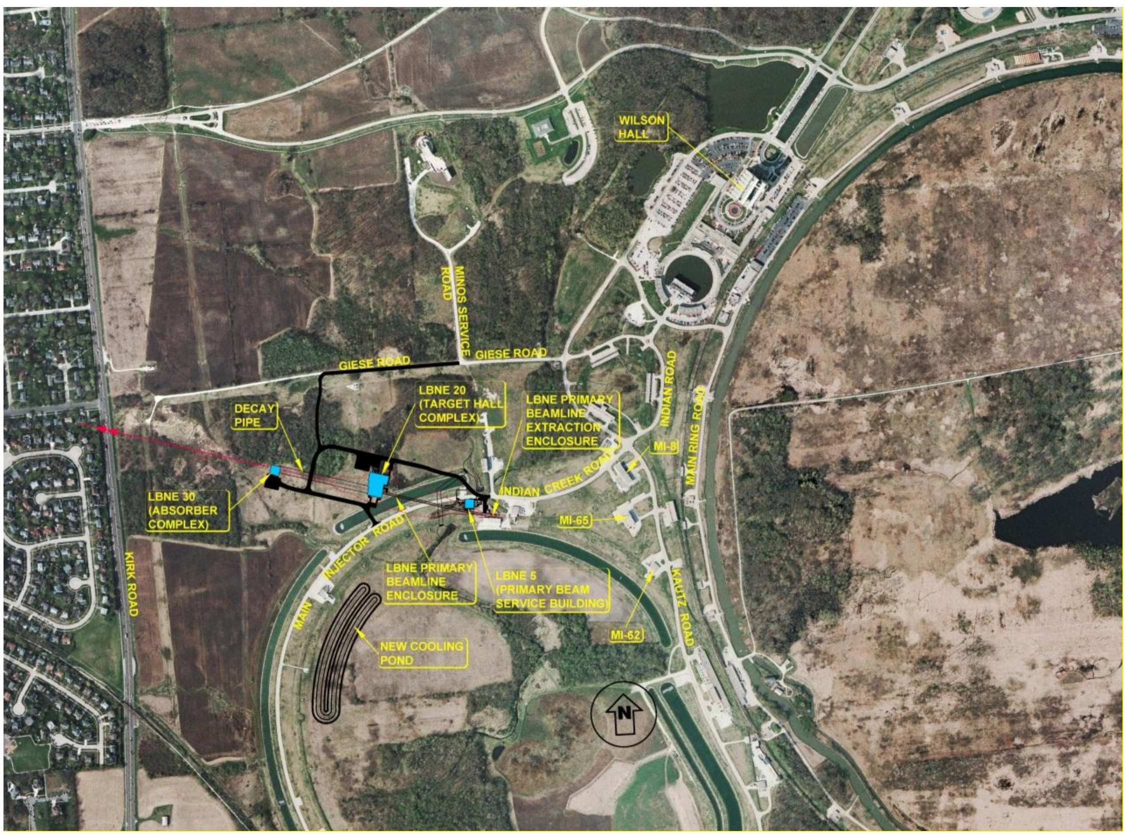
Long-Baseline Neutrino Experiment (LBNE) Project
Conceptual Design Report

Volume 5: Conventional Facilities at the Near Site

October 2012



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Acronyms and Abbreviations

A	amps
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
ADAAG	Americans with Disabilities Act Accessibility Guidelines
AHJ	Authority Having Jurisdiction
AHR	Air Handling Room
AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning
CAMs	Control Account Managers
CD	Critical Decision (CD-0, CD-1, etc)
CDR	Conceptual Design Report
CF	Conventional Facilities (Civil design and construction)
cfm	cubic feet per minute
CHW	Chilled Water
DocDB	Document Data Base (LBNE-doc-####)
DOE	Department of Energy
DUSEL	Deep Underground Science and Engineering Laboratory
DWS	Domestic Water Service
EA	Environmental Assessment
EDIA	Engineering, Design, Inspection, Administration
ED&I	Engineering, Design, and Inspection
EENF	Environmental Evaluation Notification Form
ES&H	Environment, Safety, and Health
ft	feet
ft^2	square feet
FEMA	Federal Emergency Management Agency
Fermilab	Fermi National Accelerator Laboratory
FESS	Facilities Engineering Services Section (at Fermilab)
FIRUS	Facilities Information Reporting Utility System
FLS	Fire Life Safety
FNAL	Fermi National Accelerator Laboratory
FONSI	Finding of No Significant Impact
GCL	Geosynthetic clay liner
gpm	gallons per minute
gsf	gross square feet
HEPA	High Efficiency Particle Arrestor
hp	Horse Power
HVAC	heating ventilating and air conditioning
HW	Hot Water
ICW	Industrial Cooling Water
kV	kilo (1000) volts

kVA	kilo volt amps (or kilowatt, electrical power)
kw	kilowatt
KRS	Kautz Road Substation
LEED	Leadership for Energy Efficient Design
LANL	Los Alamos National Laboratory
LAr	Liquid Argon
LBNE	Long-Baseline Neutrino Experiment
lf	lineal feet
LCW	Low Conductivity Water
m	meter
MEP	Mechanical, Electrical, and Plumbing
MI	Main Injector
MSL	mean sea level
MSS	Master Substation
MVA	Mega Volt Amps
n+1	The required number of units (n) plus one additional unit
ND	Near Detector
NEC	National Electric Code
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NSSF	Near Surface Storage Facility
NuMI	Neutrinos at Main Injector (Neutrino Beam at Fermilab)
ODH	Oxygen Depletion Hazard
ORNL	Oak Ridge National Laboratory
P5	Particle Physics Project Prioritization Panel
PDR	Preliminary Design Report (DUSEL)
plf	Pounds per Linear Foot
psf	Pounds per Square Foot
RAW	Radioactive Water
RH	Relative Humidity
sf	square feet
SMACNA	Sheet Metal and Air Conditioning Contractors Association
SR3	survey riser 3
STA (Sta.)	Station (100’) (e.g. STA 20+52 = 2052’ from start (STA 0+00))
T	tons
UFAS	Uniform Federal Accessibility Standards
UPS	Uninterruptable Power Supply
WBS	Work Breakdowns Structure
WCD	water Cherenkov detector
Wg	Water Gage

Definitions

STA or Station is a Civil Engineering/ Land Surveying term used to describe a distance of 100 foot increments, or portions thereof from STA 0+00 or the starting point along a line or alignment. It is used as an address or location for design and construction layout.

Some examples:

STA 1+00, which means 100 feet, from Station 0+00 which is typically used as the starting point,

STA 1+50 means 150 feet from Station 0+00

STA -2+38.8 is a distance of 238.8 feet before or upstream of Station 0+00

STA 12+47, 35’ LT is a distance along the line and an offset from the line, i.e.,1247’ from Station 0+00 and 35’ left (LT) of the line or alignment while facing down station.

Beam-Off: This refers to access to a facility, room, underground space, etc., (area). If the area is called out as beam-off, it means that access to that area is restricted by an interlock system and one can only access when the proton beam is off. In an emergency situation, if access is required into/thru a beam-off area then the interlock door is opened, the beam shuts off and emergency access is allowed/available.

Beam-On: This means access to an area that is called out as beam-on is allowed when the proton beam is on.

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1 Introduction

1.1 Introduction to LBNE

The Long-Baseline Neutrino Experiment (LBNE) Project team has prepared this Conceptual Design Report (CDR) which describes a world-class facility to enable a compelling research program in neutrino physics. The ultimate goal in the operation of the facility and experimental program is to measure fundamental physical parameters, explore physics beyond the Standard Model and better elucidate the nature of matter and antimatter.

Although the Standard Model of particle physics presents a remarkably accurate description of the elementary particles and their interactions, it is known that the current model is incomplete and that a more fundamental underlying theory must exist. Results from the last decade, revealing that the three known types of neutrinos have nonzero mass, mix with one another and oscillate between generations, point to physics beyond the Standard Model. Measuring the mass and other properties of neutrinos is fundamental to understanding the deeper, underlying theory and will profoundly shape our understanding of the evolution of the universe.

1.1.1 About this Conceptual Design Report

The LBNE Conceptual Design Report is intended to describe, at a conceptual level, the scope and design of the experimental and conventional facilities that the LBNE Project plans to build to address a well-defined set of neutrino-physics measurement objectives. At this Conceptual Design stage the LBNE Project presents a *Reference Design* for LBNE and alternative designs that are still under consideration for particular elements.

- an intense neutrino beam aimed at a far site
- detectors located downstream of the neutrino source
- a massive neutrino detector located at the far site
- construction of conventional facilities at both the near and far sites

The selected near and far sites are Fermi National Accelerator Laboratory (Fermilab), in Batavia, IL and Sanford Underground Research Facility (SURF), respectively. The latter is the site of the formerly proposed Deep Underground Science and Engineering Laboratory (DUSEL) in Lead, South Dakota.

This CDR is organized into six stand-alone volumes, one to describe the overall LBNE Project and one for each of its component subprojects:

Volume 1: The LBNE Project

Volume 2: The Beamline at the Near Site

Volume 3: Detectors at the Near Site

Volume 4: The Liquid Argon Detector at the Far Site

Volume 5: Conventional Facilities at the Near Site

Volume 6: Conventional Facilities at the Far Site

Volume 1 is intended to provide readers of varying backgrounds an introduction to LBNE and to the following volumes of this CDR. It contains high-level information and refers the reader to topic-specific volumes and supporting documents, listed in Section 1.1.5. Each of the other volumes contains a common, brief introduction to the overall LBNE Project, an introduction to the individual subproject, and a detailed description of its conceptual design.

1.1.2 LBNE and the U.S. Neutrino-Physics Program

In its 2008 report, the Particle Physics Project Prioritization Panel (P5) recommended a world-class neutrino-physics program as a core component of the U.S. particle physics program [**1**]. Included in the report is the long-term vision of a large detector at the formerly proposed Deep Underground Science and Engineering Laboratory (DUSEL) in Lead, S.D. (now SURF), and a high-intensity neutrino source at Fermilab.

On January 8, 2010, the Department of Energy (DOE) approved the Mission Need for a new long-baseline neutrino experiment that would enable this world-class program and firmly establish the U.S. as the leader in neutrino science. The LBNE Project is designed to meet this Mission Need.

With the facilities provided by the LBNE Project, the LBNE Science Collaboration proposes to mount a broad attack on the science of neutrinos with sensitivity to all known parameters in a single experiment. The focus of the program will be the explicit demonstration of leptonic CP violation, if it exists, by precisely measuring the asymmetric oscillations of muon-type neutrinos and antineutrinos into electron-type neutrinos and antineutrinos.

The experiment will result in precise measurements of key three-flavor neutrino-oscillation parameters over a very long baseline and a wide range of neutrino energies, in particular, the CP-violating phase in the three-flavor framework and the mass ordering of neutrinos. The unique features of the experiment – the long baseline, the broad-band beam, and the high resolution of the detector – will enable the search for new physics that manifests itself as deviations from the expected three-flavor neutrino-oscillation model. The scientific goals and capabilities of LBNE are outlined in Volume 1 of this CDR and the 2010 Interim Report of the Long-Baseline Neutrino Experiment Collaboration Physics Working Groups [**2**].

Siting the Far Detector deep underground, a scope opportunity that LBNE may seek to pursue in the future with non-DOE funding, would provide opportunities for research in additional areas of physics, such as nucleon decay and neutrino astrophysics, in particular, studies of neutrino bursts from supernovae occurring in our galaxy.

1.1.3 LBNE Project Organization

The LBNE Project Office at Fermilab is headed by the Project Director and assisted by the Project Manager, Project Scientist and Project Systems Engineer. Project Office support staff include a Project Controls Manager and supporting staff, a Financial Manager, an Environment, Safety and Health (ES&H) Manager, a Computing Coordinator, Quality Assurance, Procurement and Risk Managers, a documentation team and administrative support.

The Beamline, Liquid Argon Far Detector and Conventional Facilities subprojects are managed by the Project Office at Fermilab, while the Near Detector Complex subproject is managed by a Project Office at Los Alamos National Laboratory (LANL).

More information on Project Organization can be found in Volume~1 of this CDR. A full description of LBNE Project management is contained in the LBNE Project Management Plan [**3**].

1.1.4 Principal Parameters of the LBNE Project

The principal parameters of the major Project elements are given in Table 1-1.

Table 1-1: LBNE Principal Parameters.

Project Element Parameter	**Value**
Near- to Far-Site Baseline	1,300 km
Primary Beam Power	708 kW, upgradable to 2.3 MW
Protons on Target per Year	6.5×10^{20}
Primary Beam Energy	60–120 GeV (tunable)
Primary Beam Type	Horn-focused with decay volume
Neutrino Beam Energy Range	0.5–5 GeV
Neutrino Beam Decay Pipe Diameter x Length	4 m × 204 m
Near Site Neutrino Detector Type	LArTPC
Near Site Neutrino Detector Active Mass	18 ton
Far Detector Type	LArTPC
Far Detector Active (Fiducial Mass)	35 (10) kton
Far Detector Depth	3 m overburden

1.1.5 Supporting Documents

A host of information related to the CDR is available in a set of supporting documents. Detailed information on risk analysis and mitigation, value engineering, ES&H, costing, project management and other topics not directly in the design scope can be found in these documents, listed in Table 1-2. Each document is numbered and stored in LBNE's document database, accessible via a username/password combination provided by the Project. Project documents stored in this database are also made available to internal and external review committees through Web sites developed to support individual reviews.

Table 1-2: LBNE CD-1 Documents.

Title	LBNE doc Number(s)
Alternatives Analysis	4382
Case Study Report; Liquid Argon TPC Detector	3600
Configuration Management Plan	5452
DOE Acquisition Strategy for LBNE	5442
DOE Preliminary Project Execution Plan	5443
Integrated Environment, Safety & Health Management Plan	4514
LAr-FD Preliminary ODH Analysis	2478
LBNE Reconfiguration Final Report	Linked from LBNE web site (lbne.fnal.gov) under "Reports and Documents"
Global Science Objectives & Science Requirements, and Traceback Reports	4772
Preliminary Hazard Analysis Report	4513
Preliminary Security Vulnerability Assessment Report	4826
Procurement Plan	5329
Project Management Plan	2453
Project Organization Chart	5449
Quality Assurance Plan	2449
Report on the Depth Requirements for a Massive Detector at Homestake	0034
Requirements, Beamline	4835
Requirements, Far Detector	3747
Requirements, Far Site Conventional Facilities	4958
Requirements, Near Detectors	5579
Requirements, Near Site Conventional Facilities	5437
Risk Management Plan	5749
Value Engineering Report	3082
Work Breakdown Structure	4219

1.2 Introduction to LBNE Conventional Facilities at the Near Site

The objective of this volume of the Conceptual Design Report (CDR) is to document the Conventional Facilities required to house the Long Baseline Neutrino Experiment (LBNE) on the Fermilab site, which is also referred to as the Near Site. Facilities in this scope of work include the Beamline facilities and a small muon alcove area in the Absorber Hall. For this muon alcove, the design of the technical components and their subsequent construction and fit out in are the responsibility of the Near Detector L2 project. The scope discussed in this volume represents the full scope, at a Conceptual Design level, for all Conventional Facilities required to support the Project, included in Volume 2, The *Beamline at the Near Site*, and Volume 3, *Detectors at the Near Site*. A complete discussion on alternative design configurations and options considered during the Concept Design phase is available the *LBNE Alternatives Analysis* [**4**]. This Conceptual Design effort has been completed in support of obtaining DOE approval for CD-1 and as such, the programmatic requirements described in this volume are developed to a level to support the Conceptual Design milestone of this Project. Further detailed development of all aspects of the design and requirements will be required to support future phases of the Project.

The Main Injector (MI) Accelerator is part of the existing Fermilab infrastructure and as discussed in Volume 2. The numerical addresses (e.g. MI-10, MI-14, MI-60, etc.), around the MI, are used to indicate the points of extraction, or locations of technical components, along the Main Injector. The baseline design for the LBNE Project extracts a proton beam from the MI-10 point of the Main Injector which, in conjunction with the Far Detector location, determines the location of the Near Site Conventional Facilities. The Near Site Conventional Facilities not only provide the support buildings for the underground facilities, but also provides the infrastructure to house the Beamline technical systems from the extraction point, through the target and absorber. The required infrastructure is summarized below and detailed in this volume in Chapter 3, *The Facility Layout*, Chapter 4, *New Surface Buildings*, and Chapter 5, *New Underground Structures*.

After the proton beam is extracted at MI-10 at the starting point (STA 0+00 which is approximately 0.76 ft upstream of the first extraction Lambertson magnet), about 30 ft below grade, the Beamline will continue along the Primary Beam Enclosure at an incline into and through an embankment constructed of engineered fill which reaches a maximum height of about 58 ft above existing grade. After reaching the apex of the embankment the Beamline declines back toward existing grade and through the Target Hall, a 668-ft (203.7-m) long Decay Pipe, and the Absorber Hall. Downstream of the Absorber Hall, the Beamline is directed through bedrock, allowing muons to range out before the beam reaches the site boundary. Figure 1-1 shows a schematic longitudinal section of the entire Near Site, with an exaggerated vertical scale of 3 to 1 to show the entire Project alignment in one illustration. As the beam extraction point from the MI is near MI-10 Service Building, and the target is above existing grade or shallow, the Project reference design is referred to as LBNE MI-10 Shallow. Other options that were considered are discussed in the *LBNE Alternatives Analysis* [**4**].

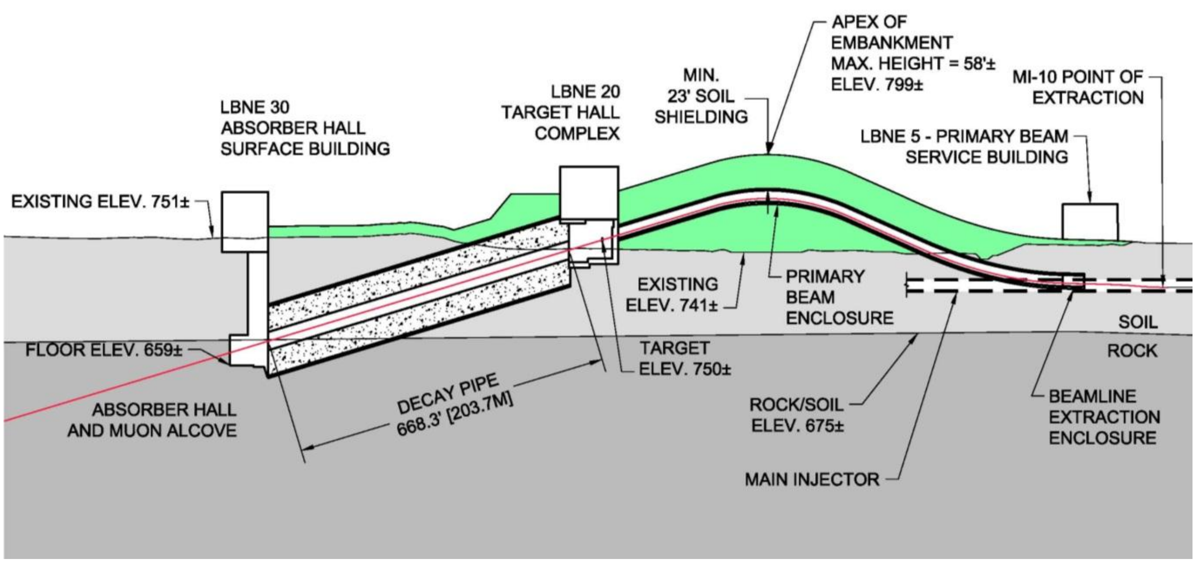

Figure 1-1: LBNE MI-10 Shallow Near Site schematic longitudinal section view.

Specifically, the beam will travel approximately 1078 ft (328.7 m) from the extraction point through the proposed Primary Beam Enclosure to the Target Hall where it interacts with a target and a focusing horn system to create an intense neutrino beam that will be directed through a 668-ft (203.7-m) long decay pipe through a hadron absorber and muon detectors, where the beam will then leave the Absorber Hall. The neutrino beam will then continue through the earth's mantle directed toward a detector located more than 1,300 km (~808 miles) away at the Sanford Underground Research Facility (SURF) located in Lead, South Dakota. SURF is referred to as the Far Site.

The Near Site Conventional Facilities LBNE Project layout at Fermilab, the Near Site, is shown in Figure 1-2. Following the beam from southeast to northwest, or from right to left in Figure 1-2, is the Extraction Enclosure, the Primary Beam Enclosure and its accompanying surface-based Service Building (LBNE 5), Target Complex (LBNE 20) located in the engineered fill embankment, the Decay Pipe, the underground Absorber Hall with Muon Alcove, and its surface-based Service Building (LBNE 30).

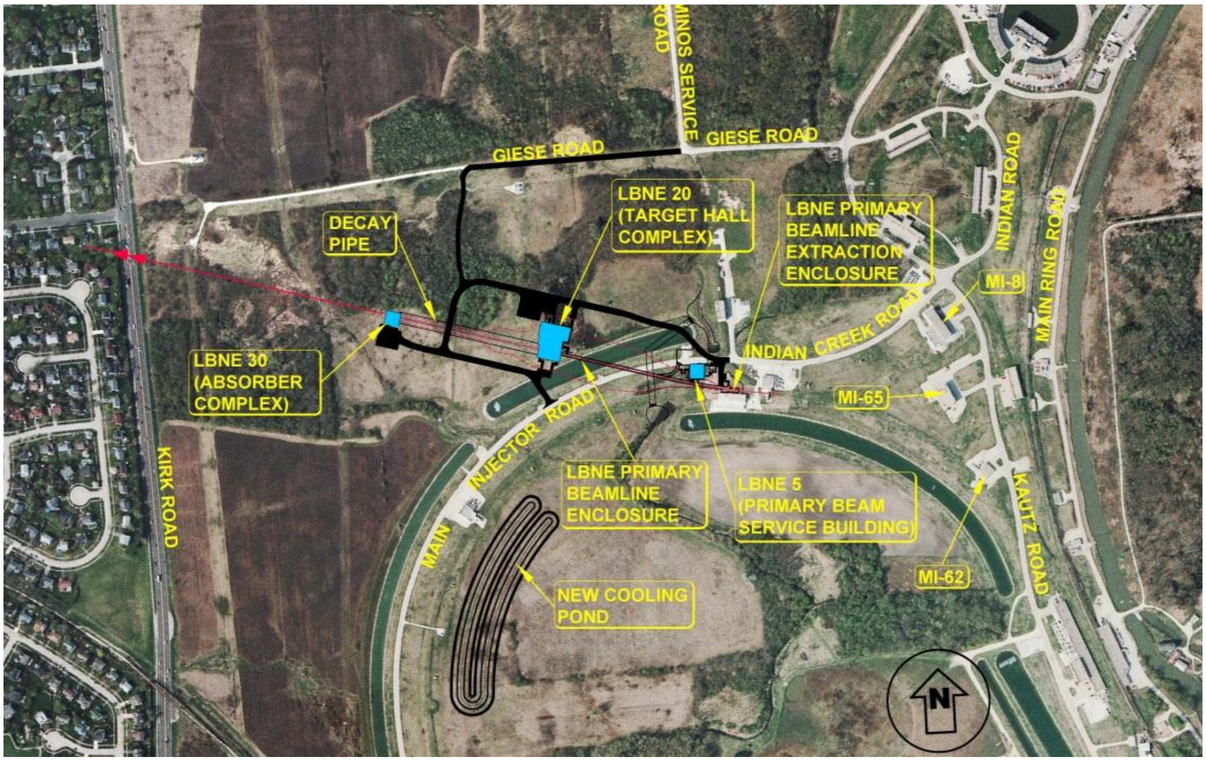

Figure 1-2: LBNE Near Site Project Layout at Fermilab.

The beamline is designed for initial operation at proton-beam power of 708 kW, with the capability to support an upgrade to 2.3 MW. Those components of the conventional facilities that cannot be upgraded efficiently in a cost effective manner are designed for a proton- beam power of 2.3 MW. Examples of these components include the Decay Pipe and associated shielding (Section 5.2), and the cast-in-place concrete and steel shielding in the Target Complex (Section 4.2), and Absorber Hall (Section 5.3).

1.3 Project Participants

The LBNE Beamline and a muon Near Detector system located in the Muon Alcove of the Absorber Hall, are planned to be located on the Fermilab site, which is managed by the Fermi Research Alliance, LLC. The design and construction of LBNE Near Site Conventional Facilities will be executed in conjunction with the Facility Engineering Services Section (FESS) staff.

The LBNE Project Conventional Facilities is managed by staff organized according to the Work Breakdown Structure (WBS) and is led by the Conventional Facilities Project Manager (WBS Level 2). The supporting team includes a Conventional Facilities Level 3 Near Site Manager, who is a part of, and works directly with, the FESS engineering staff. The Level 3 Near Site Manager is also the LBNE Project liaison with the Beamline Level 2 Project and the Near Detector Complex L2 Project to ensure the beamline and detector requirements are met and is responsible for all LBNE scope at the Near Site.

The Conventional Facilities Level 3 Near Site Manager has, and will continue to oversee, multiple engineering design and construction consultants. Design consultants have specific areas of expertise in excavation, rock support, geotechnical engineering, deep foundations, geosynthetic barrier systems, fire/life safety, electrical power distribution, cyberinfrastructure, cooling with chilled water, and heating/ventilation systems. Design consultants for LBNE's Conceptual Design were: M+W Group Inc. and AECOM for surface facilities and infrastructure, and W.D. Wightman & Company for rock excavation and support. In addition, Ed Kavazanjian, Ph.D. provided an independent review and assessment of the Geomembrane barrier system of the Decay Region that is discussed in Section 5.2.1.

Interaction between FESS engineers, LBNE Near Site design teams, and design consultants was completed with weekly conferences, periodic design interface workshops, and electronic mail. The Conventional Facilities Level 3 Near Site Manager coordinates all information between design consultants to assure that design efforts remain on track.

1.4 Codes and Standards

Conventional Facilities to be constructed at the Near Site shall be design and constructed in conformance with the Fermilab ES&H Manual (FESHM) Chapter 1070, Work Smart Set, revision 8, dated August 2011 (http://esh.fnal.gov/xms/FESHM), but particularly the latest edition of the following codes and standards:

- Applicable Federal Code of Federal Regulations (CFR), Executive Orders, and DOE Requirements
- 2009 International Building Code (IBC)
- "Fire Protection/Life Safety Assessment for the Conceptual Design of the Near Site of the Long Baseline Neutrino Experiment (LBNE) MI-10 Shallow – CD-1 Reference Design", dated August 10, 2012, by Aon/Schirmer Engineering
- The Occupational Health and Safety Act of 1970 (OSHA)
- NFPA 101, Life Safety Code
- NFPA 520, Standard on Subterranean Spaces, 2005 Edition
- NFPA 72, National Fire Alarm Code
- American Concrete Institute (ACI) 318
- American Institute of Steel Construction Manual, 14^{th} Edition
- ASHRAE 90.1-2007, Energy Standard for Buildings

- ASHRAE 62, Indoor Air Quality
- 2009 National Electrical Code (NEC)
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Material (ASTM)
- American National Standards Institute (ANSI)
- National Institute of Standards & Technology (NIST)
- Insulated Cable Engineers Association (ICEA)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- American Society of Plumbing Engineers (ASPE)
- American Water Works Association (AWWA)
- American Society of Sanitary Engineering (ASSE)
- American Gas Association (AGA)
- National Sanitation Foundation (NSF)
- Illinois Plumbing Code
- Standard Specifications for Water and Sewer Main Construction in Illinois, Sixth Addition 2009, issued by the Illinois Society of Professional Engineers
- Federal American's with Disabilities Act (ADA) along with State of Illinois ADA amendments. These requirements shall only be applied to those facilities which are located at the ground surface and accessible to the public.

2 Existing Site Conditions

The LBNE Project area is located in the western portion of the Fermilab site in Batavia, Illinois. The sections below describe the known and anticipated surface conditions at the site and also include site geology, groundwater conditions, and natural gasses.

2.1 Surface Development, Topographic and Environmental Conditions

The site is partially developed with existing surface and underground structures for the support of ongoing research at the laboratory. Existing underground structures include building foundations, buried utilities, shallow tunnel enclosures constructed by cut-and-cover methods, the associated remnants from previously constructed braced excavation structures, and the existing Neutrinos at Main Injector (NuMI) tunnel which was excavated in the same rock units that LBNE underground enclosures will encounter.

Existing facilities on or adjacent to the Fermilab property that will interface with or constrain the development of the Project are the Main Injector, Kautz Road, Indian Creek Road (also known as the Main Injector Road), the Main Injector Cooling Pond F, and Kirk Road.

The site surface topography is predominantly flat with areas of prairie grass, heavy brush, woodlands, wetlands and developed sites. Surface elevations within the Project area range from about 740 ft to 760 ft above mean sea level (MSL). The topography in the Project area will not be an impediment to the development of the construction sites or the use of standard heavy equipment for construction.

2.2 Overview of Site Geology

Subsurface conditions at the Near Site are comprised of glacial, glaciofluvial and glaciolacustrine deposits, along with flat lying bedrock strata of the middle to lower Silurian period. In descending order, the Silurian rock formations include the Markgraf and Brandon Bridge Members of the Joliet Formation, the Kankakee Formation and the Elwood Formation. .

Glacial processes during the Wisconsin glaciation resulted in the deposition of a thick blanket of glacial tills, lacustrine silts and clays, and outwash sands and gravels across the Project area. The total thickness of these overburden sediments in the Project area ranges from about 50 ft to 85 ft. The majority of the sediments are over consolidated glacial till deposits consisting of silt, sand, gravel, cobbles and boulders in a predominantly clay matrix.

The Project area is situated on the eastern flank of a broad structural arch known as the Kankakee Arch, separating the Michigan and Illinois bedrock basins. The rock stratigraphy is composed of a sequence of sedimentary rocks consisting of dolomitic limestone, dolomite, siltstone and shale, generally Silurian in age. The underground structures for this Project will be excavated in formations of these rock types. The bedrock surface is an erosional unconformity where overlying rocks of the Upper Paleozoic Era have been removed by glaciation. The overall dip of the bedrock strata in this region is around 10 ft to 15 ft per mile to the southeast. Bedrock outcrop exposures are rare, except in quarries (North Aurora and Elmhurst) and river bluffs, as the rock strata are overlain by thick glacial deposits.

The Fermilab site is located in a zone of the central mid-continent that is tectonically stable and a region of very low seismic risk. The closest known earthquake source zones capable of producing ground motions of any significance are located several hundred miles to the south. Active faults are not known to exist in the Project area.

Additional descriptions of subsurface materials, geologic profiles and boring logs along the Near Site Project alignment are provided in the *LBNE Site Investigation Geotechnical Engineering Services Report* [**5**] prepared by Groff Testing Corporation, dated February 26, 2010, and a second independent evaluation is documented in the *Geotechnical Investigation, Heuer Review* [**6**].

2.3 Overview of Site Groundwater Conditions

The groundwater regime within the Project area is controlled by the glacial drift aquifer, bedrock aquifers and aquitards. The glacial drift aquifer can be categorized as buried and basal drift aquifers. The buried aquifers occur as isolated lenses or layers of permeable silt, sand and gravel outwash, separated by relatively impermeable clayey and silty tills. The basal aquifers are associated with localized lenses or layers of permeable silt, sand and gravel.

The upper bedrock aquifer consists of the upper weathered and jointed bedrock regardless of stratigraphy or lithology but dominantly the Silurian dolomite formations. The aquifer has a low primary permeability and a much higher secondary permeability consisting of local flow systems mostly associated with discontinuities in the rock mass. The upper bedrock aquifer is a groundwater source for many private and public wells in the Batavia area, including the main water supply for Fermilab. The potentiometric surface of the upper bedrock aquifer is approximately 10 ft below the bedrock surface; however, groundwater elevations may vary.

Underground enclosures of the LBNE Project will be primarily constructed in the drift aquifer and the upper bedrock aquifer. A deeper bedrock aquifer will not be encountered during construction of any of the Project facilities.

2.4 Occurrence of Natural Gasses

Throughout northern Illinois isolated pockets and production quantities of methane occur in organic silts and sands associated with interglacial periods, especially the Sangamon soil unit which represents a long time interval between the Illinois and Wisconsin stages of glaciation. Methane and hydrogen sulfide gasses in bedrock formations are uncommon and are usually a result of contaminated groundwater where present.

During geotechnical investigations for the nearby NuMI Project, boreholes and representative soil and rock samples were monitored with flammable gas detection meters in the field for the presence of methane. Methane gas was not detected and is not anticipated to be encountered during the LBNE Project excavations as further described in the *LBNE Site Investigation Geotechnical Engineering Services Report* [**5**].

3 The Facility Layout

The LBNE Conventional Facilities on the Near Site consist of six functional areas – two surface buildings and a near surface shallow buried structure located in an embankment constructed of engineered fill at the Target Complex, and three underground facility enclosures. The two surface buildings and single shallow buried structure are shown in blue in Figure 1-2. Construction will be executed and packaged in a logical sequence based on programmatic and funding driven limitations.

Figure 1-2 shows the Project site aerial view with LBNE facilities highlighted. The Project limits are bounded by Giese Road to the north, Kautz Road to the east, Main Injector Road to the south, and Kirk Road to the west. The Beamline is shown in red in Figure 1-2. The three surface and near-surface buildings consist of:

- Primary Beam Service Building (LBNE 5)
- Target Hall Complex (LBNE 20)
- Absorber Hall Service Building (LBNE 30)

The three underground facilities consist of:

- Beamline Extraction Enclosure and Primary Beam Enclosure
- Decay Pipe
- Absorber Hall, Muon Alcove and support rooms

Each underground facility has a surface/above-ground service building that functions as a conveyance conduit for conventional and programmatic (for the technical systems) utilities as well as a location for equipment conveyance and personnel access and egress from the underground enclosures. Note that the shallow above and below grade Target Hall is included in the surface based Target Hall Complex at LBNE-20. Figure 1-1 shows the beamline facilities longitudinal section view and how the surface facilities relate to their corresponding underground facilities.

Based on the Conceptual Design, there will be 165,041 yd^3 of earth excavation, 13,540 yd^3 of rock excavation, 94,900 yd^3 of cast-in-place concrete, 1,900 lf of cut-and-cover excavation, two shafts (Absorber Hall equipment handling, components handling and access/egress), and three new surface buildings with a combined floor space area of 33,100 sf, and 15,100 sf of underground facilities (Primary Beam Enclosure and Absorber Hall/Muon Alcove) floor space.

The conceptual design drawings, consisting of an approximately 75-page set of drawing sheets called *LBNE Conventional Facilities at Fermilab* [**7**], depict the general Project layout, transverse and longitudinal cross sections of surface and underground facilities, overall Project and individual surface and underground facilities plan views, single line diagrams of mechanical, electrical, plumbing, and fire protection routing and layout, as well as details and general conceptual specifications of the Conventional Facilities as required by the technical system groups.

The LBNE Conventional Facilities CDR Drawings [**7**] are the source of most of the figures in this volume. These drawings may be referenced for greater design detail of the Conventional Facilities planned at the Near Site.

3.1 Project-Wide Considerations

There are several design considerations that apply to many of the facilities that will be constructed for LBNE and are not necessarily specific to any single structure or system. These considerations include the structural and architectural treatment of surface structures, structural and excavation approaches to underground or shallow buried structures, environmental protection, fire protection and life safety systems, safeguards and security, emergency shelter provisions, energy conservation, and DOE space allocation. These Project-wide considerations are addressed in this section.

3.1.1 Structural and Architectural for Surface Structures

The structural building and construction systems for the Near Site Conventional Facilities will be constructed utilizing conventional methods similar to systems established at Fermilab for the near-surface structures. The architectural features of the Near Site Conventional Facilities will include three surface or near-surface buildings:

- Primary Beam Service Building (LBNE 5)
- Target Hall Complex (LBNE 20)
- Absorber Service Building (LBNE 30)

The Primary Beam Service Building and the Absorber Service Building will be constructed as a braced-frame, steel and concrete construction with prefinished metal siding. The construction type and style will be consistent with similar adjacent facilities on the Fermilab campus. The Target Complex support service rooms will be constructed of pre-cast and cast-in-place concrete and braced-frame, steel construction with prefinished metal siding as well as natural concrete finish. A Project-specific style of architecture will be developed to unify and mitigate the presence of new buildings upon the surrounding environment.

The applicable requirements of the Uniform Federal Accessibility Standards (UFAS), Americans with Disabilities Act (ADA) and the Americans with Disabilities Act Accessibility Guidelines (ADAAG) will be incorporated into the design of this project. Compliance with the ADA will be based upon an evaluation of the job descriptions and required tasks for the personnel assigned to work in these surface buildings and underground facilities. Those areas of the buildings and underground facilities that will require accessibility as well as the established routes to those areas will be designed in full compliance with the existing statutes.

3.1.2 Structural and Excavation for Underground Structures

The construction systems for the underground portion of the LBNE Conventional Facilities will be constructed utilizing conventional underground excavation methods.

Most of the below-grade facilities to be built will be constructed using standard open cut methods. This includes much of the Beamline Extraction Enclosure and Primary Beam Enclosure, the Target Complex, the Decay Pipe, and the Absorber Hall. However, some of the Primary Beam Enclosure and all of the Target Complex will be constructed in an embankment constructed of engineered fill that reaches a maximum height of about 58 ft above existing grade. The toe of the embankment is shown as a red dashed line in Figure 3-1. The extent and height of the embankment will cause consolidation (settlement) of native in situ soils resulting in potential adverse impacts to existing facilities including the Main Injector. Figure 3-1 also shows the locations, limits, and types of braced excavation and retaining wall systems that are planned to provide protection of the Main Injector. Because of the consolidation of in situ soils caused by the embankment most of the Primary Beam Enclosure and a portion of the Target Hall Complex will be supported using drilled shaft foundations which are described in greater detail in Chapter 4.

The Decay Pipe and the Absorber Hall will be constructed using open cut methods requiring excavation down to, and into, the bedrock underlying the project site. Open cuts will be as deep and about 70 feet in soil and another 25 feet or so in rock. Rock will be excavated using quarry type drill and blast techniques. All structures will be covered with the required minimum 23 ft of earth shielding above and around all beamline enclosures.

Rock support of excavations in rock will be provided by rock bolts or rock dowels. Shotcrete will be applied to exposed rock faces. A portion of the Absorber Hall will be excavated in rock.

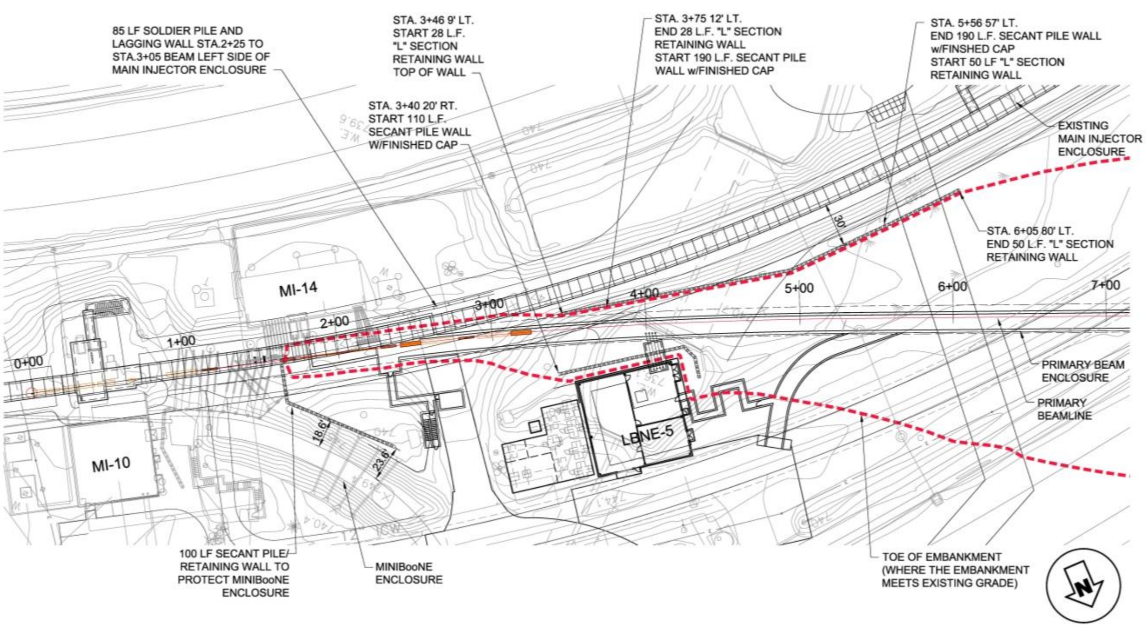

Figure 3-1: Braced Excavation and Retaining Wall Systems with red dashed line showing the toe of the embankment.

3.1.3 Environmental Protection

The overall environmental impact of this Project will be evaluated and reviewed as required to conform to applicable portions of the National Environmental Policy Act (NEPA). All required permits will be obtained prior to the start of construction. During the upcoming Preliminary Design phase of the Project, environmental consultants will locate and define the limits of all areas impacted by the project including wetland areas, floodplain and storm water management areas, sites of archaeological concern, and any other ecological resource areas. They will then assist the Fermilab NEPA Program Manager and DOE in the preparation of an Environmental Assessment.

A wetland delineation and wetland study has been conducted in areas that are anticipated to be disturbed by LBNE construction activities. The *Wetland Report* was prepared by Patrick Engineering, Inc., in August 2010 [**8**]. The Wetland Delineation, Floodplain, and Cultural Resources Map, (see Figure 3-2) show that limited wetlands, and floodplain, as well as two archaeological sites that may be encountered in the area of LBNE 20, LBNE 30, and possibly other areas. Every effort will be made to avoid, minimize, and/or mitigate disturbance to the two archaeological sites; potential impacts will be evaluated during the NEPA process.

In compliance with U.S. Army Corp of Engineers requirements, LBNE must mitigate the disturbance of wetland areas caused by construction activities. To mitigate impacts, LBNE intends to purchase wetland credits from a wetland bank. The number of credits to be purchased will be based on the area and quality of wetland acres disturbed.

Any volume of the floodplain along the Project alignment that may require filling, notably at and near the LBNE 20 site and along the shielding embankment over the Primary Beam Enclosure, will be delineated and the required compensatory floodplain storage volume will be designed and constructed according to FEMA regulations.

Every effort will be made to pursue pollution prevention opportunities. Pollution prevention (source reduction) is recognized as a good business practice that also enhances site operations. Pursuing pollution prevention enables Fermilab to accomplish its mission of achieving environmental compliance, reducing risks to health and the environment, and preventing/minimizing future DOE legacy environmental issues.

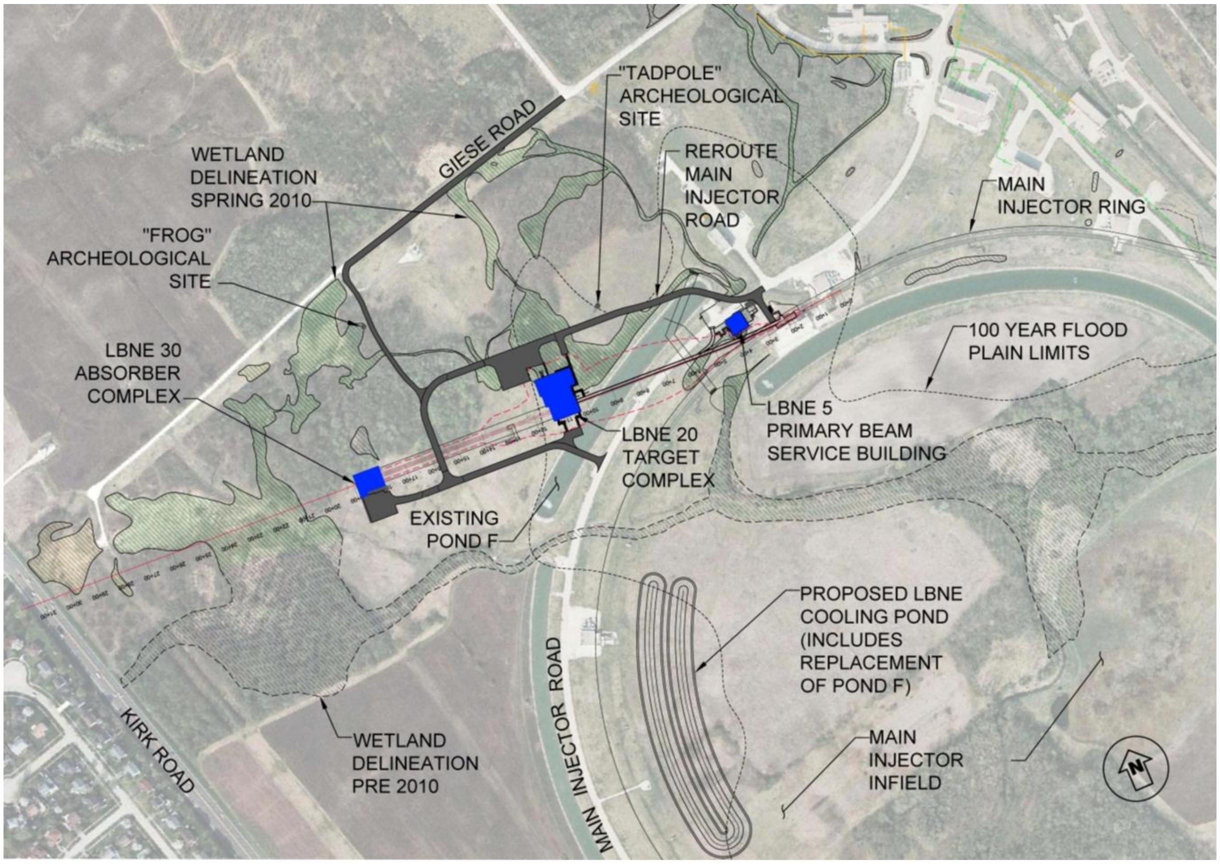

Figure 3-2: Wetland Delineation, Floodplain, and Cultural Resource Map.

3.1.4 Fire Protection / Life Safety Systems

A Fire Protection-Life Safety (FLS) Assessment/Report was completed by Aon/Shirmer Fire Protection Engineering Corp. for the LBNE Project [**9**].

Consistent with the FLS report, facility access and egress will be designed and provided in accordance with all applicable National Fire Protection Association (NFPA) Life Safety Codes and Standards including NFPA 520: *Standard on Subterranean Spaces*, which requires adequate egress in the event of an emergency. Egress paths for surface (service buildings) and underground facilities (tunnels and halls) have been conceptually designed to limit the travel paths to egress shafts, stairways, and safe/fire rated corridors to the exterior and surface to a safe gathering location. The specific egress routes are described in Chapter 5.

Facility fire detection and suppression systems, as well as personnel occupancy requirements, will be defined in accordance with NFPA 101: Life Safety Code. Fire alarm systems will be designed with a minimum standby power (battery) capacity. These batteries will be capable of maintaining the entire system in a non-alarm condition for 24 hours, and to 15 minutes in full-load alarm condition. Fire alarm/fire suppression systems for the LBNE Conventional Facilities will be designed in accordance with the applicable sections of the Fermilab Engineering Standards Manual which requires that facilities be equipped with a hard-wired, zoned, general evacuation fire alarm system that also includes:

- Manual fire alarm stations at the building exits
- Sprinkler system water flow and valve supervisory devices
- Combination fire alarm horn/strobe located throughout the building
- A 24-V hard-wire extension from the existing control panel
- Connection to the site-wide Facilities Information Reporting Utility System (FIRUS) monitoring system
- Smoke detection and line type heat detection as required.

Automatic sprinkler systems will be designed to a minimum of an Ordinary Hazard Group 1 classification, in accordance with NFPA's latest edition. The NFPA design and construction standards to be used relative to fire alarm systems are referenced in the LBNE Requirements Document [**10**].

3.1.5 Safeguards and Securities

Direction for security issues related to the design of this Project is taken from the current operating procedures for the Fermilab site.

Service buildings and facilities will be accessible to required Fermilab personnel and contractors during normal work hours. Access to the controlled areas during normal working hours will be controlled internally by the appropriate technical division occupants of each respective building or underground enclosure.

During non-working hours when the buildings and facilities are unoccupied, all exterior roll-up and personnel access doors into the buildings and facilities will be locked. Security card access will be installed in buildings to allow access during non-working hours.

3.1.6 Emergency Shelter Provisions

Required provision for occupant protection in the event of tornadoes or other extreme weather conditions will be incorporated into the design of the service buildings. Guidelines established by the Federal Emergency Management Agency (FEMA) in publications TR-83A and TR-83B and referenced in Section 0111-2.5, DOE 6430.1A, will be used to assess the design of the buildings to insure safe areas within the buildings for the protection of the occupants. These protected areas will also serve as dual-purpose spaces with regard to protection during a national emergency in accordance with the direction given in Section 0110-10, DOE 6430.1A.

FEMA guidelines indicate that protected areas are:

- on the lowest floor of a surface building
- in an interior space, avoiding spaces with glass partitions
- areas with short spans of the floor or roof structure are best; small rooms are usually safe, large rooms are to be avoided.

3.1.7 Energy Conservation

Early 2012, in a position paper titled "Fermilab Strategy for Sustainability," the likelihood of attaining the LEED Gold certification for LBNE facilities was discussed. The context for that analysis was the requirement by DOE that all new buildings and major building modification over $5M must obtain LEED Gold certification from the U.S. Green Building Council (USGBC). That paper was written in part to support a Fermilab request to DOE for an exemption from the LEED Gold requirement for LBNE. The LEED Gold requirement was first articulated in a memo by then-Secretary Samuel Bodman on February 29, 2008, and was subsequently incorporated into DOE's Strategic Sustainability Performance Plans (SSPPs) for 2011 and 2012.

In April, 2012, it was determined by DOE that the "Bodman memo" had, in fact, been rescinded, and DOE removed the LEED Gold requirement for new projects. The 2013 SSPP does not include any LEED requirements, but relies on all new construction meeting the federal Guiding Principles (GP) for High Performance and Sustainable Buildings. The GP were first officially articulated in the 2006 Federal Leadership in High Performance and Sustainable Buildings interdepartmental MOU, which was signed by 20 federal departments. The five GP are as follows:

1. Employ Integrated Assessment, Operation, and Management Principles
2. Optimize Energy Performance
3. Protect and Conserve Water
4. Enhance Indoor Environmental Quality
5. Reduce Environmental Impact of Materials

These GP were included explicitly in Executive Orders 13423 and 13514, then in DOE Order 430.2B and its replacement, DOE Order 436.1. Each of the five GP has a set of specifically required goals intended to implement it. There are 34 such specific and mandatory goals. The GP can be found in detail at http://www.wbdg.org/references/fhpsb_new.php. Compliance with the GP appears to be the main formal requirement for demonstrating sustainability in new construction projects. Sustainability is also a prominent goal in DOE Order 413.3B, however, the means of achieving the goal is less prescriptive and formal in DOE Order 413.3B than what is required by the Guiding Principles. DOE 413.3B requires only that a Sustainability Plan appropriate to the project be developed and implemented. It does not dictate means and/or methods.

Efforts to apply the GP and develop a Sustainability Plan for the project should complement each other. Both processes will be informed by widely available resources. In making the argument that LEED certification for LBNE is unrealistic, we have committed to the use of LEED concepts and principles to inform decisions about sustainable design, but to avoid confusion, it may be preferable to avoid the term "LEED" altogether and say that we will use USGBC as a resource. There are numerous other resources for sustainable design available to Fermilab, including for example, "Laboratories for the 21st Century" or Labs21, which was developed by DOE and USEPA. It has the virtue of being aimed specifically at buildings that use higher than average amounts of energy. Unlike LEED and USGBC, Labs21 is not in the business of certification. It is mostly a clearinghouse for all sorts of technical guides relating to designing more efficient buildings. Several DOE sites already rely on Labs21 for performance benchmarking.

The LBNE Project has already begun evaluating LBNE facilities using the Guiding Principles criteria, and we have provisionally taken credit for 11 of the 34 total required items, based on the near site. The requirements in the Guiding Principles (GP) are more policy/process oriented, whereas the LEED credits are more building/site oriented. For the near site, we believe that LBNE can eventually meet almost 50% of the GP requirements simply by citing Fermilab-level policies, or overall Lab performance. Of the remaining individual requirements of the Guiding Principles, almost all of them are easily incorporated into the design of the project. Examples are the use of water conserving fixtures, energy efficient lighting, metering, and using materials with recycled and/or bio-based content.

The most difficult of the individual requirements to comply with is to reduce the energy use by 30% relative to the baseline building performance prescribed by the ASHRAE 90.1-2007 standard. This goal originates in the Energy Policy Act (EPAct) of 2005 and the Energy Independence and Security Act (EISA) of 2007. This goal becomes particularly difficult for the types of facilities, i.e. unconventional, high energy using, that Fermilab typically builds.

LBNE confirms the commitment to meet as many of the GP requirements as is reasonably feasible, recognizing that compliance in many of the planned facilities LBNE is designing may not be straightforward. In these cases LBNE will take every opportunity to inform our design decisions by taking advantage of resources such as the USGBC, and Labs21.

3.1.8 DOE Space Allocation

The elimination of excess facility capacity is an ongoing effort at all DOE programs. Eliminating excess facilities (buildings) to offset new building construction (on a building square foot basis) frees up future budget resources for maintaining and recapitalizing DOE’s remaining facilities.

The LBNE Near Site project has obtained a DOE Space Allocation/Space Bank waiver, which assigns elimination of excess facilities capacity elsewhere in DOE labs to offset the new LBNE building square footage. The LBNE Project waiver covers up to 142,000 gross square feet (gsf). The Near Site portion of the Project, as defined by the Conceptual Design, includes a total of 48,200 gsf including underground and surface facilities.

See the LBNE Space Bank Waiver Correspondence [**11**] and related DOE policies and procedures.

3.2 Project Site Infrastructure (WBS 130.06.02.05.02)

The locations of the six Near Site Conventional Facility components define the LBNE Conventional Facilities at the Near Site. Facility locations were selected based on the programmatic requirement for extracting beam from the existing Main Injector near MI-10 and the planned location of the Far Detector. A significant portion of the Project site infrastructure is provided for the benefit of the entire Project and is not provided in response to a requirement of a specific site address, such as LBNE 20. This section describes Project site infrastructure systems that apply Project-wide.

The scope of the LBNE Conventional Facilities will include the work required to provide Project site road access and the creation of hardstands, parking areas and site restoration. Also included is the extension of the utilities to the Project site.

3.2.1 Roads and Infrastructure

The existing Giese Road will be improved and extended to provide access to the Main Injector Road reroute to access LBNE 20 and LBNE 30 from the north. The road will be constructed according to the standards for all Fermilab roads and will be suitable for all-weather and emergency access during construction and Project beamline operations. AASHTO HS20-44 highway standard loading will be incorporated into the design.

Parking and staging areas will be incorporated into the design of each surface building. Designs will provide for the operation phase, with parking and hardstand requirements for construction and installation designed to be temporary. It is anticipated that most of the scientific components will be manufactured elsewhere and delivered on a just-in-time delivery basis.

As part of the civil work, the existing Main Injector Cooling Pond F and associated infrastructure will be entirely removed/filled-in to create space required for the embankment and the Target Complex (LBNE 20). A new cooling pond will be designed and reconstructed, along with the additional Project-required cooling capacity, in the infield of the Main Injector. Any compensatory floodplain storage volume that is required due to filling in the floodplain, for site grading and drainage, will be mitigated (reconstructed) in the infield of the Main Injector or near LBNE 30.

3.2.2 Electrical

Fermilab is supplied electrical power through the northern Illinois bulk power transmission system that is operated by a local investor-owned utility. The site interconnects with the bulk transmission system at two locations. Service connections, at 345 kV voltage, are made to one of two transmission lines at each location. At the interconnection sites, Fermilab takes power and delivers it along Fermilab owned and operated transmission lines to two separate electrical substations where it is transformed to 13.8 kV for site-wide distribution.

Fermilab maintains two separate types of power systems, pulsed power and conventional power. The technical systems pulsed power loads are large and can cause power quality issues for the conventional facilities if interconnected. Therefore two separate systems are maintained. The electrical systems located throughout the LBNE Project will conform to the National Electric Code (NEC) and applicable sections of the Fermilab Engineering Standards Manual.

The electrical power requirements for the LBNE Project are significant and will require the extension and expansion of the existing 13.8-kV electric distribution facilities. The improvements include electrical substation modifications, the extension of existing 13.8-kV distribution feeders from a nearby feeder for pulsed power and the expansion of Kautz Road substation for the conventional power. The LBNE Project will also require the relocation of the existing electrical power ductbank system around the proposed facilities. Existing ductbanks will be rerouted along the proposed roadways to the LBNE facilities and continue to reconnect to the existing ductbanks to maintain the existing infrastructure.

Figure 3-3 shows the proposed project electrical power routing plan for both pulsed and conventional power. Figure 3-4 shows the location of MI power systems duct bank and feeders, both pulsed and conventional, that will need to be removed and rerouted around the proposed facilities and embankment due to the embankment fill as well as other LBNE facilities interferences and conflicts.

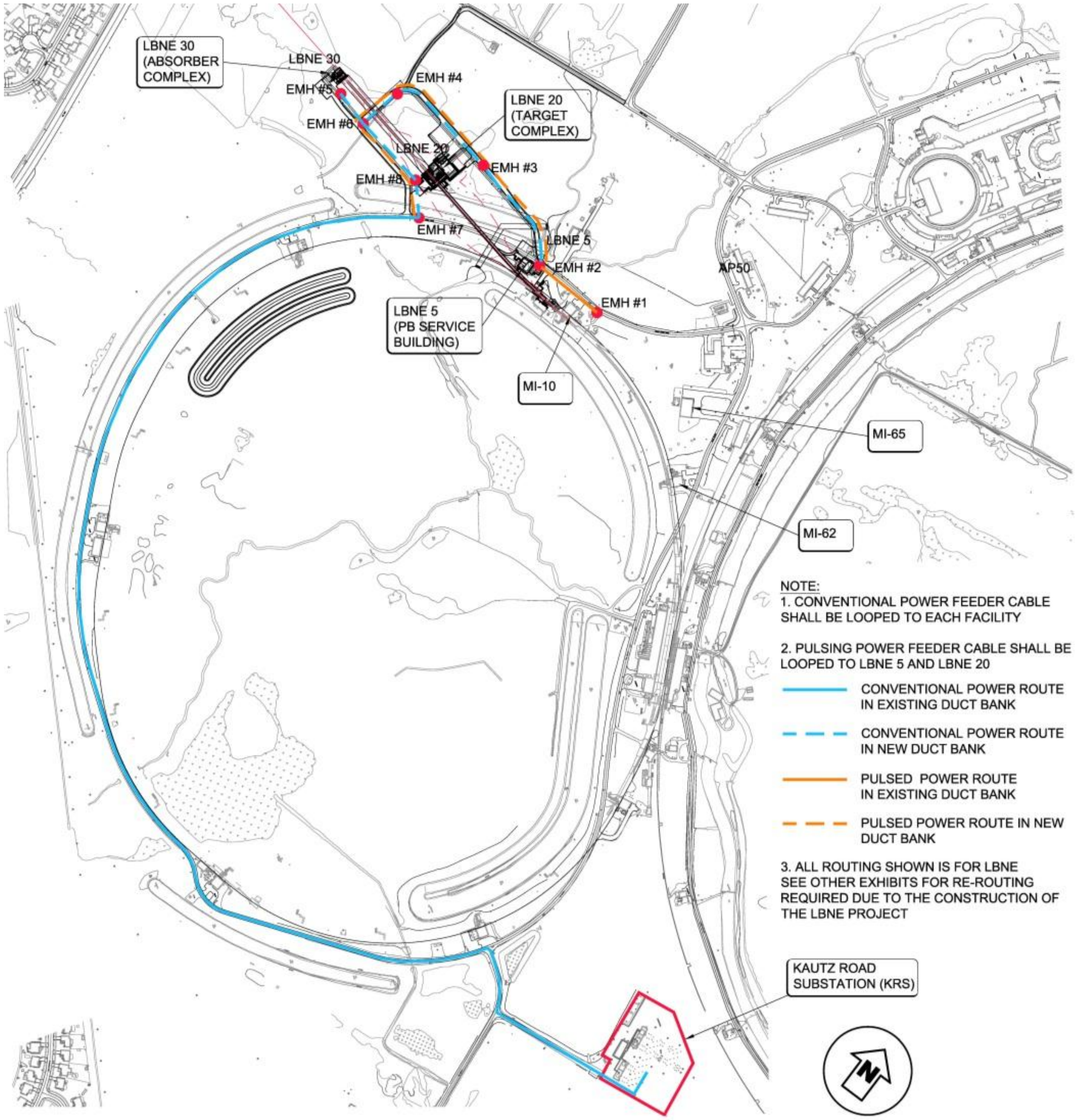

Figure 3-3: Electrical Power Routing Plan.

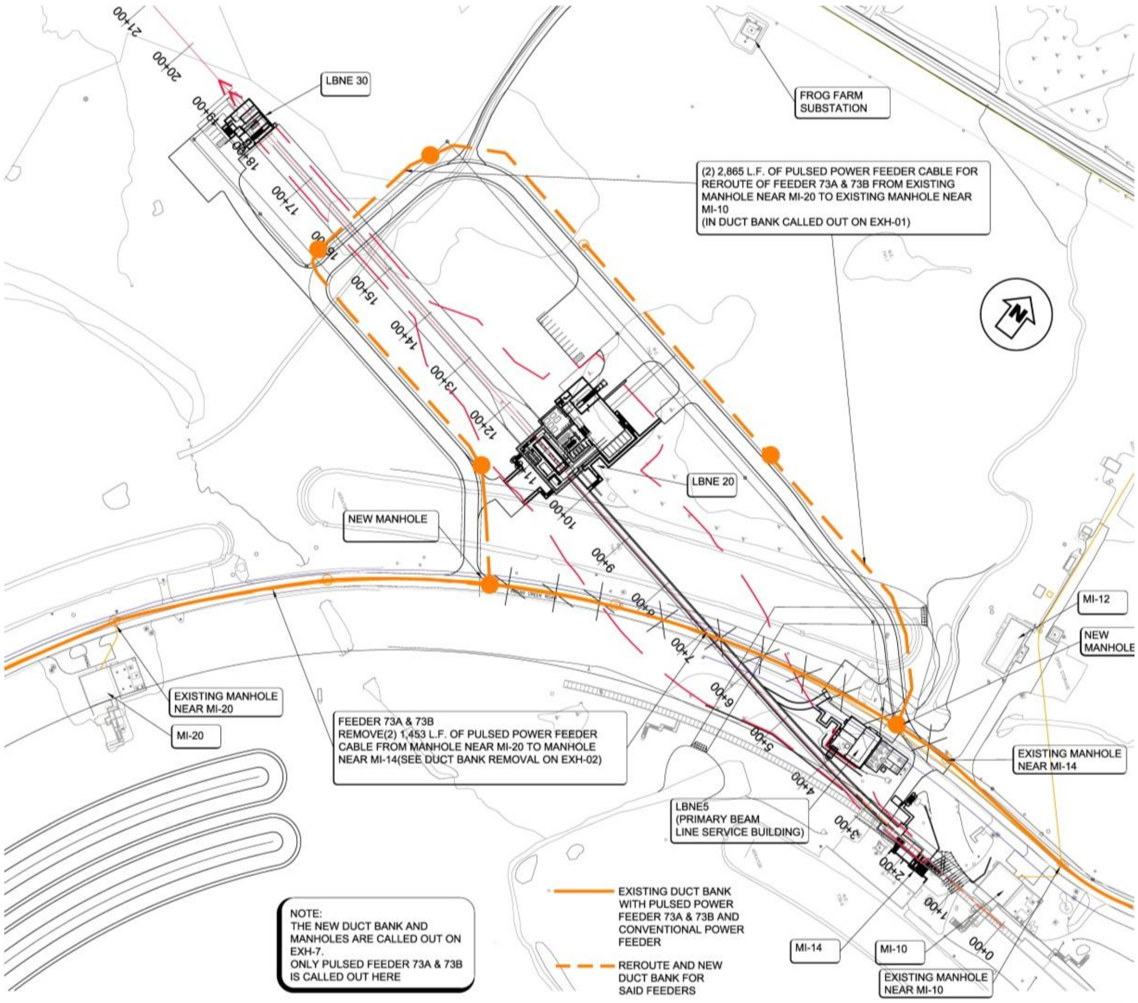

Figure 3-4: Rerouting of Existing Power System Ductbank.

3.2.2.1 Pulsed Power System

The pulsed power system for LBNE will be served from the existing Kautz Road substation, feeder 96/97 at 13.8 kV. The pulsed power system requires a harmonic filter to maintain power quality. The existing feeder 96/97 is connected to a harmonic filter at the Kautz Road substation.

The feeder system from the substation to the LBNE Project will be provided by connecting to an existing pulsed power feeder that is currently serving the Main Injector. The feeder is configured as a loop for operational flexibility. The LBNE pulsed power services to LBNE 5 and LBNE 20 will be inserted into the loop, maintaining the configuration.

Sectionalizing switches, 13.8 kV, 600 A, will be installed at various locations along the feeder route. A switch will be installed at each location where pulsed power is required. The switches will serve to provide operational flexibility in load and fault isolation.

Pulsed power service at LBNE 5 and LBNE 20 will be routed to a 13.8-kV site switch. Each site will have an interconnection for transformers to the 13.8-kV pulsed power system. The remainder of the electrical equipment for service from the substation into the buildings will be provided by the Beamline Level 2 Project. The Conventional Facility scope of work will prepare each site by installing concrete pads and conduits for the equipment installation by the Beamline Level 2 Project.

3.2.2.2 Conventional Power System

The conventional power system for LBNE will be served from Kautz Road substation at 13.8 kV where two new feeders will be constructed. The feeder equipment will include the cable and a new 13.8-kV Kautz Road substation circuit breaker. The feeder system from the Kautz Road substation to the LBNE Project will be provided by installing the new underground feeder cables in existing spare ductbank. The feeder will be constructed in a looped configuration to enable cable segment isolation, fault clearing and service restoration without cable repair or replacement and extended service outage.

Sectionalizing switches, 13.8 kV, 600 A, will be installed at various locations along the feeder route. A switch will be installed at each location that conventional power is required. The switches will serve to provide operational flexibility in load and fault isolation.

Conventional power service is required at the three sites, LBNE 5, LBNE 20, and LBNE 30. The 13.8-kV feeder will be routed to each site sectionalizing switch. The switches will serve primary electrical power to the site conventional service 750-kVA transformer. Each site will be provided with fully constructed electrical service to the buildings. Secondary conductors from the transformer will be constructed at each building and will terminate at the main service electrical panelboard.

3.2.3 Mechanical and HVAC

The heating, ventilation and air conditioning (HVAC) systems located throughout the LBNE Project will conform to ASHRAE 90.1, ASHRAE 62, applicable NFPA requirements and applicable sections of the Fermilab Engineering Standards Manual. The design parameters for the general HVAC are summarized below:

- Air conditioned facilities will be maintained between 68° to 78°F.
- The relative humidity in air conditioned spaces will be maintained below 50%. There is no minimum requirement.
- Ventilated spaces will be maintained at maximum approximately 10ºF above ambient.
- HVAC for the Target Chase, Target Hall, Decay Pipe and Absorber Hall are specially designed systems that are detailed in other sections of this document.

All HVAC systems will be design and installed with Metasys automated building controls capable of local and remote monitoring, control and operation optimization. Direct Digital Controls will be further investigated during subsequent phases in accordance with the applicable codes and Federal life cycle costing analysis.

3.2.4 Plumbing and Cooling Systems

The industrial cooling water (ICW), domestic water service (DWS) and sanitary sewer and other related utility services for the Project will be extended from existing services found along the Main Injector Road utility corridor to LBNE 5, the Target Complex and the Absorber Hall at LBNE 30. All domestic plumbing work will be installed in accordance with the Illinois Plumbing Code and Standard Specifications for Water and Sewer Main Construction in Illinois, and applicable sections of the Fermilab Engineering Standards Manual.

Details of the anticipated utility work are listed below:

- ICW will be used for fire protection in the sprinkler systems.
- An adequate supply of drinking water is available through an existing DWS supply line in the MI area for LBNE 20 and LBNE 30.
- The connection to the Sanitary Sewer service will be extended from existing Fermilab system for buildings LBNE 20 and LBNE 30.
- Adequate cooling capacity for the LCW system required for the beamline magnets and power supplies will be provided at LBNE 5 through heat rejection to the Cooling Pond Water (CPW) system. The design, procurement and installation of the LCW system itself are included in the Beamline Level 2 Project.

3.2.5 Data and Communications

The existing Fermilab data, telephone communications and controls network will be extended from existing sources at the MI-8 service building to the LBNE 5, Target Complex (LBNE 20), and Absorber Hall (LBNE 30), to provide normal telecommunication and controls communication support to the new LBNE facilities. Connections will be included in the form of new stub-ups for future expansion of the existing fiber network. The existing duct bank network and proposed extensions are shown as green in Figure 3-5. The required communications ductwork and manholes will be designed, estimated and constructed as part of the conventional facility portion of the Project. The Conventional Facilities work will also include supplying and installing (pulling and connecting) the required fiber-optic lines.

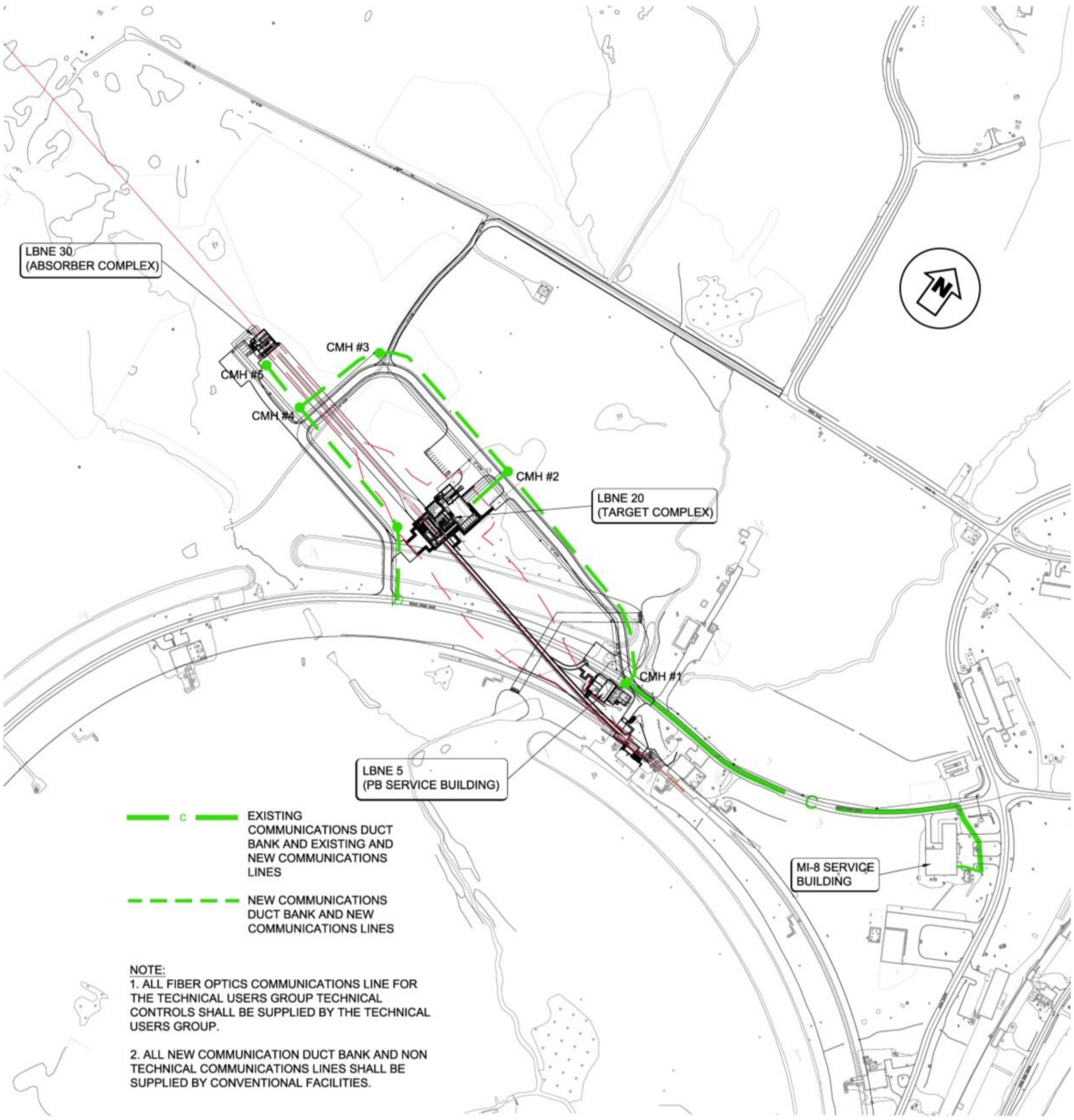

Figure 3-5: LBNE Communications Routing Plan.

4 New Surface Buildings

The LBNE Conventional Facilities on the Near Site will include surface buildings at LBNE 5, and LBNE 30. A near-surface, shallow, buried structure will be located in an embankment constructed of engineered fill at LBNE 20. This section provides additional details regarding these surface based structures.

4.1 Primary Beam Service Building (LBNE 5) (WBS 130.06.02.05.03.01)

One of three at-grade service buildings is the Primary Beam Service Building (LBNE 5). A facility layout and floor plan of LBNE 5 is shown in Figure 4-1. The function of LBNE 5 is to provide housing for primary beam support equipment and utilities, and access for personnel and light equipment to the Primary Beam Enclosure below. This single-story, steel-framed, metal-sided service building will have approximately 3,600 sf of floor space (60 ft by 60 ft), with a minimum 12-ft interior clear height. The building will be positioned off center and right of the beamline and will have a corridor (conduits, Gerardi Coffin, and penetrations) for technical and conventional utilities routing to the Primary Beam Enclosure. The Gerardi Coffin is a near surface cast in place concrete vault that serves as a routing corridor for technical and conventional utility systems between the LBNE 5 Service building and the Primary Beam Enclosure. The coffin will include appropriate shielding to avoid direct "shine" into the LBNE 5 Service building and the surface.

Utilities conveyed to the Primary Beam Enclosure will consist of low conductivity water (LCW), technical (pulsed) and conventional power, and communication/control lines. Access to and egress from the Primary Beam Enclosure will be provided thru the Egress Labyrinth and Magnet Installation Tunnel as described later in this section.

Space is provided in the power supply room for installation of dipole and quadrupole power supplies within the building as well as water-cooling lines and related equipment. A pump room is provided for CPW/LCW heat exchangers, and LCW pumps; and a control room is provided for technical system controls. Electrical switchgear and power transformers will be installed on the open-equipment transformer pad adjacent to the building, as shown in Figure 4-1.

Figure 4-2 shows a detailed view of the building floor plan, the power supply room, control room, and pump room. Figure 4-3 shows the connection to the egress labyrinth and magnet installation tunnel to the Primary Beam Enclosure at the pump room. Figure 4-4 shows the location of the corridor for utilities conduits routing to/thru the Gerardi Coffin and into the Primary Beam Enclosure, as also shown in Figure 4-5 in section view.

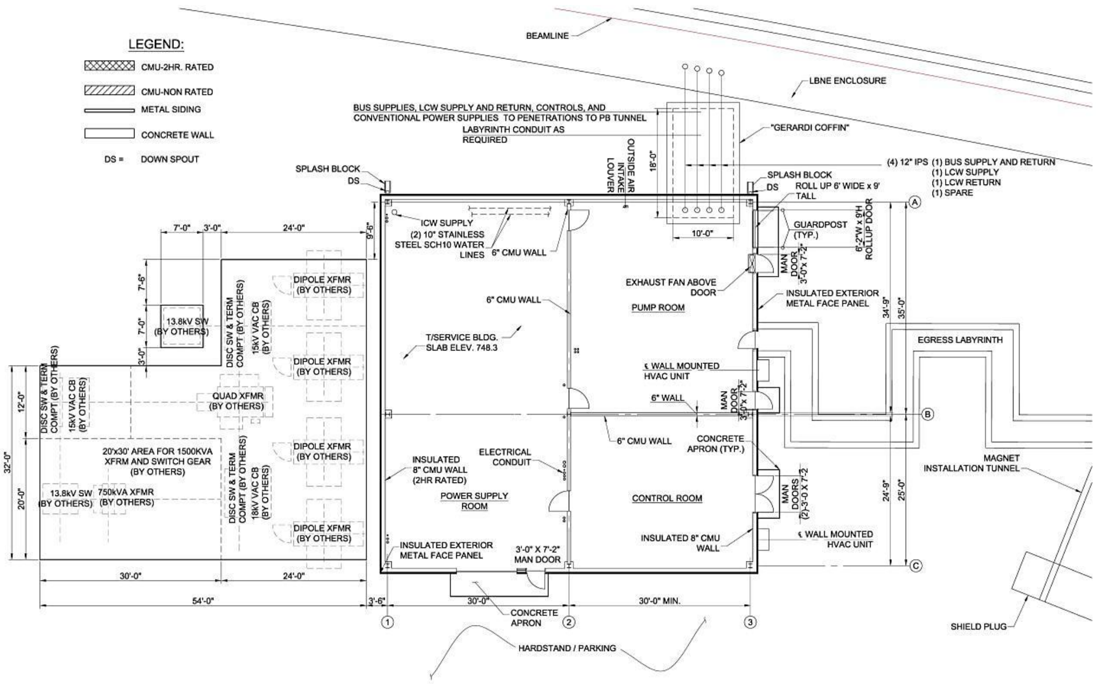

Figure 4-1: Primary Beam Service Building (LBNE 5) and Exterior Transformer Pad.

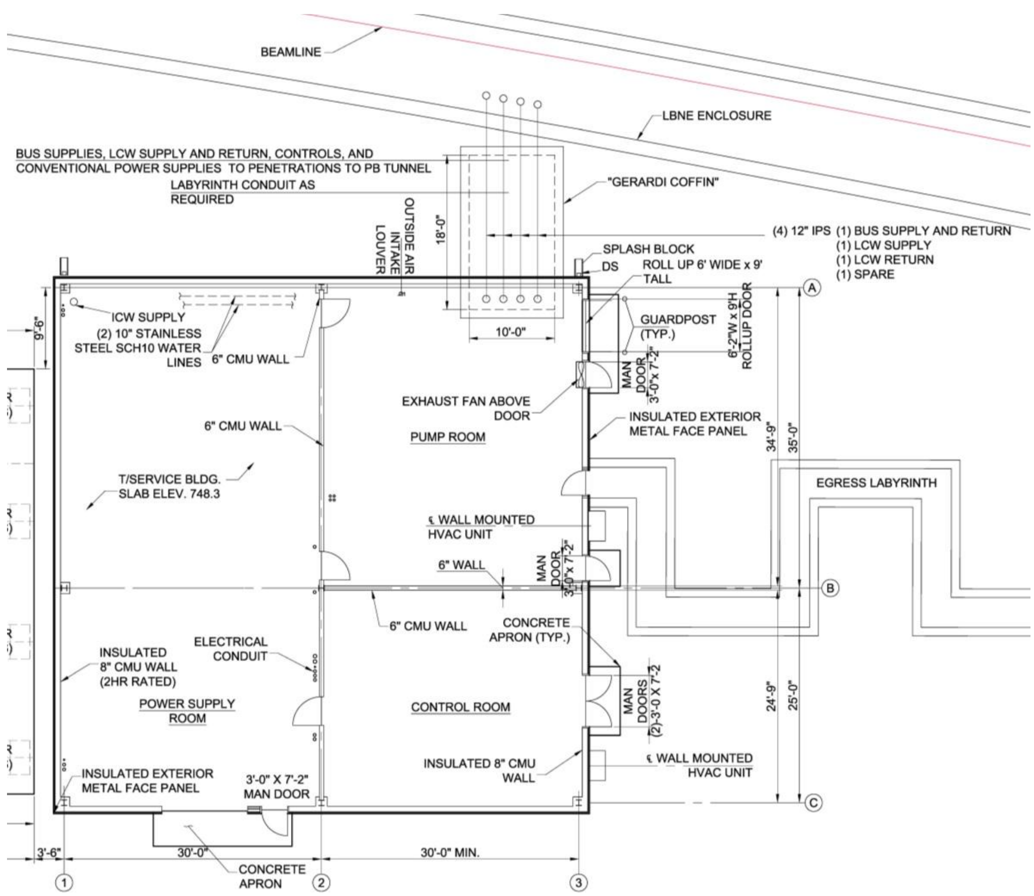

Figure 4-2: Primary Beam Service Building (LBNE 5) Floor Plan.

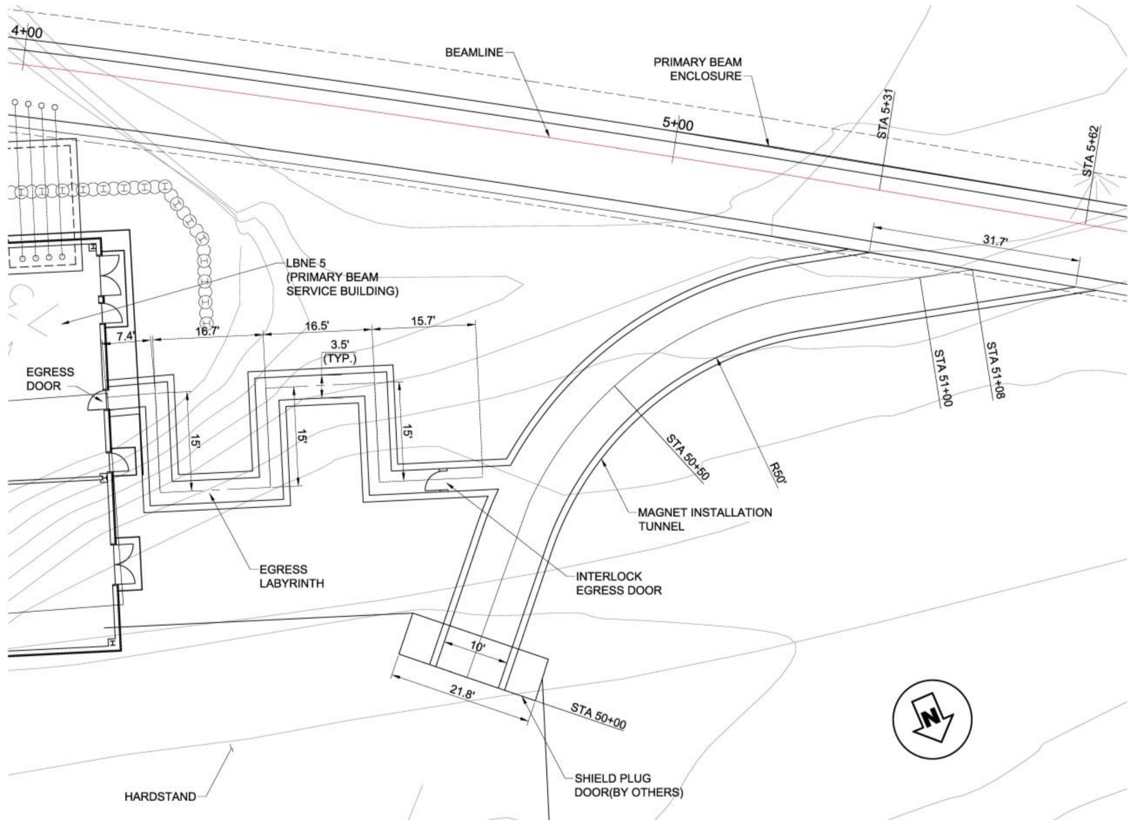

Figure 4-3: Primary Beam Service Building (LBNE 5) Egress Labyrinth.

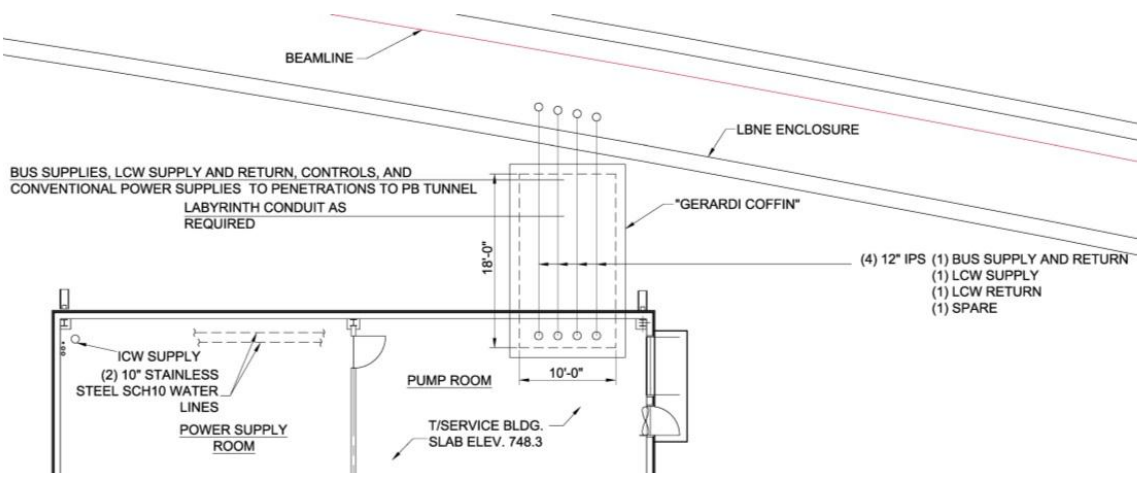

Figure 4-4: Primary Beam Service Building (LBNE 5) Corridor for Utility Penetrations.

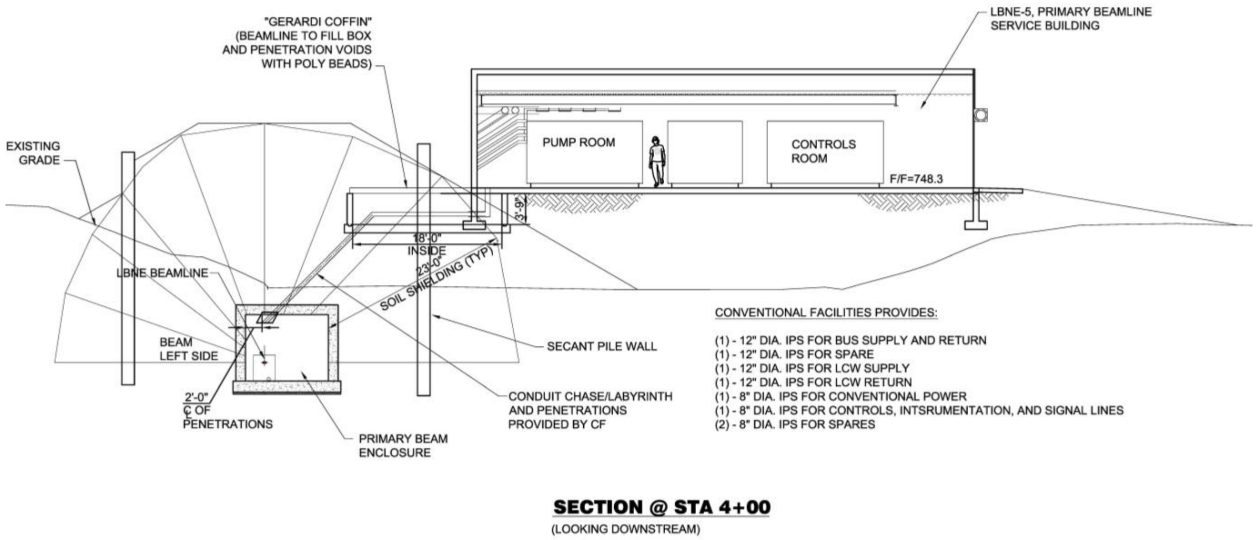

Figure 4-5: Utility Routing Between LBNE 5 and Primary Beam Enclosure.

4.1.1 Mechanical

Heat rejection for the LCW system will utilize CPW from the modified Main Injector Cooling Pond network. The building will be heated with electric unit heaters to maintain a minimum winter temperature of 68ºF. The power supply room and the pump room will be ventilated using outside air fans to maintain summer maximum temperatures of about 10ºF above ambient outdoor temperature. The electronics/control room will be cooled by wall mounted cooling units to maintain summer maximum temperatures of 78ºF. There will be no natural gas or sanitary sewer service, and restroom facilities will be available in the existing MI-12 Service Building that is located about 350 ft to the north. One of the building's roof support beams will be sized and configured to serve as a maintenance monorail for equipment removal and replacement.

4.1.2 Electrical

The electrical facilities provided at LBNE 5 will support the requirements of the Beamline in accordance with the Fermilab standards, NEC, and other applicable codes. The building site will have two separate electrical services. A conventional power system will be provided for electrical service to the building systems, lighting, HVAC, crane, miscellaneous loads, and low power technical system components such as racks and computers. A technical system power system space will be provided for electrical service to large technical systems such as beam power supplies. Conventional Facilities will provide 13.8-kV primary electrical power to outdoor switchgear and prepare a space at LBNE 5 for the technical systems transformers and components to be installed by the technical systems. An emergency/standby power system with generator will be installed to serve critical loads for life safety and technical system components.

The building will be outfitted with panelboards, lighting, power receptacles, emergency/standby power systems and HVAC components to support the requirements of the beamline. A main switchboard/panelboard will be installed to distribute power to large dedicated loads and sub-panelboards in local building and underground areas. Emergency/standby power will be provided at a dedicated emergency power panelboard.

The lighting system and the level of lighting provided shall be installed according to the lighting level required by the use of the space. All lighting installed in areas that are exposed to radiation must be protected from the radiation or be resistant to the degrading and contaminating effects of radiation on electronic components. All emergency lighting in the Primary Beam Enclosure shall be powered from a separate remote battery powered uninterruptable power supply (UPS) system that is completely isolated from sources of radiation. This system will remain operable until the standby generator is available to provide power or power is restored.

Power receptacles will be provided in the building and underground areas for use as needed during outfitting and operation. The receptacles will be configured based on site equipment standards. All loads that require emergency/standby power will be served from the dedicated panelboard. The HVAC equipment will be served from the nearest conventional power panelboard as needed.

The LBNE 5 exterior transformer cast in place concrete pad will be sized for one 4,000-kVA TeV-style power supply transformer and switchgear, one 2,000-kVA transformer with a 15-kV motor-driven switch and a 750-kVA house power transformer.

The pad and the programmatic pulsed power duct banks to the pad and from the pad into the building (below the floor) are designed and will be constructed under the Conventional Facilities scope. The technical systems transformers and power supplies are designed and constructed by the Beamline Level 2 Project scope of work.

Table 4-1 shows the PBE Service Building (LBNE 5) electrical power loads, both normal power and the standby power generators.

Table 4-1: Primary Beam Service Building (LBNE 5) Electrical Power Loads.

Equipment Description	**Normal Power (kw)**	**Standby Power Generators (kw)**
Packaged AHU	73	
Electric Heater (2 heaters/room; 3 rooms = 6 total)	210	210
Lighting & Receptacle	42	11
Pump Room Ventilating Fan (3 hp; 5,000 cfm)	3	3
Power Supply Room Ventilating Fan (5 hp; 10,000 cfm)	5	5
Total Connected Load	**229**	**124**

4.1.3 Plumbing

The Primary Beam Service Building (LBNE 5) will be equipped with a wet pipe sprinkler system served from the site-wide industrial cooling water (ICW) network that is extended to the building from the existing nearby system. There is no domestic water, sanitary sewer or natural gas services provided to this building.

4.1.4 Fire Protection/Life Safety Systems

Egress paths for surface (service buildings) and underground facilities (tunnels and halls) have been conceptually designed to limit the travel path distances to egress shafts, stairways, and safe/fire rated corridors to the exterior and surface to a safe gathering location. See Section 3.1.4 of this volume for a general overview of fire protection and fire life/safety requirements.

Conventional Facilities is responsible for the design and construction of fire/life safety systems including the mechanical (emergency ventilation), electrical (emergency generator for lighting, ventilation, sump pumping, fire alarms, and communication), and plumbing (fire suppression/sprinkler piping and fixtures, and emergency sump pumping) systems.

Emergency egress routes for the Primary Beam Service Building (LBNE 5) will allow exiting thru a choice of four single exterior doors, one exterior double door, or an overhead roll-up door. Section 5.1.4 describes the egress paths from the Primary Beam Enclosure Building.

4.2 Target Hall Complex (LBNE 20) (WBS 130.06.02.05.03.02)

The Target Complex (LBNE 20) will be a 22,200 sf near-surface facility constructed in the engineered fill embankment, that combines the Target Hall, corresponding beam-on and beam-off support rooms (power supply, piping system carrying radioactive water (RAW), and air handling rooms), and the Target Hall service rooms (a truck bay with a lay down/staging area, morgue area, mechanical/utilities rooms, and rest room). Beam-on spaces are accessible by personnel while the beam is energized, and beam-off spaces are only accessible when the beam is not energized. These support and service rooms accommodate the support equipment and utilities and provide access needed to assemble and operate the equipment and conventional and programmatic/technical components for the Target Hall.

The Target Hall, shown in Figure 4-6, is located in the center of the Target Hall Complex, with beam-on and beam-off service and support rooms adjacent on the beam right side (as one faces downstream), which is also the north side of the Target Hall.

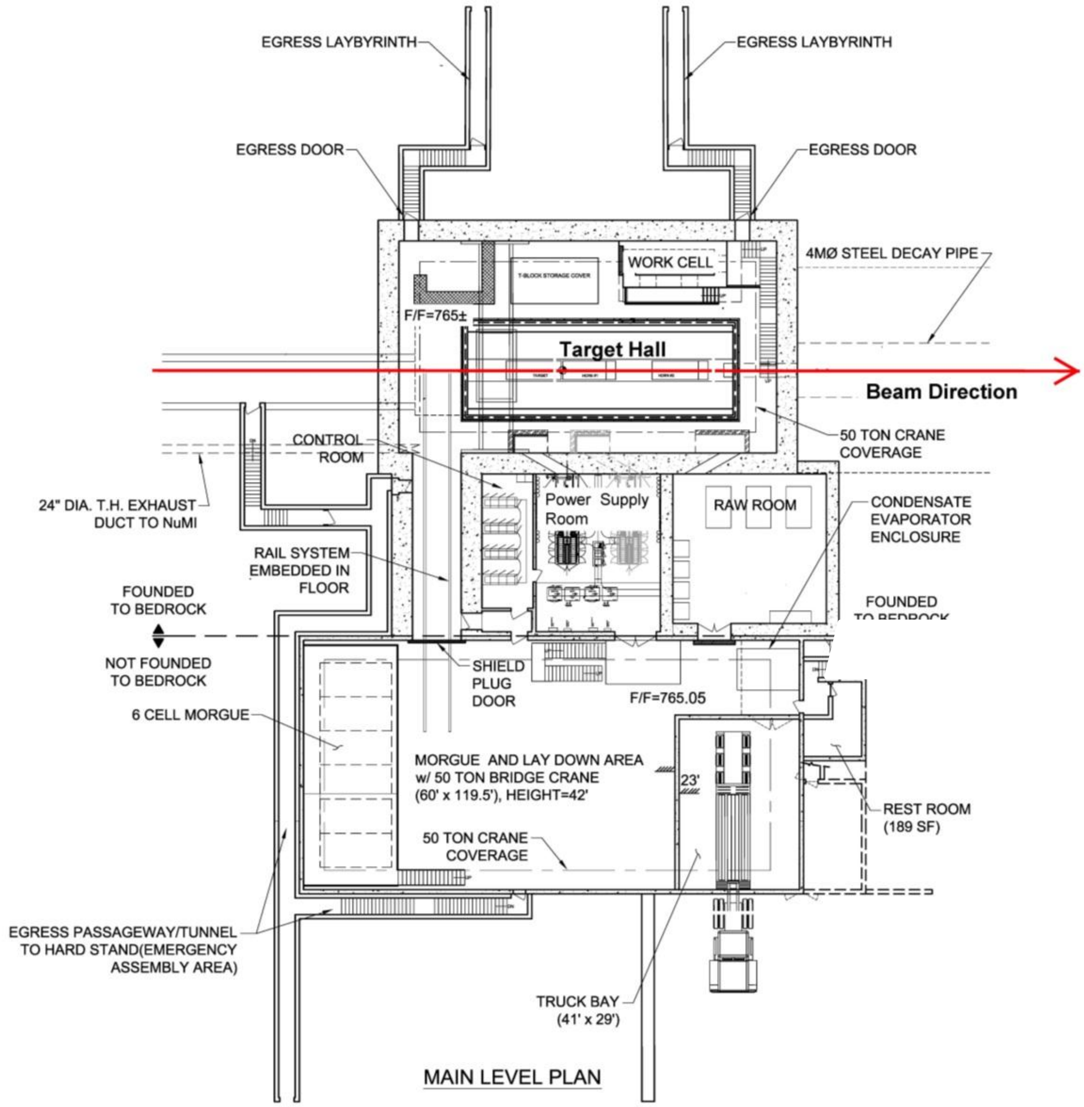

Figure 4-6: Target Complex; Main Level Floor Plan.

The Target Hall will house the target and focusing horns in a shielded target chase enclosure below the floor. The required concrete and steel shielding will be provided around these beamline target components. The Target Hall and target chase (section views shown in Figure 4-7) consist of steel shielding blocks, and the target and horns, along with the associated power feeds, cooling water channels, and gaps/spaces for air cooling. Some steel shielding blocks will be permanently cast into concrete and will be provided by the Beamline Level 2 Project, and installed by Conventional Facilities. Other shielding blocks will be moveable, and those will be provided by the Beamline Level 2 Project.

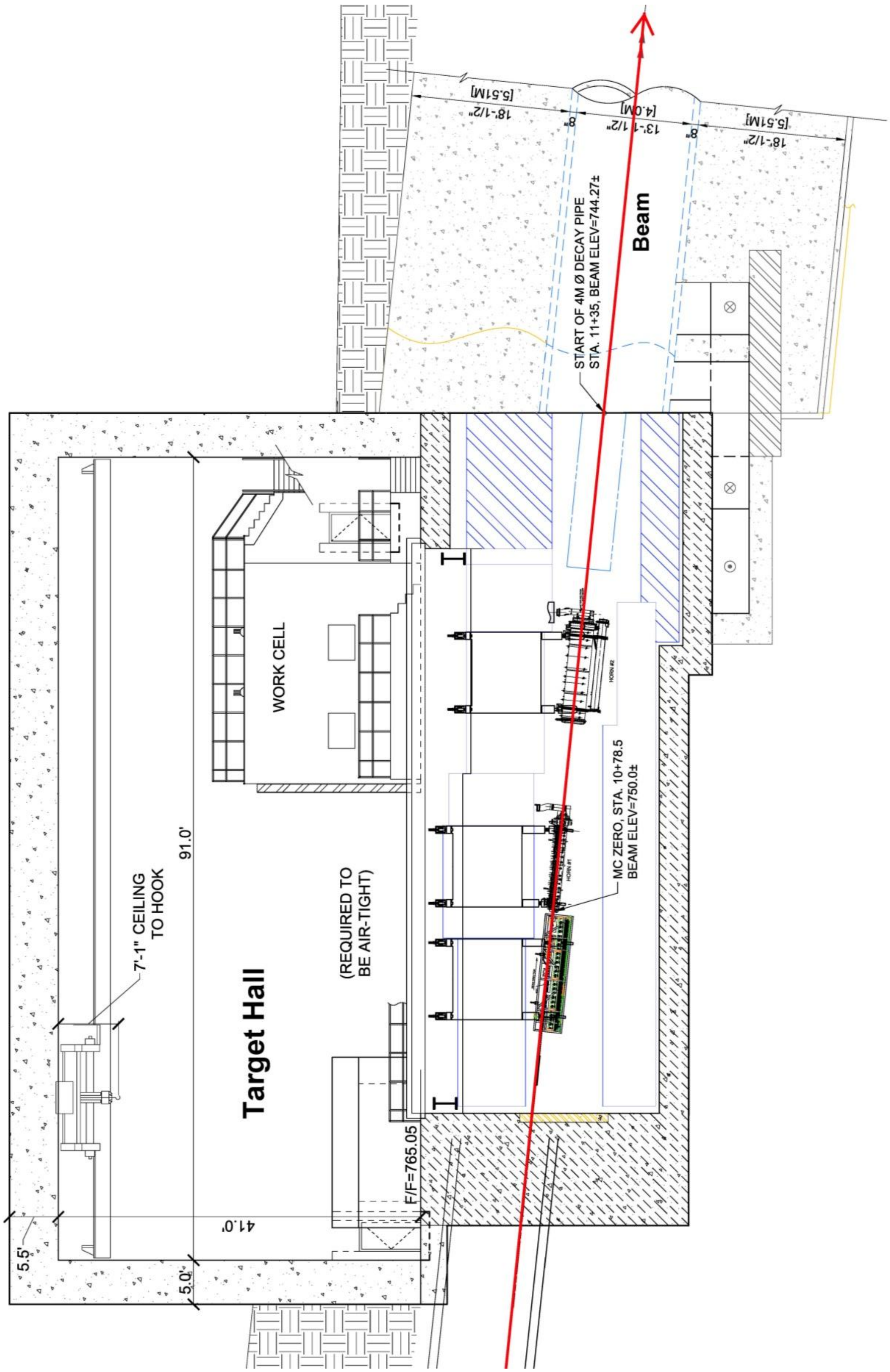

Figure 4-7: Target Hall/Chase Long Section.

The Target Hall will have a 50-ton overhead bridge crane running the length of the hall that will be used for installing and removing target modules and horn components in the chase, as well as transporting these components to the work cell. The crane will be equipped with redundant drive systems and removable remote electronics to ensure reliance during remote handling operations. This bridge crane will also be used to install, remove and reset shielding blocks, hatch covers, as well as other equipment and components.

The stand-alone cast-in-place concrete hot handling work cell (see Figure 4-8) will be shielded from the rest of the Target Hall for personnel protection and, will be used for both prepping new or refurbished target components.

This civil/conventional fit-out work will also include internal concrete masonry unit (CMU) walls, poured/cast-in-place structural concrete walls and abutments (with the required thickness for shielding), the cast-in-place work cell, doors, internal stairways, and the 50-ton overhead bridge crane in the Target Hall.

The wall and ceiling thicknesses in LBNE 20 are designed for the required beam shielding. The Target Hall, including the egress labyrinth and rail transport passageway walls will be 5-ft thick cast-in-place (CIP) structural concrete walls with a 5.5-ft thick CIP structural roof for the 700kW beam power, upgradable to 7-ft thick for a possible future upgrade to 2.3 MW. The air handing room, RAW room, and truck bay, morgue, will have 3-ft thick CIP structural concrete walls except that any portions of all rooms adjacent to the Target Hall will have 5-ft thick CIP structural concrete walls. All other rooms will have 1-ft thick CIP structural concrete walls. The Target Hall and Air Handling Room, and Decay Pipe/target chase air ducts will be lined, on the exterior, with an air seal geomembrane, as these facilities are required to be air and water tight.

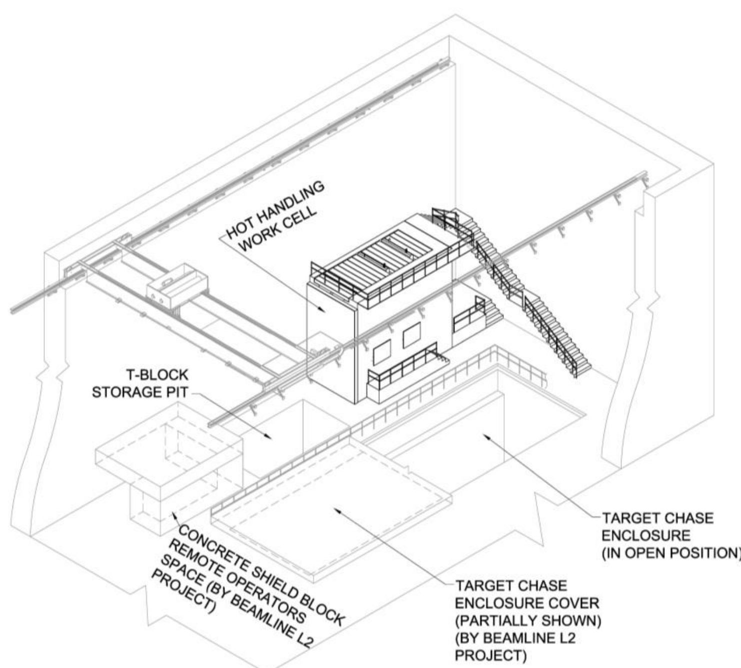

Figure 4-8: Target Hall 3-D view showing the hot handling Work Cell located in the downstream beam-left corner of the Target Hall The beamline direction is from left to right in this figure.

Adjacent to the Target Hall, on beam-right side, which is also the north side of the Target Hall (shown in Figure 4-8), on the Main Level, is the radioactive water (RAW) room, Power Supply room, Controls/Instrumentation room, and rail system egress corridor. Adjacent to these service/support rooms are the morgue/laydown area/morgue with a 50-ton bridge crane used for unloading Target Hall and target components, shielding blocks and equipment. These target components will be staged in the laydown area for eventual transport into the Target Hall using an in-the-floor rail/track system thru a shield plug door (provided by the Beamline Level 2 Project) opening during beam-off. The 50-ton bridge crane will also be used to move spent or damaged components (target modules, horns, etc.) to the 6-cell side-load morgue. This 60-ft wide by 25-ft long by 13-ft high, concrete shielded, 6-cell morgue will be used for temporary storage of hot/spent/damaged targets, horns and other components before transporting these components to a final storage facility which is not part of the LBNE Project scope. Devices removed from the Target Hall will be transported during beam-off. The laydown area will also be used to store temporary shielding blocks and related components, and will be used for Target Hall component staging. Additional spaces are provided for fixture and tool storage a shielded frisking area, and a target insert mock-up area. This area will be equipped with proper ventilation, fire protection, lighting and life safety. A restroom and the Fire/Life Safety room are also located on this Main Level.

On the Lower Level (shown in Figure 4-9), adjacent to Target Chase Enclosure, and below the RAW room and Power Supply room, is the Air Handling room. Adjacent to the Air Handling Room is the depressed Truck Dock with 50-ton bridge crane coverage.

Located on the Upper Level (shown in Figure 4-10), and above the RAW room and Power Supply room, will be the Mechanical/Electrical room, which will house the Target Complex HVAC, boiler and chiller pumps, water treatment/expansion tanks, and electrical panels and transformers.

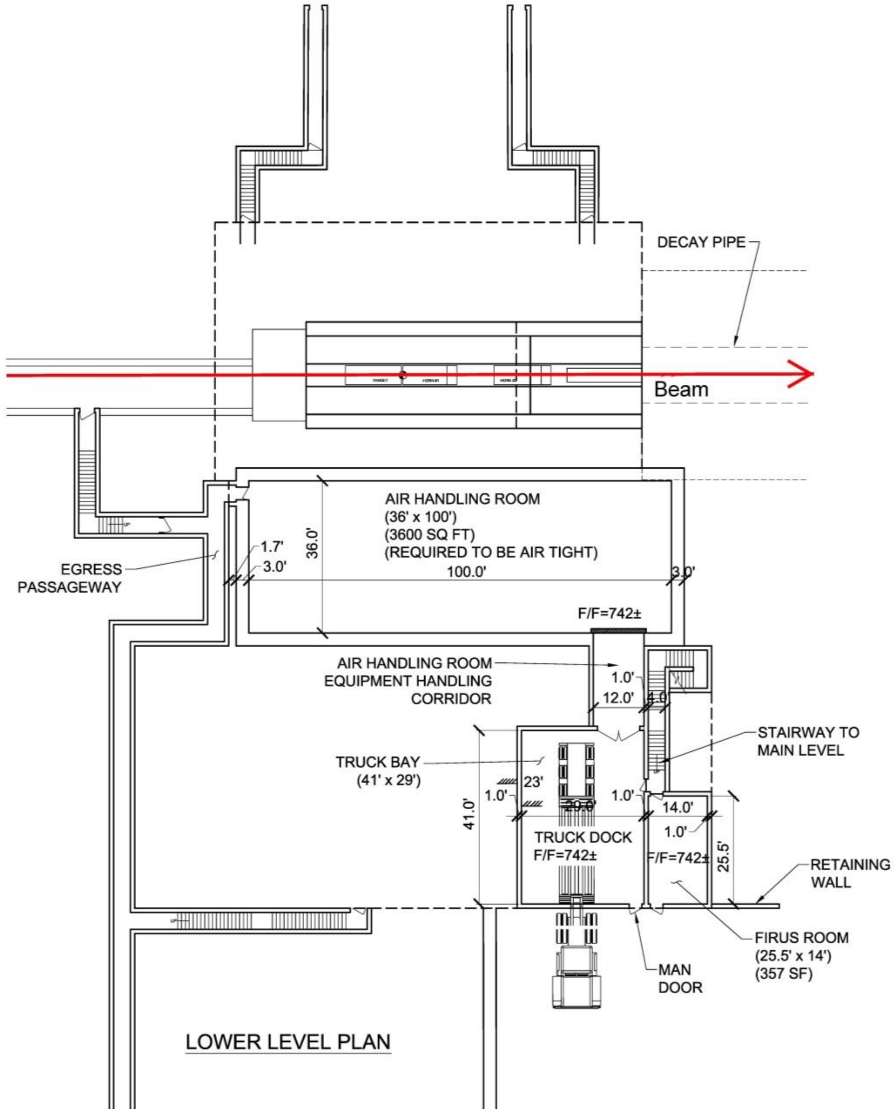

Figure 4-9: Target Complex; Lower Level Air Handling room.

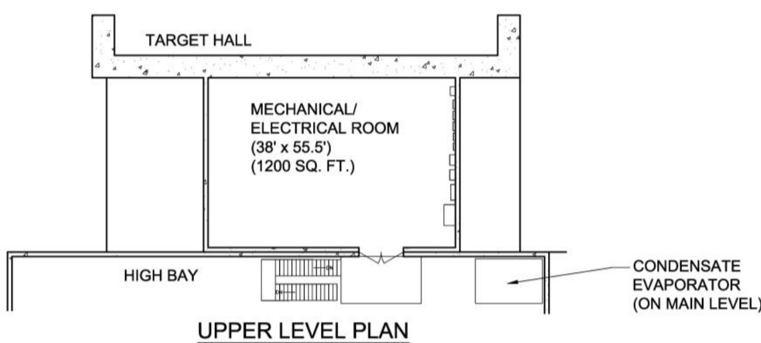

Figure 4-10: Target Complex; Upper Level, Mechanical/Electrical room.

To mitigate the impacts of settlement on the Primary Beam Enclosure and a portion of the Target Complex, 4-ft diameter drilled shafts will be constructed to support these structures. Drilled shafts will extend down to, and will bear on, the top of rock. An overall plan view of the extent of the embankment is shown in Figure 4-11, which also shows the plan view location of drilled shafts that will be constructed. Greater detail of the drilled shaft locations are provided in Figure 4-12 and Figure 4-13.

Analysis of the loading of a larger embankment than is currently planned as part of the MI-10 Beamline configuration indicated that the drilled shafts to rock that would be used to support the Primary Beam Enclosure would settle as much as 11mm in response to elastic shortening of the concrete drilled shaft caused by the settling soil transmitting friction to the drilled shafts as the embankment settles [**12**]. Analysis of the larger embankment estimated that 50% of the settlement will occur within one month of placing the embankment. Estimates include 90% of the settlement occurring within one year and 100% within two years. For these reasons, the Conventional Facilities plan is to include placement of the embankment as an early item to be constructed so that the area is preloaded to induce most settlement of underlying soils before the Beamline is constructed. Because some settlement may continue after construction of these structures, a grouting program will be established to fill the potential gap between the bottom of the structure and the embankment.

The settlement analysis work also included estimates of the impact of settlement on the Main Injector. Calculations show that about 2 mm of settlement are expected with about 1 mm of horizontal movement. For these reasons, braced excavation and retaining wall systems shown in Figure 3-1 are being provided for protection of the Main Injector. The conceptual level settlement analysis is currently being updated to include consideration of the smaller 58-ft tall embankment. During Preliminary and Final Design the settlement analysis will be re-visited again as additional Project-specific geotechnical information is developed.

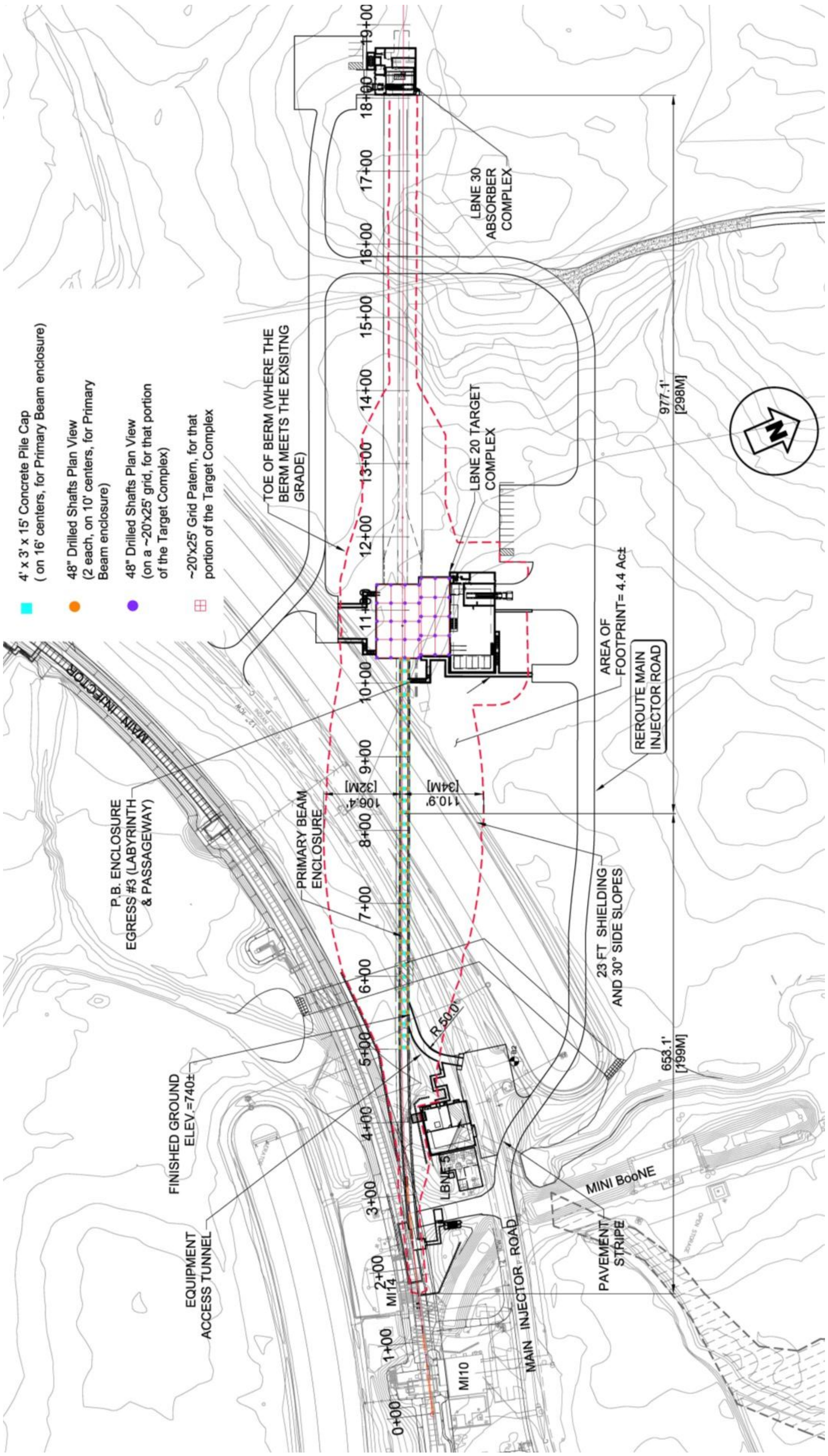

Figure 4-11: Plan view of toe of the embankment and drilled shaft locations.

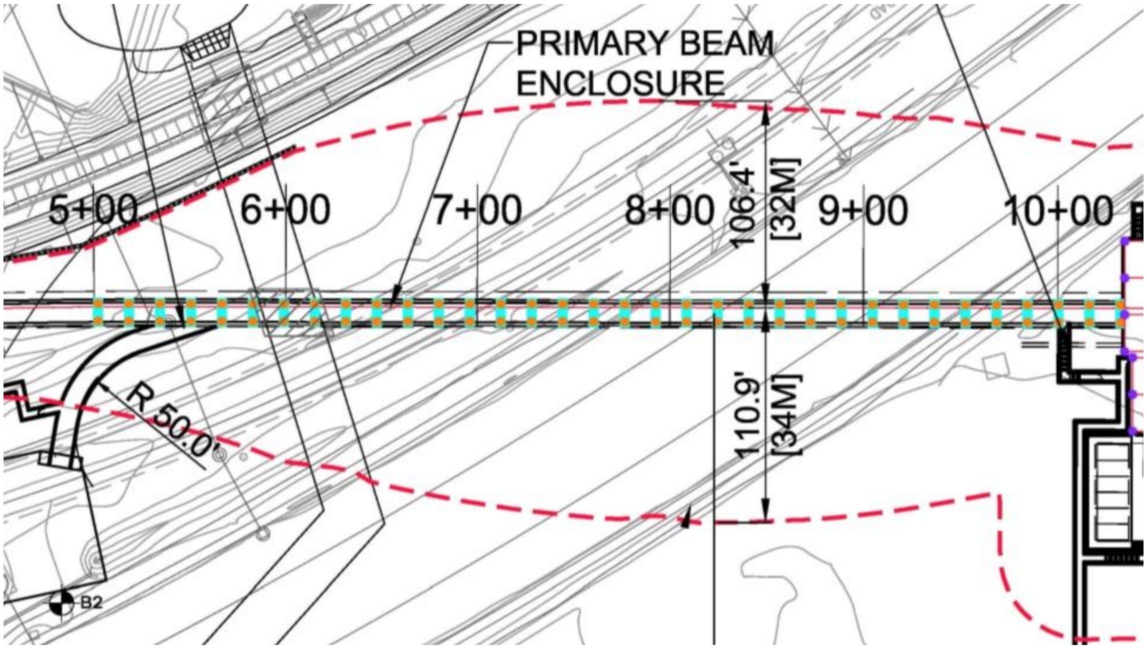

Figure 4-12: Drilled shaft pier cap locations for the Primary Beam Enclosure.

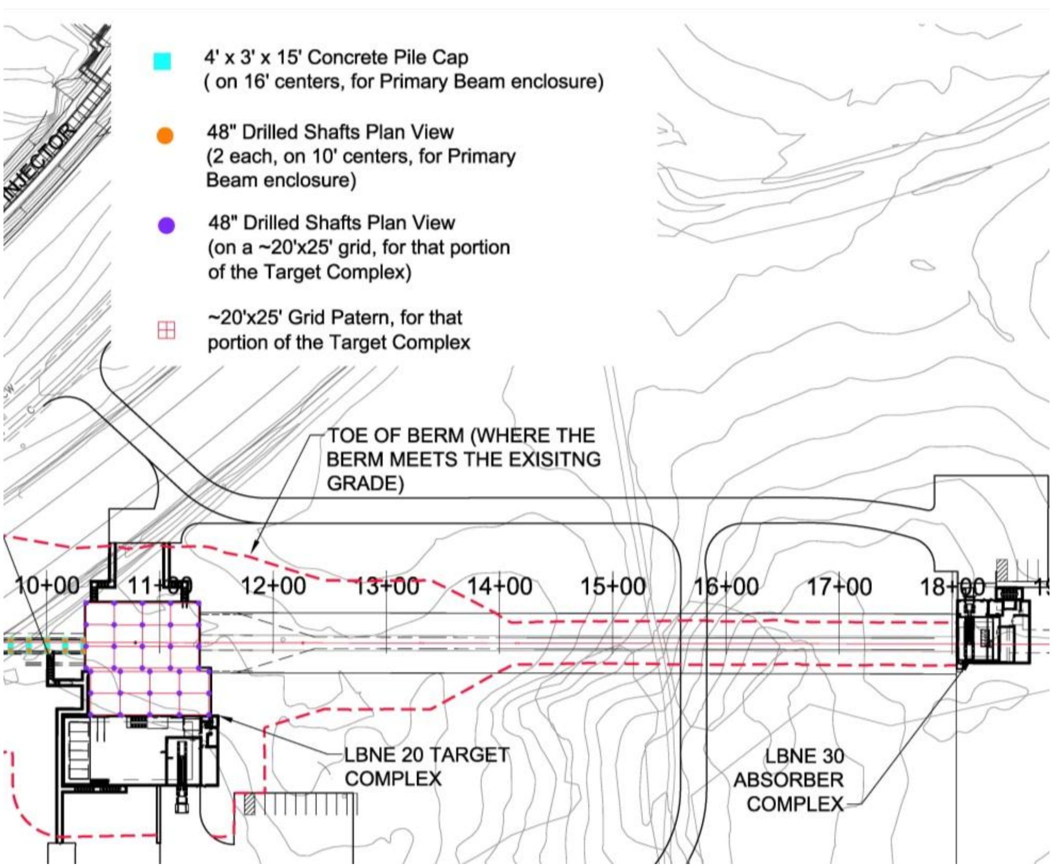

Figure 4-13: Drilled shaft locations for the Target Complex.

4.2.1 Mechanical

The entire Target Hall Complex (LBNE 20) shown in Figure 4-6 will be conditioned to 68°F (winter) or 78°F (summer) using chilled water/hot water (CHW/HW) air handling units (AHUs). Additional HW unit heaters will be strategically located as necessary to insure winter time minimum temperatures. CHW will be provided by packaged air-cooled chillers located on the LBNE 20 hardstand. The chilled water system will contain an appropriate level of propylene glycol to prevent freezing damage to all associated components. HW will be provided by natural gas hot water heaters.

The Target Hall chase/Decay Pipe AHU will be provided with an 85,000-CFM (cubic feet per minute) custom built air conditioning unit capable of removing heat and moisture from the target chase and decay pipe. The supply air shall be divided to supply 35,000 CFM to the chase and 50,000 CFM to the Decay Pipe at a temperature of 59°F+/-2°F and 18% relative humidity (RH) maximum. The return air condition will be in the range of 90°-100°F and 35% RH. The unit will utilize CHW, HW desiccant wheels for dehumidification, and bag-in/bag-out High Efficiency Particle Arrestor (HEPA) air filter systems. All materials of the unit that come in contact with the airstream or condensate will be resistant to corrosion from the radio-chemically induced nitric acid that is present in the air. The AHU will be constructed minimizing single points of failure. Ductwork to and from the target chase and Decay Pipe will be routed through passageways/ducts between the Target Hall and the AHU room. Duct materials will be welded steel constructed to Sheet Metal and Air Conditioning Contractors Association (SMACNA) 10 in water gage (wg) pressure class.

Condensate from the target chase/decay pipe AHU will contain tritium and some nitric acid. The condensate shall be captured and routed to a holding tank in the AHU room. The holding tank will have secondary containment and multiple pumps (n+1) for pumping the condensate to the evaporation system in the LBNE 20 Service Building. A secondary pump (manually controlled) will be provided to pump condensate to a convenient location in the accessible common underground area for barreling condensate (barreling provides back-up in case of evaporator system or other failure). All piping will be stainless steel or schedule-80 PVC and any piping outside the AHU room will have secondary containment (double walled).

The Target Hall air conditioning unit will be a small similarly designed unit to the target chase/Decay Pipe AHU providing one air change per hour, approximately 4,000 CFM, to the Target Hall. The two units will be located in the same room. The air supply and return will be ducted through the pressure equalization duct that connects the hall to the AHU room. The condensate from this unit will be routed to the condensate holding system.

Target Hall negative pressure during beam-on will be provided by an exhaust duct near the upstream end of the Target Hall. This duct exits the hall at the upstream end above the Primary Beam Enclosure. Outside of the building, but within an ES&H secured area, a fan will be provided to exhaust 6,000 CFM discharging air vertically at a height of 14 feet during beam-off for Target Hall purge. During beam-on operation the Target Hall will be maintained at a negative pressure relative to the outside air by taking an airflow of 1,250 CFM directed to the NuMI survey riser 3 (SR3) through a below-grade duct. A fan will be provided within an ES&H secured areaway at the NuMI SR3 location to direct the airflow down into the NuMI Target Hall.

The 1,200 sf Mechanical/Electrical room will house the conventional and programmatic mechanical equipment including: chilled water pumps, hot water pumps, heat exchangers, evaporators, exterior air cooled chillers, natural gas boilers, hot water pumps, CHW/HW air handlers, and ventilation/exhaust fans. Target Hall controls are housed here as well as fire protection systems and plumbing for occupants. The wet pipe sprinkler system for this complex is served from the sitewide ICW network that is extended to the building from the existing nearby system. Any space where the application of water could constitute a radiation-related risk as determined by LBNE and the AHJ will not have sprinkler systems.

Also located in the Mechanical/Electrical room are systems dedicated to serve the Target Hall Complex. These include the CHW/HW dedicated outside air system (DOAS) AHU that provides conditioned ventilation air to the Target Hall support areas; and the condensate evaporation system. Condensate from the target chase/Decay Pipe AHU system is pumped to an elevated holding tank in the second floor room. The holding tank shall have a nitric acid neutralization system to pH balance the condensate before it is evaporated. From this tank the condensate is gravity fed into evaporators. The evaporated discharge is drawn to roof mounted exhaust fans and discharged vertically at high velocity.

The 3,500-sf air handing room will house the 85,000-CFM AHU and desiccant dryers to supply air cooling, dehumidification, and bag-in/bag-out HEPA air filter systems for the Target Hall, target chase, and Decay Pipe. The power supply room will house the power supply cabinet and relays, and a penetration supported by a 30-in diameter steel pipe cast into the 5-ft thick concrete Target Hall wall for the power strip line.

Target Hall support areas containing the power supply, RAW skid and utility rooms shall be conditioned by a locally placed small chilled water/hot water AHU. Ventilation for these areas shall be provided by a dedicated outside air system (DOAS) located in the service building mechanical area. The DOAS shall provide adequate personnel ventilation and dehumidified neutral air to the space for humidity control and positive pressurization with respect to the Target Hall. Maximum final space condition shall be 73°F +/- 5°F and 50% RH.

4.2.2 Electrical

The electrical facilities provided at LBNE 20 Target Hall Complex, will support the requirements of the technical systems in accordance with the Fermilab standards, NEC, and other applicable codes. The building site will have two separate electrical services: one serving the conventional system and the other serving the technical systems (pulsed power). A conventional 13.8-kV power system will be provided for electricity service to the building systems, lighting, HVAC, crane, misc. loads, and low power technical system components such as racks and computers. A technical system, (pulsed power), 13.8 kV power system will be provided for electricity service to large technical systems such as beam power supplies. The conventional systems group will provide the 13.8-kV primary electrical power to an outdoor switchgear, one for each power system. Conventional Facilities will provide a prepared space at LBNE 20 for the technical system transformers and components to be installed by the Beamline Level 2 Project. Two transformers for Conventional Facilities will be installed at LBNE 20, one to serve the building loads and the other to serve the 4.16-kV chillers. An emergency/standby power system with generator will be installed to serve critical loads for life safety and technical system components as well as the crane systems.

The building will be outfitted with panelboards, lighting, power receptacles, emergency/standby power systems and HVAC components to support the requirements of the technical systems. A main switchboard/panelboard will be installed to distribute power to large dedicated loads and sub-panelboards in local building and underground areas. Emergency/standby power will be provided at a dedicated emergency power panelboard.

The lighting system will be installed according to the lighting level required by the use of the space. All lighting installed in areas that are exposed to radiation must be protected from the radiation or be resistant to the degrading and contaminating effects of radiation on electronic components. All emergency lighting in the Target Complex will be powered from a separate remote battery powered UPS system that is completely isolated from sources of radiation. This system will remain operable until the standby generator is available to provide power or power is restored.

Power receptacles will be provided in the LBNE 20 area for use as needed during outfitting and operation. The receptacles will be configured based on site equipment standards. All loads that require emergency/standby power will be served from the dedicated panelboard. The HVAC equipment will be served from the nearest conventional power panelboard as needed.

Table 4-2 shows the Target Hall Complex (LBNE 20) electrical power loads, for both normal power and the standby power generators.

Table 4-2: Target Hall Complex Electrical Power Loads.

Equipment Description	**Normal Power (kw)**	**Standby Power Generators (kw)**
Chiller (400 ton) (3 ea.)	1123	
Chilled water pumps [total] (2200 gpm, 100 hp) (2 ea., 1 full time)	70	
Condensate pumps (3 total)	3	
Sump pump (3 total)	3	3
Hot water pump	19	
MAU (makeup air): Support, morgue, truck dock/control rooms (3 total)	15	
MAU Desiccant	12	
RCU Desiccant (Target Hall)	203	
RCU Desiccant (other)	24	
RCU: Utility Room, Power Supply Room (2 total)	16	
AHU: service, MEP, Target Hall (3 total)	43	
Dehumidifier	5	
Exhaust fans: morgue, truck dock, Target Hall, Target Chase (4 total)	22	
Lighting & Receptacle & Experimental	233	58
50 ton bridge crane -Target Hall, morgue/laydown (2 total)	98	98
Total Connected Load	**1889**	**159**

4.2.3 Plumbing

Fire protection systems and plumbing systems, including a restroom, are included. The wet pipe sprinkler system for this complex is served from the sitewide ICW network that is extended to the building from the existing system. Target Pile and Decay Pipe AHU cooling water is supplied from the air cooled chiller in the LBNE 20 mechanical room which is a closed-loop glycol system. Natural gas is routed to this building from the site-wide network to be used for hot water heating for domestic water and building heat.

A duplex ground water sump system is located in the target support area. The system receives drainage from the Target Hall under drainage network. This system discharges directly to the site-wide ICW system.

4.2.4 Fire Protection/Life Safety Systems

Egress paths for surface (service buildings) and underground facilities (tunnels and halls) have been conceptually designed to limit the travel path distances to egress shafts, stairways, and safe/fire rated corridors to the exterior and surface to a safe gathering location. See Section 3.1.4 of this volume for a general overview of fire protection and fire life/safety requirements.

Conventional Facilities is responsible for the design, cost/scheduling and construction of these systems including the mechanical (emergency ventilation), electrical (emergency generator for lighting, ventilation, sump pumping, fire alarms, and communication), and plumbing (fire suppression/sprinkler piping and fixtures, and emergency sump pumping). Any space where the application of water could constitute a radiation-related risk as determined by LBNE and the AHJ will not have sprinkler systems.

The three-level Target Complex has several egress routes which are shown in Figure 4-14, Figure 4-15, and Figure 4-16.

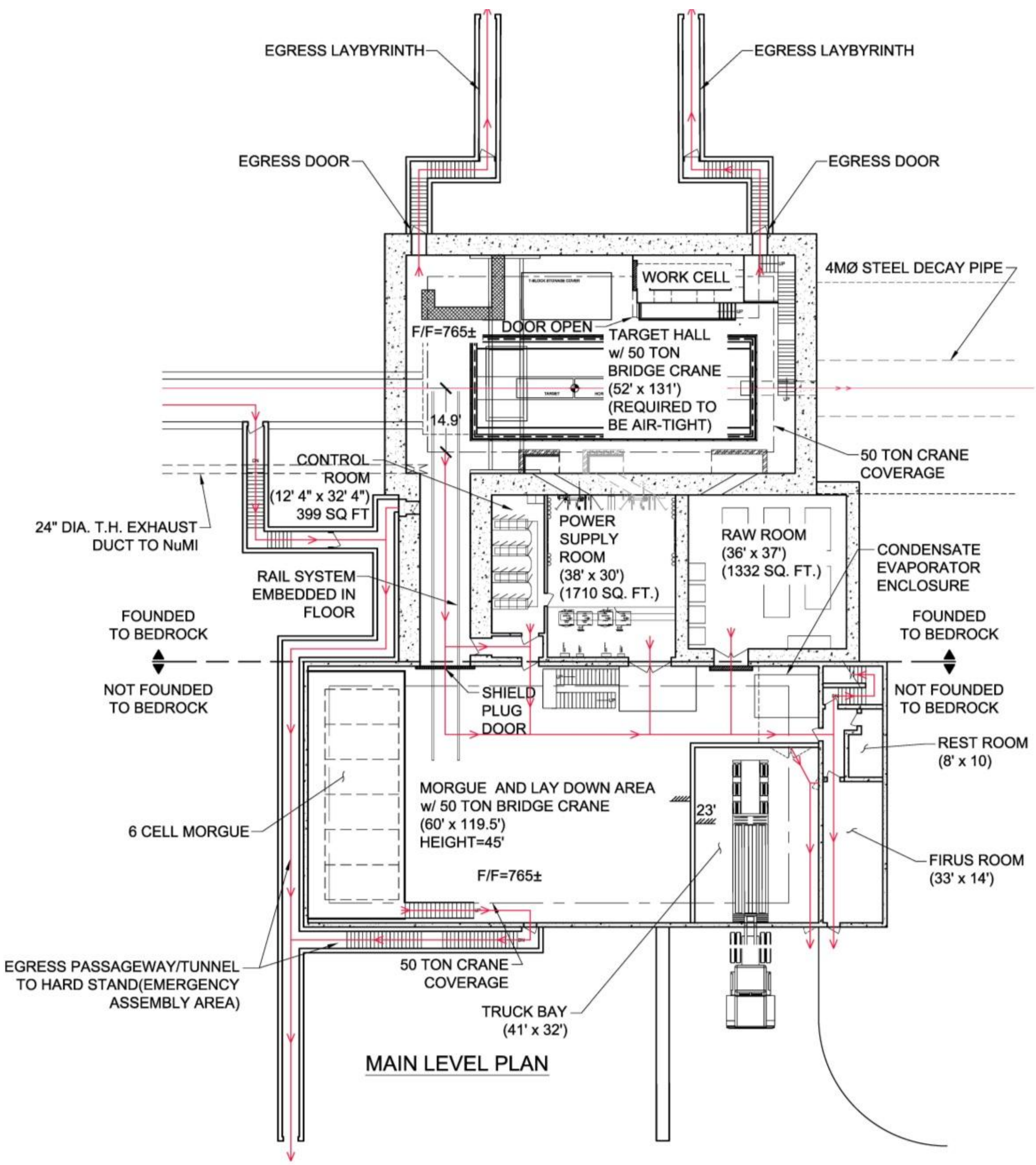

Figure 4-14: Target Complex; Main Level, Egress Routing.

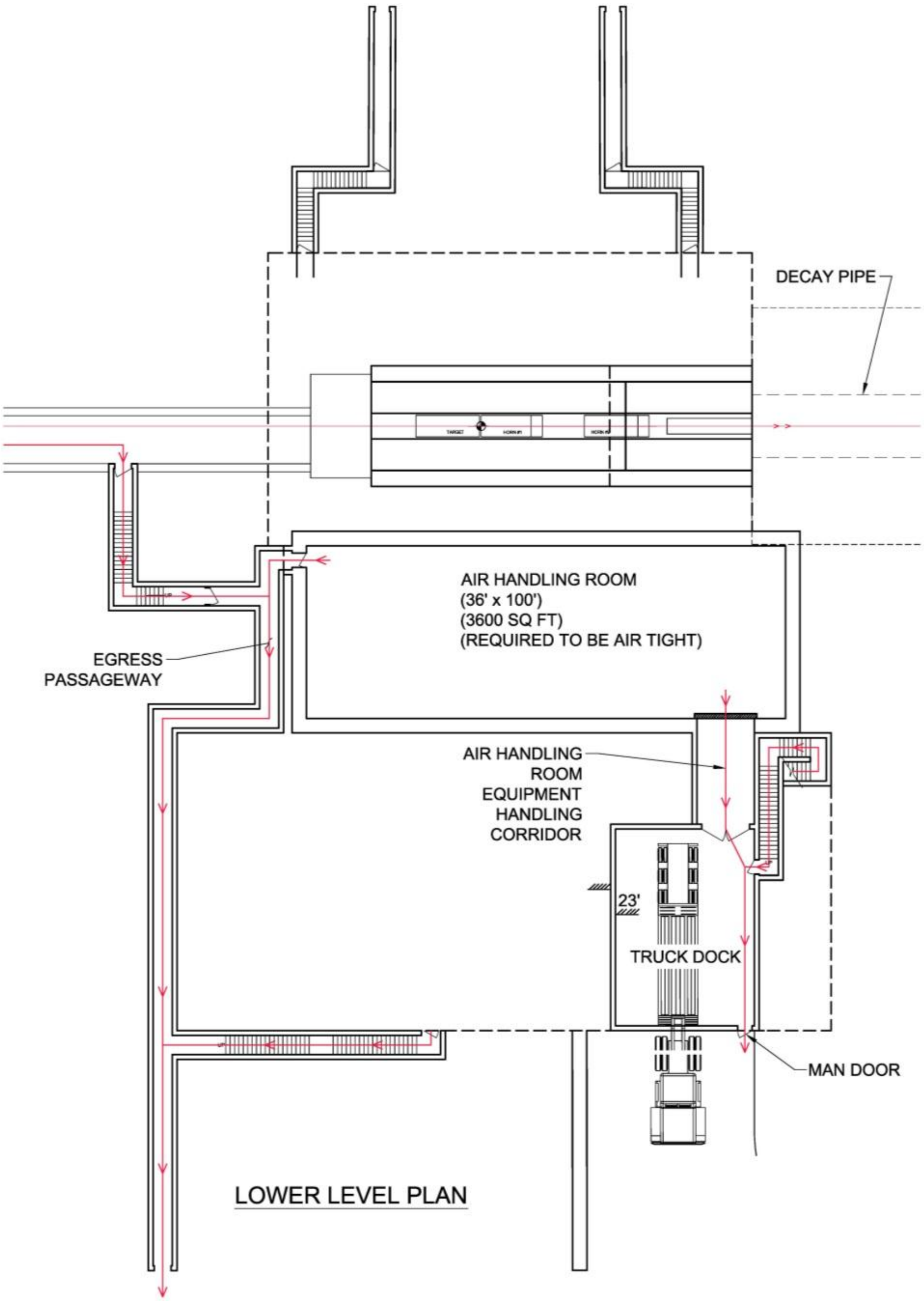

Figure 4-15: Target Complex; Lower Level, Egress Routing.

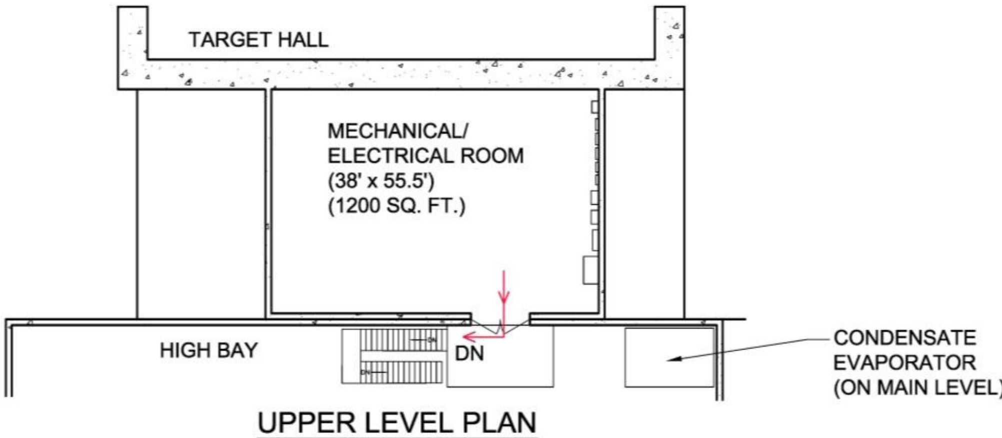

Figure 4-16: Target Complex; Upper level, Egress Routing.

4.3 Absorber Service Building (LBNE 30) (WBS 130.06.02.05.03.03)

The Absorber Service Building (LBNE 30), shown in Figure 4-17 consists of the 53-ft wide by 62-ft long above-grade building to accommodate the support equipment and access needed for the assembly and operation of the equipment and technical components of the Absorber Hall, Muon Alcove, and support rooms which are 83 ft below the service building floor. LBNE 30 will be located over a 19-ft by 22-ft access/egress shaft and over the 30-ft wide by 40-ft long equipment shaft to the below-grade Absorber Hall, Muon Alcove, and support rooms.

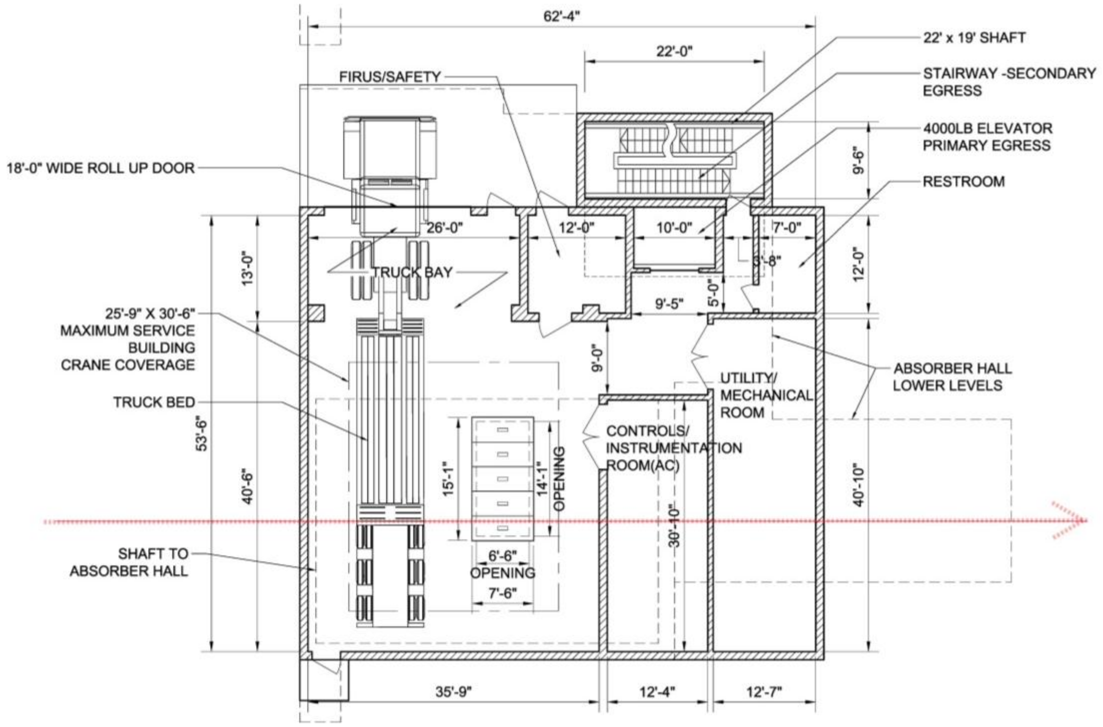

Figure 4-17: Absorber Service Building (LBNE 30) Floor Plan.

The 3,285-sf near-surface building will be concrete with steel framing and metal siding with a cast-in-place concrete foundation. The floor of this building will be 14 ft below grade to reduce the bridge crane hook height/vertical travel distance to the Absorber Hall and Muon Alcove floor (83 ft below as described in Section 5.3). This building has a 35-ft clear crane height for the truck bay area and will house the open truck bay, laydown area with a 6.5-ft wide by 15-ft long concrete shield hatch cover floor opening, roughly centered over the equipment shaft to the Absorber Hall and Muon Alcove below, a 30-ton bridge crane, instrumentation/controls room, fire/life safety room, and a mechanical equipment and utility room, including: chilled water (CHW) pumps, hot water (HW) pumps, heat exchangers, exterior air cooled chillers, natural gas boilers, hot water pumps, CHW/HW air handlers, ventilation/exhaust fans for the surface building and desiccant dryers (dehumidifiers for the Absorber Hall, Muon Alcove, and support rooms). The truck bay with a ramp up to finished grade is provided for equipment to be unloaded using the overhead crane and lowered down the shaft to the Absorber Hall and Muon Alcove.

4.3.1 Mechanical

The air in the Absorber Service Building (LBNE 30) will be conditioned to 68ºF (winter) and 78ºF (summer) using CHW/HW AHUs. Additional HW unit heaters will be strategically located, as necessary to insure winter time minimum temperatures. CHW will be provided by packaged air cooled chillers located on the LBNE 30 hardstand. The chilled water system shall contain an appropriate level of propylene glycol to prevent freeze damage to all associated components. HW will be provided by natural gas hot water heaters. Also located in the mechanical area are CHW/HW dedicated outdoor air AHUs with desiccant dehumidification that provide dry neutral temperature ventilation air to the below grade general areas and exit passageways.

4.3.2 Electrical

The electrical facilities provided at LBNE 30 Absorber Service Building will support the requirements of the Beamline technical systems in accordance with the Fermilab standards, NEC, and other applicable codes. The building site will have one electrical service. A conventional 13.8-kV electrical power service will be provided to the building systems, lighting, HVAC, crane, miscellaneous loads, and low power technical system components such as racks and computers. A beamline technical system (pulsed power), 13.8-kV power system is not required and will not be provided. The Conventional Facilities scope of work will provide the 13.8-kV primary electrical power to an outdoor 600-A switchgear. Two transformers for Conventional Facilities will be installed at LBNE 30, one to serve the building loads and the other to serve the 4.16-kV chillers. An emergency/standby power system with generator will be installed to serve critical loads for life safety and technical system components. A dedicated separate emergency/standby power system will be provided for the three Absorber Hall sump pump systems.

The building will be outfitted with panelboards, lighting, power receptacles, emergency/standby power systems and HVAC components to support the requirements of the technical systems. A main switchboard/panelboard will be installed to distribute power to large dedicated loads and sub-panelboards in local building and underground areas. Emergency/standby power will be provided at a dedicated emergency power panelboard.

The lighting system will be installed according to the lighting level required by the use of the space. All lighting installed in areas that are exposed to radiation must be protected from the radiation or be resistant to the degrading and contaminating effects of radiation on electronic components. All emergency lighting in the Absorber Service Building will be powered from a separate remote battery powered UPS system that is completely isolated from sources of radiation. This system will remain operable until the standby generator is available to provide power or power is restored.

Power receptacles will be provided in the building and underground areas for use as needed during outfitting and operation. Receptacles will be configured based on site equipment standards. All loads that require emergency/standby power will be served from the dedicated panelboard. The HVAC equipment will be served from the nearest conventional power panelboard as needed.

Table 4-3 shows the Absorber Service Building (LBNE 30) electrical power loads, both normal power and standby power generators.

Table 4-3: Absorber Hall and Absorber Service Building (LBNE 30) Electrical Power Loads.

Equipment Description	**Normal Power (kw)**	**Standby Power Generators (kw)**
Chiller (300 tons) (2 ea.)	562	
Chilled water pump (1,400 gpm, 50 hp) (2 ea., 1 full time)	37	
Condensate pump (3 total)	3	
Hot water pump	5	
Refrigerated Dehumidifier	12	
Sump pump (6 total, 4 running full time)	163	25
Manual Pumps – Decay pipe water (2 total)	31	31
Holding tank pump (2 total, 1 running full)	38	
Fan coil	1	

Equipment Description	Normal Power (kw)	Standby Power Generators (kw)
Elevator	37	37
AHU Surface Building	27	
AHU desiccant	6	
Dehumidifier	5	
Exhaust fan	2	2
Lighting & receptacle & Experimental	85	21
30-ton bridge crane	49	49
Total Connected Load	**1060**	**302**

4.3.3 Plumbing

Fire protection systems and plumbing systems, including restrooms, are included. The wet pipe sprinkler system for this complex is served from the site wide ICW network that is extended to the building from the existing system. Natural gas is routed to this building from the site-wide network to be used for hot water heating for domestic water and building heat.

4.3.4 Fire Protection/Life Safety Systems

Egress paths for surface (service buildings) and underground facilities (tunnels and halls) have been conceptually designed to limit the travel path distances to egress shafts, stairways, and safe/fire rated corridors to the exterior and surface to a safe gathering location. See Section 3.1.4 of this volume for a general overview of fire protection and fire life/safety requirements.

Conventional Facilities is responsible for the design and construction of these systems including the mechanical (emergency ventilation), electrical (emergency generator for lighting, ventilation, sump pumping, fire alarms, and communication), and plumbing (fire suppression/sprinkler piping and fixtures, and emergency sump pumping). Any space where the application of water could constitute a radiation-related risk as determined by LBNE and the AHJ will not have sprinkler systems.

5 New Underground Structures

The LBNE Conventional Facilities on the Near Site will include new underground structures including the Beamline Extraction Enclosure and Primary Beam Enclosure, the Decay Pipe, and the Absorber Hall and Support Rooms. This section provides additional details regarding these facilities.

5.1 Beamline Extraction Enclosure and Primary Beam Enclosure (WBS 130.02.05.04.01 and 130.06.02.05.04.02)

The first underground functional area is the Beamline Extraction Enclosure and Primary Beam Enclosure. This area, consisting of the upstream Beamline Extraction Enclosure and the downstream Primary Beam Enclosure are required to allow the beam to be extracted from the Main Injector and transported 328 m (1078 ft) to the LBNE Target Complex (to the target). The construction of the upstream portion of this area will consist of a cut-and-cover below-grade section. The downstream portion of this area includes a transition from the below-grade section to an above-grade section located within an embankment. Some of these areas will be constructed using cast-in-place concrete sections and other areas will be pre-cast concrete enclosure sections. The Beamline Extraction Enclosure and Primary Beam Enclosure are shown in aerial view in Figure 5-1.

Due to the construction of this facility over the existing Main Injector (MI) Road, Cooling Pond F, and associate existing underground and overhead utilities, rerouting of the road and utilities, plus construction of a new cooling pond will be required.

The Beamline Extraction Enclosure portion, shown in plan view in Figure 5-2, will start from the existing Main Injector near MI-10, and extend approximately 43 ft to the start of the Primary Beam Enclosure.

Figure 5-3 shows a section view of the Beamline Extraction Enclosure at the existing MI-14 Service Building. An open cut braced excavation will be performed at MI-14 that will expose the MI Enclosure. As shown in Figure 5-4, a cast in place (CIP) structural concrete cocoon will be constructed around the MI Enclosure to protect it from the loading of the additional soil shielding fill required for LBNE and to add structural integrity to the MI Enclosure before the side wall of the MI Enclosure is removed. This opening will allow construction of a 12-in diameter steel beamline transport pipe to divert beam to the Primary Beam Enclosure, and will also allow beamline water cooling lines, power, and utility routing from the MI to the Primary Beam Enclosure.

The excavated area (as shown in Figure 5-3) will be backfilled with light weight flowable concrete fill. Secant pile braced excavation walls will be constructed to protect the existing MiniBooNE beamline enclosure. An extensive system of secant pile walls and H-pile and lagging braced excavation walls will be constructed (as detailed in Figure 3-1) to protect the Main Injector Enclosure from lateral loading from the 58-foot high embankment.

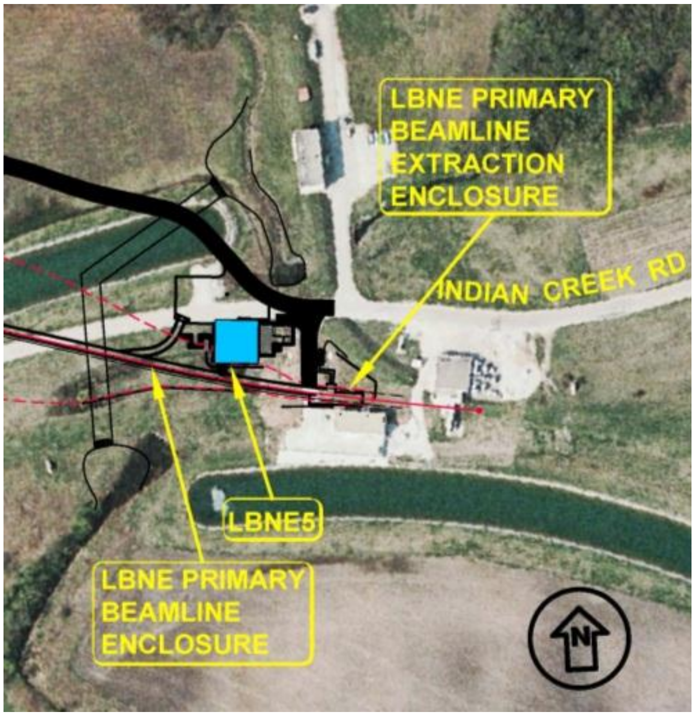

Figure 5-1: Beamline Extraction Enclosure and Primary Beam Enclosure – Aerial View.

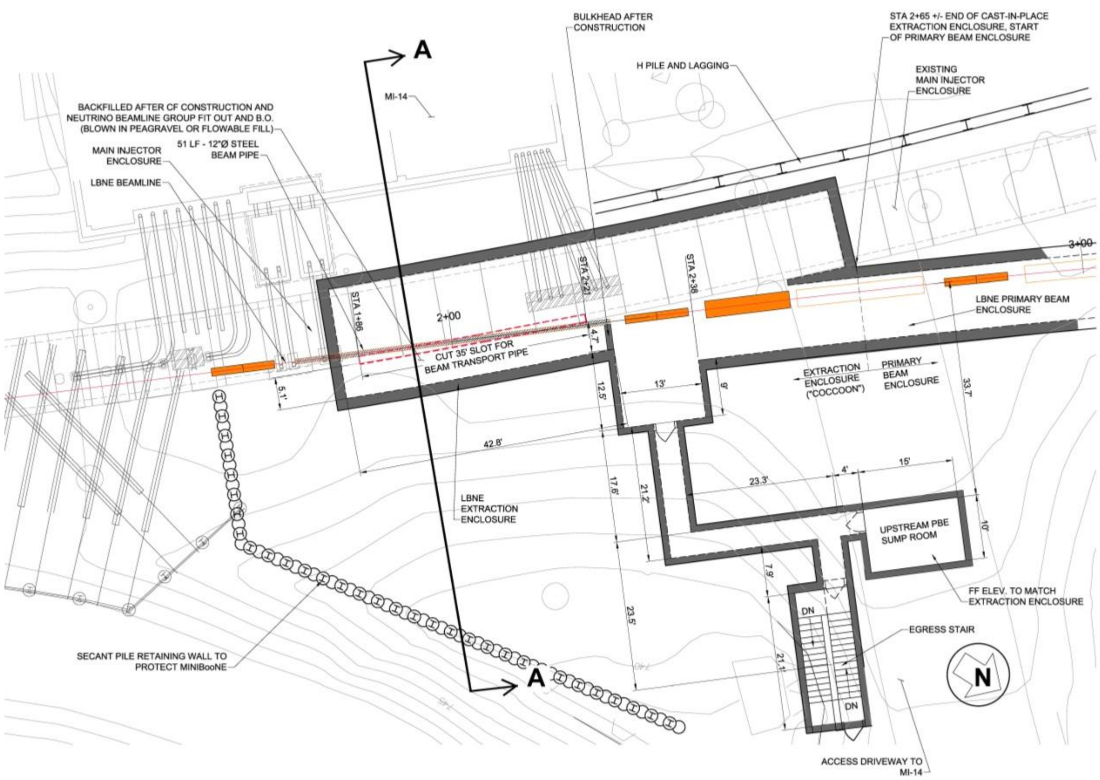

Figure 5-2: Beamline Extraction Enclosure and Primary Beam Enclosure with Section A-A cut shown to show location of section shown in Figure 5-3.

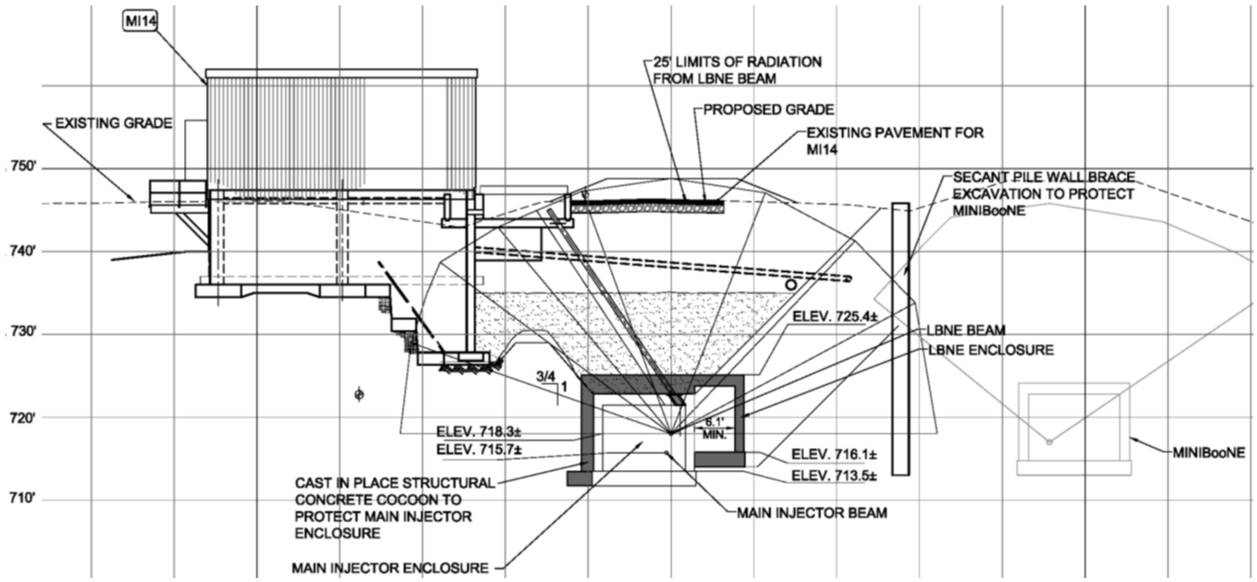

Figure 5-3: Beamline Extraction Enclosure section view at MI-14 showing the structural concrete cocoon around the MI enclosure (Section A-A as noted in Figure 5-2).

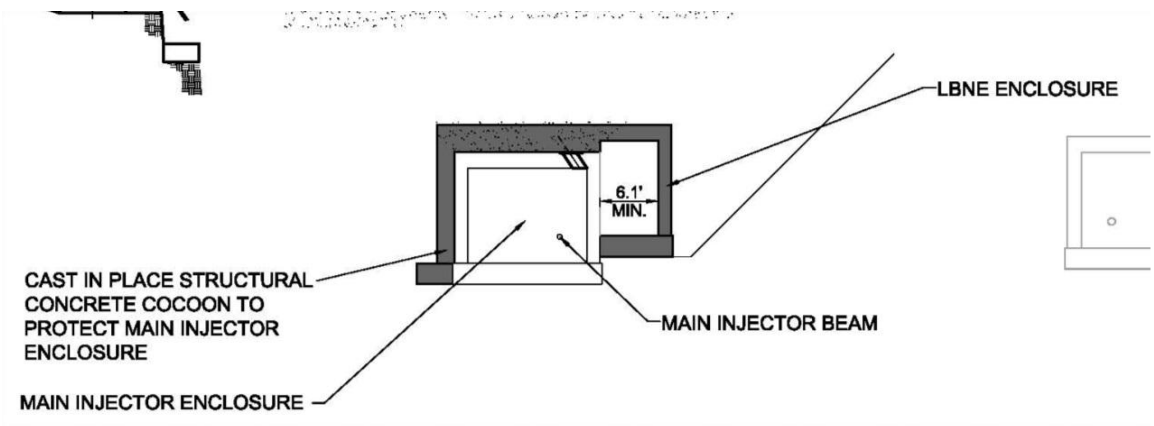

Figure 5-4: Beamline Extraction Enclosure at the connection to the MI enclosure showing the structural concrete cocoon around the MI enclosure.

The 778-ft long Primary Beam Enclosure will start at the end of the extraction enclosure and continue along a 15% incline into and through the above-grade embankment, and then at a 10% decline to and through the Target Hall. The depth of the enclosure will be 32.5 ft from the top of the soil shielding fill to the invert/floor. This will provide a minimum of 23 ft of soil and concrete shielding (measured from the center of the beamline) for both the 700-kW and 2.3-MW beam power levels. The apex of the embankment over the Primary Beam Enclosure will be approximately 58 ft above existing grade. With the required minimum 23 ft of soil shielding, the apex of the beamline will be 35 ft above existing grade as shown in Figure 1-1.

Figure 5-5 shows a cross section in the soil overburden which will be constructed in a cut-and-cover excavation from STA 2+68 to STA 10+43. From about STA 5+00, the Primary Beam Enclosure will be constructed in the embankment with the required 23 ft of soil shielding cover up to STA 10+43. The enclosure will be a combination of cast-in-place concrete where construction constraints require, as well as precast concrete inverted U-shaped sections constructed on a cast-in-place concrete slab. Figure 5-5 also graphically depicts the required minimum 23 ft of soil shielding.

The Primary Beam Enclosure has interior dimensions measuring 10 ft wide and 8 ft high. These dimensions match that of the existing Main Injector enclosure. Figure 5-6 shows a typical cross section of the Primary Beam Enclosure that shows the locations of the technical components and technical and conventional utilities.

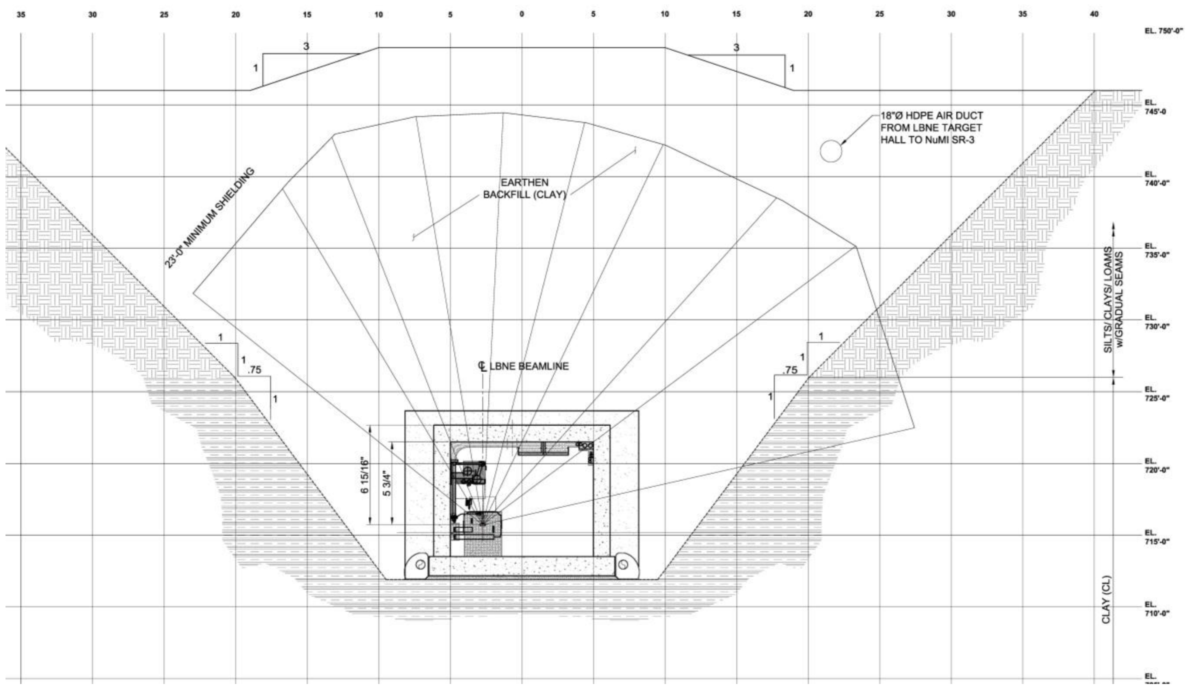

Figure 5-5: Primary Beam Enclosure section view. Shown as constructed in open cut trench.

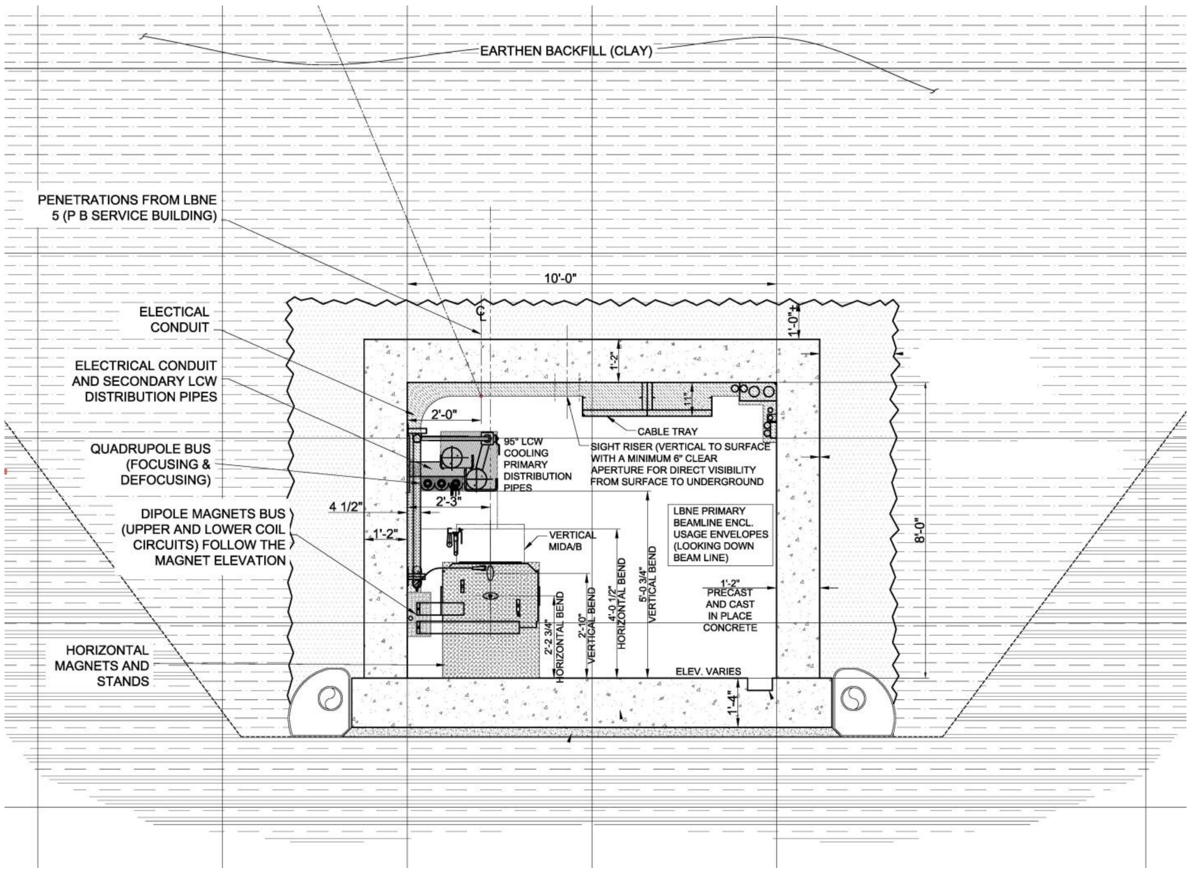

Figure 5-6: Primary Beam Enclosure showing technical components, typical enclosure section.

Site work for the construction of the engineered embankment, the Primary Beam Enclosure, and the Target Complex (LBNE 20) includes the re-routing of Main Injector Road which is shown in Figure 5-7. Existing underground utilities, including electrical power and communications duct banks have been identified in this area and must also be re-routed around the embankment. The portion of underground work from the extraction enclosure at STA 0+00 to STA 4+50 will be completed during a scheduled Main Injector shutdown. The toe of the embankment is shown as a red dashed line in Figure 5-7.

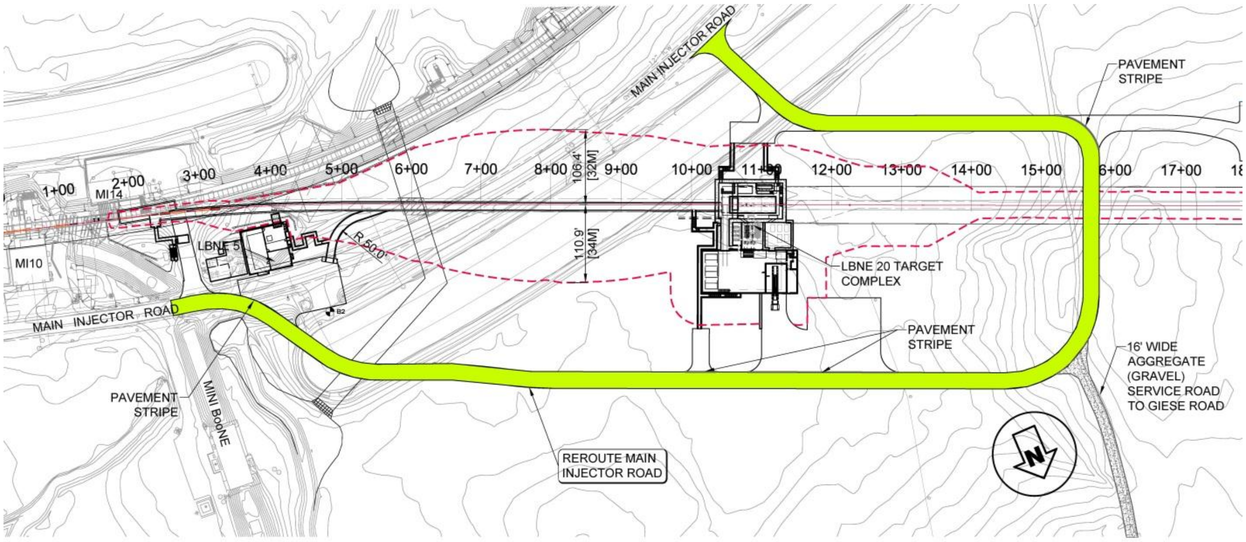

Figure 5-7: Plan View Re-route of MI Road.

5.1.1 Mechanical

Ventilation air is provided from the Target Hall support area and the Main Injector tunnel connection then exhausted through a vent shaft at the high mid-point of the enclosure.

5.1.2 Electrical

The Primary Beam Enclosure will be outfitted with electrical facilities to support the small programmatic equipment and periodic maintenance tasks. Conventional Facilities will provide lighting and electrical facilities to support all mechanical systems, small programmatic loads, and power receptacles needed for maintenance. The power will be delivered from the nearest surface building to 480-V panels in the enclosure. Dry type transformers with 208/120-V panelboards will be provided in the enclosure for small power devices and receptacles.

Lighting and emergency signage will be provided with remote or isolated ballast and alternate power sources. Batteries and electronic ballasts will not be allowed in areas that are subject to radiation due to the degradation of electronics and the possible creation of mixed waste with the batteries.

5.1.3 Plumbing

The entire Primary Beam Enclosure is equipped with a floor trench drain and exterior underdrains, a fire department stand pipe and hose connection fire suppression system, as well as LCW cooling lines, and power and control lines for the equipment. Site risers to the surface, will be constructed at the required spacing along the Primary Beam Enclosure, and will provide a minimum 6-in clear aperture for magnet/beam alignment. Enclosure underdrain water collection is provided at both low ends of the enclosure. These duplex sump pumps discharge to grade where they will flow into existing ditches or cooling ponds.

5.1.4 Fire Protection/Life Safety Systems

Conventional Facilities is responsible for the design, cost/scheduling, and construction of the fire protection and life safety systems including the mechanical (emergency ventilation), electrical (emergency generator for lighting, ventilation, and sump pumping, fire alarms, and communication), and plumbing (fire suppression/sprinkler piping and fixtures, and emergency sump pumping). Any space where the application of water could constitute a radiation-related risk as determined by LBNE and the AHJ will not have sprinkler systems.

Egress paths from underground facilities (tunnels and halls) have been conceptually designed to limit the travel path distances to egress shafts, stairways, and safe/fire rated corridors to the surface. See Section 3.1.4 of this volume for a general overview of fire protection and fire life/safety requirements. The Primary Beam Enclosure is designed to have three egress routes which are shown in Figure 5-8. From the approximate midpoint of the tunnel, the egress route requires traveling approximately 183-ft downstream to the safe rated corridor adjacent to the beam-right Rail System/Egress corridor and morgue which then exits to the exterior and surface to a safe gathering location.

From the same midpoint of the Primary Beam Enclosure, the egress route requires traveling approximately 250-feet upstream to either the magnet installation tunnel and egress labyrinth to and through the Primary Beam Enclosure Service Building (LBNE 5) to the exterior, or upstream of the magnet installation tunnel, to the safe/fire rated egress stair that is approximately 370 feet away near the extraction enclosure, allowing access to the surface and the designated safe gathering area.

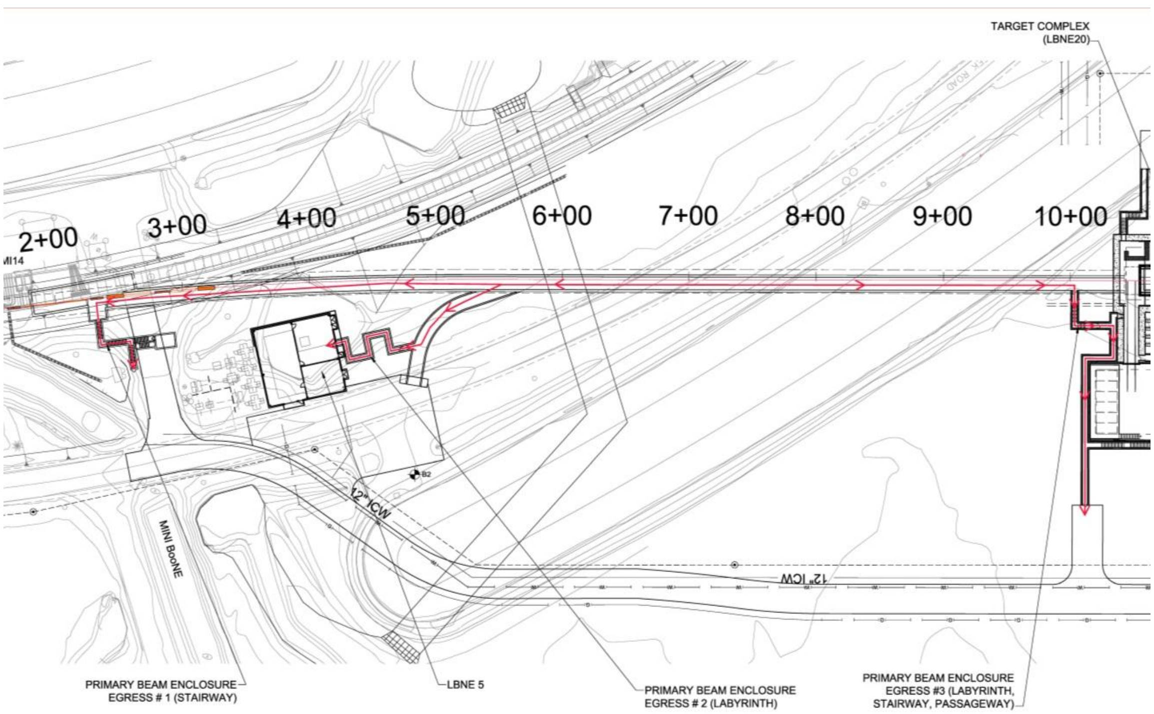

Figure 5-8: Primary Beam Enclosure Egress Routes.

5.2 Decay Pipe (WBS 130.06.02.05.04.03)

The LBNE Decay Pipe (cross section shown in Figure 5-9) begins at the downstream end of the target chase/Target Hall and continues 668 ft (203.7m) at a decline of approximately 10% to the Absorber Hall, which is approximately 94 ft below grade.

The Decay Pipe consists of two concentric pipes; the inner pipe is a 13 ft-2 in (4-m) diameter pipe and the outer pipe is a 14 ft-5 in (4.4-m) diameter pipe. Both pipes are ½-inch thick steel pipes surrounded by the required 18 ft-0.5 in (5.5-m) cast-in-place concrete shielding. The direction of supply airflow for Decay Pipe cooling is down through the 20-cm annulus between the two concentric decay pipes and returns through the inner decay pipe for the air-cooling of the beam heat load deposited in the steel and concrete shielding surrounding the decay pipe (see Figure 5-10). Shown in Figure 5-9, is a 12-in diameter gasketed concrete pipe (cast into the Decay Pipe concrete shielding backfill) air duct connection from the interior of the Absorber to the Target Hall. This will allow a negative air pressure to be maintained in the Absorber Hall.

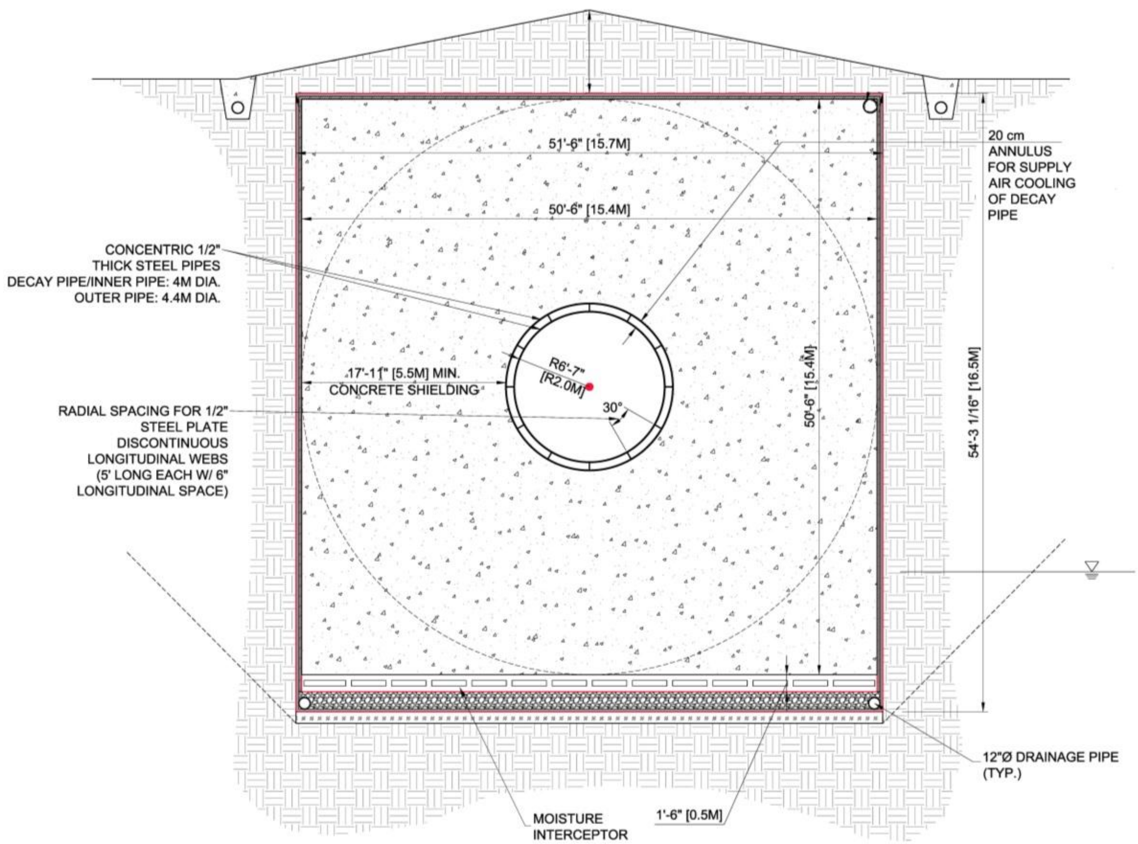

Figure 5-9: Decay Pipe Cross Section.

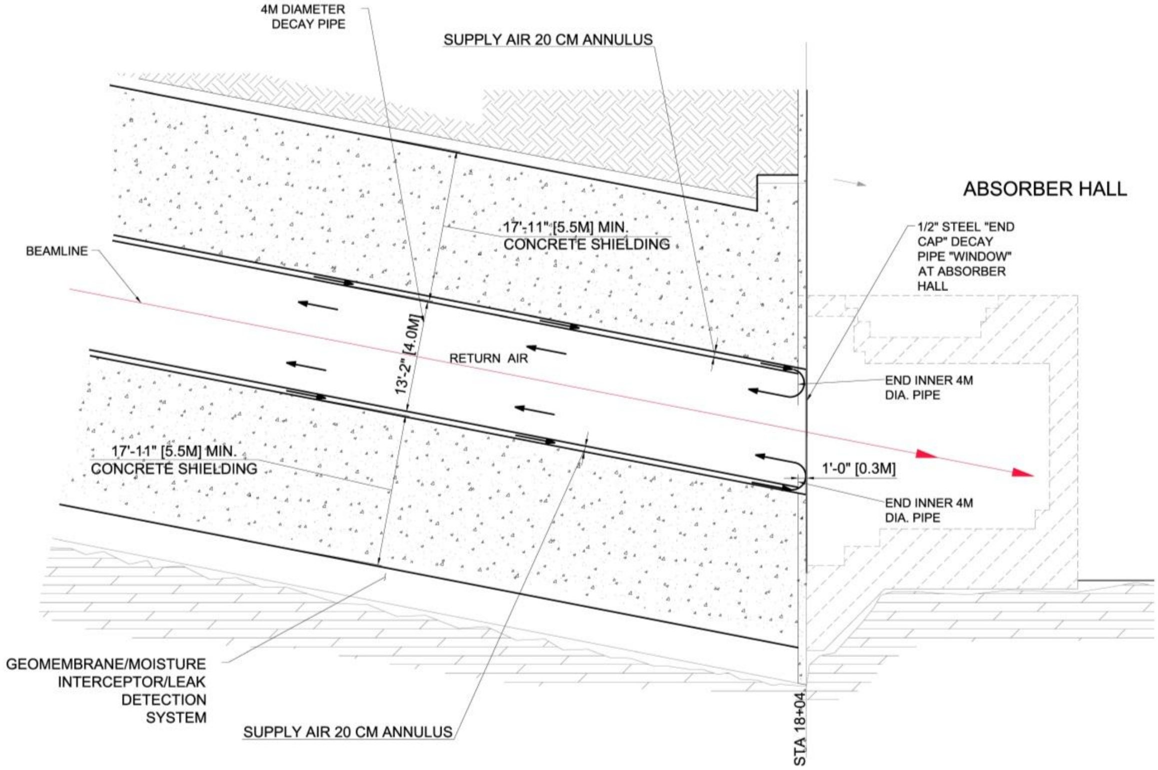

Figure 5-10: Longitudinal section of the Decay Pipe at Absorber Hall.

5.2.1 Decay Region Geosynthetic Barrier System

A geosynthetic barrier system, as shown in Figure 5-11 and Figure 5-12, along with the moisture interceptor system is designed and will be constructed to protect the decay region from potential groundwater infiltration and also to protect the surrounding groundwater from any possible tritiated water being created and escaping from the decay region. The use of the geosynthetic system in the decay region is a unique application of standard and common practices and materials used for decades in the landfill industry. This system will create a three-dimensional barrier system between the decay region and the environment.

The proposed liner system design includes two geomembrane barrier layers, an outer composite geosynthetic clay liner (GCL) barrier, and a geonet leak detection layer placed between the GCL and the inner geomembrane layer as shown in Figure 5-11.

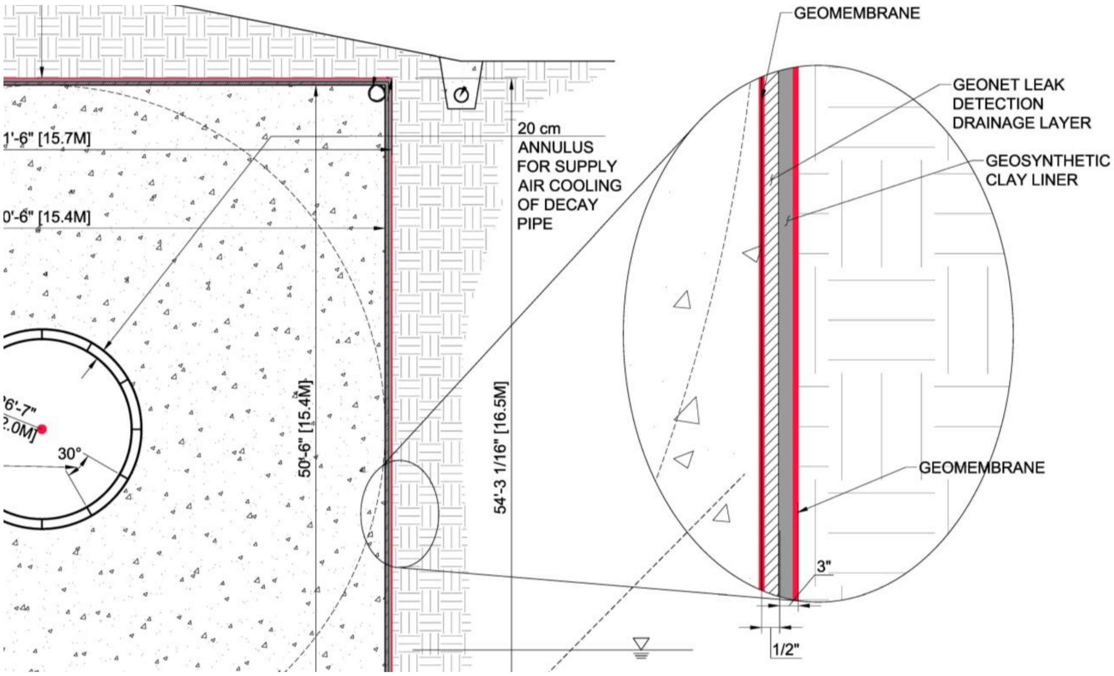

Figure 5-11: Geomembrane system section view
(from outside [right] to inside [left] in the exploded view).

At the base of the decay region cross section the geonet leak detection layer is replaced with 18 inches of open graded (no fines) aggregate/gravel with 12-inch (300-mm) diameter perforated drainage pipes as shown in Figure 5-12. This pipe underdrain system will drain down a 10% slope the length of the Decay Pipe to a collection system at the upstream face of the Absorber Hall and into the decay pipe tritium monitoring sump system.

Surface water drainage and infiltration over the top of the concrete box is managed by crowning the ground surface above the top of the box to shed surface water off to the side to drainage swales and a drain tile system, as shown in Figure 5-9.

An independent study and review was conducted by a leading expert in the geosynthetic industry who generally concurred with the application and details of the geomembrane barrier system. The review provided some comments which will be considered during Preliminary Design [**13**] [**14**] [**15**].

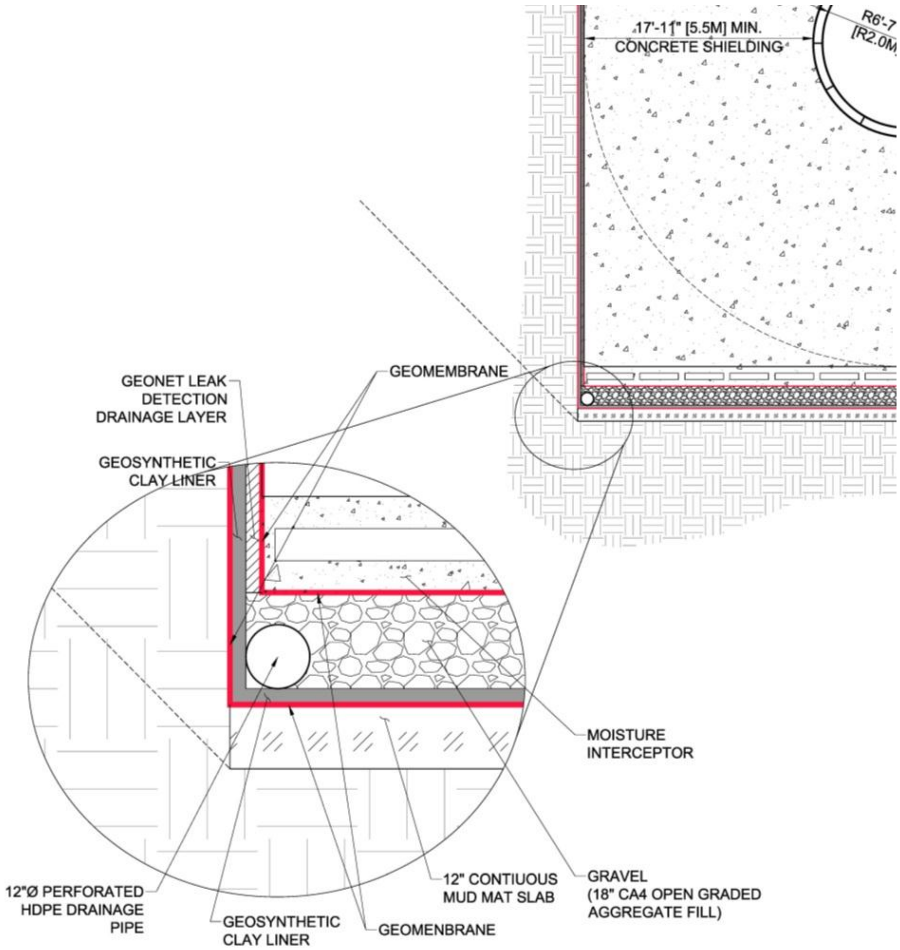

Figure 5-12: Decay Pipe cross section showing the base of the Decay Pipe barrier system.

5.3 Absorber Hall and Support Rooms (WBS 130.06.02.05.04.04)

The Absorber Hall will be approximately 94 ft below existing grade as shown in plan view in Figure 5-13, Figure 5-14, Figure 5-15 and in longitudinal cross section in Figure 5-16. The Absorber Hall will house the concrete shielded hadron absorber and monitor, the Muon Alcove, and the absorber support rooms, all constructed in an open cut soil excavation to bedrock and then a drill-and-blast rock excavation to the base of the underground facility. Also housed in the Absorber Hall and Muon Alcove is the Near Detector Level 2 Project's beamline – measurement system (BLM) (muon detectors) and a Global Data Acquisition system (GDAQ). A geosynthetic barrier system will be included between the rock/open cut earth excavation and the internal concrete structure to seal the facility from groundwater infiltration. The underground Absorber Hall will be a three-level cast in place concrete structure. The lower level of the Absorber Hall will house the absorber pile/enclosure/hadron monitor, Muon Alcove, and sump and pump systems, and will provide access to the base of the egress shaft. The middle level of this underground facility will house the top of the absorber pile and the RAW Room. The upper level of this underground facility will house the Instrumentation room.

The 9-ft thick roof/ceiling of the underground portion of the facility will serve to provide concrete shielding between the Absorber Hall and the above ground Absorber Service Building (LBNE 30). A portion of the concrete foundation walls for the above ground service building serves as the shaft walls to the underground facilities' equipment and utilities access corridor, which is accessed via a 6.5-ft wide by 15-ft long opening in the truck bay floor of the above ground service building which has 30-ton bridge crane coverage. This opening will have a 9-ft thick concrete shield block air sealed hatch cover that will be provided by the Beamline Level 2 Project.

A separate 19-ft x 22-ft cast in place concrete shaft is designed for personnel access and will provide both primary and secondary egress routes by elevator and stairway to the surface. The stairway egress will exit to the surface outside of the LBNE 30 surface building. The corridor from the Absorber Hall/Muon Alcove (lower level) to the egress shaft will have a shielding labyrinth constructed of portable shielding blocks. An interlock and air seal door system will separate the Absorber Hall/Muon Alcove from the rest of the underground rooms. The CF outfitting of this 5,343 sf facility includes conventional and technical/programmatic utilities (to the base of the shaft); air handling equipment, emergency systems, a 4,000-lb capacity personnel elevator, and the sump and pump room systems.

The scope of the Conventional Facilities Absorber Hall and support rooms includes the design and construction of the underground facility. This includes the absorber pile cast-in-place concrete shielding enclosure that will house the hadron monitor. Slots/voids will be cast into the beam-right side of the absorber concrete shielding pit to create a morgue for storing spent absorber components. The scope also includes the associated Conventional Facilities outfitting with required utilities.

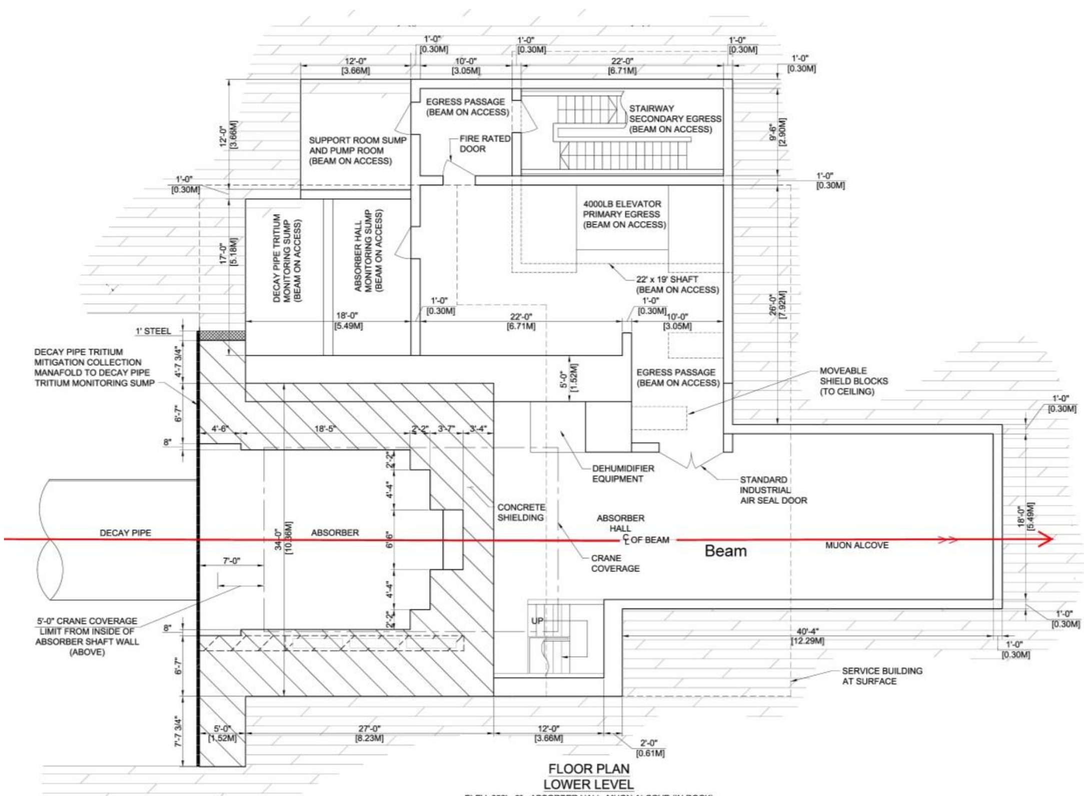

Figure 5-13: Absorber Hall, Muon Alcove; Lower level, plan view in bedrock.

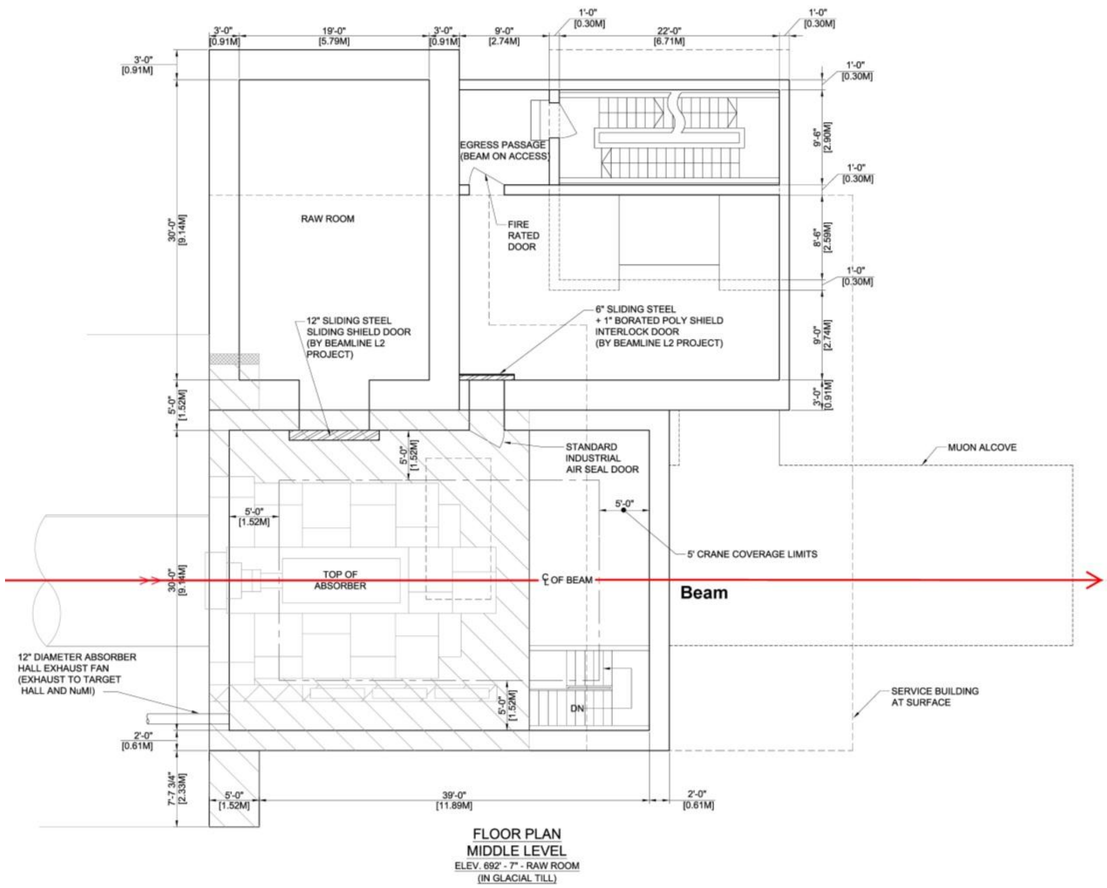

Figure 5-14: Absorber Hall, RAW Room; Middle Level plan view in soil.

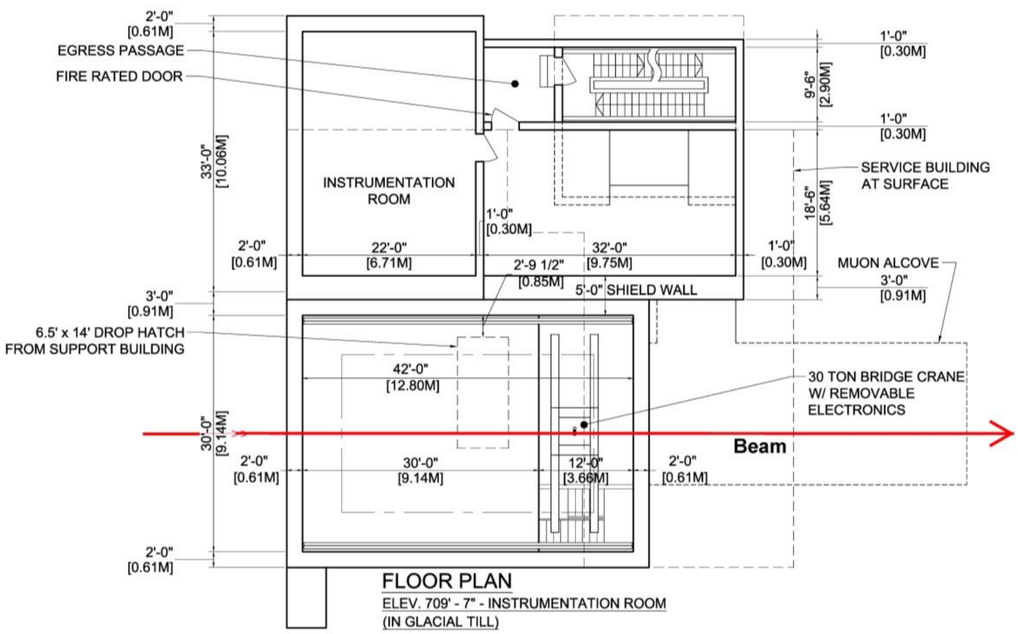

Figure 5-15: Absorber Hall Instrumentation Room; Upper Level, plan view in soil.

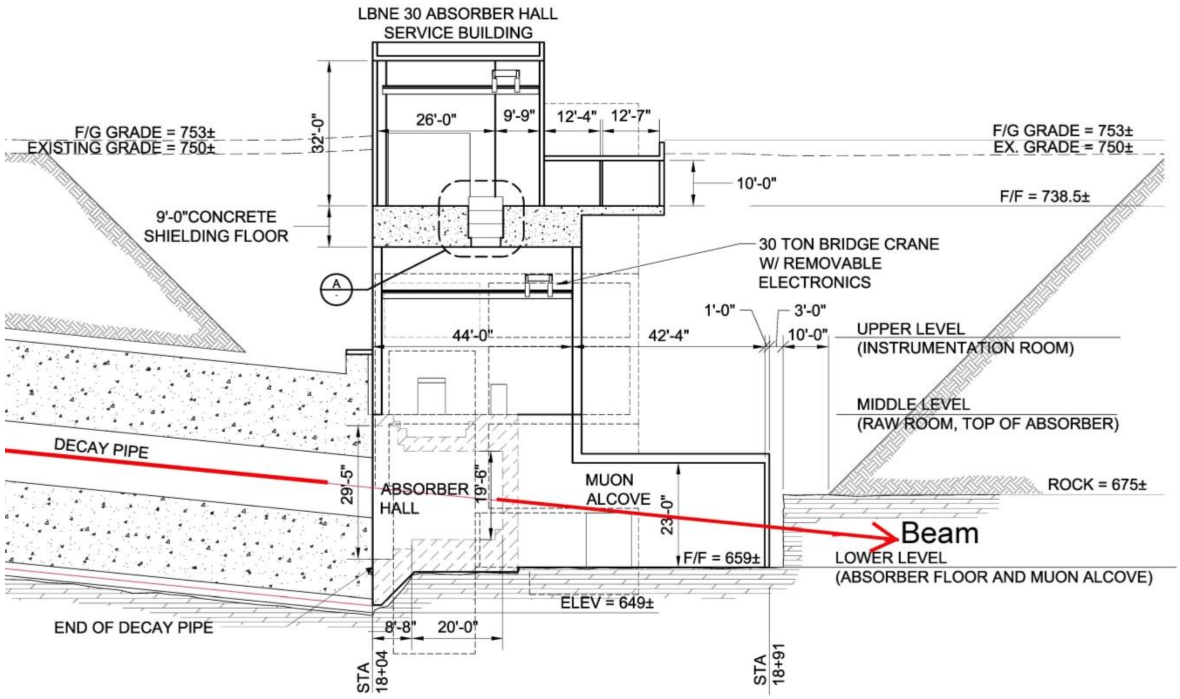

Figure 5-16: Absorber Hall longitudinal cross section cut along the Decay Pipe centerline.

5.3.1 Grouting of the Rock Mass in the Decay/Absorber Region

The downstream end of the Decay Region and the base of the Absorber Hall will penetrate the top of rock to a depth of up to about 25 ft. The soil/rock interface and the upper portion of the rock mass is regionally known as a water bearing zone or aquifer. Due to the importance of providing as dry a Decay Region and Absorber Hall as possible, a systematic program to grout the rock mass to seal off fractures and bedding planes is included in the conceptual design. This grouting program will be executed prior to any excavation and will augment the groundwater barrier system installed between the rock face and the internal concrete structure.

As shown in Figure 5-17 for the Absorber Hall area, a grouting program has been developed that includes a 10-foot by 10-foot grid of primary grout holes that will be drilled and grouted to create an impermeable grouted zone about 20 feet thick around the entire perimeter of the Decay Region and Absorber Hall rock excavations [**16**]. Secondary and tertiary grout holes will be drilled and grouted on split spacing between the primary grout holes as needed, as dictated by grout takes within holes that are drilled.

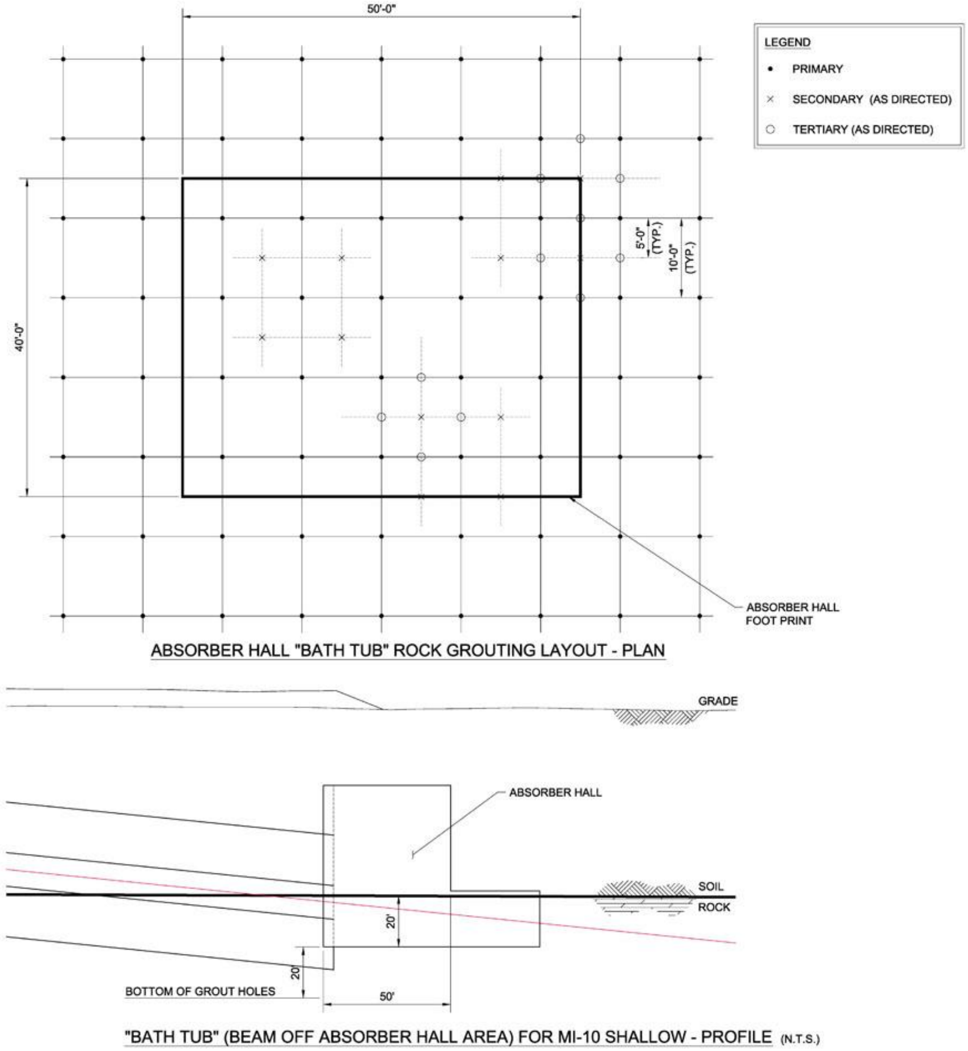

Figure 5-17: Grouting Plan and Section.

5.3.2 Mechanical

Ventilation for this area is to be provided by a dedicated outside air system (DOAS) located in the LBNE 30 service building mechanical area. The DOAS shall provide adequate personnel ventilation and dehumidified neutral air to the underground space for humidity control and positive pressurization with respect to the Absorber Hall. Maximum final space humidity shall be 50% RH.

A 2,400-CFM custom built combined refrigeration/desiccant air conditioning unit will be provided that is capable of removing of heat and moisture from the Absorber Hall. The space condition of the Absorber Hall will be kept at 80ºF +/- 5ºF. All materials of the unit that come in contact with the airstream or condensate will be resistant to corrosion from the slight level nitric acid that is present. The AHU shall be constructed minimizing single points of failure.

Condensate from this system will contain tritium and have a slight level of nitric acid. The condensate will be captured and routed to a holding tank in the Absorber Hall. The holding tank shall have secondary containment and multiple pumps (n+1) for pumping the condensate to the Target Hall condensate holding tank. A secondary pump (manually controlled) shall be provided to pump condensate to a convenient valved location for barreling during beam-on operations. All piping will be stainless steel or high pressure radiation resistant plastic pipe. All ground water intrusion will be contained and routed outside of this room to the main ground water drainage system.

5.3.3 Electrical

The Absorber Hall will be outfitted with electrical facilities to support the small programmatic equipment and periodic maintenance tasks. Conventional Facilities will provide lighting and electrical facilities to support all mechanical systems, small programmatic loads and power receptacles needed for maintenance. The power will be delivered from the Absorber Hall Service Building main panelboard to 480 V panels in the lower Absorber Hall. Dry type transformers with 208/120 V panelboards will be provided in the hall for small power devices and receptacles.

Lighting and emergency signage will be provided with remote or isolated ballast and alternate power sources. Batteries and electronic ballasts will not be allowed in areas that are subject to radiation due to the degradation of electronics and the possible creation of a mixed waste disposal problem with the batteries.

5.3.4 Plumbing

The underground absorber area sump pump system will consist of three duplex pump systems. The first will receive any drainage from the Decay Pipe enclosure system. This system will be provided a dedicated monitoring sump with switchable automatic/manual controls and a holding tank so that contaminating drainage can be held and monitored. The second system receives drainage from the decay enclosure under drainage and is discharged to the third and main sump pump system. This system will be sized to serve the entire upstream underground facilities with redundant back up pumps and emergency back-up power. The system shall be designed to a 0.9999 reliability level. This system shall discharge to a surface holding tank near LBNE 30. Duplex pumps within the holding tank shall discharge to the site-wide ICW system.

5.3.5 Fire Protection/Life Safety Systems

Conventional Facilities is responsible for the design and construction of these systems including the mechanical (emergency ventilation), electrical (emergency generator for lighting, ventilation, sump pumping, fire alarms, and communication), and plumbing (fire suppression/sprinkler piping and fixtures, and emergency sump pumping). Any space where the application of water could constitute a radiation-related risk as determined by LBNE and the AHJ will not have sprinkler systems.

Each of the three levels of the underground Absorber Hall, Muon Alcove and support rooms has a safe/fire rated egress corridor leading to the 19-ft by 22-ft egress shaft that houses a separate primary egress elevator to the service building (LBNE 30) at the surface and also a secondary egress stairway to the surface.

Egress paths for underground facilities (tunnels and halls) have been conceptually designed to limit the travel path distances to egress shafts, stairways, and safe/fire rated corridors to the surface. See Section 3.1.4 of this volume for a general overview of fire protection and fire life/safety requirements.

Figure 5-18 shows the egress paths in red from the Absorber Hall to the LBNE 30 Service Building at the surface and to the exterior safe gathering area. Two routes to the surface are provided, one using the Primary Egress elevator, the other using the Secondary Egress Stairway.

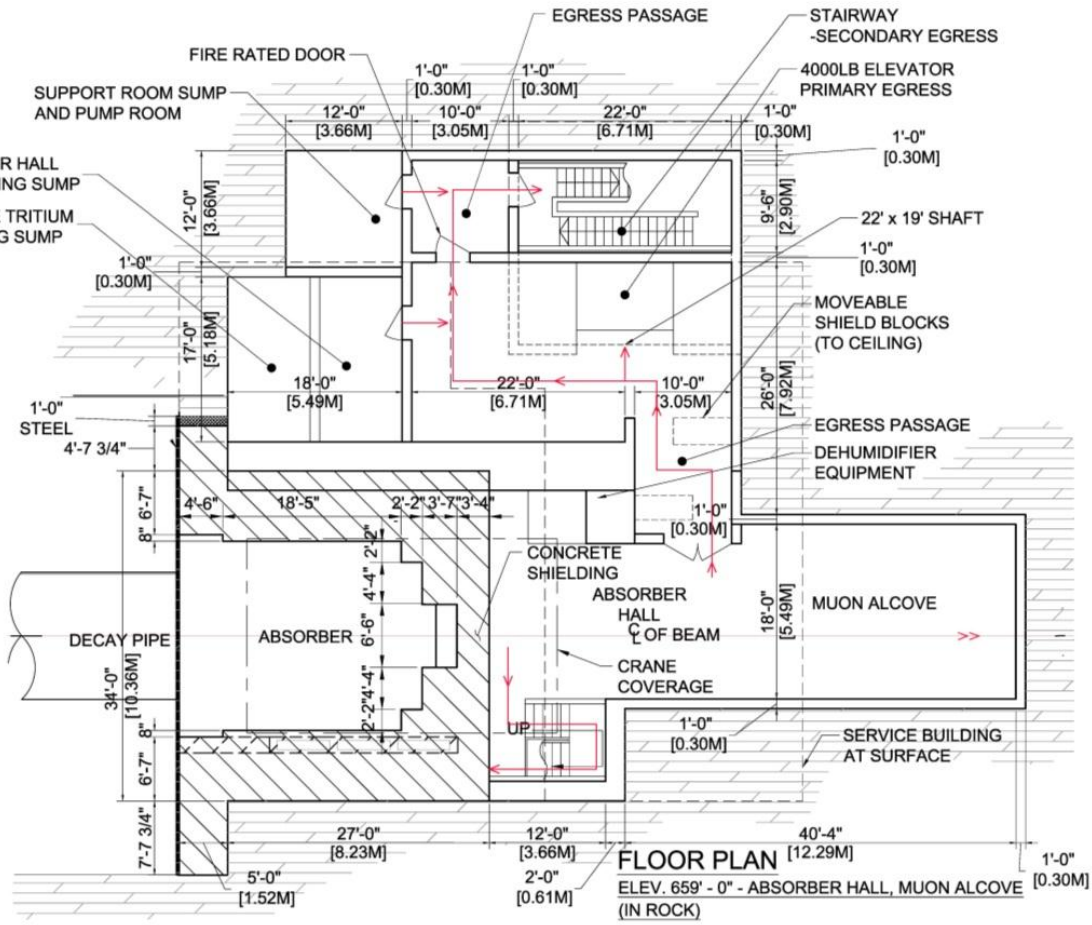

Figure 5-18: Absorber Hall, Muon Alcove, and support rooms: Upper Level, egress routing.

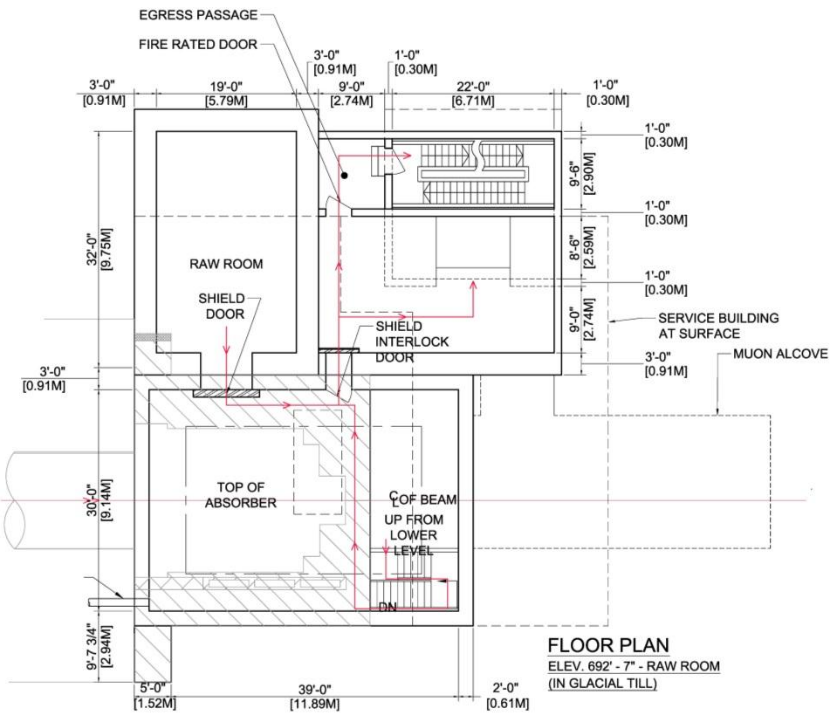

Figure 5-19: Absorber Hall, RAW Room: Middle Level, egress routing.

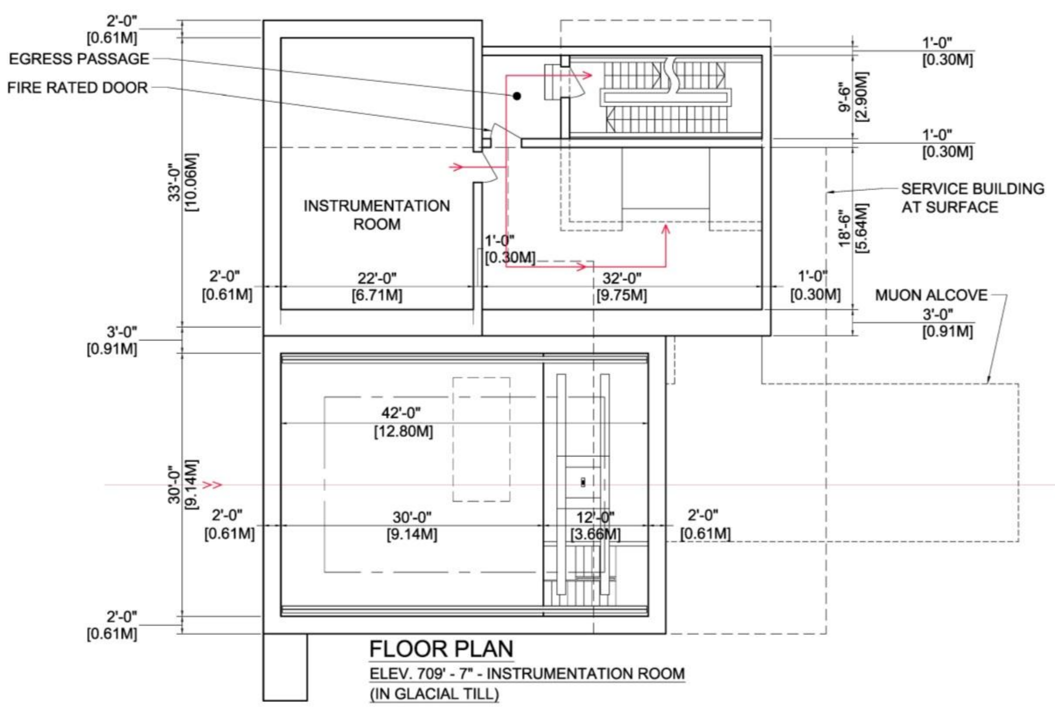

Figure 5-20: Absorber Hall, Instrumentation Room: Upper Level, Egress Routing.

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