Evaluation of Real-Time Radiation Monitoring

Contents

1.0 Background

In Section 4.3.2, "Other Emergency Preparedness Insights," of its report on lessons learned from the Fukushima accident (Agencywide Documents Access and Management System (ADAMS) Accession No. ML111861807), the Nuclear Regulatory Commission's (NRC's) Near-Term Task Force (NTTF) provided observations regarding radiological assessment capabilities during an accident. The NTTF stated that accurate and timely dose data are critical to validating dose projections and ensuring dose reduction for the public, and that having publicly available dose data provides a level of public confidence. In its evaluation, the NTTF stated that, "As long as field teams are adequately staffed, equipped, and capable of transit given the nature of the natural disaster, field monitoring remains an effective method to acquire radiation data." Based on this evaluation, the NTTF made Recommendation 11.3:

> Study the efficacy of real-time radiation monitoring[1] onsite and within the EPZs [emergency planning zones] (including consideration of AC [alternating current] independence and real-time availability on the Internet).

The staff agrees with the NTTF that timely and accurate radiological assessment data are an intrinsic part of an emergency response. The staff is of the position that an adequate radiological assessment capability already exists at the plants licensed by the NRC. In the wake of the 1979 Three Mile Island (TMI) accident, the NRC required applicants and licensees to implement radiation monitors to provide continuous indication at fixed locations.

The NRC subsequently retracted the requirement (see Section 3.4 below) based on an evaluation of the effectiveness of such systems, which concluded that the ability of a 16-32 station system to provide sufficiently reliable technical information to be used in a decision-making process was highly questionable. As an example, the fixed station environs monitor (FSEM) stations in a 16-station system, equidistantly spaced on a one-mile radius from the plant, will be about 2050 feet apart on the circumference. Because of local geography, bodies of water, right of access, access to power and communications, and other constraints to siting, it is unlikely that all monitoring stations can be spaced equidistantly around a given circumference, making the spacing between stations even larger. For any given plume, the maximum dose rate occurs at the plume centerline and drops off asymptotically on all three axes towards the plume edges. Under stable meteorology typical of nighttime conditions, the plume will be narrow, as little as 775 feet at a distance of one mile[2]. These plume widths were calculated at the point where the dose rate is 10 percent of the centerline value. For a plume that passes between two FSEMs, the indications on each will significantly underestimate the dose rate. A similar outcome applies to elevated plumes that pass overhead. Only a ground level plume, whose centerline aligns with a FSEM, will have a representative indication.

2.0 Current Status

The staff has determined that FSEMs will not substantially enhance a licensee's current capabilities for making protective action recommendations for the public. The staff finds that the

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1 This paper refers to these radiological monitors as "fixed-station environs monitors" or "FSEMs."

2 "Meteorology and Atomic Energy 1968," TID24190, July 1968, US AEC, Equation 3-3.5.6 https://www.orau.org/ptp/PTP%20Library/library/Subject/Meteorology/meteorology%20and%20atomic%20energy.pdf.

current monitoring and assessment capabilities, in conjunction with plant data assessments, are adequate to support response decisions.

Further, the staff believes the distribution of the assessment data should be limited to the cognizant State and local officials who have the responsibility and competency to understand the data and to determine whether public protective measures need to be implemented and which actions should be taken. Those who do not understand FSEM data or its limitations could misuse the information, which may acerbate shadow evacuations, reducing the effectiveness of the protective actions decided upon by the cognizant public officials.

Accordingly, the staff proposes to close Recommendation 11.3 with no further staff or licensee action.

3.0 Discussion

This section describes the staff's evaluation of Recommendation 11.3 and includes current post-accident radiological monitoring capabilities, a general regulatory review, a review of relevant emergency preparedness regulations, as well as regulatory actions on radiation monitoring post-TMI. The 1982 assessment of FSEMs, a review of selected existing FSEM installations, fixed-station environmental monitoring in Japan, public protective action recommendations in the United States, public protective action recommendations in Japan, backfitting considerations, and overall conclusions are also provided.

3.1 Current Post-accident Radiological Monitoring Capabilities

NRC regulations[3], informed by regulatory guidance[4], require applicants to establish, and for licensees to maintain, capabilities to monitor and assess radiological conditions during normal operations and accident conditions. These regulations ensure that the licensee has access to information that enables it to identify conditions adverse to safety and to respond appropriately. The regulations do not require the licensee to make this radiological monitoring and assessment data publicly available.

No single assessment capability is applicable to all release conditions, but the collective capability addresses most likely release situations. This discussion focuses on those assessment capabilities that support public health and safety by supplying pertinent data for public protective action recommendation (PAR) decision-making. During an emergency response, the licensee provides this assessment data to the offsite response organizations to inform their decision-making. These capabilities are routinely demonstrated in evaluated drills and exercises. Other uses of the data obtained from these capabilities, such as routine effluent and environmental monitoring, are not addressed in this discussion. These emergency response capabilities include:

- Installed effluent radiation monitoring systems (including high-range effluent monitors) that continuously monitor liquid and gaseous release pathways to the environment for radioactive material released by normal operations, including anticipated operational

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[3] For example, Title 10, *Code of Federal Regulations*, Part 50, "Domestic Licensing of Production and Utilization Facilities" (10 CFR 50).

[4] "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," NUREG-0654/FEMA-REP-1, November 1980. http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0654/.

occurrences, and from postulated accidents. These monitors provide operators in the control room with indication of release stream concentrations and provide alarms if pre-determined thresholds are exceeded and may provide protective signals that activate release mitigation design features (e.g., release pathway isolation or diversion through filters). Selected monitor channel displays are provided in the technical support center and emergency operations facility. All identified gaseous and liquid effluent release pathways, expected to be used in the event of a postulated accident, are monitored[5]. If a release is ongoing via a monitored release pathway, an indication on an installed effluent monitor can be the most reliable indicator of the radioactive release.

- Installed containment high-range radiation monitoring (CHARM) systems that continuously monitor radiation dose rates in the containment atmosphere. These monitors provide control room operators with indication of the radioactive material in the containment and provide alarms if pre-determined thresholds are exceeded. A CHARM provides indication of reactor coolant system and fuel fission product barriers status and, in severe cases, the presence of radioactivity that, should the containment barrier be challenged, warrants public protective actions. A release does not need to be ongoing for a CHARM to provide information supporting public PAR decision-making.

- Radiological assessment via field monitoring and sampling within the plume exposure pathway EPZ by the licensee is required by NRC regulations. This monitoring is an intrinsic part of the facility emergency response. Licensees are required to provide methods, equipment and expertise to make rapid assessments, including field team notification, activation, composition, transportation, communications, monitoring equipment, and estimated deployment times[6]. Although field monitoring and sampling are useful only with an ongoing release, they are also a means for detecting, and subsequently assessing, unmonitored releases and confirming dose assessments. They would also fill a void should the installed radiation monitoring equipment lose power.

- Radiological assessment via dose assessment methodologies is a significant component of the licensee's capability to assess and monitor the potential offsite consequences on a continuous basis. These capabilities not only use actual meteorological information and effluent radiation monitor indications, but also provide the capability to perform assessments based on field measurements, sample analysis results, containment radiation monitors, and identification of selected plant parameters (e.g., time since core uncovery, time of reactor shutdown, containment leakage rate, reactor coolant system leakage rate, availability of filters or containment sprays).

- FSEMs are in place at some sites. Some licensees implemented the guidance of Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Environs Conditions During and Following an Accident," Revision 2 (ADAMS Accession No. ML060750525) before it was retracted in Revision 3. Although some licensees have requested relief from resultant commitments, others maintained the systems. In some of these cases, licensees are maintaining the systems under agreement with State and local officials. In other cases, State and/or local officials are maintaining the systems.

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5 *Ibid*. 5, Appendix A, "General Design Criteria for Nuclear Power Plants," Section VI, "Fuel and Radioactivity Control," Criterion 64 — Monitoring Radioactivity Releases.

6 *Ibid*. 5, Section II.I, "Accident Assessment."

- Many of the radiological assessment capabilities discussed earlier have predetermined thresholds that serve as emergency action levels (EALs) in activating emergency response actions under the licensee's emergency plan[7], including PARs.

- State and local officials maintain field-monitoring capabilities and they can call upon Federal resources to supplement these capabilities during prolonged responses[8]. The licensee and State or local response organizations initially implement the capabilities concurrently as first responders. When the source is under control and early protective action decisions have been implemented, licensees generally re-direct field-monitoring resources to onsite radiation protection concerns, as Federal resources (e.g., Federal Radiological Monitoring and Assessment Center (FRMAC)) become available. The mission of the FRMAC is to coordinate and manage all Federal radiological environmental monitoring and assessment activities during a nuclear or radiological incident within the United States in support of State, local, tribal governments, Department of Homeland Security, and the Federal coordinating agency. The licensee and NRC may provide liaisons to the FRMAC when activated for an emergency.

3.2 General Regulatory Overview

During an emergency response, the licensee is required to make pertinent information related to the emergency to the State and local officials who are responsible for determining the need for public protective actions. These information exchanges are predicated on protecting public health and safety by ensuring that these officials have the data needed to make informed decisions on public protective actions.

Unless the licensee requests withholding from disclosure under 10 CFR 2.390 or the material contains security information, all written reports submitted by licensees in response to a regulatory requirement are entered into the facility's docket file as publicly-available documents.

3.3 Relevant Emergency Preparedness Regulations

Applicants are required to submit, and licensees are required to maintain and follow, an emergency plan that meets each of 16 planning standards of § 50.47(b).[9] The following planning standards are of particular relevance to the current discussion:

Planning standard § 50.47(b)(4) provides:

> A standard emergency classification and action level scheme, the bases of which include facility system and effluent parameters, is in use by the nuclear facility licensee, and State and local response plans call for reliance on information provided by facility licensees for determinations of minimum initial offsite response measures.

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7 *Ibid*. 5, Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," Section IV.B, "Assessment Actions."

8 Federal Emergency Management Agency, "Program Manual: Radiological Emergency Preparedness," Criterion I.7 & I.8, https://www.fema.gov/media-library-data/1438012300285-2b6b1bef656460f45c45c7e48c91d03c/REPProgramManualJuly2015SECURE.pdf.

9 These planning standards are specified in the Federal Emergency Management Agency (FEMA) regulations at 44 CFR Part 350.5.

Although FSEMs may provide data for these declarations, the absence of FSEMs will not preclude the licensee's ability to make an emergency classification and, if necessary, an appropriate PAR. Selected plant parameters can provide indication of core damage and result in a timely and appropriate emergency declaration prior to the onset of a radioactivity release that could be measured in the plant environs.

Planning standard § 50.47(b)(5) provides:

> Procedures have been established for notification, by the licensee, of State and local response organizations and for notification of emergency personnel by all organizations; the content of initial and follow-up messages to response organizations and the public has been established; and means to provide early notification and clear instruction to the populace within the plume exposure pathway Emergency Planning Zone have been established.

Although FSEMs could provide data for these notifications, the absence of FSEMs, with or without real-time internet access to radiological assessment data, will not preclude the licensee's ability to provide timely notifications and PARs to State and local officials nor will it preclude the ability of those officials to make and implement public protective actions. To the contrary, the public availability of FSEM data online could cause some members of the public to take premature or unwarranted actions that could acerbate the shadow evacuation[10] phenomenon, impeding the implementation of protective actions in accordance with State and local emergency plans.

Planning standard § 50.47(b)(9) provides:

> Adequate methods, systems, and equipment for assessing and monitoring actual or potential offsite consequences of a radiological emergency condition are in use.

Although FSEMs could provide data towards this end, they are limited in that a radioactivity release must be in progress before they would detect the radiological condition. The absence of FSEMs will not preclude the licensee's ability to provide timely data to State and local officials, nor will it preclude the ability of those officials to make and implement public protective actions. See Section 3.1 of this paper.

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[10] A shadow evacuation is the self-initiated evacuation of people from areas outside a declared evacuation area. Shadow evacuees can congest roadways and impede the egress of those evacuating from an area of higher risk.

Planning standard § 50.47(b)(10) provides:

> A range of protective actions has been developed for the plume exposure pathway EPZ for emergency workers and the public. In developing this range of actions, consideration has been given to evacuation, sheltering, and, as a supplement to these, the prophylactic use of potassium iodide (KI), as appropriate. Evacuation time estimates have been developed by applicants and licensees. Licensees shall update the evacuation time estimates on a periodic basis. Guidelines for the choice of protective actions during an emergency, consistent with Federal guidance, are developed and in place, and protective actions for the ingestion exposure pathway EPZ[11] appropriate to the locale have been developed.

Supplement 3, "Guidance for Protective Action Strategies," to NUREG-0654[12], informs planning standard § 50.47(b)(10). Section 2.6 of Supplement 3 emphasizes the NRC protective action strategies:

> A General Emergency is expected to be declared, based on plant conditions before a radiological release could potentially begin. Licensees will perform radiological assessments throughout the emergency and will recommend to OROs[13] the need to take or expand protective actions if dose projections show that protective action criteria could be exceeded. Dose projections that are based on effluent monitor data and verified by field monitoring data would provide the strongest basis for a PAR; however, effluent monitor data alone can be sufficient if other data (e.g., plant conditions, area or process monitors) verify the occurrence of a radiological release. Although verification of dose projection data is desirable, the licensee should not delay PARs while waiting for field monitoring data or sample analysis.

Although FSEMs could provide data in support of PAR decision-making, they are limited in that a radioactivity release must be in progress before the FSEMs can indicate the dose. Public protective actions are most effective if implemented prior to the onset of the release. The absence of FSEMs will not preclude the licensee's ability to provide a timely PAR to State and local officials, nor will it preclude the ability of those officials to make and implement public protective actions. See also Section 3.8 of this paper.

3.4 Regulatory Actions on Radiation Monitoring Post-TMI

Following the TMI accident, the NRC issued new guidance[14] for real-time radiological monitoring specifically for the purpose of emergency response.

- Section 2.1.8 of NUREG-0578 , "TMI-2 Lessons-Learned Task Force Status Report and Short-Term Recommendations" (ADAMS Accession No. ML090060030), recommended

[11] The State and local governments are responsible for monitoring the ingestion pathway EPZ.
[12] *Ibid*. 6, Supplement 3, "Guidance for Protective Action Strategies."
[13] Offsite response organizations (OROs) are those entities having responsibility for managing the implementation of measures to protect public health and safety.
[14] The staff issued Generic Letter 82-33, "Supplement 1 to NUREG-0737 – Requirements for Emergency Response Capability," which explicitly stated that the guidance documents were not to be treated as requirements.

increased range noble gas effluent monitors, increased range containment monitors, and improved iodine monitoring. It did not explicitly identify FSEMs.

- SECY-79-450, "Action Plan for Promptly Improving Emergency Preparedness" (ADAMS Accession No. ML12236A917), included the following item:

  > Assure that improved licensee offsite monitoring capabilities (including additional TLDs or equivalent) have been provided for all sites.[15]

- A September 1979 letter from D.G. Eisenhut (ADAMS Accession No. ML031320328) to all operating nuclear power plants set forth requirements from the NRC Office of Nuclear Reactor Regulation. Enclosure 7 to that letter identified a near-term requirement:

  > Assure that improved licensee offsite monitoring capabilities including additional thermoluminescent dosimeters (or the equivalent) have been provided for all sites.

  Enclosure 8 of the Eisenhut letter clarified this requirement to "Improve offsite monitoring capability and assigned an implementation category of A1 (i.e., prior to operating license issuance or by mid-1980). The requirement did not explicitly identify FSEMs.

- An October 30, 1979 letter from H.R. Denton (ADAMS Accession No. ML031320403) to all operating reactors provided implementation schedules for the NUREG-0578 items. With regard to radiation monitoring, the letter provided clarification on NUREG-0578 items 2.1.8.b and 2.1.8.c. FSEMs were not identified.

- NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident" (ADAMS Accession No. ML072470526), provides a comprehensive and integrated plan for the actions now judged necessary to address the lessons from the TMI-2 accident. Table 1 assigned priorities and implementation dates for the action items. Of relevance were action items:

  - Item II.F.1, "Additional Accident Monitoring Instrumentation," identified the need for certain accident-monitoring instrumentation. Included were requirements for: (1) noble gas effluent radiation monitors; (2) provision for continuous sampling of plant effluents for post-accident releases of radioactive iodines and particulates; and, (3) containment high range area radiation monitor (CHARM). None of the guidance required FSEMs be installed.

  - Item III.A.1, "Improve Licensee Emergency Preparedness – Short Term," stated that licensees would upgrade emergency preparedness in accordance with the requirements described in SECY 79-450. The item did not identify FSEMs in the discussion, but Page III.A.1-9 stipulated "Establishing improved offsite radiological monitoring capability in accordance with the NRR/RAB Technical Position."[16]

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15 Thermoluminescent dosimeters (TLDs) are a radiation measurement device.

16 Generic Letter 79-065, "Radiological Environmental Monitoring Program Requirements" – including Radiological Assessment Branch Technical Position, "An Acceptable Radiological Environmental Monitoring Program (November 1979)." http://www.nrc.gov/reading-rm/doc-collections/gen-comm/gen-letters/1979/gl79065.html. The BTP discusses an increase in the number of "direct radiation stations" and notes that the NRC will place a similar amount of stations in the area between

- Item III.D.2, “Offsite Dose Measurements,” Item 4, “Offsite Dose Measurements,” stated that additional means are required for determining dose rates and doses associated with large accidental releases of radionuclides. The item stated that:

  > RES [the NRC’s Office of Nuclear Regulatory Research] will study the feasibility of environmental monitors capable of measuring real-time rates of exposures to noble gases and radioiodines. . . . . . The feasibility and desirability of providing the information in the control room or in another appropriate technical support center will be determined. . . This activity supports proposed revisions to Regulatory Guide 1.97 (Item II.F.3). . .

  The item also stated that the NRC would place 50 TLDs around each site in coordination with the States and utilities. This program, which has a nexus to the September 1979 letter from D.G. Eisenhut, was operated by the NRC in order to provide continuous measurement of ambient radiation levels around nuclear facilities.[17] However, the item regarding real-time environmental monitors has no direct nexus to NUREG-0578.

- The NRC published NUREG-0737, “Clarification of TMI Action Plan Requirements,” to provide a more detailed explanation of the TMI Action Plan items approved by the Commission for implementation. The NUREG-0660 requirements regarding: (1) noble gas effluent radiation monitors; (2) provision for continuous sampling of plant effluents for post-accident releases of radioactive iodines and particulates; and, (3) containment high range area radiation monitor (CHARM), were carried over as Item II.F.1.

  - Item II.F.1 of NUREG-0737, “Clarification of TMI Action Plan Requirements,” provided detailed guidance for these three requirements. None of the guidance required FSEMs be installed.

  - Item III.A.1 of NUREG-0660 was carried over as Items III.A.1.1, III.A.1.2, and III.A.2. None of the guidance required FSEMs be installed.

  - Item III.D.2 of NUREG-0660, “Public Radiation Protection Improvement,” which included offsite monitoring, was not carried over to NUREG-0737.

- Regulatory Guide 1.97, Revision 2, was issued in December 1980. Earlier versions provided broad guidance without tabulations of parameters. Revision 2 was significantly more prescriptive and contained the following Type E[18] variable:

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the two rings designated in Table 1. However, this requirement was not referring to FSEMs but, rather, TLDs.

17 The program was subsequently cancelled due to financial considerations.

18 Those variables to be monitored for use in determining the magnitude of the release of radioactive materials and continually assessing such releases.

Variables	Range	Purpose
Radiation Exposure Meters (continuous indication at fixed locations)	Range, location, and qualification criteria to be developed to satisfy NUREG-0654, Section II.H.5b and 6b requirements for emergency radiological monitors	Verify significant releases and local magnitudes

Other Type E variables in Regulatory Guide 1.97 relied on portable instrumentation. The staff could not determine where the referenced criteria resided, as the next revision to Regulatory Guide 1.97 omitted the FSEMs. It is also unclear where this specific variable was first identified. The regulatory analysis attached to Regulatory Guide 1.97 stated that NUREG-0578, the draft Task Action Plan A-34[19] and ANSI/ANS-4.5[20] provides ample bases for revising Regulatory Guide 1.97. However, neither of these references provided a nexus to FSEMs. Some of these references are circular in nature. For example, ANSI/ANS-4.5-1980, provided in part:

> In the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.97, Revision 2, Type E variables have been introduced. Type E variables, monitored to determine the magnitude of the release of radioactive materials and for continually assessing such releases, for providing defense-in-depth, and for diagnosis, have not been included in this standard since the writing group does not consider that these variables are within the scope of accident monitoring instrumentation.

- Revision 3 to Regulatory Guide 1.97 was issued in May 1983. Relevant to this paper was the omission of FSEMs, leaving the reliance on portable survey instruments. A footnote explained the omission as follows:

> It is unlikely that a few fixed station monitors could provide sufficiently reliable information to be of use in detecting releases from unmonitored containment release points. However, there may be circumstances in which such a system of monitors may be useful. The decision to install such a system is left to the licensee.

The attached regulatory analysis for Revision 3 of the guide, provided:

> Regulatory Guide 1.97, Revision 2, was issued as an active guide in December 1980. The guide was issued with an outstanding question raised by the industry and supported by the Advisory Committee on Reactor Safeguards regarding the practicality of deploying at fixed locations environs radiation monitors capable of detecting radioactive material releases from an unidentified breach of the containment. These monitors were listed in the guide but implementation of these provisions of the guide was delayed pending the outcome of a study that was to develop guidance as to their number and location.

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19 "Resolution of Generic Safety Issues," NUREG-0933, Item A-34: "Instruments for Monitoring Radiation and Process Variables During Accidents," http://nureg.nrc.gov/sr0933/.

20 ANSI/ANS-4.5-1980, "Criteria for Accident Monitoring Functions in Light-Water-Cooled Reactors," American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois, 60525.

- The NRC published Generic Letter No. 82-33, "Supplement 1 to NUREG-0737 – Requirements for Emergency Response Capability," to distill the basic requirements from a range of guidance documents. In a departure from the previously issued guidance, the NRC specified that the document be used by NRC reviewers and licensees regarding acceptable means for meeting the basic requirements. Section 6 of this document identified Regulatory Guide 1.97 Revision 2 as a source of guidance for instrumentation in the Control Room, the Technical Support Center and the Emergency Operations Facility.

3.5 1982 Assessment of Fixed-Station Environmental Monitors

The staff contracted with Exxon Nuclear Idaho Co, Inc. for an assessment of FSEMs, which was reported in NUREG/CR-2644, "An Assessment of Offsite, Real-Time Dose Measurement Systems for Emergency Situations." This report addressed several aspects of the FSEM concept, with the following items being primary:

- The ability of an FSEM system to detect and quantify monitored and unmonitored releases;
- The ability of an FSEM system to detect and quantify an unmonitored release in the presence of a known release;
- An assessment of the uncertainties associated with estimating the magnitude of an unmonitored release;
- The number of stations required to detect a release and the uncertainty associated with the detected value;
- The availability, cost, and the instrumentation requirements for a FSEM system;
- To provide cost data relative to the installation, operation, and maintenance of a FSEM system; and,
- To determine the characteristics and information return for a FSEM system within a 0.5 mile radius with capital costs limited to $500,000.

Much of the analysis used a statistical approach. The study's authors also collected information from FSEM vendors. As identified above, the study focused on the ability of a FSEM system to reliably detect and measure an unmonitored release during an emergency. The majority of release pathways from the facility expected to be used during accidents are monitored by continuous radioactive effluent monitors. However, there can be unanticipated pathways created during an accident. A primary purpose of a FSEM system is to detect and measure such releases thereby providing information needed for public protective action decision-making. The ability of a FSEM system to achieve this purpose is dependent on the number of stations, their location, and the distance between stations.

With regard to the number of stations that would be needed for reliable detection and measurement, the study authors concluded that a system consisting of 16 or even 32 stations may not provide information on centerline dose values and plume location as a plume could pass between two stations undetected[21]. Even if detected, the dose could be underestimated unless the plume centerline passed directly over one of the sparsely placed stations.

The study also looked at the usefulness of close-in stations to detect and measure unmonitored releases from a release plume, but concluded that building shine[22] from the site buildings could prevent detection of the unmonitored release[23]. The authors considered directional shielding for the stations but noted that this shielding could degrade the ability of the station to detect and measure a monitored release. The authors concluded that little or no information regarding a release plume could be obtained from stations located close to the reactor building.

With regard to costs, the study's authors included the cost of the FSEMs, the cost of installation of the stations (e.g., right of way purchasing, providing electrical service, and data communications, structural support, and contractor support), design and engineering, and the cost of data processing equipment. The authors highlighted the variability of installation costs, noting that the requirements for a FSEMs system in a flat terrain situation is different from one in more rugged terrain or ones involving bodies of water (e.g., a river). Local environmental extremes could increase costs for cooling or heating. For a 16-station system, the authors estimated a range of $670, 000 to $1,620,000. The staff did not perform an independent estimate for this paper. However, given inflation since 1982, the current costs would be significantly greater.

These costs did not include operational or maintenance costs. The authors noted that increasing the number of sensors to improve the system detection and measurement efficiency would increase the costs. The authors concluded that for $2M, one might construct a reasonable system, but in no case would information accurate to a factor of 5 or 10 be obtained.

The study concluded that it is was unlikely that a few fixed-station area monitors could provide sufficiently reliable information to be of use in detecting releases from unmonitored containment release points. The NRC staff at that time agreed with the conclusion of this study, and the requirement for fixed station environs radiation monitors was omitted from the parameter tables of Regulatory Guide 1.97, Revision 3, which was issued in May 1983.

In 1990, FEMA reported on a review by the Federal Radiological Preparedness Coordinating Committee (FRPCC) of the use of FSEMs[24]. The review considered the evaluation in NUREG/CR-2644. The FRPCC stated, "Since this type of monitoring system cannot guarantee the detection of all offsite releases, the use of fixed offsite monitors for emergency response purposes for initial detection of an airborne release is not recommended."

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21 For a system of 16 stations spaced equidistantly around the circumference of a 1600-meter (one mile) radius circle, the stations would be 628 meters apart. The width of a plume (i.e., 10% of the centerline dose) starting at the center of the station array would be 236 meters under F stability conditions.

22 At the very high containment concentrations capable of causing offsite doses comparable to a General Emergency, the radiation emanating from the surface of the containment (not leakage) can be a significant source of onsite dose rates. This varies based on the plant design. Radiation emanating from the dome can scatter off the sky and significantly increase ground level dose rates. Either source will confound detection of an unmonitored release. Containment domes are generally half the thickness of the girth walls.

23 There are also concerns regarding building wake effects that can vary with wind direction.

24 "Guidance on Offsite Emergency Radiation Measurement Systems: Phase 1 – Airborne Release," FEMA-REP-2 Revision 2, June 1990, https://www.fema.gov/media-library-data/20130726-1830-25045-8755/fema_rep_2_main_document.doc.

3.6 Review of Selected Existing Fixed-Station Environmental Monitor Installations

The Illinois Emergency Management Agency (IEMA) was contacted for information on their monitoring capabilities to supplement data the author obtained from the IEMA public website[25]. IEMA designed, installed, operates, and maintains an extensive monitoring system that monitors plant parameter, effluent, and environs conditions at seven nuclear power sites in Illinois that include 11 commercial nuclear power plants and three permanently shut down nuclear facilities. There are three components to this monitoring capability: a reactor data link, a gaseous effluent monitoring system and, of relevance here, a gamma detection network.

The gamma detection network has 16 detectors (i.e., FSEMs) placed radially around each of the 11 nuclear power plants at a distance of approximately 2-5 miles from each plant in Illinois. Some stations have meteorological sensors. The stations are powered by solar panels with backup battery power, thereby minimizing the costs associated with providing AC power at the fixed stations. IEMA uses radio transmission to eliminate the need for hardwire communications. State construction resources were used to install the fixed stations. With these arrangements, IEMA estimated an overall cost of about $20,000 per station (does not include the central processing capability). IEMA has three full time technicians on staff to maintain the stations. Although IEMA was able to achieve significant economies, this may not be the case for licensees who are more likely to contract for the design, installation, and operation of equipment for a single site.

Data from these subsystems are collected and monitored on a 24/7 basis. IEMA developed software that monitors and analyzes the data and notifies on-call IEMA personnel of abnormal situations. The data are provided to the State Radiological Emergency Assessment Center. IEMA does not make any of the data publically available on a live basis.

The New Jersey Department of Environmental Protection, Bureau of Nuclear Engineering (NJDEP) maintains a continuous radiological environmental surveillance telemetry system (CREST) surrounding the Oyster Creek plant and Artificial Island (the location of the Salem and Hope Creek plants)[26]. The Artificial Island site has 10 sensors positioned in available compass sectors from just outside the site and up to 8 miles from the site[27]. The Oyster Creek site has 16 stations in each available compass sectors from just outside the site and up to 2.7 miles from the site. Each station has wind speed and wind direction sensors. The collected data is transmitted minute-by-minute to a central computer at a State office in Trenton. If radiation levels exceed a predetermined threshold, an alarm is triggered and the NJDEP staff is notified to investigate. The CREST data are not made publicly available on a real-time basis, but are

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25 "Remote Monitoring of Nuclear Power Plants in Illinois," Illinois Emergency Management Agency, https://www.illinois.gov/iema/NRS/Documents/BNFS_RMSBrochure.pdf.

26 "Environmental Surveillance and Monitoring Report for the Environs of New Jersey's Nuclear Power Generating Stations:2008," http://www.state.nj.us/dep/rpp/bne/bnedown/envir_sur_mon_rpt/2008EnvironSurv-MonitReport.pdf.

27 The Artificial Island site is bounded by the Delaware River to the west; all stations are within New Jersey. On the New Jersey side of the river, the site is surrounded by a marsh area extending about four miles to the east. Only the site access road traverses this area. This area is an example of why equidistantly spaced stations can be impractical at many sites.

made available to participating governmental agencies (e.g., The State of Delaware, Department of Defense, etc.)[28].

The Indian Point site employs an offsite 16-station environmental system. These Reuter-Stokes stations are located 22.5 degrees apart one mile from the plant. The information from the system is available to local government agencies but not publicly available on a real-time basis.

The Environmental Protection Agency (EPA) maintains a near real-time radiation-monitoring network, called RadNet[29], which records beta and gamma radiation, and samples and analyzes various environmental media. There are 130 stations across the 50 United States. The near real-time ambient radiation levels are collected, and absent any abnormalities, are posted to a public website within three hours (i.e., not real-time)[30]. Abnormal readings are reviewed for quality control purposes before being released. Analysis results for the environmental media samples are posted to a publically accessible database when available.

3.7 Fixed-Station Environmental Monitoring in Japan[31,32,33]

At the time of the 2011 Fukushima Dai-ichi event, there were two nuclear data systems in use in Japan. The first was the Emergency Response Support System (ERSS) that received plant status information and real-time environmental sent by licensee. The ERSS displays were located at the Nuclear and Industrial Safety Agency (NISA) emergency response center and the emergency operations centers of Ministry of Education, Culture, Sports, Science and Technology (MEXT) and related local governments. The second system was the System for Prediction of Environmental Emergency Dose Information (SPEEDI). The objective of this system was to provide national and local governments with useful data for formulating effective protective measures by promptly calculating how radioactive material released into the environment is diffused, and the exposure dose, and displaying the same in the form of dose contours on a map. Local governments have established telemetered FSEMs in the environs of a nuclear power plant. Each monitoring station has wind speed and wind direction sensors. For the Fukushima Prefecture, there were 16 stations at the time of the accident at Fukushima Dai-ichi.

Under the SPEEDI architecture that existed at the time of the Fukushima Dai-ichi accident, the local governments streamed the collected data to Nuclear Safety Technology Center, (NUSTEC). ERSS data from the licensee was streamed to NUSTEC, and meteorological data

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28 Private correspondence between NRC NSIR/DPR and Region 1 staff and NJDEP staff. ADAMS Accession No. ML16048A070

29 http://www2.epa.gov/radnet.

30 https://radiation.zendesk.com/hc/en-us/articles/212053808-When-is-air-data-available-to-the-public-

31 "Fukushima, One Year Later: Initial Analyses of the Accident and its Consequences," Institut De Radioprotection Et De Sûreté Nucléaire (IRSN), March 2012, http://www.irsn.fr/EN/publications/technical-publications/Documents/IRSN_Fukushima-1-year-later_2012-003.pdf.

32 "System for Prediction of Environmental Emergency Dose Information Network System," M. Misawa and F Nagamori, in FUJITSU Science and Technology Journal, October 2008, http://www.fujitsu.com/global/documents/about/resources/publications/fstj/archives/vol44-4/paper05.pdf.

33 "SPEEDI and WSPEEDI: Japanese Emergency Response Systems to Predict Radiological Impacts in Local and Worldwide Areas Due to a Nuclear Accident," M. Chino. Et al, Japan Atomic Energy Research Institute, in "Radiation Protection Dosimetry," 1993, http://rpd.oxfordjournals.org/content/50/2-4/145.

was streamed from the Japan Weather Association. At NUSTEC, the collected data generated dose contour plots streamed to the local governments and used to make decisions on public protective actions. There is no indication that the data was intended to be made publicly available on a real-time basis.

During the accident, several conditions occurred that rendered the SPEEDI system ineffective for its intended purpose. First, the earthquake and tsunami had rendered many of the Fukushima Prefecture SPEEDI monitors inoperable during the radiological release periods. Second, because the plant was not sending ERSS data due to the loss of power, there were no source term data to drive the dose assessment software. While the system did display contour plots driven by the meteorology data, the contours were inaccurate due to the missing source term. These contour plots (and not plant conditions) were the basis of public protective actions and the implementation of those actions was impeded. Further, because the prefecture's sensors were located onshore from the Fukushima Dai-ichi plants, the operable sensors were unable to monitor the releases occurring between March 12 and 14 that spread mainly northward along the coast, northeast, and east over the Pacific Ocean. On March 15 and 16, the release spread over Japan. On March 16 and the following days the releases once again spread eastward over the Pacific.

In October 9, 2014, a newspaper, "Asahi Shimbun, Asia and Japan Watch," ran an article[34] headlined "SPEEDI radiation forecasting dropped by the Nuclear Regulation Authority (NRA) as primary alert system." The article stated that the scarcity of information in the immediate aftermath of the Fukushima accident hampered the ability of SPEEDI to forecast the spread of radioactive materials from the site, causing it not to be used in making evacuation decisions. Revised emergency preparedness and response guidelines downgraded the importance of data provided by SPEEDI, now calling it just "reference information." (See Section 3.9 of this paper.)

3.8 Public Protective Action Recommendations in the United States[35,36]

As the insights from the severe accident studies performed following the Three Mile Island (TMI) accident became available, the staff developed the philosophy that initial protective actions decisions for General Emergencies be based on plant condition and its prognosis. The EAL scheme used at U.S. nuclear power plants is such that a General Emergency could be declared based upon plant conditions (e.g., status of plant fission product barriers, safety system status, AC power availability, etc.) *before* a substantial radiological release could potentially begin and *before* effluent and environs monitors could detect the release.

Accordingly, on declaration of a General Emergency, protective action strategy guidance proposes an initial public PAR to State and local emergency management agencies. The licensee should not wait on collection and analysis of radiological assessment data provided by radiation monitors to formulate the initial PAR. Once the initial protective action is determined, the licensee is expected to use all available information, including changes in plant condition and available radiological assessment data in expanding the PAR, as needed.

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34 http://ajw.asahi.com/article/0311disaster/fukushima/AJ201410090062.

35 "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants: Guidance on Protective Action Strategies," NUREG-0654 Supplement 3, dated November 2011. ADAMS Accession No. ML113010596.

36 "Pilot Program: NRC Severe Reactor Accident Incident Response Training Manual: Public Protective Actions — Predetermined Criteria and Initial Actions," NUREG-1210 Volume 4, dated February 1987, http://www.osti.gov/scitech/biblio/6876619.

The EAL schemes for declaring emergency classification levels (ECLs) are required by 10 CFR 50.47(b)(4). Section IV.B of Appendix E requires that these schemes be based on in-plant conditions and instrumentation in addition to onsite and offsite monitoring. NRC-endorsed EAL schemes also consider the integrity of the fission product barriers. A General Emergency is associated with events that involve actual or imminent substantial core degradation or melting with potential for the loss of containment integrity, which are readily identified by other diverse EALs before a release could be detected by an onsite or offsite radiation monitor. Radioactive releases sufficient to drive public protective actions are associated with fuel or core damage events. While information from radiological monitoring and assessment can provide potentially useful information for declaring an emergency, the absence of such data will generally not preclude the timely declaration of a General Emergency and the requisite recommendation of adequate protective actions for the public.

3.9 Public Protective Action Recommendations in Japan

At the time of the Fukushima accident, the requirement in Japan had a two-level response. The first level, a "Specific Event," would be triggered at an observed dose rate of 5 μSv/h (0.5 mrem/hr.) at one point for more than 10 minutes or two points simultaneously. The second level, a "Nuclear Emergency," would be triggered at an observed dose rate of 500 μSv/h (50 mrem/hr.) at one point for more than 10 minutes or two points simultaneously. There were also triggers for loss of reactor coolant system without emergency core cooling system, loss of all alternating current, and anticipated transient without scram[37].

The public protective action protocol was based on measurement of certain radiological doses beyond the site boundary. For example, the press release that declared the Nuclear Emergency at 1903 on March 11, 2011, included:

> . . . Note: At present, no impacts from radioactive materials upon the area outside of the facilities have been confirmed. Consequently, at the current time, residents of the area target under this declaration and other persons in the area do not need to take any special actions immediately. Persons affected are asked not to begin evacuation. . .[38]

This protocol was substantially modified in 2013 based upon the lessons from the Fukushima Dai-ichi event[39]. Under the revised scheme, the planning areas surrounding a plant now include a Precautionary Action Zone (PAZ) of five km. (3.1 miles). In this zone, a declaration of a General Emergency would result in an unconditional evacuation of the public, without any extra consultation. With this change, the Japanese protective action protocol aligns with the current NRC guidance.

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37 "Convention on Nuclear Safety National Report of Japan for the Fifth Review Meeting," September 2010, Government of Japan, specifically Article 16, "Emergency Preparedness," https://www.nsr.go.jp/data/000110059.pdf.

38 The tsunami struck at 1546, causing a loss of all AC power, and loss of all cooling. By 1800, the reactor water level was at top of fuel. These conditions would have resulted in a declaration of general emergency at a U.S. plant. At the time, the Japanese did not consider plant conditions in making protective action recommendations.

39 "Operational Status of Nuclear Facilities in Japan: 2013 Edition," Japan Nuclear Energy Safety Organization (JNES)," Section XVII-3, "Nuclear Emergency Preparedness," JNES 2013, http://www.nsr.go.jp/archive/jnes/atom-library/unkan/e-unkanhp2/e-unkanhp2-2013/book1/#page=1.

Once the residents of the PAZ have been evacuated, the evacuation zone is gradually enlarged within the Urgent Protective Action Zone (UPZ), if the accident continues or accidents occur at multiple units as based on EALs. The UPZ is an area approximately 5 to 30 km (3.1 to 18.6 miles) away from the plant. Protective actions could include sheltering and the use of thyroid prophylaxis.

Once these actions are implemented, further protective actions would be based on the operational intervention levels of measured in-field radiation levels of 500 μSv/h (50 mrem/hr.) within the PAZ and UPZ. Evacuation would occur within hours to within a day of the General Emergency declaration. Beyond the UPZ, a temporary relocation of residents could occur within a day to within a week if the measured dose rate exceeded 20 μSv/h (2 mrem/hr).

3.10 Conclusions

The staff is proposing that NTTF Recommendation 11.3 be closed with no further action on the part of the staff or licensees. The staff based this conclusion on the following:

1. The existing means of performing radiological monitoring and assessment beyond the site boundary and within the plume exposure EPZ, as described in the licensee, State, and local emergency response plans, are adequate to support PAR decisions once the initial plant-based PAR is issued.

2. The inherent inability of FSEMs to provide reliable indications of the dose from a radioactive plume under all conditions.

3. The primary role of radiological monitoring and assessment is to provide the licensee, and State and local officials with sufficient information to support PAR decision-making necessary for protecting public health and safety. These public officials have the competency and the authority to evaluate the available monitoring and assessment data and to provide protective action information and instructions to the affected public within the EPZ. Requiring the FSEM data to be publically available on a real-time basis will not enhance the ability of these public officials to implement effective public protective actions, and in some cases could reduce the capability.

4. Of the licensee, and State and local officials maintaining existing FSEM systems at a total of ten sites, none makes the data publically available on a real-time basis. Providing the data to people who are untrained in interpretation of the data may impede the emergency response by triggering an inappropriate response.

5. The Japanese SPEEDI system was intended to provide dose contour plots of radioactive material to national and local officials. However, many of the FSEMs in the Fukushima Prefecture were rendered unavailable by the tsunami. When the plant lost power, it lost the ability to provide source term data that SPEEDI was to use to calculate the dose contour plots. During significant periods of the event, the winds blew away from the plant and out over the ocean precluding the release being detected or measured by the onshore stations. In 2013, the Japanese Government reduced its reliance on SPEEDI as a means of making protective action decision.

6. The licensee PAR strategies, consistent with NRC guidance, calls for initial PARs to be primarily based upon plant conditions, rather than on radiological measurements, and without the delay of awaiting the onset of a radioactive material release or the availability of radiation monitoring and assessment results. The absence of FSEMS would not preclude the issuance of timely and appropriate PARs necessary for protecting public health and safety.

7. The installation of FSEMs would not result in a substantial increase in the protection of public health and safety or common defense or security, and would not likely meet the value – impact analysis required by the backfit rule.

4.0 Stakeholder Interactions

The staff's analyses and recommendation for closure of Recommendation 11.3 was presented to stakeholders at the following venues:

- The March 2016 joint NRC/FEMA Steering Committee meeting. In attendance at this meeting were NRC and FEMA representatives from both Headquarters and Regional offices.

- The May 2016 National Radiological Emergency Preparedness Conference held in Charleston, South Carolina.

- A May 25, 2016, public meeting to inform stakeholders of the staff action on this recommendation and to solicit stakeholder comments. A summary of the meeting is available in ADAMS at Accession No. ML16165A249.

- The June 2016 Nuclear Energy Institute (NEI) Conference held in Indianapolis, Indiana.

5.0 Resources

No further resources are needed.