NanoRem Case Study Sustainability Assessment Background and Workbook

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WP8: Up-Scaling, Risk and Sustainability

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This report draws heavily from the NICOLE Road Map for sustainable remediation (www.nicole.org) and the SuRF-UK guidance on sustainable remediation (www.claire.co.uk/surfuk) in particular for framing and Tier 1 assessment.

Executive Summary

This document has two broad purposes: to provide a background and NanoRem context for sustainable remediation and to provide a procedure to carry out a qualitative sustainability assessment of the nanoremediation technologies to be used at the field test sites. Each nanoremediation will be benchmarked against at least one possible alternative remediation strategy.

The concept of risk-based contaminated land management, based on prevention of unacceptable risks to human health and the environment, has developed significantly over the last two decades or so. More recently, interest has been shown in including sustainability as a decision-making criterion, and sustainable remediation has become an area of intense development across the world. As part of this global effort, several EU countries (Italy, the UK and the Netherlands) have set up a "sustainable remediation forum", following the example of SURF in the USA. These are closely aligned with sustainable remediation discussions taking place in the two major European contaminated land stakeholder networks, the COMMON FORUM and NICOLE.

For the NanoRem project a sustainability assessment procedure has been developed that is based on recognised good practice (the NICOLE Roadmap and SuRF-UK framework) and is consistent with risk-based land management. The procedure involves three stages:

1. *Preparation* - agreeing in advance how the sustainability assessment will be reported; who will be involved in dialogue as part of the process, and how communication will take place with other stakeholders.
2. *Definition* - providing a clearly defined assessment procedure, considering: objectives, boundaries, scope, method and uncertainty.
3. *Execution* - carrying out the assessment procedure defined with an appropriate level of dialogue and ensuring that the procedure, its findings and its underlying assumptions are clearly communicated to all relevant parties.

Given its subjectivity, sustainability assessment is carried out on a comparative basis, typically benchmarking against a "no intervention" scenario and at least one remediation alternative considered by the field test site team as being a feasible treatment alternative for the site.

SuRF-UK sustainability assessment's approach has been developed to support decision making, for example during project planning or the selection of best remedial approach. These decisions have already been made at the NanoRem pilot sites, so essentially the sustainability assessment being carried out is retrospective in nature. However, it is still considered a valuable exercise to document the views of key stakeholders involved in negotiating the NanoRem pilot trials on wider social, economic and environmental issues associated with deployment at the site.

It is proposed that the assessment will be carried out by the field test site teams, those most familiar with the site and key stakeholders, using standard reporting templates. The field test site teams will be supported by independent assessors from r3 and CL:AIRE in planning and executing the assessments. In addition to site-specific support, the assessors will also take a view across all of the field test site sustainability assessments to report on any common sustainability issues and themes, as well as points of difference that might be useful in a general sense for the future use of nanoremediation.

NanoRem offers a unique opportunity to discuss the sustainability of nanoremediation in both a site-specific and generic way that can better inform site owners, regulators and consultants who are

involved in future nanoremediation projects of the potential benefits and challenges associated with the application of this technology

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Glossary

This glossary is adapted from SuRF-UK (CL:AIRE 2010) and also includes terms for the NICOLE Road Map (NICOLE 2011) and the FP7 HOMBRE Project 265097 (www.zerobrownfields.eu).

Term	Contemporary Usage
Assessor	Any person who is involved in the process of assessing and judging [the sustainability of remedial strategies or techniques].
Best Available Technique (BAT)	The most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole - 'techniques' shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned, -'available' techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator, 'best' shall mean most effective in achieving a high general level of protection of the environment as a whole1.
Best Practical Environmental Option (BPEO)	The outcome of a systematic consultative and decision making procedure which emphasises the protection and conservation of the environment across land, air and water. The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole, at acceptable cost, in the long term as well as short term. (This is a UK definition[2] – other countries have similar definitions.)
Brownfield land	Land that has been previously used, interchangeably termed Previously Developed Land. Brownfield land *may* also be contaminated as a result of those previous uses.
Carbon balance / footprint	A carbon footprint is a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced, typically measured in units of tonnes of carbon dioxide equivalent. A carbon balance is calculated by estimating the mass of carbon dioxide e.g., emitted in the various process steps of a system. The scope of a carbon footprint analysis may account for emissions on-site only, on-site including emissions from electricity generation, or throughout the entire supply chain. Related concepts are water and waste footprints.

[1] As defined in the EC Integrated Pollution Prevention and Control Directive (IPPC), 96/61/EC
[2] As defined by the 12th Report of the UK Royal Commission on Environmental Pollution

Term	**Contemporary Usage**
Contaminated land	Land, which by virtue of the presence of contaminants in, on or under the land meets a national statutory definition of contaminated land.
Contaminant	Any physical, chemical, biological, or radiological substance or matter, which in sufficient concentration not normally present in the environment has the potential to cause harm to human health or the environment.
Core aspect	Describes the activities and their outcomes that are a result of the core objectives and project specific factors and constraints. [See Environment Agency, 2000b.]
Core objectives	Those remediation objectives that need to be achieved in order to enable redevelopment; to reduce risks to human health, the environment and construction; to reduce liabilities, or some combination of the preceding, reached after consideration of site specific factors / constraints and taking into account the views of the stakeholders for that site. [See Environment Agency, 2000b.]
Cost Benefit Analysis (CBA)	A form of economic analysis in which costs and benefits are converted into monetary values for comparison.
Decision making role	The decision making role describes the type of decision making being supported, e.g. for managing a single site, or for prioritising a number of sites. This deals with the overarching decision being made at the site.
Decision support system	A Decision Support System is the complete decision making approach, including all of its components.
Decision support tool	A Decision Support Tool supports one or more components of decision making. (Note some writers use “tool” and “system” interchangeably.)
Eco-efficiency	Is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle.
Evaluating wider impacts	Assessment systems for the key elements of sustainability appraisal (economic, environmental, resource and social evaluations)
Field test site	Contaminated site, which will be partly used to test the remediation via nanoparticles. The test area will be used for the controlled testing, optimization, validation or demonstration of a technology under real conditions.
Framework	A skeletal and fundamental structure, as for a written work, outlining a set of assumptions, concepts, values, and practices that constitutes a way of viewing reality.
Green remediation	United States Environmental Protection Agency (US EPA) definition of “The practice of considering all environmental effects of remedy implementation and incorporating options to maximise net environmental benefit of clean up actions.”
Headline indicator	Some indicators may be selected as headline indicators – usually because they describe key issues. They are often supported by a subset

Term	**Contemporary Usage**
	of indicators. Usually they form a quick guide or overview and can be used to engage public awareness and focus attention.
Indicator	An indicator is a single characteristic that can be compared between options to evaluate their relative performance towards specific sustainable development concerns. Indicators need to be measurable or comparable is some way that is sufficient to allow this evaluation.
Land contamination	Land which is affected by contaminants that may or may not meet a (national) statutory definition of contaminated land.
Land Cycle	The life cycle of a particular piece of land, to encompass its full history of operations, present setting, future aspirations and what is required to achieve those aspirations.
Life Cycle	Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal [See ISO 14040:2006(E)]. Product System is defined as a collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product. [See ISO standards 14044, 14047, 14048, and 14049].
Life Cycle Assessment (LCA)	Compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle [See ISO 14040:2006(E)].
Life Cycle Inventory Analysis (LCI)	Phase of Life Cycle Analysis involving the compilation and quantification of inputs and outputs for a product throughout its life cycle [See ISO 14040:2006(E)].
Multi-criteria analysis (MCA)	Any structured approach to determine overall preferences among alternative options, where the options accomplish several objectives. It is often used in government to describe those methods which do not rely predominantly on monetary valuations [See Department for Communities and Local Government 2009].
Non-core aspect	Describes the effects of and/or desires for a project not addressed by its core aspects. See also core aspect. [See Environment Agency, 2000b.]
Non-core objectives	Those secondary remediation objectives that need to be achieved after the core objectives have been set. For example, increasing the retail value of the site. [See Environment Agency, 2000b.]
Previously developed land	See 'Brownfield Land'.
Qualitative assessment	A non-quantitative assessment. One which measures impacts and benefits in a descriptive manner and without quantification.
Quantitative assessment	An assessment that uses (ideally objective) measurements of impacts and benefits in a numerically-based manner.
Remediation option	A means of reducing or controlling the risks associated with a particular pollutant linkage to a defined level.

Term	**Contemporary Usage**
Remediation strategy	A plan that involves one or more remediation options to reduce or control the risks from all the relevant pollutant linkages associated with the site.
Roadmap	A diagram showing the major steps necessary to reach a goal or decision.
Risk assessment	Quantitative or qualitative estimation and evaluation of the risks to the environment (e.g. groundwater and ecosystems) and human health posed by specific substances via named pathways, commonly done in a site-specific context.
Risk benefit analysis	Risk-benefit analysis is the comparison of the risk of a situation to its related benefits.
Risk management	The processes involved in identifying, assessing and determining risks, and the implementation of actions to mitigate the consequences or probabilities of occurrence
Site/project specific	Pertaining to an individual site or project / dependent on individual site or project characteristics.
Stakeholder	Any individual or group that may be affected by, or have a direct interest in (and are therefore consulted about), the environmental contamination, or by a decision taken to manage such contamination. Stakeholders may include national, regional, and local regulators, members of the general public or their elected representatives, businesses, citizen groups including NGOs, site owners, environmental industry, and public health officials.
Sustainable development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987).
Sustainability assessment	The process of gaining an understanding of possible outcomes across all three elements (environmental, social and economic) of sustainable development.
Sustainability management	The discipline of integrating sustainability assessment into contaminated land management decision making
Sustainable remediation	A sustainable remediation project is one that represents the best solution when considering environmental, social and economic factors – as agreed by the stakeholders
Verification	The process of demonstrating that the risk has been reduced to meet remediation criteria and objectives, based on a quantitative assessment of remediation performance.

1 Introduction and aim

NanoRem (*Taking Nanotechnological Remediation Processes from Lab Scale to End User Applications for the Restoration of a Clean Environment*) is a research project, funded through the European Commission's Framework 7 research programme. NanoRem focuses on facilitating practical, safe, economic and exploitable nanotechnology for *in situ* remediation. This is being undertaken in parallel with developing a comprehensive understanding of the environmental risk-benefit for the use of nanoparticles (NPs), market demand, overall sustainability, and stakeholder perceptions.

NanoRem has set itself the goal of achieving a step change in the development and use of nanoremediation technology in Europe. To reach this goal does not only depend on the creation of new research information, but also on the transmission to remediation practitioners and encouraging their use of that information. Its strategy to achieve this aim depends on three strands working together in an integrated way:

1. Providing evidence that addresses crucial gaps in knowledge about nanoparticles and their properties (in particular related to fate, transport and ecological impacts): observations of the behaviour of nanoparticles in-ground during practical trials; and well documented and independently scrutinised case studies of field scale deployments.
2. Ensuring the quality of this evidence, and ensuring that any applications in the field are seen as robust tests, both in the national jurisdiction where they are taking place and at a European level. This will be achieved by:
   - Subjecting evidence to review and scrutiny by an independent project advisory board and the various European stakeholder networks involved with contaminated land management (see below)
   - Providing transparent approaches to the assessment of deployment risks in NanoRem case studies that are firmly supported by existing evidence and can be broadly regarded as best available practice for decision making on a pan-European basis (and not just the national jurisdiction of where a trial takes place)
   - Providing at least a qualitative understanding of the life cycle impacts of the production of NPs used in NanoRem case studies *and a qualitative sustainability assessment of the nanoremediation used, benchmarked against at least one possible alternative remediation strategy*.
3. Communicating the evidence and developing shared conclusions.

This document has two broad functions. Chapter 2 provides a background and NanoRem context for sustainable remediation. The remainder of the document is a workbook for applying sustainability assessment at NanoRem field test sites. The background is intended to provide the rationale for the workbook.

In addition, it may also be prudent to include a general consideration of sustainability as a general good practice at field test sites across all phases of work from site investigation to remediation investigation to minimise the sustainability impacts of the work carried out, whatever approach is selected. Guidance on Sustainable Management Practices is available from CL:AIRE (2014A).

<u>The aim of this workbook</u> is to provide a procedure and approach to record keeping and reporting that can be used to provide *a qualitative sustainability assessment of the nanoremediation used benchmarked against at least one possible alternative remediation strategy*. The goal of the workbook is to provide a basis for sustainability assessment at selected field test sites (see Section 2.4) where an assessment can be carried out and transparently reported by the local project team with the support of an **independent assessor** from r^3 environmental technology or CL:AIRE, as

required. It is desirable that this process also involves other local stakeholders involved with the field test site.

Note: This workbook does not relate to Deployment Risk Assessment. NanoRem is anxious that all stakeholders can see that it has taken a transparent and ethical approach to its deployment of NPs in the field, with deployment risk assessment following best available guidance. To this end it carried out an expert elicitation workshop and technical review over 2013 resulting in the development of a common protocol for case studies and their local stakeholders to follow for deployment risk assessment (LQM 2014).

2 Sustainable remediation in the context of NanoRem

2.1 In a nutshell

The NICOLE Road Map for Sustainable Remediation (NICOLE 2011) describes sustainable remediation as follows:

1. A sustainable remediation project is one that represents the best solution when considering environmental, social and economic factors – as agreed by the stakeholders.
2. Similar to the concept of risk management and risk assessment, sustainable remediation can be divided into two inter-related components:
    a. *Sustainability management:* the discipline of integrating sustainability assessment into contaminated land management decision making
    b. *Sustainability assessment:* the process of gaining an understanding of possible outcomes across all three elements (environmental, social and economic) of sustainable development.
3. Sustainability assessment is a tool that supports sustainability based decision-making within a management plan, and also the review and verification of sustainability performance during the implementation of remediation.
4. The aim of a sustainability assessment is to build trust and consensus between stakeholders; the simplest tools, indicators or qualitative approaches will be sufficient in the earliest stages and can be further developed in line with the project complexity.
5. The earlier stakeholders consider sustainability principles, the more opportunities there are to improve sustainable outcomes and so provide greater benefit, as shown in Figure 1.

More information on the technical basis and scope of sustainable remediation is available in Bardos *et al.* 2011A, Bardos *et al.* 2011B, and SURF 2009.

2.2 Background and principles

In the past decade or so, management of historically contaminated land has largely been based on prevention of unacceptable risks to human health and the environment, to ensure a site is 'fit for use'(Vegter *et al.* 2002). More recently, interest has been shown in including sustainability as a decision-making criterion. Sustainable remediation has become an area of intense development across the world (Bardos *et al.* 2013). Public and Private Sector organisations have become involved in a number of projects and networks intended to improve remediation practice and make it more sustainable. As part of this global effort, several EU countries including Italy, the UK and the Netherlands have set up a "sustainable remediation forum", following the example of SURF in the USA (e.g. SuRF NL 2011). These are closely aligned with sustainable remediation discussions taking place in the two major European contaminated land stakeholder networks, the COMMON FORUM and NICOLE, see Table 1.

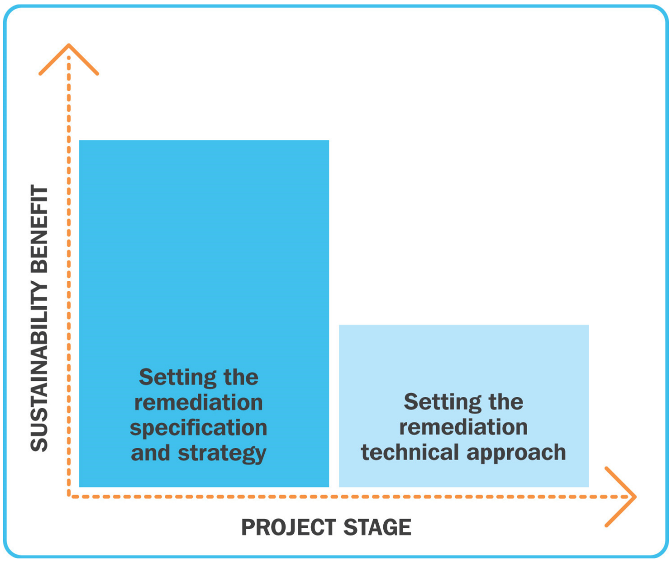

Figure 1 Illustration of sustainability gain dependent on the stage of the project at which it is introduced - from NICOLE (2011)

Table 1. The COMMON FORUM and NICOLE

COMMON FORUM	The COMMON FORUM on Contaminated Land, initiated in 1994, is a network of contaminated land policy makers, regulators and technical advisors from Environment Authorities in European Union member states and European Free Trade Association countries (www.commonforum.eu).
NICOLE	The Network for Industrially Contaminated Land in Europe (NICOLE) began in 1995. It is primarily a network of industrial problem holders and service providers, contractors and consultants (www.nicole.org).

"Sustainable Development" has been defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). The emerging international consensus is that in broad terms sustainable remediation is the achievement of a net benefit overall across a range of environmental, economic and social concerns that are judged to be representative of sustainability (Bardos *et al.* 2013, Bardos 2014). The scope of sustainability is broad, ranging over the three elements of sustainability (environment, economy and society), as illustrated by the example from the UK in Table 2 (CL:AIRE 2011). This is a much broader scope than the related concept of "green remediation" which focuses only on the environmental footprint of remediation processes (US EPA 2008).

There is also a developing consensus that what sustainability encompasses is highly site specific and depends on opinions from a range of stakeholders with interests in a particular site. As such sustainability is subjective rather than objectively quantifiable. However, while sustainability is not capable of direct measurement, there is general agreement that it is possible to assess sustainability on a site specific basis, compare possible rehabilitation options, and monitor sustainability "performance" once a chosen option is implemented.

A number of underpinning principles also seem to be broadly accepted. These are largely consistent with the six key sustainable remediation principles published by SuRF-UK (CL:AIRE 2010), set out in Table 3. The fundamental rationale for carrying out remediation work is to manage risks; if there are no risks there is no case for remediation. Conversely, the urgency of the need for remediation depends on the importance of the risks identified. *Sustainability cannot be used as a general excuse to avoid a necessary risk management action*. Sustainable remediation is therefore a process of finding the optimum means of managing risks to the benefit of society as a whole.

Table 2: Overarching SuRF-UK Sustainable Remediation Considerations (CL:AIRE 2010)

Environment	Social	Economic
Emissions to Air	Human health & safety	Direct economic costs & benefits
Soil and ground conditions	Ethics & equity	Indirect economic costs & benefits
Groundwater & surface water	Neighbourhoods & locality	Employment & employment capital
Ecology	Communities & community involvement	Induced economic costs & benefits
Natural resources & waste	Uncertainty & evidence	Project lifespan & flexibility

Table 3 SuRF-UK Principles for Sustainable Remediation (CL:AIRE 2010)

1	**Protection of human health and the wider environment**. Remediation [site-specific risk management] should remove unacceptable risks to human health and protect the wider environment now and in the future for the agreed land-use, and give due consideration to the costs, benefits, effectiveness, durability and technical feasibility of available options.
2	**Safe working practices**. Remediation works should be safe for all workers and for local communities, and should minimise impacts on the environment.
3	**Consistent, clear and reproducible evidence-based decision-making.** Sustainable risk-based remediation decisions are made having regard to environmental, social and economic factors, and consider both current and likely future implications. Such sustainable and risk-based remediation solutions maximise the potential benefits achieved. Where benefits and impacts are aggregated or traded in some way this process should be explained and a clear rationale provided.
4	**Record keeping and transparent reporting**. Remediation decisions, including the assumptions and supporting data used to reach them, should be documented in a clear and easily understood format in order to demonstrate to interested parties that a sustainable (or otherwise) solution has been adopted.
5	**Good governance and stakeholder involvement.** Remediation decisions should be made having regard to the views of stakeholders and following a clear process within which they can participate.
6	**Sound science.** Decisions should be made on the basis of sound science, relevant and accurate data, and clearly explained assumptions, uncertainties and professional judgment. This will ensure that decisions are based upon the best available information and are justifiable and reproducible.

2.3 NanoRem's approach to sustainability assessment

From the point of view of NanoRem, as a pan-European project, the most appropriate points of linkage are to the pan-European networks, NICOLE and COMMON FORUM. NICOLE has published outline guidance, a sustainable remediation "road-map" (NICOLE 2011), and both networks have collaborated on a joint position statement about the importance of sustainable remediation (NICOLE and COMMON FORUM 2013). NICOLE has provided an overall description of sustainable remediation in its four page road map. While it has not provided detailed guidance on how sustainability assessment should be accomplished, it has set out a broad approach, which is shown in Figure 2 below.

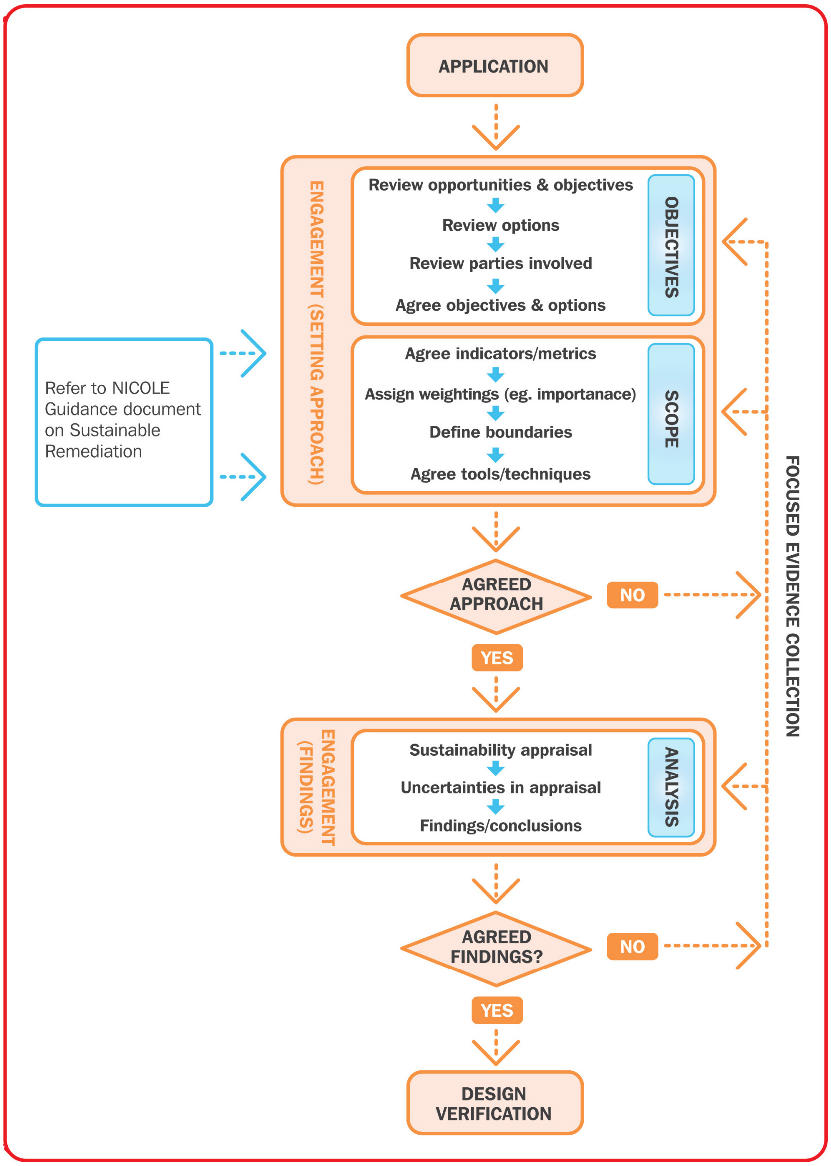

Figure 2 The general approach to sustainability assessment described in the NICOLE Road Map (NICOLE 2011)

A more elaborated detailed procedure is needed for practical use for NanoRem's field test sites. The COMMON FORUM – NICOLE Joint Position Statement highlights the guidance from SuRF-UK as being relevant for sustainable remediation: "Drawing from the work of CLARINET, the concept of 'sustainable remediation' has been described in the SuRF-UK Framework for Assessing the Sustainability of Soil and Groundwater Remediation (CL:AIRE, 2010), the NICOLE Roadmap for Sustainable Remediation (NICOLE, 2010) and elsewhere. The approaches to assessing sustainable remediation described in these reference documents, are considered good practice, consistent with existing risk-informed contaminated land management practice, and are recommended as a basis for future practice on the management of soil, sediment and groundwater contamination in Europe." SuRF-UK has recently published guidance to support the development of sustainability assessment procedures (CL:AIRE 2014B) which is freely downloadable from www.claire.co.uk/surfuk.

Since the SuRF-UK framework (CL:AIRE 2010) and the NICOLE Road Map (NICOLE 2011) are consistent and are also consistent broadly with thinking in SuRF-NL and SuRF-Italy, NanoRem will use the NICOLE description of sustainable remediation (see Section 2.1); and will apply the SuRF UK methodology for sustainability assessment. This will provide a consistent platform and approach to sustainability assessment across all of the field test sites where sustainability assessment is carried out.

2.4 NanoRem's approach to benchmarking, retrospection, level of quantification and the roles of participants

Given its subjectivity, sustainability assessment needs to be carried out on a comparative basis. Conventionally this might be against a "no intervention" scenario. Although this is an unlikely scenario for the various NanoRem field test sites, it is recommended to include it as a benchmark to understand the impact of the intervention options. NanoRem will also benchmark the sustainability of nanoremediation as an approach against at least one remediation alternative considered by the local case study team as being a valid treatment alternative for the site, and possibly a no intervention scenario.

SuRF-UK sustainability assessment's approach has been developed to support decision making, for example during project planning or the selection of best remedial approach. These decisions have already been made at the NanoRem field test sites, so essentially the sustainability assessment being carried out is *retrospective* in nature, comparing nanoremediation against the selected benchmark using the available information.

NanoRem does not have the resources for carrying out quantitative assessments so work will be based on qualitative assessments (although this may use simple rankings for instance). The evidence base for each individual assessment will need to be clearly reported.

It is proposed that the lead will be provided by a member of the NanoRem field test team. This person will have significant knowledge of the site and the project, and with the decision-making process that has led to nanoremediation being proposed for the field test. The lead assessor will be a NanoRem project partner, typically the consultant or contractor involved in the design of the field test.

The lead assessor will carry out the initial project framing (preparation and definition) with the support of other NanoRem field test participants and an independent assessor. The lead assessor will also ensure that stakeholders are identified and engaged throughout the process, but in particular during its execution.

The role of the **independent assessor** will be to facilitate the sustainability assessment process by the field test site team, and provide technical support for them. This role may vary from site to site, but can offer:

- Provision of the Workbook and associated documents and templates to the lead assessor
- Initial briefing on the NanoRem sustainability assessment procedure (e.g. using web-based technologies)
- Support on preparation and definition to the lead assessor
- Attendance at the execution of the sustainability assessment, to answer any queries arising
- Support on reporting the sustainability assessment outcomes.

The independent assessor will also take a view across all of the sustainability assessments to report on any common sustainability issues and themes across case studies, as well as points of difference, that might be useful in a general sense for the future use of nanoremediation.

The **other stakeholders** involved may vary from site to site, depending on project circumstances, in particular the parties involved in or affected by the decision. A core stakeholder group will include the problem holder, service provider and regulator (environmental and planning). Other stakeholders to consider include:

- Site users (e.g. workers and visitors)
- Site neighbours (e.g. local communities, adjacent owners)
- Those with financial interests (e.g. bankers, insurers)
- Others (e.g. non-government organisations, local interest groups).

The stakeholder's role is to be actively involved in the decision-making process at as early a stage as possible, but in particular during execution of the NanoRem sustainability assessment.

Work will focus on one or two of the field test sites after injections have taken place. The benefits of carrying out the assessment post-injection are that:

- Technical information will be available to reduce uncertainty when considering nanoremediation against well-established technologies
- As much information as possible will be available to support the assessment, and therefore reduce the need for iteration
- The availability of field test data provides an option of carrying out an "optioneering" assessment for a hypothetical remediation project
- It will be an opportunity to gather important stakeholders together and provide an outline of the field test results.

The expectation is that case study participants from WP10 will support the assessor in planning a qualitative assessment using the spreadsheet tool discussed later in the report, most likely by e-mail and teleconference. This framing will be used to facilitate a sustainability assessment with the selected wider stakeholders involved with the site. The meeting will be organised by the WP10 members concerned for any particular site in discussion with the independent assessor, who will facilitate the meeting if requested and record the outcomes. Where there are differences of opinion that are not resolved during the discussions, they will be recorded along with the reasons for them.

The independent assessor will prepare a brief sustainability assessment report for each field test site, presenting the stakeholder assessment spreadsheet as an annex. Each report will discuss the general qualitative sustainability assessment outcome, including any judgement calls the independent assessor has made to resolve differences in opinion (this may include sensitivity analyses). In addition the report will include a discussion of the process, the level of stakeholder involvement and how outcomes were reached.

3 Overview of the NanoRem sustainability assessment procedure

The various international sustainable remediation initiatives in Section 2.2 recognise the need for some form of at least comparative sustainability assessment as a basis for decision making, for example for options appraisal (as described above). The components of sustainability assessment comprise agreeing clear objectives for the assessment, clear boundaries, an agreed scope (range of sustainability considerations, i.e. indicators) and a methodology for combining individual comparisons for particular indicators into an over-arching view of sustainability (e.g. CL:AIRE 2010, Holland *et al.* 2011, NICOLE 2011). Figure 3, below, shows the SuRF-UK approach to sustainability assessment (CL:AIRE 2014B), which NanoRem will use. Key features of this approach are its structure, where assessment work is carried out in a progressive way to avoid hidden assumptions, and its concept of "framing" where there are stages of preparation for a sustainability assessment, followed by a stage for defining how the assessment will be done, before it is finally executed. The SuRF-UK approach is very much based on a "bottom-up" concept where those involved with a project set their own objectives, boundaries, scope and method based on their site specific requirements and local stakeholder requirements.

There are three broad stages in sustainability assessment:

1. *Preparation, to provide a clear specification for the sustainability assessment.* This involves agreeing (and documenting) in advance how the sustainability assessment will be reported; who will be involved in dialogue as part of the process, and how communication will take place with other stakeholders.
2. *Definition, to provide a clearly defined assessment procedure, considering: objectives, boundaries, scope, method and uncertainty.* This ensures that the sustainability assessment procedure is clearly documented, supported by its key users and can be transparently reported and communicated to all relevant parties.
3. *Execution, to carry out the assessment procedure defined.* This is implementation of the assessment procedure with an appropriate level of dialogue; and ensuring that the procedure, its findings and its underlying assumptions are clearly documented and communicated to all relevant parties.

Taken together, preparation and definition provide the framework that the sustainability assessment will work from, whether it is qualitative, semi-quantitative or quantitative. SuRF-UK refers to these two stages together as "framing". As Figure 3 shows, each of these stages has been divided into individual steps which will be followed for each NanoRem case study sustainability assessment. These steps and how they will be carried out for NanoRem case studies are set out in Chapter 5.

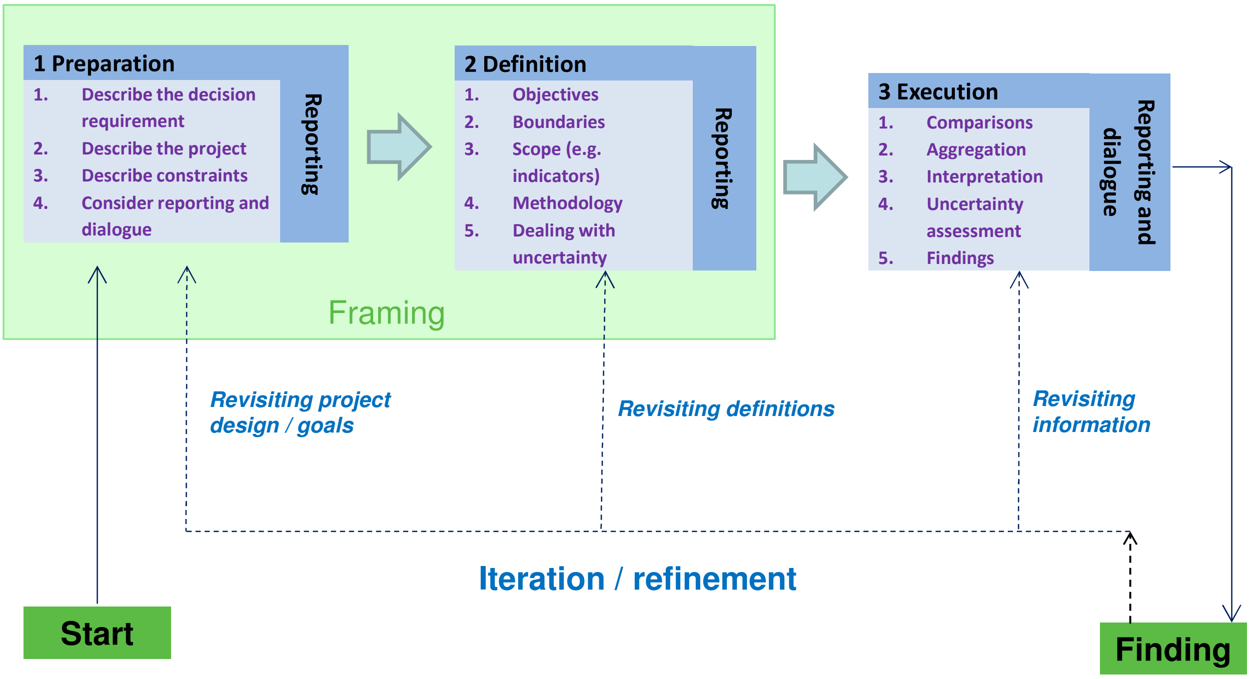

FIGURE 3 SuRF-UK Approach to Sustainability Assessment (CL:AIRE 2014B)

Sustainability assessment may be an iterative process, with successive iterations refining the sustainability assessment. For NanoRem, the extent of iteration is likely to be an initial assessment by the project team, including the independent assessor, to provide an initial "model" to avoid trying to work from a "blank canvas" with a large group. This facilitates discussion with wider stakeholders to refine the assessment in a subsequent iteration. This is likely to be the mode of operation for the NanoRem case studies. Points of difference will be recorded and some form of uncertainty assessment will be used to evaluate the effect of two different opinions on the overall sustainability outcome.

It is clearly important to NanoRem that the wider stakeholders involved with an assessment agree with the framing (preparation and definition stages), otherwise they will not be able to support its outcomes. The independent assessor will present the framing to the stakeholder group and seek approval, or make changes as applicable, before carrying out the assessment. In addition, judgements have to be made about how convincing the framing would be to the wider European audience of the NanoRem project. *A key role of the* ***independent assessor*** *will be to assist the field test site project team and stakeholders in devising a sustainability assessment approach likely to be seen as valid by this wider EU audience*.

The NanoRem project does not have the resources to carry out detailed additional investigations to collate new information to support sustainability assessment (for example field scale measurements). The NanoRem sustainability assessments are by their nature retrospective and being benchmarked against a theoretical alternative remediation option and baseline "no intervention" approach. This will provide information about the sustainability interests of the different stakeholder groups involved, the context of the field test site and the *relative* sustainability of nanoremediation against a benchmark. An alternative to a retrospective assessment open to the project team is an "optioneering" assessment, using the results of the field tests as a treatability study to support the option of nanoremediation.

NanoRem is resourced only to carry out a qualitative assessment. If this finds that, in the comparison with benchmark technologies, the sustainability of nanoremediation is very similar to that of an effective alternative remediation strategy; that fact is an important finding for NanoRem.

4 Dialogue, transparency, reporting and evidence

Sustainability assessment for remediation is subjective and depends on engaging local stakeholders to provide their opinions and evidence, as well as the NanoRem team, for maximum effectiveness. The intention of NanoRem is that the sustainability assessment is an accurate reflection of the field test project as envisioned by the project team and the local stakeholders involved with the project (site owner, regulator etc). Stakeholders will be selected by the project team. Where, for whatever reason, a stakeholder cannot be involved, the project team may provide a "second guess" for their opinion. However, the origin of all information and opinions, and any assumptions made, will be clearly stated in the sustainability assessment report for the project. The independent assessors will also be able to provide a view from a different Member State.

Reporting and dialogue is a key part of all three stages of the sustainability assessment process, as described in Chapter 3. Dialogue is the process of interacting with the stakeholders (interested parties) in a project. Broadly speaking these will fall into two groups:

- Dialogue Partners: Those whose opinions need to be considered and will fundamentally influence the sustainability assessment.
- Wider audience: Those who the sustainability assessment will be communicated to, but who will not play an active role in determining it.

It is important that mixed messages are not delivered and that any reporting to bodies outside of the immediate project group is agreed in advance. It is recommended that communications outside the core group are handled by a single, named individual.

Engagement for dialogue will be highly site/project specific, and a wider project plan for dialogue and communication may exist, which may define who the key stakeholders are and how they should be approached. The test site teams will need to determine what engagement is necessary and with whom to achieve a robust and credible sustainability assessment. The **independent assessor** will provide advice about this.

It is vitally important that the sustainability assessment is fully documented. Transparency is the underpinning principle of sustainability assessment reporting. A suggested format and rationale for reporting the NanoRem sustainability assessments is provided in Chapter 5. This follows closely the SuRF-UK sustainability assessment steps. A spreadsheet which can be used for record keeping, shown in Chapter 5, is downloadable from SuRF-UK (www.claire.co.uk/surfuk).

The independent assessor will record details in a **log book** for the sustainability assessment. Table 4 sets out a template for this **log book** which is in a diary format. This can also be transferred to a spreadsheet template.

Table 4 Sustainability Assessment Log Book Format

Date	Assessment Step	Type of issue	Summary of key points	Participants
	As shown in Chapter 5 of the	For example: • A decision reached	Describe what was agreed / what the issue is / what the uncertainty is etc.	Names / organisations of those who

	workbook	• Checklist validated • Difference in opinion → uncertainty • Action agreed • Assumption made • Conclusion (e.g. for interpretation or uncertainty analysis during the execution stage		took part

Figure 4 sets out the components of sustainability assessment that need to be reported and the connections between them:

- Assumptions: what assumptions were made to allow a practical sustainability assessment exercise to take place (for example about boundary conditions, when impacts would be considered *de minimis*). Document the assumptions for each step of the process in preparation, definition and execution. This should be done sequentially, recording at the start of each step what has been agreed/assumed during the preceding step/s.
- Framing: recording the decisions made, the rationale behind them, and who was involved in the agreement.
- Evidence: document the evidence for each step. As sustainability assessments are based upon sound science, it is important that supporting data is produced to support the evidence put forward as part of the discussion. This documentary evidence and opinions supplied, and the decisions made based upon them, need to be clearly recorded.
- Assessment: carefully describe the assessment process, how individual assessments were made and how these were linked to assumptions, evidence and the framing agreed for the process. Describe how any uncertainties in the outcome were considered.
- Stakeholder engagement: record how stakeholder inputs were considered in the different steps of the sustainability assessment.

It is important to record any key issues that may need to be tested as “uncertainties”. It may become apparent during discussion that members of the group have differences in opinion which cannot be resolved and which can cause uncertainly in the assessment. These may arise principally because of differences in opinion in what should be included/excluded in the assessment, and difficultly in comparing different options due to incomplete information. It is important that the mechanism for dealing with these uncertainties is addressed and recorded.

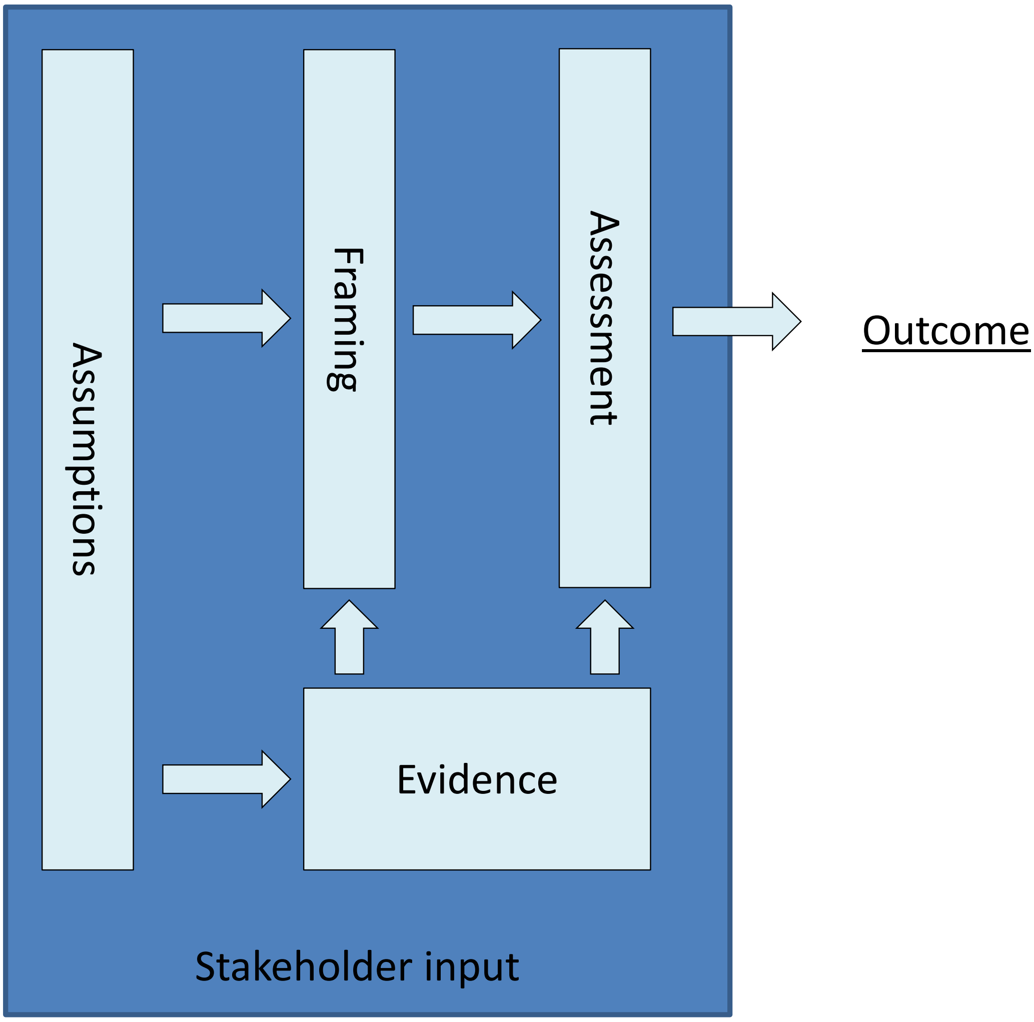

Figure 4: Components of sustainability assessment that should be reported

5 Sustainability Assessment Procedure Step by Step

A PDF slide set providing further information in support of the *framing* steps is downloadable from www.claire.co.uk/surfuk in the section "supporting information".

5.1 Preparation

Preparation is needed to provide a clear specification for the sustainability assessment to be undertaken. There are a number of steps to be completed to successfully plan for the assessment, namely: to describe the decision requirement, to describe the project, to describe the constraints, and to consider the reporting requirements. As the NanoRem field test sites are already selected the sustainability assessment is retrospective, but an option is to consider a hypothetical options appraisal to identify key sustainability issues for nanoremediation in comparison to other established technologies. The preparation steps are described in detail below, adapted for NanoRem.

Preparation Step 1: Describe the decision required

Description	The project team need to come to an agreed description as to why the assessment is being undertaken, including the description of how the output of the assessment is likely to be used, and how this is to be linked to the wider project management process. They also need to identify those whose opinions will be important for the sustainability assessment, and who the sustainability assessment seeks to inform, as these stakeholders will need to be involved in dialogue at some point. The project team also need to consider how and when this communication will take place with wider stakeholders who may be interested in the assessment outcomes but will not be involved in the assessment process.
Tasks	a) List the project team members in initial sustainability assessment work and the **independent assessor** supporting them b) Describe the assessment function. For example, to support project design as a part of options appraisal. c) Describe what decisions/actions are going to be informed by the sustainability assessment and how it is linked to the wider project management process / decisions. d) List the "dialogue partners" and their roles, in particular the users of the sustainability assessment (e.g. client, consultant, regulator, planner etc.) and anyone else who needs to be a part of the sustainability assessment process for it to be credible. e) Describe any wider audience for the sustainability assessment and what their needs might be.
NanoRem context	The sustainability assessment being carried out is retrospective in nature, comparing nanoremediation against the selected benchmark using the available information. The principal goal of the assessment is to provide an indication of the relative sustainability of nanoremediation for research purposes to identify any common themes as part of NanoRem WP9. A broad EU audience of practitioners and researchers will use the NanoRem outputs. It is therefore important that NanoRem's individual sustainability assessment case studies take into account the European state of the art in sustainability assessment for sustainable remediation.

Reporting – template available as an XLS download from SuRF-UK

URS

Preparation 1A - The function of the assessment

Table P1A

The Sustainability Assessment can be used for different functions:
a) Stage A: From a planning point of view with consideration of different land uses; and/or,
b) Stage B: When the land use is already confirmed and the focus is only on the implementation of the remediation system

Consideration	Answer
To what extent does this assessment cover Stage A?	
To what extent does this assessment cover Stage B?	

Preparation 1B - Describe the decisions to be made and the stakeholders involved

Table P1Ba

List the decisions/actions that are expected to be supported by the sustainability assessment and describe how it is linked to the wider project management scheme:

Decisions / Actions	How does this link to the wider project management?

Table P1Bb

List the "dialogue partners" and their roles:
- Users of the sustainability assessment (e.g. client, consultant, regulator, planner etc.)
- Other parties who will need to play an active role in the sustainability assessment (e.g. the planner asks for some form of community input)

User/Other active party	Dialogue Partner	Role

Table P1Bc

List the "wider audience" (if any) for the sustainability assessment, who will be told about the findings but will not play an active role in the assessment process.

List of wider audience members

Preparation Step 2: Describe the project

Description	The aim of this stage is to clearly describe the project being considered. This description needs to set out the project objectives, and the options being compared to reach those objectives. The description of options has to be consistent in that each option must have the same start and end points. It is important to fully consider contexts, for example if one treatment option yields a material reusable on site, and another a material that needs to be landfilled, the end points are the impacts of the re-use on site and the impacts of the disposal to landfill, respectively. No particular option should gain an unfair assessment advantage because a segment of its impacts are being ignored. This discussion goals and options will also help define the system boundary that the sustainability assessment will need to be based on (during the Definition stage of framing).
Tasks	a) Clearly describe the project goals b) Clearly describe the options for delivering the project that are to be compared using sustainability assessment
NanoRem context	The project being considered is the use of nanoremediation to reach a desired set of remediation or management objectives that may be actual or hypothetical. This is the project that needs to be described. The options being compared are the nanoremediation trial and the benchmarking approach decided on by the project team as described in Section 2.4.

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Preparation 2 - Describe the Project

The goals and options will define the system boundary that the sustainability assessment will need to be based on.

Table P2a

List and describe the project goals in as much detail as possible:

Project Goals

Table P2b

List and describe the options for delivering the project that are to be compared using sustainability assessment:

Option	Option Goal	Option Name	Description

Preparation Step 3: Describe constraints

Description	Constraints are limitations or restrictions and may be environmental (structural), economic or social in nature. Constraints may be related to: • Site features or conditions. For example site topography, hydrogeological conditions, access to services such as mains electricity. • Project conditions. For example, limits to available time or budget. • Regulations and policy (government or corporate). For example allowable road traffic, allowable hours of operation. • Decisions that have already been taken and will not be revisited. For example, on-going / future land-use. As well as constraints there may be site features, project conditions, regulations & policy and pre-existing decisions that create opportunities to create sustainability gains. Constraints (and opportunities) affect the available range of options and how options may be compared for particular sustainability criteria. They may also lead to minimum thresholds that have to be achieved for different sustainability considerations. It is important that project constraints are clearly described so that all stakeholders can understand their impact on choice of options and the framing of the sustainability assessment.
Tasks	a) Clearly describe key constraints and opportunities b) Tabulate the constraints and any consequential thresholds for them.
NanoRem context	Constraints and opportunities will tend to be site related than technology related. Note the SuRF-UK downloadable template does not include a specific area for opportunities, but opportunities can be included in the constraints table (Table P3a) as long as they are clearly identified as such.

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Preparation 3 - Describe Constraints

Table P3a

Tabulate the constraints and any consequential thresholds for them.

Constraint	Constraint Description	Threshold (if applicable)

Preparation Step 4: Plan Reporting and dialogue

Description	Chapter 4 describes reporting and dialogue for sustainability assessment. The purpose of this step is to agree at an early stage the reporting and dialogue strategy which will be adopted for this particular assessment.
Tasks	a) Plan how reporting and dialogue will be undertaken, specifying who will be involved and when. b) Who will be involved? When will they be involved? Explain why things will be done in this way. c) Describe how they will be involved (getting and using stakeholder inputs / resolving conflicting views). d) Agree the reporting approach / template.
NanoRem context	The reporting template and approach described in this workbook will be used for reporting the NanoRem sustainability assessments. A two phase discussion with stakeholders is suggested, starting with an initial sustainability assessment carried out as a discussion between members of the project team with the independent assessor, which is then offered for consultation and dialogue to a wider group of stakeholders in a second stage of iteration (see Chapter 3). Whether this approach is pursued is at the discretion of the project team.

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URS

Preparation 4 - Dialogue and Reporting

Plan how reporting and dialogue will be undertaken, specifying who will be involved and when.
Who will be involved? When will they be involved?
Include notes on this in the grey box below:

Table P4a

List the project timeline / milestones and include who will be involved at each stage:

Date	Milestone	Description	Attendees	Extent of Attendee Involvement

Table P4b

Describe how the results will be communicated during the project and for the final reporting:

5.2 Definition

The goal of this stage is to reach a clear definition of the sustainability assessment approach that is to be undertaken which can be discussed with (and ultimately supported by) its key users, considers all key factors, is transparently reported and communicated to all relevant parties. This will reduce the potential for disagreement at the end of the assessment. It uses the outputs of the preparation stage as a starting point and includes five steps dealing with: objectives, boundaries, scope, methodology, and reviewing uncertainties.

Definition Step 1: Objectives

Description	Defining the sustainability objectives involves the summarisation of the preparation stage to provide a concise description of what the sustainability assessment is considering, what its purpose is, what factors affect it, who it will be discussed with and how it will be reported.
Tasks	a) Summarise the preparatory work • The decision making being supported • The function of the sustainability assessment • The project (goals and options) being considered • The constraints (and opportunities) affecting choices and resulting thresholds • The plan for reporting and dialogue
NanoRem context	Within SuRF-UK's framework (similar to the NICOLE Road Map), two broad stages of decision making are identified: *Stage A*, project planning and overall remediation design; and *Stage B* choice of remediation options (using SuRF-UK terminology). All of the NanoRem sustainability assessments are at *Stage B*

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Definition 1 - Agreeing Objectives

Summarise the preparatory work carried out in the previous tabs in the space below:

1) Which part of the decision making process is this assessment supporting (Stage A and/or Stage B)? Provide the reasoning.

2) Summarise the function of the sustainability assessment

3) Summarise the project goals and options being considered:

4) Summarise the constraints affecting the choices and the associated thresholds:

5) Summarise the plan for reporting and dialogue:

Definition Step 2: Boundaries

Description	Boundary conditions determine which effects will be considered within a sustainability assessment to ensure a fair, like-for-like comparison of options, they rationalise the use of effort, and usefully distinguish effects.
Tasks	a) Describe the assessment boundary conditions • System (that treats all options equally) • "life cycle" (e.g. dealing with equipment that will be re-used, level of detail of the assessment) • Spatial (e.g. to distinguish local from global effects) • Temporal (e.g. to distinguish temporary from permanent effects)
NanoRem context	Nothing additional

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Definition 2 - Boundary Conditions

Boundary conditions determine which effects will be considered within a sustainability assessment to ensure a fair, like-for-like comparison of options, they rationalise the use of effort, and usefully distinguish effects.

Complete the table with the boundary settings for each factor listed:

Table D2

Boundary Aspect	Inclusions/Exclusions

Definitions: System (that reflects all options equally); "Lifecycle" (e.g. dealing with equipment that will be re-used); Spatial (e.g. to distinguish local from global effects); Temporal ((e.g. to distinguish temporary from permanent effects)

Definition Step 3: Specify the scope of the assessment

Description	Sustainability assessment comprises the compilation of a broad range of individual assessments for specific factors considered important in understanding sustainability for a particular site and project (see Section 2.2). This step is where the scope of the sustainability assessment is decided, identifying what effects are going to be considered under the general heading of sustainability. These choices could be made by benchmarking against a generic list of possible assessment criteria (indicators), although not all ~~(?)~~ of these may be selected as relevant.
Tasks	a) Describe the range of sustainability considerations included in the assessment b) Describe the level of detail c) Describe how criteria were included / excluded d) Record for each criterion why it was included / excluded in the scope of sustainability
NanoRem context	The SuRF-UK indicator set will be used by NanoRem (CL:AIRE 2010). In order to provide the most complete assessment possible, it is suggested that no criteria will be excluded. This may mean that some additional individual considerations are tied for all options under consideration.

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Definition 3 - Specify the Scope of the Assessment

1) Describe the range of sustainability considerations included in the assessment:

2) Describe the level of detail:

3) Describe how criteria were included / excluded:

Table D3a

Detail the assessment criteria to be used and the way they will be scored:

Assessment criteria	Justification for Exclusion (if applicable)	Level of confidence in data used for justification (if applicable)
Environmental		
Emissions to air		
Soil and ground conditions		
Groundwater and surface water		
Ecology		
Natural resources and waste		
Economic		
Direct economic costs and benefits		
Indirect economic costs and benefits		
Employment and employment capital		
Induced economic costs and benefits		
Project lifespan and flexibility		
Social		
Human health and safety		
Ethics and equality		
Neighbourhoods and locality		
Communities and community involvement		
Uncertainty and evidence		

Definition Step 4: Decide methodology

Description	The "engine room" of the sustainability assessment is where individual comparisons across options are carried about and then aggregated into an overall sustainability assessment. The SuRF-UK Framing and Tier 1 Assessment slide decks describe a range of ways in which this might be achieved. Comparisons should be made on a criterion by criterion basis to ensure exhaustive consideration of sustainability effects and avoid unintentional confusion of effects.
Tasks	a) Define / agree the methodology by which options are going to be compared for the different individual sustainability criteria being considered. For example, will they be ranked or given some kind of label ("very good", "good", "bad" etc)? b) Define / agree the methodology by which individual comparisons will be aggregated into broader assessment of sustainability and how the assessment outcomes will be presented, interpreted and communicated. c) Where thresholds are being used: decide what to do if an option fails to meet a threshold for a particular criterion.
NanoRem context	NanoRem will be carrying out qualitative sustainability assessment. A simple ranking system will be used by NanoRem (1 being the best performer for a particular criterion, 2 next best etc). This will avoid complexity where English is not first language. These rankings should not be regarded as quantitative or semi-quantitative as they carry no reflection of a metric or value; they simply reflect a qualitative comparison outcome. The use of rankings for individual criteria allows patterns to emerge across sustainability assessment overall, and does facilitate aggregation (with the proviso that this is a not a quantity, other than say to reflect the option with the most "1's" for example. The use of colour has also been found to be useful for qualitative sustainability assessment.

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Definition 4 - Methodology

1) Define / agree the methodology by which options are going to be compared for the different sustainability criteria being considered. I.e. how those individual comparisons will be aggregated into broader assessment of sustainability; and how the assessment outcomes will be presented, interpreted and communicated.

Assessment criteria	Ideal
Environmental	
Emissions to air	
Soil and ground conditions	
Groundwater and surface water	
Ecology	
Natural resources and waste	
Economic	
Direct economic costs and benefits	
Indirect economic costs and benefits	
Employment and employment capital	
Induced economic costs and benefits	
Project lifespan and flexibility	
Social	
Human health and safety	
Ethics and equality	
Neighbourhoods and locality	
Communities and community involvement	
Uncertainty and evidence	

2) Define the tier of the assessment:

3) Decide upon the type of comparative approach you are going to use (tick the chosen option (✓):

***Note**: Comparisons should be made on a criterion by criterion basis to ensure exhaustive consideration of sustainability effects and avoid unintentional confusion of effects.*

Method 1	Ranking options by comparing across a range of available options	
Method 2	Ranking by comparing against a baseline performance criterion on an option by option basis	
Method 3	Ranking by pair-wise comparison	

Definition Step 5: Dealing with uncertainties

Description	There are likely two broad causes of uncertainty for qualitative sustainability assessment. • Disagreement or uncertainty over what should be considered within the definition of the sustainability assessment (objectives, options, boundaries or scope) – definitional • Insufficient or conflicting information describing individual sustainability criteria / indicators – informational. Uncertainties may emerge during the assessment work because of limitations on information. Uncertainties may also emerge as a result of the dialogue process because of differences in opinion. A convenient means of assessing the impact of uncertainty on outcome is to use sensitivity analysis. • Comparing the outcome for sustainability assessment scenarios reflecting different definitions. • Comparing the outcome for sustainability assessment scenarios reflecting the possible extremes in the range for a criterion based on available information and opinions.
Tasks	a) Agree an approach for identifying uncertainties and reviewing their potential effect on sustainability assessment outcomes.
NanoRem context	NanoRem will use simple sensitivity analyses, if necessary, to assess the impact on the overall outcome.

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Definition 5 - Dealing with Uncertainty

Agree an approach for identifying uncertainties and reviewing their potential effect on sustainability assessment outcomes.

At Tier 1 there are likely two broad causes of uncertainty
- Disagreement or uncertainty over what should be considered within the definition of the sustainability assessment (objectives, options, boundaries or scope) – definitional
- Insufficient or conflicting information describing individual sustainability criteria / indicators – informational
Uncertainties may emerge during an assessors work or as a result of the dialogue process.

1) Describe the approach for identifying uncertainties:

Definitional Uncertainty	Informational Uncertainty	Extent of Informational Uncertainty

5.3 Execution

The goal of this stage is to implement the sustainability assessment approach that has been defined. The key steps in this are: carrying out comparisons across options for each individual sustainability criterion, aggregating these individual assessments into an overall assessment of sustainability, interpreting the aggregated assessment, appraisal of any uncertainties, and concluding the findings of the sustainability assessment. It is based on simple tables using qualitative categories, such as "good" or "neutral" or "better", or simple rankings, such as the example in Figure 5.

Environment	Option 1	Option 2
Emissions to Air	Good	Fair
Soil and ground conditions	Very good	Fair
Groundwater & surface water	Very good	Good
Ecology	Good	Poor
Natural resources & waste	Fair	Excellent

Figure 5 Example qualitative sustainability assessment reporting table for a simple comparison

Before execution of the sustainability assessment begins (especially if the execution is undertaken sometime after the first two phases) it is essential to ensure that the approach is defined and agreed by all participating stakeholders and that all the necessary information is in place. Figure 6 provides checklists for this. Once this has been ascertained the agreement should be recorded in the sustainability assessment **log book**.

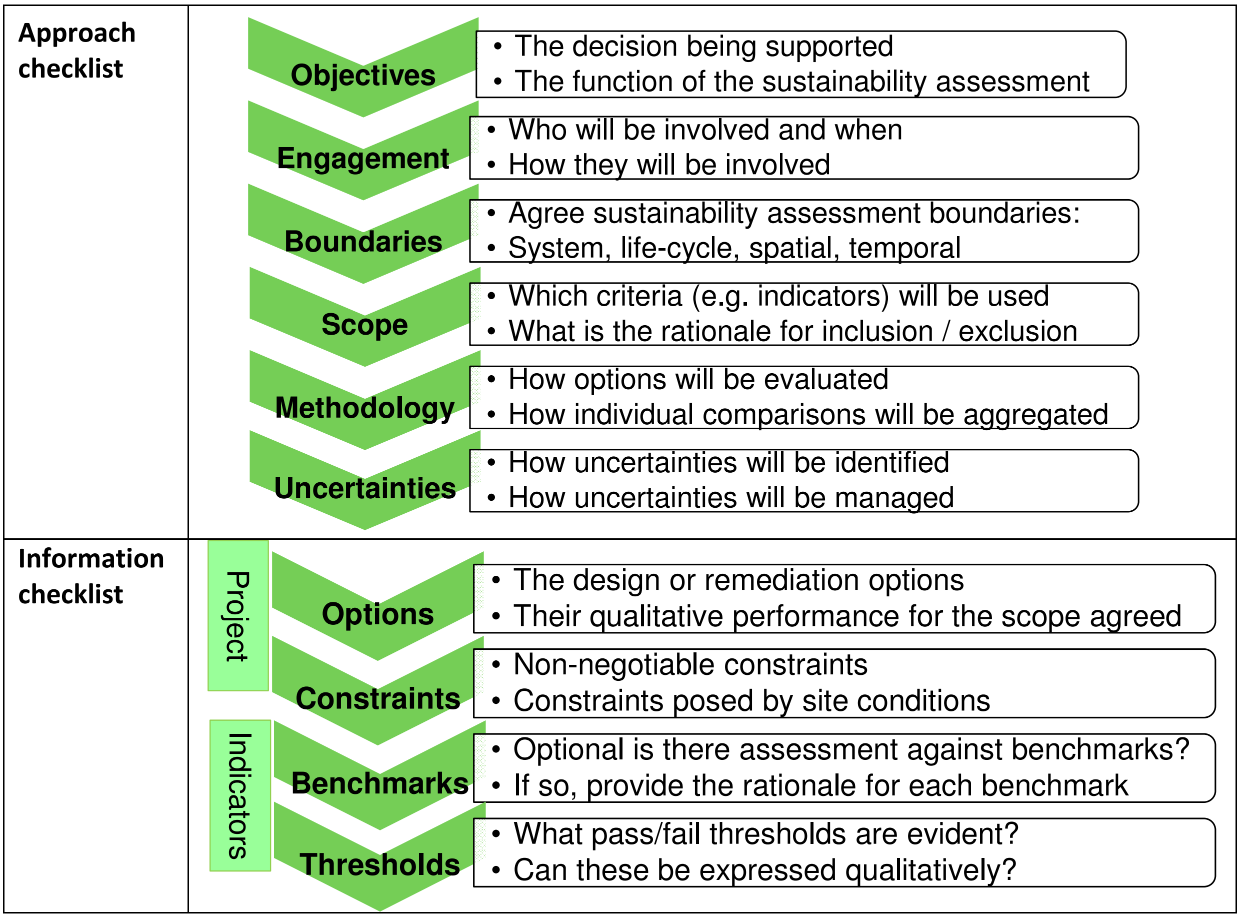

Figure 6 Checklists prior to execution of sustainability assessment

Execution Step 1: Making comparisons

Description	In this step comparisons across all options are made for each sustainability criterion. These are made sequentially and exhaustively. Options are always compared on a criterion by criterion basis, never on a combined basis across several agreed criteria at once. Where criteria appear to be overlapping this should be noted and a decision may be made to combine or reduce them. However, it is important that this is not done in a way that compromises the transparency and comprehensive nature of the sustainability assessment. For example reducing a range of criteria from resource use to road traffic to CO_2 emissions decreases transparency and also weakens the assessment as other outcomes (e.g. congestion, safety from traffic) are no longer considered. Note the approach to comparisons will have been set during "framing". The outcome for each comparison, and the evidence on which it was based must be accurately recorded. During the initial stages of an assessment process comparisons may well be the work of a single assessor or small project team. During a dialogue process comparisons can be revisited with several participants, for example via a structured meeting. Differences of opinion may identify *informational* uncertainties. These should be clearly reported and the reasons for the uncertainty made explicit. These records should be taken at the level of individual comparisons. *Definitional* uncertainties should already be known. The SuRF-UK approach to sustainability assessment is comparative and assumes that: • A decision is being taken to choose between two or more available options, or • A decision is being based against a reference scenario. In either case, it can be useful to also include a "no intervention" scenario to understand what changes are caused by the interventions being considered.
Tasks	a) Prepare comparison tables (it can be helpful to include two tables, one showing the comparison outcomes, and the other showing the evidence (or linking to the evidence) on which the individual comparisons are made b) Carry out the comparisons: • Each comparison MUST be supported by a written rationale specific for each criterion • The same system boundary and "life cycle" boundary conditions set up in the framing work must apply to all of the comparisons being considered for all options and all indicators • All options must be evaluated for all criteria • Comparisons should be made on a criterion by criterion basis to ensure exhaustive consideration of sustainability effects and avoid unintentional merging or confusion of effects • Start with a full comparison: all options, all criteria c) Grouping criteria (indicators) to look at particular situations d) Separate tables may be drawn up for specific time or distance considerations • E.g. considering only local effects (using the spatial boundaries) or excluding temporary effects (using the temporal boundaries) • However, these "sub-tables" should always be accompanied by a full comparison table

NanoRem context	When the preparation and definition stages have been successfully completed and agreed the execution stage can be undertaken. This is undertaken by the production and population of a number of spreadsheets where the assigned assessment criteria identified are compared against each of the remedial options. In practice a number of spreadsheets are produced which provide a matrix of the appropriate sustainability indicators (identified earlier, in definition), against the remediation options to be considered. The project team should clearly set out which remedial options should be considered. It is recommended that "no intervention" is included as one of the options considered. At each phase of iteration, those involved should review the spreadsheet and confirm their acceptance of them before undertaking the assessment. The completion of the spreadsheets will often be undertaken at a face to face meeting of the participating stakeholders, chaired by the assessor. The meeting will compare and contrast each option against all of the assessment criteria identified and will record the decision and how the decision was reached. It should be noted that where differences of opinion occur, it may identify informational uncertainties. Where these occur they should be clearly reported, and the reasons for the uncertainties made explicit. The reporting templates below are based on comparisons for each of the 15 overarching SuRF-UK categories. Experience in the UK indicates that satisfactory comparisons can be made considering the overarching categories in the round, for example, considering all aspects related to air impacts in one comparison. However, this very much depends on the attitude of the stakeholders and the prevailing culture in terms of recording evidence. Annex 1 sets out a template based on individual indicators, which is also available as a spreadsheet from r3. Level of detail will be at the discretion of the independent assessor

Reporting – template available as an XLS download from SuRF-UK (comparison table and evidence table) – These show summary information across SuRF-UK headline categories

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Execution - Supporting Table

Use this sheet to record specific information that provides the basis for the decision making process, in terms of how well each Option performs according to the listed criteria. Such information may be qualitative, semi-quantitative or quantitative in nature depending upon how much is known at the time. If more detail is required it may be useful to list the relevant indicators for each of the 15 listed criteria as separate rows, where these may cover several items, for example in the case of ENV 5 Natural Resources and Waste, if there are several resources and waste streams to consider (e.g. water, land, energy/fuels, aggregates, recycled materials etc.)

SuRF ref.	Assessment Criteria	Option 1	Option 2	Option 3	Option 4	Option 5
	Environmental					
ENV1	Emissions to air					
ENV 2	Soil and ground conditions					
ENV 3	Groundwater & Surface Water					
ENV 4	Ecology					
ENV 5	Natural resources and waste					
	Economic					
ECON 1	Direct economic costs and benefits					
ECON 2	Indirect economic costs and benefits					
ECON 3	Employment and employment capital					
ECON 4	Induced economic costs and benefits					
ECON 5	Project lifespan and flexibility					
	Social					
SOC 1	Human health and safety					
SOC 2	Ethics and equality					
SOC 3	Neighbourhoods and locality					
SOC 4	Communities and community					
SOC 5	Uncertainty and evidence					

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Execution - Assessment Table

Use this sheet to record the outcome of the assessment by indicating the relative performance of each Option in terms of each criterion in the relevant cell. The assessment can be descriptive e.g. Poor, Fair, Good, Colour coded or numerically ranked from relatively poor to relatively very good against the rest (refer to Defn 4_Methodology). Summarise the justification of scores by reference to the key issues identified in the Execution Supporting work sheet. Record the inherent uncertainties in making the assessment and describe the degree of uncertainty associated with assessment against each criterion (Refer to Defn 5 Uncertainty).

Assessment criteria	Remediation Options for Assessment					Justification of Scores (refer to 'Execution Supporting' tab for more detail)	Uncertainty Arising (Description)	Uncertainty Arising (Extent)
	Option 1	Option 2	Option 3	Option 4	Option 5			
Environmental								
Emissions to air								
Soil and ground conditions								
Groundwater and surface water								
Ecology								
Natural resources and waste								
Economic								
Direct economic costs and benefits								
Indirect economic costs and benefits								
Employment and employment capital								
Induced economic costs and benefits								
Project lifespan and flexibility								
Social								
Human health and safety								
Ethics and equality								
Neighbourhoods and locality								
Communities and community involvement								
Uncertainty and evidence								

Execution Step 2: Aggregation

<table>
<tr><td>Description</td><td>At its simplest, aggregation may be no more than tabulating individual comparisons in summary tables, for example as shown in the reporting templates for Execution Step 1. In this situation the pattern of comparisons (e.g. rankings) may indicate a clear result, for example based on the number of overall best or second best placings. However this table is potentially at the limit of what can be meaningfully interpreted in a single table. Where sustainability assessments are derived from comparisons of single indicators as criteria, then some form of summarising activity will be necessary to collate an overall picture. Qualitative sustainability assessment should never lose sight of the fact that its simple comparisons, even if expressed as numeric rankings, are not quantitative. No value or weighting is assigned to the ranking. Therefore any operations to summarise rankings must be simple and transparent and not result in a perceived “value” other than as an overall ranking. Possible approaches include:
• Use of frequencies, e.g. number of best and second best ranks for individual criteria within a single overarching category,
• Average rankings within a single overarching category.

The approach to aggregation will have been agreed during “framing”. The process of aggregation of individual comparisons, and the approach on which it is based must be accurately recorded.</td></tr>
<tr><td>Tasks</td><td>a) Review comparison tables
b) Add simple aggregation operations if this improves clarity
c) Provide summary tables if appropriate (e.g. overall rankings by sustainability element: economic, environmental or social; or over all rankings by SuRF-UK headline category, see Table 2).</td></tr>
<tr><td>NanoRem context</td><td>NanoRem will not apply weightings when aggregating qualitative rankings. This is because the rankings themselves do not convey any form of value that allows an arithmetic expression to be valid. Approaches based on scoring (where some kind of semi-quantitative value is included) and weightings are Tier 2 (semi-quantitative assessments) as defined by SuRF-UK and are out of scope of the available NanoRem resources.

During the initial stages of an assessment process aggregation may well be the work of the case study project team with the support of the independent assessor. It seems likely that aggregation of comparisons following a dialogue process may also be most efficiently carried out by a single assessor, who then offers the completed work for review by those involved in the dialogue process.

The structured approach to aggregation may be applied by the NanoRem team to better communicate outputs. However, reporting during the case study work itself can be simpler. This simpler reporting will in any case have collated all necessary data for the more elaborate presentation shown in Figure 7. R3 can provide this visual reporting subsequently.</td></tr>
</table>

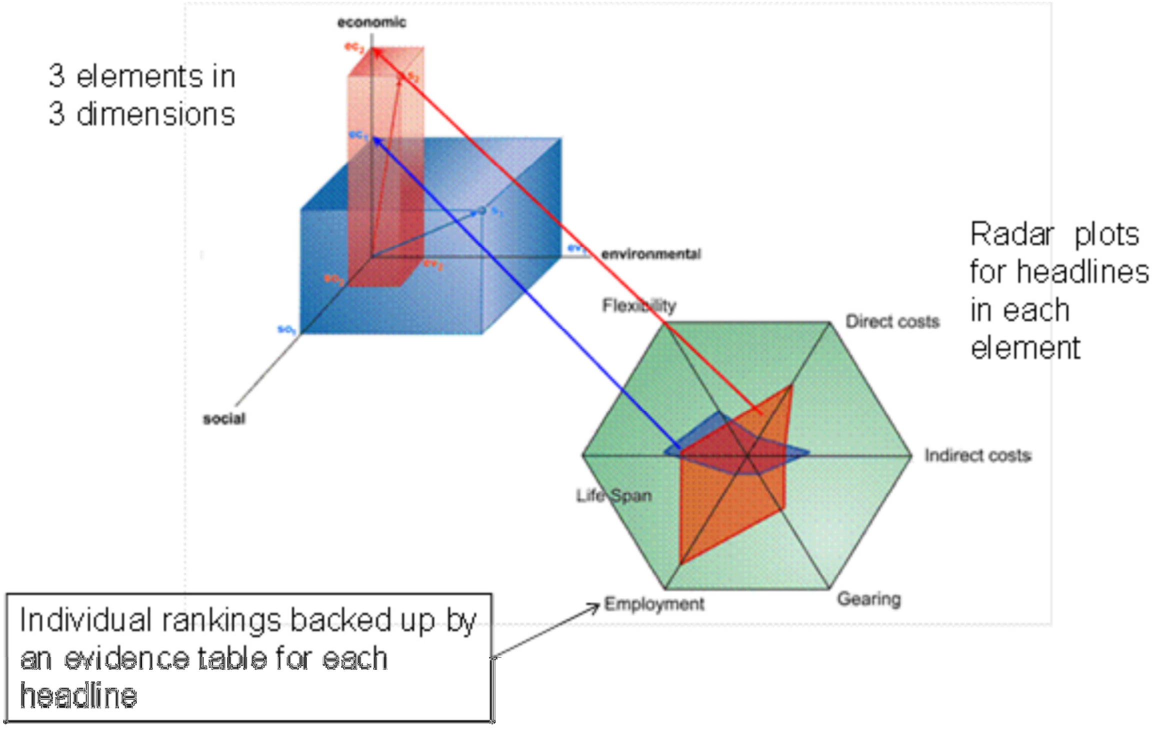

Figure 7 Illustrative structured aggregation approach (note this figure is not showing the current SuRF-UK headlines)

Reporting –

A variety of reporting approaches are possible (as discussed above). Reporting may consist of additional formatting to the templates shown above, for example to add colours associated with rankings, or additional rows to include summary rankings (averages or frequencies). Reporting may use a structured approach as illustrated in Figure 7 above. The tasks carried out in implementing this reporting should be recorded in the **log book**.

Execution Step 3: Interpretation

Description	The most obvious initial question is: *does the comparison yield a clear "winner", supported by all parties*.
	• If "yes", sufficient decision making support has been provided.
	• If no,
	  ○ Two or more options are tied so decisions between them may be based on operational convenience, cost etc. OR
	  ○ The assessment is inconclusive and requires further effort to improve its reliability (see Execution Step 5).
	
	Interpretation of qualitative assessment is typically based on comparison tables. The comparison table is a very simple form of aggregation of individual comparisons into an overall assessment of sustainability. Comparison tables can be very effective and simple communication tools where some options are clearly superior to, or distinct from, others. However, the effectiveness of a comparison table diminishes as the complexity of comparison criteria and options included increases. In this case summary aggregation will be needed as described in Execution Step 2.
	
	Note: qualitative sustainability assessment does not consider the scale or importance of differences. These considerations may be important in distinguishing between options which do not show clear or distinct trends. If these considerations are needed this indicates the need for a Tier 2 assessment.

Tasks	a) Review comparison tables and aggregation to see if it supports a view of a preferred option b) Review comparison tables and aggregation to determine if additional sustainability assessment work is needed at Tier 2 c) Record conclusions of the interpretation. These may be reviewed in the light of Execution Step 4.
NanoRem context	NanoRem's sustainability assessments are retrospective benchmarking options against one or more viable alternative remediation options for a case study site. Their purpose is not to revisit the decision to use nanoremediation as a remedial option, but to understand whether there are any general sustainability drivers (positive or negative) affecting the deployment of nanoremediation across the field test sites. NanoRem's sustainability assessments may be used for option appraisal if that is a requirement for the deployment (e.g. for regulatory purposes).

Reporting –

The tasks carried out in interpreting the sustainability assessment comparisons and aggregation and the conclusions of the interpretation should be recorded in the **log book**.

Execution Step 4: Managing uncertainties

<table>
<tr><td>Description</td><td>Any uncertainties identified during the definition and execution phases should be collated and restated in a single section or table, which should be circulated to the participating stakeholders for their agreement. The easiest way to assess the implications of these uncertainties is to undertake a sensitivity analysis and assess the changes in the overall sustainability assessment resulting from altering these criteria. The changes made to the input data for individual criteria should be agreed in advance and clearly documented in the log book. The effect this has on the comparison of these individual criteria, and any overall change in the sustainability assessment should be reviewed and documented.

Sensitivity analysis can be a useful means of managing differences in opinion occurring during dialogue. The structure of the Tier 1 assessment should enable the sources of differences of opinion to be precisely described. The sensitivity analysis may not remove these differences in opinion as uncertainty but can indicate whether its effect on the outcome is sufficient that:
• More detailed assessment is needed (at Tier 2 or 3).
• There are major differences of opinion between the assessors / stakeholders that may undermine its effectiveness for decision support so that earlier assessment stages need to be revisited.
• Alternatively the sensitivity assessment may indicate that the effect of uncertainties on outcome is not substantive, i.e. that it would not affect the likely selection of remedial option.

Notes on managing uncertainties:

The possibility of uncertainties will have been considered during “framing”, and can arise from
• Differences in opinion about what should be included in the assessment, e.g. boundary conditions, criteria, and/or
• Difficulty in comparing different options for a particular criterion, for example, because of differences in opinion or insufficient information.

How uncertainties will be managed will also have been set out during “framing”
• The simplest approach is to compare “what if” scenarios - sensitivity analysis
• Make different tables representing the different extremes causing the uncertainty, for example comparing a table that considers “what if we consider particulate emissions” on air quality to “what if we don’t”
• This allows you to determine the effect of uncertainties on the overall sustainability assessment.</td></tr>
<tr><td>Tasks</td><td>a) Uncertainties identified during the definition and execution phases should be collated and restated in a single section or table.
b) The effect of uncertainties on sustainability assessment outcome is reviewed using the approach already agreed during framing (e.g., sensitivity analyses).
c) Record any impacts on the conclusions of the interpretation step.</td></tr>
<tr><td>NanoRem context</td><td>NanoRem‘s interest is very much to record differences in opinion both in definition and in comparisons, and to understand and record the reasons for them.</td></tr>
</table>

Reporting –
The tasks carried out in dealing with uncertainties, their outcomes and their effect on the conclusions of the interpretation should be recorded in the **log book**.

Execution Step 5: Agree findings

<table>
<tr><td>Description</td><td>SuRF-UK describes four possible types of finding:
1. The comparison tables are clear enough to show that:
• One particular option is more sustainable than others, or
• The option being benchmarked performs favourably – or does not.
2. The process of discussion identifies improvements that can be made to the design of one or more options, so decision-making may be postponed until this is completed
3. The Tier 1 assessment contains too much uncertainty to come to a clear decision, in which case a Tier 2 Assessment is indicated
4. Two or more options are tied, then either a Tier 2 Assessment is indicated, or it is agreed between stakeholders that either option would be an acceptable choice and can be implemented.

Where the uncertainties in the sustainability assessment mean that there is no clearly favoured option then the further steps needed to improve assessment reliability need to be agreed and clearly recorded.

For some comparisons improving reliability may need additional investigation, for example more quantitative assessments, surveys or more detailed modelling.

Dialogue can be a useful tool for resolving uncertainties, where the stakeholders involved agree that an “average” of their range of opinions is an acceptable individual comparison. Potentially this may be assisted by seeking additional external opinions.

In the worst case the assessor may need to revisit the initial preparatory stages of the sensitivity assessment and identify for the client which features appear to be triggering uncertainty (aims, functions, options, constraints etc).</td></tr>
<tr><td>Tasks</td><td>a) Review the interpretation work, taking into account any outcomes from uncertainty analysis.
b) Agree the overall findings within the project team and with the wider stakeholders.
c) Take note of any dissenting opinions, if these have not been satisfactorily resolved.</td></tr>
<tr><td>NanoRem context</td><td>Findings for NanoRem‘s interests will focus on key sustainability factors and any differences in opinion both in definition and in comparisons, and to understand and record the reasons for them.</td></tr>
</table>

Reporting –
Agreed findings (and any dissenting views) should be recorded in the **log book**.

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Annex 1 Reporting template example for comparisons at the level of individual indicators

This template can be provided in spreadsheet format by r3. The illustration below includes example rankings for illustrative purposes only and combines comparisons and aggregation of individual indicator comparisons into average rankings for overarching categories (one of several possible aggregation approaches). Provided courtesy of C-CURE Solutions Ltd

Element	Overarching category	Individual Factors	Relevant	Ideal Condition	Stop Condition	Importance	Permanence	Proximity	Outlier	Evidence 1	Comparison					Evidence 2
			1= yes 0 = no			*high/med/low*	*temp / permanent*	*local / distant*	*comments (blank entry = none)*	*Rationale for exclusion of indicator*	*Stop condition*	*Lime*	*C-Cure A*	*Removal to landfill and replace with clean subsoil*	*No intervention*	*Rationale for ranking*
Environmental	***Impacts on air***	Climate change – emissions of GHG, e.g. CO_2, CH_4, N_2O (as CO_2 equivalents)	1	negative GHG emission		Medium	Permanant	Distant				3	2	4	1	Lime production and removal to landfill and movement of fill are highly fossil carbon energy intensive. C-CURE allows some fossil carbon to be offset by sequestering carbon and energy recovery during char production; no intervention leads to no additional polluting atmospheric emissions
		Acid rain – emissions of no_x, so_x and NH_3 (also relate to air quality)	0							Trivial emissions for all options						
		Ozone depletion – emissions of ozone depleting substances	0							Trivial emissions for all options						
		(local) air quality – gaseous emissions e.g. Of CO, particulates (PM10, PM2.5), O_3, vocs, trace elements	1	no emission		High	Temporary	Local	Removal to landfill - bad			2	2	4	1	Based on likely emissions from vehicle exhausts which will be related to transport requirements, seen as greatest for removal to landfill, and not occuring for "no intervention"
		Release of bioaerosols and allergens	0							No emissions created						
		For odour see *Impacts on neighbourhoods or regions*	0							Considered elsewhere in the SA						
		For dust see *Impacts on neighbourhoods or regions*	0							Considered elsewhere in the SA						
	Mean											2.5	2	4	1	
Environmental	***Impacts on soil (and ground conditions)***	Changes in chemical status	1	Suitable for growth of heather using native material		High	Permanent	Local				2	1	3	3	Imported subsoil is foreign to the site; use of lime will require repeat treatments, C-CURE dosage intended to support plant growth, no substaintial growth of plants witll occure without intervention
		Changes in soil nutrient status	1	Suitable for growth of heather using native material		High	Permanent	Local				2	1	2	2	Imported subsoil is foreign to the site; use of lime may conflict with heather propagation and precipitate free phosphate, C-CURE dosage intended to support plant growth, no substaintial growth of plants will occure without intervention
		Contamination by trace elements, organic compounds, litter, or other undesirable materials	1	Suitable for growth of heather using native material		High	Permanent	Local				2	2	4	1	Least likelihood of contamination is from no intervention, contamination (e..g. By litter is unlikely for C-CURE or lime materia). However, imported subsoil may be poorly specified
		Changes in buffering capacity and CEC	1	Suitable for growth of heather using native material		High	Permanent	Local				2	1	2	4	Imported subsoil is foreign to the site; C-CURE addition increases soil buffering, lime does not, no substantial growth of plants witll occure without intervention
		Changes in pH	1	Suitable for growth of heather using native material		High	Permanent	Local				2	1	2	4	Imported subsoil is foreign to the site; C-FCURE and lime will be able to manage pH, no change in pH will occure without intervention
		Changes in redox	1	Suitable for growth of heather using native material		High	Permanent	Local				1	1	3	4	Imported subsoil is foreign to the site; C-FCURE and lime will be able to manage redox, no change in pH will occure without intervention
		Changes in soil carbon (if not already considered under Impacts on air)	0							Counted under climate change and also soil organic matter below.						
		Changes in physical status	1	Suitable for growth of heather using native material		High	Permanent	Local				1	1	3	4	Current physical context unsuitable for plant growth, cultivation with lime or C-CURE will be beneficial, possible problems of compaction for added subsoil
		Changes in soil texture	1	Suitable for growth of heather using native material		High	Permanent	Local				1	1	4	1	Current physical context unsuitable for plant growth, cultivation with lime or C-CURE will be beneficial, added subsoil is a foreign material
		Changes in soil condition (organic matter / bulk density)	1	Suitable for growth of heather using native material		High	Permanent	Local				2	1	4	2	Addition of C-CURE will reduce soil bulkdensity and improve condition, addition of lime will not change bulk density (same for "no intervention", added subsoil is a foreign material
		Changes in soil water holding capacity	1	Suitable for growth of heather using native material		High	Permanent	Local				2	1	2	2	Addition of C-CURE will improve WHC, addition of lime will not change WHC (same for "no intervention", added subsoil is a foreign material
		Thermal pollution	0							Trivial emissions for all options						
		Changes in biological functions	1	Suitable for growth of heather using native material		High	Permanent	Local				2	1	2	2	Addition of C-CURE potentially improves provison of surfaces for microbial activity, addition of lime and no intervention does not, imported subsoil is a foreign material
		Changes in soil fertility	0	Suitable for growth of heather using native material						Considered under changes in biological functions						
		Control of pathogens	0							Pathogens unlikely						
		Changes in soil ecology – see below	0							Counted under ecology						
		Changes in soil biodiversity – see below	0							Counted under ecology						
		Changes in geotechnical performance	0							No built contructions planned						
		Ground stability	0							No built contructions planned						
		Potential for soil gas generation (e.g. CO_2, CH_4)	0							No built contructions planned						
		Changes in drainage	0							Because the whole site is metal contaminated						
		Erosion and soil loss	1	None		Medium	Permanent	Local				1	1	1	4	All interventions reduce erosion compared with no intervention
		Impacts on sites of geological importance (e.g. SSSIs)	0							No important geological feature						
	Mean											1.666666667	1.08333333	2.666666667	2.75	