Portland General Electric Company
Trojan ISFSI
71760 Columbia River Hwy
Rainier, Oregon 97048

March 10, 2020
VPN-001-2020

Trojan ISFSI
License SNM-2509
Docket 72-017

ATTN: Document Control Desk
Director, Division of Spent Fuel
Management, Office of Nuclear
Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Trojan Site-Specific Independent Spent Fuel Storage Installation (ISFSI)
License Change Application (LCA) 72-08, Potential Explosion Effects on ISFSI

Pursuant to 10 CFR 72.56, Portland General Electric (PGE) submits this license change application (LCA) for an amendment to Trojan Independent Spent Fuel Storage Installation (ISFSI) specific license No. SNM-2509. PGE seeks NRC approval of a change to the Trojan ISFSI Safety Analysis Report (SAR) description of the evaluation of the explosion accident event originating from cargo transported by rail and waterborne vessels that could potentially affect the ISFSI. The explosion accident event has been reevaluated because of the discovery of a new ship anchorage point installed by the United States Army Corps of Engineers in the Columbia River just outside the Trojan ISFSI Controlled Area Boundary (CAB).

When it was discovered, PGE evaluated the potential dose consequences to personnel occupying ships at anchor from ISFSI operations and found that the estimated dose received by those personnel was insignificant (i.e., well within the regulatory limits in 10 CFR 72.104). Further, PGE determined via survey that any anchored ship would be outside the 200-meter ISFSI CAB and that Trojan continued to meet the annual dose requirements of 10 CFR 72.104 as confirmed by dosimetry data acquired from environmental dosimeters located around the CAB.

However, during a subsequent NRC inspection of the ISFSI (see Inspection Report 072000170/ 2015001), the inspector questioned the potential for the new anchorage point to create new, or more severe offsite explosion effects on the ISFSI compared to those discussed in the Trojan ISFSI SAR (see URI 72-17/1501-01, Use of Prescott Anchorage Bounded by Trojan's FSAR). In response to this question, PGE initiated an evaluation of potential explosion events and began by reviewing the explosion event evaluation described in the ISFSI SAR. That review concluded

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that certain statements in the Trojan ISFSI SAR pertaining to the deterministic evaluation of the design basis explosion event were unable to be confirmed. Therefore, PGE commissioned a comprehensive new evaluation of potential explosion events on the Trojan ISFSI from both rail and shipping traffic, including consideration of vessels periodically stationed at the new anchorage point in the Prescott Anchorage Area. The current description of the explosion event in the ISFSI SAR will be replaced by a description of the new evaluation in two locations in the document.

When this proposed SAR change was reviewed by PGE pursuant to the requirements in 10 CFR 72.48(c)(2), a determination was made that NRC approval was required before the change could be implemented. The enclosed LCA requests NRC approval of the subject SAR change. No changes to the Trojan ISFSI Technical Specifications or Technical Specification Bases are requested as part of this LCA. PGE requests an implementation period of 90 days after approval of the amendment to update the ISFSI SAR and make other necessary changes.

This application is executed in original form and signed under oath or affirmation as required by 10 CFR 72.16(b) and (c). Please contact Mr. Mark Tursa of my staff at 503-556-7030 if you have questions regarding this correspondence.

Sincerely,

Bradley Y. Jenkins
Vice President, Utility Operations

Enclosures:
1. LCA 72-08, Revision 0
2. Sargent & Lundy Calculation No. 2017-09306, "Offsite Transportation Explosion Hazard Evaluation," Revision 0

c: Director, NRC Region IV, DNMS
Todd Cornett, Siting Division Administrator, ODOE

State of Oregon,)
)
)
County of Multnomah)

I, Bradley Y. Jenkins, being duly sworn, subscribe to and say that I am the Vice President, Utility Operations for Portland General Electric Company, the applicant herein; that I have full authority to execute this oath; that I have reviewed the foregoing; and that to the best of my knowledge, information, and belief the statements made in it are true.

Date: March 10, 2020

Bradley Jenkins

Bradley Y. Jenkins
Vice President, Utility Operations

On this day appeared before me Bradley Y. Jenkins, to me known to be the individual who executed the foregoing instrument, and acknowledged that he signed the same as his free act.

GIVEN under my hand and seal this 10th day of March 2020.

Karen Jean Lewis

Notary Public in and for the State of Oregon
Multnomah County

OFFICIAL STAMP
KAREN JEAN LEWIS
NOTARY PUBLIC-OREGON
COMMISSION NO. 978394
MY COMMISSION EXPIRES AUGUST 26, 2022

Residing at Portland, Oregon

My commission expires August 26, 2022

ENCLOSURE 1

TO VPN-001-2020

Trojan ISFSI

License Change Application (LCA) 72-08

LICENSE CHANGE APPLICATION (LCA) 72-08
CHANGES TO TROJAN ISFSI LICENSE NO. SNM-2509

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1. Summary of Proposed Changes

This License Change Application (LCA) 72-08 proposes changes to Trojan ISFSI SAR Sections 2.2 and 8.2 to update the discussion of the explosion accident design criteria and event evaluation. This LCA also proposes to add new Table 8.2-7 to the ISFSI SAR. Section 8.2.8.2 is further updated to incorporate by reference the Sargent & Lundy (S&L) explosion evaluation (Reference 1 of this LCA 72-08 and Reference 19 of PGE-1069 proposed Rev. 16, Trojan ISFSI SAR) in lieu of repeating all of the information contained in the evaluation in the SAR. The changes to each SAR section are summarized below and proposed mark-ups of the Trojan ISFSI SAR are provided in Attachment A to this enclosure.

2. Description and Evaluation of Proposed Changes

2.1 Background

In August 2012, the United States Army Corps of Engineers (USACE) installed an anchor buoy for the newly-designated Prescott Anchorage Area on the Columbia River near the Trojan ISFSI site. PGE was not notified of the installation of the new anchor buoy, which is located in the Columbia River just beyond the Trojan ISFSI 200-meter controlled area boundary (CAB). The potential impacts of the anchorage of ships at this proximity to the Trojan ISFSI was not previously evaluated. Upon learning of the new anchorage location, PGE performed an evaluation of the potential dose consequences to personnel located on an anchored ship and, as confirmed by dosimetry located around the ISFSI CAB, confirmed there would be no significant dose to personnel aboard a ship conservatively assumed to be anchored at the 200-meter CAB. That is, the actual ISFSI environmental dosimetry results since the ISFSI was fully loaded, from dosimetry placed at the CAB, were well within the regulatory limits specified in 10 CFR 72.104.

However, during a subsequent NRC inspection of the ISFSI, a question was posed by the inspector as to the potential for the new anchorage point to create new, or more severe offsite explosion effects on the ISFSI compared to those discussed in the Trojan ISFSI SAR. In response to this question, PGE entered the issue into its corrective action program (CAP) to formally evaluate the impact of potential explosion events on the Trojan ISFSI (Reference 2). The evaluation began with reviewing the explosion event evaluation described in the ISFSI SAR and supporting documents. That review concluded that certain statements in the Trojan ISFSI SAR pertaining to the deterministic evaluation of the design basis explosion event were unable to be confirmed. Several of these statements were extracted from the contemporaneous Trojan power plant 10 CFR Part 50 FSAR for the (now-terminated) Trojan plant operating license at the time the Trojan ISFSI license application was being prepared. The basis for these statements was not able to be substantiated as part of this CAR evaluation. Therefore, PGE commissioned a comprehensive new evaluation of potential explosion events on the Trojan ISFSI from both rail and shipping traffic, including consideration of the new anchorage point in the Prescott

Anchorage Area. The current description of the explosion event in the ISFSI SAR will be replaced by a description of the new evaluation in two locations in the document.

2.2 Assessment of the Current Trojan ISFSI SAR Description of the Explosion Event

Trojan ISFSI SAR Sections 2.2.3.1 and 8.2.8.2 describe the design criteria and evaluation of potential explosion events in reasonable proximity to the ISFSI site. These events include potential explosions from cargo transported on the Columbia River and the nearby railroad line. Both SAR sections currently discuss the probability of a rail or shipping explosion event being so small that the event can be considered not credible (i.e., the probability is less than 1×10^{-6} per year). However, in addition to describing the probability of an explosion the SAR also discusses the consequences of such an accident; specifically, the resultant overpressure that would be experienced by the casks on the ISFSI pad.

This deterministic evaluation was included in the ISFSI licensing basis as an approved explosion evaluation that could be relied on if the probability of the explosion accident event increased above 1×10^{-6} per year after initial licensing. However, several statements in the current SAR appear to have incorrectly characterized the deterministic explosion event. Upon further review as part of the Reference 2 extent-of-condition, the SAR statements do not have the technical basis to conclude that the explosion accident consequences are within the previously-established acceptance criteria. A summary of these discrepancies is provided below to provide context for PGE requesting NRC approval of a new explosion event evaluation in this LCA that includes both deterministic and probabilistic components as discussed in Section 2.3 below.

Either or both of Sections 2.2.3.1 and 8.2.8.2 of the current ISFSI SAR include the following statements pertaining to an explosion event that could affect the Trojan ISFSI:

1. Section 2.2.3.1 states "The FSAR analysis used an overpressure limit of 2.2 psi. This overpressure is the maximum overpressure that can be generated by the atmospheric shock from an explosion." These two statements are not consistent in that the 2.2 psi is represented both as an acceptance criterion and as the maximum calculated overpressure as a result of an explosion.

2. Section 8.2.8.2 states that the casks are able to withstand a tornado wind pressure of 2.3 psi (based on 360 MPH wind velocity) and up to 5.87 psi is required for the casks to slide or overturn. Section 8.2.8.2 further states that using an overpressure acceptance criterion of 4.4 psi (twice the 2.2 psi value) is conservative because it is less than the 5.87 psi required to slide the Concrete Casks. The basis for the 4.4 psi value is not clear but appears to have been chosen by the Trojan power plant designers to ensure the pressure of a reflected wave was less than the 5 psi limit for safety-related plant structures.

3. Section 2.2.3.1 states "The minimum weight of explosives that could cause a 2.2 psi overpressure was calculated by the FSAR analysis as 70,000 (pounds of TNT equivalent)." There is no distance specified in the SAR for this combination of explosive material quantity and the 2.2 psi overpressure value. PGE has surmised, based on a review of Trojan power plant drawings, that the 250 feet distance is the approximate distance between the rail line and the nearest former safety-related power plant structure. In its initial CAR evaluation, PGE concluded that the detonation of 70,000 lbs TNT equivalent would produce a substantially higher overpressure than 2.2 psi at 250 feet based on the review of relevant literature. In fact, PGE's internal estimates of the overpressure that would be caused by the explosion of 70,000 lbs TNT equivalent at 250 feet are on the order of 27 psi. At a more realistic distance of 750 feet (representing the span between the rail line and the Concrete Casks on the ISFSI pad), PGE estimated in an informal calculation that the overpressure from the detonation of 70,000 lbs of TNT equivalent to be approximately 3.4 psi.

Because the SAR contains information pertaining to the explosion event that that is not consistent or clearly supportable as to its technical basis, a new explosion evaluation was performed. This new evaluation forms the basis of the new SAR information proposed by this LCA to replace the existing SAR information.

2.3 Summary of the New Trojan ISFSI Explosion Evaluation

The S&L analysis (Reference 1) used a combined deterministic and probabilistic approach to evaluate sources of explosion from rail and river movement of chemicals in proximity to the ISFSI. This included explosions at the source (vessel or railcar) and, for certain chemicals, the ignition of a vapor cloud traveling from the source to the ISFSI site. Key information from the Reference 1 report is summarized in the subsections below with references to the S&L report provided for additional information.

The discussion in the following subsections is intended to provide a summary of the Reference 1 document without excessive repetition of information. The discussion below is completely consistent with Reference 1, although certain editorial changes have been made to improve clarity for the NRC staff reviewers in an effort to reduce the number of potential questions, improve the overall efficiency of the review, and assist the NRC staff with the writing of the Safety Evaluation Report for the application.

2.3.1 Acceptance Criteria (Reference 1, Section 1.0)

Both deterministic acceptance criteria and probabilistic acceptance criteria used in the new explosion evaluation. The probabilistic acceptance criteria are only applied for explosion events whose consequences do not meet the deterministic acceptance criteria.

Deterministic Evaluation Acceptance Criteria

a) The distance between the hazardous chemical source and the site must be greater than the distance calculated for the quantity of chemical to cause a 2.2 psig overpressure at the ISFSI using the method described in Regulatory Guide (RG) 1.91 (Reference 3 of LCA 72-08 and Reference 20 of PGE-1069 proposed Rev. 16, Trojan ISFSI SAR) and the Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering (2nd Edition). (See below for additional discussion pertaining to the choice of 2.2 psig as the overpressure limit.) In addition, consistent with RG 1.91, if the calculated overpressure at the ISFSI is less than or equal to 1.0 psig, blast-generated missile effects and ground motion are considered acceptable and need not be evaluated further.

b) For a traveling vapor cloud, the gas plume must disperse enough to ensure the concentration of the chemical is less than the lower explosive limit (LEL) for that chemical at the ISFSI location.

The external pressure limit for the cask system was chosen to be 2.2 psig. This is consistent with the value cited Trojan ISFSI SAR Section 2.2.3.1 and incudes significant conservatism when compared to the design basis accident external limit of 60 psig for the Holtec MPC (HI-STORM 100 FSAR, Revision 1, Table 2.2.1). Further, because they are ventilated, the Concrete Casks have no established external pressure limit. As stated in Trojan ISFSI SAR Section 8.2.8.2, the loaded Concrete Casks can withstand up to 5.87 psi pressure without sliding. Therefore, the 2.2 psig overpressure acceptance criterion includes a factor of safety of over 25 for MPC external pressure limit and over 2.5 for cask sliding.

Probabilistic Evaluation Acceptance Criterion

For those analyzed explosion events whose results exceed one or more of the deterministic acceptance criteria, the frequency of a hazardous release for a chemical must be shown to be less than $1x10^{-6}$ hazards per year (Reference 3, p. 6) to consider that explosion event non-credible.

2.3.2 Definitions (Reference 1, Section 3.0)

A small number of terms used in the Reference 1 explosion evaluation and this LCA are excerpted below:

Chemical: Any substance or material that could potentially be a hazard

Lower Explosive Limit (LEL): The LEL of an explosive chemical is the lowest concentration of that chemical capable of supporting an explosion, per the SFPE Handbook (p. 3-312).

Upper Explosive Limit (UEL): The UEL of an explosive chemical is the highest concentration of that chemical capable of supporting an explosion (SFPE Handbook, p. 3-312).

Vapor Cloud Explosion (VCE): A VCE is an explosion as a result of a mass of gas in a vapor cloud being ignited (SFPE Handbook, p. 3-325).

Boiling Liquid Expanding Vapor Explosion (BLEVE): A BLEVE is a violent rupture of a pressure vessel containing a chemical that is a gas at standard conditions but is stored as a pressurized saturated liquid (SFPE Handbook, p. 3-327).

2.3.3 Input Data (Reference 1, Section 4.0)

2.3.3.1 Distances between the ISFSI Site and Explosion Sources

The distances between the ISFSI facility location and the rail line, Columbia River shipping channel, and the Prescott Anchorage Area were taken from sources such as drawings, charts, and other tools, such as Google Maps™.

2.3.3.2 Site Meteorology

Site maximum and minimum ambient temperatures are 107°F and -3°F, respectively, per Trojan ISFSI SAR Section 2.3.1.2. Other meteorological data are shown in Appendix 1 of Reference 1 (wind frequency and distribution) and Table 4.2-1 of Reference 1 (atmospheric stability class per RG 1.23, Revision 1).

2.3.3.3 Chemical Data

Water: Density = 61.91 lbm/ft^3 at 107°F and 1 atmosphere
Thermal Conductivity = 0.634 W/m-K at 107°F
Specific Heat = 4.179 kJ/kg-K at 107°F

2.3.3.4 Other Input Parameters

Sections 4.3 through 4.10 of Reference 1 provide the chemical, railway transportation, and waterborne transportation data relevant to the explosion evaluation, including chemical and physical properties.

2.3.4 Assumptions (Reference 1, Section 5.0)

The assumptions used in the Reference 1 explosion evaluation are condensed and summarized below. Please refer to Section 5.0 of Reference 1 for the sources of the assumptions.

1. Liquid leaks form a circular puddle centered at the release point and have a uniform depth of 1 cm. Minimizing the puddle depth maximizes the surface area, and therefore the evaporation rate. A 1 cm minimum thickness is consistent with the guidance in NUREG-0570, "Toxic Vapor Concentrations in the Control Room Following a Postulated Accidental Release," June 1979 (Reference 5).

2. When determining plume rise, it is assumed that the chemicals reach atmospheric pressure and temperature immediately after the release. This is acceptable because a release from a source at a higher pressure would have rapid turbulent mixing, and quickly reach steady conditions; and a release from a source at atmospheric pressure will be a liquid which evaporates due to the wind, which would cause mixing.

3. RG 1.23 does not include an upper bound on the temperature gradient for Stability Class G. Therefore, for Stability Class G it is assumed that the maximum temperature gradient is 8°C/100m. This assumption is based on engineering judgment considering the other temperature gradient values in RG 1.23.

4. Atmospheric pressure is assumed to be 14.7 psia. This is reasonable because the site is adjacent to the Columbia River off the Pacific Ocean (i.e., essentially at sea level).

5. Based on the vapor pressure of fuel oil, kerosene, and motor oil, it is assumed that gas oil, lube oil, petroleum crude oil, petroleum jelly, asphalt, and other chemicals with petroleum or oil in their name have a vapor pressure less than 10 mm Hg at 100°F.

6. For waterborne commerce, the USACE provides the total number of vessel trips in a year and the yearly mass shipped for each commodity. However, a specific commodity's yearly number of trips or mass per trip is not known. Thus, yearly shipment quantities in terms of mass are assumed to be evenly distributed volumetrically throughout the total number of trips in a year.

7. Chemicals that are modeled as being liquids are assumed to be stored at atmospheric temperatures. This increases the initial mass that flashes to vapor, which maximizes concentration and energy.

8. Methane is transported via cargo ships condensed to a liquid at close to atmospheric pressure by cooling it to below its boiling point, -259°F. Liquefied methane is conservatively assumed to be stored at -220°F in this analysis. Assuming liquid at a higher temperature increases the initial mass that flashes to vapor which maximizes concentration and energy.

9. The molecular weight of gasoline that is used for dispersion analyses, 86.91, is calculated assuming the relative vapor density is 3 (86.91 = 3 x 28.97, the molecular weight of air) and density is proportional to molecular weight per the ideal gas law.

Using the lowest vapor density in the range of interest per Table 4.3-1 of Reference 1 is conservative because a smaller molecular weight will lead to a smaller conversion from volume based concentration (ppm) to mass based concentration (mg/m3 or lbm/ft3). The vapor density of gasoline used for stationary explosion analyses is assumed to be 4. This maximizes the mass of vapor in a tank. The vapor pressure of gasoline is assumed to be 1 atm (14.7 psia) at 107°F (i.e., the normal boiling temperature at atmospheric pressure is assumed to be 107°F). This is consistent with the Material Safety Data Sheet for gasoline, which states that the Reid vapor pressure at 100°F is between 6 and 15 psia. The same vapor pressure assumption is used for naphtha. This is reasonable since the vapor pressure of naphtha at 70°F, 0.732 lbf/in2 (38 mm Hg), is much less than the vapor pressure of gasoline at 20°C (68°F), 220-450 mm Hg.

10. All chemicals are assumed to follow the ideal gas law.

11. When determining the explosive pressure in an enclosed vapor cloud explosion for a chemical that is liquid at atmospheric conditions and stored in a tank as a liquid, the mass of vapor is calculated assuming the entire volume of the tank is vapor at the UEL. This methodology is also applied for dust cloud explosions. This is conservative because it results in the largest possible amount of explosive mass. To simplify the analysis of the railcar vapor cloud explosions, UEL is ignored (i.e., a UEL of 100% is assumed); this is further conservative since a vapor cloud explosion cannot actually occur if the entire tank is filled with vapor (the fuel-air ratio would be too rich).

2.3.5 Methodology (Reference 1, Section 6.0)

The methodology used in the Reference 1 explosion evaluation consisted of the following four tasks:

1. Chemical screening to eliminate non-hazardous sources
2. Calculating the explosive overpressure due to a chemical explosion
3. Determining the concentration in relation to the LEL from a chemical vapor release that travels to the ISFSI site
4. Performing a probabilistic analysis, if necessary, for chemicals that exceed the limits (acceptance criteria) in the deterministic analysis.

2.3.5.1 Screening of Explosion Sources (Reference 1, Section 6.1)

The first step of the analysis was to eliminate the non-hazardous chemicals being shipped via railcar and vessel. Chemicals can be screened out by meeting either of the following:

1. Material is non-explosive.

2. Vapor pressure of liquid chemical is less than 10 mm Hg (0.013 atm) at 100°F. Per RG 1.78 (Reference 4), this is an acceptable screening criterion in the analysis of toxicity, which is often on the order of parts per million (0.0001%). Therefore, it is reasonable to use for explosion analyses because explosive limits are typically greater than a tenth of a percent (0.1%).

In addition, chemicals that are bounded by explosions of the same chemical both in terms of distance and mass are screened out. From Assumption 5, gas oil, lube oil, petroleum crude oil, petroleum jelly, asphalt, and other chemicals with petroleum or oil in their name have a vapor pressure less than 10 mmHg and are therefore screened out.

Chemicals that cannot be screened out by the above methods are then analyzed using the methods described below.

2.3.5.2 Determination of the Explosive Overpressure Due to a Chemical Explosion

The explosive overpressure at the nearest ISFSI cask due to a chemical explosion is calculated using one of the following methods, summarized below. For additional detail, please refer to Section 6.2 of Reference 1.

2.3.5.3 TNT Equivalency

The TNT Equivalence technique for determining explosive overpressure is taken from RG 1.91. With this technique, the mass of chemical that explodes is converted into an equivalent mass of TNT. The standoff distance is calculated using Equation 6.2-1 of RG 1.91, repeated below. Transportation routes and nearest approaches are identified in Sections 4.6 and 4.7 of Reference 1.

$$R_{min} = Z \cdot W^{1/3} \qquad \text{(Equation 2.3-1)}$$

Where:

R_{min} = Distance from explosion (ft) for desired maximum blast wave pressure
Z = Scaled distance ($ft/lb_m^{1/3}$) (from Figure 3-16.14 from the SFPE Handbook)
W = Equivalent mass of TNT (lb_m)

For this analysis, the SFPE Handbook, the book *Explosion Hazards and Evaluation* (Baker, et. al.), and NUREG-1805, "Fire Dynamics Tools (FDT^S) Quantitative Fire Hazard Analysis Methods for the Nuclear Regulatory Commission Fire Protection Inspection Program," provide methodology for determining the equivalent mass of TNT for vapor cloud explosions in Equation 2.3-2 below.

From these references and Table B.3 of the FEMA "Handbook of Chemical Hazard Analysis Procedures," a yield of 0.1 is a conservative upper bound for an unconfined vapor cloud large explosion for the chemicals in this evaluation. It is worth noting that the SFPE Handbook states

that some small explosions are estimated to have a yield of 0.01. However, large explosions are those of interest in this analysis. For the explosion of vapor confined in a tank, a yield of 1.0 is used per NUREG-1805 (p. 15-9]. This TNT equivalence is then used in Equation 2.3-1 above to determine standoff distance.

$W_{TNT} = (\alpha \cdot \Delta H_C \cdot m)/\Delta H_{TNT}$ (Equation 2.3-2)

Where:

W_{TNT} = TNT Equivalent mass (kg)
α = Yield fraction (-)
ΔH_C = Heat of combustion of the chemical (kJ/kg)
ΔH_{TNT} = Heat of explosion/detonation in a TNT explosion = 4500 kJ/kg
$\dot{m}$ = Mass of chemical exploded (kg)

For solid explosives in this evaluation, the equivalent mass of TNT is simply equal to the yield multiplied by the mass of the explosive. Yield fractions for the various solid explosives in this analysis are identified Section 4.4 of Reference 1.

For vapor cloud explosions of normal boiling point (NBP) chemicals, the mass of chemical exploded is the full volume of the container filled with vapor at the chemical's UEL, with exception of the analysis of BNSF railcar vapor cloud explosions which conservatively ignores UEL, i.e., a UEL of 100% is assumed (Assumption 11). Because density is higher at low temperatures, the site design minimum temperature is used in the ideal gas law to determine the explosive mass. Equations 24.45 and 24.46 in the *Mechanical Engineering Reference Manual* (MERM) (12th Edition) provide the basis for the ideal gas relation shown in Equation 2.3-3 below:

$m = (P \cdot 144 \cdot V)/((R_o/MW) \cdot T)$ (Equation 2.3-3)

Where:

P = Absolute pressure (psia)
V = Volume (ft^3)
R_o = Universal Gas Constant = 1545 $ft\text{-}lb_f/lb_{mol}\text{-}^oR$
MW = Molecular Weight (lb_m/lb_{mol})
T = Temperature (^oR)

For vapor cloud explosions of low boiling point (LBP) chemicals that are stored pressurized as liquefied gases (e.g., ammonia, methane, propane, etc.), the mass of chemical exploded is equal to the mass that initially flashes to vapor upon release. In this case, factoring of the UEL is not applied since it is inherent in the use of the yield fraction for an unconfined vapor cloud explosion, $\alpha = 0.1$, as discussed above. The initial puff mass is found by multiplying the liquid (shipment) mass by the expansion mass quality, *x* (see discussion on BLEVE in Section 2.3.5.5 below for the mass quality derivation). Alternatively, the initial puff mass can be found by the

product of the liquid mass and the flashing fraction, F_i (see Section 2.3.5.5 for the flashing fraction calculation).

For solid explosives, the mass of the chemical is simply equal to the shipment mass.

2.3.5.3 Heat of Combustion Alternative Calculation

For the chemicals butyl acrylate, 1-difluoroethane, ethylene glycol diethyl ether, and 1-methoxy-2-propanol, documented heats of combustion could not be found by S&L. Therefore, the heat of combustion (kJ/kg) for each was calculated as described in Section 6.2.1.1 of Reference 1.

2.3.5.4 Combustible Dust

Explosive overpressure is also calculated for solids that are identified as combustible in dust form. Evaluation of combustible dust clouds is inherently conservative since a small explosion must first occur to result in dust becoming airborne (Baker et. al.). This dust would then serve as the fuel source for a second explosion. The combustible dust mass and resulting explosion overpressure are related using Equation 70.5 from the SFPE Handbook:

$$M_{exp} = (P_{es}/DLF) \cdot (C_w/P_{max}) \cdot (V_b/\eta_D) \qquad \text{(Equation 2.3-4)}$$

Where:

M_{exp} = Dust mass (kg)
P_{es} = Overpressure due to last wave (bar)
DLF = Dynamic load factor (-) = 1.5 (per SFPE Handbook, p. 2774)
C_w = Minimum flammable concentration (kg/m^3)
P_{max} = Maximum explosion pressure (bar)
V_b = Blast volume (m^3) = $2/3\pi R^3$ = Hemispheric volume with R = standoff distance from detonation source
η_D = Entrainment fraction (-) = 0.25 (SFPE Handbook, P. 2774)

For dust cloud explosions, the mass of chemical exploded is the full volume of the container filled with dust at the chemical's UEL (Assumption 11).

2.3.5.5 Boiling Liquid Expanding Vapor Explosion

The vessel rupture blast wave generated during a BLEVE is characterized by the energy released in the fluid expansion from the vessel rupture pressure to atmospheric pressure. This energy is given by Equation 3-14 of the SFPE Handbook (p.3-327]:

$$E_e = m(u_r - u_a) \qquad \text{(Equation 2.3-5)}$$

Where:

E_e = Blast wave energy for fluid expansion (kJ or Btu)
m = Mass of fluid in the storage vessel (kg or lbm)
u_r = Fluid internal energy at rupture conditions (kJ/kg or Btu/lbm)
u_a = Fluid internal energy after expansion (kJ/kg or Btu/lbm)

The mass of fluid is conservatively computed based on the vessel volume and the density of saturated liquid at atmospheric pressure, even though the liquid storage temperature is greater than the normal boiling point temperature, and the liquid density decreases with increasing temperature. The initial internal energy, u_r, is taken as that of saturated liquid at the ambient temperature.

The expansion process is modeled as occurring isentropically, and thermodynamic data are used to determine the mass fraction of liquid which expands to vapor. The initial entropy of the liquid at the time of tank rupture is denoted by s_r. The entropy of the liquid-vapor mixture after expansion is s_2. Because the expansion process is isentropic, by definition $s_r = s_2$.

The entropy of any single-component two-phase mixture is given by Equations 24.41 and 24.36 of MERM as:

$$s = s_f + x(s_g - s_f) \qquad \text{(Equation 2.3-6)}$$

where 'x' is the mass quality, and the 'f' and 'g' subscripts refer respectively to saturated liquid and vapor. For expansion to atmospheric pressure, the entropy of saturated liquid and saturated vapor are known. The fraction of initial liquid mass which flashes to vapor can be determined from the following relation, using the known initial entropy of the single-phase liquid.

$$s_2 = s_r = s_f + x(s_g - s_f) \qquad \text{(Equation 2.3-7)}$$

Solving for the mass quality gives:

$$x = (s_r - s_f)/(s_g - s_f)$$

To maximize the value of x, the value of s_r is conservatively taken as that of saturated liquid at the ambient temperature, even though the chemical may be stored in insulated tanks.

Once the mass quality is determined, the internal energy of the isentropically expanded liquid-vapor mixture, u_a, can be determined according to the following relation:

$$u_a = u_f + x(u_g - u_f) \qquad \text{(Equation 2.3-8)}$$

With u_a computed, the value of E_e can be calculated and the blast wave overpressure determined through conversion to equivalent mass of TNT and the use of the scaled distance parameter as described in Section 2.3.5.3.

2.3.5.6 Traveling Vapor Cloud Explosion

For chemicals that pose an explosive hazard due to a traveling vapor cloud, the concentration of the vapor resulting from a chemical release was analyzed in Reference 1. RG 1.78 and NUREG-0570 describe the methods for evaluation used. The standoff distance is defined as the distance where the concentration of the flammable vapor at the location of the cask is just less than the LEL. Note that an unconfined vapor cloud explosion would not generate sufficient overpressure to damage the cask. If the concentration of the flammable vapor is above the LEL at the cask location, a damaging detonation could occur at the ISFSI.

An important component of calculating the vapor cloud concentration is accounting for atmospheric dispersion downwind of the chemical leak. Dispersion causes the vapor to become less concentrated with distance. When calculating atmospheric dispersion, conservative meteorological conditions are used. The worst case wind speed must be found iteratively. A low wind speed may be conservative in some cases while a high wind speed may be more conservative in others because of the effects of meander (discussed further in Section 6.3 of Reference 1). As suggested in RG 1.78 (p. 4), the worst case weather conditions that are exceeded less than 5% of the year at the site were used.

There are two methodologies that can be followed in order to determine the concentration following a release. First, the entire mass of the chemical can be analyzed as being released as a vapor all at once. This is a puff release. Dilution of the initial puff may occur if gases are stored under pressure prior to release due to air entrainment. Second, if the chemical is stored as a liquid, it can spill from its container and evaporate over time. If the chemical has been pressurized, some of the mass may instantly flash to vapor in an initial puff. Combined, this is a puff-plume release. A puff release is more conservative because the peak concentration of chemical is higher. The chemical concentration was calculated using Mathcad, based on the methodology discussed in Sections 6.3.1 through 6.3.3 of Reference 1, which are not repeated here due to length.

Additional discussion of the traveling vapor cloud analysis is included in the Mathcad models, which are documented in Appendices 4 and 6 of Reference 1.

2.3.5.7 Probabilistic Analysis

For transported chemicals that do not meet the acceptance criteria from the above deterministic analyses, a probabilistic analysis was used to address the potential threat. Probabilistic analysis was necessary for several vessel explosions hazards in this evaluation. The purpose of a probabilistic analysis is to show that the frequency of a hazard is less than $1x10^{-6}$

hazards per year, based on RG 1.91 [Ref 2.2, p.6]. In addition, the Standard Review Plan, NUREG-0800 Section 2.2.3 states that a hazard occurring with a probability of $1x10^{-7}$ per year, or greater, is a design basis event when accurate data are used. If data are not available to make an accurate estimate, a hazard is a design basis event if the probability of occurrence is greater than $1x10^{-6}$ per year provided qualitative arguments can be made to show the realistic probability is lower. For this analysis, a rate of a hazard for each vessel trip was calculated. This rate was then used to determine a number of allowable shipments of each chemical. The number of allowable shipments was compared to the actual number of shipments in order to determine if the hazard is of acceptably low probability to dismiss as a credible event.

Please refer to Section 6.4 of Reference 1 for a more detailed discussion of the probabilistic analysis method and the specific determination of the allowable number of vessel trips to exceed the $1x10^{-6}$ probability threshold (section 6.4.1) as well as the likelihood of an explosion while a ship is at anchor at the Prescott Anchorage (Section 6.4.2).

The actual number of vessel trips of each chemical is unknown. However, data from the USACE have been collected that are used to provide an estimate for the number of trips (see Section 4.7.2 of Reference 1). The USACE data were reviewed for the ten years from 2006 through 2015. The USACE data include information on the total number of vessel trips in a year and the yearly mass shipped for each commodity. Section 7.4 of Reference 1 provides the calculation of the number of shipments for each chemical that can be compared to the number needed to exceed the $1x10^{-6}$ probability threshold.

2.3.6 Sources of Explosion Evaluated (Reference 1, Section 7.0)

The S&L analysis identified, screened, and evaluated the sources of explosion from rail and river traffic for impacts on the Trojan ISFSI. The identification, screening, and evaluation of the explosion sources associated with each of the two transportation modes are summarized in Subsections 2.3.6.1 and 2.3.6.2 below. The detailed discussion of the explosion numerical analysis in provided in Section 7.0 of Reference 1.

2.3.6.1 Rail Chemicals

Burlington Northern Santa Fe (BNSF) identified the commodities that were shipped on their railroad near the Trojan ISFSI site in 2016. The complete list of commodities shipped by BNSF rail is provided in Table 7.1-1 of Reference 1. There were a total of 101 commodities identified and dispositioned as "Analyze" (49), "Non-explosive" (28), "Bounded" (17) or "Low Vapor Pressure" (7). Commodities dispositioned "Non-explosive" or "Low Vapor Pressure" were screened out of further evaluation because they did not represent an explosion threat. The commodities dispositioned as "Bounded" were addressed by the evaluation of another commodity, which provided a conservative result compared to the first commodity.

The type of explosion analysis performed is indicated in Table 7.1-1 of Reference 1 for the commodities that did not screen out or were not considered bounded. Explosive chemical vapors were analyzed for both stationary and traveling vapor cloud explosions (VCE). If the chemical is normally stored as a pressurized liquid – has a low boiling point (< 107°F) – then it was also analyzed for a boiling liquid expanding vapor explosion (BLEVE). Solid explosives are analyzed as stationary explosions only.

The only analyzed chemical transported on the Portland & Western Railroad (PNWR) near the Trojan ISFSI site is ethanol shipments for the Global Partners Port Westward industrial park located in Clatskanie, Oregon. The ethanol shipments are analyzed for both stationary and travelling vapor cloud explosions.

Railcar commodity shipment weights are not provided. Therefore, the BNSF (4-axle) railcar gross weight restriction of 286,000 lbm is used. This is conservative because maximum cargo capacity is much less than the gross railcar weight.

2.3.6.2 Vessel Chemicals

Data from the USACE were used to determine the commodities that are transported on the Columbia River. The vessel commodities are listed in Table 7.2-1 of reference 1. The same approach was used to disposition the vessel commodities as was used for the rail commodities. There were a total of 136 vessel commodities identified and dispositioned as "Analyze" (21), "Non-explosive" (107), "Bounded" (0) or "Low Vapor Pressure" (8). Commodities dispositioned "Non-explosive" or "Low Vapor Pressure" were screened out of further evaluation because they did not represent an explosion threat. Table 7.2-2 of Reference 1 lists the 21 commodities, the associated chemical used in the analysis, and the type of hazard analyzed for each (e.g., vapor cloud explosion, BLEVE, stationary explosion, etc.). Table 7.2-3 identifies the analyses performed by grouping the commodities by chemical and the type of explosion hazard analysis required.

2.3.6.3 Spill Size Probability and Vessel Trips

A key input to each explosion analysis is to determine the spill size (mass) of each chemical that is assumed to explode in the analysis. S&L used data from the United States Coast Guard (USCG) and the Office of Hazardous Materials Safety (OHMS) to determine the probability and sizes of spills. Section 7.3 of Reference 1 provides a detailed description of the determination of spill size probability. Based on the USCG and OHMS data, Table 7.3-1 of Reference 1 provides the spills per vessel mile for seven ranges of spill size from very small to large. Spills in the zero to 100 gallons dominate the probability at 0.9467 with the remainder of the ranges making up the remainder, with the spill probability reducing with increasing spill size. As a conservative approach, the spills per mile for all spill sizes were summed and a total spill per vessel mile of 1.80×10^{-6} was used in the probability analyses, where applicable (see Section 2.3.7.2).

For the spill per vessel mile to be useful, the Columbia River vessel miles needed to be determined with respect to vessel proximity to the Trojan ISFSI. Section 7.4 of Reference 1 provides a detailed description of the determination of the annual number of vessel trips and the mass of chemical per vessel. The results for 14 chemicals are listed in Table 7.4-2 and are used in the subsequent probabilistic analysis for the hazard if the deterministic analysis exceeds the acceptance criteria.

2.3.7 Results (Reference 1, Section 8.0)

The results of the explosion analyses are detailed in Section 8.0 of Reference 1 and are summarized below by source (rail or vessel) and explosion type (solid explosion, stationary explosion, VCE, BLEVE, and traveling vapor cloud explosion).

2.3.7.1 Rail Explosions

2.3.7.1.1 Solid Explosive and Stationary Vapor Cloud Explosions on Railcar

Blast wave pressures from solid explosives and vapor cloud explosions on BNSF and PNWR railcars are calculated in Appendix 3 of Reference 1 using the TNT equivalence method documented in NUREG-1805 and SFPE Fire Protection Handbook. The results are summarized in Table 8.1-1 of Reference 1. The analysis of each of the 46 hazards results in a blast wave pressure at the Trojan ISFSI site of less than 1.0 psig. Therefore, none of the solid or stationary sources of explosion on a rail car exceed the deterministic acceptance criteria of 2.2 psig for pressure and 1.0 psig for blast-generated missile effects and ground motion.

2.3.7.1.2 Boiling Liquid Expanding Vapor Cloud Explosions on Railcar

Blast wave pressures from a BLEVE on a BNSF railcar are calculated in Appendix 3 of Reference 1 using guidance from the SFPE Handbook. The ethanol shipment on PNWR is not a BLEVE hazard (i.e., does not have a low boiling point). Acetaldehyde, butylene, vinyl chloride (hydrocarbons, liquid, N.O.S.), and methyl chloride have both a boiling point and vapor density greater than or equal to that of propane; therefore, a BLEVE from these commodities is bounded by a BLEVE from propane. Dichloromethane and isoprene have both a boiling point and vapor density greater than that of butane; therefore, a BLEVE from these commodities is bounded by a BLEVE from butane. Results are summarized in Table 8.1-2 of Reference 1. The analysis of each of the 14 BLEVE hazards result in a blast wave pressure at the Trojan ISFSI site of less than 0.1 psig. Therefore, none of the sources of BLEVE on a rail car exceed the deterministic acceptance criteria of 2.2 psig for pressure and 1.0 psig for blast-generated missile effects and ground motion.

2.3.7.1.3 Traveling Vapor Cloud Explosions from Railcar

The BNSF and PNWR vapor cloud explosions hazards are analyzed in Appendix 4 of Reference 1 to determine the concentration from a chemical release at the Trojan ISFSI site using the dispersion analysis methods described in RG 1.78 and NUREG-0570. The calculated concentrations were compared to the LEL for each chemical and results are summarized in Table 8.1-3 of Reference 1. It was determined that 36 of the 42 chemicals analyzed produced a concentration less than its respective LEL at all stability classes and wind speeds. The outliers, including butane, butylene, isobutene, isobutylene, propane, and propylene were evaluated further.

BNSF railcar releases of butane, butylene, isobutene and isobutylene will not result in a concentration greater than the chemical LEL at the Trojan ISFSI site for Stability Classes A through E, at any wind speed. For Stability Class F, these releases will result in a concentration greater than the chemical LEL at the Trojan site for wind speeds greater than 3.01 m/s. From Section 4.2 of Reference 1, these conditions exist 0.24 percent of the time (irrespective of wind direction). Additionally, postulating that all wind speeds of Stability Class G (0.88 percent frequency) exceed the LEL, the combined frequency is 1.12 percent. Thus, the BNSF shipments of butane, butylene, isobutene and isobutylene are acceptable per the guidance in RG 1.78 (as described in Section 6.3 of Reference 1) because the meteorological conditions that lead to a hazard occur less than 5 percent of the time.

BNSF railcar releases of propane and propylene will not result in a concentration greater than the chemical LEL at the Trojan ISFSI site for Stability Classes A through E, at any wind speed. For Stability Class F, these releases will result in a concentration greater than the chemical LEL at the Trojan site for wind speeds greater than 2.01 m/s. From Section 4.2 of Reference 1, these conditions exist 0.84 percent of the time (irrespective of wind direction). Additionally, postulating that all wind speeds of Stability Class G (0.88 percent frequency) exceed the LEL, the combined frequency is 1.72 percent. Thus, the BNSF shipments of propane and propylene are acceptable per the guidance in RG 1.78 (as described in Section 6.3 of Reference 1) because the meteorological conditions that lead to a hazard occur less than 5% of the time.

In summary, based on a combined deterministic and probabilistic evaluation, there is no credible traveling vapor cloud explosion threat to the Trojan ISFSI.

2.3.7.2 Waterborne Vessel Transportation Explosions

2.3.7.2.1 Solid Explosive and Stationary Vapor Cloud Explosions on Vessel

Blast wave pressures from solid explosives and vapor cloud explosions on vessels traversing the Columbia River, 957 ft from the Trojan ISFSI site at its nearest approach, are calculated in Appendix 5 of Reference 1 using the TNT equivalence and combustible dust methods documented in NUREG-1805 and the SFPE. The results are summarized Table 8.2-1 of

Reference 1. Also included in Table 8.2-1 is each chemical's number of trips and mass shipped per vessel from Table 7.4-2 of Reference 1 because it is pertinent to the probabilistic analysis of outliers.

The dust explosions of petroleum coke and sulfur produce a blast pressure wave at the ISFSI less than the deterministic acceptance criteria of 1.0 psig and 2.2 psig, and are, therefore, acceptable with no further evaluation. Of the remaining 13 hazards, two produce a blast wave greater than 1.0 psig and 11 produce a blast wave greater than 2.2 psig. Therefore, probabilistic analysis was performed to determine the frequency of a hazardous explosion occurring.

A 1.0 psig overpressure was used in the probabilistic analysis as a conservative bounding acceptance criterion. The probability calculations are performed in Appendix 5 of Reference 1. The following is an example of one probability analysis summary for ammonium nitrate: The standoff distance for 1.0 psig overpressure from an explosion of 3,897 tons of ammonium nitrate is 1.27 miles. Using the probabilities established in NUREG/CR-6624, "Recommendations for Revision of Regulatory Guide 1.78," (Reference 6) and determined from the Marine Casualty and Pollution Data for Researchers database (excerpted into Attachment E to Reference 1) the annual hazard frequency for ammonium nitrate is calculated as follows:

Incidents per Mile = 1.8×10^{-6} (Reference 1, Table 7.3-1)

Spills per Incident = 0.025 (2.5% per Reference 1, Section 7.3)

Explosions per Spill = 0.005 (0.5% per Reference 1, Section 7.3)

Miles per Trip = 2.73 mi (Columbia river length within 1.27 miles of the ISFSI per Reference 1, Section 4.7.1)

Annual explosion frequency per trip is the product of the above terms=

$$(1.8 \times 10^{-6}) \cdot (0.025) \cdot (0.005) \cdot (2.73) = 6.14 \times 10^{-10} \text{ Explosions per trip}$$

Dividing the annual probability acceptance criterion of 1×10^{-6} (in explosions per year) by the computed annual frequency (in explosions per trip) yields the annual number of allowable trips for ammonium nitrate, below which the probability of an explosion yields a non-credible event:

$$1 \times 10^{-6} / 6.4 \times 10^{-10} = 1{,}629^{*} \text{ Trips per year}$$

As shown in Table 7.4-2 of Reference 1, the annual number of trips for ammonium nitrate is 1,285. Therefore, an explosion of the applicable quantity of ammonium nitrate on the Columbia River within the distance to the ISFSI that would cause a pressure wave

greater than 1.0 psig is deemed not credible based on the probabilistic acceptance criterion.

* Note that Reference 1 states that the computed annual explosion frequency is divided by the annual probability acceptance criterion. In fact, the opposite is correct.

The same probabilistic calculation was performed for the remaining 12 hazards and is presented in Table 2.3-1 below, which is excerpted from Table 8.2-1 in Reference 1:

Table 2.3-1
Results of Probabilistic Evaluation of Stationary Explosion on Vessel

Chemical	Annual Number of Trips	Annual Hazard Frequency (Explosions per trip)	Allowable Number of Trips*
Acetic acid (Carboxylic Acid)	48	1.33×10^{-10}	7,519
Acetone	43	1.33×10^{-10}	7,519
Ammonia	849	3.85×10^{-10}	2,597
Ammonium Nitrate	1,285	6.14×10^{-10}	1,629
Benzene	476	1.33×10^{-10}	7,519
Ethanol (Alcohols)	1,599	1.33×10^{-10}	7,519
Explosives	10	8.93×10^{-10}	1,120
Gasoline	1,671	1.33×10^{-10}	7,519
Methane	96	6.14×10^{-10}	1,629
Methanol (Alcohols)	1,599	1.33×10^{-10}	7,519
Naphtha	140	1.33×10^{-10}	7,519
Propane	21	6.14×10^{-10}	1,629
Vinyl Chloride	42	6.14×10^{-10}	1,629

* Value below which the explosion hazard frequency is below 1×10^{-6} per yr, making the event non-credible per RG 1.91 and NUREG-0800.

With exception of the solid explosives (petroleum coke and sulfur), these stationary explosion hazards also require probabilistic analysis for traveling VCE (see Section 2.3.7.2.3). Therefore, the stationary hazard frequency must be combined with the traveling VCE hazard frequency to determine the overall allowable number of trips. This calculation is performed in Section 8.2.4.

2.3.7.2.2 Boiling Liquid Expanding Vapor Explosions on Vessel

Blast wave pressures from a BLEVE on vessels traversing the Columbia River in proximity to the Trojan ISFSI are calculated in Appendix 5 of Reference 1 using guidance from the SFPE Handbook. The results of the analysis show that each of the four BLEVE hazards results in a blast wave pressure at the Trojan ISFSI that exceeds the deterministic acceptance criteria of

1.0 psig and 2.2 psig. Similar to the vessel stationary explosions in Section 2.3.7.2.1, a BLEVE probabilistic analysis was performed as documented in Appendix 5 of Reference 1 for 1.0 psig overpressure. For each BLEVE hazard, the standoff distance for 1.0 psig overpressure was calculated to be less than 0.5 miles. The Columbia River length within 0.5 miles of the ISFSI site is 0.87 miles. Using this length in the same probability calculation shown in Section 2.3.7.2.1, the annual hazard frequency for each BLEVE hazard is 1.96×10^{-10}. The computed allowable number of trips per year below which a BLEVE is considered non-credible for each of the chemicals is 5,109 per Appendix 5 of Reference 1. The number of actual trips for each chemical is fewer than 100 (Reference 1, Table 8.2-1). Therefore, a BLEVE originating from a vessel on the Columbia River that could affect the ISFSI is not credible. As discussed in Section 2.3.7.1, these chemicals also required evaluation for a traveling VCE explosion (see Section 2.3.7.3 below).

2.3.7.3 Traveling Vapor Cloud Explosion from Vessel

Ten traveling vapor cloud explosion (VCE) hazards shipped on the Columbia River were analyzed as documented in Appendix 6 of Reference 1 using the dispersion analysis methods described in RG 1.78 and NUREG-0570. Each of the chemical releases results in a computed concentration at the ISFSI site greater than the chemical LEL. Therefore, a probabilistic analysis was required to determine the frequency of a hazardous release and compare it to the probabilistic acceptance criterion of than 1×10^{-6} hazards per year.

The traveling vapor cloud hazard frequency was determined for each chemical using spill size probability from NUREG/CR-6624 and Marine Information for Safety and Law Enforcement (MISLE) data, joint wind speed-wind direction-stability class data, and waterway route lengths. Summaries of the evaluation for each chemical are provided in the ten subsections in Section 8.2.3. In some cases, it was necessary to refine the analysis to show that the probabilistic acceptance criterion is met (e.g., each wind direction is analyzed individually as opposed to using the worst direction in the group). Recall that each traveling VCE hazard required a probability analysis for both a stationary explosion and traveling VCE. The combined probability of a hazard is provided below.

For vessel shipments of the chemicals listed below in Table 2.3-2, a probability analysis was required for both a stationary explosion (Sections 2.3.7.2.1 and 2.3.7.2.2) and a traveling VCE (Section 2.3.7.2.3). To determine that the overall hazard probability of each chemical is acceptable, the hazard frequency of both types of explosions was combined. For the stationary explosion hazard frequency, the bounding frequency between the stationary vapor cloud explosion hazard (Section 2.3.7.2.1) and BLEVE hazard (Section 2.3.7.2.2) was used. In all cases, the stationary vapor cloud explosion hazard frequency was bounding. The combined hazard frequency was calculated as shown below in Table 2.3-2. Also reproduced from Table 7.4-2 of Reference 1 is each chemical's actual number of trips on the Columbia River. The overall allowable number of trips for each chemical is found by dividing the probabilistic acceptance criterion of 1×10^{-6} by the combined hazard frequency*.

* Note that Reference 1 states that the computed annual hazard frequency is divided by the annual probability acceptance criterion. In fact, the opposite is correct.

Table 2.3-2
Vessel Shipments with Combined Hazard Frequency

Chemical	Annual Number of Trips	Stationary Hazard Frequency	Traveling VCE Hazard Frequency	Combined Hazard Frequency	Overall Allowable Number of Trips**
Acetic acid (Carboxylic Acid)	48	1.33×10^{-10}	4.35×10^{-10}*	5.68×10^{-10}	1,761
Acetone	43	1.33×10^{-10}	4.35×10^{-10}*	5.68×10^{-10}	1,761
Ammonia	849	3.85×10^{-10}	6.84×10^{-10}	1.07×10^{-9}	936
Benzene	476	1.33×10^{-10}	4.82×10^{-10}	6.15×10^{-10}	1,627
Gasoline	1,671	1.33×10^{-10}	4.35×10^{-10}	5.68×10^{-10}	1,761
Methane	96	6.14×10^{-10}	7.83×10^{-9}	8.44×10^{-9}	118
Methanol/Ethanol (Alcohols)	1,599	1.33×10^{-10}	4.35×10^{-10}*	5.68×10^{-10}	1,761
Naphtha	140	1.33×10^{-10}	1.04×10^{-9}	1.17×10^{-9}	856
Propane	21	6.14×10^{-10}	6.06×10^{-9}	1.65×10^{-9}	150
Vinyl Chloride	42	6.14×10^{-10}	9.69×10^{-9}	1.03×10^{-8}	97

* Results are obtained from a bounding analysis of gasoline.
** Value below which the explosion hazard frequency is below 1×10^{-6} per yr, making the event non-credible per RG 1.91 and NUREG-0800.

As shown in Table 2.3-2, the number of trips for all chemicals is less than the number of trips below which the probabilistic acceptance criterion indicates that the event is non-credible. Therefore, there are no credible explosions originating from the Columbia River that could affect the Trojan ISFSI.

2.3.8 Conclusions (Reference 1, Section 9.0)

As discussed above, the deterministic and (if applicable) the probabilistic acceptance criteria for each of the potentially hazardous chemicals are met. None of the chemicals create an unacceptable consequence due to explosive overpressure (i.e., no cask sliding and no loss of confinement of the spent fuel, shielding, heat rejection capability, or structural stability of important to safety components). A summary of the hazard analysis results is provided below. Table 2.3-3 below (excerpted from Table 9.0-1 of Reference 1), details those chemicals that are acceptable based on a deterministic analysis and those chemicals that are acceptable based on a probabilistic analysis. Accident probability is not increased by ships using the Prescott Anchorage as determined in Section 6.4.2 of Reference 1.

For each chemical requiring probabilistic analysis, Reference 1 determined that the frequency is less than 1 x 10^{-6} hazards per year acceptance criterion. Several conservatisms are used in the probability analyses. Significant conservatisms in the vessel traveling VCE analyses are listed below:

1. The spill size assumed for each case was the maximum in the range of spill sizes. For instance, a spill of 51,000 gallons was modeled as a spill of 287,000 gallons of chemical.

2. Data for the entire Columbia River System was used and the estimation of the number of shipments for each chemical is biased high as discussed in Section 7.4 of Reference 1.

3. Storage conditions for chemicals were selected in order to maximize the release rate, which maximizes the concentration of the chemical at the Trojan ISFSI site. In some cases, chemicals that are typically stored or transported as liquids are modeled as gases (e.g., propane, methane, etc.).

4. For a specific weather stability class, only certain wind speeds may result in a hazard; however, a probability of 1.0 for adverse wind speed was used in the probability calculation.

Table 2.3-3
Trojan ISFSI Offsite Transportation Explosion Hazard Evaluation Results

Source	**Nearest Approach** (miles)	**Type of Explosion**	**Deterministic Analysis Results** (blast wave pressure)	**Probabilistic Analysis Results**
BNSF Railcar*	1.09	Solid Explosives and Stationary VCE	All Hazards < 1.0	N/A
		BLEVE	All Hazards < 1.0	N/A
		Traveling VCE	Butane, Butylene, Isobutene, Isobutylene, Propane and Propylene > LEL for Weather < 5% of the Time Remainder < LEL	N/A
PNWR Railcar*	0.14	Solid Explosives and Stationary VCE	Ethanol < 1.0	N/A
		BLEVE	N/A	N/A
		Traveling VCE	Ethanol < 1.0	N/A
Columbia River Vessel**	0.18	Solid Explosives and Stationary VCE	Petroleum Coke < 1.0 psig Sulfur < 0.1 psig Remainder > 2.2 psig or > 1 psig	Actual trips fewer than minimum required to be a credible event
		BLEVE	All Hazards >2.2 psig	
		Traveling VCE	All Hazards > LEL	

* Section 8.1 of Reference 1
** Section 8.2 of Reference 1

2.4 Summary Changes to Trojan ISFSI SAR

Trojan ISFSI SAR Section 2.2.3.1 is proposed to be modified to reflect the revised approach and acceptance criteria for the Reference 1 explosion analysis. Section 8.2.8.2 is proposed to be revised to reflect the revised approach and acceptance criteria for the Reference 1 explosion analysis and to incorporate the Reference 1 calculation by reference into the SAR. See Attachment A to this enclosure for SAR mark-ups.

3. Environmental Impact Consideration of Proposed Changes

This LCA proposes to replace the current evaluation of explosions in the Trojan ISFSI SAR. There are no modifications to the design or operation of the ISFSI included in this LCA. The Environmental Report for the original license application (as augmented for license renewal) remains applicable and bounding. Therefore, the associated NRC Environmental Impact Statement for the original license and Environmental Assessment for license renewal remain valid with this proposed change.

As shown above in Section 2, "Description and Evaluation of Proposed Changes," the changes proposed herein do not impact public health and safety. As such, this amendment request satisfies the criteria specified in 10 CFR 51.22(c)(11) for a categorical exclusion from the requirements to perform an environmental assessment or to prepare an environmental impact statement. The specific criteria of 10 CFR 51.22(c)(11) are addressed as follows:

(i) The proposed amendment does not result in a significant change in the types or significant increase in the amounts of any effluents that may be released offsite.

As shown in Section 2 above, the changes proposed herein involve adopting a revised evaluation of the explosion accident event as described in the Trojan ISFSI SAR. The physical and operational characteristics of the Trojan ISFSI are not proposed to be altered. The proposed changes do not affect the intent of any procedure related to ISFSI operations or activities. Therefore, the proposed amendment does not result in a change in the types or increase in the amounts of any effluents that may be released offsite.

(i) The proposed amendment does not result in a significant increase in individual or cumulative occupational radiation exposure.

As shown in Section 2 above, the changes proposed herein involve adopting a revised evaluation of the explosion accident event as described in the Trojan ISFSI SAR. The proposed changes do not affect the intent of any procedure related to ISFSI operations or activities. Therefore, the proposed amendment does not result in a significant increase in individual or cumulative occupational radiation exposure.

(iii) The proposed amendment does not result in a significant construction impact

As shown in Section 2 above, the changes proposed herein involve adopting a revised evaluation of the explosion accident event as described in the Trojan ISFSI SAR. This change does not involve the construction of any ISFSI component, system, or structure onsite, nor does it impact the ISFSI site. Thus, the proposed amendment does not result in a significant construction impact.

(iv) The proposed amendment does not result in a significant increase in the potential for or consequences from radiological accidents.

The evaluations for each change as provided in Section 2 above conclude that the proposed changes do not involve an increase in the frequency, likelihood, or consequences of an event or accident previously evaluated, and do not create the possibility of a different kind of accident or result from any accident previously evaluated. Thus, the proposed amendment does not result in a significant increase in the potential for or consequences from radiological accidents.

Based on the preceding analysis, it is concluded that the proposed change to the Trojan ISFSI License satisfies the criteria delineated in 10 CFR 51.22(c)(11) for categorical exclusion from the requirements of an environmental impact statement or environmental assessment. Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment is required.

4. Schedule Consideration

This LCA is a corrective action for an item in the Trojan ISFSI corrective action program that will remain open until a decision is reached by the NRC on the LCA. There are no physical modifications or operating changes awaiting approval of this LCA. PGE requests approval of this LCA by one year from the date of the LCA submittal. PGE requests an implementation period of 90 days after approval of the amendment to update the ISFSI SAR and make other necessary changes.

5. Impact on Trojan ISFSI Aging Management Program

The proposed changes in this LCA pertain only to a new explosion analysis and associated SAR changes. No change to any structure, system or component design, operation, material of fabrication, or service conditions is proposed. Therefore, the changes proposed in this LCA have no impact on the Trojan ISFSI aging management program.

6. References

1. Sargent & Lundy Calculation No. 2017-09306, "Offsite Transportation Explosion Hazard Evaluation," Initial Issue, March 2018.
2. PGE Corrective Action Request IC-16-001, "Prescott Ship Anchorage."
3. USNRC Regulatory Guide 1.91, "Evaluations of Explosions Postulated to Occur at Nearby Facilities and on Transportation Routes Near Nuclear Power Plants," Revision 2.
4. USNRC Regulatory Guide 1.78, ""Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," Revision. 1
5. USNRC NUREG-0570, "Toxic Vapor Concentrations in the Control Room Following a Postulated Accidental Release," June 1979.
6. USNRC NUREG/CR-6624, "Recommendations for Revision of Regulatory Guide 1.78," November 1999.

Revision 16 to PGE-1069
Trojan Independent Spent Fuel Storage Installation (ISFSI) Safety Analysis Report (SAR)

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2.2 NEARBY INDUSTRIAL, TRANSPORTATION AND MILITARY FACILITIES

Potential accidents as a result of external activities in the vicinity of the ISFSI site have been studied to determine their effect on the safety of the ISFSI. This section outlines the activities of the nearby industrial facilities, transportation arterials, and military installations and their potential effects on ISFSI safety. The risk to the operation of the ISFSI resulting from these activities is shown to be minimal.

2.2.1 LOCATIONS AND ROUTES

Most of the local commerce is related to forest products and is centered in Longview, Washington; Rainier, Oregon; and Kalama, Washington.

Due to the emphasis on forest products, industrial development in the area is heavily oriented to river transportation. An aluminum plant, small smelter, and boat manufacturer in Longview, a steel mill, chemical plants, and grain elevators in Kalama, and a fertilizer plant in Columbia City are the only large industries not related to the timber or paper industry. There are also several small quarry sites and gravel pits in the area, the closest being in Goble.

In August 2012, the United States Army Corps of Engineers (USACE) installed an anchor buoy for the newly-designated Prescott Anchorage Area on the Columbia River to the east of the Trojan ISFSI site. The anchorage is located just beyond the Trojan ISFSI 200-meter controlled area boundary.

Transportation routes consist of two major highways, two railroads, the Columbia River and an airport and airways. U.S. Highway 30 runs north-south adjacent to the PGE property boundary approximately 1/2 mile from the ISFSI, and is a light-duty, two-lane highway connecting Portland on the south to Astoria, at the mouth of the Columbia River. Interstate 5 (I-5) is part of the West Coast north-south interstate system extending from Mexico to Canada. I-5 in this area is across the Columbia River in Washington approximately 1-3/10 miles east of the ISFSI at its nearest point. The Portland & Western Railroad, Inc. right-of-way passes through the PGE property, approximately 700 feet from the ISFSI. The main line railroad track between Portland and Seattle is located across the Columbia River in Washington, approximately 1-1/10 miles from the ISFSI.

The Columbia River serves as the deep-sea access channel to the important ports of Portland, Oregon and Vancouver, Washington. A 40-foot channel is maintained for deep-draft ocean vessels as far upriver as Portland. The center line of the 600-foot wide ship channel is approximately 3/10 mile from the ISFSI. Upstream from Portland and Vancouver, a 17-foot channel is maintained for barge traffic, extending to Pasco, Washington and a distance into the Snake River (Reference 3). Locks are provided at each of the dams on the river coincident with the 17-foot channel (Reference 4).

About 2300 oceangoing ships a year pass by the ISFSI site on the Columbia River. The major portion of the cargo exported is wheat and logs. Inbound cargo consists of miscellaneous goods such as petroleum, iron and steel products, automobiles, and ores (Reference 1). Portland is one of the largest ports in terms of tonnage on the Pacific Coast and thus it maintains a large number of supporting facilities.

Longview, Washington, downstream of the site also has facilities for oceangoing ships. The Port of Longview maintains facilities for unloading and storage of ship cargo. Significant facilities are a bulk loader with storage for 14,000 metric tons of talc; storage tanks with capacity for 40,000 tons of calcinated coke; a grain elevator, currently not in use, with a capacity of 7.8 million bushels; and log storage yards. Among the commodities routinely stored at the port are pencil pitch (or coaltar pitch), ammonia sulfate, and potash. Additionally, at the port Wilson Oil (doing business as Wilcox & Flegel) operates a petroleum bulk plant which has 14 storage tanks with a total capacity of 26,190 barrels of storage (Reference 2).

The Kelso-Longview Airport is 5.3-miles north of the site and has a 4,391-foot paved runway oriented northwest-southeast. The airport is not a scheduled airline stop, but is the base for approximately 80 single and twin-engine, private and corporate aircraft. The airport handles about 18,000 takeoffs and landings per year. The largest planes using the field are a Siddely Hawker, a Cessna Citation, and a Falcon Jet (Reference 5). The Portland International Airport is located 33 statute miles south of the site, and is the only major airport within a 60-mile radius of the site. Portland inbound and outbound air traffic is controlled for a distance of 30 miles from the airport by Portland Air Traffic Control. Area-wide in-flight traffic control is regulated by Seattle Air Traffic Control (Reference 6).

There are no major military bases in the vicinity of the ISFSI site. The nearest military facilities are Reserve Headquarters for the various branches in Portland and Vancouver (30-40 miles south of the site), and Coast Guard and Naval facilities in Portland, Longview and at the mouth of the Columbia River (Reference 7).

A natural gas main extending to Wauna, Oregon, downriver of the site, runs along the hillside west of the site, approximately 1-1/2 miles from the site. The main is a 16 inch, 3-million foot^3/hour line, buried a minimum of 3 feet (Reference 8). In addition, there is an odorizer station on the line at Goble, a river crossing at Deer Island, 4-1/2 miles south of the site, and a river crossing at Rainier.

U.S. Highway 30 provides highway access to the ISFSI site and serves as the traffic arterial between Portland and the communities on the Oregon bank of the Columbia River, carrying an average of 5300 vehicles per day (Reference 9). The highway runs through the communities of Scappoose, Warren, St. Helens, Columbia City, Deer Island and Goble, south of the site; and Rainier, Clatskanie, Westport and Astoria north and west of the site. A bridge at Rainier connects U.S. Highway 30 with Longview, Washington, and a bridge at Astoria, the western terminus of the highway, connects to Megler, Washington.

U.S. Highway 26 provides a shorter Portland-to-Astoria route; thus, it carries the bulk of traffic between the two, leaving U.S. Highway 30 to carry local passenger traffic, log trucks, tourists, farm vehicles and truck deliveries to the river communities. There is some shipment of petroleum products via U.S. Highway 30. Gasoline, diesel and heating oils in tank trucks are regularly delivered to towns beyond the site from suppliers in Portland and St. Helens.

Interstate 5 is the primary north-south traffic route between Portland and the Puget Sound area (Seattle, Tacoma, Olympia) carrying an average of approximately 46,000 vehicles per day. Of this total, approximately 20 percent is made up of truck combinations and the remaining 80 percent is passenger traffic (Reference 10). It is estimated that about one-tenth of the truck traffic could be carrying flammable or hazardous material, of which petroleum products would make up the majority.

An average of two freight trains per day pass through the PGE property on the Portland & Western Railroad, Inc. right-of-way, carrying general commodities, with an annual gross tonnage of 6 million tons (Reference 11). Lumber and forest products make up the bulk of the shipping most of the year. During the peak fishing season, some canned and frozen seafood is carried by rail from the Astoria canneries. An average of about 200 shipments per year with 2-3 cars per shipment of chlorine and caustics are shipped to the Georgia-Pacific Corporation in Wauna, Oregon, on the lower river via the Portland & Western line. Other chemicals shipped include preservatives, fertilizer, resins and paints and a small amount of petroleum and propane.

Three railroads use the tracks on the Washington side of the river: Burlington Northern, AMTRAK, and Union Pacific railroads. Thirty-five to forty freight trains and six passenger trains pass the ISFSI site per day on these tracks (Reference 12). The freight carried varies widely with large quantities of wood products, aluminum, paper products, grains, agricultural products and foodstuffs making up the bulk. Chemicals shipped include large quantities of fertilizers, phenols, caustics, propane and various resins, acids, paints and lumber treatments.

Sharply rising ground to the west and similar high ground across the river to the east provide natural barriers for the site. The ISFSI itself is afforded additional protection on the north and east by earthen berms approximately 50 feet high, on the south and west by the buildings ranging from approximately 30 to 45 feet high, and on the south by the 45-foot rise (previous location of cooling tower).

2.2.2 DESCRIPTION OF PRODUCTS AND MATERIALS

Products and byproducts of the timber industry in the area range from unfinished timber to finished construction lumber, cabinetry, plywood and veneer. Some hardwood products are made in Longview on a small-scale operation, while paper and wood fiber products make up a large percentage of the production of the area. Some chemical use and storage is associated with these industries. Chemicals include resins used in plywood, veneer and chipboard production, acids used in paper and pulp production, and lumber pressure treatments and finish coatings

(stains and varnishes). Chemicals are stored either in tank cars on sidings, or in storage tanks connected to the industry involved (Reference 13).

The aluminum plant in Longview is an aluminum reduction facility operated by Longview Aluminum which produces raw metal in the form of ingots, billet bars, etc. The use of chemicals at this plant corresponds to that of any aluminum plant; namely coke, pitch, chlorine and liquefied nitrogen. Chemical storage facilities at the plant consist of stockpiles, tanks and rail tankers and transportation is by rail tank cars (Reference 13).

Kalama Chemical, Inc., produces phenols with some secondary production of benzoates. The facility receives its raw material, toluene from tankers and stores it in an 80,000-barrel tank. The finished product is shipped by rail tank car (Reference 13).

Hoechst Celanese Corporation, Inc., is located approximately 3-miles southeast of the ISFSI in Kalama, Washington and produces a bleaching agent used in the pulp and paper industry. The facility receives sulfur dioxide by rail tank car and has a storage capacity for this chemical of 300,000 pounds.

All Pure Chemical Company is located approximately 2-miles southeast of the ISFSI in Kalama, Washington. The company produces a number of products including sodium hypochlorite, household ammonia, and water treatment chemicals. It is involved in the repackaging and distribution of chlorine gas. The chlorine gas is received in 90-ton rail tank cars and is repackaged into 1-ton cylinders. The 90-ton rail tank car is the maximum storage capacity for the chlorine gas at the facility.

A listing of nearby industrial facilities, supplementing the summarization above, is provided as Table 2.2-1. The geographic locations of the nearby industrial facilities are shown on Figures 2.2-1 and 2.2-2.

2.2.3 EVALUATION OF POTENTIAL ACCIDENTS

This section provides an evaluation of the capability of the ISFSI to safely withstand the effects of an accident at, or as a result of the presence of, industrial, transportation and military installations or operations within 5 miles of the site. Potential accidents considered include explosions of chemicals, flammable (including natural) gases or munitions; industrial and forest fires; and accidental releases of toxic gases.

2.2.3.1 Explosions

Shipments of commercial cargo past the site create the possibility of nearby explosions. For the most part, the rugged construction of the Concrete Casks would protect the spent nuclear fuel from such explosions. In addition, the ISFSI would be shielded from the direct force of these explosions by the earthen berms on the north and east, by the buildings to the south and west, and the 45-foot rise (previous cooling tower location) to the south.

Explosions unrelated to transportation are not considered significant. The quarry operations south of the site are located in the hills west of the Columbia River. Presently, there is no storage of explosives at the operating quarry, which is 2 miles from the site. The quarry is not a large operation and only a limited amount of explosives are used. Because of the distance from the site and the protection afforded by the hillside and ridge between the quarry and the site, the quarry operation does not present a hazard to the safety of the ISFSI. The natural gas main runs along the hillside west of the site, approximately 1-1/2 miles from the site. The operation of this line will not present a hazard to the ISFSI from explosion because of the relatively low explosive capacity of the gas and the distance from the ISFSI.

The potential for explosions to affect Trojan ISFSI important to safety structures was evaluated deterministically for a variety of potential sources of explosion from commodities transported by rail and ship near the Trojan ISFSI site. For those explosion events whose results exceeded one of the acceptance criteria (as described in Section 8.2.8.2.1) a probabilistic evaluation was performed to determine the annual probability of the explosion occurring within the proximity of concern for the ISFSI. If the annual probability of occurrence of a particular explosion within that proximity was determined to be less than 1×10^{-6} per year, that explosion was deemed not credible and the consequences were ignored.

The primary concern from a postulated explosion from a nearby railcar or vessel is the blast wave overpressure loading upon the Concrete Casks. This includes explosions at the railcar/vessel from solid explosives, vapor cloud explosions (VCE), and boiling liquid expanding vapor explosions (BLEVE). Additionally, the potential for a chemical vapor release traveling to the ISFSI site with a concentration greater than or equal to the lower explosive limit (LEL) of the chemical has been evaluated.

As described in Section 8.2.8.2, the results of the explosion evaluation show that there are no credible explosion events that would create an overpressure above the 2.2 psi threshold (FSAR analysis overpressure limit for Trojan Nuclear Plant safety-related structures) for the Concrete Casks, above the 1.0 psi threshold for consideration of blast-generated missiles, or above the LEL for any explosive chemical vapor that has traveled to the ISFSI site. As described in Section 8.2.8.2, the Concrete Cask is able to withstand tornado wind pressure up to 2.3 psi and wind pressure as high as 5.87 psi without sliding or overturning. The MPC is designed for a 60 psig external pressure (Reference 14, Table 2.2.1).

Therefore, transportation related explosions would not affect the safe storage of spent nuclear fuel.

2.2.3.2 Toxic Chemicals

The effects of toxic chemicals on human habitability were extensively analyzed for operation of the Trojan Nuclear Plant and addressed in detail in the FSAR. These analyses were predicated on maintaining control room habitability during a toxic gas event. Continuous manning of the

The April 29, 1965, earthquake caused lower intensities in the site area than the 1949 earthquake. The intensity at Kelso and Longview was VI; at Rainier it was V; and at Goble only IV.

2.6.2.4 Seismic Margin Earthquake

The maximum intensity that has been reported at Rainier is VIII. Since this intensity occurred on overburden, it is probable that on rock at the site the intensity for this same shock was not over VII. Intensity VII correlates with a horizontal acceleration of 0.12 g according to Hershberger (Reference 10). This historical data formed the bases for assigning the Safe Shutdown Earthquake (SSE).

The SSE was determined such that any probable earthquake experienced at the site would not exceed the intensity selected. An intensity of VIII was selected since it was probable that an earthquake of that magnitude had never been experienced at the site. An intensity VIII is equivalent to an acceleration of 0.25 g.

There have been significant changes in the perception of earthquake hazards in the Pacific Northwest since the time of the initial design and licensing of the Trojan Plant. It is now commonly believed among the geoscience community that large subduction zone earthquakes likely occurred along the Oregon-Washington-Vancouver Island coast (known as the Cascadia margin, or Cascadia Subduction Zone) within the recent past (Holocene), and that the potential for such events to occur in the future should be considered in any evaluation of safety and reliability of critical facilities during earthquake loading.

In 1987, in response to the emerging issue of potential subduction zone earthquakes, PGE initiated a program of close monitoring of earthquake hazard research conducted along the Cascadia margin. The results of these studies, together with studies initiated by PGE, have been used to characterize the maximum events that could be expected to occur in the region and the resulting free-field ground motions that may occur at the site. This maximum potential earthquake that could affect the site is called the Seismic Margin Earthquake (SME).

These studies determined a value for the SME peak horizontal ground acceleration of 0.38 g (Reference 11). A 1994 earthquake in Northridge, California slightly changed the conclusions of these studies in that the controlling earthquake varies from the intraslab source for peak ground acceleration, to the crustal earthquake for periods between 0.1 and 0.6 seconds, to the interface source for longer periods, whereas in the original study, only the intraslab and interface sources were controlling (Reference 12). Nonetheless, the response spectra are bounded by the Regulatory Guide 1.60 spectrum shape when anchored at the 0.38 g peak acceleration. Therefore, input from recent earthquakes shows that the SME is the appropriate design basis event for the ISFSI, and the ISFSI design considers the SME peak horizontal acceleration of 0.38g.

8.2.7.3 Accident Dose Calculations

There are no radiological releases or adverse radiological consequences from this event.

8.2.8 EXPLOSIONS OF CHEMICALS, FLAMMABLE GASES, AND MUNITIONS

This analysis addresses the hazards posed by potential explosions on transportation routes and in the vicinity of the ISFSI.

8.2.8.1 Cause of Accident

As presented in Section 2.2.3.1, the only source of potential explosions near the Trojan site that could affect important to safety structures is shipment of commercial explosive cargo near the plant. Trojan plant structures and the ISFSI site itself contain no significant amounts of explosive materials. The small quantities of gasoline or fuel oil that may be contained in the fuel tanks of vehicles (e.g., forklifts and mobile cranes) or standby power supply engines near the ISFSI present an insignificant explosion hazard. Explosions unrelated to transportation are not considered significant. Refer to Section 2.2.3.1 for additional information on potential sources of explosions in the vicinity of the site.

Trains and waterborne vessels routinely carry cargo in proximity to the Trojan ISFSI site, including volatile chemicals in various quantities. Cargo vessels also occasionally anchor at the Prescott Anchorage in the Columbia River just beyond the Trojan ISFSI controlled area boundary. PGE estimates that the nearest point of a vessel at anchor to the controlled area boundary is approximately 100 feet (33.5 meters). The frequency of rail shipments and accidents are tracked by the owner of the railroads that use the tracks – Burlington Northern and Santa Fe (BNSF) and Portland and Western Railroad (PNWR). The frequencies of the Columbia River shipments are tracked by the U.S. Army Corps of Engineers and accident rates are tracked by the Board of Maritime Pilots. Based on historical data, accidents due to moving rail and Columbia River vessel traffic are rare. Accidents involving ships at anchor are also rare.

8.2.8.2 Accident Analysis

The Concrete Casks have been shown in Section 8.2.4 to withstand a tornado wind pressure of 331.8 psf (or 2.3 psi) and missile impacts without sliding or overturning. The magnitude of explosion that would result in overturning or sliding of a Concrete Cask was determined as follows:

The force required to slide a Concrete Cask is:

$$F_{slide} = W_{cask} \times 0.3 = 292{,}700 \text{ lbs} \times 0.3 = 87{,}810 \text{ lbs}$$

where:

0.3 is the friction coefficient between the Concrete Cask and the Storage Pad

W_{cask} = Loaded Concrete Cask weight

The initial moment required to uplift a Concrete Cask is:

$$M = 292{,}700 \text{ lbs} \times 58.5 \text{ in} = 17.1 \times 10^6 \text{ lbs-in}$$

where:
58.5 inches is the moment arm

The force required to develop the above moment:

$$F_{overturn} = M / (L/2) = 17.1 \times 10^6 \text{ lbs-in} / (211.5 \text{ in} /2) = 161{,}702 \text{ lbs}$$

where:

L = Length of the Concrete Cask

The force required to slide the Concrete Cask is smaller and, therefore, is controlling. The minimum pressure on the Concrete Cask to result in this force is:

$$p = F_{slide} / (C_f A_p) = 87{,}810 / (0.52)(199.75)(144) = 5.87 \text{ psi}$$

where:
C_f = Net pressure coefficient = 0.52 (Reference ANSI A58.1, Table 12)

A_p = Projected area of Concrete Cask normal to wind
= 136 x 211.5/144 = 199.75 ft²

Therefore, the pressure required to cause Concrete Cask sliding is 5.87 psi.

PGE commissioned an evaluation of the threat of explosions from cargo carried by rail and waterborne vessels in proximity to the ISFSI. Summaries of the methodology and results of the evaluations of potential explosions from rail and vessel cargo excerpted from Reference 19 are provided in Subsections 8.2.8.2.1 and 8.2.8.2.2 below. See Reference 19 for specific data sources and detailed discussion of methodology, assumptions, inputs, calculations, results, and conclusions.

8.2.8.2.1 Explosion Accident Evaluation Methodology

Many commodities are moved by rail and water past the ISFSI in varying quantities and frequencies. The full breadth of commodities was identified and initially screened to determine if further evaluation was required based on the chemical involved. Each commodity was classified as explosive or non-explosive. Non-explosive commodities were not evaluated further. Explosive chemicals were then reviewed to see which quantities and chemical types could be grouped together in a bounding explosion analysis. Each chemical making it through the screening process was evaluated as an explosive with an appropriate quantity and distance from the ISFSI, based on the rail and shipping data. Depending on the type and form of chemical involved, one or more of the following explosion analyses were performed:

1. Stationary Vapor Cloud Explosion (VCE)
2. Solid (Dust) Explosion
3. Boiling Liquid Expanding Vapor Explosion (BLEVE)
4. Traveling VCE

- For the first three types of explosion, two acceptance criteria were applied:
    - Less than 2.2 psig wave pressure for structural integrity of structures, systems and components. This is less than half of the pressure required to cause sliding of a loaded Concrete Cask and less than 4% of the 60 psig external accident design pressure for the Holtec MPC-24/24E canisters that provides the confinement boundary for the Trojan spent fuel (per Table 2.2.1 of the HI-STORM 100 System FSAR, Revision 1).
    - Less than 1.0 psig wave pressure to eliminate the need to consider ground motion and blast-generated missile effects per NRC Regulatory Guide 1.91 (Reference 20).
- The acceptance criterion for the traveling VCE event was a concentration of the chemical at the ISFSI site less than the lower explosive limit (LEL) for that chemical.

For explosion events analyzed that resulted in exceedance of one or more of the deterministic acceptance criteria, a probabilistic evaluation was performed. The acceptance criterion for the probabilistic evaluation was an annual frequency of the explosion occurring of less than 1×10^{-6} per year. Explosion events having an annual frequency of occurrence less than 1×10^{-6} were considered not credible.

8.2.8.2.2 Results of the Explosion Evaluation

A total of 101 commodities were considered for rail. Of these, 49 were comprised of chemicals requiring analysis, 28 were non-explosive chemicals, 17 were chemicals bounded by another analysis (i.e., a larger quantity of that chemical or another more explosive chemical), and seven

were chemicals with low enough vapor pressure (<10 mm Hg at 100°F) that they could be ignored.

A total of 136 commodities were considered for waterborne vessels. Of these, 21 were comprised of chemicals requiring analysis, 107 were non-explosive chemicals, none were bounded by another analysis, and eight were chemicals with low enough vapor pressure (<10 mm Hg at 100°F) that they could be ignored.

The results of the explosion evaluation are shown in Table 8.2-7. There are no explosion events from rail or waterborne commodities that produce unacceptable effects at the Trojan ISFSI.

8.2.8.2.3 Prescott Anchorage Accident Probability

The following characteristics of the Prescott Anchorage serve to minimize any increase in accident probability:

1. Probability of collision accidents is not increased by ships using the anchorage due to the position of the anchorage outside of the channel. Additionally, per the Columbia River Anchorage Guidelines (Reference 19), the Prescott anchorage is provided with a stern buoy to prevent the anchored vessel from swinging into the channel.

2. Probability of groundings is similarly not increased by the anchorage since the anchorage position is deep. The Lower Columbia Region Harbor Safety Committee characterizes the risk of grounding in this anchorage as "low" (Reference 19). The depth of the position is listed as 52-ft to over 65-ft which can safely accommodate fully laden vessels.

3. Probability of allisions is not increased by the anchorage since there are no fixed objects within the anchorage position.

In general, no new types of accidents are created by the Prescott anchorage since the use of other anchorage positions is already included in river accident statistics.

Per the Anchorage Guidelines (Reference 19), a fully laden vessel may use the Prescott anchorage for no longer than 72 hours without permission of the Captain of the Port. Other vessels would normally stay at the anchorage for no more than seven days. No vessel may occupy the anchorage for more than 30 consecutive days without a permit from the Captain of the Port. The Prescott anchorage was used 25 times in 2016, primarily for empty vessels awaiting a berth at one of the loading docks along the river (Reference 19).

The failure rate for a single-walled chemical tank is 1×10^{-4} releases per year where 10% of those result in the entire contents being spilled instantaneously, per the FEMA Handbook of Chemical Hazard Analysis Procedures (Reference 19). Therefore, the complete spill frequency

for a single walled chemical tank is 1×10^{-5}. Using this spill rate is reasonable because it is likely that tanks on vessels, particularly tanks of highly combustible materials, are more robust than a single-walled tank. Based on information from 2016 (Reference 19), 10% of vessels using the anchorage are considered loaded in the analysis. Of those loaded vessels, 31.4% are considered to be carrying explosive cargo. This percentage is found by dividing the sum of all explosive hazard annual trips (12,218 trips; Reference 19) by the total number of trips in a year (38,905 trips, taken from 2012 which had the lowest total number of trips in the ten years of USACE data, Reference 19). Assuming that the average anchorage time is eight hours and that all hazardous spills lead to an explosion, the anchorage annual explosion frequency is calculated to be:

$$1 \times 10^{-5} \text{ spill/yr} \cdot 25 \text{ vsl/yr} \cdot 10\% \text{ vsl}_{loaded}/\text{vsl} \cdot 31.4\% \text{ vsl}_{haz}/\text{vsl}_{loaded} \cdot 8 \text{ hr/vsl}_{haz} \cdot 1 \text{ yr}/8766 \text{ hrs} = 7.17 \times 10^{-9}$$

This anchorage hazard probability is negligible in the total probability of site damage from offsite explosion hazards.

8.2.8.3 Accident Dose Calculations

There are no radiological consequences from this accident.

8.2.9 FIRES

Section 2.2.3.3 provides information regarding the hazard to the ISFSI presented by fires. No significant fires are expected at the ISFSI. The major transient combustible used within the ISFSI would be the gasoline, propane, hydraulic fluid, or diesel fuel oil used in transport vehicles and the mobile crane. Transport vehicles would be used during the initial movement of the Concrete Casks to the pad, and a mobile crane would be used for the infrequent event of loading of Transport Casks. When these vehicles are in use, they will be accompanied by personnel who would detect and suppress the small fires associated with fuel leaks. If left in the ISFSI area, these unattended vehicles would be staged and secured west or south of the Casks where spills would flow away from the Casks. In addition, the mobile crane is limited to less than 1000 gallons of combustible fluid, including diesel fuel, hydraulic fluid, and engine crankcase oils. Refueling of the mobile crane is performed outside the ISFSI area whenever possible, and in no case is the refueling tanker left unattended inside the ISFSI yard.

The plant is protected from industrial and forest fires by natural barriers and by the distance between combustibles and the ISFSI Concrete Casks. Additional protection is provided by the paved open areas surrounding the ISFSI. In addition, the massive concrete walls of the Concrete Casks provide shielding from the effects of thermal flux generated by nearby fires. Therefore, fires pose an insignificant hazard to the ISFSI.

8.2.10 DELETED

8.2.11 VOLCANISM

8.2.11.1 Cause of Accident

Volcanic activity near the Trojan ISFSI is addressed in Section 2.6.6. Four volcanoes are located in the general area, the closest one being 34 miles from the site.

8.2.11.2 Accident Analysis

The discussion of volcanoes in Section 2.6.6 concludes that the potential eruptions pose a minimal risk to the ISFSI. Nevertheless, the effects that are believed to be of concern are potential sources of air inlet blockages including ash fall, mud flow, and flooding. As discussed in Sections 2.4 and 2.6.6, although these potential sources are not considered to represent significant risk the full blockage of the air inlets has been analyzed in Section 8.2.7 and shown not to result in exceeding temperature limits or to adversely affect the safe storage of spent fuel.

8.2.11.3 Accident Dose Calculations

The effects of volcanically-induced hazards pose a negligible risk to the ISFSI, and no radiological consequences are anticipated from this event.

8.2.12 LIGHTNING

8.2.12.1 Cause of Accident

This event would be caused by meteorological conditions at the site. Lightning striking one of the Concrete Casks is not a likely event, because the ISFSI Storage Pad is surrounded on two sides by an earthen berm and some lightning protection will be afforded by the lighting towers that will be located around the Storage Pad (Reference 7). In addition, the Trojan ISFSI is in a low isokeraunic level area; the mean annual days of thunderstorm activity at the ISFSI will be less than ten.

8.2.12.2 Accident Analysis

Even if the Concrete Cask were to be hit by lightning, the likely path to ground would be from the steel Concrete Cask lid to the steel base plate via the steel Concrete Cask liner and the steel air inlet ducts. The MPC is surrounded by these steel structures and would not provide a likely ground path. Therefore, a lightning strike would not affect MPC integrity. The heat absorbed would be insignificant from the standpoint of MPC cooling due to a very short duration of the event. If the lightning entered or exited the Concrete Cask via the concrete shell, some local spalling of concrete may occur. A significant loss of concrete shielding would not be expected. Concrete Cask operation would not be adversely affected.

8.2.12.3 Accident Dose Calculations

Based on the evaluation above, the radiological consequences of this accident would be similar or less than those discussed in Section 8.2.4 for a localized loss of concrete shielding following a tornado missile strike.

8.2.13 OFF-SITE SHIPPING EVENTS

At the Transfer Station, positioning stops are attached to the structure to accurately position a Concrete Cask or Transport Cask relative to the Transfer Cask that is rigidly restrained within the Transfer Station.

Adapter plates are used in the top of the Concrete Cask and Transport Cask that mate with the Transfer Station stops for accurate horizontal positioning. The Transfer Station shield ring, when lowered into position for MPC transfer, mates with the Concrete Cask or Transport Cask adapter plate such that the inside diameter of the Concrete Cask or Transport Cask, the inside diameter of the shield ring, and the inside diameter of the Transfer Cask are aligned. With these alignment design features, interferences during MPC movements are not likely to occur. The following events are analyzed, however, in order to bound any similar events.

8.2.13.1 Interference During Raising or Lowering the MPC

The MPC catches on the Transfer Cask while being moved. While proper procedures to ensure alignment of the components should prevent this condition from occurring, it is analyzed nevertheless to bound similar occurrences.

8.2.13.1.1 Cause of Accident

The cause is operator error for failing to assure adequate clearance and/or alignment.

This event may be detected by audible noise emitted by the MPC as it contacts the Transfer Cask or visually by upward movement of the Transfer Cask.

8.2.13.1.2 Accident Analysis

The locations where the MPC is moved relative to the Transfer Cask are the previous Fuel Building, at elevation 45 ft., while loading the MPC into the Concrete Cask, or at the Transfer Station during movements between a Concrete Cask or Transport Cask.

At the Transfer Station, an impact limiter which is designed to preclude unacceptable damage to the fuel is located beneath the receiving cask. No damage to the fuel would occur in the unlikely event of a failure in the lifting system.

8.2.13.1.3 Accident Dose Calculation

There are no radiological releases or adverse radiological consequences from this event.

8.2.13.2 Interference During MPC Lowering into a Concrete Cask or Transport Cask

The MPC catches on the Concrete Cask or Transport Cask edge or side while being lowered into a Concrete Cask or Transport Cask.

While proper procedures to ensure alignment of the components should prevent this condition from occurring, it is analyzed nevertheless to bound similar occurrences.

8.2.13.2.1 Cause of Accident

The cause is operator error for failing to assure adequate clearance and/or alignment.

This event may be detected by audible noises emitted from the MPC sliding on the Transfer Cask, Concrete Cask, or Transport Cask, or visually by a slackening of the slings which connect the MPC to the crane hook.

8.2.13.2.2 Accident Analysis

Since the only force acting on the MPC during lowering is gravity, the worst case condition would be a load of 1g on the MPC bottom or side if it were to be completely supported from its interference. The stresses applied to the MPC in this scenario are bounded by those analyzed in Sections 8.2.13.3 and 8.2.13.4. The Transfer Cask and Concrete Cask are both analyzed to support the weight of the MPC.

To recover from this event the operator would immediately halt lowering the MPC, inspect the area for interference, and then raise the MPC back into the Transfer Cask. If interference still existed after another attempt to lower the MPC, the operator would raise the MPC back into the Transfer Cask and investigate the Concrete Cask, Transport Cask, or the Transfer Cask for obstructions or foreign objects.

8.2.13.2.3 Accident Dose Calculation

There are no radiological releases or adverse radiological consequences from this event.

8.2.13.3 MPC Drop into Concrete Cask or Transport Cask

The MPC is dropped vertically into the Concrete Cask or Transport Cask during MPC handling for transfer off site.

8.2.13.3.1 Cause of Accident

Postulated crane failure.

8.2.13.3.2 Accident Analysis

MPC lifting operations may be performed on the ISFSI reinforced Transfer Pad in order to transfer a loaded and sealed MPC from a Concrete Cask to the Transport Cask. During these operations, the loaded MPC will be raised from within the Concrete Cask and subsequently lowered vertically into the HI-STAR 100 Transport Cask.

For the postulated scenario (drop of an MPC into the Concrete Cask or Transport Cask), only an end drop is applicable because the MPC is transferred vertically into a Concrete Cask or Transport Cask. The end drop height is assumed to be the distance between the bottom of a raised MPC in the Transfer Cask and the bottom of the Concrete Cask or Transport Cask cavity. The distance of 249 inches for the Transport Cask is bounding (see Section 8.2.13.3.3).

The Transfer Station design utilizes an impact limiter embedded in the Transfer Station foundation mat to mitigate the consequences of a hypothetical MPC drop during MPC transfer from the Concrete Cask to a Transport Cask. The design concept of the Transfer Station is summarized below.

The Transfer Station is a fixed structure supported on a reinforced concrete mat foundation placed directly on sound rock. An impact limiter is located directly below the MPC transfer position and flush with the top of the Transfer Station mat. The impact limiter is designed to provide defense-in-depth to ensure that the consequences of hypothetical drops of a loaded MPC into either a Concrete Cask or a Transport Cask are acceptable.

Prior to MPC transfer operations, an empty Transfer Cask will be placed into position in the Transfer Station (directly above the impact limiter) using a mobile crane, aligned into its proper position, and restrained in place. At this point and during subsequent MPC transfers, the Transfer Cask will remain fixed in place and vertical and horizontal design load reactions will be resisted by the Transfer Station structure.

In preparation for an MPC transfer, a loaded Concrete Cask will be transported on air pads from its storage position to the vicinity of the Transfer Station. After being prepared (lid removed, etc.), the Concrete Cask will be moved into position beneath the Transfer Cask and directly over the impact limiter embedded in the Transfer Station foundation mat. Shielding will then be placed in position to cover the gap between the Transfer Cask and Concrete Cask. The shielding is an integral part of the Transfer Station design and is positioned using hydraulic jacks.

After preparing the Transfer Cask and attaching appropriate rigging to the MPC, the MPC will be lifted by the mobile crane from the Concrete Cask into the Transfer Cask (see Figure 8.2-6). The Transfer Cask shield doors will be closed, and the MPC will be lowered to rest. The

shielding and Concrete Cask will then be removed, and the prepared Transport Cask will be transported on air pads to the loading position beneath the Transfer Cask. The shielding will be replaced and the MPC subsequently lowered from the Transfer Cask into the Transport Cask.

As indicated above, in overall concept, the Transfer Station is essentially a passive support structure for the Transfer Cask during vertical MPC movements between the Concrete Cask and the Transport Cask.

8.2.13.3.3 MPC Drop Analysis

A postulated MPC drop accident during inter-cask transfer operations at the Trojan ISFSI Transfer Station was analyzed (Reference 16) to demonstrate that: (1) the fuel assemblies will not be damaged such that retrievability would be adversely affected; (2) the MPC confinement integrity and the shell stability will be maintained; (3) the MPC fuel basket structure will not be subjected to unduly large deformations; and (4) the criticality control elements (Boral) will stay in place. The MPC was assumed to drop vertically from a height of 249 inches onto the bottom of the Concrete Cask cavity, which rests atop the Transfer Station embedded impact limiter. The base of the impact limiter is conservatively assumed fixed in all directions in order to simulate a rigid foundation.

The postulated MPC drop event was analyzed as a transient, nonlinear problem involving a number of structural components in dynamic contact. The finite-element method was used to conduct the numerical simulation for the drop event to obtain a conservative damage estimation. The impact damage is evaluated in terms of impact deceleration, stress, and deformation in the structural members involved in the impact.

A commercial computer code developed by the Livermore Software Technology Corporation and QA validated by Holtec International, LS-DYNA, was used to numerically model the impact problem. LS-DYNA is the same computer code used for dynamic analyses described in the HI-STORM 100 System FSAR.

To bound the physical problem, the following assumptions were made (Reference 16):

1. The loaded MPC is assumed to weigh 78,700 lbs in the analysis, which is the maximum allowed weight of the heaviest Trojan MPC-24E or MPC-24EF as indicated in Table 4.2-4. In the LS-DYNA model, a smaller weight of 69,765 lbs is conservatively used for the fully loaded MPC model to maximize the impact deceleration. This assumed 24 assemblies but with no fuel inserts or spacers.

2. The concrete discontinuity at the bottom of the Concrete Cask due to the air inlets is not considered in the analysis. This is a simplifying and conservative assumption, since the existence of air inlets actually helps to absorb more impact energy and hence to reduce the deceleration of the MPC.

3. The reinforced concrete foundation is assumed to be rigid and, therefore, is not modeled. Instead the bottom of the impact limiter is fixed against translation in all three directions. This assumption makes the impact target stiffer than the actual Transfer Pad since the model is incapable of absorbing energy through the concrete foundation.

A quarter-symmetric finite element model was developed based on the actual configuration of the Trojan MPC-24E. The MPC lid and baseplate were modeled with solid elements. A $^1/_{16}$-inch radial gap was included in the model between the MPC lid and shell. Shell elements were used to model the MPC shell. The MPC shell was discretized using very fine grids, especially at the connection regions with the lid and the baseplate. The MPC fuel basket was also modeled in detail reflecting the actual cell configuration. In order to incorporate the potential for internal impacts between the MPC fuel basket and the MPC enclosure vessel, the fuel basket and its contents were simulated as discrete masses with appropriate contact stiffnesses defined at the potential impact interfaces. To accurately represent the mass distribution inside the MPC, the stored fuel assemblies were individually modeled as rectangular solids based on the enveloping dimensions of a Westinghouse 17 x 17 PWR assembly. The weight density of the fuel assemblies is set so that the total weight of the loaded MPC equals 78,700 lbs, as reported in Table 4.2-4. This modeling approach bounds the fuel assembly types currently in use at Trojan.

For simplicity, only the lower portion of the Concrete Cask, which consists of the inner steel liner and the outer concrete, was modeled. As a result, the upper portion of the cask could not absorb any impact energy, thereby making the analysis more conservative.

The finite element model of the impact limiter includes the 3-inch thick top plate, the impact foam, and the thin stainless steel shell. A specific LS-DYNA material model together with the manufacturer's performance data was used to characterize the behavior of the impact limiter.

Finally, appropriate boundary conditions were applied to the symmetric surfaces of the LS-DYNA model. In addition, twenty-eight contact interfaces were defined among the modeled structural components.

Based on the results, the maximum deceleration of the dropped MPC was slightly less than 54g, which is less than the MPC design basis deceleration limit of 60g. A partially loaded MPC (i.e., with as few as 20 of 24 cells filled) would experience a slight increase in deceleration. The bounding, partially loaded MPC with 20 cells filled conservatively assumes 20 fuel assemblies with no inserts, but with 20 spacers. This results in an MPC weight of 69,616 lbs, almost equal to the fully loaded deceleration model weight of 69,765 lbs noted above. Since the percentage difference is only 0.21%, the weight difference has a negligible effect on the deceleration results. Therefore, the stored fuel assemblies will not be damaged due to the postulated MPC drop accident. The maximum Von Mises stress in the shell was calculated to be 24,092 psi, which is well below the failure stress of the material (65,200 psi at 450°F from Table 3.1.14 of the HI-STAR FSAR). Therefore, the MPC confinement integrity is maintained after the postulated drop accident. In addition, a review of the analysis results of the MPC shell does not identify

any gross deformation or buckling in the shell. The maximum stress intensities at critical locations (such as the MPC lid-to-shell weld) are well within the Level D service condition limits specified in the ASME Code.

The calculated maximum stress of the MPC fuel basket is 20,838 psi, which is well below the material failure stress (55,450 psi at 725°F, from Table 3.1.14 of HI-STAR FSAR), and also significantly smaller than the critical buckling stress (49,220 psi, from Section 3.4.4.3.1.3 of the HI-STAR FSAR). The analysis results demonstrate that MPC fuel basket will not be subjected to unduly large deformation. Finally, a review of the sheathing weld stress analysis documented in Appendix 3.M of the HI-STAR FSAR indicates that the sheathing weld shear stress is only 3,956 psi under a 60g vertical load. Therefore, the criticality control elements (Boral) of the MPC fuel basket will stay in place in the postulated drop event.

In conclusion, the consequences of the postulated free-fall drop accident of a loaded MPC from a HI-TRAC Transfer Cask into a HI-STAR 100 Transport Cask or Concrete Cask at the Transfer Station satisfy the acceptance criteria.

8.2.13.3.4 Accident Dose Calculation

There are no radiological releases or adverse radiological consequences from this event.

8.2.13.4 <u>Loaded Transport Cask Drop</u>

A vertical or horizontal drop of a loaded Transport Cask is speculated to occur during transfer to a heavy-haul trailer or rail car prior to the installation of transportation packaging impact limiters.

Section 9.7.5 establishes that a program provide the requirements governing handling or lifting fuel bearing components including Transport Casks. Handling/lifting of spent fuel or handling/lifting of loads over spent fuel are performed only in accordance with approved lift plans. An evaluation of consequences of a drop or handling accident shall be performed prior to initiating the handling/lifting activities. This evaluation shall include both the fully loaded and the bounding (i.e., lightest) partially loaded MPC as analyzed in Reference 16.

In accordance with the program described in Section 9.7.5, an evaluation to criteria equivalent to those specified in NUREG-0612 will be performed of the entire fuel transfer and loading process. Handling of the Transport Cask at the ISFSI could utilize increased safety factors in the rigging to preclude drops or impact limiters to mitigate the effects of drops prior to installation of the transportation packaging.

8.3 SITE CHARACTERISTICS AFFECTING SAFETY ANALYSIS

The ISFSI site is located as depicted in Figures 2.1-1 and 2.1-2. The installation accommodates 34 loaded Concrete Casks and its layout is shown in Figure 2.1-3. The loaded Concrete Casks reside on a thick concrete slab with fifteen feet center-to-center spacing and an aisle through the middle of the array. The Controlled Area for the ISFSI site is shown on Figure 2.1-2. The ISFSI site is well shielded by an embankment on the north and east sides. Figure 2.1-2 shows the accessibility of the site to truck, rail, and barge transportation. Section 2.2.3 notes that the nearest natural gas line is approximately 1.5 miles from the site; operation of this gas line will not present a hazard to the ISFSI from explosion because of the distance from the site.

Site characteristics that affect the safety analysis are summarized in Table 8.3-1.

8.4 REFERENCES

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Table 8.2-6

Bounding χ/Q Values for the Controlled Area Boundary and Nearest Residence for Accident Conditions

Location	Distance for Developing χ/Q	χ/Q
Controlled Area Boundary (200 meters)	200 meters	3.25E-04
Nearest Resident (approximately 660 meters)	600 meters	4.80E-05

Table 8.2-7

Trojan ISFSI Offsite Transportation Explosion Hazard Evaluation Results

Source	Nearest Approach (miles)	Type of Explosion	Deterministic Analysis Results (blast wave pressure)	Probabilistic Analysis Results
BNSF Railcar*	1.09	Solid Explosive and Stationary VCE	All Hazards < 1.0 psig	N/A
		BLEVE	All Hazards < 1.0 psig	N/A
		Traveling VCE	Butane, Butylene, Isobutene, Isobutylene, Propane and Propylene > LEL for Weather < 5% of the Time. Remainder < LEL	N/A
PNWR Railcar*	0.14	Solid Explosive and Stationary VCE	Ethanol < 1.0 psig	N/A
		BLEVE	N/A	N/A
		Traveling VCE	Ethanol < 1.0 psig	N/A
Columbia River Vessel**	0.18	Solid Explosive and Stationary VCE	Petroleum Coke < 1.0 psig Sulfur < 0.1 psig Remainder > 2.2 psig or > 1.0 psig	Actual trips fewer than minimum required to be a credible event.
		BLEVE	All Hazards > 2.2 psig	
		Traveling VCE	All Hazards > LEL	

* Section 8.1 of Reference 19

** Section 8.2 of Reference 19