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DELIVERABLE D4a: Ecological Risk Characterisation: An Interim Method for the ERICA Integrated Approach

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ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management) will provide an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of contaminants emitting ionising radiation, with emphasis on biota and ecosystems. The project started in March 2004 and is to end by February 2007.

Erica tetralix L.

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Executive Summary

Ecological Risk Assessment (ERA) is an increasingly important component of any decision-making process that aims to provide transparent management decisions on environmental practices and associated problems. It is the method of risk assessment being applied and developed as part of the ERICA integrated approach, including the various aspects of planning, problem formulation, assessment, risk characterisation and decision and management. One of the challenges in developing risk assessment guidelines is to provide a method that can be applicable to different cases and contexts, including historical and ongoing activities (retrospective risk assessment), future activities (prospective risk assessment), and evaluation of both chronic (e.g. routine) and acute (e.g. accidental) releases. In this respect, ERICA is proposing a flexible approach to risk assessment and risk characterisation, in the form of a tiered approach, which allows for greater integration between the assessment, characterisation and decision-making aspects of ERA.

This document introduces the tiered assessment as an interim method for the ERICA integrated approach which focuses on the technical aspects of the actual ERA method. It does not consider in detail how the ERICA integrated approach will handle the stakeholder and decision-making aspects which will be discussed and expanded by other participants in the ERICA project. This part of the deliverable (D4a) provides general guidelines and principles to demonstrate how ecological risk assessment and management processes can be applied across the range of activities that use radioactive substances. These guidelines and principles have been derived on the basis of the review presented in Deliverable Part b (D4b).

Although the method has not been fully developed, there are a number of reasons for introducing this interim approach at such an early stage in the project. Firstly, the good practice guidance for risk characterisation (deliverable D6) is not due until month 34 (out of 36) of the ERICA project. The ERICA consortium felt that this left too little time for detailed interaction with the ERICA end user group (EUG). Hence, the risk assessment guidelines described in the following sections have been drafted to facilitate, and stimulate, discussion between the EUG and other interested stakeholders and the ERICA participants as an interim stage in the development. Secondly, the ERICA consortium needs to agree on a basic approach to test and apply the assessment and modelling tools being developed in other parts of the project, as well as the basic guidelines for decision-making.

The proposed risk assessment guidelines are based on a tiered design as outlined in Figure I. The following text outlines some of the key requirements/processes associated with each tier of the assessment and which are then discussed within this document.

Problem formulation

- Defines the scope, purpose and endpoints of the assessment;
- Will consider what is already known about the site, its historic use and the proposed or operational practice being assessed;
- Some stakeholder engagement is required in the problem formulation to ensure that all aspects are considered;
- Uses a conceptual model to lay out the issues in a clear and transparent manner;
- Defines any source – pathway – receptor linkages present.

Tier 1 (Screening)

- Evaluates the risk using a conservative approach;
- Uses maximum environmental activity concentrations derived from measured or modelled concentrations in various environmental media – and takes no account of spatial or temporal variation;
- Compares the measured/modelled activity concentrations for each radionuclide being considered against the lowest environmental media limiting activity concentration backcalculated from Predicted No-Effect Dose Rates (PNEDR)(section 2.1.3 describes this in more detail);
- Has the advantage of identifying which radionuclides present at the site would contribute most to the exposure of the reference organisms. This can then guide decisions of resource allocation for acquisition of additional information if the assessment proceeds to the higher tiers.

Tier 2 (Generic assessment)

- Incorporates dispersion modelling techniques (using site-specific models or default models that will be made available within the ERICA assessment tool);
- Introduces available site-specific data or encourages its collection;
- Compares the predicted dose rates to the same limiting dose rate (PNEDR) considered in tier 1, but by using dose rates. This introduces the flexibility to use different, but justified, radiation weighting factors for different radiation types. It is also possible to carry out the calculation for all reference organisms, not only the one that led to the minimum value of the environmental media activity concentration;
- May involve evaluation of the likely biological effects of exposure to ionising radiation by comparing predicted dose rates to data held on effects, for example within the FREDERICA database;
- Involves some, but probably limited, stakeholder engagement at this stage.

Tier 3 (Detailed assessment)

- Full site-specific assessment, requires gathering of additional data as necessary – this may include ecological survey work, measurement of radionuclide concentrations, measure (air kerma) dose rates using TLDs and monitors etc;
- Evaluates all the key impacts on the site including non-radioactive contaminants (although there might be limited consideration of this in the earlier tiers);
- Consider the background radiation levels in the area being assessed;
- Introduces probabilistic techniques to aid in the assessment;
- Has no defined prescribed screening level but includes involvement of stakeholders to consider whether the practice is acceptable in terms of its environmental impact compared with the economic and social benefits.

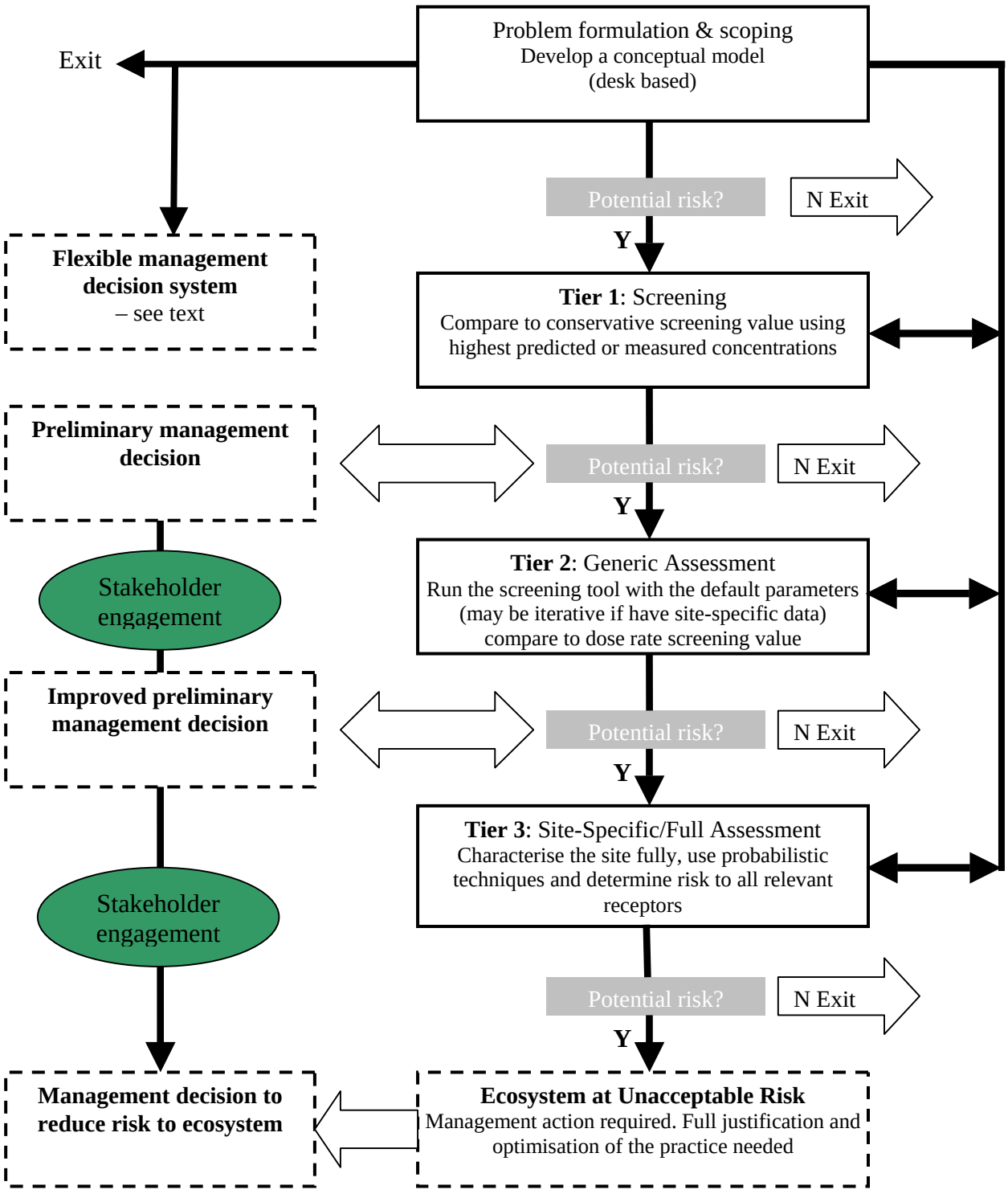

Figure I. Overview of the interim ERICA tiered approach to risk assessment

Table of contents

1 Introduction and statement of purpose

Ecological Risk Assessment (ERA) is an increasingly important component of any decision-making process that aims to provide transparent management decisions on environmental practices and associated problems. It is the method of risk assessment being applied and developed as part of the ERICA integrated approach, including the various aspects of planning, problem formulation, assessment, risk characterisation and decision and management. One of the challenges in developing risk assessment guidelines is to provide a method that can be applicable to different cases and contexts, including historical and ongoing activities (retrospective risk assessment), future activities (prospective risk assessment) and evaluation of both chronic (e.g. routine) and acute (e.g. accidental) releases. ERICA is proposing a flexible approach to risk assessment, in the form of a tiered approach, which allows for greater integration between the risk assessment, risk characterisation and decision-making aspects of ERA.

Generally, ecological risk assessment is performed in a regulatory context with the purpose of providing relevant information to determine whether there is an unacceptable risk to an ecosystem from a given emission at a specific site. Risk characterisation – the synthesis of all available information to guide, inter alia, the ranking of risks and/or comparison with predetermined criteria or standards – is the ultimate step of an ERA. In many countries, the procedure adopted for the characterisation of risk is performed as part of an Environmental Impact Assessment (EIA), resulting in a defined product – the Environmental Impact Statement (EIS) – that forms the concrete basis for decisions. Within both ERA and EIA, the assessment is seen as largely science-oriented and underpinned by observations, supported by experimental data and modelling approaches. However, there is an important and obvious connection between risk characterisation and decision-making, which is, to a large extent, driven by legislation and underpinning values. In routine cases, risk characterisation would reflect existing regulations. However, the assessment, provided it is scientifically sound, may *provide the grounds for formulating* the relevant regulations, again emphasising the iterative nature of the whole assessment/management cycle. The proposed ERICA integrated approach outlined below could be performed as part of an EIS or used as a standalone assessment. The key point is the interaction between the different tiers of the integrated approach and how this influences the decision making process. Figure 1.1 demonstrates the relationship between the assessors, decision makers and stakeholders. The initial phase of the process requires a definition of the problem to be assessed. This may involve a wide range of stakeholders, as well as decision makers and is a key component of the overall assessment (consequently the problem formulation stage will involve the assessor, the decision maker and the stakeholders as reflected in Figure 1.1). As decisions are taken that progress the assessment process through the tiers there is a changing input from both the stakeholders and the assessors. For example, in the case of a Tier 1 assessment, the stakeholders should be involved to determine overall acceptability of the assessment (equivalent to a yes/no decision) and so have relatively little input (blue bar) into the process. Furthermore, the assessors conduct simple, conservative assessments that involve relatively little effort (red bar). At Tier 3, the assessors and stakeholders should be fully involved in the overall assessment and in the decision making process (blue and green bars) and the overall assessment effort will be greatly increased (red bar). The decision making process should consider, with increasing effort, the points identified in Figure 1.1 as the assessment proceeds from Tier 1 to the higher tiers.

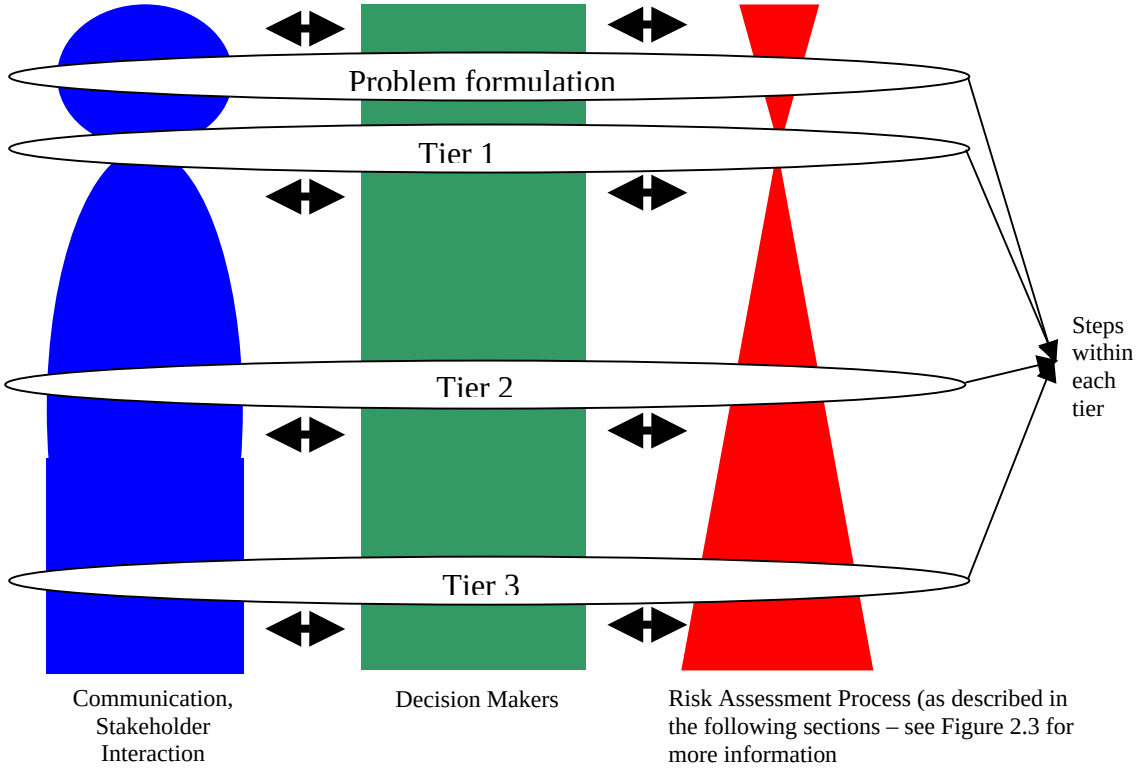

Figure 1.1: Overview of the proposed ERICA tiered approach. The width of the coloured bars reflects the level of engagement/involvement required for the assessment process and highlights (in red) the amount of effort required in the assessment process.

The present document introduces the tiered assessment as an interim method for the ERICA integrated approach. The document focuses on the technical aspects of the actual risk assessment/characterisation method and does not consider in detail how the ERICA integrated approach will handle the stakeholder and decision making aspects. This will be discussed and expanded by other participants in the ERICA project. This section provides general guidelines and principles to demonstrate how ecological risk assessment and management processes can be applied across the range of activities that use radioactive substances. These guidelines and principles have been derived on the basis of the critical literature review presented in Deliverable 4b.

Although the method has not been fully developed, there are a number of reasons for introducing this interim approach at such a relatively early stage in the project. Firstly, the good practice guidance for risk characterisation (deliverable D6) is not due until month 34 (out of 36) of the ERICA project. The ERICA consortium felt that this left too little time for detailed interaction with the ERICA end user group (EUG). Hence, the risk assessment guidelines described in the following sections have been drafted to facilitate and stimulate discussion between the EUG and other interested stakeholders and the ERICA participants as an interim stage in the development. Secondly, the ERICA consortium

needs to agree on a basic approach to test and apply the assessment and modelling tools being developed in other parts of the project, as well as the basic guidelines for decision-making.

This interim tiered approach will be amended within D6 to also include guidance on how to establish this information within a range of different ecosystems at different spatial and temporal scales. D6 will also contain worked examples of the assessment approach for different tiers. The guidelines are not meant, at this stage, to provide detailed prescriptive guidance, but aim to highlight the basic concepts to, hopefully, gain general acceptance in the methodology. The full integration of the risk assessment guidelines and an operating guide for the ERICA integrated assessment tool will be prepared within Deliverable 10.

Finally, the guidelines also reflect the input received at the End User Group meeting in Aix in September 2004 (ERICA Deliverable D7b, 2004) following the first discussions on the tiered approach. Table 1.1 details the comments received and how these have been dealt with by the ERICA consortium.

Table 1.1: Comments received from EUG members and the resulting actions taken by the ERICA consortium on the interim tiered assessment approach as outlined in Aix en Provence, Sept 04.

EUG Comments	ERICA Responses
Tier 0 was thought to be questionable, consideration of when probabilistic approach should be introduced, non-movable benchmark but could use different safety factors, describe safety factors in more detail, need better defined exits from the tiered approach Further develop the tiered-approach	This chapter describes a refined, more thought through interim tiered approach for further comment
Define benchmark and screening levels Draft a document related to benchmarks in relation to decision making situations for stakeholders to comment	Chapter 2 contains sections which briefly describe methods to the generation and justification of the benchmark and screening levels in different circumstances but this aspect will be discussed further in later EUG meetings (e.g. in Germany, April 05) and in ERICA deliverable D5

2 Tiered assessment

The proposed risk assessment guidelines are based on a tiered design and take into account the steps outlined in FASSET [FASSET, 2002] and reiterated in this report in Figure 2.1. This highlights the key points to any ecological risk assessment, which includes planning, problem formulation, assessment, risk characterisation and decision and management. The approach outlined here also includes, as a key part of the integrated ERICA approach, communication and stakeholder interaction to ensure that the overall output of the assessment reaches an adequate level of acceptability.

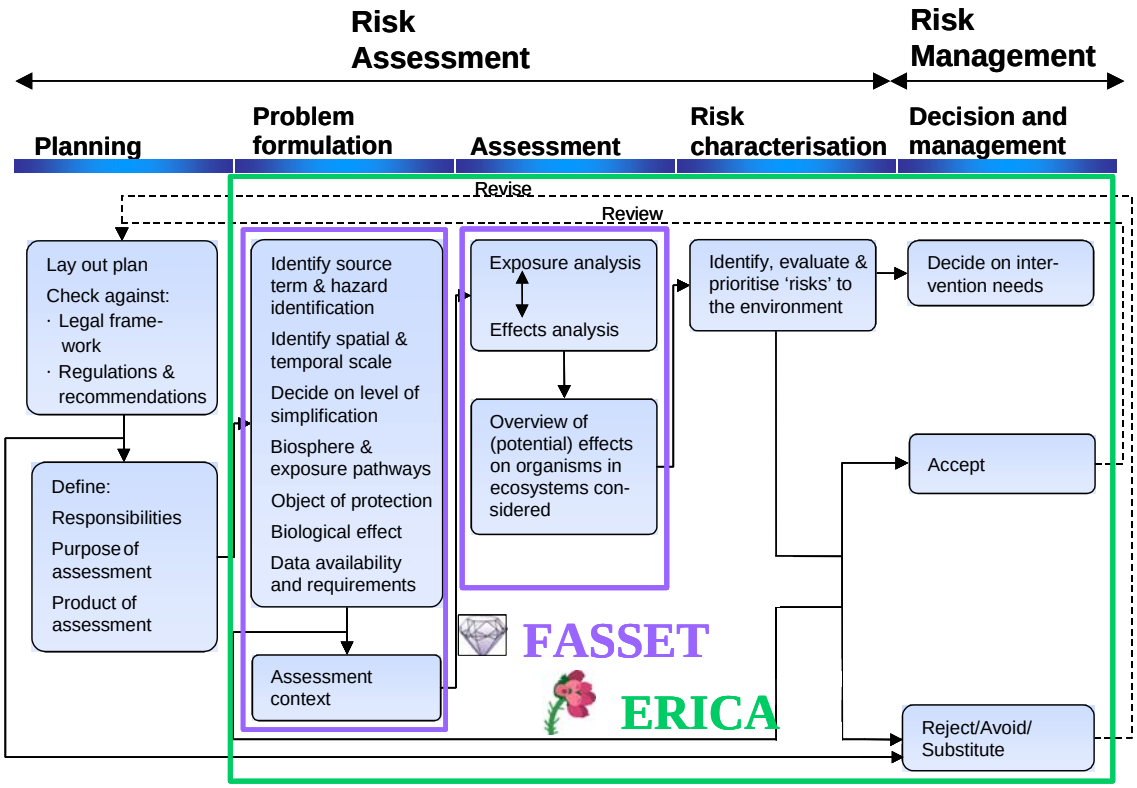

Figure 2.1: Schematic representation of different steps in environmental risk assessments, based on FASSET [2002]. The scope of the FASSET project, as well as the wider scope of the ERICA project, are indicated in blue and green, respectively.

2.1 Designing the tiered approach

The key component of any tiered design is a progression through a series of tiers/assessments, which reflect greater refinement in the quality and quantity of information gathered and consequently a progressive reduction in uncertainty, Figure 2.2. Tiered approaches used elsewhere have been

reviewed in Deliverable 4b, whereas this document describes the proposed ERICA ERA approach as outlined in Figure 2.3.

The proposed framework also highlights the need to identify and characterise the problem correctly, to screen and prioritise the risk among radionuclides and ecological receptors and to consider different management options and how best to appraise them before starting. The process can also be treated as being iterative with a management option being able to move through the tiers in either direction according to the economic and social costs of the management options. This is explored further below.

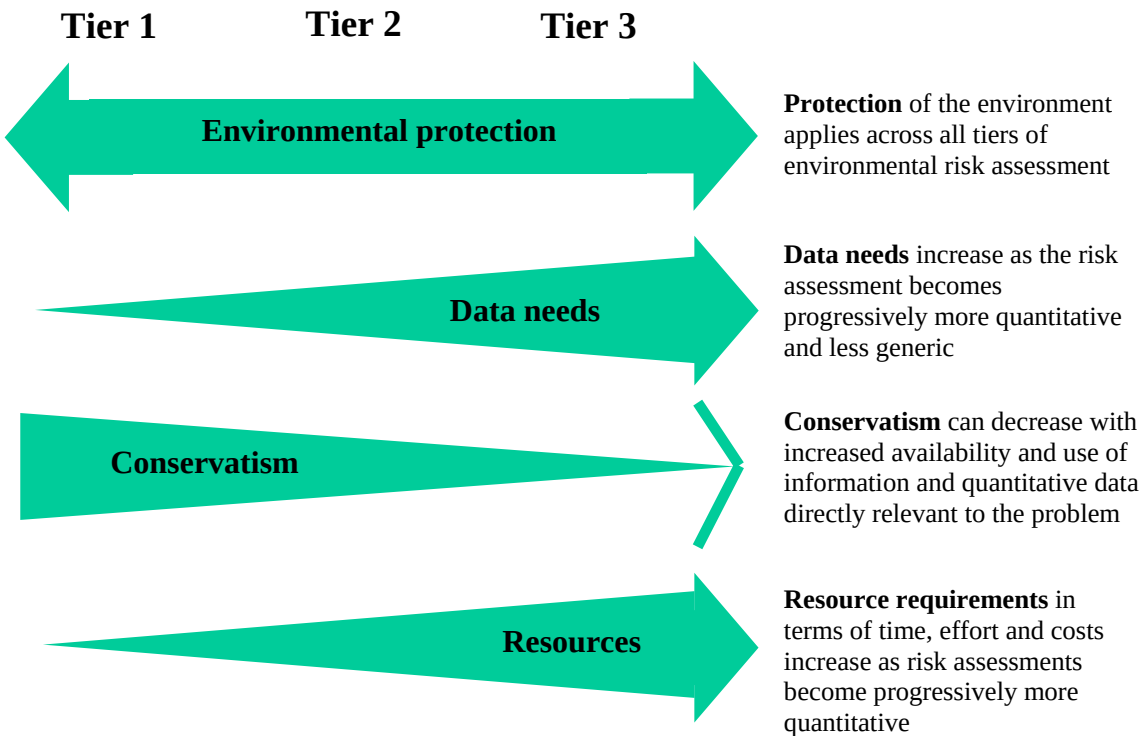

Figure 2.2: **Illustration of how data needs and uncertainty/conservatism issues change through the tiered approach. The level of detail in a risk assessment should be proportionate with the nature and complexity of the risk being addressed and consistent with decision-making needs.**

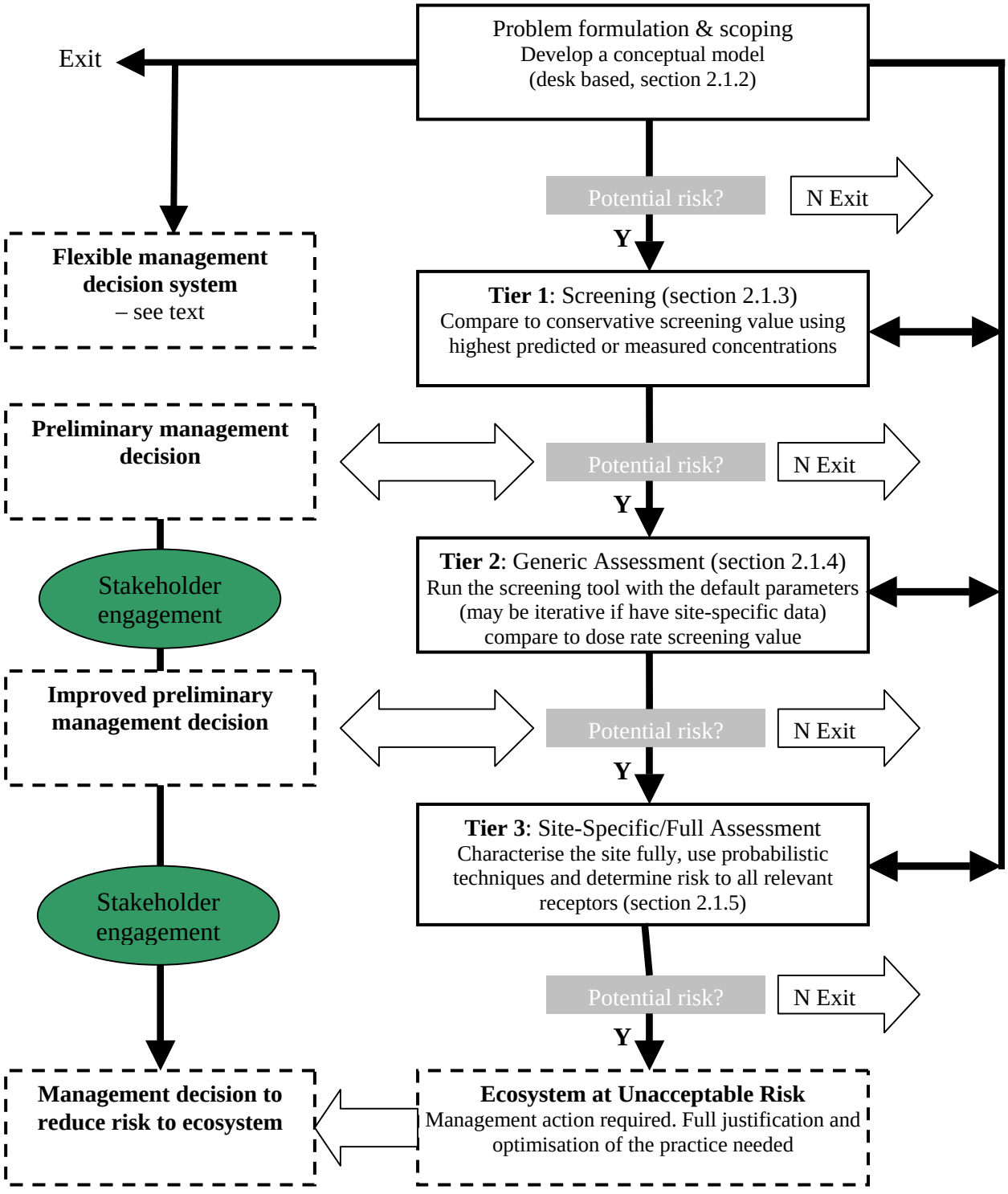

Figure 2.3: **Overview of the interim ERICA tiered approach to risk assessment. Although an iterative process, the approach is flexible so that the assessor can skip tiers or move forward and backwards through the tiers.**

2.1.1 Basic Information required

At each assessment stage or tier there are a number of steps that should be undertaken as outlined in Figure 2.4. These steps should be repeated and the resulting information reviewed at the start of each tier. The degree of detail in the information collected at each tier may vary. For example, you would not be expected to undertake a full temporal and spatial assessment of the site at tier 1 but simply to locate the highest measured or predicted radionuclide activity concentration in the area being assessed. Examples of the type of information that may be gathered and refined at each tier are:

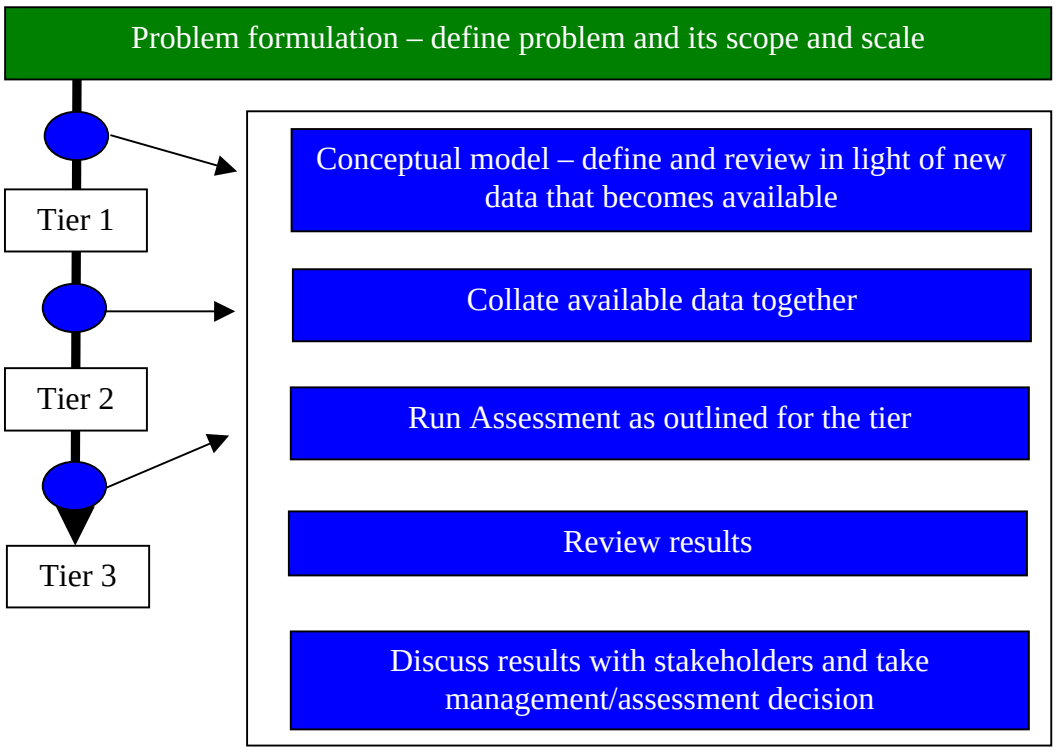

Figure 2.4: Steps to be taken at each tier.

- define the scope of the problem, the purpose of the assessment and what endpoints are being considered;
- what is already known about the site and its historic use and the proposed or operational practice being assessed;
- what are the potential contaminants, pathways, and receptors for radioactive substances being considered;
- review the available data (all sources of information that may affect the transfer of radioactive substances and the subsequent exposure of receptors). For example, published and unpublished site data (or predicted concentrations in the case of a prospective assessment), local meteorological data, other studies ongoing in the region, information from stakeholders etc;

- the sensitivity of the site (for example are the receptors present on site);
- the inherent radiotoxicity of radioactive substances and their bioavailable forms (likely to be tier 3 only);
- the potential of exposure of receptors (persistence of exposure (for example long lived radioactive substances which may accumulate in the environment);
- the potential for radioactive substances to bioaccumulate through food chains;
- data gaps and their significance;
- social and economic values including the views of stakeholders.

The latter points may become more important as the assessment progresses through the tiers.

2.1.2 Problem formulation and scoping

Clearly setting out the problem at hand and identifying any boundaries within which any decisions are to be applied is critical to successful ERA. As a first step in the problem formulation stage, there is a need to simply identify whether the full assessment is required and this may be undertaken by a simple desk study review of the proposed or current activity/process conducted at the site, the evaluation of any receptors that may be present on the site and to establish whether there are any pathways which would link the source of the radioactive substances to the receptors. This may involve expert judgement and dialogue with stakeholders. The overall aim of the problem formulation and scoping exercise is to determine whether non-human species of interest are likely to be exposed to radioactive substances. For example, it may be that under conservation legislation there is a need to demonstrate protection of a terrestrial site near a facility, which is authorised to release radioactive substances to a river. However, if there is no feasible, realistic mechanism by which radioactive substances can be transported to the terrestrial site from the river, then using a clearly documented assessment approach could eliminate the need for further risk assessment in this case.

It is crucial that the evidence collecting during the problem formulation stage be clearly documented in a transparent and understandable way. Commonly, in such cases a conceptual model is developed which describes what is known about the site (which may include, or at least reference, any available data), its geographical limits, identifies radioactive substances of interest, potential pathways and receptors and considers the likelihood of exposure and identifies any data gaps. Essentially, a conceptual model is a narrative summarising the site conditions, current knowledge and the problem faced. The level of detail that is required will be influenced by a number of factors but should comprise some or all of the information held in section 2.2.1 (basic information required).

Figure 2.5 outlines one type of generic conceptual model that may be used as the basis for evaluating likely pathways, sources and receptors. The conceptual model may be presented in a table, diagram, pictorial or flowchart but should also include a narrative description, which describes the links and transfer pathways etc to be considered. An alternative version may be to use interaction matrices as shown in Figure 2.6. It is the process of generating the conceptual model and the ease of interpretation and acceptability to stakeholders that is important.

A checklist for the items to include in the conceptual model will be provided in the full guidance (D6).

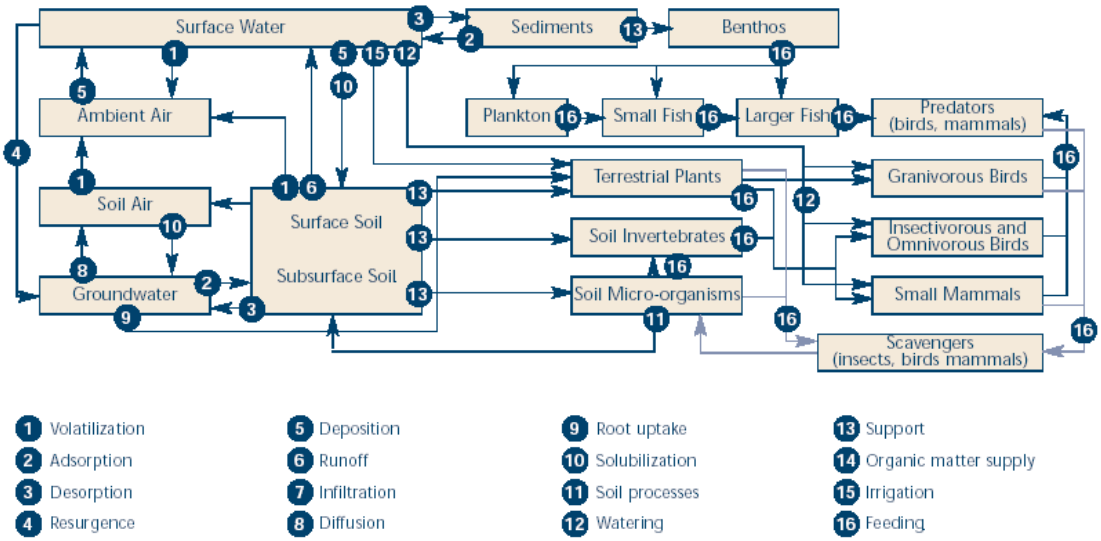

Figure 2.5: Generic conceptual model [Weeks et al., 2004].

Substrate	a)Settlement b)Deposition	a)Settlement b)Consumption	a)Settlement b)Consumption	a)Settlement b)Consumption	a)Settlement b)Consumption	a)Settlement b)Consumption c)Material supply	a) Water transport b) Dehydration	Seeping Throughflow
Root growth	**Primary producers (a)**	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib b)Food supply	a)Stimul./Inhib b)Food supply	a)Stimul./Inhib.	a)Stimul./Inhib b)Food supply d)Material supply	Root uptake	
a)Decomposition b)Bioturbation	a)Stimul./Inhib	**Decomposers (a,b,c)**	a)Stimul./Inhib b)Food supply	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib b)Food supply d)Material supply	Decomposition	a)Interception b)Retard./Accel. c)Uptake/Excret. d)Covering
Bioturbation	a)Stimul./Inhib. b)Feeding	a)Stimul./Inhib b)Food supply c)Feeding	**Filter feeders (a,b,c)**	a)Stimul./Inhib. c)Feeding	a)Stimul./Inhib b)Food supply c)Feeding	a)Stimul./Inhib b)Food supply d)Material supply		a)Decomposition b)Retard./Accel. c)Uptake/Excret. d)Movement
Bioturbation	a)Stimul./Inhib c)Feeding	a)Stimul./Inhib. b)Food supply c)Eating mushrooms	a)Stimul./Inhib. b)Food supply	**Herbivores (a)**	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib b)Food supply d)Resource		a)Water-pumping b)Retard./Accel. c)Uptake/Excret.
Bioturbation	a)Stimul./Inhib.	a)Stimul./Inhib. b)Food supply c)Feeding	a)Stimul./Inhib. b)Food supply c)Feeding	a)Stimul./Inhib c)Feeding	**Carnivores (a,b,c)**	a)Stimul./Inhib b)Food supply c)Feeding d)Resource		a)Movement b)Retard./Accel. c)Uptake/Excret.
Disturbance *(dredging, digging)*	a)Stimul./Inhib. b)Feeding c)Dispersal/ Extermination	a)Stimul./Inhib. b)Food supply c)Feeding d)Dispersal/	a)Stimul./Inhib. c)Feeding d)Dispersal/ Extermination	a)Stimul./Inhib c)Feeding d)Dispersal/ Extermination	a)Stimul./Inhib b)Food supply c)Feeding d)Dispersal/	**Humans (a)**	a)Water extraction b)Artific.infiltr.	a)Movement b)Retard./Accel. c)Uptake/Excret.
a)Erosion b)Water content change	a) Settlement b) Water uptake	a) Settlement b) Water uptake		a) Settlement b) Water uptake	a) Settlement b) Water uptake	a) Settlement b) Water use	**Groundwater**	a)Movement b)Retard./Accel. c)Uptake/Excret. d)Covering
Runoff	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water use	Richarge/discharge	**Surface water**

Figure 2.6: Generic conceptual model developed with the interaction matrix method. The Leading diagonal elements (LDEs) correspond to the components identified as being relevant conceptual model objects in the contaminant migration within the ecosystem. The Off-diagonal elements (ODEs) are interactions between LDEs (transfer processes between components). To identify the transfer processes the matrix should be read clockwise. Modified from Kautsky [Kautsky, 2001].

It is advisable to involve stakeholders (regulators, industry and other interested parties) in this process as describing the problem in agreed clear and unambiguous terms will provide an important baseline

which can be used should the process or eventual decision be challenged or audited. Any uncertainties in the conceptual model should be identified and listed. The conceptual model should be reviewed at tiers 2 and 3 to record any new data or insight about the site under assessment. For example, in tier 1 it is assumed that the receptors considered have 100% spatial and temporal overlap with the area where radioactive substances are present. This may result in overestimation of risk, especially for animals. This is appropriate at the initial stages of the assessment but may be refined at the later stages by reviewing the conceptual model which should contain information on lifestyle of mobile species present at a particular site. In addition, as further work is undertaken some of the exposure pathways, receptor species or radioactive substances that were initially defined in the conceptual model as credible or important may prove to be unfounded and can be refined or removed. Lack of data or information is a reason to progress through the tiered assessment approach. More guidance on both the level of detail to be included in the conceptual model and the role/involvement of stakeholders will be provided in the ERICA handbook (Deliverable D6).

Management options available

Management options and stakeholder engagement in the decision making process is being considered within work package 3 of the ERICA project. However, a number of management options have been identified at each stage of the tiered assessment approach that are/may be available to the assessor/decision maker for illustrative purposes within the text. For example, following the derivation of the conceptual model there are several management options available:

1) Early termination of the assessment process, if warranted, for example because the receptors of concern are not present (thus ensures a more efficient use of available resources on sites with a higher priority for assessment/remedial work.
2) Continue on the assessment path to tier 1.
3) Identification of potential risk that justify moving to a tier 2 or 3 assessment.

2.1.3 Tier 1 (Screening)

Having identified in the problem formulation and conceptual model stage that a site could be impacted by radioactive substances and that there are, in theory, radionuclide source-pathway-receptor linkages, the next step is to evaluate the risks using a conservative screening approach. Again, this step is to screen out those sites where an unacceptable risk is unlikely to be realised, to better direct available resources to more pressing sites.

The screening approach adopted in tier 1 should be based on conservative assumptions, so that sites that are truly benign may be eliminated from further investigation with a high degree of confidence. The assessment is generic and consequently utilises little site-specific information. However, there is a need to minimise the number of false negatives (that is failing to detect sites that really pose a risk to the receptors). The advantages of this screening tier is that the assessments can be conducted relatively quickly, are desk based and do not require resources to undertake additional measurements. Tier 1 assessments may use maximum environmental concentrations often derived from actual or proposed/requested discharge limits or measured or modelled concentrations and consider the impact to the most radiosensitive receptors. For example, the screening assessment may be undertaken using the highest observed or predicted environmental concentration within the assessment site area (which takes no account of spatial or temporal variation) in soil, sediment, water or air. This activity concentration should then be compared to the screening level based on the lowest environmental media limiting concentration back calculated from Predicted No-Effect Dose Rates (PNEDR) (the

derivation of the environmental media limiting concentration is discussed briefly below and will be explored further in ERICA deliverable D5). This approach should be conservative because the highest observed or predicted concentration in the environment is being compared with the lowest environmental media limiting activity concentration for any reference organism. Alternatively, extreme assumptions may be used, such as a scenario where the receptor is directly drinking and/or immersed in the radionuclide discharge from the point source (or multiple sources added together). The tier 1 should be conducted for soil, water and sediment independently to be able to demonstrate adequately that there is no likely impact. This may be refined further if there is a known source-receptor pathway that is specific to the site.

To summarize, tier 1 assessments take the form of a comparison between the measured or model predicted activity concentrations of known or potential radioactive substances present at a site and the lowest environmental media limiting concentrations for the individual radioactive substances. The lowest environmental media limiting concentration for each radionuclide can be calculated by determining the environmental activity concentration (in soil, water or air) for each radionuclide that is required to give a PNEDR to the most radiosensitive ecological receptor. This assumes that the PNEDR is based on a 'safe' dose rate below which no significant effect of the radiation may be observed. How the safe dose rate will be determined is discussed further in ERICA deliverable D5 but **for illustrative purposes only** the following example is given to demonstrate the process:

Derivation of PNEDR value

By evaluating the data on known radiation effects on different wildlife groups, and/or by considering uncertainties, determine the dose rate which is considered to be limiting (e.g. the PNEDR). For the purposes of this example, it is assumed that the value 10 μGyh^{-1} is selected.

Derivation of environmental media limiting concentration

Using the ERICA assessment tool (and the default concentration ratios (CR) therein), the activity concentration in the media for each reference organism in the assessment tool is determined which would give rise to the PNEDR. This will produce a range of activity concentrations for the different reference organisms. To ensure conservatism within the tier 1 assessment, the lowest activity concentration that would give rise to the PNEDR for the particular scenario is selected.For example for a aquatic ecosystem it might be the activity concentration for a seabird that is the most limiting for ^{137}Cs but for ^{99m}Tc it might be the crustacean reference organism. However, it would be the activity concentration in water for the seabird and the crustacean that would be used in the assessment for comparing the measured or predicted environmental concentrations for ^{137}Cs and ^{99m}Tc respectively.

There are some implications in the derivation of the environmental media limiting activity concentrations for each radionuclide in that for many of the radionuclide/reference organism combinations there are no measured CR values that can be used to derive a default CR value. Guidance will be provided, as it was in the FASSET project, on how to deal with situations where there are no measured CRs available. However, this may lead to hyper-conservatism in the approach and may be something that needs to be considered further within the assessment. Further guidance on this aspect will be provided within the ERICA project deliverables.

Chemical toxicity and non-radioactive contaminants

Chemical toxicity associated with some radionuclides (e.g. Uranium and Thorium) and where appropriate of non-radioactive contaminants that may be released with the radioactive substances should also be considered. This should be undertaken by comparing the concentrations of the

contaminants in question to the chemical predicted no effect concentration (PNEC) values. Further guidance on this aspect will be provided in D6 along with recommended PNEC values where available.

Whilst the assessment process, at each tier, will determine whether the site being considered is at an unacceptable risk to the non-human species, one useful additional feature of the tier 1 approach is to rank the radionuclides in terms of their contribution to the overall exposure of the species. This highlight those radionuclides that should be targeted in terms of data gathering and research to fill data gaps etc. However, because the assessment works on the total dose received, all the radionuclides should be assessed in each tier. We suggest that those lower ranking radionuclides should be assessed using the default settings in the assessment tool at the higher tiers. The decision on where the cut-off in the ranking should be decided by the assessor in consultation, where appropriate, with stakeholders.

Management options available

The management options that are available are:

- Terminate the assessment because there is a very low risk of potential impact to the most radiosensitive receptor (although a discussion about what is an acceptable/unacceptable risk needs to be undertaken, perhaps with stakeholders – further guidance on this aspect will be provided in later ERICA deliverables).
- Move on to a tier 2 or directly to a tier 3 assessment because a potential risk has been identified or there is insufficient data available on which to base a decision (the decision to move directly to tier 3 would depend upon the magnitude of the risk, availability of site specific data and the assessors requirements).
- Measurements of the activity concentrations of radioactive substances known or potentially present on site may be made and the assessment re-run in the case where insufficient data is available. This would introduce the need to consider the sampling strategy over the spatial area under assessment to detect the likely maximum activity concentration in the environment for the tier 1 assessment. Tiers 2 and 3 may require this data to be collected anyway so if the assessment is required to move to tier 2 just because of lack of data this may be a more cost effective option.
- The site operator responsible for releasing radioactive substances under authorisation may decide to opt for further discharge controls/reduced authorised discharges to avoid the additional costs of undertaking tier 2 and 3 assessments although the tier 1 assessment will need to be re-run to demonstrate that the additional controls would work to reduce the risk to any receptor. Subsequent monitoring and surveillance will be needed to demonstrate that the risk is indeed low but this may be part of an ongoing programme anyway. In this way, the economics and resource allocation needed to undertake the risk assessment/discharges are balanced and the operator/source of radioactive substances has options to reduce the level of discharge. In such cases, any changes of this nature should be agreed with the relevant regulator.

More detail on the management options will be provided in Deliverable D6.

2.1.4 Tier 2 (Generic Assessment)

The aim of the tier 2 assessment is to run through a generic assessment of the dose rates to different reference organisms as listed elsewhere in the ERICA project. The assessment would be performed using available site-specific data to modify the default parameters. The reference organisms will be representative of a number of receptors that may be found at the site under assessment. The endpoint

of interest is the estimated dose rate for each reference organism which can be related to known biological effects of the radiation (mutation, morbidity, reproductive capacity and mortality) as identified from, for example, the FREDERICA database to determine the PNEDR for each radionuclide/reference organism combination. Obviously, there are knowledge gaps in our understanding of the effects of radioactive substances on different wildlife groups. Deliverable 4b provides advice on how to handle these gaps in the absence of any new information being made available and this will be developed further in D5. The primary aim of protection of the environment from radioactive substances, as identified elsewhere with the FASSET and ERICA project documentation, is to ensure that the structure (e.g. maintenance of the population) and function (e.g. supporting processes that are typical of a particular habitat) of the ecosystem is maintained.

The output of the tier 2 assessment (in dose rates) should be compared with the PNEDR(s) used to derive the environmental media limiting activity concentrations in tier 1. However, the assessment should focus on using site-specific data. Site-specific data might also consider aspects such as the dispersion characteristics of the releases into the environment, time delays and hence radioactive decay in transit, to the release point etc. This is a key addition to the tier 2 assessment. The ERICA assessment tool contains a number of dispersion models that may be used in the absence of a site specific dispersion model, such as the IAEA SRS 19 dispersion model [IAEA, 2001]. The site would only be assessed as acceptable if the estimated/predicted dose rates to the reference organisms are below that of the tier 1 or 2 dose rates in use in the assessment. The selection of the appropriate dose rate(s) for comparison will have been determined in advance of the assessment at either, or both, the problem formulation stage and tier 1.

In the case of a retrospective assessment the input data (discharges, environmental and biota concentrations etc) may be available or could be determined and/or measured. The assessment should consider the spatial and temporal distributions of the available data to establish activity concentrations to use in the assessment. It is suggested that a geometric mean of the available spatial data should be used but the area assessed should be considered and defined. The assessment may also consider dilution of radioactive substances from the release point into the environment and half-life and/or decay products of radioactive substances sufficiently short lived. For retrospective assessments, the activity concentrations predicted using the default concentration factors should be compared with any known measured data. The predicted activity concentrations should be slightly higher (for conservatism) than the measured values.

In the case of a prospective assessment, the input data should be derived from transfer models, which should be available as part of the case supporting the request for the activity that will give rise to the radionuclide release. It is important to decide on the timescale for the assessment and we suggest that the models should be set to run for a time period of at least 50 years so that the majority of environmental compartments will be in equilibrium – although some slow kinetic processes related to nuclides with complex chemistries (e.g. ^{79}Se and ^{129}I) which may be sensitive to redox variation and/or with biogeochemistry linked to the carbon cycle might not be in equilibrium and may need to be considered as a special case.

In both cases, the assessment will consider the dose rate to all the reference organisms. The background radiation exposure levels should be identified (if known) or the regional background dose rate should be identified if possible. The dose rate determined to the reference organisms can then be compared with this background dose rate. Any assumptions made in the dose rate estimates should be recorded within the tier 2 report and the conceptual model should be reviewed in light of any additional site-specific information that becomes available during the course of the initial or

reiterations of the tier 2 assessments. All sources of uncertainty should be considered carefully as part of the assessment process and the likely affect of the uncertainties should be described on the dose rates estimated/predicted to determine whether this would substantially affect the result of the assessment. An example of uncertainty might include that the default, rather than site-specific data, is used or that there is a degree of uncertainty in the assessment of the biological effect level used for determining the dose rate screening level(s). Likewise, there may need to be a view taken on the uncertainties associated with making the spatial/temporal data used more representative than using the maximum activity concentration data as proposed in tier 1. It is suggested that each uncertainty be recorded and some form of qualitative assessment be undertaken for tier 2. If the uncertainties are likely to give rise to assessments that would be deemed unacceptable, then these should move to a tier 3 assessment.

Currently, we think that the screening level should be based on the dose rate used to define the environmental media limiting activity concentrations in tier 1. The difference is that the tier 2 assessments should make use of the dose rate rather than the activity concentrations because this will give the assessor greater flexibility in the application of radiation weighting factors etc on the output. The realism will be built to the assessment using more appropriate activity concentrations as the input values and may also include some measured dose rate data in the form of external dose measurements which could be used to compare the estimated values against and the inclusion of the dispersion modelling aspects.

The assessment should be reviewed with stakeholders to come to an agreed decision on the acceptability of the output and to determine which of the following management options should be adopted.

Management options available

There are several options available including:

- Terminate the assessment because a very low risk of potential impact has been identified using the generic risk assessment which has estimated a dose below the screening level and no further action is required.
- Terminate the assessment because a very low risk of potential impact has been identified using the generic risk assessment which has estimated a dose below the screening level and further monitoring is required to ensure that conditions do not deteriorate.
- Move on to a tier 3 assessment because a potential risk to one or more receptors has been identified or there is insufficient data available on which to justify a decision (although there is also the option to obtain more site specific data and re-run the assessment).
- Remaining uncertainties in the evidence obtained are large and therefore it is not possible to decide with adequate certainty whether risk management action is appropriate. This may relate to the continued use of conservative assumptions because of the lack of data. In this case, it is necessary to undertake further site-specific investigation.
- Undertake risk management/mitigation to reduce the level of risk associated with a clearly identified receptor/reference organism-radionuclide pathway and/or to reduce uncertainty in the assessment process because of lack of data (for example, if there is no specific assessment data available for a particular radionuclide present at the site of interest).

- The site operator responsible for releasing radioactive substances under authorisation may decide to opt for further discharge controls/reduced authorised discharges to avoid the additional costs of undertaking tier 3 assessments although the tier 2 assessment will need to be re-run to demonstrate that the additional controls would work to reduce the risk to any receptor. Subsequent monitoring and surveillance will be needed to demonstrate that the risk is indeed low but this may be part of an ongoing programme anyway. In this way, the economics and resource allocation that is needed to undertake the risk assessment/discharges are balanced and the operator/source of radioactive substances has options to reduce the level of discharge. In such cases, it is expected that any changes of this nature would be agreed with the relevant regulator.

More detail on the management options will be provided in Deliverable D6.

2.1.5 Tier 3 (Detailed Assessment)

When the generic risk assessment (tier 2) results indicate that there may be an impact on the reference organisms inhabiting a particular site there is a need to address this through a full site investigation which will primarily consist of gathering all available site-specific data and addressing the data gaps for radioactive substances of interest and the reference organisms (or representative species that can be assessed) through a programme of environmental monitoring and measurement. These data should be entered into the assessment tool to reduce the uncertainties associated with the previous assessments. In addition to the measurement data, each site should be evaluated to assess it's ecological condition using information on aspects such as biodiversity and vegetation structural indices and to establish the spatial and temporal extent and variability of the radionuclide contamination/dispersion and also how the different species interact with the areas showing higher radionuclide concentrations. The aim of this assessment tier is to reduce the uncertainties but also to determine the magnitude of the risks to the receptors/reference organisms. Depending upon the scale of the monitoring data that is required, thermoluminescent dosimeters (TLDs) and the measurement of air kerma may be employed to evaluate dose rates to representative organisms as part of the evidence that should be collected to support the assessment process at this tier 3 stage along with other field based sampling/monitoring methods.

The background radiation exposure levels should be determined either by measurement or reference to background rates typical for the underlying geology for the area under assessment. This background dose rate can then be compared with those calculated for the reference organisms. In addition to the radioactive substances that may be present, there is also a need to consider the presence of non-radioactive substances in the overall site impact assessment.

So far, the evaluations have been deterministic assessments of risk, in which a single value representing the whole of the exposure set is compared with a single value representing the entire effects dataset. In the earlier tiers, these estimates have also been selected conservatively (i.e. taking the most radiosensitive species or maximum concentration) and thus reflect worst case scenarios. This approach is the current standard practice and should be somewhat precautionary and thus lead to an over-estimation of the risk. The problem with this approach is that it may provide estimates that are overly conservative, but it is not possible to determine by how much and thus resources could be wasted in assessing or managing risks that are actually relatively small. Another disadvantage is that the deterministic approach fails to communicate the variability of real outcomes and the degree of uncertainty about those outcomes. These disadvantages can be overcome by the introduction of probabilistic modelling techniques in tier 3 to evaluate the likely significance of the exposure to radioactive substances in the environment.

Probabilistic methods use distributions to quantify variability and/or uncertainty in the inputs and outputs of the assessment. Within the ERICA assessment tool, Monte Carlo probabilistic methods have been incorporated for use in the tier 3 assessments. These methods can be applied to quantify the variability and uncertainty of the exposure estimates and/or the predicted effects and can be used to estimate both their frequency and magnitude with associated confidence levels to show the degree of scientific certainty attached to them. Using sensitivity analysis, the tier 3 assessment can also identify which parameters have the greatest impact on the risk estimate thus allowing decision-makers to target risk management strategies to address the areas of greatest uncertainty. D4b reviews the selection of probability distribution functions (pdfs) for use in the assessment - using a probabilistic approach will permit the determination of not only the magnitude of an effect but also its likelihood. This provides additional information for discussion on whether a process/practice is acceptable. The probability distributions should be determined for the estimated/predicted dose rates and also for the corresponding effects data if available. Where necessary, additional data on effects of exposure to radioactive substances should be considered and may need to be undertaken.

There may also be a need to undertake the evaluation in the context of other non-radioactive contaminants that may be released or present. On a weight of evidence approach all information that may be relevant should be collected - this will include biological surveys, biomarker data, concentration data and evaluation of possible pathways etc. and filling of data gaps with a targeted sampling/monitoring programme. Other aspects for consideration should include the duration of the exposure, the recovery potential of a site, the resilience of a site, the level of conservation status/ecological importance of a site in terms of its structure and functioning and generally a good understanding of the local ecosystems that may be impacted by radioactive substances.

Any assumptions made in the derivation of the dose rate estimates should be recorded within the tier 3 report and the conceptual model should be reviewed in light of any additional site-specific information that becomes available during the course of the initial or reiterations of the tier 3 assessments. All sources of uncertainty should be considered carefully as part of the assessment process and the likely affect of the uncertainties should be described on the dose rates estimated/predicted to determine whether this would substantially affect the result of the assessment. Examples of possible causes of uncertainty have been given in the tier 2 section. Each uncertainty should be recorded and a quantitative assessment undertaken. If the uncertainties are likely to give rise to assessments that would be deemed unacceptable, then these should be raised with the relevant stakeholders and the acceptability of the proposed practice/process may well be questioned to the point of not granting a permit.

Currently, we think that there should be no screening level/benchmark level for a tier 3 assessment. Instead the assessment should evaluate the likely biological effects by predicting/estimating the dose rates likely to be experienced by the non-human biota identified during stakeholder consultation as being important. This information may be obtained from experimental/field data such as that collated in radiation effects databases like FREDERICA. These details should be reviewed in consultation with stakeholders to determine the acceptability of process or practice. There should be attempts to make the overall tier 3 assessment as realistic as possible using, for example, more appropriate activity concentrations as the input values and may also include some field studies in the area of the current or proposed process or practice that currently gives or will give rise to the release of radioactive substances. It is therefore critical that the assessment should be reviewed with stakeholders to come to an agreed decision on the acceptability of the output and to determine which of the following management options should be adopted. This may mean reviewing the mechanism for stakeholder

engagement to capture all relevant views within the assessment. There will be ongoing discussions within the ERICA consortium and with the EUG on how to define what is acceptable within the context of the tier 3 assessment and this will be explored further in later ERICA deliverables.

Tier 3 assessments should also reconsider the inclusion of non-radioactive contaminants in the assessment and should follow the appropriate guidance (if available) on how these should be assessed. Some limited guidance will be provided in D6 on this topic for those circumstances where an assessment approach for non-radioactive contaminants is not available.

Management options available

The final management options will vary depending upon the output of the assessment but may include:

- Permission for the activity may be granted (prospective case) or removed/reduced (retrospective case).
- Further data collation and review including full ecological assessment of the area potentially impacted by radioactive substances and an increased and more in-depth monitoring programme.
- Changes to the practice giving rise to the discharges to optimise the process and thus reduce the release of radioactive substances or to maximise their dispersion in the environment to reduce the potential for radionuclide accumulation and hence exposure. This may include improved abatement techniques, on site storage etc. This may be explored through the application of best practical environmental option (BPEO) studies.

More detail on the management options will be provided in Deliverable D6.

2.1.6 Quality control within the assessment process

For the assessments, at whichever tier, to be transparent, there needs to be clearly laid out and easy to understand guidance for the assessor on how to record clearly their decisions/actions and any underpinning assumptions that were made. A checklist will be provided in Deliverable D6 to help with this but assessors should ensure the following as a minimum:

Problem formulation

- State clearly the purpose of the assessment;
- Record the conceptual model (graphically or in tabular form along with a clearly written concise summary);
- Record or list the data sources available containing the site information;
- Identify any knowledge gaps and assumptions;
- Record any stakeholder involvement and comment;
- Record and justify the outcome of the problem formulation phase and the management option taken clearly in its own section.

Tier 1

- Record the screening level (dose rate or environmental concentrations) used;
- Identify any continuing knowledge gaps and assumptions;
- Record and justify the outcome of the tier 1 assessment and the management option taken clearly in its own section.
- Consider the uncertainties included in the assessment qualitatively, could these affect the outcome of the assessment?

Tier 2

- Check carefully that all input data are correct and save the calculation results;
- Justify and record any site-specific input information used;
- Record the screening level used;
- Provide an updated conceptual model as appropriate;
- Record and justify the outcome of the tier 2 assessment and the management option taken clearly in its own section.
- Consider the uncertainties included in the assessment qualitatively, could these affect the outcome of the assessment?

Tier 3

As tier 2 plus

- Record and justify the outcome of the tier 3 assessment and the management option taken clearly in its own section.
- Consider the uncertainties included in the assessment quantitatively, could these affect the outcome of the assessment? Introduction of probabilistic assessment of the uncertainties?

A follow up review of the effectiveness of the management option should be undertaken at an appropriate time interval to demonstrate that a) the assessment has identified and managed any potential risk, b) that the radioactive substances still being released are conforming to the stated aim of the assessment and c) that there have been no unforeseen effects.

Prospective Assessments

When undertaking a prospective assessment the potential impact of the new activity (as predicted) should be considered in the context of other existing sources of radioactive substances in the environment (retrospective assessments should also consider this but there is a question over whether the proposed discharge would be acceptable if the environmental loading of anthropogenic radioactivity was already high). For example, in many river catchments there may be multiple sources of authorised discharges of radioactive substances but it is the combination of these discharges that may impact on biota. Consequently, the dose predicted by the assessment should be considered as additive on top of the other sources of radioactive substances in the vicinity. The derivation of the predicted environmental concentrations of the different radioactive substances should be clearly recorded in the assessment report and the proposed management option should include a view on the monitoring and surveillance requirements to ensure compliance with the assessment if the activity is

given permission to start. The monitoring and surveillance data should be reviewed after a period of two or three years. It is suggested that the modelling approaches should make use of standard texts of concentration factors.

There is also a need to undertake options analysis on the proposed discharges from a site to review how these might be performed with the principles of ALARA (as low as reasonably achievable) and BPEO (best practical environmental option) in mind.

There may also be the need to undertake additional experimental work to derive concentration ratios for radionuclide/species combinations that are specific to the site under assessment and possibly also the need to conduct effect studies to determine the dose response relationship for the key assessment endpoints. There are potentially significant cost implications for this.

The biggest difference between a prospective and retrospective assessment is the availability of data/modelling approaches being used. The retrospective assessments will usually have monitoring data available that can be supplemented with additional sampling as the assessment moves through the tiers. With prospective assessments the data is usually unavailable or very limited and there is a reliance on modelling approaches to predict the likely activity concentrations in different environmental compartments. In this case, if permission is granted for a practice to be conducted that may give rise to the release of radioactive substances based on a first pass of the assessment process as outlined in Figure 2.3 using the model predicted data, there should be a reassessment as part of the licence conditions for the practice after a specified number of years. The number of years before reassessment may vary with the type of practice that is being monitored/assessed but a period of between 5 and 10 years should be adequate during which time there needs to be an adequate environmental monitoring programme, perhaps advised by the first risk assessment evaluation. The reassessment should compare the model predicted environmental concentrations to the actual measured results and then undertake a reassessment using the risk assessment procedure outlined here. Depending upon the results of the comparison, it may not be necessary to conduct a full reassessment.

2.2 Derivation of the Predicted No Effect Dose Rate (PNEDR) and its application

There are numerous aspects to the derivation of the predicted no effect dose rate (PNEDR) value and then the details of how it will be applied to the different tiers. There has been some limited discussion about how the ERICA Consortium currently views this aspect of the project and the Consortium is looking to engage with the EUG on the most appropriate methods for deriving the PNEDR value, the degree of conservatism that should be included and whether we should look to incorporate probabilistic approaches into the derivation process. This aspect will be taken forward within the ERICA deliverable D5 and will be the subject of much discussion over the remaining period of the project.

3 Conclusions

The ERICA Consortium has adopted this interim risk assessment/characterisation approach, which is based on a tiered assessment. It uses a first problem formulation step followed by a three-tiered assessment approach, where tiers become increasingly complex and more resource intensive. The integration of the tiered assessment approach within the ERICA work packages is now being undertaken. For example, the assessment tool being developed within work package 1 is being modified so that it can be used for each of the different tiers. Furthermore, the management and stakeholder engagement at the different levels is now being taken forward by work package 3 and work package 2 will continue to consider the derivation of the predicted no effect dose rate using different methods in consultation with the EUG.

This document describes the interim method for risk assessment/characterisation within the ERICA integrated approach with the aim of stimulating discussion within and between the ERICA Consortium, the EUG and other interested parties to explore aspects such as:

- the methods for deriving the PNEDR;
- how to evaluate the PNEDR values that are generated by different methods;
- the application of the PNEDR to the derivation of the environmental media limiting concentrations for tier 1 (given the uncertainties associated with, in particular, the concentration ratios);
- how to determine what is an acceptable risk at the different tiers;
- to evaluate the management options available at the different tiers and to provide guidance on their application in different situations;
- to consider how the proposed ERICA integrated approach will handle issues related to temporal and spatial variation, how to deal with acute (accidental) releases;
- to determine what are the key knowledge gaps/uncertainties in the approach and to provide advice and guidance on how these should be addressed;
- to propose scenarios for the ERICA consortium to work through as case studies to demonstrate how the ERICA integrated approach should be undertaken;
- how to make the information on the ERICA integrated approach concise, user friendly and ensure uptake by a broad selection of end users.

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Appendix - Acronyms and Glossary

Absorbed dose	Quantity of energy imparted by ionising radiation to unit mass of matter such as tissue. Unit gray, symbol Gy. 1 Gy = 1 joule per kilogram.
Activity concentration	the activity per unit mass or volume in which the radionuclides are essentially uniformly distributed, e.g. Bq kg^{-1}, Bq l^{-1}
Air kerma	The kerma value for air. Under charged particle equilibrium conditions, the air kerma (in gray) is numerically approximately equal to the absorbed dose in air (in gray). See also kerma
ALARA	"As low as reasonably achievable", refers to actions directed to limiting doses to individuals, the number of exposed individuals, and the probability of receiving a dose.
Authorisation	The granting by a regulatory body or other governmental body of written permission for an operator to perform specified activities.
Benchmark	Concentration, dose or dose rate that are assumed to be safe based on exposure–response information (e.g. ecotoxicity test endpoints).
Bioavailability	
Biodiversity	The number and abundance of species found within a common environment. This includes the variety of genes, species, ecosystems, and the ecological processes that connect everything in a common environment
BPEO	Best Practicable Environmental Option.
Conceptual model	Representation of the environmental system and of the physico-chemical and biological processes that determine the transport/transfer of contaminants from sources through environmental media to ecological receptors within the system.
Contaminant	Any physical, chemical, biological, or radiological substance or matter that has a potentially adverse effect on air, water, or soil, with the implication that the amount is measurable.
Dispersion model	Model for the representation of the spreading of radionuclides in air (aerodynamic dispersion) or water (hydrodynamic dispersion) resulting mainly from physical processes affecting the velocity of different molecules in the medium.
Dose	See absorbed dose
Dose rate	Dose (normally absorbed dose) received over a specified unit of time.

Ecological receptor	Living organisms at various organisation level (i.e. ecosystems, communities, populations, individual organisms (except humans – note that humans are included when the term "environmental receptors" is used) potentially exposed to and adversely affected by stressors because they are present in the source(s) and/or along stressor migration pathways.
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ERA	Ecological Risk Assessment
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EUG	End Users Group, formed under ERICA to provide advice to the ERICA Consortium from the perspective of being users of ERICA outputs.
Exposure	The co-occurrence or contact between the endpoint organism and the stressor (e.g., radiation or radionuclide).
Exposure pathway	A route by which radiation or radionuclides can reach humans and cause exposure – an exposure pathway may be very simple, e.g. external exposure from airborne radionuclides, or a more complex chain, e.g.
FRED	FASSET Radiation Effects Database, see www.erica-project.org
Kerma	The quantity K, defined as: $K = \frac{dE_{TR}}{dm}$ where, dEtr is the sum of the initial kinetic energies of all charged ionising particles liberated by uncharged ionizing particles in a material of mass dm. Unit: gray (Gy).
Licence	1) A legal document issued by the regulatory body granting authorisation to perform specified activities related to a facility or activity. 2) Any authorisation granted by the regulatory body to the applicant to have the responsibility for the siting, design, construction, commissioning, operation or decommissioning of a nuclear installation. 3) Any authorisation, permission or certification granted by a regulatory body to carry out any activity related to management of spent fuel or of radioactive waste.
Morbidity	A loss of functional capacities generally manifested as reduced fitness, which may render organisms less competitive and more susceptible to other stressors, thus reducing the life span.
Mortality	Death; the death rate; ratio of number of deaths to a given population.

Permission	See licence
Permit	See licence
PNEDR	Predicted No-Effect Dose Rate
Radiation weighting factors	Its value represent the relative biological effectiveness of the different radiation types, relative to X- or gamma-rays, in producing endpoints of ecological significance.
Radioactive material	1. Material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity. • Some States use the term radioactive substance for this regulatory purpose. However, the term radioactive substance is also sometimes used to indicate that the scientific use of radioactive (see radioactive (1)) is intended, rather than the regulatory meaning of radioactive (see radioactive (2)) suggested by the term radioactive material. It is therefore essential that any such distinctions in meaning are clarified. 2. Any material containing radionuclides where both the activity concentration and the total activity in the consignment exceed the values specified in paras 401–406 of "Regulations for the Safe Transport of Radioactive Material, 1996 Edition (As Amended 2003) Requirements Details". IAEA Safety Standards Series No. TS-R-1 2004
Radioactive substance	See radioactive material (1). It should be noted that radioactive substance is sometimes used to indicate that the scientific use of radioactive is intended, rather than the regulatory meaning of radioactive.
Radioecological sensitivity	A combination of features which include the exposure situation and biology of an organism, that contribute to the sensitivity of the organism to presence of radioactive substances in its environment
Radionuclide	An unstable nuclide that undergoes spontaneous transformation, emitting ionising radiation.
Receptor	See ecological receptor.
Reference organism	A series of entities that provide a basis for the estimation of radiation dose rate to a range of organisms that are typical, or representative, of a contaminated environment. These estimates, in turn, would provide a basis for assessing the likelihood and degree of radiation effects.
Risk	A statistical concept describing the expected frequency or probability of undesirable effects arising from exposure to a contaminant.

Risk characterisation:	The synthesis of information obtained during risk assessment for use in management decisions. This should include an estimation of the probability (or incidence) and magnitude (or severity) of the adverse effects likely to occur in a population or environmental compartment, together with identification of uncertainties.
Source	Anything that may cause radiation exposure — such as by emitting ionising radiation or by releasing radioactive substances or materials — and can be treated as a single entity for protection and safety purposes.
TLD	Thermo-luminescent Dosimeter
Uncertainty	Uncertainty is a statistical term that is used to represent the degree of accuracy and precision of data. It often expresses the range of possible values of a parameter or a measurement around a mean or preferred value.

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