

GEOTECHNICAL INSTRUMENTATION

**\*\*From Cornwall BRS 0172(6)**

- xx. DESCRIPTION. This work shall consist of furnishing, installing, and maintaining Type I settlement platforms, vibrating wire piezometers, and inclinometers in conformance with the design shown in the Plans, at the locations indicated in the Plans and as directed by the Engineer.
  
- xx. GENERAL REQUIREMENTS. Data obtained from the Contractor's observations of the response of these instruments, in concert with the other data, will give the Engineer a measure of how much settlement and lateral movement has occurred and how much more can be anticipated. Settlement data, interpreted by the Engineer, together with inclinometer data will provide the Engineer with information for analysis as to whether or not the embankment is performing as anticipated. The Contractor's attention must be directed at proper installation, protection of installed equipment, and coordination of this sensitive work with other construction activities. The Contractor should monitor the geotechnical instrumentation a minimum of once per day during filling activities and weekly thereafter, or as ordered by the Engineer. Field reports summarizing the geotechnical instrumentation results should be submitted to the Engineer weekly.
  
- xx. MATERIALS. Materials shall meet the requirements of the following Subsections:

Sand Borrow.....	703.03
Miscellaneous Hardware.....	709.01
Nonstructural Lumber.....	709.02
Timber Preservative.....	726.01
PVC Tubing.....	740.02
Steel Pipe, Galvanized.....	740.05
High Density Overlaid Plywood.....	750.06

Cement grout shall consist of a mixture of 1 liter (0.25 gallon) of high yield sodium Bentonite clay (dry), 28 liters (7.5 gallons) (1 bag) of cement, and 66.6 liters (17.6 gallons) of water.

Bentonite grout shall consist of a mixture of 5 liters (1.3 gallons) of high yield sodium Bentonite clay (dry), 28 liters (7.5 gallons) (1 bag) of cement, and 66.6 liters (17.6 gallons) of water.

Bentonite seal shall consist of a mixture of 11.4 liters (3 gallons) of high yield sodium Bentonite clay (dry) and 53 liters (14 gallons) of water.

The bentonite seal or grout shall be mixed in such a manner and at such a time that the swelling of the bentonite mixture shall occur with the material in place within the hole.

- (a) Settlement Platform, Type I. The following materials are required for Settlement Platform, Type I:

- (1) The riser pipe for settlement platforms shall be 76 mm (3 inch) I.D. standard weight pipe conforming to Subsection 740.05.

- (2) All lumber for settlement platforms shall be pressure treated in conformance with Subsection 726.01. All plywood for settlement platforms shall conform with Subsection 750.06. Plywood shall be treated for soil contact retention in accordance with APR C-9.

(b) Inclinometer. The following materials and equipment are required for the Inclinometer:

- (1) Inclinometer Casing. An 85 mm (3.34 inch) O.D., 72.9 mm (2.87 inch) I.D. ABS plastic inclinometer casing fabricated with four internal, longitudinal grooves, precisely manufactured to fit the wheel dimensions of the inclinometer sensor. The inclinometer casing shall consist of self-aligning casing quick-connect or coupling sections, couplings compatible with casing, pop rivets, and end caps.

The inclinometer casing material shall be supplied by one of the following manufacturers:

DGSI	Durham Geo Slope Indicator Co.
Standard Casing	12123 Harbour Reach Drive
QC Casing	Mukilteo, WA 98275
	Tel.: (866)916-0541
	<a href="http://www.slopeindicator.com">www.slopeindicator.com</a>

Roctest	Roctest, Inc.
Model ICA-2000	Joe Church
Model GEO-LOK	<a href="mailto:joe.church@roctest.com">joe.church@roctest.com</a>
	Tel.: (843)754-4769
	<a href="http://www.roctest.com">www.roctest.com</a>

RST Instruments, Ltd.	RST Instruments, Ltd.
Standard Casing	200-2050 Hartley Ave.
Snap Seal Casing	Coquitlam, BC
	Canada V3K 6W5
	Tel.: (800)665-5599
	<a href="http://www.rstinstruments.com">www.rstinstruments.com</a>

- (2) Carrying Case. A metal carrying case shall be furnished with each probe. This carrying case shall provide the probe protection, both during storage and during transportation to and from the measuring site, from incidental damage and excessive mechanical shock and vibrations.
- (3) Inclinometer Suspension Cable. The inclinometer suspension cable shall be of adequate length so that it may be used for all inclinometer holes on the project. The inclinometer suspension cable shall be a continuous length with no splices or other defects. The limits of its outside diameter shall be 10.6 mm (0.42 inch). It shall have a continuous unspliced stranded core and one-piece waterproof neoprene jacket for its entire length. The suspension cable shall contain adhesive layers between the stranded steel core, the individual electrical conductors, and the neoprene jacket to prevent creep and lap during

use. The cable shall be marked at 0.1 m (1 inch) increments by means of external colored bumps vulcanized to the external neoprene jacket.

The 1 meter (1 foot) marks shall be of a different color than the 0.1 meter (1 inch) marks. The external marks shall indicate the distance from the measuring point on the pulley assembly at the casing color to the midpoint between the wheel assembly axes on the inclinometer probe.

- (4) Cable Reel. The cable reel shall be a handcrank-operated cable reel assembly capable of holding the inclinometer cable described earlier.

The reel is to include a protective case and all mechanical and electrical connectors, with protective covers needed to operate the inclinometer system. The reel shall be of such design as to allow operation of the inclinometer system while the drum is rotating.

All mechanical and electrical components of the cable reel are to be accessible for field servicing.

The cable reel shall be a Durham Slope Indicator Company model No. 50503100 Slip-Ring Reel, or approved equal.

- (5) Inclinometer Readout. The Contractor shall supply the Engineer a computerized readout capable of obtaining inclinometer data, processing checksum statistical routines, and storing data for each inclinometer installation.

The inclinometer readout shall be as supplied by the following supplier, or approved equal:

DGSI	Durham Geo Slope Indicator Co.
Digitilt Datamate II	12123 Harbour Reach Drive
	Mukilteo, WA 98275
	Tel.: (570)437-2744
	www.slopeindicator.com

- (6) Software. The Contractor shall supply software which will be capable of reducing raw data from the DGSI Digitilt Datamate II, or approved equal.

The software shall be capable of performing the following requirements:

- a. Operate with Microsoft Windows 95 or higher.
- b. Import data from the DGSI Digitilt Datamate II, or approved equal.
- c. Provide tabular output.
- d. Provide graphical output to windows compatible printers.

The software shall be supplied by the following supplier, or approved equal:

DGSI  
DigiPro

Durham Geo Slope Indicator Co.  
12123 Harbour Reach Drive  
Mukilteo, WA 98275  
Tel.: (866)916-0541  
www.slopeindicator.com

The Contractor shall repair or replace, if necessary, and otherwise maintain the readout system for the duration of the Contract.

(c) Vibrating Wire Piezometer. The following materials will be required for Piezometer, Vibrating Wire:

- (1) Transducer. A vibrating wire piezometer consists of a transducer capable of transforming a piezometric pressure into resonant frequencies which can be transmitted and displayed. The piezometers shall have an average accuracy of 0.50 percent over its entire range of 0 to 689 kPa (100 lb/in<sup>2</sup>) with a resolution to 0.1 percent of full scale. The size of the transducer shall not exceed 19 mm (0.75 inch) in diameter by 124 mm (4.875 inches) in length. Calibration data shall be provided with each instrument. The transducer shall be capable of operation in temperatures from -28 to 60°C (-20 to 140°F) and have thermal constant of 2 minutes per degree of Celsius.

The transducer shall have an overpressurization capability of 200 percent. Each piezometer shall be provided with a 50-micron sintered stainless steel filter. All materials shall be stainless steel except as otherwise specified or recommended by the manufacturer.

The interior shall be hermetically sealed to provide a stable, inert atmosphere around the wire to ensure long life of the gauge. Each piezometer shall be equipped with a thermistor with a range of -51 to 60°C (-60 to 140°F) with an accuracy of +/-1°F and a thermal shift corrected to 0.002 percent full scale per degree Fahrenheit. A 762 mm (30 inch) long cloth bag with drawstring that will encase the cell shall be furnished with each cell.

- (2) Readout Device. The vibrating wire readout device shall be supplied by the same manufacturer as the vibrating wire piezometer. It shall be capable of reading pore pressures to 689 kPa (100 psi) with a resolution of 0.1 HZ and provide digital display. A battery charger that is capable of recharging the unit's battery from a 110-volt, alternating current source shall be provided. Leads capable of attaching to the connectors on the piezometer electrical cable shall be provided by the Contractor for connecting the readout to the leads on the vibrating wire piezometers.

The Contractor shall supply the Engineer a vibrating wire readout system with a minimum resolution of 0.01 microseconds and a minimum 5 digit display.

- (3) Conductor. Each vibrating wire piezometer shall be furnished with a thick vinyl jacketed 4-conductor (2 pair), color coded, 22 gauge cable of sufficient length in order that there will be no splices or connections except at the cell and Field Control Station, or as ordered by the Engineer. The color coding of each cable shall be the same. The length of each cable shall have a minimum allowance of 10% slack plus and additional 3 meters (10 feet). The conductors shall be solid wire of commercially annealed copper. The conductor shall meet the requirements of ASTM Designation B3-69. Each cable shall be attached to the appropriate piezometer cell and permanently marked with the number of the instrument to which it is attached. The markings shall be every 3 meters (10 feet) over the length of the cable and shall be applied by the manufacturer prior to shipment to the construction site. Each cable shall be mounted on a reel and protected to prevent damage during shipping. Each reel shall be stenciled or labeled with the name of the instrument. Only new, unused cable will be accepted.

The vibrating wire piezometer and readout device shall be supplied by one of the following manufacturers:

Geokon  
VW Piezometer Model 4500S  
Readout Box model GK-403

Geokon, Inc.  
48 Spencer St.  
Lebanon, NH 03766  
Tel.: (603)448-1562  
[www.geokon.com](http://www.geokon.com)

DGSI  
VW Piezometer order # 52611030  
VW Quatro Logger order# 52614020

Durham Geo Slope  
Indicator Co.  
12123 Harbour Reach Drive  
Mukilteo, WA 98275  
Tel.: (866)916-0541  
[www.slopeindicator.com](http://www.slopeindicator.com)

Roctest  
VW Piezometer Model PWS  
VW Readout Model MB-6TL

Roctest, Inc.  
Joe Church  
[joe.church@roctest.com](mailto:joe.church@roctest.com)  
Tel.: (843)754-4769  
[www.roctest.com](http://www.roctest.com)

The Contractor shall repair or replace, if necessary, and otherwise maintain the readout system for the duration of the Contract. Please note the Field Control System shall be maintained after the removal of the temporary detour embankments. The Contractor may have to relocate the Field Control System during and after the removal of the temporary detour embankments.

- xx. INSTALLATION. The Contractor shall submit to the Engineer for approval an installation schedule, instrumentation installation procedures, and

a complete listing of materials a minimum of 3 weeks prior to installation.

All geotechnical instrumentation locations shall be surveyed, in both location and elevation, prior to, and after, installation.

The following are the basic drilling requirements for installation of the geotechnical instrumentation:

Drilling personnel shall have three years experience in installing geotechnical instrumentation. A qualified geotechnical engineer shall oversee the installation of all geotechnical instrumentation.

The Contractor shall utilize a grout pump and tremie pipe capable of delivering both grout types to a depth of 26 meters (85 feet).

Approximate vibrating wire piezometer sensor elevations are provided on the Plans for estimating purposes only. Actual installation elevations will be determined by the Engineer based upon actual soil conditions.

Only flush-jointed casing shall be used for installation of the geotechnical instruments. Hollow-stemmed augers will not be permitted.

Boreholes shall be cased continuously. "Open-holed" or "mudded" borings will not be permitted.

The minimum casing inside diameter for each instrument shall be as shown in the Plans.

The maximum borehole deviance from vertical shall be 2 degrees.

Standard penetration testing (SPT) shall be performed in accordance with ASTM D 1586. Intervals will be as determined by the Engineer. The following are the estimated SPT's and split spoon samples for each instrumentation component:

Pay Item	Estimated No. of SPT's Per Location
Piezometer, Vibrating Wire	5
Inclinometer	13

No additional compensation will be provided if more SPT's or split spoon samples are required.

The Contractor shall place the split spoon samples recovered from each hole in new, large-mouth, round, clear glass jars.

The hole number and sample recovery depth shall be clearly marked on each jar and the cap. The recovered samples shall then be given to the Engineer for storage.

When withdrawing the drill casing during instrument installation, care shall be taken to minimize the increments and rate of casing withdrawal so that collapse of the borehole does not occur, and to ensure that material does not build up inside the casing as the casing is withdrawn. The casing shall be withdrawn without rotation.

The Contractor shall provide a log of each soil test boring and a record of the configuration of the installed instrumentation installation.

- (a) Settlement Platform, Type I. Settlement Platform, Type I shall be placed at the locations indicated on the plans or as directed by the Engineer.

The base of the Type I settlement platform shall be covered with one foot of sand borrow prior to proceeding with the embankment construction.

The riser pipes shall be accurately and consecutively numbered in 0.1 meter (1 inch) intervals from the bottom of the settlement platform. The number and graduations shall be marked on the riser pipes by scoring the riser pipe with a pipe cutter and marking the score mark and graduations with quick-drying yellow paint immediately after each section of pipe is added. Lengths of pipe shall be added as the embankment progresses and shall be of sufficient length to reach at least 0.5 meter (18 inches) above the existing surface of the embankment at all times. The Type I settlement platform shall be protected against damage from vehicles by timber bollards as shown in the Plans.

The Contractor shall maintain and keep in good order all settlement platforms and shall notify the Engineer immediately of all repairs to or restorations of damage to disturbed settlement platforms.

All embankment construction in any locations where a settlement platform has been disturbed or damaged shall be halted until the Engineer has been notified and the necessary maintenance has been performed.

When the embankments have been completed, the Contractor shall cut off and cap the riser pipe at an elevation designated by the Engineer.

The riser pipe shall be installed in approximately 1.5 meter (5 foot) lengths.

If the wood base option is selected, a 300 mm by 300 mm by 6 mm (12 inch x 12 inch x 1/4 inch) thick steel plate shall be provided under the plywood, centered on the riser pipe as a bottom flange for the bolted connection.

All hardware and bolts shall be galvanized in accordance with AASHTO M 111M/M 111.

Any section of riser pipe damaged or bent during the Contract period shall be immediately removed and replaced at the Contractor's expense.

- (b) Inclinometer. Inclinometers and bore hole casings shall be installed at the locations indicated in the Plans or as directed by the Engineer in accordance with the manufacturer's instructions.

The bore hole casing shall be installed at the locations indicated on the plans or as directed by the Engineer and installed in accordance with the manufacturer's instructions.

The bore hole casing shall extend 5 meters (16 feet) into the underlying dense sand and gravel or as directed by the Engineer.

The casing shall be slowly withdrawn while bentonite grout is placed in the bore hole until the bore hole is completely full.

Care shall be taken to ensure that the inclinometer casing is held in alignment and position during grouting operations.

The inside of the inclinometer casing shall be thoroughly flushed after the bentonite grout has set up to remove any grout or sediment. After flushing has been completed, approximately one liter (one quart) of sand borrow shall be placed in the bottom of the casing.

The exposed portion of the inclinometer casing shall be painted fluorescent orange and the inclinometer number stenciled in black on the casing.

The inclinometer shall be protected against damage from vehicles by timber bollards as shown in the Plans. Inclinometers shall be maintained by the Contractor for the duration of the project.

When an inclinometer becomes damaged or inoperable, all embankment construction operations shall cease unless otherwise ordered by the Engineer. The Engineer shall determine if replacement is required or if sufficient information has been obtained and the installation may be abandoned. Embankment construction may resume upon written authorization by the Engineer.

- (c) Vibrating Wire Piezometer. Piezometers shall be installed at the locations indicated in the Plans or as directed by the Engineer in accordance with the manufacturer's instructions. Piezometers shall be installed a minimum of one week before the installation of impact displacement piers and/or prefabricated vertical wick drains to obtain baseline readings.

The Contractor shall use personnel experienced with the installation of piezometers.

During the drilling of the bore hole, standard penetration tests (SPT) and split spoon samples shall be conducted at intervals determined by the Engineer to verify that the piezometer will be located in the organic silt or silt and clay strata.

The bore hole should extend a minimum of 300 mm (12 inches) below the proposed piezometer tip elevation and should be washed clean of drill cuttings. The bottom of the boreholes should then be backfilled with clean, fine sand to a point 50 mm (6 inches) below the piezometer tip. The piezometer shall be encapsulated

in a canvas cloth bag containing clean, saturated Ottawa sand prior to lowering the piezometer into the bore hole.

After the piezometer cell has been installed, the Contractor shall withdraw the casing 600 mm (2 feet) while placing 600 mm (2 feet) of sand borrow. The Contractor shall then grout the remainder of the hole by lowering the drill rods to the layer of sand and slowly pumping the bentonite grout through the rods so that any water in the drill hole is expelled completely.

The casing shall be removed after the grout has been placed to within 1.5 m (5 feet) of the ground surface. As the casing is being withdrawn from the hole, additional grout shall be placed to ensure that the grout remains within 1.5 m (5 feet) of the ground surface.

The signal cable shall be positioned so that the cable will exit the borehole in a broad sweep. The cable shall be placed in a 600 mm x 600 mm (2 feet x 2 feet) trench to the Field Control Station. The trench shall be backfilled with sand borrow and compacted to protect the cable.

Each cable shall be clearly marked at the Field Control Station by means of a stamped metal tag.

Piezometers shall be maintained by the Contractor throughout the duration of the project. When a piezometer becomes damaged or inoperable, all embankment construction operations within 30 m (100 feet) of the installation shall cease unless otherwise ordered by the Engineer. The Engineer shall determine if replacement is required or if sufficient information has been obtained and the installation may be abandoned. Embankment construction may resume upon written authorization by the Engineer.

All geotechnical instrumentation shall be in place and accepted by the Engineer prior to proceeding with embankment construction.

xx. MAINTENANCE. The Contractor shall maintain the geotechnical instrumentation equipment for the duration of the project and shall repair or replace any such equipment which fails to function properly.

Any instrumentation that becomes damaged or inoperable through no fault of the Contractor and requires replacement shall be replaced and paid for at the unit price bid for the respective instrumentation.

Any instrumentation that becomes damaged or inoperable as a result of the Contractor's operations shall be replaced by the Contractor at no cost to the State.

The liability of the Contractor under this Contract is absolute and is not dependent upon question of negligence on the part of the Contractor or the Contractor's agents, servants, or employees.

Any oversight by the Engineer in ordering specific precautionary measures will not relieve the Contractor of responsibility in case of

any alteration, movement, or disturbance of the geotechnical instrumentation other than due to settlement of the embankments.

- xx. METHOD OF MEASUREMENT. The quantities of Special Provision (Piezometer, Vibrating Wire) and Special Provision (Settlement Platform, Type I) to be measured for payment will be the number of each installed and maintained in the complete and accepted work.

The quantity of Special Provision (Settlement Platform, Type I) to be measured for payment will be the number of settlement platforms installed and maintained in accordance with this specification.

The quantity of Special Provision (Inclinometer Casing) to be measured for payment will be the number of meters (linear feet) of inclinometer casing installed and maintained in the complete and accepted work.

- xx. BASIS OF PAYMENT. The accepted quantity of Special Provision (Piezometer, Vibrating Wire) will be paid for at the Contract unit price per each. Payment will be full compensation for furnishing, transporting, handling, and placing the materials specified, including cables, readout devices, field control stations, backfill, and appurtenances; trenching and backfilling; maintaining the piezometer as necessary; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Special Provision (Settlement Platform, Type I) will be paid for at the Contract unit price per each. Payment will be full compensation for furnishing, transporting, handling, and placing the materials specified, including pipe, gauge units, clamps and fittings, backfill, protective devices, and appurtenances; maintaining the settlement platform as necessary, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Partial payments for Special Provision (Piezometer, Vibrating Wire) and Special Provision (Settlement Platform, Type I) will be made as follows:

- (a) When instrumentation has been delivered on-site, a payment of 25 percent of the Contract unit price will be allowed.
- (b) When instrumentation has been installed and is properly functioning, a further payment of 50 percent of the Contract unit price will be allowed.
- (c) The remaining 25 percent of the Contract unit price will be paid upon completion of the project or removal/abandonment of the equipment as determined by the Engineer.

The accepted quantity of Special Provision (Inclinometer Casing) will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for furnishing, transporting, handling, and placing the materials specified, including sensors, readout devices, and appurtenances; maintaining the inclinometer as necessary; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

At the completion of the project, the geotechnical instrumentation and appurtenances, including all readout devices, will become the property of the State.

Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
900.620 Special Provision (Piezometer, Vibrating Wire)	Each
900.620 Special Provision (Settlement Platform, Type I)	Each
900.640 Special Provision (Inclinometer Casing)	Meter