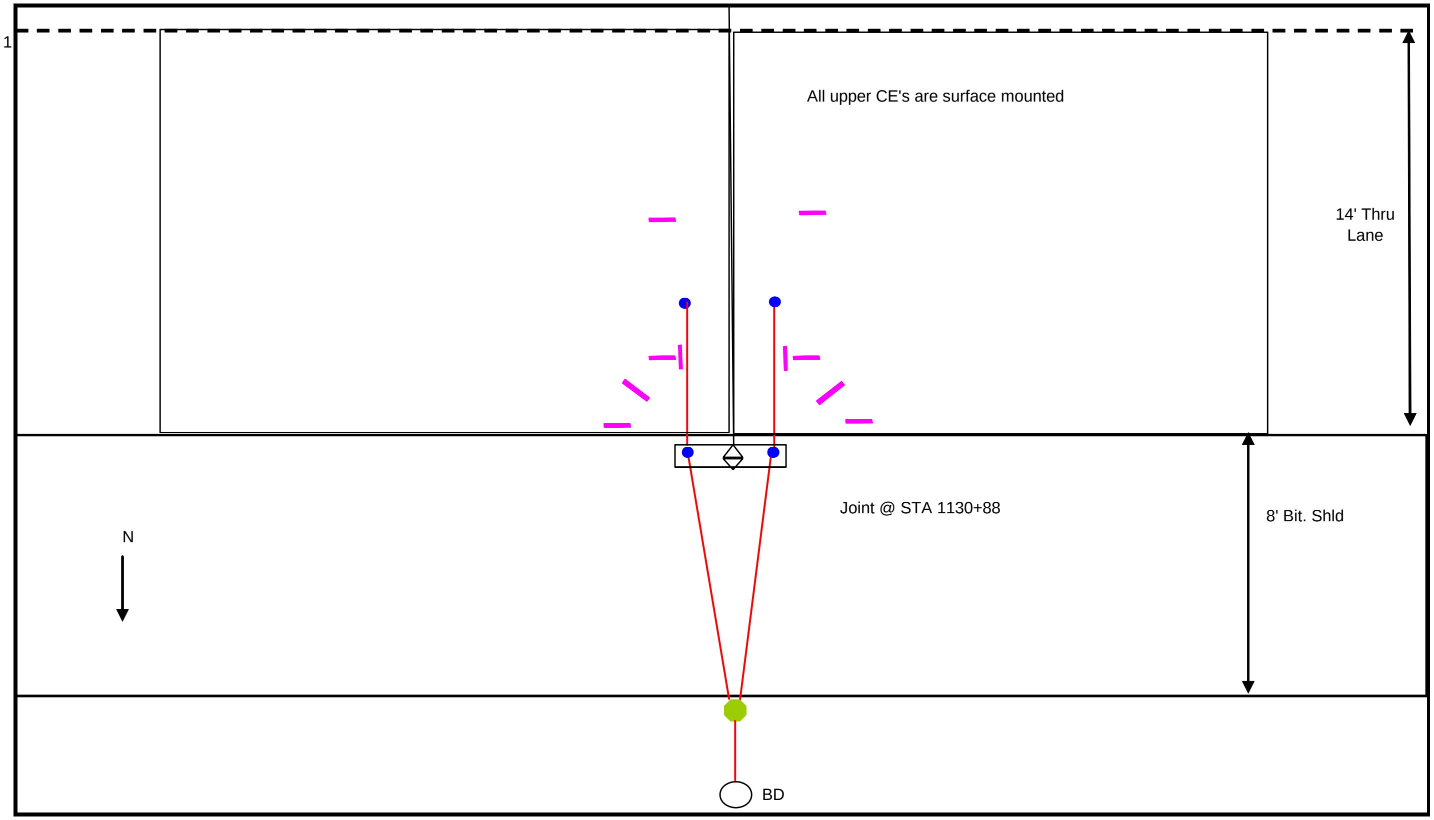
Figure 47. Instrumentation for Cell 305

MnROAD Instumentation Summary For PCC Overlay Experiment

Cell	5 - 405
Project	8680-157

Section View





Sensor Requirement

Code	Number	Sensor	Description
CE	16	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
DT	2	LVDT	Linear Variable Displacement Transducer (Vertical Panel Displacement)

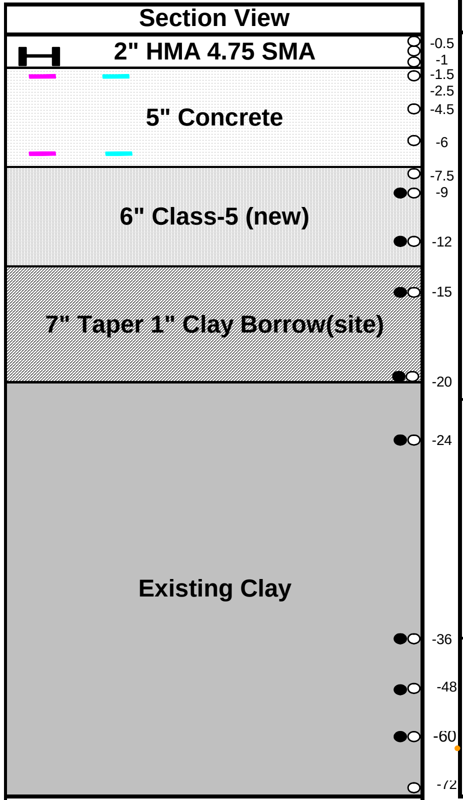
Legend

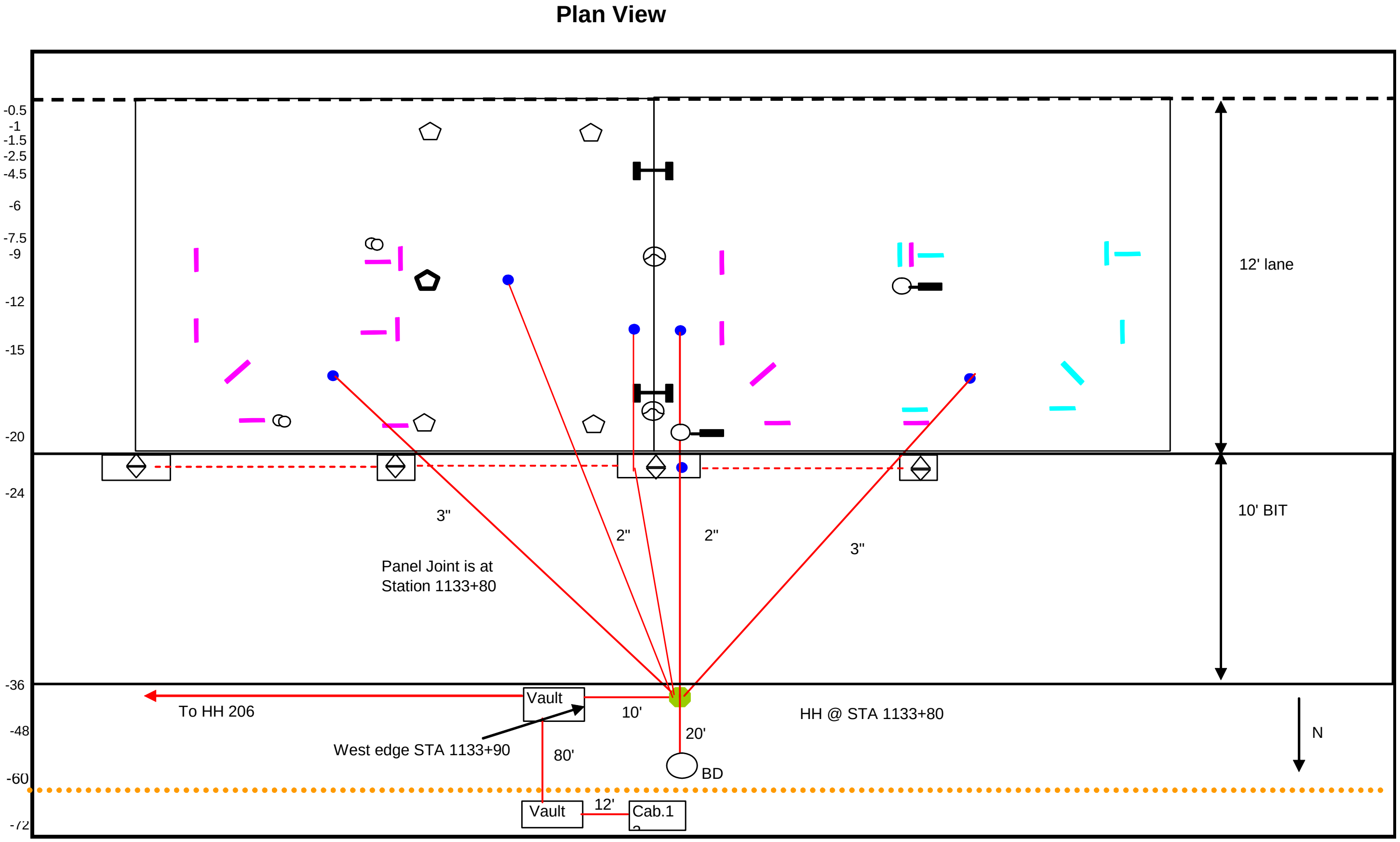
●	Risers	◇	DT
- - -	Centerline	•••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
X	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	—	CE sensor
●	Handhole	—	VW Sensors

Figure 48. Instrumentation for Cell 405

MnROAD Instumentation Summary For Composite Pavement Experiment

Cell	6 - 106
Project	8680-157



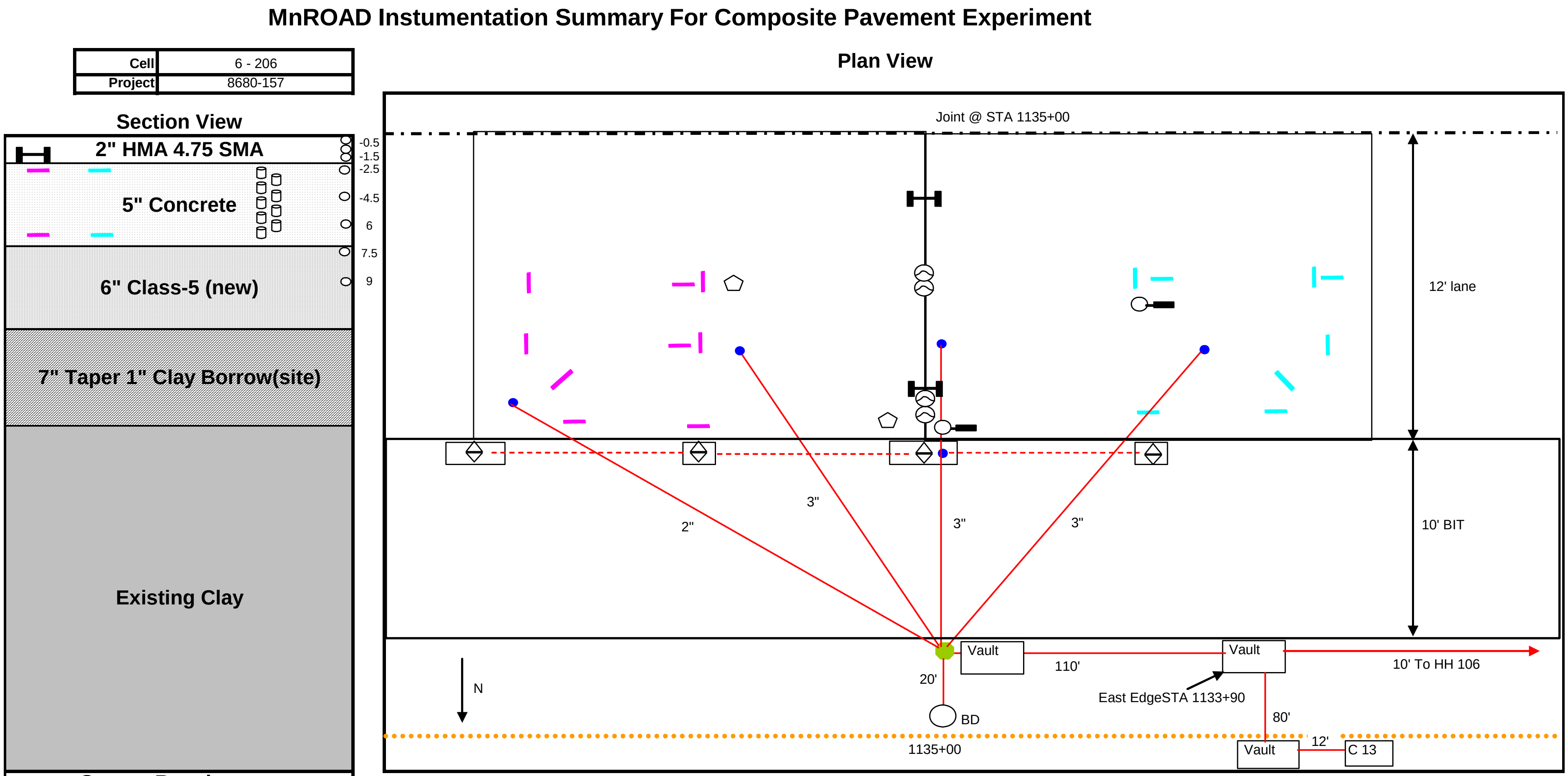


Sensor Requirement

Code	Number	Sensor	Description
TC	32	ThermoCouple (Temperature)	Measures Temperature. Installed in 8 and 16 sensor thermocouple trees (4-8).
AS	2	Asphalt Strain Gauge (LE)	
CE	24	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain
DT	6	Linear Variable Displacement	Dynamic Vertical Displacement
HC	4	Horizontal Clip Gauge	Strain Across Joint (Longitudinal)
IV	4	Invar Rod	Vertical Displacement (Control)
PT	2	Static Pressure	Normal Pressure
WM	10	Moisture (Frost)	Bound matrix moisture content
EC	8		

Legend			
🔵	Risers	◇	DT
- - -	Centerline	••••••	Chain Link Fence
◎	WM	—	Conduit
⊖	HC	○	TC Sensors
⬠	TC/ M Tree	●	EC Sensors
🟢	Handhole	▬	CE sensor
○▬	PT	▬	VW Sensors

Figure 49. Instrumentation for Cell 106



Sensor Requirement

Code	Number	Sensor	Description
TC	32	ThermoCouple (Temperature)	Measures Temperature. Installed in 8 and 16 sensor thermocouple trees (2-8 and 1-16).
AS	2	Asphalt Strain Gauge (LE)	
CE	9	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain
DT	6	Linear Variable Displacement	Dynamic Vertical Displacement
HC	4	Horizontal Clip Gauge	Strain Across Joint (Longitudinal)
IK	9	Maturity	Maturity Sticks
IV	4	Invar Rod	Static Reference Point for Vertical Measurement
PT	2	Static Pressure	Normal Pressure
EC	8	ECH$_2$O - TE (Moisture)	Measures Volumetric Moisture Content, Temperature and Electric Conductivity

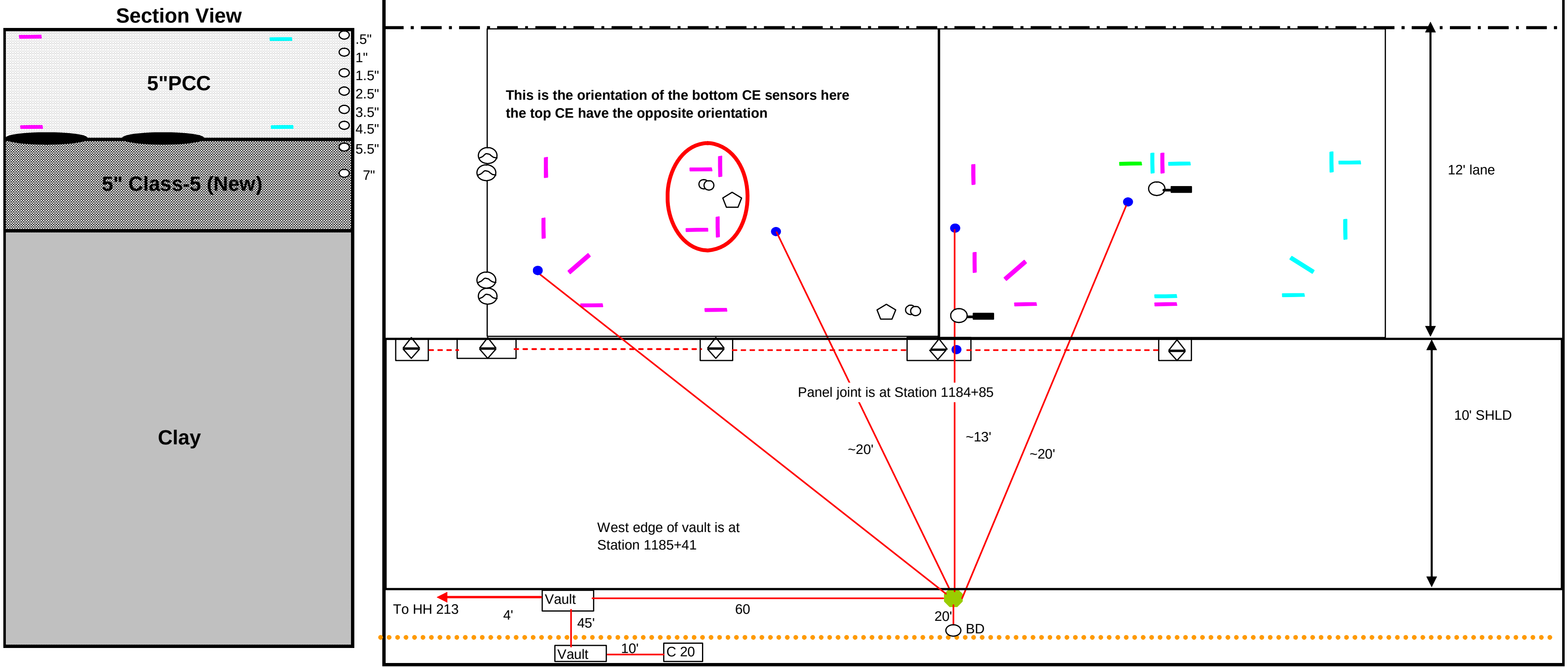
Legend

●	Risers	◇	DT
– – –	Centerline	••••••	Chain Link Fence
⊜	HC	—	Conduit
⬠	TC/ M Tree	○	TC Sensors
●	Handhole	●	EC Sensors
○▬	PT	▯	IK
		—	CE sensor
		—	VW Sensors

Figure 50. Instrumentation for Cell 206

MnROAD Instumentation Summary for Thin Concrete

Cell	13 - 113
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
CE	24	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal, Angled, and Transverse)
IV	5	10' Invar Rod	Vertical control for LVDT
DT	7	Linear Variable Displacement T	Measures panel displacement in the vertical due to dynamic loading.
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain
TC	16	Thermocouple	Temperature Measurement (2 Trees- two TC$_8$)
HC	4	Horizontal Clip Gauge	Measures Panel Joint opening
PT	2	Pressure Cell	Measures normal stress due to environmental loading.
WM	12	Humidity Sensor	Measures Frost Depth
IK	9	Maturity Sensor	Records PCC Pavement Curing Rate

Legend

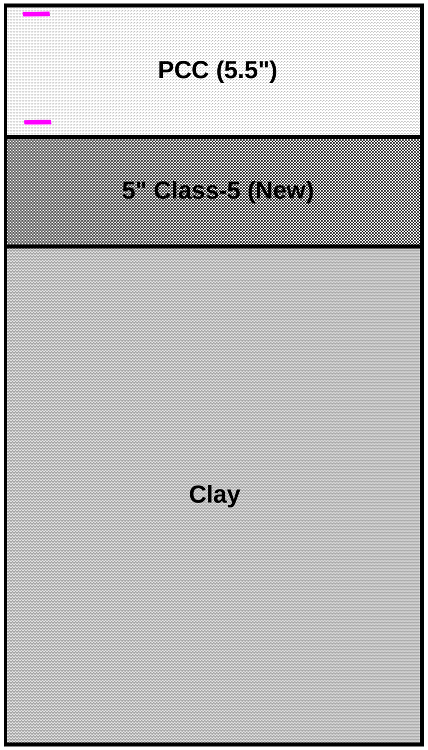
●	Risers	◇	DT
▬ ▬ ▬	Centerline	••••••	Chain Link Fence
○▬	PT	—	Conduit
○○	WM	○	TC Sensors
⊖	HC	●	EC Sensors
⬠	TC/ M Tree	▯	IK
●	Handhole	▬	CE sensor
		▬	VW Sensors

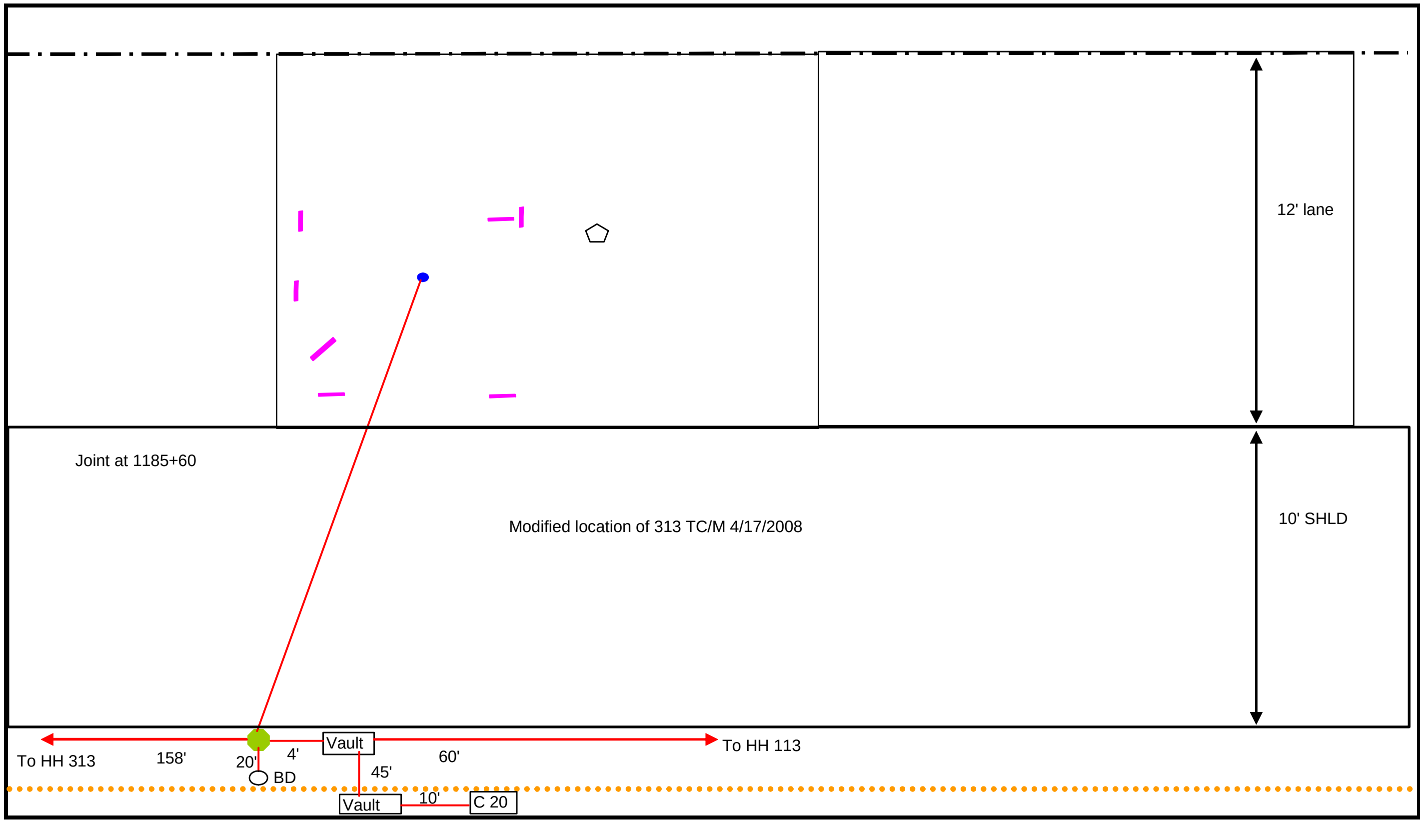
Figure 51. Instrumentation for Cell 113

MnROAD Instumentation Summary for Thin Concrete

Cell	13 - 213
Project	8680-157

Section View





Sensor Requirement

Code	Number	Sensor	Description
CE	12	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)

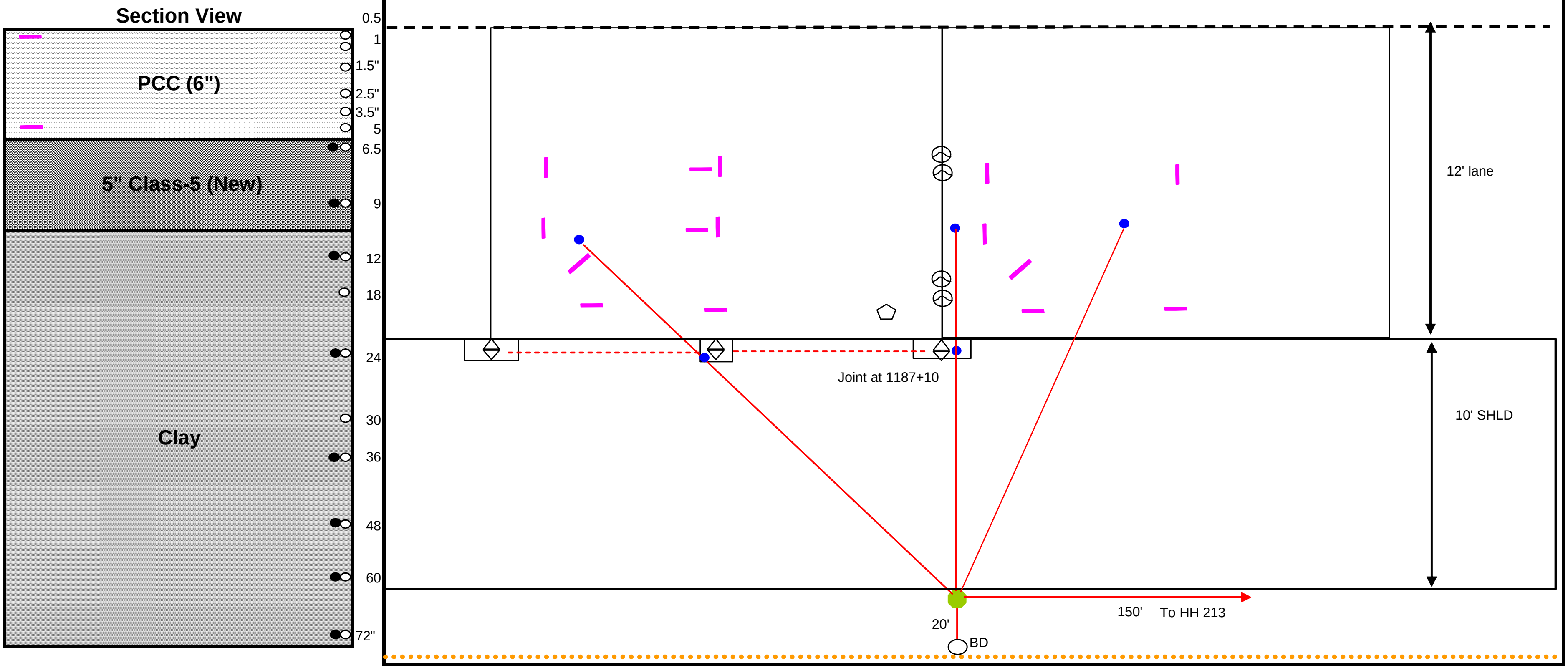
Legend

●	Risers	◇	DT
‒ ‒ ‒	Centerline	••••••	Chain Link Fence
○▬	PT	―	Conduit
○	WM	○	TC Sensors
○	HC	●	EC Sensors
⬠	TC/ M Tree	▯	IK
●	Handhole	▬	CE sensor

Figure 52. Instrumentation for Cell 213

MnROAD Instumentation Summary for Thin Concrete

Cell	13 -313
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
CE	24	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal, Angled, and Transverse)
IV	3	10' Invar Rod	Vertical control for LVDT
DT	5	Linear Variable Displacement T	Measures panel displacement in the vertical due to dynamic loading.
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain
TC	24	Thermocouple	Temperature Measurement (2 Trees- one **TC$_{16}$** and one TC$_{8}$)
HC	4	Horizontal Clip Gauge	Measures Panel Joint opening
EC	8	Moisture Sensor	Measures Frost Depth
IK	9	Maturity Sensor	Records PCC Pavement Curing Rate

Legend

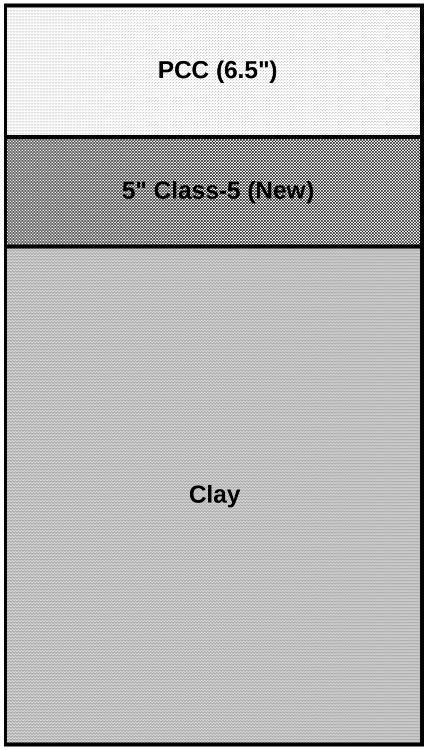
●	Risers	⇕	DT/IV
- - -	Centerline	••••••	Chain Link Fence
○▬	PT	—	Conduit
∞	WM	○	TC Sensors
⊖	HC	●	EC Sensors
⬠	TC/ M Tree	▯	IK
●	Handhole	▬	CE sensor

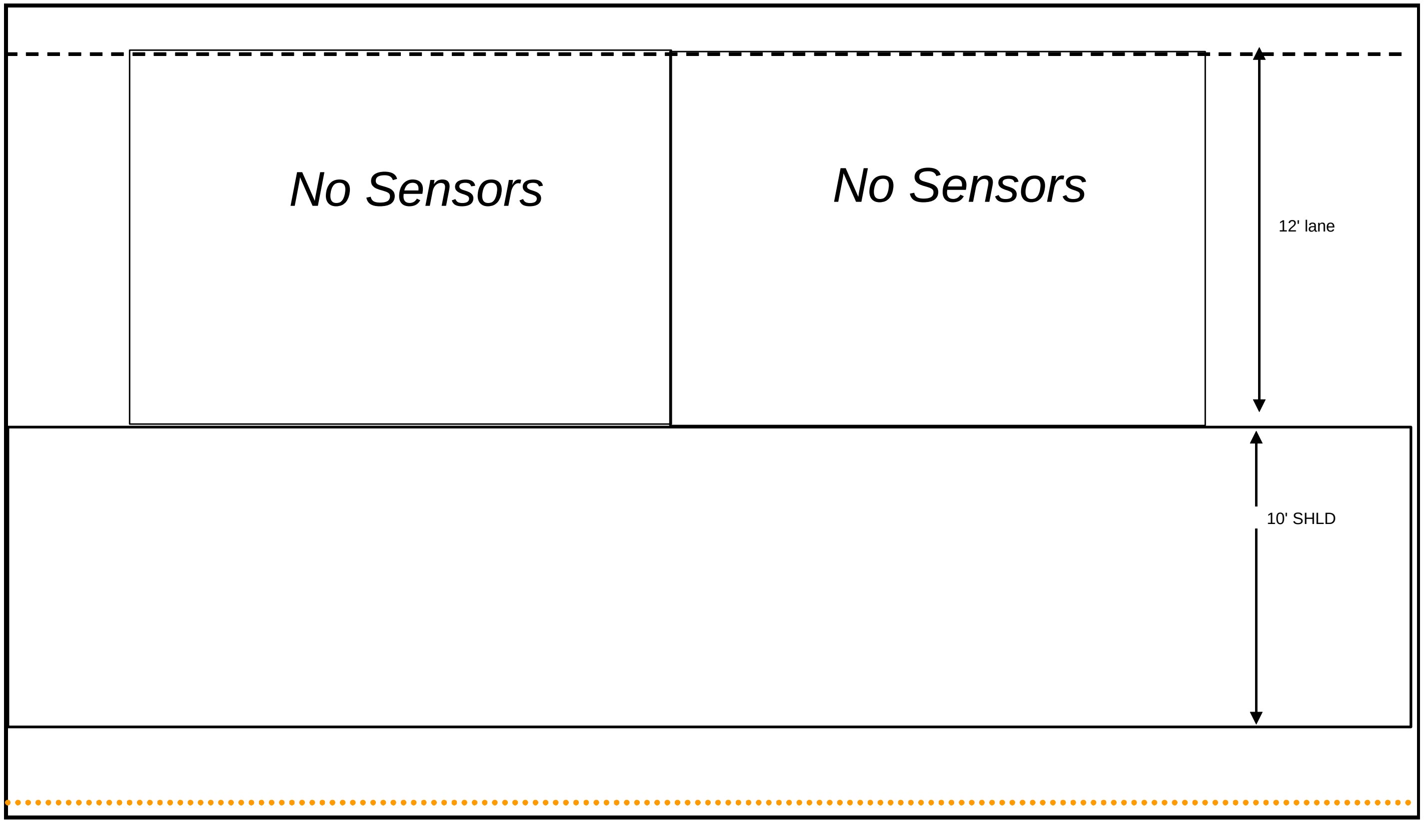
Figure 53. Instrumentation for Cell 313

MnROAD Instumentation Summary for Thin Concrete

Cell	13 -413
Project	8680-157

Section View





Sensor Requirement

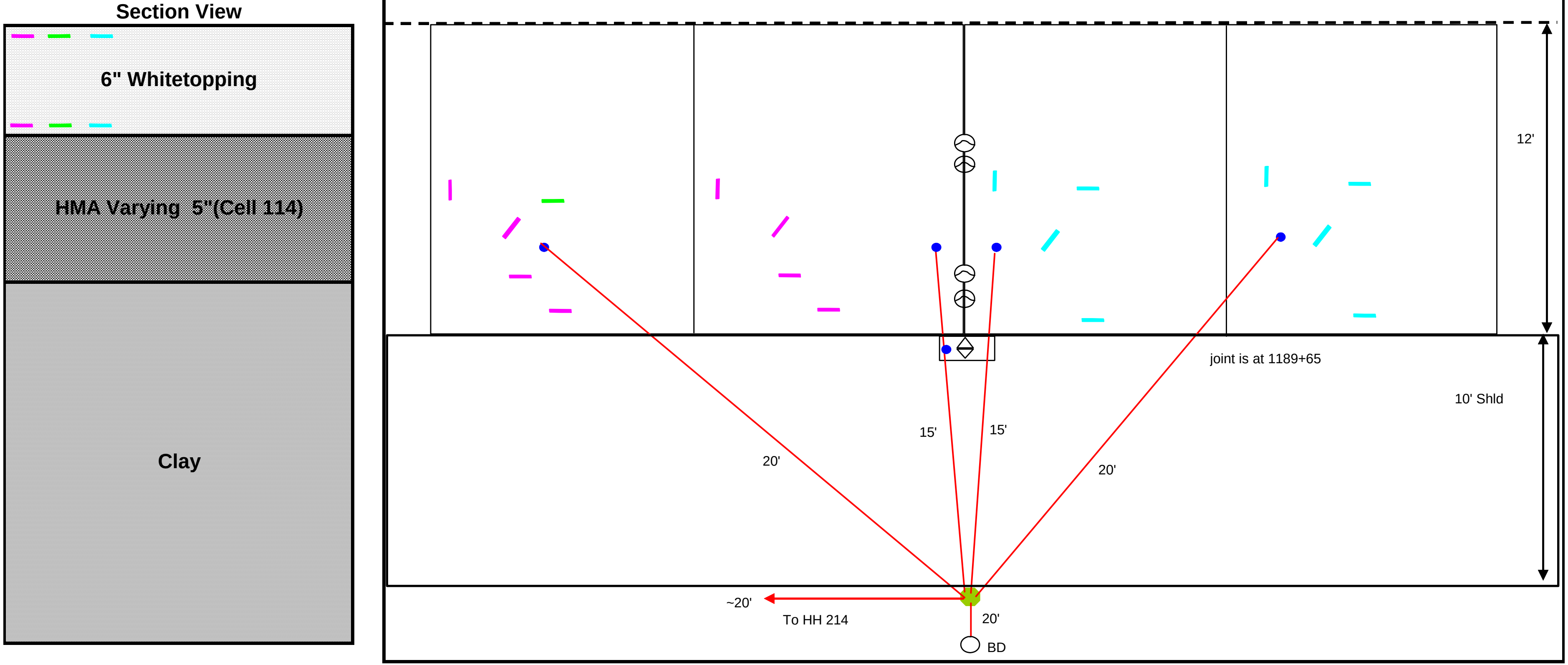
Code	Number	Sensor	Description
No Sensors			

Legend			
●	Risers	◇	DT
- - -	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
○	WM	○	TC Sensors
○	HC	●	EC Sensors
⬠	TC/ M Tree	⌷	IK
●	Handhole	▬	CE sensor
○▬	PT	▬	VW Sensors

Figure 54. Instrumentation for Cell 413

MnROAD Instumentation Summary for Whitetopping

Cell	114
Project	8680-157



Sensor Requirement

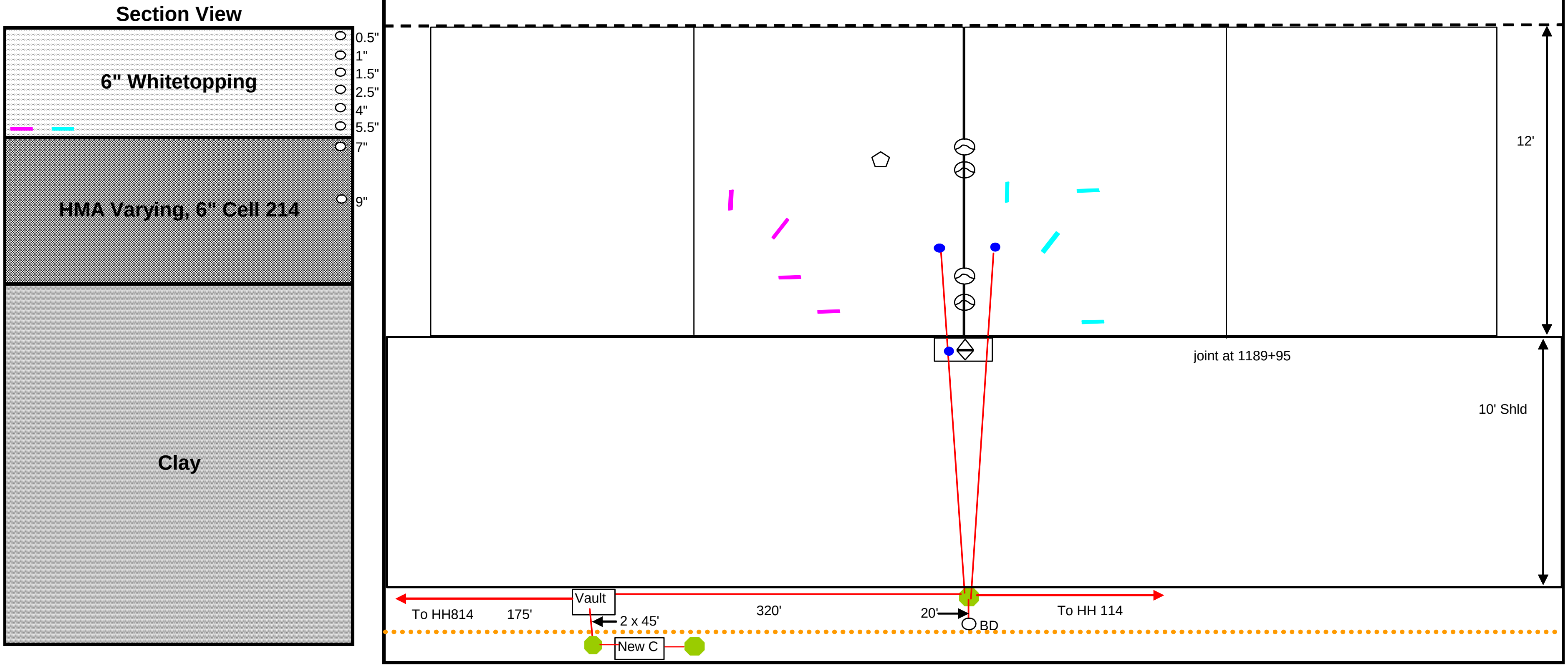
Code	Number	Sensor	Description
CE	16	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal, Angled, and Transverse)
IV	1	10' Invar Rod	Vertical control for LVDT
DT	2	Linear Variable Displacement	Dynamic Vertical Displacement
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain
TC	16	Thermocouple	Temperature Measurement (2 Trees- one **TC**$_{16}$ and one TC$_{8}$)
HC	4	Horizontal Clip Gauge	Measures Panel Joint opening
IK	9	Maturity Sensor	Records PCC Pavement Curing Rate
VG	2	Maturity Sensor	

Legend			
●	Risers	⛁	IK
- - -	Centerline	•••••••	Chain Link Fence
▬	VW Sensors	—	Conduit
▬	CE Sensors	○	TC Sensors
⊖	HC	●	EC Sensors
⬠	TC/ M Sensor	▬	VG
●	Handhole		

Figure 55. Instrumentation for Cell 114

MnROAD Instumentation Summary for Whitetopping

Cell	214
Project	8680-157



Sensor Requirement

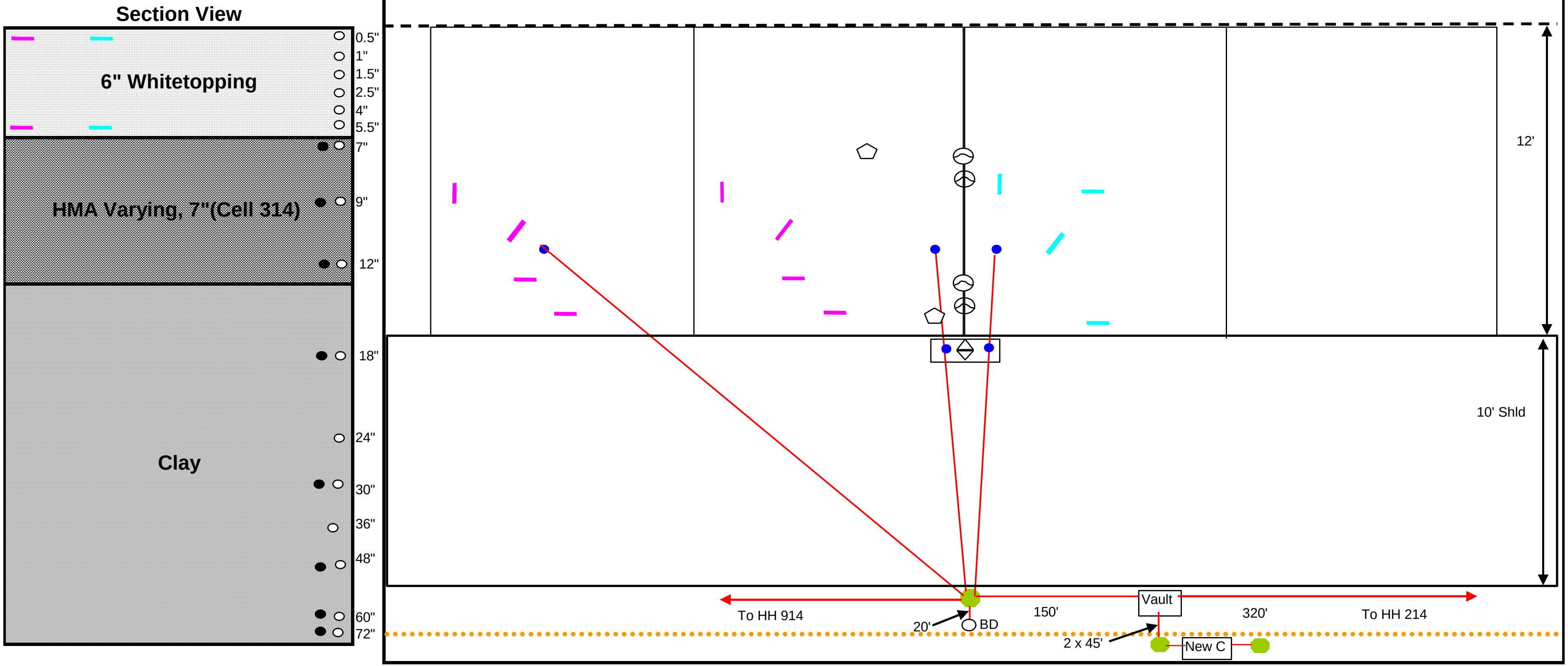
Code	Number	Sensor	Description
CE	4	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	4	Vibrating Wire Strain Gauge	Static (Environmental) Strain
DT	2	Linear Variable Displacement	Dynamic Vertical Displacement
HC	4	Strain Gauge	Horizontal Clip Gauge, Longitudinal Strain Across Transverse Joints
IV	1	10' Invar Rod	Vertical control for LVDT

Legend			
●	Risers		
– – –	Centerline	••••••	Chain Link Fence
▬	VW Sensors	—	Conduit
▬	CE Sensors	○	TC Sensors
⊖	HC	●	EC Sensors
⬠	TC/ M Sensor		
●	Handhole		

Figure 56. Instrumentation for Cell 214

MnROAD Instumentation Summary for Whitetopping

Cell	814
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
CE	16	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	8	Vibrating Wire Strain Gauge	Static (Environmental) Strain
DT	2	Linear Variable Displacement	Dynamic Vertical Displacement
TC	24	Thermocuple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from surface
HC	4	Strain Gauge	Horizontal Clip Gauge, Longitudinal Strain Across Transverse Joints
IV	1	10' Invar Rod	Vertical control for LVDT
EC	8	ECH$_2$O - TE (Moisture)	Measures Volumetric Moisture Content, Temperature and Electric Conductivity

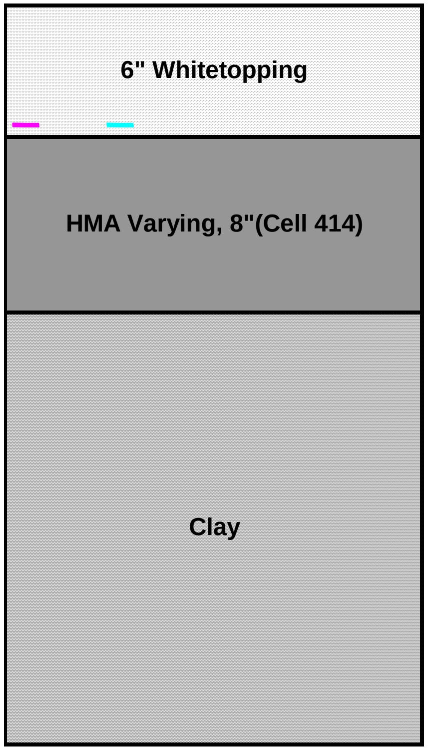
Legend			
●	Risers		
– – –	Centerline	••••••	Chain Link Fence
▬	VW Sensors	—	Conduit
▬	CE Sensors	○	TC Sensors
⊖	HC	●	EC Sensors
⬠	TC/ M Sensor		
●	Handhole		

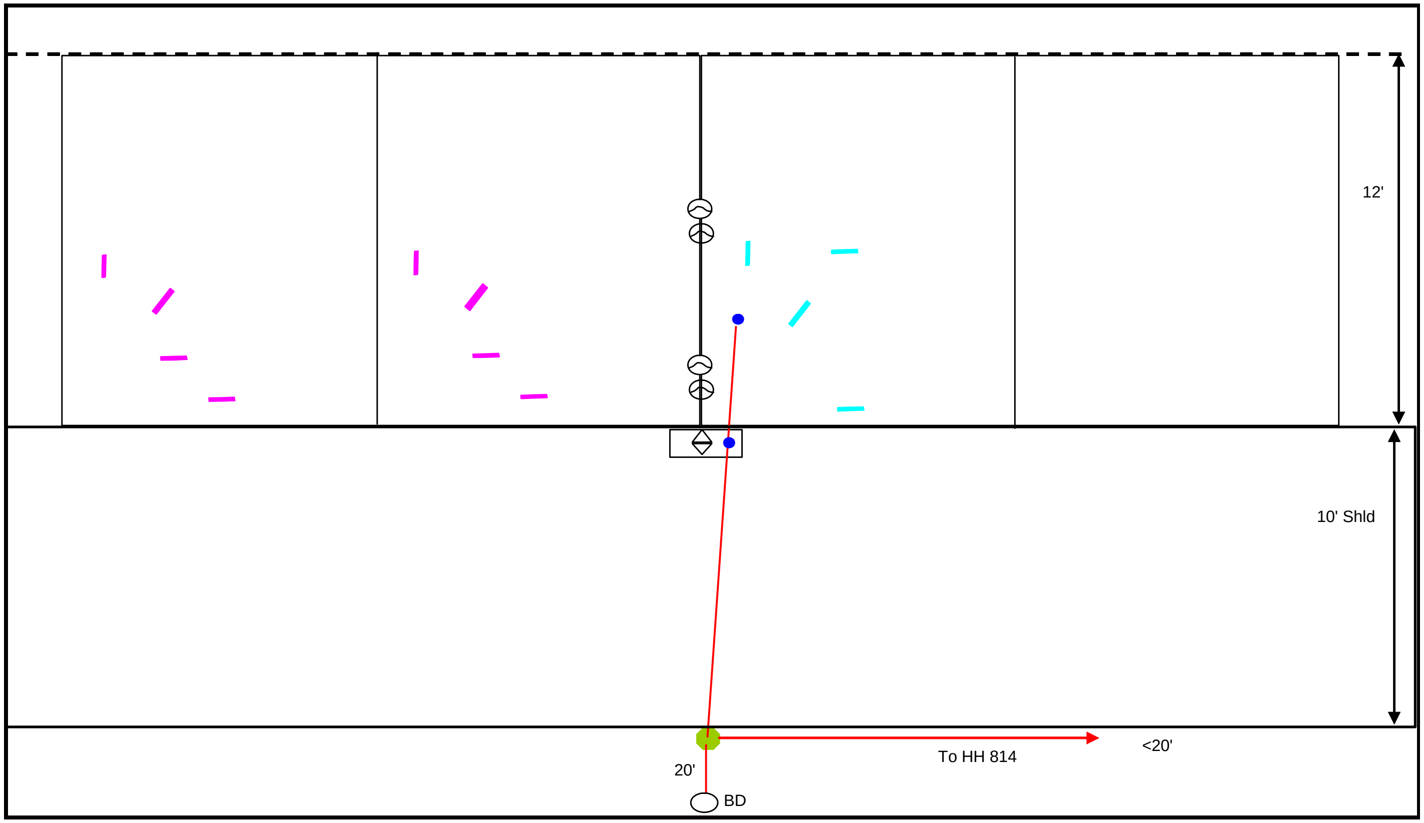
Figure 57. Instrumentation for Cell 814

MnROAD Instumentation Summary for Whitetopping

Cell	914
Project	8680-157

Section View





Sensor Requirement

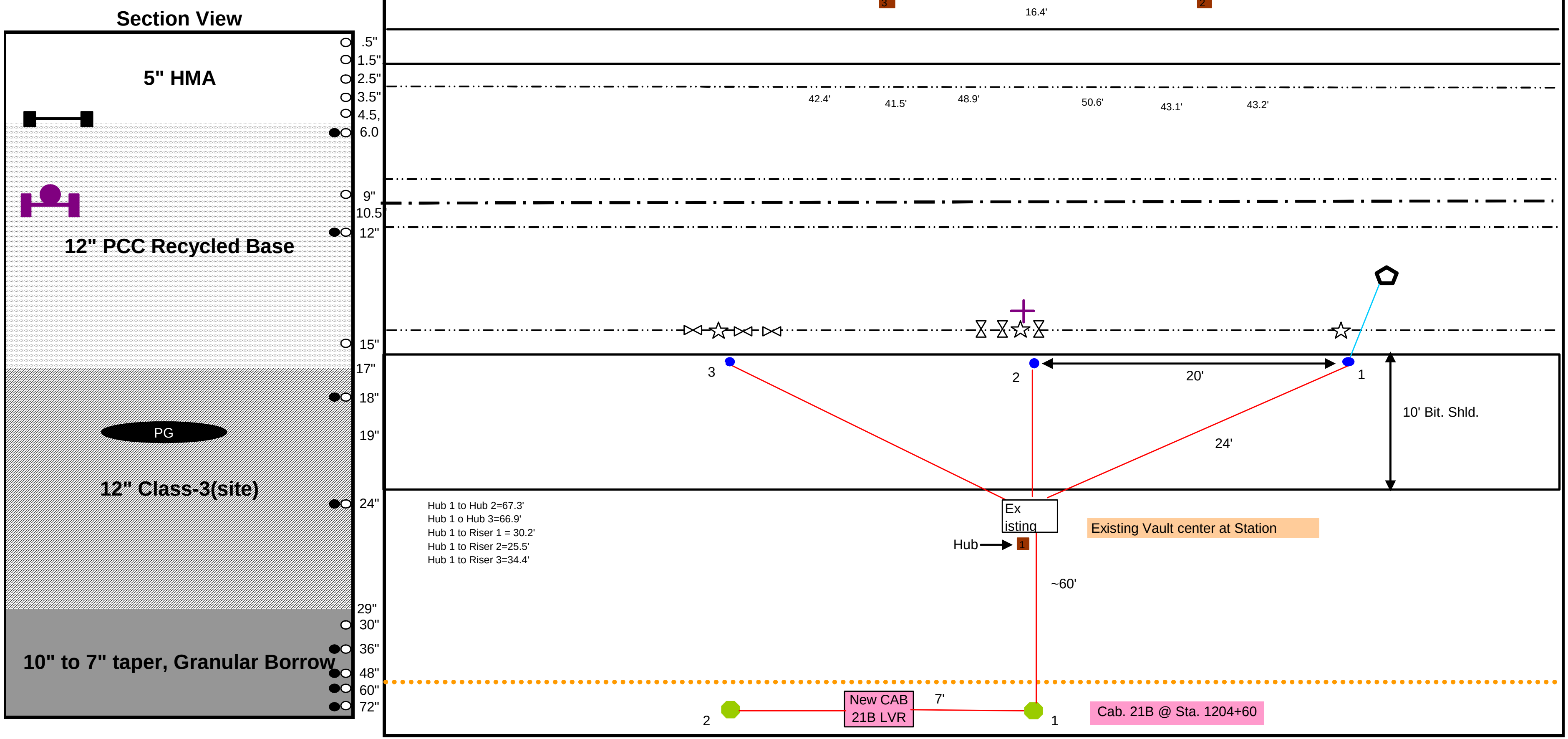
Code	Number	Sensor	Description
CE	4	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	4	Vibrating Wire Strain Gauge	Static (Environmental) Strain
DT	2	Linear Variable Displacement	Dynamic Vertical Displacement
HC	4	Strain Gauge	Horizontal Clip Gauge, Longitudinal Strain Across Transverse Joints
IV	1	10' Invar Rod	Vertical control for LVDT

Legend			
●	Risers	▯▯▯	IK
– – –	Centerline	•••••••	Chain Link Fence
▬	VW Sensors	—	Conduit
▬	CE Sensors	○	TC Sensors
⊖	HC	●	EC Sensors
⬠	TC/ M Sensor		
●	Handhole		

Figure 58. Instrumentation for Cell 914

MnROAD Instumentation Summary For Recycled Unbound Base Experiment

Cell	16
Project	8680-157



Sensor Requirement

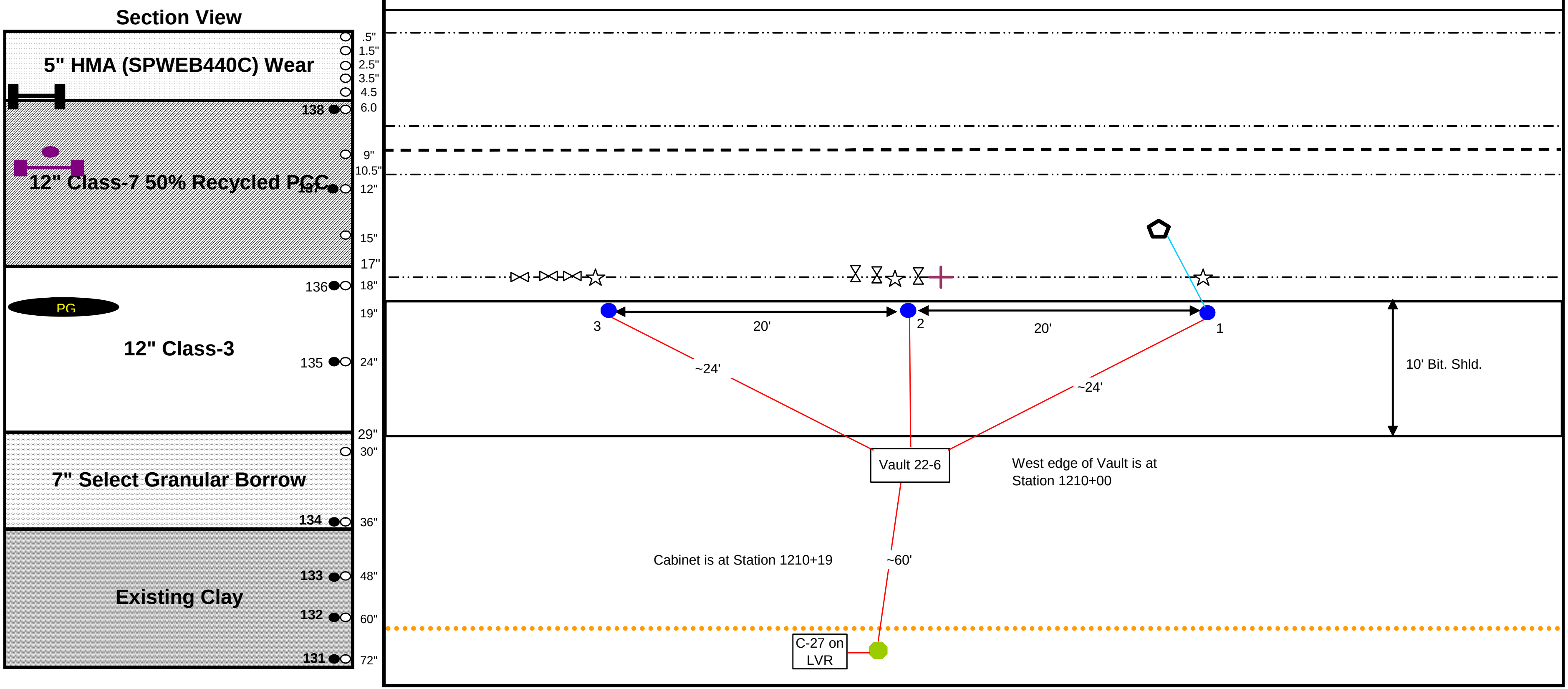
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture	Measures volmetric moisture content, temperature, electric conductivity
TE	3	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	3	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	3	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface
SCG	2		

Legend			
●	Risers	—··—··	Wheelpath (9.5' offset from CL)
— — —	Centerline	•••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	●	Handhole
—	SCG Sensors		

Figure 59. Instrumentation for Cell 16

MnROAD Instumentation Summary For Recycled Unbounded Base Experiment

Cell	17
Project	8680-157



Sensor Requirement

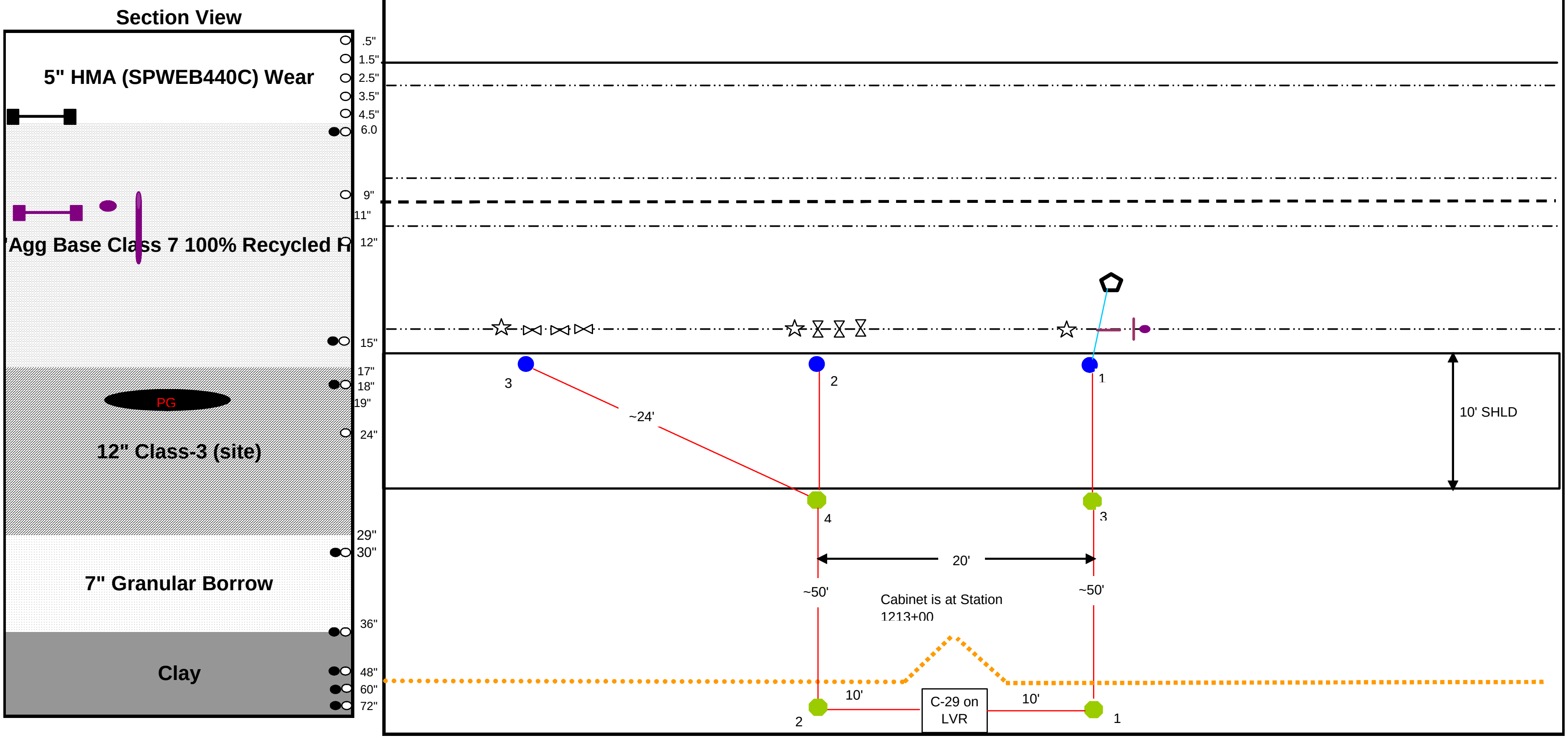
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	3	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	3	CTL Strain Gauge, LE	Embedded longitudinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	3	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface
SCG	2		

Legend			
●	Risers	−·−·−	Wheelpath (9.5' offset from CL)
– – –	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	●	Handhole
—	SCG Sensors		

Figure 60. Instrumentation for Cell 17

MnROAD Instumentation Summary For Recycled Unbounded Base Experiment

Cell	18
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	3	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	3	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	3	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface
SCG	3		

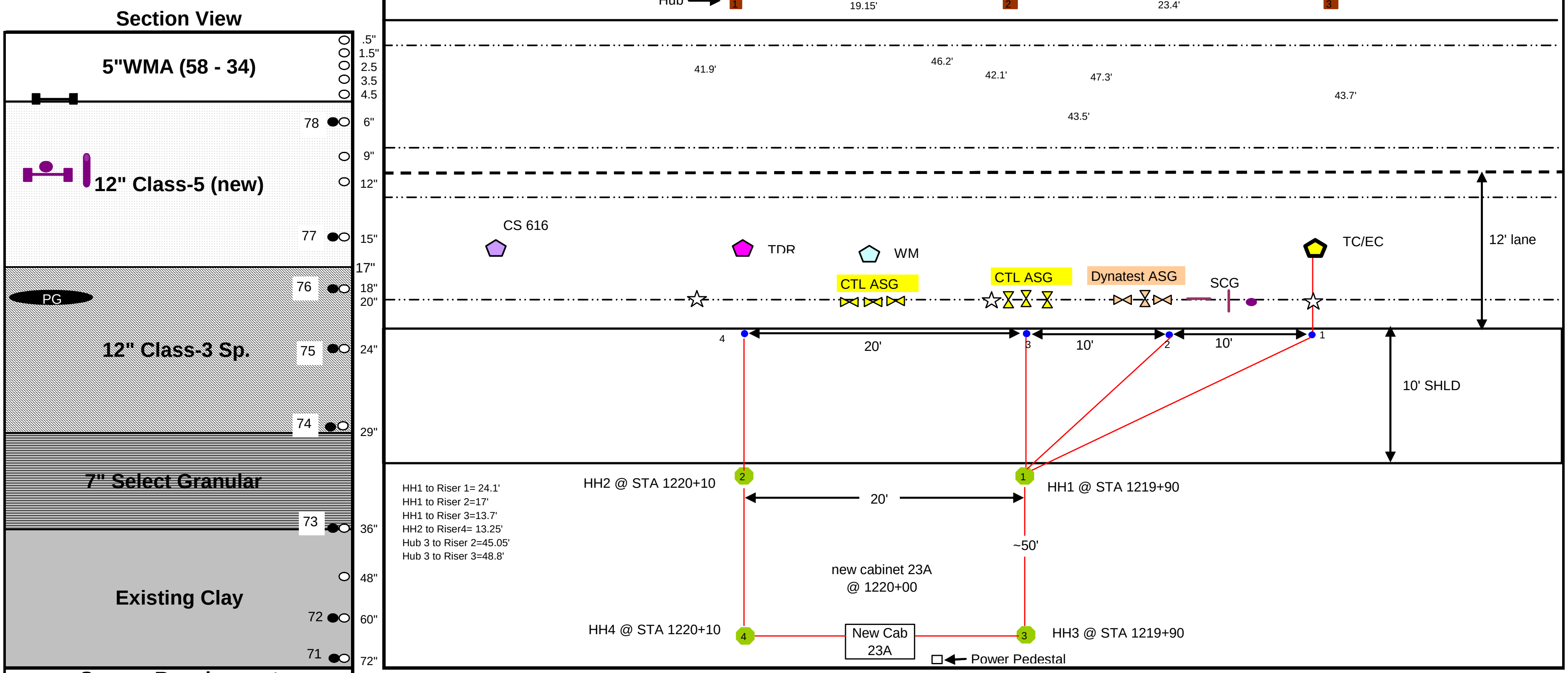
Legend

●	Risers	—··—··	Wheelpath (9.5' offset from CL)
— — —	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	——	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	⬢	Handhole
——	SCG Sensors		

Figure 61. Instrumentation for Cell 18

MnROAD Instumentation Summary For Control Base Surface

Cell	19
Project	8680-157



Sensor Requirement

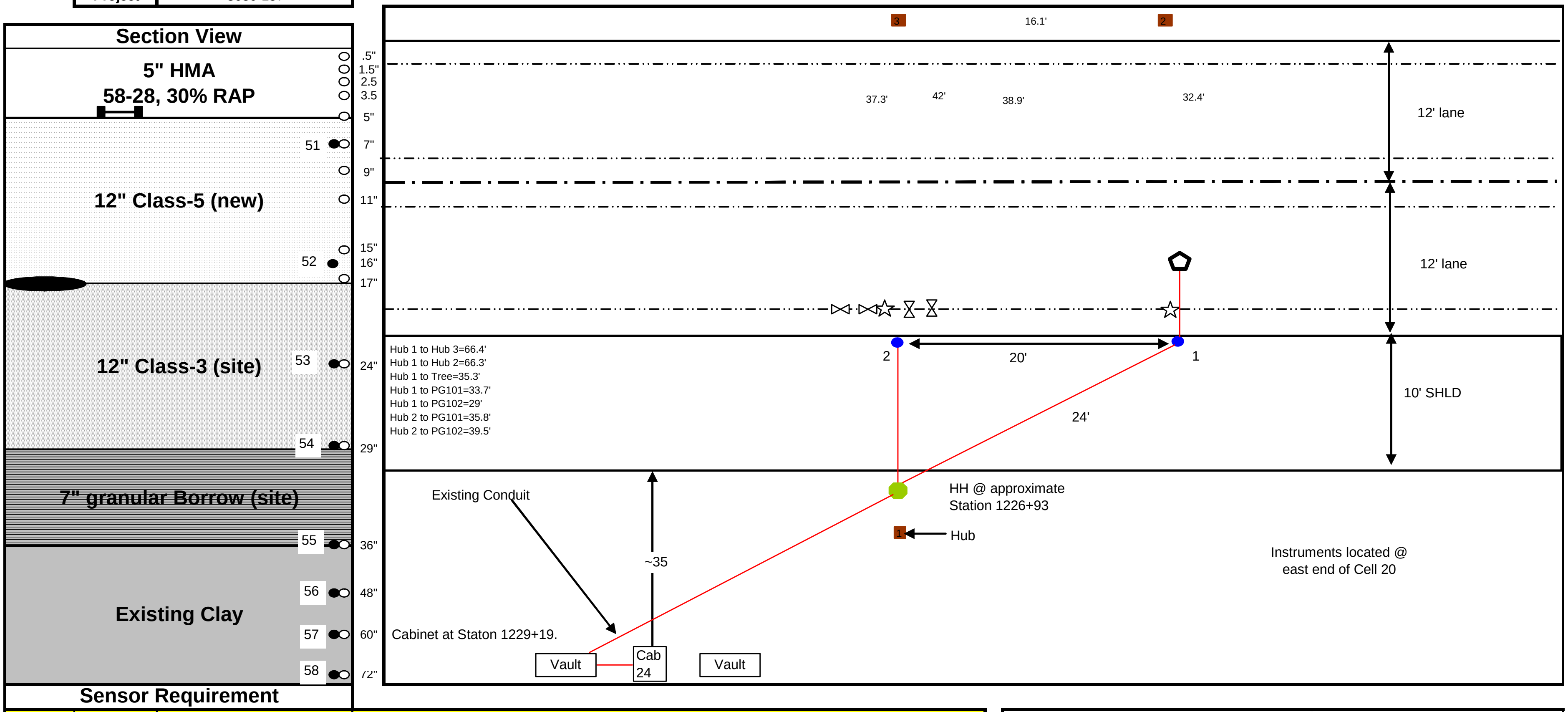
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	3	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	3	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	3	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface
LE	2	Dynatest Strain Gauge	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
TE	1	Dynatest Strain Gauge	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
SCG	3		

Legend			
●	Risers	—··—··	Wheelpath (9.5' offset from CL)
– – –	Centerline	•••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	⬢	Handhole
—	SCG Sensors		

Figure 62. Instrumentation for Cell 19

MnROAD Instumentation Summary For Low Temperature Cracking Experiment

Cell	20
Project	8680-157



Sensor Requirement

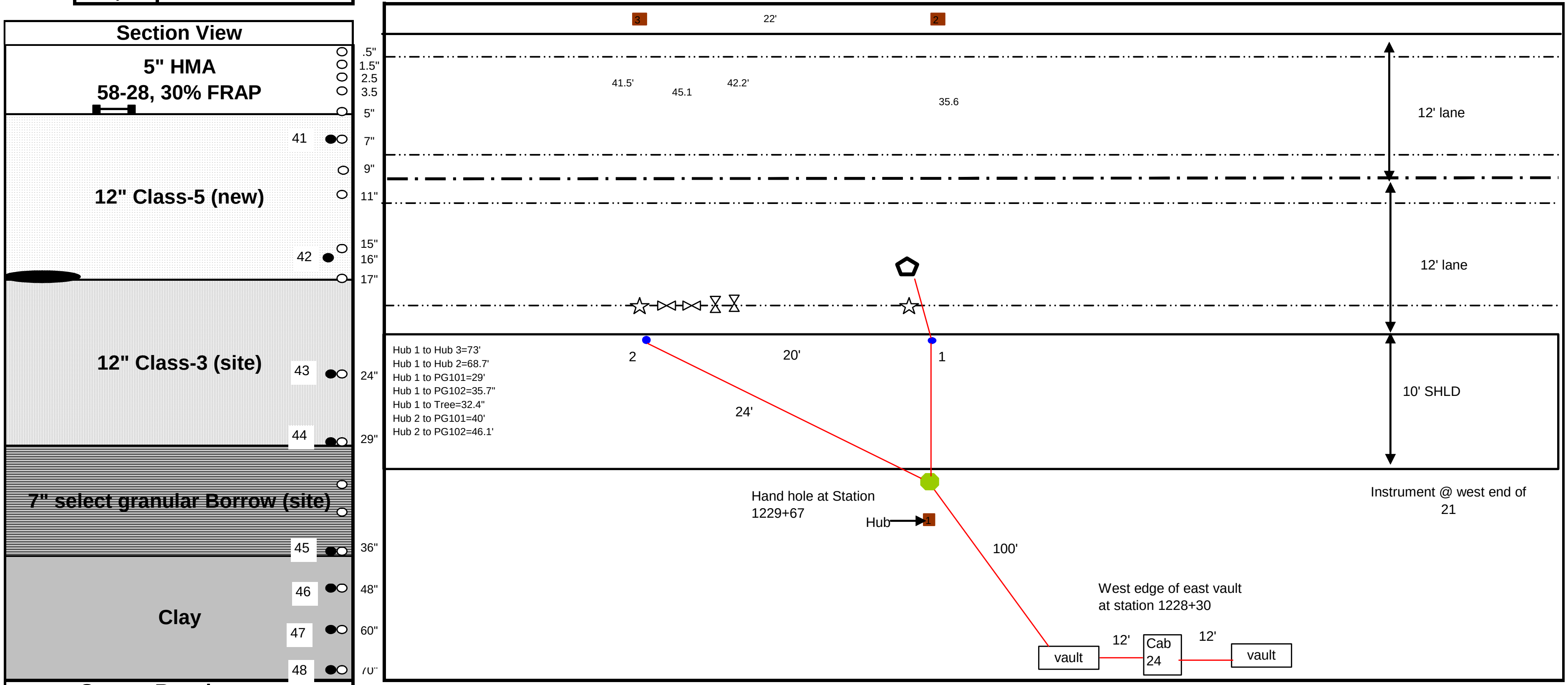
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measure volmetric moisture content, temperature, electric conductivity
TE	2	CTL Strain Gauge, TE	Embedded transverse strain gauge-measures transverse strain at the bottom of bound layers
LE	2	CTL Strain Gauge, LE	Embedded longitdinal strain gauge-measures longitdinal strain at the bottom of bound layers
PG	2	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

Legend			
●	Risers	−··−··	Wheelpath (9.5' offset from CL)
▬ ▬ ▬	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	―	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	●	Handhole

Figure 63. Instrumentation for Cell 20

MnROAD Instumentation Summary For Low Temperature Cracking Experiment

Cell	21
Project	8680-157



Sensor Requirement

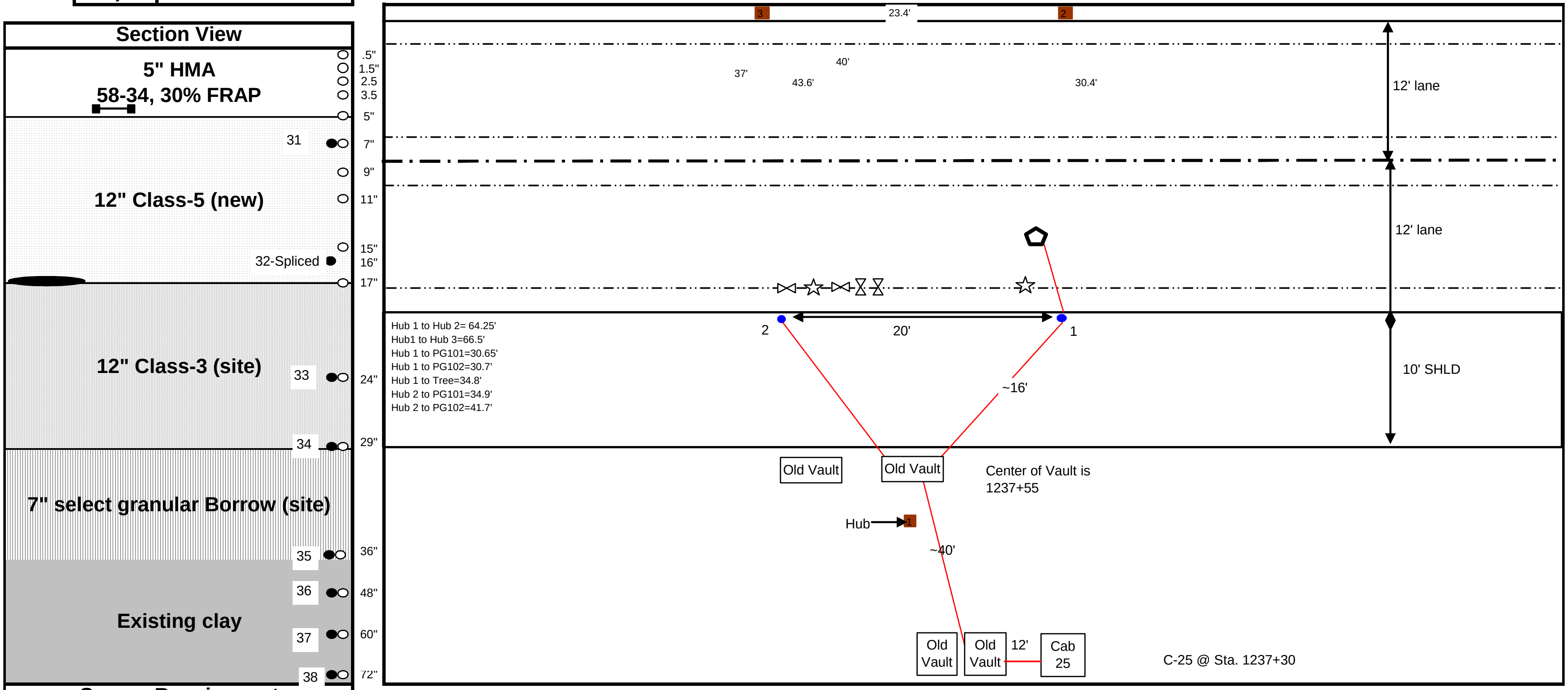
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measure volmetric moisture content, temperature, electric conductivity
TE	2	CTL Strain Gauge, TE	Embedded transverse strain gauge-measures transverse strain at the bottom of bound layers
LE	2	CTL Strain Gauge, LE	Embedded longitdinal strain gauge-measures longitdinal strain at the bottom of bound layers
PG	2	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

Legend			
●	Risers	—··—··	Wheelpath (9.5' offset from CL)
— — —	Centerline	••••••	Chain Link Fence
⋈	LESensors	——	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	●	Handhole

Figure 64. Instrumentation for Cell 21

MnROAD Instumentation Summary For Low Temperature Cracking Experiment

Cell	22
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measure volmetric moisture content, temperature, electric conductivity
TE	2	CTL Strain Gauge, TE	Embedded transverse strain gauge-measures transverse strain at the bottom of bound layers
LE	2	CTL Strain Gauge, LE	Embedded longitdinal strain gauge-measures longitdinal strain at the bottom of bound layers
PG	2	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

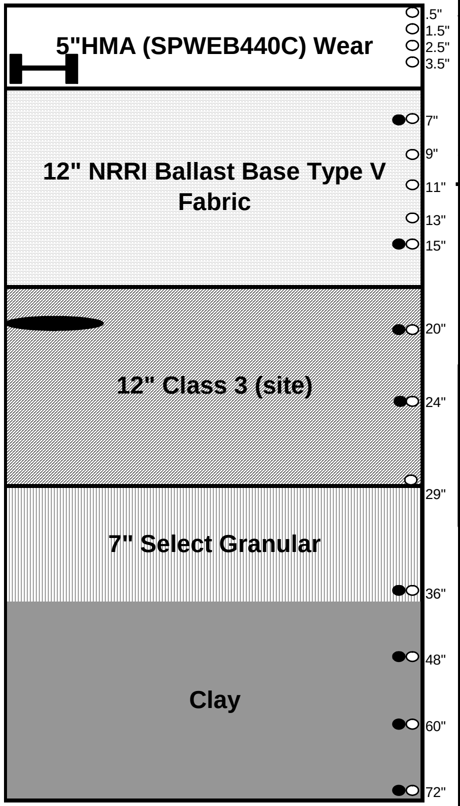
Legend			
●	Risers	−··−··	Wheelpath (9.5' offset from CL)
━ ━ ━	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧖	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	🟩	Handhole

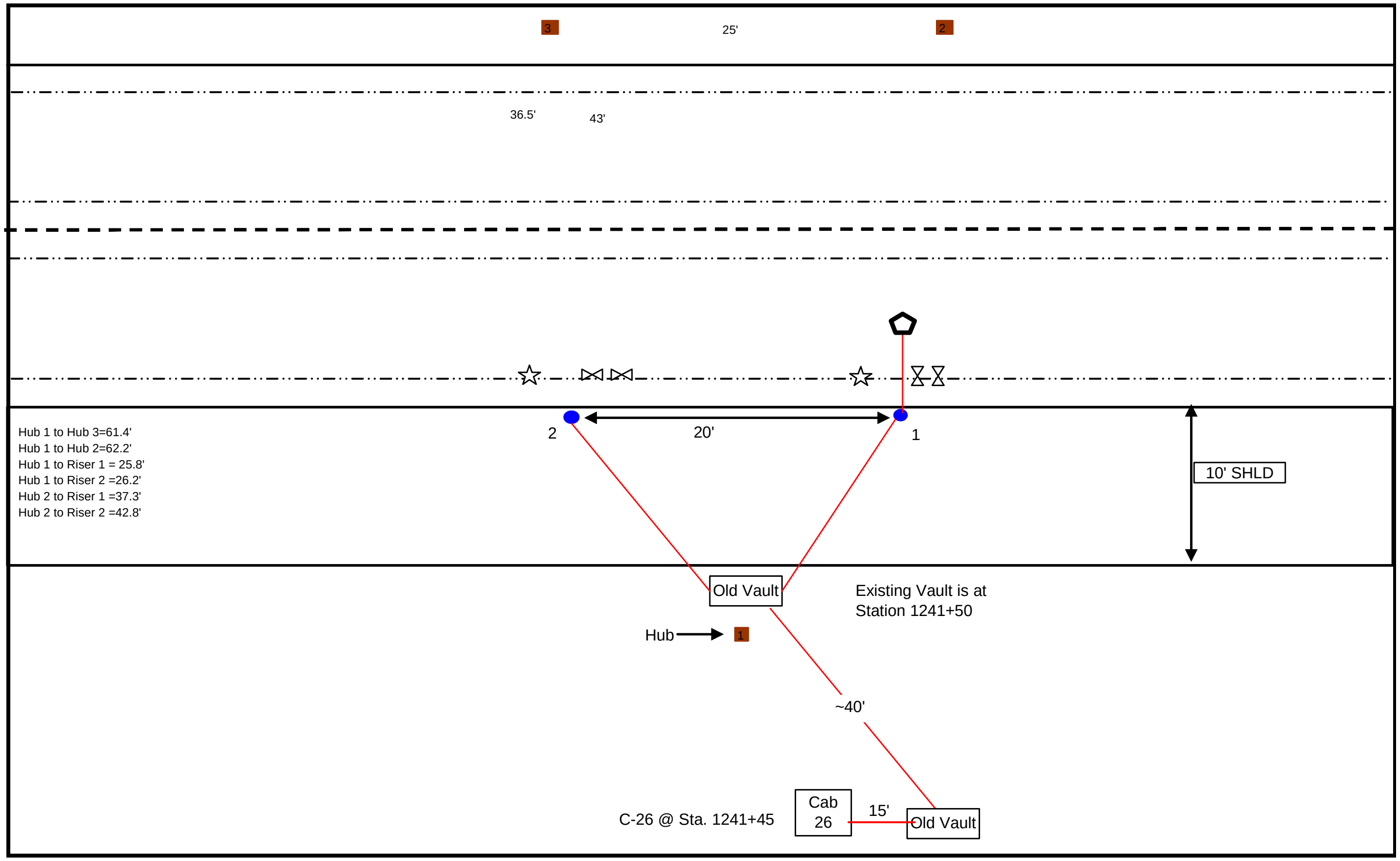
Figure 65. Instrumentation for Cell 22

MnROAD Instumentation Summary For Base Study Experiment

Cell	23
Project	8680-157

Section View





Sensor Requirement

Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH_2O-TE (Moisture)	Measure volmetric moisture content, temperature, electric conductivity
TE	2	CTL Strain Gauge, TE	Embedded transverse strain gauge-measures transverse strain at the bottom of bound layers
LE	2	CTL Strain Gauge, LE	Embedded longitdinal strain gauge-measures longitdinal strain at the bottom of bound layers
PG	2	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

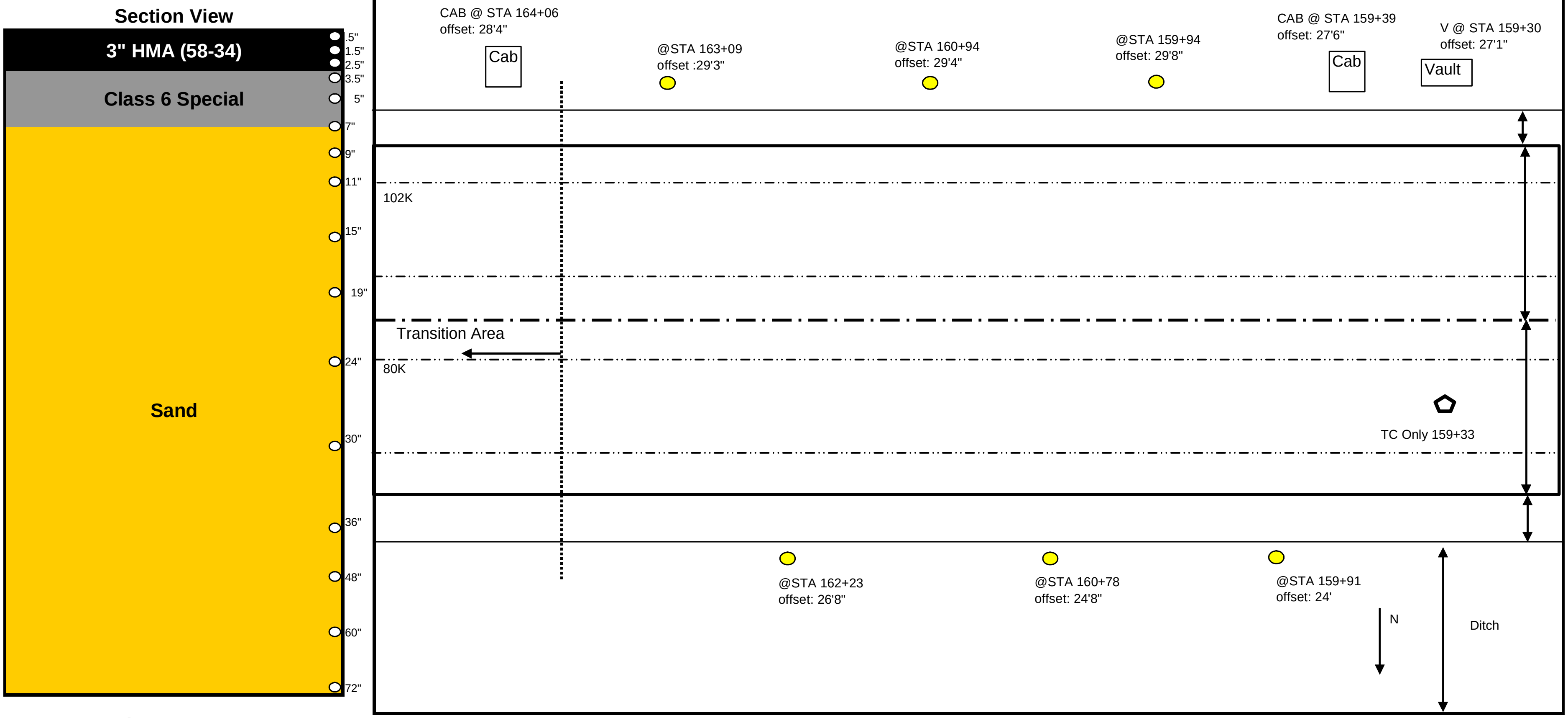
Legend

●	Risers	—··—··	Wheelpath (9.5' offset from CL)
– – –	Centerline	••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧖	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	●	Handhole

Figure 66. Instrumentation for Cell 23

MnROAD Instrumentation Summary, WMA Control & Aging Study

Cell	24
Project	Aging Study



Sensor Requirement

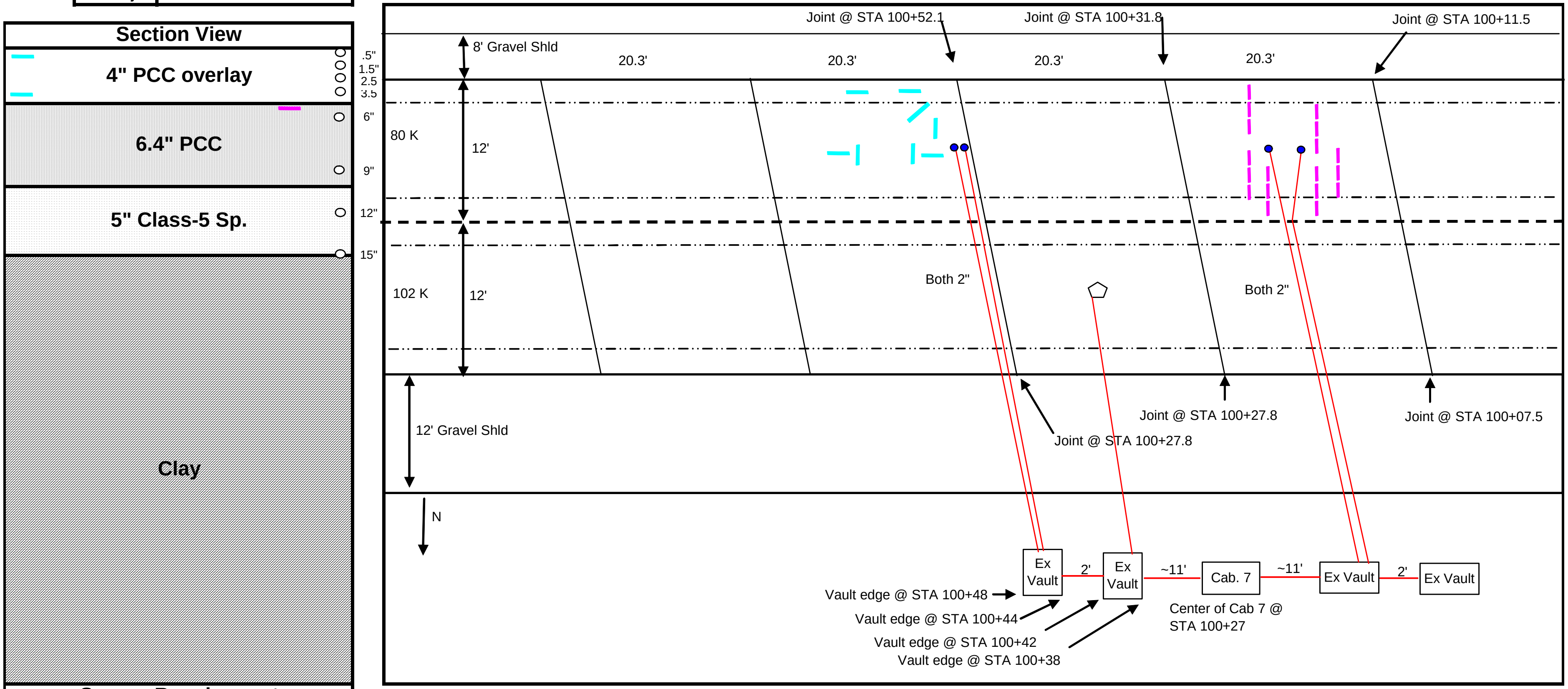
Code	Number	Sensor	Description
TC	0	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 8' from the surface
EC	0	EcH2O-TE (Moisture)	Measure volmetric moisture content, temperature, electric conductivity
TE	0	TE Sensor	Embedded transverse strain gauge-measures transverse strain at the bottom of bound layers
LE	0	LE Sensor	Embedded longitudinal strain gauge-measures longitdinal strain at the bottom of bound layers
PG	0	PG Sensor	Measures normal stress at base/subgrade interface

Legend			
●	Risers	−··−··	Wheelpath (9.5' offset from CL)
— — —	Centerline	••••••	Chain Link Fence
⋈	TE Sensors	—	Conduit
X	LE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	○	Monitoring Well
●	Handhole		

Figure 67. Instrumentation for Cell 24

MnROAD Instumentation Summary For Porous Concrete "Overlay"

Cell	39
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
CE	18	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain

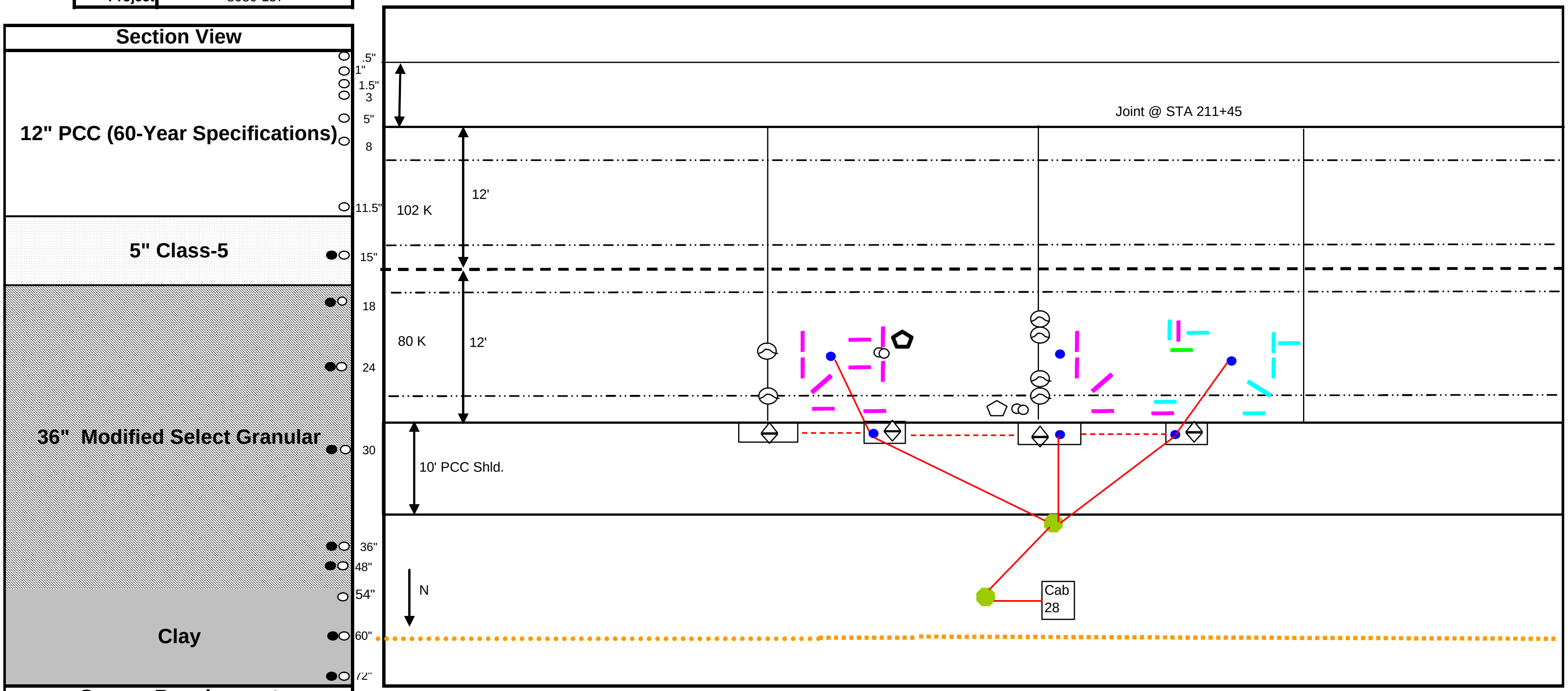
Legend

●	Risers	−··−··	Wheelpath (9.5' offset from CL)
– – –	Centerline	•••••••	Chain Link Fence
⋈	TE Sensors	—	Conduit
⧗	LE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor	✚	Maturity
●	Handhole	—	CE sensor
		—	VW Sensors

Figure 68. Instrumentation for Cell 39

MnROAD Instumentation Summary For 60-Year PCC

Cell	53
Project	8680-157



Sensor Requirement

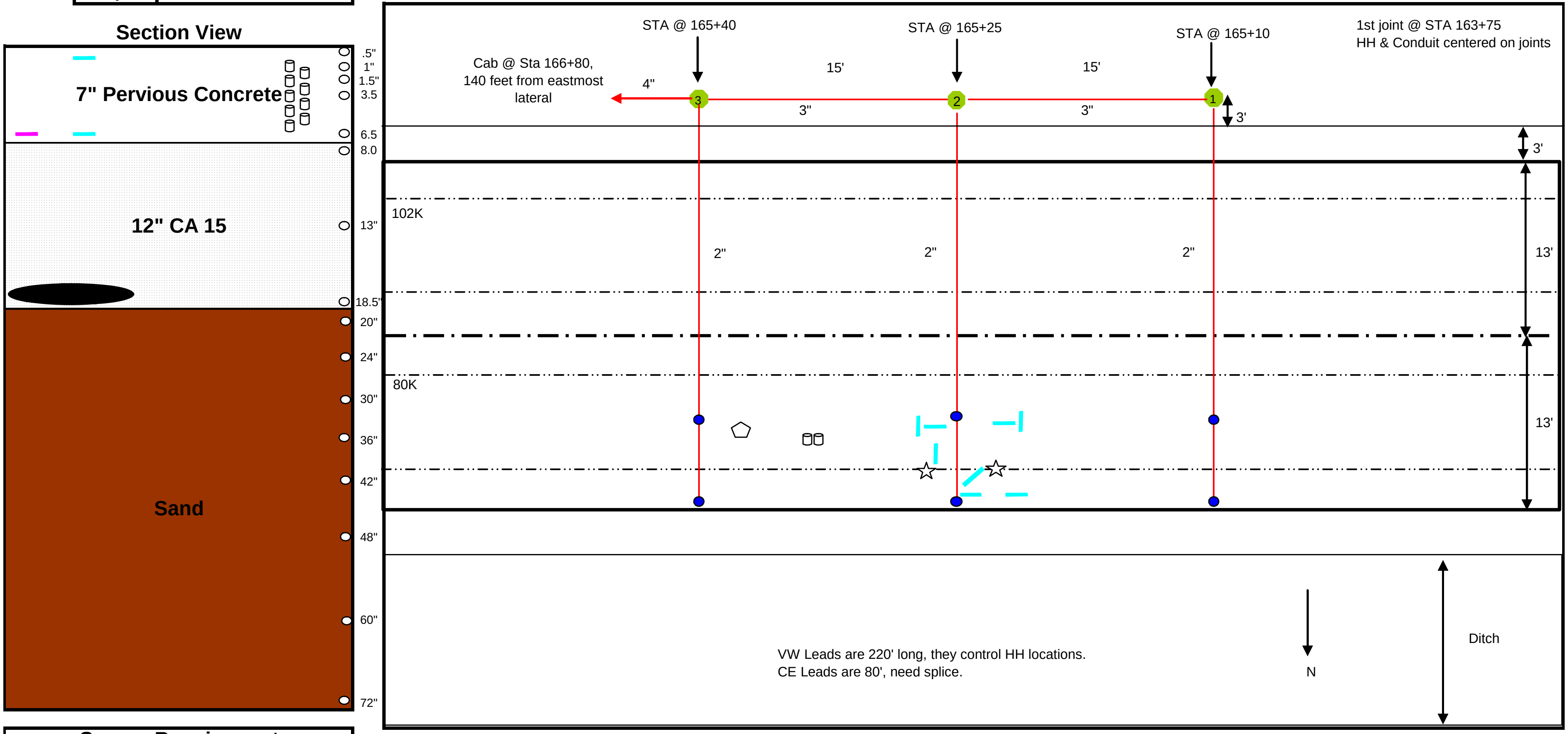
Code	Number	Sensor	Description
TC	24	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
DT	6	Linear Variable Displacement T	Measures panel displacement in the vertical due to dynamic loading.
CE	24	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain (Longitudinal and Transverse)
HC	6	Horizontal Clip Gauge	Measures Panel Joint Opening
IK	15	Maturity Sensor	Records PCC Pavement Curing Rate
IV	4	Invar Rod	Vertical Displacement (Control)
WM	12	Moisture (Frost)	Gypsum Moisture Sensor monitors the propogation of frost
VG	3		Static Strain

Legend			
●	Risers	▯▯▯	IK
– – –	Centerline	◇	DT
—	VW Sensors	—	Conduit
—	CE Sensors	○	TC Sensors
⊖	HC	●	EC Sensors
⬠	TC/ M Sensor	—	VG
●	Handhole	◎	WM

Figure 69. Instrumentation for Cell 53

MnROAD Instumentation Summary, Pervious PCC over Sand

Cell	85
Project	8680-157



VW Leads are 220' long, they control HH locations.
CE Leads are 80', need splice.

Sensor Requirement

Code	Number	Sensor	Description
TC	8	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC		Decagon ECH$_2$O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
PG	2	Geokon Pressure Cell (Normal Pressure	Measures normal stress at base/subgrade interface
IK	9	Maturity	Maturity Sensors
CE	8	Concrete Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	16	Geokon Vibrating Wire Strain Gauge	Static (Environmental) Strain

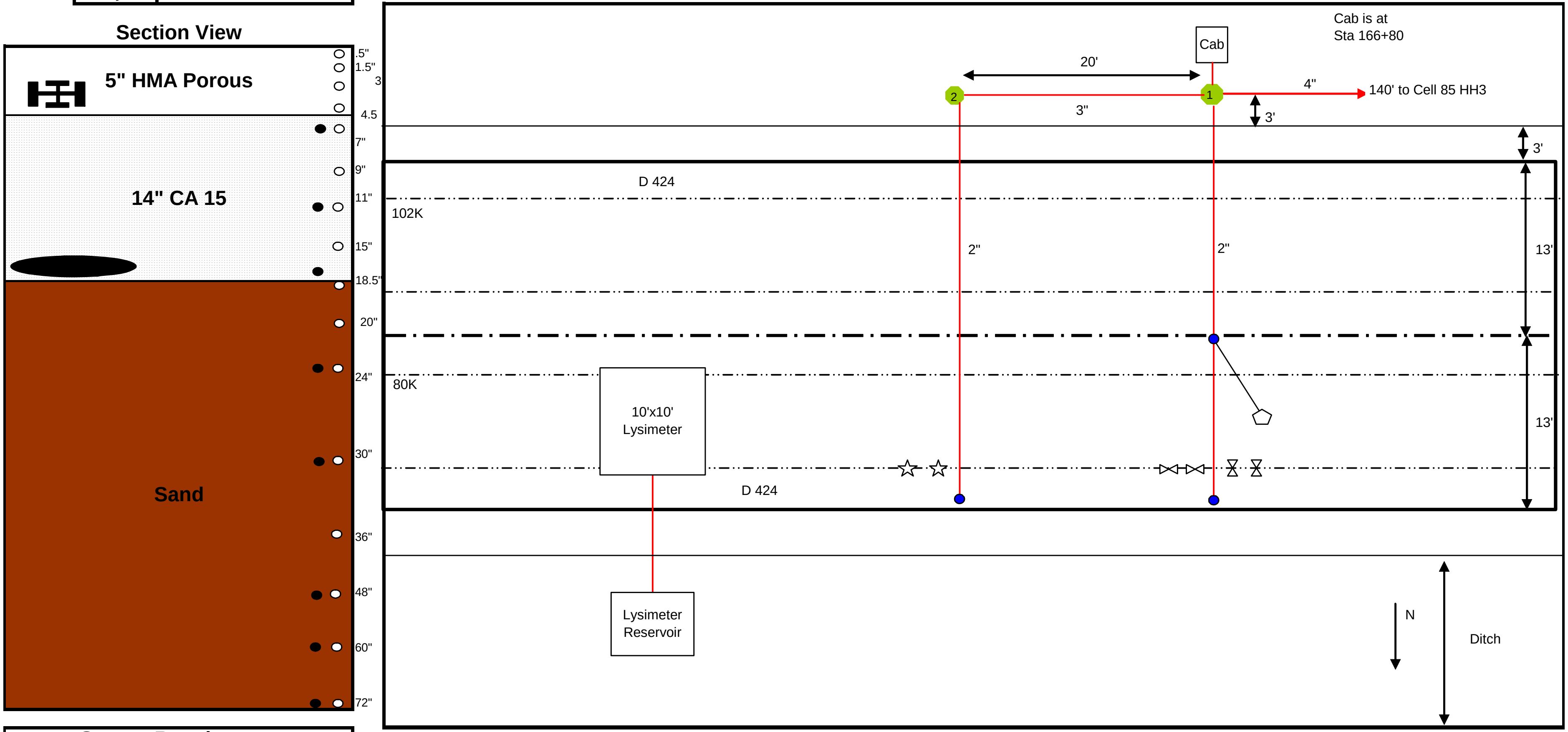
Legend

●	Risers	—··—	Wheelpath (9.5' offset from CL)
▬ ▬ ▬	Centerline	—	Conduit
⋈	LE Sensors	○	Thermocouples
⧗	TE Sensors	●	Moisture Sensor
☆	PG Sensor	▯▯▯	Maturity
⬠	TC/ M Sensor	▬	CE sensor
●	Handhole	▬	VW Sensors

Figure 70. Instrumentation for Cell 85

MnROAD Instumentation Summary, Porous HMA over Sand

Cell	86
Project	8680-157



Sensor Requirement

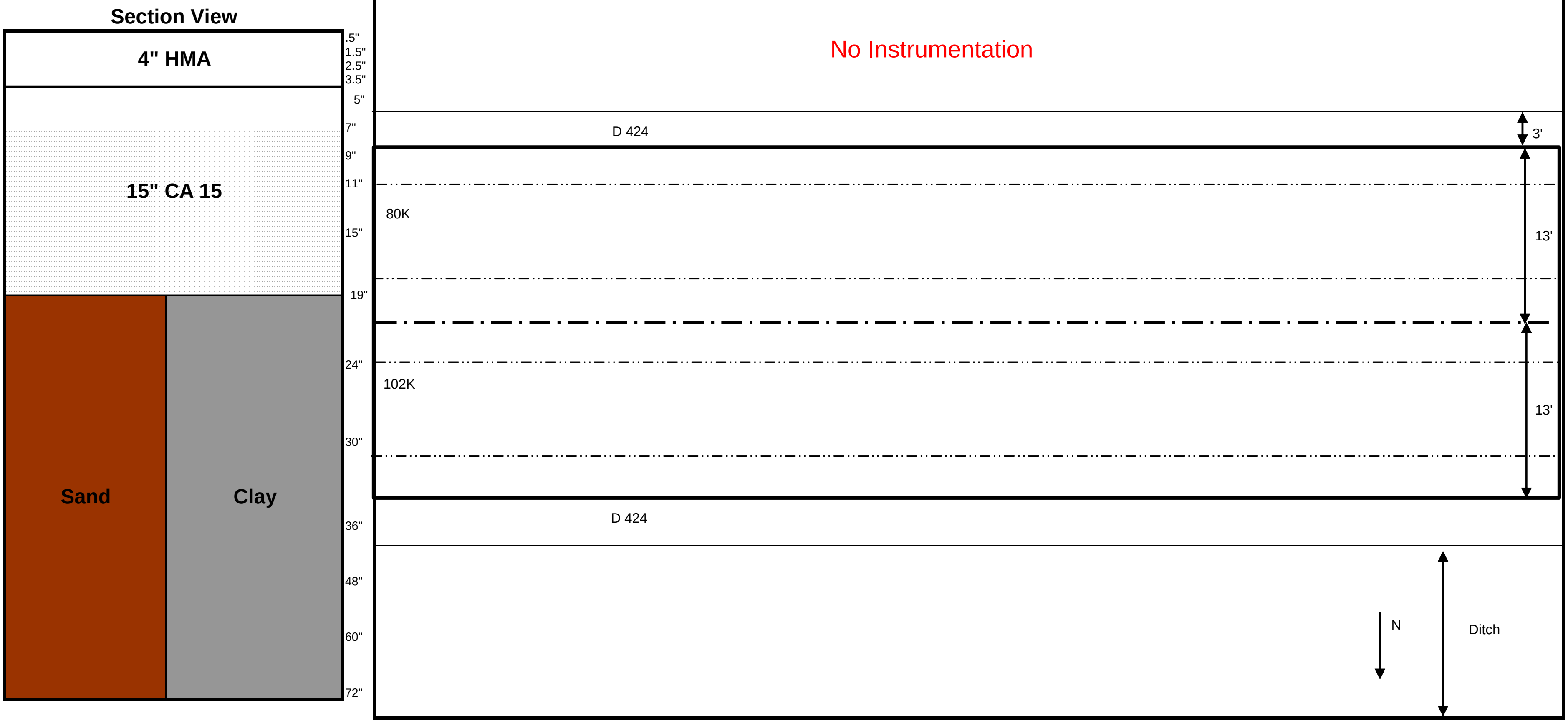
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	2	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	2	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	2	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

Legend			
●	Risers	—··—··	Wheelpath (9.5' offset from CL)
▬ ▬ ▬	Centerline	•••••••	Chain Link Fence
⋈	LE Sensors	—	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensors		
●	Handhole		

Figure 71. Instrumentation for Cell 86

MnROAD Instumentation Summary, Pervious/Porous Control Section

Cell	87
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
TC	0	ThermoCouple (Temperature	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 8' from the surface
EC	0	EcH2O-TE (Moisture)	Measure volmetric moisture content, temperature, electric conductivity
TE	0	TE Sensor	Embedded transverse strain gauge-measures transverse strain at the bottom of bound layers
LE	0	LE Sensor	Embedded longitdinal strain gauge-measures longitdinal strain at the bottom of bound layers
PG	0	PG Sensor	Measures normal stress at base/subgrade interface

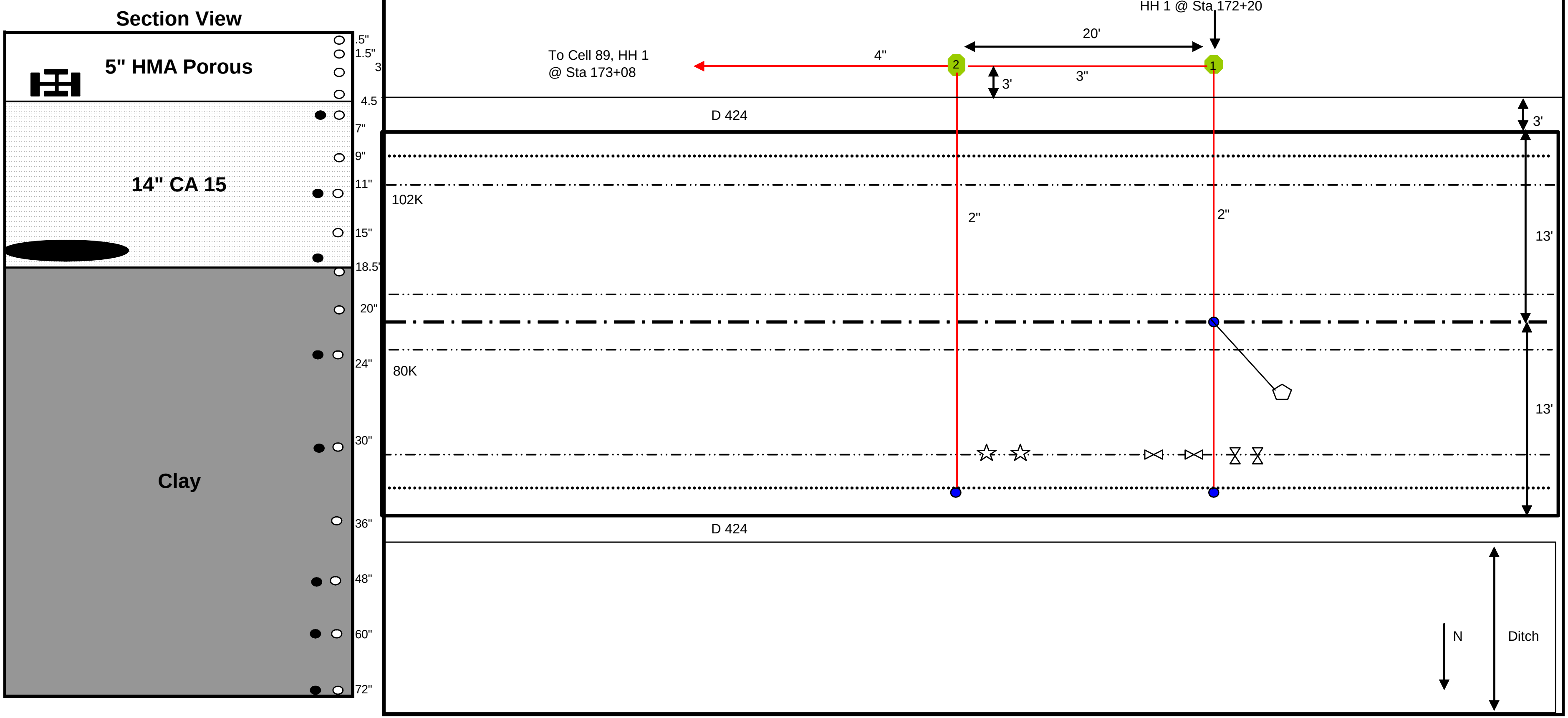
Legend

●	Risers	−··−··	Wheelpath (9.5' offset from CL)
— — —	Centerline	•••••••	Chain Link Fence
⋈	LE Sensors	——	Conduit
⧗	TE Sensors	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor		
⬢	Handhole		

Figure 72. Instrumentation for Cell 87

MnROAD Instumentation Summary, Porous HMA over Clay

Cell	88
Project	8680-157



Sensor Requirement

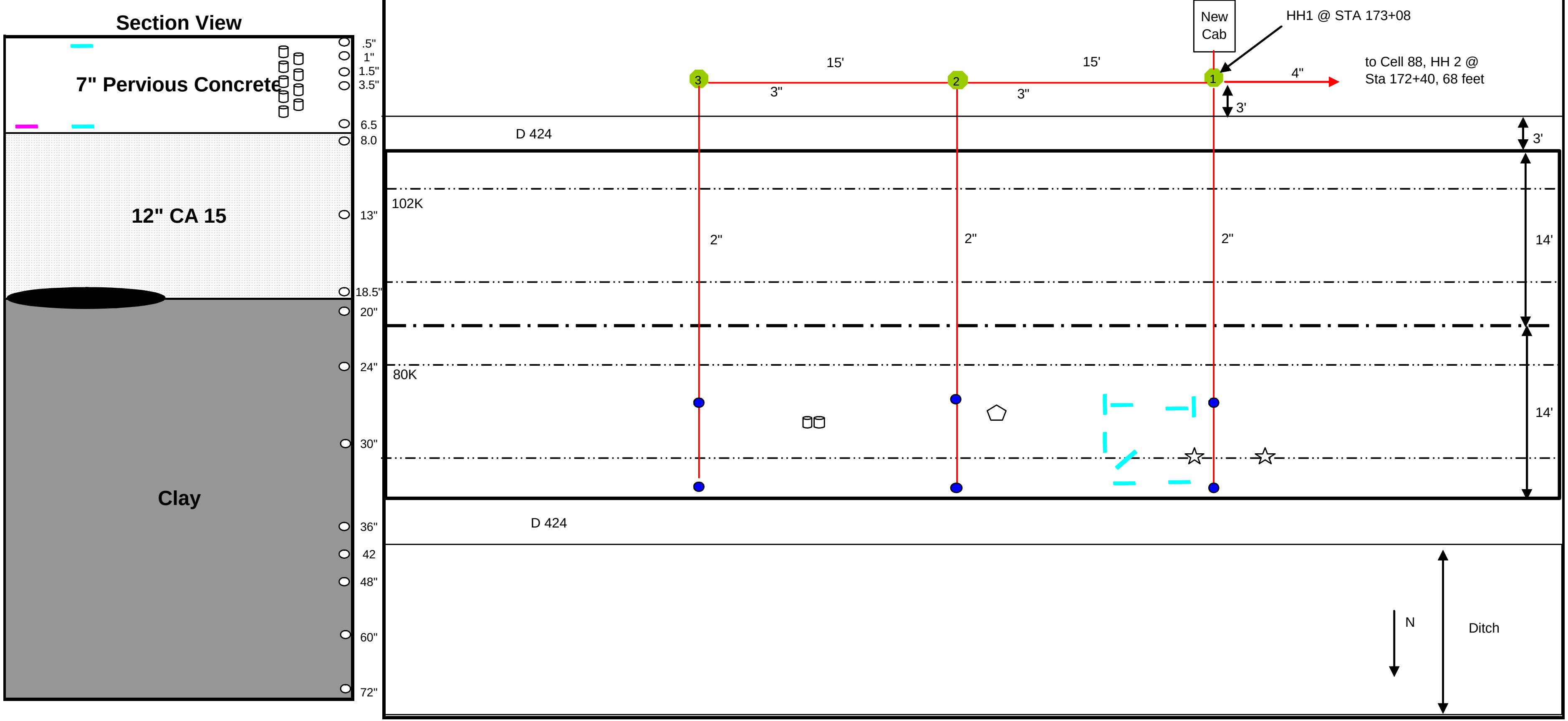
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH$_2$O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	2	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	2	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	2	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

Legend			
●	Risers	—··—	Wheelpath (9.5' offset from CL)
– – –	Centerline	••••••	Chain Link Fence
⋈	LE	—	Conduit
⧖	TE	○	TC Sensors
☆	PG Sensor	●	EC Sensors
⬠	TC/ M Sensor		
●	Handhole		

Figure 73. Instrumentation for Cell 88

MnROAD Instumentation Summary, Pervious PCC over Clay

Cell	89
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
TC	8	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 8' from the surface
EC		EcH2O-TE (Moisture)	Measure volmetric moisture content, temperature, electric conductivity
PG	2	PG Sensor	Measures normal stress at base/subgrade interface
IK	9	Maturity	Wireless Maturity Sticks
CE	8	Embedded Strain Gauge	Dynamic Strain Measurement (Longitudinal and Transverse)
VW	16	Vibrating Wire Strain Gauge	Static (Environmental) Strain

Legend			
●	Risers	-··-··	Wheelpath (9.5' offset from CL)
- - -	Centerline	—	Conduit
⋈	LE Sensors	○	TC Sensors
⧖	TE Sensors	●	EC Sensors
☆	PG Sensor	⌸⌸⌸	Maturity
⬠	TC/ M Sensor	▬	CE sensor
●	Handhole	▬	VW Sensors

Figure 74. Instrumentation for Cell 89

CHAPTER 5 – SUMMARY

Construction Contract

As noted earlier, the general contractor for this project was PCI. Contract payments are outlined in Table 33, separated by study. The Whitetopping Design study was used for Cell 14 as well as the transition areas and pay items shared across many cells (i.e., traffic control, turf establishment, etc.).

Table 33. Payments to Construction Contractor

Group	Plan Column	Study	Bid Totals	Overruns	Project Totals
1	TPF-5(165)	Whitetopping Design	$439,145.55	$89,150.00	$528,295.55
2	MPR-6(016)	Unbonded Concrete Overlay	98,962.75	3,073.00	102,035.75
3	TPF-5(149)	Thermally Insulated Concrete Pavements	116,167.85	3,643.00	119,810.85
4	TPF-5(132)	Low Temperature Cracking (II)	344,582.65	17,017.00	361,599.65
5	TPF-5(129)	Recycled Unbound Pavements	425,120.40	12,093.00	437,213.40
6	MPR-6(023)	Taconite Aggregates in Pavement Applications	120,575.70	23,368.00	143,943.70
7	TPF-5(153)	Preventive Maintenance HMA	20,876.85	11,420.00	32,296.85
8	MPR-6(027)	Pervious Concrete Pavement Study	142,336.36	10,407.00	152,743.36
9	MPR-6(024)	Permeable Pavement Performance in Cold Regions	84,489.29	15,102.00	99,591.29
10	MPR-6(017)	Inv of HP Concrete Pavement (60yr)	112,909.31	713.00	113,622.31
11	MPR-6(015)	Pervious Concrete Mix Design	80,644.69	0.00	80,644.69
12	MPR-6(031)	Thin Design PCC	107,016.90	1,542.00	108,558.90
		TOTAL	**$2,092,828.30**	**$ 187,528.00**	**$2,280,356.30**

Four Work Orders were executed as part of this contract. Work Order No. 1 was signed September 25, 2008 and included additional costs required for the Meridian ballast in Cells 85 through 89. The material specified would not support the paving equipment. The layer thickness of the CA-15 aggregate was reduced by 4” and replaced by railroad sub-ballast. Work for item 2105.607, Furnish Railroad Track Sub-ballast increased the contract by $16,758.00.

Work Order No. 2 was signed October 31, 2008, and included a change in the asphalt material for Cells 86 and 88. The plans called for a PG 64-34 to be used in the asphalt mixture on Cells 86 and 88. The asphalt cement failed one of the required trial mix tests, and the Mn/DOT research engineer requested that the PG grade be changed to 70-28. This change increased the unit price of the asphalt mixture by $18.15/ton. The total increase to the contract as a result of this work order was $7,405.20.

Work Order No. 3 was executed to provide for the Contractor not achieving the required depth of the texturing during longitudinal tining. This was partly due to his operation and partly due to Mn/DOT installing sensors in the concrete behind the paver, but in advance of the texture. The time it took to install the sensors took longer than anticipated which made it harder to obtain the proper depth of tining. Grinding was required, and the Contractor and Mn/DOT agreed to share the costs. The invoice amount for the grinding is $3,190.00, of which $1,595.00 plus 10% Prime Contractor markup of $159.50, or $1,754.50 was added to the contract.

Work Order No. 4 was executed to modify staging for the East and West transition areas. The plans called for milling and overlaying the East and West ends of the project which tied into the MnROAD test section. The staging was modified which enabled the work to be done during the daytime which was safer for the traveling public and provided for a better end result product. Black out paint and pavement marking removal was required to do this work, and was added to the contract. The total cost to add this material was $2,401.85.

One Supplemental Agreement was executed to allow more time for construction. It noted that sensor delivery was delayed by one month, which required an extension of the original contract completion date of October 15, 2008. It received final signatures on January 9, 2009, and extended the contract time to require completion by November 12, 2008. No cost was added to the contract as part of this Agreement.

Design Changes

Several changes were made during the construction season. Each is outlined in Table 34.

Table 34. Changes to Construction Plans

Description	Basis for Change	Documentation
Reduce aggregate base thickness and replace with railroad sub-ballast on Cells 85-89	Original material would not support paving equipment.	Work Order No. 1
Subgrade removal on Cells 6, 13	Clay borrow prevented stable base construction	None – overrun on quantities
Cell 53 subgrade dimensions	Changed to accommodate utility construction	None – change in field
Asphalt binder grades on porous AC layer in Cells 86 and 88	Changed from PG 64-34 to 70-28 to pass TSR test	Work Order No. 2
Cell 6 taconite HMA mix design	Changed to meet supplied aggregate specifications	None
Cell 5 low texture and friction numbers	Longitudinal tining could not achieve sufficient friction. Will diamond grind to achieve sufficient friction and split cost 50/50	Work Order No. 3
East and West transition area staging was changed	Black out paint and pavement marking removal was needed to adjust pavement markings for staging	Work Order No.4
Contract time extension	Sensor delivery delayed one month	Supplemental Agreement No. 1

Lessons Learned

During construction, MnROAD staff made several determinations about construction processes. They include:

1. The most important lesson learned during this construction season is to require earlier construction end dates for the contract. This contract originally specified an end of construction as October 15th, which was extended due to unforeseen delays. However, this late date also made it difficult to finish construction, all punch list items, and initial monitoring measurements before the ground froze and the construction season ended. The construction end should be specified earlier to remedy this problem.
2. Researchers also learned not to add clay borrow over an existing clay subgrade. The base on several cells was soft and it was difficult to support construction traffic over the clay on clay areas.
3. Researchers also learned the importance of maintaining oversight over all partnership projects to ensure consistency between cells and projects. This is especially true when some research elements are not included in a construction contract.
4. Several materials and/or designs in the construction plans (i.e., CA-15 aggregate base, Cell 53 subcut, concrete surface textures) were not feasible. This reminded researchers that both design and constructability need to be balanced during a project.

5. Mn/DOT and the plant and paving crews at Hardrives successfully built our first porous asphalt paving job together. It took several false starts and practice runs before settling on the proper techniques.
6. Open lines of communication between researchers, field inspectors, and contractors (and countless other key players) are essential in constructing a research project that meets everyone’s needs.

APPENDIX A – MNROAD CELL MAPS

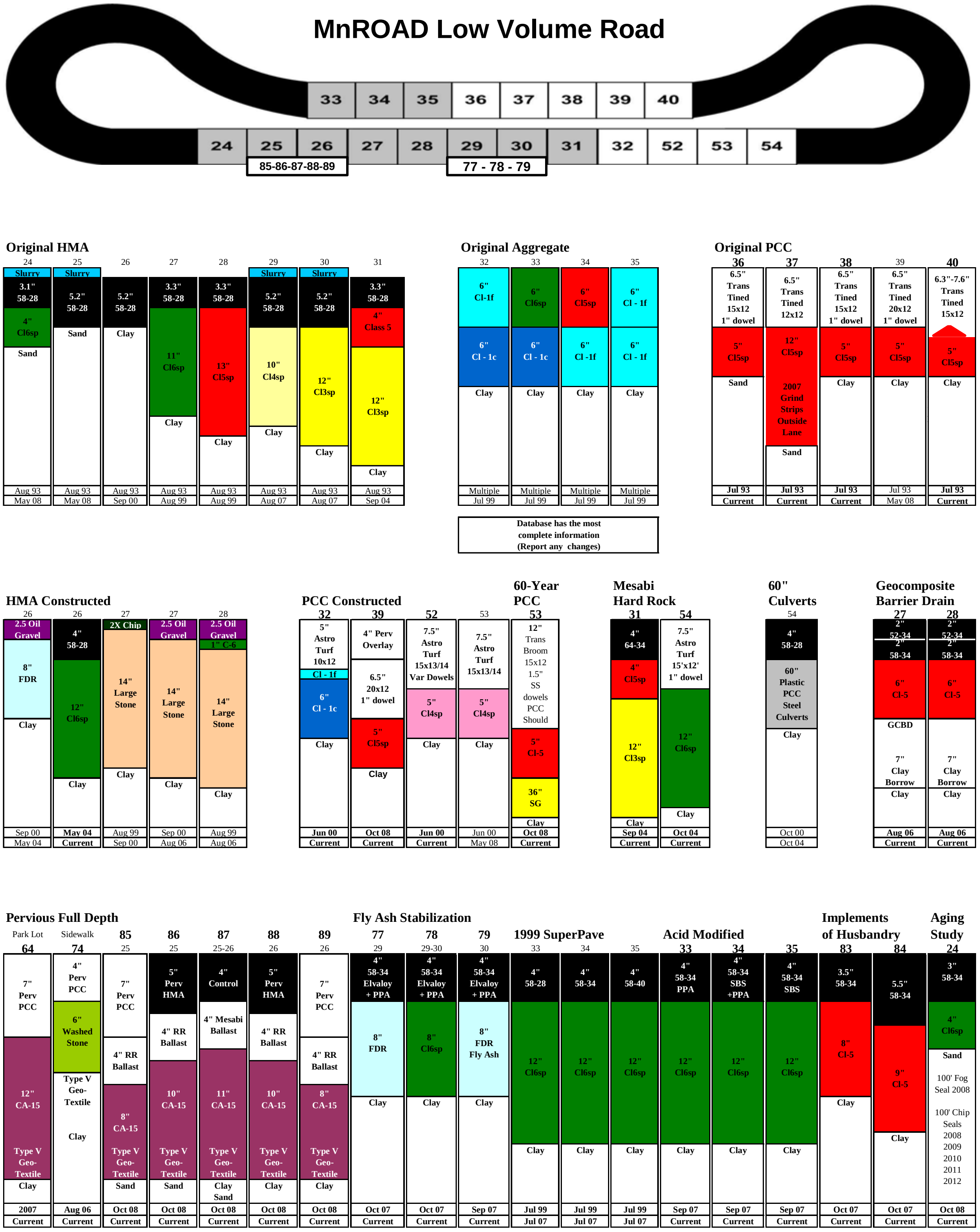


Figure A-1. MnROAD Low Volume Road

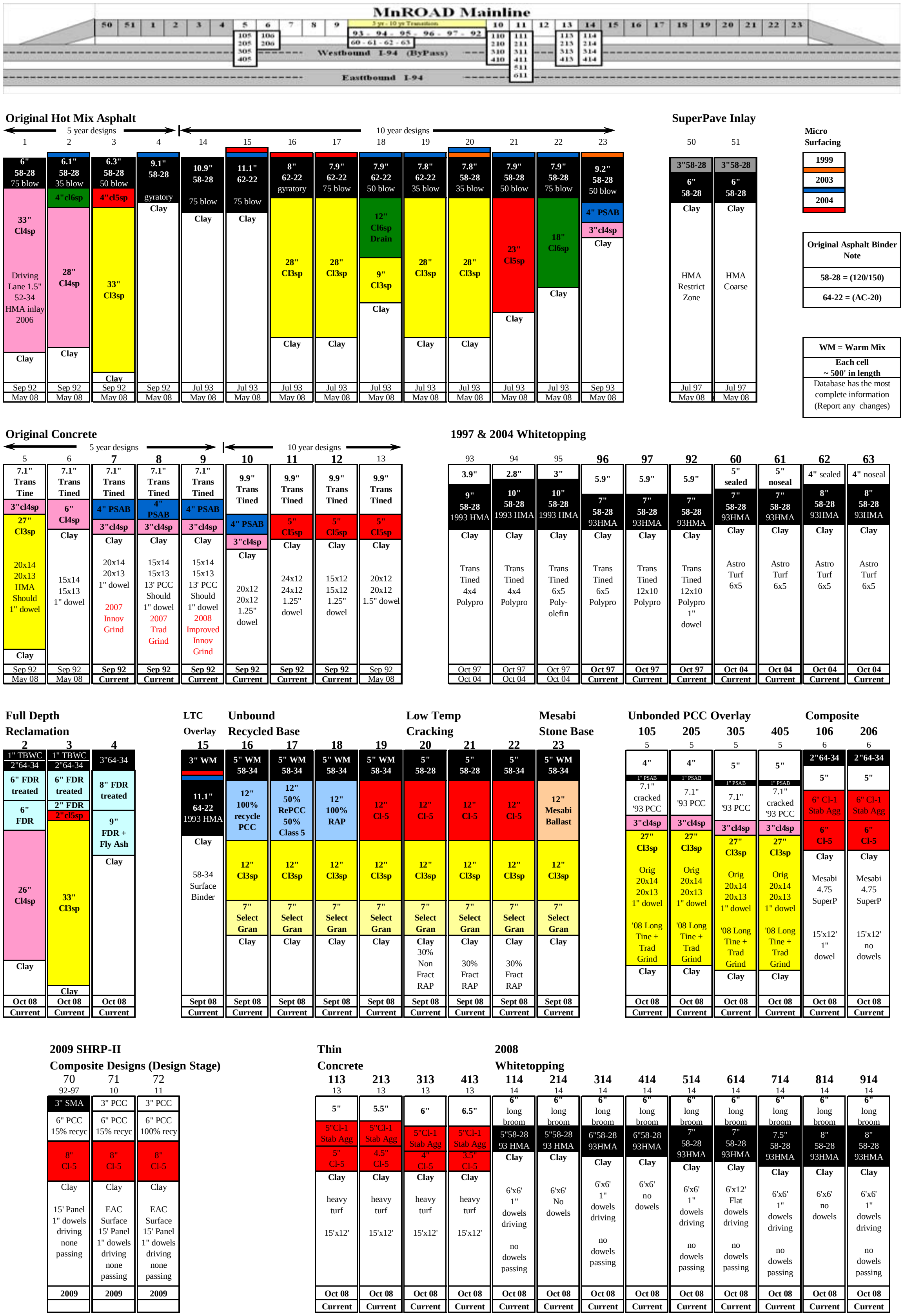


Figure A-2. MnROAD Mainline

APPENDIX B – SENSOR LOCATIONS

Table B-1. Sensor Locations - Cell 2

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	STATION	OFFSET (FT)	NORTHING	EASTING
2	PG	101		-16	1109+86.5	-9		
2	PG	102		-16	1110+6.5	-9		
2	PG	103		-16	1110+26.5	-9		
2	TE	101	TRANSVERSE	-9	1109+89.3	-8.9	208359.995	538537.358
2	TE	102	TRANSVERSE	-9	1109+87.5	-9	208361.005	538535.87
2	TE	103	TRANSVERSE	-9	1109+85.3	-8.9	208362.226	538533.966
2	TE	104	TRANSVERSE	-3	1109+89.3	-8.9	208359.995	538537.358
2	TE	105	TRANSVERSE	-3	1109+87.5	-9	208361.005	538535.87
2	TE	106	TRANSVERSE	-3	1109+85.3	-8.9	208362.226	538533.966
2	LE	101	LONGITUDINAL	-9	1110+09	-8.9	208349.009	538553.718
2	LE	102	LONGITUDINAL	-9	1110+06.9	-8.9	208350.168	538551.929
2	LE	103	LONGITUDINAL	-9	1110+04.7	-8.9	208351.381	538550.227
2	LE	104	LONGITUDINAL	-3	1110+09	-8.9	208349.009	538553.718
2	LE	105	LONGITUDINAL	-3	1110+06.9	-8.9	208350.168	538551.929
2	LE	106	LONGITUDINAL	-3	1110+04.7	-8.9	208351.381	538550.227
2	TC	101		-0.5	1110+26.5	-5.9	208336.774	538566.563
2	TC	102		-1.5	1110+26.5	-5.9	208336.774	538566.563
2	TC	103		-2.5	1110+26.5	-5.9	208336.774	538566.563
2	TC	104		-3.5	1110+26.5	-5.9	208336.774	538566.563
2	TC	105		-5	1110+26.5	-5.9	208336.774	538566.563
2	TC	106		-7	1110+26.5	-5.9	208336.774	538566.563
2	TC	107		-9	1110+26.5	-5.9	208336.774	538566.563
2	TC	108		-11	1110+26.5	-5.9	208336.774	538566.563
2	TC	109		-13	1110+26.5	-5.9	208336.774	538566.563
2	TC	110		-15	1110+26.5	-5.9	208336.774	538566.563
2	TC	111		-24	1110+26.5	-5.9	208336.774	538566.563
2	TC	112		-28	1110+26.5	-5.9	208336.774	538566.563
2	TC	113		-36	1110+26.5	-5.9	208336.774	538566.563
2	TC	114		-48	1110+26.5	-5.9	208336.774	538566.563
2	TC	115		-60	1110+26.5	-5.9	208336.774	538566.563
2	TC	116		-72	1110+26.5	-5.9	208336.774	538566.563
2	EC	101		-5	1110+26.5	-5.9	208336.774	538566.563
2	EC	102		-9	1110+26.5	-5.9	208336.774	538566.563
2	EC	103		-15	1110+26.5	-5.9	208336.774	538566.563
2	EC	104		-24	1110+26.5	-5.9	208336.774	538566.563
2	EC	105		-36	1110+26.5	-5.9	208336.774	538566.563
2	EC	106		-48	1110+26.5	-5.9	208336.774	538566.563
2	EC	107		-60	1110+26.5	-5.9	208336.774	538566.563
2	EC	108		-72	1110+26.5	-5.9	208336.774	538566.563

Table B-2. Sensor Locations - Cell 3

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	STATION	OFFSET (FT)	NORTHING	EASTING
3	PG	101		-14	1117+66.5	-8.9		
3	PG	102		-14	1117+86.5	-8.9		
3	PG	103		-14	1118+6.5	-9.2		
3	TE	101	TRANSVERSE	-9	1117+69.6	-8.9	207912.376	539176.872
3	TE	102	TRANSVERSE	-9	1117+67.7	-8.9	207913.464	539175.389
3	TE	103	TRANSVERSE	-9	1117+65.6	-8.9	207914.705	539173.595
3	TE	104	TRANSVERSE	-3	1117+69.6	-8.9	207912.376	539176.872
3	TE	105	TRANSVERSE	-3	1117+67.7	-8.9	207913.464	539175.389
3	TE	106	TRANSVERSE	-3	1117+65.6	-8.9	207914.705	539173.595
3	LE	101	LONGITUDINAL	-9	1117+89.0	-9	207900.934	539192.576
3	LE	102	LONGITUDINAL	-9	1117+87.2	-8.9	207901.88	539191.062
3	LE	103	LONGITUDINAL	-9	1117+85.1	-8.8	207903.084	539189.182
3	LE	104	LONGITUDINAL	-3	1117+89.0	-9	207900.934	539192.576
3	LE	105	LONGITUDINAL	-3	1117+87.2	-8.9	207901.88	539191.062
3	LE	106	LONGITUDINAL	-3	1117+85.1	-8.8	207903.084	539189.182
3	TC	101		-0.5	1118+2.5	-5.9	207890.413	539201.638
3	TC	102		-1.5	1118+2.5	-5.9	207890.413	539201.638
3	TC	103		-2.5	1118+2.5	-5.9	207890.413	539201.638
3	TC	104		-3.5	1118+2.5	-5.9	207890.413	539201.638
3	TC	105		-5	1118+2.5	-5.9	207890.413	539201.638
3	TC	106		-7	1118+2.5	-5.9	207890.413	539201.638
3	TC	107		-9	1118+2.5	-5.9	207890.413	539201.638
3	TC	108		-11	1118+2.5	-5.9	207890.413	539201.638
3	TC	109		-13	1118+2.5	-5.9	207890.413	539201.638
3	TC	110		-15	1118+2.5	-5.9	207890.413	539201.638
3	TC	111		-24	1118+2.5	-5.9	207890.413	539201.638
3	TC	112		-28	1118+2.5	-5.9	207890.413	539201.638
3	TC	113		-36	1118+2.5	-5.9	207890.413	539201.638
3	TC	114		-48	1118+2.5	-5.9	207890.413	539201.638
3	TC	115		-60	1118+2.5	-5.9	207890.413	539201.638
3	TC	116		-72	1118+2.5	-5.9	207890.413	539201.638
3	EC	101		-5	1118+2.5	-5.9	207890.413	539201.638
3	EC	102		-9	1118+2.5	-5.9	207890.413	539201.638
3	EC	103		-13	1118+2.5	-5.9	207890.413	539201.638
3	EC	104		-15	1118+2.5	-5.9	207890.413	539201.638
3	EC	105		-28	1118+2.5	-5.9	207890.413	539201.638
3	EC	106		-36	1118+2.5	-5.9	207890.413	539201.638
3	EC	107		-60	1118+2.5	-5.9	207890.413	539201.638
3	EC	108		-72	1118+2.5	-5.9	207890.413	539201.638

Table B-3. Sensor Locations - Cell 4

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	STATION	OFFSET (FT)	NORTHING	EASTING
4	PG	101		-13	1122+11.5	-9.5		
4	PG	102		-13	1122+31.5	-9.5		
4	PG	103		-13	1122+51.5	-9.5		
4	TE	101	TRANSVERSE	-9	1122+09.2	-9.4	207645.728	539532.402
4	TE	102	TRANSVERSE	-9	1122+07	-9.3	207647.006	539530.704
4	TE	103	TRANSVERSE	-9	1122+05	-9.3	207684.313	539529.157
4	TE	104	TRANSVERSE	-3	1122+09.2	-9.4	207645.728	539532.402
4	TE	105	TRANSVERSE	-3	1122+07	-9.3	207647.006	539530.704
4	TE	106	TRANSVERSE	-3	1122+05	-9.3	207684.313	539529.157
4	LE	101	LONGITUDINAL	-9	1122+28.9	-9.5	207633.869	539548.124
4	LE	102	LONGITUDINAL	-9	1122+26.8	-9.4	207635.017	539546.443
4	LE	103	LONGITUDINAL	-9	1122+24.8	-9.2	207636.141	539544.737
4	LE	104	LONGITUDINAL	-3	1122+28.9	-9.5	207633.869	539548.124
4	LE	105	LONGITUDINAL	-3	1122+26.8	-9.4	207635.017	539546.443
4	LE	106	LONGITUDINAL	-3	1122+24.8	-9.2	207636.141	539544.737
4	TC	101		-0.5	1122+51.8	-5.7	207616.871	539563.969
4	TC	102		-1.5	1122+51.8	-5.7	207616.871	539563.969
4	TC	103		-2.5	1122+51.8	-5.7	207616.871	539563.969
4	TC	104		-3.5	1122+51.8	-5.7	207616.871	539563.969
4	TC	105		-5	1122+51.8	-5.7	207616.871	539563.969
4	TC	106		-7	1122+51.8	-5.7	207616.871	539563.969
4	TC	107		-9	1122+51.8	-5.7	207616.871	539563.969
4	TC	108		-11	1122+51.8	-5.7	207616.871	539563.969
4	TC	109		-13	1122+51.8	-5.7	207616.871	539563.969
4	TC	110		-15	1122+51.8	-5.7	207616.871	539563.969
4	TC	111		-24	1122+51.8	-5.7	207616.871	539563.969
4	TC	112		-30	1122+51.8	-5.7	207616.871	539563.969
4	TC	113		-36	1122+51.8	-5.7	207616.871	539563.969
4	TC	114		-48	1122+51.8	-5.7	207616.871	539563.969
4	TC	115		-60	1122+51.8	-5.7	207616.871	539563.969
4	TC	116		-72	1122+51.8	-5.7	207616.871	539563.969
4	EC	101		-5	1122+51.8	-5.7	207616.871	539563.969
4	EC	102		-9	1122+51.8	-5.7	207616.871	539563.969
4	EC	103		-11	1122+51.8	-5.7	207616.871	539563.969
4	EC	104		-20	1122+51.8	-5.7	207616.871	539563.969
4	EC	105		-36	1122+51.8	-5.7	207616.871	539563.969
4	EC	106		-48	1122+51.8	-5.7	207616.871	539563.969
4	EC	107		-60	1122+51.8	-5.7	207616.871	539563.969
4	EC	108		-72	1122+51.8	-5.7	207616.871	539563.969

Table B-4. Sensor Locations - Cell 105

CELL	MODEL	SEQ	SN	ORIENTATION	DEPTH (in)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
105	CE	101	236	LONGITUDINAL	0.25	1126+64.28	-13.7	207372.274	539896.21	
105	CE	102	231	LONGITUDINAL	3.76	1126+64.28	-13.7	207372.274	539896.21	949.19
105	CE	103	233	39o	0.25	1126.65.14	-12.0	207370.401	539895.85	
105	CE	104	105	39o	3.76	1126.65.14	-12.0	207370.401	539895.85	949.22
105	CE	105	237	LONGITUDINAL	0.25	1126+65.27	-11.2	207369.707	539895.48	
105	CE	106	102	LONGITUDINAL	3.76	1126+65.27	-11.2	207369.707	539895.48	949.21
105	CE	107		TRANSVERSE	0.25	1126+66	-11.0			
105	CE	108		LONGITUDINAL	0.25	1126+66	-7.0			
105	CE	109	97	LONGITUDINAL	0.25	1126+70.21	-13.6	207368.626	539900.88	
105	CE	110	165	LONGITUDINAL	3.76	1126+70.21	-13.6	207368.626	539900.88	949.28
105	CE	111	96	39o	0.25	1126+69.53	-12.0	207367.787	539899.38	
105	CE	112	163	39o	3.76	1126+69.53	-12.0	207367.787	539899.38	949.26
105	CE	113	95	LONGITUDINAL	0.25	1126+69.26	-11.1	207367.216	539898.60	
105	CE	114	76	LONGITUDINAL	3.76	1126+69.26	-11.1	207367.216	539898.60	949.27
105	CE	115		TRANSVERSE	0.25	1126+68	-11.0			
105	CE	116		LONGITUDINAL	0.25	1126+68	-7.0			
105	DT	101		VERTICAL	0.75	1126+67	-14.2			
105	DT	102		VERTICAL	0.75	1126+67	-14.2			
105	IV	101			8.00	1126+67	-14.3	207370.979	539898.97	948.96

Table B-5. Sensor Locations - Cell 205

CELL	MODEL	SEQ	ORIENTATION	DEPTH (in)	STATION	OFFSET (FT)	Northing	Easting	Elevation
205	CE	117	LONGITUDINAL	3.76	1128+42.61	-13.7	207263.785	540037.736	951.38
205	CE	118	TRANSVERSE	3.76	1128+42.50	-11.1	207261.846	540036.113	951.44
205	CE	119	LONGITUDINAL	3.76	1128+43.03	-11.2	207261.607	540036.592	951.46
205	CE	120	TRANSVERSE	3.76	1128+42.6	-7.1	207258.594	540033.743	951.51
205	CE	121	LONGITUDINAL	3.76	1128+43.07	-7.1	207258.322	540034.120	951.51
205	CE	122	LONGITUDINAL	3.76	1128+47.00	-13.6	207261.095	540041.200	951.72
205	CE	123	39°	3.76	1128+47.84	-12.1	207259.375	540040.944	951.54
205	CE	124	TRANSVERSE	3.76	1128+49.04	-11.2	207257.888	540041.310	951.44
205	CE	125	TRANSVERSE	3.76	1128+49.12	-6.6	207254.253	540038.629	951.48
205	CE	126	LONGITUDINAL	3.76	1128+53.05	-13.7	207257.444	540046.032	951.52
205	CE	127	39°	3.76	1128+52.22	-12.1	207256.73	540044.427	951.6
205	CE	128	TRANSVERSE	3.76	1128+51.1	-11.2	207256.633	540042.949	951.53
205	CE	129	TRANSVERSE	3.76	1128+51.11	-6.6	207253.052	540040.219	951.54
205	CE	130	LONGITUDINAL	3.76	1128+57.55	-13.6	207254.643	540049.552	951.54
205	CE	131	TRANSVERSE	3.76	1128+57.58	-7.2	207249.518	540045.659	951.62
205	DT	103	VERTICAL	0.75	1128+42.5	-14.2			
205	DT	104	VERTICAL	0.75	1128+50	-14.2			
205	DT	105	VERTICAL	0.75	1128+50	-14.2			
205	DT	106	VERTICAL	0.75	1128+57.5	-14.2			
205	HC	101	HORIZONTAL	1.00	1128+50	-13.0			
205	HC	102	HORIZONTAL	3.00	1128+50	-12.5			
205	HC	103	HORIZONTAL	1.00	1128+50	-7.0			
205	HC	104	HORIZONTAL	3.00	1128+50	-6.5			
205	IK	101	VERTICAL	1.00	1128+58.67	-13.6	207253.932	540050.416	951.87
205	IK	102	VERTICAL	2.00	1128+59.2	-13.6	207253.615	540050.844	951.8
205	IK	103	VERTICAL	3.00	1128+58.68	-13.5	207253.878	540050.390	951.74
205	IK	104	VERTICAL	1.00	1128+59.44	-12.1	207252.322	540050.151	951.9
205	IK	105	VERTICAL	2.00	1128+59.87	-12.2	207252.127	540050.548	951.81
205	IK	106	VERTICAL	3.00	1128+59.51	-12.1	207252.274	540050.203	951.75
205	IV	102		8.00	1128+42.67	-14.4	207264.358	540038.248	951.24
205	IV	103		8.00	1128+50.4	-14.4	207259.874	540044.100	951.6
205	IV	104		8.00	1128+57.18	-14.5	207255.555	540049.777	951.71
205	TC	101	VERTICAL	0.50	1128+35.67	-13.4	207267.803	540032.064	954.55
205	TC	102	VERTICAL	1.00	1128+35.67	-13.4	207267.803	540032.064	
205	TC	103	VERTICAL	1.50	1128+35.67	-13.4	207267.803	540032.064	
205	TC	104	VERTICAL	2.00	1128+35.67	-13.4	207267.803	540032.064	
205	TC	105	VERTICAL	3.00	1128+35.67	-13.4	207267.803	540032.064	
205	TC	106	VERTICAL	4.00	1128+35.67	-13.4	207267.803	540032.064	
205	TC	107	VERTICAL	5.00	1128+35.67	-13.4	207267.803	540032.064	
205	TC	108	VERTICAL	8.00	1128+35.67	-13.4	207267.803	540032.064	
205	TC	109	VERTICAL	0.50	1128+41.04	-7.1	207259.545	540032.502	954.55
205	TC	110	VERTICAL	1.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	111	VERTICAL	2.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	112	VERTICAL	2.50	1128+41.04	-7.1	207259.545	540032.502	
205	TC	113	VERTICAL	3.50	1128+41.04	-7.1	207259.545	540032.502	
205	TC	114	VERTICAL	4.50	1128+41.04	-7.1	207259.545	540032.502	
205	TC	115	VERTICAL	6.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	116	VERTICAL	9.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	117	VERTICAL	11.50	1128+41.04	-7.1	207259.545	540032.502	
205	TC	118	VERTICAL	15.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	119	VERTICAL	18.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	120	VERTICAL	24.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	121	VERTICAL	36.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	122	VERTICAL	48.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	123	VERTICAL	60.00	1128+41.04	-7.1	207259.545	540032.502	
205	TC	124	VERTICAL	72.00	1128+41.04	-7.1	207259.545	540032.502	

205	VW	101	LONGITUDINAL	1.00	1128+57.54	-12.1	207253.44	540048.614	951.4
205	VW	102	LONGITUDINAL	3.00	1128+57.48	-12.1	207253.511	540048.589	951.57
205	VW	103	LONGITUDINAL	1.00	1128+57.09	-7.1	207249.774	540045.236	951.85
205	VW	104	LONGITUDINAL	3.00	1128+57.13	-7.1	207249.768	540045.279	951.72
205	VW	105	TRANSVERSE	1.00	1128+58.16	-7.2	207249.18	540046.133	951.95
205	VW	106	TRANSVERSE	3.00	1128+58.14	-7.2	207249.212	540046.124	951.78
205	VW	107	LONGITUDINAL	1.00	1128+62.07	-13.1	207251.48	540052.821	951.95
205	VW	108	LONGITUDINAL	3.00	1128+62.08	-13.1	207251.484	540052.840	951.81
205	VW	109	39°	1.00	1128+62.90	-12.1	207250.224	540052.905	951.93
205	VW	110	39°	3.00	1128+62.09	-12.1	207250.234	540052.905	951.977
205	VW	111	TRANSVERSE	1.00	1128+64.05	-11.1	207248.722	540053.203	951.95
205	VW	112	TRANSVERSE	3.00	1128+64.04	-11.1	207248.756	540053.210	951.77
205	VW	113	TRANSVERSE	1.00	1128+63.53	-7.7	207246.299	540050.691	951.96
205	VW	114	TRANSVERSE	3.00	1128+63.53	-7.6	207246.267	540050.666	951.81
205	VW	115	LONGITUDINAL	1.00	1128+64.08	-7.7	207245.958	540051.125	952.02
205	VW	116	LONGITUDINAL	3.00	1128+64.05	-7.7	207245.988	540051.105	951.87
205	XV	101	LONGITUDINAL	1.00	1128+57.54	-12.1	207253.44	540048.614	951.4
205	XV	102	LONGITUDINAL	3.00	1128+57.48	-12.1	207253.511	540048.589	951.57
205	XV	103	LONGITUDINAL	1.00	1128+57.09	-7.1	207249.774	540045.236	951.85
205	XV	104	LONGITUDINAL	3.00	1128+57.13	-7.1	207249.768	540045.279	951.72
205	XV	105	TRANSVERSE	1.00	1128+58.16	-7.2	207249.18	540046.133	951.95
205	XV	106	TRANSVERSE	3.00	1128+58.14	-7.2	207249.212	540046.124	951.78
205	XV	107	LONGITUDINAL	1.00	1128+62.07	-13.1	207251.48	540052.821	951.95
205	XV	108	LONGITUDINAL	3.00	1128+62.08	-13.1	207251.484	540052.840	951.81
205	XV	109	39°	1.00	1128+62.90	-12.1	207250.224	540052.905	951.93
205	XV	110	39°	3.00	1128+62.09	-12.1	207250.234	540052.905	951.977
205	XV	111	TRANSVERSE	1.00	1128+64.05	-11.1	207248.722	540053.203	951.95
205	XV	112	TRANSVERSE	3.00	1128+64.04	-11.1	207248.756	540053.210	951.77
205	XV	113	TRANSVERSE	1.00	1128+63.53	-7.7	207246.299	540050.691	951.96
205	XV	114	TRANSVERSE	3.00	1128+63.53	-7.6	207246.267	540050.666	951.81
205	XV	115	LONGITUDINAL	1.00	1128+64.08	-7.7	207245.958	540051.125	952.02
205	XV	116	LONGITUDINAL	3.00	1128+64.05	-7.7	207245.988	540051.105	951.87
205	EC	101		11.50	1128+41.04	-7.1	207259.545	540032.502	
205	EC	102		15.00	1128+41.04	-7.1	207259.545	540032.502	
205	EC	103		18.00	1128+41.04	-7.1	207259.545	540032.502	
205	EC	104		24.00	1128+41.04	-7.1	207259.545	540032.502	
205	EC	105		36.00	1128+41.04	-7.1	207259.545	540032.502	
205	EC	106		48.00	1128+41.04	-7.1	207259.545	540032.502	
205	EC	107		60.00	1128+41.04	-7.1	207259.545	540032.502	
205	EC	108		72.00	1128+41.04	-7.1	207259.545	540032.502	

Table B-6. Sensor Locations - Cell 305

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
5	CE	132	LONGITUDINAL	0.396	1129+32.43	-13.6	207209.1	540108.988	952.48
5	CE	133	TRANSVERSE	0.396	1129+32.38	-11.1	207207.176	540107.45	952.55
5	CE	134	LONGITUDINAL	0.396	1129+32.92	-11.2	207206.872	540107.896	952.53
5	CE	135	TRANSVERSE	0.396	1129+32.47	-7.1	207203.947	540105.092	952.57
5	CE	136	LONGITUDINAL	0.396	1129+33	-7.2	207203.638	540105.523	952.58
5	CE	137	LONGITUDINAL	0.396	1129+37.03	-13.6	207206.323	540112.656	952.65
5	CE	138	39^{o}	0.396	1129+37.81	-12.1	207204.653	540112.357	952.66
5	CE	139	TRANSVERSE	0.396	1129+38.99	-11.2	207203.186	540112.717	5952.61
5	CE	140	TRANSVERSE	0.396	1129+38.99	-7.2	207200.034	540110.306	952.64
5	CE	141	LONGITUDINAL	0.396	1129+43	-13.6	207202.706	540117.406	952.66
5	CE	142	39^{o}	0.396	1129+42.09	-12.1	207202.002	540115.722	952.74
5	CE	143	TRANSVERSE	0.396	1129+40.97	-11.2	207201.978	540114.282	952.69
5	CE	144	TRANSVERSE	0.396	1129+40.97	-7.2	207198.836	540111.874	952.7
5	CE	145	LONGITUDINAL	0.396	1129+47.63	-13.6	207199.842	540121.046	952.69
5	CE	146	TRANSVERSE	0.396	1129+47.47	-7.1	207194.802	540116.977	952.77
5	DT	107	VERTICAL	0.0625	1129+32.5	-14.2			
5	DT	108	VERTICAL	0.0625	1129+40	-14.2			
5	DT	109	VERTICAL	0.0625	1129+40	-14.2			
5	DT	110	VERTICAL	0.0625	1129+47.5	-14.2			
5	HC	105	HORIZONTAL	0.083	1129+40	-13.0			
5	HC	106	HORIZONTAL	0.33	1129+40	-12.5			
5	HC	107	HORIZONTAL	0.083	1129+40	-7.0			
5	HC	108	HORIZONTAL	0.33	1129+40	-6.5			
5	IK	110		0.083	1129+31.43	-13.5	207209.628	540108.133	952.82
5	IK	111		0.208	1129+31.05	-13.5	207209.86	540107.825	952.72
5	IK	112		0.33	1129+31.41	-13.5	207209.625	540108.104	952.59
5	IK	113		0.083	1129+31.45	-12.1	207208.518	540107.305	952.86
5	IK	114		0.208	1129+30.99	-12.1	207208.776	540106.925	952.73
5	IK	115		0.33	1129+31.49	-12.1	207208.516	540107.35	952.63
5	IV	105		0.667	1129+32.56	-14.5	207209.753	540109.647	952.02
5	IV	106		0.667	1129+40.01	-14.0	207205.147	540115.509	951.86
5	IV	107		0.667	1129+47.47	-14.5	207200.645	540121.45	952.42
5	TC	125		0.042	1129+38.02	-13.3	207205.464	540113.239	952.97
5	TC	126		0.083	1129+38.02	-13.3	207205.464	540113.239	
5	TC	127		0.125	1129+38.02	-13.3	207205.464	540113.239	
5	TC	128		0.208	1129+38.02	-13.3	207205.464	540113.239	
5	TC	129		0.375	1129+38.02	-13.3	207205.464	540113.239	
5	TC	130		0.458	1129+38.02	-13.3	207205.464	540113.239	
5	TC	131		0.708	1129+38.02	-13.3	207205.464	540113.239	
5	TC	132		0.958	1129+38.02	-13.3	207205.464	540113.239	
5	TC	133		0.042	1129+34.52	-6.6	207202.292	540106.396	953.02
5	TC	134		0.083	1129+34.52	-6.6	207202.292	540106.396	
5	TC	135		0.125	1129+34.52	-6.6	207202.292	540106.396	
5	TC	136		0.208	1129+34.52	-6.6	207202.292	540106.396	
5	TC	137		0.375	1129+34.52	-6.6	207202.292	540106.396	
5	TC	138		0.458	1129+34.52	-6.6	207202.292	540106.396	
5	TC	139		0.708	1129+34.52	-6.6	207202.292	540106.396	
5	TC	140		0.963	1129+34.52	-6.6	207202.292	540106.396	

5	VW	117	LONGITUDINAL	0.083	1129+47.54	-13.1	207199.478	540120.644	952.75
5	VW	118	LONGITUDINAL	0.33	1129+47.55	-13.0	207199.42	540120.621	952.86
5	VW	119	LONGITUDINAL	0.083	1129+46.92	-7.1	207195.155	540116.549	953.06
5	VW	120	LONGITUDINAL	0.33	1129+46.89	-7.2	207195.207	540116.558	952.84
5	VW	121	TRANSVERSE	0.083	1129+47.99	-7.2	207194.523	540117.417	953.17
5	VW	122	TRANSVERSE	0.33	1129+48.04	-7.1	207194.478	540117.442	952.92
5	VW	123	LONGITUDINAL	0.083	1129+52.02	-13.1	207196.747	540124.203	953.17
5	VW	124	LONGITUDINAL	0.33	1129.+52.05	-13.0	207196.691	540124.19	952.95
5	VW	125	39°	0.083	1129+52.79	-12.1	207195.485	540124.206	953.13
5	VW	126	39°	0.33	1129+52.83	-12.1	207195.459	540124.233	952.89
5	VW	127	TRANSVERSE	0.083	1129+53.97	-11.1	207194.014	540124.559	953.14
5	VW	128	TRANSVERSE	0.33	1129+53.97	-11.1	207194.021	540124.57	952.91
5	VW	129	TRANSVERSE	0.083	1129+53.37	-7.2	207191.312	540121.741	953.2
5	VW	130	TRANSVERSE	0.33	1129+53.41	-7.2	207191.241	540121.728	952.95
5	VW	131	LONGITUDINAL	0.083	1129+53.92	-7.2	207190.981	540122.18	953.24
5	VW	132	LONGITUDINAL	0.33	1129+53.93	-7.2	207190.975	540122.187	953.01
5	XV	117	LONGITUDINAL	0.083	1129+47.54	-13.1	207199.478	540120.644	952.75
5	XV	118	LONGITUDINAL	0.33	1129+47.55	-13.0	207199.42	540120.621	952.86
5	XV	119	LONGITUDINAL	0.083	1129+46.92	-7.1	207195.155	540116.549	953.06
5	XV	120	LONGITUDINAL	0.33	1129+46.89	-7.2	207195.207	540116.558	952.84
5	XV	121	TRANSVERSE	0.083	1129+47.99	-7.2	207194.523	540117.417	953.17
5	XV	122	TRANSVERSE	0.33	1129+48.04	-7.1	207194.478	540117.442	952.92
5	XV	123	LONGITUDINAL	0.083	1129+52.02	-13.1	207196.747	540124.203	953.17
5	XV	124	LONGITUDINAL	0.33	1129.+52.05	-13.0	207196.691	540124.19	952.95
5	XV	125	39°	0.083	1129+52.79	-12.1	207195.485	540124.206	953.13
5	XV	126	39°	0.33	1129+52.83	-12.1	207195.459	540124.233	952.89
5	XV	127	TRANSVERSE	0.083	1129+53.97	-11.1	207194.014	540124.559	953.14
5	XV	128	TRANSVERSE	0.33	1129+53.97	-11.1	207194.021	540124.57	952.91
5	XV	129	TRANSVERSE	0.083	1129+53.37	-7.2	207191.312	540121.741	953.2
5	XV	130	TRANSVERSE	0.33	1129+53.41	-7.2	207191.241	540121.728	952.95
5	XV	131	LONGITUDINAL	0.083	1129+53.92	-7.2	207190.981	540122.18	953.24
5	XV	132	LONGITUDINAL	0.33	1129+53.93	-7.2	207190.975	540122.187	953.01

Table B-7. Sensor Locations - Cell 405

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
5	CE	147	LONGITUDINAL	0.021	1130+85.12	-13.6	207116.229	540230.192	
5	CE	148	LONGITUDINAL	0.396	1130+85.12	-13.6	207116.229	540230.192	953.02
5	CE	149	39°	0.021	1130+85.95	-12.0	207114.433	540229.853	
5	CE	150	39°	0.396	1130+85.95	-12.0	207114.433	540229.853	954.31
5	CE	151	LONGITUDINAL	0.021	1130+86.08	-11.1	207113.616	540229.393	
5	CE	152	LONGITUDINAL	0.396	1130+86.08	-11.1	207113.616	540229.393	954.47
5	CE	153	TRANSVERSE	0.021	1130+87	-11.0			
5	CE	154	LONGITUDINAL	0.021	1130+87	-7.0			
5	CE	155	LONGITUDINAL	0.021	1130+91.10	-13.6	207112.547	540234.898	
5	CE	156	LONGITUDINAL	0.396	1130+91.10	-13.6	207112.547	540234.898	954.5
5	CE	157	39°	0.021	1130+90.18	-12.1	207111.934	540233.266	
5	CE	158	39°	0.396	1130+90.18	-12.1	207111.934	540233.266	954.51
5	CE	159	LONGITUDINAL	0.021	1130+90.07	-11.2	207111.289	540232.631	
5	CE	160	LONGITUDINAL	0.396	1130+90.07	-11.2	207111.289	540232.631	954.55
5	CE	161	TRANSVERSE	0.021	1130+89	-11.0			
5	CE	162	LONGITUDINAL	0.021	1130+89	-7.0			
5	DT	111	VERTICAL	0.0625	1130+88.17	-14.2			
5	DT	112	VERTICAL	0.0625	1130+88.17	-14.2			
5	IV	108		0.667	1130+88.17	-14.4	207115.022	540233.102	953.26

Table B-8. Sensor Locations - Cell 106

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
6	AS	101	LONGITUDINAL	0.167	1133+80	-4.0			
6	AS	102	LONGITUDINAL	0.167	1133+80	-10.0			
6	CE	101	LONGITUDINAL	0.562	1133+72.5	-11.5			
6	CE	102	TRANSVERSE	0.187	1133+72.5	-6.0			
6	CE	103	LONGITUDINAL	0.187	1133+77	-11.5			
6	CE	104	39°	0.187	1133+76.8	-10.2			
6	CE	105	TRANSVERSE	0.187	1133+79	-9.0			
6	CE	106	TRANSVERSE	0.187	1133+79	-6.0			
6	CE	107	LONGITUDINAL	0.187	1133+87.50	-11.5	206930.6	540468.887	
6	CE	108	LONGITUDINAL	0.562	1133+87.50	-11.5	206930.6	540468.887	957.17
6	CE	109	TRANSVERSE	0.187	1133+87.54	-9.0	206928.6	540467.406	
6	CE	110	TRANSVERSE	0.562	1133+87.54	-9.0	206928.6	540467.406	957.25
6	CE	111	LONGITUDINAL	0.187	1133+88.2	-9.0	206928.32	540467.801	
6	CE	112	LONGITUDINAL	0.562	1133+88.02	-9.0	206928.32	540467.801	957.26
6	CE	113	TRANSVERSE	0.187	1133+87.61	-6.3	206926.638	540465.787	
6	CE	114	TRANSVERSE	0.562	1133+87.61	-6.3	206926.368	540465.787	957.32
6	CE	115	LONGITUDINAL	0.187	1133+88.07	-6.2	206926.018	540466.1	
6	CE	116	LONGITUDINAL	0.562	1133+88.07	-6.2	206926.018	540466.1	957.32
6	CE	117	LONGITUDINAL	0.187	1133+92.33	-11.6	206927.739	540472.788	
6	CE	118	LONGITUDINAL	0.562	1133+92.33	-11.6	206927.739	540472.788	957.21
6	CE	119	39°	0.187	1133+92.42	-10.2	206926.578	540472.002	
6	CE	120	39°	0.562	1133+92.42	-10.2	206926.578	540472.002	957.26
6	CE	121	TRANSVERSE	0.187	1133+93.62	-9.2	206925.058	540472.354	
6	CE	122	TRANSVERSE	0.562	1133+93.62	-9.2	206925.058	540472.354	957.29
6	CE	123	TRANSVERSE	0.187	1133+93.50	-6.1	206922.65	540470.356	
6	CE	124	TRANSVERSE	0.562	1133+93.5	-6.1	206922.65	540470.356	957.37
6	DT	101		0.0625	1133+72.5	-12.2			
6	DT	102		0.0625	1133+80	-12.2			
6	DT	103		0.0625	1133+80	-12.2			
6	DT	104		0.0625	1133+87.5	-12.2			
6	DT	105		0.0625	1133+95	-12.2			
6	DT	106		0.0625	1133+95	-12.2			
6	HC	101	LONGITUDINAL	0.25	1133+80	-11.0			
6	HC	102	LONGITUDINAL	0.5	1133+80	-10.5			
6	HC	103	LONGITUDINAL	0.25	1133+80	-6.0			
6	HC	104	LONGITUDINAL	0.5	1133+80	-5.5			
6	IV	101		0.5	1133+72.5	-12.2			
6	IV	102		0.5	1133+80	-12.2			
6	IV	103		0.5	1133+87.5	-12.2			
6	IV	104		0.5	1133+95	-12.2			
6	PT	101		0.583	1133+72.51	-7.0	206936.101	540454.214	957.18
6	PT	102		0.583	1133+78.98	-11.3	206935.589	540461.978	957.13
6	TC	101		0.042	1133+82.44	-11.2	206933.44	540464.686	957.48
6	TC	102		0.083	1133+82.44	-11.2	206933.44	540464.686	
6	TC	103		0.125	1133+82.44	-11.2	206933.44	540464.686	
6	TC	104		0.208	1133+82.44	-11.2	206933.44	540464.686	
6	TC	105		0.375	1133+82.44	-11.2	206933.44	540464.686	
6	TC	106		0.5	1133+82.44	-11.2	206933.44	540464.686	
6	TC	107		0.667	1133+82.44	-11.2	206933.44	540464.686	
6	TC	108		0.792	1133+82.44	-11.2	206933.44	540464.686	
6	TC	109		0.042	1133+81.1	-0.9	206926.07	540457.367	957.66
6	TC	110		0.083	1133+81.1	-0.9	206926.07	540457.367	
6	TC	111		0.125	1133+81.1	-0.9	206926.07	540457.367	
6	TC	112		0.208	1133+81.1	-0.9	206926.07	540457.367	
6	TC	113		0.375	1133+81.1	-0.9	206926.07	540457.367	
6	TC	114		0.5	1133+81.1	-0.9	206926.07	540457.367	
6	TC	115		0.625	1133+81.1	-0.9	206926.07	540457.367	
6	TC	116		0.75	1133+81.1	-0.9	206926.07	540457.367	
6	TC	117		0.042	1133+85.86	-11.0	206931.167	540467.256	957.51
6	TC	118		0.083	1133+85.86	-11.0	206931.167	540467.256	
6	TC	119		0.125	1133+85.86	-11.0	206931.167	540467.256	
6	TC	120		0.208	1133+85.86	-11.0	206931.167	540467.256	
6	TC	121		0.375	1133+85.86	-11.0	206931.167	540467.256	
6	TC	122		0.5	1133+85.86	-11.0	206931.167	540467.256	
6	TC	123		0.625	1133+85.86	-11.0	206931.167	540467.256	
6	TC	124		0.75	1133+85.86	-11.0	206931.167	540467.256	

6	TC	125		0.042	1133+86.48	-5.8	206926.657	540464.854	957.64
6	TC	126		0.083	1133+86.48	-5.8	206926.657	540464.854	
6	TC	127		0.125	1133+86.48	-5.8	206926.657	540464.854	
6	TC	128		0.208	1133+86.48	-5.8	206926.657	540464.854	
6	TC	129		0.375	1133+86.48	-5.8	206926.657	540464.854	
6	TC	130		0.5	1133+86.48	-5.8	206926.657	540464.854	
6	TC	131		0.625	1133+86.48	-5.8	206926.657	540464.854	
6	TC	132		0.75	1133+86.48	-5.8	206926.657	540464.854	
6	TC	133		1	1133+86.48	-5.8	206926.657	540464.854	
6	TC	134		1.25	1133+86.48	-5.8	206926.657	540464.854	
6	TC	135		1.67	1133+86.48	-5.8	206926.657	540464.854	
6	TC	136		2	1133+86.48	-5.8	206926.657	540464.854	
6	TC	137		3	1133+86.48	-5.8	206926.657	540464.854	
6	TC	138		4	1133+86.48	-5.8	206926.657	540464.854	
6	TC	139		5	1133+86.48	-5.8	206926.657	540464.854	
6	TC	140		6	1133+86.48	-5.8	206926.657	540464.854	
6	TC	141		0.042	1133+86.04	-1.0	206923.166	540461.356	957.74
6	TC	142		0.083	1133+86.04	-1.0	206923.166	540461.356	
6	TC	143		0.125	1133+86.04	-1.0	206923.166	540461.356	
6	TC	144		0.208	1133+86.04	-1.0	206923.166	540461.356	
6	TC	145		0.375	1133+86.04	-1.0	206923.166	540461.356	
6	TC	146		0.5	1133+86.04	-1.0	206923.166	540461.356	
6	TC	147		0.625	1133+86.04	-1.0	206923.166	540461.356	
6	TC	148		0.75	1133+86.04	-1.0	206923.166	540461.356	
6	VW	101	LONGITUDINAL	0.25	1133+68.00	-11.0	206942.02	540453.08	957.38
6	VW	102	LONGITUDINAL	0.5	1133+68.01	-10.9	206941.986	540453.067	957.15
6	VW	103	39^{o}	0.25	133+67.29	-10.1	206941.768	540451.993	957.36
6	VW	104	39^{o}	0.5	1133+67.23	-10.1	206941.816	540451.945	957.14
6	VW	105	TRANSVERSE	0.25	1133+66.05	-9.1	206941.694	540450.365	957.41
6	VW	106	TRANSVERSE	0.5	1133+66.04	-9.1	206941.75	540450.394	957.16
6	VW	107	LONGITUDINAL	0.25	1133+65.95	-6.0	206939.298	540448.408	957.45
6	VW	108	LONGITUDINAL	0.5	1133+66.01	-6.1	206939.366	540448.528	957.25
6	VW	109	TRANSVERSE	0.25	1133+66.53	-5.9	206938.903	540448.839	957.45
6	VW	110	TRANSVERSE	0.5	1133+66.49	-5.9	206938.895	540448.773	957.22
6	VW	111	LONGITUDINAL	0.25	1133+72.64	-10.9	206939.134	540456.714	957.43
6	VW	112	LONGITUDINAL	0.5	1133+72.68	-10.9	206939.12	540456.474	957.16
6	VW	113	LONGITUDINAL	0.25	1133+71.92	-6.1	206935.745	540453.202	957.49
6	VW	114	LONGITUDINAL	0.5	1133+71.95	-6.1	206935.759	540453.254	957.25
6	VW	115	TRANSVERSE	0.25	1133+72.89	-6.0	206935.125	540453.947	957.53
6	VW	116	TRANSVERSE	0.5	1133+72.88	-6.0	206935.117	540453.936	957.31
6	WM	101		0.75	1133+91.55	-11.6	206928.178	540472.141	957.23
6	WM	102		1	1133+91.55	-11.6	206928.178	540472.141	
6	WM	103		1.5	1133+91.55	-11.6	206928.178	540472.141	
6	WM	104		3	1133+91.55	-11.6	206928.178	540472.141	
6	WM	105		5	1133+91.55	-11.6	206928.178	540472.141	
6	WM	106		0.75	1133+88.1	-5.6	206925.512	540465.765	957.39
6	WM	107		1	1133+88.1	-5.6	206925.512	540465.765	
6	WM	108		1.5	1133+88.1	-5.6	206925.512	540465.765	
6	WM	109		3	1133+88.1	-5.6	206925.512	540465.765	
6	WM	110		5	1133+88.1	-5.6	206925.512	540465.765	
6	XV	101	LONGITUDINAL	0.25	1133+68.00	-11.0	206942.02	540453.08	957.38
6	XV	102	LONGITUDINAL	0.5	1133+68.01	-10.9	206941.986	540453.067	957.15
6	XV	103	39^{o}	0.25	133+67.29	-10.1	206941.768	540451.993	957.36
6	XV	104	39^{o}	0.5	1133+67.23	-10.1	206941.816	540451.945	957.14
6	XV	105	TRANSVERSE	0.25	1133+66.05	-9.1	206941.694	540450.365	957.41
6	XV	106	TRANSVERSE	0.5	1133+66.04	-9.1	206941.75	540450.394	957.16
6	XV	107	LONGITUDINAL	0.25	1133+65.95	-6.0	206939.298	540448.408	957.45
6	XV	108	LONGITUDINAL	0.5	1133+66.01	-6.1	206939.366	540448.528	957.25
6	XV	109	TRANSVERSE	0.25	1133+66.53	-5.9	206938.903	540448.839	957.45
6	XV	110	TRANSVERSE	0.5	1133+66.49	-5.9	206938.895	540448.773	957.22
6	XV	111	LONGITUDINAL	0.25	1133+72.64	-10.9	206939.134	540456.714	957.43
6	XV	112	LONGITUDINAL	0.5	1133+72.68	-10.9	206939.12	540456.474	957.16
6	XV	113	LONGITUDINAL	0.25	1133+71.92	-6.1	206935.745	540453.202	957.49
6	XV	114	LONGITUDINAL	0.5	1133+71.95	-6.1	206935.759	540453.254	957.25
6	XV	115	TRANSVERSE	0.25	1133+72.89	-6.0	206935.125	540453.947	957.53
6	XV	116	TRANSVERSE	0.5	1133+72.88	-6.0	206935.117	540453.936	957.31
6	EC	101		0.75	1133+86.48	-5.8	206926.657	540464.854	
6	EC	102		1	1133+86.48	-5.8	206926.657	540464.854	
6	EC	103		1.25	1133+86.48	-5.8	206926.657	540464.854	
6	EC	104		1.67	1133+86.48	-5.8	206926.657	540464.854	
6	EC	105		2	1133+86.48	-5.8	206926.657	540464.854	
6	EC	106		3	1133+86.48	-5.8	206926.657	540464.854	
6	EC	107		4	1133+86.48	-5.8	206926.657	540464.854	
6	EC	108		5	1133+86.48	-5.8	206926.657	540464.854	

Table B-9. Sensor Locations - Cell 206

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATIONS
6	AS	103	LONGITUDINAL	0.167	1135+.5	-4.0			
6	AS	104	LONGITUDINAL	0.167	1135+.5	-10.0			
6	CE	125	LONGITUDINAL	0.562	1135+08.08	-11.6	206857.279	540564.613	957.86
6	CE	126	TRANSVERSE	0.562	1135+08.08	-9.2	206855.384	540563.162	957.94
6	CE	127	LONGITUDINAL	0.562	1135+08.56	-9.2	206855.122	540563.565	957.95
6	CE	128	TRANSVERSE	0.562	1135+08.09	-6.1	206852.957	540561.315	958.02
6	CE	129	LONGITUDINAL	0.562	1135+08.65	-6.2	206852.68	540561.807	958.03
6	CE	130	LONGITUDINAL	0.562	1135+12.44	-11.5	206854.583	540568.04	957.89
6	CE	131	39°	0.562	1135+13.97	-10.8	206853.074	540568.817	957.93
6	CE	132	TRANSVERSE	0.562	1135+14.58	-9.0	206851.329	540568.242	957.98
6	CE	133	TRANSVERSE	0.562	1135+14.47	-6.1	206849.055	540566.36	958.06
6	DT	107		0.0625	1134+92.5	-12.2			
6	DT	108		0.0625	1135+.5	-12.2			
6	DT	109		0.0625	1135+.5	-12.2			
6	DT	110		0.0625	1135+8	-12.2			
6	DT	111		0.0625	1135+15.5	-12.2			
6	DT	112		0.0625	1135+15.5	-12.2			
6	HC	105	LONGITUDINAL	0.25	1135+0.5	-11.0			
6	HC	106	LONGITUDINAL	0.5	1135+0.5	-10.5			
6	HC	107	LONGITUDINAL	0.25	1135+0.5	-6.0			
6	HC	108	LONGITUDINAL	0.5	1135+0.5	-5.5			
6	IK	101		0.25	1135+06.46	-11.5	206858.25	540563.326	958.17
6	IK	102		0.375	1135+05.83	-11.5	206858.633	540562.816	958.04
6	IK	103		0.5	1135+06.28	-11.5	206858.333	540563.159	957.95
6	IK	104		0.25	1135+06.22	-10.0	206857.16	540562.188	958.24
6	IK	105		0.375	1135+05.92	-10.0	206857.318	540561.923	958.11
6	IK	106		0.5	1135+06.26	-9.9	206857.101	540562.183	958
6	IV	105		0.5	1134+92.5	-12.2			
6	IV	106		0.5	1135+.5	-12.2			
6	IV	107		0.5	1135+8	-12.2			
6	IV	108		0.5	1135+15.5	-12.2			
6	PT	103		0.583	1134+93.35	-7.0	206862.656	540550.175	957.92
6	PT	104		0.583	1134+99.81	-11.3	206862.119	540557.906	957.84
6	TC	149		0.042	1135+02.05	-11.4	206862.805	540559.728	958.18
6	TC	150		0.083	1135+02.05	-11.4	206862.805	540559.728	
6	TC	151		0.125	1135+02.05	-11.4	206862.805	540559.728	
6	TC	152		0.208	1135+02.05	-11.4	206862.805	540559.728	
6	TC	153		0.375	1135+02.05	-11.4	206862.805	540559.728	
6	TC	154		0.5	1135+02.05	-11.4	206862.805	540559.728	
6	TC	155		0.625	1135+02.05	-11.4	206862.805	540559.728	
6	TC	156		0.667	1135+02.05	-11.4	206862.805	540559.728	
6	TC	157		0.042	1135+06.34	-5.7	206853.651	540559.649	958.35
6	TC	158		0.083	1135+06.34	-5.7	206853.651	540559.649	
6	TC	159		0.125	1135+06.34	-5.7	206853.651	540559.649	
6	TC	160		0.208	1135+06.34	-5.7	206853.651	540559.649	
6	TC	161		0.375	1135+06.34	-5.7	206853.651	540559.649	
6	TC	162		0.5	1135+06.34	-5.7	206853.651	540559.649	
6	TC	163		0.625	1135+06.34	-5.7	206853.651	540559.649	
6	TC	164		0.75	1135+06.34	-5.7	206853.651	540559.649	

6	VW	117	LONGITUDINAL	0.25	1134+88.70	-11.0	206868.628	540548.895	958.1
6	VW	118	LONGITUDINAL	0.5	1134+88.7	-11.0	206868.626	540548.9	957.84
6	VW	119	39°	0.25	1134+88.04	-10.1	206868.299	540547.809	958.14
6	VW	120	39°	0.5	1134+87.96	-10.1	206868.392	540547.782	957.86
6	VW	121	TRANSVERSE	0.25	1134+86.69	-9.0	206868.267	540546.092	958.11
6	VW	122	TRANSVERSE	0.5	1134+86.74	-9.0	206868.252	540546.143	957.91
6	VW	123	LONGITUDINAL	0.25	1134+86.84	-6.0	206865.771	540544.362	958.19
6	VW	124	LONGITUDINAL	0.5	1134+86.82	-6.0	206865.763	540544.336	958
6	VW	125	TRANSVERSE	0.25	1134+87.25	-6.1	206865.587	540544.738	958.19
6	VW	126	TRANSVERSE	0.5	1134+87.25	-6.0	206865.521	540544.684	957.95
6	VW	127	LONGITUDINAL	0.25	1134+93.09	-11.1	206866.05	540552.455	958.09
6	VW	128	LONGITUDINAL	0.5	1134+93.08	-11.2	206866.088	540552.464	957.9
6	VW	129	LONGITUDINAL	0.25	1134+92.66	-6.1	206862.319	540549.054	958.23
6	VW	130	LONGITUDINAL	0.5	1134+92.73	-6.1	206862.274	540549.102	957.95
6	VW	131	TRANSVERSE	0.25	1134+93.80	-6.1	206861.647	540549.968	958.28
6	VW	132	TRANSVERSE	0.5	1134+93.76	-6.1	206861.688	540549.95	957.97
6	XV	117	LONGITUDINAL	0.25	1134+88.70	-11.0	206868.628	540548.895	958.1
6	XV	118	LONGITUDINAL	0.5	1134+88.7	-11.0	206868.626	540548.9	957.84
6	XV	119	39°	0.25	1134+88.04	-10.1	206868.299	540547.809	958.14
6	XV	120	39°	0.5	1134+87.96	-10.1	206868.392	540547.782	957.86
6	XV	121	TRANSVERSE	0.25	1134+86.69	-9.0	206868.267	540546.092	958.11
6	XV	122	TRANSVERSE	0.5	1134+86.74	-9.0	206868.252	540546.143	957.91
6	XV	123	LONGITUDINAL	0.25	1134+86.84	-6.0	206865.771	540544.362	958.19
6	XV	124	LONGITUDINAL	0.5	1134+86.82	-6.0	206865.763	540544.336	958
6	XV	125	TRANSVERSE	0.25	1134+87.25	-6.1	206865.587	540544.738	958.19
6	XV	126	TRANSVERSE	0.5	1134+87.25	-6.0	206865.521	540544.684	957.95
6	XV	127	LONGITUDINAL	0.25	1134+93.09	-11.1	206866.05	540552.455	958.09
6	XV	128	LONGITUDINAL	0.5	1134+93.08	-11.2	206866.088	540552.464	957.9
6	XV	129	LONGITUDINAL	0.25	1134+92.66	-6.1	206862.319	540549.054	958.23
6	XV	130	LONGITUDINAL	0.5	1134+92.73	-6.1	206862.274	540549.102	957.95
6	XV	131	TRANSVERSE	0.25	1134+93.80	-6.1	206861.647	540549.968	958.28
6	XV	132	TRANSVERSE	0.5	1134+93.76	-6.1	206861.688	540549.95	957.97

Table B-10. Sensor Locations - Cell 113

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
13	CE	101	LONGITUDINAL	0.396	1184+78.28	-11.5	544509.252	203833.583	971.58
13	CE	102	TRANSVERSE	0.021	1184+78.29	-6.0			
13	CE	103	LONGITUDINAL	0.021	1184+82	-11.5			
13	CE	104	39o	0.021	1184+82.8	-10.0			
13	CE	105	TRANSVERSE	0.021	1184+84	-9.0			
13	CE	106	TRANSVERSE	0.021	1184+84	-6.0			
13	CE	107	LONGITUDINAL	0.021	1184+93.62	-11.5	544521.423	203824.243	
13	CE	108	LONGITUDINAL	0.396	1184+93.62	-11.5	544521.423	203824.243	971.64
13	CE	109	LONGITUDINAL	0.021	1184+93.52	-9.0	544519.826	23822.322	
13	CE	110	TRANSVERSE	0.396	1184+93.52	-9.0	544519.826	23822.322	971.7
13	CE	111	TRANSVERSE	0.021	1184+94.06	-9.0	544520.266	203822.008	
13	CE	112	LONGITUDINAL	0.396	1184+94.06	-9.0	544520.266	203822.008	971.71
13	CE	113	LONGITUDINAL	0.021	1184+93.60	-5.9	544517.984	203819.789	
13	CE	114	TRANSVERSE	0.396	1184+93.60	-5.9	544517.984	203819.789	971.79
13	CE	115	TRANSVERSE	0.021	1184+94.01	-5.9	544518.313	203819.544	
13	CE	116	LONGITUDINAL	0.396	1184+94.01	-5.9	544518.313	203819.544	971.79
13	CE	117	LONGITUDINAL	0.021	1184+97.75	-11.5	544524.695	203821.723	
13	CE	118	LONGITUDINAL	0.396	1184+97.75	-11.5	544524.695	203821.723	971.67
13	CE	119	39o	0.021	1184+98.48	-10.3	544524.514	203820.296	
13	CE	120	39o	0.396	1184+98.48	-10.3	544524.514	203820.296	971.71
13	CE	121	TRANSVERSE	0.021	1184+99.75	-10.1	544525.421	203819.386	
13	CE	122	TRANSVERSE	0.396	1184+99.75	-10.1	544525.421	203819.386	971.72
13	CE	123	TRANSVERSE	0.021	1184+99.82	-6.1	544523.043	203816.167	
13	CE	124	TRANSVERSE	0.396	1184+99.82	-6.1	544523.043	203816.167	971.78
13	DT	101		0.0625	1184+77.5	-12.2			
13	DT	102		0.0625	1184+85	-12.2			
13	DT	103		0.0625	1184+85	-12.2			
13	DT	104		0.0625	1184+92.5	-12.2			
13	DT	105		0.0625	1185+00	-12.2			
13	DT	106		0.0625	185+00	-12.2			
13	DT	107		0.0625	? (Flat dowels)	-12.2			
13	HC	101	LONGITUDINAL	0.083	1185+00	-11.0			
13	HC	102	LONGITUDINAL	0.33	1185+00	-10.5			
13	HC	103	LONGITUDINAL	0.083	1185+00	-6.0			
13	HC	104	LONGITUDINAL	0.33	1185+00	-5.5			
13	HC	105	DELETE						
13	HC	106	DELETE						
13	IK	101		0.083	1184+92.69	-11.4	544520.615	203824.72	971.98
13	IK	102		0.208	1184+92.29	-11.6	544520.407	203825.11	971.87
13	IK	103		0.33	1184+92.63	-11.4	544520.581	203824.77	971.76
13	IK	104		0.083	1184+92.73	-9.9	544519.729	203823.5	972
13	IK	105		0.208	1184+92.23	-9.9	544519.375	203823.85	971.94
13	IK	106		0.33	1184+92.70	-9.9	544519.731	203823.55	971.79
13	IV	101		0.33	1184+77.5	-12.2			
13	IV	102		0.33	1184+85	-12.2			
13	IV	103		0.33	1184+92.5	-12.2			
13	IV	104		0.33	1185+00	-12.2			
13	IV	105		0.33	? (Flat dowels)	-12.2			
13	PT	101		0.417	1184+78.38	-7.1	544506.652	203830.03	971.71
13	PT	102		0.417	1184+85.11	-11.1	544514.434	203829.11	971.62
13	TC	101		0.042	1184+86.92	-11.3	544516.005	203828.18	971.94
13	TC	102		0.083	1184+86.92	-11.3	544516.005	203828.18	
13	TC	103		0.125	1184+86.92	-11.3	544516.005	203828.18	
13	TC	104		0.208	1184+86.92	-11.3	544516.005	203828.18	
13	TC	105		0.292	1184+86.92	-11.3	544516.005	203828.18	
13	TC	106		0.375	1184+86.92	-11.3	544516.005	203828.18	
13	TC	107		0.458	1184+86.92	-11.3	544516.005	203828.18	
13	TC	108		0.583	1184+86.92	-11.3	544516.005	203828.18	

13	TC	109		0.042	1184+92.73	-6.0	544517.352	203820.39	972.07
13	TC	110		0.083	1184+92.73	-6.0	544517.352	203820.39	
13	TC	111		0.125	1184+92.73	-6.0	544517.352	203820.39	
13	TC	112		0.208	1184+92.73	-6.0	544517.352	203820.39	
13	TC	113		0.292	1184+92.73	-6.0	544517.352	203820.39	
13	TC	114		0.375	1184+92.73	-6.0	544517.352	203820.39	
13	TC	115		0.458	1184+92.73	-6.0	544517.352	203820.39	
13	TC	116		0.583	1184+92.73	-6.0	544517.352	203820.39	
13	VG	101	LONGITUDINA	0.083	1184+79.33	-5.6	544506.462	203828.22	971.94
13	VG	102	LONGITUDINA	0.208	1184+79.30	-5.6	544506.454	203828.25	971.75
13	VW	101	LONGITUDINA	0.083	1184+73.75	-11.0	544505.333	203835.92	971.89
13	VW	102	LONGITUDINA	0.33	1184+73.77	-11.0	544505.379	203835.94	971.66
13	VW	103	39o	0.083	1184+73.09	-10.2	544504.341	203835.71	971.92
13	VW	104	39o	0.33	1184+73.14	-10.2	544504.349	203835.64	971.67
13	VW	105	TRANSVERSE	0.083	1184+71.72	-9.0	544502.49	203835.54	971.96
13	VW	106	TRANSVERSE	0.33	1184+71.70	-8.9	544502.449	203835.52	971.71
13	VW	107	LONGITUDINA	0.083	1184+71.75	-6.2	544500.868	203833.38	972.01
13	VW	108	LONGITUDINA	0.33	1184+71.79	-6.2	544500.895	203833.35	971.76
13	VW	109	TRANSVERSE	0.083	1184+72.38	-6.3	544501.391	203833.02	971.99
13	VW	110	TRANSVERSE	0.33	1184+72.35	-6.3	544501.361	203833.03	971.73
13	VW	111	LONGITUDINA	0.083	1184+78.33	-11.0	544509.008	203833.19	971.9
13	VW	112	LONGITUDINA	0.33	1184+78.31	-11.1	544508.999	203833.2	971.68
13	VW	113	LONGITUDINA	0.083	1184+77.80	-6.1	544505.547	203829.55	972.01
13	VW	114	LONGITUDINA	0.33	1184+77.79	-6.0	544505.527	203829.52	971.86
13	VW	115	TRANSVERSE	0.083	1184+78.80	-6.1	544506.372	203828.97	972.02
13	VW	116	TRANSVERSE	0.33	1184+78.79	-6.1	544506.341	203828.94	971.8
13	WM	101		0.5	1184+85.5	-11.5			
13	WM	102		0.75	1184+85.5	-11.5			
13	WM	103		1	1184+85.5	-11.5			
13	WM	104		1.5	1184+85.5	-11.5			
13	WM	105		2	1184+85.5	-11.5			
13	WM	106		3	1184+85.5	-11.5			
13	WM	107		0.5	1184+93	-6.5			
13	WM	108		0.75	1184+93	-6.5			
13	WM	109		1	1184+93	-6.5			
13	WM	110		1.5	1184+93	-6.5			
13	WM	111		2	1184+93	-6.5			
13	WM	112		3	1184+93	-6.5			
13	XG	101		0.083	1184+79.33	-5.6	544506.462	203828.22	971.94
13	XG	102		0.208	1184+79.30	-5.6	544506.454	203828.25	971.75
13	XV	101		0.083	1184+73.75	-11.0	544505.333	203835.92	971.89
13	XV	102		0.33	1184+73.77	-11.0	544505.379	203835.94	971.66
13	XV	103		0.083	1184+73.09	-10.2	544504.341	203835.71	971.92
13	XV	104		0.33	1184+73.14	-10.2	544504.349	203835.64	971.67
13	XV	105		0.083	1184+71.72	-9.0	544502.49	203835.54	971.96
13	XV	106		0.33	1184+71.70	-8.9	544502.449	203835.52	971.71
13	XV	107		0.083	1184+71.75	-6.2	544500.868	203833.38	972.01
13	XV	108		0.33	1184+71.79	-6.2	544500.895	203833.35	971.76
13	XV	109		0.083	1184+72.38	-6.3	544501.391	203833.02	971.99
13	XV	110		0.33	1184+72.35	-6.3	544501.361	203833.03	971.73
13	XV	111		0.083	1184+78.33	-11.0	544509.008	203833.19	971.9
13	XV	112		0.33	1184+78.31	-11.1	544508.999	203833.2	971.68
13	XV	113		0.083	1184+77.80	-6.1	544505.547	203829.55	972.01
13	XV	114		0.33	1184+77.79	-6.0	544505.527	203829.52	971.86
13	XV	115		0.083	1184+78.80	-6.1	544506.372	203828.97	972.02
13	XV	116		0.33	1184+78.79	-6.1	544506.341	203828.94	971.8

Table B-11. Sensor Locations - Cell 213

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
13	CE	125	LONGITUDINAL	0.438	1185+52.77	-11.5	544568.362	203788.253	971.81
13	CE	127	TRANSVERSE	0.021	1185+52.78	-6.0			
13	CE	128	LONGITUDINAL	0.438	1185+53.21	-6.0	544565.384	203783.647	971.91
13	CE	129	LONGITUDINAL	0.021	1185+57.23	-11.5	544571.926	203785.571	
13	CE	130	LONGITUDINAL	0.438	1185+57.23	-11.5	544571.926	203785.571	971.8
13	CE	131	39o	0.021	1185+57.90	-10.3	544571.697	203784.168	
13	CE	132	39o	0.438	1185+57.90	-10.3	544571.697	203784.168	971.82
13	CE	133	TRANSVERSE	0.021	1185+59.25	-9.0	544571.962	203782.291	
13	CE	134	TRANSVERSE	0.438	1185+59.25	-9.0	544571.962	203782.291	971.85
13	CE	135	TRANSVERSE	0.021	1185+59.07	-6.0	544570.001	203780.035	
13	CE	136	TRANSVERSE	0.438	1185+59.07	-6.0	544570.001	203780.035	971.91
13	TC	125		0.042	1185+50.97	-5.6	544563.36	203784.677	972.31
13	TC	126		0.083	1185+50.97	-5.6	544563.36	203784.677	
13	TC	127		0.125	1185+50.97	-5.6	544563.36	203784.677	
13	TC	128		0.208	1185+50.97	-5.6	544563.36	203784.677	
13	TC	129		0.292	1185+50.97	-5.6	544563.36	203784.677	
13	TC	130		0.417	1185+50.97	-5.6	544563.36	203784.677	
13	TC	131		0.542	1185+50.97	-5.6	544563.36	203784.677	
13	TC	132		0.75	1185+50.97	-5.6	544563.36	203784.677	
13	TC	133		0.542	1185+50.97	-5.6	544563.36	203784.677	
13	TC	134		0.75	1185+50.97	-5.6	544563.36	203784.677	
13	TC	135		1	1185+50.97	-5.6	544563.36	203784.677	
13	TC	136		2	1185+50.97	-5.6	544563.36	203784.677	
13	TC	137		3	1185+50.97	-5.6	544563.36	203784.677	
13	TC	138		4	1185+50.97	-5.6	544563.36	203784.677	
13	TC	139		5	1185+50.97	-5.6	544563.36	203784.677	
13	TC	140		6	1185+50.97	-5.6	544563.36	203784.677	

Table B-12. Sensor Locations - Cell 313

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
13	CE	137	LONGITUDINAL	0.479	1187+02.54	-11.5	544687.235	203697.143	972.18
13	CE	138	TRANSVERSE	0.021	1187+02.54	-6.0			
13	CE	139	LONGITUDINAL	0.021	1187+7	-11.5			
13	CE	140	39o	0.021	1187+7.8	-10.3			
13	CE	141	TRANSVERSE	0.021	1187+9	-9.0			
13	CE	142	TRANSVERSE	0.021	1187+9	-6.0			
13	CE	143	LONGITUDINAL	0.021	1187+17.56	-11.5	544699.17	203688.029	
13	CE	144	LONGITUDINAL	0.479	1187+17.56	-11.5	544699.17	203688.029	972.21
13	CE	145	TRANSVERSE	0.021	1187+17.54	-9.1	544697.696	203686.142	
13	CE	146	TRANSVERSE	0.479	1187+17.54	-9.1	544697.696	203686.142	972.25
13	CE	147	LONGITUDINAL	0.021	1187+-9.1	-9.1	544698.054	203685.86	
13	CE	148	LONGITUDINAL	0.479	1187+-9.1	-9.1	544698.054	203685.86	972.25
13	CE	149	TRANSVERSE	0.021	1187+17.52	-6.1	544695.83	203683.741	
13	CE	150	TRANSVERSE	0.479	1187+17.52	-6.1	544695.83	203683.741	972.32
13	CE	151	LONGITUDINAL	0.021	1187+17.89	-6.1	544696.115	203683.496	
13	CE	152	LONGITUDINAL	0.479	1187+17.89	-6.1	544696.115	203683.496	972.31
13	CE	153	LONGITUDINAL	0.021	1187+22.07	-11.6	544702.794	203685.34	
13	CE	154	LONGITUDINAL	0.479	1187+22.07	-11.6	544702.794	203685.34	972.21
13	CE	155	39o	0.021	1187+22.67	-10.3	544702.467	203683.935	
13	CE	156	39o	0.479	1187+22.67	-10.3	544702.467	203683.935	972.26
13	CE	157	TRANSVERSE	0.021	1187+24.09	-9.1	544702.845	203682.088	
13	CE	158	TRANSVERSE	0.479	1187+24.09	-9.1	544702.845	203682.088	972.28
13	CE	159	TRANSVERSE	0.021	1187+24.21	-6.0	544701.094	203679.605	
13	CE	160	TRANSVERSE	0.479	1187+24.21	-6.0	544701.094	203679.605	972.33
13	DT	108		0.0625	1187+10	-12.2			
13	DT	109		0.0625	1187+17.5	-12.2			
13	DT	110		0.0625	1187+17.5	-12.2			
13	DT	111		0.0625	1187+25	-12.2			
13	HC	105	LONGITUDINAL	0.083	1187+10	-11.0			
13	HC	106	LONGITUDINAL	0.417	1187+10	-10.5			
13	HC	107	LONGITUDINAL	0.083	1187+10	-6.0			
13	HC	108	LONGITUDINAL	0.417	1187+10	-5.5			
13	HC	111	DELETE						
13	HC	112	DELETE						
13	IK	108		0.083	1187+16.59	-11.5	544698.402	203688.63	972.66
13	IK	109		0.25	1187+15.89	-11.5	544697.853	203689.05	972.49
13	IK	110		0.417	1187+16.42	-11.6	544689.31	203688.79	972.35
13	IK	111		0.083	1187+16.32	-10.0	544697.256	203687.56	972.72
13	IK	112		0.25	1187+16.01	-10.2	544697.14	203687.94	972.58
13	IK	113		0.417	1187+16.72	-10.0	544697.212	203687.59	972.38
13	IV	106		0.417	1187+10	-12.2			
13	IV	107		0.417	1187+17.5	-12.2			
13	IV	108		0.417	1187+25	-12.2			
13	TC	117		0.042	1187+10.98	-11.5	544693.926	203692	972.68
13	TC	118		0.083	1187+10.98	-11.5	544693.926	203692	
13	TC	119		0.125	1187+10.98	-11.5	544693.926	203692	
13	TC	120		0.208	1187+10.98	-11.5	544693.926	203692	
13	TC	121		0.292	1187+10.98	-11.5	544693.926	203692	
13	TC	122		0.417	1187+10.98	-11.5	544693.926	203692	
13	TC	123		0.542	1187+10.98	-11.5	544693.926	203692	
13	TC	124		0.75	1187+10.98	-11.5	544693.926	203692	
13	EC	101		0.542	1187+10.98	-11.5	544693.926	203692	
13	EC	102		0.75	1187+10.98	-11.5	544693.926	203692	
13	EC	103		1	1187+10.98	-11.5	544693.926	203692	
13	EC	104		2	1187+10.98	-11.5	544693.926	203692	
13	EC	105		3	1187+10.98	-11.5	544693.926	203692	
13	EC	106		4	1187+10.98	-11.5	544693.926	203692	
13	EC	107		5	1187+10.98	-11.5	544693.926	203692	
13	EC	108		6	1187+10.98	-11.5	544693.926	203692	

Table B-13. Sensor Locations - Cell 114

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
14	CE	101	LONGITUDINAL	0.021	1189+73.88	-11.7	203532.217	544902.702	
14	CE	102	LONGITUDINAL	0.479	1189+73.88	-11.7	203532.217	544902.702	972.494
14	CE	103	LONGITUDINAL	0.021	1189+74.94	-11.2	203531.213	544903.262	
14	CE	104	LONGITUDINAL	0.479	1189+74.94	-11.2	203531.213	544903.262	972.493
14	CE	105	45o	0.021	1189+74.95	-10.2	203530.389	544902.64	
14	CE	106	45o	0.479	1189+74.95	-10.2	203530.389	544902.64	972.516
14	CE	107	TRANSVERSE	0.021	1189+76.00	-9.8	203529.41	544903.215	
14	CE	108	TRANSVERSE	0.479	1189+76.00	-9.8	203529.41	544903.215	972.52
14	CE	109	LONGITUDINAL	0.021	1189+79.96	-11.7	203528.508	544907.512	
14	CE	110	LONGITUDINAL	0.479	1189+79.96	-11.7	203528.508	544907.512	972.491
14	CE	111	LONGITUDINAL	0.021	1189+80.93	-11.1	203527.498	544907.956	
14	CE	112	LONGITUDINAL	0.479	1189+80.93	-11.1	203527.498	544907.956	972.496
14	CE	113	45o	0.021	1189+80.96	-10.2	203526.7	544907.394	
14	CE	114	45o	0.479	1189+80.96	-10.2	203526.7	544907.394	972.519
14	CE	115	TRANSVERSE	0.021	1189+81.98	-9.7	203525.683	544907.893	
14	CE	116	TRANSVERSE	0.479	1189+81.98	-9.7	203525.683	544907.893	972.528
14	DT	101		0.0625	1189+71	-12.2			
14	DT	102		0.0625	1189+71	-12.2			
14	HC	101	LONGITUDINAL	0.083	1189+71	-11.0			
14	HC	102	LONGITUDINAL	0.417	1189+71	-10.5			
14	HC	103	LONGITUDINAL	0.083	1189+71	-7.5			
14	HC	104	LONGITUDINAL	0.417	1189+71	-7.0			
14	IK	101		0.083	1189+78.82	-11.7	203529.22	544906.632	972.917
14	IK	102		0.25	1189+78.36	-11.6	203529.43	544906.243	972.731
14	IK	103		0.417	1189+78.77	-11.6	203529.19	544906.535	972.565
14	IK	104		0.083	1189+79.94	-10.3	203527.43	544906.658	972.934
14	IK	105		0.25	1189+79.62	-10.1	203527.5	544906.313	972.805
14	IK	106		0.417	1189+80.12	-10.1	203527.2	544906.713	972.607
14	IV	101		0.417	1189+71	-12.2			
14	VG	101	LONGITUDINAL	0.083	1189+80.03	-9.1	203526.46	544906.034	972.85
14	VG	102	LONGITUDINAL	0.417	1189+80.04	-9.2	203526.5	544906.07	972.578
14	VW	101	LONGITUDINAL	0.083	1189+61.98	-11.6	203539.406	5444893.214	972.874
14	VW	102	LONGITUDINAL	0.417	1189+61.94	-11.6	203539.43	544.893.182	972.56
14	VW	103	LONGITUDINAL	0.083	1189+61.98	-9.1	203537.44	544891.705	972.921
14	VW	104	LONGITUDINAL	0.417	1189.61.97	-9.2	203537.47	544891.723	972.576
14	VW	105	45o	0.083	1189+62.95	-10.1	203537.59	544893.052	972.907
14	VW	106	45o	0.417	1189+62.96	-10.1	203537.62	544893.086	972.571
14	VW	107	TRANSVERSE	0.083	1189+63.98	-9.2	203536.26	544893.319	972.899
14	VW	108	TRANSVERSE	0.417	1189+63.97	-9.2	203536.31	544893.342	972.602
14	VW	109	LONGITUDINAL	0.083	1189+67.90	-11.7	203535.86	544897.951	972.894
14	VW	110	LONGITUDINAL	0.417	1189+67.85	-11.7	203535.87	544897.895	972.54
14	VW	111	LONGITUDINAL	0.083	1189+67.99	-9.1	203533.73	544896.437	972.905
14	VW	112	LONGITUDINAL	0.417	1189+67.97	-9.1	203533.8	544896.459	972.61
14	VW	113	45o	0.083	1189+68.94	-10.1	203533.94	544897.797	972.943
14	VW	114	45o	0.417	1189+68.96	-10.1	203533.95	544897.819	972.598
14	VW	115	TRANSVERSE	0.083	1189+69.88	-9.2	203532.67	544898	972.935
14	VW	116	TRANSVERSE	0.417	1189+69.88	-9.2	203532.69	544898.011	972.58
14	XG	101		0.083	1189+80.03	-9.1	203526.46	544906.034	972.85
14	XG	102		0.417	1189+80.04	-9.2	203526.5	544906.07	972.578
14	XV	101		0.083	1189+61.98	-11.6	203539.406	5444893.214	972.874
14	XV	102		0.417	1189+61.94	-11.6	203539.43	544.893.182	972.56
14	XV	103		0.083	1189+61.98	-9.1	203537.44	544891.705	972.921
14	XV	104		0.417	1189.61.97	-9.2	203537.47	544891.723	972.576
14	XV	105		0.083	1189+62.95	-10.1	203537.59	544893.052	972.907
14	XV	106		0.417	1189+62.96	-10.1	203537.62	544893.086	972.571
14	XV	107		0.083	1189+63.98	-9.2	203536.26	544893.319	972.899
14	XV	108		0.417	1189+63.97	-9.2	203536.31	544893.342	972.602
14	XV	109		0.083	1189+67.90	-11.7	203535.86	544897.951	972.894
14	XV	110		0.417	1189+67.85	-11.7	203535.87	544897.895	972.54
14	XV	111		0.083	1189+67.99	-9.1	203533.73	544896.437	972.905
14	XV	112		0.417	1189+67.97	-9.1	203533.8	544896.459	972.61
14	XV	113		0.083	1189+68.94	-10.1	203533.94	544897.797	972.943
14	XV	114		0.417	1189+68.96	-10.1	203533.95	544897.819	972.598
14	XV	115		0.083	1189+69.88	-9.2	203532.67	544898	972.935
14	XV	116		0.417	1189+69.88	-9.2	203532.69	544898.011	972.58

Table B-14. Sensor Locations - Cell 214

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
14	CE	117	LONGITUDINAL	0.479	1190+03.99	-11.7	203513.923	544926.617	972.519
14	CE	118	LONGITUDINAL	0.479	1190+04.93	-11.2	203512.96	544927.062	972.52
14	CE	119	45o	0.479	1190+04.88	-10.2	203512.186	544926.404	972.548
14	CE	120	TRANSVERSE	0.479	1190+05.92	-9.8	203511.216	544926.966	972.549
14	DT	103		0.0625	1190+01	-12.2			
14	DT	104		0.0625	1190+01	-12.2			
14	HC	105	LONGITUDINAL	0.083	1190+01	-11.0			
14	HC	106	LONGITUDINAL	0.417	1190+01	-10.5			
14	HC	107	LONGITUDINAL	0.083	1190+01	-7.5			
14	HC	108	LONGITUDINAL	0.417	1190+01	-7.0			
14	IV	102		0.417	1190+01	-12.2			
14	VW	117	LONGITUDINAL	0.417	1189+97.94	-11.7	203517.56	544921.776	972.597
14	VW	118	LONGITUDINAL	0.417	1189+97.99	-9.2	203515.575	544920.318	972.656
14	VW	119	45o	0.417	1189+99.05	-10.2	203515.741	544921.782	972.625
14	VW	120	TRANSVERSE	0.417	1190+00	-9.2	203514.345	544921.903	972.629
14	TC	101		0.042	1190+02.25	-7.1	203511.328	544922.425	972.804
14	TC	102		0.083	1190+02.25	-7.1	203511.328	544922.425	
14	TC	103		0.167	1190+02.25	-7.1	203511.328	544922.425	
14	TC	104		0.25	1190+02.25	-7.1	203511.328	544922.425	
14	TC	105		0.375	1190+02.25	-7.1	203511.328	544922.425	
14	TC	106		0.5	1190+02.25	-7.1	203511.328	544922.425	
14	TC	107		0.625	1190+02.25	-7.1	203511.328	544922.425	
14	TC	108		0.792	1190+02.25	-7.1	203511.328	544922.425	
14	XV	117		0.417	1189+97.94	-11.7	203517.56	544921.776	972.597
14	XV	118		0.417	1189+97.99	-9.2	203515.575	544920.318	972.656
14	XV	119		0.417	1189+99.05	-10.2	203515.741	544921.782	972.625
14	XV	120		0.417	1190+00	-9.2	203514.345	544921.903	972.629

Table B-15. Sensor Locations - Cell 814

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
14	CE	121	LONGITUDINAL	0.021	1193+51.71	-11.6			
14	CE	123	LONGITUDINAL	0.021	1193+52.71	-11.2			
14	CE	125	45o	0.021	1193+52.69	-10.2			
14	CE	127	TRANSVERSE	0.021	1193.53.74	-9.7			
14	CE	129	LONGITUDINAL	0.021	1193+58	-11.5			
14	CE	131	LONGITUDINAL	0.021	1193+59	-11			
14	CE	133	45o	0.021	1193+59	-10			
14	CE	135	TRANSVERSE	0.021	1193+60	-9.5			
14	CE	137	LONGITUDINAL	0.479	1193+51.71	-11.6	203302.306	545202.527	972.182
14	CE	138	LONGITUDINAL	0.479	1193+52.71	-11.2	203301.366	545203.061	972.195
14	CE	139	45o	0.479	1193+52.69	-10.2	203300.595	545202.448	972.217
14	CE	140	TRANSVERSE	0.479	1193.53.74	-9.7	203229.582	545202.998	972.233
14	DT	105		0.0625	1193+49	-12.2			
14	DT	106		0.0625	1193+49	-12.2			
14	HC	109	LONGITUDINAL	0.083	1193+49	-11.0			
14	HC	110	LONGITUDINAL	0.417	1193+49	-10.5			
14	HC	111	LONGITUDINAL	0.083	1193+49	-7.5			
14	HC	112	LONGITUDINAL	0.417	1193+49	-7.0			
14	IV	103		0.417	1193+49	-12.2			
14	VW	129	LONGITUDINAL	0.417	1193+45.71	-11.6	203305.93	545197.75	972.259
14	VW	130	LONGITUDINAL	0.417	1193+46.74	-10.1	203304.14	545197.67	972.284
14	VW	131	45o	0.417	1193+45.68	-9.1	203303.94	545196.18	972.344
14	VW	132	TRANSVERSE	0.417	1193+47.65	-9.0	203302.72	545197.73	972.327
14	TC	109		0.042	1193+51.79	-8.6	203299.89	545200.76	972.66
14	TC	110		0.083	1193+51.79	-8.6	203299.89	545200.76	
14	TC	111		0.167	1193+51.79	-8.6	203299.89	545200.76	
14	TC	112		0.25	1193+51.79	-8.6	203299.89	545200.76	
14	TC	113		0.375	1193+51.79	-8.6	203299.89	545200.76	
14	TC	114		0.5	1193+51.79	-8.6	203299.89	545200.76	
14	TC	115		0.625	1193+51.79	-8.6	203299.89	545200.76	
14	TC	116		0.792	1193+51.79	-8.6	203299.89	545200.76	
14	TC	117		0.042	1193+49.41	-11.1	203303.29	545200.39	972.602
14	TC	118		0.083	1193+49.41	-11.1	203303.29	545200.39	
14	TC	119		0.167	1193+49.41	-11.1	203303.29	545200.39	
14	TC	120		0.208	1193+49.41	-11.1	203303.29	545200.39	
14	TC	121		0.334	1193+49.41	-11.1	203303.29	545200.39	
14	TC	122		0.458	1193+49.41	-11.1	203303.29	545200.39	
14	TC	123		0.583	1193+49.41	-11.1	203303.29	545200.39	
14	TC	124		0.75	1193+49.41	-11.1	203303.29	545200.39	
14	TC	125		1	1193+49.41	-11.1	203303.29	545200.39	
14	TC	126		1.5	1193+49.41	-11.1	203303.29	545200.39	
14	TC	127		2	1193+49.41	-11.1	203303.29	545200.39	
14	TC	128		2.5	1193+49.41	-11.1	203303.29	545200.39	
14	TC	129		3	1193+49.41	-11.1	203303.29	545200.39	
14	TC	130		4	1193+49.41	-11.1	203303.29	545200.39	
14	TC	131		5	1193+49.41	-11.1	203303.29	545200.39	
14	TC	132		6	1193+49.41	-11.1	203303.29	545200.39	
14	XV	129		0.417	1193+45.71	-11.6	203305.93	545197.75	972.259
14	XV	130		0.417	1193+46.74	-10.1	203304.14	545197.67	972.284
14	XV	131		0.417	1193+45.68	-9.1	203303.94	545196.18	972.344
14	XV	132		0.417	1193+47.65	-9.0	203302.72	545197.73	972.327

Table B-16. Sensor Locations - Cell 914

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
14	CE	122	LONGITUDINAL	0.479	1193+81.63	-11.7	203284.144	545226.295	972.14
14	CE	124	LONGITUDINAL	0.479	1193+82.68	-11.2	203283.112	545226.829	972.147
14	CE	126	45o	0.479	1193+82.69	-10.2	203282.308	545226.231	972.177
14	CE	128	TRANSVERSE	0.479	1193+83.65	-9.8	203281.429	545226.763	972.118
14	CE	130	LONGITUDINAL	0.479	1193+87.63	-11.8	203280.569	545231.118	972.109
14	CE	132	LONGITUDINAL	0.479	1193+88.70	-11.2	203279.485	545231.641	972.135
14	CE	134	45o	0.479	1193+88.66	-10.2	203278.735	545231.009	972.169
14	CE	136	TRANSVERSE	0.479	1193+89.56	-9.8	203277.829	545231.457	972.167
14	DT	107		0.0625	1193+79	-12.2			
14	DT	108		0.0625	1193+79	-12.2			
14	HC	113	LONGITUDINAL	0.083	1193+79	-11.0			
14	HC	114	LONGITUDINAL	0.417	1193+79	-10.5			
14	HC	115	LONGITUDINAL	0.083	1193+79	-7.5			
14	HC	116	LONGITUDINAL	0.417	1193+79	-7.0			
14	IV	104		0.417	1193+79	-12.2			
14	VW	121	LONGITUDINAL	0.083	1193+75.63	-11.6	203287.801	545221.523	972.228
14	VW	122	LONGITUDINAL	0.417	1193+75.61	-11.7	203286.115	545221.546	972.466
14	VW	123	LONGITUDINAL	0.083	1193+76.59	-10.3	203286.052	545221.399	972.254
14	VW	124	LONGITUDINAL	0.417	1193+76+58	-10.2	203285.88	545219.981	972.56
14	VW	125	45o	0.083	1193+75.56	-9.2	203285.904	545219.986	972.308
14	VW	126	45o	0.417	1193+75.55	-9.2	203284.665	545221.497	972.579
14	VW	127	TRANSVERSE	0.083	1193+77.5	-9.2	203284.686	545221.542	972.333
14	VW	128	TRANSVERSE	0.417	1193+77.52	-9.2	203287.759	545221.516	972.523
14	XV	121		0.083	1193+75.63	-11.6	203287.801	545221.523	972.228
14	XV	122		0.417	1193+75.61	-11.7	203286.115	545221.546	972.466
14	XV	123		0.083	1193+76.59	-10.3	203286.052	545221.399	972.254
14	XV	124		0.417	1193+76+58	-10.2	203285.88	545219.981	972.56
14	XV	125		0.083	1193+75.56	-9.2	203285.904	545219.986	972.308
14	XV	126		0.417	1193+75.55	-9.2	203284.665	545221.497	972.579
14	XV	127		0.083	1193+77.5	-9.2	203284.686	545221.542	972.333
14	XV	128		0.417	1193+77.52	-9.2	203287.759	545221.516	972.523

Table B-17. Sensor Locations - Cell 16

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	STATION	OFFSET (FT)	NORTHING	EASTING
16	PG	101		-19	1204+31.3	-9.3	202643.675	546057.904
16	PG	102		-19	1204+51.2	-9.4	202631.628	546073.818
16	PG	103		-19	1204+70.8	-9.6	202619.917	546089.523
16	TE	103	TRANSVERSE	-5	1204+54	-9.5		
16	TE	102	TRANSVERSE	-5	1204+52	-9.5		
16	TE	101	TRANSVERSE	-5	1204+49	-9.5		
16	LE	103	LONGITUDINAL	-5	1204+74	-9.5		
16	LE	102	LONGITUDINAL	-5	1204+69	-9.5		
16	LE	101	LONGITUDINAL	-5	1204+67	-9.5		
16	TC	101		-0.5	1204+26.4	-6.4		
16	TC	102		-1.5	1204+26.4	-6.4		
16	TC	103		-2.5	1204+26.4	-6.4		
16	TC	104		-3.5	1204+26.4	-6.4		
16	TC	105		-4.5	1204+26.4	-6.4		
16	TC	106		-6	1204+26.4	-6.4	202644.365	546052.328
16	TC	107		-9	1204+26.4	-6.4		
16	TC	108		-12	1204+26.4	-6.4		
16	TC	109		-15	1204+26.4	-6.4		
16	TC	110		-18	1204+26.4	-6.4		
16	TC	111		-24	1204+26.4	-6.4		
16	TC	112		-30	1204+26.4	-6.4		
16	TC	113		-36	1204+26.4	-6.4		
16	TC	114		-48	1204+26.4	-6.4		
16	TC	115		-60	1204+26.4	-6.4		
16	TC	116		-72	1204+26.4	-6.4		
16	EC	101		-6	1204+26.4	-6.4		
16	EC	102		-12	1204+26.4	-6.4		
16	EC	103		-18	1204+26.4	-6.4		
16	EC	104		-24	1204+26.4	-6.4		
16	EC	105		-36	1204+26.4	-6.4		
16	EC	106		-48	1204+26.4	-6.4		
16	EC	107		-60	1204+26.4	-6.4		
16	EC	108		-72	1204+26.4	-6.4		
16	SCG	101	LONGITUDINAL	-5.5	1204+50	-9.5		
16	SCG	102	TRANSVERSE	-4	1204+50	-9.5		

Table B-18. Sensor Locations - Cell 17

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH	STATION	OFFSET (FT)	NORTHING	EASTING
17	PG	101		-19	1209+80.3	-10	202310.283	546494.054
17	PG	102		-19	1210+01.4	-9.4	202296.946	546510.506
17	PG	103		-19	1210+20.5	-9.4	202285.3	546525.601
17	TE	103	TRANSVERSE	-5	1210+03	-9.5		
17	TE	102	TRANSVERSE	-5	1210+01	-9.5		
17	TE	101	TRANSVERSE	-5	1209+99	-9.5		
17	LE	103	LONGITUDINAL	-5	1210+24	-9.5		
17	LE	102	LONGITUDINAL	-5	1210+22	-9.5		
17	LE	101	LONGITUDINAL	-5	1210+20	-9.5		
17	TC	101		-0.5	1209+83	-6		
17	TC	102		-1.5	1209+83	-6		
17	TC	103		-2.5	1209+83	-6		
17	TC	104		-3.5	1209+83	-6		
17	TC	105		-4.5	1209+83	-6		
17	TC	106		-6	1209+83	-6		
17	TC	107		-9	1209+83	-6		
17	TC	108		-12	1209+83	-6		
17	TC	109		-15	1209+83	-6		
17	TC	110		-18	1209+83	-6		
17	TC	111		-24	1209+83	-6		
17	TC	112		-30	1209+83	-6		
17	TC	113		-36	1209+83	-6		
17	TC	114		-48	1209+83	-6		
17	TC	115		-60	1209+83	-6		
17	TC	116		-72	1209+83	-6		
17	EC	101		-6	1209+83	-6		
17	EC	102		-12	1209+83	-6		
17	EC	103		-18	1209+83	-6		
17	EC	104		-24	1209+83	-6		
17	EC	105		-36	1209+83	-6		
17	EC	106		-48	1209+83	-6		
17	EC	107		-60	1209+83	-6		
17	EC	108		-72	1209+83	-6		
17	SCG	101	LONGITUDINAL	-5.5	1209+97	-9.5		
17	SCG	102	TRANSVERSE	-4	1209+97	-9.5		

Table B-19. Sensor Locations - Cell 18

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	STATION	OFFSET (FT)	NORTHING	EASTING
18	PG	101		-19	1212+91.8	-9.2	202120.075	546740.86
18	PG	102		-19	1213+11	-9.4	202108.569	546756.217
18	PG	103		-19	1213+31	-9.5	202096.486	546772.103
18	TE	101	TRANSVERSE	-5	1213+07.7	-9.4	202110.567	546753.583
18	TE	102	TRANSVERSE	-5	1213+09.7	-9.3	202109.363	546755.112
18	TE	103	TRANSVERSE	-5	1213+11.6	-9.4	202108.179	546756.679
18	LE	101	LONGITUDINAL	-5	1213+27.5	-9.3	202098.473	546769.277
18	LE	102	LONGITUDINAL	-5	1213+29.5	-9.3	202097.298	546770.897
18	LE	103	LONGITUDINAL	-5	1213+31.5	-9.3	202096.071	546772.399
18	TC	101		-0.5	1212+88.5	-5.7		
18	TC	102		-1.5	1212+88.5	-5.7		
18	TC	103		-2.5	1212+88.5	-5.7		
18	TC	104		-3.5	1212+88.5	-5.7		
18	TC	105		-4.5	1212+88.5	-5.7		
18	TC	106		-6	1212+88.5	-5.7	202119.359	546736.024
18	TC	107		-9	1212+88.5	-5.7		
18	TC	108		-12	1212+88.5	-5.7		
18	TC	109		-15	1212+88.5	-5.7		
18	TC	110		-18	1212+88.5	-5.7		
18	TC	111		-24	1212+88.5	-5.7		
18	TC	112		-30	1212+88.5	-5.7		
18	TC	113		-36	1212+88.5	-5.7		
18	TC	114		-48	1212+88.5	-5.7		
18	TC	115		-60	1212+88.5	-5.7		
18	TC	116		-72	1212+88.5	-5.7		
18	EC	101		-6	1212+88.5	-5.7		
18	EC	102		-12	1212+88.5	-5.7		
18	EC	103		-18	1212+88.5	-5.7		
18	EC	104		-24	1212+88.5	-5.7		
18	EC	105		-30	1212+88.5	-5.7		
18	EC	106		-36	1212+88.5	-5.7		
18	EC	107		-60	1212+88.5	-5.7		
18	EC	108		-72	1212+88.5	-5.7		
18	SCG	101	VERTICAL	-11	1212+86.1	-9.3	202123.63	546736.398
18	SCG	102	TRANSVERSE	-11	1212+87.2	-9.2	202122.948	546737.174
18	SCG	103	LONGITUDINAL	-11	1212+88.2	-9.2	202122.34	546737.979

Table B-20. Sensor Locations - Cell 19

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH	NORTHING	EASTING	ELEVATION	STATION	OFFSET (FT)
19	PG	101		-20	201682.647	547312.538	966.72	1220+11.7	-9.8
19	PG	2		-20	201694.728	547295.954	966.69	1219+91.2	-9.3
19	PG	3		-20	201706.843	547280.149	966.76	1219+71.3	-9.3
19	LE	1	LONGITUDINAL	-5	201690.786	547301.227	967.86	1219+97.8	-9.4
19	LE	2	LONGITUDINAL	-5	201689.591	547302.89	967.85	1219+99.8	-9.4
19	LE	3	LONGITUDINAL	-5	201688.396	547304.466	967.86	1220+01.8	-9.4
19	TE	1	TRANSVERSE	-5	201696.944	547293.322	967.9	1219+87.7	-9.4
19	TE	2	TRANSVERSE	-5	201695.707	547294.912	967.92	1219+89.8	-9.4
19	TE	3	TRANSVERSE	-5	201694.431	547296.491	967.91	1219+91.8	-9.4
19	TC	1		-0.5	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	2		-1.5	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	3		-2.5	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	4		-3.5	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	5		-4.5	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	6		-6	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	7		-9	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	8		-12	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	9		-15	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	10		-18	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	11		-24	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	12		-30	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	13		-36	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	14		-48	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	15		-60	201705.866	547275.267	967.94	1219+68	-5.5
19	TC	16		-72	201705.866	547275.267	967.94	1219+68	-5.5
19	EC	1		-6	201705.866	547275.267	967.94	1219+68	-5.5
19	EC	2		-12	201705.866	547275.267	967.94	1219+68	-5.5
19	EC	3		-18	201705.866	547275.267	967.94	1219+68	-5.5
19	EC	4		-24	201705.866	547275.267	967.94	1219+68	-5.5
19	EC	5		-36	201705.866	547275.267	967.94	1219+68	-5.5
19	EC	6		-48	201705.866	547275.267	967.94	1219+68	-5.5
19	EC	7		-60	201705.866	547275.267	967.94	1219+68	-5.5
19	EC	8		-72	201705.866	547275.267	967.94	1219+68	-5.5
19	SCG	3	VERTICLE	-5	201704.153	547283.817	967.9	1219+75.8	-9.4
19	SCG	2	TRANSVERSE	-5	201703.566	547284.557	967.92	1219+76.8	-9.4
19	SCG	1	LONGITUDINAL	-5	201702.951	547285.347	967.9	1219+77.8	-9.4
19	DYN-LE	3	LONGITUDINAL	-5	201701.653	547286.885	967.9	1219+79.8	-9.3
19	DYN-TE	2	TRANSVERSE	-5	201700.542	547288.61	967.91	1219+81.8	-9.4
19	DYN-LE	1	LONGITUDINAL	-5	201699.308	547290.183	967.9	1219+83.8	-9.4
19	WM TREE	1			201685.101	547303.139	967.93	1220+02.7	-6
19	TDR/STRIP	1			201682.022	547307.181	968.84	1220+07.8	-6
19	CS 616	1			201669.019	547323.567	967.84	1220+28.7	-5.7

Table B-21. Sensor Locations - Cell 20

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	NORTHING	EASTING	ELEVATION	STATION	OFFSET (FT)
20	PG	1		-5	201279.01	547838.22	966.84	1226+74.5	-9.2
20	PG	2		-5				1226+95	-9.5
20	TE	1	TRANSVERSE	-5	201269.49	547850.75	966.93	1226+90.2	-9.3
20	TE	2	TRANSVERSE	-5	201268.26	547852.35	966.9	1226+92.2	-9.3
20	LE	1	LONGITUDINAL	-5	201267.01	547853.91	966.87	1226+94.2	-9.3
20	LE	2	LONGITUDINAL	-5	201265.81	547855.5	966.88	1226+96.2	-9.8
20	TC	1		-0.5	201275.88	547836.34	967.03	1226+75	-5.6
20	TC	2		-1.5	201275.88	547836.34		1226+75	-5.6
20	TC	3		-2.5	201275.88	547836.34		1226+75	-5.6
20	TC	4		-3.5	201275.88	547836.34		1226+75	-5.6
20	TC	5		-5	201275.88	547836.34		1226+75	-5.6
20	TC	6		-7	201275.88	547836.34		1226+75	-5.6
20	TC	7		-9	201275.88	547836.34		1226+75	-5.6
20	TC	8		-11	201275.88	547836.34		1226+75	-5.6
20	TC	9		-15	201275.88	547836.34		1226+75	-5.6
20	TC	10		-17	201275.88	547836.34		1226+75	-5.6
20	TC	11		-23	201275.88	547836.34		1226+75	-5.6
20	TC	12		-30	201275.88	547836.34		1226+75	-5.6
20	TC	13		-36	201275.88	547836.34		1226+75	-5.6
20	TC	14		-48	201275.88	547836.34		1226+75	-5.6
20	TC	15		-60	201275.88	547836.34		1226+75	-5.6
20	TC	16		-72	201275.88	547836.34		1226+75	-5.6
20	EC	1		-7	201275.88	547836.34		1226+75	-5.6
20	EC	2		-15	201275.88	547836.34		1226+75	-5.6
20	EC	3		-17	201275.88	547836.34		1226+75	-5.6
20	EC	4		-23	201275.88	547836.34		1226+75	-5.6
20	EC	5		-30	201275.88	547836.34		1226+75	-5.6
20	EC	6		-36	201275.88	547836.34		1226+75	-5.6
20	EC	7		-60	201275.88	547836.34		1226+75	-5.6
20	EC	8		-72	201275.88	547836.34		1226+75	-5.6

Table B-22. Sensor Locations - Cell 21

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	NORTHING	EASTING	ELEVATION	STATION	OFFSET (FT)
21	PG	1		-5	201101.144	548072.53	966.33	1229+68.7	-9.5
21	PG	2		-5	201089.508	548088.07	966.22	1229+88.1	-9.5
21	TE	1	TRANSVERSE	-5	201092.241	548084.26	966.34	1229+83.4	-9.4
21	TE	2	TRANSVERSE	-5	201091.06	548085.87	966.31	1229+85.4	-9.4
21	LE	1	LONGITUDINAL	-5	201089.938	548087.61	966.3	1229+87.5	-9.6
21	LE	2	LONGITUDINAL	-5	201088.786	548089.13	966.3	1229+89.4	-9.5
21	TC	1		-0.5	201089.508	548088.07	966.22	1229+68.9	-5.7
21	TC	2		-1.5	201089.508	548088.07		1229+68.9	-5.7
21	TC	3		-2.5	201089.508	548088.07		1229+68.9	-5.7
21	TC	4		-3.5	201089.508	548088.07		1229+68.9	-5.7
21	TC	5		-5	201089.508	548088.07		1229+68.9	-5.7
21	TC	6		-7	201089.508	548088.07		1229+68.9	-5.7
21	TC	7		-9	201089.508	548088.07		1229+68.9	-5.7
21	TC	8		-11	201089.508	548088.07		1229+68.9	-5.7
21	TC	9		-15	201089.508	548088.07		1229+68.9	-5.7
21	TC	10		-17	201089.508	548088.07		1229+68.9	-5.7
21	TC	11		-24	201089.508	548088.07		1229+68.9	-5.7
21	TC	12		-30	201089.508	548088.07		1229+68.9	-5.7
21	TC	13		-36	201089.508	548088.07		1229+68.9	-5.7
21	TC	14		-48	201089.508	548088.07		1229+68.9	-5.7
21	TC	15		-60	201089.508	548088.07		1229+68.9	-5.7
21	TC	16		-72	201089.508	548088.07		1229+68.9	-5.7
21	EC	1		-7	201089.508	548088.07		1229+68.9	-5.7
21	EC	2		-15	201089.508	548088.07		1229+68.9	-5.7
21	EC	3		-17	201089.508	548088.07		1229+68.9	-5.7
21	EC	4		-24	201089.508	548088.07		1229+68.9	-5.7
21	EC	5		-30	201089.508	548088.07		1229+68.9	-5.7
21	EC	6		-36	201089.508	548088.07		1229+68.9	-5.7
21	EC	7		-60	201089.508	548088.07		1229+68.9	-5.7
21	EC	8		-72	201089.508	548088.07		1229+68.9	-5.7

Table B-23. Sensor Locations - Cell 22

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	NORTHING	EASTING	ELEVATION	STATION	OFFSET (FT)
22	PG	1		-5	200643.61	548703.419	965.14	1237+48.4	-9.2
22	PG	2		-5	200630.665	5448721.961	965.1	1237+71	-9.2
22	TE	1	TRANSVERSE	-5	200633.649	548718.667	965.16	1237+66.6	-9.8
22	TE	2	TRANSVERSE	-5	200632.545	548720.371	965.22	1237+68.6	-9.8
22	LE	1	LONGITUDINAL	-5	200631.264	548722.018	965.19	1237+70.8	-9.7
22	LE	2	LONGITUDINAL	-5	200630.041	548723.713	965.23	1237+72.8	-9.7
22	TC	1		-0.5	200640.212	548700.478	965.19	1237+47.9	-4.7
22	TC	2		-1.5	200640.212	548700.478		1237+47.9	-4.7
22	TC	3		-2.5	200640.212	548700.478		1237+47.9	-4.7
22	TC	4		-3.5	200640.212	548700.478		1237+47.9	-4.7
22	TC	5		-5	200640.212	548700.478		1237+47.9	-4.7
22	TC	6		-7	200640.212	548700.478		1237+47.9	-4.7
22	TC	7		-9	200640.212	548700.478		1237+47.9	-4.7
22	TC	8		-11	200640.212	548700.478		1237+47.9	-4.7
22	TC	9		-15	200640.212	548700.478		1237+47.9	-4.7
22	TC	10		-17	200640.212	548700.478		1237+47.9	-4.7
22	TC	11		-24	200640.212	548700.478		1237+47.9	-4.7
22	TC	12		-30	200640.212	548700.478		1237+47.9	-4.7
22	TC	13		-36	200640.212	548700.478		1237+47.9	-4.7
22	TC	14		-48	200640.212	548700.478		1237+47.9	-4.7
22	TC	15		-60	200640.212	548700.478		1237+47.9	-4.7
22	TC	16		-72	200640.212	548700.478		1237+47.9	-4.7
22	EC	1		-7	200640.212	548700.478		1237+47.9	-4.7
22	EC	2		-15	200640.212	548700.478		1237+47.9	-4.7
22	EC	3		-17	200640.212	548700.478		1237+47.9	-4.7
22	EC	4		-24	200640.212	548700.478		1237+47.9	-4.7
22	EC	5		-30	200640.212	548700.478		1237+47.9	-4.7
22	EC	6		-36	200640.212	548700.478		1237+47.9	-4.7
22	EC	7		-60	200640.212	548700.478		1237+47.9	-4.7
22	EC	8		-72	200640.212	548700.478		1237+47.9	-4.7

Table B-24. Sensor Locations - Cell 23

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH	NORTHING	EASTING	ELEVATION	STATION	OFFSET (FT)
23	PG	1		-20	200420.733	549028.837	964.19	1241+42.9	-9.5
23	PG	2		-20	200409.434	549045.618	964.15	1241+63.2	-9.5
23	TE	1	TRANSVERSE	-5				1241+37	-9.5
23	TE	2	TRANSVERSE	-5				1241+39	-9.5
23	LE	1	LONGITUDINAL	-5				1241+57	-9.5
23	LE	2	LONGITUDINAL	-5				1241+59	-9.5
23	TC	1		-0.5	200419.369	549024.092	965.41	1241+39.8	-6
23	TC	2		-1.5	200419.369	549024.092		1241+39.8	-6
23	TC	3		-2.5	200419.369	549024.092		1241+39.8	-6
23	TC	4		-3.5	200419.369	549024.092		1241+39.8	-6
23	TC	5		-7	200419.369	549024.092		1241+39.8	-6
23	TC	6		-9	200419.369	549024.092		1241+39.8	-6
23	TC	7		-11	200419.369	549024.092		1241+39.8	-6
23	TC	8		-13	200419.369	549024.092		1241+39.8	-6
23	TC	9		-15	200419.369	549024.092		1241+39.8	-6
23	TC	10		-20	200419.369	549024.092		1241+39.8	-6
23	TC	11		-24	200419.369	549024.092		1241+39.8	-6
23	TC	12		-30	200419.369	549024.092		1241+39.8	-6
23	TC	13		-36	200419.369	549024.092		1241+39.8	-6
23	TC	14		-48	200419.369	549024.092		1241+39.8	-6
23	TC	15		-60	200419.369	549024.092		1241+39.8	-6
23	TC	16		-72	200419.369	549024.092		1241+39.8	-6
23	EC	1		-7	200419.369	549024.092		1241+39.8	-6
23	EC	2		-15	200419.369	549024.092		1241+39.8	-6
23	EC	3		-20	200419.369	549024.092		1241+39.8	-6
23	EC	4		-24	200419.369	549024.092		1241+39.8	-6
23	EC	5		-36	200419.369	549024.092		1241+39.8	-6
23	EC	6		-48	200419.369	549024.092		1241+39.8	-6
23	EC	7		-60	200419.369	549024.092		1241+39.8	-6
23	EC	8		-72	200419.369	549024.092		1241+39.8	-6

Table B-25. Sensor Locations – Cell 24

CELL	MODEL	SEQ	ORIENTATION	DEPTH (in)	STATION	OFFSET (FT)
24	TC	101	VERTICAL	-0.50	159+33	-6.0
24	TC	102	VERTICAL	-1.50	159+33	-6.0
24	TC	103	VERTICAL	-2.50	159+33	-6.0
24	TC	104	VERTICAL	-3.50	159+33	-6.0
24	TC	105	VERTICAL	-5.00	159+33	-6.0
24	TC	106	VERTICAL	-7.00	159+33	-6.0
24	TC	107	VERTICAL	-9.00	159+33	-6.0
24	TC	108	VERTICAL	-11.00	159+33	-6.0
24	TC	109	VERTICAL	-15.00	159+33	-6.0
24	TC	110	VERTICAL	-19.00	159+33	-6.0
24	TC	111	VERTICAL	-24.00	159+33	-6.0
24	TC	112	VERTICAL	-30.00	159+33	-6.0
24	TC	113	VERTICAL	-36.00	159+33	-6.0
24	TC	114	VERTICAL	-48.00	159+33	-6.0
24	TC	115	VERTICAL	-60.00	159+33	-6.0
24	TC	116	VERTICAL	-72.00	159+33	-6.0

Table B-26. Sensor Locations - Cell 39

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
39	CE	180	TRANSVERSE	-4.25	100+24	-10			
39	CE	181	TRANSVERSE	-4.25	100+24	-9			
39	CE	182	TRANSVERSE	-4.25	100+24	-8			
39	CE	183	TRANSVERSE	-4.25	100+24	-4			
39	CE	184	TRANSVERSE	-4.25	100+24	-3			
39	CE	185	TRANSVERSE	-4.25	100+24	-2			
39	CE	186	TRANSVERSE	-4.25	100+23	-3			
39	CE	187	TRANSVERSE	-4.25	100+23	-2			
39	CE	188	TRANSVERSE	-4.25	100+23	-1			
39	CE	189	TRANSVERSE	-4.25	100+17	-9			
39	CE	190	TRANSVERSE	-4.25	100+17	-8			
39	CE	191	TRANSVERSE	-4.25	100+17	-7			
39	CE	192	TRANSVERSE	-4.25	100+16	-4			
39	CE	193	TRANSVERSE	-4.25	100+16	-3			
39	CE	194	TRANSVERSE	-4.25	100+16	-2			
39	CE	195	TRANSVERSE	-4.25	100+17	-3			
39	CE	196	TRANSVERSE	-4.25	100+17	-2			
39	CE	197	TRANSVERSE	-4.25	100+17	-1			
39	VW	100	LONGITUDINAL	-0.25	100+62.04	11.2	202991.776	545859.443	971.69
39	VW	101	LONGITUDINAL	-0.75	100+62.07	11.2	202991.798	545859.491	971.53
39	VW	102	LONGITUDINAL	-0.25	100+62.13	5.8	202996.002	545862.792	971.77
39	VW	103	LONGITUDINAL	-0.75	100+62.26	5.8	202996.053	545862.75	971.57
39	VW	104	TRANSVERSE	-0.25	100+61.67	5.8	202996.326	545862.462	971.77
39	VW	105	TRANSVERSE	-0.75	100+61.68	5.8	202996.308	545862.461	971.59
39	VW	106	LONGITUDINAL	-0.25	100+54.62	10.8	202996.607	545853.802	971.72
39	VW	107	LONGITUDINAL	-0.75	100+54.64	10.8	202996.585	545853.809	971.54
39	VW	108	39°	-0.25	100+54.08	9.9	202997.66	545853.917	971.73
39	VW	109	39°	-0.75	100+54.03	10	202997.632	545853.837	971.54
39	VW	110	TRANSVERSE	-0.25	100+53.02	9.4	202998.696	545853.381	971.76
39	VW	111	TRANSVERSE	-0.75	100+53.06	9.4	202998.682	545853.419	971.54
39	VW	112	TRANSVERSE	-0.25	100+53.59	5.8	203001.194	545856.012	971.81
39	VW	113	TRANSVERSE	-0.75	100+53.59	5.8	203001.186	545856.006	971.61
39	VW	114	LONGITUDINAL	-0.25	100+53.19	5.7	203001.521	545855.76	971.78
39	VW	115	LONGITUDINAL	-0.75	100+53.16	5.8	203001.503	545855.708	971.62
39	TC	100		-0.5	100+39.01	-6.1	203019.547	545851.71	971.86
39	TC	101		-1.5	100+39.01	-6.1			
39	TC	102		-2.5	100+39.01	-6.1			
39	TC	103		-3.5	100+39.01	-6.1			
39	TC	104		-6	100+39.01	-6.1			
39	TC	105		-9	100+39.01	-6.1			
39	TC	106		-12	100+39.01	-6.1			
39	TC	107		-15	100+39.01	-6.1			
39	XV	100	LONGITUDINAL	-0.25	100+62.04	11.2	202991.776	545859.443	971.69
39	XV	101	LONGITUDINAL	-0.75	100+62.07	11.2	202991.798	545859.491	971.53
39	XV	102	LONGITUDINAL	-0.25	100+62.13	5.8	202996.002	545862.792	971.77
39	XV	103	LONGITUDINAL	-0.75	100+62.26	5.8	202996.053	545862.75	971.57
39	XV	104	TRANSVERSE	-0.25	100+61.67	5.8	202996.326	545862.462	971.77
39	XV	105	TRANSVERSE	-0.75	100+61.68	5.8	202996.308	545862.461	971.59
39	XV	106	LONGITUDINAL	-0.25	100+54.62	10.8	202996.607	545853.802	971.72
39	XV	107	LONGITUDINAL	-0.75	100+54.64	10.8	202996.585	545853.809	971.54
39	XV	108	39°	-0.25	100+54.08	9.9	202997.66	545853.917	971.73
39	XV	109	39°	-0.75	100+54.03	10	202997.632	545853.837	971.54
39	XV	110	TRANSVERSE	-0.25	100+53.02	9.4	202998.696	545853.381	971.76
39	XV	111	TRANSVERSE	-0.75	100+53.06	9.4	202998.682	545853.419	971.54
39	XV	112	TRANSVERSE	-0.25	100+53.59	5.8	203001.194	545856.012	971.81
39	XV	113	TRANSVERSE	-0.75	100+53.59	5.8	203001.186	545856.006	971.61
39	XV	114	LONGITUDINAL	-0.25	100+53.19	5.7	203001.521	545855.76	971.78
39	XV	115	LONGITUDINAL	-0.75	100+53.16	5.8	203001.503	545855.708	971.62
39	WM	101		-59.5	100+39.01	-6.1			
39	WM	102		-48	100+39.01	-6.1			
39	WM	103		-36	100+39.01	-6.1			
39	WM	104		-24	100+39.01	-6.1			
39	WM	105		-12	100+39.01	-6.1			
39	WM	106		-4	100+39.01	-6.1			
39	WM	107		-0.5	100+39.01	-6.1			

Table B-27. Sensor Locations - Cell 53

CELL	MODEL	SEQ	ORIENTATION	DEPTH (FT)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
53	CE	101	LONGITUDINAL	0.979	211+37.68	-11.6	202295.166	546680.754	968.2
53	CE	107	LONGITUDINAL	0.021	211+52.7	-11.6	202286.017	546692.66	
53	CE	108	LONGITUDINAL	0.979	211+52.7	-11.6	202286.017	546692.66	968.81
53	CE	109	TRANSVERSE	0.021	211+52.58	-9.1	202284.112	546691.057	
53	CE	110	TRANSVERSE	0.979	211+52.58	-9.1	202284.112	546691.057	968.87
53	CE	111	LONGITUDINAL	0.021	211+53.05	-9.1	202283.867	546691.454	
53	CE	112	LONGITUDINAL	0.979	211+53.05	-9.1	202283.867	546691.454	968.86
53	CE	113	TRANSVERSE	0.021	211+53.11	-5.7	202281.096	546689.414	
53	CE	114	TRANSVERSE	0.979	211+53.11	-5.7	202281.096	546689.414	968.95
53	CE	115	LONGITUDINAL	0.021	211+53.69	-5.6	202280.675	546689.813	
53	CE	116	LONGITUDINAL	0.979	211+53.69	-5.6	202280.675	546689.813	968.98
53	CE	117	LONGITUDINAL	0.021	211+57.1	-11.6	202283.358	546696.174	
53	CE	118	LONGITUDINAL	0.979	211+57.1	-11.6	202283.358	546696.174	968.8
53	CE	119	39o	0.021	211+57.63	-10.1	202281.887	546695.708	
53	CE	120	39o	0.979	211+57.63	-10.1	202281.887	546695.708	968.86
53	CE	121	TRANSVERSE	0.021	211+59.09	-9.1	202280.143	546696.215	
53	CE	122	TRANSVERSE	0.979	211+59.09	-9.1	202280.143	546696.215	968.88
53	CE	123	TRANSVERSE	0.021	211+59.1	-6.1	202277.811	546694.436	
53	CE	124	TRANSVERSE	0.979	211+59.1	-6.1	202277.811	546694.436	968.95
53	DT	101		0.0625		-12.4			
53	DT	102		0.0625		-12.3			
53	DT	103		0.0625		-12.3			
53	DT	104		0.0625		-12.4			
53	DT	105		0.0625		-12.4			
53	DT	106		0.0625		-12.4			
53	HC	101		0.083		-11.3			
53	HC	102		0.917		-11			
53	HC	103		0.083		-6.3			
53	HC	104		0.917		-5.9			
53	HC	105		0.5		-11.4			
53	HC	106		0.5		-5.9			
53	IK	101		0.083	211+31.69	-11.4	202298.674	546675.89	969.71
53	IK	102		0.292	211+31.15	-11.6	202299.12	546675.559	969.54
53	IK	103		0.5	211+31.61	-11.4	202298.708	546675.822	969.39
53	IK	104		0.708	211+31.15	-11.5	202299.064	546675.507	696.15
53	IK	105		0.917	211+31.73	-11.4	202298.686	546675.955	968.9
53	IK	106		0.083	211+31.6	-10	202297.577	546674.942	969.75
53	IK	107		0.292	211+31.26	-9.9	202297.784	546674.665	969.56
53	IK	108		0.5	211+31.67	-10	202297.609	546675.056	969.34
53	IK	109		0.708	211+31.16	-9.9	202297.797	546674.555	969.14
53	IK	110		0.917	211+31.4	-10	202297.733	546674.807	968.95
53	IV	101		0.5	211+37.64	-12.4	202295.819	546681.201	968.73
53	IV	102		0.5	211+45.14	-12.3	202291.19	546687.101	968.69
53	IV	103		0.5	211+52.59	-12.4	202286.751	546693.09	968.73
53	IV	104		0.5	211+60.13	-12.4	202282.141	546669.05	968.66
53	TC	101		0.042	211+46.95	-11.3	202289.275	546687.918	968.93
53	TC	102		0.083	211+46.95	-11.3	202289.275	546687.918	
53	TC	103		0.167	211+46.95	-11.3	202289.275	546687.918	
53	TC	104		0.25	211+46.95	-11.3	202289.275	546687.918	
53	TC	105		0.417	211+46.95	-11.3	202289.275	546687.918	
53	TC	106		0.667	211+46.95	-11.3	202289.275	546687.918	
53	TC	107		0.917	211+46.95	-11.3	202289.275	546687.918	
53	TC	108		1.25	211+46.95	-11.3	202289.275	546687.918	
53	TC	109		0.0417	211+52.62	-5.8	202281.508	546689.11	969.1
53	TC	110		0.083	211+52.62	-5.8	202281.508	546689.11	
53	TC	111		0.125	211+52.62	-5.8	202281.508	546689.11	
53	TC	112		0.25	211+52.62	-5.8	202281.508	546689.11	

53	TC	113		0.417	211+52.62	-5.8	202281.508	546689.11	
53	TC	114		0.667	211+52.62	-5.8	202281.508	546689.11	
53	TC	115		0.917	211+52.62	-5.8	202281.508	546689.11	
53	TC	116		1.25	211+52.62	-5.8	202281.508	546689.11	
53	TC	117		1.5	211+52.62	-5.8	202281.508	546689.11	
53	TC	118		2	211+52.62	-5.8	202281.508	546689.11	
53	TC	119		2.5	211+52.62	-5.8	202281.508	546689.11	
53	TC	120		3	211+52.62	-5.8	202281.508	546689.11	
53	TC	121		4	211+52.62	-5.8	202281.508	546689.11	
53	TC	122		4.5	211+52.62	-5.8	202281.508	546689.11	
53	TC	123		5	211+52.62	-5.8	202281.508	546689.11	
53	TC	124		6	211+52.62	-5.8	202281.508	546689.11	
53	VG	101	LONGITUDINAL	0.083	211+37.26	-7.2	202291.956	546677.759	969.7
53	VG	102	LONGITUDINAL	0.5	211+37.23	-7.2	202291.988	546677.755	969.33
53	VG	103	LONGITUDINAL	0.917	211+37.21	-7.2	202292.022	546677.745	968.9
53	VW	101	LONGITUDINAL	0.083	211+33.1	-11.1	202297.602	546676.855	969.74
53	VW	102	LONGITUDINAL	0.917	211+33.16	-11.2	202297.597	546676.92	968.95
53	VW	103	39o	0.083	211+33.10	-10.1	202296.814	546676.245	969.76
53	VW	104	39o	0.917	211+33.1	-10.1	202296.799	546676.229	968.94
53	VW	105	TRANSVERSE	0.083	211+31.27	-9.2	202297.173	546674.212	969.77
53	VW	106	TRANSVERSE	0.917	211+31.29	-9.2	202297.146	546674.224	698.96
53	VW	107	LONGITUDINAL	0.083	211+31.1	-6.1	202294.843	546672.212	969.85
53	VW	108	LONGITUDINAL	0.917	211+31.11	-6.1	202294.856	546672.241	969.03
53	VW	109	TRANSVERSE	0.083	211+31.65	-6.1	202294.498	546672.645	969.84
53	VW	110	TRANSVERSE	0.917	211+31.68	-6.2	202294.513	546672.695	969
53	VW	111	LONGITUDINAL	0.083	211+37.60	-11	202294.725	546680.314	969.73
53	VW	112	LONGITUDINAL	0.917	211+37.55	-10.9	202294.712	546680.24	968.89
53	VW	113	LONGITUDINAL	0.083	211+36.96	-6.1	202291.293	546676.876	969.85
53	VW	114	LONGITUDINAL	0.917	211+37	-6.2	202291.289	546676.921	969.02
53	VW	115	TRANSVERSE	0.083	211+38.07	-6.2	202290.643	546677.773	969.82
53	VW	116	TRANSVERSE	0.917	211+38.16	-6.1	202290.519	546677.798	969
53	WM	101		1.208	211+46.55	-11.6	202289.81	546687.826	969.69
53	WM	102		1.5	211+46.55	-11.6	202289.81	546687.826	
53	WM	103		2.5	211+46.55	-11.6	202289.81	546687.826	
53	WM	104		3.5	211+46.55	-11.6	202289.81	546687.826	
53	WM	105		4.33	211+46.55	-11.6	202289.81	546687.826	
53	WM	106		4.67	211+46.55	-11.6	202289.81	546687.826	
53	WM	107		1.208	211+52.58	-5.8	202281.489	546689.04	969.87
53	WM	108		1.5	211+52.58	-5.8	202281.489	546689.04	
53	WM	109		2.5	211+52.58	-5.8	202281.489	546689.04	
53	WM	110		3.5	211+52.58	-5.8	202281.489	546689.04	
53	WM	111		4.33	211+52.58	-5.8	202281.489	546689.04	
53	WM	112		4.67	211+52.58	-5.8	202281.489	546689.04	
53	XG	101	LONGITUDINAL	0.083	211+37.26	-7.2	202291.956	546677.759	969.7
53	XG	102	LONGITUDINAL	0.5	211+37.23	-7.2	202291.988	546677.755	969.33
53	XV	103	LONGITUDINAL	0.917	211+37.21	-7.2	202292.022	546677.745	968.9
53	XV	101	LONGITUDINAL	0.083	211+33.1	-11.1	202297.602	546676.855	969.74
53	XV	102	LONGITUDINAL	0.917	211+33.16	-11.2	202297.597	546676.92	968.95
53	XV	103	39o	0.083	211+33.10	-10.1	202296.814	546676.245	969.76
53	XV	104	39o	0.917	211+33.1	-10.1	202296.799	546676.229	968.94
53	XV	105	TRANSVERSE	0.083	211+31.27	-9.2	202297.173	546674.212	969.77
53	XV	106	TRANSVERSE	0.917	211+31.29	-9.2	202297.146	546674.224	698.96
53	XV	107	LONGITUDINAL	0.083	211+31.1	-6.1	202294.843	546672.212	969.85
53	XV	108	LONGITUDINAL	0.917	211+31.11	-6.1	202294.856	546672.241	969.03
53	XV	109	TRANSVERSE	0.083	211+31.65	-6.1	202294.498	546672.645	969.84
53	XV	110	TRANSVERSE	0.917	211+31.68	-6.2	202294.513	546672.695	969
53	XV	111	LONGITUDINAL	0.083	211+37.60	-11	202294.725	546680.314	969.73
53	XV	112	LONGITUDINAL	0.917	211+37.55	-10.9	202294.712	546680.24	968.89
53	XV	113	LONGITUDINAL	0.083	211+36.96	-6.1	202291.293	546676.876	969.85
53	XV	114	LONGITUDINAL	0.917	211+37	-6.2	202291.289	546676.921	969.02
53	XV	115	TRANSVERSE	0.083	211+38.07	-6.2	202290.643	546677.773	969.82
53	XV	116	TRANSVERSE	0.917	211+38.16	-6.1	202290.519	546677.798	969
53	EC	101		1.25	211+52.62	-5.8	202281.508	546689.11	
53	EC	102		1.5	211+52.62	-5.8	202281.508	546689.11	
53	EC	103		2	211+52.62	-5.8	202281.508	546689.11	
53	EC	104		2.5	211+52.62	-5.8	202281.508	546689.11	
53	EC	105		3	211+52.62	-5.8	202281.508	546689.11	
53	EC	106		4	211+52.62	-5.8	202281.508	546689.11	
53	EC	107		5	211+52.62	-5.8	202281.508	546689.11	
53	EC	108		6	211+52.62	-5.8	202281.508	546689.11	
53	EC	109		7	211+52.62	-5.8	202281.508	546689.11	

Table B-28. Sensor Locations - Cell 85

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
85	PG	1		-18.5	165+23.35	-9.6	205100.803	543017.357	961.01
85	PG	2		-18.5	165+27.28	-9.4	205098.247	543020.357	961.04
85	VW	1	LONGITUDINAL	-0.5	165+22.81	-12	205103.013	543018.38	962.62
85	VW	2	LONGITUDINAL	-6.5	165+22.84	-12	205103	543018.405	962.28
85	VW	3	TRANSVERSE	-0.5	165+22.22	-6.6	205099.095	543014.624	962.6
85	VW	4	TRANSVERSE	-6.5	165+22.2	-6.5	205099.019	543014.575	962.27
85	VW	5	LONGITUDINAL	-0.5	165+22.75	-6.5	205098.7	543014.994	962.61
85	VW	6	LONGITUDINAL	-6.5	165+22.66	-6.6	205098.79	543014.954	962.23
85	VW	7	LONGITUDINAL	-0.5	165+24.90	-11.9	205101.673	543019.975	962.66
85	VW	8	LONGITUDINAL	-6.5	165+24.87	-11.9	205101.701	543019.961	962.27
85	VW	9	39°	-0.5	165+24.97	-9.9	205100.01	543018.797	962.65
85	VW	10	39°	-6.5	165+24.96	-9.9	205100.032	543018.794	962.31
85	VW	11	TRANSVERSE	-0.5	165+26.84	-10.1	205099.009	543020.38	962.62
85	VW	12	TRANSVERSE	-6.5	165+26.79	-10	205099.003	543020.309	962.3
85	VW	13	LONGITUDINAL	-0.5	165+26.48	-6.4	205096.358	543017.901	962.63
85	VW	14	LONGITUDINAL	-6.5	165+26.49	-6.6	205096.438	543017.973	962.27
85	VW	15	TRANSVERSE	-0.5	165+26.91	-6.5	205096.158	543018.28	962.62
85	VW	16	TRANSVERSE	-6.5	165+26.95	-6.5	205096.091	543018.278	962.32
85	TC	1		-0.63	165+37.51	-6.6	205089.765	543026.736	962.68
85	TC	2		-1	165+37.51	-6.6	205089.765	543026.736	
85	TC	3		-2.5	165+37.51	-6.6	205089.765	543026.736	
85	TC	4		-3.5	165+37.51	-6.6	205089.765	543026.736	
85	TC	5		-7	165+37.51	-6.6	205089.765	543026.736	
85	TC	6		-8	165+37.51	-6.6	205089.765	543026.736	
85	TC	7		-13	165+37.51	-6.6	205089.765	543026.736	
85	TC	8		-18.5	165+37.51	-6.6	205089.765	543026.736	
85	TC	9		-20	165+37.51	-6.6			
85	TC	10		-24	165+37.51	-6.6			
85	TC	11		-30	165+37.51	-6.6			
85	TC	12		-36	165+37.51	-6.6			
85	TC	13		-42	165+37.51	-6.6			
85	TC	14		-48	165+37.51	-6.6			
85	TC	15		-60	165+37.51	-6.6			
85	TC	16		-72	165+37.51	-6.6			
85	IK	1		-1.5	165+32.5	-8			
85	IK	2		-2.5	165+32.5	-8			
85	IK	3		-3.5	165+32.5	-8			
85	IK	4		-4.5	165+32.5	-8			
85	IK	5		-1	165+32.5	-8			
85	IK	6		-2	165+32.5	-8			
85	IK	7		-3	165+32.5	-8			
85	IK	8		-4	165+32.5	-8			
85	IK	9		-5	165+32.5	-8			
85	WM	1		-2	165+37.51	-6.6			
85	WM	2		-6	165+37.51	-6.6			
85	WM	3		-9	165+37.51	-6.6			
85	WM	4		-15.5	165+37.51	-6.6			
85	WM	5		-21.5	165+37.51	-6.6			
85	WM	6		-34	165+37.51	-6.6			
85	WM	7		-48	165+37.51	-6.6			
85	WM	8		-60	165+37.51	-6.6			
85	WM	9		-72	165+37.51	-6.6			
85	XV	1	LONGITUDINAL	-0.5	165+22.81	-12	205103.013	543018.38	962.62
85	XV	2	LONGITUDINAL	-6.5	165+22.84	-12	205103	543018.405	962.28
85	XV	3	TRANSVERSE	-0.5	165+22.22	-6.6	205099.095	543014.624	962.6
85	XV	4	TRANSVERSE	-6.5	165+22.2	-6.5	205099.019	543014.575	962.27
85	XV	5	LONGITUDINAL	-0.5	165+22.75	-6.5	205098.7	543014.994	962.61
85	XV	6	LONGITUDINAL	-6.5	165+22.66	-6.6	205098.79	543014.954	962.23
85	XV	7	LONGITUDINAL	-0.5	165+24.90	-11.9	205101.673	543019.975	962.66
85	XV	8	LONGITUDINAL	-6.5	165+24.87	-11.9	205101.701	543019.961	962.27
85	XV	9	39°	-0.5	165+24.97	-9.9	205100.01	543018.797	962.65
85	XV	10	39°	-6.5	165+24.96	-9.9	205100.032	543018.794	962.31
85	XV	11	TRANSVERSE	-0.5	165+26.84	-10.1	205099.009	543020.38	962.62
85	XV	12	TRANSVERSE	-6.5	165+26.79	-10	205099.003	543020.309	962.3
85	XV	13	LONGITUDINAL	-0.5	165+26.48	-6.4	205096.358	543017.901	962.63
85	XV	14	LONGITUDINAL	-6.5	165+26.49	-6.6	205096.438	543017.973	962.27
85	XV	15	TRANSVERSE	-0.5	165+26.91	-6.5	205096.158	543018.28	962.62
85	XV	16	TRANSVERSE	-6.5	165+26.95	-6.5	205096.091	543018.278	962.32
85	Detect Loop	1				Center at 6.5'			

Table B-29. Sensor Locations - Cell 86

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	NORTHING	EASTING	ELEVATION	STATION	OFFSET (FT)
86	PG	1		-18.5	204992.209	543158.668	961.34	167+01.5	-9.4
86	PG	2		-18.5	204989.984	543162.419	961.35	167+05.9	-9.9
86	TE	1	LONGITUDINAL	-4.5				166+77	-9.5
86	TE	2	LONGITUDINAL	-4.5				166+79	-9.5
86	LE	1	TRANSVERSE	-4.5				166+81	-9.5
86	LE	2	TRANSVERSE	-4.5				166+83	-9.5
86	TC	1		-0.5				166+76	-6
86	TC	2		-1.5				166+76	-6
86	TC	3		-3				166+76	-6
86	TC	4		-4.5				166+76	-6
86	TC	5		-7				166+76	-6
86	TC	6		-9				166+76	-6
86	TC	7		-11				166+76	-6
86	TC	8		-15				166+76	-6
86	TC	9		-18.5				166+76	-6
86	TC	10		-20				166+76	-6
86	TC	11		-24				166+76	-6
86	TC	12		-30				166+76	-6
86	TC	13		-36				166+76	-6
86	TC	14		-48				166+76	-6
86	TC	15		-60				166+76	-6
86	TC	16		-72				166+76	-6
86	EC	1		-7				166+76	-6
86	EC	2		-11				166+76	-6
86	EC	3		-18.5				166+76	-6
86	EC	4		-24				166+76	-6
86	EC	5		-30				166+76	-6
86	EC	6		-48				166+76	-6
86	EC	7		-60				166+76	-6
86	EC	8		-72				166+76	-6
86	Detect Loop	1							Center at 6.5'
86	Lysimeter	1							Center at 6.5'

Table B-30. Sensor Locations - Cell 88

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	NORTHING	EASTING	ELEVATION	STATION	OFFSET (FT)
88	PG	1		-18.5	204669.103	543580.39	964.08	172+32.9	-9.5
88	PG	2		-18.5	204666.697	543583.831	964.1	172+37.0	-9.7
88	TE	1	LONGITUDINAL	-4.5				172+17	-9.5
88	TE	2	LONGITUDINAL	-4.5				172+19	-9.5
88	LE	1	TRANSVERSE	-4.5				172+21	-9.5
88	LE	2	TRANSVERSE	-4.5				172+23	-9.5
88	TC	1		-0.5				172+16	-6
88	TC	2		-1.5				172+16	-6
88	TC	3		-3				172+16	-6
88	TC	4		-4.5				172+16	-6
88	TC	5		-7				172+16	-6
88	TC	6		-9				172+16	-6
88	TC	7		-11				172+16	-6
88	TC	8		-15				172+16	-6
88	TC	9		-18.5				172+16	-6
88	TC	10		-20				172+16	-6
88	TC	11		-24				172+16	-6
88	TC	12		-30				172+16	-6
88	TC	13		-36				172+16	-6
88	TC	14		-48				172+16	-6
88	TC	15		-60				172+16	-6
88	TC	16		-72				172+16	-6
88	EC	1		-7				172+16	-6
88	EC	2		-11				172+16	-6
88	EC	3		-18.5				172+16	-6
88	EC	4		-24				172+16	-6
88	EC	5		-30				172+16	-6
88	EC	6		-48				172+16	-6
88	EC	7		-60				172+16	-6
88	EC	8		-72				172+16	-6
88	Detect Loop	1							Center at 6.5'
88	Lysimeter	1							Center at 6.5'

Table B-31. Sensor Locations - Cell 89

CELL	MODEL	SEQ	ORIENTATION	DEPTH (INCH)	STATION	OFFSET (FT)	NORTHING	EASTING	ELEVATION
89	PG	1		-18.5	173+05.81	-9.7	204624.808	543638.38	964.46
89	PG	2		-18.5	173+09.64	-9.5	204622.312	543641.297	964.45
89	VW	1	LONGITUDINAL	-0.5	173+11.07	-12	204623.473	543643.991	966.03
89	VW	2	LONGITUDINAL	-6.5	173+11.06	-12	204623.483	543643.984	965.66
89	VW	3	TRANSVERSE	-0.5	173+10.67	-6.6	204619.378	543640.343	966.01
89	VW	4	TRANSVERSE	-6.5	173+10.61	-6.6	204619.428	543640.308	965.308
89	VW	5	LONGITUDINAL	-0.5	173+11.15	-6.5	204619.062	543640.711	965.99
89	VW	6	LONGITUDINAL	-6.5	173+11.13	-6.5	204619.086	543640.7	965.68
89	VW	7	LONGITUDINAL	-0.5	173+13.34	-11.9	204622.035	543645.742	966.03
89	VW	8	LONGITUDINAL	-6.5	173+13.33	-11.9	204621.981	543645.694	965.7
89	VW	9	39°	-0.5	173+13.33	-10	204620.472	543644.537	966.02
89	VW	10	39°	-6.5	173+13.28	-9.8	204620.387	543644.415	965.67
89	VW	11	TRANSVERSE	-0.5	173+15.3	-10	204619.263	543646.092	966
89	VW	12	TRANSVERSE	-6.5	173+15.26	-10.1	204619.361	543646.119	965.67
89	VW	13	LONGITUDINAL	-0.5	173+14.66	-6.5	204616.889	543643.471	966.03
89	VW	14	LONGITUDINAL	-6.5	173+14.75	-6.4	204616.782	543643.493	965.66
89	VW	15	TRANSVERSE	-0.5	173+15.11	-6.5	204616.638	543643.842	966.02
89	VW	16	TRANSVERSE	-6.5	173+15.13	-6.5	204616.605	543643.839	965.68
89	TC	1		-0.625	173+20.81	-6.5	204613.164	543648.364	966.05
89	TC	2		-1.5	173+20.81	-6.5	204613.164	543648.364	
89	TC	3		-2.5	173+20.81	-6.5	204613.164	543648.364	
89	TC	4		-3.5	173+20.81	-6.5	204613.164	543648.364	
89	TC	5		-7	173+20.81	-6.5	204613.164	543648.364	
89	TC	6		-8	173+20.81	-6.5	204613.164	543648.364	
89	TC	7		-13	173+20.81	-6.5	204613.164	543648.364	
89	TC	8		-18.5	173+20.81	-6.5	204613.164	543648.364	
89	TC	9		-20	173+20.81	-6.5			
89	TC	10		-24	173+20.81	-6.5			
89	TC	11		-30	173+20.81	-6.5			
89	TC	12		-36	173+20.81	-6.5			
89	TC	13		-42	173+20.81	-6.5			
89	TC	14		-48	173+20.81	-6.5			
89	TC	15		-60	173+20.81	-6.5			
89	TC	16		-72	173+20.81	-6.5			
89	IK	1		-1.5	173+30.5	-8			
89	IK	2		-2.5	173+30.5	-8			
89	IK	3		-3.5	173+30.5	-8			
89	IK	4		-4.5	173+30.5	-8			
89	IK	5		-1	173+30.5	-8			
89	IK	6		-2	173+30.5	-8			
89	IK	7		-3	173+30.5	-8			
89	IK	8		-4	173+30.5	-8			
89	IK	9		-5	173+30.5	-8			
89	XV	1	LONGITUDINAL	-0.5	173+11.07	-12	204623.473	543643.991	966.03
89	XV	2	LONGITUDINAL	-6.5	173+11.06	-12	204623.483	543643.984	965.66
89	XV	3	TRANSVERSE	-0.5	173+10.67	-6.6	204619.378	543640.343	966.01
89	XV	4	TRANSVERSE	-6.5	173+10.61	-6.6	204619.428	543640.308	965.308
89	XV	5	LONGITUDINAL	-0.5	173+11.15	-6.5	204619.062	543640.711	965.99
89	XV	6	LONGITUDINAL	-6.5	173+11.13	-6.5	204619.086	543640.7	965.68
89	XV	7	LONGITUDINAL	-0.5	173+13.34	-11.9	204622.035	543645.742	966.03
89	XV	8	LONGITUDINAL	-6.5	173+13.33	-11.9	204621.981	543645.694	965.7
89	XV	9	39°	-0.5	173+13.33	-10	204620.472	543644.537	966.02
89	XV	10	39°	-6.5	173+13.28	-9.8	204620.387	543644.415	965.67
89	XV	11	TRANSVERSE	-0.5	173+15.3	-10	204619.263	543646.092	966
89	XV	12	TRANSVERSE	-6.5	173+15.26	-10.1	204619.361	543646.119	965.67
89	XV	13	LONGITUDINAL	-0.5	173+14.66	-6.5	204616.889	543643.471	966.03
89	XV	14	LONGITUDINAL	-6.5	173+14.75	-6.4	204616.782	543643.493	965.66
89	XV	15	TRANSVERSE	-0.5	173+15.11	-6.5	204616.638	543643.842	966.02
89	XV	16	TRANSVERSE	-6.5	173+15.13	-6.5	204616.605	543643.839	965.68
89	Detect Loop	1				Center at 6.5'			