PORTSMOUTH-KITTERY
16189B

November 17, 2020

SPECIAL PROVISION

SECTION 677 – INTELLIGENT TRANSPORTATION SYSTEMS (ITS) EQUIPMENT

Item 677.42 – Roadway Weather Information Station (RWIS) System

This special provision provides for installation of permanent, ground-mounted Roadway Weather Information System (RWIS), supports, foundations, and all sensors and equipment necessary to provide a working RWIS system. All provisions of Section 677 (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification), except as modified or changed below, shall apply.

Add to Description (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification):

1.4 This work shall consist of furnishing, installing, wiring, connecting, configuring, testing, and providing GPS as-built documentation of a new, permanent roadway weather information station (RWIS) system, including designing and installing sensor support structures, equipment cabinets, sensors, concrete work pads, hardware, software, integration, training, technical assistance and warranty, as well as any additional components and efforts necessary to provide a fully operational RWIS system.

1.4.1 This work shall also consist of designing and constructing either a steel-reinforced concrete circular shaft foundation, constructed within a drilled excavation, or a steel-reinforced concrete spread footing foundation for the RWIS sensor support structure. The Contractor may select either foundation type for RWIS foundation locations.

1.4.2 The design and construction of ground mounted cabinet enclosure foundations, when required to install the equipment proposed by the Contractor, shall also be included in the RWIS system work.

Modify Section 2.3.8.6 and Section 2.3.8.7 (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification) to read:

2.1.1 Device housings, structures, support structures and foundations shall be designed and constructed to comply with all applicable sections of the current edition of *AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* and the current version of *ANSI/TIA-222 Structural Standard for Antenna Supporting Structures, Antennas and Small Wind Turbine Support Structures* with all published addendums. [continued

in Section 2.1.2 (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification)]

2.3.8 The submittal for device support structures shall include the following for approval in accordance with Section 105.02: [continued in Section 2.3.8.1 (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification)]

2.3.8.6 Top of foundation reactions from the support structure design (LRFD), in conjunction with section 2.3.8.1 above, shall be submitted to the Department for verification of the foundation design provided by the Contractor.

2.3.8.7 The submittal shall include a foundation system design for the proposed support structure and selected foundation system (i.e., drilled shaft or spread footing). The support structure foundation shall be designed by the Contractor in accordance with Section 2.10 and Section 3.13 below. [continued in Section 2.3.8.8 (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification)]

Add to 2.3 Technical Submittal (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification):

2.3.9 Additional submittal requirements for RWIS system installations shall include the following:

2.3.9.1 A System Network diagram detailing end-to-end connections between the RWIS equipment and cloud based Vaisala Navigator system.

2.3.9.2 Documentation of any software modifications required to interface to the existing NHDOT Advanced Transportation Management System (ATMS) or Vaisala Navigator system.

2.3.9.3 Underwriter's Laboratory approval certifications for all proposed equipment.

2.3.9.4 Typical life expectancy of each system component.

2.3.9.5 A list of parts that will require periodic replacement, including their typical life expectancy.

2.3.9.6 The address where the proposed equipment will be produced and serviced and the turnaround time for replacement and/or repair of equipment.

2.3.9.7 Available maintenance plans.

2.3.9.8 Environmental operating requirements for all equipment and associated equipment including heating, cooling, circuit, and grounding requirements.

2.3.9.9 A video recording, conducted from the precise site location and camera height of the proposed Closed Circuit Television (CCTV) camera installation. Recordings shall be of multiple, accurate 360-degree field-of-view video images, with camera tilt range from 20 degrees

above horizon to 90 degrees below horizon. The recording shall showcase all points of interest for traffic monitoring operations at the proposed site, such as roadway travel lanes, ramps and parking areas.

2.3.9.10 Documentation and user instructions for any MVDS system control software provided by the MVDS manufacturer.

2.3.9.11 Testing plans for the RWIS system, including all RWIS environmental sensors and equipment.

2.3.9.12 Complete electronic user documentation for each subsystem unit, including instructions on operation, calibration and data retrieval, and instructions on operation of the hinged support structure lowering system.

2.3.9.13 Maintenance manuals for each subsystem unit, which shall include circuit diagrams, a parts list with cross-reference of all components by manufacturers, and instructions suitable for technicians to perform routine services and minor repairs.

Add to 2.4 Flexible Liquid Tight Conduit (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification):

2.4.7 The Contractor may choose to use rigid metallic conduit in place of flexible liquid tight conduit. Rigid metallic conduit shall be stainless steel, or galvanized meeting the requirements of section 614 for steel conduit.

Add to Materials (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification):

2.6 RWIS System Components. The default RWIS system shall include the following components unless explicitly excluded in the Contract Documents:

2.6.1 A hinged, self-lowering, trussed tower support structure, unless otherwise specified, including an electrical conductor cable for earth grounding. The support structure shall meet the requirements of 2.9 below.

2.6.2 Concrete foundations for the support structures and any ground mounted cabinets, as required. Support structure foundations shall meet the requirements of 2.10 below.

2.6.3 Concrete work pads located at equipment cabinets. Concrete pads shall meet the requirements of Section 608 for concrete sidewalks.

2.6.4 An ultrasonic heated wind sensor, capable of measuring wind speed and direction.

2.6.4.1 Wind sensors shall be capable of measuring wind speeds between 0 and 213 ft/sec, with an accuracy of +/-0.33 ft/sec, or ±2% of the wind speed reading, whichever is greater. The wind speed measurement resolution shall be 0.03 ft/sec.

2.6.4.2 The wind sensors shall measure wind direction in 360°, with an accuracy of +/-2°, and a measurement resolution of 0.1°.

2.6.4.3 Wind sensors shall be capable of operating in temperatures between -40°F and +140°F.

2.6.4.4 Wind sensors shall be heated to prevent accumulation of freezing rain, snow and ice.

2.6.4.5 Wind sensors shall be IP66 and IP67 rated.

2.6.4.6 Sensor shall be capable of communications via RS485, RS422, RS232, or SDI-12 ports.

2.6.4.7 Wind sensors shall be supplied with a manufacturer recommended cage to prevent interference from birds.

2.6.5 A humidity and temperature probe system, capable of measuring relative humidity, air temperature and dew point.

2.6.5.1 The humidity probe shall include a continuous heating feature to prevent condensation on the probe.

2.6.5.2 Probes shall be supplied with radiation and precipitation shields as recommended by the manufacturer.

2.6.5.3 Humidity and temperature sensors shall be capable of operating in temperatures between -112°F and +140°F.

2.6.5.4 Humidity and temperature sensors shall be capable of measuring between 0% and 100% relative humidity, and measuring temperatures between -112°F and +140°F.

2.6.6 A combined precipitation sensor and precipitation identifier sensor, capable of measuring and identifying present weather conditions, such as precipitation and visibility.

2.6.6.1 Precipitation sensors shall be supplied with manufacturer recommended heaters for use during winter conditions.

2.6.6.2 Precipitation sensors shall be capable of identifying a minimum of four different types of precipitation, as well as visibility conditions such as fog, mist, haze or clear conditions.

2.6.6.3 Visibility measurement range shall be up to a minimum of 6500 feet.

2.6.6.4 Precipitation measurements shall measure intensity, accumulation, and amount of new snow.

2.6.6.5 Precipitation sensors shall be capable of operating in temperatures between -40°F and +140°F, at 0 to 100% relative humidity, and shall be IP66 rated.

2.6.6.6 Sensor shall be capable of communication via either an RS-232 or RS-485 port.

2.6.7 A barometric pressure sensor.

2.6.7.1 Pressure sensors shall be capable of measuring pressures between 600 and 1100 millibars, at a resolution of 0.1 millibar.

2.6.7.2 Pressure sensors shall be capable of operating in temperatures between -40°F and +140°F.

2.6.8 A non-invasive, remote road-surface temperature sensor, capable of measuring pavement surface temperature, ambient air temperature, and relative humidity.

2.6.8.1 Road-surface temperature sensors shall be capable of operating in temperatures between -40°F and +140°F, at 0 to 100% relative humidity.

2.6.8.2 Sensors shall be capable of remotely measuring the temperature of the roadway surface infrared radiation.

2.6.8.3 Temperature sensors shall be capable of measuring roadway surface temperatures between -40°F and +140°F, at a resolution of 0.18°F.

2.6.8.4 Remote sensors shall be capable of measuring the roadway surface temperature from a distance of up to 49 feet when installed at an angle between 45° and 85° from horizontal.

2.6.9 A non-invasive, remote road-surface condition sensor, capable of measuring pavement surface state and grip. A combined sensor that also includes the specifications as listed above in 2.6.8 of the non-invasive, remote road-surface temperature sensor can be used.

2.6.9.1 Road-surface condition sensors shall be capable of operating in temperatures between -40°F and +140°F, at 0 to 100% relative humidity.

2.6.9.2 Remote sensors shall be capable of detecting the roadway surface conditions from a distance of up to 49 feet when installed at an angle between 30° and 85° from horizontal.

2.6.9.3 Road-surface condition sensors shall be capable of identifying and classifying the presence of precipitation or freezing conditions overlaying the roadway surface, such as snow, frost, ice and slush, or when the roadway is dry, moist or wet.

2.6.9.4 Road-surface condition sensors shall be capable of measuring the thickness of surface cover of both water and ice up to 2 mm thick, and snow up to 10 mm thick, with a surface cover thickness measurement resolution of 0.01 mm.

2.6.9.5 Road-surface condition sensors shall be capable of estimating a level of grip for tires on the roadway surface.

2.6.10 One probe measuring subsurface temperature of the paved roadway.

2.6.10.1 Subsurface probe shall be capable of measuring temperatures between -40°F and +176°F.

2.6.10.2 Subsurface probe housing shall be water-tight, maintenance free, and capable of enduring long term installation under roadway surfaces in all weather conditions.

2.6.11 A Remote Processing Unit (RPU), including but not limited to all cables, antennae and adapters as needed to provide power and communications to all installed RWIS equipment. The RPU shall monitor and control all field sensors.

2.6.11.1 The RPU shall include an enclosure to house all components, equipment, wires and cables. The RPU enclosure shall meet NEMA 4X requirements. Enclosures shall be sufficiently sized to enclose all of the RWIS components, electrical, and communications interface equipment with a 10% spare equipment capacity. The enclosure shall be mountable either to the RWIS support structure or concrete foundation, as recommended by the manufacturer.

2.6.11.2 RPU shall include a data management unit, capable of performing all calculations on sensor data to output accurate readings, and providing data storage of measurements.

2.6.11.3 The data management unit shall provide accurate system time synchronization for all instrument readings.

2.6.11.4 The data management unit shall contain enough ports to interface with all installed RWIS sensors, and interface with the external Vaisala Navigator reporting system via the communication systems proposed for the site.

2.6.11.5 The RPU shall include a digital interface, capable of providing power to analog sensor and converting analog signals to digital communication. The digital interface shall include enough ports for all installed analog devices. If more ports are needed to interface with all installed sensors, additional digital interfaces shall be provided with the RPU as required.

2.6.11.6 The RPU shall include a power management unit, capable of supplying power and communications to all installed RWIS sensors.

2.6.11.7 The power management unit shall include enough ports to provide reliable power and communications to all sensors, and input of power feed to the unit.

2.6.11.8 The power management unit shall provide surge protection to all connected devices.

2.6.11.9 The power management unit shall be capable of controlling and cycling the power of each sensor remotely.

2.6.11.10 Data management units, digital interfaces, and power management units shall be capable of operating at temperatures between -40°F and +140°F, between 5% and 93% relative humidity, non-condensing.

2.6.11.11 The system shall have the ability to accept additional sensors and detectors as future needs arise.

2.6.11.12 The RPU enclosure shall include at least one 120 VAC utility duplex outlet.

2.6.12 A 100 Mbps, managed Ethernet switch.

2.6.12.1 The Ethernet switch shall be a self-contained unit capable of 24-hour per day unattended operation, manufactured by Cisco, RuggedCom, Etherwan, or approved equal. Ethernet Switch shall be of rugged design and suitable for reliable operation. Ethernet Switch shall be configured for minimum maintenance and need for adjustment after initial setup.

2.6.12.2 The Ethernet switch shall be IP20 rated, capable of operating in temperatures between -14°F and 140°F, and relative humidity between 5% and 95% non-condensing.

2.6.12.3 The Ethernet switch shall be UL listed.

2.6.12.4 The Ethernet Switch shall have dual speed 10/100 Mbps Ethernet ports with RJ45 connectors. The Contractor shall determine the number of ports required for the specific project installation and provide a switch with the required number of ports, plus a minimum of 2 spare Ethernet ports with RJ45 connectors, or a minimum of 5 total dual speed 10/100 Mbps Ethernet ports, whichever is greater.

2.6.12.5 The Ethernet switch shall feature auto negotiation of data transmission, autocrossing detection, and store-and-forward switching.

2.6.12.6 The Ethernet switch shall comply with IEEE 802.3.

2.6.13 A battery backup system, capable of providing uninterrupted backup power to all installed sensors, cameras and communication equipment for a minimum of 24 hours.

2.6.13.1 Components of the battery backup system shall be NEC compliant and UL listed.

2.6.13.2 The battery backup system shall be suitable for outdoor use, and capable of operating in ambient temperatures between -22°F and +122°F, and a relative humidity of 100% condensing.

2.6.13.3 The battery backup system shall be housed in a weatherproof, locking cabinet enclosure meeting NEMA 3R rating and suitable for mounting either to the RWIS support structure or ground mounting on a concrete foundation as recommended by the manufacturer.

Cabinets shall be sufficiently sized to enclose all system components, with a 10% spare equipment capacity. Additional battery cabinets, if required by the system, shall meet the same requirements.

2.6.13.4 External batteries shall be maintenance-free and designed for deep-cycle operation. Battery life shall be rated for greater than 500 cycles at 80% depth-of-discharge.

2.6.13.5 The backup power system shall include an environmentally-hardened battery charger. Chargers shall be temperature compensated to provide consistent charging power to the batteries.

2.6.13.6 The backup power system shall include an integral power inverter to provide AC power to all systems.

2.6.13.7 The battery backup system shall include a low-voltage disconnect that will disconnect the system load from the batteries before complete battery discharge and damage can occur.

2.6.13.8 The battery backup system shall be capable of automatically recovering and restarting if battery voltage rises to an acceptable level.

2.6.13.9 The battery backup system shall be sized and function in such a way that there will be zero transfer time in the event of AC power loss. The backup system shall provide power with no loss of service to the environmental sensors, data being collected, RPU, or any other equipment installed.

2.6.14 A CCTV camera with Pan-Tilt-Zoom (PTZ) capabilities.

2.6.14.1 All proposed CCTV cameras shall include a Milestone XProtect Corporate Edition (latest version) device license with Milestone Care Premium Support for 1 year. A compatibility list can be found on the Milestone website.

2.6.14.2 The CCTV camera and associated equipment shall provide video coverage as directed by the ITS Project Manager (227-0016).

2.6.14.3 The CCTV camera shall be Underwriter's Laboratory (UL) approved. UL certification shall be provided with the catalog cuts in the Technical Submittal.

2.6.14.4 The CCTV camera shall weigh no more than 10 pounds.

2.6.14.5 The CCTV camera shall be digital, IP addressable and Ethernet ready.

2.6.14.6 The CCTV interface shall be an RJ45 type connector for 10BASE-T/100BASE-TX, and shall include an IP66-rated RJ45 connector kit.

2.6.14.7 The CCTV camera shall be compatible with existing CCTV software at the NHDOT Transportation Management Center (TMC), including the Milestone Video Management System, Corporate Edition, latest version.

2.6.14.8 The CCTV shall have the following image setting functionalities: Wide dynamic range (WDR), manual shutter time, compression, color, brightness, sharpness, white balance, exposure control, exposure zones, backlight compensation, fine tuning of behavior at low light, rotation, text and image overlay, 32 individual 3D privacy masks, image freeze on PTZ, electronic image stabilization and automatic defog.

2.6.14.9 The CCTV shall provide a camera imaging system that automatically shifts from daytime mode to nighttime mode, and shifts from color mode to a black-and-white mode under very low light conditions, in order to render a more detailed video image.

2.6.14.10 The CCTV shall provide automatic and manual control of camera imaging characteristics (such as exposure and contrast).

2.6.14.11 The CCTV shall return operational status and report system faults to the NHDOT TMC.

2.6.14.12 The CCTV shall receive and process camera positioning and camera configuration commands received from the NHDOT TMC.

2.6.14.13 The CCTV shall have the capability to be viewed, controlled, and tested locally at the camera site utilizing a laptop computer with OEM software. This shall include the capability to locally retrieve operational status and fault data for the CCTV.

2.6.14.14 The CCTV camera dome shall be constructed of clear polycarbonate with a sun shield.

2.6.14.15 The lower exterior dome shall be made of seamless polycarbonate, optically clear with no distortion, optical discontinuities, or anomalies of any type in any portion of the dome up to 20-degrees above horizontal.

2.6.14.16 The CCTV camera dome drive system shall consist of an integral camera pan-tilt assembly with a variable high speed drive unit with continuous 360-degree rotation, CMOS camera, optical and digital zoom, auto focusing, motorized zoom lens and integral camera control receiver.

2.6.14.17 The CCTV shall have user-defined "pre-sets" for position, zoom, exposure and focus, to be defined by the NHDOT Transportation Systems Management and Operations (TSMO) Bureau.

2.6.14.18 The CCTV shall have a minimum Pan/Tilt/Zoom functionality of: 100 preset positions, 360° endless pan at a speed of 0.05 - 450°/sec; Tilt - 220° at a speed of 0.05 - 450°/sec.

2.6.14.19 NHDOT TMC control of CCTV PTZ features shall have a latency of no greater than one second.

2.6.14.20 The CCTV shall have an automatic variable pan-tilt speed adjustment operating as a function of degree of zoom.

2.6.14.21 The CCTV shall have a minimum 30x optical zoom and 12x digital zoom, total 360x zoom.

2.6.14.22 The CCTV shall have the following intelligent video analytics: video motion detection, auto-tracking.

2.6.14.23 The CCTV shall have alarm triggers from multiple sources including intelligent video, PTZ position.

2.6.14.24 The CCTV shall have a minimum 1/3-inch progressive scan CMOS image sensor.

2.6.14.25 The CCTV shall have a minimum illumination of: Color: 0.2 lux at 30 IRE; B/W: 0.04 lux at 30 IRE.

2.6.14.26 The CCTV shall have minimum resolution range of: HDTV 320x180 up to 1280x720, 720p.

2.6.14.27 The CCTV shall provide H.264 (MPEG-4 Part 10/AVC) and Motion JPEG video compression formats.

2.6.14.28 The CCTV shall have a minimum frame rate of: H.264 25/30 frames per second (fps) (50/60 Hz) in all resolutions, M-JPEG: up to 25/30 fps (50/60 Hz) in all resolutions.

2.6.14.29 The CCTV shall be capable of multi-streaming in H.264 and Motion JPEG formats: Multiple individually configured streams in maximum resolution at 30/25 (60 / 50 Hz) fps. The frame rate and bandwidth shall be controllable.

2.6.14.30 The CCTV shall have the following security features: password protection, IP address filtering, HTTPS encryption, IEEE 802.1X network access control, digest authentication, user access log.

2.6.14.31 The CCTV shall support the following protocols: IPv4/v6, HTTP, HTTPSa, SSL/TLSa, QoS Layer 3 DiffServ, FTP, CIFS/SMB, SMTP, Bonjour, UPnPTM, SNMPv1/v2c/v3 (MIB-II), DNS, DynDNS, NTP, RTSP, RTP, TCP, UDP, IGMP, RTCP, ICMP, DHCP, ARP, SOCKS, SSH, and NTCIP.

2.6.14.32 The CCTV shall conform to the ONVIF Profile S standard and have an open Application Programming Interface for software integration.

2.6.14.33 The CCTV camera shall be able to process, at a minimum, the following alarm events:

(a) File upload: FTP, HTTP, and network share.

(b) Email notification: email, HTTP and TCP.

(c) Data transmitted from CCTV camera: PTZ preset, guard tour, video recording to edge storage, auto-tracking, day/night mode, and pre- and post-alarm video buffering.

2.6.14.34 The CCTV shall include transient voltage surge suppression (TVSS) to protect against transients and surges within 5 feet of the camera enclosure.

2.6.14.35 The CCTV shall be powered by an industrial grade Power Over Ethernet Injector (POEI).

2.6.14.35.1 The POEI shall provide operating power and Ethernet data to the CCTV. The POEI power consumption shall not exceed 60 watts.

2.6.14.35.2 The POEI shall include integral TVSS to protect against transients and surges on the incoming power and data (Ethernet) connections to the POEI, as well as to protect against transients and surges on the outgoing data (Ethernet) connection to the camera. The TVSS shall be a product approved by the CCTV manufacturer for use with the camera.

2.6.14.36 The CCTV shall be housed in an environmentally hardened aluminum enclosure suitable for continuous outdoor use and shall feature an internal temperature regulation system. The CCTV shall be IP66-, NEMA 4X-, and IK09-rated and shall have an operating temperature range of -40 °F to +122 °F, minimum.

2.6.15 A Motor Vehicle Detection Sensor (MVDS).

2.6.15.1 The MVDS shall be of the same make and model as others provided on the Contract for use in New Hampshire.

2.6.15.2 The MVDS shall be compatible with the NHDOT's existing statewide ATMS.

2.6.15.3 The MVDS shall be capable of integrating and providing data to the ATMS. The MVDS shall be managed and controlled from the ATMS at NHDOT's TMC.

2.6.15.4 The data produced by the MVDS shall be consistent with National Transportation Communications for ITS Protocol (NTCIP) objects.

2.6.15.5 The MVDS device shall transmit, receive, and analyze an FCC certified, low-power microwave radar signal to detect vehicle presence, provide a detection output, and generate volume, occupancy, and speed data.

2.6.15.6 The MVDS shall be suitable for continuous duty, non-environmentally controlled, outdoor use.

2.6.15.7 The detector unit shall be enclosed in a rugged weatherproof case meeting NEMA 4X standards. The total weight of the detector unit assembly shall not exceed 5 pounds.

2.6.15.8 The detector unit shall have an operating temperature range of -40° F to +140° F, minimum.

2.6.15.9 The detector unit shall be resistant to vibration and shock in accordance with applicable NEMA TS 2-2003 requirements, or approved equivalent.

2.6.15.10 Any components of the MVDS system housed inside a remote ITS equipment cabinet shall be field hardened and rated by the manufacturer to meet the requirements of the NEMA TS2 Standard. The design shall be inherently temperature compensated to prevent abnormal operation. The circuit design shall include such compensation as is necessary to overcome effects due to temperature in the specified environmental range.

2.6.15.11 The MVDS shall include an OEM approved power supply system consisting of a circuit breaker, AC surge protector, lightning surge protection, and an AC/DC converter. Solar or DC powered sites shall include a circuit breaker and surge protection devices for both lightning and transient voltage.

2.6.15.12 The MVDS unit shall be operable from 10 – 24V DC dissipating not more than 15W.

2.6.15.13 The MVDS detector shall be capable of receiving power and communicating through an RS-232 or RS-485 cable, supplied by the MVDS manufacturer. Cables shall be shielded, UV-resistant and rated for outdoor use. Cable connector pins must be soldered to the cable conductors, assembled and tested by the cable manufacturer.

2.6.15.14 The MVDS detector unit shall include a single MIL-Spec (MS) connector which provides power to the unit, output contact closure wire pairs for each of the required detection zones and serial communication lines for programming and testing. Connections shall be environmentally sealed.

2.6.15.15 A serial-to-Ethernet converter device shall be provided to convert serial data communications from the detector unit to Ethernet data for transmission through the proposed communication system. The device shall be compatible with the proposed communication system for the site, and capable of transmitting reliable data to the NHDOT ATMS.

2.6.15.16 The MVDS shall store average interval data in non-volatile flash memory.

2.6.15.17 The MVDS shall have the capability to be controlled and tested locally at the MVDS site utilizing a laptop computer with manufacturer software. Data collected by the MVDS shall also be viewable at the MVDS site through the same software.

2.6.15.18 The MVDS shall comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules or the appropriate Spectrum Management Authority. The MVDS shall not interfere with any known equipment.

2.6.15.19 The MVDS shall transmit on a frequency band of 24-24.25 GHz (K-band) or another approved spectral band.

2.6.15.20 No component of the MVDS system shall emit a noise level exceeding the peak level of 55 dBA when measured at a distance of three feet away from its surface.

2.6.15.21 The MVDS unit shall achieve a Mean Time Between Failures (MTBF) of 10 years or more.

2.6.15.22 The MVDS sensor shall have a minimum 250-foot detection range and the capability to detect a minimum of 12 lanes of traffic, by lane and by direction.

2.6.15.23 The MVDS mounting shall be capable of rotating the detector unit up to 120 degrees left or right from vertical.

2.6.15.24 The MVDS's field of view shall cover an area defined by a beam of known shape and characteristics, and its maximum detection range shall be as follows:

(a) Elevation beam width of 50° to 70°.

(b) Azimuth beam width of 6° to 15°.

(c) Minimum detection ranges from 6 feet to 250 feet.

2.6.15.25 The MVDS shall be capable of meeting the minimum data collection accuracy levels as specified in 3.15.8 below.

2.6.16 A cellular modem-based communication system, unless otherwise specified or directed by the Engineer. Cellular systems shall meet requirements of Section 2.5.

2.6.17 All mounting accessories for sensors, equipment and control cabinets as required.

2.6.18 All additional required conduit, wiring, junction boxes, mounting equipment and appurtenances to form a fully functional RWIS system.

2.6.18.1 All exposed instrument interconnecting wires shall be UV rated and weatherproof, when not housed within conduit.

2.7 All RWIS site sensors and equipment shall be suitable for continuous outdoor use, in all types of weather conditions.

2.7.1 All RWIS site sensors and equipment shall be supplied with power and communications cables directly from the manufacturer, as required for the installation. All cables shall also be suitable for outdoor use, in all types of weather conditions.

2.8 Ground rods for grounding systems shall be ¾ -inch in diameter, and no less than 8–feet in length after installation

2.9 RWIS Support Structure.

2.9.1 The RWIS support structure shall be hinged to allow operators to manually raise or lower the sensors for the purpose of maintenance without a lift truck. The hinged support structure shall be a trussed tower.

2.9.2 The RWIS support structure shall be designed and constructed to a height suitable to provide a mounting and operating location for all proposed sensors and detectors, as required by the equipment manufacturers, at the proposed roadside offset location. The support structure height shall not exceed 40 feet.

2.9.3 The RWIS support structure and all associated members shall be designed/approved by a NH licensed Professional Engineer and designed and fabricated in accordance with the current edition of *AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, ANSI/TIA-222 Structural Standard for Antenna Supporting Structures, Antennas and Small Wind Turbine Support Structures,* and *NHDOT Standard Specifications,* except as noted below:

Basic Wind Speed: 1700-year Mean Recurrence Interval (MRI) basic wind speed of 130 mph (209 km/hr) shall be used for the whole state of NH except in the Special Wind Region (i.e. regions along the NH-VT border and Franconia Notch) as shown in *AASHTO LRFD Specifications, Fig. 3.8-2b*. The maximum-recorded wind speed in this area shall be used as the basic wind speed if it is greater than the NH basic wind speed of 130 mph (209 km/hr).

Fatigue Importance Category: Cantilevered Category II (poles with distance to roadway > height of pole)

Fatigue Importance Category: Cantilevered Category I (poles with distance to roadway ≤ height of pole)

Risk Category of Structures: All towers shall be calculated for Risk Category III as shown in ANSI/TIA-222 unless otherwise directed.

2.9.4 The tower structure shall be assembled from ASTM A572 Gr. 50, ASTM A53 Gr. B, or ASTM A500 Gr. B steel hot dipped galvanized per ASTM A123; or 6061 T6 aluminum, solid or hollow rods meeting the requirements for ASTM B221 or B429.

2.9.5 The trussed tower structure and all associated ancillary members shall be aluminum or steel, galvanized in accordance with the current *AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*; *ANSI/TIA-222 Structural Standard for Antenna Supporting Structures, Antennas and Small Wind Turbine Support Structures*; and *NHDOT Standard Specifications* Section 550.2.9.

2.9.6 The calculations shall include the trussed tower structure, base, and anchor rod design. The calculations shall be analyzed at the structure base and at 5-foot intervals along the full height of the trussed tower.

2.9.7 The support structure shall be designed to support the environmental sensors and equipment, plus additional 15 pound loads located at the top of the structure and at every 5-foot interval down to the middle height of the proposed truss structure.

2.9.8 The hinged support structure shall have the ability to be manually lowered using a heavy-duty hand-powered stainless steel winch and cable with an automatic brake and a removable hand crank.

2.9.9 The hinged support structure shall be supplied with earth ground terminals (ground rods) with a resistance of no greater than 15-ohms.

2.9.10 The hinged support structure shall include an anti-climb kit consisting of three 10 ft. panels installed on the tower base section.

2.10 Support Structure Foundations.

2.10.1 The foundation shall be designed by a Professional Engineer licensed in the State of New Hampshire in accordance with the current edition of *AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, ANSI/TIA-222 Structural Standard for Antenna Supporting Structures, Antennas and Small Wind Turbine Support Structures*, and *NHDOT Standard Specifications* Section 550. Foundations shall be cast in place.

2.10.2 Concrete shall be Class A for drilled shaft foundations and Class B for spread footing foundations, and shall conform to *NHDOT Standard Specifications* Section 520.

2.10.3 All reinforcing steel shall conform to AASHTO M 31M/M 31, Grade 60(420), and shall conform to *NHDOT Standard Specifications* Section 544, unless noted otherwise.

2.10.4 Anchor rods for the foundation shall be straight rods and conform to the requirements of ASTM F1554 Grade 55 (minimum). Do not use ASTM A615 reinforcing steel. Galvanize the entire rod per ASTM A153. Each anchor rod shall be supplied with a minimum of three hex nuts (ASTM A563 or ASTM A194) and a minimum of two flat hardened washers (ASTM F436). Lock washers shall not be used. The embedded end of the anchor rod shall have either one nut tack welded or double nuts. Bent (hooked or J-bolt) anchor rods shall not be used.

2.10.5 Stainless steel standard grade wire cloth surrounding the tower base plate shall have

¼-inch maximum opening with minimum wire diameter of AWG No. 16. Stainless steel banding to secure the wire cloth shall be ¾" wide.

2.11 System Control and Communications.

2.11.1 All environmental sensors shall be provided by the Contractor from one single manufacturer for synchronicity, and shall include all materials necessary to connect to the RPU and associated software system.

2.11.2 The environmental sensor communication links shall be capable of integrating into the data and power management units located in the RPU cabinet.

2.11.3 The data produced by the sensor subsystems shall be consistent with NTCIP objects.

2.11.4 All environmental sensors shall report fault and low battery information to the RPU when capable.

Modify 3.3 Flexible Liquid Tight Conduit (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification) to read:

3.3.1 Any conduit installed above grade for communications and electrical cabling shall be flexible liquid tight or rigid metallic conduit meeting the requirements of these specifications.

3.3.2 Connections of above grade flexible liquid tight or rigid metallic conduit to underground PVC conduit shall be made watertight. [Continued in Section 3.3 (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification)]

Add to 3.6 ITS Device and System Testing (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification):

3.6.9 The Contractor shall develop and prepare a stand-alone test plan for each RWIS field site, as well as a Central Control Test for the entire system (i.e. monitoring and control of the RWIS from the NHDOT TMC). The purpose of these tests is for the Contractor to demonstrate that the installed system meets the requirements of this Contract.

3.6.10 CCTV and MVDS testing shall be completed by the Contractor, following NHDOT standard testing plans for ITS devices, located on NHDOT's website (https://www.nh.gov/dot/business/contractors.htm). Nighttime Testing is only required for CCTV cameras.

3.6.11 The Contractor shall furnish the following information with the final testing reports:

3.6.11.1 A complete list of the equipment installed including model numbers, serial numbers, and accessories that have been provided.

3.6.11.2 Documented system ground resistance measurements.

3.6.11.3 As-built site diagrams that show instrument, equipment, and cabinet layouts.

3.6.12 Test results shall be packaged and submitted to NHDOT within one week of test completion.

3.6.13 Stand-Alone Test Requirements.

3.6.13.1 ITS Device Stand-Alone Testing shall be performed after the field installation of all equipment is complete, but before connection with any communications system, network, or the NHDOT TMC in Concord. The test shall exercise all stand-alone functional operations of the sensors, backup power, Ethernet switches, communication equipment, and all other equipment installed, and demonstrate compliance with the functional requirements defined in this specification. Stand-alone testing shall be conducted at device field locations using computers and software supplied by the Contractor. If an ITS device fails to pass its stand-alone test, the Contractor shall correct the problem or replace the unit and retest it until satisfactory results are achieved.

3.6.13.2 Stand-Alone testing shall include, but not be limited to:

(a) Verification by means of inspection that all approved equipment has been installed in accordance with the Contract Documents.

(b) Verification by means of inspection and ground resistance measurement that all ITS devices hardware, mounting, cabinets, equipment, and utility service grounding is in accordance with the NHDOT "Standard Specifications for Road and Bridge Construction", NEC, the manufacturer's recommendations, or the contract requirements, whichever is more stringent.

(c) Verification by using a three-probe ground tester, that the site grounding system meets a maximum resistance to ground of 25 Ohms, or as recommended by the equipment manufacturers, whichever is less.

(d) Verification that all interconnecting cables, monitors, network equipment and equipment controllers are installed in accordance with and comply with the specifications.

(e) Verification that the battery backup system provides the required run time without utility power as specified in the Contract Documents.

(f) Verification that all installed equipment communicates correctly to a local computer connected through the Ethernet switch in each ITS Equipment Cabinet. Ethernet switches and all connected devices shall be configured with IP addresses as supplied by the NHDOT.

3.6.13.3 Stand-alone testing of both CCTV and MVDS, as required by NHDOT standardized testing plans.

3.6.14 Central Control Test Requirements.

3.6.14.1 Central Control testing shall be conducted after the successful completion of ITS Device Stand-Alone testing and associated communications system testing, and shall be used to verify that the Contractor has correctly implemented communication links to any communications hubs, network, and/or backbone communication systems. It is assumed that the appropriate communications network has been fully installed and tested prior to the start of this Central Control Test. All central control testing shall be conducted at the NHDOT TMC. Tests will be coordinated with the NHDOT TMC. Testing shall utilize Contractor supplied software for testing the ITS devices, backup power, Ethernet switches, and communication equipment as needed.

3.6.14.2 Central Control testing shall include, but not be limited to:

(a) Verification that database parameters and addressing for new devices were properly entered to allow communications between the NHDOT TMC workstations and the new ITS field devices.

(b) Verification that the MVDS, RWIS sensors, and CCTV cameras communicate and are controlled by NHDOT's ATMS and Vaisala Navigator system.

3.6.14.3 Central Control testing of both CCTV and MVDS, as required by NHDOT standardized testing plans.

Add to Construction Requirements (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification):

3.12 RWIS Equipment Installation.

3.12.1 The mounting and alignment of the system components onto the support structure, separate electric and communications conduit for the system, data integration, wireless communication capability, and testing of the RWIS system shall be completed by the Contractor in collaboration with the Department, specifically the Bureau of TSMO.

3.12.2 The Contractor shall install all sensors, equipment and system components in accordance with the manufacturers' recommendations.

3.12.3 At the direction of the NHDOT TMC ITS Project Manager, the RWIS system components shall be delivered to NHDOT prior to field installation for bench configuration and testing. Contact the ITS Project Manager at the NHDOT TMC (603-227-0016) for instructions.

3.12.4 All RWIS sensors shall be mounted to the support structure, except as follows:

3.12.4.1 The barometric pressure sensor shall be mounted to either the RWIS control cabinet or RWIS support structure as recommended by the sensor manufacturer.

3.12.4.2 Subsurface temperature probe shall be installed under the paved roadway surface.

3.12.5 Non-invasive, remote road-surface temperature and condition sensors, CCTV camera and MVDS equipment shall be mounted to the RWIS support structure, unless otherwise shown on the plans or as directed by the Engineer.

3.12.6 Non-invasive sensors shall be mounted at an install angle between 30° and 85° from horizontal, at a height recommended by the manufacturer for proper calibration and function.

3.12.6.1 Non-invasive sensors shall be aimed for consistent reading of conditions at the center of the travel way pavement. Care shall be taken to avoid reading of any pavement markings or other obstructions that may cause inaccuracies in the sensor data.

3.12.6.2 Non-invasive sensors shall be re-calibrated by the Contractor after final pavement has been placed.

3.12.7 Subsurface probe shall be installed before the final wearing surface of pavement is applied. Installation shall meet the requirements of Section 616 for Inductive Loop Detectors, except as follows:

3.12.7.1 Pavement slot cutting shall be at a width and depth recommended by the subprobe manufacturer for the size and type of cable required.

3.12.7.2 Testing of subprobe cable resistance, unless included in the RWIS testing plan submittal, will not be required. The Contractor shall ensure proper installation of the probe and cables by verifying data from the probe is being collected at the RPU or through the Vaisala Navigator system. Any damage to the cable or malfunction of the temperature subprobe shall be corrected by the Contractor.

3.12.7.3 Subsurface temperature probes shall be installed in a pavement core hole at a depth of 17 inches under the paved roadway surface, or as recommended by the manufacturer. The subprobe shall be installed under shoulder pavement as directed by the Engineer. In areas where shoulder width is less than 8 feet, the probe shall be installed in the center of the nearest travel way.

3.12.8 All sensors, detectors and cameras shall be mounted to avoid interference by any other device, guardrail, vegetation or other obstructions, and ensure full functionality of all installed hardware.

3.12.9 All sensors and equipment shall be mounted in such a way to not interfere with the hinged support structure lowering operation.

3.12.10 Wind sensor shall be installed near the top of support structure to prevent measurement inaccuracies due to detection of traffic wind gusts. The protective bird cage shall be installed as recommended by the manufacturer.

3.12.11 Temperature and humidity probe shall be attached to the support structure near roadway level as recommended by the manufacturer. Probe precipitation and radiation shield shall be installed as recommended by the manufacturer.

3.12.12 RPU and battery backup systems shall be mounted either to the support structure, or ground mounted concrete foundations.

3.12.12.1 The Contractor shall determine if the RWIS system components will be housed in ground mounted or pole mounted cabinets based upon the manufacturer recommendations for the proposed equipment, as approved by the Engineer. The Contractor shall construct foundations for the proposed cabinets as required.

3.12.12.2 In cases where the RPU or battery backup cabinet is to be ground mounted, the cabinets shall be affixed to concrete foundations with a minimum depth of 42", and measuring 6" wider than cabinet base.

3.12.12.3 RPU and battery backup enclosures shall be mounted at suitable locations for maintenance access and shall not conflict with any other installed equipment or the hinged support structure lowering operation.

3.12.13 A concrete work pad measuring 5'x3'x4" minimum and meeting requirements of Section 608 for concrete sidewalks shall be installed at all cabinet door locations. The pad shall have a 2% slope, and the Contractor shall grade the surrounding area to eliminate any trip hazards and provide positive drainage away from the pad.

3.12.14 The battery backup system shall provide backup power to all RWIS environmental sensor equipment, CCTV camera, MVDS, RPU, and communication equipment installed.

3.12.14.1 RWIS systems shall be connected to the battery backup system in such a way that there will be zero transfer time in the event of AC power loss.

3.12.15 Utility power outlets shall be installed for use by a technician. Outlets shall not be used to power any permanently installed equipment.

3.12.15.1 The utility power outlet shall be hard wired to the AC power supply and not the battery backup system.

3.12.15.2 The utility power outlet shall be installed within the RPU enclosure cabinet and not on the enclosure door.

3.12.16 The Ethernet switch shall be installed within the RPU enclosure cabinet, either to a DIN rail or secured to enclosure shelving. The switch shall be oriented to allow viewing of connections and status LED indicators.

3.12.16.1 The Ethernet switch shall include all accessories required for a full and complete installation, including but not limited to connecting cables, power supplies, and mounting hardware.

3.12.16.2 The Ethernet switch shall accept communication inputs from the RWIS RPU, CCTV and MVDS, and route it to the proposed RWIS site communication system.

3.12.16.3 The CCTV and MVDS communications shall bypass the RWIS RPU system and connect directly to the proposed Ethernet switch.

3.12.17 The Contractor shall install CCTV cameras to provide unobstructed roadway views as indicated or directed by the Engineer.

3.12.17.1 The Contractor shall establish camera preset views as directed by the Engineer. Preset camera views will be based on video recordings provided as part of the technical submittal, see Section 2.3.9 above.

3.12.17.2 The CCTV camera shall be mounted to the support structure using mounting hardware and accessories as recommended by the CCTV camera manufacturer.

3.12.17.3 The CCTV camera shall be connected to the proposed communication system using manufacturer recommended cabling. Ethernet connections shall be shielded and environmentally sealed.

3.12.17.4 Power over Ethernet Injectors shall be securely installed in the RPU enclosure.

3.12.18 The Contractor shall install, aim and calibrate all MVDS devices to accurately report speed, volume, occupancy, and vehicle classification.

3.12.18.1 The MVDS shall be mounted in a side-fired configuration on the proposed support structure in order to monitor the vehicles traveling along the adjacent highway.

3.12.18.2 The MVDS shall be mounted and angled up to 120 degrees left or right from vertical, as recommended by the manufacturer, to accurately aim the detection beam and collect accurate traffic data.

3.12.18.3 The Contractor shall install the detector unit at a height above the road surface, as recommended by the manufacturer, based on the offset from the edge of travel lanes and the number of lanes being detected.

3.12.18.4 The MVDS shall be mounted so that the detection beam transmits perpendicular to the roadway traffic.

3.12.18.5 All MVDS systems and cabling shall be mounted to avoid interference by any other installed device, communication system equipment, guardrail, vegetation or other obstructions, and ensure full functionality of the installed hardware.

3.12.18.6 When more than one MVDS is mounted to the same structure, or within 20 feet of another MVDS, the sensors shall be configured to operate on different radio frequency channels to avoid interference.

3.12.18.7 Cables supplied by the MVDS manufacturer shall provide connection between the MVDS detector and the cabinet equipment in a continuous length. Splicing of the cable shall not be permitted. Cable connections shall be environmentally sealed.

3.12.18.8 The Contractor shall apply a dielectric compound to the detector unit connection, as recommended by the MVDS manufacturer.

3.12.18.9 All MVDS instrument interconnecting wires shall be UV rated and weatherproof, or housed within conduit.

3.12.18.10 The Contractor shall supply all connecting cables required to connect the MVDS to the proposed communication system.

3.12.18.11 Except for the detector unit, all MVDS equipment shall be installed in a suitable equipment cabinet as shown on the plans or as directed by the Engineer.

3.12.18.12 Each MVDS installed shall include all equipment necessary to collect, store and transmit data through its own data stream, and shall operate independently from any other MVDS installed.

3.12.19 Cell communication equipment shall be installed in accordance with Section 3.4.

3.12.20 All mounting hardware and cross arms necessary for all above ground sensors, as recommended by the manufacturers, shall be provided and installed by the Contractor.

3.12.21 All additional required conduit, wiring, pull boxes, mounting equipment, and accessories to form a fully functional RWIS system shall be provided by the Contractor.

3.12.21.1 All instrument interconnecting wires shall be UV rated and weatherproof, or housed within conduit.

3.12.21.2 Where conduit is used, separate conduits shall be used for each instrument.

3.12.21.3 Conduits shall be sufficient size in accordance with the National Electric Code (NEC).

3.13 RWIS Support Structure and Foundation.

3.13.1 The hinged support structure shall fold parallel with the roadway, in the direction of travel, unless otherwise noted on the plans or as directed by the Engineer.

3.13.2 The support structure shall be installed such that the top of the truss structure lowers in a direction that does not interfere with traffic or local site constraints (including right of way, vegetation, drainage features, slopes, guardrail, or others) and that the installed equipment is accessible from the ground without the use of a ladder higher than eight feet.

3.13.3 All tools required to operate the hinged support structure lowering system shall be provided by the Contractor.

3.13.4 Support structures shall be installed plumb in accordance with the manufacturer’s recommendations.

3.13.5 Support structures shall not be installed until the concrete base has cured for at least 7 days and attained a compressive strength of at least 80% of the concrete design strength.

3.13.6 See Appendix A of this Special Provision for additional installation requirements. These installation requirements shall be made applicable to the hinged, trussed-tower support structure.

3.13.7 Geotechnical Engineering Services. All geotechnical services for this work will be provided by NHDOT Materials and Research. The Contractor shall review the project Geotechnical Report for boring information relevant to the proposed foundation location, and provide a foundation design for review and approval based on the proposed mounting structure and geotechnical information.

3.13.8 Concrete shall be constructed in accordance with Section 520. Reinforcing steel shall be constructed in accordance with Section 544.

3.13.9 Backfill shall be constructed in accordance with Section 209 or Section 508 as required in the Contract Documents.

3.13.10 The applicable provisions of Section 550.3 apply to structural steel connections made with high strength bolts (e.g. ASTM A325). The installation procedures for anchor rods are different than for high strength bolts and shall conform to the following:

(a) *AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*;

(b) *FHWA Guidelines for the Installation, Inspection, Maintenance and Repair of Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (Publication No. FHWA NHI 05-036 March 2005).

(c) *ANSI/TIA-222 Structural Standard for Antenna Supporting Structures and Antennas and Small Wind Turbine Structures.*

3.13.11 Concrete foundations shall be constructed against undisturbed material.

3.13.12 Support structure foundations shall be placed in a dewatered drilled hole or in an excavated hole using the proper forms.

3.13.12.1 If the drilled hole method is performed and the soils are found to be unsuitable, an excavated hole shall be completed as approved by the Engineer.

3.13.12.2 The foundation shall have a formed appearance from the top of the shaft to a depth of at least 12 inches below the final grade, with the top having a smooth level finish.

3.13.13 The top of the foundation should be placed a minimum of 4 inches higher than the adjacent highest soil.

3.13.14 The bottom of the foundation shall be placed a minimum of 5’-0” below the lowest finished grade for frost protection.

3.13.15 The top of the foundation shall be coated with water repellent to 1’-0” below finished grade in accordance with section 534.

3.13.16 For the drilled shaft option, the RWIS support structure foundation shall be constructed in accordance with the requirements described in Appendix B of this Special Provision, and the contract plans.

3.13.16 Install stainless steel wire cloth at the base of the support structure with a 2” lap and secure with stainless steel banding after anchor bolts are tightened. The purpose of the screen is to eliminate debris beneath the base plate, keep animals out and protect electrical wires if no other base protection is provided. Secure cloth in a manner that will permit its removal for maintenance. Grout shall not be used between the opening of the structure base plate and the top of the foundation.

3.13.17 Trenches for the adjacent conduits shall be hand dug near the proposed footing, disturbing as little soil as possible in placing the conduits. The resulting trenches shall be backfilled with structural fill conforming to Section 508.

3.14 Grounding, Bonding and Transient Voltage Surge Suppression.

3.14.1 The Contractor shall furnish and install TVSS devices for all power and communications conductors. TVSS devices shall be installed for all conductors leaving the RPU and battery backup enclosures, and on all CCTV and MVDS wiring.

3.14.2 The Contractor shall provide and install a TVSS between the AC power mains and all installed equipment.

3.14.3 The hinged support structure shall be supplied with an air terminal that is bonded by an insulated wire to the earth terminal-wire attachment at the base of the structure.

3.14.4 The support structure’s air terminal and ground terminal wires shall be bonded to structure using an attached electric lug that allows for removal of the wires and independent resistance measurement of the earth ground resistance.

3.14.5 The support structure shall be supplied with an air terminal that is attached to a minimum #6 AWG stranded bare copper wire bonded to the grounding system at the base of the support structure.

3.14.6 Cabinet enclosure ground connections shall be made to a suitable common threaded heavy-gauge lug that can be attached to both sides (inside and outside) of the cabinet. The lug shall have the same composition as the cabinet.

3.14.7 The Contractor shall supply and install a ground array system to be installed at the base of the RWIS. The ground rod array system shall be connected to the RWIS through an

appropriate ground clamp. A #6 AWG copper wire shall be installed between the RWIS support structure and equipment cabinets, providing a common ground system for each terminus.

3.14.8 The support structure shall be bonded to the earth terminal using an earth ground array system with a resistance no greater than 25 Ohms to ground. All metallic enclosures, lightning arrestors, and instrument mounting brackets shall be bonded to this system.

3.14.8.1 Additional ground rods shall be installed to meet the manufacturer's recommended resistance to ground, or a maximum of 25 ohms, whichever is less.

3.14.8.2 The external earth terminals shall not be encased in any foundation.

3.14.9 All electrical connections to and within the grounding system shall be exothermically welded where possible.

3.14.10 Anti-oxidation electrical compound shall be used on all attachment points of the ground system where dissimilar metals intended for grounding and bonding come in contact with each other and on ground wire attachment points when exothermic welding cannot be used.

3.14.11 The support structure shall be supplied with a lightning dissipater that is attached to a #6 AWG stranded bare copper wire bonded to the ground terminal.

3.14.12 The RWIS support structure lightning dissipater shall consist of a series of at least four spot dissipaters in a candelabra arrangement with a single mounting assembly. The lightning dissipater system shall include surge suppressor devices of the type recommended by the lightning dissipater manufacturer, and shall properly interface with the pole mounted dissipater, and the size and type of cables installed at the RWIS site.

3.14.13 The lightning dissipater shall be attached to the RWIS support structure using manufacturer-recommended clamps that are attached to the structure. These clamps shall rigidly hold the lightning dissipater to the support structure in winds up to 100 MPH.

3.14.14 The lightning dissipater shall be offset from the RWIS support structure and provide protection for the RWIS above installed equipment without interfering with the functionality of any equipment or sensors.

3.15 System Control, Communications and Performance.

3.15.1 The Contractor shall coordinate any software modifications required to interface the installed equipment to the existing NHDOT ATMS or Vaisala Navigator system. The Contractor shall be responsible for the end-to-end integration of the RWIS site equipment with the Vaisala Navigator application, and for the end-to-end integration of the RWIS site equipment, CCTV camera and MVDS with NHDOT's ATMS.

3.15.2 NHDOT and other stakeholders shall have access to Navigator information and NHDOT's ATMS concurrently with this installation.

3.15.3 The RWIS sites shall comply with Navigator II standards by using SNMP for Weather data and FTP for CCTV Images from the RPUs.

3.15.4 The Contractor shall provide Milestone XProtect Corporate Edition camera licenses to the Department for each CCTV camera installed. The Contractor shall purchase the initial camera licenses plus the first year renewal cost, with upgrade protection. Licenses shall be provided for the Milestone software version used by the NHDOT TMC at the time of camera installation.

3.15.5 The MVDS shall be calibrated by the Contractor, and shall include individual lane calibration for all possible travel lanes and directions of travel at the installation site, or as directed by the Engineer.

3.15.6 The MVDS detection zones shall be set up using manufacturer software and a laptop computer supplied by the contractor.

3.15.7 The MVDS shall be calibrated to provide volume, speed, and occupancy for the proposed detection zones, and shall be calibrated to collect data at polling cycle intervals of 30 seconds.

3.15.8 The MVDS shall be installed and calibrated to collect data meeting the following minimum accuracy limits:

3.15.8.1 The MVDS shall record motor vehicle volume data, per lane, within 10%.

3.15.8.2 The MVDS shall record motor vehicle speed data, per lane, within 10%.

3.15.8.3 The MVDS shall record individual vehicle speeds within 5%.

3.15.8.4 The MVDS shall record motor vehicle occupancy data, per lane, within 20%.

3.15.9 The Contractor shall be responsible for integrating end-to-end connectivity between the all equipment installed and the NHDOT wireless communications or fiber backbone, or securing cellular carrier services.

3.15.10 The Contractor shall install wireless hardware and antennas, if required, as shown on the plans to provide complete communications connection between the field equipment and the NHDOT TMC.

3.16 ITS Cables.

3.16.1 All equipment shall be installed using the Manufacturer’s recommended cables.

3.16.2 The Contractor shall furnish, install, connectorize, and test all Category 6 (Cat. 6) cables, of the types required for the application, at locations shown in the plans or as required to construct a complete, functional system.

3.16.2.1 The Cat. 6 cables shall not exceed 325 feet in length unless the Contractor is granted written permission from the Engineer.

3.16.3 All cables shall be installed in a continuous run. Splicing will not be allowed.

3.16.4 All above ground cables shall be installed in flexible liquid tight conduit or rigid metallic conduit in accordance with Section 3.3.

Add to Method of Measurement (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification):

4.8 RWIS Systems, including foundations, will each be measured by the unit installed and integrated. Where more than one unit is specified in the contract, separate item numbers will appear for each unit.

Add to Basis of Payment (Special Provision to Section 677 - Intelligent Transportation Systems (ITS) Equipment – Base Specification):

5.7 The accepted quantity of the RWIS System will be paid for at the contract lump sum price complete in place. Payment shall be full compensation for the preparation and submittal of the Technical Submittal, the design, fabrication and installation of the trussed tower support structure and foundation, all installed sensors, mounting hardware, MVDS system, CCTV camera system, RPU, Ethernet switch, power over Ethernet injectors, battery backup system, equipment enclosures, any required equipment enclosure foundations, work pads, flexible or rigid conduit installed above ground, electrical and communication wiring of all equipment within enclosures or installed on the support structure, surge protection, grounding and bonding, connection to electrical and communication services, training, testing and providing as-built record documentation.

5.7.1 Partial payment for this item shall be in accordance with section 5.2 of the Base Spec.

5.7.2 The Contractor shall be responsible for all communication and electrical costs until system acceptance is achieved.

5.7.2.1 There shall be no separate payment for cellular communications equipment or antennas, as they are to be subsidiary to the RWIS Item in accordance with Section 4.3 of the Base Spec.

5.7.3 Any costs associated with 3.12.7.2 for correcting installation of the subprobe will be at the Contractor’s expense.

5.7.4 Installation of concrete work pad and any site grading required by section 3.12.13 shall be subsidiary to the work.

5.7.5 All conduit and pull boxes, except flexible liquid tight conduit or rigid metallic conduit installed above ground, will be paid for under Section 614.

5.7.6 Work or costs associated with any software modifications, including all licensing and integration fees required to integrate the installed equipment into the NHDOT's ATMS and Vaisala systems, shall be subsidiary to the work.

5.7.7 If more than one ground rod is required to achieve the required earth grounding resistance, all additional ground rod installation and ground wire connections will be subsidiary to the RWIS.

5.7.8 Excavation required to construct foundations shall be subsidiary to the work.

Pay items and units:

677.420_	Roadway Weather Information Station (RWIS) System	Unit

Appendix A

General Installation Requirements for RWIS Support Structure and Foundation

The applicable provisions of 550.3 apply to the steel structure installation of connections made with high strength bolts (e.g. ASTM A325). The installation procedures for anchor rods are different than for high strength bolts and shall conform to the following:

1. Current *AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals;*
2. *FHWA Guidelines for the Installation, Inspection, Maintenance and Repair of Structural Supports for Highway Signs, Luminaires, and Traffic Signals (Publication No. FHWA NHI 05-036 March 2005).*
3. *Current ANSI/TIA-222 Structural Standard for Antenna Supporting Structures, Antennas, and Small Wind Turbine Support Structures.*

Procedure for Installing Anchor Rods in the Foundation for Double-Nut Connections
The procedure for installing anchor rods in the foundation for double-nut connections is as follows:

1. The Foundation Contractor shall submit a written plan and procedure to the Department for approval for the installation, pretensioning, inspection, and testing of anchor rods.
2. The Contractor shall furnish necessary equipment, including a torque wrench, used for tensioning the rods or for final torque verification, that has a torque indicator that is calibrated annually. A certificate of calibration shall be furnished to the Department at the jobsite. A torque multiplier may be used. For hydraulic wrenches, the Contractor shall furnish a chart correlating torque with hydraulic pressure readings.
3. Anchor rods shall be installed as a group in the concrete form and secured against relative movement and misalignment, such as with a template set composed of metal rings with nuts on both sides at two locations along the length of the anchor rods. One of the rings is usually above the top of the concrete and is reused as a template.
4. The template set (or other device) with anchor rods shall be secured in its correct position in the concrete form in accordance with the drawings. The exposed threads shall be taped with duct tape to prevent contamination by concrete.
5. The concrete shall be placed and cured in accordance to Section 520.
6. If a top template is above the concrete surface, it may be removed 24 hours after placing the concrete.
7. The exposed part of the anchor rods shall be cleaned with a wire brush or equivalent and lubricated. Use an approved paraffin-based stick wax, as listed on the NHDOT

Qualified Products List for Item 550 fasteners, applied to the threads and the nut face in contact with the washer.

8. After at least 24 hours after placing concrete, the anchor rods shall be inspected visually to verify that there is no visible damage to the threads and that their position, elevation, and projected length from the concrete are within the tolerances specified on the drawings. In the absence of required tolerances, the position, elevation, and projected length from the concrete shall be according to the AISC *Code of Standard Practice for Steel Buildings and Bridges.* The misalignment from vertical shall be no more than 1:40. It is good practice to use a steel or wood template with the required hole pattern to check the base of the post and the anchor rods.

   To check the thread condition the nuts shall be turned onto the rods full length well past the elevation of the bottom of the leveling nut and backed off by one worker using an ordinary wrench without a cheater bar. The threads are considered damaged if more than minimal effort (i.e. an unusually large effort) is required to turn the nut.

9. The structure shall not be placed onto the leveling nuts until the foundation concrete has cured for at least 7 days minimum or attained a minimum of at least 80 percent of its design compressive strength and the foundation backfilled to final ground.

10. Final ground elevations shall be taken from the roadway cross sections. If actual final ground elevations differ by more than 1'-0", then a complete redesign of the sign foundation will be required.

Procedure for Pretensioning Anchor Rods in Double-Nut Joint Moment Connections.

The procedure for pretensioning anchor rods in double-nut joint moment connections in the installed concrete foundation is as follows:

1. The proper position of the anchor rods and the proper hole pattern on the post shall be verified (preferably with a template).
2. It shall be verified that the nuts can be turned onto the rods well past the elevation of the bottom of the leveling nut and backed off by one worker using an ordinary wrench without a cheater bar.
3. If the threads of anchor rods were lubricated more than 24 hours before placing the leveling nuts or have been wet since they were lubricated, the exposed threads of the anchor rod shall be re-lubricated. Leveling nuts shall be cleaned and the threads and bearing surfaces lubricated.
4. Leveling nuts shall be placed on the anchor rods and set level.
5. Leveling nut washers shall be placed on the anchor rods.
6. The template shall be placed on top of the leveling nuts to check the level of the nuts. Verify that the maximum clear distance between the bottom of the bottom leveling nut and the top of the concrete is not more than one anchor rod diameter. The preferred clear distance is one inch. Start by placing the leveling nuts one half inch

clear distance above the concrete foundation. Bring all the nuts to the same level as the highest nut above the foundation. Do not exceed the maximum clear distance of one anchor rod diameter between the concrete foundation and the bottom of the leveling nuts. Remove the template once all the nuts are level.

7. The baseplate and structural element (e.g. post, end frame, or structure leg) shall be placed with a crane.
8. The post, end frame, or structure leg shall be plumbed or the base plate leveled, and the anchor rods pretensioned. The following is the installation sequence for double-nut joints using the "turn-of-the-nut" method of pretensioning.
9. Top nut washers shall be placed. (Note: Do not use lock washers when anchor rods are pretensioned for double-nut connections using the pretension procedures described herein.)
10. Lubrication of the fastener components is required for proper installation. Anchor rod threads, nut threads, and the bearing surface of top nuts shall be lubricated, and the top nuts placed and tightened to the snug-tight condition (20-30% of the verification torque). See section FHWA Guideline Reference and Table 3. (Note: A snug-tight condition is the tightness attained by the full effort of a person using a wrench with a handle length equal to 14 times the diameter of the bolt but not less than 18 inches. Apply the full effort as close to the free end of the wrench as possible. Pull firmly by leaning back and using the entire body weight on the end of the wrench until the nut stops rotating.)
11. Leveling (bottom) nuts shall be tightened to the snug-tight condition (i.e. 20-30% of the verification torque. See Table 3.) following a star pattern for two full tightening cycles. (Note: Use a minimum of two separate passes of tightening. Sequence the tightening in each pass so that the opposite side nut will be subsequently tightened (i.e. following a star pattern shown in Figure 8) until all the nuts in that pass have been snugged.)

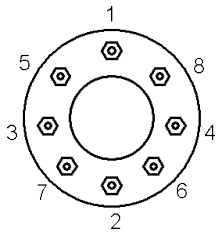

Figure 8. Star Pattern Tightening Sequence.

12. At this point, the installation crew shall verify if beveled washers are necessary. Beveled washers may be necessary under the leveling or top nut if any face of the base plate has a slope greater than 1:20 and/or any nut could not be brought into firm contact with the base plate. If any beveled washer is required, the installation crew shall disassemble the joint as necessary, add the beveled washer(s) and retighten (in a star pattern) to the snug-tight condition for the top and leveling nuts.

13. Pretensioning by "Turn-of-the-Nut": Pretension the anchor rods to the minimum Installation Pretension listed in Table 3 in the following manner. Before turning the top nuts further, the reference position of the top nut in the snug-tight condition shall be marked relative to the rod and base plate with a suitable marking using a permanent paint marker. Mark the rod, nut, and base plate with marks in a straight line when viewed from above. Top nuts shall be turned in increments following a star pattern for at least two full tightening cycles to attain the nut rotation specified in Table 1 if UNC threads are used. After pretensioning, the nut rotation shall be verified.

Table 1 - Nut Rotation for Turn-Of-Nut Pretensioning

Anchor Rod Diameter, in.	Nut Rotation from Snug-Tight Condition a, b, c	
	F1554 Grade 36	F1554 Grades 55 and 105 A615 and A706 Grade 60
1 1/2 or less	1/6 Turn (60°)	1/3 Turn (120°)
>1 1/2	1/12 Turn (30°)	1/6 Turn (60°)

a. Nut rotation is relative to the anchor rod. The tolerance is plus 20 degrees.
b. Applicable only to double-nut joints.
c. Beveled washer shall be used if:
   i) the nut is not in firm contact with the base plate; or
   ii) the outer face of the base plate is sloped more than 1:40.

14. The load may be released from the crane.

15. Initial check- A torque wrench shall be used to verify that a torque at least equal to the computed verification torque, Tv, is required to additionally tighten the leveling nuts and the top nuts. See Section FHWA Guideline Reference and Table 3. An inability to achieve this torque (meaning that the nut moves before the torque is achieved) shall be interpreted to indicate that the threads have stripped and shall be reported to the Department. (Note: The installation procedure relies on the "Turn-of-the-Nut" method to achieve the Installation Pretension. Although torque is considered to be a poor way to ensure pretension (due to variable thread condition) it is the only way to check tension after tightening.) The Department may reject, and subsequently require replacement of, the entire base installation if the threads have stripped. All costs associated with replacing the base installation, if rejected, or performing other repairs shall be borne by the Contractor.

16. Relaxation check- After at least 48 hours have elapsed, and in the presence of the Department, the torque wrench shall be used to verify that a torque at least equal to 110 percent of the verification torque, Tv, is required to additionally tighten the leveling nuts and the top nuts on the anchor rods. See FHWA Guideline Reference and Table 3. An inability to achieve this torque (meaning that the nut moves before

the torque is achieved) shall be interpreted to indicate that the threads have stripped and shall be reported to the Department.

17. Ultrasonic testing (UT) - The Contractor shall ultrasonically test (UT) the installed anchor rods using straight-beam transducers to verify the absence of flaws. (See Appendix A for UT procedures.) The Department will reject, and shall require replacement of, the entire base installation if reflectors are found with an indication rating less than 15 decibels. All costs associated with replacing the base installation, if rejected, will be borne by the Contractor.
18. During maintenance activities the Department intends to verify that the top nuts are not loose. Under no circumstance shall any nut be tack welded to the washer or the base plate nor shall the leveling nut be tack welded as a method of preventing nut loosening.

FHWA Guideline Reference:

1. In the FHWA Guideline document, the snug-tight condition for anchor rods is defined as nuts tightened to a torque between 20 and 30 percent of the verification torque computed using the following equation:

   $T_v = 0.12 d_b F_I$ where

   T_v = verification torque (inch-kips)

   d_b = nominal body diameter of the anchor rod (inches)

   F_I = minimum installation pretension (kips) equal to 50 percent of the specified minimum tensile strength of F1554 Grade 36 rods, and 60 percent for all other threaded fasteners.

   (Note: the torque in "in-kips" can be multiplied by 83.3 to get ft-lb).

2. A very large torque may be required to properly tighten anchor rods greater than 1 inch in diameter. A "cheater bar" such as a pipe or extension handle as much as 10 feet long may be required for the torque wrench. For snugging the leveling nuts, an open-end wrench with a ten-foot long pipe or extension handle will typically suffice. Tightening the top nuts for anchor rods greater than 1 inch in diameter may require either of the following:

   - A hydraulic torque wrench, or
   - A box end "slug" or "knocker" wrench with a 10-ft, long pipe or extension handle.

   The box end wrench may be moved by impacts with a 16-pound sledgehammer or by the efforts of three or more workers. It is essential that the workers have good traction during this effort.

Table 2 - Tensile Properties for Anchor Rods

Tensile Property	ASTM F1554 Rod Grade 36	ASTM F1554 Rod Grade 55	ASTM F1554 Rod Grade 105	ASTM A706 Bars Grade 60 *
Minimum Yield Strength F_y, (ksi)	36	55	105	60
Minimum Tensile Strength F_u, (ksi)	58	75	125	80

* Reinforcing bars shall not be used for non-redundant, fatigue-susceptible support structures such as cantilevered overhead sign structures and high mast luminaires.

Table 3 - Minimum Anchor Rod Pretension for Double-Nut Moment Joints

ASTM F1554 Grades 36, 55, and 105 rod material:

Nom. Bolt diam D, (in)	Gross Area (sq in)	UNC Stress Area (sq in)		**Installation Pretension, Fi (kips)**	Snug Tight Torque check 20-30% Tv (ft-lb)	Verification Torque check Tv (ft-lb)	Relaxation Check 110% Tv (ft-lb)
Yield 36		Min. Tensile, Fu, 58 ksi	0.50 Fu (ksi)				
1.00	0.79	0.61	29	**18**	35-53	177	195
1.25	1.23	0.97	29	**28**	70-105	351	387
1.50	1.77	1.41	29	**41**	123-184	613	674
1.75	2.41	1.90	29	**55**	193-289	964	1,060
2.00	3.14	2.50	29	**73**	250-435	1,449	1,594
2.25	3.98	3.25	29	**94**	424-636	2,120	2,332
Yield 55		Min. Tensile, Fu, 75 ksi	0.60 Fu (ksi)				
1.00 *	0.79	0.61	45	**27**	55-82	274	302
1.25	1.23	0.97	45	**44**	109-164	545	600
1.50	1.77	1.41	45	**63**	190-285	951	1,047
1.75	2.41	1.90	45	**86**	299-449	1,496	1,645
2.00	3.14	2.50	45	**113**	450-675	2,249	2,474
2.25	3.98	3.25	45	**146**	658-987	3,289	3,618
Yield 105		Min. Tensile, Fu, 125 ksi	0.60 Fu (ksi)				
1.00	0.79	0.61	75	**45**	91-137	457	503
1.25	1.23	0.97	75	**73**	182-273	909	1000
1.50	1.77	1.41	75	**105**	317-476	1586	1744
1.75	2.41	1.90	75	**143**	499-748	2493	2742
2.00	3.14	2.50	75	**188**	750-1125	3749	4123
2.25	3.98	3.25	75	**244**	1096-1645	5482	6030

ASTM A615 and A706 bar material **:							
Yield 60		Min. Tensile, Fu, 80 ksi	0.60 Fu (ksi)				
1.00	0.79	0.61	48	**29**	59-88	293	322
1.25	1.23	0.97	48	**47**	116-175	582	640
1.50	1.77	1.41	48	**68**	203-304	1,015	1,116
1.75	2.41	1.90	48	**91**	319-479	1,595	1,755
2.00	3.14	2.50	48	**120**	480-720	2,399	2,639
2.25	3.98	3.25	48	**156**	702-1053	3,509	3,859

** Reinforcing bars shall not be used for non-redundant, fatigue-susceptible support structures, such as cantilevered overhead sign structures and high mast luminaires.

*Example:

Fi = (0.60) (Fu) (Stress Area)	Fi = (.6)(75 ksi)(0.61 sq in) = 27 kips
Tv = (Fi) (D) (0.12) (83.3)	Tv = (27 k)(1.0 in)(0.12)(83.3) = 274 k-ft
Snug = (Tv) (30%)	Snug = (274 k-ft)(.3) = 82 k-ft
Check = (Tv) (110%)	Check = (274 k-ft)(1.1) = 302 k-ft

Anchor Rod Inspection by Ultrasonic Testing (UT)

1. Certification - The UT operator must be certified as ASNT Level II, on recommended practice SNT-TC-1A, or specifically trained by an ASNT Level III for this application.
2. Preparation -

a. Grind the top surface of all anchor rods to be as smooth as possible, flat (i.e., a level surface), square (i.e. perpendicular to the shank), and with all galvanizing, rust, dirt, and debris removed. The finished contour shall allow intimate transducer contact. Sand off any rust bloom that may have formed after grinding.

b. Note that some rods may be marked to serve as bench marks. Only grind the rod enough to remove paint and to smooth the surface and not change its elevation.

c. Some rods may have a slanted end and cannot readily be ground to a flat, perpendicular surface. Note such rods on the inspection form for future attention.

3. Calibration -

a. Check calibration at each location before inspecting any anchor rods.

b. Operate the UT per AWS D1.5 unless described or approved otherwise.

c. Calibrate the ultrasonic unit for straight beam probe method using a 10-inch screen with a 1-inch diameter (2.25 MHz) straight beam probe. The probe is placed on a 10-inch calibration block (DSC block or a threaded section of anchor bolt) and the indications on the screen are adjusted so that the back reflection is positioned at 10 inches. Next, place the probe on a 10-inch long test bar (i.e. the threaded section of anchor bolt) that has a 1/8 inch deep saw cut at a set distance (3-inch from the end opposite the probe) in the threaded portion of the rod. Peak the back reflection from the 1/8 inch deep saw cut until the indication is at 60 or 80 percent of screen height. The dB

reading is recorded to establish the "REFERENCE LEVEL." The "SCANNING LEVEL" is set by adding 14 to 30 dB over the reference level.

4. Test - Apply couplant to the top of the rods. Ultrasonically test the anchor rods using a circular motion inspection pattern and record the results. When scanning the anchor rods, there should be no indications on the CRT screen between the Main Bang (zero depth) and the end of the screen (10-inch depth). Any indication that is displayed after the Main Bang is a possible flaw. Record the depth of the discontinuity observed and the amount of dB required to bring the indication to the "REFERENCE LEVEL" on the screen. This is recorded as the "INDICATION LEVEL."
5. Cleanup - After UT inspection is completed, wipe off all the couplant with a wet rag, allow it to dry completely, and paint the rod ends with one or more coats of liquid cold galvanizing or zinc-rich paint to a minimum 3 mils dry film thickness (DFT). Check coating thickness with a gage.

Appendix B

S P E C I A L P R O V I S I O N

SECTION 509 -- DRILLED SHAFTS

Description

1.1 This work shall be covered under Item 677.420X (RWIS System).

Materials

2.1 Concrete. The Contractor's mix design shall meet the requirements of a Class A concrete in accordance with Section 520, except as modified herein. The slump shall be 8 inches plus or minus 1 inch after batching. The maximum aggregate size shall be 3/8 inches. The concrete shall be designed with the necessary admixtures to maintain the required slump and sufficient workability throughout the entire concrete placement and temporary casing removal operation.

2.2 Reinforcing Steel. Reinforcing steel shall conform to Section 544 and shall be Grade 60.

2.2.1 Clearance Spacers for Reinforcing Cage. Spacers used to provide the required sidewall and bottom clearance for the reinforcing cage shall be constructed of non-corrosive material that is equal in quality and durability to the shaft concrete, and shall be subject to approval. The spacers shall be of adequate dimension to ensure that the minimum clearance tolerances for the reinforcing cage are met, and that the reinforcing cage location is maintained during the concrete placement.

2.3 Temporary Casing for Drilled Shafts. Temporary casing shall be metal, smooth, watertight and of ample strength to withstand installation and removal stresses, and the pressure of both fluid concrete and the surrounding soils and/or water pressure, if the casing is to be pumped dry. Temporary casing shall have a minimum outside diameter equal to the design outside diameter of the drilled shaft.

2.4 Drilling Slurry. Slurry used in the drilling process shall be mineral, polymer or blended mineral-polymer slurries that conform to the requirements defined herein.

2.4.1 Mineral Slurry. The mineral slurry shall be sodium bentonite or attapulgite, and shall have both a mineral grain size that will remain in suspension and sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. The percentage and specific gravity of the material used to make the mineral suspension shall be sufficient to maintain the stability of the excavation and to allow proper concrete placement. The acceptable range of physical properties for the mineral slurry include the following:

Table 1 – Mineral Slurry Property Requirements

Property (Units)	At Time of Slurry Introduction	In Hole at Time of Concreting	Test Method
Density (pcf)	64.3 to 69.1	64.3 to 75.0	API 13B-1 Section 1
Viscosity (sec./quart)	28 to 45	28 to 45	API 13B-1 Section 2.2 Marsh Funnel and Cup
pH	8 to 11	8 to 11	pH paper or meter
Sand Content	Less than 4% (by volume)	Less than 4% (by volume)	API 13B-1 Section 5

Notes:
1. Increase density by 2 pcf in salt water.
2. Tests should be conducted when the slurry temperature is above 40°F.

2.4.2 Polymer Slurry. A submittal shall be provided for all polymer slurries proposed for use. The submittal shall include a detailed plan for quality control of the polymer slurry and shall include: a) tests and test methods to be performed, and b) the minimum and maximum property requirements that must be met to ensure that the slurry functions as intended, considering the subsurface conditions, the shaft construction method, the slurry manufacturer's recommendations and these provisions. The polymer slurry is subject to approval.

2.4.3 Blended Mineral-Polymer Slurry. If the Contractor proposes to use a blended mineral-polymer slurry, a detailed report specific to the project and prepared by a qualified slurry consultant shall be submitted. The report shall include the qualifications of the slurry consultant and shall describe the slurry materials, mix proportions, mixing methods and quality control methods. The blended mineral-polymer slurry is subject to approval.

2.4.4 Slurry Testing. The Contractor shall provide all the necessary equipment and personnel to test the slurry using the prescribed methods. The frequency of tests shall be as directed. A copy of the Test Method Specifications shall also be provided.

Construction Requirements

3.1 Qualifications. The Contractor and the Contractor's project superintendent for the drilled shaft work covered under this special provision shall have a minimum of three years experience in constructing drilled shaft foundations within the past five years. The Contractor's project superintendent shall be present at all times during execution of the work covered by this special provision. The Contractor's drill operator shall have a minimum of two years experience within the last four years. A summary of the experience and qualifications shall be submitted in writing to the Engineer at least four weeks prior to the start of the drilled shaft installation. The submittal shall include the name, address and phone number of the owner's representative who can verify the information provided. Acceptance of the Contractor or any Firm to perform the drilled shaft work shall be subject to approval.

3.2 Installation Plan Submittal. At least four weeks prior to constructing drilled shafts, the Contractor shall submit an installation plan in accordance with 105.02 to the Engineer for review and approval. This plan shall be stamped by a licensed NH Professional Engineer knowledgeable in the design and construction of drilled shafts.

3.2.1 The Contractor's submittal shall contain as a minimum, the following specific information:

a. A complete description of the equipment to be used, including manufacturer's specifications and catalog data for all rigs, drilling tools, rock coring tools, cleaning equipment, desanding equipment, pumps, tremie pipes, casing, and other necessary tools

b. A description of the overall construction operation sequence and the sequence of shaft construction

c. Method of constructing the drilled shaft within the horizontal location tolerances including details of frames and templates

d. The method of shaft excavation and cleaning including obstruction removal, temporary casing installation and removal, and bedrock excavation

e. If slurry is proposed for shaft excavation, the type of slurry and the details of the methods to mix, circulate, de-sand and dispose of the slurry

f. The method of shaft construction, including details of reinforcing steel installation, reinforcing steel overlaps and connections, and concrete placement

g. Method of forming the exposed portion of the drilled shaft

h. Details of the proposed concrete mix design

i. Methods of complying with all applicable environmental regulations

3.2.2 The Engineer will evaluate the Installation Plan for conformance with the plans, specifications and this special provision. Within 21 days after receipt of the plan, the Engineer will notify the Contractor of additional information or changes needed to meet the contract requirements. Approval of the installation plan shall not relieve the Contractor of the responsibility to install the drilled shafts in accordance with the plans and specifications.

3.3 Subsurface Information. The geotechnical report for the RWIS foundation is available through the Materials and Research Bureau (603-271-3151). Appointments to review the report shall be made at least 3 days in advance. It is the Contractor's sole responsibility to make interpretations and draw conclusions with respect to the character of material to be encountered and its effect on the drilled shaft installation.

3.4 Pre-Drilled Shaft Construction Meeting. A meeting shall be held prior to initiating the drilled shaft construction. The purpose of the meeting shall be to review all aspects of the drilled shaft construction and to facilitate coordination between all parties involved. Individuals attending the meeting shall include the Engineer, the Geotechnical Engineer from the Materials and Research Bureau, the Contractor, the Firm performing the drilled shaft work and all other personnel deemed appropriate by the previously mentioned personnel. The Geotechnical Engineer shall be notified at least 7 days in advance.

3.5 Drilled Shaft Tolerance. The drilled shafts shall be constructed to the following tolerances:

a. The drilled shaft shall be within 3 inches of the plan position in the horizontal plane at the top of shaft elevation. In situations where the anchor rods will be located within a rock socket, the center of the rock socket shall be within 1 inch of the plan position in the horizontal plane at the top of shaft elevation. (Note: the center of the drilled shaft is defined as the center of the reinforcing cage). Additionally, the minimum required clear distance between the outside of the cage and the excavation sidewall shall be provided.

b. The vertical alignment of a vertical drilled shaft excavation shall be within 2 percent of plumb over the total length of the shaft.

c. The shaft and rock sockets shall have the diameter and configuration that is indicated in the contract plans.

d. The excavation equipment and methods shall be designed so that the completed shaft excavation will have a planar bottom. The cutting edges of excavation equipment shall be normal to the vertical axis of equipment within a tolerance of 3/8 inch per foot of diameter.

e. The bottom of the reinforcing cage shall be placed 3 inches, plus or minus 1 inch above the bottom of the shaft excavation.

f. During concrete placement, the top of the reinforcing steel cage shall not move more than 1 inch above or below the plan position.

g. The top elevation of the shaft concrete shall be as indicated on the plans.

h. The anchor rods shall be set to the dimensions and tolerances shown on the plans and detailed in Appendix A.

i. The exposed portion of the shaft and to a depth of at least 12 inches shall have a formed appearance with the top having a smooth level finish.

3.6 Drilling Equipment and Tools. The excavation and drilling equipment shall have adequate capacity including power, torque and down thrust to excavate a hole of both the maximum diameter and to a depth of 25 percent beyond the estimated lengths in the contract. The excavation equipment and tools shall be of adequate design, size and strength to perform the work as indicated on the plans or described herein. When the material encountered cannot be drilled using conventional drill buckets and earth augers with soil and rock teeth, the Contractor shall provide special drilling equipment/procedures including but not limited to rock core barrels, rock tools, chisels, boulder breakers, air tools and other equipment necessary to construct the shaft excavation to the required depth.

3.7 Construction Methods. The Contractor shall perform the excavation required for the shafts, through whatever materials and groundwater that are encountered, to the dimensions and elevations shown on the plans or otherwise required by these special provisions. The Contractor's methods and equipment shall be suitable for the intended purpose and the materials encountered. Drilled shafts shall be constructed as indicated on the plans by the most appropriate method described below. Permanent casing will not be permitted.

3.7.1 Dry Construction Method. The dry construction method without temporary casing shall be used only if the groundwater table and soil conditions are suitable to permit construction of the shaft in a relatively dry excavation, and where the sides and bottom of the shaft may be visually inspected by the Engineer immediately prior to placing concrete in the excavation. The dry method consists of excavating the shaft, removing accumulated water and loose material from the excavation, placing the reinforcing cage, and concreting the shaft in a dry excavation as defined below.

3.7.1.1 The dry construction method will only be approved if the sides and bottom of the excavation remain stable and if any loose material and water can be satisfactorily removed immediately prior to inspection and concrete placement without detrimental caving. Residual water depths of 3 inches or less shall be considered as dry. The Contractor shall use the temporary casing and/or slurry displacement method(s) for shafts that do not meet the above requirements.

3.7.2 Temporary Casing Construction Method. The temporary casing method consists of excavating the shaft after a temporary casing is installed, and then placing the reinforcing cage and shaft concrete in the excavation, after which the casing is removed.

3.7.2.1 The temporary casing shall be advanced into the ground by twisting, driving or vibrating prior to drilling below the bottom of the casing. Drilling ahead of the temporary casing will be permitted only if the sides of the excavation remain stable prior to advancing the temporary casing through the pre-drilled depth.

3.7.2.2 If the Contractor elects to remove a casing from the shaft and substitute a longer casing in caving soils, the excavation shall be stabilized with slurry or backfilled before the substitution is made. Other methods, subject to the approval of the Engineer, may be used to control the stability of the excavation and protect the integrity of the foundation soils. The slurry

displacement method with temporary casing may be necessary if the casing does not prevent water or soils from entering the excavation at the bottom of the casing.

3.7.2.3 Telescoping through larger diameter casing will be permitted and shall meet the casing removal requirements defined in 3.11.

3.7.2.4 The temporary casing construction method will only be approved if all loose material can be satisfactorily removed and if the sides and the bottom of the excavation remain stable throughout the concreting and casing withdrawal process.

3.7.3 Slurry Displacement Construction Method. The slurry displacement method may be used with or without casing if the requirements of 2.4 are met. This method consists of using a drilling fluid to maintain stability of the excavation while advancing the excavation to final depth, placing the reinforcing cage and concreting the shaft.

3.7.3.1 Concreting the drilled, slurry filled excavation shall be completed the same day that the shaft excavation is completed. If this is not possible, the excavation shall be re-drilled, cleaned and the slurry tested before concreting. Slurry shall be continually fed into the shaft excavation as drilling progresses so that the top of the slurry remains a minimum of 5 feet above the groundwater table or higher if needed to maintain a stable excavation. The pump used to reclaim the slurry shall be self-priming. A standby pump shall be available during the drilling operation.

3.8 Shaft Excavation. The shaft excavation shall consist of soil and obstruction removal, and also bedrock excavation to create a rock socket. Shaft excavations shall be made at the locations shown on the project plans. Excavations shall be made according to the dimensions shown on the plans, and within the tolerances set forth in 3.5 and the following. The bedrock surface elevation and the bottom elevation of the rock socket shall be determined by the Engineer during the excavation. Excavation methods that result in disturbance of soil or rock materials below the bottom of shaft shall not be used. Dewatering of the shaft excavation for excavation purposes will not be required. All excavated materials shall be disposed of in approved areas.

3.8.1 Soil Excavation. The soil, which is defined as all the material above the bedrock surface except obstructions, shall be completely removed within the shaft excavation to the required depth. Excavation of the soil shall be performed with conventional drilling tools as described in 3.6. Material, which in the judgment of the Engineer cannot be removed after reasonable effort using conventional tools, shall be considered as an obstruction and shall be treated as described in 3.8.2. Reasonable effort shall include operating the approved drilling equipment at maximum power, torque and down thrust for a period of at least 15 minutes.

3.8.2 Obstruction Removal. Obstructions shall be defined as any natural material or man-made objects above the bedrock surface that cannot be removed by conventional excavation methods and tools described in 3.6 and 3.8.1. Fill materials placed as part of this contract will not be considered as obstructions. Drilling tools lost in the excavation will not be considered

obstructions and shall be removed by the Contractor without compensation. Special drilling tools or removal procedures described in 3.6 that are not detrimental to the shaft excavation shall be employed by the Contractor to remove obstructions. Blasting of obstructions shall not be permitted unless specifically approved in writing by the Engineer. The Contractor shall provide the necessary means to accurately measure the obstruction lengths and all measurements shall take place in the presence of the Engineer.

3.8.2.1 Obstruction removal shall be paid as extra work in accordance with Section 109.04. Obstruction removal requiring specialized methods will be measured by the linear foot to the nearest 0.1 of a foot from the top of the obstruction to the bottom of the obstruction. No measurements will be taken unless this work is authorized by the Engineer prior to the start of obstruction clearance operations. Obstruction removal will not be measured at any depth within fill material placed as part of this construction project.

3.8.3 Rock Socket Excavation. For design purposes, the rock socket excavation shall extend from the lowest point of the bedrock surface within the drilled shaft excavation to the bottom of the minimum rock socket length indicated in the contract plans, or to the prescribed foundation depth, whichever is reached first. The rock socket diameter shall be within the tolerances set forth in 3.5. Methods and tools used to excavate the rock socket shall include, but are not limited to the special methods described in 3.6. Blasting for the rock socket excavation shall not be permitted. A separate pay item will be included in the contract for projects that require a rock socket.

3.8.4 Shaft Excavation Acceptance. A shaft excavation including the rock socket shall be accepted by the Engineer based on the results of a visual inspection.

3.8.4.1 Acceptance of the shaft excavation by the Engineer shall be required prior to placement of the steel reinforcement cage and concrete. The completed shaft excavation shall be thoroughly cleaned of all sediment including loose soil, debris and loose or pulverized bedrock prior to inspection. The excavation bottom shall be cleaned so that a minimum of 50 percent of the base will have less than 1/2 inch of sediment and at no place on the base more than 1-1/2 inches of sediment.

3.8.4.2 The Contractor shall make the completed excavation available to the Engineer for inspection. The Contractor shall also provide suitable access for inspection, safety lines and equipment, communication equipment, electric power, and devices for checking dimensions, alignment and plumbness as needed.

3.8.4.3 Should the Engineer have reason to believe that the drilled shaft excavation techniques or workmanship has been deficient with respect to a given shaft excavation such that the integrity of the excavation is in question, work on the drilled shaft shall be stopped. The Contractor will not be allowed to proceed with the shaft excavation in question or any subsequent shaft excavations until the deficient excavation techniques or workmanship have been changed to the Engineer's satisfaction.

3.9 Steel Reinforcement Construction and Installation. The reinforcing steel, which consists of longitudinal bars and transverse bars or spirals along with stiffeners, spacers and centralizers, shall be assembled into a cage prior to installation according to the plans. The reinforcing bars shall be 100 percent tied and braced sufficiently to allow lifting and installation as a single unit without damage, racking or deformation. Splicing of the longitudinal bars shall not be allowed, except using approved mechanical splices or approved overlap lengths. The reinforcement cage shall be placed into the shaft excavation to within the horizontal and vertical tolerances described in 3.5.

3.9.1 Spacers and other means as necessary shall be used to maintain the horizontal tolerance criteria set forth in 3.5. The spacers shall be securely attached to the reinforcing cage and shall be in firm contact with the sidewalls of the drilled shaft excavation. The spacers shall be used at regular intervals of 5 feet or less. When the size of the longitudinal reinforcing steel exceeds one inch, such spacing may be increased to a maximum of 10 feet. Each shaft shall have a minimum of 2 rows and 3 vertical lines of spacers. The spacers shall be dimensioned to meet the tolerance criteria set forth in 3.5.

3.9.2 An approved method to restrain the upward and downward movement of the reinforcing cage shall be used to prevent uplift or downdrag of the cage during concrete placement. The elevation of the top of the reinforcing steel shall be checked before and after the concrete is placed. If movement greater than that allowed under 3.5 has occurred, the drilled shaft shall be considered defective and corrective measures shall be undertaken by the Contractor to the satisfaction of the Engineer. Furthermore, no additional shafts shall be constructed until the Contractor has modified his restraining system to prevent the uplift or downdrag problem from reoccurring. Corrective measures shall be the responsibility of the Contractor and shall be at no cost to the Department.

3.10 Concrete Placement. Applicable portions of Section 520 shall be followed for concrete placement, except as modified herein. Either the free fall method or underwater placement method shall be used, as defined below. For both methods, concrete shall be placed in one continuous operation from the bottom to the top of the shaft, unless otherwise approved. Removal of the temporary casing shall be in conformance with 3.11. Cold joints in the concrete shall not be allowed unless approved.

3.10.1 Concrete Placement – Free Fall Method. The free fall method of concrete placement shall only be allowed in a stable, dry excavation as defined in 3.7.1. Excavations that have a greater depth of water or measurable seepage shall be concreted using underwater placement procedures.

3.10.1.1 Free falling concrete shall be placed at the center of the excavation using a hopper with attached hose, or other approved system that centers the concrete fall into the excavation. The maximum concrete drop height shall be limited to a height that is less than 20 times the inside diameter of the reinforcing cage. Shorter drop heights and other adjustment in the placement procedure shall be required as directed, to prevent the concrete from striking the reinforcing cage during placement.

3.10.2 Concrete Placement – Underwater Method. Underwater placement procedures shall be required within excavations where the criteria for a dry excavation and free fall placement methods cannot be met. The underwater placement method consists of placing the concrete below the water at the bottom of the drilled shaft excavation, using either tremie or pumping methods and equipment as defined below. The water level within the drilled shaft shall be at a stabilized, static level at the time of concrete placement.

3.10.2.1 Concrete Placement Pipe. The placement pipe used for the tremie or pumping methods shall consist of a steel or iron tube of sufficient length and diameter to discharge concrete at the bottom elevation of the excavation. Aluminum pipe will not be permitted. The minimum pipe diameter shall be 10 inches for the tremie placement method and 4 inches for the pumping placement method. The length of the placement pipe shall be clearly marked in one foot increments along the outside of the pipe, measured upward from the discharge end. The inside and outside surfaces of the tremie pipe shall be clean and smooth to permit both flow of concrete and unimpeded withdrawal during concrete placement. The wall thickness of the pipe shall be adequate to prevent crimping and bending. The pipe wall and joints shall be strong enough to resist concrete pumping pressures and shall be watertight.

3.10.2.2 The discharge end of the placement pipe shall be equipped with a watertight valve or disposable plate that prevents water from filling the interior of the pipe when inserted into the excavation. Alternately, a plug that maintains separation between the concrete and water within the pipe may be used at the top of the pipe. The valve, plate or plug shall provide a seal in the pipe until concrete discharge begins, to minimize contamination of the concrete. Disposable plates or plugs shall be of a material non-detrimental to the drilled shaft, as approved by the Engineer. Air inflated plugs shall not be used. The discharge end of the pipe shall be designed to allow free radial flow of concrete during placement operations.

3.10.2.3 The placement pipe shall be installed in the center of the shaft excavation and extend to the bottom of the excavation. The pipe shall be properly secured and braced within the excavation to prevent uplift or drift during concrete discharge. The pipe and bracing shall be designed to allow progressive and steady removal as the concrete fills the excavation. Methods to remove air trapped in tremie or pump pipes shall be provided if necessary as determined by the Engineer.

3.10.2.4 The placement pipe discharge end shall be immersed in at least 5 feet of concrete at all times after the start of concrete placement. The flow of concrete in the pipe shall be continuous, and a positive pressure differential shall be maintained at all times to prevent water or slurry intrusion into the pipe. If at any time during concrete placement the pipe discharge orifice is removed or uplifts from the fluid concrete with concrete discharge occurring, the entire drilled shaft shall be considered defective. In such a case, the Contractor shall completely remove the reinforcing cage and concrete by approved methods. The shaft shall then be redone according to these provisions. All costs for replacement of defective shafts shall be the responsibility of the Contractor and shall be at no cost to the Department. If concrete discharge has not occurred, then the placement pipe shall be re-immersed into the concrete with a closed

valve, disposable plate or plug on the discharge end, so that water and air are not delivered into the fluid concrete.

3.10.2.5 The Contractor shall maintain the concrete in a workable state throughout the entire underwater placement operation, and also during temporary casing removal operations (described in 3.11). In addition to designing the concrete mix with any necessary admixtures, the Contractor shall lubricate the pumping system and cool the placement pipes as necessary, to maintain acceptable workability of the concrete. Concrete that has lost sufficient workability to the extent that the provisions of 3.10.2 cannot be met will result in rejection of the drilled shaft, as described in 3.10.2.4.

3.10.2.6 In cases where the concrete cutoff grade is below the ground surface, the concrete shall be placed a minimum of 2 feet above the plan top elevation, unless otherwise approved. The excess 2 feet of concrete shall then be removed back down to the proposed concrete grade or lower, if necessary to reach sound concrete using chipping or other approved methods.

3.11 Temporary Casing Removal. Temporary casings shall not be left in place and shall be completely removed.

3.11.1 During all phases of the temporary casing removal, the height of concrete within the casing shall be maintained at a sufficient height above the bottom of casing so that the internal fluid concrete pressure exceeds the external fluid and soil pressure at all levels below the temporary casing. For drilled shafts less than 20 feet in length, removal of the temporary casing shall not be initiated until after the concrete has been placed to at least the top elevation of the drilled shaft, unless otherwise approved.

3.11.2 During the temporary casing removal, the concrete surface within the casing shall be monitored to verify that the concrete surface does not drop below the level required through 3.11.1 at the time of removal. A means of access to measure the concrete surface during all phases of the temporary casing removal shall be provided. If necessary to meet the requirements of 3.11.1, concrete shall be added in an approved manner during the temporary casing removal.

3.11.3 Static pull or rotary extraction methods shall be required to remove the temporary casing. Vibratory methods to initially free the temporary casing are subject to approval.

3.11.4 If telescoped temporary casings have been used, the casings shall be concreted and pulled progressively from the inner casing to the outer casing in an approved manner.

3.12 Anchor Rods. The anchor rods embedded into the shaft for the support pole connection shall be installed prior to, or immediately after concrete placement while the concrete is still plastic. Drilling to set the anchor rods after concrete placement shall not be allowed. The anchor rods shall be set to the dimensions and tolerances shown on the plans and in Section 677. Material requirements and payment for anchor rods shall be covered under Section 677.

3.13 Acceptance of Completed Drilled Shaft. The final acceptance of each drilled shaft shall be the decision of the Engineer based on the conformance to tolerance limits set forth in 3.5. If the drilled shaft integrity is questionable, the Engineer shall require a core hole through the shaft to evaluate its condition. If a defect is confirmed, the Contractor shall pay for all coring costs. If no defect is encountered, the Department shall pay for all coring and grouting costs. In the case that any shaft is deemed unacceptable, the Contractor shall submit a plan for remedial action with calculations and working drawings prepared and stamped by a licensed NH Professional Engineer. Materials and work required to perform remedial shaft actions, including engineering analysis and redesign, shall be provided at no cost to the Department.

3.14 Contractor's Records. The Contractor shall keep a record independent of that which may be kept by the Engineer, of all pertinent data relative to the installation of the drilled shaft. This record shall be available for the Engineer's inspection, and shall be transmitted as directed. The Contractor's record shall include the following:

a. Shaft location and dates of installation.

b. Slurry data including test data.

c. Total length of each shaft.

d. Plumbness of shaft.

e. Placement and condition of reinforcing cage

f. The time, method and duration of the concrete placement, with a log of the temperature at the time of placement.

g. The quantity of concrete versus depth of filled shaft

3.14.1 Additionally the Contractor shall maintain a construction method log during shaft excavation. The log shall contain information such as: the top and bottom elevation of each soil and obstruction layer, the bedrock surface elevation, groundwater depth, drilling rate and remarks. The log shall be provided to the Engineer a minimum of 24 hours prior to concreting the drilled shaft.