Health and Safety Executive

Health and Safety Executive

Hazardous Installations Directorate

Offshore Division

Technical policy for KP4: Ageing and Life Extension Inspection Programme, 2010 - 2013

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1. Policy Statement

Duty holders should be able to demonstrate that specific and appropriate consideration has been given to ageing[1] and life extension[2] matters in the asset integrity management systems of all offshore installations operated on the UKCS to ensure that the associated risks are controlled and safety is ensured at all times.

Demonstration is required that the asset integrity management system addresses ageing and life extension considerations for all relevant major hazard areas, including:

- organisational factors;
- structural integrity;
- materials (including corrosion);
- maritime integrity;
- mechanical integrity;
- process plant integrity;
- fire and explosion integrity
- electrical and control systems integrity;
- wells;
- pipelines.

Identification, understanding and evaluation of all relevant ageing mechanisms are required.

Duty holders need to demonstrate that any degradation and deterioration of offshore structures is kept within acceptable limits. This demonstration requires the implementation of an appropriate asset integrity management system which incorporates the following elements:

- protective measures (usually implemented during original design and construction) to ensure that the risk of loss of asset integrity meets ALARP criteria;
- adequate assessment and reassessment of asset integrity to appropriate current codes and standards, with use of the latest research findings where

[1] Ageing equipment or structure is that for which there is evidence or likelihood of significant deterioration and damage taking place since new, or for which there is insufficient information and knowledge available to know the extent to which this possibility exists.

[2] Life extension refers to continued operation of an installation beyond the design life assumed at the time of design or revised following a reassessment.

appropriate, to provide duty holders with sufficient information on asset integrity;

- allowance in the integrity assessment process for modifications, changes in mode of operation and damage sustained to the installation;
- consideration of the interaction between, and the cumulative effect of, changes and deterioration processes;
- the monitoring of integrity in-service in order to detect degradation;
- the assessment of any anomalies found to enable determination of appropriate action;
- an appropriate verification system to provide assurance of the asset integrity management process and the significance of deterioration and damage relating to the potential effect on the functionality, availability, reliability and safety of safety critical elements (SCEs).

2. Background

A significant number of platforms in the UK sector of the North Sea are approaching or have exceeded their original design life[3], typically specified as 20 or 25 years. Approximately 50% of the total population of fixed platforms on the UKCS has exceeded the original design life and this proportion is steadily increasing with time. With a continued requirement to produce oil or gas, either from the original fields or as a base for neighbouring subsea completions, the majority of installations are likely to remain operational for a significant period of time in the foreseeable future.

The ageing offshore infrastructure presents a constant and growing challenge. Ageing is characterised by deterioration which, in the severe operational environment offshore, can be significant with serious consequences for installation integrity if not managed properly. Equipment may become less reliable, obsolete or simply no longer fit for service. This increases the possibility of hydrocarbon leaks and may reduce the reliability of systems to control and mitigate events. Furthermore, reservoir pressures decrease and water cuts increase such that hazard profiles change. In the extreme case, failure could cause the total loss of an installation, with little chance of survival. Thus, there is a need to give careful consideration to the implications of ageing and life extension on installation integrity, including where there is insufficient information on whether it is occurring, to re-evaluate the effects that ageing plant and changing process parameters have

[3] The design life is the assumed period for which a structure or component is to be used for its intended purpose with anticipated maintenance but without substantial repair from ageing processes being necessary [ISO 19902] – this is usually taken to be the fatigue life of the structure.

on the hazard profile of an installation and to demonstrate continued safe performance beyond the original design life.

The need to address the issue of ageing infrastructure is identified in OSD's priority on Asset Integrity [1], the purpose of the work being to promote awareness and management of the risks associated with ageing plant in the offshore oil and onshore major hazard industries. In addressing the management of ageing, it should be recognised that the two principal elements of an offshore installation, i.e. the structure and the topsides process plant, require different approaches. The structure is a relatively "static" item with a defined design life while the topsides process plant and ancillary systems will change with time, both from modifications and wearout. The ageing process may also occur at differing rates. Best practice is seen as managing the ageing process for the structure and topsides by evaluation and monitoring of integrity using methods that are appropriate to each element, some methods being relevant to both.

Evidence from OSD's past enforcement activities has indicated substantial shortcomings in the integrity management of the offshore infrastructure. Key Programme 3 (KP3**)** [2], conducted in the period 2004 – 2007, investigated asset integrity with respect to all relevant major accident hazards, targeting the management of the risk of failure of safety critical elements (SCEs) associated with structure, plant, equipment and systems. Significant issues were found in KP3, particularly with respect to the following aspects of the asset integrity management process:

- maintenance of SCEs;
- clearance of backlogs;
- assessment of deferrals;
- measurement of compliance with performance standards;
- corrective maintenance.

The subsequent KP3 review [3] found that improvements in asset integrity management were implemented following the execution of the programme but that nevertheless considerable work was still required. Furthermore, KP3 concentrated on the present condition of assets. With the growing number of ageing installations and the increasing demand to use offshore facilities beyond their design life, there is a need to focus on the integrity management process for ageing installations with a view to ensuring that the associated risks are adequately controlled. It needs to be recognised that the hazard profile of an installation changes as an installation changes, particularly if it is modified. KP4 is intended to move duty holders towards a more proactive approach to the management of ageing and life extension.

3. Regulatory Requirements

The regulatory requirements for the asset integrity management of structures operated on the UKCS are specified in:

- The Offshore Installations (Safety Case) Regulations 2005 (SCR05) [4], which make preparation of a safety case a formal requirement.
- The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996 (DCR) [5], which require the duty holder to ensure that suitable arrangements are in place for maintaining the integrity of the installation, through periodic assessments and carrying out any remedial work in the event of damage or deterioration. The DCR place a requirement on the duty holder to design installations to withstand such forces acting on it that are reasonably foreseeable and that in the event of foreseeable damage it will retain sufficient integrity to enable action to be taken to safeguard the health and safety of personnel on or near it.
- The Provision and Use of Work Equipment Regulations 1998 (PUWER) [6], which require the risks from hazards due to equipment failure to be controlled and specifies the requirement for appropriate inspection and maintenance procedures to be in place.
- The Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 (PFEER) [7], which require that the duty holder takes appropriate measures with a view to protecting persons on the installation from fire and explosion through inherent safety by design, preventive, detection, control and mitigation measures (which include plant and management systems).
- The Pipelines Safety Regulations 1996 (PSR) [8], which require the operator to ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair throughout the life cycle and that all hazards relating to the pipeline with the potential to cause a major accident have been identified and the risks arising from those hazards have been evaluated.

The above regulations are underpinned by the Health and Safety at Work etc. Act 1974 (HSW) [9] and the Management of Health and Safety at Work Regulations 1999 (MHSWR) [10].

The related issues of ageing and life extension were addressed explicitly for the first time in the 2005 revision of the Offshore Installations (Safety Case) Regulations (SCR05). SCR05 requires the duty holder to carry out a 5-yearly thorough review of the safety case to confirm that it continues to demonstrate the effective identification, management and control of major accident hazard risks on the installation. SCR05 also requires the submission of a revised safety case to HSE where material changes to the previous safety case have occurred, including extension of use of the installation beyond its original design life. In general, the duty holder needs to provide evidence that foreseeable damage to the installation, escalation potentials and all likely scenarios have been considered. This includes the demonstration that major hazards arising from ageing processes have been identified, that they are adequately controlled and that the relevant statutory provisions will be complied with. Thus, it is of utmost importance that deterioration and degradation are incorporated into a well-formed asset integrity management (AIM) system and associated plan. The purpose of an AIM plan is to provide a link between the assessment process and the inspection strategy for the installation and maintain asset integrity on an ongoing basis.

4. Standards and Guidance

4.1 Standards

Life extension assessment is a distinct activity which has only recently been formally recognised by the offshore industry, largely due to the recent introduction of regulatory requirements and the new ISO standards for offshore structures, ISO 19900 [11] and ISO 19902 [12]. However, whilst the ISO 19900 series of standards provides a good basis for the assessment of life extension, the standards are still evolving. Neither ISO 19904 [13] for semi-submersibles, which was published in 2006, nor ISO 19905 [14] for jack-ups contains specific recommendations on life extension, although some industry codes and regulatory guidance are becoming available in selected areas.

4.2 Guidance

Guidance on the consideration of ageing of the installation during the 5-yearly thorough review process is provided in Offshore Information Sheet 4/2009 [15]. Additionally, some general information on ageing semi-submersibles is given in Offshore Information Sheet 5/2007 [16]. Guidance on thorough reviews, including the need to consider ageing processes, is given in Offshore Information Sheet 4/2006 [17].

Particularly useful and comprehensive information on the management of equipment containing hazardous fluids or pressure, including the assessment of the risks of accumulated damage and deterioration, is given in HSE Research Report 509 [18] whilst guidance on managing the effects of ageing on safety critical elements can be found in [19].

Useful general information on safety management is given in [20].

5. Ageing and Life Extension in the Asset Integrity Management System

The management of ageing and life extension is an integral part of the asset integrity management system. This should be recognised explicitly in duty holders' safety management systems with clear identification of the allocation of responsibilities for the safe operation of ageing installations. The general principles of the safety management system are described in HS(G)65 [21] and illustrated in Figure 1. Additional information is given in [11].

The principal elements of the management system (POPMAR) are:

- **Policy** - Are there effective policies in place that set a clear direction for the organisation to follow (e.g. safety policy, strategic objectives)?
- **Organisation -** Is there an effective management structure and are arrangements in place for delivering the policy (e.g. organisational structure and responsibilities, management responsibilities, resources, competence, training, use of contractors, communications)?

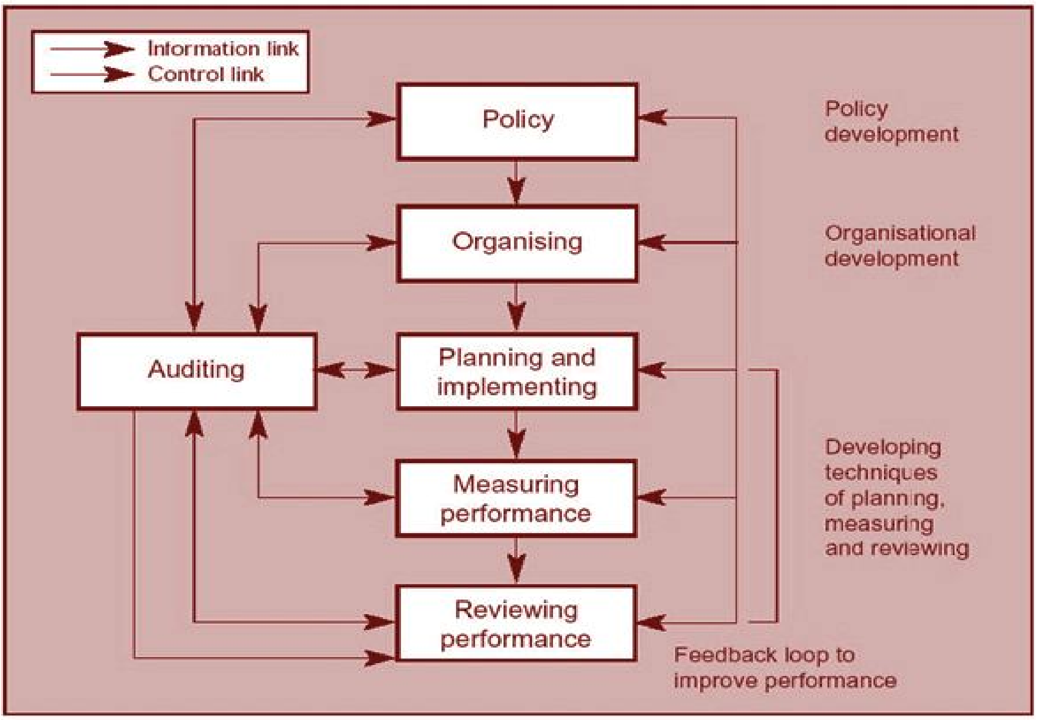

Figure 1: Key Elements of Successful Health and Safety Management (HSG65)

- **Planning and Implementation -** Is there a planned and systematic approach for implementing the policy through an effective health and safety management system, (i.e. hazard identification, risk evaluation, asset integrity, procedures, management of change, contingency and emergency planning)?
- **Measurement of Performance** - Is performance measured against agreed standards to reveal when and where improvement is needed (i.e. monitoring, records, remedial actions, incident reporting and follow-up)?
- **Audit and Review** - Does the organisation learn from all relevant experience and apply those lessons (i.e. internal and independent audits, management review)?

Additionally, a positive safety culture requires clear leadership, effective communications and continuous learning and improvement [20].

Considerations in the application of the model to the management of ageing and life extension are presented below.

Policy

The duty holder safety culture stems from the senior management. Hence, recognition of the significance of ageing issues and ownership of and responsibility for the policy on ageing and life extension should be taken directly by the duty holder senior management. This links directly to OSD's priority on Leadership [1].

The asset integrity management policy should give explicit recognition to ageing and life extension as a key component of the asset integrity management system and needs to be communicated and understood at all levels. It needs to include reference to design codes and standards which address the effects of ageing. These need to be reviewed and updated, as appropriate.

Organisation

The asset integrity management system should specify the organisational structure for ageing issues, setting out responsibilities and job descriptions, both within the company and with contractors and other third parties. Effective communications are essential to an effective management system and these need to be clearly defined. The appropriate level of resources for the management of ageing needs to be determined and made available.

Competency in ageing matters is a key issue. Relevant staff need to be able to demonstrate competency in their area of responsibility with respect to ageing issues. In addition to having suitable professional qualifications, a competency development / training programme should be in place for critical staff to ensure that competency levels are maintained. Contractors and third parties need to be able to demonstrate the requisite level of competency. Additionally, arrangements need to be in place to ensure that competency is ensured following staff changes (both within the organisation and as a result of changing contractors) and that corporate knowledge is maintained.

Planning and Implementation

The specific hazards arising from ageing and life extension need to be identified and the associated risks evaluated. This assessment should be performed following modifications or changes to the operational environment. Procedures in the AIM system should recognise the handling of ageing and life extension issues and identify ageing components and structure. They should be reviewed and updated as appropriate (e.g. due to life extension or to address ageing processes) and include contingency measures for the handling and assessment of accidents and incidents associated with ageing. The operational inspection procedure should specify the need to identify ageing mechanisms. The AIM procedure should ensure that ageing, where identified, is monitored, that records are maintained, that non-compliances are identified and corrective action is taken. The AIM system should include procedures for the reporting and follow-up of incidents caused by ageing mechanisms.

Measurement of Performance

Key performance indicators (KPIs) can be used to identify how effectively the risks to ageing are being controlled. Three levels of KPIs are identified in Table 1.

Level	Key Performance Indicators
High	• Senior management commitment • Investment and long-term planning: a commitment to proactive investment • Planning for success: providing competent staff and sufficient resource • A role for technical engineering
Intermediate	• Trend analysis of safety critical elements • Reviews of maintenance strategy • Root cause analysis of ongoing maintenance problems
Low	• Number of temporary repairs in place

Table 1: Levels of Key Performance Indicators

Performance should be monitored using both leading and lagging key performance indicators (KPIs). Best practice is seen as a proactive management culture using (preferably) leading indicators that can provide information that is useful in predicting future ageing-related issues. All indicators should be designed to provide information for effective proactive management.

Some KPIs to be considered are presented below.

<u>Leading Indicators</u>

- Number of planned inspections
- Number and frequency of audits
- Trend Analysis
- Planned replacement schedules for plant and equipment
- Test quality to provide lifecycle information
- Number of emergency response exercises planned
- Planned number of tests done on safety critical equipment
- Training plans for identified staff and staff numbers attending
- Planned procedure reviews.

<u>Lagging indicators</u>

- Number of major failures of plant and equipment
- Number of uncontrolled releases of product
- Number of reworks to maintenance activities
- Number of outstanding audit / inspection action items
- Number of alarm / instrument failures during testing

- Number of incidents when working under a permit to work system
- Number of incidents due to human error.

Audit and Review

The AIM system should include an audit programme to ensure all elements of a management system related to the controlling of ageing plant and equipment issues are maintained. It is important that the audit schedule is adhered to. The audit findings on asset performance (including improvements, failures, anomalies etc.) should be subject to review by the management and reported up the management chain to the highest levels.

Risk-Based Approach To Ageing

Operators who use ageing plant need to adopt a risk-based approach that entails:

- recognition of ageing and where it is or may be occurring;
- review of coverage, frequency and depth of inspection and maintenance, or
- re-rating or replacement;
- justification of the plant remaining in service.

In order to be able to adequately manage the risks from ageing it is necessary to identify those elements with safety-related functions and determine the degree of deterioration – the process is summarised below:

(1) Establish and record information
(2) Analyse
(3) Predict degradation consequences
(4) Determine degradation rates
(5) Estimate failure probabilities
(6) Report confidence levels
(7) Establish remediation requirements and prioritise actions
(8) Complete necessary actions
(9) Audit the process
(10) Review
(11) Implement change
(12) Record actions
(13) Monitor/inspect
(14) Record information.

This process requires regular review.

Information gathering is the first stage of such a process and needs to include the collection of data from appropriate sources, such as:

- Asset registers
- Tag / equipment lists
- Operations data – temperatures, pressures, load cycles etc.
- Maintenance & breakdown records

- Inspection records
- Accident and incident reporting
- Hazard study / review
- Integrity reviews
- Operational risk assessments
- Defined life repair registers
- Horizon scanning for new and emerging standards, guidance, regulation, etc..

In addition, a review of outstanding actions should be carried out to determine if ageing matters are being adequately managed in relation to:

- o maintenance backlog;
- o outstanding verification scheme issues;
- o outstanding inspection / survey.

Reporting should be grouped by engineering discipline, severity (consequences) and work load (man-hours effort) to establish the adequacy of resources and priority.

6. Key Issues for Ageing Installations

Life extension of offshore installations raises safety issues relating to asset integrity that go beyond traditional practice in the offshore sector. There is a need for better awareness of the hazards arising from ageing processes and preparedness for the possibility of accumulating and accelerating damage that might occur in the life extension phase.

Ageing processes can be considered as systematic changes that alter the risk profile of an installation and include:

- degradation of plant, equipment or structures as a result of time-based erosion, corrosion, fatigue or damage not redressed by existing maintenance, inspection and verification activities.
- introduction of new or revised regulation, standards, guidance or good practice that require an increase (or relaxation) of integrity, reliability or availability.
- changes to plant, equipment or structures over time that cause a discrete or cumulative reduction in safety.
- changes to use or any processes, process fluids or process conditions that increase severity or frequency of demand on integrity.
- changes to personnel or operations that reduce the ability, competence and knowledge profile of personnel involved in all aspects of design, safety evaluation, installation, operation maintenance and decommissioning of an installation. Important factors to consider are the change of ownership of installations to smaller companies with little or no prior experience of operating on the UKCS, the contracting out of functions with loss of corporate

memory and the loss of historical (design and inspection) data with the resultant loss of information about the condition and performance of the installation.

The integrity management of ageing installations and the successful implementation of an asset integrity management plan for life extension depends on:

- understanding the degradation processes;
- accurate knowledge of both the condition of a structure / component;
- the response of the structure in the aged condition;
- an implementation strategy (including a gap analysis identifying the differences between current practice and good practice;
- dealing with the increasing risk of failure with time which enables the greater likelihood of deterioration to be predicted, detected and assessed.

These, in turn, require appropriate inspection techniques and engineering analysis methods. It is important to achieve the correct balance between engineering analysis and inspection for the effective integrity management of offshore installations in general and this is even more so for ageing installations where there is a greater likelihood of deterioration that needs to be both detected and assessed.

However, ageing offshore installations are subject to considerable uncertainties. Information on the condition may not necessarily be available, either because of the global inspection methods used (e.g. general visual inspection and flooded member detection) or because the components may be difficult or impossible to inspect (e.g. piles). Furthermore, data on the original design criteria, material properties, fabrication quality and installation performance are also required but may not necessarily be available. This highlights the need for detailed information on the condition of the structure / components / equipment, inspection strategies that provide accurate information on their condition and an understanding of their performance. Thus, there is a requirement for more extensive data for life extension assessment.

7. Indicators of Ageing

Ageing is more likely to be an issue in the following situations:

- a high cycling rate of extreme temperatures, pressures loads or flexing (which may lead to fatigue);
- a history of operating at the limit of, or beyond, its original design envelope;
- a demanding pressure and / or temperature envelope (high or low extremes);
- aggressive chemicals (corrosive or abrasive);
- use of many different materials of construction (indicator of aggressive conditions and potential for interface corrosion issues);

- aggressive environmental conditions (e.g. salty atmosphere, hot and/or humid conditions, fumes, standing water);
- insulated pipework and equipment with potential for corrosion under the insulation;
- key parts of the plant or structure that are difficult to access or inspect;
- a history of poor maintenance and inspection;
- hardware and software that is obsolescent or no longer supported by the manufacturer.

The clearest evidence will be where:

- there are frequent or recurring defects and failures, or increasing trends of unplanned maintenance and repair work and breakdowns;
- there are signs of ageing: cracking, corrosion, creep and increasing corrosion rates;
- plant has had to be re-rated (i.e. where plant has had to be downgraded to a lower rating, e.g. pressure, temperature, loading, stream concentration or flow due to deterioration);
- operators have had to increase the frequency of their inspection and testing regimes for specific components or plants, or operators have moved from a same period / same inspection regime to a risk based one where periodicity and depth of inspections have changed.

The following could indicate situations where the potential for ageing is not being identified or monitored:

- records of, for example, corrosion monitoring activities and pressure vessel inspections and their findings are not being kept and reviewed for any lessons, trends or looming issues. An extreme case of this is that these monitoring activities and inspections are not being carried out at all;
- operators are not using the findings of plant tests and inspections to check/ modify their testing and inspection frequencies;
- significant safety related equipment is not listed on the asset register or in the maintenance management system;
- there is no procedure for assessing under insulation corrosion.

8. Remedial Actions

Procedures for the handling of deterioration and degradation are an essential element of a well-formed asset integrity management system. Remedial actions will depend on the degree of failure to satisfy relevant standards or original design intent and may entail:

- reanalysis of integrity to ascertain the theoretical level of integrity impairment leading to an action plan;

- inspection to ascertain the level of integrity impairment leading to reassessment of integrity;
- reduced or increased inspection intervals;
- repairs;
- derating of pressurised components;
- replacement of obsolete equipment;
- downmanning;
- evacuation;

or any combination of the above.

It is expected that protective measures will be provided during the initial design and construction / manufacturing stages and by monitoring carried out during the life cycle.

9. The Thorough Review Process

Management of the ageing process needs to identify the degradation issues specific to the Installation to minimise the corresponding potential increase of risks to persons. The risk may change as a result of a modification or it may gradually alter as the reservoir changes or the condition of the plant deteriorates. The processes in place should monitor these trends and identify the point where the sum of the changes is sufficient to require a formal reassessment of the hazards. The other two factors that should be taken into account when determining the need to reappraise the risks are the improvements in good practice and advances in knowledge since the last assessment was undertaken.

The safety case has made major advances in identifying and selecting options to reduce risk. The Thorough Review process should give greater consideration and emphasis to the following options for the management of the ageing process:

- the provision of effective information to help platform managers, supervisors operators and technicians understand the hazards, their responsibilities and the role of the SCEs in managing the hazards;
- the development of a fully integrated strategy to manage each hazard with a comprehensive set of SCEs with effective performance, including optimisation of periodic inspection to ensure that any degradation remains within acceptable limits. This may require gaps to be filled or performance standards to be clarified.
- the application of tighter operating limits: limiting hazardous operations, staffing levels and, if necessary, production in very high risk facilities and modules;
- optimisation of the integrity management process to minimise the chance of leaks due to mechanical / structural failure or corrosion;

- optimisation of the resources, supervision, controls and competence of personnel operating and maintaining the installation;
- maximisation of the reliability of the existing detection, control and mitigation systems;
- optimisation of the design and performance of the detection and control systems so that the severity of hazards is actively managed to limit the effects within the desired hazard classification;
- revision of the specification and performance of protection systems to take account of research knowledge so that they match the hazards and fulfil specific roles;
- the addition of further barriers to escalation.

The choice of improvements should not be piecemeal but form part of an integrated strategy to mange each hazard. In choosing new systems or upgrading existing ones, the additional risks associated with the installation, modification and maintenance should be factored into the risk equation. There should be a very significant risk benefit. Section 7 of PS_07_06 [22] describes processes for;

(a) determining the totality of the change and the need to carry out a reassessment; and

(b) the reappraisal of the risks. [23] should be consulted with regard to risk assessment.

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