SP-150726a
(New)

SPECIAL PROVISIONS
FOR
INSTRUMENTATION AND MONITORING

Johnson County
NHS-080-6(372)239--11-52

Effective Date
December 8, 2020

THE STANDARD SPECIFICATIONS, SERIES 2015, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

150726a.01 GENERAL.

A. Scope of Work.

1. In accordance with these special provisions, and as shown on the plans, furnish, install, protect, maintain, and monitor instrumentation consisting of six vibrating wire piezometers; two ShapeArrays, approximately 90 feet and 150 feet in length; four settlement plates; and a remote sensing, near real-time, automated data acquisition system, which includes two monitoring stations.

2. The settlement plates (SP) will be installed by the Contractor; however, the monitoring of the settlement plates, shall be included in this work and monitored in accordance with Article 2526.03, G of the Standard Specifications.

B. Definitions.

Instrumentation: various sensors, instruments, or systems used to measure settlement (elevation changes), piezometric trends (pore water pressure changes), and temperature.

Monitoring: the measurement of instrumentation, as well as the transmission, reduction, presentation, and evaluation of the instrumentation data.

Instrumentation Program: general specifications, details, and plans regarding instrumentation (and associated monitoring). Also, general reference to the full instrumentation and monitoring system.

Geotechnical Instrumentation Engineer: personnel (hired by the Contractor) responsible for proper installation and performance of both field components and the web-based data presentation and reporting system, as well as instrumentation deliverables and documents.

Vibrating Wire (VW): a type of instrumentation sensor technology, manufactured by GEOKON, Inc., RST, Inc., or approved other, known for its long-term performance and resilience.

VW Piezometer (PZ): a sensor customarily installed and sealed within a borehole; used to measure piezometric pressure (pore water pressure), which can be converted to the effective groundwater table elevation (piezometric head or hydraulic head).

ShapeArray (SAA): an automated string (array) of connected tiltmeters, that can be installed horizontally in a shallow trench within a protective conduit (trench backfilled with sand); used to measure a complete profile of settlement beneath an embankment.

Communication Cable: (also referred to as Data Cable) the data transmission wire pre-attached to an automated sensor by its manufacturer, with exposed leads or plugs that can be manually measured or connected directly to a datalogger or cloud-connector (usually routed through conduit) for automated monitoring.

VW Datalogger: physical hardware, manufactured by GEOKON, Inc., or RST, Inc., that automatically measures the vibrating wire instrumentation sensors (vibrating wire communication cables are connected to this, and this connects to a THREAD)

THREAD: physical hardware, manufactured by Sensemetrics, Inc. (THREAD X-Series), or approved equivalent, that automatically and immediately transmits instrumentation data (from VW dataloggers and/or ShapeArrays) through a wireless mesh and/or cellular network to the cloud, whereby data is automatically and remotely reduced, presented, and accessible via a secure, web interface hosted by Sensemetrics, Inc., or approved other.

Monitoring Station (MS): a pole-mounted arrangement, assembled by the Geotechnical Instrumentation Engineer, located at each designated instrumentation cross-section, consisting of a solar panel, VW datalogger, THREAD, cable connections, and mounting hardware.

Automated Data Acquisition System (ADAS): all monitoring station components (solar panel, VW dataloggers, and THREADs) and the online Sensemetrics monitoring system, working together to provide automated instrumentation measurements, accessible via a near real-time, customized web interface.

Instrumentation Cross-Section: a specific area of the Project where a series of instrumentation will be installed and monitored, named in reference to the nearby structure.

- **Ramp E**, located at **STA 5566+00**
- **Ramp F**, located at **STA 6532+75**

Each cross-section will contain the same instrumentation and monitoring systems. Each will include 3 VW piezometers (1 beneath centerline, 1 beneath edge of embankment, and 1 beneath midpoint of embankment slope), 1 SAA, 1 monitoring station, and 2 settlement plates.

C. Purpose.

Instrumentation is implemented to monitor performance of bridge approach embankments and engineered subgrades, using automated pore water pressure and settlement measurements (via VW Piezometers and ShapeArrays, respectively), as well as manual confirmation of settlement (via settlement plates). The purpose of the VW piezometers is to monitor excess pore water pressures in the soil to confirm that primary consolidation is complete, the rate has stabilized, and that clay gained enough shear strength to allow staged construction. The ShapeArray is used to monitor settlement (downward elevation change) and shape of deformation, to confirm primary consolidation is complete, confirm rate has stabilized, isolate zones of instability, and corroborate VW piezometer data to allow staged construction. Settlement plates will be manually surveyed at specified intervals, to measure settlement (downward elevation change) near the top of the

constructed embankment, to confirm the rate has stabilized to permit road construction and corroborate ShapeArray and VW piezometer measurements. Automated instrumentation will remain in use after embankment construction and into the warranty period, to monitor long-term embankment performance.

D. Quantities.

ID	Type	Approx. Depth (PZ) or Length (SAA)*	Approx. Data Cable Length*	Location	Stationing	Offset
		feet	*feet*			*feet*
E_PZ_1	PZ	25	140	Ramp E	5566+00	0 L
E_PZ_2	PZ	25	120	Ramp E	5566+00	20 L
E_PZ_2	PZ	25	80	Ramp E	5566+00	55 L
E_SAA	SAA	90	15	Ramp E	5566+00	0 – 90 L
E_MS	MS	--	--	Ramp E	5566+00	90 L
E_SP_1	SP	--	--	Ramp E	5566+00	0 L
E_SP_2	SP	--	--	Ramp E	5566+00	20 L
F_PZ_1	PZ	25	175	Ramp F	6532+75	0 L
F_PZ_2	PZ	25	155	Ramp F	6532+75	20 L
F_PZ_3	PZ	25	110	Ramp F	6532+75	85 L
F_SAA	SAA	150	15	Ramp F	6532+75	0 – 150 L
F_MS	MS	--	--	Ramp F	6532+75	150 L
W_SP_1	SP	--	--	Ramp F	6532+75	0 L
W_SP_2	SP	--	--	Ramp F	6532+75	20 L

* to be finalized in IMS submittal

E. Drawings.

1. INS-01 Instrumentation Plan (Ramp E)

2. INS-02 Instrumentation Plan (Ramp F)

3. INS-03 Instrumentation Plan (Instrumentation Cross-Section)

4. INS-04 Instrumentation Plan (ShapeArray Anchor Detail and Connection)

F. References.

The following publications (and denoted extent) form a part of these special provisions, and are either referred to herein by basic designation or their information is generally inferred:

1. Mikkelson and Green, “Piezometers in Fully Grouted Boreholes.” Proceeding of FMGM 2003, Field Measurement in Geomechanics, Oslo, Norway, Sept. 2003.

2. Geokon, Inc., “Table 1 showing Cement/Bentonite/Water ratio for two grout mixes”. Installation C, Instruction Manual, Model 4500 series Vibrating Wire Piezometers.

150726a.02 QUALIFICATIONS.

1. The Contractor shall hire a geotechnical engineering consultant (referred herein to as Geotechnical Instrumentation Engineer) to procure, test, program, coordinate, install, and monitor all appropriate instrumentation, appurtenances, and monitoring systems.

2. The Geotechnical Instrumentation Engineer shall:
   a. Demonstrate experience with the required instrumentation, including three instrumentation and monitoring projects, utilizing all required sensors and monitoring systems, in the past 5 years
   b. Include a Professional Geotechnical Engineer registered in the State of Iowa, who will oversee all field installations of instrumentation and monitoring systems.

150726a.02 SUBMITTALS.

A. Record of Experience.

1. Submit documentation detailing the record of experience of the Geotechnical Instrumentation Engineer that was selected to implement all construction and performance instrumentation and monitoring systems. At a minimum, this document shall detail the following:
   a. Experience requirements previously stated.
   b. Resumes of personnel that will be responsible for implementing this project's instrumentation and monitoring systems.

2. Submit the Record of Experience at least 1 month prior to delivering instrumentation, appurtenances, and/or monitoring systems to the project site.

B. Instrumentation Methods Statement.

1. Submit an Instrumentation Methods Statement (IMS) to the Engineer for review and approval by the Engineer. The IMS shall include, but not be limited to:
   a. Installation, maintenance, and monitoring methods and procedures, including:
      - Final proposed locations of all instrumentation and monitoring stations
      - Sequence of instrumentation installation relative to the rest of the Work
      - Specific methods for maintenance, protection, repair, and replacement of instrumentation, including anticipated timeline for such activities.
      - Detailed description of the ADAS, including the method for implementing and accessing the instrumentation monitoring system website.
      - Detailed description of the hand-off of the SAAs and ADAS to the Department.
      - Proposed modifications to what is detailed herein and on the Plans.

   b. Model numbers and catalog data sheets for all proposed instrumentation, including proposed cable lengths
   c. Instrumentation Plan (map) relative to the Project containing sensor and monitoring station locations, including proposed modifications to what is detailed herein and on the Plans
   d. Example instrumentation installation records and wiring diagrams.

2. Submit the IMS at least 1 month prior to procuring and/or installing any performance instrumentation, appurtenances, and/or monitoring systems, or with sufficient time without impacting the construction schedule. No additional time will be granted for any delays due to replacing non-accepted type or range of instrumentation.

C. Installation Records.

Submit a completed installation record for each instrumentation sensor (or sensor array) installation, within 1 week following its installation. Each installation record shall have a depiction of the location plan-view, a sketch or diagram of the sensor (or sensor array), the sensor ID number, the date it was installed, all relevant baseline information, the GPS coordinates, elevation, and

other important installation details. Complete a new installation data sheet for any repaired or replaced sensor (or sensor array).

D. Wiring Diagrams.
Submit a completed wiring diagram for each monitoring station, within 2 weeks of the final connections. Each wiring diagram shall include a photograph and/or diagram of the ADAS component, with cables and wires labeled according to the unique instrumentation ID, and other important details. Include a physical copy of each wiring diagram in the respective protective enclosure.

E. Monitoring Data.
Maintain the ADAS such that the Engineer can access data at any time, to download or view; eliminating the need for reporting. The Geotechnical Instrumentation Engineer shall coordinate a training meeting to facilitate online access, use of online platform, and guide the Department to manually enter surveyed settlement plate data. All monitoring data shall be available for archival viewing or download until 6 months after instrumentation has been removed from the project (or until successful online transfer to the Department).

150726a.03 PRODUCTS.

A. General.
Warranties and guarantees on new materials and equipment shall apply to the items furnished by the Contractor. It will be the Contractor's responsibility to obtain all the necessary instrumentation, related appurtenances, protective systems, monitoring equipment, and available documentation. The Contractor is advised that there is often a "lead time" for the manufacturing and shipping of instrumentation and associated monitoring equipment.

B. Piezometers.

1. Vibrating Wire Piezometers.
Vibrating wire piezometers shall be standard, groutable, unvented, with stainless steel filters, and shall be Model 4500S as manufactured by Geokon, Inc., Model VW2100 as manufactured by RST Instruments, Ltd., Part number 52611030 as manufactured by Durham Geo Enterprises, Inc., or approved equal. The vibrating wire piezometer manufacturer shall have ISO 9001:208 certification. The vibrating wire piezometers shall fulfill the following requirements:

Technical Specifications:	***Minimum Requirements:***
Standard Range	50 psi
Over Range	2 x rated pressure
Resolution	0.025% F.S.
Accuracy	± 0.1% F.S.
Nonlinearity	< 0.5% F.S.
Temperature Range	-20°C to +80°C
Length x Diameter	133 x 19.1 mm (maximum size)

2. Vibrating Wire Piezometer Communication Cables.
Vibrating wire piezometer communication cables shall consist shielded cable with four 22-gauge tinned-copper conductors within a polyurethane jacket, as recommended, supplied, and connected to the sensor by the vibrating wire tiltmeter manufacturer.

3. Tremie Pipe.
Tremie pipe shall consist of PVC (1 inch minimum diameter) with factory threaded flush joints, and will be used to both grout the boreholes from the bottom up and set the VW piezometers tip-down (adhered to the outside of the tremie pipe) at their specified depths.

4. Cement-Bentonite Grout.
In order to support the "fully grouted" method for vibrating wire piezometer installation, cement-bentonite grout shall be composed of a mixture of water, Portland cement, and bentonite. Based off known soil conditions for this Project, and extrapolating from the "Grout for Soft Soils" details in Table 1, of P.E. Mikkelson and G.E. Green's FMGM paper entitled "Piezometers in Fully Grouted Boreholes", the grout mixture shall meet:

	Grout for Soft Soils	
Materials	Weight	Ratio by Weight
Water	75 gallons	6.6
Portland Cement	94 lbs. (1 sack)	1
Bentonite	39 lbs. (as required)	0.4
Notes	When placed, cement-bentonite grout shall be in colloidal form attained by high speed mechanical mixing. Borehole grouted from bottom, filled to top.	

C. ShapeArrays.

1. ShapeArrays.
ShapeArrays shall consist of rigid segments separated by flexible joints comprised of triaxial MEMS gravity sensors. The SAA manufacturer shall have ISO 9001:208 certification. The SAAs shall fulfill the following requirements:

Technical Specifications:	***Minimum Requirements:***
Segment Length	500 mm
Joint diameter	19 mm
Waterproof	2000 Kpa (200 m water)
Temperature Range	-35°C to +60°C
Angular range of MEMS sensors	± 360°
Deformation accuracy	± 1.5 mm for 32 m SAA
Long-term reliability MTBF	38 years for 32 m SAA
Notes:	Horizontal Installation, housed within 2 inch, Schedule 80, PVC conduit

2. ShapeArray Communication Cables.
SAA communication cables shall be shielded with waterproof jacket, as manufactured and supplied by the SAA manufacturer, with an Amphenol connector to connect directly to the THREAD.

3. Conduit.
Conduit that the SAA will be inserted horizontally within shall consist of 2 inch, Schedule 80, gray PVC electrical conduit with bell ends. End caps shall consist of gray PVC, designed to cap 2 inch, Schedule 80 gray PVC electrical conduit. Conduit, including end caps, shall be connected using PVC primer and cement (or approved combination) manufactured for gray PVC electrical conduit, and allowed proper set times prior to SAA installation. Conduit shall be placed according to the Drawings and manufacturer recommendations.

4. SAA Install Kit.
SAA installation kit shall be supplied by the SAA manufacturer, including adapters for 2 inch conduit installation, and reference end assembly (near-end) to permit secure mounting and survey confirmation.

D. Settlement Plates.
Settlement plates shall be installed as the embankment construction is completed, and consist of a 24 inch by 24 inch, 3/4 inch thick section of plywood, with a standard black 3/4 inch floor flange

will be bolted to the center, according to the Standard Specifications. A riser pipe consisting of a 3/4 inch inner diameter steel threaded rod (5 foot section) will be mounted to the floor flange, with additional riser pipes (of same dimensions and detail) and couplings used as necessary. Plastic sleeves will be placed around the riser pipes, from the settlement plate to above grade.

E. Vibrating Wire Analyzer.

The portable vibrating wire analyzer, used for gathering baseline readings, shall be manufactured by Campbell Scientific, GEOKON, or approved equivalent. The VWA shall be available on site throughout the monitoring period for manual confirmation, as directed by the Engineer.

F. Monitoring Stations.

1. General.

Each instrumentation cross-section shall include one monitoring station, consisting of a pole-mounted assembly of hardware for automated embankment monitoring. Each monitoring station shall consist of three major monitoring-related products (and related appurtenances): a solar panel, a VW datalogger, and a THREAD.

2. Solar Panel.

The ready-to-mount solar panel, supplied by the THREAD manufacturer, shall utilize renewable energy to power the THREAD (which will in turn power the VW datalogger) at each monitoring station.

3. VW Datalogger.

Manufactured and quality tested through ISO 9001:2015, the VW datalogger, shall comprise a self-contained, 4-channel logger, connecting to the vibrating wire instrumentation installed beneath the embankment via their communication cable leads routed to the monitoring station. The VW datalogger shall be manufacturer-modified to connect to, and immediately transmit vibrating wire measurements to, the THREAD.

Technical Specifications:	***Minimum Requirements:***
Measurement Accuracy	±0.05% F.S. (450-4000 Hz)
Measurement Resolution	1 part in 20,000
Program Memory	24K Flash
Data Memory	320K EEPROM
Temperature Range	−30°C to +50°C
L × W × H	260 × 160 × 91 mm
VW Channels	4
Power	Direct connection to THREAD
Notes:	Must be customized by the manufacturer to connect to THREAD

A VW Datalogger-to-THREAD cable is required for each Monitoring Station.

4. THREAD.

The THREAD shall connect to the VW datalogger—and power the GEOKON datalogger—while also automatically collecting the vibrating wire measurements immediately. Utilizing its second port, the THREAD shall also connect directly to the ShapeArray, and automatically collect those measurements immediately as well. Next, the THREAD, through its wireless/cellular antennas, shall transmit instrumentation data through a wireless mesh and/or cellular network to the cloud, whereby data is automatically, immediately, and remotely reduced, presented, and accessible via a secure, web interface hosted by Sensemetrics and managed by the Geotechnical Instrumentation Engineer.

G. Automated Data Acquisition System.

1. **Monitoring Station components.**
   The hardware required for the Automated Data Acquisition System (ADAS), including the solar panels, VW Dataloggers, and THREADs, is specified in the previous section.

2. **Sensemetrics Platform.**
   - **a.** The Sensemetrics cloud-based platform shall automatically retrieve the measurements collected on site by the VW Datalogger and THREAD, and immediately populate the online interface with near-real time data. The browser-based software interface shall be configured to communicate with each THREAD and calibrated according to sensor calibration certificates, baseline readings, and measured sensor elevations, such that measurements will be automatically reduced and presented in graphical and tabular form.
   - **b.** Monitor the online platform throughout construction through project completion through the warranty period. Decommission and archive the online platform such that the Department can access instrumentation data for up to 1 year later (or until successful online transfer of data to the Department).

150726a.04 CONSTRUCTION.

A. Preparation.

1. **Confirmation testing.**
   Prior to arrival on site for installation, inspect and test all received instrumentation, cables, and appurtenances for proper operation in accordance with the procedures recommended by the respective manufacturers. Immediately repair (or replace) any improper sensor function, or lack of continuity in the communication cables, in accordance with manufacturer recommendations, and as approved by the Engineer. Similarly inspect and test, and if required, repair (or replace), Dataloggers, modems, readout devices, and appurtenances shall be. No additional time will be granted for any delays due to replacing/repairing damaged instrumentation or related components. Include confirmation testing results in each submitted Installation Record.

2. **Location.**
   Stake or mark (and measure) the prospective (and installed) location of all instrumentation, with GPS coordinates recorded to the nearest 0.1 foot, and elevation survey accuracy to the nearest 0.01 foot.

B. Installation.

1. **General.**
   The Geotechnical Instrumentation Engineer, specifically their professional geotechnical engineer registered in the State of Iowa, shall oversee all installations of vibrating wire piezometers, ShapeArrays, and Monitoring Stations. Coordinate instrumentation installation, protection, and maintenance activities with the remainder of the work. Unless otherwise approved by the Engineer, the installation of instrumentation relative to the construction sequence shall satisfy the requirements for items detailed herein and on the contract documents.

2. **Sequence.**
   - **a. General.**
     - **1)** The Sequence is where instrumentation fits into the bigger picture of the Project; a chronology of various construction activities surrounding the various instrumentation installations. The subsequent section, Procedure, will describe the specific sequence (procedure) of the various instrumentation installations themselves.
     - **2)** Instrumentation installation activities are required at two distinct junctures during embankment construction and will need to fit into the general construction sequence as detailed chronologically below, in order to provide the Contractor and Department

with meaningful instrumentation data. The State has the right to refuse payment for any instrumentation not installed at the appropriate juncture. The same general sequence applies to each instrumentation cross-section.

b. Before the Embankment is Constructed.

1) Subgrade corrections (i.e. topsoil removal, pavement removal, subcuts, etc.).

2) Wick drain installation and placement of drainage sand layer above subgrade soils.

3) Automated instrumentation (VW piezometers and ShapeArray) installation, including drilling, instrumenting boreholes, installing SAA anchor and monitoring station, and trenching in conduit and cable runs (avoiding wick drains).

4) Automated data acquisition system (ADAS) testing; fully functional via the Sensemetrics online platform. Trench backfilled. ADAS tested again.

5) Hold period of at least 24 hours for fully grouted boreholes to set up; confirmed by piezometer measurement trends via online platform. The Engineer will give go-ahead.

6) Additional fill placement above the instrumentation, and on top of the drainage sand layer. Construction traffic shall exercise caution within 2 vertical feet above instrumentation sensor locations and conduit. Advance fill placement is acceptable in areas 100 feet away from each GIMP cross-section. Protect monitoring station and immediate surroundings.

c. After the Embankment is Constructed.

1) Embankment construction continuing above automated embankment instrumentation, lift by lift.

2) Within 24 hours of the last lift placed to complete the embankment construction, final instrumentation (settlement plates) installation and immediate surveying.

3) Waiting period commencement for embankment and/or preload monitoring, with ongoing surveying.

3. Procedure.

a. General.

1) The installation procedures for all instrumentation and monitoring systems shall abide by the following, listed in order of precedence:

- Instructions and recommended best practices provided by the respective instrumentation and/or monitoring system manufacturer.
- The contract documents
- The Instrumentation Methods Statement (IMS)
- Project experience of the Geotechnical Instrumentation Engineer

2) The following discussion has been arranged per the Sequence section above (chronologically), highlighting the two distinct junctures and the two sets of instrumentation installations accordingly.

b. Borings.

1) Drill borings at the three piezometer locations within each instrumentation cross-section (beneath the centerline, beneath edge of embankment, beneath midpoint of embankment slope)

2) Drill borings to a nominal depth of 30 feet

3) Log borings, with boring logs submitted with their respective instrumentation installation record per ASTM D2488 standard with sampling at 5 foot intervals.

4) Each boring will contain one VW piezometer (six total)

c. VW Piezometers.

1) Install VW piezometers 25 feet below the ground surface (or as directed by the Engineer based off boring conditions), according to the contract documents and the manufacturer's recommendations, and any modifications proposed (and accepted by the Engineer) in the IMS.

2) Install VW piezometers per the fully grouted method, per the ratio below and on the contract documents.

	Grout for Soft Soils	
Materials	Weight	Ratio by Weight
Water	75 gallons	6.6
Portland Cement	94 lbs. (1 sack)	1
Bentonite	39 lbs. (as required)	0.4
Notes	When placed, cement-bentonite grout shall be in colloidal form attained by high speed mechanical mixing. Borehole grouted from bottom, filled to top.	

3) Immediately record baseline readings prior to installation using the VW Analyzer.
4) Affix piezometers to the tremie pipe at a location correlating to approximately 25 feet deep, prior to grouting the borehole.
5) Record piezometer depths to the nearest 0.1 foot, including measurement from bottom of tremie pipe to affixed piezometer. Record tremie pipe quantity and lengths installed within borehole. Do not cut or modify any tremie pipes during/after installation
6) Grout borehole from the bottom to top. Abandon tremie pipe (with piezometer attached) in place. Top off borehole with grout if subsidence occurs.
7) Once borehole grout sets up, survey top of tremie pipe for elevation to the nearest 0.1 foot, in order to back calculate installed piezometer elevation. All relevant measurements and baseline readings to be included on Installation Records.
8) Run communication cables from each piezometer through separate protective schedule 40, 2 inch conduit to the monitoring station, and connect to the VW dataloggers.
9) Embed protective conduit at least 2 feet below the finished ground surface, and feature strain-relief measures for both the cable and the conduit.

d. ShapeArrays.

1) Install ShapeArrays according to the contract documents and the manufacturer's recommendations, and any modifications proposed (and accepted by the Engineer) in the IMS.
2) Install one ShapeArray at each instrumentation cross-section:
- Ramp E: Approximately 90 feet in length
- Ramp F: Approximately 150 feet in length

3) Pull each ShapeArray through schedule 80 conduit (no other conduit shall be within 6 inches laterally), and set into the bottom of a sandy bottom, leveled shallow trench that spans from the future centerline (far end) to outside of the embankment toe (reference end).
4) Connect the reference end to a foundation element, such that it will not move throughout the monitoring period.
5) Drill at least a 6 foot deep borehole at the reference point, backfill the bottom 3 feet with concrete, and place (in the wet) a metal pipe for anchoring the ShapeArray's reference end.
6) Fasten the ShapeArray to, and seal within, the conduit, then fasten to the galvanized anchor mechanism.
7) Connect the SAA communication cable to the monitoring station.
8) As soon as the ShapeArray is determined to be functional via the online platform of the ADAS, backfill the shallow trench.
9) Survey the SAA Reference End monthly, or more frequent if Reference End movement is suspected.
10) Retain empty SAA reels for decommissioning.

e. Settlement Plates.

1) Install settlement plates according to the contract documents, located directly above the instrumented boreholes.
2) Install settlement plates on a level (sandy) surface, at the bottom of a small 2 to 3 foot deep excavated hole (only deeper if the embankment will sit during winter months).

3) Immediately backfill the hole as soon as the settlement riser pipes, and plastic pipes surrounding them, are determined to be plumb.

4) A survey crew shall be on site during installation to immediately record the baseline readings and surrounding grade elevation.

f. Monitoring Station & ADAS.

1) Install monitoring stations according to the contract documents and the manufacturer's recommendations.

2) Confirm field hardware connections to online platform configurations

3) Manually input settlement measurements into online platform within 48 hours of surveying

150726a.05 MONITORING & MAINTENANCE.

A. General Maintenance.

The Contractor shall be responsible for all instrumentation maintenance, repairs, and replacements to ensure all instrumentation and monitoring systems are in proper working order and fully operational throughout the monitoring period, up until 6 months following substantial completion of the abutment. The instruments and appurtenances shall be checked for proper operation in accordance with the procedures recommended by the respective manufacturers, or to the discretion of Engineer. Any instrumentation, ADAS components damaged by the Contractor, its Subcontractors, or others (i.e. from vandalism, weather, flooding, negligence, etc.), shall be immediately repaired or replaced at no cost to the State. The Engineer reserves the right to halt construction until non-working instrumentation and/or monitoring systems are repaired or replaced (Contractor is encouraged to keep extra sensors, spare components, and supplies on site). Instrumentation may only be decommissioned/transitioned as approved by the Engineer.

B. General Monitoring.

The Contractor and Geotechnical Instrumentation Engineer shall be responsible for monitoring all instrumentation at specified intervals, evaluating all instrumentation data, assisting decisions regarding instrumentation data, providing written recommendations, and immediately notifying the Engineer if there are data threshold exceedances, or if the ADAS has not been fully operational for a defined period of time. During construction, the Engineer will independently verify the construction instrumentation on an ongoing basis. Verification will include evaluation of the readings with respect to historical and/or anticipated readings, observe data trends, respond to the notification group concerning validity of automated alarms and/or instrumentation readings, and to immediately halt construction activities where necessary if a valid action level alarm has been exceeded (only permitting construction activities following Contractor corrective action acceptable to the Engineer or the Department accepts the risk of proceeding with given conditions). Following construction, and during the warranty period, the Engineer will independently verify the Contractor's performance instrumentation on a monthly basis.

C. Reading Frequencies.

In the absence of unusual events, the Contractor will be responsible for monitoring all instrumentation at the frequencies presented below. The Engineer reserves the right to increase or decrease reading frequencies at any time, requiring the Contractor to reprogram the dataloggers and online platform within 24 hours.

Instrument	***Reading Frequency*** *(beginning at midnight)*
VW piezometers and SAAs	1 hour

D. Notification Group.

Designated Project personnel deemed the "Notification Group" will be identified upon commencement of the project, and are subject to receiving the automatic notifications and reporting, and. At a minimum, the Notification Group shall consist of two personnel each from the following parties: Contractor, Instrumentation Consultant, and Engineer.

E. Online Platform Configuration.
Customize the online interface to include the following:

1. A map/plan, including project elements and sensor locations (that point to respective data graphs)

2. SAA graphs, plotting settlement vs. time (with ability to toggle between normal time and logarithmic time)

3. VW Piezometer graphs, plotting piezometric head (elevation in feet) vs. time (with ability to toggle between normal time and logarithmic time)

4. Monitoring Station diagnostic graphs, including voltage, temperature, barometric pressure vs. time

5. Automatic alerts consisting of automatic emails to the Notification Group, triggered by either data outages (any ongoing interruption longer than 12 hours for any sensor) and data thresholds

6. Notation on graphs of embankment construction filling and waiting periods, and other noteworthy items post-construction

7. Automatic weekly reports for the SAAs and VW piezometers, including graphs (both normal and logarithmic time)

150726a.06 DECOMMISSIONING.
Maintain automated instrumentation and monitoring systems until 6 months following substantial completion of the abutment, or as directed by the Engineer, whichever is sooner. Written authorization from Engineer is required before any decommissioning may occur.

A. Instrumentation.
Remove both ShapeArrays and cabling, according to manufacturer recommendations, and deliver to the Department.

B. Monitoring Station.
Remove both Monitoring Stations, and deliver solar panels, VW Dataloggers, THREADs, and interconnecting cables to the Department. Remove, or cut flush with grade, exposed metal mounting pole, conduit, and VW cables.

C. Online Platform.
All automated data shall be available for viewing or download until 6 months after monitoring station decommissioning, or until successful virtual archival or transfer to the Department, whichever is sooner.

150726a.07 METHOD OF MEASUREMENT.
Measurement for Instrumentation and Monitoring will be lump sum.

150726a.08 BASIS OF PAYMENT.

A. Payment for Instrumentation and Monitoring will be at the contract unit price per lump sum.

B. Payment is full compensation for:
- Authoring required submittals
- Procuring all instrumentation, monitoring systems, and related appurtenances
- Installing all instrumentation, monitoring systems, and related appurtenances, including, but not limited to, vibrating wire piezometers, ShapeArrays, settlement plates, monitoring stations,

and a remote sensing, real-time, automated data acquisition system (ADAS)

- Protecting, maintaining, and monitoring all instrumentation, monitoring systems, and related appurtenances
- Troubleshooting, repair, and replacement of instrumentation, monitoring systems, and related appurtenances
- Initial set-up and ongoing service fees for online platform of ADAS
- Configuration of online platform of ADAS
- Data evaluation, analysis, reporting, communication, recommendations, and engineering time related to instrumentation data
- Decommissioning all instrumentation, monitoring systems, and related appurtenances

C. Settlement plate installation shall be compensated per Article 2106.05 of the Standard Specifications.