Procedure

Engineering Standard X-PRO-STD-013
Engineering Technical Hazard Study

Document number: PRO-02140

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(Refer Controlled Document in REX for Author, SME, Owner and Approver details)

Contents

1. Purpose

This document is part of a suite of Seqwater Engineering Standards which are in alignment with the Seqwater Quality Management System. Their purpose is to provide a consistent approach to the development, modification, and management of Seqwater infrastructure that is fit for purpose, economic over the life of the asset, and meets Seqwaters Work Health and Safety obligations.

The purpose of this Procedure is to establish a structured approach for conducting Engineering Technical Hazard Studies.

The aim of engineering technical hazard studies is to review the hazards, control measures and operability concerns associated with the design of new infrastructure, plant, equipment, or systems or the modification of existing ones at various stages of a project's lifecycle.

The purpose of this procedure is to provide guidelines on when and how to undertake a technical hazard study and outlines the methodologies to be applied.

This document includes the details of various hazard identification methods with particular emphasis on Hazard Identification (HAZID), Hazard and Operability (HAZOP) and Control Systems Hazard and Operability (CHAZOP) study techniques.

As outlined in the Seqwater Engineering Standard X-PRO-STD-009 Engineering Design, Construction, Operation and Maintenance (PRO-01617), a technical hazard study is required for all new and modified designs to ensure alignment with Seqwater's operational requirements and risk management expectations.

The selection of the technical hazard study methods and the level of study will largely depend on the nature and phase of the project. A Registered Professional Engineer of Queensland (RPEQ) involved in the design is typically responsible for defining and approving both the hazard study method and the level of technical hazard study to be undertaken, in accordance with the guidelines outlined in this procedure. The Seqwater Engineering Standards and Assurance (ESA) team may also support the designer in determining the necessity and timing of a technical hazard study. Technical hazard studies are a critical component of the Safety in Design (SiD) process, ensuring that potential risks are identified and mitigated early in the project lifecycle. However, these studies are only one element of a broader Safety in Design framework.

Depending on the nature and complexity of the design or project, additional assessments may be required. These can include SiD reviews, constructability reviews, water quality hazard analysis and risk assessments. These additional reviews are not covered in the technical hazard study procedure itself. For overall guidance on the SiD process, Engineering Standard X-PRO-STD-009 Engineering Design, Construction, Operation and Maintenance (PRO-01617) should be referred to.

2. Scope

This Procedure applies to all Seqwater employees, contractors, suppliers and consultants working for, or on behalf of, Seqwater unless otherwise stated. Deviation from the requirements in this Procedure requires written agreement from Seqwater as per the deviation process detailed in X-PRO-STD-008 Asset Standards Management and Application (PRO-02205).

Seqwater undertakes regular updates of its Engineering Standards. Before utilising this Procedure, the complete list of Seqwater Engineering Standards should be reviewed to ensure currency and applicability of standards to be applied to the works.

This Procedure follows Seqwater's requirements to meet corporate risk appetite at all stages of the design process work where health and safety hazards must be identified and managed in accordance with the Corporate Safety - Hazard Identification and Risk Management Procedure (PRO-00657).

This Procedure outlines the Seqwater's minimum requirements for hazard studies to be applied to any new assets constructed for, or modifications to existing assets owned by Seqwater. Notwithstanding the requirements outlined in this Procedure the responsibility for demonstrating risk attainment of As Low As Reasonably Practicable (ALARP) / So Far As Is Reasonably Practicable (SFAIRP)[1] rests with the project team.

The Seqwater Engineering Standards and Assurance (ESA) team can provide guidance and technical assurance to the project team on the requirements to demonstrate ALARP / SFAIRP. Whether the engineering change is managed externally or internally, an RPEQ engineer shall be responsible for approving the level of technical hazard study to be undertaken. That RPEQ shall be listed as an approver on the Engineering Statement Forms ES1 – Design (TEM-00216) and ES2 – Construction (TEM-00217).

Advice must be sought from the Seqwater Document Owner, via the Engineering Mailbox, to clarify any ambiguities in relation to this Procedure.

[1] ALARP pertains to implementation of risk reduction measures to the extent that it would be grossly disproportionate to the benefits of risk reduction for further risk reduction measures. ALARP is the term commonly used in technical risk management. SFAIRP is used in legislation context including the *Queensland Work Health and Safety Act, 2011*. ALARP and SFAIRP are essentially the same, except that upon achieving an acceptable risk threshold through ALARP, SFAIRP requires that further risk reduction measures should be implemented if viable (financially or otherwise).

3. Engineering Technical Hazard Study

The foundation of an effective safety and risk management system is the comprehensive identification and assessment of potential hazards throughout the project lifecycle. Hazard identification represents the first step in the Workplace Health and Safety (WHS) risk management process, as outlined in Corporate Safety – Hazard Identification and Risk Management Procedure (PRO-00657).

Technical hazard studies are conducted to identify hazards, evaluate and recommend appropriate control measures, improve safety performance, reduce operational costs, and ensure compliance with regulatory requirements, whether for a new design or modifications to an existing one.

The technical hazard studies, together with design reviews and risk assessments, provide an effective and efficient process for designing and constructing new infrastructures, plants, equipment or systems. This integrated approach ensures that:

- New installations or modifications to existing plants and systems comply with all relevant legislations and adhere to good engineering practices;
- Health & safety, environmental, water quality, production and commercial risks are thoroughly considered;
- Designers can systematically identify risks associated with the intended use, selected materials, and possible methods of construction, maintenance, operation and demolition;
- Risks are controlled using Hierarchy of Controls through Elimination, Substitution, Isolation, Engineering, Administration or Personal Protective Equipment (PPE) as shown in Figure 1 below.

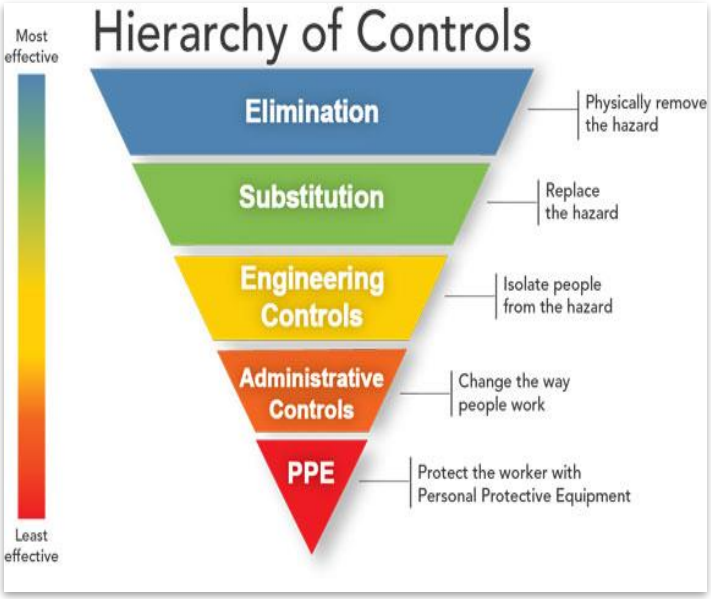

Figure 1 - Hierarchy of Controls for Risk Management

The implementation of risk controls and mitigation measures shall be to the extent of ALARP / SFAIRP.

In the industry, a broad range of methods are used for technical hazard studies throughout the project life cycle. A number of common technical hazard study methods mentioned below should generally be considered for Seqwater projects:

- Hazard Identification (HAZID) Study
- Construction Hazard Assessment Implication Review (CHAIR) Methodology
- Consequence Modelling
- Hazard and Operability (HAZOP) study
- Control System HAZOP (CHAZOP) Study
- Safety Integrity Level (SIL) Study.

In addition of the above hazard study methods, the project may consider to use other suitable methods to evaluate the health, safety, environment, water quality, production and commercial risks. Additional workshops, safety reviews or risk assessments may also be needed which are not discussed and covered in this procedure. Any task specific risk assessment requirements and methods are also not included in this Procedure.

3.1. Technical Hazard Study Levels

For new projects, the greatest benefit is achieved by conducting multiple hazard studies throughout the design process. The design process can be represented as a series of phases that ultimately align the broader project management lifecycle.

In the early 1980's, six (6) levels of technical hazard studies were developed for process industries. These structured studies align with the project management phases and provide a systematic approach to ensuring that health, safety and environmental performance objectives are met throughout the project.

A typical technical hazard study life cycle model with six (6) levels is shown in Figure 2 below.

It is expected that the majority of Seqwater projects shall perform at least Technical Hazard Study Level 1 termed as "Hazard Identification" or HAZID study. But a project with a process system must conduct a Technical Hazard Study Level 3 (HAZOP study) in additional to a Level 1 HAZID study. However, as stated in Section 1, a RPEQ engineer shall determine the appropriate level of hazard study required considering the following criteria:

- The nature of the project
- The size of the project
- Complexity of the process
- Nature of hazards associated with the design, construction and operations
- Hazards identified at previous technical hazard studies or SiD reviews.

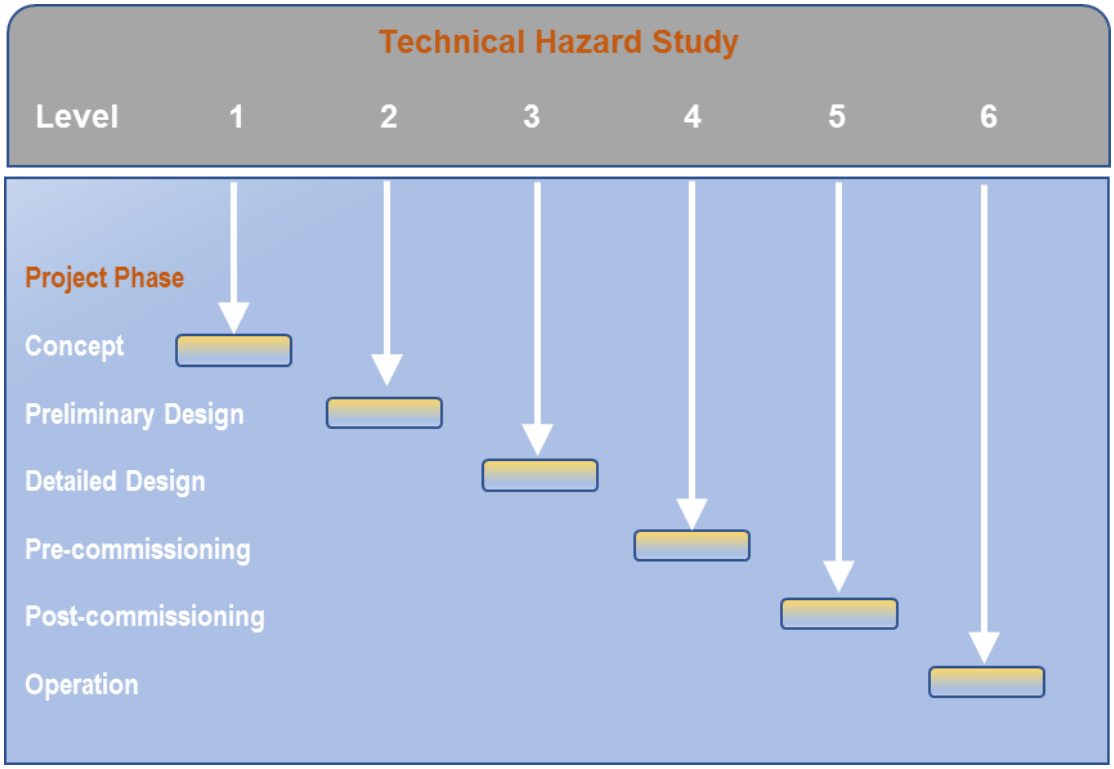

Figure 2 - Technical Hazard Study Levels by Project Phase

3.1.1. Technical Hazard Study – Level 1

The Technical Hazard Study Level 1 shall be undertaken as early as possible of the project preferably at the phase of concept design, but it can also extend into the preliminary design phase depending on the project's complexity and risk profile.

This study shall identify hazards that may exist or occur during all phases of the project or may influence the preferred design selected. The study outcome shall identify:

- The significant construction, installation, operation, maintenance, repair and demolition risks associated with the project.
- The information and studies needed to address health, safety and environmental issues.
- The relevant legislations/standards applicable to the project and defines any constraints.

Hazard Identification or HAZID study is recommended at this level and is mandatory for all projects. Section 3.2 provides the details of a HAZID study methodology.

CHAIR1 study as discussed in Section 3.4 can be considered as an alternative to HAZID study but this method is predominantly recommended for civil/construction focused projects.

3.1.2. Technical Hazard Study – Level 2

This study shall take place during the project Definition Stage or Preliminary Design stage when the flow sheets have been developed and at a stage when the process conditions are understood.

The study is mainly aimed at identifying any significant hazards by examining the flowsheet and ensure that the risks are addressed in the design phase of the process.

For a process system, the study should cover emergency shutdown, pressure relief philosophy, safety philosophy, potential fire or environmental pollution from loss of containment, any health protection measures and others. Where needed, a preliminary control scheme should be developed to make decisions on process safety trips and alarms for the control system design.

No generic hazard study method is prescribed for this level of study since it shall depend on the nature of the project. Environmental review and impact assessment, safety review, preliminary 3D model review, consequence modelling, quantified risk assessment or other forms of hazards assessment may be necessary depending on the nature of the project. Appendix C provides a generic checklist that may be considered at this phase of study before the detailed design work starts to address the common problems generally applicable to a process system.

On some occasions, HAZID study may also be conducted at this level instead of the design concept phase with the recommendation of a RPEQ engineer.

For large projects involving process systems, a coarse HAZOP may be conducted at the preliminary design stage using the Process Flow Diagram (PFD) and preliminary P&IDs with the prior approval of a RPEQ. However the coarse HAZOP shall not be considered as an alternative to a full HAZOP when the firm design is developed.

3.1.3. Technical Hazard Study – Level 3

The Technical Hazard Study Level 3 is conducted at the project detailed design phase. This study involves a detailed and systematic line-by-line review of the infrastructure, plant or facility, operating and maintenance procedures, construction methods to identify potential consequences from the deviation of design intent or construction activities.

The following hazard study methods are recommended at this level, but the ultimate choice shall largely depend on the nature of the project:

- Hazard and Operability Study (HAZOP) for process systems
- CHAIR 2 and CHAIR 3 Study
- Review of 3D Models for Plant Layout, Constructability and Maintainability Reviews
- Control System HAZOP Study (CHAZOP) for process systems
- Safety Integrity Level (SIL).

Among the methods listed above, a full HAZOP study is mandatory for process systems. This study should be conducted when the design is nearly complete and approaching the “Issued for Construction” stage. Prior to the full HAZOP study, the comprehensive design review must be completed and any resulting actions must be addressed.

Details of the HAZOP study methodology are provided in Section 3.3.

A brief description of the other hazard study methods is provided in Section 3.4 to Section 3.8.

3.1.4. Technical Hazard Study – Level 4

The Technical Hazard Study Level 4 is designated as a pre-commissioning check. Its primary focus, through a checklist-based approach, is to verify that the plant has been constructed following the design intent and that all actions identified in previous hazard studies have been appropriately addressed.

In summary, this study level will focus on the following:

- Ensure that the equipment, piping, valves, instruments and other hardware are built as intended, and no significant alterations of the design intent have occurred,
- Check that all actions raised during earlier hazard studies, design reviews, risk assessments have been incorporated into the design,
- Check operating and emergency procedures are documented and comply with previous hazard study actions,
- Verify that any statutory requirements are met and the system is ready for functional testing,
- Review commissioning and operating instructions for safety.

The primary focus of the Level 4 technical hazard study is to conduct a comprehensive review of the design and construction. This assessment is performed at the end of the construction stage to ensure that the equipment has been built as intended and that there are no significant deviations from the original design intent.

3.1.5. Technical Hazard Study – Level 5

The Level 5 checklist-based hazard study is a post commissioning review carried out to examine that the plant or facility can be operated as intended and that the design intent has been met. This study also serves as a final preparedness check by the operations team before routine production begins. The review typically includes confirmation that:

- the plant or facility is safe to operate as per the design intent,
- final operating procedures documented and applied into operator training,
- training of operators has been completed, as far as practicable,
- validation of all safety instrumented systems (if applicable) and safety devices has been carried out,
- functional testing of trip systems has been completed to verify logic functionality and response times.

There are no formal guidewords for this study. Instead, prompt questions or review topics such as those provided in Appendix C, may be used to guide the assessment.

3.1.6. Technical Hazard Study – Level 6

The Hazard Study Level 6 is a periodic, formal review (typically conducted every five years) to ensure the plant or facility continues to operate in accordance with the design intent and to validate that earlier hazard study recommendations remain effective and relevant.

It is recommended that this study be undertaken a few months into steady-state operations and repeated periodically throughout the plant's operational life. The objective is to revalidate earlier studies such as HAZOP and others in light of actual operational experience and any changes that may have occurred since initial commissioning.

The purpose of Technical Hazard Study Level 6 includes:

- Confirming that all outstanding issues from the previous studies have been completed;
- Assessing whether the operational experiences so far match the assumptions made about the process or its operability during the previous studies;
- Identify for any significant deviations from the intended operating procedures; and
- Capturing lessons learned to inform future projects and continuous improvement.

As with Study Level 5, there are no formal guidewords. Instead, prompt questions and review topics, provided in Appendix C, may be used to guide the discussion and evaluation.

3.2. HAZID Study

HAZID, or Hazard Identification, is a structured, systematic study conducted during the early stage of project's life cycle. Its purpose is to identify all foreseeable hazards associated with the project's design, construction, decommission and any proposed modifications to existing operations. The goal of the HAZID study is to identify both internal hazards (e.g., process-related issues, equipment failures) and external hazards (e.g., natural events, nearby facilities, utility failures) at an early stage, assess their potential consequences, and recommend appropriate measures to eliminate or mitigate the associated risks—thereby ensuring a safer and more reliable project outcome.

The HAZID study is typically carried out in a brainstorming workshop setting by a multi-disciplinary team using a structured approach based on predefined guidewords.

3.2.1. HAZID Objective and Methodology

The primary objectives of the HAZID study are:

- To identify potential hazards, determine consequence and perform risk ranking;
- To propose recommendations to eliminate, control or mitigate hazards;
- To provide early safety and risk inputs into the project design and SiD process.

The HAZID study shall require a preliminary risk assessment to be performed to prioritise the hazards identified following the Seqwater risk management process as illustrated in PRO-00657 Corporate Safety - Hazard Identification and Risk Management Procedure. Such risk assessment should include the inherent risk of the associated hazards where possible and the residual risk with the proposed control measures in place. Seqwater corporate risk matrix should be used for the risk ranking following the guidelines provided in FRA-00014 Enterprise Risk Assessment Framework.

Although inherent and residual risk assessments are generally recommended for the HAZID study, the study team shall ultimately decide at the start of the HAZID study the appropriate combination of risk analysis components from inherent risk, residual risk, target risk etc.

Figure 3 shows a recommended flowchart of the HAZID methodology.

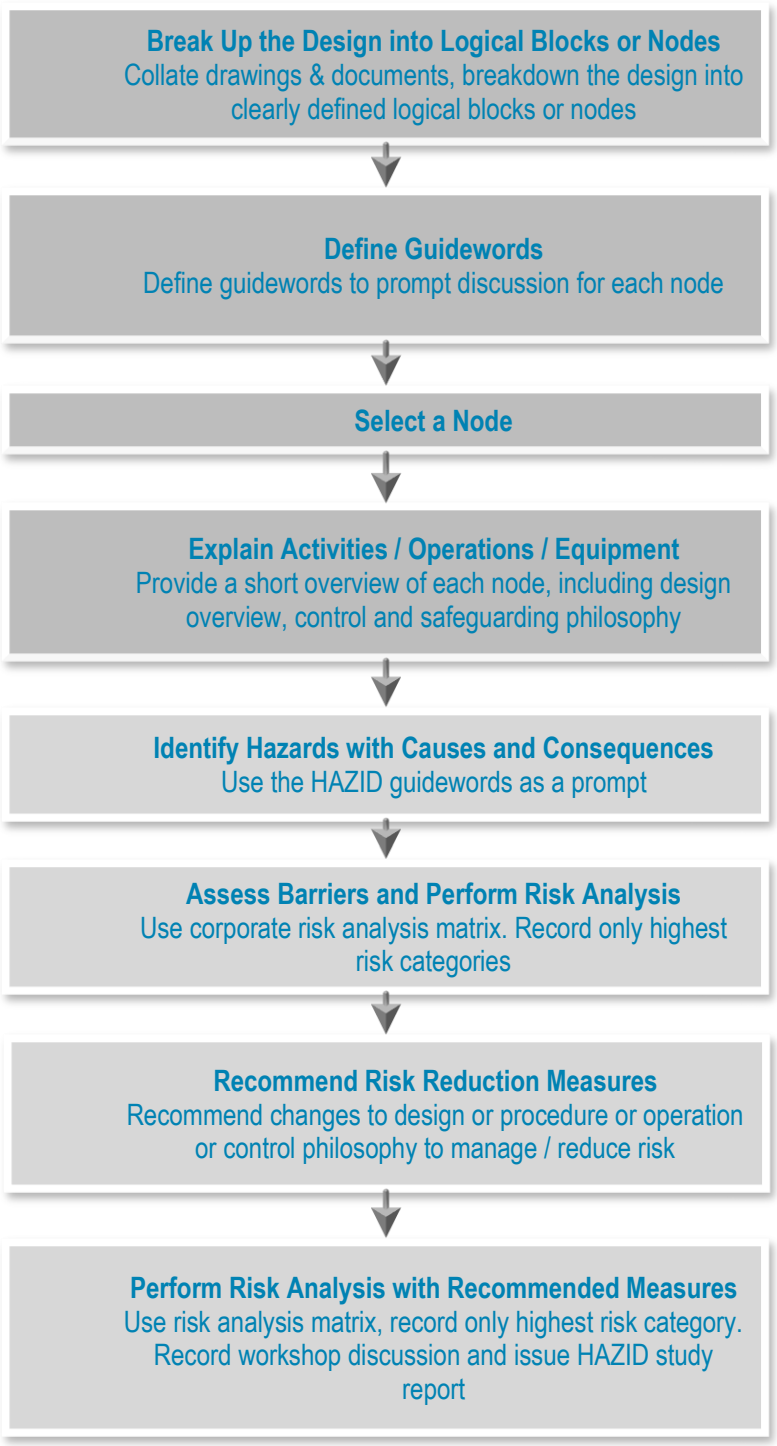

Figure 3 - HAZID Methodology Flowchart

A HAZID study should:

- Partition the design process into logical blocks or nodes of appropriate size for analysis.
- For each logical block, use various Guidewords to assist with the identification of hazards.

- Determine the associated risks and dictate if the safety risk can be eliminated.
- If the safety risk cannot be eliminated, determine how it might be reduced.
- Assess whether the proposed risk controls (i.e. expected safeguards, etc.) are appropriate (is the risk as low as reasonably practicable).
- Document comments, actions and recommendations – determine appropriate method for design issues still to be resolved.

To perform the HAZID study, the following information is recommended to be made available:

- Process description and block diagram
- Overview of location
- General layout diagram
- Outline of control philosophy
- Utility requirements and availability
- Outline of chemical hazards and interactions
- Relevant environmental information
- Relevant health information
- Information on previous incidents relevant with the project.

A typical list of HAZID Guidewords is provided in Appendix A. The Guidewords can be modified prior to performing the HAZID review based on specific analysis of the early stage or concept design information available by the review team. The Guidewords act as an aid to stimulate brainstorming and are not a complete list of causes. It is important to note that the Guidewords provided are to be used as a prompt to trigger the discussion of issues and not to be used as a checklist of issues to be considered.

It is recommended the facilitator issues a Terms of Reference (TOR) document outlining the HAZID methodology and study scope prior to the workshop.

3.2.2. HAZID Study Team

The participants of the HAZID team is flexible depending on the actual scope of the project but it is expected that the participants shall have an informed view on the overall health & safety issues, environment impacts, constructability, operability and maintainability.

The HAZID team should typically involve as a minimum:

- Study Facilitator
- Study Scribe
- Project Manager
- Site / Operation Representative
- Designers involved undertaking the design
- Relevant Seqwater functional engineer/ technical specialist (Process/Mechanical/Civil/Electrical/Control)
- Water Quality Representative (where needed)
- Environmental / Health & Safety Representative (where needed).

The Facilitator shall be an independent person or at least not directly involved with the design process who ensures that established protocols are followed. Preferably, the Facilitator should be an experienced engineer/professional who had prior involvement in risk assessments and hazard studies.

Generally, the Facilitator needs to be assisted by a nominated scribe responsible for recording the meeting minutes and notes.

The Project Manager with the consultation of the Lead RPEQ Design Engineer and the Facilitator should ensure the appropriate and optimum representation of the HAZID study team considering the nature of the project.

3.2.3. HAZID Study Recording and Action

A HAZID study report should be issued immediately after the HAZID workshop outlining the recommendations and residual risk. The HAZID study report should serve as a permanent document for the HAZID study and is used by all people involved with the project. The study report should include all recommendations with the name of the responsible person for actions. The recommendations should be standalone to interpret with background information of what, where and why this is suggested.

Seqwater Hazard Technical Study Record Sheet Template X-TMP-STD-008 (TEM-00213) includes a typical worksheet for HAZID study with Guidewords which should be used to record the HAZID meeting minutes and should be attached with the HAZID study report.

Hazards identified during the early stage of the project from the HAZID study should be carried forward to the next design phase and included in the SiD hazard register or project risk register where available.

The Project Manager shall be in charge to track down the progress of the HAZID study recommendations.

3.3. HAZOP Study

HAZOP stands for HAZard and OPerability. HAZOP is a systematic and structured review of a planned or existing process and operations for hazards and operability issues. This is achieved by evaluating possible deviations from the design intent for a section of the process under review. The HAZOP study is traditionally applied to process plants. *AS IEC 61882 Hazard and Operability Studies (HAZOP studies) - Application Guide* provides the principles and procedures of HAZOP studies that need to be applied.

HAZOP is the study that most people are aware of but often do not realise is only one level of hazard study. HAZOP should be conducted at a stage when the P&IDs are at nearly complete, and the design has reached a point considered to be a “firm” or finalised design.

Before conducting a HAZOP**, the design must be thoroughly reviewed and revised to address any major issues.** All relevant documents must be updated to reflect the outcomes of the design review prior to the HAZOP. This ensures that the HAZOP remains focused on identifying and evaluating hazards and operability concerns, rather than being diverted by unresolved or incomplete aspects of the design.

The objectives of the HAZOP study are to:

- Investigate how the system and plant deviate from the design intent;
- Determine how the deviation may impose risks to the process operability and environment;
- Recommend actions to mitigate the identified process operability, environmental and safety issues; and
- Present the results and recommendations.

3.3.1. HAZOP Methodology

The HAZOP examination is a qualitative structural study and essentially questions every part of a process design or operation to discover how deviations from the design intent or normal operation can occur and whether these deviations can increase hazards. The HAZOP study uses a full description of the process which will invariably use P&IDs to question systematically every part of the design.

The questioning primarily focuses on a set of Guidewords designed to explore all conceivable ways in which the design and operations could deviate from the original design intent, potentially leading to hazards or operability problems.

The HAZOP study is done in a brainstorming workshop by a multi-disciplinary team. The study team recommends actions to mitigate hazards and operational problems.

The customary HAZOP methodology flowchart as shown in Figure 4 should be followed.

3.3.2. HAZOP Technique

The HAZOP technique has the potential to identify hazards and operability issues. However, it requires significant resources and must be integrated into the overall project management framework to be truly effective.

For project specific applications, the HAZOP methodology outlined above is implemented through the following steps:

- Define the purpose, objectives, and scope of the HAZOP study.
- Assemble a HAZOP study team (include all stakeholders).
- Prepare for the study.
- Carry out the team review in a workshop.
- In the workshop, agree on a set of Guidewords / prompts to assist the brainstorming process.
- Partition the process into nodes of appropriate size, utilising the P&IDs and examine line by line.
- Design engineer, typically process engineer, to provide an overview to the HAZOP study workshop of the design, such as design intent, design envelope, set points, operating modes, etc.
- For each node, use various Guidewords to assist with the identification of safety aspects/issues.
- Discuss associated plant safeguards and determine if the abnormal plant operation is controlled safely and effectively.
- If the safety risk cannot be eliminated, identify measures to reduce it to an acceptable level. Assess whether the proposed controls (i.e. expected safeguards, etc.) are appropriate.
- Summarise the comments, actions and recommendations and document them into the HAZOP Study Report.
- Track to close out of HAZOP actions and ensure results are implemented and recorded or deferred to a later project stage and document them in the HAZOP Close Out Report.

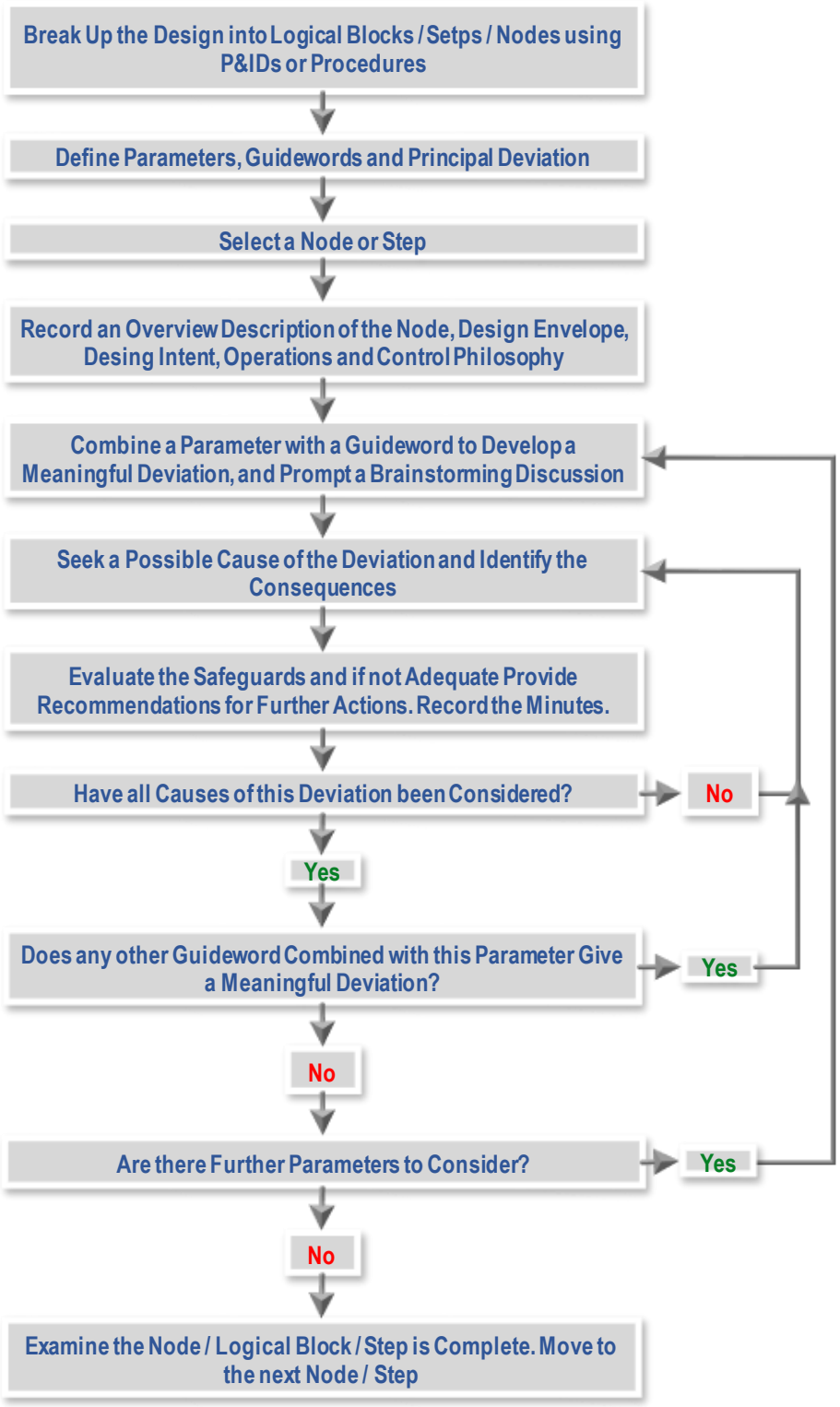

Figure 4 - HAZOP Methodology Flowchart

In addition to the above steps, the following guidelines can be considered as “HAZOP Golden Rules” for a HAZOP proceeding:

- recording of detailed node description and design intent
- causes within the node, consequence can be anywhere
- analysis of ultimate, unmitigated consequences
- description of the action of safeguard
- what-where-why as standalone (WWWS) recommendations
- full recording of the workshop.

The following documents shall be available during the HAZOP workshop:

- Process Flow Diagram (PFD)
- Piping and Instrumentation Diagrams (P&IDs)
- Mass and Energy Balance
- Cause & Effect Diagram
- Functional Design Description documents
- Operating Procedure
- Plant Layout and General Arrangement
- Equipment Data Sheet.

3.3.2.1. HAZOP techniques for sequential operations

The standard HAZOP approach of examining a system line by line as described in Section 3.3.2 is ideal for continuous processes but not quite appropriate to the thorough examination of sequential operations or for a batch process. The guidewords, deviations and parameters for a batch process HAZOP need to be different from that of a continuous process HAZOP and the general method of application is also different. The following are the two most important factors for batch processes:

- the role of operating procedures and operator actions
- the discrete-event character of batch processes.

Because operators play a larger part in batch operations, more considerations should be given to operator actions for a batch process HAZOP.

Procedural HAZOP, which is an examination of an existing or a planned work procedure to identify issues for operational or quality problems, uses similar technique to that of batch process HAZOP.

3.3.2.2. HAZOP techniques for package equipment

When package equipment or systems are to be procured for a process plant, a HAZOP of the procured package and its associated interfaces shall be required. This HAZOP may be conducted as “by exception” basis.

A “by exception” HAZOP involves reviewing the existing HAZOP actions to identify any changes introduced by the new equipment and to determine if any additional actions are required as a result of its integration.

A separate HAZOP for the package system itself is generally not required, provided the vendor has already supplied adequate HAZOP documentation for the system in advance.

3.3.3. HAZOP Guidewords

As mentioned before, the continuous HAZOP shall be conducted by dividing the overall process design into several small sections called “nodes” (using P&IDs). The Guidewords and process parameters as specified in Table 1 are considered principal deviations for continuous process system and shall be used to assess each node.

Table 1 Principal Deviations for Continuous Process HAZOP

Principal Deviations for Continuous Process Plant						
Process Parameter	**Guideword**					
	No	Low	High	Reverse	Misdirect	As well as/other than
Flow	No Flow	Less Flow	More Flow	Reverse flow	Misdirected flow	As well as/other than flow
Temperature	-	Low temp	High temp	-	-	-
Pressure		Low pressure	High pressure	-	-	-
Level		Low level	High level	-	-	-
Composition	-	Low comp	High comp	-	-	-

In addition of the above general principal deviations, the following additional Guidewords shall be used for each node analysis:

- Different water quality
- Impurities (gaseous, liquid, solid)
- Testing (trips and alarms, product)
- Plant Items (operable & maintainable)
- Electrical (area classification, isolation, earthing)
- Instruments (sufficient for control, location, over instrumented)
- Sampling (sufficient sample points)
- Previous Incidents
- P&ID Items (missing and incorrect information).

Additional deviations or guidewords as decided by the HAZOP team should be used to analyse each node.

In addition to the above generic deviations, a number of HAZOP Overview Guidewords should be used at the end of each HAZOP session to assess the issues related to the overall design, maintenance and plant operability. However, if the overview Guidewords are assessed in a prior CHAIR study, SiD review or risk assessment workshop, then further assessment in the HAZOP workshop may not be required.

Appendix D provides a comprehensive set of Guidewords, organised separately for continuous processes and batch / procedural process HAZOPs, along with associated deviation scenarios following the structure outlined above. Appendix D also includes a set of HAZOP Overview Guidewords.

3.3.4. The HAZOP Workshop and Team

The HAZOP workshop is carried out by a multidisciplinary team that includes members with in-depth knowledge of the process or plant under review, as well as engineers contributing expertise from their respective disciplines. A design engineer plays a key role in orientating the team to the design being reviewed, both at the outset and throughout the workshop. At a minimum, the design engineer should be able to explain the process operation, control philosophy, typical operation and design envelops, and other relevant considerations.

The participants of the HAZOP team are flexible depending on the actual scope of the project but it is expected that the participants shall have an informed view on the overall health & safety issues, environment impacts, constructability, operability, quality and maintainability.

A successful HAZOP workshop relies on all team members bringing an open-minded and imaginative approach to identifying potential hazards and operability issues.

The HAZOP team shall typically involve as a minimum:

- Study Facilitator/ Leader
- Study Scribe
- Project Manager
- Operation Representative
- Designers involved undertaking the design
- Relevant Seqwater functional engineer/ technical specialist (Process/Mechanical/Civil/Electrical/Control)
- Water Quality Representative
- Environmental / Health & Safety Representative (where required).

A HAZOP workshop should not proceed in the absence of an Operation Representative.

3.3.5. Study Facilitator

The success of a HAZOP study relies largely on the facilitator's ability to effectively engage the study team, leveraging their collective experience and technical knowledge to rigorously evaluate the process design. As such, the selection of a qualified and competent facilitator is a critical factor in ensuring the overall quality and effectiveness of the study.

Ideally, the HAZOP facilitator should be a trained professional certified by a recognised organisation. In addition, it is preferable that the facilitator possesses a strong background in process engineering or has substantial experience in process design. This technical foundation enables the facilitator to guide discussions with insight, identify potential hazards, and ensure that all credible scenarios are thoroughly examined.

The HAZOP facilitator should be independent or, at the very least, not directly involved with the design process to maintain objectivity throughout the review. Prior to the workshop, the facilitator typically reviews the process documentation to define and allocate HAZOP nodes. These nodes should be identified ahead of time, and the HAZOP spreadsheet should be pre-populated accordingly.

During the workshop, the facilitator is responsible for guiding the team through a systematic review of each node using established guidewords to prompt meaningful input from attendees. A key responsibility of the facilitator is to ensure that the HAZOP remains focused on hazard identification and operability assessment, rather than devolving into a detailed design review. Any design-related issues raised during the session should be noted in a "parking lot" for follow-up by the appropriate design team, without diverting the workshop's focus.

Prior to the workshop, the facilitator should issue the HAZOP Terms of Reference (TOR) document to all participants outlining the workshop scope, methodology, identified nodes, guidewords with marked up P&IDs showing the node boundaries and the HAZOP spreadsheet to be pre-populated with the nodes.

Upong completion of the workshop, the final HAZOP report should include the completed HAZOP spreadsheet and the marked up P&IDs used during the review, providing a clear and auditable record of the study.

The HAZOP facilitator shall issue the HAZOP study report for review within a few days from the conclusion of the HAZOP workshop. This timely distribution ensures that the team members can review the report while the workshop discussions, decisions and context remain fresh in their memory, supporting more effective validation and feedback.

3.3.6. HAZOP Records and Action List

A HAZOP record sheet shall be used to systematically document the proceedings and outcomes of a HAZOP workshop. There are various formats and software tools available for this purpose. At Seqwater, the X-TMP-STD-008 Technical Hazard Study Record Sheet Template (TEM-00213) is the recommended format. This template includes standard HAZOP guidewords and is designed to ensure consistency and completeness in recording HAZOP assessments. Regardless of the format or software used, the minimum information that must be recorded on the HAZOP sheet includes:

- Project Name
- Date of the workshop
- Name and role of HAZOP team members
- P&ID and other drawing numbers
- Node or logical block detailed description including relevant equipment and / or instrument tag number, design conditions, set points etc.
- Guideword (s), cause (s) and consequence (s) identified during the review
- Existing safeguards and controls
- HAZOP recommendations or corrective actions
- Name of the responsible person assigned to each action.

Each HAZOP action must be clearly referenced with supporting information, such as the relevant drawing number (e.g., P&ID), equipment tags, or instrument identifiers. This ensures that actions are traceable to the exact location or system under review.

The HAZOP record must be fully auditable. This means the documentation should clearly explain the rationale behind each recommendation. In cases where no recommendation is made, the record must demonstrate that the deviation was thoroughly considered by the HAZOP team and was determined to be either non-hazardous or acceptable under ALARP / SFAIRP principles.

A formal HAZOP study report shall be issued promptly following the completion of the HAZOP workshop. The purpose of this report is to provide a clear, auditable, and comprehensive summary of the study's outcomes, enabling effective follow-up and action tracking.

This report must include:

- Summary of the HAZOP workshop, including an auditable record of discussions, deviations considered, and the decision-making process.

- All identified recommendations and actions, clearly outlined and cross-referenced with the relevant nodes, equipment, and drawings (e.g., P&IDs). Each recommendation must be written as a standalone statement that clearly communicates:
    - What is being recommended,
    - Where it applies (e.g., system, equipment, or location),
    - Why the recommendation is being made, supported by relevant background information and rationale.
- Names of responsible persons assigned to each action, ensuring accountability for follow-up and implementation.

3.3.7. Implementation of HAZOP Actions

The HAZOP is not complete until the actions are appropriately closed out. The following points need to be considered for the successful implementation of HAZOP actions:

- Relevant personnel are made responsible for ensuring that the approved actions are completed by the due date.
- The project manager records the project evaluations, proposed actions and sets up an “action tracking” system.
- The project manager tracks action progress and organises regular meetings with all relevant persons until the actions have been completed, approved and closed out. The project team should include appropriately qualified technical persons to sign off actions, including RPEQ accredited engineers where required.

Suitable action close out should include mark up of P&IDs and associated documentation and reports. It is not sufficient to note in the actions tracking system that the action is complete but not provide documentation to show the change. Once all recommended actions have been addressed and verified, a HAZOP Close-Out report must be prepared. This report should:

- Confirm that all actions have been completed
- Include evidence of implementation (e.g., updated drawings, procedures, or design modifications)
- Be incorporated as part of the final project safety documentation as part of the formal project close out process.

The HAZOP Close-Out Report must be issued and reviewed prior to the commencement of construction, ensuring that all identified safety concerns have been appropriately managed during the design phase.

Additionally, during pre-commissioning check or Hazard Study Level 4 as described in Section 3.1.4, the HAZOP Close-Out Report serves as a critical reference document. It provides assurance that all HAZOP recommendations have been implemented or appropriately addressed, and it supports the ongoing verification of safety throughout the project life cycle.

3.4. Construction Hazard Assessment Implication Review (CHAIR) Methodology

Construction Hazard Assessment Implication Review (CHAIR) has been specifically developed for the construction industry by WorkCover New South Wales in the late 1990’s. CHAIR is designed to identify and minimise or eliminate risks in a design as soon as possible in the life of a project.

The CHAIR study is structured to bring together all the key stakeholders involved in design and facilitate a discussion triggered by guidewords or prompts to identify and eliminate or minimize hazards.

There are three phases of CHAIR study as stated below:

- CHAIR 1: CHAIR 1 is performed at the early stage or conceptual stage of design to identify and eliminate hazards. This is the best opportunity to make fundamental change although much of the design still to be determined.
- CHAIR 2: CHAIR 2 mainly focuses on construction and demolition issues just prior to construction when the full design is known.
- CHAIR 3: CHAIR 3 focuses on maintenance and repair issues and conducted at the same time of CHAIR 2 study.

CHAIR study methodology is similar to HAZID study as outlined in Section 3.2.1. A full list of Guidewords to prompt discussions for three CHAIR phases are provided in Appendix B. The CHAIR Guidewords are reported here as obtained from earlier NSW WorkCover (now known as SafeWork NSW) documents.

CHAIR 1 Guidewords are based on the assumption that the study should be structured on the design being divided into logical blocks or nodes. CHAIR 1 Guidewords have been organised into two types “Generic” and “Overview”. Generic Guidewords should be used into each logical block or node analysis to assist with the identification of safety issues. Overview Guidewords should be used at the end of CHAIR 1 study to review issues that relate to the whole design concept.

CHAIR 2 and CHAIR 3 should also be conducted by partitioning the design into logical blocks or nodes of appropriate size. It is strongly recommended to use the 3D Models for the constructability and maintainability reviews during CHAIR 2 and CHAIR 3 studies.

A CHAIR study is primarily focused on construction related risks and is no longer supported on the SafeWork NSW Website. Additionally, it does not address operability concerns, limiting its application in projects involving complex process systems. A CHAIR 1 study can serve as an alternative to a HAZID study at the early stage of design. The key distinction between the two lies in the guidewords used and the terminology adopted during the study.

At Seqwater, preference is given to the HAZID study over CHAIR 1 study during the early design phase for projects that include process systems, due to its broader focus on both hazards and operability. However, CHAIR 1 study should still be considered suitable for projects that are primarily civil or construction-focused.

Regardless of the study used in early design, both CHAIR 2 and CHAIR 3 studies are recommended to be conducted for all projects prior to the commencement of construction, to ensure that construction and maintenance safety risks are adequately identified and managed.

3.5. Consequence Modelling

Consequence assessment is important to assess any release to the environment either from loss of containment or regular venting of hazardous, toxic and flammable materials. Consequence modelling is a risk analysis technique that determines the impacts of process accidents on people, the environment and property.

Consequence modelling has the following popular applications that may be required for Seqwater Operations:

- Hazardous Area Classification
- Vent Modelling
- Gas Dispersion Modelling
- Facility Siting

- Site Layout Optimization
- Equipment Separation Distances
- For Quantitative Risk Analysis (QRA) study

Consequence modelling is typically performed during the preliminary design phase or as part of the Hazard Study Level 2. Its primary purpose is to optimise the quantity and placement of hazardous materials within the facility, thereby enabling the selection of design options that minimise overall risk.

A variety of commercial software modelling tools are available to support consequence modelling. These tools simulate the discharge and dispersion of hazardous, toxic and flammable materials release to the environment, providing critical data to inform risk assessments and design decisions.

3.6. Control Systems Hazard and Operability (CHAZOP) Study

The process plant control system and associated equipment may exhibit a different spectrum of failure modes compared to those typically considered in a conventional HAZOP study. Therefore, to effectively assess hazards and operability issues specific to control systems, a dedicated study known as the Control Systems Hazard and Operability (CHAZOP) study is required.

CHAZOP is a comprehensive, systematic and structured examination of the control system and/or Information System of the proposed design. This discrete study is particularly important when instrumentation is designed, installed and operated as a standalone package unit. Including automated safety-related systems.

Typically, the CHAZOP study should be performed after the completion of the main HAZOP and following the review of Functional Design Specification and SCADA/PLC network concept design.

3.6.1. CHAZOP Methodology

The basic methodology of CHAZOP is similar to HAZOP; however, instead of focusing on piping, valves or equipment, CHAZOP concentrates on control loops, control sequences, application programs, hardware design of Programable Logical Controller (PLC) operator workstations, cyber security and related systems. It is important to note that every Input / Output (I/O) channel related to the safety related signals must be thoroughly analysed during the CHAZOP study.

CHAZOP is a HAZOP-like brainstorming workshop activity in which the cause and hazardous consequences of control system shortcomings, failures and operability problems are considered using Guidewords. The workshop makes recommendations for further study or design changes where required. The overall system can be divided into several nodes based on functional areas for examination. Note that CHAZOP nodes or functional areas shall be different to the HAZOP nodes.

CHAZOP team shall have more specialist personnel, comprising control, instrument and electrical engineers but there should always be some cross membership of the HAZOP and CHAZOP teams for the continuity of thoughts.

It is recommended that the CHAZOP team mainly focus on:

- Control failures that raise the probability of previously identified HAZOP process hazards.
- Protective interlock control failures that may cause reduced production output or major safety incidents.
- Failures of hardware, software and communication systems for the PLC unit.

The following documents shall be available during the CHAZOP workshop:

- Piping and Instrumentation Diagrams (P&IDs)
- Cause & Effect Diagram

- Functional Design Description documents
- Architecture of control system depicting networks, highways, links, bridges etc.
- Information on power feed structure (single line diagram or similar)
- Data sheets for all field devices connected to the control system showing full specification including failure modes
- Data sheets, operating manual, wiring diagram etc. for all hardware within the CHAZOP study scope
- Physical layout and siting of system cabinets, I/O racks, terminals etc.
- Chanel/Loop diagrams
- Description of functionality of any non-standard equipment

The output of the CHAZOP study is a detailed list of possible consequences of control system failure with the severity of the outcomes. If the outcome does not meet risk target, further actions shall be required.

3.6.2. CHAZOP Guidewords

Table 2 below provides example of generic CHAZOP Guidewords with meaning, deviation and example of typical problems.

Table 2 Generic CHAZOP Guidewords with Deviations

Guideword (with Meaning)	Type of deviation	Comments
Loss (the partial or complete loss of function)	No/frozen signal No power No communication No/Loss of Operator Interface Memory Corrupted	The impact on the design intent of the loss of a function. May apply to either power supply, processor capability, memory, communications channels or to I/O signals, operator interface
Range (the distortion of I/O signal)	Distortion of signal Signal out of range	The impact on the design intent either signal is distorted or going out of range
Mixture (the combination of I/O signal)	Channel segregation Failure modes	The combination of I/O channels. The failure pattern of inappropriate combinations of I/O channels in relation to the hardware organisation of the system.
Version (Incompatibility of functionality of the system)	Operating system Software packages	Incompatibility of and/or changes to functionality of the system software.
Failure (failure of hardware components or software)	PLC unit Failure Random Failure of Hardware Software Failure Sequence Failure PLC Architecture Interference	May apply to entire PLC, hardware components, software, sequence, and Interference

Guideword (with Meaning)	Type of deviation	Comments
Security (Integrity of the system)	Cyber security Abnormal behaviour and/or loss of functionality breach of confidentiality breach of trust	The integrity of the system. The potential consequences of unauthorised access to the system, malicious or otherwise.

For CHAZOP, each node can be divided under various categories for ease of analysis as stated below:

- Control Loop
- Control Sequence
- Communication Network
- Operator Interfaces (Local and Remote)
- Power Supply
- Hardware
- Software
- Security.

Appendix E provides the CHAZOP Guidewords under various categories. Seqwater *Technical Hazard Study Template X-TMP-STD-008* also includes the CHAZOP Guidewords and record sheet under various categories. Where applicable, each category and guideword need to be examined for each node.

Similar to HAZOP, CHAZOP study and close out reports shall be issued upon completion of the assessment and close out of actions.

3.7. Safety Integrity Level (SIL) Study

A key aspect of designing both instrumented and non-instrumented safeguards is ensuring that their effectiveness — or risk reduction capability — is defined in line with the required level of protection. In many cases the safeguards proposed for managing a hazard involve an instrumented trip or a safety critical alarm, both of which require effective and sustainable assurance. This introduces the concept of “safety integrity” and is quantified using a performance scale known as the Safety Integrity Level (SIL).

A process facility may require multiple layers of protection, depending on associated risks. The first layer of protection is obtained from the Basic Process Control System (BPCS), which controls process or water quality parameters. However, that BPCS can occasionally fail, potentially leading to significant safety or health hazards. When such failure occurs, and operator intervention is insufficient, the next layer of protection is provided by the Safety Instrumented System (SIS) which operates independently of the BPCS.

Unlike the BPCS, the SIS does not control the process but monitors many of the same variables and intervenes when a variable deviates from its normal range. Each SIS may perform one or more Safety Instrumented Functions (SIFs), with the required risk reduction required for each defined by its SIL. The SIL represents the level of confidence that the system will perform the required function when demanded. For each hazard identified through Process Hazard Analysis (PHA) and Layers of Protection Analysis (LOPA), a target SIL level needs to be assigned using an established methodology or study.

SIL is a measure of the SIF’s performance, expressed in terms of Probability of Failure on Demand (PFD). Selecting the appropriate SIL during the design of a SIF is critical to achieving the required level of risk reduction and overall

safety. Functional safety standards based on *IEC 61508* and *AS IEC 61511* define four SIL levels from SIL 1 through SIL 4. SIL 1 represents the lowest level of safety performance, while SIL 4 provides the highest.

SIL studies are a formal method of determining the required SIL based on agreed risk tolerance criteria. Various techniques – such as risk matrices, risk graphs and LOPA analysis are commonly used to assign a SIL. Following the SIL determination study, a separate SIL verification study is typically conducted to confirm that the SIFs meet their targeted SIL levels. This verification includes the use of modelling techniques such as Reliability Block Diagram (RBD), Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA). A range of commercial software tools are available to support the SIL verification process.

The SIL determination study should be conducted during the early stages of detailed design or during the preliminary design phase. The need for SIFs and the corresponding SIL study shall be defined based on project requirements.

Seqwater Standard I-SPE-STD-005 High Priority Alarms and Interlocks Management (SPE-00356) provides further guidance on safety interlocks and trips and includes a number of areas where functional safety should be considered.

3.8. Technical Hazard Study Summary Table

The size and scope of an engineering project has a significant influence on the appropriate hazard study levels and methods to be applied.. A RPEQ with experience in hazard studies shall determine the appropriate hazard study levels and methodologies based on the specific project characteristics.

As a general guideline, Table 3 provides guidance on the various hazard identification levels and methods discussed in this document for project considerations.

Please note that the table does not include requirements related to design reviews, the full scope of a SiD process, water quality hazard assessments, or other risk assessment requirements specific to the project. .

Table 3 Technical Hazard Study Summary Table

Technical Hazard Study Level	Design Stage	Recommended Hazard Study Method	Alternative or Additional Hazard Study Method	Comments
1	Concept	HAZID Study : This is to identify major hazards at the early design stage and allow them to be considered in the next design stages.	CHAIR1 Study: Similar objective of HAZID study but mainly recommended for civil/construction focused projects.	CHAIR1 study is preferred e over HAZID study only for civil/construction-focused projects and where a process system is absent.
2	Preliminary Design	No specific study method recommended, but environmental impact assessment, safety review, consequence modelling, 3D model reviews, checklist and other methods can be considered.	A Coarse HAZOP may be considered for large projects, using flow charts, block diagrams, or preliminary P&IDs of the process system.	A Coarse HAZOP is only recommended only for large-scale projects or when advised by a suitably qualified RPEQ.

Technical Hazard Study Level	Design Stage	Recommended Hazard Study Method	Alternative or Additional Hazard Study Method	Comments
3	Detailed Design	HAZOP, CHAZOP, CHAIR 2, CHAIR 3 study. The recommended HAZOP study shall review the design line-by-line to identify deviations from the intended design intent.	A SIL Study may be considered depending on project requirements.	HAZOP and CHAZOP studies are mandatory for process systems and must be conducted once the P&ID design has reached 90% completion, and after design reviews, and the review of Functional Description documents. CHAIR 2 and CHAIR 3 studies, including 3D model based constructability reviews or similar assessments, shall be conducted before the commencement of construction for all projects.
4	Pre-commissioning	Checklist-based pre-commissioning study is to verify that the plant or facility is built following the design intent and project scope.		This is the final inspection before the plant is commissioned.
5	Post-commissioning	Checklist based post commissioning study is to ensure that the plant or facility is safe to operate as per the design intent.		This is the final check prior to hand-over to Operations.
6	Operation	Post start up review and safety audit after a few months of operation		This is a periodic review to ensure that the plant is operating as per the design intent.

4. Definitions and Abbreviations

Table 4 Definitions and Abbreviations

Term	Definitions
Employees	Means persons employed directly by Seqwater in a permanent, temporary or casual capacity.
Worker(s)	Includes all permanent, temporary, and casual employees of Seqwater, and: • vocational and work experience placements • volunteers • suppliers, contractors, and consultants temporarily engaged to do work for or on behalf of Seqwater.
Seqwater Approval / Agreement / Acceptance	Written sign-off gained via the deviation process, as detailed in *X-PRO-STD-008 Asset Standards Management and Application Procedure*.
Contractor	An entity engaged by Seqwater to undertake work in accordance with an agreed contract with a defined scope of work.
Seqwater Engineering Standard	Includes Standard Procedures and Standard Specifications and associated supporting documents such as Standard Drawings, Guidelines, Lists, Datasheets, Manuals, Registers, and Templates.
Engineering Statement	A confirmation of professional opinion by a Competent Engineer that: • an asset's design or construction has been completed by a person or persons who have the skills to do so; and • an asset creation or modification has considered the requirements of the *Professional Engineers Act 2002* (QLD) and that risks to health and safety have been eliminated or minimised so far as is reasonably practicable.
Hazard	A situation that has the potential to harm a person and/or the environment and/or damage property.
HAZOP Study Nodes	The locations (on piping and instrumentation drawings, and procedures) at which the process parameters are investigated for deviations.
HAZID or CHAIR Study Logical Block or Nodes	The locations (on General Arrangement, Process Block Diagram and Layout Drawings) at which the construction, operations, maintenance task parameters are investigated for hazards.
Guidewords	These are simple words which are used to qualify or quantify the intention in order to guide and stimulate the brainstorming process and so discover deviations. Each Guideword is applied to the process variables at the point in the plant (study node) which is being examined.
Manufacturer / Supplier / Vendor / Original Equipment Manufacturer (OEM)	The entity that manufacturers or supplies equipment to meet the specifications of the Contractor.
Owner / Principal / Seqwater	The entity that engages the Contractor to undertake the work and takes custody of the outcome. The Owner may delegate responsibilities to other entities to act on its behalf (e.g. a consultant).

Term	Definitions
RPEQ - Registered Professional Engineer Queensland	An engineer registered under the *Professional Engineers Act 2002* (QLD). This is minimum requirement for undertaking and/or supervising professional engineering services in Queensland.
Safety in Design	The process of the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of the product being designed. It encompasses all design facilities, hardware, systems, equipment, products, layout and configuration.
Reasonably Practicable	Has the same meaning given under the *Work, Health and Safety Act 2011* (QLD). The following matters must be considered to determine what is Reasonably Practicable on a case-by-case assessment: • the likelihood of the hazard or the risk concerned occurring • the degree of harm that might result from the hazard or the risk • what the person concerned knows, or ought reasonably to know, about the hazard or risk, and ways of eliminating or minimising the risk • the availability and suitability of ways to eliminate or minimise the risk • after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.
REX	Seqwater Electronic Document and Records Management System.
Risk	Risk is the likelihood and consequence of injury or harm occurring when exposed to a Hazard.
shall / must	Indicates a mandatory requirement.
should	Indicates a recommendation.
Technical Hazard Studies	Studies that are conducted to identify hazards, review and recommend control measures, improve safety measures and comply with regulatory requirements for a new design or for the modification of an existing design
ALARP	As Low As Reasonably Practicable
BPCS	Basic Process Control System
CHAIR	Construction Hazard Assessment Implication Review
CHAZOP	Control Systems Hazard and Operability
FMEA	Failure Mode and Effect Analysis
FTA	Fault Tree Analysis
HAZID	Hazards Identification
HAZOP	Hazard and Operability Study
LOPA	Layers of Protection Analysis
P&ID	Piping and Instrumentation Diagram
PFD	Process Flow Diagram
PFD	Probability of Failure on Demand

Term	Definitions
PHA	Process Hazard Analysis
PPE	Personal Protective Equipment
RBD	Reliability Block Diagram
RPEQ	Registered Professional Engineer of Queensland
SFAIRP	So Far As Is Reasonably Practicable
SiD	Safety in Design
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System
WHS	Workplace Health and Safety

5. Roles and Responsibilities

Table 5 Roles and Responsibilities

Role	Responsibility
General Manager Engineering	Accountable for the implementation and management of this procedure.
Principal Engineering Standards and Assurance	Responsible for the implementation and management of this Procedure.
RPEQ (working within area of competence)	RPEQs' are responsible for ensuring that due process has been followed in completing any design affecting plant. This includes: • Ensuring the design complies with relevant Standards, Codes and Engineering practices. • Ensuring people completing the design and design verification are competent to do so. • Ensuring people completing the design and design verification are Registered RPEQs' working within their area of competence, or are directly supervised by a Registered RPEQ who is practicing within their discipline and area of competence.
Workers / Employees	Be aware of and comply with this Procedure.

6. References and Related Materials

The documents listed in Table 6 below, and the requirements therein, are relevant to this Procedure. In their latest editions, these documents form a part of this document. Note that this is not an exhaustive list of documents relevant to the works.

Seqwater undertakes regular updates of its Engineering Standards. Before utilising this document, the complete list of Seqwater Engineering Standards should be reviewed to ensure currency and applicability for the proposed works.

Table 6 References and Related Material

Description	Location
PRO-01873 Engineering Standard X-PRO-STD-001 Asset Standards Document Classification and Naming Structure Procedure	REX
PRO-01874 Engineering StandardX-PRO-STD-004 Development and Review of Asset Standards Procedure	REX
PRO-02205 Engineering Standard X-PRO-STD-008 Asset Standards Management and Application Procedure	REX
PRO-01617 Engineering Standard X-PRO-STD-009 Engineering Design, Construction, Operation and Maintenance Procedure	REX
TEM-00216 Engineering Standard X-TMP-STD-005 Engineering Statement Template – ES1 Design	REX
TEM-00217 Engineering Standard X-TMP-STD-006 Engineering Statement Template – ES2 Construction	REX
TEM-00224 Engineering Standard X-TMP-STD-022 Asset Standards Deviation Request Template	REX
TEM-00213 Engineering Standard X-TMP-STD-008 Engineering Technical Hazard Study Template	REX
SPE-00356 Engineering Standard I-SPE-STD-005 High Priority Alarms & Interlocks Management	REX
PRO-00657 Hazard Identification and Risk Management Procedure	REX
POL-00013 Risk Management Policy Statement	REX
TEM-00008 HSW Risk Assessment Template	REX
FRA-00014 Enterprise Risk Management Framework	REX
AS/NZS 4360 Risk Management	SAI Global
Queensland Professional Engineers Act 2002	Board of Professional Engineers Queensland
Queensland Work Health and Safety Act 2011	Department of Justice and Attorney General – WH&S Queensland

Description	Location
AS IEC 61882 Hazard and operability studies (HAZOP studies) - Application guide	SAI Global
AS IEC 61511 Functional safety - Safety instrumented systems for the process industry sector	SAI Global
IEC 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems	SAI Global
IChemE 2011, Symposium Series No 156 On the Integration of Hazard and Risk Studies into a Project Environment, Ennis T.	N/A
Elsevier 2015, HAZOP Guides to Best Practice, 3rd Edition, Crawly, F and Tyler, B.	N/A
WorkCover NSW (Now SafeWork NSW) 2001 CHAIR Safety in Design Tool	N/A
Process Automation Handbook – A Guide to Theory and Practice, Love, J.	N/A

7. Changes from previous version

This Procedure will be regularly reviewed in accordance with the requirements of the Seqwater Controlled Document Management Procedure. Reviews will include consideration of suggestions for alteration or improvement made in accordance with Seqwater Procedure X-PRO-STD-004 Development and Review of Asset Standards. Changes made from the previous version are summarised in Table 7 below.

Table 7 Changes from previous version

Section Number	Change
All	Document re-formatted to meet current Seqwater presentation requirements and align with current organisational structure. References updated and minor wording revisions to clarify requirements have been applied throughout the document.
Appendix C	Hazard Study Level 5 and Level 6 Checklist added

Appendix A – HAZID Guidewords

Table 8 HAZID Guidewords List

Section Number	Change
Environmental Issues	Bush Fire Flood High Wind/Storm Lightning Erosion Subsidence Seismic Activity Noise Proximity to Population Natural/Wildlife Hazards Cultural Heritage Emission to air Soil contamination Release to water bodies Loss of Containment
Health Issues	Allergenic Asphyxiation Biological Hazards Carcinogenic Disease Fatigue Heat / UV-Radiation Radio Frequency Electromagnetic Energy (RF-EME) Mechanical Hazards Mental Issues Physical (noise, ergonomics, vibration) Radioactive Toxicity
Process Issues	Overpressure Overfill High/Low Temperature Vacuum Chemical Reaction Leakage or Spill Hazardous Substance Control/Operational Philosophy Ignition Source Corrosion Explosion Fire Venting Draining Flushing Pipeline / Piping location Start-up/Shutdown Water Quality Waste Generation System Software Package Hazardous Area

Section Number	Change
Utility Failure	Potable Water Service Water Firefighting Water Instrument Air Power Supply Sewerage Waste Storage and Treatment Fuel Storage High/Low Voltage
Security Issues	Cyber Security Fraud and Scams Piracy, Theft Sabotage Vandalism Malicious Act Vehicle Accident Terrorism Pandemic Civil Protest
Implementation Issues	Asbestos Removal Design Guidelines and Codes External Standards Internal Standards Legislation Requirements Construction Issues (i.e. size, height, location, timing, ergonomics etc.) Commissioning and Testing Demolition Existing Operations Simultaneous Operations Documentation & Quality Control
Maintenance Hazards	Commonality of Equipment Heavy Lifting Requirement Manual Handling Access Requirements Confined Space Equipment layout
Others	Project Management Future Development Schedule Others

Appendix B – CHAIR Guidewords

Table 9 CHAIR 1 – Guidewords - Generic

Guideword	Risk Issue
Size	Too large Too small Too long Too short Too wide Too narrow
Heights / Depths	Working at heights Falls/struck by falling objects Scaffolding (shape, space to fit) Confined space Access/egress
Position / Location	Too high Too low Too far Misaligned Wrong position
Poor Ergonomics	Posture/manual handling Repetitive strain injury /discomfort/fatigue/stress Effect on PPE Visibility (lighting sightlines, blind spots) Slips, trips, falls
Movement / Direction	Stability Compression Physical damage Vibration Friction/slip Rotation Upwards/downwards Reverse Expansion/tension Rollover
Load / Force	High/excess Low/insufficient Additional loads (construction) Dynamics Temporary Weakness
Energy	Low/high energy Tension/compression Potential/kinetic Inertia/moment
Timing	Too late/too early Too short/too long Incorrect sequence Extended delays
Egress / Access	No. of exit points Emergency egress Size - width, height, length Obstructions Lighting Entry/exit points External impacts Maintenance People and equipment movements
Maintenance / Repair	Posture/manual handling Size/width Access/egress/heights Dropped objects Weight Discomfort/stress/PPE Visibility/slips/trips Rotating equipment Other

Table 10 CHAIR 1 – Guidewords - Overview

Category	Guideword
Environmental Conditions	Extreme weather Temperature Ground Noise Water
External Safety Interfaces	Members of the public Traffic Adjacent property Power/services External fire/emergency plans Day/night/weekend
Toxicity	Lead/asbestos Handling Precautions Ventilation
Fire / Explosion	Prevention systems Detection systems Fire protection Emergency isolation systems Inert atmosphere Emergency procedures
Environmental Impact	Vapour emissions Dust emissions Effluent Noise Ground seepage Waste minimisation
Utilities & Services	Lighting Air Water Fuel/electricity Oxygen Radio frequency electromagnetic radiation
Commissioning / Start-up / Shutdown	Requirements Sequence
Safety Equipment	Personnel protection Safety showers Barriers/guards
Natural Hazards	Earthquake Flood Thunderstorm (lightning protection) High winds
Inspection / Testing	Eliminating Isolation Access
Demolition	Ease Issues Documentation
Documentation	Operations Maintenance Inspection and testing Sequence Emergency Records/reports
Quality Control	Inspection and testing Quality assurance
Construction Equipment	Sequence Timing, access

Table 11 CHAIR 2 – Guidewords

Guideword	Risk Issue
Eliminate	Falls (of people) Falling material/objects Stepping on or striking against objects Caught or trapped Lifting and carrying - over exertion Asphyxiation/drowning Machinery Electricity Transport/mobile equipment Toxicity, fires and explosion
Substitute	Falls (of people) Falling material/objects Stepping on or striking against objects Caught or trapped Lifting and carrying - over exertion Asphyxiation/drowning Machinery Electricity Transport/mobile equipment Toxicity, fire and explosion
Combine	Construction/lifting sequence Timing Locations
Avoid	Construction/lifting sequence Timing/locations Temporary instability Access/egress Delays Confined space Erection/dismantling Heat/cold/noise
Other Issue	Modification Isolation Engineering controls Personnel Protective Equipment Alter/rearrange Increase/reduce Simplify

Table 12 CHAIR 3 - Guidewords

Maintainability Aspect
Posture/manual handling
Access/egress
Heights/dropped objects
Weight
Discomfort/stress
Personnel Protective Equipment
Visibility
Slips, trips, and falls
Rotating/moving equipment
Is repair different?
Others that may apply (list below)

Appendix C – Hazard Study Level 2, Level 5 and Level 6 Checklists

Table 13 Hazard Study Level 2 Checklist[2]

No	Checklist
1	Are equipment and piping materials of construction in compliance with codes and standard specifications?
2	Are valve types and materials in compliance with standard specifications and best practices?
3	Has over pressure protection been applied as appropriate?
4	Are maintenance vents and drains considered and shown in the drawings?
5	Are the standards of isolation appropriate for the risks?
6	Do the vents go to a safe location?
7	Do the drains go to a safe capture system?
8	Are there any pockets in the lines which may require drains?
9	Are the main process and water quality parameters (pressure, flow, level, pH, turbidity and chlorine) adequately controlled and are there adequate diagnostics to assess problems?
10	Do any control parameters require independent verification?
11	Do the protective systems give adequate protection against the known hazards?
12	Have process conditions and consequence at start-up and shutdown been addressed? Are any vents, recycle lines, and bypasses required?
13	Does the over/under pressure relief indicated look “adequate”?
14	Are liquid capture bunds required?

Table 14 Hazard Study Level 5 Checklist

No.	Checklist
1	Are equipment and controls installed according to design specifications?
2	Are process parameters within expected limits? Any early deviations?
3	Are operating and maintenance procedures being followed?
4	Have operators reported unexpected issues, alarms, or confusion?
5	Have safety systems been tested since start-up? Any failures?
6	Is the permit to work system functioning as intended during commissioning and early operations?
7	Are personnel trained and competent for their tasks?

[2] This checklist is adapted from Elsevier 2015, HAZOP Guides to Best Practice, 3rd Edition with modifications

Table 15 Hazard Study Level 6 Checklist

No	Checklist
1	Are previous risk assessments and assumptions still valid?
2	Have there been any process, control, or personnel changes?
3	Do current operations meet legal and internal safety requirements?
4	Have incidents or near-misses occurred? What changes followed?
5	Are any safety-critical systems degraded or at end-of-life?
6	Are emergency plans and drills up to date and effective?

Appendix D – HAZOP Guidewords

Table 16 HAZOP Guidewords – Generic (by node) (Continuous Process)

Guideword (HAZOP) by Node	Example of Possible Cause
High Flow	Pump Racing, Delivery Vessel Pressure Lost, Suction Pressurised, Scale Dislodged, Leak in Heat Exchanger, Loss of Auto Control, Operator Error, Failure of Pipe, Trap, etc.
Low Flow	Pump Failure, Scaling of Delivery, Foreign Body or Sediment, Poor Suction Condition, Cavitation, Leak in Heat Exchanger, Drain Leaking, Valve Jammed, Loss of Auto Control, Operator Error, Failure of Joint, Pipe, Trap, etc.
Zero Flow, Empty	Pump Failure, Delivery Vessel/Main Pressurised, Gas Locking, Blockage, Presence of Foreign Body, Scale, Suction Vessel Empty, Loss of Auto Control, Operator Error, Failure of Joint, Pipe, Trap, etc.
Reverse Flow / Misdirected Flow	Pump Failure, Pump Reversed, Delivery Vessel/Main Over-pressure, Poor Isolation, Gas Locking, Surging, Back Siphoning, Loss of Automatic Control, Operator Error, Pipe Failure, etc.
High Level	Pump Racing, Operator Error, Instrument Failure, Wrong Pump, Wrong Tank Selection, Loss of auto control etc.
Low Level	Operator Error, Wrong Tank Selection, Instrument Failure, Tank Leak, Drain Valve Open etc.
High pressure (venting, relief rate)	Boiling, Cavitation, Freezing, Chemical Breakdown, Flashing, Condensation, Sedimentation, Scaling, Foaming, Gas Release, Priming, Exploding, Imploding, Changes in Viscosity, Density, External Fire, Weather Conditions.
Low pressure (venting, relief rate)	Boiling, Cavitation, Freezing, Chemical Breakdown, Flashing, Condensation, Sedimentation, Scaling, Foaming, Gas Release, Priming, Exploding, Imploding, Changes in Viscosity, Density, External Fire, Weather Conditions.
High temperature	Boiling, Cavitation, Freezing, Chemical Breakdown, Flashing, Condensation, Sedimentation, Scaling, Foaming, Gas Release, Priming, Exploding, Imploding, Changes in Viscosity, Density, External Fire, Weather Conditions.
Low temperature	Boiling, Cavitation, Freezing, Chemical Breakdown, Flashing, Condensation, Sedimentation, Scaling, Foaming, Gas Release, Priming, Exploding, Imploding, Changes in Viscosity, Density, External Fire, Weather Conditions.
Impurities (Gaseous, Liquid, Solid)	Ingress of Air, Water, Steam, Fuel, Lubricants, Corrosion Products, Other Process Materials from High Pressure System, Leakage from Heat Exchanger System
Change in composition / Change in concentration / Two phase flow / Reactions	Two-phase flow, Reactions, Erosion, Corrosion
Different Water Quality	Changes in Turbidity, pH, Alkalinity, Organics content in Raw Water
Testing	Equipment (including trips and alarms, vacuum and pressure testing with harmless material) Product (how do we know it meets specifications, what quality control is in place)
Plant Items (O&M)	Operable and Maintainable (access, isolation, spares, purging, drying, cooling, warming, drains and vents)
Electrical	Area Classification, Isolation, Earthing

Guideword (HAZOP) by Node	Example of Possible Cause
Instruments	Sufficient for Control, Over instrumented, Correct Location
Sampling	Sufficient Sampling Points
Previous Incidents	Are there any previous incidents that should be considered within the design to eliminate a re-occurrence or to mitigate the risk
P&ID Items	Missing Information, Improper Representation, Incorrect Information

Table 17 HAZOP Guidewords - Overview

Category	Guideword
Toxicity	Chemical Types – gaseous emissions, hazards, onsite and offsite issues
Service Required	Air, Nitrogen, Water etc.
Materials of Construction	Vessels, Pipelines, Pumps, Piping, others
Commissioning	How will it be completed; what difficulties of hazards can be foreseen?
Start Up	First start up methods, difficulties, hazards routine start up methods, too many interlocks
Shutdown	Isolation, Purging, Difficulties, Hazards
Breakdown	Power Failure, Air, Steam, Water Vacuum, Fuel, Vents, Computer and others Major causes of breakdown, emergency procedure and communications, which way should valve move?
Effluent –	Gaseous, Liquid, Solid . Reactions in Drains, Treatment Methods OK?
Noise	Sources, Problems? Control Measures Oversight – difficulties – siting issues
Fire/Explosion	Protection, Prevention, Control, Location of Safety Showers, Deluges, Hydrants, Shutoff Valves & Controls
Safety Equipment	Personal, Fire Detection, Fire Fighting, Means of Escape. Access, Egress, Difficulties, Hazards
Quality & Consistency	What will most cause quality to fail or vary? How to prevent those occurrences?
Reliability & Bottlenecks	What are the least reliable components, most limiting components? How do they affect during operation during down periods or at capacity?
Efficiency	Where will the plant lose materials, conversion etc.? Can it be improved?
Simplicity	Can we omit plant or simplify control? Can the level of manual intervention be reduced?

Table 18 HAZOP Guidewords (Sequential Operations - Batch and Procedural HAZOP)

Guideword	Meaning	Examples of Deviation
NO (NOT OR NONE)	The activity is not carried out or ceases	No flow in pipe, No reactant charged to process, Check omitted, valve not opened
MORE OF	A quantitative increase in an activity	More (higher, longer) quantity, flow, temperature, pressure, batch, concentration, time
LESS OF	A quantitative decrease in an activity	Less (lower, shorter) of above
MORE THAN or AS WELL AS	A further activity occurs in addition to the original activity	Impurities present, extra phase (Solid or gas in liquid phase) extra (unplanned) process operation, extra valve opened
PART OF	The incomplete performance of an activity	Reduced strength, missing component, operation only part completed
REVERSE	Inversion of the activity	Back-flow or back pressure, heat rather than cool
SOONER / LATER THAN	An activity occurring at the wrong time relative to other works	The activity occurs at the wrong time
OTHERS		Wrong material charged. Failure of services. Non-routine conditions: start up, shutdown, maintenance, cleaning etc.

Appendix E – CHAZOP Guidewords

Table 19 CHAZOP Guidewords

Category	Guideword
Control Loop	No Signal / Signal Lost More Signal/ High Signal / Out of Range Signal / Failed On Less Signal / Low Signal / Failed Off Distortion of Signal/ Incorrect Signal / Frozen Signal / Other As Well As / Interference Scan Rate Tuning, Testing and Verification Maintainability of Field Devices Reliability of Field Devices
Control Sequence	No Sequence / Sequence Fails to Initiate More Sequence / Sequence Fails to End More / Operator Entries Less / Sequence Stops Partway Less / Feedback Requirements Sequence Order Incorrect / Other Sequence Timing Incorrect / Other
Communication Networks	No / Complete Network Failure Partial / Incomplete Transmission More /Excessive Traffic / Alarm Flood Incorrect Addressing As Well As / Interference
Operator Interfaces (Local and Remote)	No / Loss of Interface Incorrect Data Less / Insufficient Data More /Excessive Traffic / Alarm Flood Partial Failure
Power Supply	No Power / Loss of Power More / Over-Voltage Current Overload Less / Under-Voltage Overload Reverse Current Partial Failure Maintainability
Hardware	No /Total CPU or Sub-system Failure / Entire PLC Failure Random Failure (i.e. Cabinet, Controller, I/O Cards) Inappropriate Combination of I/O Channel Less / Partial Failure More / CPU Over-Load Other / Erratic Operation Power Supplies / UPS Environment Impacts: Heat, Vibration, Rain

Software	Software Failure Change of Functionality in System Software / Incompatibility Memory Corrupted Logical Structure Control of Modifications Testing and Verification Adequate Documentation and Annotation
Security	Cyber Security Software Security Safeguards Abnormal Behaviour Loss of Functionality Breach of Confidentiality