Appendix V

Risk Assessment Workshop Report

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Prepared By	Date

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Approved By	Date

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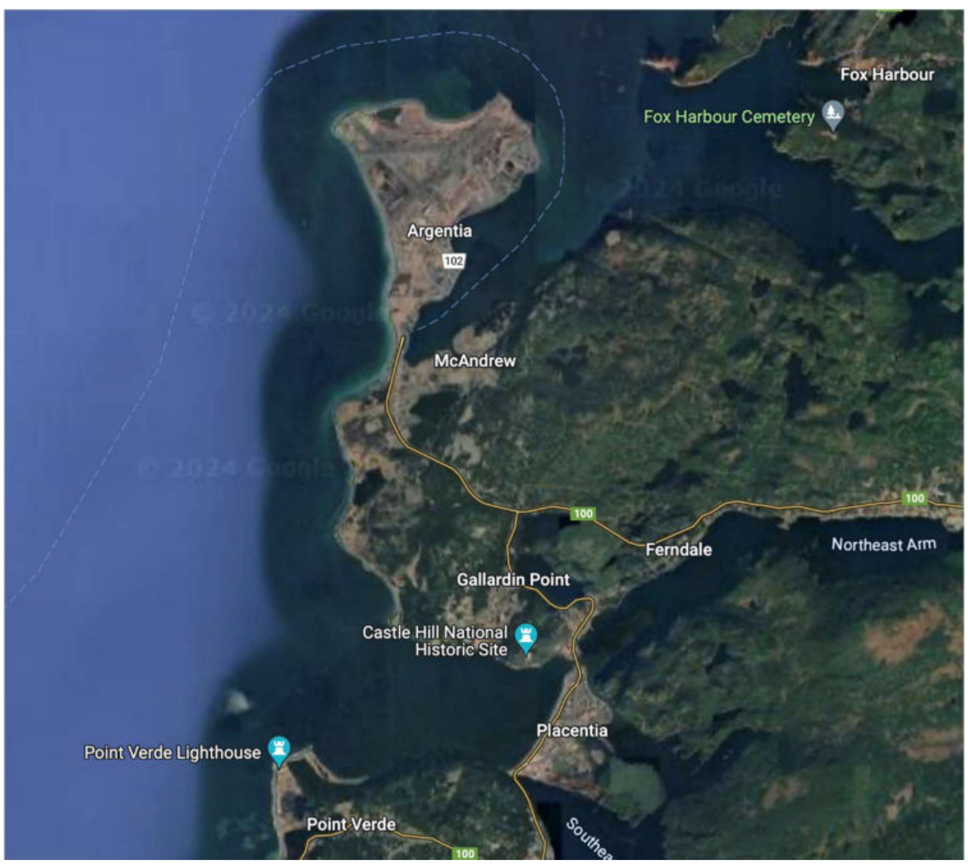
1.0 INTRODUCTION

The Pattern Canada Argentia Renewables Wind Energy to Green Hydrogen and Ammonia Project is in Argentia within the municipal boundary of Placentia on the Avalon Peninsula of Newfoundland and Labrador.

The Project is a green hydrogen and ammonia production, storage, and export facility powered the Argentia Wind Facility. The Argentia Green Fuels Facility will produce hydrogen through the electrolysis of water using renewable and low-carbon energy sources. Nitrogen captured by air separation units will also use renewable energy. Ammonia will be produced from hydrogen and nitrogen in the ammonia synthesis unit via the Haber-Bosch process. Wind energy generation and the power supply available from the NHL grid constitutes a unique scenario where the energy used to produce hydrogen and ammonia is truly green. Green fuels synthesis requires a large energy input; however, renewable and low-carbon energy sources make it green hydrogen versus the alternative use of petroleum producing grey hydrogen product.



trajectorE was engaged by Pattern Energy as part of the project to conduct a series of Structured What-If Analysis workshops were held over the course of three days. The first session occurred over the course of two days (February 21st & 23rd, 2024) focusing on Hydrogen and Ammonia Production, Ammonia Storage and Ammonia Ship Loading and the second session occurring on May 3rd, 2024, to cover Hydrogen Storage at the site. Event scenarios that were identified during the SWIFT workshop that involved a release of ammonia were modelled using an atmospheric dispersion modelling software program for denser-than-air releases (SLAB). Hydrogen release effects modelling was conducted using fundamental predictive point source and explosion modelling for dispersion, thermal impacts due to fire, and overpressure due to explosion. The modelling results can be found in separate reports: Ammonia Dispersion Cloud Modelling Report, PATT-2401-HRP-002 and Hydrogen Release Effects Report, PATT-2401-HRP-003.

For the purposes of this assessment only the Hydrogen & Ammonia Plant and Loading Facility is considered; the Wind Farm has been excluded.

2. STRUCTURED WHAT-IF ANALYSIS RISK ASSESSMENT

2.1 METHODOLOGY

The Structured What-If Analysis (SWIFT) is a type of high-level Process Hazard Analysis (PHA) – one of the key components of Process Safety Management (PSM), shown below in Figure 2.1.

Figure 2.1 – Process Safety Management Elements.

The SWIFT uses a structured brainstorming technique to identify major potential hazards and then using a risk matrix the likelihood and impact of said hazards is quantified. Through this mitigation measures to be considered for each hazard can be identified during the planning and design stage of the project.

For each of the workshop sessions a variety of subject matter experts were involved to leverage their knowledge on the process and project, while also drawing on experience to identify and quantify the risks and further recommend mitigation measures. A Facilitator from trajectorE was responsible for ensuring the team followed the structured process for the risk assessment. A record of deviations, risk rankings and recommendations were recorded by a “Scribe”.

For each of the workshop sessions the scope of the project was divided into nodes based upon the conceptual plant layout. Prior to the beginning of brainstorming hazards, the battery limits of each node were discussed. Brainstorming of hazards for each node was prompted by a set of guidewords. The guidewords used in the session were as follows:

- Process Upset
- Equipment Failure
- Instrumentation Failure
- Utility Failure
- Weather
- Human Error
- Procedures
- Training
- Security

Using these guidewords each node was assessed by following the below sequential steps:

- Possible hazardous events identified contained within the area of the node as it relates to each guideword.
- Cause of each event identified in step 1 identified.
- Consequence of the event identified.
- Categorization of the event assigned.
- Risk associated with each event was quantified using the Risk Matrix supplied by trajectorE in Appendix A.
- Recommendations were made based on the event and associated Risk Ranking.

Note that the SWIFT review is not intended to be a design review, therefore any design discussions along with any other discussion which fell outside of the scope of the review were recorded in the Parking Lot found in Appendix D.

2.2 SCOPE OF WORKSHOP

The What-If workshop series was conducted based on several principles. The risk assessment is based upon information from the Argentia Renewables Green Ammonia Plant Feasibility Study from Atkins Realis (formerly SNC Lavalin). The only potential changes to the design that was considered was during the second session of the workshop (Node D) the concept of a above ground compressed Hydrogen buffer tank (~17 ton capacity). All other potential changes to the design that would be expected to take place during normal design development in subsequent engineering phases were not considered. Where items were raised related to potential improvements during the risk assessment, these were noted in the Parking Lot in Appendix D. Other principles used to complete the SWIFT workshop sessions were as follows:

1) The level of detail of discussion commenced with <15% of engineering completion.
2) Assumed normal stable plant operating conditions.
3) Physical boundaries confined within the three nodes shown (Nodes A, B, C & D)
4) Where information is lacking the worst-case scenario event is assumed.
5) Assumed that engineering work is completed at standard best practice.
6) The assessment is focused on process safety hazards not occupational health and safety hazards.
7) Risks were assessed based on unmitigated, worst-case events based on the knowledge of the team involved in the workshop. Mitigation measure, while fully expected to be implemented, were not included in the risk assessment at this time.

The project has also been divided up into Nodes A, B, C and D based on location on the Concept Site Plot Plan. Definition of Nodes on the plot plan can be found in Appendix B. Each node was defined as:

- Node A – Hydrogen & Ammonia Production
- Node B – Ammonia Storage
- Node C – Ammonia Ship Loading
- Node D – Hydrogen Storage

2.3 STRUCTURED WHAT-IF ANALYSIS SESSION

The SWIFT workshops were held over three days on February 21st & 23rd and May 3rd, 2024 online via Microsoft Teams meeting. Partaking in each session was a group of individuals from Pattern Energy and trajectorE Engineering and each session was facilitated by trajectorE. Table 2.1 below summarizes the list of attendees for each day.

Table 2.1 – List of SWIFT Workshop Attendees

			Session 1		Session 2
Name	**Organization**	**Role**	**Day 1**	**Day 2**	**Day 3**
Dariel Adato Felhandler	Pattern Energy	Sr. Preconstruction Manager, Green Fuels	✓	✓	✓
Scott Dufour	Pattern Energy	Business Development, Green Hydrogen	✓	✓	✓

Lauge Nielsen	Pattern Energy	Canadian Markets and Asset Expansion Director	✓	✓	
Don Stevens	trajectorE	Senior Process Consultant	✓	✓	
Heiko Leers	trajectorE	Senio Process Consultant			✓
Craig Ryan	trajectorE	Emergency Response Specialist	✓	✓	✓
Sean Breen	trajectorE	Process Engineer	✓	✓	
Andrew Sinclair	trajectorE	Facilitator	✓	✓	✓
Kirsten Moores	trajectorE	Scribe	✓	✓	✓

The Event Scenarios, Causes, Consequences, Risks and Recommendations can be found in the Worksheet in Appendix C. Any other issues outside of the scope of the sessions that were identified can be found in the Parking Lot in Appendix D.

2.4 RESULTS OF WORKSHOP

A total of 72 "What-If" Scenarios were identified during the series of SWIFT sessions. Some of these scenarios were not risk ranked due to being outside of the scope of the sessions for various reasons including if the impact was production related or not directly related to Health and Safety, Environment or Community Impact. However, these scenarios were left in the worksheet for completeness and should be considered in future PHA's for the project. The scenarios that were ranked are shown below in Table 2.2 and 2.3. Some scenarios identified fall under multiple categories and as a result for the purposes of tallies shown in Tables 2.2 and 2.3 have been counted towards multiple associated categories.

Table 2.2 – Risks by Level

Level	Total Risks
Very Low	0
Low	0
Medium	47
High	14
Very High	0
Extreme	0

Table 2.3 – Risks by Category

Categories	Total Risks
Health & Safety	54
Environment	10

Community Impact	4

Out of the 72 event scenarios, 8 were identified as triggers for potential ammonia release. These events were identified as high-risk events requiring further analysis, through vapor cloud modelling. There were also 10 event scenarios identified as triggers for potential hydrogen release. These are identified in Table 2.4 and 2.5 and modelled for potential impact in a separate reports.

It should also be noted that Argentia Renewables plans to install double wall ammonia storage tanks, as well as auto-isolating valves on both hydrogen and ammonia tanks. These will substantially reduce the probability and impact of an ammonia or hydrogen spill or leakage event.

Table 2.4: Ammonia Release Event Scenarios

Event Scenario	Scenario #	Event Description	Type of Release
Ammonia Synthesis Area	1	Failure of reactor in electrolyser. Contents empties within 10 minutes	Catastrophic Failure of Reactor
	2	Steam generation system failure because of a tube rupture. Causing a runaway reaction and possible ammonia release	Full Pipe Rupture Ammonia Synthesis Unit
Ammonia Transfer Lines	3	Transfer line failing as a result of vehicle striking the pipe, poor maintenance, overpressure etc.	Full Pipe Rupture – One 12” Line
Recycle Line	4	Over pressure or poor maintenance of cycle line resulting in full pipe rupture	Full Pipe Rupture – 12”
Loading Arm	5	Over pressure of both loading arms causing full rupture	Full Pipe Rupture – Both 12” Lines
	6	Over pressure of one loading arm causing full pipe rupture	Full Pipe Rupture – One 12” Line
Ammonia Storage Tank	7	Catastrophic release of ammonia from storage tank. Full vessel emptied in 10 minutes	Catastrophic Failure of Tank
	8	Inlet pipe to ammonia tank full rupture of pipe	Full Pipe Rupture - Ammonia Inlet Pipe

Table 2.5: Hydrogen Release Event Scenarios

Event Scenario	Scenario #	Event Description	Type of Release
Air Separation Unit	1	Mixing Drum Pipe Rupture	Full flow
	2	Catastrophic Failure of Mixing Drum	Full Flow+Vessel empty
Electrolyser/H2 Storage Unit	3	Pipe Rupture for electrolyser discharge header	Full Flow
	4	Catastrophic Failure of Electrolyser H_2 Side Containment	Full Flow+Vessel empty
	6	Catastrophic Failure for Electrolyser Containment	Vessel Explosion
Ammonia Synthesis Unit	7a	Pipe Rupture of Recirculation line after NH_3 Condenser	Full Flow
	7b	Pipe Rupture of Reactor inlet piping	Full Flow
	8	Catastrophic Failure of Reactor	Full Flow+Vessel empty

3.0 RECOMMENDATIONS

It is expected that through prudent and responsible engineering design development many of the risks identified will be mitigated during upcoming design phases of the project. To ensure that all recommendations shown in the SWIFT Worksheet in Appendix C are actioned and fully managed it is recommended that this list of risks be transferred to the overall project risk register and tracked and managed accordingly.

Issues that were identified in the series of SWIFT workshop sessions but that fell outside of the scope of the risk assessment or were tabled to the Parking Lot in Appendix D. These should also appropriately be addressed as the project progresses as determined by the project team.

After completion of the first SWIFT Session (Nodes A, B & C), all associated scenarios which had the potential of forming a downwind ammonia vapor cloud were subsequently used as inputs to prepare cloud modelling assessment. In addition, release events that had the potential to result in a hydrogen release were also used as inputs to hydrogen release effects modelling.

Ammonia modelling was conducted using commercial atmospheric dispersion modelling software and explained in Ammonia Dispersion Cloud Modelling Report, PATT-2401-HRP-002. Hydrogen release effects modelling was conducted using fundamental predictive point source and explosion modelling for dispersion, thermal impacts due to fire, and overpressure due to explosion. This is separately reported in Hydrogen Release Effects Report, PATT-2401-HRP-003.

Periodic updates to these models should be made to address upcoming design changes. Emergency response detailed planning should incorporate the results of this analysis.

APPENDIX A
RISK MATRIX

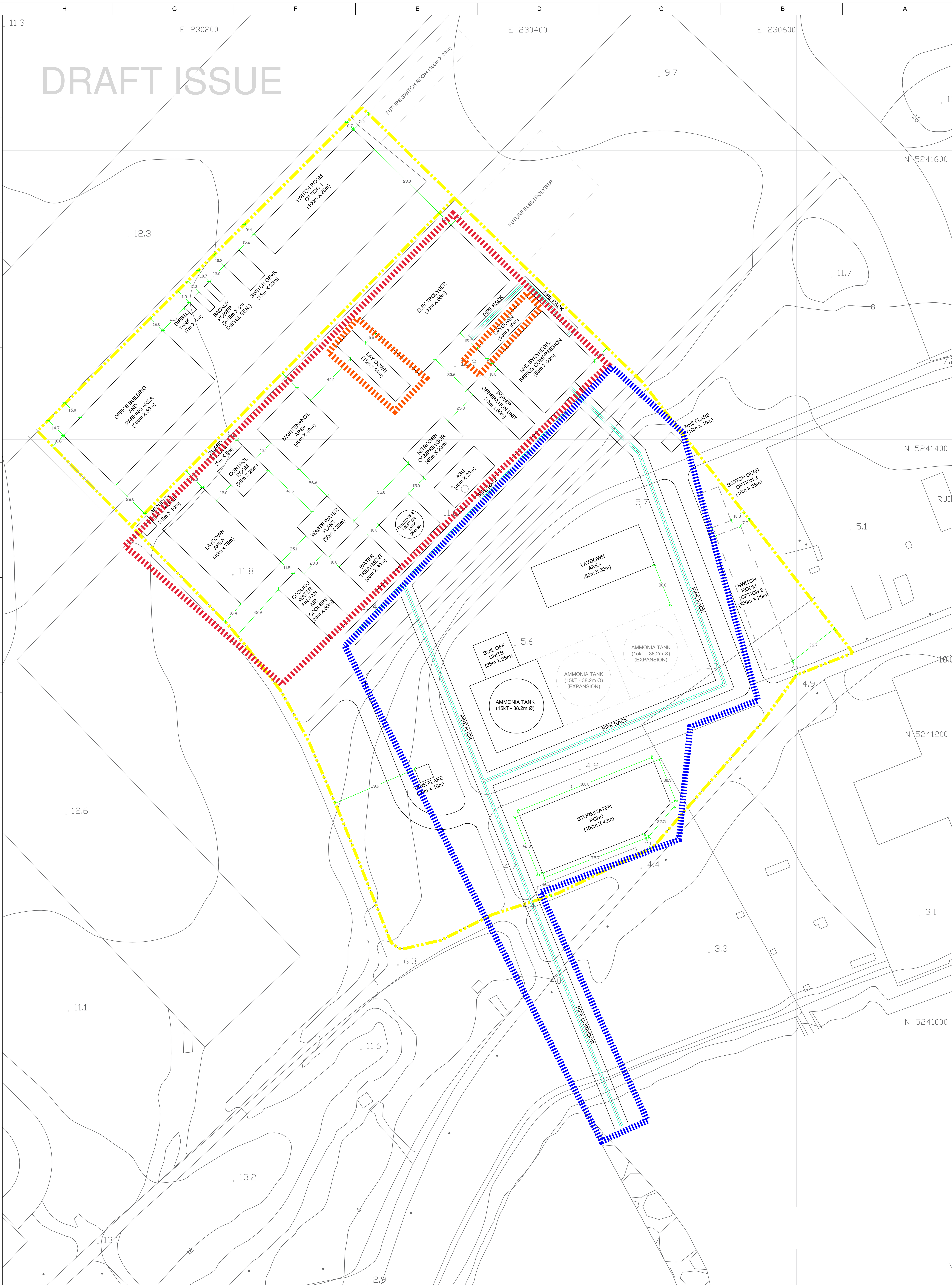
Impact Ranking	Health & Safety	Environment	Community Impact
1	Slight Health Effects/injury	Limited spill/release <70L contained within site footprint	Local community impact
2	Minor Health Effects/injury requiring medical assistance - Recovery within hours	Reportable on site spill/release >70L contained within site footprint	Local municipality impact. Reversible in short term
3	Moderate health effects/injury requiring medical treatment - restricted work day case	Reportable spill/release outside of site footprint (on land)	Regional district/provincial impact. Reversible in the mid term
4	Major Health effects/injury requiring emergency medical treatment (LTI)	Reportable offsite marine spill	Regional impact. Reversible in the long term
5	Fatality or life-altering injury	Major uncontained environmental spill. Causing major harm to local ecosystems requiring extensive cleanup	Permanent impact

Likelihood Ranking	Probability of Occurring in a Given Year	Description
1	<1%	For a system failure: this event has not happened in industry in the last 50 yrs For a natural hazard (earthquake, flood, windstorm, etc): 1 in 100yrs or longer
2	1-10%	One occurrence during the life of the facility (20-30years)
3	11-33%	One occurrence at the most in a ten-year period of operation
4	34-99%	One occurrence in 1 year of operation
5	100%	Could occur once a month or more

		IMPACT				
		1	2	3	4	5
LIKELIHOOD	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Risk Levels (<=)	Level
2	VERY LOW
4	LOW
9	MEDIUM
12	HIGH
16	VERY HIGH
25	EXTREME

APPENDIX B
SITE PLOT PLANS WITH NODES



00	13.10.23	ISSUED FOR REVIEW	TS	BH	CN
REV	DATE	REVISION DESCRIPTION	DRN	CHK	APP

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APPROVED	CN	13.10.2023

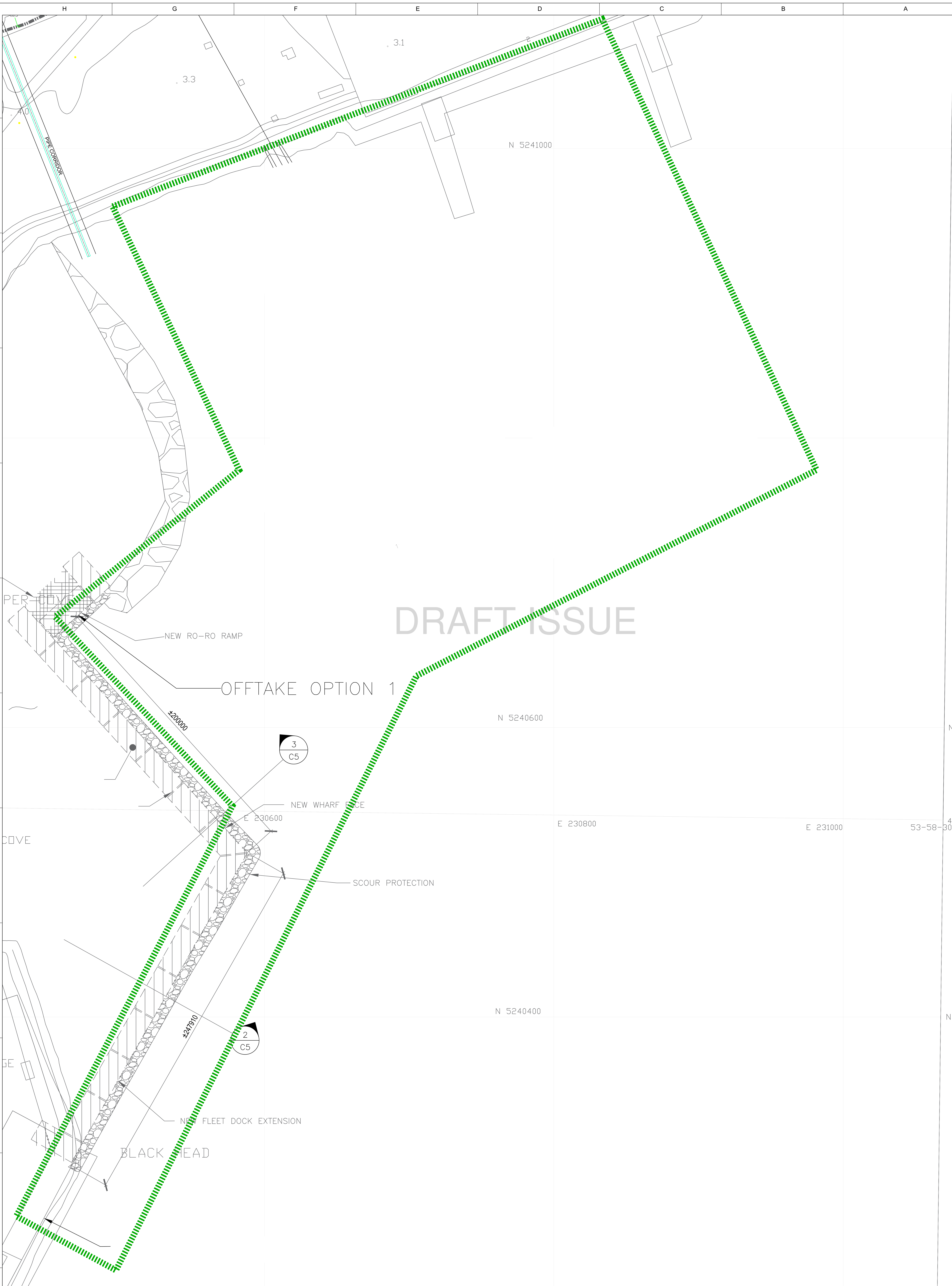
SCALE 1:1000 FORMAT B1

PROJECT
Argentia Renewables - Feasibility Study

DRAWING TITLE
CONCEPT PLOT PLAN

DRAWING NUMBER SNC-XX-XX-DDRW-Z-0002

REV 00



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00	13.10.23	ISSUED FOR REVIEW	TS	BH	CN

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APPROVED	CN	13.10.2023
SCALE 1:1000	FORMAT	B1

PROJECT: Argentia Renewables - Feasibility Study

DRAWING TITLE: CONCEPT SITE PLAN

DRAWING NUMBER: SNC-XX-XX-DDRW-Z-0001

REV: 00

APPENDIX C
SWIFT WORKSHEET

NODE A

Guidewords	Ref. No.	Events: What if?	Potential Consequences	Category	Impact	Existing Safeguards	Likelihood	Risk Ranking	Recommendations
Process Upset	A.1	Catalyst run off in ASU. As a result of an ASU process upset.	Exothermic reaction (Reactor failure). Possible explosion	Health&Safety	5	Proper engineering design practice	1	5	1. Process Safety awareness training for employees. 2. Trigger ERT to respond
	A.2	Compressed hydrogen release or a fire in the electrolyser. The Electrolyser Building is a confined space posing an added hazard. The release or fire could be a result of seal failure, flange leaks or failure of the gas collection system	Fire Explosive	Health&Safety	5	Proper engineering design practice	1	5	1. Hydrogen gas monitors 2. Proper Alarms 3. Ventilation 4. Fire suppression 5. Hazardous area classification for electrical systems
	A.3	Ammonia release in the Ammonia synthesis area. In the form of fugitive emissions. A result of slow leaks from flanges, seals, etc.	Operator exposure	Health&Safety	3	Proper engineering design practice	4	12	1. Personal gas monitors 2. Area monitors 3. Proactive repairs of high exposure areas 4. Breathing apparatus' (escape pack) in high risk areas
	A.4	Ammonia release in the Ammonia synthesis area. As a result of a catastrophic failure of mixing drum or pipeline	Vapor Cloud formed Esphyxiation	Health&Safety	5	Proper engineering design practice	2	10	1. Proper maintenance procedures and training 2. Personal gas monitors 3. Area Monitors 4. Escape packs 5. Properly trained ERT team
	A.5	Oxygen fire resulting from disruption of oxygen venting (excess oxygen)	Fire (accelerated)	Health&Safety	5	Proper engineering design practice	1	5	1. Locate vent at high elevation
	A.6	Waste water discharge to environment off spec (temperature, composition, etc.). A result of possible failure of the water treatment system	Off spec environmental release (reportable)	Environment	4	Proper engineering design practice	3	12	1. Proper waste water monitoring and testing program
Equipment Failure	A.7	An explosive atmosphere created in the Electrolyser area from Membrane failure (membrane rupture mixing hydrogen and oxygen)	Production loss Explosive atmosphere created Explosion if ignition source present	Health&Safety	5	Proper engineering design practice	1	5	
	A.8	ASU: Compressor trip, valves not operating	See above A.1						
	A.9	Failure of the ammonia flare	Environmental release.	Environment	3	Proper engineering design practice	3	9	1. Proper maintenance procedures and training 2. Stable propane supply
	A.10	Cooling tower failure	See above A.1-8						
	A.11	Compressor failure causing an overpressure of Nitrogen	Asphyxiation	Health&Safety	5	Proper engineering design practice	1	5	1. Proper maintenance 2. Alarms
	A.12	Steam generation system failure due to tube ruptures.	Runaway reaction Release	Health&Safety	5	Proper engineering design practice	2	10	1. Proper maintenance 2. Alarms 3.Procedures 4. Testing 5. Redundancy within design
	A.13	Fire protection system failure during a fire event	Fire scenario covered above. See A.2 & A.5						
Instrumentation Failure	A.14	Control system failure. This could have multiple potential causes such as no backup battery, network issues, etc.	Risk not individually assessed as consequences could be any of the others mentioned in this assessment						1. Ensure design consider fail safe states
Utility Failure	A.15	Water supply system failure	Emergency Plant shutdown	Health&Safety	3	Pressure relief system	1	3	1. Install process water tank (buffer)
	A.16	Power failure (NL Hydro feed or Pattern energy wind farm feed)	Production loss Emergency shutdown	Production loss not risk ranked as part of ERP Risk Assessment		Proper engineering design practice Emergency Generator to put plant in safe mode (Emergency shutdown)	Production loss not risk ranked as part of ERP Risk Assessment		
	A.17	Air supply failure	Production Loss	Production loss not risk ranked as part of ERP Risk Assessment					
Weather	A.18	Instrument air lines freeze	Production loss	Production loss not risk ranked as part of ERP Risk Assessment					
	A.19	Electrolyser (too cold or too hot for operation). Due to loss of heat in building during a cold weather event	Need to verify with the vendor on temperature extremes for electrolyser. Moved to Parking Lot						
	A.20	Road wash outs. As a result of extreme weather event	Site team safely stranded temporarily (Production loss)	Production loss not risk ranked as part of ERP Risk Assessment					
	A.21	Surge from ocean (tidal wave/washout) from an extreme weather event	Flood Equipment Damage Production loss	Environment	5		1	5	1. consider flood mitigation in design 2. establish weather conditions in design basis FEL2 onward
	A.22	Cooling towers frozen from extreme weather event	See A.10						
	A.23	Tropical Storm/Hurricane/Wind storm	Building damage		5		1	5	1. establish weather condition basis in FEL 2 onward
Human Error	A.24	Control room operator ignoring warning alarms/signals	Could result in a wide variety of consequences		5		2	10	1. Implementing ISA 18 Alarm Management Standard
	A.25	Maintenance personnel not following best practices for regular maintenance (PMs and inspections skipped)	Could result in any of the equipment failures mentioned about (A.7-13)		5		2	10	1. Robust maintenance program
	A.26	Lack of communication/ miscommunication between control room operator and marine terminal (ammonia storage, vessel loading area)	Production loss Over pressure of storage tank (overfilling tank)	Risk ranked on Node C. See C.5					
Procedures	A.27	Startup after scheduled maintenance outages (loss of control in the plant)	Not Risk ranked as outside of scope of review.						1. Prepare SOPs for plant startup and shutdown
	A.28	Ammonia release, fire,etc affecting other stakeholders in the area (Marine Atlantic,etc). This is as a result of not communicating with Port of Argentia "neighbors" about a ship for the Ammonia plant coming	Any process upset, equipment failure scenarios discussed above	Captured above in scenarios A.1 - 6					1. Incident protocol (call list including "neighbors" in PoA)
	A.29	Ship arrives unscheduled during non loading period. A result of poor communication between parties on when loading period is	Can't fill ship until loading period commences Production loss / demurrage cost for ship delay	Production loss / cost impact not risk ranked as part of ERP Risk Assessment					
Training	A.30	Improper training for different operating scenarios (emergency shutdown, startup after planned maintenance,etc)	See above A.27						
	A.31	Emergency scenario training is insufficient	People at risk unknowingly	Health&Safety	5		2	10	1. Develop training program (ammonia awareness program)
Security	A.32	Cyber security breach of control system	Malicious release of dangerous gases or other high risk scenarios	Occupational Health&Safety	5		2	10	1. Control system to implement cybersecurity best practices 2. Implement cyber security awareness training for workforce
	A.33	Breach of security (unauthorized personnel entering site) using water ways or land	Theft Production disruption Mischief	Outside of scope of risk review					

NODE B									
Guidewords	**Ref. No.**	**Events: What if?**	**Potential Consequences**	**Category**	**Severity**	**Existing Safeguards**	**Likelihood**	**Risk Ranking**	**Recommendations**
Process Upset	B.1	Overpressure of feed line. As a result of a surge event (unexpected valve closure)	Ruptured line causing a leak of ammonia	Health&Safety	4	Best practice engineering	2	8	1. Routing of the line away from high traffic areas
	B.2	Over or under pressure of storage tank (tank failure). Could be a result of control system failure(temp control, level control, etc) or boil off package failure	Rupture of tank (release of ammonia)	Health&Safety	5	Best practice engineering Secondary containment included in tank design	1	5	
	B.3	Over or under pressure of storage tank (tank failure). Could be a result of control system failure (level control, temp control, etc)	Rupture of tank (release of ammonia)	Community Impact	5	Best practice engineering Secondary containment included in tank design ERP plan in place for surrounding community	1	5	
Equipment Failure	B.4	Storage tank failure resulting from compromised tank integrity (corrosion)	Minor ammonia leak	Health&Safety	3	Best practice engineering Secondary containment included in tank design	2	6	3. Preventative Maintenance Program to be established
	B.5	Failure of feed line. Where both the feed line and tank connection fail	Slow leak of ammonia. See above B.1						
	B.6	Failure of recirculating pump	See above B.1-B.3						
Instrumentation Failure	N/A								
Utility Failure	B.7	Boil off package lost as a result of a loss of power	Ammonia released through flare	Risk assessment not required. Assumed flare is working in this case. If assumed flare fails refer to A.9					
Weather	B.8	Snow or ice build up in area as a result of a weather event.	Ice break off resulting in equipment failure (see B.4-6) Ice hitting people (outside of scope)						
Human Error	B.9	Transfer line rupture. As a result of a vehicle striking the transfer line	Ruptured line and release of ammonia	Health&Safety	4	Best engineering design practice	2	8	6. Strategic pipe routing 7. Physical barriers in place
	B.10	Release of ammonia. Due to the line not being properly maintained	Maintenance personnel exposed to ammonia	Health&Safety	2	Best engineering design practice	3	6	5. Ammonia awareness training 6. Proper PPE 3.Maintenance Procedures 4. LOTO
Procedures	N/A								
Training	N/A								
Security	N/A								

NODE C									
Guidewords	**Ref. No.**	**Events: What if?**	**Potential Consequences**	**Category**	**Severity**	**Existing Safeguards**	**Likelihood**	**Risk Ranking**	**Recommendations**
Process Upset	C.1	Surge event causing a loading arm failure by over pressurizing the line. Resulting in a piping system rupture over water.	Environmental spill (marine), affecting pH level and short term habitat impact on marine life in the harbour.	Environment	4	Best engineering practice.	2	8	Define and model potential marine impact and implement appropriate preventative measures and clean-up plans.
Equipment Failure	C.2	Loading arm failure when Ferry loading/offloading passengers, ammonia vapor cloud travels toward ferry terminal (mechanical failure of structure or piping system failure). Could be a result of weather event, operator fatigue, etc.	Full force spray out of the weakest point of arm until shut off	Community Impact	4	Best engineering practice	1	4	1. Communication Protocols to be developed in conjunction with PoA & Marine Atlantic for loading boat
Instrumentation Failure	N/A								
Utility Failure	N/A								
Weather	C.3	High winds at loading time during which a line break or leak occurs.	Line break/leak in a marine environment	Environment	5	Best engineering practice	1	5	1. Cut off wind speed for loading 2. Communication protocols with ship 3. Consider anemometer to be used
Human Error	C.4	Incorrectly hooked up loading hose. Hose becomes dislodged causing a release onto ships deck	Personnel exposure	Health&Safety	4	Best engineering practice	1	4	1. PPE 2. Training 3. Procedures
	C.5	Start loading before ship crew is ready or vice versa (plant crew is not ready). As a result of miscommunication between the crews.	Personnel exposure	See C.4 for Risk Ranking and Recommendations					
	C.6	Major breakage in line due to incorrect boat mooring	See above C.1, C.2, C.4						
	C.7	Overfilling ship due to failing to shut off feed to the ship in a timely manner.	Release on ship deck (personnel exposure) See above	See C.4 for Risk Ranking					1. Ship should comply with appropriate standards & regs (proper equipment)
Procedures	N/A								
Training	N/A								
Security	C.8	MARSEC rules violated at the loading dock. Note: Besides plant security during ship loading MARSEC rules apply for international ship activities. (Marine)	MARSEC Level 3 event Production loss	Not risk ranked due to being outside scope. However, should be considered in future studies					1. MARSEC requirements need to be considered in design

NODE D									
Guidewords	**Ref. No.**	**Events: What if?**	**Potential Consequences**	**Category**	**Severity**	**Existing Safeguards**	**Likelihood**	**Risk Ranking**	**Recommendations**
Process Upset	D.1	Overpressure of the storage tank as a result of overfilling.	Catastrophic failure of the hydrogen tank	Occupational Health&Safety	5	Best engineering practice	2	10	1.Review tank wall design 2.Consider overpressure design controls 3.Consider lowest traffic area for tank location
	D.2	Overpressure of the storage tank as a result of overfilling.	Jet flame (flange fire)	Occupational Health&Safety	4	Best engineering practice	2	8	1.Flame detection system 2.Robust Maintenance Program 3.Failsafe control system 4.Consider appropriate fixed fire suppression
	D.3	Overheating of the storage tank causing overpressure with impingement of flame.	Catastrophic failure of the hydrogen tank	Occupational Health&Safety	5	Best engineering practice	2	10	1. Review tank wall design 2. Consider overpressure design controls 3. Consider lowest traffic area for tank location
	D.4	Overheating of the storage tank causing overpressure with impingement of flame.	Jet flame (flange fire)	Occupational Health&Safety	4	Best engineering practice	2	8	1. Flame detection system 2.Robust Maintenance Program 3.Failsafe control system 4.Consider appropriate fixed fire suppression
	D.5	Over pressure of piping causing a failure	Jet flame (flange fire)	Occupational Health&Safety	4	Best engineering practice	2	8	1.Proper procedures and training 2.Flame detection system 3.Robust Maintenance Program 4.Failsafe control system 5.Consider appropriate fixed fire suppression
Equipment Failure	D.6	External damage to the hydrogen tank affecting the integrity	Catastrophic failure of the hydrogen tank	Occupational Health&Safety	5	Best engineering practice	2	10	1.Access restriction to tank area 2.Procedures for working around hydrogen system 3.Guarding of hydrogen tank 4.Training 5.Location of tank away from high traffic areas
	D.7	External damage to the hydrogen tank affecting the integrity	Jet flame (flange fire)	Occupational Health&Safety	4	Best engineering practice	2	8	1.Access restriction to tank area 2.Procedures for working around hydrogen system 3.Guarding 4.Training 5.Location of tank away from high traffic areas 6.Consider appropriate fixed fire suppression
	D.8	Material failure in hydrogen storage tank	Catastrophic failure of hydrogen tank	Occupational Health&Safety	5	Best engineering practice	1	5	1.Ensure material of construction is correct 2.QA/QC during tank construction (i.e weld inspections, etc)
	D.9	Piping and/or valves failure for the hydrogen piping as a result of external damage	Jet flame (flange fire)	Occupational Health&Safety	4	Best engineering practice	2	8	1.Access restriction to tank area 2.Procedures for working around hydrogen tank 3.Guarding 4.Training 5.Location of tank away from high traffic areas 6.Consider appropriate fixed fire suppression
	D.10	Piping and/or valves failure for the hydrogen piping as a result of material failure	Jet flame (flange fire)	Occupational Health&Safety	4	Best engineering practice	2	8	1.Ensure material of construction is correct 2.QA/QC during tank construction (i.e weld inspections, etc) 3.Consider appropriate fixed fire suppression 4.Robust maintenance management system 5.Management of change for replacement parts
Instrumentation Failure	D.11	Instrumentation fails leading to any of the above events(level, pressure sensors, etc)	See above D.1-D.10						
Utility Failure	D.12	Power failure causing instrumentation failure	See above D.11						1. Back up power for instrumentation
Weather	D.13	Snowstorm causing the tank to be inaccessible during jet flame event	Jet flame event persists longer than needed	Occupational Health&Safety	5	Best engineering practice	1	5	1.Procedure (snow clearing during winter) 2.Snow clearing considered during design (roadways large enough to accommodate equipment)
	D.14	Lightening strike on hydrogen tank	Catastrophic failure of hydrogen tank	Occupational Health&Safety	5	Best engineering practice	1	5	1.Lightening protection for tank
Human Error	D.15	Incorrect valve positioning (either open or closed) causing a build up of pressure.	Pipe over pressure event leading to jet flame	Occupational Health&Safety	4	Best engineering practice	2	8	1.Training and procedures 2.Overpressure protection
	D.16	Contact with hydrogen tank by vehicle affecting tank integrity	Jet flame (flange fire)	Occupational Health&Safety	4	Best engineering practice	2	8	1.Access restriction to tank area 2.Procedures for working around hydrogen tank 3.Guarding 4.Training 5.Location of tank away from high traffic areas 6.Consider appropriate fixed fire suppression
Procedures	D.17	Incorrect operation of hydrogen tank on ramp up, shutdown, or emergency shut down	Catastrophic Failure of hydrogen tank	Occupational Health&Safety	5	Best engineering practice	1	5	1.Start up, emergency shutdown and planned shutdown procedures
	D.18	Poor maintenance of tank components compromising integrity of the system	Jet flame (flange fire)	Occupational Health&Safety	4	Best engineering practice	2	8	1.Ensure material of construction is correct 2.QA/QC during tank construction (i.e weld inspections, etc) 3.Consider appropriate fixed fire suppression 4.Robust maintenance management system 5.Management of change for replacement parts
Training	D.19	Incorrect identification of a leak (hydrogen versus ammonia)	Jet flame leading to catastrophic failure of tank	Occupational Health&Safety	5	Best engineering practice	1	5	1.Fire detection system 2.Develop procedure for secondary validation of fire 3.Consider apropriate fixed fire suppression 4.Emergency response procedure for hydrogen leak 5.Training and Procedures
	D.20	Incorrect identification of a leak (hydrogen versus ammonia)	Jet flame undetected leading to personnel injury	Occupational Health&Safety	4	Best engineering practice	2	8	1.Fire detection system 2.Develop procedure for secondary validation of fire 3.Consider apropriate fixed fire suppression 4.Emergency response procedure for hydrogen leak 5.Training and Procedures
	D.21	Incorrect response to hydrogen leak scenario	Jet flame undetected leading to personnel injury	Occupational Health&Safety	4	Best engineering practice	2	8	1.Training and Procedures 2.Third party responder training and drills (Coordination with local emergency services)
Security	N/A								

APPENDIX D
PARKING LOT

Parking Lot/ Issue Summary
NODE A
What is the volume of vapor released which triggers a report to the government regulator?
Ask vendors what risks exist if water is lost to electrolyser?
Clarify whether regulatory cyber security requirements applicable to Pattern if power being generated to grid (NL Hydro)
Hydrogen tanks (not in FEL 1 docs) should be noted for future PHA's
Follow up with vendor on specifics of membrane failure
Ask vendor about electrolyser operating specifications (temperature extremes, etc)
NODE B
Permitting requirements around Ammonia, hydrogen?
Consider whether flare runs continually or intermittently (is flare event even required)
NODE C
Ensure that authorization for workers in shipping facility (international) is taken into account. Usually there is certain security clearance requirements for those working in international ports
Explosion modelling for blast radiuses of tank ruptures
Water suitability assessment (Coast Guard)
NODE D
What are the regulations and limits around a hydrogen event (Flare or release to atmosphere) from emissions standpoint