SECTION 16781 - OUTDOOR FIBER OPTIC CABLE SYSTEMS

City of San Diego, CWP Guidelines

PART 1 -- GENERAL

1.1 WORK OF THIS SECTION

A. The WORK of this Section includes providing and installing a fiber optic conduit system including fiber optic cable (FOC), conduit, pullboxes, splices, terminations and testing.

B. The Work includes splicing and testing individual fiber cables installed under this CONTRACT, and testing a completed [ ] -fiber link from [ ] to [ ].

C. Specific requirements are shown in the Specifications, Plans and/or in Appendix A

1.2 RELATED REQUIREMENTS

A. The WORK of the following Sections applies to the WORK of this Section. Other Sections of the Specifications, not referenced below, shall also apply to the extent required for proper performance of this WORK.

1. Section 01300 - CONTRACTOR Sumittals
2. Section 01530 - Protection of Existing Facilities
3 Section 02200 - Earthwork
4. Section 01700 - Project Closeout

1.3 STANDARD SPECIFICATIONS

A. The earthwork portions of the work shall be governed by the Standard Specifications for Public Works Construction (SSPWC), commonly known as the “Greenbook”.

B. Except as otherwise indicated in this Section of the Specifications, the CONTRACTOR shall comply with the Standard Specifications for Public Works Construction (SSPWC), as specified in Section 01090 - REFERENCE STANDARDS.

1.4 SHOP DRAWINGS AND SAMPLES

A. The following shall be submitted:

1. **Catalog Data:** Catalog data on conduit system, pullboxes, conduit fittings, conduit plugs, pull rope, identification tape, warning signs.

2. Detailed bill of materials.

3. Drawings indicating the locations of all pullboxes with station numbers.

4. Catalog data on all testing devices proposed for use plus certifications of accuracy, calibration, and traceability to standards of the National Institute for Standards and Testing.

5. Cable pulling calculations for all conduit runs. Indicate on the submittal any additional pullboxes that are required, including station number and a written description of the location.
6. A cable pulling and splicing work plan shall be submitted a minimum of 45 days prior to the planned initiation of cable pulling. The pulling plan and pull tension calculations may be prepared by using a software program such as Pull-Planner 2000 by American Polywater Corporation, **or equal**. The cable pulling and splicing work plan must be approved a minimum of 15 days prior to pulling cable. Work plan shall include the following:

    a. Pull tension calculations
    b. Calculated amount of lubrication required
    c. Detailed description of pull operation methods for all conduit runs
    d. Tools and equipment to be used for cable installation and testing
    e. Physical location of equipment setup and type
    f. Exact location of splice points
    g. Safety and manual assist cable pulling operations
    h. Detailed schedule for pulling and testing cables

7. Information on at least one successfully performing fiber optic cable installation of comparable size and complexity installed in the recent past with name, address, and telephone number of facility owner, name of project and completion date, and type of conduit system and length of cable pulled.

8. The name and qualifications of the supervisory personnel that will be directly responsible for the installation of the conduit system.

1.5 STANDARDS

A. **Cable Certification:** The cable manufacturer shall certify that the cable is suitable for direct installation in 2-inch to 4-inch conduit in an underground environment. The CONTRACTOR shall submit a sample and its certification to the CONSTRUCTION MANAGER for approval prior to installation. The CONTRACTOR shall submit laboratory test reports on representative samples of similar cable design to demonstrate compliance with the following requirements prior to cable installation:

1. Tensile Strength per EIA-RS-455-33A and EIA-RS-455-28A
2. Jacket Shrinkage per EIA-RS-455-86
3. Cable Twist per EIA-RS-455-85
4. Environmental Temperature Cycling per EIA-RS-455-3A
5. Flexing per EIA-RS-455-104
6. Impact Resistance per EIA-RS-455-25A
7. Compressive Strength per EIA-RS-455-41
8. Freezing Test per EIA-RS-455-98A
9. Mechanical Bend Test per EIA-RS-455-37

B. The cable manufacturer shall be ISO 9001 registered.

1.6 APPLICABLE DOCUMENTS

A. The optical fiber cable shall conform to the latest issue of the following standards documents which are incorporated by reference into this specification:

1.	EIA-455	Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Connecting and Terminating Devices.
2.	EIA-359	Standard Colors for Color Identification and Coding.
3.	MIL-202	Test Methods for Electronic and Electrical Component Parts.
4.	MIL-454	Standard General Requirements for Electronic Equipment.
5.	MIL-810	Environmental Test Methods and Engineering Guidelines.

B. All fiber optical cables shall be constructed in accordance with EIA-455 and one hundred percent (100%) of all optical fibers and jacketing shall meet or exceed the requirements contained in this specification.

1.7 QUALITY ASSURANCE

A. All work described in this Section shall meet or exceed the applicable provisions of the following documents:

1. ANSI, C8.471983, American National Standard Institute for Polyolefininsulated Thermoplastic Jacketed Communication Cables.

2. EIA-455 (addendum 1 through 5) Standard Test Procedures for Fiber Optics, Cables, Transducers, Connecting and Terminating Devices.

3. EIA-455-27A, Method of Measuring (Uncoated) Diameter of Optical Waveguide Fibers.

4. EIA-455-28A, Method For Measuring Tensile Failure Point of Optical Waveguide Fibers.

5. EIA-455-34, Interconnection Device Insertion Loss Test.

6. EIA-455-89, Fiber Optic Cable Jacket Elongation and Tensile Strength.

7. Underwriters Laboratories (UL) Standard 651 (Conduit)

8. Underwriters Laboratories (UL) Standard 514 (Accessories)

9. National Electrical Manufacturers Association (NEMA) TC-2 (Conduit)

10. National Electrical Manufacturers Association (NEMA) TC-3 (Accessories)

1.8 WARRANTY

A. The Contractor shall provide an unconditional warranty on all installed cable for a minimum period of two (2) years.

PART 2 -- PRODUCTS

2.1 MATERIALS

A. **Conduit:** Conduit shall be three- or four-inch diameter (or as shown on the drawings or in Appendix A) Schedule 80 PVC electrical conduit including fittings for underground installation.

B. **Cabinets:** Cabinets shall be standard CALTRANS Type 332, furnished without traffic control components. Cabinet material shall be 0.125 inch aluminum, with full front and back doors, shall have stainless steel handles with padlock feature, and shall be furnished with Best locks (lock core will be provided by the City). Finish shall be natural aluminum. Cabinets shall accommodate 19-inch standard EIA rack assemblies. Cabinets shall be installed on reinforced concrete pads.

C. **Pullboxes:** Pullboxes shall be Caltrans standard No. 6, approximately 32 inches wide by 49 inches long by 36 inches deep, designed for H-20 traffic loading unless otherwise indicated. Covers for pullboxes in paved areas shall be galvanized steel, rated for H-20 traffic loading. Covers for pullboxes in sidewalks and unpaved areas shall be concrete. Bolts shall be 316 stainless steel. Covers shall have the words "MWWD Fiber Optic" in raised letters on the top. Covers shall have locking devices and form a watertight seal to prevent surface water from entering. Knockouts in the sidewalls shall permit underground conduit side entry and exit.

D. **Conduit Duct Plugs:** Jackmoon Simplex Duct Plugs with bushing sleeves **or equal**.

E. **Pull Rope:** Low friction, polyethylene jacketed polypropylene rope with 1800 psi tensile strength. Provide Vikamatic "Fiber Glide" **or equal**.

F. **Fiber Optic Cable**

$#

NTS: Standard fiber optic cables are generally stocked by suppliers in units of 12 fibers. Select the number of fibers required from the choices in brackets below. Other fiber counts are available but may increase the procurement lead-time. Although 6-fiber cables are available, a minimum of 12 is recommended for cable strength. Although fibers are generally used in pairs, cables are designated in units of individual fibers. Since most of the costs for fiber optic cables are in the cable installation, at least 100% spare fibers are recommended for future applications.

#$

1. **Cable type:** All-dielectric outdoor plant stranded loose-tube, gel-filled fiber optic cable, Corning Altos [012][024][036]RW4-14101A20 or Lucent Lightpack 7D1X-[012][024][036]-BXD.
2. **Number of fibers:** [012][024][036] fibers.
3. **Buffer Tubes:** All optical fibers shall be grouped and placed inside a loose buffer tube. The tubes shall be color coded and arranged symmetrically around the central member.
4. Each fiber shall be numbered and color-coded.
5. The colors of the individual fibers shall be stable across the specified storage and operating temperature range and not subject to fading or smearing onto each other or into the gel filling material. Colors shall not cause fibers to stick together.
6. The fibers shall not adhere to the inside walls of the loose buffer tube. Buffer tubes shall be kink resistant within the specified minimum bend radius.
7. Filler may be included in the cable core composition to lend symmetry to the cable cross-section where needed.
8. A central anti-buckling member shall be included into the cable to prevent buckling of the cable. The anti-buckling member shall be composed of a glass reinforced plastic rod.
9. Each buffer tube shall be filled with a non-hygroscopic, non-nutritive to fungus, electrically non-conductive, homogenous gel. The gel shall be free from dirt and foreign matter. The gel shall be readily removable with conventional nontoxic solvents.

10. Buffer tubes shall be stranded around a central member using the reverse oscillation, or "S-Z", stranding process.
11. The cable core shall contain a water-blocking material. The water blocking material shall be non-nutritive to fungus, electrically non-conductive and homogenous. It shall also be free from dirt and foreign matter and shall be readily removable with conventional nontoxic solvents.
12. Binders shall be applied with sufficient tension to secure the buffer tubes to the member without crushing the buffer tubes. The binders shall be non-hygroscopic, non-wicking and dialectic with low shrinkage.
13. Tensile strength shall be provided by a combination of high tensile strength dielectric yarns. The high tensile strength dielectric yarns shall be helically stranded evenly around the cable core.
14. The all-dielectric cable shall be sheathed with medium density polyethylene (MDPE). The minimum nominal jacket thickness shall be 1.4 mm. Jacketing material shall be applied directly over the tensile strength members and water blocking material. The jacket or sheath shall be free of holes, splits, and blisters. The cable jacket shall contain no metallic elements and shall be of a consistent thickness.
15. The cable shall contain at least one ripcord under the sheath for easy sheath removal.

G. **Fan-Out Termination for Loose Tube Cables**

1. Individual fibers within the loose tube cable require handling protection inside the termination cabinets. Fan-out kits shall be installed in the patch panel enclosures to transition the loose tube fibers to ruggedized tight-buffered fiber pigtail cables. Fan-out tubes or furcation kits shall not be used. Optical fusion splices shall connect the loose tube fibers to the tight-buffered pigtail cables. The optical splice loss shall comply with the specifications for optical splices. Splice protection sleeves shall be employed on all splices to protect the splices. A wall-mountable splice center shall house the splices and serve to fully protect excess lengths of loose tube fibers from exposure.

2. The tight-buffered pigtails shall be terminated with ST™ connectors as specified.

H. **Fan-out Pigtail Cable Specifications**

1. Singlemode fiber (Corning SMF-28™ **or equal**) shall be used in the pigtails. Optical characteristics shall comply with the optical fiber performance specifications.

Buffer material	Thermoplastic
Buffer O.D.	900 um
Strength Member	Kevlar
Jacket Material	PVC
Jacket O.D.	3.0 mm
Temperature Range	-20 to + 70 C

I. **Fiber Optic Termination Patch Panels**

1. Where shown on the plans or in Appendix A, the fiber optic cable shall terminate inside a communications cabinet on a termination patch panel. All fiber sub-cables within the cable shall be terminated with ST™ compatible connectors. The patch panel shall have a fiber capacity

equal to the total number of fibers (connected and spare) for all cables to be connected. Patch panels shall be designed for either rack mounting on a standard equipment rack or housed in an enclosure for direct wall mounting. The patch panel shall contain ST™ type bayonet couplings. All unused couplings shall have protective dust covers. All panels shall be furnished with locking doors. Factory-terminated, tight-buffered, agamid-reinforced fiber optic jumper assemblies or interconnect cables, standard 3.0 mm O.D., shall connect the optical cable terminations to the patch panel couplings. Panels shall be equal to the following manufactured by Secure:

Mounting	Fiber Capacity	Model Number
Rack	48	C.H.-02U
Rack	72	C.H.-03U
Wall	48	AC-048L with lock
Wall	72	AC-072L with lock

2. The termination patch panel shall be equipped with a suitable means for routing and securing of cables and shall provide a suitable means of protection for the mounted fiber connectors, to prevent damage to fibers and connectors during all regular operation and maintenance functions. All cables shall be provided with strain relief. Bend diameters on cable fibers and jumpers must be greater than four (4) inches at all times to ensure optical and mechanical integrity of the optical fibers.

J. **Optical Connectors**

1. All connectors shall be field-install able and perfectly matched to the cable used. The connectors shall provide tight fitting termination to the cladding and buffer coating. Epoxy-based or "hot melt " adhesives shall be used to bond the fiber and buffer to the connector ferrule and body prior to polishing the end face. No dry-termination or "quick crimp" connectors are allowed.

2. After termination with connectors, the fiber ends must be visually inspected at a magnification of not less than 100 power to check for cracks or pits in the end face of the fiber. If any irregularities found cannot be removed by further polishing, the entire process must be redone by cutting off and disposing the connector body.

3. Connectors shall have a maximum allowable connection loss of 0.3 dB per mated pair, as measured per EA.-455-34. No index-matching gel is to be used, dry interfaces only. Singlemode connectors shall be capable of field installation on 9/125 micron fibers with 900 micron buffers (OD).

4. Each connector shall be of the industry standard ST type compatible, designed for singlemode tolerances, and shall meet or exceed the applicable provisions of EA.-455-5, 455-2A, and 455-34, and shall be capable of 100 repeated matings with a maximum loss increase of 0.1 dB. Connectors shall incorporate a key-way design and shall have a zirconia ceramic ferrule. Connector bodies and couplings shall be made of corrosion-resistant and oxidation-resistant materials, such as nickel plated zinc, designed to operate in humid environments without degradation of surface finishes.

K. **Splice Closures**

1. Splice closures shall be of the re-enterable type, with an external moisture-proof shell, inner closure and encapsulant.

2. Closure shall have removable interior splice trays.

3. Closures shall be Corning Cable Systems (Secure) type SCN **or equal**.

2.2 TRENCH BACKFILL MATERIALS:

A. Slurry backfill for the installation of conduits that will contain fiber optic cable shall be a medium to dark, red or orange color to clearly distinguish the concrete backfill from other concrete and soil. The concrete shall be pigmented by the addition of commercial quality cement pigment to the concrete mix. The red or orange concrete pigment shall be LM Scofield Company; Orange Chromix Colorant; Davis Colors, **or equal**.

B. For trenches in pavement areas, only the top 4 inches of concrete backfill will be required to be pigmented concrete. At the option of the Contractor, the full depth may have the pigment.

PART 3 -- EXECUTION

3.1 CONDUIT INSTALLATION

A. **General**

1. Conduit sections shall be joined in accordance with the Manufacturers' recommendations. All joints shall be watertight.

2. All conduit shall be cleaned and tested prior to installation of cables.

3. CONTRACTOR shall install pull rope in the conduit.

4. Conduits entering pullboxes shall be sealed with Jackmoon Simplex duct plugs.

5. The conduit shall gradually and smoothly slope up to the elevation of the pullbox entrance. Use of manufactured bends shall be limited to an absolute minimum. Factory bends, if required, shall be no more than 22½ degrees.

6. Conduit trenching and backfill shall comply with San Diego Regional Standard Drawing G-33, Type A, with the following change to Note 10: Select material with a minimum sand equivalent of 50 shall be backfilled to 3 inches minimum above the conduit. Sand cement slurry backfill may not be substituted for select material.

7. A trace wire shall be installed along the entire fiber optic cable route for use in active cable location. The trace wire shall be a #8 AWG bare-copper solid strand. No insulation or other coating material shall be on the trace wire. The trace wire shall provide a termination at each pullbox for connection to testing equipment.

8. **Identification Tape:** A 6-inch wide magnetically detectable warning tape with orange protective polyethylene jacket resistant to alkalies, acids, and other destructive elements shall

be installed along the entire length of the conduit route. The polyethylene tape shall be continuously imprinted "CAUTION-FIBER OPTIC CABLE". The warning tape shall be Teletrace by Vikamatic, **or equal**.

B. **Conduit Installation along Pipelines**

1. Conduits shall be installed on one side of the trench, at least 2 inches and not more than 12 inches from the trench wall, at a depth of 3 to 4 feet below grade along the entire pipeline route. The conduit shall not cross over the pipe.

2. For conduits installed with a pipeline, conduits shall clear concrete structures and vaults associated with the pipeline by a minimum of one foot.
3. Conduit shall be installed in the annular space between the carrier pipe and the casing or tunnel liner for all two-pass tunnel or jack and bore sections of the pipeline alignment.

4. On installations along pipelines, CONTRACTOR shall install marker signs for fiber optic cable on all marker posts for the pipeline as indicated.

3.2 FIBER OPTIC CABLE INSTALLATION

A. **General**

1. The Contractor shall determine a suitable cable installation method to ensure that all cable installation requirements shall be met in all conduit sections. All work shall be carried out in accordance and consistent with the highest standards of quality and craftsmanship in the communication industry with regard to the electrical and mechanical integrity of the connections; the finished appearance of the installation; as well as the accuracy and completeness of the documentation.

2. The Contractor shall make a physical survey of the project site for the purpose of establishing the exact cable routing and cutting lengths prior to the commencement of any work or committing any materials.

3. The cable shall be carefully inspected for jacket defects as it is removed from the reel. If defects are noticed, the pulling operation shall be terminated immediately and the CONSTRUCTION MANAGER notified.

4. Fiber optic cables shall be installed in continuous lengths without intermediate splices throughout the project. Cable installation personnel shall be familiar with the manufacturer's recommended procedures including, but not limited to the following:

   a. Proper attachment to the cable strength elements for pulling during installation. Depending on cable design, this will involve direct attachment to internal strength members or attaching an external "Kellums" or split mesh grip using a 600 lb breakaway swivel.
   b. Cable tensile limitations and tension monitoring procedures.
   c. Cable bending radius limitations.
   d. Cable twisting limitations.

B. **Cable Protection During Installation**

1. All fiber optic cable shall be pulled in conduit except as specified on the plans. Care shall be exercised during cable pulls through conduit bends and looping in pullboxes.

2. The Contractor shall comply with the cable manufacturer's recommended installation procedures at all times. Cable installation procedures shall conform to Belcore guidelines.
3. To reduce the possibility of damage to the outer jacket of the fiber optic cable, protective measures shall be used when the cable is installed. The requirements herein shall be followed, but does not limit the installation to only those identified. The purpose of the installation specifications is to ensure protection of the fiber optic cable when it is installed. Other protective measures not specified herein may be taken during installation if it will ensure protection of the cable.

4. A cable feeder guide shall be used between the cable reel and the face of the duct and conduit to protect the cable and guide it off the reel and into the duct. The cable shall be carefully inspected for jacket defects as it is removed from the reel. If defects are noticed, the pulling operation shall be terminated immediately and the CONSTRUCTION MANAGER notified.

5. Precautions shall be taken during installation to prevent the cable from being kinked, crushed or twisted. A pulling eye shall be attached to the cable end and be used to pull the cable through the duct and conduit system. As the cable is pulled off the reel and into the cable feeder guide, it shall be lubricated with a lubricant that shall be of the water- based type and approved by the cable manufacturer.

6. Crushed or kinked cable shall be replaced with new cable.

7. Dynamometers or break away pulling swings shall be used to ensure the pulling line tension does not exceed the installation tension values specified by the cable manufacturer. The mechanical stress placed upon the cable during installation shall not be such that the cable is twisted and stretched. Maximum allowable cable strain during installation shall be less than 0.75 %.

C. **Lubrication:** As the cable is pulled into the conduit system, it shall be sufficiently lubricated with a lubricant that shall be the water-based type and approved by the cable manufacturer. Lubricant shall be applied at a rate to provide a continuous 10-mil coating, as recommended by the manufacturer. Lubricant shall be Polywater F® manufactured by American Polywater **or equal**.

D. To accommodate long continuous installation lengths, bi-directional "center pull" techniques for pulling of the fiber optic cable is acceptable and shall be implemented as follows:

1. From the midpoint, pull the fiber optic cable into the conduit from the shipping reel in accordance with the manufacturer's specifications.

2. When this portion of the pull is complete, the remainder of the cable must be removed from the reel to make the inside end available for pulling in the opposite direction.

3. This is accomplished by hand pulling the cable from the reel and laying into large "figure eight" loops on the ground.

4. The purpose of the figure eight pattern is to avoid cable tangling and kinking.

5. The loops shall be laid carefully one upon the other (to prevent subsequent tangling) and shall be in a protected area.

6. The inside reel end of the cable is then available for installation.

7. In some cases, it may be necessary to set up a winch at an intermediate cable vault.

8. The required length of cable shall be pulled to that point, and brought out of the cable vault and coiled into a figure eight.

9. The figure eight is then turned over to gain access to the free cable end. This can then be reinserted into the duct system for installation into the next section.

E. When power equipment is used to install fiber optic cables, the pulling speed shall not exceed 30 meters per minute. The pulling tension, bending radius and twist limitation for fiber optic cable shall not be exceeded under any circumstances.

F. Large diameter wheels, pulling sheaves, and cable guides shall be used to maintain the appropriate bending radius. Tension monitoring shall be accomplished using commercial dynamometers or load-cell instruments.

G. The pulling eye/sheath termination hardware on the fiber optic cables shall not be pulled over any sheave blocks.

H. All pulls shall be documented by a graph which is annotated with the following information:

1. Reel number
2. Station from and station to
3. Date and time
4. Explanations of abnormalities in readings or interruptions
5. Sign-off by CONTRACTOR and CONSTRUCTION MANAGER

I. Under no conditions shall the FOC be left exposed or unattended.

J. **Repairs:** Repair of cable jacket shall not be permitted. Jacket damage shall require removal and re-installation of a new cable run at the Contractor's expense.

K. **Installation at Pullboxes**

1. The pulling of the cable shall be hand assisted at each handhole or pullbox. The cable shall not be crushed, kinked or forced around a sharp corner. Sufficient slack shall be left at each end of the cable to allow proper cable termination.

2. The cable shall be looped in all pullboxes as noted on the plans to provide approximately fifteen (15) feet of extra cable in the pullbox. At termination points, such as at cabinets or computers, a fifteen (15)-foot loop shall also be provided wherever space permits. The fiber optic cable shall be coiled and secured with cable ties in the pullbox. The Contractor shall ensure that the minimum bending radius of the fiber optic cable is not compromised when preparing this stored cable slack.

3. Imprinted plastic coated cloth identification/warning tags shall be securely attached to the cables in at least two locations in each handhole. Tags shall be by Brady or Thomas & Betts.

4. When all cables at each pullbox are securely racked, unused conduits and void areas around conduit containing cables shall be sealed.

5. **Cable Marking:** At each pullbox and at each cabinet, the cable shall be visibly marked with yellow warning tape as follows:

"CAUTION - FIBER OPTIC CABLE"

L. **Splicing**

1. Splicing of fiber optic cable shall not be permitted except in emergency conditions or as specified on the plans or in the special conditions for a specified project. Fiber optic cable runs and required looping of the cable shall be provided in one continuous length. When splicing is authorized by the CONSTRUCTION MANAGER, splicing shall be by trained, authorized persons only. Any allowed splicing of fiber optic cable shall be by fusion splice only, no mechanical splices are permitted.

2. All fusion splicing equipment shall be in good working order, properly calibrated, and meeting all industry standards and safety regulations. Cable preparation, closure installation and splicing shall be accomplished in accordance with accepted and approved industry standards.

3. Spices shall be made in pullboxes and shall use re-enterable splice closures.

4. The average splice loss shall be 0.1 dB or less per splice. The average splice loss is defined as the summation of the loss as measured in both directions using an optical time domain reflectometer (OTDR) through the fusion splice, divided by two. No individual splice loss measured in a single direction shall exceed 0.15 dB.

5. Upon completion of the splicing operation, all waste material shall be deposited in suitable containers, removed from the job site, and disposed of in an environmentally acceptable manner.

3.3 PULLBOXES

A. **Field Location of Pullboxes**

1. The drawings diagrammatically indicate the desired location of pullboxes, conduit runs and other items. Exact locations shall be determined by the CONTRACTOR based on physical size and arrangement of equipment, finished elevations, calculated cable pulling tensions, field obstructions, and the criteria below. Locations shown on the drawings should be followed as closely as possible, however, pullboxes shall be located according to the following criteria:

   a. At no point shall the cable pulling tension exceed 600 pounds. If cable pulling tension is calculated to exceed 600 pounds, additional pullboxes shall be provided at no extra cost to the OWNER.

   b. The maximum distance between any two pullboxes shall not exceed 1,200 feet.

   c. Within the 1,200-feet distance, the CONTRACTOR shall install pullboxes at locations wherever the cumulative change of direction of the conduit exceeds 180 degrees.

   d. The minimum bending radius for conduit shall be 3 feet.

   e. A pullbox shall be installed on one side of a tunneled crossing. However, for any crossing which requires more than 180 degrees of conduit bends to account for elevation differences or route adjustments, a pullbox shall be provided on both sides of the crossing.

f. Pullboxes shall be installed a minimum of 12 inches from all structures.

B. **Construction**

1. The CONTRACTOR shall install the pullbox covers so that the top of the cover is flush with the restored pavement. Pullboxes installed in soil areas shall be installed so that the top of the cover is at least one inch but not more than 4 inches above the final grade level of the restored surface to prevent accumulation of dirt, silt and debris on the top of the hand hole cover. Pullboxes installed in areas not subject to flooding or standing water shall have a minimum of five (5) ¾-inch drainage holes in the bottom of the box.

2. CONTRACTOR shall perform conduit integrity tests for each section between the pullboxes after backfilling and compaction using the test and procedures described in this Section. These tests shall be performed prior to installation of the pull rope.

3. Pullbox conduit entries shall be sealed with duct plugs to prevent the intrusion of water and debris into the pullboxes.

4. Pullboxes shall be installed on a compacted level foundation consisting of 4 inches of granular material complying with Section 02200.

5. Compaction around pullboxes and associated details shall be performed in accordance with Section 02200.

6. Upon final acceptance of the conduit system all pullboxes shall be free of debris and water, and be ready for cable installation.

3.4 MODIFICATIONS

A. All dimensions and exact locations of underground substructures shall be field verified. Minor changes in locations of pullboxes which result in no additional costs for material or labor shall be made at no additional cost to the OWNER. However, the CONTRACTOR shall prepare proposals consisting of detailed material lists, cost estimates, and schedules for rerouting the conduit around existing unforeseen underground utilities and structures which result in additional cost. The CONSTRUCTION MANAGER will consider the proposals in accordance with the provisions of the General Conditions.

B. The CONTRACTOR shall consider the following when preparing proposals:

1. Manufactured bends shall be minimized

2. Required bends shall be less than 22½ degrees
3. Clearances between conduits and other structures shall be:

Structures	Minimum Separations
Power or other foreign conduit	12 inches
Pipe for gas, oil, water, sewage	6 inches when crossing; 12 inches when parallel

3.5 CONDUIT SYSTEM CLEANING AND TESTING

A. Following the backfill placement and compaction, all conduits shall be cleared of loose material by brush and compressed air.

B. Conduit shall be tested for leakage by air testing at 5 psi, maintaining the pressure for one hour without showing any leakage.

C. Following the leakage test, a test mandrel **d** inch smaller than the inside diameter shall be passed through all conduits to detect alignment and deformation problems. Mandrel shall be passed in both directions.

D. Cleaning and testing of the conduit shall be performed by the CONTRACTOR and witnessed by the CONSTRUCTION MANAGER. The cleaning and testing operation shall be conducted for each conduit section between adjacent pullboxes, a section at a time, for the entire route. The results of tests shall be documented by the CONTRACTOR and signed by the CONSTRUCTION MANAGER and the CONTRACTOR.

E. The CONTRACTOR shall provide a five-day advance notice of the schedule and location of test to the CONSTRUCTION MANAGER.

F. The CONTRACTOR shall remove and replace conduit which fails either test and shall repeat the test.

3.6 FIBER OPTIC CABLE TESTING

A. **General:** The CONTRACTOR shall perform pre-installation and post-installation FOC tests. The CONSTRUCTION MANAGER shall be notified a minimum of 10 days in advance so that these tests are witnessed. All test equipment shall be traceable to LIST standards.

B. **Test equipment:** The CONTRACTOR shall use the following to perform pre-installation and post-installation FOC tests:

1. **Optical Time Domain Reflectometer (OTDR):** The OTDR shall be laser precision, ALT Inc MODEL 5200 LRFL, **or equal**.

C. **Pre-Installation Tests**

1. The purpose of these tests is to perform acceptance tests on the cable prior to installation to verify that the cable conforms to the manufacturer's specifications, and is free of defects, breaks and damages by transportation and manufacturing processes.
2. Prior to removal of each cable from the delivery reel, all optical fibers within the cables shall be tested by the CONTRACTOR using an OTDR. The OTDR tests shall consist of end-to-end length and fiber attenuation (dB/km) measurements to ensure proper performance of the fiber optic cable. The tests shall be performed from both ends of each fiber to ensure complete fiber continuity within the cable structure.

3. Pre-installation, "on-reel" test results shall be compared with the manufacturer's test report delivered with the cable. Gross dissimilarities shall be noted and remedied between the contractor and manufacturer. In all cases, all fibers must meet the optical attenuation specifications prior to cable installation.

4. The CONTRACTOR shall perform tests on all reels of cable. The CONSTRUCTION MANAGER shall be notified a minimum of 15 days prior to any test.

5. The CONTRACTOR shall document each test and submit the report to the CONSTRUCTION MANAGER for review. Documentation shall consist of both hard copy and 3½-inch electronic disk complete with all application software.

6. Cable shall not be installed until the CONSTRUCTION MANAGER has reviewed the test report.

7. Maximum allowable attenuation is 0.5 dB/km at 1310 and 1550 nm. The CONTRACTOR shall replace any cable in which any fiber does not meet this requirement.

D. **Post-Installation Tests:** After FOC has been installed the following tests shall be performed:

1. A recording OTDR shall be used to test for end-to-end continuity and attenuation of each optical fiber. The OTDR shall be equipped with a 1310 nm and 1550 nm light source for the single mode fiber (SMF). The OTDR shall have an X-Y plotter to provide a hard copy record of each trace of each fiber. The OTDR shall be equipped with sufficient internal masking to allow the entire cable section to be tested. This may be achieved by using an optical fiber pigtail of 30 feet or more to display the required cable section.

2. The maximum permissible end-to-end loss shall be 0.5 dB/km. The CONTRACTOR shall replace any cable in which any fiber does not meet this requirement.

3. The OTDR shall be calibrated for the correct index of refraction to provide proper length measurement for the known length of reference fiber.

4. A transmission test shall be performed with the use of a 1310 and 1550 nm stabilized light sources and 1310 nm/1550 nm power meters for SMF. This test shall be conducted in both directions on each fiber of each cable.

5. Hard and electronic copy of test documentation shall be submitted to the CONSTRUCTION MANAGER. The documentation shall include the trace plot, index, dB/km loss, cable length, date and time of test, wavelength, pulse width, the test site, cable ID, fiber number and type, and operator's initials. The CONTRACTOR shall compare the pre-installation test results to the post-installation results. If a deviation of greater than one dB occurs, the CONSTRUCTION MANAGER shall be notified in writing by the CONTRACTOR, and the cable shall be removed and replaced at no additional cost to the OWNER.

6. Upon completion of the previous tests all FOC coils shall be secured with ends capped to prevent intrusion of dirt and water.

E. **Required OTDR Trace Information**

1. All traces shall display the entire length of cable under test, highlighting any localized loss discontinuities (installation-induced losses and/or connector losses). The trace shall display fiber length (in kilofeet), fiber loss (dB), and average fiber attenuation (in dB/km) as measured between two markers placed as near to the opposite ends of the fiber under test as is possible while still allowing an accurate reading. Care shall be taken to ensure that the markers are placed in the linear region of the trace: away from the front-end response and far-end Fresnel reflection spike. Time averaging shall be used to improve the display signal to noise ratio. The

pulse width of the OTDR shall be set to a sufficient width to provide adequate injected power to measure the entire length of the fiber under test.

2. If connectors exist in the cable under test, then two traces shall be recorded. One trace shall record the fiber loss (dB) and average attenuation (dB/km) of the entire cable segment under test, including connectors. The second trace shall display a magnified view of the connector regions, revealing the connector losses (dB). All connector losses shall be measured using the 5-point splice loss measurement technique.

3. The OTDR trace shall also include the following information:

   a. The date and time of the test
   b. The cable ID number
   c. The cable segment ID number
   d. The fiber color or sub-cable number
   e. Launch point connector number
   f. The optical wavelength used for the test
   g. The refractive index setting of the OTDR
   h. The pulse width setting of the OTDR
   i. The averaging interval of the test

3.7 RECORD DRAWINGS

A. In compliance with Section 01700, the CONTRACTOR shall upon completing the construction of the fiber optic system, shall submit to the CITY Record Drawings showing the following:

1. Horizontal alignment of fiber optic conduit

2. Vertical alignment of fiber optic conduit

3. Location of all pullboxes using Station Number, and the exact Northing and Easting of each pullbox using the North American Datum (NAD) 83 coordinate system.

** END OF SECTION **

Appendix A
Special Project Requirements

Location	Segment[1]	Cable Type	Drawing	Requirement