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ES&H Section

E. P. NOTE 26

Options and Considerations in the Decontamination and Decommissioning of the Neutrinos at the Main Injector (NuMI) Beamline

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I. INTRODUCTION

The Fermilab Neutrinos at the Main Injector (NuMI) beam constitutes one of the world's foremost facilities in the ongoing and growing effort to study the neutrino sector of particle physics. The scientific productivity of this facility is already recognizable in the form of cutting edge results obtained to date by the MINOS experiment. It is thus envisioned that the NuMI beamline will be operated for many years. As a part of DOE and Fermilab's dedication to environmental protection, the NuMI Environmental Assessment (NuMI EA) contains a commitment to collect information necessary to provide for the eventual decommissioning of this project. Given the evident success of the MINOS experiment coincident with other successful explorations of the neutrino sector worldwide, plans are underway to expand and enhance the capabilities of the NuMI beamline. These improvements, if implemented in the form of the SNuMI beamline, would support of further experiments such as MINERνA, NOνA, and perhaps others. Implementing this revised program requires require the delivery of proton beam power of up to four times the design level specified in the NuMI Project documentation and assessed in the NuMI EA.

The NuMI EA recognized that radioactivity production in the beamline components and its environs is an important consideration. The production of this radioactivity will continue through the life of the NuMI facility as it supports the MINOS experiment and others that will use this facility in the future. It is now prudent to examine the body of data on radioactivity production gleaned during its initial period of operations and develop concepts for decommissioning this facility at some future date, subsequent to the cessation of its operations.

The purpose of this note is to document actions that might be taken subsequent to operations of the NuMI facility to protect members of the public and the environment from the hazards due to this radioactivity production. Following the cessation of operations of the NuMI Beamline a Decontamination and Decommissioning (D&D) Plan will be needed. This note outlines the important radiological considerations pertinent to D&D with an emphasis on those unique to the NuMI facility. The topics discussed may also overlap with other considerations related to the evaluation of the proposed program for the NuMI Beamline. Here, it is recognized that ongoing efforts are underway to better define crucial parameters needed to provide complete understanding. Consequently, this document will require revision as the level of understanding several issues improves.

This note identifies questions for further consideration with the intent of stimulating further discussion and investigation. Future revisions of this document will attempt to answer the salient questions and apply new information to relevant topics.

II. THE RADIOLOGICAL CONDITIONS

A. Conditions During Current and Envisioned NuMI Operations

The NuMI Beamline, as designed for the MINOS experiment, is intended to deliver a beam power of 0.4 MW instantaneously and 4 x 10^{20} 120 GeV protons annually to its target. These protons are used to produce charged hadrons that are focussed so that their neutrino progeny have a selected energy spectrum and are directed toward the MINOS Far Detector at the Soudan Underground Laboratory in Minnesota. This process unavoidably produces a large fluence of hadrons, both charged and neutral, that interacts in the target, the iron and concrete shield surrounding the target, the air in the NuMI Target Hall, and the shielding around the Decay Pipe and in the Hadron Absorber. Operating the focusing horns used in this target station as the protons are delivered exposes a large volume of material, particularly air, to this hadron fluence.

Operating the NuMI beamline produces a great variety of radionuclides in the materials comprising the NuMI Target Station and other beamline components. Most of these radionuclides are solids at room temperature that permanently remain in the solid material shields. However the situation for radionuclides produced in fluids such as air and water is different and requires active controls. As is standard at Fermilab, the cooling water systems are closed systems and are managed as radioactive water systems. However, the situation concerning production in air at this beamline requires unique attention. A variety of radionuclides are produced in the air in the NuMI Target Hall. Those that have half-lives of significance are the typical gamma-ray emitters seen at other Fermilab target stations that have half-lives of less than about an hour (e.g., ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar) as well as the longer-lived ^{7}Be (half-life of 53.3 days) and ^{3}H (half-life of 12.3 years). ^{7}Be, produced as a solid, is readily removed from the air. Except for ^{3}H, the other radionuclides either mostly decay in transit down the Decay Tunnel or are released as gases.

^{3}H is well-known to readily combine with other atoms of hydrogen and oxygen into water molecules denoted as HTO. Any diatomic hydrogen containing a tritium atom (i.e., TT, HT, and, rarely, DT) that is not combined with water would be released as gaseous hydrogen. The behavior of HTO in media is almost identical to that of water. TDO and T_2O molecular forms could exist but would be exceedingly rare and would also behave like water. It is also known that water containing HTO can migrate into concrete and steel where it is available for delayed release.

The general delivery method of HTO from the NuMI Target Station to the Fermilab surface waters is, as of December 2006, now understood although important details await better analysis and the results of studies now underway. By design, the air movement is from the target station down (northwestward) the NuMI Decay Tunnel toward ventilation stack EAV2. The velocity of the air is set to be relatively slow during beam-on operational periods. The slow velocity allows for considerable decay of the abundantly-produced short-lived radionuclides to keep airborne radionuclide emissions well within the conditions of Fermilab's air permit and as low as reasonably achievable (ALARA).

During personnel accesses, the ventilation rate is increased to provide a safe working atmosphere for both industrial hygiene and radiation protection purposes. Unlike other Fermilab accelerator and beamline enclosures, due to its nature as an artificial cavern in a hydrogeologically wet environment, the Decay Tunnel represents a cool environment that is always saturated with water vapor at a relative humidity of nearly 100 per cent. Thus, the water vapor emerging from the relatively dry air of the Target Station, including the HTO, readily condenses in its long journey down the Decay Tunnel and meets water from the surrounding media being collected in the NuMI Sump in the course of the continuous dewatering of the tunnel.

The NuMI Sump discharge represents a volume flow of about 175 gallons per minute as of December 2006. This volume flow and the concentration of HTO in it is now regarded as the only significant source of the present level of HTO concentrations in Fermilab surface waters and in the Industrial Cooling Water (ICW) system. As of December 2006, radionuclides other than HTO have not been seen in the Sump Discharge. The ongoing environmental monitoring program will continue to assess the water in the NuMI Sump for other radionuclides.

Subsequent to the identification of measurable HTO concentrations in the surface waters in November 2005, investigations of the NuMI Sump as the principal source of the HTO commenced. Not long thereafter, the condensate from a chiller in the Target Station was found to be discharging into the NuMI Sump. The interception of this condensate and its separate collection reduced the concentration of HTO measured in the NuMI Sump by about a factor of two and represents the first success achieved in efforts to reduce the concentrations of HTO in the NuMI Sump.

More detailed measurements carried out during 2006 found that the concentration of HTO in the NuMI Sump is rather sharply correlated in time with the status of a variety of parameters of the Target Station ventilation system indicative of this mechanism of HTO delivery to the Sump Discharge. This reinforced the early conclusion that production of HTO in the air in the target station is the major source of the HTO in the NuMI Sump. This conclusion led to the installation of an extensive dehumidification system in the Target Station during the major accelerator maintenance shutdown of spring 2006. Initial operation of this system has achieved a further reduction of about another factor of two in the concentration of HTO measured in the NuMI Sump since operations resumed. This reduction achieved is in line with expectations.

As of December 2006, an ongoing and somewhat imprecisely known “baseline” level of the concentration of HTO in the NuMI Sump persists during both operational and non-operational periods. The value of this “baseline” level is to a limited degree quantitatively understood as of December 2006. During the 3-month spring 2006 shutdown the concentration of HTO continued at a roughly constant value. Excursions above this baseline level were correlated with operational parameters such as the target chase chiller being turned off, the target chase being open, and the status (on, off, or flow rate) of individual components of the ventilation system. During this shutdown the baseline concentration could not be studied by testing individual system parameters one

at a time because of the need to carry out many shutdown tasks simultaneously, including work on the targeting system and installation of the dehumidification system.

The approximate constancy of the baseline concentration during the spring 2006 shutdown implies that some sort of long-term storage mechanism for the HTO is present. An extensive search has found no "open water pools" of sufficient size to account for the observed baseline level. Thus, it is apparent that the HTO produced during operations is finding its way into some materials or geological media and then is being released back to the Target Hall or Decay Tunnel where it can be collected in the NuMI Sump. Since the end of the shutdown, the correlations of the HTO concentrations in the Sump Discharge with operational conditions have continued.

The major facet of this problem not fully understood as of December 2006 is the nature of the storage mechanisms for HTO in the engineered materials including the iron and concrete shielding in the Target Station, in the concrete shielding surrounding the NuMI Decay Pipe, and in the rock walls and other geological media comprising the cavern at all locations. In particular, it would be useful to fully understand the "capacity" of these storage mechanisms as well as the probable time-dependence of the release of HTO to the Sump.

Beginning in June 2006, personnel from the Lawrence Berkeley National Laboratory (LBNL) have collaborated with Fermilab staff on a project to improve the level of understanding of this phenomenon. A progress report by the LBNL personnel has recently been received and is currently under review (Pr06). Although it is the subject of ongoing review, discussion, and interpretation, this interim report collects in one place much of the information available on this target station. Efforts are underway to continue these investigations to further clarify the situation.

As of early December 2006, correlations of the measured concentrations of HTO with beam power since June 2006 have been hindered by a series of unplanned operational downtimes. An improved understanding of this correlation is sorely needed and being vigorously pursued.

B. Considerations Pertaining to D&D Measures Subsequent to NuMI Operations

Planned new experiments will require increases in beam power and likely will result in increased HTO concentrations. Understanding these potential concentrations and their time dependence will influence approaches taken to manage them during the operational life of the NuMI Beamline and beyond. Scientists plan to operate the NuMI Beamline for the MINOS experiment for some number of years. Other emerging proposals for exploring the neutrino sector of particle physics that would use the NuMI Beamline. These include MINERνA, SNuMI, and NOνA. While the basic nature of beamline operations would remain unchanged, the beam power would increase from the value of 0.4 MW specified for MINOS to a level of up to 1.5 MW envisioned for NOνA, still using 120 GeV protons. Without significant changes in the configuration of the Target

Station, the production of tritium would be proportional to the beam targeting rate and hence, on an instantaneous basis, to the beam power.

With such a planned increase in the beam power necessary to support these new experiments, one can reasonably expect the concentrations of HTO to correspondingly increase in the NuMI Sump. It is important to understand the potential concentrations that might result and their time dependence in order to effectively manage them on the Fermilab site during the operational life of the NuMI Beamline.

The eventual decontamination and decommissioning (D&D) of the NuMI Beamline will provide all of the challenges pertaining to existing and "historic" target stations at Fermilab as well as novel ones intrinsic to its design and placement in a relatively deep tunnel. The D&D effort must be one that meets DOE requirements, environmental regulations that may be in place at the time of D&D, and expectations of the neighboring communities and citizenry.

The more conventional challenges at the time of D& D include the proper disposition of beamline components and removable shielding. Radioactivity levels in these components will be large compared with many other such installations at Fermilab, but the technical challenges associated with their disposition are not drastically different in concept. These are well-understood and will not be discussed further here. The present understanding based upon Fermilab observations and the LBNL work as of December 2006 is that the removable shielding components, at the time of D&D, will contain a significant fraction of the inventory of radionuclides, including some of the HTO. The removal of this material would, of course, serve to remove the HTO from eventual migration into the cavern environment.

Simply stated, the most obvious difference between the NuMI facility and other Fermilab target stations and accelerator/beamline enclosures is that NuMI facility and tunnel is relatively wet while the others are generally dry. The others are well above the aquifer and separated from it vertically by a layer of rather impervious clay. The downward migration velocities for water, including water containing HTO is lengthy at the other target stations, whereas NuMI traverses an aquifer. The presence of the NuMI tunnel in the aquifer is a foremost consideration in the planning for D& D activities.

The NuMI tunnel dewatering system may need to continue pumping water from the tunnel after experimental operations cease. The NuMI tunnel during its operational period is, of necessity, continuously dewatered by a large pumping system having an extensive emergency backup power system. This system, by establishing a hydrostatic potential gradient, assures that radionuclides produced in the environs of the NuMI tunnel and transportable by water are eventually collected and subsequently discharged to the Fermilab surface water and ICW systems by pumping the water from the NuMI Sump. The dewatering is, of course, essential to the operation of the facility due to the need to keep the experimental apparatus dry and accessible and also serves to capture water-borne radionuclides, especially ^{3}H as HTO.

Should pumping cease at some point in time following the cessation of operations, it is not clearly evident that any radionuclides mobile in water that might be stored in materials such as the concrete surrounding the Decay Pipe or in the cavern rock walls would be prevented from entering the aquifer. Thus, the continued operation of this system for some period of time subsequent to the end of the operational period could be a crucial component of a D&D plan.

The time-dependences of storage mechanisms in conjunction with the physical half-lives of the radionuclides present, most notably ^{3}H, would ultimately determine the duration of the time period where continued pumping of the tunnel would be needed. As already stated, the details of the mechanisms involved in the storage of HTO in the materials comprising to the NuMI tunnel are only qualitatively understood as of December 2006. As a matter of conjecture they might be reasonably approximated by an exponential function or the sum of a series of exponential functions reflective of multiple storage and flow mechanisms. Of course the governing functional relationship may well end up being more complex. A simplified model may be useful in making preliminary estimates. However, a full-scale hydrogeologic model would undoubtedly greatly improve the accuracy and this is being sought as a result of the collaboration with LBNL.

A brief synopsis of a possible simplified methodology to estimate HTO concentrations follows. Upon cessation of beam, a given radionuclide will decay away according to its physical half-life, the characteristic of radionuclides most commonly tabulated, $t_{1/2}$. In the context of this discussion it is more convenient to work with the physical mean-life, τ_{phys}, the time for the activity to decrease by $1/e$, where e is the base of the Naperian logarithm system. The connection between these two quantities is

$$\tau_{phys} = \frac{t_{1/2}}{\ln 2} = \frac{t_{1/2}}{0.693}. \qquad (1)$$

As an example, for tritium, τ_{phys} =12.32/0.693 = 17.77 years.

The simplest kinetic model for the storage of radionuclides in the medium might be its characterization by a single exponential time constant denoted by τ_{stor}. The effective mean-life, τ_{eff}, is thus given by

$$\frac{1}{\tau_{eff}} = \frac{1}{\tau_{phys}} + \frac{1}{\tau_{stor}}. \qquad (2)$$

A more complex but also more accurate model might find that the value of τ_{stor} could be time-dependent. The right-most term in Eq. (2) could be a summation over the characteristic times of several processes. Inspection of this equation makes it clear that for extremely long storage mean-lives compared with the physical mean-life ($\tau_{stor} >> \tau_{phys}$), $\tau_{eff} \approx \tau_{phys}$ while for extremely short storage mean-lives compared with the physical mean-life ($\tau_{stor} << \tau_{phys}$), $\tau_{eff} \approx \tau_{store}$. One could thus expect the time dependence

of the concentration of a given radionuclide in the NuMI Sump to be approximated by the following:

$$C(t) = C_o \exp(-t / t_{eff}) \,, \tag{3}$$

where C_o represents the concentration at the end of a period of operations and $C(t)$ the concentration at time t following cessation of operations, in the context of D&D activities, the time after the final beam shutdown. If one were to set a goal for the concentration of a given radionuclide, C_{goal}, there is a corresponding time, t_{goal}, that would achieve that value of C_{goal};

$$t_{goal} = -\tau_{eff} \ln\left[\frac{C_{goal}}{C_o}\right]. \tag{4}$$

A detailed, trustworthy model is highly desirable. Further complexities are possible, even including mechanisms that couple with each other. The real-world situation may well be much more complicated than this simple analytical picture.

Some numerical examples involving HTO may be useful as illustrations using this simplified approach. Although other radionuclides potentially could be present, tritium is nearly certain to be that with the longest mean-life by far. As an illustration, assume that the tritium concentration in the Sump Discharge at the final termination of operation of NuMI is 50 pCi/ml and that it is desirable to achieve a concentration goal of C_{goal} = 1 pCi/ml, the required limit of detection specified for HTO in drinking water by USEPA (EPA). If t_{stor} is very long compared with the physical mean-life ($\tau_{eff} \approx \tau_{phys}$), it is found from Eq. (4) that t_{goal} = 70 years. If, however, $\tau_{stor} \approx \tau_{phys}$, then $\tau_{eff} \approx 0.5\,\tau_{\mathrm{phys}}$ = 8.88 years. In that scenario, t_{goal} = 35 years.

The studies done as of December 2006 are inadequate to estimate a value of τ_{stor} in a fully quantitative manner. However in the LBNL progress report (Pr06), Fig. 5.6-4 provides results from a sophisticated modeling program that can be used to estimate possible values of τ_{stor} in the concrete shield surrounding the Decay Pipe and in the cavern rock. The LBNL progress report indicates that storage in the concrete is the most important "bank" for the HTO followed by the cavern rock in the time period after cessation of the irradiation. This tentative conclusion is consistent with both the slower diffusivity of water through concrete and the location of the concrete nearer the beam center line.

The form of the graphical results presented in fig. 5.6-4 of Ref (Pr06) is indicative, in the sense of Eq. (3), of multiple, complicated storage mechanisms. During an early period following beam shutdown, some mechanisms involved with the clearing of HTO occur over rather short time scales. After this early period, slower mechanism become dominate and after a shutdown of about three years the slope of the curve for concrete is consistent with an approximate value of τ_{eff} of approximately 1200 days or about 3.3 years, inclusive of additional reduction resulting from the physical decay. The slope of the curve for rock is reflective of more rapid clearance mechanisms. For purposes of this

illustration, the value for the concrete provides a way to do a crude, conservative estimate. During the 3 month shutdown of spring 2006 a value of τ_{eff} this large would not have had an observable effect on the measurements in the concentration of HTO seen in the NuMI Sump. If this value of τ_{eff} turns out to be "typical", and one applies this to the numerical example given above, then $t_{goal} \approx 13$ years. Obviously a better understanding of these mechanisms is of crucial importance for planning D&D activities. As a part of D&D activities it is clearly also necessary to establish a goal for the maximum HTO concentrations in the NuMI Sump. The standard promulgated in Ref. (EPA) may be appropriate. Improved results for long-term irradiations derived from ongoing studies should be helpful providing more accurate estimates than those obtained from the very early results of LBNL study as reported in December 2006.

C. List of Questions Requiring Further Study to Properly Define the D&D Plan

This section identifies additional questions whose answers may help define the components of an appropriate D&D plan.

1. Do goals need to be established for concentrations of radionuclides in the surface waters on the Fermilab site?

2. What goal should be adopted for the HTO concentrations in the NuMI Sump at the end of the D&D process?

3. What are the nature, capacity, and time-dependence of the storage mechanism for HTO in the materials comprising the NuMI Beamline?

4. What is the correlation of HTO concentrations in the NuMI Sump with NuMI Beam Power or NuMI integrated protons under both planned and future operational conditions?

5. What concentrations of radionuclides will be built up on the permanently installed engineered materials and in the cavern itself over the lifetime of the facility at present and increased design intensities?

6. What is a plausible and technically defensible time-dependence for the concentrations of HTO in the Sump Discharge both during and subsequent to beam operations at current and proposed beam intensities?

7. In the context of the answers to the other questions, what methods can be used to successfully manage the projected concentrations of HTO in the NuMI Sump and in the Fermilab surface waters when the projections related to Question 4 become available?

8. What is the maintenance impact of continued operation of the NuMI tunnel dewatering system in a reliable, dependable manner in terms of ongoing operational costs, equipment maintenance considerations, and staffing?

III. DECONTAMINATION AND DECOMMMISSIONING OPTIONS

In this section alternatives for D&D are identified and briefly discussed. Answers to questions posed in Section 2.C. and other specific questions related to each alternative would refine these discussions.

A. Continue Pumping the NuMI Tunnel

At the time that the pumping operation would cease, the NuMI tunnel will certainly fill with water. In this alternative, the pumping system would be maintained and operated until concentrations of all radionuclides present in the NuMI Sump meet established, acceptable goals. Doing this would require the continued operation and maintenance of the pumping system along with the associated staff support. Periodic sampling and analysis activities would continue to monitor progress toward achieving the specified goals. The continued discharge into Fermilab surface waters and ICW system would also require ongoing monitoring of those entities and continuation of the staff and equipment resources necessary to accomplish that.

Should Fermilab continue to operate as an accelerator facility or similar activity for purposes other than the NuMI-based neutrino physics program, the monitoring and analysis activities related to the D&D of NuMI likely would represent a small increment of the ongoing monitoring effort. The duration of this period would be estimated with improved precision as the understanding of the processes involved becomes more completely quantified.

B. Cease Pumping the NuMI Tunnel

Upon ceasing operations and removing equipment, in this alternative one would choose to simply turn off the pumps. This alternative would allow the tunnel to fill with water and the concentrations of radionuclides would, by means of dilution, reach values lower than those present during the last stage of operations if the latter is conducted at high beam powers. However, the presence of this water might result in the leaching of other radionuclides aside from ^{3}H into the aquifer. An ongoing monitoring program would be needed to assess the concentrations of radionuclides present in the tunnel water that under this scenario would be considered to be Class I groundwater (i.e., potential drinking water) under Illinois Environmental Protection Agency specifications. The information available as of December 2006 is insufficient to conclude that the concentrations would be within those considered acceptable in a Class I groundwater resource. Furthermore, the volume of water that could become affected would be much later. If the concentrations of radionuclides in this water exceed the accepted goals, it is plausible that the pumping program might have to be restored as a part of a remediation program.

C. Install a Collection System Upstream of Decay Pipe

In this alternative, under post-operational conditions, one would attempt to install a collection system to capture the water carrying the activation products before it becomes

diluted by the groundwater inflow. Subsequent to operations this alternative perhaps could be more straightforward to implement when unconstrained by the need to preserve shielding, etc. but would represent a considerable effort of a scope that is presently unknown and a feasibility that is not assured. Fermilab and LBNL studies as of December 2006 indicate the contribution to the NuMI Sump following operations would be dominated by HTO emerging from the concrete shielding around the Decay Pipe and the cavern rock. The component due to air movement from the Target Station downstream would decline rather rapidly. Thus, to choose this option, improved understanding of the relative contributions of the various storage mechanisms is sought. The choice of this alternative would continue to require a dry, pumped tunnel, but plausibly has the advantage of effecting lower concentrations in the NuMI Sump being pumped and possibly shorten the time duration of the pumping period. It also may not be possible to completely capture all activation products before further dilution by the incoming groundwater.

D. Remove Activated Materials

"Readily" removable activated materials such as beamline components and the Target Station shielding would likely be accomplished in any chosen D&D plan. In fact, the degree to which this can be done may favorably affect all alternatives for D&D purposes by removing a significant amount of HTO. It is now known that the modular steel and concrete shielding located in proximity to the target and focusing horns is capable of storing a considerable volume of water (Pr06). Removal of this material may significantly decrease the concentrations of HTO emerging from the NuMI Sump.

A more complicated extension of this alternative would be to remove the concrete which shields the decay pipe. Doing this completely may not be technically feasible given the tunnel configuration, especially that involved with the left (beam's eye view) side inaccessible region. If feasible, at all, the task of removing this concrete would be arduous and such an action might well temporarily release the HTO stored within it at an accelerated rate. Selection of this alternative would require detailed planning including cost and schedule considerations. Maintenance of an accessible tunnel through continued pumping would be required. It is plausible that removal of this concrete could require a period of several years. The information presently available as discussed, for example, in the LBNL progress report (Pr06), allows for the possibility that the "natural" mechanisms for clearing HTO from the concrete and rock might reach the concentration goal on about the same time scale.

E. Sealing the Tunnel

One could envision and attempt to seal the tunnel to prevent the migration of HTO into the tunnel from the concrete shielding surround the Decay Pipe and from the cavern rock. This approach might presume that the tunnel ventilation has been turned off once the sealing work was completed. The task of doing this type of sealing is a huge one and is possibly not feasible especially due to the many inaccessible surfaces, particularly on the left (beam's eye view) side. The sealing process would have to be done with pumping

operations continuing in order to provide access and the monitoring and analysis program would need to be continued. Even if feasible, such a sealing operation would, in effect, defeat the ability of the hydrostatic gradient created by the pumping action to assure the inward, instead of outward, migration of radionuclides to the aquifer. The concentrations of radionuclides excluded from the tunnel in this manner would have to be assessed and monitored in an ongoing program to assure that they represent no risk to the Class I resource.

F. Combinations of the Above

There are possible combinations of these alternatives that could be devised. These should be discussed in subsequent versions of this analysis as further studies are done by Fermilab personnel and others and as operational experience with the NuMI beamline is acquired.

IV. CONCLUSIONS/RECOMMENDATIONS FOR FURTHER WORK

The radiological parameters associated with the NuMI beamline would continue to be assessed and evaluated as these operations continue. In parallel, radiological environmental monitoring activities would be carried out in accordance with Fermilab's Environmental Management Systems (EMS). Members of the Fermilab staff would further develop plans for D&D activities based upon the details of this information as it emerges. Ongoing efforts will be made to assure adequate collection of data to support successful planning activities.

As NuMI operations continue, the relevant data would need to be collected and adequately documented in a manner that will facilitate information retrieval. Efforts would need to continue to pursue the answers to the questions raised in this note and perhaps new ones that may emerge. As a matter of management, this would need continued coordination between several Fermilab organizations.

It is clear that the D&D of the NuMI beamline will require a significant level of planning to accomplish in a manner that is consistent with Fermilab and DOE's commitments to assure adequate protection of workers, members of the public, and the environment. A formal D&D Plan will be essential to achieving the identified goals.

References

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