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for protecting people and the environment

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Long Term Post-Remediation Management of Areas Affected by Past Activities or Events

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DRAFT SAFETY GUIDE

New Safety Guide

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1. INTRODUCTION

BACKGROUND

1.1. Remediation is defined in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [1] as: "Any measures that may be carried out to reduce the radiation exposure due to existing contamination of land areas through actions applied to the contamination itself (the source) or to the exposure pathways to humans. Complete removal of contamination is not implied".

1.2. Residual radioactive contamination in sites or areas affected by past activities or events might pose risks to people and the environment, even after completion of remediation activities. When contamination is not completely removed by remedial actions, it is necessary to manage the risks from residual contamination using controls to restrict the uses of the remediated areas and to maintain control over the source and exposure pathways in the long term. This control may be active (monitoring, surveillance, remedial work) or passive (land use control), as explained in the definition of the term 'institutional control' in the IAEA Safety Glossary [2].

1.3. Sites and areas affected by residual radioactive material are located in many regions of the world and in different types of environment and are considered within the requirements established for existing exposure situations in Section 5 of GSR Part 3 [1].

1.4. IAEA Safety Standards Series No. GSG-15, Remediation Strategy and Process of Remediation of Areas Affected by Past Activities or Events [3], provides recommendations for the remediation process, including post-remediation management. However, these recommendations do not explicitly consider the implementation of a comprehensive and integrated approach to post-remediation management that ensures the continued effectiveness of remediation and the protection of people and the environment in the long term. This new Safety Guide provides specific recommendations on post-remediation management to support the general recommendations provide in GSG-15 [3].

1.5. The legal and regulatory framework for remediation of affected areas is also subject to the requirements established in IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [4], which defines the components of a comprehensive administrative and legal system and assigns responsibilities to the different authorities involved. The requirements established in IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [5], are also applicable, with due application of a graded approach and in the context of existing exposure situations (see para. 2.7(g) of GSR Part 4 (Rev. 1) [5]).

1.6. Requirements for the management of radioactive waste — including waste generated by remediation — are established in IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [6], and IAEA Safety Standards Series No. SSR-5, Disposal of Radioactive Waste [7].

OBJECTIVE

1.7. The objective of the Safety Guide is to provide recommendations on the regulatory framework, planning and implementation of long term post-remediation management and post-remediation control measures for remediated areas that still contain residual radioactive

material. These recommendations will support States in meeting the requirements of GSR Part 3 [1] and, where relevant, GSR Part 1 [4], GSR Part 4 (Rev. 1) [5], GSR Part 5 [6] and SSR-5 [7].

1.8. This Safety Guide is intended to be used by regulatory bodies, technical support organizations, organizations responsible for long term management of remediated areas, community groups, local governments and organizations and other interested parties involved in post-remediation management of areas.

SCOPE

1.9. The scope of this Safety Guide covers the post-remediation management of sites and areas affected by residual radioactive material, considered within the requirements established in Section 5 of GSR Part 3 [1] for existing exposure situations. This includes sites or areas that have undergone remediation, sites or areas for which remediation has been considered and determined not to be justified or optimal, but where post-remediation management is necessary, and sites or areas for which remediation or post-remediation management activities are being planned, including:

(a) Sites or areas affected by past activities that were never subject to regulatory control, or that were subject to regulatory control but not in accordance with current requirements.
(b) Sites or areas where regulatory control has evolved to meet current standards, but where contamination exists because of past activities, resulting in the need for a combination of decommissioning and remediation. Such sites or areas include those that have been affected by past activities that are considered existing exposure situations, but which also contain authorized facilities or activities that are being operated in accordance with the requirements for planned exposure situations. For such a 'hybrid' site, the decommissioning is outside the scope of this Safety Guide, whereas the post-remediation management is within the scope.
(c) Areas affected by a nuclear or radiological emergency, after the emergency has been declared to be ended.

1.10. This Safety Guide focuses on post-remediation management to ensure long term protection of people and the environment against radiation risks. Non-radiological risks are not considered in this Safety Guide. However, the relationship between radiological and non-radiological risks is expected to be considered within the context of an integrated approach for post-remediation management.

1.11. This Safety Guide does not cover decommissioned facilities or closed radioactive waste disposal facilities that have been released from regulatory control with restrictions. However, some recommendations could be applicable to such sites.

STRUCTURE

1.12. Section 2 provides recommendations on the national framework for long term post-remediation management, including the governmental, legal and regulatory framework. Section 3 provides recommendations on the planning aspects of post-remediation, including transition from remediation to post-remediation and transfer of regulatory responsibilities. Sections 4 and 5 address post-remediation management activities: Section 4 focusses on active measures such as monitoring and maintenance; Section 5 provides recommendations on

passive measures in the form of administrative controls. Section 6 provides recommendations on involvement of interested parties in post-remediation management. Section 7 provides recommendations on the management system for post-remediation activities. Section 8 provides recommendations on long term challenges and risks. Section 9 provides recommendations on preservation of post-remediation records and knowledge management. Section 10 provides recommendations on funding mechanisms and financial assurance for post-remediation management.

1.13. Annexes I and II provide examples of the reuse of remediated sites in Germany and the United States of America, respectively.

2. NATIONAL FRAMEWORK FOR LONG TERM POST-REMEDIATION MANAGEMENT

NATIONAL POLICY AND STRATEGY FOR LONG TERM POST-REMEDIATION MANAGEMENT

2.1. Requirement 1 of GSR Part 1 [4] states:

> **"The government shall establish a national policy and strategy for safety, the implementation of which shall be subject to a graded approach in accordance with national circumstances and with the radiation risks associated with facilities and activities, to achieve the fundamental safety objective and to apply the fundamental safety principles established in the Safety Fundamentals."**

2.2. Paragraph 2.3 of GSR Part 1 [4] states that "National policy and strategy for safety shall express a long term commitment to safety. The national policy shall be promulgated as a statement of the government's intent. The strategy shall set out the mechanisms for implementing the national policy."

2.3. Long term management of remediated sites and areas and post-remediation control measures should be a part of the national policy and strategy for safety. The parts of the policy that relate to the post-remediation management of sites and areas should be consistent with the overall policy for remediation, and should apply to all sites and areas in the State that have been remediated or have been identified as needing remediation, while also reflecting national priorities. Owing to the long term character of post-remediation control measures, it is important that resilient financial mechanisms are in place to support the policy and strategy.

2.4. The national policy for post-remediation should include the following:

(a) The protection of people and the environment as the overall safety objective;
(b) The need to comply with all relevant laws and regulatory requirements;
(c) Ensuring that post-remediation activities are justified and optimized and that reference levels are complied with;
(d) Ensuring cost effectiveness;
(e) The adoption of a graded approach in which the post-remediation measures applied to a site or area are commensurate with the risks associated with that site or area;
(f) The roles and responsibilities of the government, the regulatory body and other authorities, and, as applicable, responsible parties;

(g) Ensuring that there is an open and transparent process involving the public and other interested parties when decisions are made concerning post-remediation;
(h) Preserving and transferring knowledge related to the steps that led to the decision to remediate, and to the selection of remediation options and activities, for future generations;
(i) Establishing the mechanisms for providing funds for the safe long term post-remediation management of sites and areas;
(j) Ensuring that there are adequate human resources available to provide for the safe post-remediation management of sites and areas, including, as necessary, resources for training and R&D;
(k) Ensuring the necessary institutional controls and monitoring arrangements for the safe post-remediation management of sites and areas;
(l) Establishing strategies for addressing long term challenges and risks associated with remediated sites and areas.

2.5. As indicated in para. 2.1, the government is required to establish the national policy and strategy; however, all interested parties should be involved and consulted. If changes in the policy are approved by the government, consideration should be given to the need to modify legislation and the national infrastructure for long term post-remediation management.

2.6. The national policy for post-remediation should establish the basic principles that guide the approach to post-remediation in the State and that should be addressed in the national strategy and the legal and regulatory framework for post-remediation. The strategy should set out the mechanisms for achieving the goals and requirements established in the national policy.

2.7. The national strategy on remediation and long term post-remediation strategy should reflect the national policy and vision of the future use of remediated sites and areas, the need for post-remediation control measures, and the potential use and re-habitation of these sites and areas. Further information is provided in Ref. [8].

2.8. The national policy may be implemented through a national strategy covering all remediated sites and areas, regional strategies, or site or area specific strategies. Whichever approach is used, it should cover all the sites and areas that are subject to post-remediation control measures. Site specific strategies should take into account the unique aspects of the site or area, including both the remediation that was performed, the characteristics of the local environment and the views of interested parties.

2.9. The national strategy should include high level objectives to ensure safe management of post-remediation sites and areas. This includes having a robust record management system to share information and data, committing to building strong relationship with all interested parties, keeping up to date with new technologies for optimizing post-remediation management.

2.10. Paragraph 2.3 of GSR Part 1 [4] states that “The national policy and strategy for safety shall be implemented in accordance with a graded approach, depending on national circumstances, to ensure that the radiation risks associated with facilities and activities, including activities involving the use of radiation sources, receive appropriate attention by the government or by the regulatory body”. Depending on the risks associated with a remediated site or area, the complexity of the post-remediation management strategy and/or the stringency

of restrictions should be approved either by law, by decree, by means of an industry standard, or through a site-specific remediation and post-remediation programme.

2.11. The national strategy for post-remediation should include provisions for the following:

(a) Alignment of activities performed by the organization responsible for post-remediation with the objectives of the national strategy, subject to approval by the regulatory body.
(b) An effective transition from remediation to post-remediation management, including the transfer of regulatory responsibilities.
(c) Development of an implementation plan for the period covered by the strategy.
(d) A review of existing technical resources for post-remediation in the country. This review should also consider the potential need for national research and development for effective post-remediation management.
(e) Control mechanisms to ensure timely implementation of the strategy, including accountability criteria and periodic reviews. Additionally, mechanisms should be established for regular reviews and updates of the strategy, with clearly defined milestones.
(f) Periodical assessment and analysis of the strategy based on lessons learned from past experiences. The aim of this assessment should be to identify deficiencies in the national post-remediation framework, clarify roles and responsibilities of national organizations, and improve funding arrangements for long term post-remediation management. Insights gained from other States with similar challenges should also be used to inform the development of more effective strategies.

LEGAL AND REGULATORY FRAMEWORK FOR LONG TERM POST-REMEDIATION MANAGEMENT

2.12. Requirement 2 of GSR Part 1 (Rev. 1) [4] states that "**The government shall establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities are clearly allocated.**" The objective of the legal and regulatory framework for long term management of remediated sits or areas should be to ensure the long term safety of such sites or areas.

2.13. Requirement 9 of GSR Part 1 [4] states that "**The government shall establish an effective system for protective actions to reduce undue radiation risks associated with…contamination from past activities or events, consistent with the principles of justification and optimization**."

2.14. The legal and regulatory framework should include regulatory requirements relevant to post-remediation management including, if applicable, authorization, and other requirements for the post-remediation management of remediated sites or areas. The framework should include the regulatory body (see Requirement 3 of GSR Part 1 (Rev. 1) [4]) or other relevant authority to regulate post-remediation activities, including, as necessary enforcement of regulatory requirements.

2.15. The legal and regulatory framework associated with post-remediation management should include principles, objectives and guidelines for post-remediation including requirements for justification and optimization of post-remediation control measures for affected sites or areas. In addition, this framework should include provisions for:

(a) Management of radioactive waste arising from the post-remediation activities such as maintenance.
(b) Development, review, and approval by the regulatory body or other authority of the methodology for verifying and reassessing the adequacy of the measures implemented.
(c) Conditions under which remediated sites or areas can be released from regulatory control, if applicable, after completion of the post-remediation control measures.
(d) Definition of the possible restrictions and controls to be imposed on remediated sites or areas, where applicable.
(e) Legal mechanisms to implement administrative controls, including land use restrictions, resource use limitations, and food and drinking water safety measures.
(f) Financing mechanisms to cover the costs associated with post-remediation and adequate human resources within the responsible party for post-remediation.
(g) Establishment of both radiological and non-radiological criteria to ensure and demonstrate the protection of people and the environment.
(h) Assignment of responsibilities among relevant parties.
(i) Addressing long term challenges and risks for remediated sites or areas.
(j) Consultations with interested parties.
(k) Effective knowledge management regarding remediated sites or areas.
(l) Occupational health and safety during post-remediation management of sites or areas.

ROLES AND RESPONSIBILITIES FOR LONG TERM POST-REMEDIATION MANAGEMENT

Responsibilities of the government

2.16. Requirement 49 of GSR Part 3 [1] states:

> "**The government shall ensure that provision is made for identifying those persons or organizations responsible for areas with residual radioactive material; for establishing and implementing remediation programmes and post-remediation control measures, if appropriate; and for putting in place an appropriate strategy for radioactive waste management**."

2.17. The government should assign the responsibility for regulating the long term post-remediation management of sites or areas impacted by past activities or events to the regulatory body or another relevant authority.

2.18. Paragraph 2.17 of GSR Part 3 [1] states that "The government shall ensure that the regulatory body has the legal authority, competence and resources to fulfil its statutory functions and responsibilities". This legal authority and competences should extend to regulatory control of sites and areas in the post-remediation phase and, in accordance with para. 5.3 (c) of GSR Part 3 [1], may include relevant authorities other than the regulatory body. This could be the authority responsible for environmental protection, public health management, or the regional or local authorities where such sites or areas are situated.

2.19. The government (or, where appropriate, the regulatory body or other relevant authority) should ensure that provisions are made for identification of organizations responsible for planning, implementation, verification, re-evaluation, maintenance and regulatory control of the post-remediation measures for long term management of remediated sites and areas and specify the responsibilities of each of the organizations involved.

2.20. The government should establish arrangements for ensuring that organization(s) responsible for the post-remediation management have the necessary financial, technical and human resources.

2.21. Where several authorities (at a national and regional level) are assigned responsibilities for post-remediation control, the government is required to make provision for effective coordination of their functions to avoid gaps or duplication (e.g. in planning, implementing, verifying, re-evaluation, maintenance of regulatory oversight) and to avoid conflicting requirements being placed on the responsible party (see Requirement 7 of GSR Part 1 (Rev. 1) [4]). The authorities involved should collaborate effectively, sharing the necessary information associated with the post-remediation management of the site or area to ensure a successful transition to the post-remediation phase.

Responsibilities of the regulatory body or other relevant authority

2.22. Paragraph 5.13(e) of GSR Part 3 [1] states that "**The regulatory body…or other relevant authority shall take responsibility, in particular for…establishment of regulatory requirements for control measures following remediation**." Such regulatory requirements may cover both planning and implementation of post-remediation activities, such as:

(a) Planning for long term care and maintenance;
(b) Implementation of controls;
(c) Design and implementation of monitoring and surveillance programmes;
(d) Setting and monitoring performance criteria for structures, and/or for remediated sites and areas overall;
(e) Periodic evaluation of the effectiveness and efficiency of post-remediation activities and control measures;
(f) Verification and reporting on results of periodic evaluation, maintenance and monitoring;
(g) Record keeping and archiving;
(h) Resources, including for maintenance and monitoring.

2.23. Paragraph 5.15 of GSR Part 3 [1] states:

> "After the remedial actions have been completed, the regulatory body or other relevant authority:
>
> (a) Shall review, amend as necessary and formalize the type, extent and duration of any post-remediation control measures already identified in the remedial action plan, with due consideration of the residual radiation risks.
>
> (b) Shall identify the person or organization responsible for any post-remediation control measures.
>
> (c) Shall, where necessary, impose specific restrictions for the remediated area to control:

(i) Access by unauthorized persons;

(ii) Removal of radioactive material or use of such material, including its use in commodities;

(iii) Future use of the area, including the use of water resources and its use for the production of food or feed, and the consumption of food from the area.

(d) Shall periodically review conditions in the remediated area and, if appropriate, shall amend or remove any restrictions."

2.24. Paragraph 2.41 of GSG 15 [3] states:

"For sites or areas subject to post-remediation management, the relevant authority is required to maintain an appropriate level of oversight…. This oversight should be designed to verify that the site or area remains safe and secure, that any access control measures have not been compromised, that new exposure pathways have not developed and that the remediation objectives and end state criterion continue to be met, and to ensure that a system of record keeping is established and maintained."

2.25. The responsibilities of the regulatory body or other relevant authority in relation to post-remediation management should include:

(a) Developing, adopting and promoting criteria and guidance for post-remediation control measures, including for justification and optimization of post-remediation restrictions, monitoring, surveillance and maintaining post-remediation measures;

(b) Reviewing and, if applicable, approving information submitted by organizations responsible for post-remediation control measures, including post-remediation plans and designs, and monitoring and surveillance programmes and their periodic review;

(c) Reviewing periodic reports on the assessment and verification of the adequacy, effectiveness and efficiency the implementation of post-remediation control measures;

(d) Issuing, amending, suspending or revoking authorizations for post-remediation control measures (i.e. where these are subject for authorization in accordance with regulatory requirements);

(e) Performing checks (e.g. through independent measurements) of post-remediation control measures and verifying their performance;

(f) Taking appropriate actions, including enforcement, whenever regulatory requirements for the post-remediation control measures are not met;

(g) Evaluating reports on unplanned occurrences and events and approving additional post-remediation control measures, as necessary;

(h) Coordinating the regulation of post-remediation control measures with other relevant authorities that are responsible for non-radiological hazards or other features associated with the remediated site or area;

(i) Ensuring that relevant documents and records are prepared by the person or organization responsible for post-remediation control measures and kept for an agreed time and maintained to a specified quality.

2.26. The regulatory body or other relevant authority should address the need for and extent of regulatory control over any future use of a remediated site or area. This would include, for example, controls over commodities or other materials originating from the site or area, and

over any workplaces or other facilities established following remediation. Decisions on the need for controls in remediated sites and areas might change with time. With regard to exposure due to radionuclides in commodities, para. 5.22 of GSR Part 3 [1] states:

> "The regulatory body or other relevant authority shall establish specific reference levels for exposure due to radionuclides in commodities such as construction materials, food and feed, and in drinking water, each of which shall typically be expressed as, or be based on, an annual effective dose to the representative person that generally does not exceed a value of about 1 mSv."

Information on regulatory control of radionuclides in commodities (building and construction materials, and food) is provided in Refs [9–11].

2.27. The regulatory body or other relevant authority should:

(a) Arrange for evaluation of post-remediation options for achieving the long term objectives, and for evaluation of the efficiency of any post-remediation actions planned and implemented;
(b) Ensure that information is available to exposed individuals on potential health risks and on the means available for reducing their exposures and the associated risks.

Responsibilities of persons or organizations for post-remediation control measures

2.28. The designation of persons or organizations responsible for planning and implementing post-remediation measures after completion of remedial actions should be defined in the legal framework (see also para. 2.16).

2.29. Paragraph 5.16 of GSR Part 3 [1] states:

> "The person or organization responsible for post-remediation control measures shall establish and maintain, for as long as required by the regulatory body or other relevant authority, an appropriate programme, including any necessary provision for monitoring, to verify the long term effectiveness of the completed remedial actions for areas in which controls are required after remediation."

2.30. The responsibilities of persons or organizations for planning and implementing post-remediation control measures should include the following:

(a) Ensuring the availability of resources, including financial, to guarantee the implementation of post-remediation control measures, and to ensure the necessary expertise and knowledge for long term management of remediated sites and areas;
(b) Preparing and submitting for approval to the regulatory body: the design and plan for post-remediation control measures; reports on monitoring, surveillance, inspections, maintenance, verification and re-evaluation of post-remediation control measures; and supporting documentation, as necessary;
(c) Performing the post-remediation control measures (after approval by the regulatory body, if required), and demonstrating that the long term goals of remediation are sustainably achieved and maintained;

(d) Ensuring suitable arrangements for management of any radioactive waste arising from post-remediation management activities (e.g. maintenance), in compliance with regulatory requirements;
(e) Informing and gaining input from interested parties on the post-remediation control measures, and on the results of the verification of their adequacy and effectiveness.

2.31. The designated responsible person or organization has the prime responsibility for safety (see Requirement 5 of GSR Part 1 (Rev. 1) [4]) for the site or area and for post-remediation control measures in remediated sites or areas. Although the performance of specific post-remediation tasks may be delegated to a subcontractor, the ultimate responsibility remains with the designated responsible person or organization.

2.32. The person or organization assigned responsibility for long term management of a remediated site or area should ensure that it maintains competence over the period necessary.

2.33. The person or organization assigned responsibility for long term management of a remediated site or area should establish and maintain an appropriate management system commensurate with the complexity of the site or area, the types of contamination (which may also include non-radiological contaminants), the types of engineered barrier and the post-remediation control measures. Requirements for the management system are established in IAEA Safety Standards Series No. GSR Part 2, The Management System for Facilities and Activities [12] (see also Section 7 of this Safety Guide).

2.34. The responsible party should develop a post-remediation control programme, as means of implementing long term management strategy of the remediated site or area, that allows for additional remedial activity based on findings in periodic evaluations. Paragraph 10.3 of GSG-15 [3] states:

> "Post-remediation management includes the justification and implementation of any post-remediation controls, and the periodic re-evaluation of the effectiveness and robustness of the remedial actions taken. If a determination is made during re-evaluation that the action is less effective than anticipated, additional actions may be necessary."

2.35. If a remediated site or area gives rise to radiation exposure to workers involved in post-remediation control measures, the regulatory requirements for occupational radiation protection should be applied. The employers of these workers are required to ensure that worker exposures are controlled in accordance with Requirements 19–28 of GSR Part 3 [1]. Recommendations on the control of worker exposures are provided in IAEA Safety Standards Series Nos GSG-7, Occupational Radiation Protection [13] and SSG-91, Protection of Workers Against Exposure Due to Radon [14].

3. PLANNING POST-REMEDIATION MANAGEMENT

CONSIDERATIONS FOR PLANNING POST-REMEDIATION

3.1. As indicated in para. 2.16, the government is required to ensure that provision is made for identifying those persons or organizations responsible for areas with residual radioactive material (see Requirement 49 of GSR Part 3 [1]). If the responsible person or organization for post-remediation management is different from the one performing the remediation, they

should be involved early to fully understand the context for post-remedial control measures to be implemented.

3.2. Paragraph 10.1 of GSG-15 [3] states that "Planning for post-remediation management should be initiated at the commencement of planning of the remediation itself." Consequently, planning post-remediation management should be considered when selecting remedial options for remediation of a site or area as well as in the selection of the end state and the future use of the site or area.

3.3. During the development of a remediation plan and the evaluation of options for remedial actions, the types of post-remediation management activity that they might necessitate should be considered. The selected options should be durable with the aim of reducing post-remediation management activities. Other aspects of post-remediation management that should be considered when selecting options for remediation include the need for ongoing technical capabilities that would be difficult to provide and maintain (e.g. an active versus passive water treatment system), costs, and the ability to ensure that passive institutional controls, such as land use restrictions, are adhered to.

3.4. As part of the early identification of post-remediation management activities, it should be ensured that the cost of these activities are adequately estimated (see also Section 10). Resource requirements, including financial, for post-remediation management should be reevaluated periodically as the final end state of a site or area becomes better understood. For example, during remediation, if it is determined that some original goals (e.g. removal of all contaminants in a particular part of a site) cannot be achieved, some additional measures that were not originally anticipated might be necessary, and these should be reflected in revised cost estimates for post-remediation management.

3.5. The types of post-remediation activity that are feasible for a given site or area should be considered within the context of the national strategy for post-remediation management (see paras 2.1–2.11). Site or area specific strategies should be implemented on the basis of their unique aspects as well as the input of interested parties. Elements of national strategies, including for waste management, may make some options more practical and affordable in terms of costs if they are implemented for post-remediation management at several sites or areas.

3.6. In considering post-remediation management in conjunction with the selection of options for remedial actions, there should be early engagement between the responsible person or organization and those performing the remedial actions. This is particularly important if the authority responsible for regulatory oversight of post-remediation management is different to the authority responsible for overseeing remediation of the site or area. Early engagement will also facilitate the transition between remediation and post-remediation management (see paras 3.50–3.56).

3.7. Where appropriate, any monitoring or surveillance activities that begin during remediation and that will continue during post-remediation should be performed using the same methods or procedures.

3.8. Paragraph 2.6 of IAEA Safety Standards Series No. GSG-6 [15], Communication and Consultation with Interested Parties by the Regulatory Body states that "When necessary, the regulatory body should ensure interested parties should be involved at the earliest opportunity;

in certain situations, such involvement should be ensured even before formal regulatory activities have been launched". The following benefits and goals of early involvement of interested parties with regard to post-remediation management should be considered:

(a) Understanding the concerns and opinions of interested parties and communicating with individuals to whom interested parties may express their concerns or opinions on site remediation and post-remediation management. Early visibility of the organizations or individuals that will be performing post-remediation management activities can build trust that the post-remediation management activities will be performed.
(b) The creation of additional records during remediation may be of value in the post-remediation management of a site. For example, photographs of the condition of the site at various stages of remediation can help in the future to understand why and how certain post-remediation activities were performed (see also Sections 6 and 9).
(c) Understanding what types of land use restriction, access agreements (e.g. if there may be monitoring points outside of the area or site boundary) and other institutional controls should be established for post-remediation management and if other authorities may need to be involved in establishing them.

USE AND HABITATION OF REMEDIATED SITES AND AREAS

3.9. Paragraph 5.17 of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [1] states:

> "For those areas with long lasting residual radioactive material, in which the government has decided to allow habitation and the resumption of social and economic activities, the government, in consultation with interested parties, shall ensure that arrangements are in place, as necessary, for the continuing control of exposure with the aim of establishing conditions for sustainable living".

3.10. The desired future use or habitation of a remediated site or area should be a criterion in helping to select remediation options. Ideally, the future use of the site or area is planned, designated, and implemented as a part of the remediation and should be an important element in optimizing remediation of a site or area.

3.11. The use of remediated areas can benefit communities by enhancing local economic development and serving as a community asset for recreation, learning, environmental programmes, energy development, or other uses. Post-remediation strategies to encourage use of a site or area can benefit area management by engaging communities in developing and maintaining site knowledge over generations. Experience has demonstrated that when a future use of an area or structures is valued by the community, it is less likely that the area will be developed in ways that could create unintended risks [20, 21].

3.12. As States have made progress in remediation of sites and areas, there are many examples of use even where there are active post-remediation activities such as monitoring, surveillance and continued operation of active treatment systems such as for groundwater. The following are types of use that could be considered:

(a) Recreational uses such as nature parks, trails, or sports activities.

(b) Centres that provide information on the history of area, remediation actions, current activities to maintain the remedy and prevent future radiological exposure. These types of feature contribute to maintaining institutional knowledge of the site.

(c) Designation as a wildlife and nature preserve.

(d) Industrial use to foster technologies, conduct research, or for energy production such as solar.

(e) Offices, shopping centres, airports.

(f) Growing agricultural feed for livestock or for fisheries; livestock grazing (e.g. sheep, cattle).

(g) Production of construction materials or other industrial materials.

(h) Residential use.

Specific examples are provided in annex I and II.

3.13. Paragraph 5.17(b) of GSR Part 3 [1] states:

> "For those areas with long lasting residual radioactive material, in which the government has decided to allow habitation and the resumption of social and economic activities, the government, in consultation with interested parties, shall ensure that arrangements are in place, as necessary, for the continuing control of exposure with the aim of establishing conditions for sustainable living, including:
>
> (b) Establishment of an infrastructure to support continuing 'self-help protective actions' in the affected areas, such as by the provision of information and advice, and by monitoring."

The need for self-help actions should be considered for remediated sites or areas that are intended for habitation or for uses such as agriculture, forestry or fishery. Recommendations on self-help protective actions are provided in para. 6.11 of this Safety Guide and in appendix II of IAEA Safety Standards Series No. GSG-15, Remediation Strategy and Process for Areas Affected by Past Activities or Events [3].

3.14. The involvement of the local population and possible future residents can contribute to enabling informed decision making. Any post-remediation control measures could directly affect the lifestyles of such persons (e.g. diet, leisure activities). Consequently, they should be properly informed about the factors that might contribute to their exposure, in order that they can make choices about their lifestyle and habits to further optimize their protection and safety.

3.15. The use and habitation of the areas remediated should be proposed and encouraged by local governments, landowners and communities. Use and re-habitation goals should be based on a broad consensus.

APPLICATION OF THE PRINCIPLES OF JUSTFICATION, OPTIMIZATION AND A GRADED APPROACH TO POST-REMEDIATION MANAGEMENT

3.16. Requirement 48 of GSR Part 3 [1] states that: **"The government and the regulatory body or other relevant authority shall ensure that remedial actions and protective actions are justified and that protection and safety is optimized."**

Justification

3.17. Justifying post-remediation activities involves assessing whether these activities will benefit individuals and society (including the reduction in radiation detriment), while outweighing the detrimental effects that they might cause. Protective actions may include restrictions on land and resource use, as well as limitations on food consumption. Post-remediation activities can encompass maintenance activities, facility operations, and management of residual materials. Possible detriments from post-remediation activities can include exposure of workers, other hazards during the activities, and financial cost. Justification of post-remediation activities should take into consideration societal aspects, such as the long term changes in lifestyles and traditional use of resources, and the risk perceptions, expectations and views of interested parties that might affect the use of the area.

Optimization

3.18. Optimization of protection and safety is a prospective and iterative process that involves both qualitative and quantitative judgements. Reference levels should be used as a boundary condition to define appropriate options for post-remediation management (including both active and passive controls) taking into account economic, societal, and environmental factors. The optimization of protection and safety is expected to consider the likelihood and magnitude of exposures, as well as the number of individuals exposed, while ensuring that the level of protection achieved is the best possible under the prevailing circumstances.

3.19. Considerations for optimization in post-remediation management should include an evaluation of benefits, initial costs versus long term savings, risk reduction, long term remedy performance of remedial actions and ensuring efficiency in post-remediation activities over time.

3.20. For post-remediation management, the following optimization measures should be considered:

(a) Reducing occupational exposure during sampling (e.g. by using real time measurements in the field instead of collecting samples for laboratory analysis);

(b) Use of new technologies or techniques;

(c) Looking for more efficient means of treating soil or groundwater;

(d) Improving modelling and predictions for long term management measures;

(e) Adjusting post-remediation management programmes to incorporate data on risk and likelihood of effects from aging structures or features;

(f) Adapting post-remediation controls to climate and geology changes;

(g) Identification of self-help protective actions;

(h) Identification and validation of new processes for implementing post remediation measures.

Graded approach

3.21. Paragraph 2.12 of GSR Part 3 [1] states that: “The application of the requirements for the system of protection and safety shall be commensurate with the radiation risks associated with the exposure situation.” This applies to existing exposure situations, and should be adopted as part of the approach to remediation and post-remediation.

3.22. The process of decision making to maintain regulatory control after the conclusion of the remediation process should apply a graded approach ensuring the effort involved is commensurate with the risk associated with the site or area. The decision to maintain regulatory control and on the management activities to be implemented (active and passive controls, see Sections 4 and 5) should take into consideration the magnitude of the hazards involved, the characteristics of the remediated site or area, the relative importance of radiological and non-radiological impacts in the future use of the site, and other relevant factors such as the feasibility to implement restrictions.

3.23. A graded approach should be also applied to determine the appropriate levels of analysis, documentation, actions and regulatory oversight such that effort is commensurate with the risk associated with the site or area.

SELECTION OF REFERENCE LEVELS, END STATE AND END POINT CRITERIA

Reference levels

3.24. Paragraph 1.24 of GSR Part 3 [1] states “The reference level represents the level of dose, risk or activity concentration above which it is not appropriate to plan to allow exposures to occur and below which optimization of protection and safety would continue to be implemented.”

3.25. Paragraph 5.8 of GSR Part 3 [1] states:

> “Reference levels shall typically be expressed as an annual effective dose to the representative person in the range of 1–20 mSv or other corresponding quantity, the actual value depending on the feasibility of controlling the situation and on experience in managing similar situations in the past.”

3.26. Reference levels for a site or area should be established as benchmarks for the remediation process and should then be used retrospectively to assess the effectiveness of the measures implemented (see para. 3.11 of GSG-15 [3]).

3.27. Paragraph 5.9 of the GSR Part 3 [1] states that “The regulatory body or other relevant authority shall periodically review the reference levels to ensure that they remain appropriate in the light of the prevailing circumstances”. During post-remediation management, the reference levels should remain unchanged unless new information or advancements in technology provide compelling justification for adjustments by the regulatory body or other relevant authority, as part of a periodic review process.

3.28. Paragraph 3.14. of GSG-15 [3] states:

> “Reference levels for use in remediation are typically expressed in terms of annual effective dose (i.e. above any contributions from natural background radiation). For practicality, it might be beneficial to also establish derived criteria that correspond to the

reference level and that can be easily measured (e.g. activity per unit area, per unit weight or per unit volume; gamma dose rates at 1 m height for a defined surface)."

For post-remediation management, the same approach should be applied.

End state and end point criteria

3.29. The end state is the final status of a site at the end of activities for remediation, including approval of the radiological and physical conditions of the site and remaining structures [2]. The end state should be considered as the starting point of post-remediation management. In the context of post-remediation, the end state refers to its final status once the pre-established conditions, known as end point criteria, have been achieved, considering site specific circumstances and regulatory requirements.

3.30. The end point criteria of post-remediation are met when the level of contamination is deemed by the regulatory body or other relevant authority to be equal or below the reference level established during the authorization process, the requirements for the intended future use of the site have been reached or no further passive or active actions are needed.

3.31. The establishment of the end point criteria should be discussed with interested parties (e.g. site owners, technical support organizations, regulatory bodies, local authorities, members of the public) (see also para. 2.56 of GSG 15 [3]). This process should be proportional, reflecting issues such as the radiological and non-radiological risks, the level of uncertainties, and the concerns of interested parties.

3.32. For complex sites or situations where a long timescale is foreseen, an interim state can be considered as a step towards reaching a final end state. In this case, the relationship between the interim state and the final end state, and how the progression between these states will be managed, should be described. This should include specifying timeframes, goals, and evaluation metrics for the interim state. For actions that involve long timescales, the process of determining the end state may need to be iterative and adaptive and conducted in conjunction with interim actions.

Release of portions of a site or area from regulatory control

3.33. If the regulatory body or other relevant authority agrees that the remediation activities have been completed for one or more portions of a site or area and these portions can be released from regulatory control, the regulatory body or other authority should consider whether the boundary for remediation can be reduced, allowing parts of the site or area to be made available for other uses. A phased reduction in the size of a site or area that remains under regulatory control is one way of optimizing post-remediation management measures. However, a strategy of early release from regulatory control of a portion of a site or area should not interfere with or delay the remediation of the remainder of the site or area.

3.34. The partial release of a site or area allows for adjustments to the post remediation management programme on the basis of information from site monitoring, post-remediation activities, changes in the site context (e.g. intended use of the site), or unexpected events (e.g. meteorological and geological events, vandalism or material fatigue). All these adjustments should be submitted to the regulatory body or other relevant authority for approval.

SAFETY ASSESSMENTS AND ENVIRONMENTAL IMPACT ASSESSMENT

3.35. For some sites or areas, the regulatory body or other relevant authority may require that safety assessments and environmental impact assessments be developed for the remediation of a site or area (see paras 1.10–1.24 of IAEA Safety Standards Series No. GSG-10, Prospective Radiological Environmental Impact Assessment for Facilities and Activities [16] and paras 6.16–6.24 of GSG-15 [3]). In such cases, during post-remediation management the regulatory body or other relevant authority, and responsible parties should continue to use these assessments to determine if reference levels continue to be met, as well as to evaluate whether passive (e.g. monitored natural attenuation) or active treatment systems for environmental media, such as groundwater, effectively contribute to meeting reference levels.

3.36. Reassessments of safety assessments and environmental impact assessments can be used as part of periodic review of the effectiveness and continued need for post-remediation measures as well as to optimize post-remediation management by prioritizing areas for continued monitoring.

3.37. Section 5 of Ref. [17] discusses various approaches and models that may be used for safety assessments and environmental impact assessments of sites or areas contaminated by past activities. Because of changes in codes for models as well as improved understanding of the behaviour of contaminants and potential receptors, the models used for reassessment of sites or areas during post-remediation management may need to be updated. It should also be considered whether other models may need to be used that have similar capability for assessing a particular site or area other than those that were used for deciding on remedial actions for the site or area.

3.38. Environmental impact assessments may be used to prospectively estimate the doses to important ecological receptors. In some States, environmental impact assessments may be the basis for mitigation measures that the person or organization responsible for site remediation should take to protect other environmental resources (e.g. sensitive plant and animal species, culturally significant and historic sites) in addition to controlling radiation exposures (see Section 4 of GSG-10 [16]). The regulatory body or other relevant authorities and the responsible parties for post-remediation management should evaluate these mitigation measures to determine if they need to continue as part of post-remediation management of a site or area.

SELECTING AND DESIGNING A LONG TERM POST-REMEDIATION MANAGEMENT PROGRAMME

3.39. Paragraph 5.16 of GSR Part 3 [1] states:

> “The person or organization responsible for post-remediation control measures shall establish and maintain for as long as required by the regulatory body or other relevant authority, an appropriate programme, including any necessary provisions for monitoring, to verify the long term effectiveness of the completed remedial actions for areas in which controls are required after remediation.”

3.40. Paragraph 10.2 of GSG 15 [3] states:

"The complexity of this [post-remediation management] phase will depend on whether restrictions on use or access need to be imposed and what those restrictions are. Even where there are no restrictions in place, some level of surveillance and monitoring and of involvement of interested parties may be necessary."

3.41. For a particular site or area, the regulatory body or other relevant authority and person or organizations responsible for post-remediation management should consider the following when designing a post-remediation programme:

(a) The monitoring and surveillance activities that are needed to verify the long term effectiveness of remediation (see paras 8.20 and 10.14 of GSG-15 [3]). This could include continuing monitoring and surveillance activities that started during remediation activities and were implemented for (parts of) a site or area.

(b) The need for some types of monitoring that were not conducted during the remediation phase. Examples include sampling and analysis of food resources from the area. This type of monitoring may be precautionary and subsequently terminated if the results prove that further monitoring is not needed.

(c) The safe management of waste and residues generated during post-remediation activities, in accordance with regulatory requirements.

(d) The restrictions needed on the future use of the site to comply with the end state reached at the completion of remediation activities, and how they will be implemented, maintained and controlled over time.

(e) The restrictions on access to the site or area to comply with the end state reached at the completion of remediation activities, and how these will be implemented, maintained and controlled over time.

(f) The need for sets of controls that provide for defence in depth if there are concerns about the effectiveness of having only one control in place. For example, for a site with land use restrictions (see Section 5), defence in depth involves the use of signage about the use restriction as well as other means of communicating with people living near the site or area and other interested parties, to ensure the controls are complied with.

(g) The need to continue operating treatment systems (e.g. for groundwater) and to have monitoring systems to measure their effectiveness. Even if the operation of such systems prior to transfer of the site or area from remediation to post-remediation management was successful in reaching the reference levels, the need for (and optimization of) continued treatment should be considered.

(h) Addressing concerns of interested parties, including members of the public that live in the vicinity of the site or area by including (at least for some period of time) monitoring of substances or media in which there is elevated intertest. An example could be a food resource that is used in an area.

(i) If safety assessments were developed and updated as remediation objectives were met, the most important exposure pathways to continue to assess by monitoring should be considered, including consideration of the potential exposure of persons and/or the environment if some parts of a remediation system were to fail.

3.42. Paragraph 10.17 of GSG-15 [3] states that "the results from the [post-remediation management] programme should be documented and made readily available to interested parties to assist in gaining and maintaining public confidence". The post-remediation programme for a site or area should identify specific ways and frequencies by which results

are made available. The engagement with interested parties may evolve over time; consequently, the responsible person or organization for post remediation management should request input from such parties as to how they would like to receive this information and this should be documented in the programme. Involvement of interested parties is further discussed in Section 6.

RELEASE FROM REGULATORY CONTROL

3.43. The release of remediated sites or areas from regulatory control will depend on whether the end point criteria as set forward in the agreed remediation plan have been complied with, and the foreseen end state has been met (see paras 8.28–8.43 of GSG-15 [3]). In the case of release from regulatory control, three different outcomes are possible: unrestricted access or use, restricted use, or restricted access of the site.

3.44. For a site or area released from regulatory control, there may still be a need for post-remediation management controls and restrictions, depending on the outcome of the remediation process. These post-remediation activities may be under the regulatory oversight of the same authority as for remediation or another relevant authority.

3.45. For sites or areas with restricted use (see para. 8.35 of GSG-15 [3]), such as a site where contamination occurs in the subsurface but some uses on the surface are allowed, a major objective of post-remediation management is to ensure that the administrative controls put in place are effective and that the integrity of remediation systems such as barriers, caps and covers prevents the release and/or migration of contaminants, and any inadvertent exposure that would necessitate more stringent controls.

3.46. For some remediated sites or areas, the regulatory body or other relevant authority may decide that a site in its entirety can be released from regulatory control. This is most likely to occur at sites or areas that prior to remediation were considered low to medium risk. Interested parties should be invited to provide input before a final decision is made to release the site from regulatory control.

3.47. For sites or areas fully released from regulatory control, post-remediation management activities may be limited to preservation of records and the production of information derived from these records (e.g. displays about the history of the site, fact sheets that are available on-line as well as in public places near the site) as part of long term preservation of knowledge of a site. Efforts should be made to preserve institutional knowledge about all sites or areas that have been remediated. Interested parties in the future may become aware of past radiological activities that occurred in a site or area, and States should have means of demonstrating that responsible action was taken to protect public and the environment at the site (see also Sections 6 and 9).

3.48. For some higher risk or complex sites or areas, complete release from regulatory control might never be feasible. This would be likely to be the case for sites or areas where remediation of some or all sources of radiological contamination was not justified.

3.49. The objectives of any post-remediation monitoring, maintenance, and surveillance activities as well as administrative institutional controls are to verify the long term effectiveness of remediation. This includes maintaining the integrity of the engineered structures that were put in place (e.g. barriers, caps and covers) to prevent the release or migration of radioactive

or other contaminants, such that post-remediation exposures do not exceed the reference levels established during remediation (see para. 5.17 of GSR Part 3 [1], and paras 10.3–10.6 of GSG-15 [3]). Sections 4 and 5 provide recommendations on the types of post-remediation management activity that might be performed.

TRANSITION TO POST-REMEDIATION AND TRANSFER OF REGULATORY RESPONSIBILITY

3.50. The post-remediation programme for a site or area cannot be finalized until a final remediation report has been prepared, as required by para. 5.14 (e) of GSR Part 3 [1]. Development of the post-remediation programme should begin well in advance of site remediation being completed. Having an approved or nearly final programme will significantly facilitate the transition between remediation and post-remediation management.

3.51. Post-remediation management activities for a site or area should be documented and subject to review by interested parties and approval by the regulatory body or other relevant authority (see also para. 5.15(a) of GSR Part 3 [1]). The necessary post-remediation management activities should be included as an addendum to the remediation plan or as a separate document. Annex I of GSG-15 [3] contains an example of a table of contents for a remediation plan including post-remediation planning.

3.52. As part of finalizing a post-remediation management programme for a site or area, interested parties should have an opportunity to review and provide input on it. Remediation does not imply the total removal of contaminants [2] and interested parties should be made aware of this at the start of remediation of a site or area. Similarly, it is also important to understand that there may be restrictions placed on the use of site or area after remediation because of residual contamination. The participation of the public and other interested parties in reviewing and finalizing the programme may help improve understanding and acceptance of any post-remediation controls.

3.53. A benefit of early involvement of post-remediation management personnel (responsible parties and the regulatory body or other relevant authorities) is beginning the collection of records on the site or area. This is especially important if the regulatory authorities for oversight for post-remediation activities change. As stated in para 8.47 of GSG-15 [3], these records should include “accurate and complete information concerning locations, configurations, types and amount of radionuclides remaining in the area after remediation”, for example:

(a) Records as listed in para. 8.46 of GSG-15 [3];
(b) The remediation plan (including supporting documents);
(c) Safety assessment and environmental impact assessment;
(d) The final remediation report;
(e) Procedures for any monitoring and surveillance activities that started during the active remediation phase of a site or area and will continue as part of post-remediation management.

3.54. If remediation of an area or site includes active treatment of environmental media such as surface water or groundwater, these will commonly continue as part of the post-remediation management long after other remedial aspects of a site or area are completed. Other treatments, such as bioremediation of contaminated soils or sediments, may be more passive but still need

continued resourcing (e.g. financial resources for operating costs, expertise for maintenance of systems) and measures (e.g. access controls around treatment equipment, procedures for handling any residual materials generated by operation of the system).

3.55. During the transition to post-remediation management, the results of operating the treatment systems (see para. 3.54) as well as information on the systems that need to be preserved during the transition need to be kept. This includes maintenance results, calibration procedures, and information on the supplies of consumable materials needed for uninterrupted operation of the systems.

3.56. Whether or not regulatory oversight is transferred from the regulatory body to other relevant national authorities, in some States the establishment of passive institutional controls (e.g. land use controls, restrictions on well drilling) may be the responsibility of regional or local authorities. Formal establishment of these controls should be completed before the regulatory body or other relevant authority certifies that a site or area that has undergone remedial activities can be released (or conditionally released) from regulatory control. The benefits of this include the following:

(a) If the relevant authorities involved in establishing controls have not been an active party in remediation of the site, it is an opportunity for them to understand the objectives of these controls. This can facilitate their role in enforcing any future controls and restrictions.
(b) Awareness and acceptance of these institutional controls by the public and other interested parties in terms of which new uses or historic uses can be undertaken in the remediated site or area, and which will be restricted.
(c) Identification of property ownership or tenant use of a site or area. Land ownership may be difficult to ascertain at legacy sites where accessing land or using its resources was prevented because of the radiological contamination.

PERIODIC REVIEW OF POST-REMEDIATION MANAGEMENT

3.57. Periodic, formal reviews of post-remediation management programmes for a site or area should be conducted (see fig.1 of GSG-15 [3]).

3.58. The regulatory body or other relevant authority, responsible parties, and other interested parties should review post-remediation management programmes at least every five years. In the early stages of post-remediation management there may be benefits in conducting reviews more frequently with a goal of optimizing ongoing activities. The regulatory body or other relevant authority and the responsible parties, with input from interested parties, should establish a regular schedule of review to evaluate the effectiveness of measures as well as to determine if some post-remediation management activities can be optimized or discontinued.

3.59. The regulatory body or other relevant authority and responsible parties should also review whether changing conditions around the site or area warrant further or modified post-remediation controls (see also Section 8). Safety assessment and environmental impact assessments developed as part of the design of the remediation for a site or area may be used, for example, to evaluate whether changes in land use warrant the modification of controls.

3.60. The regulatory body or other relevant authority should assess periodic reviews conducted by responsible parties, with input from interested parties being taken into account.

3.61. In addition to any periodic reviews involving the regulatory body or other relevant authorities, the responsible party should look for opportunities to improve post-remediation activities, including monitoring and surveillance, to increase the efficiency and cost-effectiveness of these activities. As an example, unmanned aerial vehicles may be used instead of on-the-ground inspections to verify the condition of engineered barriers and covers.

RADIATION PROTECTION DURING POST-REMEDIATION

3.62. The optimization of protection and safety should involve the assessment of worker exposure throughout all stages of post-remedial activities, as well as the evaluation of long term public exposure due to residual contamination after remediation. This includes the optimization of protection and safety during the management of any radioactive waste generated during post-remediation activities.

Occupational exposure

3.63. The application of regulations is required to be commensurate with the radiation risks associated with the exposure situation (see paras 2.18 and 2.31 of GSR Part 3 [1]). The level of control, monitoring, and protective measures should be proportionate to the occupational exposures received by workers in the remediated site or area.

3.64. Often, exposure levels during post remedial actions are expected to be lower than those experienced by workers during remediation activities. However, in cases where a remediated site or area still results in the exposure of workers involved in post-remediation activities employers are required to ensure that such occupational exposures are controlled in accordance with the Requirements 19–28 and paras 3.68–3.116 of GSR Part 3 [1] on occupational exposure in planned exposure situations (see para. 5.26 of GSR Part 3 [1]). Recommendations on the control of occupational exposure are provided in GSG-7 [13], SSG-91 [14] and paras 8.14, 8.15 and 8.18 of GSG-15 [3].

3.65. Employers are responsible for the protection of workers against occupational exposure (see Requirement 21 of GSR Part 3 [1]), and with regard to post-remediation management should ensure that appropriate radiation protection measures are implemented and maintained, and provide resources and oversight to ensure compliance with regulatory requirements, including the designation of a radiation protection officer (see para. 3.94(e) of GSR Part 3 [1]), where necessary.

3.66. Certain post-remediation control activities have the potential to expose workers to radiation. These activities include:

(a) Performing work on or within barriers or covers that require repair or redesign, which might involve direct contact with radioactive material;
(b) Collecting and handling samples of air, water, sewage, soil, sediments, or biological materials;
(c) Work inside water treatment plants, shafts, mining tunnels or other below ground facilities, in which exposure due to radon can be significant.

3.67. If applicable, employers are required to establish and maintain a radiation protection programme to control exposures during post-remediation activities (see Requirement 24 of GSR Part 3 [1]). Such a programme should include, as appropriate:

(a) Radiation risk assessment for all planned activities;
(b) Protective measures such as ventilation or personal protective equipment (e.g. protective masks, overalls and overshoes, in addition to standard work clothing);
(c) Monitoring of radiation levels in the workplace and worker exposures;
(d) Emergency measures for unexpected radiological events;
(e) Appropriate training for workers on radiation protection principles, potential risks, safe work practices and the use of protective equipment;
(f) Record keeping for radiation monitoring, worker doses, training, and the inspection and maintenance of protective measures in accordance with regulatory requirements.

3.68. The regulatory body or other relevant authority should oversee and approve radiation protection programmes for post-remediation management. Inspections and verifications should be conducted to validate compliance with any authorizations issued by the regulatory body or other relevant authority. Assessments of occupational exposure should consider the following exposure pathways, as appropriate:

(a) External exposure from gamma radiation;
(b) Inhalation of radon and its progeny in the air;
(c) Inhalation of contaminated dust in the air;
(d) Ingestion of contaminated soil.

3.69. Suitable equipment should be available to monitor the exposure pathways listed in para. 3.68, such as dose rate meters and personal dosimeters, passive radon detectors and active radon monitors, dust samplers and the associated analytical equipment, and surface contamination monitors. This equipment should be maintained in good working order and periodically calibrated in accordance with regulatory requirements. Internal testing and calibration often involves the use of radioactive sources (i.e. calibration sources), which might require additional authorization from the regulatory body.

3.70. The potential for spreading contamination during post-remediation activities should be addressed. Measures to avoid this include:

(a) Working procedures to prevent leaks or unnecessary spread of contamination.
(b) Installation of decontamination points near work areas for construction vehicles, equipment, and personnel (e.g. high pressure cleaners, tyre washing systems, boot washers, showers).

Public exposure

3.71. Monitoring and surveillance programmes should be established to assess levels of public exposure. The programme should also be able to indicate whether unplanned exposure has occurred or if there is a risk of it occurring. These programmes should collect data from different environmental media and receptors, including soil, water, air, flora, and fauna (particularly foodstuffs) to assess radiation levels and compare them against reference levels established by the regulatory body (see Appendix 1 to GSG-15 [3]). If this assessment indicates that public exposure exceeds these reference levels, further protective actions should be considered.

4. ACTIVE MEASURES FOR POST-REMEDIATION MANAGEMENT

4.1. As stated in para 8.31 of GSG-15 [3], a site or area can be released from regulatory control in a conditional way, which determines the approach to post-remediation management. In such cases, depending on the agreed end state and the planned use of the site or area, the responsible party for post-remediation management should establish appropriate measures and controls for use of the site. These measures and controls are referred to as 'institutional controls' [2] and can be active measures (as described in the remainder of this section) or passive (as described in Section 5) or a combination of both. An overview of possible institutional controls for long term post-remediation management is provided in Table 1.

TABLE 1. OVERVIEW OF INSTITUTIONAL CONTROLS FOR LONG TERM POST-REMEDIATION MANAGEMENT

Institutional Controls	**Types**	**Examples**	**Responsible entity**
Active measures (physical activities, such as the application of engineering controls tailored for the site.)	Monitoring	Radiological monitoring Programme Environmental monitoring programme	Approved by the regulatory body and implemented by the responsible parties
	Surveillance	Surveillance programme Geotechnical surveillance of engineered structures	Responsible parties
	Operation of facilities	Water treatment plant	Responsible parties
	Remedial work	Actions in the case of rare events	Responsible parties
	Maintenance of remediated areas	Preventive maintenance	Responsible parties
		Corrective maintenance	Responsible parties
	Management of residuals materials	Residual solid waste Residual liquid waste Chemicals Radioactive waste in solid or liquid form Scrap (contaminated and non-contaminated) Oils and greases	Approved by the regulatory body or other competent authorities and implemented by the responsible parties
	Sites access control	Video surveillance, fencing, signage	Responsible party
Passive measures (controls designed to complement active controls, rarely the sole protective measure at a site)	Restrictions on land use: - For residential use - For industrial use - For agriculture use - For recreational use	Encumbrances	Relevant authorities, including local one and regulatory body, where applicable
	Restriction on the trade of commodities	Easements	
	Restrictions on food		
	Restriction on the use of groundwater	Deeds	
	Communication and Information and education of the public	Public consultations, Support self-help measures, Citizen science (see section 6) Visitors centre (Annex II)	Local authority, regulatory body and responsible parties

4.2. As a part of the demonstration of the long term safety of a remediated site or area, post-remediation monitoring is required (see Requirement 32 and paras 5.12(f), 5.13(c) and 5.16 of GSR Part 3 [1]). The monitoring should be specific to the remediated site or area based on the following aspects:

(a) The planned use (restricted or unrestricted) of the site or area (e.g. industrial, agricultural, residential, recreation, nature reserve, military);
(b) The size of the site or area;
(c) The conditions of the site or area (e.g. dry, wet, accessibility, (hydro)geology);
(d) Ownership of the site or area (i.e. private or public);
(e) The post-remediation reference levels specified for the site or area;
(f) If applicable, the type and extent of any remaining contamination.

4.3. The responsible party should establish a written monitoring and surveillance programme that is appropriate to the remediated site or area. This programme should be submitted to the regulatory body or other relevant authorities for approval, and interested parties (e.g. members of the public, landowners, land users) should be consulted. The results of the monitoring programme should be made publicly available to strengthen trust in post-remediation management.

4.4. The results of the post-remediation monitoring and surveillance programme should be compared to the reference levels. This programme should also be used to provide indicators for the long term performance of post-remediation activities, and to help identify damages or unwanted impacts in the remediated site or area. The programme should also provide a basis for repairing, improving and/or reworking the remediated area, or for redesigning remediation technology, such as for water treatment.

4.5. The monitoring and surveillance programme should take into account the natural background radioactivity and radiation levels around the remediated site or area to distinguish between pre-existing naturally occurring radionuclides and those associated with the remediated area.

4.6. The responsible party for post-remediation management should document all the data and results from the monitoring and surveillance programme in a systematic, understandable and secure way and arrange for long term storage, preferably in a digital format.

4.7. The responsible party for post-remediation management should revise the monitoring and surveillance programme periodically to ensure that it is up to date, state of the art, effective and efficient. Post-remediation, sites or areas can be subject to unexpected and rapid change, even in the long term, due to external events or political or economic reasons. Consequently, the post-remediation monitoring and surveillance programme should be considered a living document and reviewed on a regular basis, as recommended in paras 3.57–3.61.

4.8. The responsible party for post-remediation management should ensure that suitably qualified persons (experts, specialists, professionals) are available and assigned to implement the monitoring and surveillance programme, including for doing the work in and around the site or area, in analytical laboratories and in the administration for documentation, evaluation,

assessment and reporting. The management system of the responsible party (see Section 7) should cover the monitoring, sampling and laboratory analyses.

4.9. Para. 8.20 of GSG-15 [3] states that "The monitoring performed before and during remediation should be designed to provide continuity with post-remediation monitoring activities. Appropriate modelling may help in establishing an effective and cost-efficient monitoring programme." If modelling was used to support monitoring these activities, this modelling may continue to be helpful.

Post-remediation monitoring

4.10. If the remediation did not result in the removal of all the radioactive contaminants, the responsible party should include radiation monitoring as part of the monitoring and surveillance programme. Radiation monitoring can consist of the following, as applicable:

(a) Gamma dose rate measurements in the site or area;
(b) Sampling and analysis of radionuclides in ground and surface water;
(c) Air sampling to determine concentrations of radionuclides in air;
(d) Measurement of radon and progeny in air;
(e) Sampling and analysis of materials (e.g. soil, grass, foodstuffs, wood);
(f) In-situ gamma spectroscopy.

4.11. The spatial density and the frequency of the monitoring should be determined on the basis of the nature of the contamination (e.g. radionuclides, activity concentrations, distribution and mobility) and also on the reference levels and any requirements specified by the regulatory body or other relevant authorities. The needs for seasonal variations in the monitoring programme monitoring should also be considered.

4.12. The responsible party for post-remediation should make financial provisions for adequate monitoring. For the analysis of samples, special equipped laboratories are usually needed; this should be taken into account within the development of the monitoring and surveillance programme. The costs of radiation monitoring equipment, the periodic need for calibration and maintenance and if applicable, cost of external specialists should be taken into account.

4.13. The monitoring and surveillance programme may also include measurements of non-radiological contaminants (e.g. chemical, biological), if the remediation did not result in the removal of such contaminants.

Post-remediation surveillance

4.14. Surveillance of remediated sites or areas should be performed to demonstrate their long term safety. The frequency of post-remediation surveillance should be determined on the basis of the use of the remediated site or area and on the nature of any remaining contaminants (e.g. the concentrations of radionuclides in soil and water and their mobility in the environment). Surveillance can be done on a weekly, monthly or less frequent basis. In most cases, a visual examination by specialists or experts visiting the site or area is appropriate. The site or area visits should be organized by either the responsible party or by the regulatory body or other relevant authorities. The visits may include invitations to interested parties (e.g. members of

the public, landowners, land users, political institutions, NGOs) to understand their needs and expectations.

4.15. Surveillance should include measures to inspect a site or area (visually or by taking measurements) to note any changes in its features or in how the remedial actions are performing. This may include inspecting the following:

(a) The general condition of the remediated site or area (visual overview);
(b) Obvious damages, defects or changes;
(c) Use of the site or area, as agreed or approved (and visible misuse of area, e.g. as wild dump);
(d) Functionality of site access (e.g. fences), if applicable;
(e) Functionality of hydraulic engineering and road construction;
(f) Functionality of barriers or containments (if visible);
(g) The presence (or accumulation) of vegetation and animals (e.g. invasive species);
(h) Functionality of buildings, engineered structures (e.g. for water treatment, hydraulic engineering, sample taking, measurements);
(i) Functionality of installed measurement equipment (radiological, environmental).

4.16. During site visits, the responsible party could also perform (or arrange for) sampling (e.g. samples of surface and/or groundwater), in-situ measurements (pH, conductivity, temperature, flow, dust) and radiation measurements (e.g. dose rate, radon).

4.17. The results of the surveillance should be documented in a written report containing at least the following:

(a) Date and time of surveillance;
(b) Names and function of members of the surveillance team;
(c) Reason for the surveillance (regular, extraordinary);
(d) Weather conditions;
(e) Type(s) of surveillance undertaken;
(f) Findings (supported by photographs);
(g) Corrective actions needed with timeframes for completion and responsible persons;
(h) The arrangements for sharing the results with the regulatory body or other relevant authorities, and with interested parties (public, land users, landowners)
(i) Time schedule for the next surveillance.

The report should be used as the basis for further actions and for updating the monitoring and surveillance programme.

Geotechnical surveillance of engineered structures

4.18. Geotechnical engineered structures may represent an important feature of a remediated site or area. These structures can consist of barriers, covers, static elements or other structures. The geotechnical surveillance of engineered structures should be part of the regular visits and the monitoring and surveillance programme. This surveillance should be undertaken by

knowledgeable experts (e.g. geoengineers, geologists or hydrogeologists, civil engineers or architects) as applicable.

4.19. The maintenance, repair or replacement of geotechnical engineered structures may be essential for maintaining the safety of a remediated site or area and ensuring that the associated remediation goals are achieved. The need for such activities over a long timescale should be considered.

MAINTENANCE OF REMEDIATED SITES OR AREAS

4.20. Regular maintenance of a remediated site or area is essential to ensure its long term safety and stability. The responsible party should establish a maintenance programme for all relevant infrastructure and barriers, such as buildings, facilities, roads, fences, vegetation, hydraulic engineering, tubes and pipes, pumps, water shafts, electrical components, as applicable. The maintenance programme should also cover regular care and cleaning to ensure a sustainable and long lasting operation of the infrastructure and barriers.

4.21. The maintenance programme should specify the necessary frequency for maintenance activities. Regulatory requirements should also be taken into account in this programme, such as for construction, occupational safety, fire protection and electrical safety.

Preventive maintenance

4.22. A maintenance programme is part of preventive maintenance. Preventive maintenance saves costs in the long term and ensures stable and long lasting post-remediation over decades. Preventive maintenance reduces the risk of breakdowns and accidents. It ensures the reliable performance of equipment and engineered structures and helps comply with regulatory requirements.

4.23. Targeted maintenance activities such as inspections, maintenance and improvements should be used to prevent excessive degradation or premature failure. The degree of maintenance can vary greatly: a common approach is a time- and calendar-based maintenance schedule. Alternatively, usage-based maintenance follows the actual use of the facilities and maintenance is planned based on usage parameters such as the operating hours.

4.24. Preventive maintenance involves financial and human resources; within the maintenance planning these resources should be evaluated, so they are predictable.

Corrective maintenance

4.25. Corrective maintenance may be necessary following unexpected or rare events such as heavy precipitation, storms, dryness, climate change, seismic events, vandalism or internal faults such as material fatigue, power outage or improper use. Such events can affect the long term safety of remediated areas (see Section 8). Corrective maintenance activities are not always predictable and can lead to high costs.

4.26. Corrective maintenance should be a part of the general maintenance programme. The maintenance programme should contain or should be based on an overall risk analysis, dealing with rare events. In this risk analysis possible events should be identified, evaluated and underpinned with estimated costs (see Section 8).

OPERATION OF FACILITIES IN REMEDIATED SITES OR AREAS

4.27. In some cases, it is necessary to operate special facilities in remediated areas, temporarily or even over the long term. To operate such facilities, an adequate infrastructure is necessary (e.g. access, access control, electrical power supply, site development, communications including internet access). Also, human resources and funding for operating and maintaining the facilities should be considered as part of the post-remediation management of the site or area.

4.28. Special facilities in a post-remediated site or area may include:

(a) Water treatment plants;
(b) Pumping stations with tubes, pipes, shafts and tanks;
(c) Electrical power installations with cable routes, transformer stations and generators;
(d) Tank installations for fuels, chemicals and/or sewage;
(e) Warehouses, garages for equipment and vehicles;
(f) Offices;
(g) Fences, barriers or surveillance technologies;
(h) Monitoring equipment and systems;
(i) Decontamination points.

MANAGEMENT OF RESIDUAL MATERIALS GENERATED DURING POST-REMEDIATION

4.29. Where facilities are operating in a post-remediation site or area, residual materials could be generated in form of:

(a) Residual solid wastes;
(b) Residual liquid waste such as sewage;
(c) Chemicals (e.g. from water treatment plants);
(d) Radioactive waste in solid or liquid form (e.g. naturally occurring radionuclides from water treatment plants);
(e) Scrap (contaminated and non-contaminated);
(f) Oils and greases.

4.30. Even if there are no facilities in operation in the post-remediated site or area, residual materials could still be generated as a result of maintenance activities such as grass cutting, felling wood, sludge from pipes, shafts and conduits, which should be managed properly. Also, residual materials can be generated from work undertaken in the site or area (e.g. maintaining or rebuilding barriers or covers, road construction, hydraulic engineering) which should be handled and managed appropriately.

4.31. The management of residual materials can be done within or outside the post-remediated site or area (e.g. transferred to third parties as waste, as recycling material or material for subsequent use). If the materials remain inside the remediated site or area, there should be adequate handling and management capabilities and capacities for storage, backfilling, humus heaping, disposal, water treatment or collecting, as appropriate.

4.32. The responsible party is responsible for the safe management of any residual materials arising from the post-remediation management of a site or area, and should make provisions and implement appropriate waste management arrangements as part of the post-remediation management programme.

SITE ACCESS CONTROL

4.33. To meet the requirement established in para. 5.15 (c) (i) of GSR Part 3 [1]), active access controls such as fences and signs may be needed as part of post remediation management controls for a site or area (see also paras 8.39–8.41 of GSG-15 [3]. Fences and signs should normally be constructed around an entire site or area, particularly if there is a need to demarcate the boundaries for people living and working nearby.

4.34. Signs posted for access control should provide contact details for obtaining more information about the site or area. The condition of fences, signs, and other access controls should be periodically checked as part of surveillance activities; repairs should be made, as necessary. If access to the site or area is allowed at designated points, the signs should provide information on the locations.

4.35. On a larger site or area, remediation may result in some parts having restricted use due to residual contamination. In such situations, fences and or signs should be used to restrict access to those parts of the site where higher levels of contamination remain. For such situations, it should be considered whether active access controls need to be supplemented by administrative controls (see Section 5).

4.36. The need for additional signs and fences around certain facilities in a post remediation site or area, such as active water treatment systems, should be considered. If theft or vandalism is a particular concern, consideration should be given to supplementing signs and fences with surveillance cameras.

4.37. Other types of facility where active access controls may be needed include storage areas for residual materials generated as part of post remediation management activities, and areas where equipment is stored.

4.38. When choosing the type of fencing or other active access control measures to implement, a graded approach should be used, based on the risk or consequences of someone entering the area. For example, a fence whose primary purpose is to demarcate the boundaries of an area might not need to be high and heavy-duty. However, where only trained personnel are allowed access, the fencing should be more robust.

EMERGENCY PREPAREDNESS AND RESPONSE

4.39. Paragraph 8.25 of GSG-15 [3] states that “The responsible party for remediation should ensure that relevant procedures to respond to any emergency that occurs during remediation are implemented in accordance with the emergency preparedness plan”. The responsible party for post-remediation management should adopt and adjust this emergency preparedness plan to the post-remediation conditions in the area. The plan should cover or consider where applicable, the arrangements for preparedness and response to the following events:

(a) Fire, explosions, gas leakages;

(b) Terrorism;
(c) Riots and military inventions (war);
(d) Extreme weather (e.g. storms, hurricanes, heavy precipitation);
(e) Flooding,
(f) Earthquakes and landslides,;
(g) Wildfire;
(h) Sinkholes, bumps, seismic events and (in former mining areas) firedamp;
(i) Total power outage;
(j) Workplace accidents;
(k) Machine breakdowns;
(l) Staffing shortages;
(m) Exceeding of safety limits or threshold values.

Each event should be analysed to define the arrangements needed for emergency preparedness and response. (see paras 3.43–3.44 of GSR Part 3 [1]). There is required to be regular training and exercises in the procedures to be followed (see para 3.44(c) of GSR Part 3 [1]); this should include site or area personnel as well as emergency responders (e.g. firefighters, mine rescue team, police, military, emergency doctors). The training should be practical and include specific procedures such as firefighting. The outcome of the training and the drills should be used to improve the emergency plan.

4.40. The emergency plan should give an exact and simple sequence of steps — using clear instructions — to be implemented by the responsible persons if an event occurs.

4.41. The emergency plan should be revised regularly and adopted to the special needs for the post-remediated site or area. Names, addresses, phone numbers and other contact details of the emergency responders and responsible persons should be reviewed and updated periodically (e.g. annually).

5. PASSIVE MEASURES FOR REMEDIATED SITES OR AREAS

5.1. As stated in para. 4.1, depending on the end state of the site and its intended use, post-remediation management may involve passive measures instead of, or in addition to, the active measures discussed in Section 4. These passive measures are often administrative controls established by the regulatory body or other relevant authorities (see para. 5.15(c) of GSR Part 3 [1], and paras 8.33–8.38 of GSG-15 [3]).

5.2. The regulatory body or other relevant authorities can impose restrictions for the further use of a remediated site or area, or more generally issue regulations for such sites or areas. These restrictions or regulations depend on the agreed remediation goals, the achieved end state of the remediated area, the agreed reference levels or other criteria established for the purposes of environmental protection.

LAND USE RESTRICTIONS FOR REMEDIATED SITES OR AREAS

5.3. Land use restrictions are most usually issued if the end state criteria for unrestricted use of the site or area are not achievable, but a restricted use (e.g. industrial) of the land is possible.

For the industrial use of the site or area, all the possible exposure pathways from working in the affected area should be evaluated. However, exposure pathways associated with use of the site or area for public recreation (e.g. parks, sports), living (residential) and facilities such as kindergartens, schools or playgrounds should not normally need to be considered.

5.4. Land use restriction could be of the following kind:

(a) Use of the site or area only for special purposes (e.g. as a civil dump, industrial, research, nature reserve);
(b) Use of only parts of the remediated site or area;
(c) Time restricted use of the remediated site or area;
(d) Use only by selected persons or institutions (e.g. researchers, military);
(e) No public access;
(f) No further use allowed.

5.5. When a remediated site or area is used for industrial purposes, in most cases the gamma dose rate and the exposure from migration of radioactivity into groundwater are the main exposure pathways. For the use of a remediated site or area as a park or other type of recreational area, the following exposure pathways should be evaluated:

(a) External radiation exposure due to gamma radiation;
(b) Radiation exposure from the inhalation of radon and radon progeny;
(c) Radiation exposure from the inhalation of dust contaminated with radionuclides;
(d) Radiation exposure from the ingestion of dust and soil contaminated with radionuclides (especially in the case of children playing outdoors).

5.6. The planned use of the site or area should be based on a specific assessment of radiation exposure, taking into account reference levels or other criteria (including threshold values for chemical exposure) specified by the regulatory body or other relevant authorities. Radiation exposure of the public due to the possible contamination of groundwater should be specifically assessed.

RESOURCE USE AND FOOD-STUFF RESTRICTIONS

5.7. For the use of remediated areas for agriculture, horticulture, fishery or forestry the following exposure pathways should be evaluated:

(a) Radiation exposure from the consumption of agricultural, horticultural, fishery or forestry products;
(b) Radiation exposure from the consumption of wild animals, wild plants and mushrooms;
(c) Radiation exposure from the use of the groundwater for irrigation.

5.8. If the exposure assessment indicates that the reference levels for the site or area might be exceeded, possible restrictions on use include:

(a) Time limited use of products from agriculture, horticulture, fishery or forestry (e.g. only in winter times);
(b) Quantity limits on the use of products or groundwater (e.g. quantity limitations per year);

(c) Limiting the use of products (e.g. only using wood for construction, rapeseed for fuel production, groundwater for industrial use);
(d) Limits on the types of product from agriculture, horticulture or forestry that can be used (e.g. only flowers, only horses, only oak trees);
(e) No use of agricultural, horticultural, forestry or aquatic products.

Assessments of site-specific radiation exposure scenarios should form the basis for decision making on restrictions for the remediated site or area, considering the reference levels or other criteria specified by the regulatory body or other relevant authorities.

LEGAL INSTRUMENTS FOR POST-REMEDIATION MANAGEMENT

5.9. A key component of regulatory oversight for remediated sites or areas is the use of legal instruments such as encumbrances, easements, and restrictions – commonly referred to as 'deeds'. These measures are crucial to ensure that remediated sites and areas are safely managed over the long term.

5.10. Other restrictions can occur due to other regulations, laws, legal reasons (private or public nature) or interests applicable to the location or type of use of the site or area.

5.11. Encumbrances may include specific restrictions or obligations tied directly to the remediated site or area to ensure compliance with the reference level. For example, encumbrances can limit future land use to ensure that no activities take place that could compromise the stability of remediation measures or increase the risk of recontamination. This is particularly important for remediated sites or areas with residual contamination under controlled conditions.

5.12. Easements can grant responsible parties and/or the regulatory body or other relevant authorities access to the site or area to perform post-remediation activities such as installation of technical infrastructure, sampling at monitoring points, as well as regular inspections. Such activities should be planned and implemented to help ensure that potential risks are identified and addressed at an early stage.

5.13. Deeds can be used as legally binding documents specifying the use of the remediated site or area, for example for:

(a) Infrastructure (e.g. power cables or overhead power lines, railways, roads, water and gas pipelines);
(b) Private or estate property;
(c) Access for cultural events by specific groups (e.g. indigenous population);
(d) Nature conservation area.

5.14. Although deeds have no direct impact on radiation or environmental protection regulations, they should be taken into account as an instrument for administrative control of restricted land use. Deeds may help prevent additional unplanned work, costs or time delay, (e.g. for executing necessary maintenance works) and provide additional means for sustainable long term post-remediation management.

5.15. The long term effectiveness of legal instruments depends on robust regulatory control and continued communication between relevant authorities such as local authorities and the regulatory body responsible for remediation and post-remediation. Compliance with the restrictions established by such legal instruments should be regularly reviewed to prevent violations or to correct them promptly.

5.16. It should be ensured that the provisions of legal instruments are flexible enough to adapt to changing conditions, such as new technological developments or environmental changes.

OTHER REGULATIONS

5.17. The presence of other (i.e. non-radioactive) contaminants should be considered when determining restrictions on the use of resources and foodstuff and the use of the post-remediated site or area. These restrictions can be issued by other relevant authorities (e.g. dealing with environmental protection, water resources, agriculture, mining activities).

5.18. In addition to established legal instruments such as easements, encumbrances, and restrictions, there are a number of other possible regulations that authorities may implement to ensure the long term safety and sustainability of remediated sites or areas. These additional measures provide extra assurance, especially in cases where complex risks or unpredictable developments need to be addressed.

5.19. As stated in para. 2.21, the respective responsibilities and involvement of all relevant authorities should be clearly defined, and their activities should be coordinated for effective and efficient post-remediation management of the site or area.

5.20. Another important regulation might address long term financial assurance for post-remediation management (see also Section 10). For example, responsible parties could be obliged to set aside financial reserves or guarantees to ensure that future monitoring or remediation costs are covered. This minimizes the risk that financial constraints will prevent necessary measures from being implemented.

5.21. If there is an intended change in land use, the responsible party should evaluate the impact of this change. The local authorities should have a procedure to assess this request and involve, where appropriate, the regulatory body to redefine the end state criteria and the restricted reuse of the land. For example, permits might be required before new construction or development projects can begin on remediated sites. Such requirements should be designed to ensure that the original remediation measures are not compromised by subsequent new uses of the site.

6. INVOLVEMENT OF INTERESTED PARTIES FOR REMEDIATED AREAS

6.1. The government and persons or organizations responsible for safety in post-remediation management of sites or areas are required to consult with interested parties (see paras. 5.3(d), 5.12(e) and 5.17 of GSR Part 3 [1]). Effective communication and consultation with interested parties should continue through all phases of remediation, including post-remediation management (see GSG-15, fig. 1 [3]). Information on communication and stakeholder involvement in environmental remediation projects is provided in Ref. [18].

COMMUNICATION AND CONSULTATION WITH INTERESTED PARTIES IN POST-REMEDIATION MANAGEMENT

6.2. Early and continuous involvement of interested parties should be arranged to ensure the identification of concerns and needs of affected communities, which should be integrated into the planning of long term management of remediated sites or areas. Local residents and environmental groups, in particular, can provide valuable information regarding the use of the remediated sites or areas and any associated hazards that might not be sufficiently considered in the post-remediation programme.

6.3. Involving external third parties, such as independent experts or specialized organizations should also be considered. These can contribute to incorporating objective assessments and innovative approaches into the post-remediation programme. They can also offer a neutral perspective and ensure that the remediation and its long term monitoring are transparent and credible. Ongoing dialogue with third parties also helps to build trust in the post-remediation management programme and increase social acceptance. This is particularly important to avoid potential conflicts and promote a sustainable solution that is supported by all parties involved.

6.4. Communication and consultation with interested parties should be integrated in the management system for the long term management of remediated sites or areas, with emphasis on a transparent, inclusive, and collaborative approach. Well-structured communication enables the early identification of potential conflicts and improves collaboration between various parties. Communication should be integrated into the planning process from the beginning to ensure that all relevant interested parties are adequately informed and their concerns are included in decision making processes.

6.5. It should be ensured that the channels and methods of communication used effectively reach different target groups. These channels and methods may include information sessions, public consultations, informational leaflets, online platforms, and meetings with affected groups. Each interested party may have different needs and expectations regarding the delivery of information; as such communication should be tailored to their specific needs.

6.6. Post-remediation consultation with interested parties should be a two-way process, providing information and active listening and gathering feedback. This can be done through surveys, workshops, discussion forums, or special working groups, where experts and community representatives jointly develop solutions. The dialogue should be open and respectful, with particular attention paid to the concerns of affected communities.

6.7. Post-remediation communication and consultation with interested parties should include the collection of feedback and evidence to demonstrate that the opinions and concerns gathered are considered and integrated into decision making. Interested parties should be regularly informed about the progress of the post-remediation programme, as well as changes made in response to the implementation of suggestions. This strengthens trust and fosters long term cooperation. If concerns or proposals are not adopted, a clear explanation should be provided as to why this is the case, ensuring transparency and avoiding misunderstandings.

6.8. Consultation should not only occur during the planning and implementation phases of remediation but should continue throughout the entire long term management of the remediated site or area.

6.9. Periodic reviews and reporting of the implementation of the post-remediation management programme should be performed in close coordination with interested parties and should consider any changes in the surrounding environment or the needs of affected groups.

6.10. Some types of use of the site may inherently involve communicating with interested parties about the long term management and history of a remediated site or area. For example, explanatory signs and displays — or in some cases, museums or visitor centres — could be provided at the entrance to the site or area.

6.11. If a post-remediation management programme for a site or area includes the adoption of self-help protective actions (see 5.17(b) of GSR Part 3[1], and para. 10.12 and appendix II of GSG-15 [3]) an effective and ongoing dialogue between the regulatory body or other relevant authorities and local interested parties should be established. There should not be overreliance on these measures since implementation of them cannot be guaranteed. Examples of self-help measures include washing of food to potentially reduce internal radiation dose, or agreeing to have animals such as fish caught in streams or rivers to be periodically analysed. The regulatory body or other relevant authorities for such self-help actions should provide timely feedback to local interested parties on the results. Regular dialogue and retraining of local interested parties on implementing such actions should also be provided.

ROLE OF 'CITIZEN SCIENCE' IN BUILDING COMMUNITY TRUST AND KNOWLEDGE

6.12. Citizen science, which involves the participation of non-experts in scientific projects, plays an increasingly important role in building trust and knowledge within the public, also in the context of long term post-remediation management of sites or areas. Citizen science promotes active and accompanied citizen participation in the collection, analysis, and interpretation of data, which not only deepens their knowledge of environmental issues but also strengthens their trust in the scientific process and decision makers. It helps to prevent incorrect measurements by citizens, for example, through the use of non-calibrated equipment.

6.13. With regard to post-remediation management, citizen science should be adopted as a means of obtaining observations and data from local people, providing valuable input to the long term monitoring and documentation of remediated sites or areas. This approach should also be used to foster a sense of co-responsibility within the affected communities.

6.14. The active involvement of the public in scientific projects promotes an understanding of the underlying scientific processes and demonstrates how scientific decisions are made. This is particularly important in the remediation of contaminated sites or areas, as the scientific and technical decisions involved can often be complex, and the public may have concerns about potential risks. Thus, it should be ensured that persons who participate in data collection and analysis not only understand the technology behind the remediation processes but also the decisions made and their impact on their immediate environment.

6.15. Residents close to sites or areas being remediated may possess in-depth knowledge of their surroundings that might not always be captured by scientific methods. The aim should be to capture this knowledge and use it when identifying potential hazards or determining the long term monitoring programme. People should be encouraged to observe and report any local changes that might otherwise be overlooked, contributing to more precise and effective monitoring.

6.16. Consideration should be given to inviting local members of the public to help maintain some types of active institutional control such as fences and signs. This would be most effective at remote sites or areas where the party responsible for post-remediation is not continuously present at the site or area.

STRATEGY FOR DEALING WITH SOCIAL MEDIA ISSUES

6.17. A policy and strategy for ensuring transparent communication and building public trust should be established by the responsible party for the long term post-remediation management of a site or area; this should include a social media strategy. Social media platforms provide a direct means of engaging with the general public, disseminating information quickly, and fostering a dialogue between responsible authorities, affected communities, and other stakeholders. These communication channels can help reduce uncertainties, clarify misunderstandings, and actively promote the acceptance of remediation efforts and their long term management.

6.18. To ensure an effective social media strategy in the context of post-remediation management, the responsible party should begin by identifying the relevant target audience(s) and the platforms on which these groups are most active, to ensure that the information reaches the audiences where it will have the greatest impact.

6.19. The responsible party for post-remediation management should determine how the information will be conveyed. The communication on social media should not just disseminate facts but also engage in dialogue with the public. The opportunity for interaction — whether through comments, likes, or direct messages — should be used to provide quick and direct responses to questions and concerns from the public.

6.20. The responsible party for post-remediation management should regularly monitor social media. This includes not only monitoring comments and discussions but also quickly identifying misinformation. In such cases, the aim should be to provide a prompt and accurate response to guide the discourse and correct any false information.

6.21. Communication on social media should remain consistent and up to date. During the long term management of a remediated site or area, new developments or challenges may arise that require adjustments of the strategies. Continuous update of information and regular progress reports or results should be provided to maintain the public's trust and engagement.

6.22. The social media strategy should include a clear plan for crisis communication through social media and be part of the emergency plan (see paras 4.39–4.41). In case of unexpected events during post-remediation management, quick and accurate responses on social media should be prepared to inform and reassure the public. This can help prevent panic or misinformation and ensure that the right information reaches the right audience.

MULTI-GENERATIONAL INVOLVEMENT OF INTERESTED PARTIES IN POST-REMEDIATION MANAGEMENT

6.23. Post-remediation management should be designed to extend beyond the duration of the remediation project and to engage future generations. This involves continuous dialogue and engagement processes to ensure that future generations are considered in the vision and the decisions about the continued use or care of the site or area.

6.24. The responsible party for long term management of a remediated site or area should consider and address the issues associated with involving and engaging interested parties who represent multiple generations, who often have varying ideas and expectations regarding the long term management of remediated sites or areas, which can complicate dialogue and collaboration. One of the major challenges is the exchange of knowledge between generations. Younger generations often have a different approach to information and new technologies, which older generations might not be as familiar with. However, older generations often have a deeper, personal connection to the remediated site and can contribute valuable historical perspectives or local knowledge.

6.25. The responsible party for post-remediation management should implement knowledge management arrangements to ensure that different forms of generational knowledge are integrated to improve long term monitoring, communication and decision making.

6.26. Older generations may feel a stronger sense of responsibility for the history and preservation of local resources, while younger generations may be more focused on future perspectives and integrating modern sustainable solutions. These differing perceptions should be combined to develop a balanced approach that considers both the needs of current and future generations and long term sustainability.

6.27. The challenges are further intensified by the varying communication habits and preferences of different generations. While older generations tend to prefer traditional communication methods such as meetings, printed materials, or face-to-face conversations, younger generations often rely on digital platforms, such as social media, websites, or online fora. The responsible party for post-remediation management should implement a flexible and diverse approach to communication that reaches all age groups and considers long term perspectives.

7. MANAGEMENT SYSTEM FOR REMEDIATED SITES OR AREAS

7.1. Requirement 5 of GSR Part 3 [1] states that "The principal parties shall ensure that protection and safety are effectively integrated into the overall management system of the organizations for which they are responsible."

7.2. Requirement 6 of GSR Part 2 [12] states that: "The management system shall integrate its elements, including safety, health, environmental, security, quality, human-and-organizational-factor, societal and economic elements, so that safety is not compromised."

7.3. The management system should be defined through a structured set of documents that outline the overall controls and measures the responsible party for post-remediation should develop and implement to achieve the post-remediation objectives. These controls and measures should apply to all activities conducted by the responsible party. Post-remediation actions should be performed in accordance with the management system by properly trained and qualified workers, following established working procedures defined by the responsible party for post-remediation.

7.4. The documentation of the management system should be tailored to the organization of the responsible party and the post-remediation programme. The documentation should be clear and easily understandable for the workers and, as necessary, be flexible to accommodate

changes. It should be developed in compliance with regulatory requirements and conditions defined by the regulatory body or other relevant authority.

7.5. If the organization responsible for post-remediation management at the site or area is different from the responsible party for the remediation activities, early engagement between the both organizations should be arranged. All records and archives related to the remediation should be transferred to the new organization and integrated into its management system.

7.6. The management system should also specify any work delegated to external organizations. It should clearly define the lines of communication and interfaces between internal and external organizations and subcontractors as well as the responsibilities of each organization for assigned tasks.

MANAGEMENT OF DOCUMENTATION FOR POST-REMEDIATION MANAGEMENT

7.7. The top level of the documentation associated with the post-remediation management of a site or area should outline the responsible organization's vision, mission, and goals, as well as its organizational structure and clearly defined responsibilities. The second level of the documentation should outline the management system processes used to achieve the post-remediation goals, as well as the associated responsibilities and lines of communication. These processes can be grouped in accordance with the following areas, as applicable:

(a) Surveillance;
(b) Maintenance (preventive and corrective);
(c) Environmental monitoring;
(d) Operation of facilities;
(e) Administrative controls;
(f) Emergency preparedness and response;
(g) Management of residual materials;
(h) Radiation protection, including the integration of occupational radiation protection with other areas of occupational health and safety;
(i) Site security;
(j) Involvement of interested parties;
(k) Transfer of knowledge;
(l) Research and development;
(m) Management of financial resources;
(n) Human resources.

At the third level of the documentation hierarchy, detailed instructions and guidance should be provided to ensure the effective execution of post-remediation activities.

DOCUMENT CONTROL

7.8. Document control should include the following:

(a) Establishment of a system for unique identification and classification of documents to ensure proper organization and traceability;

(b) Procedures for the approval of documents before they are issued or used;

(c) A controlled distribution of documents to relevant personnel and making them accessible to authorized users as needed;

(d) Revisions and updates to documents, and procedures to ensure that the latest versions are available, and that obsolete versions are removed or appropriately archived.

(e) Defined retention periods for documents and secure archiving to preserve important records for regulatory, legal, or organizational needs;

(f) A process to control documents received from external organizations, including suppliers, contractors, the regulatory body and other relevant authorities;

(g) Protection of confidential documents from unauthorized access, modification, or loss;

(h) Specification of standard formats, templates, or guidelines for consistent documentation within the organization;

(i) Regular reviews to ensure documents remain accurate, relevant, and aligned with current processes and standards;

(j) Staff training to ensure that document control policies are understood and applied.

8. LONG TERM CHALLENGES AND RISKS FOR REMEDIATED AREAS

RARE EVENTS AND UNFORESEEN EVENTS

8.1. The management of a remediated site or area can face significant challenges posed by rare or unforeseen events that occur over the long period of post-remediation management. These events can have natural or human-made causes and can impact both the original remediation and the long term safety and monitoring of the site or area. Rare events such as geohazards or other natural disasters including earthquakes, floods, or extreme weather conditions can significantly affect the condition of the remediated site or area by damaging existing barriers or protective structures. Events such as heavy rainfall or rising groundwater levels can affect the mobility and migration of radionuclides in the environment.

8.2. To apply the concept of defence in depth at a remediated site or area, diverse and redundant technologies for barriers, covers or storages should be considered, especially if the site or area is in an environment such as a flood zone, earthquake zone or subject to large temperature fluctuations.

8.3. In addition to natural events, there are other events that present challenges to post-remediation management, such as:

(a) Technical problems or human errors. For example, material failures in remediation structures or the malfunctioning of monitoring equipment might compromise the integrity of the remediation.

(b) Changes in the use of neighbouring areas or unforeseen industrial developments.

(c) Unforeseen socio-economic or geopolitical changes. The local population could also exert unforeseen pressure on the sites due to socio-economic changes, such as rapid growth or alterations in land use, leading to potential conflicts.

To address these challenges, a flexible and adaptive post-remediation management programme should be established, which can be periodically monitored and adjusted. Plans should be developed and regularly tested to ensure a fast response to rare events. Close collaboration should be arranged between the regulatory body or other relevant authorities, the responsible parties, site owners, and other interested parties to minimize risks and ensure the long term resilience of a remediated site or area.

8.4. Response to rare or unforeseen events should be addressed in the emergency plan for a site or area (See paras 4.39–4.41).

CLIMATE CHANGE

8.5. The potential for long lasting changes in the environment due to climate change should be considered in the post-remediation management of a site or area. Climate change can lead to more extreme weather conditions than assumed during the remediation planning. Some types of remedial feature may have been designed for a certain range or frequency of events (e.g. annual precipitation, maximum intensity of a rainfall event) that are no longer valid due to climate change in the post-remediation phase. Surveillance of existing structures during post-remediation should therefore include evaluation of the integrity and durability of the structures beyond the original design basis.

8.6. Climate change may also increase the frequency or magnitude of geotechnical hazards and other rare events. For example, higher precipitation could cause landslides by saturating soils on slopes, and reduced precipitation might increase the risk of wildfires.

8.7. The post-remediation management programme should be reviewed periodically to take account of new climate conditions. For example, the responsible party might supplement a regulatory scheduled monitoring or surveillance activities with the same activities occurring after climate change driven events (i.e. event driven monitoring and surveillance).

NEW REGULATORY REQUIREMENTS

8.8. The post-remediation management programme should be approved by the regulatory body or other relevant authority. Over time, regulations, code and standards may change and the regulatory body or other relevant authority should consider how such changes might affect existing approvals.

SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENTS

8.9. New technologies may offer improvements in monitoring, control, and post-remediation oversight, but can also introduce previously unknown risks or necessitate adjustments to the post-remediation management programme. For example, the development of new measurement technologies or analytical methods could reveal previously undetected residual contamination. Such advances may challenge earlier assumptions about the safety or stability of the remediated site and may initiate a reassessment of the remediation measures implemented.

8.10. Technological progress should be balanced against the stability of the established post-remediation management programme. The introduction of new technologies should be

undertaken with care to avoid unintended side effects, such as disruptions to already stabilized ecosystems or technical structures. Only proven technologies should be considered.

8.11. Post-remediation activities may rely on technological expertise and the availability of specialized personnel. The post-remediation management programme should therefore take into account that technological advancements may involve specialized training and continuous adaptation of personnel skills.

UNCERTAINTIES OF KNOWLEDGE

8.12. The long term management of remediated areas is significantly impacted by uncertainties in existing knowledge and understanding. These uncertainties affect both the scientific evaluation of a site or area and the ability to predict future developments, potentially leading to poor decision making and planning. A key issue is the limited understanding of long term geochemical and physical processes that might occur on a remediated site or area. Many of these processes, such as the mobility of residual contamination or the stability of barriers, are not yet fully understood. The lack of long term data makes it difficult to accurately predict the behaviour of contaminants or protective measures.

8.13. To address these uncertainties, the responsible party should ensure that the post-remediation management programme (see paras 4.2–4.19) is flexible and adaptable, based on an iterative approach. The monitoring and surveillance programme should be regularly reviewed and, as necessary, updated to reflect the current state of knowledge.

OTHER RISKS AND THE USE OF A HOLISTIC APPROACH

8.14. The management of remediated sites or areas requires a holistic approach that considers the multiple potential risks and the complex interactions between technical, environmental, and socio-economic factors. This involves systematically identifying and evaluating the various risks and their interdependencies.

8.15. In some cases, social acceptance might be insufficiently weighted. Engagement with local populations and other interested parties (see Section 6) is a means of assessing the weight of social acceptance.

8.16. To address these challenges, the responsible party should undertake regular evaluations of the post-remediation management programme, fostering interdisciplinary collaboration, and establishing transparent communication and decision making processes. Only through the continuous integration of new knowledge and the active involvement of all relevant interested parties can a holistic approach be successfully implemented over the long term.

9. KNOWLEDGE MANAGEMENT FOR POST-REMEDIATION MANAGEMENT

PRESERVATION AND TRANSFER OF RECORDS TO FUTURE GENERATIONS

9.1. Paragraph 5.10(d) of GSR Part 3 [1] states:

"For the remediation of areas with residual radioactive material deriving from past activities or from a nuclear or radiological emergency…the government shall ensure that provision is made in the framework for protection and safety for:

(d) An appropriate system for maintaining, retrieval and amendment of records that cover the nature and the extent of contamination; the decisions made before, during and after remediation; and information on verification of the results of remedial actions, including the results of all monitoring programmes after completion of the remedial actions."

9.2. Paragraph 5.12(g) of GSR Part 3 [1] states:

"The persons or organizations, responsible for planning, implementation and verification of remedial actions shall, as appropriate ensure that:

(g) A system for maintaining adequate records relating to the existing exposure situation and to actions taken for protection and safety is in place."

9.3. Paragraph 10.9 of GSG-15 [3] states that "The records collected should be stored for a period of time as deemed appropriate by the regulatory body. This will ensure that the decisions and actions taken, as well as the results achieved, can be reviewed as needed in the future."

9.4. Effective record management is one of the most important elements of post-remediation knowledge management. The records collected during pre-remediation, remediation and post-remediation should be stored and archived in a comprehensive and clearly structured documentation system, ensuring the consultation by future generations in a suitable system, using a record management system. Such storage and maintenance of records should last over multiple generations. This should ensure that the decisions and actions taken, as well as the results achieved, can be reviewed as needed in the future.

9.5. The archived records should be used to create information for communication with interested parties, to evaluate the trends of post-remediation monitoring results, and as a technical basis for updating decisions on restrictions on reuse or re-habitation of a remediation site or area.

9.6. Adequate information about the remediated sites and areas should be retained, such as:

(a) The location of each remediated site or area;
(b) The essential design features of each site or area, including physical shape and barriers, description of operation and closure procedures;
(c) Conditions of any authorizations issued for remediation, if applicable;
(d) Records of the inventory of radioactive material and other hazardous materials, including chemical composition and physical characteristics of materials, if known;
(e) Data and methods used for the safety assessment;
(f) Monitoring and surveillance data;
(g) Results of the maintenance programme.

9.7. A process should be established to manage records and make them easily accessible. Record keeping is particularly important where restrictions are imposed on the future use of

areas. However, even in the situation of complete release from regulatory control, records on the history of the areas and remediation measures implemented should be available for future generations.

9.8. The organization responsible for record keeping should be designated for each site or area. A national record system may be used. Regardless of the organization or system used, it should be ensured that the record keeping system is maintained and updated and that records are available to interested parties.

9.9. The responsible parties for post-remediation management should make provisions to make copies of records available to interested parties. The technical reports submitted to the regulatory body or other relevant authority may be too detailed for members of the public. Therefore, the responsible party for post-remediation management should also develop records specifically tailored for working with interested parties that summarize activities and results.

PRESERVATION AND TRANSFER OF KNOWLEDGE OF THE REMEDIATION TO FUTURE GENERATIONS

9.10. Knowledge management should involve the collection, storage, and ongoing updating of information on all relevant aspects of the remediation of a site or area, including geological data, remediation technologies used, chemical analyses, and monitoring protocols.

9.11. Knowledge retention is particularly important when remediation projects need to be assessed over an extended time period such as the post-remediation phase. Information should be stored and mechanisms should be established to regularly review and update the knowledge. This practice ensures that important information is retained, even in the event of personnel changes or technological advancements.

9.12. Organizations responsible for post-remediation management should have strategies for proactively addressing knowledge management, The reasons for this include:

(a) Post-remediation management for a site or area with residual contamination can be a multi-generational programme. Changes in personnel because of retirement or people taking new positions are inevitable in organizations over these time frames. Important institutional knowledge, particular tacit knowledge, can be lost. Responsible parties should plan for knowledge collection, particularly if it is known when an employee is leaving.
(b) Except for high risk or complex sites or areas, responsible parties employ far fewer people for post-remediation management compared to active remediation. Consequently, turnover in personnel might have greater impacts on knowledge retention, especially of tacit knowledge.
(c) Tasks performed during post-remediation management require skilled and knowledgeable personnel, for example for risk analysis (for evaluating whether sites or areas are continuing to meet end state criteria), modelling (such as reassessing safety assessments and environmental impact assessments), civil engineering for evaluating integrity of active institutional controls (such as disposal sites, cells, and covers), and persons for monitoring, laboratory analysis of samples and maintenance and calibration of laboratory and field instruments.

9.13. Responsible parties should consider the following strategies for post-remediation knowledge management:

(a) Data from sample analysis and monitoring should always include observations about the collection and analysis by those performing it. The data alone may be sufficient to demonstrate compliance (e.g. with reference levels), but without the additional contextual information it has far less value for post-remediation.
(b) Periodically arranging for post-remediation management activities to be performed by multiple persons, such as a one with significant experience at a particular site or area and a new employee.
(c) Making sure that information prepared as part of public engagement is also available as training material for new employees. The information that the public and interested parties will increasingly need, will also benefit employees who were not present when the site or area was remediated.
(d) For expertise that might only occasionally be needed for post-remediation management, partnering with other organizations (e.g. a university, an operating nuclear facility) to create positions that are full time and more attractive for hiring and retaining people.

9.14. Long term knowledge management and the intentional transmission of information should address four main issues as described in Ref. [19]:

(a) How to transmit knowledge over long periods of time;
(a) The kind of knowledge to be stored;
(b) The types of data and information needed;
(c) The types of storage media.

9.15. The responsible parties for post-remediation management should make arrangements for early engagement with persons performing the remediation, as part of knowledge transfer about pre- and post-remedial area conditions.

9.16. Knowledge management should include sharing experiences and data across various post-remediation projects and authorities to identify and disseminate best practices. This not only enhances the effectiveness of future remediation and post-remediation efforts but can also contribute to the development of new remediation technologies and methods.

10. FUNDING FOR POST-REMEDIATION MANAGEMENT

FUNDING MECHANISMS FOR CURRENT COSTS

10.1. Funding post-remediation management has similarities to funding the remediation of sites or areas. Paragraph 5.10(a) of GSR Part 3 [1] states:

> "For the remediation of areas with residual radioactive material deriving from past activities or from a nuclear or radiological emergency…the government shall ensure that provision is made in the framework for protection and safety for:
>
> (a) The identification of those persons or organizations responsible for contamination of areas and those responsible for financing remediation programme and the determination of appropriate arrangements for alternative sources of funding if

such persons or organizations are no longer present or are unable to meet their liabilities".

10.2. For the remediation of areas, para. 5.10(b) of GSR Part 3 [1] states that "the government shall ensure that provision is made in the framework for protection and safety for the designation of persons or organizations responsible for…verifying the results of remedial actions".

10.3. Mechanisms for financing post-remediation management can include the following:

(a) Taxes or levies on current industries similar to those that originally created the contamination (e.g. levies or royalties from the sales of ore or product from present day mining operations).
(b) Levies on the price paid by consumers of electrical power from nuclear power, in cases where the contamination is from the nuclear fuel cycle.
(c) Appropriations of funds generated by general taxation such as income taxes or on profits by commercial business.
(d) Appropriations of funds generated through reuse or recycling of material (e.g. scrap metal) from a contaminated site or reprocessing (e.g. for other constituents, better recovery techniques) of tailings from mining activities. The relevant authorities should then agree that the company will perform remediation and post-remediation management in exchange for the beneficial use of the site.
(e) Designation of funds for particular accounts (e.g. a radioactive waste fund, decommissioning fund or an environmental protection fund) and policies to prevent use of the funds for other expenditures.

10.4. Paragraph 2.50 of GSG-15 [3] states:

> "The relevant authority should review the financial arrangements on a regular basis to ensure that adequate financing will continue to be available, taking account of any changes in the remediation plan resulting from new information generated during the course of remediation."

Consequently, whatever funding mechanism is used for post-remediation management, the relevant regulatory authority should review the financial arrangements on a regular basis to ensure that adequate funding will continue to be available.

FINANCIAL ASSURANCE FOR UNFORESEEN COSTS

10.5. Rare or unforeseen events at a site or area (see paras 8.2–8.5) might cause sudden degradation of engineered remediation structures or necessitate immediate action to prevent the release and spread of contaminants. The responsible party for post-remediation management should establish a dedicated fund that is only used for actions that need to be taken after rare and unforeseen events (e.g. landslides, damage from seismic events, wildfires). In some states, these funds are held by a third party so that the responsible party cannot use them for other activities.

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ANNEX I : CASE STUDY ON POST-REMEDIATION MANAGEMENT OF THE WISMUT LEGACY SITE, GERMANY

I–1. Shaft n° 382 is the name of a significant ventilation shaft of the uranium mining operations run by SDAG Wismut in the former German Democratic Republic. It was built between 1959 and 1964 to a depth of over 1,400 m, and was used for supplying fresh air to the underground workings. It was equipped with powerful ventilation systems, ensuring efficient airflow across multiple levels.

I–2. Uranium mining ceased in 1990. In 1997, Shaft n° 382 was converted into an exhaust shaft to allow the controlled release of radon and other mine gases from the remediation works. This involved reopening 47 km of previously sealed tunnels. The shaft's waste heap was used as a repository for mining debris and later covered and greened for environmental protection purposes: today, a golf course occupies the site. While the shaft itself is not accessible to the public, the nearby Markus Semmler Visitor Mine offers historical insight into uranium mining in the region.

I–3. Waste rock pile n° 382 was created between 1948 and 1958. From 1959 to 1964, the disposal of material from the construction of the ventilation shaft n° 382 took place on the waste rock pile. As a result of the mining activities, a slope was filled and formed in the shape of a table heap with a footprint of 28 ha, and a dumping volume of 3.25 million cubic meters of waste material.

I–4. With the ending of mining activities in 1991, the buildings and facilities of the mine that were no longer needed and could not be reused had to be demolished. Figure I–1 shows waste rock pile n° 382 at the end of 1992, two years after uranium production ceased.

I–5. For waste rock pile n° 382 and its surrounding areas, a need for remediation was identified due to concerns of long term stability as well as environmental protection [I–1]. The previously used areas were to be remediated for forestry use in the waste rock pile slopes and for use as a park and recreational site (golf course) in the plateau area [I–2].

I–6. The remediation of waste rock pile n° 382 involved contouring the heap and covering it with a standardized layered structure, with a thickness of 1 m (on the plateau area) and 0.3 m on the profiled slopes, as well as water and road construction, and the greening of the covered areas. Figure I–2, shows the waste rock pile and shaft n° 382 in 2000, three years after start of remediation activities.

I–7. Remediation work on waste rock pile n° 382 took place from 1997 to the end of 2010; post-remediation activities began in 2011. The aftercare period of 15 years includes a five year period following the completion of the remediation work for post-remediation activities, and a subsequent ten year period for long term tasks. Figures I–3 and I–4 show the waste rock pile n° 382 during remediation activities in 2003 and 2005.

FIG. I–1 *Waste rock pile and shaft n° 382 in 1992, two years after end of uranium production (Archive Wismut GmbH)*

FIG. I–2 *Waste rock pile and shaft n° 382 in 2000, three years after start of remediation activities (contouring) (Archive Wismut GmbH).*

FIG. I–3 *Waste rock pile and shaft n° 382 in 2003, showing contouring works and installation of the* cover *(Archive Wismut GmbH).*

FIG. I–4 *Waste rock pile and shaft n° 382 in 2005, showing that final cover is nearly finished (Archive Wismut GmbH).*

I–8. The controls on the effectiveness of the remediation measures, as required by the provisions of the radiation protection permit issued by the responsible authority for radiation protection in 2003, as well as the related monitoring programme [I–3], were integrated into a post-remediation plan that was approved in 2008.

I–9. The conditions for the termination of regulatory mining supervision were achieved and structural remediation activities approved under the mining laws, were completed in 2010. However, the restrictions on use resulting from the radiological assessment continued to apply. The post-remediation plan described the post-remediation activities, long term tasks and the monitoring of the effectiveness of the remediation measures for a period of up to 15 years after the completion of the remediation activities. The post-remediation period began on January 1, 2011. The provisions of the post-remediation plan were reviewed regularly, based on the monitoring and control results and adjusted to the current circumstances. This review was conducted annually during the five year post-remediation phase. The established controls included regular visual inspections, maintenance measures, repair works (if needed) and radiation protection measurements.

I–10. Annual reports were required to be submitted to the responsible authority, and the post-remediation plan was required to be reviewed every five years. Changes in the post-remediation plan, resulting from the findings, were submitted for approval to the responsible authority.

FIG. I–5 *Waste rock pile and shaft n° 382 in 2010, showing covering works completed and the revegetation step (Archive Wismut GmbH).*

I–11. The post-remediation plan also included a financial estimate of the cost for the planned post-remediation work within the five year period. Since there were insufficient data at that time to precisely determine the costs for long term aftercare of remediated waste rock piles, the financial need was only estimated approximately.

I–12. The long term tasks following this post-remediation phase were based on the requirements to ensure a long term stable remediation condition [I–4].

I–13. The use of the cover to control radon emanation was not an original aim of the remediation. However, the implementation of the cover in the plateau area did result in a reduction of radon emanation, which was confirmed by the results of measurements on the waste rock pile and in its surroundings. Exposures due to the use as park and recreational area (golf course) and forestry area (the slope area), were assessed as remaining within tolerable reference levels [I–5].

FIG. I–6 *Waste rock pile and shaft n° 382 in 2014, showing preparation of the golf course (Archive Wismut GmbH).*

I–14. Corresponding measurements of radon emanation and radon concentration in the near-surface air, as well as monitoring of groundwater and infiltrating water (sewage), to control the effectiveness of the completed remediation measures, also began in 2011 [I–7] and were performed until 2021.

I–15. Wells were installed for the monitoring of groundwater and infiltration water (sewage) and a radiological assessment of the impact of the associated exposure pathways was conducted [I–8]. Groundwater monitoring was terminated by the responsible authority at the end of 2014.

I–16. As a result of a final inspection in 2021 [I–9], no deficiencies were found regarding the termination of mining supervision for the area of waste rock pile n° 382. The land was made available for use, and the planned recreational use (as a golf course) was prepared in accordance with the requirements of the Special Operating Plans. Part of the area was transferred to a private company for the establishment of the golf course "Golfpark Westerzgebirge." The final transfer of ownership took place in September, 2011. The transfer of effective usage of the areas from Wismut to the private company concerning waste rock pile n° 382 occurred in 2013.

FIG. I–7 *Waste rock pile n° 382 in 2015, two years before end of post-remediation activities, golf-park in construction (red shape) (Archive Wismut GmbH).*

FIG. I–8 *Waste rock pile n° 382 in 2021, end state with established golf course (Archive Wismut GmbH).*

I–17. At the beginning of 2016, all obligations for the relevant parts of waste rock pile n° 382 were fully transferred to the new property owner. From then, it became the responsibility of the new owner to organize the necessary monitoring independently. Up until 2021, Wismut GmbH continued to perform the monitoring on behalf of the new property owner.

I–18. The new owner of the remediated areas was also informed that potential future deep excavation works might result in handling radioactive material. Works under the responsibility of the new landowner (including control measurements and transport of the material to an approved location) had to be performed in accordance with the radiation protection regulations (approval, radiation protection assessments, and monitoring). Also, the functionality of the cover had to be ensured after the works were completed.

I–19. The discharge point for the infiltration water (sewage) from waste rock pile n° 382 is located in the immediate boundary area. Therefore, the local authority became the responsible party for the discharge authorization [I–10].

FIG. I–9 *Established golf course with golf players (https://golf-bad-schlema.de/angolfen-samsonite-golf-club-tour/).*

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ANNEX II : CASE STUDY ON POST-REMEDIATION MANAGEMENT OF THE FERNALD PRESERVE SITE, UNITED STATES OF AMERICA

INTRODUCTION

Site Description

II–1. The Fernald Preserve Site is a former U.S. Department of Energy (DOE) uranium processing facility that produced high-purity uranium metal products. It operated from 1951 until 1989. The site occupies 500 ha of land in a rural area, approximately 30 km northwest of Cincinnati [II–1].

II–2. The Feed Materials Production Center (FMPC) as it was called during operation also received materials from other DOE sites to recycle and recover uranium. Finally, radioactive and other hazardous waste from other DOE sites was stored there. The FMPC's name was changed to the "Fernald Environmental Management Project" to reflect the change in mission from manufacturing to environmental remediation that commenced in 1989. Except for the need to continue to operate a groundwater and leachate treatment system, remediation was completed in 2006, and the site was transferred to the DOE Office of Legacy Management (LM) for post-remediation management.

II–3. The site is now known as the Fernald Preserve because of a decision by interested parties to use the site as a nature preserve. The site is now open to the public year-round and has 12 km of hiking trails and boardwalks that cross wetlands in the area. The Fernald Preserve also has a visitor centre exhibiting historical information regarding the site's production and remediation activities, which is also used to host environmental education activities (see Fig. II–1).

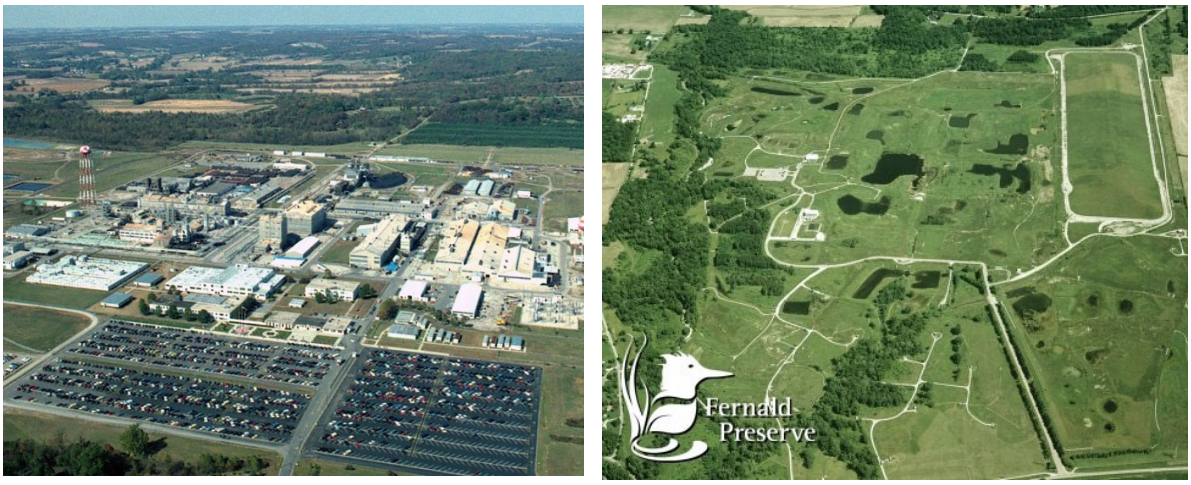

FIG. II–1. *Fernald Site in 1987 before operations ceased (left) and in 2010 (right), five years after remediation of the site was finished (from DOE LM, 2017, A Decade of Difference).*

Regulatory Context

II–4. Remediation of the Fernald Site was performed in accordance with Ref. [II–2]. The U.S. Environmental Protection Agency (EPA) and the State of Ohio Environmental Protection Agency (Ohio EPA) were regulatory authorities for the remediation and continue to provide regulatory oversight for post-remediation management.

II–5. Remediation of the Fernald Site and its conversion to a preserve had to overcome significant and legitimate distrust that regulatory authorities and the public had about the FMPC. For example, in 1984, uranium contamination was detected in wells of homeowners near the site. Also, in 1996 DOE contributed to the cost of a public water supply system for some people living near the site because of further evidence of groundwater contamination. However, there were no requirements for the FMPC to report releases of contaminants during its operation [II–3, II–4].

II–6. During the facility's operation, processing activities led to the contamination of site soil, surface water and groundwater. In addition, as part of remediation of the site, more than 300 buildings, supporting equipment, hazardous material inventories, scrap metal piles and remediation facilities were addressed. On-site buildings were decontaminated and dismantled. Although uranium was the primary contaminant of concern, other contaminants included radionuclides such as technicium-99, thorium, non-radioactive metals (including arsenic, beryllium, cadmium, silver, nickel and lead) and organic solvents.

II–7. Remediation of the Fernald Site was aided by the ability to ship high activity waste to commercial and DOE operated regional disposal facilities. However, 80% (by volume) of the radioactively contaminated material (mostly soil, but also scrap metal that could not be recycled) was disposed in the On-Site Disposal Facility (OSDF). The OSDF, which appears today as a linear hill on the west side of the area, contains about 2.3 million cubic meters of low level radioactively contaminated soil and other material.

POST-REMEDIATION MANAGEMENT PROGRAMME

Involvement of the public and other interested parties

II–8. Although growing concern about public health led to the creation of Fernald Residents for Environmental Safety and Health (FRESH) in 1984, the formation in 1993 of the Fernald Citizens Advisory Board (FCAB), funded by DOE, helped to focus public input on the desired end state for remediation of the Fernald Site [II–6]. There was widespread support among interested parties in a remediation end state that would make the site suitable for use as an ecological reserve with public access, which could also support environmental education.

II–9. Public involvement and support for the mission of what is now referred to as the "Fernald Preserve" continues to this day. For example, Ref. [II–7], is the primary document that defines LM post-remediation management activities. It is updated annually, and LM makes it available on-line for public review and comment.

Post-remediation management activities

II–10. In addition to ecological restoration of the site, major post-remediation activities include the following:

(a) Operation of the groundwater extraction and treatment system at the Fernald Preserve and the treatment of leachate from the OSDF. These are the major remaining remediation activities that are continuing as part of post-remediation management of the site. A significant regional aquifer was contaminated as part of the FMPC operations, and is being remediated to comply with standards established by the U.S. EPA [II–8]. The main contaminant of concern is uranium for which the limits in Ref. [II–8] is 30 micrograms per L, although water samples are analysed for about 50 constituents and parameters.

(b) Maintenance of the OSDF. A leachate collection system directs fluids from the OSDF to the groundwater treatment plant, although it is a small percentage of the liquids compared to groundwater that are treated. A native grass cover is maintained over the OSDF to control runoff and prevent erosion. LM partners with the U.S. Forest Service to periodically perform controlled burns to prevent the growth of deep-rooted vegetation that might damage the cover of the OSDF. Growth of the native grasses is also stimulated by periodic burning (Fig. II–2).

(c) Operation of the visitor centre, which is identified in the post-remediation management plan for Fernald as a formal passive institutional control because it provides information on the history of the site and remaining contaminants as well as passive land use restrictions to prevent inadvertent exposure (e.g. prohibitions on well drilling) as well as restrictions on hunting and fishing.

(d) Other surveillance and preventative maintenance activities such as examinations of the OSDF, sampling of groundwater and surface water, the repair of fences around the site, maintenance of trails and other visitor use facilities such as blinds for bird watchers, as well as records management.

FIG. II–2. *Controlled burn being conducted on the Fernald Preserve* .

Periodic review of post-remediation management activities

II–11. In accordance with Ref. [II–2], sites that are being remediated or are in post-remediation management undergo a review every five years. The purpose of this review is to ensure that

post remedial management activities demonstrate that the remediation measures are still protecting the public and the environment as well as to assess progress in completing groundwater remediation. Regulatory authorities and LM conduct the review, but there is also significant involvement by the public.

Natural resource damage liability and restoration of the Fernald Site

II–12. Section 107 of Ref. [II–2], the law by which the Fernald Site has been remediated, states that parties responsible for contamination and damages to natural resources can be required to pay for protection and recovery of similar environmental resources. In 2008, LM agreed to establish a trust fund of nearly $14 Million US Dollars to be used for restoration of environments at the Fernald Site as well as adjacent areas. LM, the Ohio EPA, and the U.S. Fish and Wildlife Service serve as "Natural Resource Trustees". The Trustee Council's goal is to acquire, replace, or restore any natural resources that have been harmed by past releases at the Fernald Preserve. With significant input from the public, a plan was first developed in 2010 for use of the funds.

II–13. Among the uses of the fund has been the direct purchase of land adjacent to the Fernald Site that further extends the types of habitat restored on the Fernald Site. In addition to purchase, the trustees can establish a "conservation easements" (a form of land use control), where a landowner voluntarily agrees to protect habitats on their property or to manage their land in such a way that it better protects natural resources on the Fernald Preserve. By 2015, the trust funds had been used to protect an additional 1200 ha and connect natural area land with the Fernald Preserve. A report is published annually on how the funds were used [II–9].

CLOSING REMARKS

II–14. Today, the Fernald Preserve encompasses over 142 ha acres of prairie land, 57 ha of wetlands and open water, about 162 ha of forest, and 12 km of trails. Conservation easements with adjacent projects have increased the ecological significance of the site by connecting other areas where natural habitats exist. Native grasses and plants have been restored on the property, and the restoration activities created one of the largest human-made wetlands in the region. More than 250 species of birds have been observed at the Fernald Preserve.

II–15. The site was awarded the National Federal Facility Excellence in Site Reuse Award by the US EPA in 2019 [II–5]. Use includes the Fernald Preserve Visitors Center, which has a large community meeting room available to nonprofit organizations; an extensive onsite and offsite public outreach programmes to local schools as well as the trails and interpretive signage. Site staff interact regularly with regional schools to ensure that academic standards are addressed during field trips and programmes. The curriculum is coordinated with instructors from kindergarten to 12th grade, as well as undergraduate and graduate programmes (Fig. II–3). In 2023, it was estimated that 60,000 people visited the site, including 14,000 that engaged with LM at the visitor centre [II–10].

II–16. The popularity of the site is evident from some of the special events at the site that originate from organizations other than LM. For example, in 2025 a "Winter Bird Fest" was hosted at the Fernald Preserve that included bird banding demonstrations and presentations on research on owls that are residents of the site among other events over 8 days. This and other uses continue while post-remediation management activities for residual contaminants take place.

FIG. II–3. *"Back to School" programmes and outreach brochure for the Fernald Preserve in 2024.*

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