International Atomic Energy Agency

Atoms for Peace

MISSION REPORT

IAEA INTERNATIONAL PEER REVIEW MISSION ON MID-AND-LONG-TERM ROADMAP TOWARDS THE DECOMMISSIONING OF TEPCO'S FUKUSHIMA DAIICHI NUCLEAR POWER STATION UNITS 1-4

(Third Mission)

Tokyo and Fukushima Prefecture, Japan
9 – 17 February 2015

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MISSION REPORT TO
THE GOVERNMENT OF JAPAN

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Mission date: 9 – 17 February 2015

Location: Tokyo and Fukushima Prefecture, Japan

Organized by: International Atomic Energy Agency

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Issue Date: 13 May 2015

MISSION REPORT

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EXECUTIVE SUMMARY

Following the accident at TEPCO's Fukushima Daiichi Nuclear Power Station (NPS) on 11 March 2011, the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4" (hereinafter referred to the "Roadmap") was adopted by the Government of Japan and the TEPCO Council on Mid-to-Long-Term Response for Decommissioning in December 2011. The Roadmap was revised in July 2012 and June 2013. The Roadmap includes a description of the main steps and activities to be implemented for the decommissioning of the Fukushima Daiichi NPS through the combined effort of the Government of Japan and TEPCO.

At the request of the Government of Japan, the IAEA organized two missions of the International Peer Review of the Roadmap, which were implemented within the framework of the IAEA Nuclear Safety Action Plan, in April 2013 and in November/December 2013, respectively. Those missions aimed at enhancing international cooperation and sharing with the international community information and knowledge to be acquired in the decommissioning process.

During the 58th IAEA General Conference (Vienna, 22 to 26 September 2014), the intention to receive another IAEA mission was expressed by the representative of the Government of Japan, with the aim to continue to work together with the IAEA and the international community.

Following this request, the third Mission of the International Peer Review of Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4, involving 15 international experts, took place from 9 to 17 February 2015 (hereinafter referred to as the "Mission").

The objective of the Mission was to provide an independent review of the planning and implementation of Fukushima Daiichi NPS decommissioning. The Mission was conducted based on IAEA Safety Standards and other relevant good practice, aimed at assisting the Government of Japan in the implementation of the Roadmap.

The Government of Japan and TEPCO prepared comprehensive information on the current status and future plans of the implementation on the Roadmap. The IAEA team assessed the information, and had extensive discussions with the relevant institutions in Japan, as well as visiting TEPCO's Fukushima Daiichi NPS, to better understand the situation.

The Preliminary Summary report was submitted to METI[1] on 17 February 2015 and published on https://www.iaea.org/sites/default/files/missionreport170215.pdf. This final Mission report elaborates on the findings and conclusions of the Preliminary Summary report.

After the Mission, following the request of the Government of Japan, the IAEA experts visited Japan from 17 to 21 April 2015 to obtain additional information on the management of contaminated water including contaminated rainwater as well as on TEPCO's efforts to improve public communication activities. The findings of this expert visit are included in an ANNEX to this final Mission report.

Main Findings and Conclusions

As already stated in previous IAEA mission reports, the safe decommissioning of TEPCO's Fukushima Daiichi NPS is a very challenging task that requires the allocation of enormous resources, as well as the development and use of innovative technologies to deal with the most difficult activities.

[1] METI = Ministry of Economy Trade and Industry, Japan

The IAEA team considers that Japan developed its efforts towards decommissioning the plant promptly after the accident. Since then, Japan has achieved good progress in improving its strategy and the associated plans, as well as in allocating the necessary resources towards the safe decommissioning of TEPCO's Fukushima Daiichi NPS. Since the previous IAEA missions, the Government of Japan and TEPCO have implemented planned measures aimed at reducing nuclear and radiological hazards on the site and safely decommissioning the plant.

The IAEA team considers that the creation in 2014 of a new branch of TEPCO, called Fukushima Daiichi Decontamination and Decommissioning (D&D) Engineering Company (FDEC), as the only responsible organisation for the safe implementation of the on-site radioactive waste management and decommissioning activities, is a good step forward to clarify responsibilities. In similar manner, the establishment of a national authority to develop the guiding strategy, namely the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF), is also a good demonstration of the proactive attitude of the Government of Japan and TEPCO towards addressing the many difficulties at the site. Currently around 7,000 workers are working on-site to develop and implement decommissioning activities.

The situation on-site has been improved since the last IAEA mission in 2013. Several important tasks were accomplished such as:

- Completion of the removal of fuel from Unit 4;
- The improvement and expansion of contaminated water treatment systems;
- The installation of new tanks and associated systems for contaminated water storage;
- The operation of underground water by-pass; and
- The clean-up of the site resulting in a reduction in radiological dose rate.

In similar vein, the introduction of a comprehensive monitoring programme of seawater, including control by independent laboratories, is a positive step. The IAEA's Environment Laboratories in Monaco has been cooperating with Japanese and other international marine laboratories in conducting an interlaboratory comparison exercise for seawater analysis.

The IAEA team notes with appreciation that the Government of Japan and TEPCO have given due consideration to the advice provided in previous IAEA missions to enhance planning, along with safe decommissioning and radioactive waste management activities.

The change of emphasis involved in a transition from operating a nuclear power plant to that of radioactive waste management and decommissioning is profound. It is, therefore, to be expected that the situation at the site remains very complex (despite significant progress). A range of challenging issues remain, such as the persistent underground water ingress to main buildings and the accumulation of contaminated water on-site; the long-term management of radioactive waste; as well as those related to the removal of nuclear fuel, damaged fuel and fuel debris.

Continued effective dialogue with stakeholders, strengthening trust and respect between all parties, will remain valuable in making effective progress. Reinforcing the process of safety justification within the site operator, of safety assessment by the regulatory body and dialogue between the two bodies also remains vitally important. Therefore the IAEA team encourages Japan to continue implementing and even improving its strategy to deal with these issues, so as to ensure safe decommissioning of the accident-damaged plant and management of the radioactive waste.

The IAEA team also recalls advisory points of the previous missions related to the site boundary dose limits. Progress made in this area should be assessed in relation to considerations of the number of people exposed and their respective residence times.

Acknowledgements and Advisory Points

This report provides highlights of important progress (Acknowledgments) in 20 areas such as management of radioactive waste, management of contaminated water including countermeasures against groundwater ingress, removal of spent fuel assemblies and damaged fuel debris, and institutional and organisational matters.

The report also offers 15 Advisory Points where the IAEA team feels that current practices could be improved, taking into account both international standards and the experience from planning and implementation of decommissioning programmes in other countries.

Following is a summary of Acknowledgments and Advisory Points:

1. Review of current situation of TEPCO's Fukushima Daiichi NPS

Presentations, discussions and review of provided documents were followed by the Fukushima Daiichi site visit. Acknowledgments and Advisory Points are formulated in following chapters of this Report.

2. Follow-up of the previous IAEA decommissioning missions conducted in 2013

Acknowledgement 1:

The IAEA team appreciates Japanese institutions for careful consideration of all advisory points from the previous IAEA decommissioning missions and for extensive effort to effectively implement them to the maximum extent possible.

3. Strategy and planning for the decommissioning of TEPCO's Fukushima Daiichi NPS

(3.1) Strategy and Planning, including revision of the Roadmap and development of NDF Strategic Plans for Decommissioning

Acknowledgement 2:

The IAEA team acknowledges continuous efforts of the Government of Japan, TEPCO and other organizations involved, on development of a strategy and an integrated planning for decommissioning of Fukushima Daiichi NPS. These include planned revision of the Roadmap, and the development of the NDF's Strategic Plan. It is commendable that the Strategic Plan is driven by the principle of risk reduction, and that detailed studies and analyses are being performed to identify, quantify and prioritize risks, to develop risk reduction strategies and plural scenarios for the risk reduction related activities.

In addition, the IAEA team acknowledges further progress in developing and implementing a comprehensive R&D programme to support the decommissioning works, in particular activities of IRID and JAEA towards construction of Advanced Research Facilities and the establishment of the International Research Centre for Reactor Decommissioning.

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Advisory Point 1:

Giving the complex situation at the Fukushima Daiichi NPS site, associated with large uncertainties in relation to radiological and physical status of the facilities, long term decommissioning planning has to include consideration of numerous options and scenarios. There is a need to optimize planning efforts by narrowing down the number of options for consideration. Identification of future configurations of the Fukushima Daiichi decommissioning process would provide a contribution in that direction. The IAEA team encourages all stakeholders to continue discussions, initiated in the previous period, in considering the future configuration. In addition to reduction of the number of options for consideration, identification of such future configuration will be an important input to the development of strategies and plans for management of very large amounts of radioactive waste, present now and expected to be generated during the decommissioning process.

The IAEA team encourages the Government of Japan to make the best use of TEPCO’s growing experience of implementation activities on the site, in the revision of the Roadmap and development of the NDF’s Strategic Plan.

(3.2) Institutional and organisational issues

Acknowledgement 3:

The IAEA team acknowledges the progress made by TEPCO in addressing the profound challenges arising from the accident. The tasks involving inter-connected, diverse and evolving conditions embodied in waste management and decommissioning at a post-accident site have commenced, in a thoughtful and determined manner. As an example, the creation of a specific division within TEPCO to address the challenges at Fukushima Daiichi is welcomed – “Fukushima Daiichi Decontamination and Decommissioning (D&D) Engineering Company” (FDEC). The IAEA team also notes the creation of the “Nuclear Damage Compensation & Decommissioning Facilitation Corporation” (NDF).

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Advisory Point 2:

Noting the recent introduction of the NDF, the IAEA invites the Government of Japan to consider how best to ensure the full clarity of responsibility of all the relevant actors.

Advisory Point 3:

Safety leadership, in all cases at the Fukushima Daiichi NPS site, is the primary responsibility of the Operator (TEPCO). Renewed emphasis on this aspect is particularly beneficial whenever national structures are undergoing significant change or in which large numbers of contractors are deployed. Therefore, the IAEA team strongly encourages TEPCO in their progress to reinforce safety leadership and safety culture, along with developing a Management System appropriate to radioactive waste management and decommissioning. This will provide mechanisms for *inter alia* effective control and supervision of operations on the site; robust safety justification; rigorous training, qualification and authorization of operators fulfilling defined safety roles; and systematic radiological protection.

(3.3) Preparation for licensing

<u>Acknowledgement 4:</u>

The IAEA team acknowledges the efforts of the Government of Japan and the NRA to establish a licensing/authorization process for activities and facilities on the Fukushima Daiichi NPS site, as well as TEPCO's effort to implement that licensing/authorization process and NRA to evaluate and grant authorization, if appropriate.

Recognizing that the existing licensing process for normal situations is difficult to be applied in the complex post-accident situation, a non-standard licensing/authorization process is being discussed and applied, based on demonstrating compliance with prescribed set of general safety requirements. Such process was applied to the authorization of recently completed removal of the spent fuel from the Fukushima Daiichi NPS Unit 4.

In addition to the process involving licensing/authorization by the NRA, there is a robust internal process in place within TEPCO, for internal safety evaluation and approval of works by the TEPCO's Nuclear Safety Management Committee and Decommissioning Safety Committee.

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<u>Advisory Point 4:</u>

The IAEA team encourages TEPCO to engage with the NRA in establishing clear criteria, based on risk assessment, for determining which activities require the NRA authorization and which activities can be evaluated and approved internally by the TEPCO's Committees responsible for safety.

TEPCO is encouraged to strengthen its Committees responsible for internal safety evaluations, including consideration of involving external independent experts in the safety evaluation process.

(3.4) Public relations and communication

<u>Acknowledgement 5:</u>

The IAEA team notes that the Fukushima Advisory Board has been active since its creation, providing a useful channel for strengthening public communication and stakeholder involvement in the decommissioning of Fukushima Daiichi NPS and contaminated water management. This is in line with Advisory Point 2 of the first mission as well as Advisory Point 4 of the second mission.

<u>Acknowledgement 6:</u>

TEPCO has intensified its public communication efforts, including by using social media and 'risk communicators' – engineers trained in communication to reach communities. In line with Advisory Point 3 of the second mission, TEPCO has intensified communication with the workforce, including contractors.

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<u>Advisory Point 5:</u>

Recognizing intensified communication efforts through the dissemination of comprehensive information, the IAEA team urges METI and TEPCO help lay audiences understand the relevance of this information by basing it on the health and safety aspects of both the workforce and the public, as well as protection of the environment. The IAEA team also encourages TEPCO to promote understanding by intensifying and widening its efforts to promote an interactive dialogue, including by engaging its social media audience by responding to comments and questions. Thorough analysis of how the media and the public understand disseminated information should be used to improve future communication.

(3.5) Prioritisation and Hazard Reduction

Acknowledgement 7:

The IAEA team welcomes the start of transition towards a safety assessment approach within TEPCO which takes account of several relevant factors, including workforce dose, protection of safety systems and prevention of radiological discharges.

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Advisory Point 6:

The IAEA team encourages TEPCO to develop an integrated plan for decommissioning and radioactive waste management at Fukushima Daiichi NPS. In developing this plan, certain activities will deserve more prompt attention, and consideration of the approach adopted to address this will be beneficial. The chosen approach should be firmly founded on minimising impacts to human health and on protecting the environment. It should also consider how inter-dependencies between the steps of radioactive waste management, maintaining a clear view of long-term safety, can be considered and how waste disposal may properly be assessed. Independent advice and challenge to the emerging plan is also likely to be valuable.

4. Review of specific issues

(4.1) Management of radioactive waste

Acknowledgement 8:

The IAEA team acknowledges that the government has created an organizational framework, comprised of, for example NRA, FDEC, NDF, IRID and JAEA, that used effectively can enhance the safety of the wastes arising from an expedited decommissioning by embracing long-term waste management principles. The IAEA team recognizes the effort and accomplishment of the FDEC in reducing worker exposure, dose at the site boundary and facilitating site operations for decommissioning, by the accumulation of contaminated material and debris into temporary storage.

Acknowledgement 9:

The IAEA team acknowledges that the FDEC endeavours to use good engineering principles in the design and configuration of the temporary storage locations and their design are reviewed by the FDEC safety committee and approved by the NRA when required. The IAEA team further recognizes that the FDEC develops and maintains information on the physical contents of each temporary storage location and its debris form with minimal radiological characterization for surface dose rate.

Acknowledgement 10:

The IAEA team considers that the research carried out by the JAEA on the different phases of predisposal management (characterization, treatment, conditioning, storage) of the waste from the water treatment is commendable and should be continued.

Acknowledgement 11:

The FDEC recognizes the benefits of implementing clearance processes and permitting material reuse and recycle for wastes generated during decommissioning, and thereby facilitate the long-term waste management.

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Advisory Point 7:

The IAEA team is of the opinion that the FDEC could better employ long-term radioactive waste management principles (beyond the segregation, relocation and dose reduction/shielding currently performed) such as more complete waste characterization, conditioning, and packaging. While the IAEA team holds that the FDEC could deploy such principles in its present efforts, it appreciates that waste management strategy, direction and criteria are forthcoming from the NDF.

Advisory Point 8:

The NDF is urged to give priority to issuing the waste management strategy that will enable the FDEC to implement (after the demonstration of safety and proper licensing) processes appropriate for safe long-term radioactive waste management such as waste minimization, treatment and conditioning, packaging, release, recycling, etc.

Considering that most of the contaminated rubble is likely to have only surface contamination and could be easily decontaminated to a certain extent, the IAEA team suggests that benefits of conditional clearance should be explored and implemented if appropriate, with the vision of reducing the overall amount of radioactive waste to be managed.

Advisory Point 9:

The IAEA team encourages the FDEC to reflect in its organizational structure and staffing the importance and scale of the radioactive waste management workscope. Additionally, the supporting institutions, such as JAEA, are encouraged to ensure sufficient human and technical resources are available for radioactive waste management and to support the FDEC with reliable and sustainable waste management capabilities, including the development of on-site technical capabilities.

Advisory Point 10:

The IAEA team encourages the FDEC to continue working on developing a waste inventory providing reliable physical, chemical, radiological and volumetric information, even prior to availability of the new Analysis Centre, to support future strategic planning and decisions for the waste streams. The IAEA team encourages the FDEC to continue to implement Advisory Point 8 from the previous decommissioning mission regarding the need to establish a sound radiological characterization of the waste and waste classification scheme which will enable the FDEC to further develop its strategy for the processing, storage and disposal of the waste.

Advisory Point 11:

The IAEA team recommends the long-term and operational safety of the temporary storage facilities (for emplacement, storage and retrieval phases) be evaluated for both normal and potential accident conditions, in line with the hazard of the various waste generated.

(4.2) Management of contaminated water, including ingress of groundwater

Acknowledgement 12:

The IAEA team reconfirms TEPCO's success in treating large volumes of highly radioactive water, accumulating continuously in the reactor and turbine buildings, to remove gamma emitting caesium radionuclides upfront and using the treated water after desalination to maintain stable cooling of the damaged cores. The cumulative volume treated by the two operating caesium removal systems is now more than 1 million m^3, with high caesium removal efficiency achieved consistently. TEPCO has recently added strontium removal capability to these treatment systems. Removing strontium upfront along with caesium would facilitate further management of the treated water.

Acknowledgement 13:

The IAEA team acknowledges TEPCO's efforts to mitigate the risk associated with storing large volumes of radioactive water, containing high levels of ^{90}Sr remaining after caesium removal, in numerous above ground tanks at the site. In order to augment the treatment capacity of the ALPS and the High Performance water treatment systems (ALPSs), which remove ^{90}Sr as well as all other residual radionuclides (except tritium), TEPCO has established a number of additional treatment systems dedicated specifically to removing ^{90}Sr. Their prioritizing of the bolted flange type tanks for removing ^{90}Sr is well placed, considering the higher risk of storing ^{90}Sr bearing water in these tanks. Even though strontium treated water would still require final polishing with the ALPSs, by removing at least 99% of the ^{90}Sr this approach is enabling TEPCO to reduce the inventory of radioactivity in the tanks and associated risk substantially. More than half of the nearly 600,000 m^3 of water stored in tanks has been treated so far using the ALPSs and strontium treatment systems and TEPCO expects to complete the treatment of the remaining water in the next few months.

Acknowledgement 14:

The IAEA team commends TEPCO for mobilizing the resources needed to successfully build sufficient storage capacity for contaminated water and to generally improve the safety of storage. These measures include replacement of bolted flange type tanks with newly constructed fully welded tanks, construction of dykes with enhanced water holding capacity, and provision of covers to deflect rainwater from the dykes so that the dykes can perform their intended safety function of containing potential leaks from the tanks. Again, prioritizing the bolted flange type tanks for implementing this rainwater management measure is well placed because of the vulnerability of these tanks to develop leaks.

Acknowledgement 15:

The IAEA team commends TEPCO for its efforts to address contamination in the very complicated area of infrastructure East of the Turbine Buildings with its many potential connections between the Turbine Building and the sea resulting from intentional cooling system design, ground water contamination, radionuclides connected with debris in this area, and potential leakage from the Turbine Buildings connected to the Reactor Building. Significant efforts are underway to address elements of these potential pathways including addressing the contaminated water in the Seawater Pipe Trench, however this will be a very difficult area in which to control the migration of contamination.

Acknowledgement 16:

The IAEA team considers the groundwater by-pass system designed to control the ingress of groundwater to reactor and turbine buildings has been successfully put in operation. After six months of operation, and related measures to control leaking to building, groundwater ingress has been reduced by about 25% or 100 m^3 per day. We further acknowledge that the success of the groundwater by-pass operation involved extensive communication and engagement with the many stakeholders and the public in general on the nature of the operation and the measures taken to minimize possible risks to the environment or the public. It is an important milestone in gaining the public trust and should be helpful for implementing future strategies for managing contaminated water issues.

Acknowledgement 17:

The construction of frozen (ice) wall enclosing the area around Units 1-4 on the sea-side and land-side are in various stages of completion. The ice wall on the mountain side will be placed in between the buildings and the groundwater by-pass wells, resulting in further prevention of groundwater flow towards the reactor buildings.

Acknowledgement 18:

The IAEA team notes that the rehabilitation of the subdrains and the construction of a treatment system for pumped subdrain water are nearly complete. As the subdrains are placed in operation, they are expected to further reduce the groundwater ingress by about 150 m^3, and to near zero following the installation of the land-side ice wall. The IAEA team appreciates TEPCO's planning to ensure that pumping from the subdrains is carried out while preventing the outflow of contaminated water from the buildings. After controlling the ingress of groundwater, TEPCO also plans to seal leakage points on reactor and turbine building walls.

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Advisory Point 12:

While recognizing the usefulness of the large number of water treatment systems deployed by TEPCO for decontaminating and thereby ensuring highly radioactive water accumulated at the site is not inappropriately released to the environment including the adjacent Pacific Ocean, the IAEA team also notes that currently not all of these systems are operating to their full design capacity and performance. The IAEA team encourages TEPCO to continue on-going efforts to improve the utilization of these treatment systems. In their planning of water treatment schedules, TEPCO is advised to take into consideration that testing and optimising the operating conditions of complex multi-stage water treatment systems can take time, particularly for those technologies that are new and being deployed under field conditions for the first time.

Advisory Point 13:

The IAEA team is of the opinion that the present plan to store the treated contaminated water containing tritium in above ground tanks, with a capacity of 800,000 m^3, is at best a temporary measure while a more sustainable solution is needed. Therefore the present IAEA team reiterates the advisory point of the previous decommissioning mission:

"The IAEA team believes it is necessary to find a sustainable solution to the problem of managing contaminated water at TEPCO's Fukushima Daiichi NPS. This would require considering all options, including the possible resumption of controlled discharges to the sea. TEPCO is advised to perform an assessment of the potential radiological impact to the population and the environment arising from the release of water containing tritium and any other residual radionuclides to the sea in order to evaluate the radiological significance and to have a good scientific basis for taking decisions. It is clear that final decision making will require engaging all stakeholders, including TEPCO, the NRA, the National Government, Fukushima Prefecture Government, local communities and others".

The IAEA team recognizes the need to also consider socioeconomic conditions in the consultation process and to implement a comprehensive monitoring programme to ensure that there is no detrimental impact on human health and the environment. In this regard the IAEA is ready to continue providing assistance in implementing such a comprehensive sea water monitoring programme.

Advisory Point 14:

The IAEA team advises that TEPCO should consider producing a better calibrated, robust groundwater model, which will allow TEPCO to continuously evaluate and optimize the performance of various countermeasures, such as the land-side ice wall, pumping from by-pass wells, and the operation of sub-drains. An improved model, and a continuously updated, detailed map of water levels, chemical composition, and radioactivity concentrations around the entire site (including under the higher ground west of the groundwater by-pass wells), will help to provide a baseline for monitoring and controlling the migration of any radioactivity from surface contamination.

As the multiple water capture, water treatment, and water storage activities are highly interdependent and complex, TEPCO may also consider implementing a “systems analysis” with associated system dynamics computer tools to help understand the integrated set of contaminated water management activities both on the land and sea-side, assess volumes of water and waste production, the impact of shifting schedules, as well as the interdependency of water management, waste management, and future decommissioning activities.

(4.3) Removal of spent fuel assemblies and damaged fuel debris

Acknowledgement 19:

The IAEA team recognizes the substantial efforts made by TEPCO and its sub-contractors in removing the 1,331 spent fuel assemblies from the Unit 4 by November 5, 2014, within one year of the first fuel assembly being removed, and all fuel assemblies by December 22, 2014 (1,533 new and spent fuel assemblies). A commitment to reducing worker dose through the incorporation of shielding materials in Unit 4 until a dose reduction of 72% was achieved and supporting activities which enabled the fuel removal from Unit 4. Supporting activities included the removal of 1,004 spent fuel assemblies from the Common Spent Fuel Pool (now accommodated in 19 new dry storage casks) to the Temporary Cask Custody Area and releasing storage space in Unit 6 to enable the storage of 180 new fuel assemblies.

Acknowledgement 20:

The IAEA team acknowledges the efforts being made to minimize the spread of contamination through the incorporation of learning from Unit 3 debris removal operations and the introduction of dust counter measures. The continued commitment to reduce dose exposure is also recognized in particular the introduction a ‘Dose Reduction Plan for Reactor Buildings’. These measures will benefit both workers and any potential impact on the local population.

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Advisory Point 15:

Whilst activities which lead to short-term gains demonstrates a positive attitude in reducing risks as early as practical, this needs to be considered in the framework of overall safety and the overall risk reduction. The IAEA team encourages the NDF to conduct a risk analysis in relation to pooled fuel and fuel debris plans; taking into account conventional safety and cumulative dose to workers.

1. BACKGROUND, OBJECTIVES AND SCOPE OF THE MISSION

1.1. BACKGROUND

Following the accident at TEPCO's Fukushima Daiichi Nuclear Power Station (NPS) on 11 March 2011, the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4" (hereinafter referred to the "Roadmap") was adopted by the Government of Japan and the TEPCO Council on Mid-to-Long-Term Response for Decommissioning in December 2011. The Roadmap was revised in July 2012 and June 2013. The Roadmap includes a description of the main steps and activities to be implemented for the decommissioning of the Fukushima Daiichi NPS through the combined effort of the Government of Japan and TEPCO.

Upon the request of the Government of Japan, the IAEA organized two missions of the International Peer Review of the Roadmap, which were implemented within the framework of the IAEA Nuclear Safety Action Plan, in April 2013 and in November/December 2013, respectively. Those missions aimed at enhancing international cooperation and sharing with the international community information and knowledge to be acquired in the decommissioning process.

The first mission was conducted from 15 to 22 April 2013 with the main purpose of undertaking an initial review of the Roadmap, including assessments of the decommissioning strategy, planning and timing of decommissioning phases and a review of several specific short-term issues and recent challenges, such as the management of radioactive waste, spent fuel and fuel debris, management of associated doses and radiation exposure of the employees, and assessment of the structural integrity of reactor buildings and other constructions. The Final Report of the first mission is available on the IAEA webpage http://www.iaea.org/sites/default/files/missionreport220513.pdf.

After the first mission, the Government of Japan and TEPCO revising the Roadmap took into consideration the advice in the first mission report. The revised Roadmap entitled "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4, revised 27 June 2013" is available on the website of the Ministry of Economy, Trade and Industry (METI) (http://www.meti.go.jp/english/press/2013/pdf/0627_01.pdf).

The second mission was conducted from 25 November to 4 December 2013. The objective of the second mission was to provide a more detailed and holistic review of the revised Roadmap and mid-term challenges, including the review of specific topics agreed and defined in the first mission, such as removal of spent fuel from storage pools, removal of fuel debris from the reactors, management of contaminated water, monitoring of marine water, management of radioactive waste, measures to reduce ingress of groundwater, maintenance and enhancement of stability and reliability of structures, systems and components (SSCs), and research and development (R&D) relevant to pre-decommissioning and decommissioning activities. The Final Report of the second mission is available on the IAEA webpage http://www.iaea.org/sites/default/files/IAEAfinal_report120214.pdf.

During the 58th IAEA General Conference (Vienna, 22 to 26 September 2014), the intention to receive another IAEA mission was expressed by the representative of the Government of Japan, with the aim to continue to work together with the IAEA and the international community.

Following this request, the third Mission of the International Peer Review of Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4, involving 15 international experts, took place from 9 to 17 February 2015 (hereinafter referred to as the "Mission").

The Government of Japan and TEPCO provided comprehensive information on the current status and future plans of the implementation on the Roadmap. The IAEA team assessed the information, and had extensive discussions with the relevant institutions in Japan, as well as visiting TEPCO's

Fukushima Daiichi NPS, to better understand the situation.

1.2. OBJECTIVE

The objective of the Mission was to provide an independent review of the activities associated with revisions to the planning and implementation of Fukushima Daiichi NPS decommissioning. The Mission was conducted based on IAEA Safety Standards and other relevant safety and technical advice, aimed at assisting the Government of Japan in the implementation of the Roadmap. In particular, the Mission was intended to:

- Provide advice and commentary on both the safety and technological aspects of decommissioning, waste management and other related activities;
- Provide advice to improve the planning and the implementation of pre-decommissioning and decommissioning activities at Fukushima Daiichi NPS; and
- Facilitate sharing of good practices and lessons learned for decommissioning operations after the accident with international community.

1.3. SCOPE OF THE MISSION

The scope of the Mission covered following items:

Item 1: Review of the current situation of TEPCO's Fukushima Daiichi Nuclear Power Plant (NPP);

Item 2: Follow-up of the previous IAEA decommissioning missions conducted in 2013 (i.e., measures taken or to be taken, progress made and current status, issues/challenges, perspectives and future plans, etc.);

Item 3: Review of the current status of the implementation of the Roadmap as well as viewpoints and major elements for the revision of the Roadmap;

Item 4: Review of the draft of the Strategic Plans for decommissioning developed by the Nuclear Damage Compensation and Decommissioning Facilitation Cooperation (NDF);

Item 5: Review of the progress and future plans, including R&D activities, in specific areas such as:

- management of contaminated water,
- countermeasures against groundwater ingress,
- removal of spent fuel assemblies and damaged fuel debris from Units 1-4,
- management of radioactive waste (highlighting present storage challenges, features of current waste and activities identifying waste stream), and
- institutional and organisational issues (i.e., allocation of responsibilities among the relevant bodies, staffing and training of workers, safety culture, communication with the public and dissemination of lessons learned).

Management of radioactive waste from off-site remediation activities was not within the scope of this review, however, it was considered so far as it had an impact on the decommissioning process and the collective waste management strategy.

While the current Roadmap covers Units 1-4, it is planned that the revised Roadmap will also cover Units 5-6 which were decided to be decommissioned in January 2014.

2. CONDUCT OF THE MISSION

The Mission, involving 15 international experts, was conducted from 9 through 17 February 2015. The Mission consisted of meetings with METI, NRA, TEPCO, NDF and IRID in Tokyo, a visit to TEPCO's Fukushima Daiichi NPS, and further meetings at the Fukushima Daiichi NPS (see Mission Programme in Appendix I).

The visit to TEPCO's Fukushima Daiichi NPS provided an opportunity to observe how the Roadmap activities were progressing and to hold discussions with TEPCO's experts in charge of specific tasks (e.g., radioactive waste management, contaminated water management, on-site safety and environment management).

A meeting with the Governor of Fukushima Prefecture, the IAEA Mission Team leader, deputy Team leader and several others members of the IAEA Team was held in the office of Fukushima Prefectural Government in Fukushima City.

Sufficient time was allocated, during the Mission, for drafting of the report and for further discussions with METI/TEPCO.

The IAEA team delivered a Preliminary Summary Report, with acknowledgements and advisory points for Japan's consideration, on the final day of the Mission. This report was published on the METI website and on the IAEA website (https://www.iaea.org/sites/default/files/missionreport170215.pdf). On the same day, an IAEA press conference was held in Tokyo to provide suitable opportunities for wider dialogue about the Mission and its main findings.

After the Mission, following the request of the Government of Japan, the IAEA experts visited Japan from 17 to 21 April 2015 to obtain additional information on the management of contaminated water including contaminated rainwater as well as on TEPCO's efforts to improve public communication activities. The findings of this expert visit are included in an ANNEX to this final Mission report.

3. MAIN FINDINGS, ACKNOWLEDGEMENTS AND ADVISORY POINTS

3.1. REVIEW OF CURRENT SITUATION OF TEPCO'S FUKUSHIMA DAIICHI NPS

Main Findings

The IAEA team's review of the current situation of Fukushima Daiichi NPS was based on available information provided by the Japanese counterpart and inputs obtained during the site visit.

The IAEA team notes that the situation on-site has been improved in many aspects since the last mission in November/December 2013. Completion of the removal of fresh and spent fuel from the spent fuel pool of Unit 4 is an important step. Additionally, an R&D plan was prepared, to support multiple technological options for the fuel debris removal from Units 1-3. Most of the efforts on the development of technologies and equipment are currently at an initial stage.

Improvement and expansion of contaminated water treatment systems, along with installation of more robust storage tanks and associated systems for contaminated water storage, have been achieved to strengthen the capability to deal with contaminated water.

Operation of the underground water by-pass, including comprehensive control of radioactivity before discharging to the ocean, is another measure which has made significant progress. The underground water is pumped up before it reaches contamination under the main buildings of Fukushima Daiichi NPS.

The situation remains complex due to the approx. 300 m^3/day of groundwater ingress into the NPS buildings, resulting in increasing amounts of contaminated water to be managed. As of February 2015, about 600,000 m^3 of contaminated water is stored on-site. More than half of this volume has been already been treated, removing all radionuclides other than tritium.

Significant amounts of rubble have been collected from damaged buildings and a variety of on-going works. This waste has been placed in temporary storage facilities located on the site of the Fukushima Daiichi NPS.

Clean-up of the site continues to be one of the priorities to enhance working radiological environment for employees of TEPCO and its contractors (currently around 7,000 workers).

3.2. FOLLOW-UP OF THE PREVIOUS IAEA DECOMMISSIONING MISSIONS CONDUCTED IN 2013

Main Findings

A detailed overview of the current status of implementation of the IAEA advisory points from previous decommissioning missions was provided by the Japanese counterparts. Roughly half the advisory points were considered to be completed, or close to completion, while progress with the remaining half continues. One advisory point is being considered for the future implementation.

The IAEA team was impressed by the thoughtful, diligent and continued efforts of Japanese counterparts to carefully consider all advisory points and to work on their effective implementation. It is obvious that serious intention and commitment to improve execution of the planned on-site activities is in place, as is a common approach of all the parties involved. Significant examples of work on previous advisory points are as follows:

- Formulation of basic considerations to prepare and to discuss radioactive waste end-points and decommissioning end-states with all relevant stakeholders;
- Improvements in a variety of technical aspects of water, waste and spent fuel management practices, along with the introduction of new measures to deal with recent on-site issues;
- Review of the strategy for accumulated water management and development of comprehensive plans;
- Implemented measures to reduce occupational exposure and restrict additional dose at the site boundary;
- Improvements of various aspects related to the marine monitoring and assessment of potential radiological impact;
- Promotion of stakeholder involvement, along with establishment of enhanced communication and reporting channels with concerned parties.

Sharing of good practices and lessons learned with the international community was included as an objective of both IAEA decommissioning missions. Japanese counterparts are to be appreciated for their continuous dissemination of information concerning the Fukushima Daiichi on-site activities to the international community. Recognized Japanese experts from various organizations are encouraged to attend various international events, including those organized by the IAEA and OECD/NEA, to share experiences of on-site practices and lessons learned worldwide.

Acknowledgement 1:

The IAEA team appreciates Japanese institutions for careful consideration of all advisory points from the previous IAEA decommissioning missions and for extensive effort to effectively implement them to the maximum extent possible.

3.3. STRATEGY AND PLANNING FOR THE DECOMMISSIONING OF TEPCO'S FUKUSHIMA DAIICHI NPS

3.3.1. Strategy and planning, including revision of the Roadmap and development of NDF Strategic Plans for Decommissioning

Main Findings

The strategic objectives and policies related to decommissioning of the Fukushima Daiichi NPS are presented in the Roadmap. The current version of the Roadmap was adopted in June 2013. A need for continuous revisions of the Roadmap has been recognized, in order to reflect the progress of the ongoing activities on-site, new information collected about the status of the facilities and the status of the site, and the progress and results of the associated research and development activities. During the mission the counterparts set out their plans to revise the Roadmap by early summer 2015. The revised Roadmap is expected to provide more details in Phase II, which will be broken down into smaller tasks described in more detail. In that way a Short Term Roadmap will be elaborated within the Mid-and-Long Term Roadmap. Such elaboration of the Phase II tasks should make it easier to track the progress of the Roadmap implementation during Phase II. In addition, the revised Roadmap should identify conditions and risks associated with planned decommissioning activities. The counterparts presented the major principles for the revision of the Roadmap. They include definition of clear milestones, evaluation of risks, balancing fast progress with risk minimization, further reduction of occupational exposures, benefiting from cooperation with foreign institutions and experts, and improving transparency and stakeholder involvement. The revised Roadmap should also address decommissioning of the Fukushima Daiichi NPS Units 5- 6. During the mission TEPCO presented brief information on the future utilization of the Units 5-6 as full-size mock up testing facilities.

The counterparts provided information on the reorganization of the “Nuclear Damage Compensation Facilitation Corporation”. On August 18, 2014, it was reorganized, and a new “Nuclear Damage Compensation & Decommissioning Facilitation Corporation” (NDF) was established. In addition to the previous tasks to provide financial support to facilitate compensation and to supervise the management of TEPCO, the NDF has been given a new task to support decommissioning of the damaged Fukushima Daiichi NPS reactors. The NDF is expected to analyse decommissioning activities, to identify technologies requiring research and development, and to develop a “Strategic Plan for Decommissioning of Fukushima Daiichi NPS” (Strategic Plan), which should provide an approach to conducting activities and making decisions, as well as set priorities in achieving the goals. Basic functions of the NDF comprise:

- Development of a mid-and-long-term strategy;
- Technical support in the project management;
- Planning of research and development;
- Strengthening the international cooperation.

The Strategic Plan is under development and, as with the Roadmap, an ongoing revision process is envisaged. During the Mission, an outline of the Strategic Plan was presented, as well as the guiding principles for risk reduction, which are being considered during development of the Strategic Plan, namely: safe, reliable, reasonable, speedy, site-reality oriented. According to the risk reduction principles employed in the Strategic Plan, the decommissioning of the Fukushima Daiichi NPS is recognized as a continuous risk reduction activity to protect people and the environment from the risks associated with the radioactive material resulting from the accident. Sources of risk have been identified and risks evaluated according to the probability of occurrence and the potential impact. Risk reduction strategies are being considered, including the duration of their application. The counterparts presented logic tree diagrams for risk reduction and plural scenarios considered for some of the key activities, such as fuel debris removal and management of radioactive waste.

On the basis of the Roadmap and the Strategic Plan, TEPCO through the newly established organization “Fukushima Daiichi Decontamination and Decommissioning (D&D) Engineering Company” (FDEC) is preparing Implementation Plans, which form the basis for licensing of the field activities, and is delivering decommissioning works.

Planning efforts for decommissioning of the Fukushima Daiichi NPS are supported by an extensive research and development (R&D) programme in Japan. Planning for R&D is one of the responsibilities of the NDF. During the mission, information was provided on the status of R&D activities performed by the International Research Institute for Nuclear Decommissioning (IRID) and the Japan Atomic Energy Agency (JAEA). The main areas of research performed by IRID include containment examination and repair technologies, fuel debris removal technologies, core and fuel debris evaluation technology, integrity evaluation technology, development of methods for treating damaged spent fuel, criticality management techniques, remote decontamination technologies, solid waste treatment and disposal methods, etc. In April 2013 the JAEA established “Nuclear Plant Decommissioning Safety Research Establishment”. The JAEA is investing 85 billion yen to construct two advanced research facilities to support and accelerate decommissioning works at Fukushima

Daiichi NPS site:

- Naraha Remote Technology Development Center – facility for development of remote-controlled equipment and devices – expected to be operational in summer 2015;
- Okuma Analysis and Research Center – facility for analysis and research of radioactive materials – detailed design underway, operation by the end of March 2018.

The JAEA also informed about the progress towards establishment of "International Research Center for Decommissioning", which is planned for April 2015. This research center is aimed to enhance the support to the domestic and overseas R&D activities for decommissioning and to utilize the JAEA's research and testing facilities in order to support and accelerate decommissioning works.

Acknowledgement 2:

The IAEA team acknowledges continuous efforts of the Government of Japan, TEPCO and other organizations involved, on development of a strategy and an integrated planning for decommissioning of Fukushima Daiichi NPS. These include planned revision of the Roadmap, and the development of the NDF's Strategic Plan. It is commendable that the Strategic Plan is driven by the principle of risk reduction, and that detailed studies and analyses are being performed to identify, quantify and prioritize risks, to develop risk reduction strategies and plural scenarios for the risk reduction related activities.

In addition, the IAEA team acknowledges further progress in developing and implementing a comprehensive R&D programme to support the decommissioning works, in particular activities of IRID and JAEA towards construction of Advanced Research Facilities and the establishment of the International Research Centre for Reactor Decommissioning.

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Advisory Point 1:

Giving the complex situation at the Fukushima Daiichi NPS site, associated with large uncertainties in relation to radiological and physical status of the facilities, long term decommissioning planning has to include consideration of numerous options and scenarios. There is a need to optimize planning efforts by narrowing down the number of options for consideration. Identification of future configurations of the Fukushima Daiichi decommissioning process would provide a contribution in that direction. The IAEA team encourages all stakeholders to continue discussions, initiated in the previous period, in considering the future configuration. In addition to reduction of the number of options for consideration, identification of such future configuration will be an important input to the development of strategies and plans for management of very large amounts of radioactive waste, present now and expected to be generated during the decommissioning process.

The IAEA team encourages the Government of Japan to make the best use of TEPCO's growing experience of implementation activities on the site, in the revision of the Roadmap and development of the NDF's Strategic Plan.

3.3.2. Institutional and organisational issues

Main Findings

The change from Nuclear Power Plant (NPP) operations into Radioactive Waste Management (RWM) and Decommissioning operations is profound. Even in optimal circumstances, planning for this transition requires the thoughtful application of resources, over a number of years. The following table compares a number of factors between these two operational states, in the context of Fukushima Daiichi (all comments are descriptive and subjective). Clearly, progressing from NPP to RWM and Decommissioning Operations through an emergency situation is even more challenging

Factor	**NPP Operations**	**RWM and Decommissioning operations**
Scale and extent of construction projects	Low	Very high
Rate of change through time	Very low	Very high
Consideration of controlled areas[2]	Very low	Very high, frequent changes
Range and scale of radioactive waste arisings	Few waste streams, well understood	Many waste streams, higher levels of uncertainty.
Safety assessment of activities	Largely routine and well understood	Extensive, wide variety of situations arising and the need to weigh many factors.

While this change has most effect for the operator of the site (in this case, TEPCO), it may also affect the requirements of other authorities, including the Regulatory Body and a range of governmental organisations, such as a strategic authority.

Ensuring that all the actors (site operator, regulatory body, strategic authority and government) are consistent and clear in their understanding of their various responsibilities requires careful consideration. Changes of personnel, policy developments and other factors may lead to a requirement to update the understanding of specific responsibilities. Similarly, ensuring that all personnel within all organisations understand their duties, and act consistently in accordance with these, requires sustained management attention within each organisation. This is even more relevant when a new body is created (in this case, the NDF).

The change from NPP to RWM and Decommissioning Operations may give rise to new requirements for organisations in a number of domains, including their capacity to control and supervise much more varied operations on the site; to prepare robust safety justifications for a wider range of operations (and, in the case of the Regulatory Body, to review and authorize same); to train, qualify and authorize operators for specific safety roles and to ensure systematic radiological protection.

Throughout these changes, the fundamental role of the site operator to maintain safety remains paramount. Establishing and maintaining safety leadership, with an associated culture which holds safety at its core, is a significant challenge in any large-scale industrial organisation. More so in nuclear operations and even more so in such a complex situation as is evident at Fukushima Daiichi.

To support their adaptation to these changes, the IAEA notes that the various actors in Japan are working effectively to strengthen international engagements, with fellow operators, supply chain companies, regulatory bodies, strategic authorities and multi-national agencies (including IAEA). There is much that the international community can learn from the experiences at Fukushima Daiichi and the IAEA welcomes these efforts to forge strong international relationships

[2] ***Controlled area.*** A defined area in which specific *protection* measures and *safety* provisions are or could be *required* for controlling *normal exposures* or preventing the spread of c*ontamination* during normal working conditions, and preventing or limiting the extent of *potential exposures* – IAEA Safety Glossary.

Acknowledgement 3:

The IAEA team acknowledges the progress made by TEPCO in addressing the profound challenges arising from the accident. The tasks involving inter-connected, diverse and evolving conditions embodied in waste management and decommissioning at a post-accident site have commenced, in a thoughtful and determined manner. As an example, the creation of a specific division within TEPCO to address the challenges at Fukushima Daiichi is welcomed – "Fukushima Daiichi Decontamination and Decommissioning (D&D) Engineering Company" (FDEC). The IAEA team also notes the creation of the "Nuclear Damage Compensation & Decommissioning Facilitation Corporation" (NDF).

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Advisory Point 2:

Noting the recent introduction of the NDF, the IAEA invites the Government of Japan to consider how best to ensure the full clarity of responsibility of all the relevant actors.

Advisory Point 3:

Safety leadership, in all cases at the Fukushima Daiichi NPS site, is the primary responsibility of the Operator (TEPCO). Renewed emphasis on this aspect is particularly beneficial whenever national structures are undergoing significant change or in which large numbers of contractors are deployed. Therefore, the IAEA team strongly encourages TEPCO in their progress to reinforce safety leadership and safety culture, along with developing a Management System appropriate to radioactive waste management and decommissioning. This will provide mechanisms for *inter alia* effective control and supervision of operations on the site; robust safety justification; rigorous training, qualification and authorization of operators fulfilling defined safety roles; and systematic radiological protection.

3.3.3. Preparation for licensing

Main Findings

The IAEA team considers that the licensing/authorization process is essential in ensuring safety of the facilities and activities at the Fukushima Daiichi NPS site, and in ensuring proper protection of workers, the public and the environment.

The IAEA team recognizes that it was difficult to apply the regular licensing process for normal situations to the post-accident situation at the Fukushima Daiichi NPS site. In this situation a non-standard licensing/authorization process was established and has been applied. This approach to licensing was approved by the Government of Japan.

The non-standard licensing process has been introduced on the basis of the special designation of the reactor facilities of the TEPCO's Fukushima Daiichi NPS as "Specified Nuclear Facility", done by the NRA on 7 November 2012. Such "Specified Nuclear Facility" have been required to conduct special safety management depending on the situations at the facilities. At the same time, the NRA indicated TEPCO "Matters for which the measures should be taken by TEPCO", with an objective to reduce risks and optimize efforts in ensuring safety of workers, public and the environment.

During the previous two review missions, it was explained that the main licensing/authorization document for the on-site activities is the Implementation Plan, developed by TEPCO. The Implementation Plan for activities describes how the objectives of the Roadmap and the strategic decisions of the NDF's Strategic Plan will be implemented. The Implementation Plan is supported by safety justifications/assessments and other documents, as appropriate. Progress of activities on-site is reflected in the amendments of the Implementation Plan. Specific activities are authorized on the basis of the Implementation Plan for these activities. Such an example of authorization of the spent fuel removal from Unit 4 was presented during the second mission in November/December 2013. During the latest Mission an example of the authorization process for the soil covered temporary waste storage facilities was presented and explained. TEPCO presented the type of analyses performed, safety justification provided, and the content of the safety related documentation submitted to the NRA for authorization of the construction and operation of these facilities.

During the mission TEPCO presented its internal process for approval of safety related works, which follows a graded approach based on the safety-related risks and project-related risks associated with the works. The structure and the roles of the different TEPCO's Committees, including Nuclear Safety Management Committee and Decommissioning Safety Committee, were explained, as well as the interactions between the Committees during the internal approval process. The complex situation on site with numerous activities performed in parallel makes it essential to have such an internal process in place, with clear allocation of responsibilities for independent internal safety review and approval of the activities, which do not require interaction with the NRA.

Acknowledgement 4:

The IAEA team acknowledges the efforts of the Government of Japan and the NRA to establish a licensing/authorization process for activities and facilities on the Fukushima Daiichi NPS site, as well as TEPCO's effort to implement that licensing/authorization process and NRA to evaluate and grant authorization, if appropriate.

Recognizing that the existing licensing process for normal situations is difficult to be applied in the complex post-accident situation, a non-standard licensing/authorization process is being discussed and applied, based on demonstrating compliance with prescribed set of general safety requirements. Such process was applied to the authorization of recently completed removal of the spent fuel from the Fukushima Daiichi NPS Unit 4.

In addition to the process involving licensing/authorization by the NRA, there is a robust internal process in place within TEPCO, for internal safety evaluation and approval of works by the TEPCO's Nuclear Safety Management Committee and Decommissioning Safety Committee.

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Advisory Point 4:

The IAEA team encourages TEPCO to engage with the NRA in establishing clear criteria, based on risk assessment, for determining which activities require the NRA authorization and which activities can be evaluated and approved internally by the TEPCO's Committees responsible for safety.

TEPCO is encouraged to strengthen its Committees responsible for internal safety evaluations, including consideration of involving external independent experts in the safety evaluation process.

3.3.4. Public relations and communication

Main Findings

The Government of Japan has established the Fukushima Advisory Board on Decommissioning and Contaminated Water Management with the participation of the Fukushima Prefectural Government, municipal governments, agricultural associations, fishermen's associations, commerce and industry associations, non-profit organizations, ministries and agencies as well as TEPCO. The Board has met six times since its first meeting in February 2014, with meetings aiming to enhance provision of information and collection of opinions about the policies, plans and implementations activities on the site. These actions are in line with Advisory Point 2 of the first mission as well as Advisory Point 4 of the second mission and they have potential to build trust and respect among all parties. The IAEA team notes that the Board's relevance needs to be maintained with appropriate participants, discussion topics and an open atmosphere so that all stakeholders' concerns and opinions may be given proper consideration.

To pursue timely communication with key stakeholders and enhance their understanding of the current situation of Fukushima Daiichi NPS and progress made in its decommissioning, TEPCO has developed a multi-faceted communication strategy that aims to disseminate information by using understandable language and visual elements such as infographics, photos and short videos. In addition to using conventional media channels, the strategy also includes components to reach the public directly through the website and social media. It also calls for interactive dialogue and increased visibility of TEPCO's management (i.e., TEPCO President, Chief Decommissioning Officer). TEPCO is providing journalists, community leaders and other special groups with the opportunity to tour the Fukushima Daiichi site. TEPCO has also started to analyse the conversations about TEPCO and its work on social media, so as to better understand questions, concerns and misconceptions. The IAEA team welcomes the communication strategy as a useful tool for communication that could enhance public trust and confidence and encourages continued work to ensure that its goals are reached.

In addition, to improve quality and transparency in communications, TEPCO has trained selected nuclear engineers as Risk Communicators, who regularly meet with stakeholders in at several locations including Tokyo Head Office, Fukushima City, Niigata City, Aomori Higashidori as well as Fukushima Daiichi NPS, Fukushima Daini NPS, and Kashiwazaki-Kariwa NPS. The IAEA team encourages a systematic collection and analysis of topics stakeholders discuss with risk communicators. By collecting concerns systematically, TEPCO can detect topics of concern to stakeholders and will be able to respond effectively with clear and factual information based on human health and environmental protection aspects.

To respond to Advisory Point 3 of the second mission, TEPCO has developed and strengthened its measures to communicate information about the decommissioning activities to on-site workers of TEPCO and its contractors. For example, TEPCO installed electronic bulletin boards that broadcast information relevant to the workers, such as the situation at the site, radiation level maps, safety rules and measures at the site, and emergency information. In addition, to facilitate interactive communication with on-site workers, a worker-management communication group called the "Echo Committee", which was suspended after the accident, started meeting again in April 2013 to enable workers and management to share their opinions and comments, so as to improve the working environment in the field. The IAEA team notes that the committee could function as an effective tool to enhance workers' understanding of plant conditions and the overall role of their work.

The IAEA team recognizes that Advisory Point 3 of the first mission report has been reflected in the revised Roadmap, and expects TEPCO to make clear its criteria on announcing accidents and near-misses. The IAEA team encourages TEPCO to continue its comprehensive assessment of its reporting procedures and communication activities to enhance public confidence and trust.

Additional information about TEPCO's efforts to improve its public communication activities, which was obtained during the IAEA expert visit conducted in April 2015, is presented in the ANNEX.

Acknowledgement 5:

The IAEA team notes that the Fukushima Advisory Board has been active since its creation, providing a useful channel for strengthening public communication and stakeholder involvement in the decommissioning of Fukushima Daiichi NPS and contaminated water management. This is in line with Advisory Point 2 of the first mission as well as Advisory Point 4 of the second mission.

Acknowledgement 6:

TEPCO has intensified its public communication efforts, including by using social media and 'risk communicators' – engineers trained in communication to reach communities. In line with Advisory Point 3 of the second mission, TEPCO has intensified communication with the workforce, including contractors.

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Advisory Point 5:

Recognizing intensified communication efforts through the dissemination of comprehensive information, the IAEA team urges METI and TEPCO help lay audiences understand the relevance of this information by basing it on the health and safety aspects of both the workforce and the public, as well as protection of the environment. The IAEA team also encourages TEPCO to promote understanding by intensifying and widening its efforts to promote an interactive dialogue, including by engaging its social media audience by responding to comments and questions. Thorough analysis of how the media and the public understand disseminated information should be used to improve future communication.

3.3.5. Prioritisation and hazard reduction

Main Findings

Mindful of the site operator's responsibilities for the safety of operations, against the backdrop of profound changes in the transition from NPP Operations to RWM and Decommissioning Operations, methods of safety assessment are worthy of consideration. The IAEA team saw evidence that TEPCO is aware of the challenge and is responding in a thoughtful manner. The further development of a sound safety assessment methodology merits continued diligent attention – both within the site operator and in its interfaces with the regulatory body.

The IAEA team saw evidence of thoughtful planning for the future implementation of activities (in particular, a schedule of facilities for the treatment of radioactive waste). A development of this, which has been used at other complex sites, is a schedule showing the estimated quantity, activity level and type of radioactive waste arising (all charted against time). At this stage of development, such a schedule will involve some uncertainties, for example in estimating the nature and quantity of fuel debris. Preparing a first draft schedule, however, can assist by highlighting the assumptions involved and by providing a series of requirements through time (whether for treatment and storage facilities; characterisation of waste; or R&D activities).

Such a waste management plan may also assist in planning of land use on the site and can help to identify interactions with the regulatory body, including 'hold points' (at which the consideration and approval, if justified, of the regulatory body will be required). As the waste management plan develops, it may prove helpful in forecasting discharges from the site. It may also be used to assess the inter-dependencies between stages in waste management. For example; by identifying and reducing the amount of secondary handling required.

Closely linked to the waste management plan is a decommissioning plan. This may set out the sequence, through time, of the planned decommissioning of reactors and other plants. As these two plans (waste management and decommissioning) develop, they may become integrated, allowing more detailed assessment of multiple options, including consideration of several factors (for example; hazard reduction; safety of the workforce and public; environmental protection; waste minimisation; and effective use of resources).

As the two plans develop, consideration may usefully be given to seeking an optimal path for overall hazard reduction. Whilst purely numerical methods may be a valuable input in considering hazard reduction, wider considerations of facility re-use, structural integrity of damaged buildings, skills availability and land use management may also be worthy of consideration. In any event, all decisions on which path to pursue should be founded on minimising impacts to human health and on protecting the environment.

Acknowledgement 7:

The IAEA team welcomes the start of transition towards a safety assessment approach within TEPCO which takes account of several relevant factors, including workforce dose, protection of safety systems and prevention of radiological discharges.

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Advisory Point 6:

The IAEA team encourages TEPCO to develop an integrated plan for decommissioning and radioactive waste management at Fukushima Daiichi NPS. In developing this plan, certain activities will deserve more prompt attention, and consideration of the approach adopted to address this will be beneficial. The chosen approach should be firmly founded on minimising impacts to human health and on protecting the environment. It should also consider how inter-dependencies between the steps of radioactive waste management, maintaining a clear view of long-term safety, can be considered and how waste disposal may properly be assessed. Independent advice and challenge to the emerging plan is also likely to be valuable.

3.4. REVIEWS OF SPECIFIC ISSUES

3.4.1. Management of radioactive waste

Main Findings

Radioactive waste generated from treatment of contaminated water

A number of facilities (discussed further in section 3.4.2) are being used at the site for the treatment of contaminated water. At these treatment facilities, radionuclides present in contaminated water are captured in sorbent media packed inside columns or in sludges resulting from chemical precipitation processes. Hence, spent sorbent media and sludges are the main radioactive wastes resulting from the treatment of contaminated water. Considering the high activity of radionuclides in the water and the large volumes treated, the radioactivity content of resulting wastes is very high, requiring careful attention to their handling, containment and storage.

There are four storage facilities at the site for these wastes, mainly in the form of columns containing spent media or High Integrity Containers (HICs) containing slurries. As of 26th February 2015, a total of 1894 used vessels are in storage, including 578 vessels from “Caesium adsorption apparatus”, 121 vessels from “2nd caesium adsorption apparatus”, 1097 HICs, and others. In addition, approximately 600 m^3 of sludge from a chemical precipitation process used in the initial months after the accident is stored in a concrete vault in the waste treatment facility.

To ensure safe storage of the used vessels, a number of relevant issues have to be considered, namely high radiation levels, decay heat, radiolytic hydrogen generation and corrosion or degradation of containers. The storage facilities have been designed to provide adequate shielding for radiation. As for the other issues mentioned above, effective interim measures have been taken and the mission team was informed about the research being conducted by Japan Atomic Energy Agency (JAEA) to further investigate and address these issues. JAEA is also carrying out useful work on characterization and conditioning of the different types of spent media and sludges being generated from contaminated water treatment.

Management of solid radioactive waste

Immediately after the accident, a process of management of all types of generated waste was established in the emergency situation, driven by the essential objective of reducing the dose to workers and at the boundaries of the site. In this regime, radioactive waste management mainly consisted of sorting the different material and debris by their physical type (e.g. concrete, wood, rubble, etc.) while also measuring the contact dose rates of the different materials. Characterization does not presently extend to more detailed analysis of radioisotope content.

Rubble collected after the accident and that generated during works to retrieve pooled fuel assemblies, as well as trees cut down to install water tanks and facilities, and to establish storage areas have been temporarily stored at several locations on the site.

The main target at the moment for the management of the radioactive waste is to store it in temporary storage facilities located on the site.

As of 26 September 2014, the estimated amount of waste (rubble and trees) and their management (storage) is as follows (JAEA's presentation referring to "Status of waste management of rubble and tree", TEPCO, 30 Oct 2014):

Waste	**Storage**	**Estimated Amount (m^3)**
Rubble	Solid waste storage	4,900
	Temporary storage covered with soil, temporary storage in tents and/or containers (1-30 mSv/h)	16,900
	Covered with sheet (0.1-1 mSv/h)	26,600
	Outdoor pile (<0.1 mSv/h)	66,700
Tree cut down	Outdoor pile for trunk, root, branch, leaf	62,300
	Temporary storage for branch and leaf	17,400

As of December 26, 2014, TEPCO indicates that the total estimated amount of concrete and metal debris is 134,400 m^3 and the total amount of felled trees is 79,700 m^3.

At present, the total volume generated in the next 10 years of combustible and felled trees after incineration as well as metal, concrete and other objects, with the exception of contaminated soils, is estimated at approximately 500,000 m^3.

Temporary storage facilities have already been developed on the site and additional facilities are being constructed. Wastes accumulated in temporary storage facilities at the site are planned to be transferred at a later stage, not longer than 10 years, to one or several interim storage facilities (solid waste storage buildings) planned for construction on the site.

The collected debris is classified by surface dose rate prior to being moved to temporary storage areas. Although there is no capacity at the moment to carry out detailed characterization of all the generated waste, since 2011 a series of solid and liquid samples have been characterized by JAEA as indicated below:

Waste	Sample	Number	Year
Contaminated Water	Contaminated Water in Turbine building #1 – 4 Accumulated water under Centralized Radioactive Waste Treatment Facility Water treated by Cs adsorption, Decontamination, Reverse osmosis, evaporation	13	2011-2012
	Accumulated water under Centralized Radioactive Waste Treatment Facility	2	2013
	Concentrated water by Reverse osmosis	1	
	Accumulated water under Centralized Radioactive Waste Treatment Facility including high temperature incineration facility	5	2013
	Treated water with Cs adsorption	4	
Rubble	Rubble around reactor 1,3 and 4	15	2011-2013
	Rubble in fuel pool of reactor 4	2	
	Coating (Reactor building #1, 1st floor and wall, 1st floor of #2)	3	2013
	Rubble in 1st floor of #1 and 3	9	2014
	Coating (Reactor building operating floor of #2)	1	
Vegetation	Tree cut down (branch, leaf)	5	2011-2013
	Tree near reactor #3 (branch)	2	
	Tree in site (branch, leaf, litter, topsoil)	121	2013-2014

And the following radionuclides were analysed:

γ emitters	^{60}Co, ^{94}Nb, ^{137}Cs, ^{152}Eu, ^{154}Eu
β emitters	^{3}H, ^{14}C, ^{36}Cl, ^{41}Ca, ^{59}Ni, ^{63}Ni, ^{79}Se, ^{90}Sr, ^{99}Tc, ^{129}I
α emitters	$^{233, 234, 235, 236, 238}U$, ^{237}Np, $^{238, 239, 240, 242}Pu$, $^{241, 243}Am$, ^{244}Cm, total α

The work carried out so far has been broadly successful in the context of urgency, with the aim of reducing dose to worker and at the site boundaries. However, 4 years after the accident, one can consider that the level of urgency to manage the waste, with the view to reducing dose, has decreased. Within the process of implementing a dedicated integrated waste management strategy in the perspective of long term management and safety, it is now appropriate to take stock of all the activities performed and to learn the corresponding lessons.

As an example, two soil-covered-type temporary storage facilities were developed in the early phases of the cleaning activities. Waste has been deposited in the trenches as raw material, without specific conditioning or packaging being used prior to emplacement. Similar methods are intended to be used for the storage of material in the newly planned facility of this type. The anticipated duration of storage of the waste in these facilities is estimated to be around 10 years, but not more than 15 years (limited by the longevity of the liner material, noting that the liner prevents the spread of contamination). Following the period of temporary storage, the intention is to move the waste to an interim storage facility. In any case, after the period of storage waste will have to be retrieved and transferred to another facility. Such a retrieval phase has to be anticipated carefully to ensure the safety of workers and the public during the operations. Early planning of the conditioning and appropriate packaging of the waste to be deposited in the new temporary storage facility would enhance retrievability and radiation protection of workers and the public during operations.

Acknowledgement 8:

The IAEA team acknowledges that the government has created an organizational framework, comprised of, for example NRA, FDEC, NDF, IRID and JAEA, that used effectively can enhance the safety of the wastes arising from an expedited decommissioning by embracing long-term waste management principles. The IAEA team recognizes the effort and accomplishment of the FDEC in reducing worker exposure, dose at the site boundary and facilitating site operations for decommissioning, by the accumulation of contaminated material and debris into temporary storage.

Acknowledgement 9:

The IAEA team acknowledges that the FDEC endeavours to use good engineering principles in the design and configuration of the temporary storage locations and their design are reviewed by the FDEC safety committee and approved by the NRA when required. The IAEA team further recognizes that the FDEC develops and maintains information on the physical contents of each temporary storage location and its debris form with minimal radiological characterization for surface dose rate.

Acknowledgement 10:

The IAEA team considers that the research carried out by the JAEA on the different phases of predisposal management (characterization, treatment, conditioning, storage) of the waste from the water treatment is commendable and should be continued.

Acknowledgement 11:

The FDEC recognizes the benefits of implementing clearance processes and permitting material reuse and recycle for wastes generated during decommissioning, and thereby facilitate the long-term waste management.

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Advisory Point 7:

The IAEA team is of the opinion that the FDEC could better employ long-term radioactive waste management principles (beyond the segregation, relocation and dose reduction/shielding currently performed) such as more complete waste characterization, conditioning, and packaging. While the IAEA team holds that the FDEC could deploy such principles in its present efforts, it appreciates that waste management strategy, direction and criteria are forthcoming from the NDF.

Advisory Point 8:

The NDF is urged to give priority to issuing the waste management strategy that will enable the FDEC to implement (after the demonstration of safety and proper licensing) processes appropriate for safe long-term radioactive waste management such as waste minimization, treatment and conditioning, packaging, release, recycling, etc.

Considering that most of the contaminated rubble is likely to have only surface contamination and could be easily decontaminated to a certain extent, the IAEA team suggests that benefits of conditional clearance should be explored and implemented if appropriate, with the vision of reducing the overall amount of radioactive waste to be managed.

Advisory Point 9:

The IAEA team encourages the FDEC to reflect in its organizational structure and staffing the importance and scale of the radioactive waste management workscope. Additionally, the supporting institutions, such as JAEA, are encouraged to ensure sufficient human and technical resources are available for radioactive waste management and to support the FDEC with reliable and sustainable waste management capabilities, including the development of on-site technical capabilities.

Advisory Point 10:

The IAEA team encourages the FDEC to continue working on developing a waste inventory providing reliable physical, chemical, radiological and volumetric information, even prior to availability of the new Analysis Centre, to support future strategic planning and decisions for the waste streams. The IAEA team encourages the FDEC to continue to implement Advisory Point 8 from the previous decommissioning mission regarding the need to establish a sound radiological characterization of the waste and waste classification scheme which will enable the FDEC to further develop its strategy for the processing, storage and disposal of the waste.

Advisory Point 11:

The IAEA team recommends the long-term and operational safety of the temporary storage facilities (for emplacement, storage and retrieval phases) be evaluated for both normal and potential accident conditions, in line with the hazard of the various waste generated.

3.4.2. Management of contaminated water, including ingress of groundwater

Main Findings

Management of contaminated water and groundwater ingress is a major on-going challenge at the site that needs to be addressed and requires considerable effort. These efforts have been generally guided by the “Basic Policy for the Contaminated Water Issues at the TEPCO’s Fukushima Daiichi Nuclear Power Station” formulated by the Government of Japan in 2013, focusing on a range of immediate and fundamental countermeasures. Strategic plans for addressing this issue are now provided by the newly established national authority, namely the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF), which receives policy advice from a number of Government agencies including the Advisory Committee for Contaminated Water Countermeasures. Implementation of relevant activities at the site is carried out by the “Fukushima Daiichi Decontamination and Decommissioning (D&D) Engineering Company” (FDEC) that was constituted recently and is now responsible for on-site activities. In order to better focus on field implementation of water related activities, FDEC has a designated Unit Superintendent at Fukushima Daiichi NPS who coordinates the activities of the three responsible departments, namely Water Treatment System Department, Water Treatment Management Department and Water Treatment Civil Department.

The above organizational changes reflect a clear recognition on the part of Japanese authorities of the importance of providing an adequate framework to address the challenge of contaminated water management. As noted above, important progress has been made in this area and some serious challenges remain to be addressed. The main findings of the IAEA team are elaborated below.

Treatment and storage of contaminated water

Ingress of groundwater into the reactor and turbine buildings has continued and the volume of contaminated water to be managed continues to increase. Measures taken in the recent past, namely operation of the groundwater by-pass system and stoppage of leaks into a waste treatment building (further discussed below), have resulted in reducing daily ingress of groundwater by 100 m^3/day. However, the daily increase of contaminated water continues to be 400 m^3/day, as before, because 100 m^3/day of contaminated groundwater is now being pumped into the turbine buildings from the seaside areas (Fig. 1).

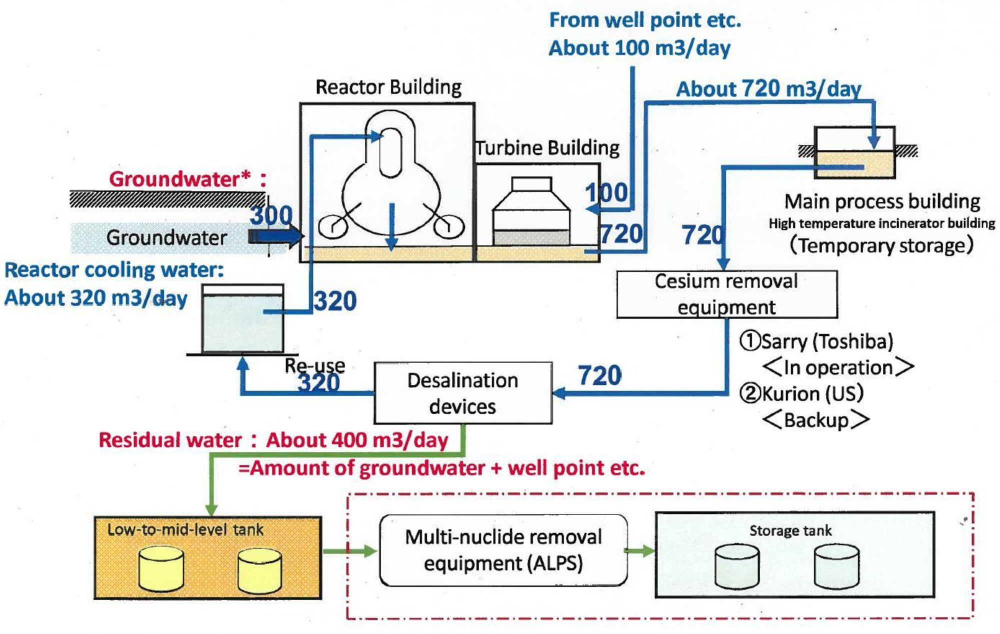

FIG. 1. Overview of contaminated water management showing current balance of water volumetric flow rates

The overall schematic for contaminated water treatment is shown in Fig. 2 below. According to TEPCO's strategy for managing contaminated water accumulating in the buildings, the water is first pumped from the turbine buildings to the Centralized Radioactive Waste Treatment Facility buildings and then treated to remove caesium isotopes using two parallel systems, namely "Caesium adsorption apparatus" and "2nd Caesium adsorption apparatus" (labelled "Kurion" and "Sarry", below). Removing the gamma emitting caesium isotopes as the first step, facilitates further use and management of the treated water. These two caesium removal systems have continued to operate successfully, consistently achieving caesium decontamination factors of 10,000 or more. As of 26th February 2015, the cumulative volume thus treated amounts to approximately 1.16 million m^3. These two systems have now been enhanced by adding strontium removal capability. As a result, the capacity for removing caesium and strontium upfront is now 1800 m^3/day (600 m^3/day for "Caesium adsorption apparatus" and 1200 m^3/day for "2nd Caesium adsorption apparatus").

Following caesium removal, the water is treated, to remove dissolved salts using the reverse osmosis (RO) process. Approximately half of the feed water is desalinated and used for cooling of the damaged cores of Units 1, 2 and 3. The remaining half is a concentrated salt solution which is highly radioactive, containing mainly ^{90}Sr. This solution is stored in above-ground tanks. Three multi-nuclide removal systems – an existing ALPS, an improved ALPS and a new high performance ALPS – are being used to treat the highly radioactive water to remove 62 radionuclides (including ^{90}Sr) to below or near detectable levels. A number of additional systems have also been deployed to remove ^{90}Sr alone from water stored in the bolted flange type tanks. These include several mobile systems (300 m^3/day x 2 systems, 480 m^3/day x 4 systems) and a stationary system (500-900 m^3/day). According to information provided during the mission, decontamination factors of several hundred are being achieved for ^{90}Sr which means at least 99% of ^{90}Sr is being removed. These treatment measures are helping to reduce the inventory of radioactivity in the tanks substantially. It should be noted that strontium-treated water would still require treatment with ALPS to remove remaining ^{90}Sr and all the other radionuclides (except tritium).

Of the total volume of approximately 600,000 m^3 water stored in about one thousand tanks at the site, more than half has been treated by the ALPSs and strontium removal systems. With current processing capacity, it will take TEPCO a few months more than their target deadline of March 2015 for completing the treatment of all stored water.

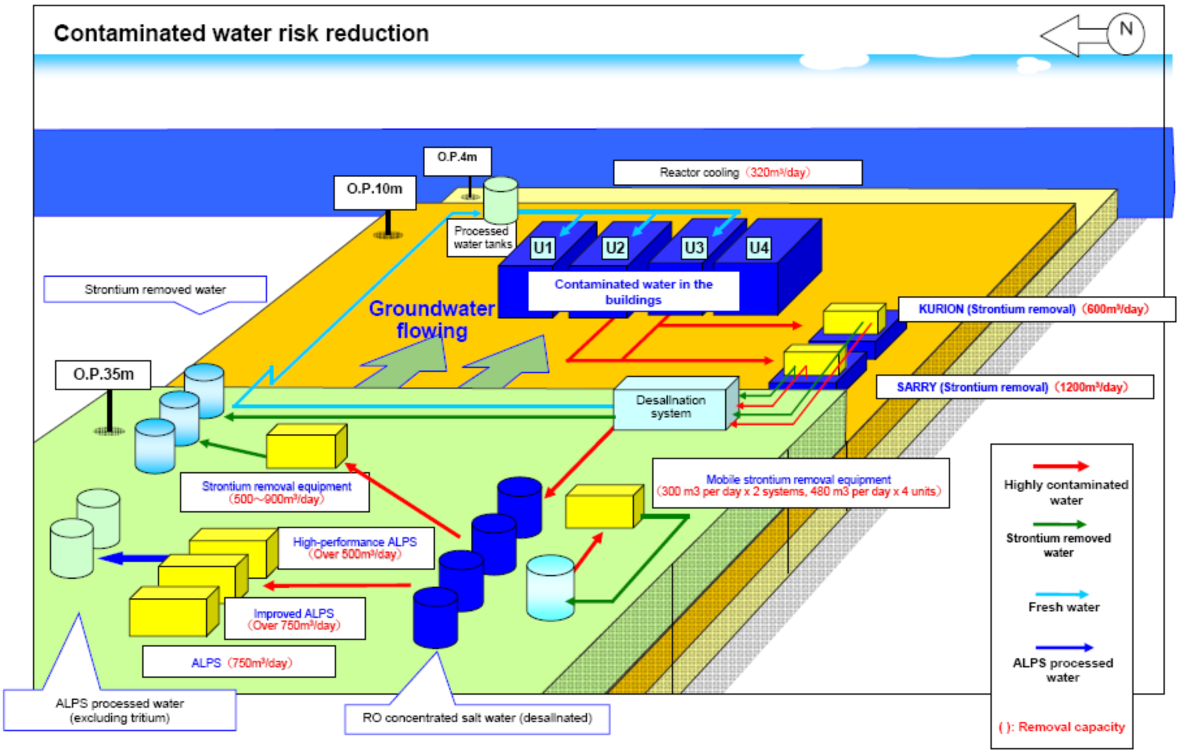

FIG. 2. Contaminated water treatment and storage scheme.

Whilst acknowledging TEPCO's efforts to reduce the risk of storing large volumes of highly radioactive water by removing strontium and other radionuclides as quickly as possible, the IAEA team believes waste minimization should also be an important consideration in such efforts.

Each new piece of equipment adds to the radioactive waste to be managed, and several more items are planned for installation. The IAEA team was informed that this was done because available treatment capacity was not sufficient to meet target deadlines. For example, the actual operating capacity of the three ALPS systems has been only 1200 m^3/day as compared to their full design capacity of 2000 m^3/day. Discussions during the mission indicate that this shortfall may be related to the complexity of the treatment flow sheets and the use of newly developed selective sorbents being industrially deployed for the first time. There is, for example, a need for frequent cleaning or replacement of the cross flow filters in the first two ALPS systems, resulting in significant downtime. Lower than expected service life of strontium sorbent in the high performance ALPS system is another example. Obviously, fine-tuning operating conditions and achieving performance targets for these systems is taking more time than initially estimated. TEPCO needs to resolve these issues promptly and optimize the various processes.

The presence of highly radioactive water in the sea-side trenches of Units 2, 3 and 4 has been a major cause of concern because of the risk of leakage and release to the sea. This issue was also discussed during the previous mission. TEPCO has since been implementing measures to remove the water and seal the trenches with filler material. Half of the water (2500 m^3) has been removed from the seawater pipe trench of Unit 2. Work is on-going to remove remaining water and seal the trenches.

TEPCO has kept pace with the increasing volume of water requiring storage by constructing new tanks. Several measures have also been taken to improve storage safety, including replacement of bolted flange type tanks with fully welded tanks and construction of dykes with enhanced water holding capacity. Rainwater deflection covers have been provided to keep rainwater away from the dykes so that any potential leaks from the tanks can be contained within the dykes. Because of their vulnerability to develop leaks, the bolted flange type tanks have been prioritized for implementing this rainwater management measure.

According to TEPCO's current plans, contaminated water – after treatment to remove all radionuclides (except tritium) – will be stored in above ground tanks. The expected total storage capacity is 800,000 m^3, with potential for further augmentation. However, storage being a temporary measure TEPCO has to find a more sustainable solution. For this TEPCO should consider all options, including the possible resumption of controlled discharges of treated water to the sea as advised during the previous mission. In the opinion of the IAEA team, any decision to resume controlled discharges should be taken after carefully considering all relevant aspects including potential impact on the health of the public, protection of the environment and socioeconomic conditions – all in consultation with relevant stakeholders.

Additional information about management of contaminated water including contaminated rainwater, which was obtained during the IAEA expert visit conducted in April 2015, is presented in the ANNEX.

Measures to reduce ingress of groundwater

Significant steps have been taken to control the ingress of groundwater to reactor and turbine buildings from the mountain-side by installing a series of by-pass pumping wells. The subdrain system around the buildings has been rehabilitated that will allow greater control of groundwater ingress in the near future. Introduction of additional measures, such as the frozen (ice) wall installation, is on-going. TEPCO is also making progress in preventing the leakage of contaminated groundwater into the sea by building impermeable walls on the sea-side and by removing some of the sources of contamination from the cooling water trench/tunnel system. An impermeable, sodium silicate wall was constructed on the sea side of Units 1-4 to prevent the migration of contaminated groundwater to the sea. This wall has blocked the natural flow of groundwater, but has created the need for an additional 100 m^3 /day of contaminated water to be pumped out and treated in order to prevent overflow to the sea.

The current efforts to model groundwater conditions have drawn on extensive historical information from the period of design and construction of the Fukushima Daiichi NPS as well as subsequent boring and water sampling efforts. The use of a Finite Element based, adaptable-grid code allows for telescoping representation of the critical subsurface geological and hydrological structures as well as the built infrastructure at the site. The groundwater model has been used to assess the impact of planned site management activities on the ingress of groundwater into the Reactor Buildings. In addition to the tracking of the volumetric flow of water, the modelling effort will need to identify specific subsurface pathways for contaminant migration, the concentrations to be expected at various places, the concentration in water pumped from the subsurface, and the effect on concentration (or migration pathways) of various remediation actions. As a result, the groundwater model needs to be made more robust for contaminant transport, pathway analysis, and uncertainty assessment. This will require a more comprehensive assessment of the geology, hydrology and contaminant distribution across the subsurface of the site. Specifically, these enhanced models will need regularly updated maps of groundwater levels, groundwater flow volumes, chemical and radioactivity concentrations across the entire site.

At a more detailed level, the IAEA team's review of the current model identified that the hydrological properties of the rock in the subsurface are represented as isotropic (i.e., having the same flow characteristics horizontally and vertically). The specific sedimentary rock that occurs in the area of the Fukushima Daiichi NPS consists of sands, silts and clays in thin layers of variable continuity. This type of rock usually has strongly anisotropic hydrological characteristics. The model performance might be improved by conducting a sensitivity analysis with a hypothetical range of parameter values to evaluate the parameters that impact the results most significantly. Then, improved estimates of these properties can be developed through laboratory testing of core flow experiments and field testing through pumping tests with arrays of installed piezometer nests. The current parameter values for hydrological conductivity, used in the model, have the potential to estimate too great a vertical recharge, thereby giving too great an estimate of the value of facing the ground surface. Additionally, these parameters may potentially estimate too large a contribution of ingress to the base of the Reactor buildings.

Data that could significantly improve the flow and contaminant computer modelling quality and understanding of the site may include:

- Calibration of the model against pre-March 2011 conditions. Until that time, the subdrain system was pumping a known amount of water and the water level was depressed to building bottom. This information, along with the age of groundwater (explained below) and known surface discharge locations (springs or water outlets in slopes or near the sea) can be used to overcome the ‘complexity’ of the geological units to build a robust and reliable model. Additionally, the model can be calibrated to the by-pass pumping.
- Mapping the source of groundwater and estimating its velocity by using chemical (chloride) and isotopic tracers and age dating of groundwater (by using tritium and helium-3 isotopes).
- Implementing a detailed, site-wide monitoring network of nested wells (piezometers) to understand the three-dimensional flow. These piezometers should be installed in each high-permeability layer separately so that water enters the piezometer from only one layer. Additionally, mapping of water levels and chemical/radionuclide concentrations in all piezometers and regular collection of these measurements (probably every month).
- Creating a site wide map of historical operations prior to the accident that might have contributed to subsurface contamination including previous spills of oil, gas, operational fluids, disposal of construction debris, and so forth.
- Use various normal operations as “tests” of the computer model including pumping of the by-pass wells and sea-side well points and drains, impact on water levels by rain events.
- Mapping evidence of ground water movement such as natural springs or increased flow when various site operations change

The significant complexity of the natural conditions at the site and the many management activities underway to address the contaminant transport and waste management makes it difficult to track interactions, progress toward successful contaminant management and to avoid unintended consequences. As a result, the management plan would benefit from implementing a systems analysis that shows how all these efforts integrate to remove current sources of contamination, manage water treatment wastes, understand the consequences of continued groundwater ingress, and address long-term remediation of the site.

Acknowledgement 12:

The IAEA team reconfirms TEPCO’s success in treating large volumes of highly radioactive water, accumulating continuously in the reactor and turbine buildings, to remove gamma emitting caesium radionuclides upfront and using the treated water after desalination to maintain stable cooling of the damaged cores. The cumulative volume treated by the two operating caesium removal systems is now more than 1 million m^3, with high caesium removal efficiency achieved consistently. TEPCO has recently added strontium removal capability to these treatment systems. Removing strontium upfront along with caesium would facilitate further management of the treated water.

Acknowledgement 13:

The IAEA team acknowledges TEPCO's efforts to mitigate the risk associated with storing large volumes of radioactive water, containing high levels of ^{90}Sr remaining after caesium removal, in numerous above ground tanks at the site. In order to augment the treatment capacity of the ALPS and the High Performance water treatment systems (ALPSs), which remove ^{90}Sr as well as all other residual radionuclides (except tritium), TEPCO has established a number of additional treatment systems dedicated specifically to removing ^{90}Sr. Their prioritizing of the bolted flange type tanks for removing ^{90}Sr is well placed, considering the higher risk of storing ^{90}Sr bearing water in these tanks. Even though strontium treated water would still require final polishing with the ALPSs, by removing at least 99% of the ^{90}Sr this approach is enabling TEPCO to reduce the inventory of radioactivity in the tanks and associated risk substantially. More than half of the nearly 600,000 m^3 of water stored in tanks has been treated so far using the ALPSs and strontium treatment systems and TEPCO expects to complete the treatment of the remaining water in the next few months.

Acknowledgement 14:

The IAEA team commends TEPCO for mobilizing the resources needed to successfully build sufficient storage capacity for contaminated water and to generally improve the safety of storage. These measures include replacement of bolted flange type tanks with newly constructed fully welded tanks, construction of dykes with enhanced water holding capacity, and provision of covers to deflect rainwater from the dykes so that the dykes can perform their intended safety function of containing potential leaks from the tanks. Again, prioritizing the bolted flange type tanks for implementing this rainwater management measure is well placed because of the vulnerability of these tanks to develop leaks.

Acknowledgement 15:

The IAEA team commends TEPCO for its efforts to address contamination in the very complicated area of infrastructure East of the Turbine Buildings with its many potential connections between the Turbine Building and the sea resulting from intentional cooling system design, ground water contamination, radionuclides connected with debris in this area, and potential leakage from the Turbine Buildings connected to the Reactor Building. Significant efforts are underway to address elements of these potential pathways including addressing the contaminated water in the Seawater Pipe Trench, however this will be a very difficult area in which to control the migration of contamination.

Acknowledgement 16:

The IAEA team considers the groundwater by-pass system designed to control the ingress of groundwater to reactor and turbine buildings has been successfully put in operation. After six months of operation, and related measures to control leaking to building, groundwater ingress has been reduced by about 25% or 100 m^3 per day. We further acknowledge that the success of the groundwater by-pass operation involved extensive communication and engagement with the many stakeholders and the public in general on the nature of the operation and the measures taken to minimize possible risks to the environment or the public. It is an important milestone in gaining the public trust and should be helpful for implementing future strategies for managing contaminated water issues.

Acknowledgement 17:

The construction of frozen (ice) wall enclosing the area around Units 1-4 on the sea-side and land-side are in various stages of completion. The ice wall on the mountain side will be placed in between the buildings and the groundwater by-pass wells, resulting in further prevention of groundwater flow towards the reactor buildings.

Acknowledgement 18:

The IAEA team notes that the rehabilitation of the subdrains and the construction of a treatment system for pumped subdrain water are nearly complete. As the subdrains are placed in operation, they are expected to further reduce the groundwater ingress by about 150 m^3, and to near zero following the installation of the land-side ice wall. The IAEA team appreciates TEPCO's planning to ensure that pumping from the subdrains is carried out while preventing the outflow of contaminated water from the buildings. After controlling the ingress of groundwater, TEPCO also plans to seal leakage points on reactor and turbine building walls.

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Advisory Point 12:

While recognizing the usefulness of the large number of water treatment systems deployed by TEPCO for decontaminating and thereby ensuring highly radioactive water accumulated at the site is not inappropriately released to the environment including the adjacent Pacific Ocean, the IAEA team also notes that currently not all of these systems are operating to their full design capacity and performance. The IAEA team encourages TEPCO to continue on-going efforts to improve the utilization of these treatment systems. In their planning of water treatment schedules, TEPCO is advised to take into consideration that testing and optimising the operating conditions of complex multi-stage water treatment systems can take time, particularly for those technologies that are new and being deployed under field conditions for the first time.

Advisory Point 13:

The IAEA team is of the opinion that the present plan to store the treated contaminated water containing tritium in above ground tanks, with a capacity of 800,000 m^3, is at best a temporary measure while a more sustainable solution is needed. Therefore the present IAEA team reiterates the advisory point of the previous decommissioning mission:

"The IAEA team believes it is necessary to find a sustainable solution to the problem of managing contaminated water at TEPCO's Fukushima Daiichi NPS. This would require considering all options, including the possible resumption of controlled discharges to the sea. TEPCO is advised to perform an assessment of the potential radiological impact to the population and the environment arising from the release of water containing tritium and any other residual radionuclides to the sea in order to evaluate the radiological significance and to have a good scientific basis for taking decisions. It is clear that final decision making will require engaging all stakeholders, including TEPCO, the NRA, the National Government, Fukushima Prefecture Government, local communities and others".

The IAEA team recognizes the need to also consider socioeconomic conditions in the consultation process and to implement a comprehensive monitoring programme to ensure that there is no detrimental impact on human health and the environment. In this regard the IAEA is ready to continue providing assistance in implementing such a comprehensive sea water monitoring programme.

Advisory Point 14:

The IAEA team advises that TEPCO should consider producing a better calibrated, robust groundwater model, which will allow TEPCO to continuously evaluate and optimize the performance of various countermeasures, such as the land-side ice wall, pumping from by-pass wells, and the operation of sub-drains. An improved model, and a continuously updated, detailed map of water levels, chemical composition, and radioactivity concentrations around the entire site (including under the higher ground west of the groundwater by-pass wells), will help to provide a baseline for monitoring and controlling the migration of any radioactivity from surface contamination.

As the multiple water capture, water treatment, and water storage activities are highly interdependent and complex, TEPCO may also consider implementing a “systems analysis” with associated system dynamics computer tools to help understand the integrated set of contaminated water management activities both on the land and sea-side, assess volumes of water and waste production, the impact of shifting schedules, as well as the interdependency of water management, waste management, and future decommissioning activities.

3.4.3. Removal of spent fuel assemblies and damaged fuel debris

Main Findings

This section comprises: a review of advice formulated in the Final Report of the previous Mission (November/December 2013); an overview of the progress to date; the plans for pooled fuel and fuel debris removal from each reactor Unit (reported in the order in which pooled fuel/fuel debris has been or is expected to be removed); generic schemes for fuel debris removal; and the evaluation of IRID's R&D activities.

Figure 3 illustrates the current fuel and fuel debris situation in Units 1-4.

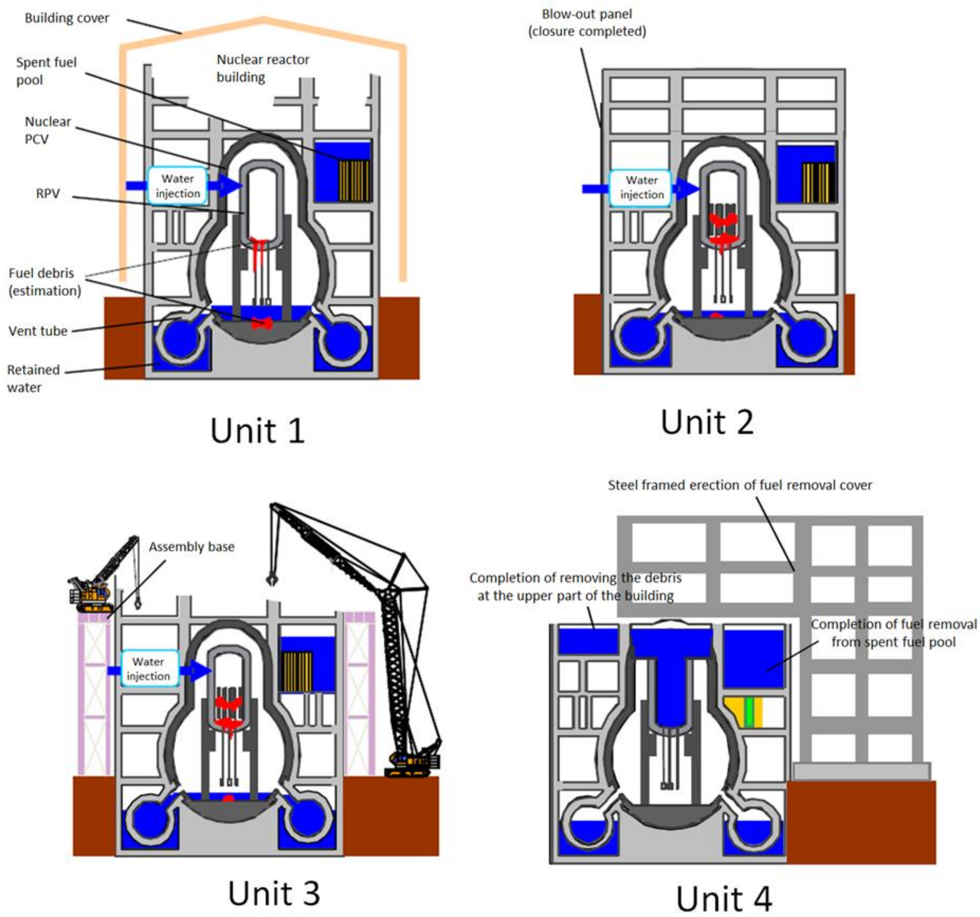

FIG. 3. Recent fuel and fuel debris status at Units 1-4.

Review of advice in the Final Report of previous Mission

Under Advisory Point 4 in the previous Mission report the IAEA team highlighted the following area for further consideration:

> *'The Roadmap identifies that the evaluation of the long-term soundness of fuel assemblies removed from spent fuel pools will be completed by 2017. Experience has shown that the data to inform on-going spent fuel integrity needs to be established up-front. Examples include: visual inspections on a number of fuel assemblies to make reference points; and trend monitoring of pool and cask liquor samples. TEPCO should consider establishing and collecting the data that will be required to confirm on-going spent fuel integrity'.*

In response to this Advisory Point, TEPCO has undertaken water quality analysis of the spent fuel pool every 3 months and has evaluated the exterior appearance of four of the spent fuel elements removed from Unit 4; oxide film thickness was measured, and the appearance of the locknut interior was observed. No problems were identified during the survey.

The IAEA team consider that an opportunity was missed, during the defueling of Unit 4, to properly trend/monitor the condition of fuel being transferred into the Common Spent Fuel Pool (CSFP). It is, however, recognised that TEPCO did respond to this part of Advisory Point 4 by undertaking a number of visual inspections on the fuel being transferred. Water sampling of the CSFP during the fuel transfers was completed every 3 months, which is not sufficient to detect any spikes in activity associated with leaking fuel being transferred into the pool. As operations in other spent fuel pools continue, TEPCO has an opportunity to trend/monitor the condition of the fuel (via enhanced water sampling). Dependent upon the operations in hand, International best practice suggests that frequencies between daily and weekly should be considered (for species such as total alpha, beta, gamma, caesium-134, 137, and chloride) with a full analysis every month.

The likely causes of the missed opportunity are the lack of available trained personnel to undertake water sampling and working to individual radiological and non-radiological species action levels (rather than considering the trend as an indicator of problems). Water sampling is undertaken by a dedicated team covering site wide water sampling operations. As such, dose uptake considerations limit the extent of water sampling which can be carried out. It is suggested that fuel handling operations sub-contractors are trained to undertake such duties; as the additional dose involved would be minimal.

Unit 4

Spent fuel removal operations at Unit 4 spent fuel pool were initiated on 18 November 2013 and completed on 5 November 2014. An additional 180 new fuel assemblies were transferred to Unit 6 by 22 December 2014. This achievement was in line with the Unit 4 fuel removal plan to complete fuel removal by the end of 2014 and demonstrates TEPCO's commitment to meeting the targets identified within the Roadmap.

In total 2537 fuel assemblies have been handled, including 1004 fuel assemblies being moved from the CSFP (now accommodated in 19 new dry storage casks) to the Temporary Cask Custody Area.

In line with a commitment by TEPCO, to reduce worker dose to one third the ambient dose rate in work areas, shielding materials were fitted to the north side of the reactor building cladding which faces Unit 3 and to strategic areas in the fuel/cask handling route on the refuelling floor of Unit 4. This resulted in a dose reduction of ~70% to workers involved.

The original plan was to move all fuel assemblies from Unit 4 to the CSFP. This plan was adapted, due to the lack of availability of dual purpose casks, required to defuel legacy fuel from the CSFP, highlighting the need for contingency options to be available. As mentioned above, Unit 4 new fuel was transferred to Unit 6. Complete removal of Unit 4 new fuel from pool storage to bonded storage was precluded on radiological grounds as there are some small pieces of rubble associated with the fuel.

Unit 3

At the time of the last peer review the majority of the rubble had been removed from the operating floor of Unit 3, apart from the fuel handling machine console and overhanging frame (which were partly or wholly submerged in the pool), and efforts to decontaminate the operating floor were due to start. The original Roadmap suggested that fuel removal activities would commence in the first quarter of 2015. There have been a number of challenges which have prevented this target from being met; these include issues related to the removal of the fuel handling machine console and related plant, and the ability to decontaminate the operating floor.

In decontaminating the operating floor of Unit 3, 80% of the targeted dose reduction was achieved. Achievement of the target was compromised by the operating floor having suffered greater damage than was originally estimated and contamination having become ingrained in cracks. In summary, the condition of the operating floor is more challenging than originally envisaged and the decontamination efforts required to reduce the dose to the target levels of 1 mSv/hr were underestimated. If the target is maintained, further review and the application of additional techniques will be required.

Based upon Unit 3 experience, it is likely that targets identified in the Roadmap relating to pooled fuel and fuel debris removal from Units 1-3 will change as the situation evolves. Continual revision of the Roadmap is recognised and the next revision is planned for spring 2015. Whilst considerable efforts and resources are being committed by TEPCO, and its supporting contractors, in seeking an early remediation of Fukushima Daiichi uncertainties remain. Carefully reflecting these uncertainties in any schedules and plans will assist in wider understanding of the progress being made.

Turning to the spent fuel removal from Unit 3; due to the high dose levels measured on the operating floor, it is intended that this will be undertaken by remote operations. The remote removal of spent fuel and remote handling of casks is already practiced in a number of Member States and relevant experience is readily available which can be drawn upon. This experience is mainly derived from large centralized pools associated with reprocessing activities. A number of challenges foreseen with remote fuel and cask handling relate to: the ability to achieve effective sealing on the transport cask, particularly if there are high levels of particulate in the pool water, decontamination of the cask; removal of small debris from on top of the fuel; and the identification/retrieval of damaged spent fuel assemblies. An initial safety/risk assessment has identified the risks associated with remote operations/fuel retrieval activities and proposed safety measures. It is suggested that this initial analysis is also reviewed through a ‘HAZID’ type of assessment. Such an analysis may, for example, consider that an adequate seal cannot be guaranteed during cask transfer, and set out how this could be accommodated.

The IAEA team understands that the NRA is being used as the independent reviewer of these plans. The IAEA team encourages TEPCO to seek independent review from fellow operators, prior to submitting licence applications to the NRA.

Unit 1

The Roadmap (revised June 2013) identifies plans for pooled fuel and fuel debris removal from Units 1 & 2; with three separate Plans for each of the Units, based upon potential Unit condition. Since the last peer review TEPCO has reviewed these plans and developed a sub-Plan of Plan 2 for each of the Units; referred to as Plan [2]’. The new Plans are based upon building structures to remove pooled fuel, followed by rework of the structure to enable fuel debris removal. The main reasoning behind this two staged approach is to allow flexibility in the method to be deployed for fuel debris removal, in response to uncertainties.

In the case of Unit 1, for example, the review has led to a decision to choose Plan [2]’ over Plan [2]. Whilst early pooled fuel removal may not be the only contributing factor to this decision it is observed that this decision results in pooled fuel removal one year earlier, but puts back fuel debris retrieval by 3 years and results in a higher radiological and conventional safety risks to the work force. Such a decision needs to be considered in the framework of overall safety and the overall risk reduction, and is reflected in Advisory Point 15.

Additional efforts related to Unit 1 have included the preparatory works for removing the containment cover which was built around Unit 1, shortly after the accident, to prevent the spread of contamination. In undertaking these preparatory works, the IAEA team recognizes the incorporation of learning from Unit 3 in terms of the method being deployed to prevent the spread of contamination and for undertaking a part cover removal and replacement exercise, to evaluate the impact before the main process is undertaken.

Unit 2

In terms of plans for pooled fuel and fuel debris removal from Unit 2 the following should be considered. Although the reactor core of Unit 2 overheated during the 2011 accident there was no resultant hydrogen explosion within the building and therefore no structural damage from this source. Unlike Units 1, 3 & 4, the storage pool was not affected by debris falling into the pool.

Data analysis of the pool water samples taken from Unit 2, carried out by the IAEA, has concluded that the current caesium levels within the pool are considered to be within the typical range for an LWR spent fuel pool. Apart from the potential impact from the initial injection of sea water, 14–24 March 2011, which may affect crevices associated with connections between the fuel bundle and top/bottom nozzles, the spent fuel is likely to be in a stable condition. Given the condition of the building and the status of the pooled fuel, there appears to be no urgent priority to remove the pooled fuel from Unit 2; although this has to be considered in relation to the overall plan on hazard reduction for the Fukushima site.

On the basis of the arguments outlined above, the IAEA team supports the decision to introduce hold points into the overall plan for Unit 2 pooled fuel and fuel debris removal. This will enable learning from Units 1 & 3 pooled fuel and preparations for fuel debris removal to be incorporated into the Unit 2 project. A secondary benefit is that this will improve resource utilisation by minimizing the overlap in pooled fuel removal between Units.

Generic Schemes for Fuel Debris Removal

The preferred plan for fuel debris removal, as identified in the Roadmap, is to flood PCVs. As pointed out by IRID, there are around 100 known points in the PCV of Unit 1 where water can leak and all these would need to be sealed. The impact of sealing the defect sites is unknown and there is risk that further leaks could develop. Given that there is significant risk associated with flooding the PCVs, contingency plans of removing fuel debris from a part-submerged PCV (or in air) are currently being evaluated.

The IAEA team notes that there is considerable risk associated with flooding PCVs. Hence, it is important to continue the efforts to locate and repair PCV leak sites, so as to minimize contaminated water issues, and that contingency plans for fuel debris removal are brought to a similar level of maturity as the preferred plan.

Evaluation of IRID's R&D activities for the fuel debris removal

The R&D plan takes into account the absence of a confirmed approach for fuel debris removal (noting that there is significant variation between the conditions in Units 1–3). In this regard the R&D plan is designed to support multiple technological options for fuel debris removal. The R&D plan provides a list of base works including the development of technologies to locate and repair PCV leaks and to provide sufficient detail of the conditions in the PCV and RPV; for example, the precise location and current characteristics of the fuel. Analysis of the possible fuel debris retrieval approaches, in terms of key procedural steps, has revealed some additional issues to be incorporated into the overall R&D plan.

At the moment, most of the efforts on the development of technologies and equipment are at an initial stage. The successful start of practical work in some areas, (for example, the identification and confirmation of some PCV leak paths) can be considered as significant progress. The modelling of the conditions within RPVs and PCVs is on-going. The distribution of radioactive substances in the PCVs and the location of fuel debris are currently based on assumptions and it must be recognized that the actual situation could be different.

The IAEA team notes that there is still a lack of baseline information on the status and conditions of the fuel debris in each affected reactor and the associated PCV. Therefore, there is presently significant uncertainty associated with the applicability and effectiveness of technologies and approaches to recover reactor internals and fuel debris. The IAEA Team still considers that priority should be given to confirming the location of fuel debris within PCVs.

Acknowledgement 19:

The IAEA team recognizes the substantial efforts made by TEPCO and its sub-contractors in removing the 1,331 spent fuel assemblies from the Unit 4 by November 5, 2014, within one year of the first fuel assembly being removed, and all fuel assemblies by December 22, 2014 (1,533 new and spent fuel assemblies). A commitment to reducing worker dose through the incorporation of shielding materials in Unit 4 until a dose reduction of 72% was achieved and supporting activities which enabled the fuel removal from Unit 4. Supporting activities included the removal of 1,004 spent fuel assemblies from the Common Spent Fuel Pool (now accommodated in 19 new dry storage casks) to the Temporary Cask Custody Area and releasing storage space in Unit 6 to enable the storage of 180 new fuel assemblies.

Acknowledgement 20:

The IAEA team acknowledges the efforts being made to minimize the spread of contamination through the incorporation of learning from Unit 3 debris removal operations and the introduction of dust counter measures. The continued commitment to reduce dose exposure is also recognized in particular the introduction a ‘Dose Reduction Plan for Reactor Buildings’. These measures will benefit both workers and any potential impact on the local population.

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Advisory Point 15:

Whilst activities which lead to short-term gains demonstrates a positive attitude in reducing risks as early as practical, this needs to be considered in the framework of overall safety and the overall risk reduction. The IAEA team encourages the NDF to conduct a risk analysis in relation to pooled fuel and fuel debris plans; taking into account conventional safety and cumulative dose to workers.

ANNEX – REPORT OF THE EXPERT VISIT IN APRIL 2015

Following a request from the Government of Japan, the IAEA sent experts to Japan from 17 to 21 April 2015 to collect additional information relevant to the Mission, particularly relating to the announcement of high contamination levels in rainwater, being discharged to the sea (which arose immediately after the Mission). The IAEA experts had extensive discussion with METI officials and TEPCO staff on challenges related to contaminated water management and public communication. The experts also visited TEPCO's Fukushima Daiichi NPS to consider the current situation – in particular measures taken by TEPCO for improving the management of contaminated water, including rainwater and groundwater (see Mission Programme in Appendix I).

Main findings

Contaminated water management

During the course of several meetings and a site visit, TEPCO provided additional information to the IAEA experts about the following contaminated water related events that happened after the third IAEA Mission in February 2015: (i) Contamination source on the rooftop of Unit 2 service entrance building and high contamination levels in water flowing through the K drainage channel; (ii) Temporary rise in beta activity in B/C drainage channel; (iii) Leakage of contaminated rainwater from the inner dyke of H4 tank area; (iv) Decrease of rainwater level in the outer dyke of H4 tank area; and (v) Accumulation of contaminated water on the lids of some High Integrity Containers (HICs). The additional information included descriptions of these events, investigations to understand their causes, and mitigating countermeasures. TEPCO also shared information about their on-going comprehensive assessment of risks, including those related to contaminated water that could have an impact outside the site boundary. In addition, TEPCO provided updates on their other on-going activities related to contaminated water management at the site. The main findings of the IAEA experts in these areas are summarized below.

Contamination source on the rooftop of Unit 2 service entrance building and high contamination levels in water flowing through the K drainage channel:

Soon after the IAEA Mission in February 2015, TEPCO announced (on 24th Feb) the detection of relatively high contamination levels (up to 23,000 Bq/L of ^{137}Cs) in rainwater accumulated on the Unit 2 service entrance building rooftop and identified this as a source of high contamination levels in K drainage channel water. This is one of several drainage channels that carry ground water and runoff water from surfaces at the site, either to the open sea or to the port (Fig. A-1). The contamination at the rooftop was attributed to radioactive materials released at the time of the accident.

At the same time TEPCO also published their data of water contamination levels in the K drainage channel since April 2014. These results show increased contamination levels associated with periods of rainfall (Fig. A-2). (TEPCO's explanation for the delay in disclosing this information, subsequent actions to improve information disclosure and the IAEA experts' views in this matter are discussed below under "Public communication").

TEPCO also reported that the activity levels in seawater at the monitoring point close to the point of discharge were the same as those at the monitoring point farther south (about 1 km from the point of discharge).

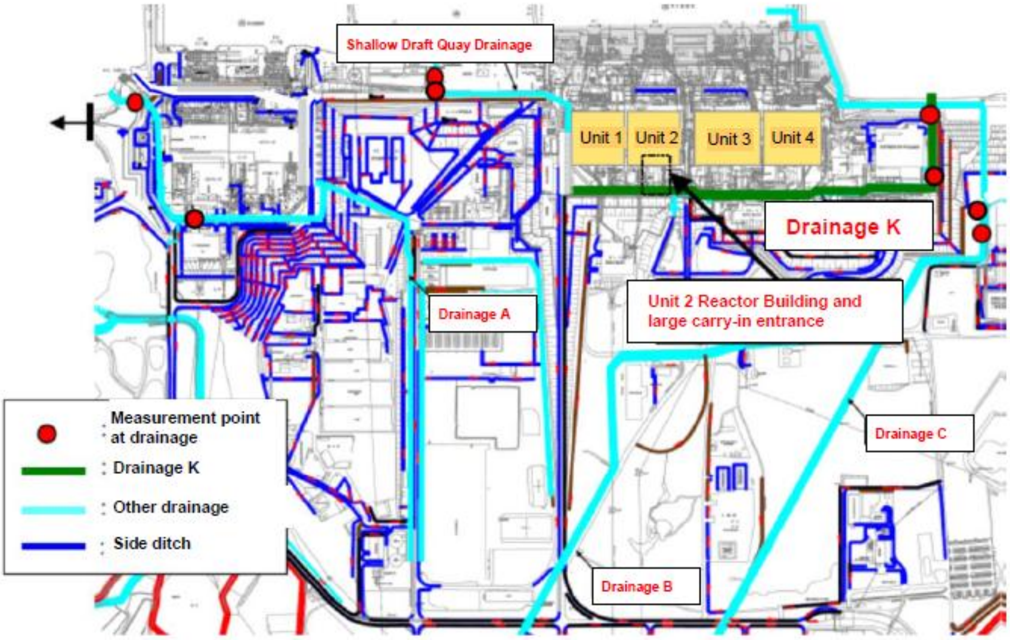

FIG. A-1. Diagram showing the location of drainage channels at 1F site

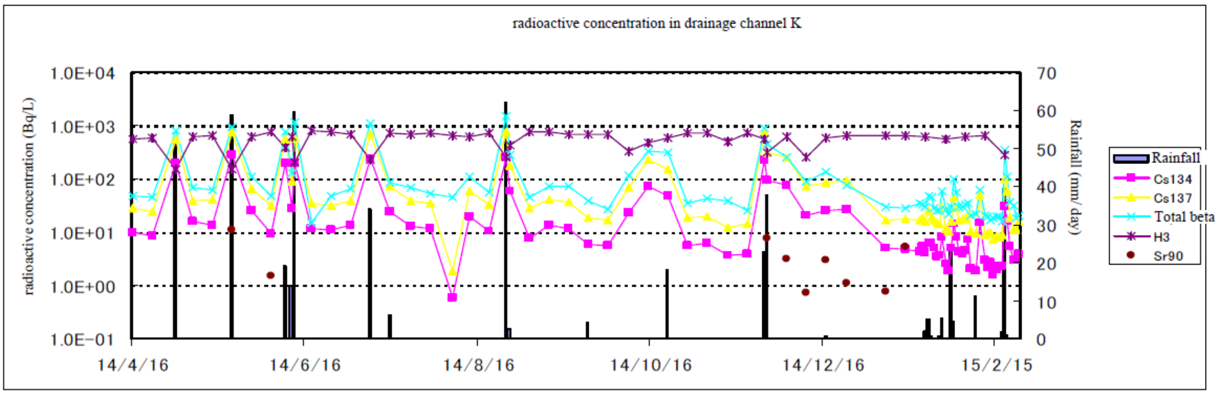

FIG. A-2. Water radioactivity and rainfall profile in K drainage channel

After determining the likely source TEPCO expeditiously implemented measures to reduce contamination spread by placing zeolite filled porous bags around the rooftop drain outlet, spreading waterproof sheets on the rooftop and placing 'purification materials' (zeolite bags and sorbent impregnated fibrous material) in the branch channel connecting the rooftop to the main channel. During the site visit, the IAEA experts observed that the dose rate near the 'purification materials' was about an order of magnitude higher than the general background in the channel, indicating that caesium was being captured. Fig. A-3 below shows TEPCO officials and IAEA experts inside K drainage channel near the point at which the branch channel connected to Unit 2 service entrance rooftop meets the K drainage channel.

Subsequently, by mid-April, the rooftop was cleaned by removing concrete blocks and sand (which were identified to be the sources of contamination) and painted (to seal any remaining contamination). As a result of these actions TEPCO expects this source of contamination to have been substantially mitigated. TEPCO informed that they will continue monitoring, in order to verify the effectiveness of these measures. TEPCO continues to investigate other possible sources of contamination.

FIG. A-3. Inside K drainage channel during the site visit

TEPCO also presented information about their on-going efforts since April 2014 to reduce water activity levels in the drainage channels at the site by cleaning up the drains and removing contaminated materials from the surrounding surfaces. For the K drainage channel, in addition to the branch channel connected to Unit 2 service entrance building, it was reported by TEPCO that ‘purification materials’ have been installed in several other branch channels and side ditches, as well as in the main channel itself.

While acknowledging these efforts, the IAEA experts encourage TEPCO to continue to focus on finding any other sources contaminating the channels. Considering that flow in the main channel can be very high (e.g. up to 14000 m^3 per day in K drainage channel during heavy rainfall), implementing treatment measures closer to the source (e.g. in the branch channels) would be a more effective and practical measure to address this problem. While investigating contamination sources and implementing countermeasures, TEPCO should pay due attention to the radiation exposure of the workers, especially in areas where the dose rate is high. It is also advisable to take into account possible release of fine particles, resulting from disintegration of caesium loaded ‘purification materials’, and implement appropriate measures to prevent released particles from reaching the sea.

Temporary rise in beta activity in B/C drainage channel:

Another topic reviewed relates to the high beta activity level alarm on 22nd February in drainage channel B/C side ditch radiation monitor indicating water with gross β activity levels up to 7230 Bq/L was flowing through the channel. Responding to this alarm, TEPCO closed the gate installed at B/C drainage channel to prevent outflow of contaminated water to the sea and stopped all related equipment processing and transferring contaminated water. Subsequently the activity levels subsided. TEPCO carried out extensive investigations to identify possible causes of the high β activity in B/C drainage channel, but they informed the IAEA experts that the results so far are inconclusive.

Several measures have either been implemented, or are planned for implementation, to address similar occurrences in the future, for example enhanced monitoring of water in the drainage channel and the port, real-time continuous radiation monitoring, remote-controlled motorized closure of the gates after an alarm and provision to pump up accumulated water when the gate is closed.

While acknowledging the prompt implementation of the above measures, the IAEA experts encourage TEPCO to continue with its investigations to find the primary source of this activity based on its radionuclide fingerprint and possible pathways, and implement appropriate preventive measures as well.

Leakage of contaminated rainwater from the inner dyke of H4 tank area:

On 6th March 2015, a TEPCO employee found contaminated rainwater (gross β activity 1600 Bq/L) leaking from the inner dyke of H4 tank area to the outer dyke through a defective pipe penetration seal. TEPCO took immediate measures to stop the leak (leaked volume approximately 25 L) by pumping off accumulated water from the inner dyke and rectifying the seal. The leakage was the result of an incorrect operating procedure that allowed water to build up in the inner dyke in H4 tank area beyond suitable operating levels. TEPCO's root cause review indicates that this happened as a result of siphoning which continued after transferring the water from H6 to H4 area. The water in the inner dyke reached the level of a defective pipe penetration seal and leaked to the outer dyke. TEPCO was able to identify the cause and took necessary actions to rectify the seal, install a valve in the transfer line and correct the procedure. Valves were also installed in transfer lines in other similar areas and TEPCO is investigating if there are any defective seals at other locations.

The IAEA experts consider these measures to be adequate for avoiding similar occurrences in future. It was verified that the standard operating procedure (SOP) for rainwater transfer has been amended suitably to include closure of the valve after transfer is completed, thereby eliminating any further transfer due to siphoning effect.

Decrease of rainwater level in the outer dyke of H4 tank area:

In another incident on 10th March 2015, approximately 750 m^3 of contaminated rainwater (gross β activity up to 8,300 Bq/L) was found to have leaked into the ground from the outer dyke in H4 tank area. In order to prevent further leakage, the remaining water in the outer dyke was pumped up and transferred to the inner dyke. Since no water was found to be flowing in the surrounding ditches and radiation monitors in the site drainage ditches did not show any significant fluctuations, TEPCO's assessment was that the leaked water did not flow out into the sea. The cause of contamination of the rainwater was attributed by TEPCO to rainfall carrying radioactivity in contaminated soil from a previous leak into the outer dyke, through gaps in its construction and by flowing over the outer dam.

The IAEA experts noted TEPCO's ongoing efforts to implement several countermeasures to prevent such incidents, not only in the H4 area but also in other tank areas. These include filling and covering of the gaps, recovery of contaminated soil and facing of surrounding areas to prevent rainwater permeation.

Accumulation of contaminated water on the lids of some High Integrity Containers (HICs):

In the beginning of April 2015 TEPCO reported finding small (1-10 L) pools of contaminated water on the lids of two HICs. The reason for accumulation of contaminated water on the lids of HICs is being investigated. According to latest reports, out of 105 HICs examined, 15 HICs – all containing carbonate slurry from the advanced ALPS facility – have been found to have this problem. Investigations so far show that the activity level of water accumulated on HIC lids is comparable to the activity level of water inside the containers. Possible causes of water ejection from the HICs are being investigated, including the possibility of water level inside the HICs having increased due to gas bubbles (probably hydrogen gas resulting from radiolysis) getting trapped in the slurry and eventually the water coming out through the vents or through gaps between the HICs and their lids. As an immediate countermeasure, the standard operating procedure has been updated to reduce the maximum filling level within the containers.

TEPCO is encouraged to continue investigations to gain a full understanding of the extent and nature of this problem, and to find possible solutions for preventing liquid release from the HICs. Assistance of research organizations (e.g. JAEA) may be sought if necessary. While these investigations continue, TEPCO should determine an adequate safe margin for clear headspace above the liquid so that leakage through the vents or other gaps is prevented. If necessary still less volume of slurry should be filled in to ensure liquid level remains sufficiently low, even though that would lead to some increase in the number of HICs generated from water processing.

Section 3.4.1 of the main report of the IAEA mission in February 2015 called for careful attention to the handling, containment and storage of wastes resulting from water processing in view of their high radiological content. The IAEA experts take this opportunity to re-emphasize the need for assuring the safety of storage of all such waste, including spent zeolite columns, HICs containing slurries of precipitates and absorbents, and other vessels. TEPCO is encouraged to implement a comprehensive periodic inspection programme as a component of a wider assurance programme.

Comprehensive risk assessment:

TEPCO is presently making a comprehensive assessment of all possible risks that might have an impact outside the site boundary and determining appropriate countermeasures to mitigate those risks. According to information shared with the IAEA experts, TEPCO has identified leakage of liquids and dispersion of dust to be risks that could have an impact outside the site. In addition to highly contaminated water, the exercise also includes possible risks from water with much lower levels of contamination (e.g. contaminated rainwater). TEPCO intends to classify these risks into five categories depending on the necessity for implementing additional countermeasures, namely (i) need further examination, (ii) countermeasures need to be taken, (iii) countermeasures in practice, (iv) follow up observation (after implementing countermeasures) in practice, and (v) no need for additional countermeasures.

The IAEA experts consider this to be a useful exercise that would help to better manage the risks. TEPCO is encouraged to complete their assessment of the risks, formulate appropriate mitigating countermeasures, and present plans for timely implementation of those countermeasures based on priority. Considering the very detailed and technical nature of this assessment, TEPCO is encouraged to consider preparing a simplified version of the assessment and related countermeasures for presenting to the public.

Other activities in contaminated water management:

The expert visit also provided an opportunity to receive updates on the current situation and progress related to other activities involving overall management of contaminated water at the site. These include survey and countermeasures concerning retained contaminated water in the drainage outlets of Units 1 to 3; progress in waterproofing and sealing of seawater piping trenches in Units 2, 3 and 4; installation of additional devices for transfer of accumulated water within buildings in order to regulate water levels within desired safe limits with respect to outside groundwater levels, and further progress in treating contaminated water since the Mission in February. The IAEA experts acknowledge TEPCO’s efforts and progress in all of these areas.

Public communication

The announcement on 24 February 2015, concerning rainwater with relatively high contamination levels at the roof top of Unit 2 service entrance building flowing into K drainage channel, resulted in some criticism, by the public and the media, of TEPCO’s information disclosure. The IAEA experts received information from TEPCO about its internal reporting mechanism associated with this event and future plans to improve both internal and external communication processes.

TEPCO explained that each engineering group was not only responsible for contamination surveys and analysis (within a defined area), but also for deciding whether the results of such surveys should be shared with other groups at the site and/or TEPCO head office.

TEPCO presented the chronology of the related activities and interactions with Japanese authorities, including METI and the NRA. TEPCO also presented its conclusion on the cause of delayed disclosure of the relevant data. The department or group in charge of sampling water and implementing cleaning activities in K drainage channel and the department in charge of radiation protection and environment in FDEC were working together. Both groups were endeavouring to find the sources of the contamination and to clean up the drainage. Their investigations detected relatively high contamination levels of rainwater on the roof of the service entrance of Unit 2 on 24 February 2015. This result was reported to the NRA, and announced to the public, on the same day.

Until then, however, the engineering groups had paid insufficient attention to making a decision on whether the previous results should be shared with relevant sections within TEPCO. This resulted in the delayed disclosure of the previous contamination data to the public. TEPCO also informed that coordination between the engineering group and the Social Communication Office had not been adequate.

In response to this event, TEPCO announced its new information disclosure principles on 30 March 2015, which said:

a) All radiation data at Fukushima Daiichi NPS should be disclosed;

b) Data will be disclosed on TEPCO website, and data which may raise public concern will be explained at its press conference.

c) TEPCO's new information disclosure rules and implementations will be checked and evaluated continuously by external parties.

TEPCO also decided that the function of the Social Communication Office and Risk Communicators would be strengthened to improve the mind-set concerning information disclosure within the entire organization, and that internal communication and coordination mechanism would be improved. Furthermore, TEPCO would create opportunities to hear opinions of, and receive advice from, community residents and increase interactions and communication with various stakeholders. TEPCO explained that it was working on developing more detailed and concrete rules and procedures for internal communication and external information provision.

TEPCO plans to upload all relevant data onto its website, including liquid and airborne activity levels at the site as well as other relevant measurements taken on the site (e.g., surface contamination, soil contamination, air dose rate, workers' exposure dose and performance of the equipment).

TEPCO expects that the volume of published data will increase significantly. To facilitate the disclosure of data, TEPCO will develop a database which can be accessed and managed by the Social Communication Office in TEPCO head office and the Risk Communicators in Fukushima Daiichi NPS, so that they can assess the significance of the data from the view point of societal interests and concerns and decide whether the data require detailed explanation at the press conference and other occasions to the public.

The IAEA experts' view that TEPCO's problem of public communication about the Drainage K issue is quite similar to some previous problems (e.g. announcement about the electrical supply failure and the contaminated water leakage which took place in March 2013), as both communication problems may be attributed to lack of coordination between Fukushima Daiichi NPS site and TEPCO's head office. Based on the self-examination about the failure of timely communication in 2013, TEPCO established the Social Communication Office under the direct supervision of TEPCO President.

The IAEA experts remind TEPCO of the following advice given during the 1st IAEA decommissioning mission which was conducted in April 2013:

> "The IAEA team encourages TEPCO to conduct a comprehensive assessment of its current procedures for reporting to concerned parties and for communicating with the public, both in normal and abnormal situations. The conclusions of this assessment should be shared with relevant parties (including the NRA and local authorities) and stakeholders, with the dual purpose of enhancing coordination among the different institutions and of helping to meet the expectations of the public."

Recognizing the important function, the IAEA experts encourage the Social Communication Office to take more proactive leadership in cooperation with the Risk Communicators to supervise the communication-related activities within TEPCO. This should include not only those at the nuclear power plant site but also those implemented by its corporate communication department, to promote internal communication and coordination in a more effective and systematic manner. The Social Communication Office should improve its competence of public and media relations in addressing their interests and concerns.

Considering the fact that the volume of data to be published on TEPCO's website will significantly increase, the IAEA experts strongly recommend TEPCO to enhance wider understanding of the data, taking into account the Advisory Point 5 of the Mission in February 2015.

APPENDIX I – MISSION PROGRAMME

IAEA INTERNATIONAL PEER REVIEW MISSION ON MID-AND-LONG-TERM ROADMAP TOWARDS THE DECOMMISSIONING OF TEPCO'S FUKUSHIMA DAIICHI NUCLEAR POWER STATION UNITS 1-4

The Mission was conducted between 9 and 17 February 2015.

The itinerary for the Mission is as follows:

Monday:	Meeting with METI/TEPCO in Tokyo
Tuesday:	Transfer to Iwaki-city (morning), discussion with METI/TEPCO at Fukushima Daiichi NPP (afternoon)
Wednesday:	Site visit at Fukushima Daiichi NPP
Thursday:	Discussion with METI/TEPCO at Fukushima Daiichi NPP
Friday:	Discussion with METI/TEPCO at Fukushima Daiichi NPP (morning), transfer to Fukushima-city, visit to Fukushima prefectural government (afternoon) and transfer to Tokyo (evening)
Saturday:	Reserved for drafting the report in Tokyo
Sunday:	Reserved for drafting the report in Tokyo
Monday:	Discussion with METI/TEPCO (checking factual accuracy and pre-finalizing the preliminary summary report) in Tokyo
Tuesday:	Presentation of the preliminary summary report to METI and press conference in Tokyo

THE EXPERT VISIT IN APRIL 2015

The expert visit was conducted between 17 and 21 April 2015.

The itinerary for the expert visit is as follows:

Friday:	Meeting with METI/TEPCO in Tokyo (afternoon)
Saturday:	Meeting with METI/TEPCO in Tokyo, Transfer to Iwaki-city (evening)
Sunday:	Site visit at Fukushima Daiichi NPP
Monday:	Discussion with METI/TEPCO at Fukushima Daiichi NPP
Tuesday:	Discussion with METI/TEPCO (checking factual accuracy and pre-finalizing the report) in Tokyo (afternoon)

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