April 2, 2015

Mr. Tom Armstrong
Supervising Planner
Bureau of Planning and Sustainability
City of Portland
1900 SW Fourth Ave, 7th Floor
Portland, Oregon 97201

RE: Pembina Pipeline Company
Propane Terminal Quantitative Risk Assessment Review

Dear Mr. Armstrong,

Akana is pleased to provide the City of Portland (City) with the results of our review of the Pembina Pipeline Company (Pembina) Propane Terminal Risk Assessment. The facility is proposed to be located at Terminal 6 at the Port of Portland (Terminal 6).

Pembina consultant DNV GL has prepared a draft quantitative risk assessment (QRA) regarding potential hazards at the facility for design and operational purposes. Pembina has provided the draft QRA to the City to evaluate as part of a rezoning request needed to construct the facility at the proposed location at Terminal 6.

Community stakeholders have expressed concerns regarding the potentially devastating effects from catastrophic fire or explosion at the facility related to rail car unloading, ship loading, or storage activities that may result from accidents or intentional efforts by external actors to cause a release from the facility.

Akana was retained by the City of Portland to conduct an independent review of the draft QRA prepared by the facility. The attached report presents a summary of that review, as well as our comments and recommendations regarding the QRA.

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If you have any questions regarding the enclosed comments or recommendations, please contact me at (503) 652-9090.

Respectfully,

Timothy J. Oliver, PE
Vice President

Timothy J Oliver

Digitally signed by Timothy J Oliver
DN: cn=Timothy J Oliver, o=Akana, ou, email=timothy.oliver@akana.us, c=US
Date: 2015.04.02 05:44:49 -07'00'

Enclosure

ENCLOSURE
QUANTITATIVE RISK ASSESSMENT
REVIEW COMMENTS AND RECOMMENDATIONS

(23 Pages)

QUANTITATIVE RISK ASSESSMENT
REVIEW COMMENTS AND RECOMMENDATIONS

This report presents the Akana review of the Pembina Pipeline Company (Pembina) Propane Export Terminal Facility Quantitative Risk Assessment (QRA) prepared by DNV GL for the proposed propane storage terminal at Port of Portland Terminal 6 (Terminal 6).

1.0 Technical Approach

Akana attended a March 10, 2015, briefing at the Port of Portland regarding the quantitative risk assessment (QRA). Akana personnel reviewed the QRA for conformance with industry-standard hazard analysis, quantitative risk assessment, and air modeling procedures. We also reviewed the location, size, and accident history of similar facilities in North America identified by Pembina to determine possible additional failure modes and assess the probability of certain accident scenarios. We have incorporated into our review a summary response to the issues raised in the Hayden Island Neighborhood Network White Paper regarding stakeholder concerns related to construction, operation, and potential releases from the terminal.

The Akana review of the QRA included a review of the document for the following elements:

+ Terminal design features
+ Risk assessment methodology
+ Hazard identification/Scenario development
+ Incident frequency evaluation
+ Air modeling inputs
+ Consequence evaluation

The review completed by Akana does not include independent modeling of the QRA failure modes and air dispersion modeling. Our review of the model is limited to an evaluation of the adequacy of the computer software used to complete the assessment and the key inputs used to complete the modeling.

2.0 Key Personnel

The Akana review was completed by a team of highly qualified engineers, safety professionals, and quantitative risk assessment personnel available to support this project. Mr. Tim Oliver, P.E., was the primary reviewer. He was supported by other technical staff on specialized issues and for quality assurance purposes, as necessary.

3.0 Quantitative Risk Assessment Review

The QRA estimates the risk from flammable releases, such as jet fires, pool fires, flash fires, vapor cloud explosions, fireballs, and Boiling Liquid Expanding Vapor Explosions (BLEVE). The risk is presented as individual risk in the form of location-specific individual risk (LSIR) contours, and as societal risk in the form of Potential Loss of Life (PLL) and FN (Cumulative Frequency [F] of Various Accidents against Number [N] of Fatalities) curves.

The QRA modeled the potential release scenarios and risks using PHAST 6.7, a commercial software package prepared by DNV. Use of PHAST 6.7 is an approved QRA model with U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) and 49 CFR Part 193 (PHMSA 2011a and 2011c). The PHMSA approval included an independent government review of a Model Evaluation Report for the software. According to Section 3.4.1 of the QRA, PHAST has also been independently evaluated by the European Commission Scientific Model Evaluation of Dense Gas Dispersion Models Project.

The QRA evaluation is in accordance with the applicable section of the Code of Federal Regulations (40 CFR Part 193.2059, Flammable Vapor-Gas Dispersion Protection). The worst-case evaluation required by the U.S. Environmental Protection Agency (EPA) Risk Management Plan (RMP) is presented in Appendix IV-1 and is in accordance with 40 CFR Part 68 and applicable EPA guidance (EPA 2009a and 2009b).

Akana also reviewed the PHMSA Office of Hazardous Materials Safety Incident Reports Database Search (https://hazmatonline.phmsa.dot.gov/IncidentReportsSearch/search.aspx). Only 50 incidents are currently listed, with the largest spill totaling 100 liquid gallons. No significant injuries, deaths, or environmental impact was reported for similar facilities in the United States.

Finally, Akana also reviewed the design and specifications for DOT 112 tank cars at 49 CFR Part 179 to identify any potential risks for release that were not considered by the QRA; none were identified.

4.0 Review Comments

The following comments are separated into General and Specific comments. General Comments apply to the overall QRA and are not specific to a particular section of the document. Specific Comments apply the noted section of the document, typically to a particular section, paragraph, sentence, or table entry.

4.1 General Comments

1. **Similar Facility Comparison.** A list of similar facilities was provided by Pembina separate from the QRA. Akana reviewed the Right to Know Network (www.rtknet.org) to evaluate the similarities between the referenced facilities and the proposed Pembina Portland terminal. Akana also reviewed the available information regarding reportable releases from these facilities to evaluate the comparative release frequencies. This list included the following sites:

    a. Targa Galena Park Marine Terminal, Texas. The latest RMP report indicates no releases for the last 5 years. The process is similar but bulk storage is in underground wells and salt domes rather than large aboveground refrigerated tanks.

    b. Enterprise Products EPLOP Marine Loading Facility, Texas. The latest RMP indicates no releases for the last 5 years. The facility includes additional on-site processing steps but no large aboveground refrigerated tanks.

    c. Petrogas Ferndale Terminal, Washington. The latest RMP indicates no releases for the last 5 years. The facility does include refrigerated storage on site, but mostly of liquefied natural gas (LNG) rather than propane.

    d. DCP Midstream, Chesapeake, Virginia. The latest RMP indicates no releases for the last 5 years. From the data available, the facility appears similar to the proposed terminal.

    e. Sunoco Marcus Hook, Pennsylvania. The latest RMP indicates one release in the last 5 years, associated with propane handling due to hose disconnection. Most of the propane storage at this facility is in caverns or pressurized spheres.

    f. Targa Hattiesburg Terminal, Mississippi. The latest RMP indicates no releases for the last 5 years. There is no refrigerated storage or ship loading on site. Most of the propane at this location is in underground storage, with 6 pressurized tanks aboveground.

    g. Enterprise Products Mont Belvieu, Texas. The latest RMP indicates no releases for the last 5 years. There is no refrigerated storage or ship loading on site at this location. This facility is also a propane production facility.

    h. Plains LPG Alto Terminal, Michigan. The latest RMP indicates no releases for the last 5 years. There is no refrigerated storage or ship loading on site.

i. Enterprise Apex Terminal, North Carolina. The latest RMP indicates one release of 2,300 pounds of propane from a refrigeration unit in last 5 years. There is no rail or ship loading at this location. Refrigerated storage capacity appears similar.

Based on public comments, Akana also reviewed the Right to Know Network RMP data for the Suburban Propane facility located in Elk Grove, California. Since construction and startup operations (in 1972) there has not been an accidental release of propane, or any other hazardous substance, at the Suburban Propane Elk Grove Terminal that has resulted in any deaths or off-site injuries, property or environmental damage, evacuations, or sheltering in place. The last unplanned and/or non-routine release of Propane was on September 13, 2005, when a nonemployee driver failed to check or relieve pressure prior to disconnecting a "live hose." The non-reportable release event was mitigated by site personnel. No action was required by off-site emergency response agencies.

Although the information available regarding these facilities indicates few significant or reportable releases, few of them (Petrogas Ferndale, DCP Chesapeake, Suburban Elk Grove) are comparable in size or operation to the proposed Pembina Portland terminal. Pembina should provide better data regarding the total number of these facilities located in the U.S., North America, and globally, and if there are safety records for those facilities.

2. **Design Information.** Limited design information consisting of a few preliminary process flow diagrams (PFD) were submitted with the QRA; piping and instrumentation diagrams (P&ID) were not included. Akana could not assess various design claims presented in the QRA such as "the flare system is designed to drop the pressure in the bullet tanks by ½ in 15 minutes." The design and capacity of the fire water storage tank or deluge system also could not be verified. No design standards were referenced in the QRA (for example, NFPA 58, API 2510, ISO 16732 or the ASME Boiler & Pressure Vessel Code). Additional information would need to be provided to assess these claims, the potential effectiveness of various design features, and their effect on the QRA.

3. **FN Curves.** The FN Curves included in the QRA (Section 1, Figure 2 and Figures 4-6 through 4-8) would appear to indicate that any expansion of the terminal beyond the currently proposed terminal configuration that would result in increased rail car deliveries, rail car unloading activities, additional bullet tanks or refrigerated storage, or ship loading activities would have the resulting effect of increasing the frequency of the release scenarios sufficiently such that the United Kingdom Health & Safety Executive (UK HSE) Criteria Line would be exceeded. Although Pembina has indicated that it has no current plans to expand the capacity of the terminal, the implication of the

presentation of this information in the current QRA is that the City of Portland should consider limiting the current and future capacity and configuration of the terminal to the design currently proposed. If this is not the intended implication of the QRA or the impact of future expansions on the total FN risk curve, the QRA should be revised to clearly indicate what level of expansion or increased capacity might be acceptable. Alternatively, the City of Portland should consider including limitations in their Intergovernmental Agreement with the Port of Portland regarding future expansion and the need for a revised QRA before any such expansion could proceed.

4. **Expert Judgment Assumptions.** Many of the assumptions included in Appendix I of the QRA reference "DNV GL Expert Judgment." Unless otherwise noted in the specific comments, the assumptions made using this expert judgment appear reasonable to the reviewer. However, the use of the term "expert judgment" does not provide a great deal of confidence to the public at large. Where possible, the QRA should be revised to provide specific references for all assumptions.

5. **Sensitivity Analysis.** No sensitivity analysis is presented in the QRA. Unless otherwise noted in the specific comments, the assumptions made regarding the PHAST input values appear reasonable to the reviewer. However, it is impossible to determine the relative impacts on the modeled results due to changes in the input values (such as number of minutes of the release or volume of the release). The QRA should be revised to include a discussion of model sensitivity.

6. **Injury Risk.** There is no discussion of injury risk versus fatality risk in the QRA. The QRA should be revised to explain why injury risk is not included in the model.

7. **Intentional Release.** There is no discussion in the QRA of the risks due to intentional releases (sabotage or terrorism). The QRA should be revised to include (1) a description of the physical security requirements that the terminal will be subject to, (2) a discussion of the projected probability and frequency of intentional acts, and (3) an assessment of whether the modeled release scenarios account for the potential types of release due to an intentional event.

8. **Railcar Movement.** The draft version of the QRA does not include an analysis of the risks due to rail car movement within the terminal boundary. According to DNV, this will be added to future versions of the QRA. The City of Portland should reevaluate future versions of the QRA to determine if the modeled risks are significantly affected by the addition of the release scenario.

9. **Population Distribution and Growth.** As noted in the uncertainty section of the Executive Summary, the QRA provides conservative impact results because the model

was developed based on the assumption that the population of each zip code included in the analysis is evenly spread throughout the total area of the zip code. The areas within the modeled impact zones are primarily industrial and undeveloped areas; the nearest residential area is located at the very limits of the potential impact zone identified in the QRA. However, this assumption does not account for population growth or seasonal use of Smith and Bybee Lakes or Kelly Point Park. The City of Portland has more detailed data regarding the population distribution within each zip code, as well as projected population growth models through 2035. The City of Vancouver may have projected population growth models as well. The QRA should be revised to address these issues in future versions of the QRA.

10. **United Kingdom References.** Many parts of the QRA, including the frequency analysis and consequence analysis, are in large part based on data and guidance from the UK. While the UK data may in fact represent the best available data and guidance, additional effort could be made to identify relevant U.S. data and guidance, where available. For example, the American Institute of Chemical Engineers Center for Chemical Process Safety publishes numerous documents on the subject of quantitative risk assessment, including frequency data.

4.2 Specific Comments

1. **Section 1, Executive Summary, Conclusions, Societal Risk, Bullet 3, Page 9.** This bullet notes that "the current model is conservative with respect to both aspects" but does not explain how the model is conservative. This statement should be revised to clearly indicate in what manner the model is conservative with regard to the earthquake hazard, especially since it contributes to such a large percentage of the overall calculated risk from the terminal.

2. **Section 1, Executive Summary, Recommendations, Page 9.** The recommendations presented in the Executive Summary do not match the recommendations presented in Section 5 of the report. Typically, new or different information is not presented in an Executive Summary. The QRA should be revised such that the Executive Summary is just that: a summary of the information presented throughout the rest of the report. The recommendations presented in Section 1 and Section 5 should be consistent.

3. **Section 1, Executive Summary, Recommendations, Impoundment Area, Bullet 4, Page 9.** This bullet notes that secondary containment design should be considered to limit and direct the size and location of potential pool fires. The site design details are not presented in the QRA, so specific design features related to this recommendation cannot be assessed or verified. The final QRA should include specific details indicating how secondary containment design at the terminal has been completed to limit the size

of potential pool fires and direct any spills away from other tanks so as to limit the potential for BLEVEs.

4. **Section 1, Executive Summary, Recommendations, Detection and Isolation, Bullet 5, Page 9.** This bullet notes that design features that result in early detection and isolation of any releases to ultimately reduce or limit the overall size of a release should be incorporated into the terminal design. The site design details are not presented in the QRA, so specific design features related to this recommendation cannot be assessed or verified. The final QRA should include specific design details indicating how early detection and isolation features have been incorporated into the design of the terminal.

5. **Section 1, Executive Summary, Uncertainty, Earthquakes, Bullet 1, Page 10.** This bullet notes that the current civil/geotechnical design earthquake is a 1-in-2,495-year event but does not identify the design standard. The design standard should be cited in this paragraph.

6. **Section 1, Executive Summary, Uncertainty, Earthquakes, Bullet 1, Page 10.** This bullet notes that the current QRA design earthquake is a 1-in-475-year event but does not identify the basis for this assumption. The basis for this assumption should be cited in this paragraph.

7. **Section 1, Executive Summary, Uncertainty, Earthquakes, Bullet 1, Page 10.** This bullet notes that the QRA is conservative due to the difference in the design basis earthquake and the QRA basis earthquake, but does not provide any information regarding the magnitude of the uncertainty. The QRA should be revised to include a quantitative evaluation of the magnitude of the degree of conservatism introduced by this difference (that is, a sensitivity analysis).

8. **Section 1, Executive Summary, Uncertainty, Design Bunding, Bullet 2, Page 10.** This bullet notes that the design of on-site rail lines provides bunding (berms) that are not incorporated into the model and therefore provides a level of conservatism. This statement cannot be verified. The QRA should be revised to incorporate the final site design features and assess the actual pool fire sizes and locations that can be expected for each release scenario.

9. **Section 1, Executive Summary, Uncertainty, On-Site Population, Bullet 3, Page 10.** This bullet notes that the QRA incorporates a higher than expected outdoor population during marine loading, thus resulting in a conservative estimate of the potential impacts. This statement cannot be verified. It is also unclear from the data provided in the body and appendix of the report whether the overall population of zip code 97212 has been distributed evenly across both the on-site and off-site areas or if the on-site

effects are limited solely to the estimate of on-site personnel. The QRA should be revised to incorporate a reasonable estimate of on-site personnel during all release scenarios.

10. **Section 2.1, Study Objectives, Bullet 2, Page 11.** This bullet indicates that the objective of the QRA is to "assess the risk to associated personnel." This statement would seem to exclude off-site impacts. The QRA should be revised to indicate that the objective of the QRA is to assess the risks to both on-site personnel as well as the off-site affected population.

11. **Section 2.2, Scope of Work, Paragraph 1, Bullet 3, Page 12.** This bullet indicates that the scope of work includes the identification of "critical issues and challenges." Critical issues and challenges are not addressed in Section 1, Executive Summary, or anywhere else in the report. The QRA should be revised to include this information.

12. **Section 2.2, Scope of Work, Paragraph 2, Page 12.** This paragraph indicates that railcar transit inside and outside the terminal, carrier transit, and collisions to a carrier or the dock are not included in the scope of the QRA but are being evaluated in separate studies. Based on the information presented by Pembina on March 10, 2015, the additional studies do not include the evaluation of risk due to railcar transit outside the terminal. Furthermore, Pembina indicated that railcar transit inside the terminal would be included in future versions of the QRA. The QRA should be revised to include risks due to railcar transit inside the terminal. This paragraph should be revised to clearly indicate the studies, scope, authors, and expected receipt date of the other studies that are referenced.

13. **Section 2.2, Scope of Work, Paragraph 3, Page 12.** This section identifies the units and systems identified at the terminal for the QRA. The report does not explain why Unit 1002, Propane Refrigeration, includes both the refrigeration process and the pressurized propane storage tanks. This section and other relevant sections of the QRA should be revised to explain the basis for the limits of each of the units and systems identified at the terminal.

14. **Section 3.1.4, Frequency Analysis, Page 15.** This section notes that the frequency data in the QRA is based on the UK HSE Hydrocarbon Release Database (HCRD), frequency data from the UK Advisory Committee on Dangerous Substances, and UK HSE historic data for releases from pressurized propane bullets and refrigerated storage tanks in the UK. The QRA does not explain if this is the most appropriate data or why data from the United States or North America is not being used. It also does not explain the applicability of off-shore data to on-shore facilities. The QRA should be revised to demonstrate that the most relevant and comprehensive frequency data has been used to complete the risk assessment.

15. **Section 3.1.5, Risk Analysis, Page 15.** This section notes that the QRA calculates and presents the risks in terms of Location Specific Individual Risk (LSIR), Societal Risk in terms of Potential Loss of Life (PLL), and FN (cumulative frequency versus total number of fatalities) curves. The QRA does not explain why these are the most appropriate methods of presenting the potential risk from this type of terminal, or if there are other risks that may be evaluated but have been excluded from this report. The QRA should be revised to demonstrate that the risks evaluated in this report are the most relevant and comprehensive methods of presenting the risks posed by the proposed terminal.

16. **Section 3.3.1, Scenario Identification, Item 1, Page 16.** This section defines an isolatable section as the area between emergency shutdown valves or devices (ESD). The location of ESDs within a terminal is a design feature rather than an element of the QRA. This section of the QRA should be revised to clearly indicate that the isolatable sections are based on the location of ESDs *as currently indicated on the preliminary design*. The authors should also revise other sections of the QRA (for example, Section 5.0, Recommendations) to indicate whether the placement of additional ESDs throughout the terminal could result in lower potential risks due to a smaller maximum available inventory for release within the revised isolatable sections.

17. **Section 3.3.1, Scenario Identification, Paragraph 2, Page 16.** This paragraph notes that the time needed to isolate a portion of the terminal by activating ESD features of the terminal will be a key factor in the outcome of the QRA. However, the balance of the QRA (including Section 3.3.3 and Appendix I) provides no information on the sensitivity of the results to changes in this key assumption. The QRA should be revised to include an analysis of the impact of changes in the period assumed to isolate a portion of the terminal on the results of the risk assessment.

18. **Section 3.4.1, QRA Consequence Modeling, Page 17.** This section notes that all releases have been modeled to the lower flammability limit (LFL) or ½LFL. No information is provided to indicate if this basis is the most appropriate for this type of terminal or the degree of conservatism presented by using this basis. The QRA also does not explain when or why one option may have been used instead of the other. The QRA should be revised to include an explanation of the basis for completing the risk assessment by modeling the releases based on the LFL or ½LFL, and how the decision was made to use each parameter for each scenario.

19. **Section 3.4.1, QRA Consequence Modeling, Paragraph 1, Page 18.** This paragraph notes that acute toxic hazards are not considered relevant to this study. Although this is a true statement based on the type of chemicals handled at the terminal (propane), this is not something that would be apparent to the nontechnical reader of the report. This

section of the QRA should be revised to include a full explanation of why modeling of acute toxic hazard is not necessary for this terminal.

20. **Section 3.4.1, QRA Consequence Modeling, Paragraph 2, Page 18.** This paragraph notes that a TNO multi-energy model was used to predict explosion effects. This model is not described or referenced anywhere else in the QRA. The QRA should be revised to clearly explain why the use of the TNO model is the most appropriate for determining the potential effects from this terminal.

21. **Section 3.4.1, QRA Consequence Modeling, Paragraph 4, Page 18.** This paragraph notes that BLEVE modeling was completed for the pressurized propane storage units. However, the paragraph does not explain why other systems at the terminal were not modeled for this event. The QRA should be revised to clearly explain why only the pressurized propane storage bullets were modeled for a BLEVE event.

22. **Section 3.5, Frequency Analysis, Page 19.** This section notes that the "best available" frequency data has been used to complete the assessment. This statement is provided without proof or reference. The section also notes that the frequency data in the QRA is based on the UK HSE HCRD, frequency data from the UK Advisory Committee on Dangerous Substances, and UK HSE historic data for releases from pressurized propane bullets and refrigerated storage tanks in the UK. The QRA does not explain if this is the most appropriate data or why data from the United States or North America is not being used. It also does not explain the applicability of off-shore data to on-shore facilities. The QRA should be revised to demonstrate that the most relevant and comprehensive frequency data has been used to complete the risk assessment.

23. **Section 3.6, Risk Evaluation, Paragraph 2, Page 19.** This paragraph describes the use of vulnerability values to estimate the number of fatalities expected for a given scenario. Although this paragraph references Appendix I for details regarding the vulnerability assumptions, additional information is needed in this section to clearly explain the effects of the vulnerability value assumptions on the outcome of the QRA. The QRA should be revised to include this additional information.

24. **Section 3.6, Risk Evaluation, Location-Specific Individual Risk Criteria, Page 19.** This paragraph describes the LSIR criteria, based upon UK HSE guidance. The description does not explain the basis for using UK guidance, or why U.S. criteria or comparable decisions for similar facilities in the U.S. or North America have not been used. The QRA should be revised to include an explanation for assessing the risk from this terminal using the UK guidance.

25. **Section 4.1.2, Location Specific Individual Risk Ranking Points, Paragraph 1, Page 23.** This paragraph notes that 11 on-site and 11 off-site receptor points were used to estimate indoor and outdoor LSIR. The QRA (including Assumption 27 in Appendix I.5.2) does not explain the basis for the selection of these points, or if they represent worst-case risks. The QRA should be revised to include a description of the selection of the receptor points, how the selection of these of these specific points represents risk from the terminal, and if and how the selection of additional or different locations would impact the results of the analysis.

26. **Section 4.1.2, Location Specific Individual Risk Ranking Points, Paragraph 1, Page 23.** The last sentence of this paragraph indicates that the indoor LSIR accounts for the fire and blast rating assumed for each building. It is unclear what assumptions have been made for rating each building or how these assumptions were made. The QRA should be revised to include a detailed explanation regarding the fire and blast rating assumptions that have been incorporated into the assessment.

27. **Figure 4-4, Receptor Locations On-Site, Page 24.** This figure does not indicate the location of the emergency generator or pumps used to power the fire water protection system in case of a loss of site power. It seems reasonable to assess the impact of potential fires or blasts on this building. The QRA should be revised so that the LSIR ranking points include an analysis of the structures housing the emergency generators and pumps for the fire water protection system.

28. **Figure 4-5, Receptor Locations Off-Site, Page 24.** This figure shows the off-site receptor locations for LSIR modeling. The locations do not appear to include several nearby industrial and warehouse facilities that could potentially be impacted by various scenarios at the terminal. Furthermore, as summarized in Table 4-2, the off-site locations do not include any indoor LSIR locations. The QRA should be revised to include an explanation regarding the exclusion of the nearby facilities and to explain why no indoor LSIR values were calculated for off-site receptors.

29. **Table 4-2, LSIR at Off-Site Receptor Locations—Outdoor and Indoor, Page 25.** This table summarizes outdoor LSIR for off-site receptors. The table title indicates that indoor risks are also summarized. The table title should be revised or indoor risks added to the table.

30. **Section 4.2.1, Potential Loss of Lives, Page 27.** The last sentence of this paragraph indicates that the current model for a release from the large refrigerated storage tank due to an earthquake is conservative with respect to both the assumed frequency and the size of the hazard zone. However, this section does not provide any details explaining why the model is conservative or the magnitude of the conservatism

incorporated in the current model. This section, as well as similar statements throughout the document (for example, Section 4.2.1, Page 32, Paragraph 2), should be revised to include a detailed discussion regarding the conservatism incorporated in the current model.

31. **Section 4.2.2, Potential Loss of Lives, Second Paragraph, Page 27.** This paragraph attempts to explain why the model is overly conservative due to the assumption that the population within a given zip code has been evenly distributed throughout the total area of the zip code (that is, the model assumes an average number of people per area, even though that area might represent a waterbody, forest, industrial area, or roadway). Because the number of persons in the hazard zone when the event occurs is part of the PLL calculation, this assumption overestimates the PLL in industrial areas near the proposed terminal. Unfortunately, this paragraph is poorly structured and worded, and fails to clearly convey this information. This section should be rewritten.

32. **Figure 4-6, Overall FN Curve Compared to UK HSE Criteria, Page 29.** This figure would appear to indicate that the total risk from the proposed terminal reaches or possibly exceeds the UK HSE Criteria Line. While the actual implications of part of the total risk curve crossing the Criteria Line are uncertain (as explained in Section 3.6 of the QRA), other sections of the QRA (for example, Section 1 Results and Section 1 Conclusions Societal Risk) indicate that although the total risk curve is very close to the Criteria Line, it does not in fact touch or cross the Criteria Line. For presentation purposes, it is recommended that Figure 2 in Section 1 and Figures 4-6, 4-7, and 4-8 be revised to clearly indicate the separation of the two curves.

33. **Section 4.2.2, Potential Loss of Lives, Page 32.** The last sentence of this section states that the model includes a higher outdoor population than expected and is thus conservative. No indication of the magnitude of the conservativeness or the impacts that a more reasonable population estimate might have on the outcome of the model are presented. This section should be revised to include this analysis.

34. **Table 4-6, Top Contributors to Fatality Range (from N= 4 to N=8), Page 32.** This table presents the risk percentage for the top 10 scenarios contributing to the cumulative frequency between 4 and 8 fatalities. It is unclear how this table was generated, given that the risk percentage will be a different value for each value of N. The report should be revised to clearly indicate how the table was generated and if the risk percentages represent an average contribution within the given range or if the given range was modeled as a single point.

35. **Section 4.3.1, Overpressure Frequency Contours, Page 32.** This section describes the impacts of various overpressure events due to explosions, as shown on Figures 4-9, 4-10,

and 4-11. Although a majority of the most likely overpressure events are confined to on-site locations at the pressurized propane bullet tanks, Figure 4-10 indicates a greater than 1-in-1,000 year possibility of a 3 pound per square inch (psi) event impacting the refrigerated storage tanks. This section indicates that a 3 psi event is sufficient to deform a steel frame building and pull it away from its foundation. However, there is no discussion in the QRA regarding the ability of the refrigerated tanks to withstand a 3 psi event. The QRA should be revised to address this issue.

36. **Section 4.3.2, Radiation Frequency Contours, Page 34.** Figures 4-13 and 4-14 in this section would appear to indicate a greater than 1-in-1,000-year fire radiation risk for pool fires and all fires in off-site locations to the south of the terminal. This location is currently a paint manufacturing operation. To prevent excess fire radiation risks to off-site receptors, it would seem likely that a recommendation (Section 1, Recommendations, Item 3) should be presented in the QRA to design the terminal such that pool fires (the major component of the fire radiation risk, according to Figures 4-13 and 4-14) are directed in a different direction, so as to reduce the potential off-site effects. This section should be revised to indicate that, because the model assumes that the pools spread evenly, the off-site risk depicted in Figures 4-13 and 4-14 is likely overstated.

37. **Section 4.4, Uncertainties, Page 37.** This section identifies five types of uncertainties and states that the QRA errs on the conservative side, but does not provide a correlation indicating the effect of each type of uncertainty on the outcome of the risk assessment (that is, making it more or less conservative). This section should be revised to include additional details regarding the effect of each type of uncertainty on the outcome of the QRA.

38. **Section 4.4, Uncertainties, Page 37.** The last sentence of this section states that "this report strives to illustrate the uncertainty either quantitatively through sensitivities, or by highlighting uncertain issue in the discussions." No sensitivity analysis is provided. Uncertainties are not addressed in every section of the report. This sentence should be deleted or (preferably) the report modified to include this information throughout the QRA.

39. **Section 5.2, Recommendations, Page 38.** Recommendation 1 indicates that a number of design features have been implemented to prevent the occurrence of BLEVEs. Due to the level of design information presented in the QRA, this statement cannot be verified. This statement should be deleted or the QRA should be revised to include sufficient design information such that this statement can be verified.

40. **I.1.2 Facility Operational Philosophy, Specifications, Bullet 1, Page I-6.** This bullet notes that there are two propane refrigeration compression trains at the terminal, but that Pembina plans to normally operate only one train at a time. It is unclear from the information presented how this information was incorporated into the QRA model and the potential impact of that assumption (that is, whether DNV modeled the risks assuming normal operation of one train, thereby underestimating the potential risk, or by assuming the operation of both trains, thereby overestimating the potential risk). This bullet should be revised.

41. **I.1.2 Facility Operational Philosophy, Specifications, Bullet 2, Page I-6.** This bullet describes potential use of Line 43 on Drawing 14088D-PR-PF-1002-001 (found in Attachment II.1). In is unclear how this information was incorporated into the QRA model and the potential impact of that information. This bullet should be revised.

42. **I.1.2 Facility Operational Philosophy, Specifications, Bullet 4, Page I-6.** This bullet describes the projected operation of the loading lines from the refrigerated tank to the carrier and the duration of the cool down operation. In is unclear how this information was incorporated into the QRA model and the potential impact of that information. This bullet should be revised.

43. **I.1.2 Facility Operational Philosophy, Specifications, Page I-6.** The last paragraph indicates that Pembina provided five different Heat and Material Balance Cases for different operating conditions. This information is not included in the QRA and could not be verified. Furthermore, the information provided does not indicate why the indicated cases were selected or why they represent the most likely or most conservative cases to be used for the purposes of the QRA. This paragraph should be revised to include this information.

44. **I.1.2 Facility Operational Philosophy, Implication of Assumptions, Page I-6.** The sentence stating: "The above assumptions each have key influences on the risk results" does not provide any useful information. This section should be revised to include detailed information regarding the impact of each assumption on the outcome of the risk assessment.

45. **I.1.4 Population/Manning, Implications of Assumption, Page I-11.** This section addresses the implications of the manning (staffing) assumptions but does not describe the implications of the assumptions made regarding population distribution. This section should be revised to include this information.

46. **I.1.4 Population/Manning, Implications of Assumption, Page I-11.** This section addresses the implications of the manning assumptions. Section 4.2.2 (Page 32) indicates

that the model includes a higher outdoor population at the jetty than is expected, resulting in a more conservative risk estimate. No information is presented in this section to substantiate that claim. This section should be revised to substantiate the claim in Section 4.2.2. or the sentence deleted.

47. **I.1.5, Wind Rose, Specifications, Paragraph 1, Page I-18.** This section notes that all calm stability weather is excluded from the model. No information is provided on the impact of this decision. The Implications of Assumption section should be revised to provide an analysis of the impacts of this decision on the outcome of the model.

48. **I.2.1, Inventory, Specifications, Bullet 5, Page I-35.** This section notes the assumptions made regarding the normal fill fractions for various equipment at the terminal. It is unclear what assumptions have been made regarding the normal fill fraction of the pressurized propane bullet tanks and the refrigerated propane storage tanks. This section should be revised to clearly indicate the assumption made regarding the normal fill fractions for the large vessels at the terminal.

49. **I.2.4, Detection/Isolation Philosophy, Specifications, Page I-39.** The second paragraph in this section notes that ESDs are designed to be triggered automatically and will not be able to be overridden by operators. However, the next paragraph contradicts this statement, indicating that ESDs are design to be operated manually. Furthermore, the Process Flow Diagrams included in Appendix II appear to indicate automatic and remotely activated isolation valves around most isolatable sections of the terminal. This section should be revised to resolve this contradiction.

50. **I.3.2, Isolation Failure, Page 43.** The Specifications Section notes that isolation failure may be included in the sensitivity analysis. Furthermore, the Implications of Assumption section notes that the probability of isolation failure has a key influence on the frequency of release events that lead to escalation. No sensitivity analysis is presented in the QRA, and no information is presented in the QRA on the effect of the assumption of no isolation failure on the results of the QRA. The QRA should be revised to include information on the impact of the no isolation failure assumption on the outcome of the QRA.

51. **I.4.4, Release/Discharge Parameters: Other Inputs, Page I-49.** This section discusses other input variables such as discharge velocity, discharge temperature, droplet diameter, and liquid fraction for modeling releases at the terminal. It is unclear from the material presented what input variables the modelers have used for this QRA, as the discussion presented in the Specifications section appears to indicate that these variables are simply calculated in PHAST. This section should be revised to clearly indicate the assumptions made by the modelers for this QRA.

52. **I.4.5, Obstructed Regions, Page I-50.** The section discusses input variables to the TNO multi-energy model for congested regions of the terminal. While the section describes the assumptions that have to be made to complete the modeling exercise, it does not clearly indicate what variable values (such as for the volume blockage ratio) were used to complete the modeling for each congested region of the terminal. This section should be revised to clearly indicate the input variables that have been assumed for each section of the terminal.

53. **I.4.5, Obstructed Regions, Figure I-10, TNO Multi-Energy Curves, Page I-51.** The text provided with this figure references "Curve 5.5." This curve is not shown on the figure. The figure should be revised to clearly indicate the location of Curve 5.5 on the graph.

54. **II.3.2, Hole Size Scenarios, Page II-5.** The definition of "full bore rupture" used in this section and in other tables in Appendix II is not clearly defined, especially as applied to the pressurized propane bullets and refrigerated storage tanks. Additional information is needed throughout this section to clearly define the terms "full bore rupture," "rupture," "Rupture 1," "Rupture 2," and "Rupture 3" as applied to the refrigerated storage tanks.

55. **Attachment II, Process Flow Diagram, LPG Ship Loading.** There is no differential pressure alarm on the filter on the pump discharge line. The filter could plug, but there is no instrumentation showing how to prevent (1) the pumps from "dead-heading" into a blocked filter, (2) the pumps over heating (due to lack of flow), or (3) over pressurizing the discharge line. Additionally, there is no pressure control valve shown indicating the ability to automatically allow recirculation in the event of a plugged filter. It could be that these details will be shown on the piping and instrumentation diagrams (P&ID), but the facility should clarify if these design considerations have been incorporated into the P&ID and if the QRA accounts for potential release scenarios due to overpressure of this unit operation.

56. **Attachment II, Process Flow Diagram , Propane Refrigeration PFD**. The note on this figure states that: "Propane Accumulator to be elevated to prevent and do not pocket. To 3rd stage suction drum." These sentence fragments are unclear and should be revised.

57. **Attachment II, Process Flow Diagram , LPG Railcar Unloading.** There are no pressure controls on the unloading vapor return compressor. It could be that these details will be shown on the P&IDs, but the facility should clarify if these design considerations have been incorporated into the P&ID and if the QRA accounts for potential release scenarios due to overpressure of this unit operation.

58. **IV.3, Release Rate, Second Bullet, Item (b), Page IV-3.** This item notes that the release rate for liquid releases is the average of 0.1 x Q_0 and the Normal Flow Rate (NFR), based on "DNV GL's internal practice applied on previous projects." The text does not provide any other basis for this approach or the effects of this assumption on the outcome of the QRA. The approach is consistent with Section IV.3 and Table III-1, but inconsistent with Assumption 18 (I.4.1, Release/Discharge Parameters: Release Rate). The text should be revised to include additional basis for this approach and its effects on the outcome of the QRA. Assumption 18 should be revised to be consistent with this section.

59. **Figure III-1, Consequence Release Model, Page IV-6.** This figure includes a box titled "Explosion Effect Blast & Fragment." The box is included inside the red dotted line, indicating that these effects were evaluated in the QRA; however, no fragment risk analysis is included. The QRA should be revised to include an analysis of fragment risks.

5.0 Review Summary

The Pembina Portland Propane Terminal QRA is generally a thorough and realistic evaluation of the potential risks and consequences that can be expected due to the operation of the proposed terminal. The document conforms to industry-standard QRA techniques, guidelines, and reference sources. It appears that Pembina has applied generally accepted risk mitigation procedures to the design of the terminal and plans to continue with an integrated QRA process throughout the final design of the terminal.

The QRA provides conservative estimates of the potential risks from the proposed terminal for numerous reasons. These include modeling the consequence analysis based on the assumption that the exposed individual remains at the same location constantly throughout an entire year and the use of UK release frequencies based on off-shore data that likely overestimate the actual release frequency that can be expected from an on-shore terminal.

Adding further conservatism, the Contingency Level Earthquake (CLE) event (1 in 475 years) is the minimum design seismic criteria for this terminal. Note that a design in accordance with the CLE frequency represents a design performance level of controlled and repairable structural damage. A 300 millimeter (12 inch) release from the largest refrigerated propane storage tank is conservatively modeled, and represents the potential consequences from a CLE earthquake. The storage tanks at the terminal are to be designed to a 1-in-2-,475-year event. This information was not updated before the current analysis was performed. The QRA model will be updated later to reflect this.

As noted in the QRA Executive Summary, because there are not requirements for individual and societal risk criteria in the US, the estimated risk levels for the terminal were evaluated

against the UK HSE risk tolerability criteria for individual and societal risk. The QRA results in risk levels that have been accepted for other high risk facilities in Oregon, such as the Umatilla Chemical Agent Disposal Facility that operated near Hermiston, Oregon (SAIC 2002).

Furthermore, the results of the QRA do not provide a basis for rejection of the rezoning request for the environmental overlay. According to QRA Table III-5, Event M03-05Z Jetty Loading Pipe Failure, has a projected frequency of 5.2E-04 per year, which corresponds to 1 leak every 1,923 years.

The majority of the issues identified by Akana relate to improvements that could be made to the report to make it more accessible to the non-technical reader. Revision of the QRA to address the general and specific comments identified in Section 4.0 of this report is unlikely to significantly alter the outcome of the modeled risks. The number of comments should not be interpreted as a commentary on the quality of the report; rather, they are meant to guide the authors to provide additional detail that may be "obvious" to individuals familiar with quantitative risk assessment and LPG terminals but not as obvious to the non-technical reader.

Given the controversial nature of the proposed terminal and recognizing that the QRA is being used as a tool by others to make permitting decisions regarding the proposed terminal, additional information could be presented in the QRA to address various stakeholder concerns. The following are suggested topics that could be addressed as part of the QRA to address these concerns:

+ **Relative Risk.** A discussion of everyday risks (for example, driving) relative to the risks associated with the proposed terminal would provide a better measure of the modeled risks from the proposed terminal for the nontechnical reader. Data from the National Safety Council could be presented.

+ **Conservative Approach.** The QRA model inputs and risks are generally conservative in nature. Additional discussion stressing the conservative nature of model inputs and results could be added to the QRA to address some stakeholder concerns.

+ **Design Standards.** The QRA could be revised to highlight the codes and standards that the terminal will be designed to and any design features that exceed minimum standards. For example, the QRA could be revised to clarify that the proposed terminal is being designed as an essential facility (Category 4), resulting in an increase of all design standards by 50 percent.

+ **BLEVE Evaluation.** Although the QRA models potential BLEVE risks while noting that there would need to be contributing factors to result in this type of an event, the QRA could be revised to provide calculations regarding maximum pool size and fire duration versus containment design, available fuel, and time to overpressure, to provide a clearer

description of the chain of unlikely events and fire duration that would be required to result in such an event.

+ **Natural Disasters**. The QRA does not address the potential for releases to be triggered by natural disasters such as flooding, tornadoes, or lightning strikes at the site. For example, the terminal is within the Zone X Flood Plain. Lightning strikes or tornadoes could also be a potential trigger for releases.

+ **Fragmentation.** The QRA notes that the risks from fragmentation are not addressed. This is offered without explanation. The QRA could be revised to explain for the nontechnical reader why fragmentation risk is not addressed.

6.0 Limitations

The QRA review completed by Akana does not constitute an independent review of the design of the terminal. Based on information presented by Pembina during the March 10, 2015, briefing, terminal design is only approximately 40 percent complete. Design information included in the QRA was reviewed to the extent necessary to determine if the risk assessment was completed in a generally acceptable manner with regards to the identification of isolatable hazard areas within the terminal and the number of potential failure points (that is, the approximate number of valves, instrumentation, flanges, and other devices where a release could occur). This review assumes that the terminal will be designed and constructed in accordance with all applicable codes and standards. None of the comments or recommendations included in this report should be construed as design recommendations and Akana cautions the City of Portland from mandating any design changes based on this assessment.

Numerous operation and design features to be incorporated into the proposed terminal were noted by Pembina during the March 10, 2015, briefing and in the QRA. However, detailed information regarding these features were not included in the QRA, and were not validated by Akana. These features include but are not limited to:

+ Fire water storage capacity and deluge system capacity and design

+ Automatic leak and fire detection system design

+ Automatic shut-off valve and isolation valve design

+ Geotechnical and structural design features such as an isolation wall and tank support pilings

+ Corrosion protection

+ Operational procedures including start-up, shutdown, malfunction, and emergency response plans

The level of review did not include independent verification of every input variable to the model. The QRA assumptions and input variables were reviewed only for general reasonableness, based on random checks using the reference guidance used by the authors, reviews of other available literature and guidance, and the professional opinion of the reviewer. Inconsistencies and other concerns are summarized in Section 4.0. The QRA did not include the detailed PFDs available to the modelers; so inputs such as propane line diameters, flow rates, temperatures, and pressures at various points in the system could not be independently verified.

Akana also did not evaluate the specifics of the modeled results. The focus of the review was on the frequency and model inputs. The model is assumed to function as designed and validated by other independent organizations (as presented in Section 3.0 above).

As noted in the QRA, the risks evaluated are limited to the potential risks due to events within the terminal boundary. The potential for rail car accidents due to increased train activity within the City of Portland are not within the scope of the QRA and are not regulated by the City.

Risks associated with transportation of the propane once it has been loaded onto a ship are being addressed by a River Security Assessment required by the U.S. Coast Guard and the Marine Safety Transportation Act (Public Law 107-295). These activities are not within the scope of the QRA and are not regulated by the City.

Finally, the comments presented are limited to significant technical issues. Comments regarding editorial issues, format, and presentation of the QRA data have not been provided.

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