UTILITIES INFRASTRUCTURE DESIGN – AIMS
ISSUED FOR CONSTRUCTION
BASIS OF DESIGN

McMurdo Station, Antarctica

Submitted to:
United States Antarctic Program
Leidos Innovations - Antarctic Support Contract

Submitted by:

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SECTION 1 EXECUTIVE SUMMARY

A. General

1. This Basis of Design (BOD) addresses one element of a major effort by the National Science Foundation (NSF) to modernize McMurdo Station, its primary U.S. Antarctic Program (USAP) facility. This modernization effort is entitled Antarctic Infrastructure Modernization for Science (AIMS) and is a multi-year, multi-project effort to upgrade facilities on Station. The overarching goal of this infrastructure modernization is to ensure that McMurdo Station remains a viable platform for supporting Antarctic science for the next 35 to 50 years. The BOD presented here is for the McMurdo Utilities Infrastructure Design Project (Project) and reflects Merrick & Company's understanding of performance criteria contained in the Project Statement of Work (SOW), augmented by information collected from McMurdo Station (Station) user interviews, and Station site investigations. This Basis of Design will guide development of construction documents for the Project.

2. Work accomplished under this Project's SOW encompasses activities performed in advance of AIMS work, as well as the AIMS work itself. The construction documents have been developed as two separate and freestanding design packages. These packages are entitled "AIMS" and "PreAIMS" and are denoted as such on all construction documents. Narrative in this BOD applies to AIMS efforts only.

3. The goals of both this Utilities Infrastructure Design Project and the overarching AIMS program include:

   a. Redevelop McMurdo Station into a more energy and operationally efficient campus, optimized for support of local and deep field science.

   b. Improve energy consumption and infrastructure support systems.

   c. Reduce maintenance requirements to the greatest extent possible.

   d. Provide predictable operational costs and operational efficiencies.

   e. Offer a reliable, safe and healthy working environment for personnel and visitors.

   f. Provide flexibility to adapt to changing needs of U.S. science in Antarctica.

g. Reflect the influential presence in Antarctica in a manner consistent with U.S stature in the international research community.

4. Utilities components of AIMS work include:

   a. Combined domestic and fire suppression water.

   b. Sanitary sewer.

   c. Heat loop (hydronic) supply and return.

   d. Fuel.

   e. Communications outside plant cabling.

   f. Power.

   g. A new water tank with associated appurtenances.

   h. A new Pump House for water distribution equipment.

   i. Modification of the existing pump Building 194 and addition of automatic tank valves in the existing Water Treatment Plant.

   j. New modular telecommunication (Node) facility.

5. Station elements impacted by AIMS construction include:

   a. Above ground utilidors.

   b. Direct-bury utility mains in limited locations.

   c. Concrete culvert utility chases for below ground utilities.

   d. Improvements to existing surface drainage ways.

   e. Site grading.

   f. Demolition of existing utility systems as new systems become operational.

B. Project Summary

1. The Utilities Infrastructure Design Project includes the design and production of construction documents (drawings, specifications, basis of design narrative, and calculations) for improved utility distribution systems at McMurdo Station, Antarctica.

2. Information contained in this AIMS Basis of Design is based upon:

a. "McMurdo Station Master Plan" prepared by OZ Architects and Merrick & Company.

b. Project meetings, user interviews, design team deployment to McMurdo in February 2016 and February 2017, and other correspondence related to the Antarctic Infrastructure Modernization for Science (AIMS) program.

c. Phasing concepts as developed by Leidos and presented to Merrick & Co.

d. Leidos meeting and presentation of delineation of work to be performed by Leidos versus work to be bid by and performed by the Ccontractor.

3. The design documentation presented herein accommodates AIMS construction to include:

a. Reconnection of existing buildings to the new exterior fiber optic and copper lines constructed in the pre-AIMS phase.

b. Water, sewer, hydronic, fuel, power, and communications service lines to support a separate project to develop a Vehicle and Equipment Operations Center (VEOC) and a temporarily coincident General Contractor (GC) staging facility.

c. Water, sewer, hydronic, fuel, power, and communications service lines to support the AIMS Core Facility project.

d. Improvements to the Station water distribution system, existing pump Building 194, new water storage tank, and new Pump House to support fire flow augmentation.

C. Delineation of Work

The McMurdo Utilities Infrastructure Design Project includes designs for work which will be executed by Leidos Innovations Corporation. Such designs are presented as part of the contract documents in order to facilitate coordination, cooperation and collaboration between the Contractor and Leidos, but are not part of the Contractor's scope of work. Information contained in this AIMS basis of design document applies to both Contractor performed work and Leidos performed work. Reference AIMS drawing packages for delineation of efforts information.

D. Stakeholder Interviews and Results

A major effort was coordinated to solicit input from the wide range of parties with activities associated with the Station. This effort primarily took the form of a series of charrettes, each focused on a major "community" (e.g., grantees, logistics and operational senior managers, tenant government agencies). A summary of the charrettes is contained in the report "Design Charrette Meeting Minutes" produced by the Antarctic Support Contract, led by Lockheed Martin at the time and now by Leidos Innovations Corporation. (Any previous reference to Lockheed Martin should now be considered Leidos).

E. Relevant Codes and Guiding Principles

1. The following codes are utilized in the design of the Project.

    a. International Building Code (IBC) 2015

    b. International Plumbing Code (IPC) 2015

    c. International Mechanical Code (IMC) 2015

    d. International Energy Conservation Code (IECC) 2015

    e. NFPA 1 – Fire Code 2015

    f. NFPA 54 – National Fuel Gas Code

    g. NFPA 70 - National Electrical Code 2014

    h. NFPA 70E - Standard for Electrical Safety in the Work Place

    i. NFPA 90A - Standard for the Installation of Air Conditioning and Ventilating Systems

    j. IESNA - Lighting Handbook (10th Edition)

    k. IESNA RP8 – Roadway Lighting

    l. IES RP-8-14 - Roadway Lighting

    m. IEEE C2-2012 - National Electric Safety Code

    n. IEEE Standard 142-2007 - Recommended Practice for Grounding Industrial and Commercial Power Systems (Green Book)

o. IEEE Standard 242-2001 - Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)

p. IEEE Standard 399 - Recommended Practices for Industrial and Commercial Power System Analysis

q. IEEE Standard 399-1997 - Recommended Practice for Power Systems Analysis (Brown Book)

r. TIA/EIA 568-B.1 - Commercial Building Telecommunications Cabling Standard, 2001

s. TIA/EIA 569-B - Commercial Building Standard for Telecommunications Spaces and Pathways, 2004

t. TIA/EIA 606-A - Administration Standard for Commercial Telecommunications Infrastructure, 2002

u. J-STD-607-A - Commercial Building Grounding and Bonding Requirements for Telecommunications, 2002

v. AHRI 1060 - Performance Rating of Air to Air Heat Exchangers for Energy Recovery Ventilation Equipment

w. AMCA 210 - Laboratory Methods of Testing Fans for Rating

x. ABMA 9 – Load Ratings and Fatigue Life for Ball Bearings

y. ABMA 11 - Load Ratings and Fatigue Life for Roller Bearings

z. ASHRAE Fundamentals - ASHRAE Handbook of Fundamentals 2013

aa. ASHRAE Guideline 0 - The Commissioning Process 2013

bb. ASHRAE Guideline 1.1 - HVAC&R Technical Requirements for the Commissioning Process, 2007

cc. ASHRAE 62.1 - Ventilation for Acceptable Indoor Air Quality 2010

dd. AABC MN-1 - National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems

ee. SMACNA 1780 – HVAC Systems Testing, Adjusting and Balancing

ff. SMACNA 1966 - HVAC Duct Construction Standards Metal and Flexible

SECTION 2 CIVIL AND SITE WORK

A. Existing Site and Utilities Description

1. McMurdo Station, Antarctica is located on the southwestern tip of Ross Island. The Station site, as defined for this Project, consists of the area bounded by Winter Quarters Bay on the west, Observation Hill and the Tank Farm on the east, McMurdo Sound on the south, and Fortress Rocks on the north. The Station is approximately 140 acres, containing buildings, utilities, roadways, and other infrastructure to support the National Science Foundation's (NSF) mission of science and exploration through the United States Antarctic Program (USAP).

2. The existing exterior utility distribution systems at the Station consist primarily of individual and a collection of Arctic pipes on aboveground pipe racks supported by stanchions, with the collective system known also as "utilidor". Arctic pipe represents the most obvious component of utilities within the Station. Arctic pipe is a system of interior carrier pipe(s) surrounded by heat trace elements, insulation and an outer corrugated metal pipe (CMP) jacket. Individual arctic pipes are currently protected from freezing via the use of electric resistive heat tracing.

   Existing utilidors span the Station site from the Power Plant (Building 196) area north to the Vehicle Maintenance Facility (VMF, Building 143) and to the Tank Farm to the east, with systems concentrated on the south side of Scott Base Road. Existing utilidors convey a range of utilities to buildings and facilities, including potable water, fire suppression water, seawater, heat distribution loop (hydronic) supply and return, fuel, sanitary sewer, communications, and power. Conventional utility poles and overhead distribution are also present for communications and power.

3. At some areas, primarily at road crossings, the existing aboveground utilidor system transitions to a belowground system to allow vehicle circulation through the Station. These belowground crossings utilize a culvert system to convey the utilities to the other side of the road or obstruction. In a few instances, Arctic pipe systems and metal conduit are directly buried beneath the soil. In other instances, such as fuel lines, outer casing pipes are placed around the interior carrier pipe and then this double-piped system is directly buried beneath the soil.

B. Concept of New Utilities System

1. With the implementation of the McMurdo Master Plan (MP), Pre-AIMS, and AIMS projects, a series of new facilities will be constructed to support the NSF's mission. The primary goal of the new construction to upgrade facilities is to increase efficiency of operations and the research mission at the Station. Several existing facilities will be demolished as new facilities are constructed and brought online. NSF's requirements for the Station's capabilities will remain the same so all activities currently supported in the existing Station will be present in the new facilities, and will be expected to be performed more efficiently. The Station's utility network will be modified to meet the new goals and facilities, including removing and replacing elements of the existing utility distribution systems.

2. The purpose of this Utilities design is to serve the new facilities as they are brought online and to continue services to existing facilities. Some existing facilities will remain in the final Station condition (i.e. after AIMS and MP completion) while other existing facilities will continue to support the NSF science mission until they are replaced by new facilities and subsequently demolished.

   This Project focuses on the exterior utility distribution systems at the Station; no work associated with this Project will occur within the existing Station production facilities (Power Plant Building 196, Water Treatment Plant Building 198, and Wastewater Treatment Plant Building 199 (WWTP)), unless otherwise noted. The current treated water production, current wastewater loading and treatment, and current power production remain as they are today.

3. The routing of new utilities as proposed in this design is based on the current understanding of Pre-AIMS and AIMS construction and facility phasing (see Section 1, Part B).

4. Merrick & Company established high-level goals in generating this design including:

   a. Reduction of reliance on heat tracing for primary freeze protection of the water distribution system by utilizing heat sourced from the hydronic system.

   b. Design of looped water distribution system where possible to provide redundancy and more robust infrastructure in case of emergency or maintenance.

c. Standardization of systems to reduce spare part inventory (and associated allocated space) and to reduce the training necessary to maintain systems.

d. Reduction of energy usage (e.g., heat loss from outdoor runs of the hydronic loop).

e. Efficient planning for location and utility needs associated with both existing and proposed facilities, understanding that some existing facilities will persist well into the future and others will only remain active until new facilities allow for their demolition.

f. Fully supporting new and existing facilities at the end of each constructed phase without reliance on future phases to complete a system.

g. Eliminating or mitigating potential conflicts between phased facility construction and existing facilities that need to remain operational.

h. Maximizing reliance on gravity for sanitary sewer mains. (New alignments will be placed at slopes greater than 0.5% prescribed in the IPC.)

i. Reduction of pedestrian and vehicle conflicts with the utility distribution systems.

5. To the maximum extent possible, this design will incorporate Station utility runs (utilidors) within new facilities. This approach takes advantage of the ambient building heat for the utilities for freeze protection, which lessens heat trace energy needs. This approach results in a reduction of per-foot cost of piping, since internal utility runs will not need heat trace, insulation, or CMP exterior jacketing. Further, efficiency and safety are gained through the ability to perform maintenance and repair for a larger portion of the overall utilities network in all weather conditions.

6. In locations where utilities cannot be placed within buildings, aboveground utilidors, belowground concrete utility trenches, and direct-bury utility mains (in a small area supporting the GC Staging Area), are designed in descending order of desirability.

   a. Aboveground utilidors will look much like the current systems in use at the Station currently, with Arctic piping and cable trays installed on pipe racks and stanchion supports. Some aboveground locations in this Project will install new utility lines on existing utilidors.

b. A below grade pre-cast concrete utility trench, consisting of a box culvert with a removable lid, will be a method of conveying underground utilities. The utility trench will be composed of pre-cast sections placed at prescribed grades. Depending on location and surrounding grade, the trench will be either partially buried or fully buried (primarily at road crossing locations).

c. Direct-bury wet utility mains (water and sewer) will be placed to support the temporary GC Staging Area. Refer to the communications and power distribution sections of this document for further information on those utilities.

7. For water, sewer, and heat loop systems, Arctic pipe systems with insulation and heat trace (as backup freeze protection) are designed. Communications conduits in a direct-bury application will also have heat trace installed as backup freeze protection. Pipelines without insulation or heat trace will be the norm for fuel lines since there is no risk of freezing. All Arctic pipe systems are proposed to be CMP-jacketed, whether they are aboveground or below. Specific information on each utility system is further defined in the paragraphs below.

8. Sanitary sewer design follows to maximum extent guidance within the International Plumbing Code.

a. Pipes slopes are above the minimums dictated in Table 704.1. Although aboveground alignments are placed on stanchions following existing grades, changes in slopes are minimized to avoid hydraulic jumps.

b. Cleanouts are placed on the sanitary lines to meet the intent of the Code with sections of lines within one hundred feet of a cleanout where possible. Cleanouts are also placed in locations where a horizontal change in direction exceeds forty-five degrees.

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C. Analysis of AIMS Utility Needs

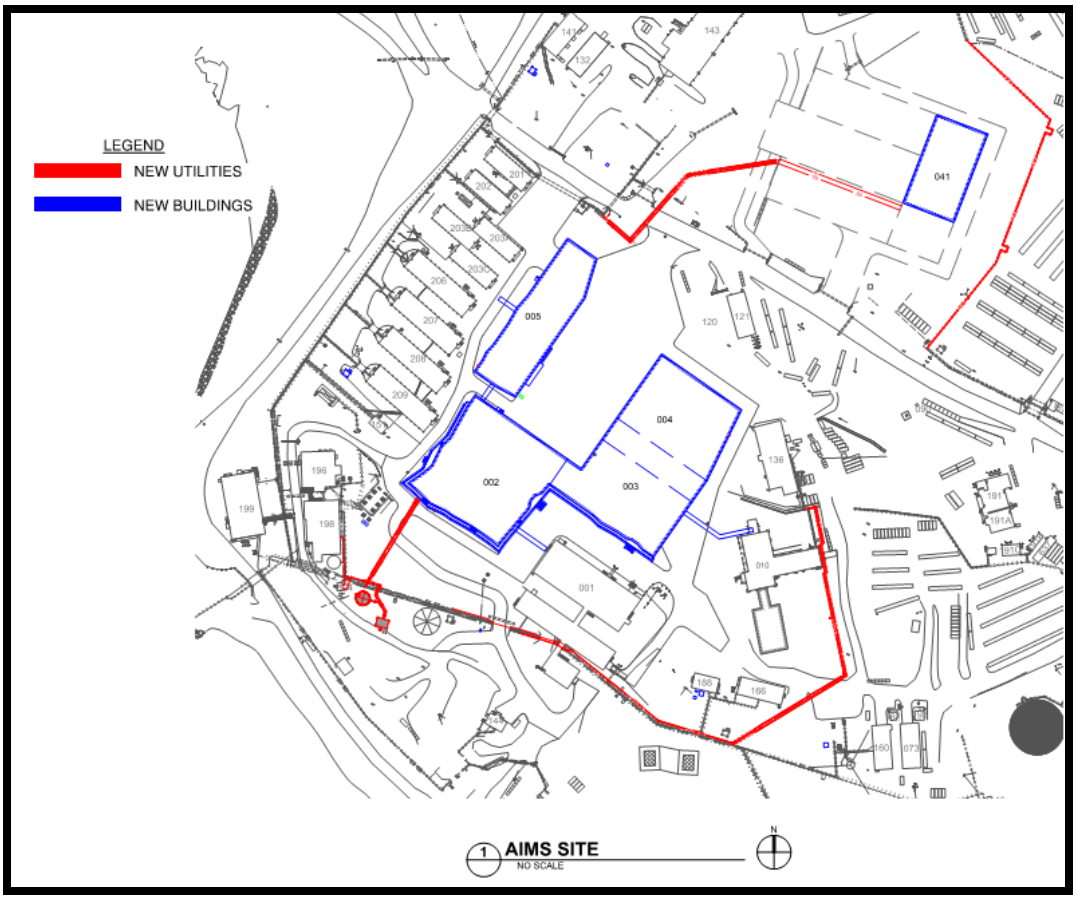

Figure 2.1 Site Plan

1. VEOC and GC Staging Area

The first facility to be constructed as a part of the AIMS project will be the General Contractor Staging area (GC Staging Area) or the Vehicle Equipment Operations Center (VEOC). The ultimate configuration of this facility is still unknown as it is a Design-Build project. Per conversations with Leidos, the GC Staging Area will be constructed initially and the full VEOC facility will be constructed later. Additions to the GC Staging Area will result in the facility becoming the VEOC.

Since the GC Staging Area will be constructed prior to the completion of Core Facilities (and the new utility mains within), the new GC Staging Area utilities will tie-in to utilities provided by this Project.

To this end, a new permanent utilidor will be constructed from the area north of Building 210 and Building 211 (to be demolished by AIMS), extended northeast under Scott Base Road west of Building 140, and terminate at a location which will serve the fully-completed VEOC facility. The tie-in near Buildings 210 and 211 will be aboveground and will then transition to a concrete utility trench for crossing of Scott Base Road. North of Scott Base Road, a portion of the utilidor will be aboveground in the Building 140 area and then transition back underground into a concrete utility trench to the termination for VEOC. From this interim termination, temporary direct-bury utilities will extend southeast to the GC Staging Area. These temporary utilities will ultimately be removed when the full VEOC facility is constructed.

a. VEOC and GC Staging Area Water Supply and Distribution

A new 8-inch HDPE carrier pipe (within Arctic pipe system) will connect to the existing 6-inch bondstrand carrier pipe near Building 210 and will be routed through the new utilidor as described above. The line will extend through the permanent portion of the utilidor and will also contain direct-bury temporary main to serve the GC Staging Area. In the interim prior to the demolition of Building 211, the existing water service line feeding Building 211 will need to be reconnected to this new water main.

Until Core Facilities and the new water distribution improvements are completed, the GC Staging Area and eventually the VEOC will rely on the existing water distribution system, including the existing high-capacity 1,000 gpm pump located in Building 194. Design analysis has indicated the water system will not be capable of providing fire flow requirements for the VEOC. To address this shortcoming, a fire water booster pump should be provided in the VEOC to augment pressure for fire suppression needs in accordance with the requirements set forth by the VEOC fire protection system design engineer.

b. GC Staging Area Sanitary Sewer

A new 6-inch HDPE carrier pipe (within Arctic pipe system) will connect to the existing 6-inch bondstrand carrier pipe near Building 210 and will be routed through the utilidor as described above. The sewer main will extend through

the permanent portion of the utilidor leading to the GC Staging Area/VEOC site and will also join water lines in being temporarily direct-buried to serve the site until VEOC is completed and GC Staging Area functions have ceased. In the interim prior to the demolition of Building 211, the existing sewer service line associated with Building 211 will need to be reconnected to this new sewer main.

c. GC Staging Area Fuel Distribution

Currently, there is no fuel distribution main in the immediate vicinity of the GC Staging Area that could be tapped for building heating needs. In lieu of constructing a long service line from an available fuel pipeline, the GC Staging Area will temporarily utilize a local day tank fuel storage tank (not a part of this Project) until the Core Facilities mains are constructed. In preparation for the final configuration, a permanent 2-inch uninsulated steel fuel main will be provided within the utilidor system described above and will extend from the future connection point north of Core Facilities to the permanent VEOC termination point. These fuel mains will be ready for connection to the final permanent configuration when Core Facilities work is completed, but they will remain capped and empty until that time.

A separate and distinct element of the existing fuel distribution system will need to be modified prior to GC Staging Area construction. Due to the grading activities associated with site preparation for GC Staging Area /VEOC, the existing fuel line utilidor east of the 340-series warehouse buildings will need to be relocated further east. This work will be a necessary part of this Project. The new fuel lines will match the existing utilidor configuration, design, and setup as the system currently in place, an aboveground pipe rack system.

d. GC Staging Area Hydronic Distribution

Similar to fuel distribution pipelines, there is no available hydronic tie-in within the vicinity of the GC Staging Area. Permanent hydronic supply and return lines will be installed within the utilidor as described above for fuel, but will not ultimately be connected until Core Facilities mains are available. Temporary hydronic distribution to the GC Staging Area is not necessary since other methods of heating are available (fuel oil boilers, etc.).

2. Core Facilities

The Core Facilities component of the AIMS portion of the McMurdo Master Plan consists of the Central Services, Emergency Operations, Field Science Support, and Trades buildings. This Project includes new utility systems that will be built to support the new Core Facilities and will include water, sewer, fuel, hydronic, power, and communications lines. In keeping with Merrick & Company's high-level utility design goals, this Project plans for significant portions of the Station utility main distribution system to be routed through the Core Facilities.

The Core Facilities project is a separate design-build (D-B) contract and is not a part of this Project. The ultimate configuration of utility mains through the facility will be the responsibility of the successful D-B Core Facilities team. This Project will route distribution mains to the future building location and accommodate future connection points that Core Facilities designers can use in their work.

a. Core Facilities Water Supply and Distribution

This Project produces a combined fire suppression and domestic water distribution system. The new Station water system will consist of a new water storage tank (to meet water reserve levels required for fire suppression needs), a new water Pump House, modifications to existing Building 194 (Pump House), new valves in Building 198 (Water Treatment Plant), and a water distribution main pipeline to the Core Facilities.

A new water storage tank will be built southeast of the existing Building 198 and the existing water Pump House Building 194 by this Project. The new tank will augment the existing water storage tanks within and near Building 198. The four existing tanks provide a total volume of approximately 200,000 gallons of reverse osmosis (RO) treated water. For the purposes of this design, a working volume of 180,000 gallons of RO-treated water was used for calculations to allow for differences in volumes such as tanks not being fully topped-off. The new water storage tank will provide approximately 70,000 gallons of additional capacity, bringing the Station total to approximately 250,000 gallons. This total amount of on-hand water will simultaneously support fire suppression needs and uninterrupted provision of drinking water for Station personnel. (Refer to the technical memoranda "Fire Flow Criteria

Determination for Water System Design" (July 29, 2016) and "Water Storage Tank Capacity Recommendation" (August 9, 2016), both prepared by Merrick & Company, for further information on capacity and storage calculations.) The new storage tank is sited to facilitate its operation at the same water level elevations and system parameters of the existing tanks in Building 198.

The new water Pump House will support and augment the existing Station pumping capacity and distribution system. The new Pump House will contain a diesel-driven 1,500-gpm high-capacity pump to meet fire suppression water distribution pressures. It will also house smaller pumps and equipment to support recirculation of tempered water in the new water storage tank, the existing water storage tanks, and within a water loop connecting all storage tanks.

The new storage tank and new Pump House will tie-in to the existing distribution system and will operate in tandem with the existing water storage and pumping facilities. A connection between the new Pump House and the existing Pump House Building 194 will allow both to draw from the available water storage and an output connection from the new Pump House to the overall distribution system will allow it to supply water to Station facilities.

As a part of this Project, the existing 1,000-gpm electric-driven pump in Building 194 will be replaced with a new 1,500 gpm electric-driven pump. This configuration provides an equally capable redundancy as well as power diversification (diesel and electric) to allow full-capacity fire suppression water in the event of an emergency.

This Project includes new water distribution mains to connect the new tank and pump systems to the existing distribution system (as described above) and also directly to the new Core Facilities. An 8-inch HDPE water main carrier pipe (within Arctic pipe) will be provided from the new Pump House area to the southwest corner of the Core Facilities.

This Project will increase water main capacity between the existing storage tanks in Building 198 and Building 194 by increasing pipe diameter to 10-inch HDPE carrier pipe (within Arctic pipe).

As currently designed, water looping (continuous slow-flow circulation) will not be fully operational until the Emergency Operations portion of the overall AIMS project is completed and the new main water line tied-in to the existing water connection built for GC Staging Area as described above. Once the Emergency Operations portion of Core Facilities is constructed, a cross-connection will be provided between the new water distribution system in the Core Facilities, the water main built for GC Staging Area (as described above), and the existing 6-inch water main present in the area of existing Building 210. Upon connection, the tempered water circulation system can be fully supported by the new Pump House. The water booster pump installed for support of the GC Staging Area/VEOC (as described above) should remain permanently even after the water loop is completed. Refer to other sections of this document for further details on structural, architectural, mechanical, power, and communications portions of this design strategy.

b. Core Facilities Sanitary Sewer

The topography of the site produces a gravity-fed sewer system installed by this Project. The Core Facilities design (under separate D-B project) may necessitate the use of small, building-specific, pre-packaged lift stations to lift sewage to the system installed by this Project.

Sanitary sewer main piping will be extended from the existing utilidor near the new water Pump House to the southwest corner of the Core Facilities along the same corridor as the new water main. Per conversations on Station, existing sewer main capacity is adequate between the tie-in and Building 199 (Wastewater Treatment Plant).

Once the Emergency Operations portion of Core Facilities is completed, the new GC Staging Area/VEOC sanitary sewer main (as described above) can be switched to the new Core Facilities main and the old connection to the existing sewer piping will be removed as part of the Core Facility project.

c. Core Facilities Fuel Distribution

Fuel distribution piping will be extended from the existing utilidor near the new water Pump House to the southwest corner of the Core Facilities along the

same corridor as the new water main and sanitary sewer. Per conversations on Station, existing fuel main capacity is adequate to serve the new facilities.

Once the Emergency Operations portion of the Core Facilities is completed, the new GC Staging Area/VEOC fuel main (as described above) can be connected to the new Core Facilities main.

d. Core Facilities Hydronic Distribution

Hydronic supply and return lines will be extended from the existing utilidor near the new water Pump House to the southwest corner of the Core Facilities along the same corridor as water, sewer, and fuel. Per conversations on Station, existing hydronic system capacity is adequate to serve the new facilities.

Once the Emergency Operations portion of the Core Facilities is completed, the new GC Staging Area/VEOC hydronic lines (as described above) can be connected to the new Core Facilities systems.

D. Grading and Drainage

1. Grading

The majority of aboveground utilidors associated with this Project will require little to no grading for construction. There will be areas where existing grades will need to modification to support the new utilities configuration, nodes, and appurtenances, but the amount of earthwork will not be significant.

Direct-bury utilities (for temporary GC Staging Area) and new buried concrete utility trenches will require excavation for construction. To the extent practical, the direct-bury utilities and concrete utility trenches will be installed at, or as close to, existing grades in order to limit the amount of excavation required. Backfill placed over the buried pipes and concrete utility trenches will be completed to smoothly match surrounding final grades.

Per conversations on Station, the GC Staging Area/VEOC site grading will be conducted prior to utilities construction under a separate project/contract. This will be necessary to achieve having permanent utilities placed at the correct vertical elevations in that area. Further, the retaining wall integral to the vehicle approach

to the VEOC building will not be built immediately, since it would not be necessary for construction and operation of the GC Staging Area. This delay in building the retaining wall is important, since the temporary utilities required for GC Staging Area could not ascend or go through the VEOC retaining wall.

Grading associated with the siting of node buildings, the new water tank, and new pump house will be required as part of this Project. Leidos will perform this grading.

2. Drainage

For the purposes of this analysis, the existing Station drainage network is broken into two separate and distinct parts.

a. South of Scott Base Road: Drainage flows overland through town primarily via surface flow and in undefined channels. Much of the existing grade and drainage patterns in this portion of the Station will be modified when construction commences on the Core Facilities. Final drainage considerations around the new facilities south of Scott Base Road will ultimately be the responsibility of the successful Core Facilities D-B team. Drainage improvements south of Scott Base Road are therefore not included within this Project.

b. North of Scott Base Road, three major drainage pathways convey meltwater from glacial ice fields above the Station and from snowmelt within the Station. This Project will change site topography and affect the existing drainage pathways. The new drainage patterns will generally follow the existing pathways. These pathways, as defined in reports written by the Cold Regions Research and Engineering Laboratory (CRREL), are “Gasoline Alley”, “McMurdo River”, and “Scott Base Road River”. *Gasoline Alley* is defined as the drainage and associated ditch west of the road that accesses Tanks D2, M1, and M3, as well as unheated storage Tanks 344 and 345. *McMurdo River* is defined as the drainage and associated ditches that headwater in the area of Fortress Rocks, and travel along the Arrival Heights road, passes the hazardous waste processing area (Building 33 and marshalling yard), continues southwest past the 340-series warehouses and finally passes east

of Building 175. *Scott Base Road River* is defined as the drainage and associated ditches on the north side of Scott Base Road, starting adjacent to the primary Station fuel tank farm in The Pass and traveling almost due west before spilling sharply downslope from the lower Ice Pier road into Winter Quarters Bay. McMurdo River joins the Scott Base Road River just downslope on the east side of Building 175. Gasoline Alley discharges into the Scott Base Road River west of Building 192, just before Scott Base Road River begins its cascade down to Winter Quarters Bay.

3. Understanding of Factors Influencing Station Drainage

Drainage runoff within the Station is unique in that virtually all of the overland flow is generated by ephemeral melting snow and ice. Austral summer solar input and warmer ambient temperatures turn the modest amount of accumulated precipitated and drift snow within the Station footprint to water in a predictable fashion. Glacial ice fields located in areas topographically above town hold massive volumes of water equivalent. Converse to the predicable flows from precipitation, during the austral summer these fields can suddenly and unpredictably release large volumes of water via subsurface melting and internal drainage. This water enters Gasoline Alley and the McMurdo River quickly and in some of the steepest terrain within the Station.

Water flow in the Station drainage system only occurs during the austral summer months (November through February) but primarily during December and January. Owing to the large difference in water amounts from the two contributing sources, and the brief window of melting opportunity, runoff events can vary widely from year to year. Factors such as localized temperatures, amount of exposed darker earth within and near the ice fields, solar gain, and cloud cover can strongly influence annual melting. While many years exhibit very small, short term runoff, evidence gathered during site visits, witness accounts, and photos provided in the CRREL reports indicate that large-scale runoff events can and have occurred within the Station, leading to overtopped culverts, washed out roadways, and emergency mitigation measures during high flow events.

During the 2017 design team deployment it was learned that an existing road embankment present above town along the roadway to Arrival Heights historically

creates a significant impoundment of water and ice behind it, acting as a dam in the Gasoline Alley tributary drainage route. This dam has failed several times in the past, releasing the impounded water through Gasoline Alley, inundating it with large amounts of flow resulting in road washouts. The dam had been re-built within the past ten years, with provisions for seepage flow beneath the dam and overflow capability via a 36-inch chase. Whether by design, or changes in environmental conditions, the Station has not been subjected to large-scale runoff events since the dam was re-built.

It is unknown if large-scale runoff events of the past solely corresponded to a dam failure above town or if other situations can occur to produce voluminous drainage. Merrick & Company suspect such high levels of runoff must be associated with a reservoir of water being suddenly released. However, analysis of runoff events and the dam is not within the scope of this Project.

Knowing that runoff flow amounts are variable for any given time-frame (hours, days, months, years) and since they can vary greatly in magnitude, this Project has adopted a design based on the flow volumes provided in the report “Flow Control and Design Assessment for Drainage System at McMurdo Station, Antarctica”, prepared by CRREL and dated November 2014. This is considered the best available data on runoff quantities for the Station. Additional information about Station drainage can be found in three other reports by CRREL, “Runoff Characterization and Variations at McMurdo Station, Antarctica”, dated May 2014, “Modeling and Designing Control Flow Systems for Drainage Channels at McMurdo Station, Antarctica”, dated 2013, and “Drainage Assessment and Flow Monitoring at McMurdo Station during Austral Summer”, dated May 2012.

For simplicity, this Project will adopt the culvert numbering scheme used in the November 2014 CRREL report referenced above.

The CRREL reports are comprehensive and discuss many aspects of Station drainage, particularly as it relates to operations and maintenance, sedimentation, and environmental impact. Salient points pertinent to this Project in these reports are summarized as follows:

a. The Station’s drainage channels and topography are steep.

b. There is no vegetation or organic content present in on-Station soils.

c. The subsurface soil conditions consist of a thin active layer (annually transitions between frozen and thawed) with permafrost beneath the active layer.

d. High runoff volumes and velocities contribute to the mobilization of sediment through erosion of the channels and ditches.

e. Sediment transported within the drainage system is discharged into the head of Winter Quarters Bay near the Ice Pier.

f. High flow amounts, coupled with potential for culvert clogging, have resulted in roadway overtopping, washing out of roadways, and emergency measures (e.g., berms) placed by operations personnel to contain flows.

g. Many ditch and channel modifications are annually installed and removed to achieve drainage effectiveness during the austral summer runoff season while making drift snow removal and channel maintenance easier during the austral spring.

h. The reports define three major drainage basins. Basin 1 discharges directly into Winter Quarters Bay without passing through the Station proper and thus it does not influence this Project. Major basins 2 and 3 are factors in this Project.

The drainage system design and analysis within this Project relates only to those engineering improvements deemed necessary to achieve effective runoff conveyance. That is, this Project identifies grades, culvert sizes, ditch slopes and revetments, and flow control features that, as a system, yield a sustainable, safe, and minimal maintenance network. Other operations and maintenance factors, as defined in the CRREL reports (e.g., snow dump locations and similar), are not a part of this Project.

4. Existing Drainage Conditions

The Scott Base Road River ultimately discharges into Winter Quarters Bay to the northeast of the Ice Pier. There are two culvert crossings before the final outfall, one each occurring at the lower Ice Pier Road (Culvert 1 per CRREL numbering, which will be used throughout) and upper Ice Pier Road crossing (Culvert 2). Culvert 1 is a 36-inch corrugated metal pipe (CMP) beneath the lower Ice Pier

Road and Culvert 2 is a 4 foot x 4 foot steel box beneath the upper Ice Pier Road. Downstream of Culvert 1, large boulders and rocks have been placed for energy dissipation of the runoff prior to final discharge into Winter Quarters Bay. A flume, consisting of a 36-inch CMP cut in half, has also been placed on the downstream end of Culvert 1. Between Culvert 1 and Culvert 2, another metal flume (also, appearing to be a 36-inch CMP cut in half) connects the two structures' flow paths. Between the upstream end of Culvert 2 and the confluence with Gasoline Alley drainage, the channel is well defined and appears to be stable. Immediately upstream of the Gasoline Alley confluence, a 4 foot x 4 foot steel box (Culvert 3) is present beneath the road to the west of Building 192. To the south of Building 192 and Building 122, the ditch is well defined and appears to be stabilized. The next upstream road crossing is a 24-inch CMP culvert (Culvert 4) to the south of Building 122 and southwest of Building 175. Upstream of Culvert 4, to the south of Building 175, the ditch looks well defined and stable. It also appears that large diameter boulders have been placed on the Building 175 side of the ditch in this area, presumably for slope stabilization. The upstream end of this reach is the confluence with McMurdo River drainage, containing a relatively level area lacking a well-defined drainage path and coincident with utility pipe racks and stanchions. Upstream of the McMurdo River confluence is Culvert 5, traversing beneath the road leading to Building 143 (VMF), to the west of Building 140. Field measurements indicate that the upstream and downstream diameters of Culvert 5 vary in size, with the upstream end being 24-inch CMP and downstream end being 36-inch CMP. This configuration is a curiosity. Upstream of Culvert 5, the ditch appears to be well defined and stable with the next culvert crossing occurring at the pedestrian access and stairs leading to Building 140 (Culvert 6), which is a 24-inch CMP. Upstream of Culvert 6, to the southeast of Building 140, the ditch appears to be well-defined and stable. The next culvert crossing occurs at the lower vehicle entrance to Building 140 (Culvert 7), which is a 24-inch CMP. The ditch upstream of this location appears to be well defined and stable. An existing 36-inch CMP is present beneath the upper vehicle access to Building 140 (Culvert 8), which also serves as the main entrance from Scott Base Road to the MCC Cargo Yard. Upstream of this entrance, the ditch starts to become shallower, less well defined, and meandering. The next culvert crossing is a 24-inch CMP at the

entrance to the “ballpark” area (Culvert 9). For the purposes of this Project, Culvert 9 represents the uppermost reach of the Scott Base Road drainage system because upstream of the “ballpark” area, the ditch is very shallow, appears stable, and does not appear to carry significant amounts of runoff.

Gasoline Alley joins the Scott Base Road River in the northern quadrant of the five-way intersection of Scott Base Road, the upper and lower roads to the Ice Pier, the road down to the WWTP and its uphill extension leading past the old Gas Boy fueling station. This intersection is northwest of Building 201. For approximately 200 feet north the existing channel is well defined and appears stable. Upstream for approximately the next 150 feet, the channel becomes undefined (no defined channel) and has been flattened out to provide vehicle access to the now-abandoned Gas Boy fueling station area near existing Tank D2. Upstream of this vehicle access area, the channel again becomes defined and also contains existing fuel distribution utility lines on pipe racks and stanchions completely within the drainage conveyance. This stretch of the existing drainage way contains large diameter rocks and boulders on the stream bed as well as signs of probable erosion from past flow events. Several instances of fully exposed (suspended) fuel pipe rack supports can be seen in the ditch. While the flow path is relatively defined, the drainage cross-section through this area varies in depth and width. Along this existing drainage way there is a 36-inch CMP drainage culvert (Culvert 23) with timber headwalls on the upstream and downstream ends. Culvert 23 provides a vehicle access point to the outside storage area (OSA) near existing Tanks M1 and M3. Farther upstream, the Gasoline Alley defined drainage channel ends at a point where significantly steeper terrain exists, coincident with the gravel roadway access westbound to South Pole Traverse storage. For the purposes of this Project, this is the upstream termination of Gasoline Alley improvements and analysis.

McMurdo River joins the Scott Base Road River channel just to the southeast of Building 175 and immediately north of Scott Base Road. There are approximately 200 feet of channel between the confluence at Scott Base Road and the downstream end of a 36-inch CMP drainage culvert (Culvert 10), with timber headwalls, east of Building 175. In this reach, the channel is well defined and

appears to be stable in the existing condition. As it works its way southwest from the Culvert 10 exit point to Scott Base Road, the channel increases in width and flattens out slightly. The two drainages (McMurdo River and Scott Base Road River) combine in this flatter, wider area beneath an existing utilidor system. Culvert 10 is approximately 105 feet in length and passes beneath a broad, undefined vehicle pathway leading to Building 143 (VMF), the northern entrance to Building 140, a vehicle parking area, and an uphill road to Arrival Heights. Upstream of Culvert 10 is another approximately 260 feet of well-defined and apparently stable drainage channel. A steel box culvert, roughly 3 feet x 3 feet (Culvert 11), conveys drainage beneath the northern vehicle entrance to the 340-series warehouses and MCC Cargo Yard. The bottom of Culvert 11 appears to be either buried or rotted away; runoff through this area is flowing along natural channel grade. For approximately 150 feet upstream of Culvert 11, the channel remains well defined and apparently stable. At this point, the channel bends to the southeast (north of Building 342) and becomes more meandering, flatter, and less defined. Topographic relief indicates very little elevation difference between the drainage channel itself and the storage areas located to the northeast of Building 342. During the 2017 design team visit, it was noted that a berm approximately 3 feet in height had been placed on the south edge of the drainage ditch near the fuel line crossing location, presumably as a protective measure to keep water from flowing into the Building 342 storage areas. Near Building 33, the channel again becomes well defined and appears to be stabilized using a placed rock drop structure. Between this drop structure and the existing steel box drainage crossing (Culvert 12, just south of Haz Waste) the channel is flatter, the flow path wider, and the ditch appears to be stabilized. Culvert 12 near Haz Waste is assumed to have the same properties as the steel box at the 340-series entrance. The presence of flow in the ditch and the configuration of this steel box prevented accurate field measurement during deployment. The upstream end of Culvert 12 is the uppermost limit of McMurdo River included in this Project.

5. Drainage Design for McMurdo Master Plan

The Station drainage network includes a variety of culvert shapes, diameters, and material types. Sections range from circular to square to open-bottom channel. Diameters of CMP vary, with some locations having smaller diameters

downstream of larger diameters. Both CMP and steel are utilized as culvert materials.

All culverts on this project are standardized at 36-inch diameter CMP pipe, except in a few noted instances. This will make maintenance practices more efficient, standardize spare part and material inventory, and mitigate cross-section conflicts. Specifically, this Project's design eliminates:

a. Smaller diameter culverts downstream of larger diameters. This avoids choke points where high flow from upstream culverts can inundate a smaller downstream culvert.

b. Both circular and rectangular cross section culverts. Different cross-sectional geometries allow some shapes of water-born detritus (e.g., rocks, ice chunks) to pass through one type of culvert while creating a clogging potential for another type of culvert.

Further, to re-establish maximum flow conveyance, existing culverts will be rehabilitated on both upstream and downstream ends to clear earth, rocks and debris that impinge on many culvert's full cross-section. These areas also need riprap armoring installed at both the inlet and outlet ends to ensure runoff energy dissipation and to provide proper support to overlying roadways. The majority of culverts will include on-off switchable heat trace to ensure removal of drift snow or frozen meltwater prior to the ensuing melt season.

6. Scott Base Road River Culverts

a. Culvert 1 has received considerable attention in recent years. It is believed that a stabilized flow regime exists downstream of Culvert 1. Thus, the existing 36-inch CMP culvert remain as-is in its current configuration.

b. The existing steel box Culvert 2 will be replaced with a 36-inch CMP. Upstream riprap mitigation will be provided for energy dissipation. It is recommended that the flume remain between Culvert 1 and Culvert 2, with the current practice of half of a 36-inch CMP considered an acceptable solution.

c. The existing steel box Culvert 3 will be replaced with a 36-inch CMP. Riprap protection will be provided on the upstream and downstream ends.

d. To remove the constriction generated by having a smaller diameter culvert downstream of a larger-diameter culvert, Culvert 4, a 24-inch CMP, will be replaced with a 36-inch CMP.

e. The existing Culvert 5 (combination of 24-inch and 36-inch CMP) will be replaced with full-length 36-inch CMP.

f. Due to its relatively good condition, Culvert 6, a 24-inch CMP, can remain as-is. This is suggested despite there being a larger diameter culvert upstream, owing to the knowledge that flow amounts in this portion of the Scott Base Road River drainage (upstream of the confluence with McMurdo River) are very small and easily handled by a 24-inch CMP.

g. Similarly, existing Culverts 7, 8, and 9 can remain as-is for the same reason provided for Culvert 6. Riprap pads will be added to upstream and downstream ends, but improvements are not required for the culverts themselves.

7. Gasoline Alley Culverts

a. Culvert 23, a 36-inch CMP, can remain as-is and in its current configuration. Upstream and downstream riprap protection will be added.

b. A new 36-inch CMP culvert with timber headwalls (very similar to what exists on Culvert 23) will be added at the Tank D2 vehicle entry location. This installation will be coupled with ditch improvements (described further below) to realize a proper channel cross-section and preserve vehicle access to the other side of the channel. This will mitigate the current issues related to a well-defined upstream channel discharging into a flat, non-defined drainage area.

8. McMurdo River Culverts

a. Culvert 10, a 36-inch CMP, can remain as-is in its current configuration.

b. Upstream of Culvert 10, a re-route of McMurdo River will be necessary to bypass the grades associated with the future VEOC facility and its approaches. Current grades shown for the VEOC project indicate that a retaining wall will be spanning the existing McMurdo River channel. The VEOC design will require that culverts be added to channel flows away from where the VEOC sits. This will be accomplished by using two, joined 36-inch CMP culverts, one from the

existing drainage channel to an area east of Building 143 (VMF) and another to take it back to the existing channel upstream of Culvert 10.

c. With the construction of these new culverts, the existing steel box Culvert 11 will no longer be necessary and will be removed.

d. Existing Culvert 12 will be replaced with a 36-inch CMP.

9. Drainage Ditches - General

As described in the CRREL reports, steep terrain within the Station contributes to high runoff flow velocities, which in turn, mobilize sediment and increase erosion within the Station. There are two proposed mitigation measures to decrease flow velocity, increase particulate settlement, and ultimately reduce erosion potential. The first measure is to provide a consistent minimum ditch cross-section for each of the three drainage pathways. The second is to provide rock check dams in the drainage pathways to decrease velocities and provide opportunities for sediment to settle out of the runoff flow.

10. Drainage Ditches – Channel Cross-Sections

The three major Station drainage corridors are reasonably well defined channels sized to convey the flow amounts established in the CRREL reports. Areas where channels are not well-defined and which will be modified in this Project are the following:

a. The culvert installation at the vehicle entrance to Tank D2 on Gasoline Alley: The existing channel in this area has been flattened out to provide a vehicle entrance. This leads to a condition where well-defined channel flow upstream of this location hits a flat, non-bound area where runoff can subsequently spread to surrounding areas. With the new culvert installation, the vehicle entrance can be raised and the coincident drainage area can be re-graded to provide a well-defined channel matching the upstream and downstream conditions. This will allow a consistent flow path through this area mitigating channel breaches onto the adjacent roadway.

b. The upper reach of Gasoline Alley: The area currently shared by the channel drainage and the existing fuel pipe rack the will be re-graded to provide a

consistent cross-section for drainage conveyance. This will be in conjunction with check dams as further described below.

c. The reach of McMurdo River north of Building 342, near the existing fuel line crossing: The drainage channel in this area does not appear to be significantly higher in elevation than the Building 342 storage area. The current expedient earthen berm on the Building 342 side of the channel to prevent overtopping into the storage yard can be removed by minimal excavation in this area to provide a well-defined ditch for flow conveyance.

11. Drainage Ditches – Rock Check Dams

Several Best Management Practices (BMPs) have been considered in this analysis as well as recommendations in the CRREL reports. These include check dams, vertical drop structures, and weirs of various shapes and materials. This Project recommends that a rock check dam concept be employed in the existing drainage channels in appropriate locations to slow flow velocity and promote sedimentation.

Rock check dams are included for the following reasons:

a. Construction materials are local to the Station and do not require costly importation from off-continent.

b. Check dams are currently in use at some locations on the Station and operations personnel already have experience with them.

c. Operations personnel can place rock check dams in the autumn.

d. Consisting of only rock materials, placement and removal is straightforward with Station equipment and labor skill sets.

e. Placement and removal is unlikely to damage materials, avoiding the need for check dam materials to be replaced very often.

f. The upstream sump area of check dams can be periodically cleaned out with available equipment to remove sediment from the drainage system and allow that material to be recycled for other Station needs.

The configuration of check dams will most often consist of a 1.5-foot tall rock weir placed within the channel.

In drainage paths with steep gradients and/or higher flow volumes, check dam placement will be at intervals associated with every 1.5-foot vertical drop in channel. The Gasoline Alley and McMurdo River drainage pathways, both having large gradients, will have frequent check dams. Having a much lower gradient, the Scott Base Road River drainage pathway will not need check dams at every 1.5-foot drop since flow amounts (and velocities) are considerably lower than the other two major pathways.

E. Utilidor Concept

1. Aboveground Utilidor

Most locations in this Project will place new utilities aboveground, similar to the way they currently exist on Station. Two concepts are utilized for aboveground utilidors: attachment to or utilization of existing pipe racks and construction of new pipe racks nearly identical to the ones currently in use.

2. Belowground Utilidor

Several concepts associated with accommodating underground utilities at the Station were considered and evaluated by this Project design team. Despite potential drawbacks, underground utilities must exist on Station to allow vehicle circulation. Additionally, some Master Plan facilities and their vertical relationships to existing grade warrant sections of underground utilities, as does the high-level goal of capitalizing on gravity flow to avoid pumping stations.

Belowground utilidor options considered varied from large cross-section, fully walkable culverts to direct burial of utility lines. Evaluating the options, including discussions with Station operations and maintenance personnel, all belowground utilidors (concrete utility trenches) will consist of buried pre-cast concrete box culvert sections of a size just adequate to transmit the necessary utility lines. They will feature a removable concrete lid to facilitate maintenance and repair activities, when necessary. This concept is currently in use on the Station at several roadway crossing locations, and, according to discussions with maintenance personnel, is a desirable way to both keep utilities underground and yet accessible when necessary. Utilization of the removable lid will require minimal excavation, where it then can be removed with integral pick hooks.

SECTION 3 STRUCTURAL

A. Design Criteria

1. The utility support structures are classified as Risk Category IV structures for wind and seismic per ASCE 7 and IBC 2015.
2. Dead Loads: Dead loads include the weight of all permanent materials and equipment supported in or on a structure, including the structure's own weight.
3. Live Loads: Minimum live loads are in accordance with IBC and ASCE 7 as follows:

AREA	LOADS
Pipe Racks	40 psf
Floor Live Loads	100 psf
Platform Live Loads	50 psf
Snow Load (Ground)	40 psf

4. Wind Loads: Wind Speed (Three-Second Ultimate Gust Speed) of 180 mph, Risk Category IV, Exposure D.
5. Seismic Loads: Minimum seismic requirements are in accordance with ASCE 7. The new support structures' classifications and applicable ground motions are determined by their use and geographical location. Within the Station, the Seismic Design criteria is based on the Golder Geotechnical Assessment Report titled Geotechnical Assessment Report, McMurdo Station, Ross Island, Antarctica – Phase II (June 2017).
   a. Seismic Accelerations: Ss = 0.454g, S1 = 0.128g
   b. Site Class = A
   c. Seismic Design Category = C for Risk Category IV Facilities
6. Deflection Criteria
   a. Lateral wind load drift requirements for the steel pipe rack structures will be limited to H/150.
   b. Lateral wind load drift requirements for the building structures will be limited to H/400.

7. Foundation Design Criteria

   a. The designs of support structure foundation systems will be based on recommendations provided by Golder Associates. The allowable bearing capacity for frozen soil is 2100 psf.

   b. Pipe rack support will use pole embedded in bedrock or fill material utilizing passive pressure for lateral resistance.

   c. Passive and active pressure used in the design of foundations and retaining walls are based on the Golder geotechnical report entitled Geotechnical Assessment Report, McMurdo Station, Ross Island, Antarctica – Phase II (June 2017).

B. Basic Materials of Construction

1. Steel

   a. Structural steel will be ASTM 992 for wide flange beam members, ASTM A500 Grade B Fy= 46 ksi for HSS members, ASTM A53 Grade B for pipe, and ASTM A36 for remaining structural shapes.

   b. Anchor Bolts: ASTM F1554 grade 36.

2. Concrete

   a. 5000 psi for the precast footings.

C. Utility Structures

1. Steel pipe and channel bent support structures will be used for the support of above ground utilities and will be designed to resist lateral loading via pole-embedded frames. Design of the lateral load resisting system for this structure will be controlled by wind loading.

2. Prefabricated structures will be used for the node buildings. These structures will be slightly elevated above grade and will be supported on wide flange beams and precast footings providing vertical and lateral support of the structures.

3. The Pump House Building will be a one-story structure elevated above grade. The building will be supported on precast footings and will be framed with wide flange beams for both the floor and roof structure. Steel tension tie rods will be used to provide lateral support of the structure.

4. The water tank will be supported on a timber foundation over compacted fill. Thermosiphons will be located in the fill material beneath the water tank timber foundation to remove heat from the fill material and to keep the ground frozen.

SECTION 4 MECHANICAL AND PLUMBING (FOR BUILDINGS)

A. Mechanical and Plumbing Design Criteria

1. Space Design Conditions

   a. Utilidor Cooling: Not Applicable

   b. Utilidor Heating: Not applicable

2. Outdoor Design Conditions

   a. Summer: 50°F DB

   b. Winter: -53°F

3. Energy Sources: The available energy sources are electricity and fuel oil.

4. Design Calculations: Heating, ventilating and air conditioning (HVAC) cooling and heating load calculations and energy analysis calculations were accomplished using Trane Trace 700, Version 6.3.2.2.

5. Direct Digital Control (DDC) Systems

   a. A Building Automation System (BAS) will be installed at the Station. It will consist of a building control network which is fully integrated into the McMurdo Utility Monitoring and Control System (UMCS) system.

   b. The building control network will be a single, complete, non-proprietary Direct Digital Control (DDC) system for control of HVAC systems. The building control network will be an open implementation of BACnet complying with ASHRAE Standard 135.

   c. The BAS will continuously monitor space temperature, humidity and moisture sensors. An alarm will be generated if any sensor indicates an abnormal condition. Moisture sensors will be provided every 20 feet and at every utilidor bulkhead to indicate a pipe leak or snow entry condition.

   d. BTU meters will be provided to monitor heating energy used for Pump House and Water Storage Tank heating.

B. Operation and Maintenance

1. Hydronic utility line water temperatures will be established based on ambient conditions to maximize efficiency.
2. All clearances associated with utilities will be determined to allow for efficient maintenance, repair and replacement of piping, sensors and controls.
3. Access doors will be provided at specific locations to facilitate maintenance within utilidors in locations where utilidor lid removal may cause major Station operations interference.

C. Testing, Adjusting, and Balancing (TAB)

Test and balance of air and hydronic systems will be achieved using a company certified for testing and balancing by the Associated Air Balance Council (AABC), National Environmental Balancing Bureau (NEBB), or the Testing Adjusting, and Balancing Bureau (TABB) in accordance with UFGS 23 05 93. The Contractor will hire the TAB firm directly, not through a subcontractor. TAB will be performed in accordance with the requirements of the standard under which the TAB Firm's qualifications are approved (i.e., AABC MN-1, NEBB TABES, or SMACNA HVACTAB). All recommendations and suggested practices contained in the TAB Standard are considered mandatory. The contract requirements will be satisfied using the provisions of the TAB Standard, including checklists, report forms, as nearly as practical. The TAB Standard will be used for all aspects of TAB, including qualifications for the TAB Firm and Specialist and calibration of TAB instruments. Where the instrument manufacturer calibration recommendations are more stringent than those listed in the TAB Standard, this Project will adhere to the manufacturer's recommendations. All quality assurance provisions of the TAB Standard such as performance guarantees will be part of this contract. For systems or system components not covered in the TAB Standard, the TAB Specialist will develop TAB procedures. Where new procedures and requirements applicable to the Contract requirements have been published or adopted by the body responsible for the TAB Standard used (e.g., AABC, NEBB, or TABB), the requirements and recommendations contained in these procedures and requirements are mandatory.

D. Commissioning

The commissioning agent shall be brought into the Project Team as soon as the Contractor is awarded the contract. All HVAC systems and equipment, including controls, and all systems requiring commissioning, will be commissioned in accordance with ASHRAE Guideline 1, ASHRAE Guideline 0, UFC 1-200-02, and LEED NC 2009. The sampling techniques discussed in ASHRAE Guideline 1 and in ASHRAE Guideline 0 will not be used. Commissioning will be performed for 100% of the HVAC controls and equipment. Hiring of the Commissioning Authority (CA), certified as a CA by AABC, NEBB, or TABB, will follow Guideline 1. The CA will be an independent subcontractor to the Contractor and not an employee or subcontractor of any other subcontractor on this Project. The CA will not have business connections with any other party on the Project. The CA will not have any other role or responsibilities outside of commissioning activities. The CA will communicate and report directly to the Government in the execution of the commissioning activities.

E. Plumbing System

A 3/4-inch CW line with a hose bib will be provided at a central location near the entry door of the new Pump House. Supply piping will be provided with insulation from below floor for entire run of pipe with a minimum of 10 watt/foot heat tape.

SECTION 5 FIRE PROTECTION

A. Fire Suppression Systems

1. The water distribution system and new pump house are designed to support fire-fighting operations at the site based on the following:
   a. Minimum flow of 1,500 GPM at minimum 20 psi at all hydrants connected to the loop.
   b. Minimum residual pressure of 60 psi for hydraulic fire suppression design at all buildings served from the loop.
2. Utilidors, the new Pump House, and the Node Buildings are not required to have fire suppression systems.
3. This Project will support allowing all Station fire suppression service in the future to be provided through the water distribution mains.
4. Freeze-proof hydrants will be provided in accordance to NFPA requirements.

SECTION 6 ELECTRICAL AND COMMUNICATIONS

A. Electrical Power Systems – Distribution

1. The existing power plant shall remain in operation and continue to provide Station power in parallel with the Wind Farm. The existing power to outlying structures and facilities shall be preserved during demolition and construction activities. The six existing pad mounted switches located at the Power Plant Switchyard shall remain for reuse, with new Station feeders originating from this location. The switches fuse configuration will remain as is and will support the feeder modifications. Modifications to the existing overhead lines are kept to a minimum as part of cost control measures to the overall construction effort. Feeders will be configured as follows:

   a. Feeder A originates at pad-mounted switch SW-2 Power Plant Switchyard and provides service to McMurdo's main campus primarily on the northwest side. Refer to Figure 6.1. Modifications are as follows:

      1. Additional loads will be added to Feeder A to support new construction. Buildings 002, 005, and VEOC (Building 041) will be added to Feeder A. Buildings scheduled to be removed from Feeder A are Buildings 178, 201, 202, 203A, 203B, 203C, 210, and 211.

      2. SWA-01 will provide a tie-switch for Feeder D and provide future service to VEOC B041, and Buildings 003 and 004. A feeder tie-switch will be provided at Building 002 and 005 (Feeder C) for back-up capabilities with Building 003 and 004 (Feeder A). SWA-01 will feed a new pad-mounted termination 4-way box. The 4-way termination box will feed VEOC and B140.

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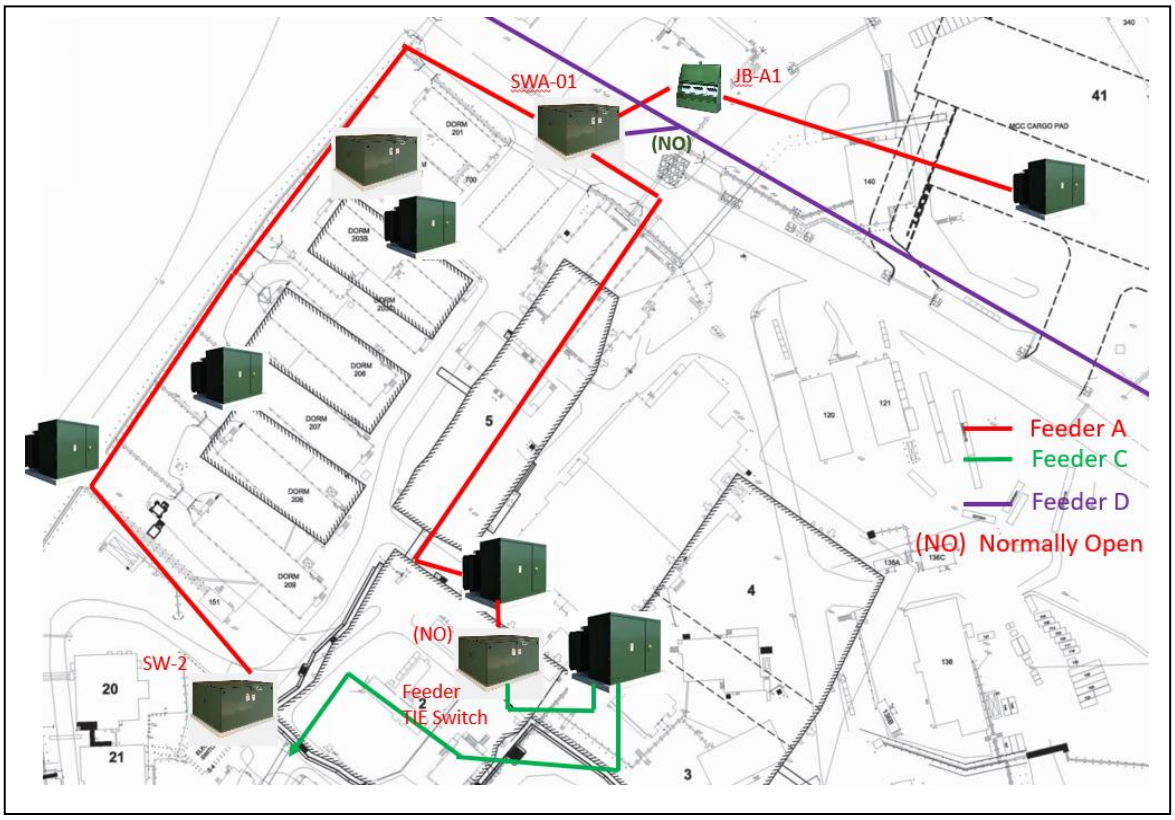

Figure 6.1 - Feeder A

b. Feeder B will be eliminated and is no longer required. Feeder B is located within the footprint of the new building services. Complete demolition will be required for this feeder. There is one transformer on Feeder B that will remain and will require new services from a different feeder during the construction phases. It will be eliminated at final buildout and it currently provides service to Building 136A and 136C. Transformer XFB-20 provides service to Building 120. Feeder B has a tie-feeder at Pole D14 common to Feeder D. This tie switch will be closed and Feeder B will be removed between Pole B1 and Pole B20. Pole B20 will remain and be renamed to Pole D14A and transformer XFB-20 will be renamed to XFD-14A. Refer to Figure 6.2.

c. Transformer XFB-15 will be relocated and will require a new service from Feeder E. Transformer XFB-15 provides electrical service for ice core freezers that will remain onsite for future research. Refer to Figure 6.2.

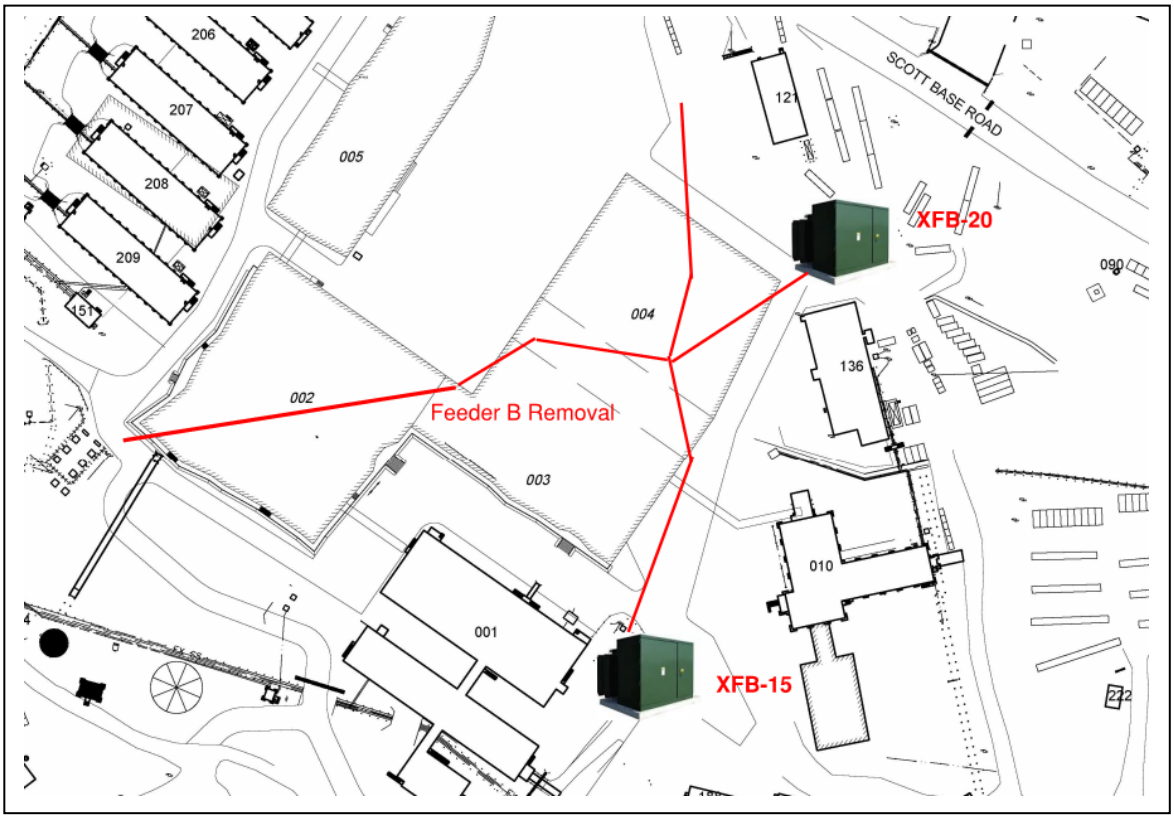

Figure 6.2 - Feeder B

d. Feeder C overhead system will be impacted by site modifications that interfere with existing Feeder C pole locations and guywires. The new water Pump House footprint, new roadway, and new utilidor to new construction all require relocation of existing poles and modification to guywires. The area is congested to the point where placement of poles and guywires without interfering with new construction is difficult to achieve. Therefore, the existing Feeder C overhead system will be relocated within the utilidor routed through the area. Feeder C will provide service to Building 4 and will provide Feeder Back-up to Feeder A at a common pad-mounted switch located adjacent of Building 2. Feeder C will continue to support Building B159, B129, B187, B124, and B37. Refer to Figure 6.3.

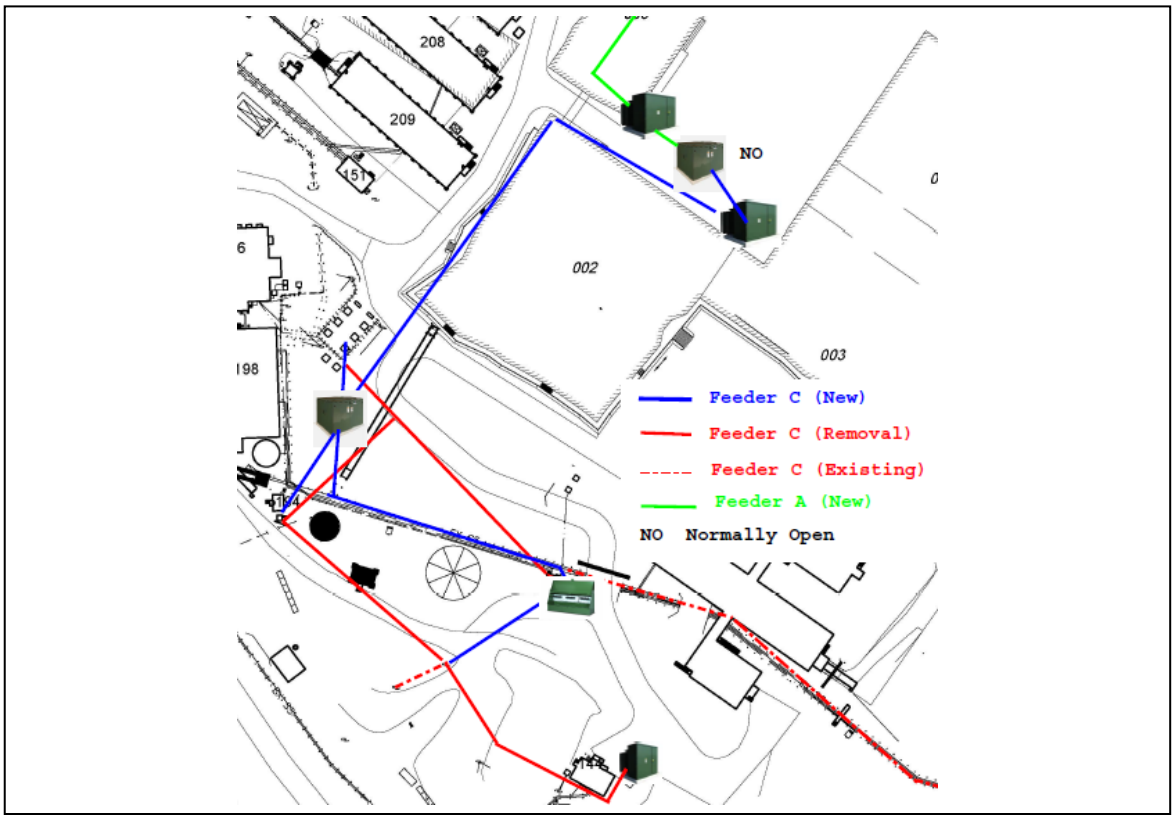

Figure 6.3 - Feeder C

e. Feeder D will be rerouted outside the footprint of the new service buildings. A new riser will be installed at pole D38 and connected to a new pad mounted switch (SWA-01) for a back-up switching capability with Feeder A. Feeder D deadends at Pole A10 where a new riser will be installed for Feeder D. Feeder D will drop down Pole A10 and be routed along the west utilidor back towards the power house and connected to Junction Box JBD-1. Refer to Figure 6.4.

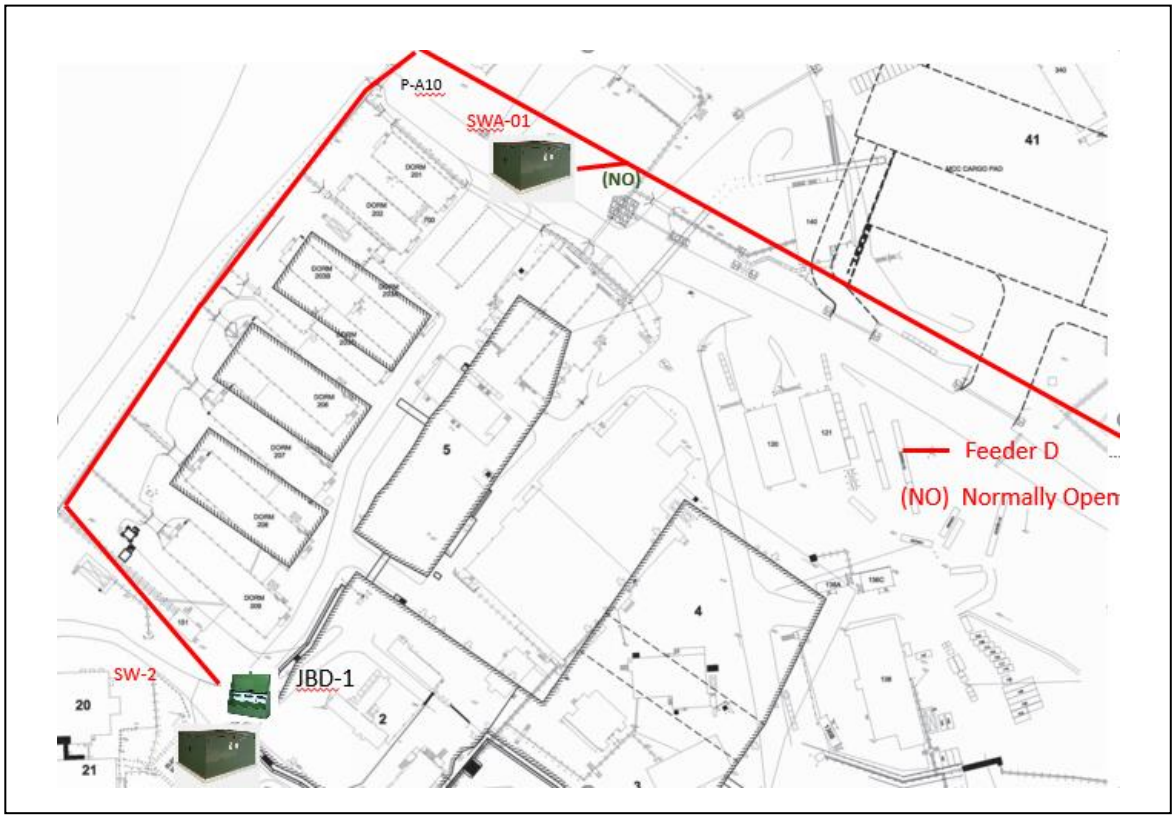

Figure 6.4 - Feeder D

f. Feeder E is a dedicated Feeder for Building 001 and Building 189. Building 189 is scheduled for demo. Transformer XFB-15A will be removed from Feeder B and relocated to Feeder E. Transformer XFB-15A will be renamed to XFE-C. Feeder E will have a common tie switch with Feeder D at SWE-01. Feeder D will be extended from Pole D35 to a new switch SWE-01. Pad-mounted switch SWE-01 will feed B10 transformer, tie-switch (Normally Open) between Feeders D & E), and feed a termination box JB-E2. JB-E2 will feed transformer XFE-C and future feed to B2 & B3. Refer to Figure 6.5.

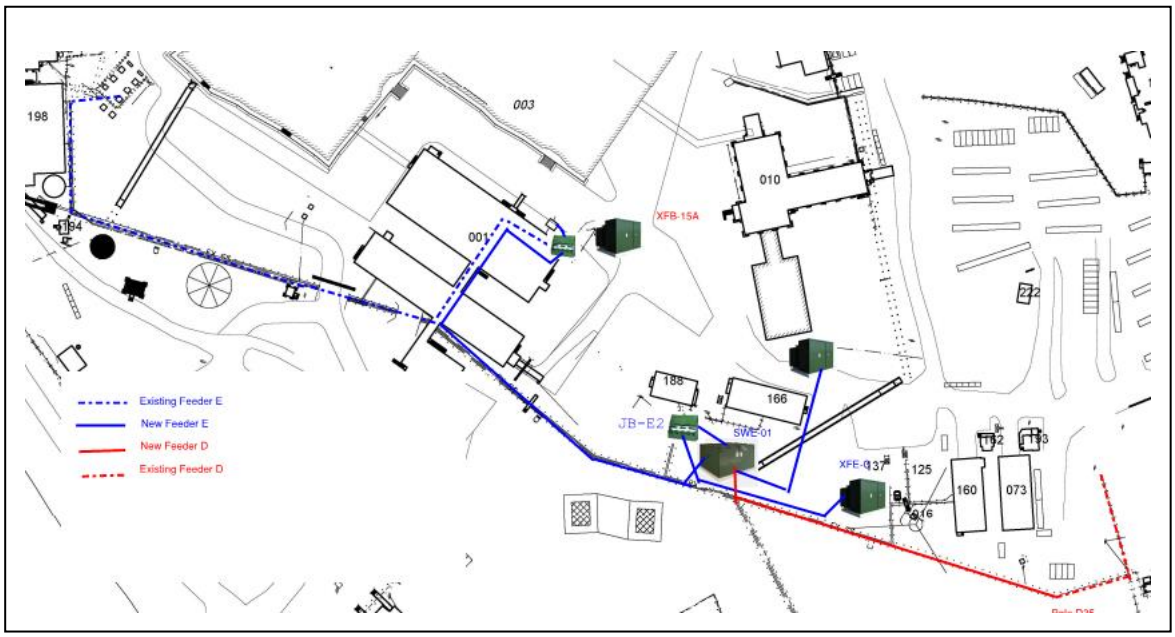

Figure 6.5 – Feeder D and Feeder E

g. The new water Pump House will be fed from a new pad mounted switch SWC-01. A new 4.16KV/480/277V, 112.5kVA pad mounted transformer will be provided to feed the new Pump House as well as heat tracing requirement for the utilidor in the area.

h. The existing overhead system will remain as is except for Feeder B and D modifications indicated above.

2. Power shall continue to be provided as a 4160 volt, 3-phase, grounded wye system. The distribution system is configured as a ground wye system where 3-phase conductors with a ground conductor are installed for system grounding.

3. The new feeder installed will support future expansion and modification to the 4.16kV distribution system in the event system upgrades both the main power plant and introduction of additional renewal power sources or other power generation technologies.

4. Size of the new feeders shall be standardized as 3#4/0 + 1#2G, Cu, EPR, TECK-90 shielded cable, 5kV red cable and will comply with NEMA WC 74 for all cable tray installed feeders. Underground feeders will be non-shield cables, and a new

pad mounted termination box will be installed at each transition location from cable tray mounted cable to underground cable.

5. Underground 5kV feeders will consist of direct buried, two 4” PVC coated rigid galvanized steel (RGS) conduits with PVC coated RGS elbows 24” below grade with one conduit containing #4/0 EPR Triplex cable. Conduit joint will be tape wrapped and end fittings will include a conduit seal to minimize moisture entering the conduit. An 8W/Ft 277V heat trace conductor will be installed within the spare conduit. Heat trace cable will be installed unterminated.

6. Existing feeders are operating below 50% capacity. Feeder modifications proposed by this design will limit feeder loading below 50% capacity to ensure proper back-up capability.

7. Overhead feeders feeding Arrival Heights and T-Site shall remain for reuse. Future expansion of the Wind Farm will require further investigation in terms of upgrades that best support the new Wind Farm configuration.

8. Building service shall be via an outdoor, pad mounted, oil filled, non-ventilated transformer. A 208Y/120V secondary service will be provided for small-scale buildings as determined by building energy studies. The transformer shall be sized to handle the facility load plus 20% spare capacity as determined by the Core Facilities design packages outside of this scope. The maximum size transformer recommended for a building transformer is a 500kVA for optimum system coordination and overcurrent protection.

9. The Node 11 power distribution system consists of a 208/120V, 3-phase, 60-amp panelboard with a power connection to Building 68 power service. Node 11 will be provided with convenience 120V receptacles, electric heating, and lighting.

B. Electrical Power Systems – Power Quality and Grounding

1. The grounding system employed for this Project will connect to an established Equipotential Reference Plane (ERP) connected to an existing submerged heavy steel construction tractor in Winter Quarter’s Bay as well as a supplemental drill-emplaced steel “electrode” set 20-feet deep just inside the shoreline. The electro conductors are in turn connected to the Power Plant main ground bar. The

existing main ground bar connects to the generator and existing grid feeder grounding conductors and will remain as-is during this Project.

2. New service feeders will include a grounding conductor sized 1/3 to the power conductors and terminated at the Power Plant main ground bar.

3. Building service transformer grounding electrodes will consist of a concrete-encased electrode (UFER) ground system (reference NEC 250.52 (A)(3), in addition to connection to the McMurdo ERP grounding system. Where new facilities are located, concrete embedded grounding conductors within the building foundation will be provided and tied to both the Station and the facility's grounding system. Each service transformer grounding electrode will consist of a 12-inch x 20-foot concrete cylinder with an embedded 4/0 copper cable.

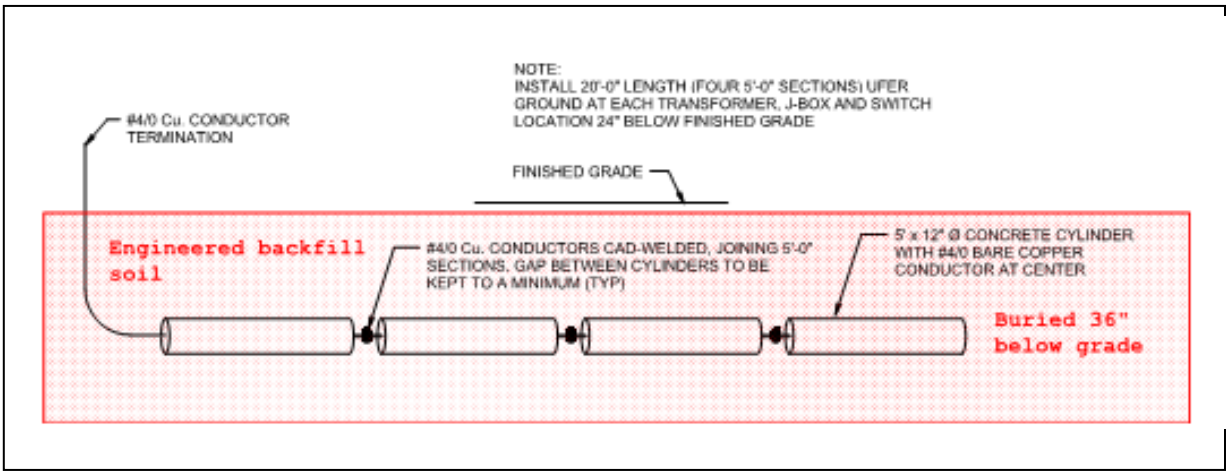

Figure 6.6 - Transformer Grounding

4. Each telecommunication node will include a Telecommunication Main Ground Bus (TMGB) where all telecommunication equipment within each node will be bonded to the TMGB with a telecommunication equipment-bonding conductor (TEBC). The TMGB will be bonded to the node electrical panel ground bus, node metallic structure, 20' concrete encased electrode (UFER) ground, and other node TMGB's. The telecommunication grounding and bonding will originate at the building service ground and extend to the building's TMGB. TMGBs between buildings and nodes will be interconnected with a telecommunication bonding backbone (TB) green insulated conductor, providing grounding equalization between buildings and nodes. Communication grounding standards and

techniques applied for this design package are from communication grounding standard J-STD-607-A (Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications. Refer to Figure 6.7 below:

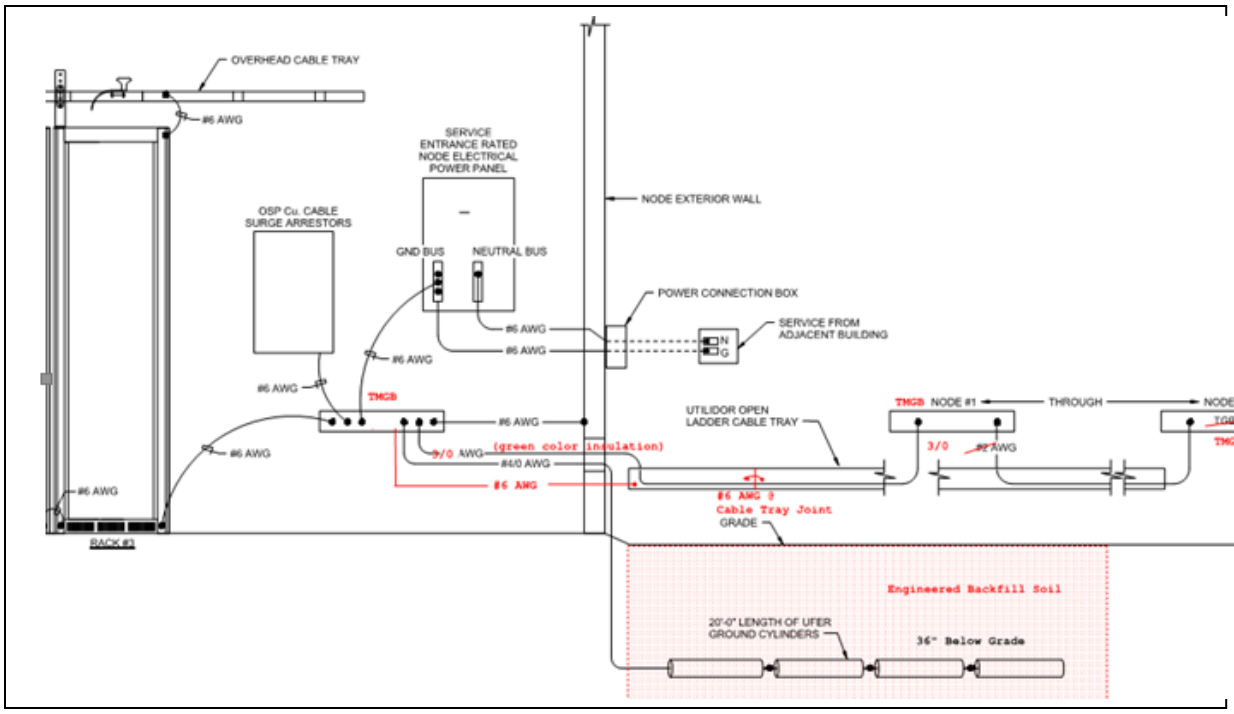

Figure 6.7 - Node Grounding Detail

5. Earth grounding for individual buildings is difficult to achieve in McMurdo Station due to soil conditions. Single ground rods offer little benefit in high soil resistivity. Soil condition vary greatly between summer and winter months and therefore difficult to achieve optimum building grounding at a local level. McMurdo Station's Equipotential Reference Plane (ERP) and the supplemental drill-emplaced steel "electrode" provides a consistent earth reference throughout the year with the installation of an electrodes in soil with constant low impedance soil conditions. Therefore, the McMurdo Station ground reference will be extended to all building electrical systems primarily through the 5kV distribution system. Each building will include a counterpoise grounding system interconnected with McMurdo Station (ERP) ground reference. Communication Nodes will include a TBB ground

reference that provides a grounding interconnection between nodes and building services for the site. The make-up of the entire interconnecting grounding system between buildings, nodes, and ERP will provide and more suitable ground reference for McMurdo Station as one interconnected ground system. Interconnecting of metallic system within a building, utilidor, and conductive utilities such as steel piping will reduce stray voltages and minimize touch and step potential hazards.

C. Lighting Systems

1. Exterior area lighting will utilize “dark sky” qualified, low ambient temperature (-40°C) LED lighting fixtures for perimeter building and pole mounted fixtures. Light poles will be placed along common pedestrian paths and main roadways. Lights will have a color temperature of 4100K and a CRI of 80 or better. Light poles will be 30-feet tall with a round tapered geometry, and equipped with an inline fuse at the base of each pole. At the node buildings and Pump House there will be exterior, building-wall mounted LED lighting with a cast aluminum housing, acrylic diffuser with tempered glass lens, and forward throw distribution.

2. Exterior conduits will be RMC or LFMC, as appropriate for location and application, with a 3/4-inch minimum trade size. Interior conduits will be RMC, EMT, LFMC or FMC, as appropriate for location and application; also with a 3/4-inch minimum trade size.

3. Electrical wiring installed in raceways, either exterior or interior, will be high-conductivity copper, 600-volt, type XHHW/XHHW-2 of #12 AWG minimum conductor size.

4. An equipment-grounding conductor shall be installed with branch circuit conductors in all raceways.

D. Special Electrical Systems

1. The Station’s primary power generators are Caterpillar diesel reciprocating generators. They will remain in operation during the construction of the new service feeders. There are two 1400 kW and one 1130kW generators located in building B196 (Plant A) and two 1400 kW generators located in building B198 (Plant B). Each plant has automated switchgear that both feed the six feeders. The

plants are normally tied together electrically and share communications between the switchgear. The plants can be separated and run independently in an emergency. The Power Plant distribution switchgear is connected to six pad mounted switches located adjacent to the plant where service feeders are distributed to the Station. This Project will coordinate feeder switching sequences where the existing power plant and feeder modifications will maintain electrical services to McMurdo throughout construction.

2. The existing Station is connected to a microgrid with three 330 kW wind turbines that will remain in operation during construction. The wind turbines are owned and operated by Antarctica New Zealand. The microgrid has a 500 kW "Power Store" flywheel system to handle sudden changes in turbine output. Scott Base, the nearby New Zealand station, is also connected to the microgrid and to the McMurdo power distribution system. Scott Base has three 225 kW generators. A control system in the McMurdo power plant can automatically start and stop the Scott Base generators to optimize which generators (including the wind turbines) most efficiently meet the overall power demand (for both McMurdo and Scott Base). This often results in McMurdo only needing to run one of its generators while meeting both McMurdo's approximately 1.8 MW power demand and Scott Base's 150kW demand. This is done by harvesting wind energy first and making up any difference between the remaining demand and the output of one (nominally) 1500kW generator with one (or sometimes two) of the Scott Base generators. This Project will provide construction coordination notes to ensure the combined power grid remains viable and safe during any shutdowns required during construction.

3. Smart grid control will be achieved within each new building power distribution system (480V and/or 208V), which is outside of this Project's scope. Smart panels will be used to control system loading controlled either by a building management system or mircogrid controller. The 5kV distribution system will primarily consist of 5kV fuse protection with limited remote switching capability. Electronic feeder protection is a second choice over standard fuses for exterior 5kV application due to extreme cold weather temperatures experienced at the Station. Grid control can be economically achieved at the utilization voltages within the building services without automatic switching at the 5kV distribution level. Each new building design

will prioritize building loads for load shedding during peak times; load switching for grid stability, and load control for optimization of steady-state condition.

E. Telecommunication System

1. The outside plant telecommunications system will be installed in four phases. Although not referenced as phases on the plans, for the following discussion the "phase" is linked to the plan titles found in the drawing package. Pre-Core Facilities Construction (phase one) will construct the final standalone node, numbered as Node 11. Additional infrastructure and cabling is provided from Node 2 to Node 10 via existing Node 4 and new Node 11, completing the outside plant site ring. This phase also provides the connectivity from the nodes to existing facilities. Central Services (phase two) is constructed by the Core Facilities contractor. Under this contract, the Core Facilities contractor provides Node 5, internal to Central Services, and all internal pathways. The outside plant contractor provides and terminates all cabling associated between Node 5 and the existing nodes. Emergency Operations (phase three) is constructed by the Core Facilities contractor. Under this contract, the Core Facilities contractor provides Node 3, internal to Emergency Operations, and all internal pathways. The outside plant contractor provides and terminates all cabling associated between Node 3 and the existing nodes. Fields / Trades (phase four) is constructed by the Core Facilities contractor. Under this contract, the Core Facilities contractor provides Node 9, internal to Field Science Support / Trades, and all internal pathways. The outside plant contractor provides and terminate all cabling associated between Node 9 and the existing nodes.

2. The primary outside plant cabling consists of a series of single mode fiber optic and copper cables providing several loops around the site. Primary outside plant cabling terminate in a total of 11 nodes. Four nodes are located within the shell of new facilities: three within the Core Facilities and one within IT&C Prime. Seven stand-alone nodes are provided. Connections from the nodes to individual facilities is provided utilizing a 25 pair copper and 12 pair single mode fiber optic connection. Select facilities have dual telecommunication feeds, originating from two separate nodes.

3. Outside plant cabling will follow the path of the new aboveground and direct-bury utilidors. The cabling will be installed primarily in a cable tray wire management system and connect directly into the buildings.

    a. Air core cable will be used in this Project rather than gel-filled, due to the greater ease of handling and installation. Since all cabling is to be terminated or spliced in a node or indoor space, the possibilities for water ingress into any cable is minimal. Further, there are cost savings associated with reduced preparation time and clean up, as well as the fact that gel-filled cable needs to be converted to premises cable within a node or indoor space in order to be terminated and connected. Given that real estate is at a premium, the decision not to install splice cases for OSP cables was made for this Project.

    b. Copper OSP is typically armored due to the potential for flying objects during storm events. In order to mitigate the potential for impact damage, armored optical fiber cable was selected as well. In Chapter 4 of the BICSI OSP Design Reference Manual, guidance is given that "the OSP designer should consider cable bend radius greater or equal to 15 times the cable diameter."

    c. Aluminum cable tray was chosen due to the performance of the material at low temperature. Steel alloys, except stainless steel which would be prohibitively expensive for this type of installation, become brittle in subzero temperatures, and is prone to impact breakage.

4. Building Main Distribution Facilities (MDF's) will be utilized to maintain telecommunication loop continuity and allow multiple telecommunication primary signals to service within a single building. The MDF shall consist of a room with minimum space of 10-feet x 12-feet and shall be sized based on EIA design standards. Detail design and construction of MDF's are outside of scope of this Project but pre-AIMS and AIMS tasking will coordinate cabling conductivity with future construction of proposed new buildings.

5. Site communication nodes (10-feet x 13-feet) will be installed at seven remote locations within the McMurdo site. Three additional building nodes are located at Buildings 003, 005 and 006, where all site infrastructure cabling will be terminated. Exterior installed single mode fiber optic (SMFO) cabling will be installed along the site utlidor system and will be routed into communication nodes. Cabling will be

terminated on floor rack-mounted 24-port optical fiber entrance patch panels with SC/APC connectors. Nodes will provide communication services to adjacent buildings providing service with back-up capability between nodes.

6. Similar to fiber optic cables, copper cables will be installed along the site utilidor system, will be routed into communication building nodes, and terminated on wall mounted entrance protector cabinets. Nodes will provide communication services to adjacent buildings providing service with back-up capability between nodes.

7. Outdoor cabling will terminate on backboard-mounted 110 blocks with service entrance overvoltage protectors in a 1:1 arrangement.

8. Plywood telephone backboards are located in each node and have a dedicated Telecommunications Main Grounding Busbar (TMGB) grounding bus with a #2 ground conductor tied to the Telecommunications Grounding Busbar (TGB) of the adjacent node buildings. The TGB is bonded to the node power distribution panel board grounding system per J-STD 607-A. Node building service electrical grounding consists of a 12” x 20’ concrete cylinder with an embedded 4/0 copper cable grounded to the TMGB ground bus. Telecommunications ground shall be bonded to the node electrical system ground, including the building service ground system as required by NEC 250.50.

9. Standalone node building power distribution system consists of a 208/120V, 3-phase, 60 amp panelboard with a power connection from an adjacent building. Each node is provided with convenience 120V receptacles, electric heating, and lighting.

SECTION 7 ARCHITECTURE

A. Guiding Principles

1. Addressing one of this Project's high-level goals, all buildings are designed to provide efficient, durable facilities that both support and reflect the long-term U.S. commitment to responsibly advancing science in Antarctica. Facility design is a direct response to each of the functional and physical requirements of Station operation.

2. Facilities design was influenced by the following conditions:

   a. The Telecommunications Node facilities are designed to be modular, prefabricated buildings. The buildings are capable of being efficiently stacked in shipping containers and assembled on-site. The facilities, designed by a single manufacturer, is a provided as a "kit of parts" that is put together by one installer.

   b. By placing the small facilities on concrete footings, the structures are capable of being adaptable to varying site conditions.

   c. The Pump House facility is designed with insulated metal panels using minimal joints, and an insulated floor and roof assembly. The durability of the materials prevents the degradation of performance in extreme cold weather, high winds, blowing snow, ice, sand, and UV exposure.

B. Telecom Node Facility

1. Massing

   The facilities employ a geometry that minimizes the volume required to accommodate the functions supported by the building. The design consists of simple box-like structures with insulated panels for the roof and walls, and fire retardant plywood laminated to the insulated floor panels.

   These facilities are modular and will arrive at the Station ready to be assembled. They are easily stacked within shipping containers. The facility height is determined by providing the necessary operating clearances of the housed telecommunication equipment. The facilities will be elevated above the ground, and with their minimal footprints will allow snow and ice to scour beneath.

Detachable platforms and stairs are provided for access and are designed for snow and ice management using open steel grating walking surfaces. Stair height will vary based on site conditions of the facility location.

2. Plan Organization

For efficiency, the building layouts consist of a simple single room which is compact, yet allows for optimal equipment use and replacement.

3. Building Enclosure

The design is functional, durable, easy to construct and easily maintainable. Wall, floor and roof panel systems are comprised of 4-inch thick pre-fabricated insulated metal panels that are of a dimension and orientation that allows for off-site construction, maintains quality during transit, and maximizes efficiency during on-site erection. Roof and wall panels are adjoined with lock connectors. Freezer doors provide an insulation value of R-32 and ensure tight, weatherproof seals.

a. Panel Details

The panels for the node buildings will be sized approximately 11 feet in height and up to 4 feet in width. All panels will be packaged for shipment in a compact “flat-pack.” All panels will be erected vertically to achieve quicker assembly and to reduce the possibility of water pooling in the seams.

b. Panel Cladding

The exterior sheathing of the building wall panels plays a critical role in determining the exterior character and durability of the facilities. Durability, including resistance to abrasion and corrosion and snow and ice management, are parameters that were considered in the selection of panels. The panel design employs a 4-inch thick extruded polystyrene foam insulation which is laminated between 26 gauge galvanized steel covers on both the interior and exterior side of the panel. The insulation value of the panel will be a minimum R-32. The edges of the panels will be CNC (Computer Numeric Control) machined tongue and groove to assure a controlled tolerance on the seam connections. The panels will be sealed at the joints with double beaded vinyl gaskets on the interior and exterior surfaces. The vinyl gasket will overlap the edges of the metal cover to assure a positive seal. The panels will be

mechanically joined using cam-lock connectors engaged with a single hex wrench. Relatively high UV exposure at the Station resulted in the selection of a Kynar finish that will better withstand fading. A limited color palette of white and grey will be used.

4. Comparison to Pre-AIMS Telecommunications Node Buildings

Both PreAIMS and AIMS Node facilities will be a family of identical units located throughout the Station grounds. Each facility will be placed on a structural platform providing the required elevation above grade, and is adaptable for variable terrain at individual erection locations.

5. Interiors of the Node Buildings

Interior walls and ceilings are the backside of the insulated metal panels and the finish will be white enamel applied by the manufacturer. Exposed interior structural framing is unfinished Flooring fire retardant plywood laminated to the insulated wall panels and finished with a commercial grade floor tile with vinyl cove base.

The door frames are pre-finished by the building manufacturer to match the panel system. The entrance door of the buildings is a weather sealed, 23 gauge insulated metal doors with a Lever lockset, latch-guard and drip caps. Associated with each door is one pre-wired, vapor proof light fixture

C. Pump House

1. Massing

The size of the Pump house minimizes the volume required to accommodate the building's functions. The design consists of a simple box-like structure with insulated panels for the roof and walls, and metal plate flooring. Facility height is determined by providing the necessary operating clearances for the housed equipment. The facility will be elevated above the ground, and together with the minimal footprint, will allow snow and ice to scour below floor level by wind action. A detachable platform and stairs provide facility access and allow for snow and ice management using open steel grating walking surfaces.

2. Building Enclosure

The design is functional, durable, easy to construct, and easily maintainable. Insulated panel systems are 3-inch thick pre-fabricated insulated metal wall panels and 4-inch thick pre-fabricated insulated metal roof panels that are of a dimension and orientation to fully capitalize on off-site construction, maintain quality during transit, and maximize efficiency during on-site erection. Roof and wall panels will be adjoined double tongue-and-groove joinery with factory-applied air and vapor seal. Heavy duty insulated doors will provide an insulation value and ensure tight, weatherproof seals. The insulation value of the panel shall have an insulation value of R-32 for a 4” panel.

3. Panel Details

Panel reveals and spacing are situated to break up the massing of the facility and an accent wall panel has been located at the entrance. Some wall panels are designed to be removable to accommodate replacement of housed equipment whose lifecycle is considerably less than the building. The use of removable panels in lieu of a roll-up door or large double doors was considered early in the design process, but removable panels were selected based on the infrequency of replacing equipment versus the thermal loss and energy expenditure through doors.

The Pump House panels will be approximately 14-feet in height and up to 40-inches in width. All panels will be packaged to be shipped to the site in a compact “flat-pack.” All panels will be erected vertically to achieve quicker assembly and to reduce the possibility of water pooling in the seams.

4. Panel Cladding

The exterior sheathing of the building wall panels plays a critical role in determining the exterior character and durability of the facilities. Durability, including resistance to abrasion, corrosion and snow and ice management, are parameters that were considered in the selection of panels. The resultant design employs a 3-inch thick extruded polystyrene foam insulation, laminated to galvanized steel covers on both the interior and exterior of the panel. The insulation value of the wall panel will be a minimum of R-22. The insulation of the roof panels will be a minimum of R-32. Relatively high UV exposure at the Station resulted in the selection of a Kynar finish that will better withstand fading.

5. Interior Design of the Pump House

The pump house interior follows the same guiding principles as the building exterior and highlights durability, ease of maintenance, and maximum equipment utilization.

Interior walls and ceilings are the backside of the insulated metal panels and its finish will be white enamel applied by the manufacturer. Exposed interior structural framing is unfinished. Flooring is patterned steel plating attached to the building's bottom structural members.

Door frames are pre-finished by the building manufacturer to match the panel system. Doors are 1-3/4 inch thick, 24-gauge metal, insulated, flush mounted, hinged, and have door closers. They will also have door sweeps and magnetic gaskets. Associated with each door will be one pre-wired, vapor proof light fixture.

SECTION 8 ENVIRONMENTAL COMPLIANCE

A. Environmental Protection Compliance

This section to be provided by Leidos ASC.

SECTION 9 APPENDICES

APPENDIX 1 SITE PHOTOGRAPHS

Observation Hill looking northwest into town

Building 155 from the northeast with Building 120 (Food Warehouse) in the foreground

Buildings 120 (Food Warehouse) and 121 (Beverage Warehouse) from the north

Building 155 from the NE with Building 211 (Lodging) on the right, looking SW along corridor to Derelict Junction

Building 155 from the NE with Building 211 (Lodging) on the right, looking SW along corridor to Derelict Junction and Building 007 (Chapel of the Snows)

NE corner of Building 155 looking SW with Building 142 (MAC Medical) on the left

Building 155 from the east

Building 155 from the east with Building 142 (MAC Medical) on the left

Building 136 (Trade Shop) from the northwest

Building 142 (MAC Medical) from the east

Building 182 (Fire House) from the northeast

North face of Building 001 (Crary Lab) from the east

Utilidor looking north with Building 107 (Southern Exposure) and Building 155 in the background

Utilidor pedestrian bridge looking NW with Building 107 (Southern Exposure), Building 155, and uppercase lodging in the background

Utilidor looking SW with Building 189 (JSOC) in the foreground and Building 165 (MAC OPS) in the background

Building 165 (MAC OPS) looking west with Building 010 (Hut Ten) and Building 007 (Chapel of the Snows) in the background

Looking NE through Derelict Junction with uppercase lodging on the left and Buildings 155, 076 (Coffee House), and 078 (Gym) on the right

Buildings 155 and 078 (Gym) from the southwest

Derelict Junction looking NE with Buildings 206 (Lodging), 203 (Lodging), 164 (Frozen Food Warehouse), and 155 in the background

Looking north at Buildings 208, 207, 206, and 203 (all Lodging) and 164 (Frozen Food Warehouse)

Derelict Junction looking east toward Observation Hill with Buildings 155, 107 (Southern Exposure), and 078 (Gym)

Derelict Junction looking NE with Building 164 (Frozen Food Warehouse) on the left and Building 155 on the right

Derelict Junction looking SW with Buildings 78 (Gym), 007 (Chapel of the Snows), and 209 (Lodging) in the background

Looking NE with Building 211 (Lodging) on the left and Building 155 on the right

Looking SW at Building 007 (Chapel of the Snows) with Building 155 on the left and Building 211 (Lodging) on the right

Utilidor east of Building 189 (JSOC) looking northeast at Building 155

Utilidor looking north at the south corner of Building 155

Looking NW at Building 155 and Building 120 (Food Warehouse)

Looking SW with Buildings 142 (MAC Medical), 108 (Gallagher's), 189 (JSOC), and 155 in the background

Looking west from south platform of Building 155 with Building 107 (Southern Exposure) and uppercase lodging

Looking SE from south platform of Building 155 with Building 108 (Gallagher's) and Building 001 (Crary Lab) in the background

Looking south from south platform of Building 155 with Building 107 (Southern Exposure), Building 001 (Crary Lab), and Building 189 (JSOC) in the background

Building 076 (Coffee House) from the north

Looking east at Buildings 076 (Coffee House), 189 (JSOC), and 001 (Crary Lab)

TECHNICAL MEMORANDUM

July 29, 2016

TO: Brandon Neahusan, Antarctic Support Contract (ASC) Project Manager

FROM: Christine Lurtz, PMP, Merrick & Co. Project Manager

CC: Eric Hein, PE, Merrick Civil/Water Engineer and Kevin Breslin, PE, FPE, Merrick Fire Protection Engineer

SUBJECT: **McMurdo Utilities Infrastructure Design**
Fire Flow Criteria Determination for Water System Design

INTRODUCTION

Merrick & Company and Michael Baker International (collectively known as the Architecture/Engineering (A/E) Team) are under contract to provide 100% design documents for the McMurdo Utilities Infrastructure Design. As part of the McMurdo Utilities Infrastructure Design, an upgraded water system will provide fire protection storage and distribution to support the series of new facilities at McMurdo Station that will be constructed as part of the McMurdo Master Plan and AIMS projects. The design fire flow is an important design criteria that the A/E needs to determine in order to progress their design.

The purpose of this memorandum is to facilitate establishing the design fire flow for the project. Alternative codes for calculating fire flow are presented for comparative purposes, constraints of firefighting at McMurdo Station are reviewed, and a recommendation is made for an adequate design fire flow and associated storage to serve McMurdo Station.

ASSUMPTIONS

- Fire protection capabilities of the new system will meet or exceed the capabilities of the existing system, so that existing buildings not programmed for demolition will be provided with equal or better protection.
- All new buildings will be sprinklered in accordance with National Fire Protection Association Standard 13 (NFPA 13). Fire sprinklers provide an excellent first line of fire fighting offense and can greatly reduce the water input provided manually by fire crews.
- The largest floor area enclosed by fire-rated separation walls within a new facility is 38,600 square feet, at the Industrial Trades Shops (Trades).
- All new buildings will be of fire-resistive construction (IBC Type IIB or better).

- McMurdo Station has a fire pumper truck with an on-board pump rated at 1,250 gpm, based on information provided by Neel Pahl, McMurdo Station Fire Chief.

FIRE WATER DEMAND BASED ON CODES

The following analysis reviews fire demand requirements based on various alternative codes that may be interpreted to apply. The analysis results in different fire flow values that can be compared with each other to reach a reasonable single value that can be used for design. A reasonable value may not necessarily be the highest value.

1. NFPA 13, Standard for the Installation of Sprinkler Systems, 2016 edition:
   - The Warehouse building is the most stringent building under this code analysis. If adequate fire protection is provided for the most stringent building, adequate fire protection will therefore be available for all other buildings.
   - The applicable part of this code is Chapter 12 for General Requirements for Storage and Chapter 16.2 for Protection of Class 1 through Class IV Commodities. The following assumptions are made. These assumptions will be made design criteria for architectural design and layout of the warehouse space.
     - Storage height: 20 feet
     - Commodity Class: II
     - Encapsulated: No
     - Aisle width: 8 feet
     - In-rack sprinklers: No
     - Ceiling sprinklers: Yes
     - Sprinkler temperature (ordinary or high): Ordinary
     - Design area of sprinkler operation (2,000 to 3,000 SF allowed): 2,000 SF
   - Based on Figure 16.2.1.3.2(b) Curve F and Figure 16.2.1.3.4.1, the required ceiling sprinkler density is 0.375 gpm/SF. The design sprinkler flow is therefore 0.375 * 2,000 = 750 gpm.
   - In accordance with paragraph 12.8, an inside hose allowance of 100 gpm is required. Per table 12.8.6, an additional outside hose allowance of 500 gpm is also required.
   - The fire flow duration is 120 minutes (2 hours) in accordance with table 12.8.6.
   - The total required fire flow based on NFPA 13 is <u>1,350 gpm</u>.

2. NFPA 11, Standard for Low, Medium and High Expansion Foam, 2016 edition
   - This code pertains to foam firefighting of fires at the oil tank farm.
   - The following assumptions are made:
     - The diameter of the largest petroleum, oil, lube (POL) tank is 120 feet, based on record drawing information.

- Per Table 5.2.4.2.2, the minimum application rate for tanks containing JP-5 is 0.16 gpm/SF. This results in a total flow of 1,800 gpm.
- The fire flow duration is 50 minutes in accordance with Table 5.2.4.2.2.
- The total required fire flow based on NFPA 11 is 1,800 gpm.

3. NFPA 1142, Standard on Water Supplies for Suburban and Rural Fire Fighting
   - We believe this code does not apply for the following reasons:
     - Per paragraph 1.1.1, NFPA 1142 applies to sites where "adequate and reliable supply systems for fire-fighting purposes" do not exist.
     - Per paragraph 1.1.2, "An adequate and reliable municipal-type water supply is one that is sufficient every day of the year to control and extinguish anticipated fires in the jurisdiction, particular building, or building group served by the water supply."
     - Per paragraph 3.3.16, a Municipal-Type Water System is a system having water pipes servicing fire hydrants and designed to furnish, over and above domestic consumption, a minimum of 250 gpm residual pressure for a 2-hour duration.
     - It is our interpretation that the water system upgrades proposed under this project will meet the definition of an "adequate and reliable municipal-type water supply" that will satisfy the site's fire protection demands. Therefore, NFPA Standard 1142 does not apply.

4. International Fire Code (IFC) Appendix B, Fire Flow Requirements for Buildings, 2012 edition
   - The Trades building is the most stringent building under this code analysis. The largest floor area encompassed by rated fire walls is 38,600 SF. Building construction is Type IIB.
   - Based on IFC Appendix B, Fire Flow Requirements for Buildings, the resulting fire flow per Table B105.1 is 4,250 gpm.
   - Paragraph B105.2, Buildings other than one- and two-family dwellings, allows a fire flow reduction for buildings equipped with fire sprinklers. All new buildings at McMurdo Station will be equipped with fire sprinklers and the reduction should be taken accordingly. The resulting fire flow is therefore 1,100 gpm. However the code specifies that the fire flow after the reduction is taken cannot be less than 1,500 gpm.
   - The total required fire flow based on IFC Appendix B is 1,500 gpm.

DISCUSSION OF PRACTICAL FIRE FIGHTING APPROACHES AND CONSTRAINTS

Setting codes aside, from a practical point of view it should be recognized that McMurdo Station is a unique installation from the standpoint of weather, type of building construction, and firefighting approaches. **Direct application of codes developed for the mainland United States may not necessarily apply on all levels.** For example:

- It does not make sense to make available a fire flow rate in excess of the flow rate that can realistically be applied by fire sprinklers and firefighting crews based on actual practices and equipment in the local environment.
- Water distribution and storage systems that are oversized can result in operational, maintenance, and health and safety risks and inefficiencies that could outweigh any additional benefit to firefighting.
- Over-application of water during a fire event could be harmful to structures, due to temperature (freezing water and ice can further damage buildings or render them unoccupiable for a longer duration), and because of building construction techniques (structural floors elevated above the ground could collapse if over-loaded with pooling water).
- Higher cost of oversized systems is a significant issue when capital budget is limited.

The water system should be right-sized, not oversized, for fire protection needs.

Site-specific considerations for determination of a design fire flow should include the following:

- Fire sprinklers are highly effective at extinguishing fires on their own, or would otherwise significantly reduce the flow of water needed via manual delivery by firefighting crews operating from the fire truck and hydrants. Gallon for gallon, sprinklers provide a much higher level of water use efficiency than manual firefighting. All new and remodeled buildings will be equipped with NFPA 13-compliant fire sprinkler systems.
- The McMurdo Fire Department has the capability to deploy hoses from the pumper truck to draw directly from the ocean as a supplemental supply of water for firefighting.
- Manual firefighting approaches are most likely to involve in-building operations, which limits the flow of water that can be applied by its operational nature. Typical fire department handheld hoses deliver an estimated 150 gpm each. Assuming three hoses are brought to bear on a fire inside a building, operated by 6 fire crewmembers (two on each hose), the maximum flow associated with hose use is 450 gpm. This flow is in addition to sprinkler flow through a limited number of “popped” (activated) sprinkler heads in the vicinity of the fire. Flow is limited.

- A high-capacity fire truck supported nozzle (estimated to be 600 gpm) brought to bear on the exterior face of a building is less likely to be used in the local environment, based on assumed application challenges in low temperatures and since building shells are constructed of fire-resistive materials. Building fires are likely to be fueled by building contents (requiring interior firefighting methods) rather than the buildings themselves.

RECOMMENDATION

Based on the considerations discussed in this memo, Merrick recommends the following fire protection criteria be used in the design of the water system:

- Fire Flow = 1,500 gpm
- Flow Duration = 120 minutes
- Fire Storage Volume = 180,000 gallons

We believe that these criteria meet a reasonable and balanced code interpretation, are adequate to protect McMurdo Station from foreseeable fire events, and appropriately balance fire protection needs with other considerations of the water system design (operational and maintenance costs, health of Station personnel related to water age, and available capital funding).

Christine Lurtz

From: Christine Lurtz
Sent: Tuesday, July 19, 2016 11:00 PM
To: Kevin Breslin; Eric Hein
Cc: Aaron Seal; Brendan Ahern; Orlando Trujillo
Subject: FW: Fire Flow Requirements

All,
Please see below and include this information in your design / calcs / recommendations / pricing going forward. Thanks. CL

Christine Lurtz, PMP, NCIDQ, LEED AP | Project Manager | Merrick & Company
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From: Neahusan, Brandon (Contractor) [mailto:Brandon.Neahusan.Contractor@usap.gov]
Sent: Tuesday, July 19, 2016 7:06 AM
To: Christine Lurtz <Christine.Lurtz@Merrick.com>; Aaron Seal <Aaron.Seal@Merrick.com>
Subject: FW: Fire Flow Requirements

From: Hilden, James (Contractor)
Sent: Monday, July 18, 2016 5:29 PM
To: Winkler, David (Contractor); Neahusan, Brandon (Contractor); Gassman, Jim (Contractor)
Cc: Epperson, Mike (Contractor)
Subject: FW: Fire Flow Requirements

Gents,
Recommendations from the Fire Chief regarding our firewater discussions this afternoon.

Regards,

James

From: Pahl, Neel (Contractor)
Sent: Monday, July 18, 2016 4:45 PM
To: Hilden, James (Contractor)
Subject: Fire Flow Requirements

Hi James,

I wrote all of this code info based on the conversation today given the available standards. I guess the bottom line is that my position is always advocating following the standards. I know that there are other opinions in the room based on practical, financial, logistical and other constraints that may well be perfectly valid. I feel that it falls to those other

people to justify why we aren't going to follow the standard. I don't want the reason to be that "we think the standard is too demanding so we're just not going to".

NFPA Standards 1142 and 11 are my go to sources, and they are what I would like to see. Below are my thoughts and back of the cocktail napkin calculations, but ultimately it will be for the engineers to figure these now, and again every time the designs changes, keeping in mind that that this isn't just for the core facility. This will need to be calculated for every building and make sure that the required fire flows are available at each respective location

Thanks

Neel

- NFPA 1142 and ISO both have guides or calculating the needed fire flow for designing a water supply for structural fire protection. The ISO version is a little more involved. The NFPA version is pretty straight forward, and I could calculate an approximate number if I had the volume of the structure. A similar exercise will need to be done for the VEOC other facilities to make sure that the water supply is adequate at those locations also.

- I need to know the diameter of the largest POL tank, but if it is 60 feet then the water/foam application rate is 1421 GPM for 50 minutes (This comes from NFPA 11).

- All this being said, I know that I might get overruled on any or all of this. The AHJ has the prerogative, per the standard, to reduce the fire flow requirements were the building is protected with an NFPA 13 compliant system (which it presumably will be). It also gives them the prerogative to increase the requirements for any of these reasons (some of which are applicable and worth contemplating).

    1. Limited fire department resources
    2. Extended fire department response time or distance
    3. Potential for delayed discovery of the fire
    4. Limited access
    5. Hazardous vegetation
    6. Structural attachments, such as decks and porches
    7. Unusual terrain
    8. Special uses and unusual occupancies

- Also, I have confirmed that our fire trucks have 2x 6" water inlets (one on each side of the truck), in addition to 3x 2 ½" inlets. They definitely have pump capacity, inlets, and discharges rated to 1250 GPM under the NFPA 1901 standard pump conditions.

TECHNICAL MEMORANDUM

August 9, 2016

TO: Brandon Neahusan, Antarctic Support Contract (ASC) Project Manager

FROM: Christine Lurtz, PMP, Merrick & Co. Project Manager

CC: Eric Hein, PE, Merrick & Co. Civil/Water Engineer

SUBJECT: **McMurdo Utilities Infrastructure Design**
Water Storage Tank Capacity Recommendation

INTRODUCTION

Merrick & Company and Michael Baker International (collectively known as the Architecture/Engineering (A/E) Team) are under contract to provide 100% design documents for the McMurdo Utilities Infrastructure Design. As part of the McMurdo Utilities Infrastructure Design, an upgraded water system will be provided to serve the station. As part of the design basis development, a determination is needed on the volume of water storage that will be provided.

The purpose of this memorandum is to provide a rational discussion for sizing the total storage for the site, present a recommendation, and facilitate decision making by the NSF to identify the storage capacity that should be carried forward for design and implementation.

Total water storage capacity at McMurdo Station needs to satisfy two purposes:

1. Provide storage volume that will be maintained for firefighting reserve. This quantity of water is referred to as "fire storage".
2. Provide storage volume that will be used to meet domestic demands of the station, or "domestic storage".

FIRE STORAGE

Fire storage volume is a function of the fire flow and duration. In a Technical Memorandum entitled "Fire Flow Criteria Determination for Water System Design" prepared by Merrick dated July 29, 2016, a fire flow of 1,500 gpm for 120 minutes was recommended as the design basis fire flow for the Station. We believe that this criteria is supported by code, is adequate to protect McMurdo Station from foreseeable fire events, and appropriately balances fire protection needs with other considerations of the water system design (operational and maintenance costs, health of Station personnel related to water age, and available capital funding).

The corresponding fire storage volume is therefore 1,500 gpm x 120 min = 180,000 gallons. This is the volume of water that will normally be maintained at all times in the water tanks, and will be readily available should an unexpected fire event occur.

DOMESTIC STORAGE

The purpose of domestic storage is twofold:

1. Manage daily diurnal demands.
2. Supply water in times of water production outage, ideally while minimizing use of the fire storage reserve.

Daily Diurnal Demands

Domestic demands fluctuate thorough the day, depending on the level of activity of station inhabitants. Typically demands are at their lowest during the night, when inhabitants are sleeping. Demands usually peak in the morning while inhabitants are showering and getting ready for the day. Demands drop off somewhat in the middle of the day, and may peak again in the evening. Also demands may fluctuate depending on day of the week, and from week to week. Since the water production equipment produces water at a constant average daily rate, the water volume in the storage tank will vary; draining during peak hours when demand exceeds production, and filling during off hours when production exceeds demand.

Accepted sizing parameters for equalizing diurnal flow is to provide a volume equal to 40% of the total daily flow. For McMurdo Station, the peak average daily flow is assumed to be 65,000 gallons. The minimum volume that should be made available for equalizing diurnal demands is therefore 25,000 gallons.

Emergency Domestic Storage

Due to the remoteness of McMurdo Station and its inaccessibility during extended periods of the year, it is prudent to provide a volume of water that can meet domestic demands should there be an emergency outage of the seawater intake or treatment equipment, which halts new water production. In an extreme case, an outage of the facilities might not be repairable without outside resources or in a reasonable short period of time, and so it is assumed an emergency evacuation of inhabitants could be necessitated. The water system must therefore supply a minimal amount of water for human needs until an evacuation can be completed. Ideally the water can be supplied while minimizing use of any fire storage water, so that fires can be fought as well. A catastrophic emergency that requires evacuation and at the same time renders water production equipment inoperable could include a large fire.

For this analysis, the following assumptions are made:

- In the event of emergency, emergency water restrictions would immediately go into effect, and remain in effect until an emergency evacuation can be completed.
- Emergency water restrictions can be stringent given the seriousness of the situation in that environment, and would include suspension of bathing, laundry, cleaning and maintenance activities, and rationing of toilet flushing.
- According to the World Health Organization (WHO), the minimum amount of water that should be provided per capita per day in emergency situations is 4 to 5 gallons. This quantity is sufficient for drinking and food preparation, but not for bathing or other non-essential activities.
- The maximum station population in the summer season is 1,000 persons.
- An emergency evacuation will take 2 weeks to substantially complete, during any time of year.

Based on these assumptions, a reasonable volume of water that can be made available for an emergency is 1,000 persons x 5 gpcpd = 5,000 gallons per day x 14 days = 70,000 gallons. Note that this volume is conservative since the population will be decreasing during the course of the evacuation, and it is likely possible to get by on fewer gallons per capita per day.

Also the Station has a portable RO unit that can be used during emergencies to produce 10 gpm, or 14,000 gpd. It is assumed the RO unit can be made operational during any time of year, can be placed in any suitable location around the Station (where unaffected by the emergency), access to raw seawater can be provided for the suction hose (even through sea ice during winter by ice coring or melting with a hotsy), and portable boilers or heaters can be employed for seawater pre-heating. The daily production of the portable RO unit (14,000 gallons) exceeds the maximum daily water demand during emergencies (5,000 gallons), so potentially the unit could supply emergency water demands indefinitely until an evacuation can be effected.

RECOMMENDATION

Based on the considerations discussed above, Merrick recommends a total of 250,000 gallons of water storage be provided for McMurdo Station. This volume is sufficient to meet the recommended fire storage of 180,000 gallons, and provides 70,000 gallons for managing domestic and emergency demands. The four existing 50,000 gallon tanks are proposed for re-use, and one new 50,000-gallon tank is proposed. For the dual water system, 100,000 gallons would be allocated to the drinking water system, and 150,000 gallons allocated to the reuse system. All tanks would be available for fire storage, though the sequence would be such that drinking water tanks are used last in a fire event. Total storage volume is the same for either a single or dual water system. The proposed location of the new tank is discussed in a separate memo.