

Proposed Propane Marine Terminal in Portland

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Abstract

In 2014, Pembina Pipeline Corporation (PPC) inked an agreement with the Port of Portland, Oregon, to build a West Coast shipping terminal to export Canadian propane. Why Portland? The simple answer: lower regulatory hurdles; if Canadian propane bound for overseas markets is transported by rail to US shipping terminals, it is largely free of export restrictions and Federal permits are not required. However, the project has already hit a snag due to the existence of a protected natural shoreline. The proposed terminal location is close to and equidistant from Portland's northern suburbs and downtown Vancouver, Washington.

Nationally, the planning and building of energy export terminals is happening at a rate that far-outstrips the ability of city councils and planning departments to keep up. Moreover, the PPC project is far from green... and according to the city, the terminal would increase Portland's CO₂ emissions by about 0.7%. The PPC terminal also offers few direct jobs, would close public waterways for days each month, and unnecessarily endanger the lives of a significant portion of the Portland and Vancouver populations.

In this paper we discuss ways in which propane transportation and storage on such a large scale is highly vulnerable and not inherently safe. Particularly in view of the expected 25+ year lifetime of the facility, we demonstrate that the PPC propane export terminal project presents an unacceptable risk, and high potential for serious impact on our entire Portland/Vancouver urban area. It also far exceeds any industrial factor originally envisioned for Portland's industrial zoning. We will comment on the environmental impact statement and environmental impact report (EIS/EIR) for a California LNG project that is similar in many ways to the PPC proposal, but which was canceled due to the improbability of mitigation of various environmental issues: everything from high density housing less than two miles away, to seismic liquefaction risk, and the pressurized storage of up to 6-million gallons of liquid propane on site. This EIS/EIR is representative of the level of planning detail that we believe should be required before large, high-impact projects get official go-ahead approval.

Simulation results obtained using well validated EPA/NOAA models for various accident and incident scenarios, whether manmade or due to natural causes, or whether due to deliberate acts of terrorism, are discussed. The results, which as presented in the form of easy-to-understand maps, demonstrate that Portland's industrial zoning is outdated, and that the thinking of our civic leaders who would support the construction of a large scale propane export terminal so close to where we Portlanders live our lives, is obsolete, and due to its role in expanding the use of fossil fuels, is at odds with Portland's widely promoted image as America's Greenest City.

We believe that our propane accident model results are of sufficient confidence to support a conclusion that a propane export terminal less than 10 miles beyond the Portland and Vancouver urban boundaries is contraindicated, and must be rejected if our cities are to live long and prosper.

We will also briefly consider some legal ramifications embedding a large propane export facility inside a busy urban area.

*Northwest Citizen Science Initiative (NWCSI) is an association of civic leaders, scientists, engineers, and environmental researchers that promote thorough, valid, and reliable methods for the scientific study and enhancement of all of Nature's systems of livability and sustainability across the Pacific Northwest.

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Statement of Copyright:

The following material is reproduced here under the fair use provision in US copyright law, for the purposes of review and comment: The Google Maps images in figure 1; the Pembina Pipeline Corp press-release photograph in figure 3; the Cosmo Oil Refinery propane incident photographs in figure 6, and data in appendix A, sourced from a French Ministry of Ecology’s analysis, research, and information on accidents (ARIA) database report on the incident; the Port of Long Beach EIR/EIS executive summary and table of contents quoted in appendices C and D.

The remainder of this document is declared by its authors, the Northwest Citizen Science Initiative, to be in the Public Domain.



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Modeling Software Authority Statement

The ALOHA (Areal Locations of Hazardous Atmospheres) program used to produce the propane threat zone maps presented in this paper originated in the 1970s as a simple tool for modeling and estimating the dispersion of gas plumes in the atmosphere. Over the years since then, it has evolved into a tool used for a wide range of response, planning, and academic purposes. It is currently distributed to thousands of users in government and industry (in the USA it is distributed by the National Safety Council).

ALOHA, now at version 5.4.4, is maintained by the Hazardous Materials Division of National Oceanic and Atmospheric Administration (NOAA), and is widely used by Fire Departments and first responders for Emergency Chemical Release Modeling.¹ The following is a list of the credentials of the ALOHA project team members and external review team (as of February 2006) who added new features related to fire and explosions (pool fire, BLEVE—boiling liquid expanding vapor explosion—, flare or jet fire, flammable explosive vapor cloud):²

ALOHA Project Team Credentials:

Jerry Muhasky PhD (Mathematics). More than ten years' experience in design of large environmental software programs. Lead programmer for ALOHA version 5.

Bill Lehr PhD (Physics). Over twenty years' experience in software model development in the environmental field. Dr. Lehr was lead scientist for the source strength component of ALOHA, version 5.

Jon Reinsch. Experienced software developer and was lead programmer for the NOAA/EPA RMPCOMP project.

Gennady Kachook. Experienced programmer and has worked on several environmental modeling programs.

Debra Simecek-Beatty. Environmental modeling specialist and has worked on several large modeling projects.

Robert Jones PhD (Chemistry). Has been lead researcher on many ALOHA updates.

¹ Jones, Robert, et al. ALOHA (Areal Locations of Hazardous Atmospheres) 5.4.4 Technical Documentation. NOAA Technical Memorandum NOS OR&R 43. November 2013.

http://response.restoration.noaa.gov/sites/default/files/ALOHA_Tech_Doc.pdf Retrieved Feb 20, 2015.

² "Technical documentation and software quality assurance for project-Eagle-ALOHA: A project to add fire and explosive capability to ALPHA." Feb 2006. Office of Response and Restoration, National Oceanic and Atmospheric Administration (NOAA); Environmental Protection Agency (EPA); Pipelines and Hazardous Materials Safety Administration, Department of Transportation.

<http://www.deq.state.ok.us/LPDnew/saratitleiii/AlohaTrainingManuals/Final%20techdoc%20and%20QA.pdf>

Retrieved Feb 20, 2015.

ALOHA 5.0+ External Review Team:

| | |
|------------------------------|--|
| James Belke | Environmental Protection Agency |
| Don Ermak | Lawrence Livermore National Laboratory |
| Martin Goodrich Baker | Engineering and Risk Consultants |
| Greg Jackson | University of Maryland |
| Tom Spicer | University of Arkansas |
| Doug Walton | National Institute of Science and Technology |
| Kin Wong | Department of Transportation |

The following is a check list of relevant features of ALOHA (our emphasis):³

ALOHA 5.0+ Features:

- Quality Control. Significant effort has been put into checking user inputs for reasonableness and for providing guidance on how to select input correctly. Numerous warnings and help messages appear on the screen throughout the model.
- Useable accuracy. Even though approximations are necessary, every effort is made to ensure that the result is as accurate as possible. When compared to the results from sophisticated, specialized models or field measurements, ALOHA generally will deviate in a conservative direction, (i.e., predict higher concentrations and larger affected areas).
- Contingency planning. ALOHA 5.0 can be used for site characterization of industrial settings. Dimensions of permanent tanks, pipes, and other fixtures can be described and saved as text or ALOHA-runnable files. Different accident scenarios can then be played to derive worst-case possibilities.
- Neutral or heavy gas models. ALOHA 5.0 is able to model heavy gases and neutral gases.
- Pressurized and refrigerated tank releases. ALOHA 5.0 will model the emission of gas from pressurized tanks or refrigerated tanks with liquefied gases. Flashing (sudden change from liquid to gas inside the tank), choked flow (blocking of the gas in an exit nozzle), and pooling of the cryogenic liquid are considered.

ALOHA Special Training Requirements/Certification:

There are no special additional requirements or certification required to use the new fire and explosion option scenarios in ALOHA 5.0+. However, since some terminology peculiar to the new scenarios will be different from those involving the toxic gas modeling, it is recommended that anyone new to fire and explosives forecasting review the user documentation and become familiar with the example problems. In particular, the modeled hazards now include overpressure and thermal radiation risk, in addition to toxic chemical concentrations.

³ Reynolds, R. Michael. "ALOHA (Areal Locations of Hazardous Atmospheres) 5.0 Theoretical Description." NOAA Technical Memorandum NOS ORCA-65 (August 1992). Pages 2-3.
<http://www.deq.state.ok.us/LPDnew/saratitleiii/AlohaTrainingManuals/ALOHA-Theoretical-Description.pdf>
 Retrieved Feb 20, 2015.

Introduction

On Aug 28, 2014, Canadian fossil fuel company Pembina Pipeline Corporation (PPC) publicly announced that it had entered into an agreement with the Port of Portland, Oregon, for the building of a new West Coast propane export terminal.⁴ The stated use of the terminal is to receive propane produced in the western provinces of Canada, and export it to international markets. The agreement includes the provision of a marine berth with rail access. The chosen location, adjacent to the Port of Portland's Terminal 6 facility, has already hit a snag due to the existence of a protected environmental zone along the river shoreline adjacent to the planned location of the propane terminal. This protection was created in 1989 to protect wildlife habitat, prevent erosion and preserve the Columbia's visual appeal.⁵ The protection includes a ban on transporting hazardous materials through the zone except by rail or on designated roads; however PPC needs to use a pipeline to cross the zone.

PPC intends the export terminal project to "initially" develop a 37,000 barrel (1.16 million US gallons) per day capacity with an expected capital investment of US\$500 million and with an anticipated in-service date of early 2018.⁶ The site of the proposed terminal is just 2¾ miles equidistant from downtown Vancouver, WA; downtown St. Johns in Portland; and the Interstate 5 Bridge across the Columbia River. Within the 24 square miles defined by this perimeter, exist many other valuable assets including the Port of Portland's Rivergate Industrial District and marine terminals; the entire Port of Vancouver; the Smith and Bybee Wetlands Natural Area; the BNSF rail bridge across the Columbia River; West Hayden Island; the Hayden Island manufactured homes community and business center; the Portland suburbs of Cathedral Park, St Johns, and Portsmouth; several of Portland's floating home communities; the BNSF rail bridge across the Columbia River; and of particular mention, the under construction Columbia Waterfront project ("The Waterfront in Vancouver, Washington"), which is in the process of developing 32 acres of long neglected riverfront land to extend Vancouver's urban core back to its riverfront roots.

While the number of accidents and incidents involving propane and other volatile energy fuels being extracted, transported and stored has not increased generally, the *severity* of incidents and accidents seems to have increased. Part of the reason may be that oil companies are having trouble building additional pipelines, so they've taken to the road.⁷ They've also taken to the rails, with trains that are longer (mile-long unit trains consisting of 100 tanker cars are now standard). Compared to two decades ago, storage tanks are larger, there are many more trains,

⁴ <http://www.pembina.com/media-centre/news-releases/news-details/?nid=135242>. Retrieved Sep 02, 2014.

⁵ House, Kelly. "Portland Propane Export Project Hits Environmental Snag." Retrieved from Oregon Live, Jan 05, 2015 http://www.oregonlive.com/environment/index.ssf/2014/12/portland_propane_export_projec.html

⁶ PR Newswire. "Pembina Chooses Portland, Oregon for New West Coast Propane Export Terminal." <http://www.prnewswire.com/news-releases/pembina-chooses-portland-oregon-for-new-west-coast-propane-export-terminal-273541321.html> Retrieved Jan 05, 2015.

⁷ Krauss, Clifford; Mouawad, Jad. The New York Times. "Accidents Surge as Oil Industry Takes the Train." http://www.nytimes.com/2014/01/26/business/energy-environment/accidents-surge-as-oil-industry-takes-the-train.html?_r=0 Retrieved Jan 07, 2015

and loads tend to be a lot more volatile (particularly with the propane-rich Bakken oil⁸). Other factors are profit pressure, many new (rookie) workers in an expanding workforce, and liability caps.

Therefore, if we factor in the humongous scale of the PPC proposal, together with PPC's stated intention to expand the facility in the future to even larger volumes; it is difficult to see how, for Portland, a "bridge-fuel" like propane (much of which actually goes to manufacture propylene, rather than be burnt as a fuel) is a bridge to anywhere except perdition. This paper discusses ways in which energy transportation and storage on such a large scale in Portland is highly vulnerable in a number of ways. Particularly in view of the expected 25+ year lifetime of the facility, we will show that it presents an unacceptable risk, and that even a minor accidental fire in one part of a propane facility can escalate to larger fires, and explosions, in other parts of the facility (domino effect), with the potential for very dire consequences and impact on our entire Portland and Vancouver urban area. Indeed, the potential for harm to our area is great, and clearly exceeds any industrial factor originally envisioned for Portland's industrial zoning.

The propane threat zone estimates discussed in this paper have been computed with the best available information we currently have from the City of Portland, Port of Portland, and PPC, and in an ongoing absence of any meaningful analysis from any of those entities. We believe the analysis benchmark that PPC should be held to before any "overlay" of the beachfront environmental zone can be even considered by Portland's Bureau of Planning and Sustainability, is the 825-page "*Draft Environmental Impact Statement/Environmental Impact Report Volume 1-2*" dated Oct 2005, submitted by the Port of Long Beach, CA, in support of their (ultimately unsuccessful⁹) application for approval of *The Long Beach LNG Import Project*.¹⁰ The Executive Summary and the contents pages from this monumental document are provided in Appendices C and D, respectively, as an example of what, in the US, is considered normal practice for energy terminal and pipeline projects. To give an idea of the depth of this document, the word "security" appears 335 times in its pages, yet, "mitigate" and "mitigation" only appear a total of 220 times. Some of the other words used frequently are: "terrorist" 217x; "terrorism" 13x; "threat" 73x; "quake" 184x; "seismic" 102x; "liquefaction" 37x. Interestingly, "propane" is mentioned 76 times, "explosion" 109x; "explod" 7x; a 20-foot high full-enclosure concrete wall is mentioned 16x; and boiling liquid vapor explosions are mentioned 19x (the site planned to use two 85-ft diameter pressurized spheres near the LNG tanks, to store "hot gas" impurity components

⁸ Stern, Marcus; Jones, Sebastian. "Too Much Propane Could Be a Factor in Exploding Oil Trains." Bloomberg News, Mar 5, 2014. <http://www.bloomberg.com/news/2014-03-05/too-much-propane-could-be-a-factor-in-exploding-oil-trains.html> Retrieved Jan 03, 2015.

⁹ Gary Polakovic "Long Beach energy project halted: The city cancels plans for a liquefied natural gas terminal. Many had voiced safety concerns." LA Times, Jan 23, 2007. <http://articles.latimes.com/2007/jan/23/local/me-lng23> Retrieved Feb 24, 2015.

¹⁰ http://www.energy.ca.gov/lng/documents/long_beach/LongBeachImport/Draft%20POLB%20EIR-EIS%20Vol.1-2%20Full%20Text%20document%20without%20figures.pdf Retrieved Feb 24, 2015.

propane and ethane from the LNG. “Sabotage” is mentioned 5x; “vapor cloud” 117x; and “vapor cloud explosion” 134x.

Propane, being a relatively new energy commodity (from the POV of high-volume terminal construction for export), whether for overseas energy production or chemical feed stock), largely had to follow the existing LNG safety regulations surrounding refrigerated storage tanks.¹¹ Indeed, as stated in the Long Beach document mentioned above, the hazards common to both propane and LNG refrigerated tanks are *torch fires* (gas and liquefied gas releases), *flash fires* (liquefied gas releases), *pool fires* (liquefied gas releases), *vapor cloud explosions* (gas and liquefied gas releases). The same document states that Propane is much more hazardous due to its propensity for *boiling liquid vapor explosions* (BLEVEs), when it is stored and/or transported in rail tankers, tanker trucks, bullet tanks, and other above-ground pressurized storage tanks.

The Need for Urban Resilience

For the cities of Portland and Vancouver to flourish and live long, we must make them as safe and as resilient as we know how. This means avoiding or eliminating the potential for serious disasters, especially man-made. Dr. Judith Rodin, in her major new book, *The Resilience Dividend*,¹² describes the concept of resiliency of cities, and not only how they can recover after a major catastrophic event, but also how to make decisions to avoid such events in the first place. Former investment banker Mark R. Tercek, now president and CEO of The Nature Conservancy, said of her work, “Judith Rodin details connections between human, environmental and economic systems, and offers a strategy to proactively address the threats they face.” Tercek’s book, co-authored with biologist Johnathan S. Adams, *Nature’s Fortune*,¹³ makes the case that investing in nature—the green infrastructure—makes for good business, and is the smartest investment we can make.

Our civic regulatory process already eliminates or mitigates a lot of potential for disaster through our building and zoning codes. Unfortunately zoning alone cannot create resiliency because it does not balance all aspects of our communities. Moreover, due to globalization, we are seeing a scale and rate of industrialization, particularly in the fossil fuels energy space, that puts an unprecedented amount of pressure on our city administrators and planners to follow the dollar. Moreover, we are asked to believe that the recent energy boom—which has been advancing with little regard to our environment—will enhance our lives, solve all of our problems, and produce thousands of family wage jobs (the truth, at least as far as the PPC propane terminal is concerned, is much closer to half a job per acre, and no more than 30–40 direct jobs total). We are also asked to accept that any consequent loss of wild habitat and

¹¹ Not all propane import/export terminals use refrigerated storage. For example, the Cosmo Oil propane and LPG terminal that blew up on March 11, 2011 in Tokyo Bay, at that time used only pressurized storage.

¹² Dr. Judith Rodin chair of the Rockefeller Foundation, and author of *The Resilience Dividend: Being Strong in a World Where Things Go Wrong*. Public Affairs, New York, 2014.

¹³ Tercek, Mark R.; Adams Jonathan S. *Nature’s Fortune: How Business and Society Thrive By Investing in Nature*. Basic Books, New York, 2013.

recreational areas, loss of air and water quality due to heavy industrialization within our city boundary is a worthwhile tradeoff. Moreover, given the potential for a credible large scale propane accident or incident at the planned terminal, and given the high probability of a long and protracted recovery from such a calamity (were a recovery even possible), it cannot be offset by a promise of good housekeeping. The handling of humongous quantities of an extremely dangerous chemical amidst our two cities, Portland and Vancouver must, therefore, be avoided at all costs. Only by saying no to large-scale propane facilities in Portland can we avoid the unthinkable. History records that despite best efforts, accidents and incidents happen. Only by making Portland as resilient as we know how, can we reap what Dr. Judith Rodin calls “the resilience dividend.”

Why Portland?

Why did Canadian company Pembina Pipeline choose Portland? Put simply, the answer is lower regulatory hurdles. Due primarily to the North American Free Trade Agreement (NAFTA), and quirky US export laws that were crafted in the days of oil shortages, we have a situation where imported Canadian natural gas liquids are largely free of export restrictions, a status shared by propane imported from Canada by train (but not by pipeline).¹⁴ Although PPC denies that this is the reason, a partial acknowledgement came from Port of Portland Executive Director Bill Wyatt, who told Oregon Live¹⁵ that propane is not regulated in the same way as natural gas or domestic oil. He added that although PPC must obtain building permits from the City of Portland, an air quality permit for the Oregon DEQ, and maybe also a water quality permit from the state, Federal permits are not required. However, he did say that Portland also has the advantage of competing railroad companies, not to mention the port’s experience with export terminals.

Nationally, these types of projects are happening at a rate that far-outstrips the ability of city councils and planning commissions to keep up. At the same time, a burgeoning population is putting an unprecedented pressure on our urban boundaries, and also on the industrial zoning which, once upon a time, was thought to be a safe distance from current (and future) residential areas. These populations would be much better served by new clean-tech industries (e.g., computer software and film animation) that are much cleaner, safer, and more easily integrated into our modern city environment than traditional heavy industries. The bottom line is that large energy facilities (such as the one that PPC wants to build in Portland) have no place within or close to our cities!

That the PPC proposal has progressed so far as to identify a site for a large propane export facility so close to where people live and play is a complete mystery. The first responsibility of

¹⁴ Irwin, Conway (Nov 20, 2013) “The US’s Absurd Oil & Gas Export Laws.”

<http://breakingenergy.com/2013/11/20/the-uss-absurd-oil-gas-export-laws/> Retrieved Jan 05, 2015.

¹⁵ Francis, Mike. Oregon Live (Sept 02, 2014) “Pembina Pipeline's Portland propane project faces lower hurdles than other terminals.” http://www.oregonlive.com/business/index.ssf/2014/09/pembina_pipelines_portland_pro.html Retrieved Jan 05, 2015.

government is the protection, health, and welfare of the population, not participation in an industry that is not as green as some would lead us to believe;¹⁶ that would use vast amounts of our resources (8,000 MWh of electricity per month; which would increase Portland's CO₂ emissions by about 0.7%,¹⁷ and which would raise a large question about awards recently received by the city¹⁸ in recognition of its Climate Action Plan to reduce greenhouse gas emissions by 80 percent from 1990 levels by 2050¹⁹), by PPC's own admission would offer very few direct jobs (30–40), would close public waterways used by the gas carrier ships for days each month, and unnecessarily endanger the lives of a significant proportion of the Portland and Vancouver population. Therefore we need to ask: Where are our city officials? To whom are they answering?

When information about PPC's desire to build a propane export terminal became public, Portlanders were surprised to hear that the city and the port had already been in secret negotiations with PPC for six months. An agreement that the Port of Portland would provide a space at Terminal 6 for construction of a facility that would include refrigerated storage for 30 million gallons of liquid propane was already in place! Amid claims from port personnel to the contrary, neither Audubon Society nor Sierra Club, nor Columbia Riverkeeper had received any communication from the port, or the city, informing them of the proposal. There was no public disclosure until after the agreement with PPC was already inked. At that point, PPC met with Hayden Island residents and hinted that the project was being fast tracked, also mentioning that if Portland did not want the terminal, PPC would withdraw and move on.²⁰ Clearly the project was being pushed through without the protective umbrella of public discussion and public process; a process more important than usual, given Portland's lack of experience with large propane projects (and PPC too, since this is also PPC's very first propane export terminal). Pembina intends to build two steel, double-walled tank-within-a-tank insulated tanks, totaling 33.6 million gallons. The design is probably similar to two the 12.5 million gallon double steel wall tanks built for Suburban Propane, in Elk Grove, CA. (figure 1). Unlike Elk Grove, Pembina tanks would be of unequal size (see artist's rendering in figure 2), the largest of which would be some 130 feet tall. The propane in such tanks is stored as a refrigerated liquid, cooled to approximately -44 °F to allow storage at close to atmospheric pressure.

¹⁶ Warrick, Joby; Washington Post. "Methane plume over western US illustrates climate cost of gas leaks." <http://www.theguardian.com/environment/2015/jan/04/leaking-methane-gas-plume-us> Retrieved Jan 07, 2015

¹⁷ Bureau of Planning and Sustainability, City of Portland, Oregon. "Terminal 6 Environmental Overlay Zone Code Amendment and Environmental Overlay Zone Map Amendment – Part 1: Environmental Overlay Zone Code Amendment." *Proposed Draft*, Dec 12, 2014. Page 29. <http://www.portlandoregon.gov/bps/article/512520> Retrieved Jan 07, 2015.

¹⁸ House, Kelly; Oregon Live. "Portland wins presidential award for climate change work." http://www.oregonlive.com/portland/index.ssf/2014/12/portland_wins_presidential_awa.html Retrieved Jan 02, 2015 .

¹⁹ City of Portland and Multnomah County: Climate Action Plan 2009 <https://www.portlandoregon.gov/bps/49989> Retrieved Jan 07, 2015.

²⁰ Hayden Island Neighborhood Network (HINooN) meeting, Oct 09, 2014.



Figure 1: Suburban Propane’s two 12-million gallon double steel wall refrigerated propane tanks, separated from four 60,000 gallon pressurized tanks (LH picture, top right), by an earthen berm. Elk Grove, CA

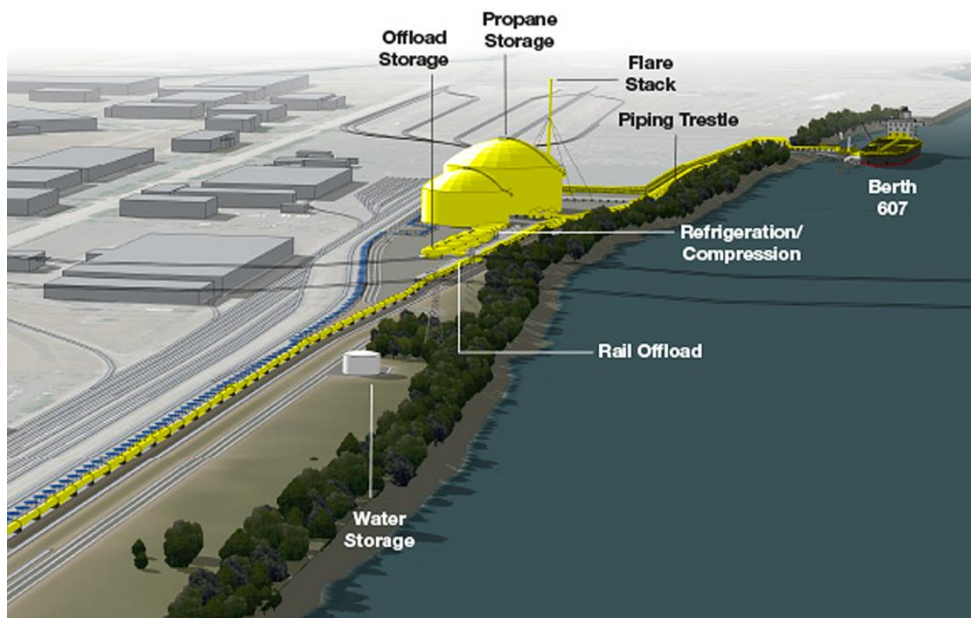


Figure 2: The two double-walled steel refrigerated storage tanks proposed by Pembina for Terminal 6, Portland, OR are of unequal size. The larger tank is 130 feet tall, dwarfing nearby trees. Shown, in front of the storage tanks, are eight 125,000 gallon pressurized bullet transfer tanks. Also shown, stretching diagonally across the picture is a 100 car unit propane train. Propane storage, plumbing, and transportation are shown with yellow highlighting.

The Elk Grove tanks appear to be similar to a design that has been replicated many times already in the LNG industry, including the Everett LNG Terminal, the CMS Energy’s Lake Charles Terminal; the El Paso Corporation’s Elba Island LNG Terminal, near Savannah, GA (phase IIA tank 42 million US gallons, diameter 258 feet, height 123 feet; phase IIIB tank 48 million US gallons).²¹

²¹ Quillen, Doug (ChevronTexaco Corp.) “LNG Safety Myths and Legends.” Conference on Natural Gas Technology Investment in a Healthy U.S. Energy Future, May 14–15, 2002, Houston, TX. <http://www.netl.doe.gov/publications/proceedings/02/ngt/quillen.pdf>

To date there have been no accidents with very large refrigerated LNG or propane tanks, although there have been threats to their safety (see *A clear and Present Danger* section, below). Whether such tanks can remain accident free remains to be seen, especially since no large-scale accident tests have ever been conducted on them. Safety margins are therefore largely theoretical, relying on simulations, and accident data from much smaller tanks.

On the other hand, accidents involving *pressurized* liquid propane storage and transportation are in the news almost every week. One of the most cited propane transportation accidents occurred in Murdock, IL, Sep 02, 1983.²² However, even though it involved a much smaller quantity of propane than held by the large refrigerated tanks mentioned above, the magnitude of the event shocked those who witnessed it. All-told, this accident involved 60,000 gallons of propane, and 50,000 gallons of isobutane, in four tanker cars. Police evacuated a one-mile radius. Things became dangerous when a 30,000 gallon propane BLEVE (Boiling Liquid Expanding Vapor Explosion) was set off by a fire in a nearby 30,000 gallon ruptured propane tanker car. As a result of the BLEVE, a 6-ton tanker car fragment was rocketed $\frac{3}{4}$ mile (3,630 feet) from the explosion. Shocked at the power of the blast, a TV news crew retreated back $2\frac{1}{2}$ miles. Later in the day, the flames triggered a second large BLEVE, this time in one of the isobutane tanks.²³

Propane 101

Propane is considered by the energy industry to be a cost effective and statistically safe fuel. However, due to the large size of transportation units nowadays (a unit train consists of a hundred DOT tanker cars of 30,000 gallons each, for a total of three-million gallons), the increasingly large scale of storage facilities, and the business pressure on suppliers to get this material to market quickly at minimal cost, there have been many incidents and accidents.

Ambient-temperature storage of liquid propane at a propane terminal is typically achieved with a row of high-pressure bullet tanks. Formerly these were sized in the 30,000 to 60,000 gallon range, but nowadays 90,000 to 125,000 gallons is now becoming more common. Likewise, -44 °F refrigerated bulk propane storage which several years ago was in the 12-million gallon ballpark, now ranges to 48-million US gallons per tank and more. As a result of these developments we cannot avoid the fact that propane storage and transfer facilities tend to house very significant amounts of chemical energy, some 4.6 quadrillion Joules (4.6 PJ), in the case of a 48-million gallons of refrigerated liquid propane.

²² Baltimore & Ohio Railroad Company freight train No. 4032 derailed near Murdock, IL, 3:30 p.m., Sept 2, 1983. National Transportation Safety Board, Washington, DC. Report and safety recommendation letter I-85-15, dated April 19, 1985. Fire impinged on four tanker cars loaded with flammable compressed gas. By 9:50 p.m., two of the tanker cars (one propane, and the other isobutane) had BLEVEd, causing $\frac{3}{4}$ of one of the tanks to rocket a distance of 3,630 feet from the derailment.

<http://www.nts.gov/layouts/nts.recsearch/Recommendation.aspx?Rec=I-85-015> Retrieved 3/7/2015

²³ Brockhoff, Lars H. Institute for Systems Engineering and Informatics. EUR 14549 EN. "Collection of Transport Accidents. Involving Dangerous Goods." 1992

When propane burns, its chemical energy is transformed into thermo-mechanical energy. A trade-off exists between the thermal and mechanical effects. How much we obtain of one or the other depends on factors such as the rapidity and degree of the conversion of the propane into a vapor, and the timing of the ignition event. The lower and upper explosive limits (known as LEL and UEL) define the flammability range, respectively 2.1% and 9.5% (by volume) for propane vapor. Before a fire or explosion can occur, three conditions must be met simultaneously: $LEL < \text{fuel} < UEL$ (i.e., a fuel mixture that is not too lean or too rich); air (which supplies oxygen); and a source of ignition (such as a flame or a spark). When sufficient oxygen is present, propane burns completely to carbon dioxide and water. The chemical reaction is $C_3H_8 + 7O_2 = 3CO_2 + 4H_2O + \text{heat}$. Unlike natural gas, propane is heavier than air (around 1.5 times as dense). A poorly mixed cloud of vapor in air may burn as a *deflagration*, at a relatively slow speed governed by the speed of diffusion of propane molecules through the cloud; whereas in a finely mixed vapor cloud we may get a *detonation*, which propagates through the cloud driven by a pressure wave that travels at the speed of sound. *Vapor Cloud Explosions* (VCE), whether due to deflagration, or to detonation, can generate *overpressure waves* that have sharp onsets as well as significant overpressures.

Depending on circumstances, other “classical” types of fires are possible, such as flash fires (a non-explosive combustion of a vapor cloud), and/or jet fires (with any remaining puddles of liquid propane burning as a relatively slow-moving pool fire). Depending on circumstances, there is the potential for the generation of fireballs that are intensely luminous in the infrared range, together with the ejection of showers of “missiles” consisting of sharp tank wall fragments and other debris. This is the Boiling Liquid Expanding Vapor Explosion, or BLEVE, which in the context of propane is applicable mainly to pressurized storage tanks. Introduced in the previous section, BLEVEs generally start when a fire heats the outer wall of the tank. If the heating occurs faster than the relief valve can vent, the pressure inside the tank rises until through the combined effects of pressure and heat-caused weakening of the metal tank wall, the tank ruptures, typically with great force. The heated contents flash-boils, instantly mixes with the air, and the resulting vapor cloud quickly ignites to create a fireball. The bursting of the tank typically ejects fragments at high velocity (10–200 m/s) in all directions; 99% of the fragments landing within a radius of 30x the fireball radius. Frequently, a major part of the tank will rocket to even larger distances, accelerated by the rapid burning of any remaining contents. Typically 100% of the propane is quickly consumed in the fireball, which due to its high luminosity at infrared wavelengths can cause significant radiant heat damage at surprisingly large distances. Another effect of the propane BLEVE is a transient spike in local atmospheric pressure, which spreads out radially from the source of ignition. The magnitude of such an overpressure wave depends on the ignition source and its strength (whether spark, flame, or detonation). If the wave is strong enough to cause injuries or property damage, it is known as a blast wave.

Before leaving this comparison of combustion scenarios, it is worth emphasizing that BLEVEs are generally not applicable to refrigerated propane storage, due to the amount of heat it

would take to boil the frigid liquid, by which time it would likely all have vented. Having said that, we need to point out that there are mechanisms involving large-scale mechanical disruption of the walls of a refrigerated storage tank, which can relatively quickly atomize a significant fraction of the liquid into a vapor mixed with air, from whence various VCE scenarios can be considered.

It is useful as well as informative, to define threat zones as contours (often given a color) of decreasing severity with distance from a deflagration or explosion. We define a zone as an area over which a given type of accident or incident can produce some similar level of undesirable consequences. For example, an orange *thermal threat zone* is defined as the area between two radiant flux contours where second-degree burns occur in less than 60 seconds (such as may occur if the infrared radiant flux exceeds 5 kW/m^2). A red *blast threat zone* is defined likewise as the area between two overpressure contours, where there is significant risk of ear and lung damage or the collapse of unreinforced buildings (such as may be caused by an 8 psi overpressure blast wave). A *shrapnel threat zone* may be defined as the area that captures 50% or 99% of the fragments from a tank explosion, in other words the area over which there is significant risk of injuries caused by flying debris or rocketing tank fragments accelerated by the blast (such as often occur in a BLEVE). In the propane BLEVEs (with ignition) discussed in this paper, at a radial distance approximately equal to the orange thermal threat zone (5 kW/m^2), the overpressure may be as high as 8.0 psi. Proceeding outwards towards lower threat, 3.5 psi is enough to rupture lungs and cause serious injury. Further out still, 1.0 psi is enough to rupture eardrums; 0.7 psi is enough to cause glass to shatter. Even a relatively small sudden overpressure (0.1 psi) may be enough to cause the breakage of small windows under strain.²⁴

Due to the high flammability of propane vapor (i.e., propane in the gaseous state mixed with air in a concentration range between the LEL and UEL), care must be exercised in its handling. Of the two different approaches to propane storage, pressurized storage at ambient temperature is the cheapest although the most dangerous. Refrigerated storage, which uses a temperature of $-44 \text{ }^\circ\text{F}$ at essentially atmospheric pressure, is the safest. However, all refrigerated propane facilities use high pressure bullet storage tanks for propane transfers to or from other high pressure storage or transportation tanks, and PPC's planned Portland propane terminal is no exception. PPC plans to have eight 125,000-gallon high-pressure bullet tanks, with a total storage capacity of one million gallons of propane. Inexplicably, such tanks are typically installed in close proximity to one-another. At Elk Grove they are spaced, broadside, about 10 feet apart). PPC's widely publicized site layout map does not significantly deviate from this practice. As will be discussed, these relatively small high pressure tanks are the Achilles' heel of propane facilities, especially wherever security is lax, representing in PPC's case a credible danger, not

²⁴Renjith, V. R., 2010, PhD thesis. "Consequence Modelling, Vulnerability Assessment, and Fuzzy Fault Tree Analysis of Hazardous Storages in an Industrial Area." Cochin University of Science and Technology, Kochi, Kerala, India. Chapter 3, Hazard Consequence Modeling.
<http://dspace.cusat.ac.in/jspui/bitstream/123456789/5059/1/Consequence%20modelling%20vulnerability%20assessment%20and%20fuzzy%20fault%20tree.pdf> Retrieved Feb 09, 2015

only to surrounding areas as far away as the major residential part of St Johns, the Port of Portland's Rivergate area, the Port of Vancouver, the 240 MW natural gas fired River Road Generating Plant owned by Clark Public Utilities, the Smith and Bybee Wetlands Natural Area, West Hayden Island, and the BNSF rail bridge across the Columbia River, but also to the big refrigerated tank (or tanks) that PPC plans to build little more than a stone's throw from the bullet tanks.

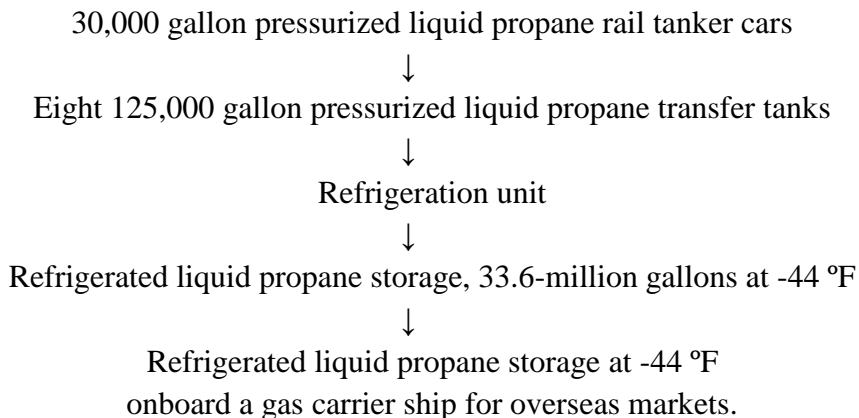
A Clear and Present Danger

The safety score for large refrigerated propane tanks would still be in the "excellent," range, had it not been for one terrorist incident. If the terrorists had succeeded, the score would have been "fail." As a result of the FBI's success in neutralizing the plot, the score is "needs improvement." Besides terrorist plots (who according to several studies, have at their disposal high explosives and trucks to carry them, commercial aircraft, drones, and shoulder-launched rocket-propelled grenades), there are a lot of other potential dangers for such tanks, ranging from earthquake risks (shaking and/or liquefaction leading to wall and roof collapse), to design errors, to accidents in other parts of propane facilities that could spread and multiply domino-fashion, to the big tank. Large tanks are only as safe as the integrity of their walls. Everything on the above list is capable of creating a fast-acting high-impact kinetic energy event which, at worst, could collapse the tank expelling its entire contents as droplets that evaporate into vapor cloud that detonates, or at best only causes a tank wall breach and consequent slower loss of contents that results in a very large pool fire, or some combination of both scenarios. The heat energy required to vaporize the refrigerated propane is a negligible fraction of the heat released when the first gallon of propane vaporizes and catches fire, so the process is completely self-driving.

Whatever causes an initial BLEVE at a propane facility, whether it be in a pressurized bullet transfer tank, or an incoming DOT rail tanker car, there is every possibility that it could quickly spread, domino fashion, from one pressurized tank to another, especially if they are closely spaced (in PPC's plan it could spread over a total of eight 125,000 gallon pressurized transfer tanks, a number which expands hugely if all one hundred 30,000 gallon tanker cars of an incoming unit train became involved). The resulting boiling liquid expanding vapor explosions (BLEVEs) could soon release enough thermo-mechanical energy in the form of radiant heat and overpressure blast damage, also generating a shrapnel-field of high-velocity missile-like tank fragments. This could not only quickly disrupt and overwhelm any remaining bullet tanks, but do so with enough force to disrupt the walls of the nearby much larger refrigerated storage tanks, from whence it is likely that the propane liquid would partly spill, and partly disperse to mix with the air as a vapor cloud, which gives us the possibilities of a fire or a detonation. If a detonation, the result would be what is known as a vapor cloud explosion (VCE). Several very serious chain reaction incidents similar to this have been reported in the past few years (check YouTube). Since it is not possible to protect large propane storage facilities from every conceivable catastrophe, the PPC facility planned for the Port of Portland's Terminal-6, would effectively

plant the potential for a hugely destructive explosion near the OR/WA state line, within the Portland/Vancouver urban area.

The tank sizes at smaller propane facilities (which typically store propane as a liquid at ambient temperature and a pressure of 250 psi) use pressurized bullet tanks in the range 30,000 to 125,000 gallons per tank. Larger propane facilities also include refrigerated tanks (typically 12-million to 48-million gallons) that store liquid propane at -44 °F, essentially at atmospheric pressure. As recently revealed by Portland’s Bureau of Planning and Sustainability,²⁵ the propane facility that PPC is planning to build in Portland consists of two large storage tanks with a total capacity of 33.6-million gallons of liquid propane refrigerated to -44 °F, together with eight 125,000 gallon pressurized transfer tanks. This facility has the ability to process one incoming unit train (100 tanker cars each holding 30,000 gallons) every two days. From when propane arrives by rail to when it leaves by ship, there are at least four risk-prone transfers of propane from one type of container to another:



However, the risks extend well beyond these necessary transfers; the storage tanks themselves also pose a risk. Either way, most of the risk ultimately comes down to the flammability of propane as a vapor mixed with air (vapor cloud), and its high energy content. Whether due to accident, or deliberate criminal act, or through natural causes, the principal chemical mechanisms are the same. Moreover, while propane may be more difficult to ignite than other fuels, once it starts burning it is difficult to stop. Irrespective of whether a vapor cloud originates as the result of a BLEVE (typically from a fire-heated pressurized tank in which the relief valve is insufficient or faulty), or whether it is the result of a sudden mechanical disruption of a (typically larger) -44 °F refrigerated tank, the end result is the same, a vapor cloud explosion or VCE.

²⁵ Bureau of Planning and Sustainability, City of Portland, Oregon. “Terminal 6 Environmental Overlay Zone Code Amendment and Environmental Overlay Zone Map Amendment – Part 1: Environmental Overlay Zone Code Amendment.” *Proposed Draft*, December 12, 2014. <http://www.portlandoregon.gov/bps/article/512520> Retrieved Jan 07, 2015.

The heat radiation and overpressure blast wave yield of propane VCEs depends a lot on details such as how much propane is available to feed it, how much pressure is built up before a tank rupture (BLEVE), or the hydrodynamic details of impacts and the high-explosive-driven shock waves (deliberate criminal acts), in other words on how fast the liquid disperses into droplets, and how much these droplets vaporize and mix with the air before ignition from flame or spark. Large refrigerated tanks are more difficult to explode, but propane facilities tend to also have large numbers of pressurized storage tanks and rail tanker cars in close proximity to the refrigerated tank, creating the potential for scenarios where an accident or incident with one of these smaller tanks can spread domino fashion, multiplying the damage through heat, and showers of missile-like, razor sharp flying tank fragments. Compared to an overpressure BLEVE of a smaller pressurized tank, the consequences of disruption of the typically nearby typically much larger refrigerated tank is potentially much more dire, even if only part of the large tank contents is ejected. Reports of suitable methods to do this abound in news reports of terrorism, so it does not take much imagination to extrapolate to the use of an aircraft collision with the tank, or the use of a large quantity of high explosives (e.g., a car or truck bomb driven into the facility and parked close to a tank), or rocket-propelled munitions such as shoulder launched armor-piercing grenades. The terrorism threat is a clear and present danger, and cannot be overlooked, as exemplified by the plot, foiled by the FBI in December 1999, of two militiamen who conspired to blow up the two 12-million gallon refrigerated propane tanks at the Suburban Propane facility in Elk Grove, near Sacramento, California. One of the conspirators was knowledgeable in bomb making, and a large amount of explosives were found in his possession.

Company officials downplayed the matter, saying that the type of threat envisioned by the militiamen could not detonate the refrigerated propane tanks because they are non-pressurized. The company surmised that the liquid propane would pool within the protective dirt berms, where it could, they said, only ignite after it had considerable time to warm up, vaporize, and mix with the air. “You could have one hell of a fire, but it would all be contained right there within the berms,” said John Fletcher, outside legal counsel for Suburban Propane.

The Suburban company view of the incident loses credibility when we factor in that the facility also has four 60,000 gallon pressurized propane tanks, which may well have been the primary target, and that the militiamen’s intention may have been to focus on destroying these, thereby releasing enough blast energy, heat radiation and flying tank fragments to trigger the rapid destruction of the secondary target, the large refrigerated tanks located in clear line of sight just 220 feet away. In our measured opinion, the consequences of a truck bomb driven through the front gate and exploding next to the neat array of pressurized tanks (see figure 2), would have been to create an increasing cascade of BLEVE type explosions, domino style, which through the combined effects of blast, heat, and bullet tank fragmentation would have destroyed the earthen berm and have initiated the destruction of the large tanks, with a significant proportion of the propane mixing with the air to create a large vapor cloud explosion and/or fireball, potentially damaging a radius up to 4½ as large as that due to the smaller pressurized tanks alone. Figure 3

shows a map of the Elk Grove site overlaid with data from an ALOHA simulation (see appendix A) of a BLEVE of just one of the 60,000 gallon pressurized storage tanks. The resulting modeled fireball engulfs almost the entire facility. There are three radiant-heat threat zones, red, orange, and yellow, with red the most serious.

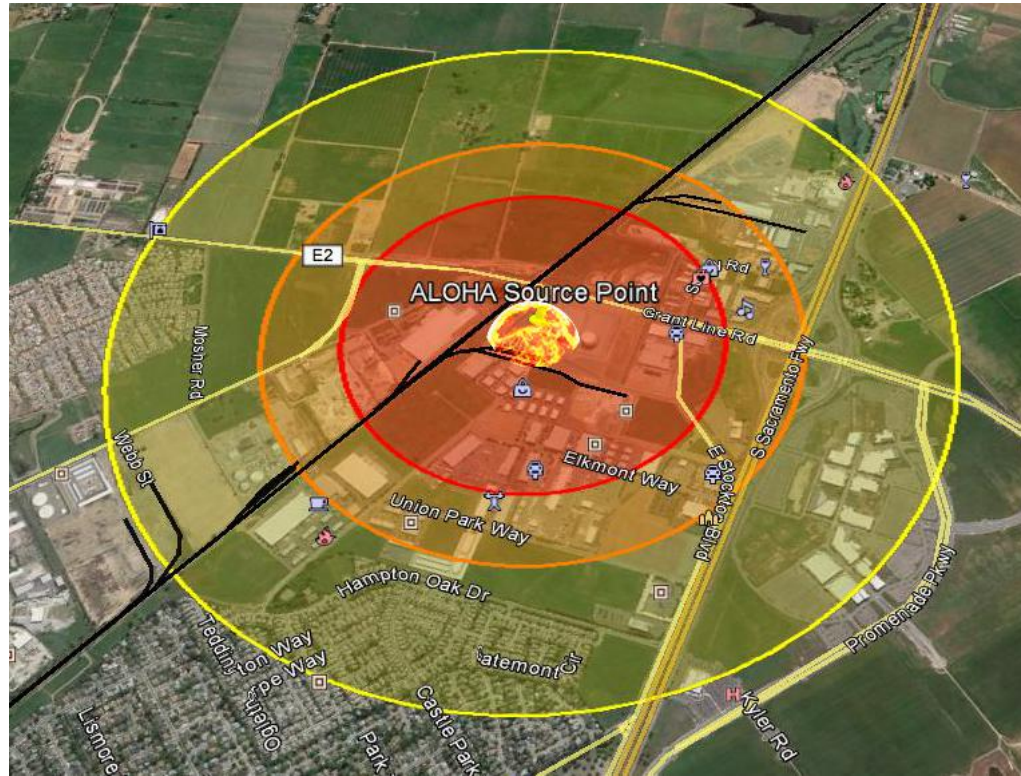


Figure 3: A Google Earth overlay showing one credible scenario had the terrorist plot that targeted the Suburban Propane facility in Elk Grove, California, not been neutralized by the FBI in 1999. It shows thermal threat zones modeled for a boiling liquid expanding vapor explosion in just one of four 60,000 gallon pressurized propane bullet tanks.at the facility. The resulting fireball would have engulfed most of the facility, and the thermal radiation effects would have extended $\frac{3}{4}$ of a mile. If you look to the RH edge of the fireball, below the “e” in “Source,” one of the facility’s two 12-million gallon refrigerated propane storage tanks can be seen on the RH edge of the fireball which would have engulfed most of the site. In a scenario that caused all four bullet tanks to explode nearly simultaneously, the model predicts that the threat zones would extend up to 50% further. Not shown in this figure are the additional effects of overpressure blast wave, and the missile ejection of shrapnel (tank fragments and other debris), which could credibly puncture the large tanks, leading to potentially even larger consequences, which at the very least could cause a large pool fire and deflagration extending well beyond the boundary of the facility. Ironically, the Elk Grove fire station is within the yellow threat zone (the red dot toward the top RH corner of this map). (Fireball diameter 308 yards; Red zone radius: $\frac{3}{8}$ mile [10 kW/m^2] potentially lethal in less than 60 seconds; Orange zone radius: $\frac{1}{2}$ mile [5 kW/m^2] 2nd-degree burns in less than 60 seconds; Yellow zone radius: $\frac{7}{8}$ mile [2 kW/m^2] pain in less than 60 seconds)

The other effects of this BLEVE, the potential destructive power of high-speed hazardous tank fragments, and the blast force from, are not modeled by ALOHA. However, there is plenty

of data collected from many such accidents to justify our expectation that these effects would be considerable, especially the fragments, and especially at close range. Indeed, due to the danger of showers of these flying fragments, many authorities now recommend an evacuation zone of 30- to 40-times the radius of a BLEVE fireball, which is at least 2.6 miles in our Elk Grove example. In other words, at least three times the radius of the yellow threat zone shown in figure 3.

Not unexpectedly, the credible viewpoint concerning the foiled terrorist plot at the Elk Grove Suburban Propane facility came from the Elk Grove Fire Department and Lawrence Livermore Laboratory scientists, who in opposition to the official company position on the matter, said that destruction and fires could have occurred at considerable distances from the plant. Indeed, Fire Chief Mark Meaker of the Elk Grove Fire Department said, “Our experts have determined there would have been significant off-site consequences.”²⁶ He added that a major explosion and fire likely would have blown the earthen berms out and led to a vapor cloud and/or pool fire that could affect nearby residents, schools and businesses, and depending on the size of the blast, residents could be endangered by heat from a large fireball, flying projectiles “like portions of tank shells flying through the air,” and a pressure wave that would emanate from the blast. “In close, there would be a high level of destruction,” said Meaker, adding that office buildings and warehouses stand within 200 yards (182 meters) of the plant, with the nearest residential neighborhood, just 0.6 of a mile (.96 km) from the plant. At any given time, Meaker estimated 2,000 people are within a mile of the plant.²⁷

In particular, the director of the Chemical-Biological National Security Program at Lawrence Livermore Laboratory, one of the world's foremost experts on explosions, said that,

... if the two accused men had been successful in the terrorist plot, a “gigantic fireball” would have been created, causing injuries and damage up to 1.2 miles away. This would, he said, have caused fatal injuries to roughly 50 percent of the people in the blast radius, while many others outside would be severely injured by debris. There would have been fatalities and injuries up to 0.8 miles from the explosion. Then, he said, the initial blast would likely have caused the two smaller on-site pressurized propane loading tanks to explode, rupturing the formaldehyde storage tank at another nearby industrial facility. This would have caused, he said, a toxic cloud that would travel for almost a mile with the prevailing wind, causing life-threatening symptoms to anyone encountering it.²⁸

What makes the Elk Grove incident and the testimonies of the fire chief and scientists particularly credible is that after the arrests of the terrorists, company officials added numerous

²⁶ Industrial Fire World, “Targets of Opportunity.”

<http://www.fireworld.com/Archives/tabid/93/articleType/ArticleView/articleId/86841/Targets-of-Opportunity.aspx> Retrieved Jan 03, 2015.

²⁷ CNN Dec 04, 1999, “Police: California men planned to bomb propane tanks.”

<http://www.cnn.com/1999/US/12/04/bomb.plot.02/index.html> Retrieved Jan 03, 2015

²⁸ Jaffe, Doug, “Elk Grove project ignores nearby propane risk.” Sacramento Business Journal, Dec 08, 2001.

<http://www.bizjournals.com/sacramento/stories/2001/12/10/editorial4.html?page=all> Accessed Jan 02, 2015.

security devices to protect the facility, including a trench designed to stop a car bomb attack at the perimeter.

According to statistics released by the FBI, between 1991 and 2001, 74 terrorist incidents were recorded in the United States, while during this same time frame, an additional 62 terrorist acts being plotted in the United States were prevented by U.S. law enforcement.²⁹ Elk Grove was one of those that were prevented, and the only one (so far) to target a propane energy storage facility. Elk Grove was not the only prevented terror plot that planned to use explosives. There was also the March 2000 plot to blow up the Federal building in Houston, TX, and in December 1999 law enforcement thwarted a plot to blow up power plants in Florida and Georgia. Of the 74 successful terrorist incidents listed for these years, 4 used hijacked U.S. commercial aircraft as missiles, a majority used arson, and there were several incendiary attacks. FBI data for all terrorism 1980–2001 (including incidents, suspected incidents and prevented incidents) shows 324 bombings (67%), 33 arson (7%), 19 sabotage/malicious destruction (4%), 6 WMD (1%), 6 hijackings/aircraft attacks (1%), 2 rocket attacks (0.4%). Further terrorist incidents have occurred in the United States since September 11, 2001, and although nothing before or since 9/11 compares in scale, lives lost, or scope, the thwarted terrorist plot at Elk Grove can remind us that as a result of the energy boom and the building of many large propane and LNG storage facilities around the country, such tanks pose a “clear and present danger” to public safety.

Potential Hazard 1: Bullet Tanks & Domino-Effect BLEVE Cascades

Pressurized, ambient-temperature liquid propane storage tanks are particularly susceptible to a process called a Boiling Liquid Expanding Vapor Explosion or BLEVE, one of the most severe accidents that can occur in the fuel process industry or in the transportation of hazardous materials.³⁰ Such tanks come in all sizes from fractions of a gallon to 125,000 gallons, with 30,000 gallons being the most common for transportation by rail and road. Although such tanks are quite robust against normal wear and tear, if a tank becomes engulfed by a fire, which typically over a few hours, raises the temperature of the tank and its contents to the point where the relief valve can no longer cope (earlier if the valve is faulty), the internal pressure in the tank will rise until the tank ruptures, causing instant boiling of the superheated liquid contents, which quickly and turbulently mix with outside air, forming a rapidly expanding vapor cloud. Indeed, since pressurized tanks store propane at temperatures well above its atmospheric boiling point of -43.7 °F, any event that causes a serious breach of the tank wall, can trigger a BLEVE.

If a suitable source of ignition is present (the initial fire will do admirably), moments later the cloud of vapor will experience ignition, adding the thermo-mechanical chemical energy of a

²⁹ <http://www.fbi.gov/stats-services/publications/terror/terrorism-2000-2001> Accessed Jan 02, 2015.

³⁰ Casal, J., et al. “Modeling and Understanding BLEVEs” Ch. 22 in Petrochemistry Handbook. <http://aevnmont.free.fr/SACH-BOOKS/Petrochemistry/Handbook%20of%20Hazardous%20Materials%20Spills%20Technology/Part%20V.%20Spill%20Modeling%22.%20Modeling%20and%20Understanding%20BLEVEs.pdf> Retrieved Jan 01,2015

Vapor Cloud Explosion, or VCE, to the mechanical energy of the original BLEVE tank burst. This gives rise to the visually most striking feature of typical propane BLEVE, the fireball. A fireball will quickly expand in a roughly spherical shape until all of the propane that burst out of the tank is consumed by it. The point where the fireball stops expanding, its volume is proportional to the mass of propane burnt, and the radius is proportional to its cube root. Propane fireballs have extremely high peak luminosity at infrared wavelengths. These effects are amenable to mathematical modeling, allowing the quantification of thermal radiation threat zones:

Thermal Threat Zones²⁴

| | | | |
|---------------|-----------------------------|---|------------------------------------|
| Red | (> 10.0 kW/m ²) | = | Potentially lethal within 60 sec. |
| Orange | (> 5.0 kW/m ² ,) | = | Second-degree burns within 60 sec. |
| Yellow | (> 2.0 kW/m ²) | = | Pain within 60 seconds. |

Apart from heat damage due to heat radiation from the fireball, BLEVEs often produce an overpressure, which if it is strong enough to causes injury or damage to structures, is termed a blast wave or shock wave:

Overpressure and Blast Threat Zones³¹

| | | | |
|---------------|-------------|---|--|
| Red | (> 8.0 psi) | = | Destruction of buildings. High risk of lethal injury. Eardrum rupture in 60% of subjects. |
| Orange | (>3.5 psi) | = | Damage to buildings. Serious injury likely. Rupture of lungs. Rupture of eardrums in 12% of subjects. |
| Yellow | (> 1.0 psi) | = | Eardrum rupture in 1% of subjects. Glass shatters. |

BLEVEs typically also project flying tank fragments at high velocity in all directions. There are many propane industry studies which show that a fireball resulting from tank failure worries fire officials less than the projectiles which are sent out at high velocity in all directions from such a blast.³² One study by the National Propane Gas Association found in 13 induced BLEVEs, that “rocket-type projectiles” or “shrapnel” from tanks as small as 80 to 100 gallons “can reach distances of up to 30 times the fireball radius.”³³ These fragments are generally not evenly distributed, and due to various factors, can be launched in any direction, with severe fragment risk up to 15 times the fireball radius, and almost all fragments inside 30 times the fireball radius.³⁴ Many authorities suggest, therefore, that the evacuation radius should be 30 times the

³¹ Roberts, Michael W., EQE International, Inc. “Analysis of Boiling Liquid Expanding Vapor Explosion (BLEVE) Events at DOE Sites.” Pages 5, 7, 10, 14, 18. mroberts@abs-group.com

http://www.efcog.org/wg/sa/docs/minutes/archive/2000%20Conference/papers_pdf/roberts.pdf

³² Industrial Fire World, “Targets of Opportunity.”

<http://www.fireworld.com/Archives/tabid/93/articleType/ArticleView/articleId/86841/Targets-of-Opportunity.aspx>
Retrieved Jan 03, 2015.

³³ Hilderbrand, Michael S.; Noll, Gregory S., National Propane Gas Association (U.S.) “Propane Emergencies” 2nd. Ed., 2007, p. 136.

³⁴ Roberts, Michael W., EQE International, Inc. “Analysis of Boiling Liquid Expanding Vapor Explosion (BLEVE) Events at DOE Sites.” Pages 10, 18. mroberts@abs-group.com

http://www.efcog.org/wg/sa/docs/minutes/archive/2000%20Conference/papers_pdf/roberts.pdf

fireball radius. Indeed, it is the typical shower of sharp-edged tank fragments projected at high velocity (up to 200 m/s or 450 mph) in all directions from propane BLEVEs that makes them particularly dangerous to other propane storage tanks, often resulting in a kind of “power amplifier” domino effect.

It was recently reported on the SmartNews section of the Smithsonian website that with just 29 dominoes, you could knock down the Empire State Building.³⁵ In a video on the website, Toronto professor Stephen Morris, demonstrate that a toppling domino can knock down another domino that is 1.5-times larger. Therefore, starting with a domino 5 mm tall, the 29th domino would be $1.5^{(29-1)} = 85,222$ -times taller, or about 1398 feet, toppling with enough kinetic energy to knock down The Empire State.

What this demonstrates is the potential for BLEVEs to propagate like a row of toppling dominoes, successively releasing increasing amounts of energy. When one pressurized propane tank (say, a typical bullet tank), is heated by a fire (either accidentally or deliberately set), to the point, as previously described, where the tank bursts, losing its contents as a boiling liquid that immediately flashes to a rapidly expanding vapor, that through contact with the fire, will instantly detonate, liberating a lot more energy than expended in the trigger event. A similar sequence of events can also be triggered by an amount of high-explosives. The result is that any propane tank BLEVE can threaten an adjacent tank with the “triple aggression” of fragment, blast, and fireball, causing it to immediately BLEVE too, and this can cascade, domino-fashion down a row of tanks.³⁶ The closer the bullet tanks are together, the faster this chain reaction occurs, potentially causing all of the bullet tanks to explode in a short space of time. How quickly this happens determines the degree to which the power of the original BLEVE is multiplied, in a trade-off of intensity and duration of the number and velocity of shrapnel and missile-like tank fragments, the intensity of the blast wave, and the size and thermal power of the ensuing fireball. Due to their important role in spreading the effects of an incident or accident from one tank to others, the three quantities, fragments, overpressure (blast), and heat flux (fireball), are known as escalation vectors.³⁷

The major risk from a pressurized propane tank BLEVE explosion to nearby refrigerated propane storage is fragment impact. The important parameters are velocity, shape and mass of the fragments, and the trajectory distance and time. BLEVE fragment ejection velocities are in the range of 10–100 m/s. When such a fragment (particularly at the higher end of the velocity

³⁵ Schultz, Colin. Smithsonian. “Just Twenty-Nine Dominoes Could Knock Down the Empire State Building.” <http://www.smithsonianmag.com/smart-news/just-twenty-nine-dominoes-could-knock-down-the-empire-state-building-2232941/?no-ist> Original idea by Lorne Whitehead, who called it the domino amplifier effect. American Journal of Physics, vol. 51, p. 182 (1983).

³⁶ Heymes, Frederic, et al. “On the Effects of a Triple Aggression (Fragment, Blast, Fireball) on an LPG Storage.” Chemical Engineering Transactions, vol. 36, 2014, pp. 355-360. <http://www.aidic.it/cet/14/36/060.pdf> Retrieved Jan 11, 2015.

³⁷ Heymes, Frederic, et al. “On the Effects of a Triple Aggression (Fragment, Blast, Fireball) on an LPG Storage.” Chemical Engineering Transactions, vol. 36, 2014, pp. 355-360. <http://www.aidic.it/cet/14/36/060.pdf> Retrieved Jan 11, 2015. p. 356.

range) impacts on and penetrates an (assumed large) refrigerated storage tank, a hydrodynamic ram is generated in the liquid which may cause the tank to burst. This produces a sequence of events³⁸ in which liquid propane is ejected as jet at a velocity high enough that with the arrival of a strong overpressure blast wave vector may experience primary break-up (atomizing into a mist of micron-sized droplets) and partial evaporation. If the onslaught from outside the tank is sufficiently aggressive, the tank contents may flash boil and/or result in a two phase flow and vapor cloud. The Depending on circumstances and timing, in addition to the possibility of total loss of containment, there may be a vapor cloud explosion (VCE), jet fires, pool fires, and structure fires, in any combination.³⁹

Relating this to the published configuration of PPC's proposed propane export terminal at Terminal 6 in Portland,⁴⁰ eight 125,000 gallon high pressure transfer tanks, stationed close to one another, totaling 1-million gallons could be set off by a BLEVE in several derailed and burning DOT-112 tanker cars⁴¹ (for example), which once started, could start quickly exploding, domino-fashion, causing enough damage to the much larger refrigerated tank(s) (33.6-million gallons) to cause an even more destructive event. Figure 4 shows simulated thermal radiation threat zones (fireball, red 10 kW/m², orange 5.0 kW/m², and yellow 2.0 kW/m²), corresponding overpressure blast wave threat zones (light blue 8.0 psi, blue 3.5 psi, and purple 1.0 psi) and a 6.7 miles radius tank fragment missile threat zone⁴² (turquoise blue) due to a 1-million gallon worst-case near simultaneous BLEVE of all eight of PPC's planned pressurized transfer tanks (see appendix A for the model data). The missile fragment threat covers 149 square miles. Figure 5 shows the blast zones for a BLEVE in just one of the 125,000 gallon bullet transfer tanks, something that could be initiated by a fire in an adjacent bullet tank, itself punctured by shrapnel from a fire and BLEVEs in a nearby fully loaded DOT-112 unit train. The threat zone radii in the 125,000 case are half as big as those for the 1-million gallon case, giving a 3.3 miles radius tank fragment missile threat zone.

³⁸ Ibid. Section 2.1, p. 356.

³⁹ Ibid. Section 3.1, p. 357.

⁴⁰ Bureau of Planning and Sustainability, City of Portland, Oregon. "Terminal 6 Environmental Overlay Zone Code Amendment and Environmental Overlay Zone Map Amendment – Part 1: Environmental Overlay Zone Code Amendment." *Proposed Draft*, Dec 12, 2014. <http://www.portlandoregon.gov/bps/article/512520>

⁴¹ A new, "safe" DOT-112 tank car derailed and exploded on Oct, 19, 2013 in Gainford, Alberta, leaving several "unsafe" DOT-111 tanker cars, still coupled together, lying safely on their sides. Following a siding derailment of 13 cars, including four DOT-111 tank cars containing crude oil, nine DOT-112 tank cars containing LPG, two LPG cars were punctured and caught fire. A third LPG car released product from its safety relief valve, which ignited. About 600 feet of track was destroyed, and a house located nearby was damaged by the fire. This was a relatively slow-speed derailment (between 15 and 25 mph), caused by rail defects. One DOT-112 car was punctured in the underbelly by the coupler from another car. This caused it to release its load (of LPG) and explode. Despite double shelf couplers designed to keep the cars coupled during derailments, the DOT-112 cars uncoupled during the derailment and apparently jackknifed across the track, making them vulnerable to secondary impacts from following cars. <http://www.tsb.gc.ca/eng/medias-media/communiqués/rail/2015/r13e0142-20150224.asp> Retrieved Feb 25, 2015.

⁴² Roberts, Michael W., EQE International, Inc. "Analysis of Boiling Liquid Expanding Vapor Explosion (BLEVE) Events at DOE Sites." Page 10. mroberts@abs-group.com
http://www.efcog.org/wg/sa/docs/minutes/archive/2000%20Conference/papers_pdf/Roberts%20abstract.pdf

In light of these results, it is the measured opinion of the authors of this white paper that a massive BLEVE in the transfer tanks could cause massive mechanical-, thermal-, and overpressure-driven disruption a nearby unit train and of one or both of the refrigerated storage tanks. The net result would be a complex deflagration involving one or both of the large refrigerated tanks, combining the worst effects of BLEVEs, and most of the other effects already mentioned.

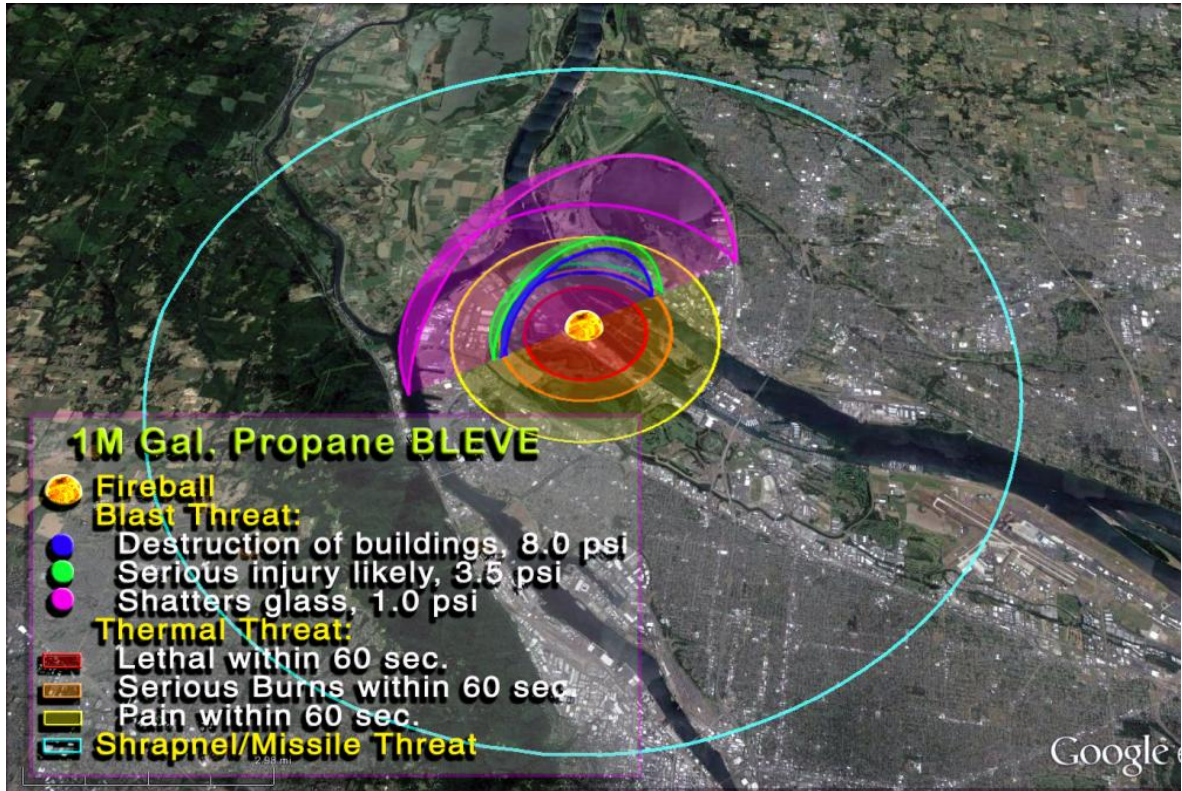


Figure 4: A Google Earth overlay showing thermal radiation and missile fragment threat zones modeled for a worst case boiling liquid expanding vapor explosion of one-million gallons of propane stored in pressurized tanks at Terminal 6 in North Portland. The black lines on the map represent the rail network.

Thermal Threat Zones: Fireball diameter 787 yards, Red zone: 1682 yards radius [10 kW/m^2] potentially lethal in less than 60 seconds; Orange zone: 1.3 miles radius [5 kW/m^2] 2nd-degree burns in less than 60 seconds; Yellow zone: 2.1 miles radius [2 kW/m^2] pain in less than 60 seconds.

Overpressure Blast Zones (shown in cut-away view): Blue zone: 1.3 miles radius [8.0 psi] destruction of buildings; Green zone: 1.5 miles radius [3.5 psi] serious injury likely; Magenta zone: 2.9 miles radius [1.0 psi] shatters glass.

Shrapnel Zone: Turquoise zone: Tank fragment missile threat zone: $30 \times$ fireball radius = 6.7 miles radius, which is also the recommended evacuation radius to avoid tank fragment missiles. Areas included within the missile threat zone are all of downtown Portland, all of North Portland, PDX airport, the eastern half of Sauvie Island, all of Hayden Island, most of Vancouver, and all of the marine terminals of the ports of Portland and Vancouver.

Potential Hazard 2: Terrorist Attack Scenarios

Typical actions by terrorists include the commandeering of commercial aircraft, but also drive-up vehicle-borne improvised explosive devices (truck bombs), the use of explosive projectiles such as shoulder-launched armor piercing rocket-propelled grenades, or the hand-placing of satchel or shaped charges. Shaped charges are specifically designed to leverage previously-mentioned hydrodynamic effects for best focus and maximum destructive power with the least amount of explosive material. Any or all of these can lead to the scenarios described in the *Potential Hazards 1* section, above.

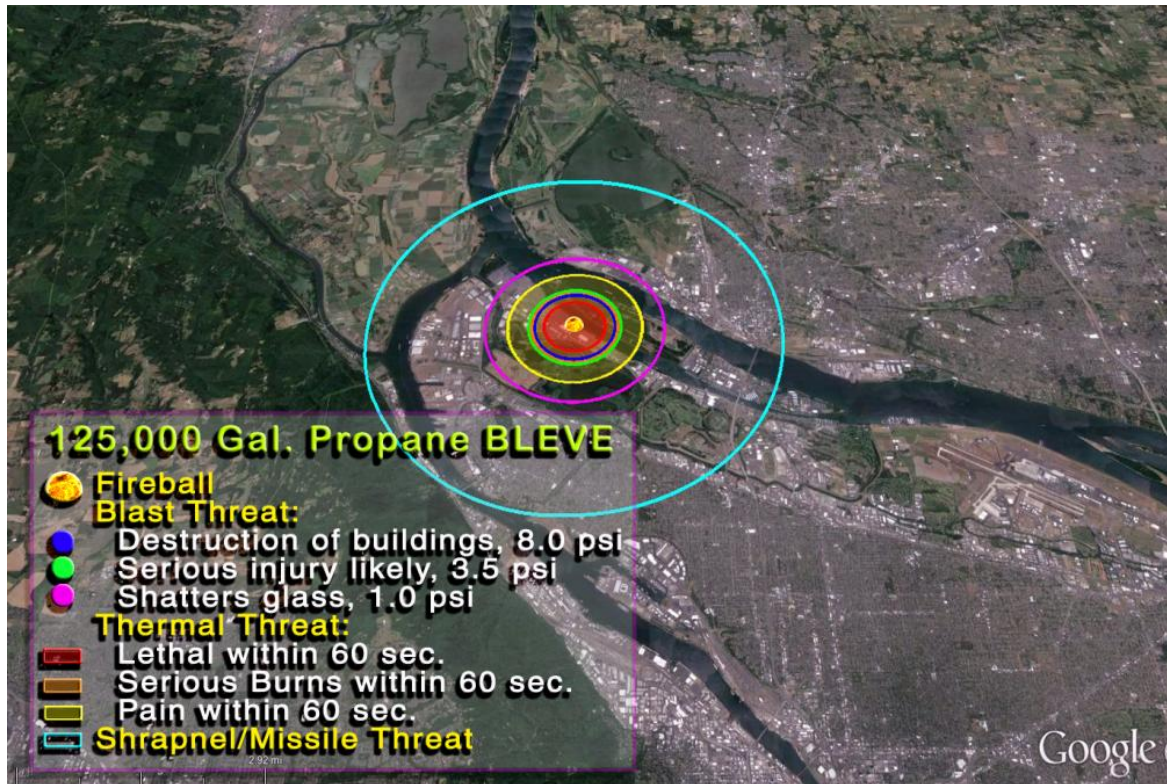


Figure 5: A Google Earth overlay showing thermal radiation and missile fragment threat zones modeled for a worst case boiling liquid expanding vapor explosion of 125,000 gallons of propane stored in pressurized tanks at Terminal 6 in North Portland. Shown at the same scale as figure 4.

Thermal Threat Zones: Fireball diameter 393 yards, Red zone: 841 yards radius [10 kW/m^2] potentially lethal in less than 60 seconds; Orange zone: 0.65 miles radius [5 kW/m^2] 2nd-degree burns in less than 60 seconds; Yellow zone: 1.05 miles radius [2 kW/m^2] pain in less than 60 seconds.

Overpressure Blast Zones: Blue zone: 0.65 miles radius [8.0 psi] destruction of buildings; Green zone: 0.75 miles radius [3.5 psi] serious injury likely; Magenta zone: 1.45 miles radius [1.0 psi] shatters glass.

Shrapnel Zone: Turquoise zone: Tank fragment missile threat zone: $30 \times$ fireball radius = 3.35 miles radius, which is also the recommended evacuation radius to avoid tank fragment missiles. Areas included within the missile threat zone are all of downtown Vancouver, all of the Portland St Johns neighborhood, part of the Portland Portsmouth neighborhood, the eastern edge of Sauvie Island, most of Hayden Island, and all of the marine terminals of the ports of Portland and Vancouver.

Potential Hazard 3: The Big One—A Magnitude 9 “Megathrust” Quake

The proposed site of PPC’s propane export terminal, adjacent to The Port of Portland’s Terminal 6, lies in the Portland basin, a well-documented area of seismic activity. Three seismic sources have been determined:

- 1) Interplate earthquakes along the Cascadian Subduction Zone located near the Pacific coast.
- 2) Relatively deep intraplate subduction zone earthquakes located as far inland as Portland.
- 3) Relatively shallow crustal earthquakes in the Portland metropolitan area.

The maximum credible events associated with these sources are postulated to be in the range of Magnitude 8.5-9.0, 7.0-7.5, and 6.5-7.0, respectively.⁴³ Indeed, the City of Portland’s Bureau of Planning and Sustainability (BPS), with input from the Port of Portland, has already authored a statement that “an earthquake [at the proposed PPC propane export facility] is one of the biggest risks to create a spill or explosion.”⁴⁴ Oddly enough, this statement was offered by the Port of Portland in support of a proposed zoning change to the protected riverfront at Terminal 6, without which PPC’s terminal cannot go ahead. It is then revealed in the same document that the port has established a risk level target of a 1% in 50 years probability of earthquake-induced collapse. In other words, approximately 0.5% risk of a collapse over the expected 25 year service life of the facility, even after all required mitigations have been incorporated into the structural design of the refrigerated storage tanks, such as the “ground improvement and/or deep foundations.... a combination of stone columns and jet grouting ground improvements” that were completed within the last five years for another marine facility just downstream. Deep foundations such as driven pipe piles are currently being considered as an alternative to support the tank.⁴⁵ To our knowledge, there has been insufficient investigatory work by engineering geologists and geotechnical engineers to map and understand the geological limitations of the planned terminal location just east of Terminal 6, a site at which the basalt bedrock may be unusually deep.⁴⁶ At a recent public meeting on Hayden Island, a Pembina representative said that their geotechnical exploration of the site reached to 165 ft, and that they had no intention of going deeper, did not need to know the bedrock depth, and intended to run several concrete-filled caisson pilings to 160 ft. On the face of it, this seems inadequate, because industry sources I have consulted recommend drilling at least 20 ft deeper than your intended pilling depth. The proposed tank design uses two large aboveground double-wall insulated steel storage tanks that together store 33.6-million gallons of refrigerated propane at -44 °F. Also in the BPS document is a statement that the geology of the site and the potential for a megathrust quake (Magnitude 9) from the Cascadia Subduction Zone (which would originate near the Oregon coast), and a Magnitude 7

⁴³ Dickenson Stephen E., et al. Assessment and Mitigation of Liquefaction Hazards to Bridge Approach Embankments in Oregon. Final Report, SPR 371. Oregon DOT Research Group, and Federal Highway Administration. Nov 2002. p. 139.

⁴⁴ Bureau of Planning and Sustainability, City of Portland, Oregon. “Terminal 6 Environmental Overlay Zone Code Amendment and Environmental Overlay Zone Map Amendment – Part 1: Environmental Overlay Zone Code Amendment.” *Proposed Draft*, Dec 12, 2014. <http://www.portlandoregon.gov/bps/article/512520>

p.18, Seismic Risks

⁴⁵ Ibid. p. 18.

⁴⁶ Professor Scott Burns, Oregon State University, private communication.

Portland Hills Fault quake (which would originate less than 5 km away) appear to agree with current geological knowledge of the region, and may in fact overstate the Portland Hills Fault potential by 0.5.⁴⁷ The BPS document also briefly mentions that the major seismic hazards for a large storage tank at Terminal 6 include soil liquefaction, lateral spreading and seiches.

A more detailed review of the seismic risks in the Portland basin and related areas⁴⁸ describes the high likelihood of prolonged ground shaking (the geological estimate is five minutes), causing the destructive effects of *primary* seismic effects: soil liquefaction (loss of strength of the soil), lateral spreading (surface soil moves permanently laterally, damaging structures such as buildings, tanks, and tank supports; an effect that could be exacerbated by slope failure of the Terminal 6 dredged shipping channel), co-seismic settlement (the ground surface is permanently lowered, and potentially becomes uneven), and bearing capacity failures (foundation soil cannot support structures it was intended to support). The alluvial soils in the Portland Basin, and in particular those surrounding the Portland peninsular, and associated with the wetlands at the confluence of the Willamette and Columbia rivers, are particularly at risk to this sequence of events. Portland's rivers, sloughs, lakes and wetlands makes for a high water table, which when coupled with an unusually large distance to bedrock, makes these water-saturated soils very vulnerable to the previously mentioned effects of ground shaking. Possible *secondary* seismic hazards relevant to the Portland basin area include: seiches (earthquake-induced standing waves in narrow bodies of water), fire, and hazardous material releases, such as liquid fuel overtopping tanks by ground-shaking-induced sloshing.

Due to the particular dangers of liquefaction to large tank structures, and as discussed above, the BPS zoning change proposal document rightly pays special attention to its mitigation in the design of the tank and its foundations. However, given that a Magnitude 9 earthquake in the Cascadia Subduction Zone could bump Portland into 6th place in the USGS list of the most powerful earthquakes ever recorded worldwide,⁴⁹ such mitigation may be woefully inadequate. With 100 times the ground movement and 1,000 times the energy of a much more common Magnitude 7 earthquake, a Magnitude 9 quake is a very powerful event. Strengthening a 30-million gallon tank against this seems hardly feasible. Scientists agree that such a large quake is overdue. Earthquake-induced failure of such a tank would only add insult to Portland and Vancouver's already massive earthquake injury.

Until proven otherwise, we must assume that the intensity of earthquake-driven liquefaction of the ground around Terminal 6 is likely to result in collapse and loss of contents of the planned large refrigerated tank structures. Given a nearby source of ignition, a massive pool fire is only

⁴⁷ Professor Scott Burns, Oregon State University, private communication.

⁴⁸ Wang, Yumei, et al. "Earthquake Risk Study for Oregon's Critical Energy Infrastructure Hub." Final Report to Oregon Department of Energy & Oregon Public Utility Commission. Oregon Department of Geology and Mineral Industries. Aug 2012. p. 39.

⁴⁹ Largest Earthquakes in the World Since 1900. The current list is: 9.5, 9.2, 9.1, 9.0, 9.0, 8.8, 8.8, 8.7, 8.6, 8.6, 8.6, 8.6, 8.5, 8.5, 8.5, 8.5, 8.5. http://earthquake.usgs.gov/earthquakes/world/10_largest_world.php Retrieved Jan 12, 2015.

one possible outcome. Another (and the one we've chosen to use here) is a very large, toxic, wind-driven heavy vapor cloud (12,600 ppm = 60% LEL) containing many flame pockets ignited by various sources of ignition across miles of the Portland or Vancouver metropolitan areas. The potential for the compounding effects of water inundation of Terminal 6 due to dam loss caused by the earthquake-induced movement of recently discovered fault lines along the Columbia River, have yet to be determined. As Ian Madin, chief scientist with the Oregon Department of Geology and Mineral Industries (DOGAMI) told the Oregonian, "None of the dams were designed with this kind of fault in the analysis." He added that the Bonneville Power Administration is spending millions to secure transformers and other links in their power system, which speaks for itself.⁵⁰



Figure 6: Cosmo Oil’s LPG terminal in Tokyo Bay is built on harbor fill consisting mainly of water-saturated sandy alluvial soils (LPG is a mixture of gases, including propane). This high seismic risk location and facility has many similarities to the site of Portland’s proposed propane export terminal. On March 11, 2011, an earthquake similar in magnitude to Portland’s expected “big one” caused structural failure and tank collapse due to soil liquefaction. A lethal domino cascade ensued, which over a period of three hours, included a large vapor cloud explosion, and five BLEVEs the largest of which had a fireball diameter of almost 2,000 feet. All told, seventeen LPG tanks were destroyed. Damage included thermal radiation, overpressure blast, and rocketing tank fragments and other debris. Cleanup took two years.

A seismic scenario, very similar to the one being discussed for Portland, developed at the Cosmo Oil LPG terminal in Tokyo Bay as a result of the Great Tohoku earthquake March 11, 2011.⁵¹ This quake registered as Magnitude 9 (Shindo 5-), with Magnitude 7 aftershocks. Built on sandy soil reclaimed from Tokyo harbor, the Cosmo facility was placed in jeopardy by earthquake-induced soil-liquefaction. Over a period of about three hours, this led to a series of propane or LPG tank collapses, a large vapor cloud explosion (VCE), a sustained fire, and a string of BLEVEs (see figure 6). The lethal domino cascade included five BLEVEs. The largest of these produced a 600 m diameter (1968 feet) fireball, from which we may infer an LPG

⁵⁰ Rojas-Burke, Joe, The Oregonian. (Aug 29, 2011) “Hidden Earthquake Faults Revealed at Mount Hood, Oregon.” http://www.oregonlive.com/pacific-northwest-news/index.ssf/2011/08/hidden_earthquake_faults_revealed_at_mount_hood_oregon.html Retrieved Jan 05, 2015.

⁵¹ This was the same earthquake that preceded the tsunami inundation and meltdown of three of the four cores at the Fukushima Daiichi nuclear reactor complex.

volume of around 500,000 gallons! All told, a total of seventeen high-pressure storage tanks were destroyed. Fortunately there was no very large (tens of millions of gallons) refrigerated storage tank on site. In total, the incident consumed 5,272 tonnes of propane/LPG, equivalent to around 2.8 million US gallons. Nearby pipes and buildings were destroyed. Heat radiation caused leaks in several nearby bitumen storage tanks; roads and buildings at the site were also damaged by soil liquefaction. Shock waves and rocketing debris from the explosions ignited fires in nearby petrochemical facilities. Vehicles and boats were destroyed, homes were damaged (windows and roofs), and nearby vehicles and homes were covered in fire debris. The damage cost was € 100 millions (multiples of US\$ 113 million), and repairs to the facility took two years. The technical lessons learned from this disaster include reinforcing the tank bases, wider tank spacing, and improvements in safety equipment to limit domino effects.⁵² See appendix A for a complete chronology.

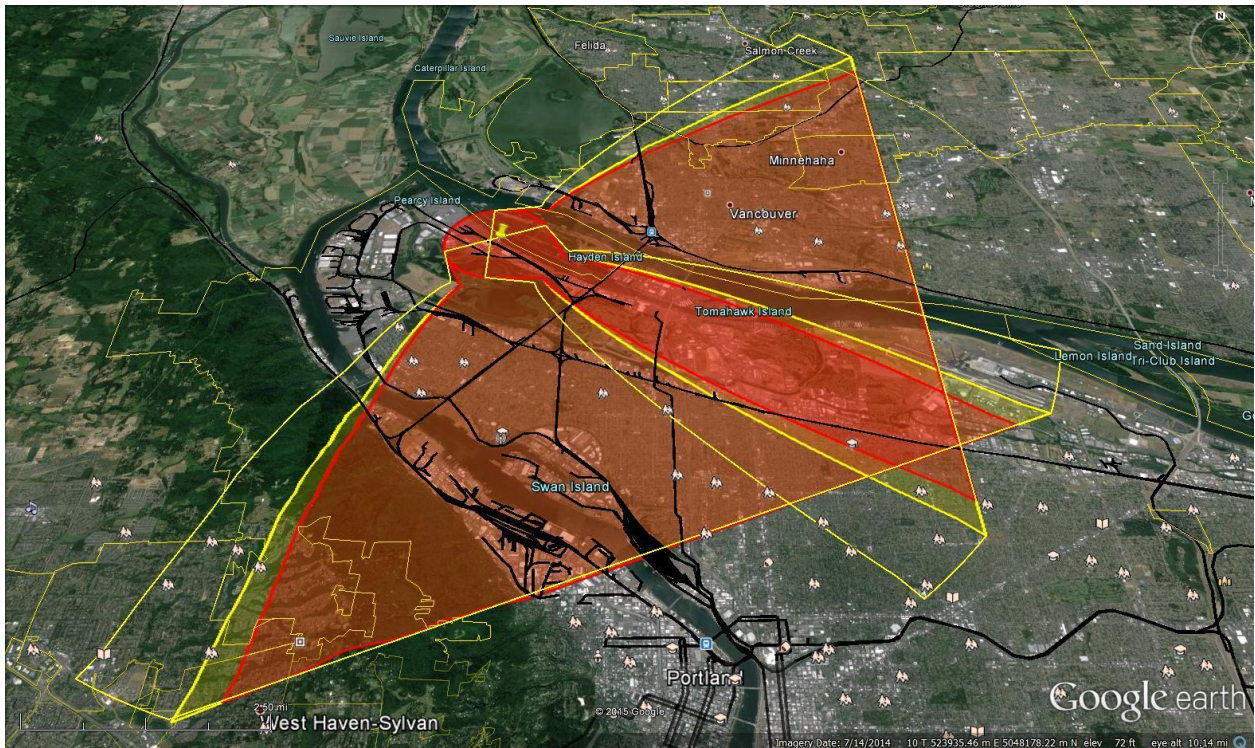


Figure 6: The Impact on Portland and Vancouver of an earthquake scenario in which a large refrigerated propane storage tank collapses at Terminal 6. We assume that cold liquid propane is ejected and/or flows at the rate of 560,000 gallons per second for one minute. The escaping liquid may flash boil and/or result in two-phase (liquid/vapor) flow. The simulation assumes that 100% of the propane evaporates into a large vapor cloud, which is blown by the wind, assumed to be 10 mph from the NW, and covers much of Portland. Overlaid on the same map is the result of a 10 mph wind from W, which covers much of Vancouver. The straight edges do not mark the edge of the vapor cloud, but simply the extent of the simulation; the cloud will therefore extend much further, with a

⁵² Overview of the Industrial Accidents Caused by the Great Tohoku Earthquake and Tsunami. Japan, March 11, 2011. ARIA. French Ministry of Ecology, Sustainable Development and Energy. Retrieved Feb 11, 2015. http://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/Overview_japan_mars_2013_GB.pdf

roughly oval outline. The red threat zone extends further than 5.8 miles (12,600 ppm = 60% LEL = Flame Pockets), and the yellow threat zone extends even further (2,100 ppm = 10% LEL).

Figure 6 shows an earthquake scenario in which large refrigerated propane storage tank(s) collapse at Terminal 6. For the purposes of the simulation, we created a 120 ft. diameter hole in a single 33.6-million gallon tank, through which the cold liquid propane is ejected and/or flows at the rate of 560,000 gallons per second for one minute. The ALOHA software reports that the escaping liquid may flash boil and/or result in two-phase (liquid/vapor) flow. In any case we assume that 100% of the propane evaporates into a large vapor cloud, which is blown by the wind, assumed to be 10 mph from the NW, and covers much of Portland. Overlaid on the same map is the result of a 10 mph wind from W, which covers much of Vancouver. The straight edges do not mark the edge of the vapor cloud, but simply the extent of the simulation; the cloud will therefore extend much further, with a roughly oval outline. The red threat zone extends further than 5.8 miles (12,600 ppm = 60% LEL = Flame Pockets), and the yellow threat zone extends even further (2,100 ppm = 10% LEL).

Legal Ramifications

Finally, we will place the proposed PPC propane export terminal under the legal microscope by using a Rest.2d Torts approach to examine the legal ramifications of siting any such large energy storage and handling facility in the center of the extended Portland/Vancouver urban area, in a geological zone subject to Magnitude 9 “megathrust” earthquakes, and earthquake-induced ground liquefaction and dam bursts, with such an earthquake in fact overdue. Specifically, Restatement (Second) of Torts, § 520 (commonly referred to as Rest.2d Torts § 520), which has been adopted by California and some other states, provides a framework for examining an activity or process to determine if it presents an unavoidable risk of serious harm to others, or their property, despite reasonable care exercised by the actor to prevent that harm. Section 520, Restatement Second of Torts enumerates the factors to be considered in determining if the risk is so unusual, either because of its magnitude or because of the circumstances surrounding it, that such an activity is “abnormally dangerous” or “ultrahazardous,”⁵³ and therefore subject to strict liability.

Given the huge potential for devastation in Portland or Vancouver (depending on wind direction) out to at least seven miles from the facility, a 1-in-200 risk is much too high. Indeed, simulation tests we have run demonstrate a credible potential for an event so destructive that the establishment of any large energy storage facility within the urban boundary of Portland, that endangers all of Portland and Vancouver qualifies as ultrahazardous, defined in Wex⁵⁴ as, “An activity or process that presents an unavoidable risk of serious harm to the other people or others’ property, for which the actor may be held strictly liable for the harm, even if the actor has

⁵³ Ultrahazardous activity. http://www.law.cornell.edu/wex/ultrahazardous_activity

⁵⁴ Wex is the Cornell University Legal Information Institute’s community-built, freely available legal dictionary and encyclopedia. <http://www.law.cornell.edu/wex>

exercised reasonable care to prevent that harm.” Oregon may well need to follow California in adopting a Rest.2d Torts approach for determining whether such ultrahazardous activities are “abnormally dangerous,” setting forth six factors which are to be considered in determining liability. These are:

- “(a) existence of a high degree of risk of some harm to the person, land or chattels of others;
- “(b) likelihood that the harm that results from it will be great;
- “(c) inability to eliminate the risk by the exercise of reasonable care;
- “(d) extent to which the activity is not a matter of common usage;
- “(e) inappropriateness of the activity to the place where it is carried on; and
- “(f) extent to which its value to the community is outweighed by its dangerous attributes.”

We comment on these factors, as follows:

- (a) Portland’s adoption of a 1% risk of tank collapse in 50 years is a high degree of risk.
- (b) The potential harm from credible tank collapse and transfer tank BLEVE scenarios is great, and worst-case Portland and/or Vancouver would likely never fully recover.
- (c) Residents cannot avoid the risk by any reasonable exercise of care, other than leaving.
- (d) Large propane facilities are not commonly embedded in cities.
- (e) Large propane facilities are inappropriate inside or close to urban boundaries.
- (f) Recognizing that Portland is considered to be well overdue for a big earthquake, and considering that propane tanks have been terrorist targets, the credible magnitude of loss for such incidents pales in comparison to the 50 direct jobs and several million dollars of taxes that Portland would receive from such a facility.

Some Rejected Energy Storage Proposals

- The Long Beach LNG Import Terminal Project, CA (onshore)
Withdrawn after 4 years of scrutiny of project (LA Times Jan 23, 2007).
Population density (< 2 miles from houses, >60/sq. mi; 3,033 households within a 2 mi radius). Seismic concerns. Flaws in the draft environmental study.
- Calpine LNG Project, Humbolt Bay, CA (onshore)
Withdrawn (LA Times Mar 18, 2004)
Population density (1 mile to pop. density >60/sq. mi).
- Shell/Betchel LNG Project, Vallejo, CA (onshore)
Withdrawn Jan 30, 2003.
Population density (1 mile to pop. density >60/sq. mi).
- Conoco LNG Project, El Paso, TX
Permit denied.
Population density (< 1 mile to pop. density >60/sq. mi).
- Broadwater Energy LNG Export Terminal, Long Island Sound, NJ
Permit denied.
Environmental issues.

Conclusion

The scale of potential disasters due to a large propane facility inside the combined Portland/Vancouver urban area more than outweighs any theoretical estimate of its improbability. We believe that our region would not properly recover from such events for decades, if ever.

To avoid this present danger, the solution is clear: We must not make the requested zoning change. We must not allow the thin end of an industrial wedge through our environmental protections, because it will set a bad precedent.

Accident data shows that the largest propane risk areas are pressurized storage, pressurized transport, and transfer. This includes any units trains incoming to the site (derailments), the movement of the tanker cars at the site (shunting derailments), and the transfer of liquid propane from one container to another (accidents with pipes, valves, hoses, and other equipment). Such dangers at the proposed site are exacerbated by the relatively close proximity of the pressurized tanks to each other, and also due to the high probability of domino amplification effects. Moreover, the proposed large refrigerated tanks, no more than a stone's throw from the pressurized transfer tanks, are likely to become involved due to the secondary effect of rocketing high-speed sharp tank fragments, generated from one or more BLEVEs in the pressurized tanks. These fragments, also known as shrapnel, travel at speeds up to 400 mph, and are capable of slicing through both walls of the refrigerated tanks, and any remaining intact pressurized tanks, which aided by hydrodynamic forces, are likely to cause loss of contents. The ballistic range of such fragments is typically many miles, which would place large parts of suburban Portland and Vancouver in jeopardy. The magnitude of credible incident and accident scenarios (similar to many of the events which seem to be ever present in our news feeds, including the finding, just days ago, that a recent multiple BLEVE in derailed DOT-112 tanker cars was primarily caused by a design oversight that is present in all DOT-112s) is sufficiently high that we conclude that planners must remotely locate such large energy storage facilities. The need to be far away from our cities and towns, and also fragile natural areas such as West Hayden Island, and the Smith and Bybee lakes; beyond the threat zones of any credible disaster (at least ten or twenty miles).

Federal and state regulators must also require that these facilities are themselves better protected from human error and any malicious intention, by the best means available. If necessary we must enact laws to ban the siting of large energy facilities inside or close to our urban areas.

Portlanders are heavily invested in Portland. Committed to finding sustainable solutions, and supporting a burgeoning artisan economy, Portlanders enjoy a unique lifestyle. Yet, while dreaming of award-winning green and self-sufficient sustainability, they achieve home ownership, and safe bicycle lanes and bridges. They also dream of one day having a functional light rail system, and of transforming Portland's major employers, the large semiconductor, electronics, sports equipment, and film companies into clean-tech success stories.

Therefore, for the city to take our “savings” and risk them on a bet that there will never be a serious propane train or tank incident or accident at Portland’s Terminal 6, in the next 25 to 50 years, is like a financial services bank taking our “investment” and reinvesting it on the tables in Las Vegas.

Banks are not allowed to do this.

City councils should not be allowed to do this either!

Sure it's true that some desperate companies have done this with investor funds, but Portland is not that desperate! Propane accidents are rarely small, so why situate a propane terminal smack in the middle of our Portland/Vancouver urban area? Why do this when it would be easy to use the same railway that would bring the propane to Portland, to take it somewhere else, at least 20 miles from where people live, work, and play? Why dash the dreams of Portlanders with a short-sighted project that will only produce 30-40 direct jobs (less than half a job per acre), that will trash Portland’s greenest city status, and that will increase US unemployment by creating stronger overseas competitors who will increase their share of the global market.

Moreover, when we consider the results of EPA/NOAA/FEMA modeling, that heat threat, blast waves, and shrapnel from even a modest propane deflagration could wipe out and/or injure all of North Portland and downtown Vancouver, Terminal 6, and all of the Rivergate facility, up to a six mile radius, Portland needs to say, “No thank you, we wish to be green!” and promote green trade and industries. Only through means such as these will our cities more surely live to ripe, resilient old age.



Appendix A: Models and Data Used in Estimating Threat Zones

1) Elk Grove Propane Facility Data

I) Pressurized liquid propane transfer bullet tanks:

| | |
|--------------------------------------|--|
| Number of tanks: | 4 |
| Storage capacity (each tank): | 60,000 gallons |
| Tank size: | Diameter 12 ft.; Length 91 ft., |
| Tank Mounting: | Horizontally, 5 ft. off ground. Spacing 10 ft. broadside |

ALOHA Model Data (Bullet tank BLEVE):

| | |
|--------------------------------------|--|
| Location (Lat., Long.): | 38.3824314392 N, 121.356808023 W |
| Surroundings: | Unsheltered |
| Chemical: | Liquid Propane |
| Chemical stored at: | 65 degrees F |
| Ground Roughness: | Urban or Forest |
| Cloud Cover: | Partly Cloudy |
| Tank Size & Orientation: | Hor. Cylinder, 12 ft. dia., 91 ft. length, 76,988 gallons |
| Tank filled: | 60,000 gallons (77.9%) |
| Propane mass: | 114,998 kg |
| Scenario: | Tank containing a pressurized flammable liquid. |
| Type of Tank Failure: | BLEVE, tank explodes and propane burns in a fireball. |
| Potential Hazards from BLEVE: | Thermal radiation from fireball and pool fire. |
| Not modeled by ALHOA: | Hazardous fragments. Downwind toxic effects of fire byproducts. |

Threat Modeled: Thermal radiation from fireball

| | |
|------------------------------------|--|
| Fireball Diameter: | 308 yards diameter |
| % propane mass in fireball: | 100% |
| Red: | 691 yards radius (10.0 kW/(sq m) = potentially lethal within 60 sec. |
| Orange: | 976 yards radius (5.0 kW/(sq m) = 2nd degree burns within 60 sec. |
| Yellow: | 1520 yards radius (2.0 kW/(sq m) = pain within 60 sec. |

II) Refrigerated liquid propane storage tanks:

| | |
|--------------------------------------|----------------------------------|
| Number of tanks: | 2 |
| Storage capacity (each tank): | 12-million gallons |
| Tank size: | Diameter 146 ft.; Height 122 ft. |
| Tank construction: | Double steel wall |
| Storage temperature: | -44 °F |

2) Proposed Portland Propane Terminal Data

1a) Pressurized liquid propane transfer bullet tanks:

| | |
|--------------------------------------|---|
| Number of tanks: | 1 |
| Storage capacity (each tank): | 125,000 gallons |
| Tank size: | Diameter 20 ft. (est.); Length 62 ft. (est.), |
| Tank Mounting: | Horizontally, 5 ft. off ground (est.), Separated broadside by 10 ft. (est.), and in pairs by 30 ft. (est.). |

ALOHA Model Data (Bullet tank BLEVE):

| | |
|--------------------------------------|--|
| Location (Lat., Long.) | 45.6276169997 N, 122.733791252 W |
| Surroundings: | Unsheltered |
| Chemical: | Liquid Propane |
| Chemical stored at: | 65 degrees F |
| Ground Roughness: | Urban or Forest |
| Cloud Cover: | Partly Cloudy |
| Tank Size & Orientation: | Hor. Cylinder, 20 ft. dia., 62 ft. length |
| Tank filled: | 125,000 gallons (86%) |
| Propane mass: | 238,638 kg |
| Scenario: | Tank containing a pressurized flammable liquid. |
| Type of Tank Failure: | BLEVE, tank explodes and propane burns in a fireball. |
| Potential Hazards from BLEVE: | Thermal radiation from fireball and pool fire. |
| Not modeled by ALHOA: | Hazardous fragments. Downwind toxic effects of fire byproducts. |

| | | |
|------------------------------------|--|---|
| Threat Modeled: | Thermal radiation from fireball | |
| Fireball Diameter: | 393 yards diameter | |
| % propane mass in fireball: | 100% | |
| Red: | 0.48 miles radius | (10.0 kW/(sq m) = potentially lethal within 60 sec. |
| Orange: | 0.65 miles radius | (5.0 kW/(sq m) = 2nd degree burns within 60 sec. |
| Yellow: | 1.05 miles radius | (2.0 kW/(sq m) = pain within 60 sec. |

| | | |
|---|---|--------------------------------------|
| Threat Modeled: | Overpressure (Blast Force) Threat Zone | |
| Type of Ignition of Vapor Cloud: | Detonation | |
| Model: | Heavy Gas | |
| Red: | 0.65 miles radius | (8.0 psi = destruction of buildings) |
| Orange: | 0.76 miles radius | (3.5 psi = serious injury likely) |
| Yellow: | 1.4 miles radius | (1.0 psi = shatters glass) |

Ib) Pressurized liquid propane transfer bullet tanks:

| | |
|--------------------------------------|---|
| Number of tanks: | 8 |
| Storage capacity (each tank): | 125,000 gallons |
| Tank size: | Diameter 20 ft. (est.); Length 62 ft. (est.), |
| Tank Mounting: | Horizontally, 5 ft. off ground (est.), Separated broadside by 10 ft. (est.), and in pairs by 30 ft. (est.). |

ALOHA Model Data (Bullet tank BLEVE):

| | |
|--------------------------------------|--|
| Location (Lat., Long.) | 45.6276169997 N, 122.733791252 W |
| Surroundings: | Unsheltered |
| Chemical: | Liquid Propane |
| Chemical stored at: | 65 degrees F |
| Ground Roughness: | Urban or Forest |
| Cloud Cover: | Partly Cloudy |
| Tank Size & Orientation: | Hor. Cylinder, 20 ft. dia., 496 ft. length |
| Tank filled: | 1,000,000 gallons (86%) (simulating 8 tanks as one) |
| Propane mass: | 1,909,103 kg |
| Scenario: | Tank containing a pressurized flammable liquid. |
| Type of Tank Failure: | BLEVE, tank explodes and propane burns in a fireball. |
| Potential Hazards from BLEVE: | Thermal radiation from fireball and pool fire. |
| Not modeled by ALHOA: | Hazardous fragments. Downwind toxic effects of fire byproducts. |

| | | |
|------------------------------------|--|---|
| Threat Modeled: | Thermal radiation from fireball | |
| Fireball Diameter: | 787 yards diameter | |
| % propane mass in fireball: | 100% | |
| Red: | 1682 yards radius | (10.0 kW/(sq m) = potentially lethal within 60 sec. |
| Orange: | 1.3 miles radius | (5.0 kW/(sq m) = 2nd degree burns within 60 sec. |
| Yellow: | 2.1 miles radius | (2.0 kW/(sq m) = pain within 60 sec. |

| | | |
|---|---|--------------------------------------|
| Threat Modeled: | Overpressure (Blast Force) Threat Zone | |
| Type of Ignition of Vapor Cloud: | Detonation | |
| Model: | Heavy Gas | |
| Red: | 1.3 miles radius | (8.0 psi = destruction of buildings) |
| Orange: | 1.5 miles radius | (3.5 psi = serious injury likely) |
| Yellow: | 2.9 miles radius | (1.0 psi = shatters glass) |

II) Refrigerated liquid propane storage tanks:

Number of tanks: 2
Storage capacity (combined) 33.6-million gallons
Individual tank sizes: Diameter (1) 190 ft., (2) 140 ft. (est.); Height 120 ft. (est.)
Tank construction: Unknown.
Storage temperature: -44 °F

ALOHA Model Data (Refrigerated tank loses contents):

Ambient Boiling Point: -43.7° F
Vapor Pressure at Ambient Temperature: greater than 1 atm
Ambient Saturation Concentration: 1,000,000 ppm or 100.0%
Wind: 10 miles/hour from W (or NW) at 3 meters
Ground Roughness: urban or forest
Cloud Cover: 5 tenths
Air Temperature: 65° F Stability Class: D
 No Inversion Height Relative Humidity: 50%
Direct Source: 560,000 gallons/sec Source Height: 0
Source State: Liquid
Source Temperature: -44 ° F
Release Duration: 60 minutes
Release Rate: 163,000,000 pounds/min
Total Amount Released: 9.80e+009 pounds

Note: This chemical may flash boil and/or result in two phase flow.

Threat Modeled:**Flammable BLEVE-generated Vapor Cloud****Model Run:**

Heavy Gas

Red: greater than 6 miles

(12600 ppm = 60% LEL = Flame Pockets)

Yellow: greater than 6 miles

(2100 ppm = 10% LEL)

3) Cosmo Oil Refinery, Port of Chiba, Tokyo Bay, March 11, 2011

Site Overview

- Refinery within an integrated petrochemical complex (area: 1.17 km²)
- Built in 1963. Capacity: 220,000 bpd
- 382 employees (2,500 for the petrochemical complex)

Earthquake Data

- Magnitude 9 (Shindo 5-), max. 7.2 magnitude aftershock

Seismic Protection

- Equipment and storage facilities built to seismic standards (liquefaction-resistant foundations). Automatic shutdown of facilities (acceleration > 0.2 m/s²)

Accident chronology

14.46: Foreshocks (acceleration: 0.11 m/s²).

14.52: Aftershocks off coast of Tokyo (0.4 m/s²). Automatic shutdown of facilities. The legs on propane tank No. 364 (still filled with water from a hydraulic proof test 12 days earlier) crack but do not break. Emergency response unit deployed.

15.15: A new aftershock (0.99 m/s²) causes the cross-bracings of the legs of tank No. 364 to break. One minute later, the tank collapses, crushing nearby pipes.

15.45: LPG begins leaking from the pipelines leading to the tank farm. The automatic safety valve is unresponsive (bypassed in open position following a malfunction on the pneumatic system a few days earlier). Fire brigade alerted.

15.48: A hot spot (nearby steam cracking unit?) ignites the LPG cloud. Fire breaks out among the LPG tanks despite the cooling rings being turned on.

17.04: First tank BLEVE. Utilities (electricity, air) downed throughout the area.

17.54: Second BLEVE. The pipes throughout the farm do not automatically shut down due to the lack of power and the considerable thermal flows render manual shutoff impossible. The decision is taken to let the fire in the tank farm burn itself out and protect the nearby facilities from the flames. A series of three other BLEVEs occurs during the night (2,000 m³ and five LPG spheres explode). One thousand local residents are evacuated for 8 hours. The fire is brought under control at 10.10 on March 21st, 2011

Casualties

- Six employees injured, one with serious burns (three Cosmo employees, three from neighbouring sites)

Damage caused by the earthquake

- [All] seventeen [LPG] tanks destroyed, of which five exploded (BLEVE, including a 600 m fireball). Nearby pipes and buildings destroyed: 5,227 tonnes of LPG burnt.

- Leaks on several bitumen storage tanks due to the heat waves [and debris impact]⁵⁵
- Roads and buildings on the site damaged by soil liquefaction
- The shock waves and debris from the explosions ignited fires in the petrochemical facilities (steam cracking unit) operated by Maruzen and JMC
- Vehicles and boats destroyed. Homes damaged (windows, roofs).
- Surrounding vehicles and homes covered with fire debris

Damage Cost

- € 100 millions

Chronology of Resumption of Operations

18-31 March 2011: Existing stocks of diesel, kerosene and petrol are shipped

Early May 2011: Bitumen around damaged storage tank cleaned up. Refined petroleum products arrive via tanker. Diesel, kerosene and petrol shipped out in tanker trucks

17 December 2011: Authorization to restart the LPG facilities at pressures > 10 bar granted following compliance inspection (operations suspended by the government since 06/2011).

12 January 2012: Refining facilities partially brought back into operation

30 March-20 April 2012: The 2 crude-oil distillation units are brought back into operation

Spring 2013: End of LPG tank farm repairs. Operation at full capacity

Technical Lessons

- Redesign of the LPG tank farm (reinforced base, wider spacing, doubled coolant flow rate). Improvement in pipe flexibility and change in pipework to limit domino effects
- Reinforcement of zone-based automatic network cutoff system

Organizational Lessons

- Overhaul of tank hydraulic proof testing procedure (fast draining). Better communication between engineering and operations teams
- Safety-awareness training for employees. Heightened inspections

⁵⁵ Krausmann, Elizabeth; Cruz, Anaa Maria. "Impact of the 11 March 2011, Great East Japan earthquake and tsunami on the chemical industry." Nat Hazards (2013) 67:811-828. Page 820.

Appendix B: ALOHA Threat-Modeling Software and Disclaimer

The propane threat zone estimates discussed in this paper have been computed with the best available information we currently have from the City of Portland, Port of Portland, and PPC, and in an ongoing absence of any meaningful analysis from any of those entities. The primary authorities for this analysis are:

- a) the ALOHA (Areal Locations of Hazardous Atmospheres), atmospheric dispersion modeling software maintained by the Hazardous Materials Division of National Oceanic and Atmospheric Administration (NOAA), widely used by Fire Departments and first responders for Emergency Chemical Release Modeling.
- b) The many published industry and scientific references cited in the paper.

ALOHA models the dispersion of a gas in the atmosphere and displays a map view of the area (footprint) in which it predicts gas concentrations typically representative of hazardous levels (Levels of Concern, or LOC). The footprint represents the area within which the concentration of a gas is predicted to exceed a LOC at some time during the release. ALOHA uses simplified heavy gas dispersion calculations that are based on the DEGADIS model, and are therefore unreliable under very low wind speeds, very stable atmospheric conditions, wind shifts and terrain steering effects, or concentration patchiness, particularly near the spill source.

ALOHA models source strength and type (direct, puddle, tank release), uses air dispersion models to calculate concentration threat zones, models and calculates overpressure blast effects from vapor cloud explosions. It also uses thermal (infrared) radiation and flammable area models to calculate the emissivity, view factor, transmissivity and duration of BLEVE fireballs; the emissivity and view factor of jet fires; the emissivity, view factor, and pool dynamics of pool fires; and the flammable area of flash fires.

ALOHA does not model hazardous missile fragments, does not model the downwind toxic effects of fire byproducts, and does not account for the effects of fires or chemical reactions, particulates, chemical mixtures, and terrain.⁵⁶ The missile fragment threat zones were modeled using the lower limit of the industry's widely accepted range of 30- to 40-times the fireball radius.⁵⁷

Google Earth was used to display ALOHA thermal and overpressure KML data on 3-D location maps. KML uses a tag-based structure with nested elements and attributes and is based on the XML standard. A big advantage of KML for the current purpose is that the threat data are automatically scaled and merged with Google Earth's maps, allowing seamless and accurate

⁵⁶ Jones, Robert, et al. ALOHA (Areal Locations of Hazardous Atmospheres) 5.4.4 Technical Documentation. NOAA Technical Memorandum NOS OR&R 43. November 2013.

⁵⁷ Roberts, Michael W., EQE International, Inc. "Analysis of Boiling Liquid Expanding Vapor Explosion (BLEVE) Events at DOE Sites." Page 10. mroberts@abs-group.com
http://www.efcog.org/wg/sa/docs/minutes/archive/2000%20Conference/papers_pdf/Roberts%20abstract.pdf

viewing from any perspective. Shrapnel threat zones, computed as 30x the ALOHA fireball radius, were generated using a KML circle generator,⁵⁸ and the XML tags were manually edited to adjust circle line-width and color.

The latest version of ALOHA (V5.4) released in February 2006 added the ability to model the hazards associated with fires and explosions. With this major update, users can now estimate the hazards associated with jet fires (flares), pool fires, vapor cloud explosions (VCE), BLEVEs (Boiling Liquid Expanding Vapor Explosions), and flammable regions (flash fires) as well as toxic threats. The ALOHA user manuals were completely updated to include extensive material associated with fires and explosion.^{59,60}

WARNING

The data computed here are for general reference and educational purposes only and *must not* be relied upon as a sole source to determine worst case or typical results of damage to propane storage vessels and loss and possible ignition of contents, or where matters of life and health and safety are concerned. This paper's authors have taken all care to ensure the accuracy of the results, but do not warrant or guarantee the accuracy or the sufficiency of the information provided and do not assume any responsibility for its use. Sufficient data has been provided for anyone to use the same software to reproduce the same general results.

⁵⁸ KML circle generator: <http://www.thesamestory.com/kmlcircle/>

⁵⁹ "Technical documentation and software quality assurance for project-Eagle-ALOHA: A project to add fire and explosive capability to ALPHA." Feb 2006. Office of Response and Restoration, National Oceanic and Atmospheric Administration (NOAA); Environmental Protection Agency (EPA); Pipelines and Hazardous Materials Safety Administration, Department of Transportation.

<http://www.deq.state.ok.us/LPDnew/saratitleiii/AlohaTrainingManuals/Final%20techdoc%20and%20QA.pdf>

Retrieved Feb 20, 2015.

⁶⁰ Reynolds, R. Michael. "ALOHA (Areal Locations of Hazardous Atmospheres) 5.0 Theoretical Description." NOAA Technical Memorandum NOS ORCA-65 (August 1992).

<http://www.deq.state.ok.us/LPDnew/saratitleiii/AlohaTrainingManuals/ALOHA-Theoretical-Description.pdf>

Retrieved Feb 20, 2015.

Appendix C: ES for the Long Beach LNG Terminal Draft EIS/EIR

[footnotes and tables removed]

On January 26, 2004, Sound Energy Solutions (SES) filed an application with the Federal Energy Regulatory Commission (Commission or FERC) under section 3 of the Natural Gas Act (NGA) and Part 153 of the Commission's regulations. SES seeks authorization from the FERC to site, construct, and operate a liquefied natural gas (LNG) receiving terminal and associated facilities in the Port of Long Beach (POLB or Port) in Long Beach, California as a place of entry for the importation of LNG. The FERC is the federal agency responsible for authorizing sites for onshore LNG import facilities. As such, the FERC is the lead federal agency for the preparation of the environmental impact statement (EIS). The FERC will use the document to consider the environmental impact that could result if it issues SES an Order Granting Authorization under section 3 of the NGA.

The Board of Harbor Commissioners (BHC) has authority over the City's Harbor District, commonly known as the POLB or Port. The City of Long Beach owns the land within the Harbor District in trust for the people of the State of California. SES would have to obtain a lease from the City of Long Beach to build and operate its proposed Long Beach LNG Import Project. SES submitted an application to the POLB for a Harbor Development Permit on July 25, 2003, seeking approval for a development project within the Port. The application was designated POLB Application No. HDP 03-079. The POLB is the lead agency in California for preparing the environmental impact report (EIR). The BHC will use the document to determine the project's consistency with the certified Port Master Plan (PMP) and the California Coastal Act of 1976 as well as to consider the environmental impact that could result if it issues Harbor Development Permits for the project.

The environmental staffs of the FERC and the POLB (Agency Staffs) have jointly prepared this draft EIS/EIR to assess the environmental impacts associated with the construction and operation of the Long Beach LNG Import Project. The document was prepared in accordance with the requirements of the National Environmental Policy Act (NEPA), the Council on Environmental Quality regulations for implementing the procedural provisions of NEPA [Title 40 Code of Federal Regulations (CFR) Parts 1500-1508], the FERC's regulations implementing NEPA (Title 18 CFR Part 380), the California Environmental Quality Act (CEQA), and the guidelines for the implementation of the CEQA (California Code of Regulations Title 14, section 15000 et seq.). The purpose of this document is to inform the public and the permitting agencies about the potential adverse and beneficial environmental impacts of the proposed project and its alternatives, and to recommend all feasible mitigation measures.

The U.S. Army Corps of Engineers (ACOE) has jurisdictional authority pursuant to section 404 of the Clean Water Act [33 United States Code (USC) 1344], which governs the discharge of dredged or fill material into waters of the United States, and section 10 of the Rivers and Harbors Act (33 USC 403), which regulates any work or structures that potentially affect the navigable capacity of a waterbody. Because the ACOE must comply with the requirements of NEPA before issuing permits under sections 404 and 10, it has elected to act as a cooperating agency with the FERC and the POLB in preparing this EIS/EIR. The ACOE would adopt the EIS/EIR per Title 40 CFR Part 1506.3 if, after an independent review of the document, it concludes that its comments and suggestions have been satisfied.

The U.S. Coast Guard (Coast Guard) within the U.S. Department of Homeland Security exercises regulatory authority over LNG facilities that affect the safety and security of port areas and navigable waterways under Executive Order 10173; the Magnuson Act (50 USC section 191); the Ports and Waterways Safety Act of 1972, as amended (33 USC section 1221, et seq.); and the Maritime Transportation Security Act of 2002 (46 USC section 701). The Coast Guard is responsible for matters related to navigation safety, vessel engineering and safety standards, and all matters pertaining to the safety of facilities or equipment located in or adjacent to navigable waters up to the last valve immediately before the receiving tanks. The Coast Guard also has authority for LNG facility security plan review, approval and compliance verification as provided in Title 33 CFR Part 105, and siting as it pertains to the management of vessel traffic in and around the LNG facility. As required by its regulations, the Coast

Guard is responsible for issuing a Letter of Recommendation (LOR) as to the suitability of the waterway for LNG marine traffic. The Coast Guard has elected to act as a cooperating agency in the preparation of this EIS/EIR and plans to adopt the document if it adequately covers the impacts associated with issuance of the LOR.

The Pipeline and Hazardous Materials Safety Administration (PHMSA) within the U.S. Department of Transportation has authority to promulgate and enforce safety regulations and standards for the transportation and storage of LNG in or affecting interstate or foreign commerce under the pipeline safety laws (49 USC Chapter 601). This authority extends to the siting, design, installation, construction, initial inspection, initial testing, and operation and maintenance of LNG facilities. The PHMSA's operation and maintenance responsibilities include fire prevention and security planning for LNG facilities under Title 49 CFR Part 193. The PHMSA is participating in the NEPA analysis under the terms of an interagency agreement between the PHMSA, the FERC, and the Coast Guard.

PROPOSED ACTION

LNG is natural gas that has been cooled to a temperature of about -260 degrees Fahrenheit so that it becomes a liquid. Because LNG is more compact than the gaseous equivalent, it can be transported long distances across oceans using specially designed ships. SES proposes to ship LNG from a variety of Asian and other foreign sources to provide a new, stable source of natural gas to serve the needs of southern California, particularly the Los Angeles Basin (LA Basin). The LNG would be unloaded from the ships, stored in tanks at the terminal, and then re-gasified (vaporized) and transported via a new 2.3-mile-long, 36-inch-diameter natural gas pipeline to Southern California Gas Company's (SoCal Gas) existing Line 765. A portion of the LNG would be distributed via trailer trucks to LNG vehicle fueling stations throughout southern California to fuel LNG-powered vehicles.

Natural gas is a mixture of hydrocarbon compounds, principally methane. It also contains small amounts of heavier hydrocarbons, such as propane, ethane (C₂), and butane, which have a higher heating value than methane. A portion of these components may need to be removed from the LNG that would be stored on the terminal site in order for the natural gas to meet the British thermal units (Btu) and gas quality specifications of SoCal Gas as well as the specifications for LNG vehicle fuel established by the California Air Resources Board (CARB). The components that are removed are called natural gas liquids (NGL). SES has stated that it would accept only lean LNG [i.e., LNG containing fewer heavy (non-methane) hydrocarbons than regular LNG] from its suppliers. However, up to 10,000 million Btu per day of C₂ recovered from the LNG would be vaporized and distributed to ConocoPhillips' existing Los Angeles Refinery Carson Plant (LARC) via a new 4.6-mile-long, 10-inch-diameter pipeline.

Specifically, SES' proposal would involve construction and operation of LNG terminal and pipeline facilities as described below.

The LNG terminal facilities would include:

- An LNG ship berth and unloading facility with unloading arms, mooring and breasting dolphins, and a fendering system;
- Two LNG storage tanks, each with a gross volume of 160,000 cubic meters (1,006,000 barrels) surrounded by a security barrier wall;
- 20 electric-powered booster pumps;
- Four shell and tube vaporizers using a primary, closed-loop water system;
- Three boil-off gas compressors, a condensing system, an NGL recovery system, and an export C₂ heater;
- An LNG trailer truck loading facility with a small LNG storage tank;
- A natural gas meter station and odorization system;
- Utilities, buildings, and service facilities; and
- Associated hazard detection, control, and prevention systems; site security facilities; cryogenic piping; and insulation, electrical, and instrumentation systems.

The pipeline facilities would include:

- A 2.3-mile-long, 36-inch-diameter pipeline and associated aboveground facilities to transport natural gas from the LNG terminal to the existing SoCal Gas system; and
- A 4.6-mile-long, 10-inch-diameter pipeline and associated aboveground facilities to transport vaporized C2 from the LNG terminal to the existing ConocoPhillips LARC.

PUBLIC INVOLVEMENT AND AREAS OF CONCERN

On June 30, 2003, SES filed a request with the FERC to implement the Commission's Pre-Filing Process for the Long Beach LNG Import Project. At that time, SES was in the preliminary design stage of the project and no formal application had been filed with the FERC. On July 11, 2003, the FERC granted SES' request and established a pre-filing docket number (PF03-6-000) to place information filed by SES and related documents issued by the FERC into the public record. The purpose of the Pre-Filing Process is to encourage the early involvement of interested stakeholders, facilitate interagency cooperation, and identify and resolve issues before an application is filed with the FERC. After receipt of SES' Harbor Development Permit application on July 25, 2003, the POLB agreed to conduct its CEQA review of the project in conjunction with the Commission's Pre-Filing Process.

As part of the Pre-Filing Process, the FERC and the POLB worked with SES to develop a public outreach plan for issue identification and stakeholder participation. As part of the outreach plan, SES met with local associations, neighborhood groups, and other non-governmental organizations to inform them about the project and address issues and concerns. In coordination with the FERC and the POLB, SES also consulted with key federal and state agencies to identify their issues and concerns.

On September 4, 2003, SES sponsored two public workshops in the Long Beach area. The purpose of the workshops was to inform agencies and the general public about LNG and the proposed project and to provide them an opportunity to ask questions and express their concerns. The FERC and the POLB participated in these workshops and provided information on the joint environmental review process. Invitations to the public workshops were sent to federal, state, and local agencies; elected officials; environmental groups; affected landowners; and tenants of the POLB. Notices of the public workshops were published in the local newspapers.

Between September 22, 2003 and November 3, 2004, the FERC and/or the POLB issued three separate notices that described the proposed project and invited written comments on the environmental issues to be addressed in the EIS/EIR. The September 22, 2003 notice also announced a joint NEPA/CEQA public scoping meeting that was held in Long Beach on October 9, 2003. All three notices were mailed to federal, state, and local agencies; elected officials; environmental and public interest groups; Native American tribes; affected landowners; POLB tenants; and local libraries and newspapers. Announcements of the public scoping meeting were published in the local newspapers. Each notice opened a formal scoping period for the project.

A transcript of the public scoping meeting and all written comments are part of the public record for the Long Beach LNG Import Project and are available for viewing on the FERC Internet website (<http://www.ferc.gov>).² The environmental scoping comments received during the public scoping periods raised issues related to the alternatives analysis, geologic hazards, contaminated soils and sediments, land use, socioeconomics, traffic, air quality, cumulative impacts, and reliability and safety.

This draft EIS/EIR was filed with the U.S. Environmental Protection Agency (EPA), submitted to the California State Clearinghouse, and mailed to federal, state, and local agencies; elected officials; environmental and public interest groups; Native American tribes; affected landowners; POLB tenants; intervenors³ in the FERC's proceeding; local libraries and newspapers; and other interested parties (i.e., miscellaneous individuals who provided scoping comments or asked to be on the mailing list). A formal notice indicating that the draft EIS/EIR is available for review and comment was published in the Federal Register, posted in the Los Angeles County Clerk's office in California, and sent to the remaining individuals on the mailing list. The public has at least 45 days after the date of publication in the Federal

Register to review and comment on the draft EIS/EIR both in the form of written comments and at public meetings to be held in Long Beach. All comments received on the draft EIS/EIR related to environmental issues will be addressed in the final EIS/EIR.

ENVIRONMENTAL ISSUES

The environmental issues associated with construction and operation of the Long Beach LNG Import Project are analyzed in this EIS/EIR using information provided by SES and further developed from data requests; field investigations; scoping; literature research; alternatives analysis; contacts with federal, state, and local agencies; and input from public groups and organizations. The Agency Staffs' analysis indicates that the project would result in certain adverse environmental impacts. As part of the environmental analysis, specific mitigation measures were identified that are feasible and that, when implemented, would reduce potential adverse impacts of project construction and operation. Table ES-1 at the end of this Executive Summary summarizes the significant impacts of the project and the mitigation measures recommended by the Agency Staffs to reduce the impacts. These impacts are described in detail in section 4.0. A brief summary by resource is provided below.

Geology

The project area is underlain by fill materials, alluvial and marine sediments, sedimentary rocks, and metamorphic basement rocks. Construction of the LNG terminal, electric distribution facilities, and pipelines would occur primarily within near-surface non-native fill deposits and unconsolidated soils and sediments. Therefore, construction and operation of the Long Beach LNG Import Project would not materially alter the geologic conditions of the area or worsen existing unfavorable geologic conditions. All active and abandoned petroleum production wells would be identified in the field just prior to the commencement of construction.

The potential for tsunamis or surface rupture to affect the project facilities is very low and, therefore, no specific mitigation is proposed. Geologic hazards present in the project area are related to seismic activity and historical subsidence associated with petroleum production in the area. Seismic activity could potentially damage the LNG terminal site facilities, shoreline structures, and pipeline and electric distribution facilities through strong shaking or secondary ground deformation such as liquefaction, shaking-induced settlement, or lateral spreading.

SES conducted a detailed analysis that resulted in seismic design criteria that meet the POLB requirements and exceed the Office of Pipeline Safety and the FERC requirements as specified in National Fire Protection Association 59A (2001). This analysis indicates that an earthquake of Richter magnitude M9.0 on the Palos Verde fault or M7.5 on the THUMS-Huntington Beach fault would be necessary to generate ground motions strong enough to rupture the LNG storage tanks and release their contents. These events have estimated return intervals of approximately 15,000 years and, therefore, are extremely unlikely to occur during the 50-year life of the project.

The Agency Staffs reviewed the current engineering designs for the LNG storage tanks and other critical terminal structures. These designs are of sufficient detail to demonstrate that the project facilities would withstand the seismic hazards that could affect the site when they are constructed to the specifications of the plans. SES would ensure that final engineering designs also meet or exceed applicable seismic standards, and would provide the final plans to the FERC and the POLB for review and approval before construction. The POLB would construct the shoreline structures to meet the stringent seismic design criteria developed for the site, and stone columns would be installed between the shoreline structures and the LNG storage tanks, thereby providing the required lateral support to limit displacement and minimize stress and strain levels well within the design limits of the LNG storage tanks and other heavy load structures in the event of an earthquake.

Regional subsidence due to ongoing hydrocarbon production is effectively monitored and controlled and, therefore, would not affect construction or operation of the project.

Soils and Sediments

Because of the highly developed, industrial nature of the area and the presence of mostly fill materials under the majority of the project facilities, the project would not reduce soil productivity by compaction or soil mixing. However, construction of the project facilities would temporarily expose the fill materials on the affected portion of Terminal Island and the native soils at the end of the pipeline routes to the effects of wind, rain, and runoff, which could cause erosion and sedimentation in the area. Erosion control measures proposed for the Long Beach LNG Import Project are detailed in SES' Sediment Control Plan that is included in its Storm Water Pollution Prevention Plan (SWPPP).

Existing soils at the LNG terminal site are not capable of adequately supporting the LNG storage tanks or other heavy load structures. As a result, SES proposes to install deep-driven pile foundations beneath the LNG storage tanks and other heavy load structures to meet the stringent static-settlement criteria for the structures at the LNG terminal. Other soil improvements at the site would include the installation of approximately 3,380 stone columns to depths of 60 to 80 feet below ground surface between the shoreline structures and the security barrier wall and an additional approximately 2,000 stone columns to a depth of 60 feet below ground surface between the security barrier wall and the LNG storage tanks. In addition to excavation for the soil improvements, construction of the project would involve excavation for the LNG spill impoundment systems and other utilities and foundations at the LNG terminal site, and trenching for the pipeline and electric distribution facilities. Contaminated soil and other hazardous materials could be encountered during any of these activities. If hazardous substances are encountered during construction, SES would notify the POLB. SES, in consultation with the POLB, would comply with all applicable environmental regulations. Before construction, SES and the pipeline contractor(s) would submit work plans that outline appropriate environmental site investigation and remediation activities to the appropriate agencies for approval. The work plans would include a site specific Health and Safety Plan, Sampling and Analysis Plan, Project Contractor Quality Control Plan, and an Environmental Protection Plan that would also include a Waste Management Plan.

Spills or leaks of fuels, lubricants, or other hazardous substances during construction and/or operation of the project could also have an impact on soils. This potential impact is expected to be minor, however, because of the typically low frequency, volume, and extent of spills or leaks, and because of the hazard detection system and other safety controls designed to prevent or contain spills and leaks at the LNG terminal site. Implementation of SES' Spill Procedure included in its SWPPP would further reduce the likelihood of a significant spill or leak occurring during construction or operation of the project, and would reduce the impact of any spill or leak that may occur.

Disturbance of the West Basin sediments during in-water activities would temporarily resuspend sediments in the water column, which could cause turbidity. An increase in sediment and turbidity levels could adversely affect water quality and aquatic organisms. Resuspension of contaminated sediments could also impact marine organisms in the area. The POLB has recently negotiated a consent agreement with the California Department of Toxic Substances Control (DTSC) for its concurrence with the Installation Restoration Site 7 (West Basin) sediment remediation. Accordingly, the dredging associated with the project would be done only with the concurrence of the DTSC. Turbidity levels would return to baseline conditions after dredging operations were completed. Disposal suitability issues would be addressed in compliance with the EPA/ACOE *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual*. Disturbance of the West Basin sediments could also encounter ordnance. Any ordnance found during dredging for the proposed project would be handled in accordance with federal regulations and the POLB's procedures.

Water Resources

Activities associated with construction of the proposed project facilities, including hydrostatic test water appropriation, the installation of deep-driven pile foundations and stone columns at the LNG terminal site, the horizontal directional drills (HDDs) of the Cerritos Channel, site excavation and dewatering, and accidental spills or leaks of hazardous materials could adversely affect groundwater quality within the project area. SES would minimize the potential for these impacts by negotiating project

water requirements with the City of Long Beach for appropriate fees and mitigation measures; driving, rather than excavating, the foundation piles at the LNG terminal site and installing a cement plug at the base of each stone column in order to prevent the creation of an opening where potential cross-contamination could occur; implementing its HDD Plan; identifying and protecting all underground piping in the construction area; evaluating all dewatered material for contamination prior to removal in accordance with the Health and Safety Plan and Sampling and Analysis Plan; and implementing its Spill Procedure to address preventive and mitigative measures that would be used to minimize the potential impact of a hazardous spill during construction of the project facilities.

Potential operational impacts on groundwater include an accidental spill or leak of hazardous materials during operation of the project facilities and water requirements for the LNG terminal vaporization process, firewater system, and miscellaneous potable water needs. The measures in SES' Spill Procedure would reduce the potential impacts on groundwater associated with a hazardous spill or leak during project operation. All of the operational water required for the LNG terminal would be obtained from the POLB and the City of Long Beach municipal water system. SES would negotiate with the City of Long Beach or a local supplier to determine appropriate fees and to ensure that the project would have no impact on water availability in the area.

Activities associated with construction of the project facilities, including reinforcement of the shoreline structures, construction of the LNG ship berth and unloading facility and associated dredging, the HDDs of the Cerritos Channel, installation of the C₂ pipeline over the Dominguez Channel, hydrostatic test water discharge, storm water runoff, and accidental spills or leaks of hazardous materials could adversely affect surface water quality and/or water circulation within Long Beach Harbor. Adherence to the measures of all applicable permits, implementation of the POLB's Dredge and Disposal Plan and SES' HDD Plan and Spill Procedure, as well as disposal of all sediments at approved sites would minimize impacts on water quality. In addition, the Agency Staffs will recommend to their respective Commissions that SES revise its HDD Plan to describe the procedures that would be followed if an existing submerged pipeline is encountered during the HDD operations.

Operational impacts on water quality include the potential to contribute additional pollutants to the waterbody via accidental spills or leaks of hazardous materials, storm water runoff, or an LNG spill. There would be no intake or discharge of sea water during operation of the project facilities. Implementation of SES' Spill Procedure included in its SWPPP would reduce the likelihood of a significant spill or leak occurring during operation of the project, and would reduce the impact of any spill or leak that may occur. In accordance with its SWPPP, best management practices (BMPs) consisting of permanent features and operational practices designed or implemented to minimize the discharge of pollutants in storm water or non-storm water flows from the LNG terminal site would be implemented to reduce the potential operation-related impacts on surface water resources.

Biological Resources

Due to the highly developed nature of the POLB and the lack of vegetative habitats, the terrestrial environment in the project area supports few wildlife species. Individuals in the area are acclimated to the industrial nature of the POLB, routinely experience disturbance associated with Port activities, and would likely relocate into adjacent habitats. The project would not have a measurable impact on the local population of any species.

Activities associated with dredging could potentially affect marine organisms by destroying the benthic infauna of the dredged sediments and temporarily displacing mobile organisms, such as fish. In addition to the direct disturbances to the bottom substrates, dredging activities would temporarily increase turbidity and the presence of suspended sediments in the water column, which could indirectly affect marine organisms. However, monitoring of larger dredging projects within San Pedro Bay has shown that turbidity associated with dredging is short term and localized and that compliance with the requirements of the Regional Water Quality Control Board's Waste Discharge Requirements and the ACOE's section 404 permit results in minimal turbidity. The short-term loss of benthic organisms in a small portion of the

harbor is generally recognized as an insignificant impact on aquatic resources and benthic communities would be expected to repopulate following the completion of construction activities.

Activities associated with the reinforcement of the shoreline structures and construction of the LNG ship berth and unloading facility could directly affect benthic and fish species during the removal or installation of any in-water structures (e.g., pilings, underwater rock buttress). Individuals of non-mobile species attached to hard substrates that are removed or covered would suffer mortality. However, these species are relatively widespread throughout the harbor and would recolonize new hard substrates within 2 to 3 years.

Noise could impact marine organisms that occur in the project area within Long Beach Harbor. Project vessels operating within Long Beach Harbor could create sounds that lead to responses in fish. Additionally, specific construction activities (e.g., driving steel piles) could also generate underwater sound pressure waves that potentially kill, injure, or cause a behavioral change in fish in the immediate vicinity of the construction activities. Given the abundance of fish in the harbor despite continuous maritime activity, marine organisms found in the project area have generally adapted to these conditions.

There is also the potential for spills, leaks, or accidental releases of potentially hazardous materials to occur during construction of the proposed project. SES' Spill Procedure specifies BMPs that would minimize the chances of a spill and, if a spill were to occur, minimize the chances of the spill reaching a waterbody and affecting marine organisms.

Dredging and construction activities associated with the Long Beach LNG Import Project would affect water-associated birds through disruptive noise and/or temporary loss or degradation of foraging habitats in the marine waters of the West Basin. Birds found in the area are acclimated to these types of activities and would use similar habitats in adjacent areas.

Consultation with the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) identified the proposed project area as designated essential fish habitat (EFH) for the Coastal Pelagics and Pacific Groundfish Management Plans. Fourteen of the 86 species managed under these two plans are known to occur in Long Beach Harbor and could be affected by the proposed project. Although disturbance of an estimated 11.9 acres of sea floor and the temporary resuspension of sediments into the water column during dredging activities could potentially adversely affect EFH (resulting in avoidance by adults and some loss of larval northern anchovy in the immediate vicinity of the dredging activity), implementation of the control measures and management practices proposed by SES or required by the regulatory agencies would serve to avoid or minimize impacts on EFH. Additionally, construction impacts would be temporary and turbidity levels would return to baseline conditions following construction.

Seven species listed as federally threatened or endangered potentially occur in the project area. The California brown pelican, California least tern, and leatherback sea turtle are federally listed endangered species and the western snowy plover, green sea turtle, olive Ridley sea turtle, and loggerhead sea turtle are federally listed threatened species. Both the U.S. Fish and Wildlife Service and NOAA Fisheries provided comments indicating that federally listed threatened or endangered species would not likely be adversely affected by the proposed project and the FERC staff concurs with these determinations. Three state-listed endangered species, the American peregrine falcon, the California brown pelican, and the California least tern, have been identified as potentially occurring in the proposed project area. The California brown pelican and the California least tern are also federally listed species and, as discussed above, would not likely be adversely affected by the project. Construction and operation of the Long Beach LNG Import Project could disturb the American peregrine falcon through temporary loss or degradation of foraging habitat and disruptive noise from construction and operation of the project facilities. However, peregrine falcons in the project area have become acclimated to POLB operations, including construction and dredging activities as evidenced by their continued use of the local bridges for nesting. In addition, the proposed project would not result in the permanent loss or degradation of existing foraging habitat or significantly increase existing noise levels during construction and operation.

Land Use, Hazardous Waste, Recreation, and Visual Resources

A total of 88.0 acres of land would be affected during construction of the Long Beach LNG Import Project (56.9 acres for the LNG terminal facilities, 30.1 acres for the pipeline facilities, and 1.0 acre for the electric distribution facilities). Of the 88.0 acres of land affected by construction of the project, 37.0 acres would be permanently affected during operation of the project facilities (32.1 acres associated with the LNG terminal, 3.9 acres associated with the pipelines, and 1.0 acre associated with the electric distribution facilities). The LNG terminal would be an industrial use that generally conforms to the overall goals of the current PMP, local zoning ordinances, and relevant regional plans and would be consistent with existing surrounding uses. However, an amendment to the PMP would be necessary to accommodate the LNG facility because LNG is not an expressly identified “hazardous cargo” as permitted within Terminal Island Planning District 4. The pipeline and electric distribution facilities would be an industrial/utility use that is consistent with existing surrounding uses and conforms to the overall goals of the current PMP, local zoning ordinances, and relevant regional plans.

All of the land and marine uses immediately adjacent to and within 1 mile of the proposed project facilities are associated with the industrial activities of the ports of Long Beach and Los Angeles or the Cities of Long Beach, Los Angeles, and Carson. No permanent residences are located within the POLB or the Port of Los Angeles. The closest potential residences are in a recreational vehicle park about 1.3 miles east-northeast of the LNG terminal site and possibly live-aboard boats at two marinas in the East Basin of the Cerritos Channel between 1.2 and 1.6 miles northwest of the LNG terminal.

The Long Beach Naval Shipyard and Station are listed as hazardous waste sites. The Navy also documented soil contamination in the area during closure of its Long Beach Complex. Several other hazardous waste sites were identified within 0.25 mile of the pipeline routes and electric distribution facilities. Because none of these sites would be crossed by the proposed facilities, Phase I Environmental Assessments were not conducted.

Although the Long Beach area provides several opportunities for recreational activities, the immediate area surrounding the LNG terminal site, pipelines, and electric distribution facilities does not provide for recreational activities due to the industrial nature of the Port and the adjacent area to the north. Construction and operation of the Long Beach LNG Import Project would not threaten the viability of a recreational resource, prohibit access to recreational resources, or cause termination of a recreational use.

Construction and operation of the LNG terminal facilities would have a permanent but not significant impact on visual resources. Although there are a substantial number of potential mobile and stationary viewers and visibility is high in some locations, the LNG facilities would be seen in the context of the existing industrial facilities at the POLB and would not adversely affect the viewshed from sensitive locations or change the character of the landscape in terms of either physical characteristics or land uses. Construction and operation of the pipeline and electric distribution facilities would not result in significant impacts on visual resources.

Socioeconomics

Construction of the project would result in a temporary increase in population and the demands on temporary housing, public services, and utilities and service systems. Due to the temporary and limited nature of these impacts they are not considered significant. Of the 60 full-time workers SES would hire to operate the project facilities, about 54 workers are expected to be from the local area. Therefore, operation of the project would not have a significant impact on population or the demand for housing. Because LNG would be a new product to the POLB, it would also be new to the local fire and emergency response services. SES is working with local emergency providers to develop procedures to handle potential fire emergencies and is working with the Long Beach City Fire Department (LBFD) to provide hazard control and firefighting training that is specific to LNG and LNG vessels. SES has also committed to funding all necessary security/emergency management equipment and personnel costs that would be imposed on state and local agencies as a result of the project and would prepare a comprehensive plan that identifies the mechanisms for funding these costs. These measures should adequately equip the LBFD to handle any

type of emergency at the proposed LNG terminal. Construction and operation of the project would have a beneficial impact on local tax revenues.

Transportation

The duration of construction for the LNG terminal is estimated to be 48 months. During this time, traffic would be generated by trucks transporting materials and equipment to and from the laydown area and project site as well as trucks transporting materials directly to the project site. Driveway access to the laydown area is located along Pier S Avenue. Also, construction worker trips would occur during the construction period. These worker trips would total approximately 808 trips (404 in and 404 out) into the area. All construction workers would park adjacent to the laydown area. The construction workers would then be transported via buses to the project site. The transporting of these workers would generate a total of 46 daily bus trips (23 in and 23 out). The transporting of construction equipment and materials would generate approximately 676 daily truck trips (338 in and 338 out) during the most active construction period. These project construction worker and truck and material haul trips would result in a temporary, short-term significant impact at the intersections of Navy Way and Seaside Avenue (evening only) and Henry Ford Avenue and Anaheim Street (evening only). The Agency Staffs will recommend to their respective Commissions that SES require the construction workforce to work 6 a.m. to 2:30 p.m. instead of 7 a.m. to 3:30 p.m. Improvements at the Henry Ford Avenue/Anaheim Street intersection would be implemented if required by the Los Angeles Department of Transportation. Operation of the project would not result in a significant impact on traffic.

The Long Beach LNG Import Project would generate a maximum of 120 ship calls and 240 ship movements within the POLB each year. This would typically mean the addition of one ship movement per day on up to 240 days of the year or possibly two ship movements in the event of a rapid discharge call with arrival, discharge, and departure occurring during one calendar day. The increase in ship traffic associated with the LNG terminal could cause vessel traffic congestion within the harbor and/or conflicts with other commercial interests if an LNG ship arrival or departure delays the movement of another vessel, either due to scheduling or traffic management resulting in slow speed or waiting time. Delays experienced by other ships are expected to be temporary and of short duration. In addition, SES would participate with the Coast Guard in the development of procedures to reduce impacts on marine transportation, including implementation of an LNG Vessel Operation and Emergency Contingency Plan that would provide the basis for operation of LNG ships within the POLB.

Cultural Resources

The FERC and the POLB, in consultation with the State Historic Preservation Office, have determined that there would be no impact on any properties listed, or eligible for listing, on the National Register of Historic Places or the California Register of Historical Resources or on any unique archaeological resources for the proposed project; therefore, no mitigation would be required. SES prepared an Unanticipated Discovery Plan to be used during construction. The plan describes the procedures that would be employed in the event previously unidentified cultural resources or human remains are encountered during construction. SES' continued cooperation with Native American tribes who were identified by the California Native American Heritage Commission as potentially having knowledge of cultural resources in the project area should address any tribal issues associated with the proposed project.

Air Quality

Construction emissions associated with the Long Beach LNG Import Project would be caused by tailpipe emissions from worker vehicles and supply trucks, as well as construction equipment and fugitive dust. The South Coast Air Quality Management District (SCAQMD) significance thresholds would be exceeded for all criteria pollutants except sulfur oxides (SO_x) on a peak daily and quarterly basis. The exceedances are considered a significant impact. To reduce project construction emissions from onsite diesel-fueled combustion equipment, SES' contract specifications would require that all off-road diesel fueled equipment powered by compression ignition engines meet or exceed the various emission

standards in accordance with table 1 of Title 40 CFR Part 89.112. For all other equipment, contract specifications would require that the newest equipment in the construction contractors' fleets be used to take advantage of the general reduction in emission factors that occurs with each model year. SES would also adhere to the POLB's air quality requirements and construction standards some of which include the use of electric-powered dredges for all hydraulic dredges and ultra-low sulfur or emulsified diesel in all other types of dredges, construction phasing to minimize concurrent use of construction equipment, turning equipment off when not in use, watering specifications, restrictions on soil excavation and hauling in windy conditions, suspension of construction activities during Stage II smog alerts, and speed limit restrictions. In addition to SES' proposed control measures, the Agency Staffs will recommend to their respective Commissions that SES require all contractors to use ultra-low sulfur or CARB-approved alternative diesel fuel in all diesel-powered equipment used onsite during construction.

The construction workforce would be relatively small (peak of about 404 workers) and would primarily consist of workers from within the Los Angeles and Orange County labor pool. The workers would commute to the temporary laydown and worker parking area on Ocean Boulevard and would then be transported to the site via buses. Materials and equipment would be shipped to the site by road, rail, or barge or to the temporary laydown area on Ocean Boulevard. The Agency Staffs will recommend to their respective Commissions that SES use alternative-fuel buses to transport workers to and from the temporary laydown and worker parking area.

Although implementation of SES' control measures and the mitigation measures recommended by the Agency Staffs would reduce emissions during the construction phase, the impacts of the project on air quality during construction are still expected to remain significant. Construction impacts would, however, be temporary and intermittent and cease at the end of the construction phase.

Operational emission sources associated with the project would include marine vessels, vaporization equipment, fugitive process emissions, on-road vehicles, and emergency generator and firewater pumps. The project's operational emissions would exceed the SCAQMD daily emission thresholds for nitrogen oxides (NO_x), reactive organic compounds (ROC), particulate matter having an aerodynamic diameter of 10 microns or less (PM₁₀), and SO_x. Therefore, the project would be significant for ozone, PM₁₀, and SO_x. The project would not be significant for carbon monoxide. SES proposes to minimize criteria pollutant emissions associated with operation of the Long Beach LNG Import Project through the following control measures: Lowest Achievable Emission Rate/Best Available Control Technology would be applied as needed to the stationary sources; LNG trailer trucks would be LNG fueled and their engines would be turned off during onsite loading; LNG ships would generate power from combustion of boil-off LNG rather than fuel oil if they are equipped to do so; fugitive ROC emissions from various points in the terminal would be minimized by design elements and through the implementation of a comprehensive leak detection and repair program; and operational personnel would be encouraged to rideshare and use mass transit.

SES would also ensure that all diesel-powered, non-road mobile terminal equipment would meet the emissions standards set forth in the EPA's Control of Emissions of Air Pollution From Non-Road Diesel Engines and Fuel and require ships calling at the terminal that do not use LNG boil-off gas in the main engines for power during unloading to use fuels such as the CARB's #2 diesel, gas-to-liquid diesel, biofuels, or a marine distillate fuel, in the ship's auxiliary power generator motors, or use exhaust treatment technology. Because the SCAQMD significance thresholds would be exceeded for NO_x, ROC, PM₁₀, and SO_x even after implementation of SES' control measures, the project's operational impact on air quality would be considered significant. Given the nature of the project operations, especially vessel operations, the Agency Staffs have determined that there are no additional feasible measures that would further reduce air emissions.

The proposed project would comply with all applicable regulations in the 2003 Air Quality Management Plan (AQMP). The AQMP includes control measures that are intended to be implemented

by federal and state governments to reduce emissions from ships and on-road trucks in order to bring the South Coast Air Basin (SCAB) into conformity with federal ambient air quality standards.

The FERC is required to conduct a conformity analysis for the Long Beach LNG Import Project to determine if the emissions associated with the project would conform to the State Implementation Plan (SIP) and would not reduce air quality in the SCAB. This draft EIS/EIR includes a draft conformity analysis; however, documentation supporting conformity with the applicable SIP and AQMP in accordance with Title 40 CFR Part 93.158 has not been filed with the FERC. Until this information is provided by SES, the Long Beach LNG Import Project is deemed to not conform to the applicable SIP and AQMP. The FERC staff recommends that SES completes a full air quality analysis and identify any mitigation requirements necessary for a finding of conformity and file this information with the FERC before the end of the draft EIS/EIR comment period for review and analysis in the final EIS/EIR.

In accordance with SCAQMD Rule 1401, a Health Risk Assessment of toxic air contaminant emissions on humans was conducted for the water heaters associated with the vaporization equipment, the unloading of the LNG ships at berth (vessel activities during that period are referred to as hotelling), movement of the LNG ships within the SCAQMD's boundary, tugboats, pilot boats, Coast Guard escort boats, and idling emissions from the LNG trailer trucks that would load at the terminal. Although the proposed project would not exceed cancer risk level significance thresholds established by the SCAQMD for toxic air pollutant health impacts, the SCAB and Port areas in particular are assumed, on the basis of the SCAQMD's Multiple Air Toxics Exposure Study in the SCAB, to suffer significant impacts related to toxic air pollutants and associated cancer risk levels. Therefore, toxic air pollutants resulting from the project would likely contribute to an existing cumulatively significant air quality impact in the SCAB.

Noise

The noise associated with construction activities would be intermittent because equipment would be operated on an as-needed basis. Construction activities at the LNG terminal and along the routes of the pipelines and electric distribution facilities would generate short-term increases in sound levels during daylight hours when construction activities would occur. The strongest source of sound during construction would be noise associated with installing deep-driven pile foundations beneath the LNG storage tanks and other heavy load structures to meet the stringent static-settlement criteria for the LNG storage tanks and other heavy load structures at the LNG terminal. Although the noise levels at the property boundary during this activity would be higher than existing noise levels, the impacts would be short term and would be contained within the industrial area immediately surrounding the LNG terminal site within the POLB.

The major noise-producing equipment associated with operation of the LNG terminal would be the boil-off gas compressors, primary and secondary booster pumps, water pumps and heaters, instrument air compressors, and fans for the heaters. Noise control measures included in the design of the LNG terminal facilities consist of buildings, barrier walls, and tanks to provide the appropriate level of noise screening. The predicted operational noise level is below the FERC limit of 55 decibels of the A-weighted scale (dBA) day-night sound level (L_{dn}) at the nearest noise-sensitive area (NSA). The predicted property boundary noise level is below the City of Long Beach noise limit of 70 dBA. To ensure that the actual noise resulting from the operation of the LNG terminal is below the FERC limit of 55 dBA L_{dn} at any nearby NSAs and the City of Long Beach property boundary noise limit of 70 dBA, the Agency Staffs will recommend to their respective Commissions that SES conduct a noise survey to verify that the noise from the LNG terminal when operating at full capacity does not exceed these limits.

Reliability and Safety

The safety of both the proposed LNG import terminal facility and the related LNG vessel transit was evaluated. With respect to the onshore facility, the FERC staff completed a cryogenic design and technical review of the proposed terminal design and safety systems. As a result of the technical review of the information provided by SES in its application materials, a number of concerns were identified by the FERC staff relating to the reliability, operability, and safety of the facility. In response to staff's

questions, SES provided written answers prior to a site visit and cryogenic design and technical review conference for the proposed project that was held in Long Beach in July 2004. Specific recommendations have been identified for outstanding issues that require resolution. Follow up on those items requiring additional action would need to be documented in reports to be filed with the FERC.

The FERC staff calculated thermal radiation distances for incident flux levels ranging from 1,600 to 10,000 Btu per square foot per hour (Btu/ft²-hr) for LNG storage tank and trailer truck loading LNG storage tank fires. An incident flux level of 1,600 Btu/ft²-hr is considered hazardous for persons located outdoors and unprotected, a level of 3,000 Btu/ft²-hr is considered an acceptable level for wooden structures, and a level of 10,000 Btu/ft²-hr would cause clothing and wood to ignite and is considered sufficient to damage process equipment. It was determined that the exclusion zone distance for the 10,000 Btu/ft²-hr incident flux would not extend beyond the property line. The LNG storage tank thermal radiation exclusion zone distance for the 1,600 and 3,000 Btu/ft²-hr incident flux would extend outside the terminal site to the east onto Pier T property. For the trailer truck loading storage tank, the thermal radiation exclusion zone distance for the 1,600 and 3,000 Btu/ft²-hr incident flux also would extend outside the terminal site to the east onto Pier T property. Although no prohibited activities or buildings currently exist within these exclusion zones, according to Title 49 CFR Part 193, either a government agency or SES must be able to exercise legal control over activities in these areas for as long as the facility is in operation. The POLB owns the land surrounding the LNG terminal site but leases parcels to other tenants. In its application, SES stated that it is currently negotiating with the POLB and adjacent tenants for restrictive covenants to limit the use of the areas impacted. The FERC staff recommends that SES provide in its comments on the draft EIS/EIR, or in a separate document submitted at the same time, evidence of its ability to exercise legal control over the activities that occur within the portions of the thermal radiation exclusion zones that fall outside the terminal property line that can be built upon.

The FERC staff also conducted flammable vapor dispersion analyses and determined that design spills for the storage tanks, process area, and trailer truck loading area would not extend beyond the terminal property line.

Thermal radiation and flammable vapor hazard distances were also calculated for an accident or an attack on an LNG vessel. For 2.5-meter and 3-meter diameter holes in an LNG cargo tank, the FERC staff estimated distances to range from 4,372 to 4,867 feet for a thermal radiation level of 1,600 Btu/ft²-hr.

In addition to the analysis conducted by the FERC staff, the POLB commissioned a study by Quest Consultants, Inc. (Quest) to identify the worst-case hazards that would result from a release of LNG or other hydrocarbons in or near SES' proposed LNG import terminal. Using a detailed methodology, Quest identified potential accidental and intentional release events involving the LNG terminal and LNG ships. Quest's final report is titled *Hazards Analysis of a Proposed LNG Import Terminal in the Port of Long Beach, California* (POLB Quest Study) and is included in its entirety in appendix F.

The POLB staff reviewed each of the release events identified by Quest using probability definitions developed by the Los Angeles County Fire Department (LACFD). Using the LACFD criteria, an event is considered possible if it could occur once every 100 to 10,000 years. Based on the chances of their occurrence, the release events that are considered possible per the LACFD criteria are a release from process equipment within the LNG terminal and a release from an LNG ship following a collision with the breakwater or with another ship outside the breakwater.

There are no residential, visitor-serving, or recreation populations and essentially no exposed Port workers within the thermal radiation exclusion zone for the 1,600 Btu/ft²-hr incident flux for a release from a rupture of process equipment at any location. Furthermore, the thermal radiation exclusion zone for the 10,000 Btu/ft²-hr incident flux for a release from a process equipment rupture would not impact the adjacent industrial facilities.

The analyses in the draft EIS/EIR and the POLB Quest Study have shown that based on the extensive operational experience of LNG shipping, the structural design of an LNG vessel, and the operational

controls imposed by the ship's master, the Coast Guard, and local pilots, the likelihood of a cargo containment failure and subsequent LNG spill from a vessel casualty – collision, grounding, or allision – is very small.

Unlike accidental causes, historical experience provides little guidance in estimating the probability of a terrorist attack on an LNG vessel or onshore storage facility. For a new LNG import terminal proposal that would store a large volume of flammable fluid near populated areas, the perceived threat of a terrorist attack is a primary concern of the local population. However, the POLB Quest Study reported that the historical probability of a successful terrorist event would be less than seven chances in a million per year. In addition, the multi-tiered security system that would be in place for an LNG import facility in the POLB would reduce the probability of a successful terrorist event.

Some commenters have expressed concern that the local community would have to bear some of the cost of ensuring the security of the LNG facility and the LNG vessels while in transit and unloading at the dock. The potential costs will not be known until the specific security needs have been identified, and the responsibilities of federal, state, and local agencies have been established in the Coast Guard's Waterway Suitability Assessment (WSA). SES has committed to funding all necessary security/ emergency management equipment and personnel costs that would be imposed on state and local agencies as a result of the project and would prepare a comprehensive plan that identifies the mechanisms for funding these costs. In addition, section 311 of the Energy Policy Act of 2005 stipulates that the FERC must require the LNG operator to develop an Emergency Response Plan that includes a Cost-Sharing Plan before any final approval to begin construction. The Cost-Sharing Plan shall include a description of any direct cost reimbursements to any state and local agencies with responsibility for security and safety at the LNG terminal and near vessels that serve the facility. To allow the FERC and the POLB the opportunity to review the plan, the Agency Staffs will recommend to their respective Commissions that SES submit the plan concurrent with the submission of the Follow-on WSA.

Cumulative Impacts

When the impacts of the Long Beach LNG Import Project are considered additively with the impacts of other past, present, or reasonably foreseeable future actions, there is some potential for cumulative effect on water resources, socioeconomics, land transportation, air quality, and noise. For the Long Beach LNG Import Project, control measures have been developed and additional mitigation measures have been recommended by the Agency Staffs to minimize or avoid adverse impacts on these resources. However, the cumulative projects represent additions of potentially significant and unavoidable emissions to the SCAB. In addition, even though project-specific toxic air pollutant health impacts would not be significant, it is likely that the incremental increase in the cancer risk level for toxic air pollutants as a result of the proposed project would contribute to an existing cumulatively significant health impact in the SCAB.

Growth-inducing Impacts

The potential growth-inducing impacts of the Long Beach LNG Import Project would be an increase in development and population in the area associated with a new source of natural gas. Most of the natural gas that would be supplied by the LNG terminal would be transported into the SoCal Gas system and would be used to meet existing and future natural gas demand in the LA Basin. The demand for energy is a result of, rather than a precursor to, development in the region. Currently, imports from out of state represent approximately 87 percent of supply and are anticipated to rise to 88 percent by 2013, meaning that additional external supplies will be needed to keep up with demand. Given the short and mid-term demand for natural gas and the need to reduce potential supply interruptions, the California Energy Commission has identified the need for California to develop new natural gas infrastructure to access a diversity of fuel supply sources and to remove constraints on the delivery of natural gas. The LNG that would be made available for vehicle fuel would be used to meet existing and projected future demand and provide a new source of fuel to facilitate conversion of diesel or gasoline-fueled vehicles to LNG, which could reduce air emissions in the area. Given the large local labor pool in Los Angeles and Orange

Counties, no substantive influx of workers would occur during construction and operation of the Long Beach LNG Import Project.

ALTERNATIVES CONSIDERED

The No Action or No Project Alternative was considered. While the No Action or No Project Alternative would eliminate the environmental impacts identified in this EIS/EIR, none of the objectives of the proposed project would be met. Specifically, SES would not be able to provide a new and stable supply of natural gas and LNG vehicle fuel to southern California. It is purely speculative to predict the actions that could be taken by other suppliers or users of natural gas and LNG in the region as well as the resulting effects of those actions. Because the demand for energy in southern California is predicted to increase, customers would likely have fewer and potentially more expensive options for obtaining natural gas and LNG supplies in the near future. This might lead to alternative proposals to develop natural gas delivery or storage infrastructure, increased conservation or reduced use of natural gas, and/or the use of other sources of energy.

It is possible that the infrastructure currently supplying natural gas and LNG to the proposed market area could be developed in other ways unforeseen at this point. This might include constructing or expanding regional pipelines as well as LNG import and storage systems. Any construction or expansion work would result in specific environmental impacts that could be less than, similar to, or greater than those associated with the Long Beach LNG Import Project. Increased costs could potentially result in customers conserving or reducing use of natural gas. Although it is possible that additional conservation may have some effect on the demand for natural gas, conservation efforts are not expected to significantly reduce the long-term requirements for natural gas or effectively exert downward pressures on gas prices.

Denying SES' applications could force potential natural gas customers to seek regulatory approval to use other forms of energy. California regulators are promoting renewable energy programs to help reduce the demand for fossil fuels. While renewable energy programs can contribute as an energy source for electricity, they cannot at this time reliably replace the need for natural gas or provide sufficient energy to keep pace with demand.

Alternatives involving the use of other existing or proposed LNG or natural gas facilities to meet the stated objectives of the proposed project were evaluated. None of the pipeline system alternatives could provide a stable source of LNG for vehicle fuel or the storage of up to 320,000 cubic meters of LNG to address fluctuating energy supply and demand (two of the three stated objectives of the Long Beach LNG Import Project). Several of the proposed LNG import systems (either offshore California or in Mexico) could provide a new source of natural gas to southern California markets; however, none of these system alternatives could meet the proposed project's stated objective of providing a stable source of LNG for vehicle fuel. Furthermore, each of the system alternatives could result in its own set of significant environmental impacts that could be greater than those associated with the proposed project.

Alternative sites for an LNG import terminal were evaluated. The examination of alternative sites for an LNG import terminal involved a comprehensive, step-wise process that considered environmental, engineering, economic, safety, and regulatory factors. The alternative sites evaluated for an LNG terminal were not found to avoid or substantially lessen any significant environmental effects of the proposed project and/or could not meet all or most of the project objectives.

An evaluation of alternative routes for the natural gas and C₂ pipelines was also conducted. The alternatives were not found to avoid or substantially lessen impacts associated with the corresponding segment of the proposed routes and/or were infeasible due to the number of existing utilities already in place along the alignments and the lack of adequate space to install the facilities.

Reduced dredge/fill alternatives and alternative ship berth configurations, dredge disposal alternatives, and alternative dredging methods were evaluated to avoid or minimize impacts on water quality or biological resources associated with the in-water work needed for construction of the LNG ship berth and unloading facility and strengthening the shoreline structures. None of these alternatives were

found to be feasible or would avoid or substantially lessen any significant environmental effects of the proposed project.

Vaporizer alternatives were also evaluated. The shell and tube vaporizer, which is the proposed vaporizer for the Long Beach LNG Import Project, was found to be efficient, readily able to be integrated with the NGL extraction system, and to utilize proven vaporizer technology. Shell and tube vaporizers are also the most compact LNG vaporizers available, an important consideration given the size of the LNG terminal site. New vaporization processes that primarily utilize air exchangers as a heat source were also evaluated because they would have lower fuel gas requirements than conventional combustion vaporizers. Reduced fuel use would lead to a corresponding reduction in air emissions and operating costs. The space requirements of these new vaporization processes, however, appear to make this approach technically infeasible at the proposed site.

ENVIRONMENTALLY PREFERABLE/SUPERIOR ALTERNATIVE

The Agency Staffs will recommend to their respective Commissions that SES' proposed project is the environmentally preferable/superior alternative that can meet the project objectives.

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