North Sea Transition Authority

Guidance on the content of an Offshore Carbon Storage Permit Applications

March 2024

Contents

The document can be found on the NSTA's website here.

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Enquiries to:
North Sea Transition Authority
Sanctuary Buildings
20 Great Smith Street
London
SW1P 3BT

Email: correspondence@nstauthority.co.uk

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List of Abbreviations	
Abbreviation	**Definition**
CCUS	Carbon Capture, Utilisation and Storage
CMP	Corrective Measures Plan
CO_2	Carbon Dioxide
CRA	Containment Risk Assessment
CS	Carbon Storage
CSDP	Carbon Storage Development Plan
GOC	Gas-oil contact
GWC	Gas-water contact
MP	Monitoring Plan
OWC	Oil-water contact
PPCP	Provisional Post-Closure Plan
PVT	Pressure, volume, temperature
RCAL	Routine core analysis
SCAL	Special core analysis
SSCC	Storage Site and Complex Characterisation

Scope and purpose of this NSTA Carbon Storage Permit Application: supplementary guidance

The North Sea Transition Authority (‘**NSTA**’) has published guidance to assist those involved in the application process for a Carbon Storage Permit. The documents submitted in support of such an application are referred to as a Carbon Storage Permit Application (‘**Storage Permit Application**’).

This document supplements that guidance and is intended to assist in the preparation of the Storage Permit Application. This guidance is not a substitute for any regulation or law and is not legal advice. It does not have binding legal effect. Where the NSTA departs from the approach set out in this guidance, the NSTA will explain this in writing to the person seeking a decision from the NSTA.

As set out in that guidance, the Licensee will normally prepare and submit the Storage Permit Application associated with the Carbon Dioxide Appraisal and Storage Licence (‘**CS Licence**’). The Licensee is, therefore, referred to in this guidance in that context. The guidance will be kept under review and amended as appropriate in the light of further experience and developing law and practice, and any changes to the NSTA’s powers and responsibilities. If the NSTA changes its guidance in a material way, it will publish a revised document.

Required contents of the Storage Permit Application

The Storage Permit Application will provide to the NSTA the set of documents as set out below. Additional details on each expected document are provided in the following sections of this guidance.

Document 1.
Carbon Storage Project Overview

Document 2.
Storage Site and Complex Characterisation

Document 3.
Carbon Storage Development Plan

Document 4.
Containment Risk Assessment

Document 5.
Monitoring Plan

Document 6.
Corrective Measures Plan

Document 7.
Provisional Post-Closure Plan

Document 8.
Financial Security

Storage Permit Applications

Set out in this guidance are the topics that should normally be addressed in the Storage Permit Application and the format in which they should be submitted. The content of the Storage Permit Application should be discussed with the NSTA and will depend on the complexity and type of carbon store and the different risks/issues identified. For example, fully appraised depleted hydrocarbon fields are likely to have different requirements to unappraised saline aquifers.

The Licensee should discuss the expected scope of the Storage Permit Application with the NSTA early in the process and is expected to engage with the NSTA, including on how the documentation will be appropriately scaled for the carbon storage project scope. Draft documents should be provided to facilitate discussion during stewardship engagements. In particular, the Licensee will provide a clear explanation why the concept described in the Carbon Storage Development Plan has been selected. It will also set out (among other things) the plans that the Licensee is submitting in terms of net zero, facilities, number of wells, volumes of CO_2 stored and injected, to bring forward a sound development. Additional details on document content are provided in the following sections of this guidance.

It is anticipated that a set of comprehensive documents will be required. All figures including maps, seismic lines and cross sections need to be of suitable resolution to be clearly legible in the final reports and should be no less than a full page in width. Licensees are encouraged to use full-page maps and sections. Maps, seismic sections, cross sections and geo-seismic lines should follow standard geoscience best practices. The columns in any Computer Processed Interpretations (‘**CPIs**’) should be readable and any colour flags for formation/fluids should be added in a legend.

The Storage Permit Application should be submitted formally by electronic means.

1. Carbon Storage Project Overview

The Carbon Storage Project Overview document should include as a minimum:

- The proposed storage project summary
- A brief description of the storage site and storage complex including a location map and conceptual diagram
- The CO_2 capture and transport systems
- Facilities, pipelines, and wells required, along with total quantity and expected duration of CO_2 injection
- The reservoir pressure limits
- Proposed maximum injection rates and pressures and CO_2 stream composition
- Key findings or conclusions from each of the Storage Permit Application documents
- Essential information on potential interactions with other users of the seabed, which could include oil and gas operations, wind farms, maritime users, as well as details of the relevant infrastructure on the seabed such as pipelines, subsea infrastructure, etc. and the location of the storage site
- A table or reference list that sets out where the specific requirements of sections 6 and 7 of The Storage of Carbon Dioxide (Licensing etc.) Regulations 2010 (the '**Storage Regulations**')[1] are covered in the Storage Permit Application

[1] The Storage of Carbon Dioxide (Licensing etc.) Regulations 2010 (legislation.gov.uk)

2. Storage Site and Complex Characterisation

Scope and purpose of the document

This Storage Site and Complex Characterisation ('**SSCC**') document is a critical input to the Storage Permit Application and informs the Carbon Storage Development Plan, Containment Risk Assessment, Monitoring Plan and Corrective Measures Plan. Through acquisition and analysis of the requisite data, a thorough characterisation of the storage site and storage complex should be demonstrable. Evidence of sufficient and robust analysis of the uncertainties and their impacts is essential.

The SSCC document should include as a minimum:

2.1 Subsurface database

Information must be provided on the available subsurface database and those elements used in the characterisation process. This includes, but is not limited to, the seismic surveys and volumes and all wells within the CS Licence. Any third-party studies or reports that have been consulted or utilised should be included in a list of references.

2.2 Regional geology and basin evolution

A summary of the regional geology of the prospective carbon store area should be presented. A stratigraphic overview including a stratigraphic column, the regional tectonic history of the area and, if applicable, the charge and leak history of any hydrocarbon reservoirs and timing of fault, fracture and trap formation should be described. A list of hydrocarbon fields, discoveries, and any identified prospects or leads in and around the storage complex should also be provided.

Aquifer information in the context of regional connectivity and hydrocarbon presence including a brief history of subsurface activity (e.g., field developments) should be discussed.

Any play maps or early regional screening work with a summary of the regional risks should be included.

2.3 Definition of storage site and storage complex

The storage site and complex in terms of geological formations, spatial extent and rationale as defined in the Storage Regulations[2] and Article 3 of the European Union Directive on carbon storage (the '**Directive**')[3] should be described and include:

[2] The Storage of Carbon Dioxide (Licensing etc.) Regulations 2010 (legislation.gov.uk)
[3] Directive 2009/31/EC of the European Parliament and of the Council

- The proposed storage formation(s), and the storage site and complex seals
- Summaries of the lithologies and the geological sequences and their lateral extents into a regional extent
- The underburden stratigraphy

2.4 Seismic interpretation and structural mapping

This section should include details of the seismic data used for interpretation. Relevant well ties should be presented.

The overall structure of the storage complex, the extent of key stratal surfaces, reservoir units and seals, their thickness, and the relationship between hydraulic units should be presented using appropriate figures and maps.

The structural framework should be described, and geometries should be detailed using maps and sections, including estimations of uncertainty associated with their interpretation and, if appropriate, different interpretation scenarios.

Rock physics analysis should be presented. The Licensee should document the 4D feasibility at different stages in the operational phase of the CS Licence within the storage site and complex including any zones adjacent to the storage site, which should be referred to in the Monitoring Plan.

2.5 Geological interpretation and storage complex description

The reservoir properties of the storage site and any permeable formations in the overburden should be fully described, as noted in Annex 1 to the Directive. Any detailed studies such as sedimentology, facies analysis, fault seal and analogues used for characterisation should be presented here. Where applicable and available, the core analysis should be included. Data used to characterise the reservoirs should be listed.Deliverables can include, but not be limited to, core descriptions, facies interpretations from core and image logs, facies distribution maps, porosity and permeability relationships, facies associations, rock quality maps and flow unit descriptions.

The site and complex seals should be characterised appropriately to allow assessment of factors such as the risk of seal fracture, the risk of CO_2 entering the seal, fracture sealing rates and potential geochemical reactions between the CO_2 and the caprock(s). Capillary entry pressures should be calculated for use in the geomechanical studies and linked to the injection pressure range. The data used to characterise the seals should be listed.

2.6 Petrophysics and fluids

The available petrophysical data in the storage site and complex should be fully documented and described. Stratigraphic information should be included.

The petrophysical interpretation and evaluation should be clearly documented. Petrophysical facies should be defined, correlated, and assessed against lithological and stratigraphic divisions and seismic facies, with any differences explained.

Any available routine core analysis (RCAL) or special core analysis (SCAL) tests should be included and referenced.

Fluid compositional analysis and data should be given for the primary containment units and any unit through which CO_2 may potentially migrate or leak. PVT modelling should be fully described.

Any fluid contacts should be described here, such as original hydrocarbon contacts (GOC, GWC, OWC) and current/remaining/residual hydrocarbon-water contacts. Any saturation height modelling used for estimation of fluid contacts should be documented

2.7 Pore pressure

An interpretation and analysis of the pore pressure regime in the storage site and complex must be provided. This should assess any changes that may occur following injection of CO_2 and any extraction of formation water. The impact of pressure changes on features including hydrocarbon fields or other proposed CO_2 storage sites that may be hydraulically connected to this proposed storage site must be included and referenced in sections 2.11 and 2.13.

2.8 Geochemistry

Geochemical information pertaining to the rocks and in-place fluids should be provided. The impact of CO2 injection (including impurities) and any formation water extraction on the rock and fluid geochemistry should be included. Where possible, the effect of geochemical interactions on caprock sealing capacity, injectivity and CO_2 trapping (mineralisation), and well cement should be quantified. The reactivity of the system and the sensitivity to key subsurface parameters should be described. A summary of the data used, assumptions and conditions applied to geochemical models should be provided.

2.9 Faults, fractures, and leak paths

Step 3.3.1 (*Risk assessment – Hazard characterisation*) of Annex I to the Directive [4]requires that the dynamic model characterises the potential for leakage from the storage complex. Potential leak paths are therefore important inputs to the dynamic model. Both natural and human-made potential leak paths should be identified and characterised here. Assessment of the risks associated with these pathways should be addressed in the Containment Risk Assessment document.

A validated structural model should be provided with appropriate analysis to aid the assessment of the probability of crossfault or along-fault leakage/migration of CO_2. Faults dissecting the storage site should be evaluated for their stability and sealing capacity (see also 2.11 Geomechanics).

Structural and stratigraphic spill points and potential leak paths through juxtaposition across faults or stratal surfaces should be clearly identified. Information on the lateral continuity, extent and quality of seals should also be included.

Information on the uncertainties associated with the interpretation of spill and leak paths should be provided.

Potential leak paths that are identified here must be documented and carried through to the Containment Risk Assessment.

The potential leak paths should be assessed as a precursor to full dynamic modelling of the CO_2 plume. The proposed spatial extents of the static and dynamic models should therefore be adequate to address potential leakage risks.

Wells within the storage complex comprise significant potential leak paths. Therefore, Licensees should demonstrate an understanding and evaluation of any historic or recent well decommissioning. Well design and construction reports and logs, integrity reports and decommissioning reports and schematics should be reviewed. Where optimum data is not available, this should be highlighted, and an explanation given of how the well assessment has been conducted. Analysis should include the potential for leakage from one well via another well.

[4] Which is incorporated into the Storage Regulations by section 7(1)(a)

2.10 Seismicity

An assessment of the natural seismicity in the region around the storage complex utilising the British Geological Survey's GeoIndex (https://www.bgs.ac.uk/map-viewers/geoindex-offshore/) should be provided to assess the level of risk to the integrity of the storage site and complex from natural or induced seismicity.

2.11 Geomechanics

The results of geomechanical studies, including principal stress orientations, local fracture gradients, rock fabrics and fault reactivation studies must be provided. Physical rock samples may be required to understand the likelihood of failure under changing pressures and stress regimes, particularly in the storage site and seal.

The details of geomechanical models should be provided, including the range of parameters modelled and an analysis of the uncertainties in the model. A scalable approach should be taken, with an explanation of how the results are incorporated into the static and dynamic models and risk analyses. The data used in the geomechanical studies should be documented, including where further data could be acquired to reduce the range of uncertainty and what impact it could have on the risks identified.

2.12 Static modelling – storage site, storage complex, aquifer, overburden

The Storage Regulations (7(1a)) require the storage complex and surrounding area to have been sufficiently characterised, in accordance with Annex 1 to the Directive. Licensees are therefore expected to build a range of static models to characterise the storage site and complex, including the caprock and any hydraulically connected areas and fluids. Multiple scenarios should be analysed to quantify the impact of subsurface uncertainty on storage capacity. Information on how the static models were built should be provided with inputs to the model documented clearly using maps and sections. The differences between models should be shown clearly.

A comprehensive description of the uncertainties associated with the models and the impact these uncertainties have on the overall range of static storage capacities must be included.

2.13 Dynamic modelling – storage site, storage complex, aquifer, overburden

Annex I to the Directive outlines the requirements for the dynamic characterisation of the storage complex, which should be demonstrated through the dynamic models. Reservoir models should have sufficient resolution and spatial coverage to properly characterise, understand and predict the dynamic behaviour of the storage site and storage complex, including any potential leakage pathways. An appropriate and realistic range of deterministic reservoir models should be presented that represent the full range of static and dynamic uncertainty that may contribute to variability in CO_2 injection forecasts. The timestep and run time should be sufficient to predict short- and long-term CO_2 behaviour, including the phase behaviour, the rate of dissolution of CO_2 in water, and any reactive processes.

Where the storage site is a depleted oil or gas field, or an aquifer with historical pressure data from nearby field production, history matching of produced fluids, pressures and any other existing dynamic subsurface data over the production period is expected. It should be demonstrated that a good history match has been achieved. Where the field has been abandoned, more recent data on the current reservoir pressure and conditions may be required.

Consideration should be given to the use of coupled models to predict and capture the interdependencies of thermodynamic and phase behaviour of injected CO_2 in the pipeline, wellbores and geological formation.

2.14 Uncertainty analysis framework

Steps 2 (*Building the three-dimensional static geological earth model*) and 3.2 (*Characterisation of the storage dynamic behaviour, sensitivity characterisation, risk assessment – Sensitivity characterisation*) of Annex I to the Directive require the uncertainty associated with each of the parameters used to build the reservoir model to be assessed by developing a range of scenarios for each parameter and calculating the appropriate confidence limits.

Individual uncertainties should have been documented in the relevant sections leading to the static and dynamic modelling descriptions. The methodology for assessing the effects of combining the uncertainties highlighted in the static and dynamic models should be provided.

The impact of static uncertainties (such as structure, hydraulic connectivity etc.) on the dynamic models and their outputs (such as CO_2 plume movement, storage capacity) should be included and quantified. The uncertainties associated with any history match must be discussed, highlighting the factors that have the greatest impact on the quality of the match.

2.15 Storage capacity estimate

The Storage Permit Application should include the total quantity of CO_2 that is proposed to be injected and stored. To validate this figure, the total storage capacity as a range with associated probabilities must be provided. The assumptions underlying the capacity estimate should be presented. Where there are multiple compartments, horizons, formations, or storage site types within the proposed storage site, capacity estimates should also be provided for each of these features. Storage capacity estimates should also be provided for any structures within the storage complex that the CO_2 may migrate into in the case of a significant irregularity or migration from the storage site.

3. Carbon Storage Development Plan

Scope and purpose of the document

The Carbon Storage Development Plan ('CSDP') outlines the development, including the wells, subsea infrastructure, pipeline(s), and other facilities infrastructure required. It should also include the proposed injection rates, pressures and volumes over the life of the store and discuss the uncertainty associated with the development plan and concept. The document should include a brief development plan overview followed by each section heading listed below. Furthermore, it should explain the basis for store management during the installation,commissioning and injection phases. For every element of the plan, the description should provide a clear overview and highlight any uncertainty.

The CSDP document should include as a minimum:

3.1 Development plan overview

This section should describe the proposed storage development concept and indicate the drilling programme, well locations and facilities and indicate provision (if any) for future flexibility and development expansion. Proposed well locations should be shown on maps and cross sections. Important dates in the development plan and operation life of the storage site should be stated, including the proposed date on which injection is to commence and the anticipated date for permanent cessation of injection together with the underlying assumptions.

3.2 Description of storage site and complex

A summary definition of the storage site and complex should be provided to enable the CSDP to be read independently from the SSCC document. It should also show the lateral extent of the storage site and storage complex and the proposed area for monitoring.

A summary of the modelling approach and the critical modelling assumptions should also be included.

The main uncertainties associated with the storage site should be summarised.

3.3 Injection plan, storage capacity, and injection profiles

This section should provide information on the well layout, expected injection rates and intervals, pressure forecasts and, if applicable, the requirement for brine water production for pressure management. The range of dynamic models, along with any other required or relevant models used to generate the injection plan should be provided including a brief explanation of how the uncertainty ranges were determined and explicit statements of probability where appropriate.

Expected CO_2 injection profiles that underpin the proposed development plan are required. The forecasts should include a description of the methods used for integrated modelling of wells, flowlines, and production facilities. Any uncertainty associated with the injection profiles must also be included.

The proposed total quantity of CO_2 to be injected and stored within the storage site is required by regulation 6(3)(c)(i) of the Storage Regulations and must be stated here.

CO_2 injection profiles should be given per pressure compartment as well as for the total storage site. For stores with more than one injection well, injection profiles must be provided on an individual well basis as well as the overall storage site. Information should be provided on an annual and cumulative basis for the life of store injection. The Licensee should consider whether a map showing the different pressure compartments and wells may be useful, as well as maps showing the evolution of the CO_2 plume.

3.4 Storage site and complex pressure forecasts

Individual well injection pressures over the injection period must be provided as well as demonstrating, through the dynamic modelling, how the pressure is expected to change within the storage site and complex and how this impacts the injection rates and pressure management of the store. Pressure forecasts must be provided over the injection period, the post-closure period, as well as an estimate of longer-term pressure changes following the post-closure period.

The maximum injection pressure and the reservoir pressure limits (referenced to a relevant datum depth) are required by sections 6(3)(c)(v) and 8(1)(c) of the Storage Regulations. If the pressure limits vary across the storage site, then this should be documented, and the information provided on a pressure compartment basis.

The maximum well operating pressure should be a safe maximum well operating injection pressure. This must take into consideration the following geomechanical properties, described in more detail in the SSCC:

- Current in-situ stress and pore pressure profile
- Caprock fracture pressure
- Reservoir fracture pressure
- Poro-elastic stress changes due to increased pore pressure
- Thermo-elastic stress changes due to the temperature difference between the injected fluids and the reservoir (this should include the Joule-Thomson cooling effect)
- Fault reactivation pressure
- Capillary entry pressure of the caprock
- Injection well design limits
- Decommissioned well barrier (plug) pressure limits

Following evaluation of these properties, the lowest fracture or failure pressure limit should be selected and referenced to a reservoir datum depth. A safety limit reduction should be applied to this pressure to define the maximum operational well injection pressure limit as part of the Storage Permit Application. Any alternative to this approach in defining maximum well operating injection pressure should be discussed with the NSTA prior to submitting the draft CSDP with clear justification provided while demonstrating that there is no significant risk of leakage. The operating pressure limits should be carried forward into the Monitoring Plan and Corrective Measures Plan for instances where the operating pressure falls outside these reservoir pressure limits.

Potential interference between the storage site and complex and other subsurface activities within the hydraulically connected area, such as hydrocarbon field development or other carbon storage projects, should be described and any such interference demonstrated. It is recognised that the pressure forecasts may need to be updated as injection progresses, and more data becomes available.

3.5 Brine production

If the CSDP includes brine production wells as part of the pressure or volume management strategy, they must be documented here. Both individual well and total brine offtake rates should be given. Information on the pressure impact of the brine production on the storage site and complex and CO_2 injection rates should be provided.

Any proposed brine management facilities should be described; including proposed method to handle or treatment of produced brine.

3.6 CO_2 sources and composition

The prospective sources of CO_2 should be provided here. If the sources are not yet confirmed, then that should be indicated.

The composition of the CO_2 sources to be injected must be provided. If multiple CO_2sources exist, the composition of each source must be given with the overall composition. This includes sources that are confirmed as well as those that are prospective.

The location of where the CO_2 will be sampled for analysis and accepted for injection should be provided.

The potential impact of the CO_2 composition on the following must be described:

a) The phase behaviour of the CO_2 for the purposes of flow assurance

b) The integrity of the pipelines, facilities, and wells in the presence of contaminants

c) The impact on storage integrity, capacity and injectivity

Where possible, the potential impact of the presence of any incidental or trace substances within the CO_2 stream on the integrity of the store and infrastructure should be captured in the dynamic modelling and any other applicable/appropriate fluid flow modelling methods and documented here.

Reference should be made to the design range of the project facilities when describing the CO_2 composition and ranges of

acceptable incidental or trace substances.

3.7 Injection facilities

A description of the major equipment, unit operation and infrastructure items required as part of the development should be provided and should detail the design and operating parameters used as the basis of design.

A clear indication of capacity constraints should be given with details of the contingencies available to maintain injection in the event of major equipment failure(s).

The scope and flexibility for future modification and expansion to address any potential for upside, incremental and satellite storage development should also be identified, including any spare capacity provided for in the facilities and pipeline design to allow for future storage development or third-party tie-ins.

The studies forming the basis for the selection of the proposed development option should be referenced.

A brief description of the operating envelope and limitations of the offshore injection facilities should be provided. This section should also include, but not be limited to:

- A summary of the main and standby capacities of major utility and service systems, together with the limitations and restrictions on operation
- The design and operating philosophy for key equipment items
- A process flow diagram
- A summary of the methods of metering and testing injected CO_2 and any brine produced
- A description of any heating requirements along with the source of power
- A brief description of any treatment facilities
- A brief description of the main control systems and their interconnections with other offshore or onshore facilities
- A summary of provision of space or utilities for proposed future storage developments or expansion
- A summary of expected injection efficiency
- A brief description of any new/emerging technologies to be deployed
- If applicable, a brief description of systems for collecting and treating brine and other discharges

A reference to a facilities basis of design (which is consistent with the CSDP) should be provided.

A description of the facilities planned to be installed and commissioned, including any to be repurposed for the project, as well as any wells either drilled, side-tracked, recompleted, or abandoned and any platform, subsea or vessel infrastructure should be provided.

Details should be provided on the operating range of pressures and temperatures and CO_2 stream specification of all infrastructure and equipment including the CO_2 compliance of materials. When re-use of existing facilities is planned, timing of feasibility studies and the integration of the re-used facilities into the project should be provided.

The section should include a diagram of the structures for the storage development, whether fixed, floating, or subsea and should also include a description of the proposed CO_2 transportation system including, where appropriate, any onshore terminal facilities. The use of unmanned or subsea facilities may set restrictions on the monitoring and remediation options, and any such restrictions should be identified here and linked to the Monitoring Plan. The potential for workover, re-completion, re-perforation, remediation, and further drilling should be described. Where options remain for improvement to the CSDP or for further phases of storage, the criteria and timetable for implementing these should be given. Some projects may include common user facilities and may have capacity constraints; the methods to be used to set injection priorities, and where applicable brine production and treatment priorities, should be given.

3.8 Well design and injection technology

The well design for injection and, if applicable, brine offtake wells and dedicated monitoring wells should be provided, including where existing wells are to be side-tracked or recompleted.

The casing scheme selection and design should be included, with a description of how this enables efficient drilling of the well from a pore pressure and drilling hazards perspective and addresses the risk of leakage from the well. The impact the casing scheme has on downhole technology selection, including any limitations, should be described.

The drilling and well workover capability should be described. The proposed completion diagrams for each well, with main component diameters and depths relative to the main lithological units and storage site and complex depths should be provided. The potential for scaling, corrosion, and other issues should be noted and appropriate provision for mitigation described. If brine producers form part of the development plan, the risk of sand production should be assessed with appropriate mitigations included in the completion design. A reference to a wells Basis of Design should also be provided, including a decommissioning plan to be referenced in the Provisional PostClosure Plan.

Monitoring and intervention technology selection should be described with clear links to the risks identified in the Containment Risk Assessment, the objectives of the Monitoring Plan and the possible corrective measures given in the Corrective Measures Plan.

A description of the methods used for integrated modelling of wells, flowlines, and production facilities and how this has been used to inform and optimise the well design should be included.

The planned data acquisition programme for the wells to be drilled including, but not limited to, wireline logs, core, and pressure data, should be outlined, making reference to any data gaps identified in the SSCC and the objectives of the Monitoring Plan.

3.9 Net zero considerations

This section should describe the expected Greenhouse Gas ('**GHG**') emissions profile of the carbon storage project. The following should be given due consideration:

- A brief description of power supply/generation, including how renewable and/or energy efficient sources were considered
- Where projects are not powered from the grid or a local renewable source, a brief description of any provision made to allow future connection to a low carbon power source
- A brief description of the rig selection criteria including assessment of energy efficiency or GHG emission reduction measures
- A brief description of measures taken to minimise equipment transportation and non-productive time
- Demonstration that the selected concept is a low emission concept compared to other concepts
- A brief evaluation of the GHG emissions profile based on project lifecycle

3.10 Project planning

Schedules defining key events and decision dates including timing of facilities reuse in the detailed design, procurement, construction, and commissioning stages of the development should be provided.

A Project Execution Plan (‘**PEP**’) should be prepared and submitted alongside the Storage Permit Application. SE05 – Robust Project Delivery[5], although not directly aimed at carbon storage projects, provides a useful framework for the Licensee to follow and assist in delivering a project where applicable.

A Supply Chain Action Plan (‘**SCAP**’) should be prepared and submitted alongside the Storage Permit Application. SE12 – Supply Chain Collaboration and Cooperation[6], although not directly aimed at carbon storage projects, provides a useful framework for the Licensee to follow that will continue to develop an effective supply chain capable of meeting the UK’s net zero obligations. The SCAP should incorporate opportunities to create supply chain and logistics synergies to minimise GHG emissions.

Commissioning plans for offshore facilities will be discussed in greater detail as the project develops, but at the Storage Permit Application stage the commissioning programme will need to demonstrate a commitment to carrying out commissioning operations in an efficient and timely manner.

3.11 Storage site management plan

A storage site management plan is required that sets out clearly the principles and objectives that the Storage Operator will hold to when making storage management decisions and conducting storage operations.

The plan should show a clear and consistent linkage between the SSCC, Containment Risk Assessment, well design, subsea or platform facilities, and process facilities. Operational constraints, as outlined in the section on the injection plan, should be clarified here. Linkage between the management plan and the range of expected CO_2 plume behaviours should be demonstrated, and how it interacts with the approach to any significant irregularities and the Corrective Measures Plan.

[5] Robust Project Delivery Stewardship Expectation 5 (nstauthority.co.uk)
[6] Supply Chain Collaboration and Cooperation Stewardship Expectation 12 (nstauthority.co.uk)

4. Containment Risk Assessment

Scope and purpose

The Containment Risk Assessment (‘**CRA’**) should outline:

a. The project overview

b. The current definition of the storage site and storage complex, identifying the lateral boundaries

c. The base case development including, but not limited to:

i. Storage capacity and final injection pressure

ii. Injection rates and number of wells over project life

iii. Prospective CO_2 sources to achieve the injection rates

d) A table ranking and summarising the key identified risks to containment

The CRA document should include as a minimum:

4.1 Risk assessment methodology

The risk assessment methodology and risk analysis techniques used to assess and analyse the potential threats to the containment of CO_2 should be outlined clearly. This should be a systematic process and include qualitative, semi-quantitative and quantitative risk analysis methods where appropriate. Any methods or analogues used in the risk assessment process should be described and referenced and Licensees should highlight where external input or expert guidance has been provided. Reference should be made to the type of store being proposed (e.g., depleted field, aquifer), the level of data available and the SSCC document. Licensees should refer to the assumptions made, areas of uncertainty, highlighting how assumptions could change based on new data.

4.2 Hazard identification and characterisation

All hazards relating to potential CO_2 leakage from the proposed storage site and storage complex should be identified and characterised. Hazard characterisation is outlined in Annex I to the Directive, which states that consideration should be given to:

a) Potential leakage pathways

b) Potential magnitude of leakage events for identified leakage pathways (flux rates)

c) Critical parameters affecting potential leakage (for example maximum reservoir pressure, maximum injection rate, temperature, sensitivity to various assumptions in the static geological Earth model(s))

d) Secondary effects of storage of CO_2, including displaced formation fluids and new substances created by the storing of CO_2

e) Any other factors which could pose a hazard to human health or the environment (for example physical structures associated with the project)

Hazard characterisation should cover the full range of potential operating conditions. The dynamic reservoir models should be used to build several scenarios for different hazard mechanisms and to determine the critical parameters that could result in potential leakage and leakage scenarios.

4.3 Risk register and analysis

A risk register should be provided containing all the identified hazards, the associated risk scenarios, and the ultimate unmitigated consequence. Risks should be scored using a risk matrix assessed against consequence categories, potential severity, and the likelihood/probability of occurrence. Licensees should be able to demonstrate the rationale behind any risk scoring.

The risk register should further contain all identified risk control measures to prevent and mitigate the identified risk scenarios. These can be either existing or additional controls proposed by the Licensee. The associated monitoring techniques and corrective measures for each risk scenario should be summarised along with any relevant data gathering, studies, modelling and analysis completed that contributes to reducing risks and/or associated uncertainty. The risk matrix should again be used to re-score the risks incorporating the risk control measures, resulting in a residual risk score.

Both unmitigated and residual risks should be plotted on the risk matrix for each consequence category to map the risks allowing for visualisation of the entire storage complex risk profile.

Risks should be ranked to identify the most significant risks to containment of CO_2 with clear rationale for the ranking provided.

Further risk analysis techniques should be applied where necessary and should include methods and techniques such as bow tie analysis, semi-quantitative analysis, and quantitative analysis. Any further analysis techniques used should assist in understanding the likelihood and severity of the risks and the effectiveness of the control measure in place, while identifying any additional control measures, monitoring, and corrective measures to manage the risks and consequences. The analysis and results of the further analysis techniques used should be provided in full and referenced or the results integrated into the risk register where possible.

Licensees should demonstrate that consideration has been given to how the different risks may change over the project lifecycle as more CO_2 is injected and the conditions and properties within the storage site change; including the impact on both operational or suspended injection wells and abandoned legacy wells and the types and quality of materials. This should be supported by evaluation of data gathered, analysis and/or studies carried out in earlier phases of the project and updated in the operational phase as data is gathered through the Monitoring Plan.

4.4 Risk evaluation

Licensees must demonstrate that under the proposed conditions of use of the storage site, there is no significant risk of leakage by evaluating levels of risk for each scenario. The results of the risk analysis techniques should therefore be compared to a clearly defined risk criteria to evaluate the levels of risk taking into account the effectiveness of the control measures in place.

5. Monitoring Plan

Scope and purpose

The Monitoring Plan ('**MP**') document should reflect the conclusions of the CRA and the CSDP and should be drawn up in accordance with Schedule 2, Paragraph 2 of the Storage Regulations and Annex II to the Directive and should be linked to the corrective measures proposed in the Corrective Measures Plan should a significant irregularity[7] or leak be detected. The plan should detail the monitoring to allow demonstration of conformance and containment, detection, and measurement of a significant irregularity or leakage event. Additionally, it should detail any enhanced or specific monitoring that will be required if a significant irregularity or leakage event is detected. The plan should be designed to inform the appropriate corrective measures to be deployed and measure the effectiveness of those measures deployed and therefore assess the integrity of the storage complex over both the short and long term.

The MP document should include as a minimum:

5.1 Plan design

Subject to the SSCC and the CRA documents, the plan must include the monitoring of the injection facilities, the storage complex, the migration and behaviour of the CO_2 and formation water or other fluids, the surrounding environment, and verify both the containment of CO_2 and conformance of the CO_2 plume behaviour over time.

The plan should also aim to verify the effectiveness of site-specific geological and engineering design preventative safeguards (barriers to prevent loss of containment). It should provide additional safeguards through an early warning system to trigger timely corrective measures designed to reduce the likelihood or the consequence of any leakage from the storage complex.

The plan should detail how monitoring activities and technologies can identify significant irregularities, or leakage from the storage complex. It should also be able to indicate if the potential risk of leakage is increasing. The planning and implementation of baseline monitoring activities during project development, and monitoring during the operational phase should be included. The pre-injection baseline data collection plan should be fully described, and the plan should also reference the monitoring requirements detailed in the Provisional Post-Closure Plan.

[7] Significant irregularity is defined in Article 3 of the Directive as meaning '*any irregularity in the injection or storage operations or in the condition of the storage complex itself, which implies the risk of a leakage or risk to the environment or human health*'

The plan design should detail the monitoring necessary to track the CO_2 plume and its impact on and interaction with any formation fluids.

Potential leakage or migration pathways identified by the CRA should be monitored.

The selected locations and spatial coverage of the monitoring methods and technologies should be provided and demonstrated to be sufficient to monitor the injection facilities, the CO_2 plume, and (where appropriate) of the surrounding environment, as defined in Paragraph 2(2) of Schedule 2 of the Storage Regulations. The link between monitoring and the Corrective Measures Plan should be clearly set out.

The dynamic models used in the CSDP that define the range of predicted plume behaviours, CO_2 injection rates, pressurevolume-temperature and saturation behaviour, and storage capacity should be used as a reference point for applicable monitoring data. The Licensee should outline in the MP the steps they will take to understand the reasons for any deviations from predicted behaviour, if the data gathered and interpreted through monitoring in the injection phase clearly deviates from that predicted, a plan should be in place and detailed here to recalibrate models and generate updated or new hazard scenarios. This will allow the CRA, MP and Corrective Measures Plan documents to be updated accordingly as required by Regulation 11 of the Storage Regulations. In cases where the deviations are indicative of a significant irregularity, Licensees are expected to have outlined in the MP the requirements for any additional data gathering or contingency monitoring. This data gathering should be linked and referenced to the Corrective Measures Plan.

In summary, and as outlined in Annex II to the Directive, for the pre-injection and operational phases, the following shall be specified:

a. Parameters monitored

b. Monitoring technology employed and justification for technology choice

c. Monitoring locations and spatial sampling rationale

d. Frequency of application and temporal sampling rationale

The plan should have sufficient resolution to assess the magnitude and severity of any significant irregularity, or leakage event and to measure and quantify the volumes of any leaking CO_2.

Annex II to the Directive further requires that the MP should describe continuous or intermittent monitoring of the following mandatory items:

- Fugitive emissions of CO_2 at the injection facility

- CO_2 volumetric flow at injection wellheads

- CO_2 pressure and temperature at injection wellheads (to determine mass flow)

- Chemical analysis of the injected material

- Reservoir temperature, pressure and density at datum (to determine CO_2 phase behaviour and state)

These parameters are required to enable the Licensee to ensure compliance with any permit granted in terms of CO_2 composition, quantity, and pressure. Additional parameters such as density may be required to determine mass flow. The NSTA CCUS measurement guidance sets out the requirement for metering purposes.

5.2 Monitoring technologies screening and selection criteria

The monitoring technologies and methods should be selected through a comprehensive screening study of existing, new, or emerging monitoring technologies and based on best practice at the time the plan is formulated or updated. The technologies should be screened for effectiveness in monitoring conformance and containment of the injected CO_2 as well as their ability to measure and quantify a leakage event where applicable. Monitoring technologies chosen for deployment will be site specific and should cover baseline, operational, and closure and post closure monitoring requirements.

Details should be provided on the resolution, accuracy, sampling frequency, reproducibility, spatial coverage, capability, response time and detection limit of the potential monitoring technologies. Licensees should justify the technology selection against a set of defined criteria. These criteria should be storage site and complex specific and Licensees should provide clear justification for any methods that are deemed not suitable.

The type of monitoring method (direct or indirect) and the medium used for investigation must also be documented.

5.3 Monitoring plan limitations and mitigations

Any limitations in the plan design, monitoring methods and technologies should be documented. This could include factors such as spatial resolution, detection limits, quantification, accuracy, and sampling frequency. Potential margins of error and measurement uncertainty should be described. Licensees should describe the methods proposed to mitigate and address these limitations and uncertainties.

6. Corrective Measures Plan

Scope and purpose

The Corrective Measures Plan ('**CMP**') should detail the corrective measures that will be taken if a significant irregularity or leakage event is detected. It should also include a table summarising and ranking the key risks to containment. The CMP should be directly linked with the CRA and MP and be specific to the storage site and complex. It should detail measures for all identified leakage pathways and specific leakage mechanisms out of the storage site and complex and include any leakage pathways to the surface.

The CMP document should include as a minimum:

6.1 Summary of corrective measure scenarios

The CRA outlines the potential risks to containment of injected CO_2 while the MP outlines the monitoring methods, technologies, and techniques to be deployed to verify conformance and containment of the injected CO_2. The CMP should therefore be closely interlinked to and reference these documents and this section should summarise the significant irregularities or leakage events where corrective measures (including preventative measures) can be deployed.

Consideration should be given to categorising significant irregularities or leakage events, for example geological, wells, or infrastructure based.

Threshold values or qualitative circumstances triggering use of a corrective measure should be fully described. These circumstances may include, but not be limited to, an anomaly or event that is not predicted in the dynamic models, or a particular significant irregularity.

6.2 Corrective measures plan per scenario

For each of the significant irregularities described, corrective measures should be proposed with the aim of detecting and understanding its causes, implications and potential overall magnitude, reconciling events with modelled outcomes and preventing leakage of CO_2. Significant irregularity events may also require additional monitoring to be deployed. A rationale should be included explaining why a given range of corrective measures may be appropriate for each significant irregularity (and any additional monitoring to verify effectiveness). Appropriate follow-on actions and measures should be identified if the initial measures are unsuccessful. The criteria for follow-on measures should be clearly outlined and Licensees may elect to use decision trees to demonstrate this. The estimated timeframe for implementation and estimated duration of each measure must be included.

In the case of leakage events, the corrective measures technologies and techniques should be described in detail including any additional monitoring required to identify the source, measure, and quantify the leak, and the timeframe for implementation. Licensees should consider further actions and corrective measures for any leakage events should the primary corrective measures not be successful.

Details should be provided on any thirdparty companies required to carry out any corrective measures along with any agreements in place. The Storage Operator will remain responsible for corrective measures as set out in the Storage Regulations.

The proposed corrective measures and associated decision-making criteria should take account of the location and nature of the significant irregularity or leakage event and the specific circumstances in which the leak occurred as well as the anticipated magnitude or flux rate of the leakage event.

The methods used to monitor the effectiveness of a given corrective measure should be detailed with reference to the MP and updated dynamic and/or migration models.

6.3 Implementation of corrective measures

Schedule 2, Paragraph 3(6) of the Storage Regulations outlines the requirement for the Storage Operator to immediately notify the NSTA in the case that it becomes aware of a significant irregularity or leak. The CMP will be incorporated in any Permit that is granted and should therefore be written in a form that can be actioned.

7. Provisional Post-Closure Plan[8]

Scope and purpose

Licensees should note that the Provisional Post-Closure Plan (‘**PPCP**’) is a provisional document and will be subject to revision following the grant of any permit, in agreement with the NSTA and other regulatory bodies, dependent on the outcome and performance of the CO_2 injection, monitoring data, analysis of relevant risks, best practice at the time, and improvements in technology. The PPCP should detail how a site will be sealed and how injection facilities at the site will be removed. It should also include the monitoring required to demonstrate the absence of any detectable leakage and the conformance of the CO_2 to that forecast in the dynamic modelling. The PPCP should also describe the monitoring required to demonstrate the long-term stability of CO2in the store, indicating that it can and will be completely and permanently contained in the storage site and storage complex, to enable the termination of the Licence and the transfer of responsibility under The Storage of Carbon Dioxide (Termination of Licences) Regulations 2011[9] (the ‘Termination Regulations’).

The PPCP document should include as a minimum:

7.1 Site closure criteria and conditions

Licensees must document the conditions that will have been met during and after the injection phase for closure to be considered viable, including how the conditions will be assessed and the possible range of outcomes that are considered viable for closure.

7.2 Post-closure period

Following site closure the Storage Operator must continue to monitor the site and therefore a draft post-closure monitoring plan is required to be included in the PPCP.

The post-closure period leading to transfer of legal obligations for monitoring and corrective measures shall be for a minimum period of 20 years as set out in the Termination Regulations, unless the NSTA considers that all evidence indicates that the stored CO_2 will be completely and permanently contained[10].

The PPCP should refer to the dynamic models and forecast behaviours, as well as linking to the CRA and the potential risks to containment expected to be present at the time of closure.

[9] The Storage of Carbon Dioxide (Termination of Licences) Regulations 2011 (legislation.gov.uk)
[10] See section 7 of the Termination Regulations

7.3 Decommissioning activities

Licensees should confirm that decommissioning options will be fully reviewed and discussed with the Department for Energy Security and Net Zero (‘**DESNZ**’) offshore decommissioning unit and the NSTA’s decommissioning team during the injection period and decommissioning planning stages. Steps taken in the design to facilitate eventual decommissioning of the injection facilities should be identified.

The planning for well decommissioning should outline the use of appropriate materials in a CO2 injection environment and use industry good practices, which should be updated as experience and knowledge in the operation of carbon storage sites matures. Any risks to containment resulting from decommissioning should be provided.

8. Proposed Financial Security

The financial security document within the Storage Permit Application should detail the amounts of financial security and the mechanism(s) for taking that financial security to satisfy the requirements in paragraph 7(1) of Schedule 2 of the Storage Regulations.

Please refer to the '*Proposal for financial security*' section in the Guidance on Applications for a Carbon Storage Permit document for details and the financial security information required for the Storage Permit Application.

Annex 1: Requirements for the definition of a Carbon Storage Site, Storage Complex and Hydraulic Unit

Introduction

As part of the carbon storage permit[11] application, the storage site (‘**site**’), storage complex (‘**complex**’) and hydraulic unit must be defined. This definition is supported by and forms part of the site characterisation (as required by regulation 7 of the Storage of Carbon Dioxide (Licensing etc.) Regulations 2010, the ‘**Regulations**’) which must be in place prior to a carbon storage permit being granted.

The Regulations incorporate, by reference, certain specific legal definitions from the EU Directive 2009/31/EC[12] which are replicated below:

- ‘**Storage site**’ means a defined volume area within a geological formation used for the geological storage of CO_2 and associated surface and injection facilities.
- ‘**Storage complex**’ means the storage site and surrounding geological domain which can have an effect on overall storage integrity and security; that is, secondary containment formations.
- ‘**Hydraulic unit**’ means a hydraulically connected pore space where pressure communication can be measured by technical means and which is bordered by flow barriers, such as faults, salt domes, lithological boundaries, or by the wedging out or outcropping of the formation.
- ‘**Migration**’ means the movement of CO_2 within the storage complex.
- ‘**Leakage**’ means any release of CO_2 from the storage complex.

This document covers the geological storage aspect of the storage site definition, which is needed to assess risk of leakage, monitoring plan and corrective measures. The associated surface and injection facilities are detailed in the Site and Complex Characterisation and the Carbon Storage Development Plan which are also provided as part of the permit application. Further information can be found in “Guidance on the content of an offshore permit application”[13].

Each storage site must be assessed, characterised and defined individually, even if there are analogous stores nearby which have already been assessed, characterised and defined and each storage site must be part of a storage complex.

Where multiple storage sites are included in a single development, each will require a separate storage permit and therefore separate storage site and storage complex definitions.

[11] As defined in the Storage of Carbon Dioxide (Licensing etc.) Regulations 2010 Directive
[12] 2009/31/EC on the geological storage of carbon dioxide
[13] Guidance on the content of an offshore permit application Operations Guidance on the content of an offshore permit (nstauthority.co.uk)

Storage site, storage complex and hydraulic unit definition

Both the storage site and storage complex must be defined geologically by trapping mechanism or combination of trapping mechanisms. Possible trapping mechanisms include but are not limited to:

- Structural closure
- Fault seal
- Lithology/porosity pinch out
- Migration assisted storage

Examples are illustrated in the Appendix.

Where no clear geological boundary exists and the CO_2 is contained by migration assisted storage, the storage site or storage complex boundary should be defined on the maximum credible distribution of the CO_2 plume as determined from a specific dynamic model demonstrating long-term storage beyond the post-closure period.

The storage site and storage complex should each be surrounded by a bounding box defined by a co-ordinate set in latitude and longitude (ED50), and upper and lower depth limits, which will be included in the carbon storage permit.

The hydraulic unit should be defined in terms of its connectivity to the surrounding area, in order to assess risk of leakage and the effects of a given storage project on other activities in the area in accordance with the Regulations.

Storage site

The storage site defines the volume within a geological formation used for the geological storage of CO_2 . The storage site definition should include:

1. **Storage unit(s) stratigraphy and lithology** – the permeable unit(s) that will contain the injected CO_2
2. **Top of storage site** – top of uppermost storage unit
3. **Base of storage site** base of lowermost storage unit
4. **Lateral limits of storage site defined by trapping mechanism** – the lateral containment limits defined geologically or by migration modelling
5. **Bounding co-ordinate set in latitude and longitude, top and base point depths** (crest and deepest point of the storage site)

Storage complex

The storage complex delineates the limits **beyond which leakage would be considered to occur**, even if the CO_2 remains in the subsurface. The storage complex definition should include:

1. **Primary storage unit(s) stratigraphy and lithology** – the permeable unit(s) that will contain the injected CO_2 as per the storage site definition
2. **Primary seal stratigraphy and lithology** – the units directly overlying and adjacent to the storage unit that are sufficiently impermeable so as to prevent the escape of injected CO_2.
3. **Secondary containment formation(s) stratigraphy and lithology** (if applicable) – additional significant permeable units that could contain CO_2 that has migrated from the storage site into the storage complex.
4. **Secondary seal stratigraphy and lithology** – overburden units that add additional seal capacity to the storage unit and/or prevent migration of CO_2 from any secondary containment formation(s).
5. **Underburden** – Any permeable units within the immediate underburden should be included in the complex
6. **Top of storage complex** – the top of the highest sealing unit that forms part of this definition. If the highest seal unit has been eroded (recent or geological unconformity), the complex top should still be defined as the top of this unit, with a clarification added that there has been erosion and over which part of the store the erosion has occurred.
7. **Base of storage complex** – the base should be below any permeable intervals in the immediate underburden that could potentially store CO_2. It should be noted that any movement below the complex base will be classed as leakage even if it remains in the subsurface.
8. **Lateral limits of storage complex, defined by trapping mechanism** – the lateral extent beyond which leakage would be considered to occur, defined geologically or by migration modelling.
9. **Bounding co-ordinate set in latitude and longitude, top and base point depths** (crest and deepest point of the storage complex)

Hydraulic unit

The hydraulic unit should be defined by:

1. **Storage unit(s) stratigraphy and lithology**
2. **Any known lateral limits** (e.g., faults, structural closure, pinch out) or evidence of widespread connectivity (e.g., pressure interference)

Evidence to be provided in support of site, complex and hydraulic unit definitions

The storage site and storage complex definitions should be accompanied by data in support of the relevant components, all of which should be available from the site characterisation work. The data provided should include, but are not limited to, the following:

- Stratigraphic column showing the stratigraphic extent of the site and complex to include:
  - Formation names & lithologies
  - Primary store and secondary containment formation(s)
  - Primary and secondary seals
  - Underburden
- Type well including well log data showing the same.
- Depth top-structure map(s) of primary and secondary containment unit(s) (base case and maximum)
- Depth map of the base of the storage site/top of the underburden. This could be derived from a mappable surface or isochores as appropriate.
- Evidence of lateral margins of both site and complex such as, but not limited to:
  - Depth maps showing faults, structural spill, permeability pinchout;
  - Output from long-term dynamic model showing lateral migration limit for migration assisted storage, with reference to the relevant report containing further modelling detail;
  - Minimum, maximum and most likely scenarios should be provided
- Representative, orthogonal depth seismic and geoschematic sections through the site, complex and hydraulic unit illustrating any uncertainties (minimum, maximum, most likely)
- Regional mapping showing the extent of the hydraulic unit(s) and any lateral barriers
- For hydraulic unit, data relating to connectivity to/isolation from the wider area, for example:
  - Fault maps and sections;
  - Facies pinchout maps and sections;
  - Dynamic data such as interference tests, pressure depletion/overpressure;
  - Pressure cell maps where appropriate
- Any other relevant data, e.g., attribute maps, fault maps, model outputs

Supporting evidence standards

- Information should be provided digitally (for example in pdf format) and at a resolution suitable for viewing detail and legibility.
- All information should be dated and have reference to relevant seismic volumes, depth conversion and any inversion (i.e., version control).
- It is important to show the uncertainty associated with the definition, particularly related to critical points in the site and complex definitions (spill points, pinchouts, etc), which should be clearly illustrated.
  - Minimum, maximum and most likely interpretations should be provided where relevant.
- All maps should show CS licence boundaries, proposed site and complex outlines, well locations, fault polygons and horizontal scale.
- Seismic lines and maps should be presented in depth, though time images may also be provided.
- All sections should show lateral and depth scales, vertical exaggeration, relevant well locations and site and complex location. Key surfaces should be labelled, and any faults shown.

Bounding polygons

- Co-ordinate sets should encompass the maximum extent of the site or complex and be defined on a minimum of 15 second increments, though finer increments may be considered, if appropriate, on a case-by-case basis.
  - If site and complex are close in areal extent, a single co-ordinate set can be provided
- Top and base depths should be as follows and defined by the range of uncertainty:
  - for storage site: the shallowest and deepest point depths of the storage site
  - for storage complex: the shallowest and deepest point depths of the storage complex

Timing

Preliminary discussions regarding the definition of the storage site, storage complex and hydraulic unit should begin during early evaluation carried out during the Appraise Phase and mature as the storage site understanding matures during site characterisation and development planning carried out during the Assess and Define Phases.

The expectation is that the storage site, storage complex and hydraulic unit definitions are mature by the end of the Assess Phase, noting that minor changes may result from Define Phase work. The final definitions shall be in place by the end of the Define Phase and the agreed definitions will be included in the Permit application as part of Storage Site and Complex Characterisation. At this point a formal store name should have been agreed[14].

Future review

The site, complex and hydraulic unit definitions shall be reviewed routinely as part of the permit consent review process (which occurs five years after grant of the storage permit and subsequently, every ten years after that) in accordance with the Regulations. Should new information, such as wells or seismic data, indicate that these definitions are no longer valid, the NSTA will at such a time consider a re-definition.

[14] Attachment 3: Carbon Store Naming Process

Appendix – Examples of trapping mechanism

The diagrams below show examples of trapping mechanisms that can be applicable to storage site or storage complex. The examples illustrated show an underfilled site. It should be noted that many stores will have a combination of trapping mechanisms.

Legend

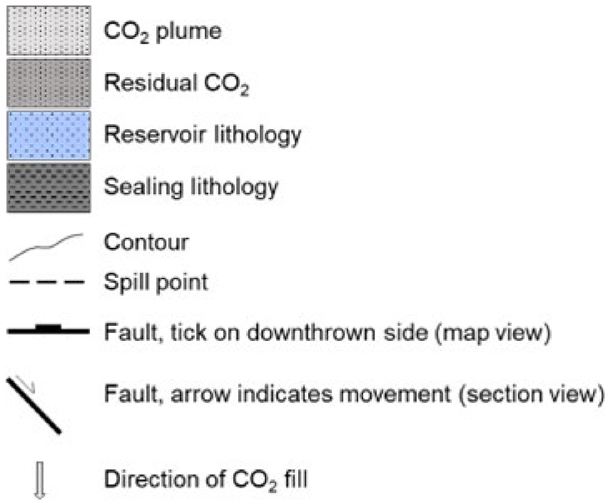
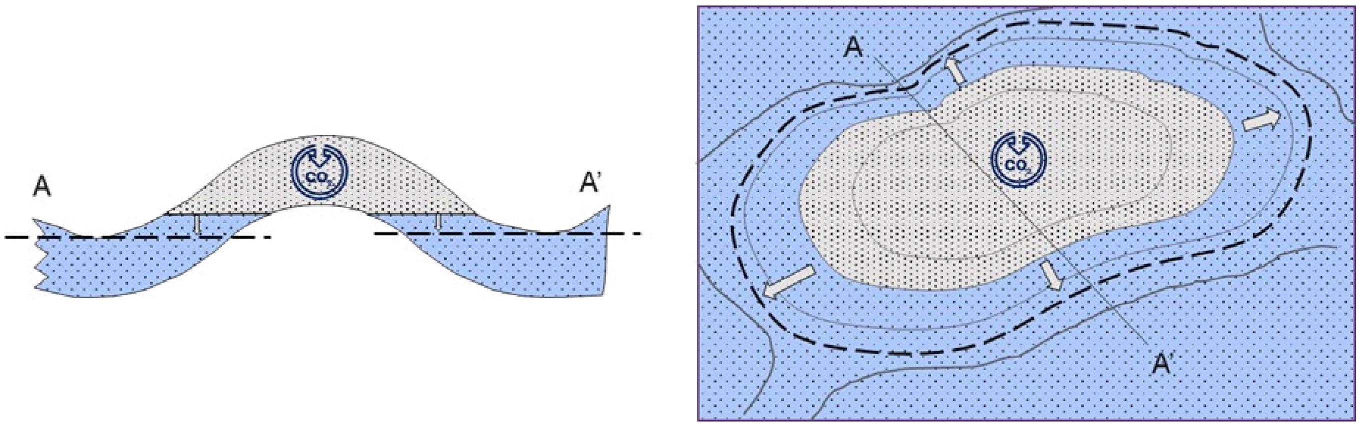
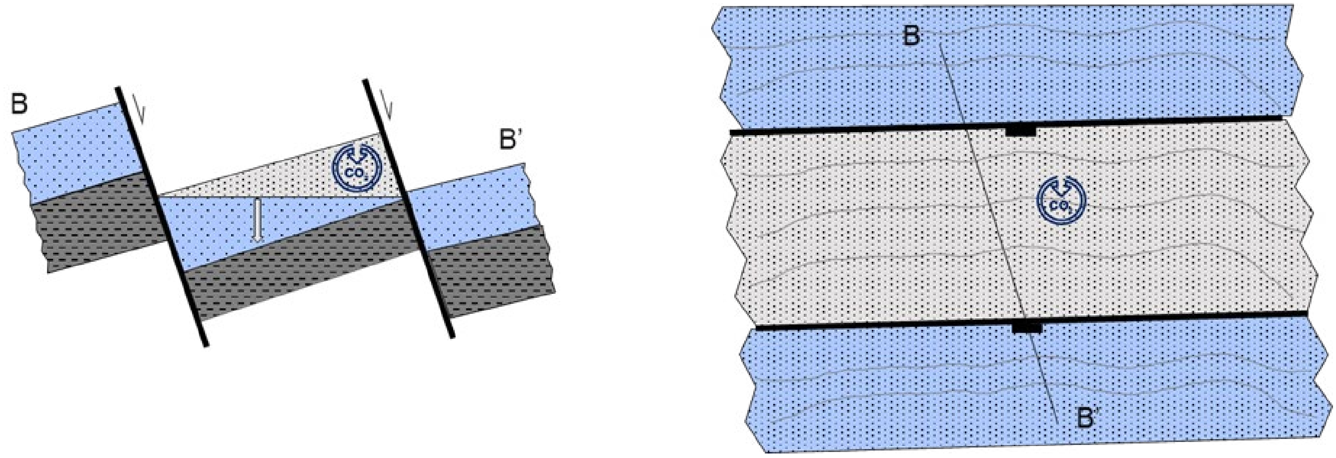


Fig.1: Four-way dip closure



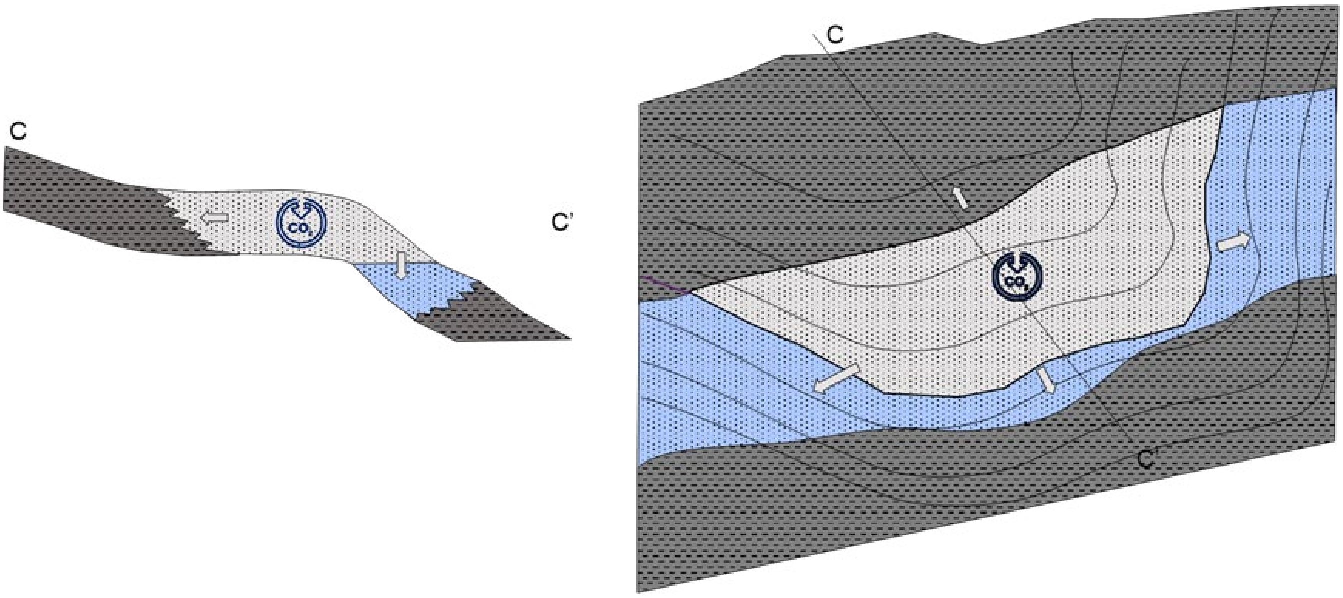
A four-way dip closure contains the injected CO_2 and is usually defined by spill points beyond which CO_2 would leave the structure. Spill points can be coincident with a previous hydrocarbon-water contact, or the spill point can be at a different level.

Fig.2: Faulted boundary



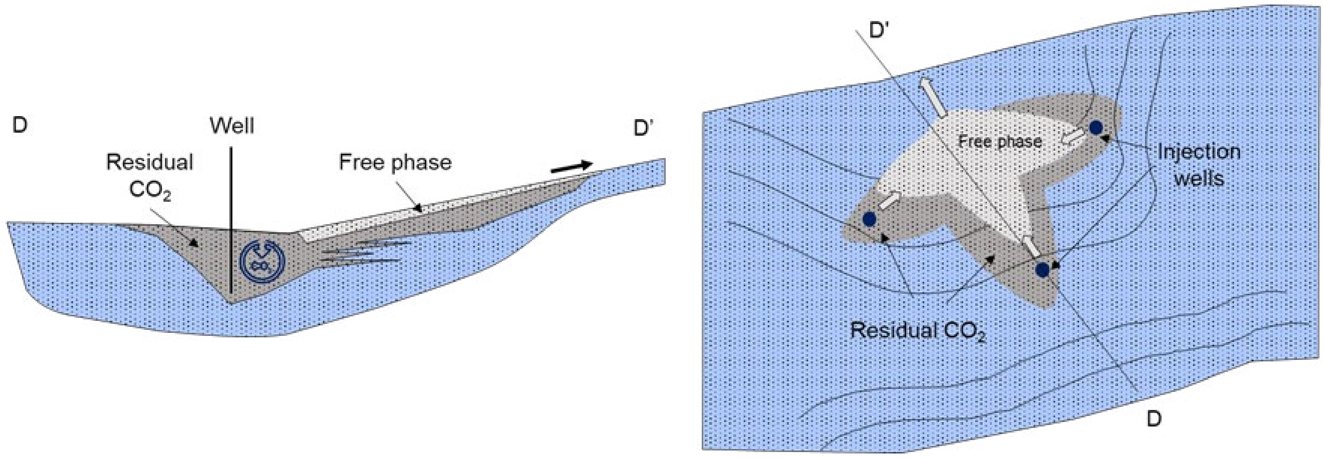
A sealing fault provides the lateral boundary to the storage site which is contained within the bedding dip. It should be ascertained that there is no significant risk of leakage across or along the fault either in the intended CO_2 column or the underlying water leg.

Fig.3: Lateral pinch out



A change in lithology and/or porosity provides the lateral limit to the storage site, e.g., a sandstone channel cutting through shales or lateral facies change resulting in a degradation of reservoir quality. The change in capillary entry pressure causes the injected CO_2 to be trapped.

Fig.4: Migration Assisted Storage (MAS)



Migration assisted storage immobilises and contains CO_2 without the need for a confining structure or geological feature. MAS is especially relevant for saline aquifers though it can also contribute to trapping in depleted field stores. The dominant trapping mechanism is residual capillary trapping of CO_2 left behind in the pore space as the free CO_2 moves through the storage reservoir. Other trapping mechanisms involved in MAS are dissolution in the formation brine, physical trapping by the seal capping the reservoir unit and minor mineralisation trapping.

North Sea Transition Authority

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