

GEOTECHNICAL INSTRUMENTATION

****From South Burlington-Colchester IM CULV(23)**

xx. DESCRIPTION. This work shall consist of furnishing, installing, monitoring, maintaining, and decommissioning the geotechnical instrumentation specified herein.

xx. GENERAL. Limits on movements to the ground, pavements, embankment slopes, and existing drainage culverts are specified herein.

The Contractor shall not disclose any instrumentation data to third parties and shall not publish data without prior written consent of the Owner.

xx. DEFINITIONS. Wherever in these provisions or in other Contract Documents the following terms or pronouns in place of them are used, the intent and meaning shall be interpreted as follows:

Action Level - The "Action" level is a geotechnical instrument reading that triggers a temporary work stoppage to review and modify work operations and procedures as needed, and implement mitigation actions as needed to ensure that the "Maximum" level is not exceeded.

Geotechnical Instrumentation - Devices measuring ground surface and subsurface movement and movement of existing pavements, culverts, or other structural improvements. Includes measurement devices and appurtenant equipment, probes, sensors, cabling, readout devices, and data loggers; including ancillary facilities required for their operation, such as boreholes, casings, housings, and covers.

Grid Crack Gauge - A device for monitoring crack/joint displacement of a structure.

Ground Monitoring Point (GMP) - A system for monitoring vertical movement (settlement or heave) at or near the ground surface using optical surveying methods.

Inclinometer (INCL) - Probe lowered within a specially grooved casing to monitor horizontal ground displacements relative to a fixed position at the bottom of the casing or borehole.

Maximum Level - The "Maximum" level is a maximum permissible geotechnical instrument reading that corresponds to a work stoppage.

Monitoring Point - See Ground Monitoring Point and Structure Monitoring Point.

Structure Monitoring Point (SMP) - A system for monitoring vertical movement (settlement or heave) at an existing above ground or underground structure using optical surveying methods.

xx. QUALIFICATIONS. The Contractor's geotechnical instrumentation specialist responsible for furnishing, installing, monitoring, maintaining, and reporting shall have three years of direct field experience and prior experience with the types of instrumentation specified herein.

All surveying activities shall be performed under the direct supervision of a licensed Professional Land Surveyor registered in the State of Vermont and having experience in measurements of the types and accuracies specified herein. The field survey party chief shall also have experience in survey measurements of the types and accuracies specified herein.

Use geologists or geotechnical engineers with a minimum of 2 years of field boring inspection and related experience to log borings and identify samples in connection with installation of inclinometer casing. Identify soil samples in a manner consistent with that described in the GDR.

Drilling contractor shall have three years experience in soil test borings and the installation of inclinometer casing.

xx. DESIGN CRITERIA. Survey precision shall be:

- (a) Initial elevations of settlement points to 0.01 foot.
- (b) Subsequent elevations of settlement points to 0.01 foot.
- (c) Level circuit closure with an error of closure of $0.017N^{1/2}$ feet or less, where N is the circuit distance in miles.
- (d) Initial horizontal coordinates of settlement points to 0.01 foot.

xx. SUBMITTALS. Not less than two weeks prior to beginning any work, the Contractor shall submit the following for review and approval:

- (a) Resumes of proposed geotechnical instrumentation personnel including geotechnical instrumentation specialist, surveyors, geologists, geotechnical engineers, and drilling contractor that demonstrate the minimum qualifications and experience specified in this Section.
- (b) Manufacturers' product data describing all instruments to be installed, including requests for consideration of substitutions.
- (c) Detailed step-by-step procedure for installation, together with a sample installation record sheet. The procedures shall be bound and inclusive. The installation procedures shall include:
 - (1) Method to be used for cleaning the inside of casing or augers.
 - (2) Specifications for proposed grout mixes, including commercial names, proportions of admixtures and water, mixing sequence, mixing methods and duration, pumping methods, and tremie pipe type, size, and quantity.
 - (3) Drill casing or auger type and size.
 - (4) Depth increments for backfilling boreholes with sand and granular bentonite.

- (5) Method of sealing joints in pipes to prevent ingress of grout.
 - (6) Method for conducting post installation acceptance test.
 - (7) Detailed step-by-step procedures for conducting all optical survey measurements to the specified accuracies, including types of surveying instruments and data reduction procedures.
- (d) A schedule indicating the proposed time sequence of instrument installation, and a schedule showing the proposed monitoring and reporting frequencies for all instruments specified herein.
- (e) Proposed daily instrumentation report format.

Within five (5) workdays of installing each instrument, submit the installation record sheet for that instrument, post-installation acceptance test, copy of the factory calibration, manufacturer's test equipment certification, and completed copy of the quality assurance checklists.

Provide updated as-built location plans with survey coordinates of all installed instrument locations three days prior to any work.

Submit instrumentation readings on the next workday by 10:00 a.m. Provide hard and electronic copies of the data. Notify the Engineer immediately of an Action level that is reached.

Submit a contingency plan to be implemented if an Action level is reached that will prevent the Maximum level from occurring and prevent damage to existing improvements.

xx. MATERIALS.

- (a) General. All instrumentation materials and instrumentation equipment shall be new.

Whenever any product is specified by brand name and model number, such specifications shall be deemed to be used for the purpose of establishing a standard of quality and facilitating the description of the product desired. The term "acceptable equivalent" shall be understood to indicate that the "acceptable equivalent" product is the same or better than the product named in the specifications in function, performance, reliability, quality, and general configuration.

- (b) Inclinometers. Inclinometer casing shall be 3.34 inch O.D. ABS plastic casing for installation in the ground, internally grooved to receive the inclinometer. Manufacturer shall be Slope Indicator, Roctest, Inc., RST Instruments, Ltd., or acceptable equivalent. Casing shall be compatible with inclinometer probe. Couplings, locking devices, caps, and grout shall be the sizes and types as recommended by the manufacturer.

- (c) Structure Monitoring Points. Provide a stainless steel bolt and/or an adhesive-backed target as manufactured by Leica, SOKKIA, Rothbucher, or acceptable equivalent.
- (d) Ground Monitoring Points. Provide a steel rod, PVC casing, and casing spacers. Top of rod shall be punch marked at its center. Provide traffic rated protective caps. The surface area within 3 inches of the point shall be clean to permit easy identification of the exact point.
- (e) Grid Crack Gauges. Provide grid crack gauges including anchors, bolts, screws, and quick-setting epoxy, as manufactured by Avongard Products (USA) Ltd., Humboldt, or acceptable equivalent.
- (f) Identification Tags. Provide each instrument with a stainless steel indented name tag designating the instrument number. Where possible without affecting instrument function, attach name tags directly to instrument using heavy black (UV-resistant) nylon tie-wrap.
- (g) For name tags that cannot be attached directly to the associated instrument, mount on the associated structure or enclosure as close as practicable to allow convenient, unambiguous reading. Mount using epoxy or other adhesive as recommended by name tag manufacturer. Use a mounting method that is approved by the Owner prior to use.

xx. EQUIPMENT.

- (a) Inclinometer Probe. An inclinometer probe shall be provided that is compatible with the inclinometer casing and portable digital readout. Manufacturer shall be Slope Indicator, Roctest, Inc., RST Instruments, Ltd., or acceptable equivalent.
- (b) Portable Readout. A portable digital readout shall be provided that is compatible with the inclinometer casing and inclinometer probe. Manufacturer shall be Slope Indicator, Roctest, Inc., RST Instruments, Ltd., or acceptable equivalent.

xx. EXECUTION.

- (a) Pre-Installation Acceptance Tests. When instruments are received at the site, the Contractor's instrumentation personnel shall perform pre-installation acceptance tests to ensure that the instruments and readout units are functioning correctly prior to installation. Pre-installation acceptance tests shall include relevant items from the following list:
 - (1) Examine factory calibration curve and tabulated data, to verify completeness.
 - (2) Examine manufacturer's final quality assurance inspection check list, to verify completeness.
 - (3) Check cable length.
 - (4) Check tag numbers on instrument and cable.

- (5) Check, by comparing with procurement document that model, dimensions, and materials are correct.
- (6) Bend cable back and forth, at point of connection to instrument, while reading the instrument, to verify connection integrity.
- (7) Perform resistance and insulation testing, in accordance with criteria provided by the instrument manufacturer, using a gage insulation or circuit tester that applies 2 volts or less for resistance testing and 15 volts or less for insulation testing.
- (8) Verify that all components fit together in the correct configuration.
- (9) Check all components for signs of damage in transit.
- (10) Check that quantities received correspond to quantities ordered.

During pre-installation acceptance testing of each instrument, the Contractor's instrumentation personnel shall complete a pre-installation acceptance test record form.

An instrument that fails the specified pre-installation acceptance test shall be repaired such that it passes a subsequent pre-installation acceptance test, or shall be replaced by an identical instrument at no additional cost to the Owner.

- (b) General Installation. The Contractor's instrumentation personnel shall install instruments that remain fully functional over the duration of the Contract. Install instruments in accordance with detailed step-by-step procedures that were submitted and reviewed by the Owner. Any component that fails to give reliable readings shall be replaced by the Contractor at no additional cost to the Owner.

The Contractor shall schedule the work activities such that all instrumentation is functional prior to the start of any excavation work.

The Contractor shall notify the Owner at least 24 hours prior to installing inclinometer casing and structure monitoring points.

All installations shall be monitored by the Contractor's qualified personnel. As each instrument is installed, an installation record sheet shall be prepared, including appropriate items from the following list:

- (1) Project name.
- (2) Contract name and number.
- (3) Instrument type and number, including readout unit.
- (4) Personnel responsible for installation.

- (5) Plant and equipment used, including diameter and depth of any drill casing or augers used.
- (6) Date and time of start and completion.
- (7) A log of subsurface data indicating the elevations of strata changes encountered in the borehole. Strata soil nomenclature shall be based on subsurface profiles in the GDR.
- (8) Type of backfill used.
- (9) As-built location in horizontal position and elevation including:
 - a. As-built orientation.
 - b. As-built lengths and volumes of backfill.
- (10) Result of post installation acceptance test.
- (11) Weather conditions at the time of installation.
- (12) A space on record sheet for notes, including problems encountered, delays, unusual features of the installation, and details of any events that may have a bearing on instrument behavior.

The Contractor shall install instrumentation, in addition to that specified herein, that the Contractor deems necessary to ensure the safety of personnel and the work, at no additional cost to the Owner.

The Contractor shall submit updated as-built instrument location plans to the Owner.

- (c) Inclinometers. Install in borehole of adequate size for inclinometer casing installation at the locations listed in Table 1. The required installation is shown on Figure 1.

Whenever withdrawing drill casing or augers during instrument installation in a borehole, care shall be taken to minimize the length of unsupported borehole and the rate of casing or auger withdrawal.

Prior to installing casing through drill casing or augers, all material adhering to the inside of the casing or augers, and all cuttings, shall be removed thoroughly.

The instrument shall be installed in the borehole in a continuous operation. Partially completed instrument installations shall not be left in unsupported boreholes overnight.

Installation procedures for inclinometer casing shall be such that all steps in the procedure can be quality assured. Granular bentonite shall be placed in depth increments not exceeding

2 feet. Volumes of each increment of backfilling with sand shall be small enough such that no bridging occurs. The depth to the top of each increment of sand or granular bentonite shall be checked after placement. Grout shall be placed using a tremie method with side discharge ports on the tremie pipe.

After installation, the casing groove spiral shall not exceed one degree per 10 feet of length, the orientation of the grooves at the top of the casing shall be within 10 degrees of the planned orientation, and no part of the casing shall deviate from vertical by more than 4 percent of the depth to that part.

One set of grooves, defined as the A-axis, shall be oriented perpendicular to the excavation. Casing groove orientation shall be maintained throughout installation.

After completion of installation, a post-installation acceptance test shall be performed to verify that there is no grout in the inclinometer casing, that groove orientation and verticality are correct, and that the inclinometer probe tracks correctly in all four orientations.

After completion of installation, establish a baseline reading. A baseline reading for an inclinometer will consist of the average of stable readings over a 72 hour period.

After completion of installation, the as-built survey coordinates for horizontal position shall be determined to an accuracy of ± 0.01 foot and the elevation of the top of the riser pipe to an accuracy of ± 0.01 foot.

- (d) Installation of Structure Monitoring Points (SMPs). Install SMPs within the existing culvert at each of the two project sites. Installation locations shall be at the crown and spaced 30 linear feet apart and at the inlet and outlet locations. Each SMP shall be tight to the culvert metal and securely affixed in a manner that is compatible with the Contractor's underground surveying method.

After completion of installation, the as-built survey coordinates for horizontal position shall be determined to an accuracy of ± 0.01 foot and the elevation to an accuracy of ± 0.01 foot.

After completion of installation, establish a baseline reading. A baseline reading for an SMP will consist of three readings with 24 hours minimum between readings.

- (e) Installation of Ground Monitoring Points (GMPs). Install GMPs at the locations listed in Table 2. The required installation is shown on Figure 2.

After completion of installation, the as-built survey coordinates for horizontal position shall be determined to an accuracy of ± 0.01 foot and the elevation to an accuracy of ± 0.01 foot.

After completion of installation, establish a baseline reading. A baseline reading for a GMP will consist of three readings with 24 hours minimum between readings.

- (f) Installation of Grid Crack Gauges. Install Grid Crack Gauges at locations determined by the Engineer. Install Grid Crack Gauges in accordance with the manufacture's recommendations. Record a baseline reading for a Grid Crack Gauge which will consist of three readings with 24 hours minimum between readings.
- (g) Monitoring. Inclinator casing deflections shall be read twice per day during the time period of embankment slope excavation and cofferdam installation. Inclinator casings shall be read daily thereafter until deflections stabilize. Thereafter, the Engineer will provide direction that readings shall be taken weekly for a minimum of 4 weeks. At the discretion of the Engineer, additional readings may be suspended.

The elevation of all structure monitoring points and ground monitoring points shall be read daily during the time period of embankment slope excavation and underground work activities including pipe jacking, pipe ramming, auger boring, contact grouting, obstruction removal, and any corrective or repair work to the pipe providing ground support. Monitoring points within 75 feet horizontally from any excavation face or leading edge of a pipe being installed by pipe ramming or pipe augering shall be read three times daily.

Grid crack gauges shall be read daily during the time period of embankment slope excavation and underground work activities including pipe jacking, pipe ramming, auger boring, contact grouting, obstruction removal, and any corrective or repair work to the pipe providing ground support.

Double the collection frequency when an Action level is reached.

Process field readings to determine inclinometer casing deflections, monitoring point elevations, and grid crack gauge displacements. Report field readings and processed data in meaningful engineering units. Plots of the inclinometer casing deformation with depth shall be provided to the Engineer.

Perform data processing within 24 hours of taking field readings, prior to the daily 10:00 a.m. reporting requirement, or prior to collecting the next round of field readings, whichever is earlier, to determine if an Action or Maximum level is reached. Notify the Engineer immediately if an Action or Maximum level is reached on any instrument.

- (h) Action and Maximum Levels. The displacement criteria provided in Table 3 establishes the Action and Maximum levels as defined herein.

If the Action level is reached, immediately halt work activities except those needed to prevent instability from occurring. Review and modify work operations and procedures, support requirements, and possible mitigation actions as needed. Meet

with the Engineer to discuss actions to be taken to prevent the Maximum level from occurring. The Engineer will provide notice in writing to resume work once the Contractor's action plan is accepted.

If the "Maximum" level is reached, immediately halt work activities except those needed to prevent instability from occurring.

- (i) Decommissioning of Instruments. At the direction of the Engineer prior to substantial completion of the work, the Contractor will remove instruments constituting an obstruction or nuisance including monitoring points, inclinometers, grid crack gauges, and observation wells SB-1(OW) and C-2(OW) which were installed by the Owner.

Any remaining portions of the instrument and casing shall be backfilled with cement grout up to a level two (2) feet below the ground surface, and with lean concrete in the upper two (2) feet. New pavement patches shall be constructed, in paved areas, of the same material and to the same thickness as existing adjacent pavement. Disturbed or damaged surfaces shall be restored to the condition existing before installation of the instrument to the satisfaction of the Owner.

TABLE 1 - INCLINOMETER INSTALLATION LOCATIONS

Project Site	Station	Offset
South Burlington	11+50	80 feet, left
Colchester	21+75	80 feet, left
Colchester	23+50	80 feet, left

TABLE 2 - GROUND MONITORING POINT INSTALLATION LOCATIONS

Project Site	Location	Approximate Station	Approximate Offset
South Burlington	East embankment slope	11+25	70 feet, left
South Burlington	East embankment slope	11+25	50 feet, left
South Burlington	East embankment slope	11+50	50 feet, left
South Burlington	East embankment slope	11+50	70 feet, left
South Burlington	Northbound lane guard rail	11+80	80 feet, left
South Burlington	Northbound lane guard rail	11+85	70 feet, left
South Burlington	Northbound lane guard rail	11+95	50 feet, left
South Burlington	Northbound lane guard rail	11+95	40 feet, left
South Burlington	East edge of grass median	12+20	70 feet, left
South Burlington	East edge of grass median	12+30	50 feet, left
South Burlington	West edge of grass median	12+60	70 feet, left
South Burlington	West edge of grass median	12+70	50 feet, left

South Burlington	Southbound lane guard rail	13+10	80 feet, left
South Burlington	Southbound lane guard rail	13+15	70 feet, left
South Burlington	Southbound lane guard rail	13+25	50 feet, left
South Burlington	Southbound lane guard rail	13+25	40 feet, left
South Burlington	West embankment slope	13+40	50 feet, left
South Burlington	West embankment slope	13+40	70 feet, left
Colchester	East embankment slope	21+30	50 feet, left
Colchester	East embankment slope	21+30	70 feet, left
Colchester	East embankment slope	21+55	50 feet, left
Colchester	East embankment slope	21+55	70 feet, left
Colchester	Northbound lane guard rail	21+95	70 feet, left
Colchester	Northbound lane guard rail	21+90	80 feet, left
Colchester	Northbound lane guard rail	22+05	50 feet, left
Colchester	Northbound lane guard rail	22+05	40 feet, left
Colchester	East edge of grass median	22+35	70 feet, left

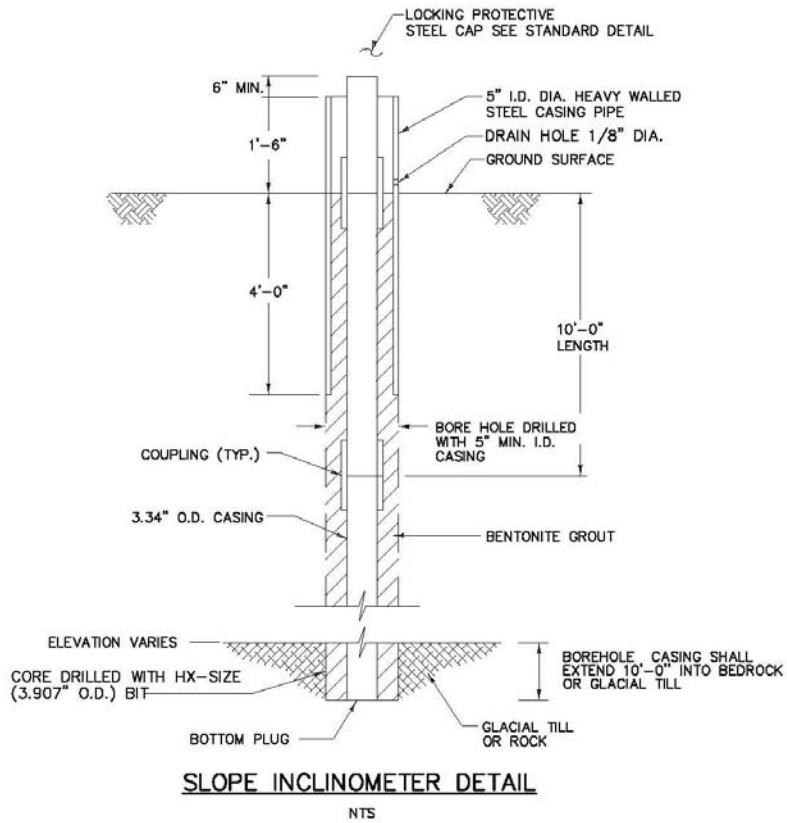
TABLE 2 - GROUND MONITORING POINT INSTALLATION LOCATIONS (CONT.)

Project Site	Location	Approximate Station	Approximate Offset
Colchester	East edge of grass median	22+45	50 feet, left
Colchester	West edge of grass median	22+75	70 feet, left
Colchester	West edge of grass median	22+85	50 feet, left
Colchester	Southbound lane guard rail	23+20	80 feet, left
Colchester	Southbound lane guard rail	23+25	70 feet, left
Colchester	Southbound lane guard rail	23+35	50 feet, left
Colchester	Southbound lane guard rail	23+40	40 feet, left
Colchester	West embankment slope	23+60	50 feet, left
Colchester	West embankment slope	23+60	70 feet, left

TABLE 3 - DISPLACEMENT CRITERIA FOR ACTION AND MAXIMUM LEVELS

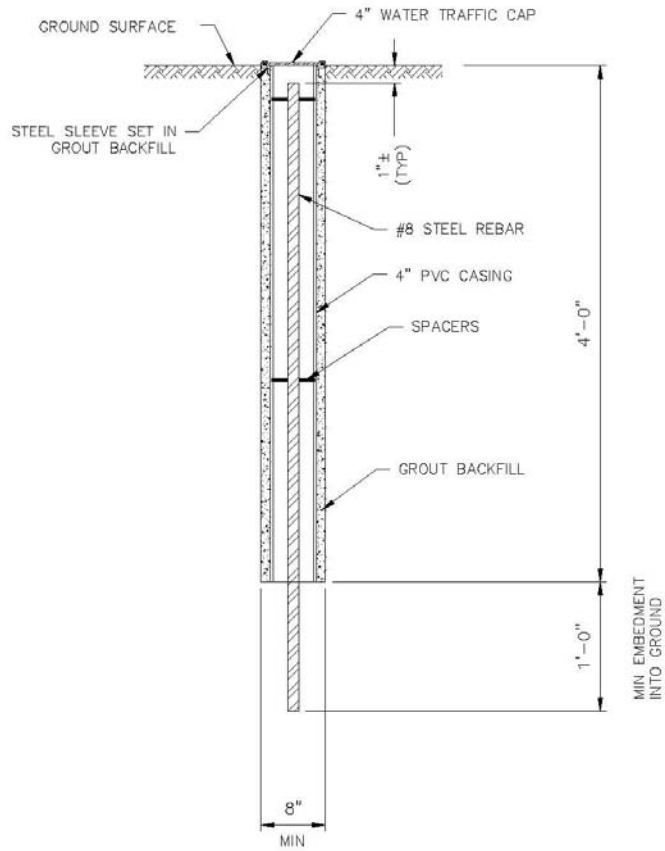
Instrument	Action Level	Maximum Level
Inclinometers	0.5 inch horizontal	0.75 inch horizontal
Monitoring Points	0.375 inch vertical	0.5 inch vertical

Grid Crack Gauges	0.375 inch total	0.5 inch total
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* DIMENSION TO BE DETERMINED FROM INCLINOMETER PULLEY ASSEMBLY

FIGURE 1 - INCLINOMETER AND LOCKING PROTECTIVE CAP



GROUND MONITORING POINT DETAIL

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FIGURE 2 - GROUND MONITORING POINT

xx. METHOD OF MEASUREMENT. The quantity of Special Provision (Grid Crack Gauge) to be measured for payment will be the number of each gauge furnished, installed, maintained, and monitored in the complete and accepted work.

The quantity of Special Provision (Ground Monitoring Point) to be measured for payment will be the number of each ground monitoring point furnished, installed, maintained, and monitored in the complete and accepted work.

The quantity of Special Provision (Inclinometer) to be measured for payment will be the number of each target furnished, installed, maintained, and monitored in the complete and accepted work.

The quantity of Special Provision (Instrument Decommissioning) to be measured for payment will be for each project site for which all instruments are decommissioned in the complete and accepted work.

The quantity of Special Provision (Structure Monitoring Point) to be measured for payment will be the number of each target furnished, installed, maintained, and monitored in the complete and accepted work.

xx. BASIS OF PAYMENT. The accepted quantities of Special Provision (Grid Crack Gauge), Special Provision (Ground Monitoring Point), Special Provision (Inclinometer), Special Provision (Instrument Decommissioning), and Special Provision (Structure Monitoring Point) will be paid for at the Contract unit price for each.

Payment shall be full compensation for furnishing, transporting, handling, and placing the materials specified; mobilizing drill rig and performing boring and logging of soil conditions; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
900.620 Special Provision (Grid Crack Gauge)	Each
900.620 Special Provision (Ground Monitoring Point)	Each
900.620 Special Provision (Inclinometer)	Each
900.620 Special Provision (Instrument Decommissioning)	Each
900.620 Special Provision (Structure Monitoring Point)	Each