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September 9, 2013

Via Electronic Mail and U.S. Mail

Mr. James Belsky, Permit Chief
Mass DEP Northeast Region
205B Lowell Street
Wilmington, MA 01887

Re: Major Comprehensive Plan Application
Salem Harbor Redevelopment Project (Transmittal No. X254064)

Dear Mr. Belsky:

Enclosed for your records please find the report entitled "Health Risk Assessment ("HRA") for the Salem Harbor Redevelopment ("SHR") Project," dated January 10, 2013, prepared by Gradient (the "SHR Report"). The SHR Report was referenced in submittals of additional information previously sent to you from TetraTech.

Sincerely,

Lauren A. Liss

LAL/dm
Enclosure

cc: Mr. Scott Silverstein
Mr. Keith Kennedy
John A. DeTore, Esq.

Footprint Power Salem Harbor
Development LP
EFSB 12-2
Information Request EFSB Set 1
Attachment EFSB-H-3-1

Health Risk Assessment (HRA) for the Salem Harbor Redevelopment (SHR) Project

Prepared for
Tetra Tech, Inc. / Energy Program
160 Federal Street, Suite 300
Boston, MA 02110

January 10, 2013

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Abbreviations

AAL	Allowable Ambient Limits
AEGL	Acute Exposure Guideline Levels
ATSDR	Agency for Toxic Substances and Disease Registry
CALEPA	California Environmental Protection Agency
CDC	Centers for Disease Control and Prevention
CHNA	Community Health Network Area
CO	Carbon monoxide
CO_2	Carbon dioxide
CPA	Comprehensive Plan Approval
DEIR	Draft Environmental Impact Report
ELCR	Excess Lifetime Cancer Risk
EPC	Exposure Point Concentration
ERPG	Emergency Response Planning Guideline
HI	Hazard Index
HQ	Hazard Quotient
HRA	Health Risk Assessment
IRIS	Integrated Risk Information System
LOAEL	Lowest-observed-adverse-effect-level
MassCHIP	Massachusetts Community Health Information Profile
MADEP	Massachusetts Department of Environmental Protection
MADPH	Massachusetts Department of Public Health
NAAQS	National Ambient Air Quality Standards
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NOAEL	No-observed-adverse-effect-level
OAQPS	US EPA's Office of Air Quality Planning and Standards
OSW	US EPA's Office of Solid Waste
PCAP	Projected Controlled Access Perimeter
PM	Particulate matter
$PM_{2.5}$	Particles less than 2.5 micrometers in diameter
PM_{10}	Particles less than 10 micrometers in diameter
REL	Reference Exposure Level
RfC	Reference Concentration
SCR	Selective Catalytic Reduction
SHGS	Salem Harbor Generating Station
SHR	Salem Harbor Redevelopment, "SHR Project" refers to the Footprint Project in Salem, MA
SIL	Significant impact level
SIR	Standardized incidence ratio
SO_2	Sulfur dioxide
TEL	Threshold Effects Exposure Limit
UF	Uncertainty Factor
US EPA	United States Environmental Protection Agency
VOC	Volatile organic compound

Executive Summary

The proposed Salem Harbor Redevelopment (SHR) Project will involve construction and operation of a new state-of-the-art combined cycle natural gas-fired electric generation facility in Salem, Massachusetts. Detailed descriptions and specifications for the proposed SHR Project are described in several reports and regulatory filings. In particular, Footprint Power Salem Harbor Development LP has filed a Petition with the Energy Facilities Siting Board (EFSB) (Footprint, 2012). In addition, on behalf of Footprint Power Salem Harbor Development LP, Tetra Tech has submitted both a draft environmental impact report (DEIR) and a comprehensive plan approval (CPA) application for the proposed SHR Project (Tetra Tech, 2012a, 2012b).

As described most recently in the DEIR (Tetra Tech, 2012a) and the CPA application (Tetra Tech, 2012b), Tetra Tech conducted air dispersion modeling of pollutant emissions from the project's main stack, predicting short-term and annual average impacts for United States Environmental Protection Agency (US EPA) criteria air pollutants (*e.g.*, $PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, and lead)[1] and for 24 air toxics. Tetra Tech then compared its maximum modeled SHR Project air impacts to health-protective ambient air quality standards (*e.g.*, the US EPA National Ambient Air Quality Standards [NAAQS]) and air toxics guidelines (*e.g.*, the Massachusetts Department of Environmental Protection [MADEP] annual Allowable Ambient Limits [AALs] and 24-hour Threshold Effects Exposure Limits [TELs]) to assess the potential for health impacts from SHR Project air emissions.

In order to support and confirm Tetra Tech's air quality impacts analysis, Gradient has prepared this human health risk assessment evaluating the likelihood of both acute non-cancer health risks and chronic non-cancer and cancer health risks that may result from people's inhalation of airborne pollutants as predicted by Tetra Tech for SHR Project stack air emissions. Gradient also assessed the health implications of maximum hourly ammonia air concentrations predicted by Tetra Tech for a worst-case aqueous ammonia accidental release scenario. Finally, Gradient collected relevant background health information for Salem and surrounding communities to determine if any types of disease (*e.g.*, cancer and asthma) were higher than expected compared to Massachusetts as a whole.

Overall, our health risk assessment for the SHR Project indicates that maximum predicted air levels of specific substances associated with SHR Project air emissions would not be expected to contribute to adverse health effects among potentially affected populations. Several separate lines of evidence from our health-risk analysis support our conclusion that the potential air emissions from the SHR Project are not expected to have an adverse effect on public health in the Salem area:

1. The maximum cumulative air concentrations (project impact plus existing background) of the criteria pollutants of concern, which include SO_2, CO, NO_2, and PM, are well below the health-protective NAAQS. Stack emissions of criteria air pollutants are thus not expected to lead to impacts on human health (*e.g.*, asthma, cardiovascular and respiratory diseases) in nearby communities, even in sensitive populations.
2. The maximum modeled ground-level concentrations of non-criteria air pollutants are well below both the MADEP 24-hour TELs and the annual-average AALs, indicating that these concentrations are not expected to cause adverse health effects, even in sensitive populations.

[1] PM = particulate matter (less than 2.5 µm in size [$PM_{2.5}$]; less than 10 µm in size [PM_{10}]); NO_2 = nitrogen dioxide; SO_2 = sulfur dioxide; CO = carbon monoxide

3. As a matter of perspective with regard to SHR Project air toxics emissions, measurements from the Lynn and Boston air toxics monitors show that maximum modeled SHR Project impacts for metals are between about 2-fold to >350-fold below measured background levels, while for VOCs, maximum SHR Project impacts are between 276-fold and >1,500-fold below measured background levels (Table 2.4).

4. Our quantitative health risk assessment (HRA) showed that, for possible non-cancer effects, all hazard quotients (HQs), calculated for an off-site resident exposed to maximum modeled incremental SHR Project stack impacts, were well below unity (HQ = 1), with none being higher than HQ = 0.01. The overall summed HI for SHR Project stack emissions is also well below 1.0, *i.e.*, HI = 0.08. These results help assure that non-cancer, adverse health effects are not to be expected from the non-criteria air-pollutant emissions.

5. Our quantitative HRA showed that conservatively projected cancer risks for maximum modeled SHR Project stack impacts of possible carcinogenic chemicals were well below the 1 in 10,000 to 1 in 1,000,000 lifetime risk range, which is considered to be acceptably low by US EPA. The overall summed cancer risk from the Project was about 1 in 10,000,000 over a lifetime, which is well below the US EPA *de minimis* risk level. The individual pollutant cancer risks were each even lower than the *de minimis* level, between about 1 in 10,000,000,000 and about 4 in 100,000,000. These results support *de minimis* cancer risk from worst-case chronic exposures to maximum modeled SHR Project stack impacts.

6. Based on the air-modeling data available, short-term SHR air emissions impacts are not expected to give rise to acute health effects. We compared SHR Project-related maximum short-term concentrations of SO_2 and NO_2 to short-term exposure guidelines and standards, including the short-term NAAQS for SO_2 and NO_2 which were specifically designed to protect against asthma exacerbation and respiratory irritation. Our comparisons show that the cumulative impacts (maximum 1-hour + ambient background) for NO_2 and SO_2 are well below the 1-hour health-protective NAAQS as well as other short-term exposure guideline levels.

7. Based on the results of an air modeling analysis performed by Tetra Tech for a worst-case accidental release scenario, storage plans for aqueous ammonia at the proposed site adequately mitigate potential human health impacts of an accidental ammonia release.

8. Our review of community health data for Salem and nearby communities has indicated that the Salem area has overall similar rates of asthma, cardiovascular conditions, and cancer compared with the state as a whole. In combination with the results of the HRA, we conclude that air emissions from operation of the proposed SHR Project are not expected to significantly alter any of these baseline health statistics.

1 Introduction

1.1 Salem Harbor Redevelopment (SHR) Project Description

As described in both a draft environmental impact report (DEIR) and a comprehensive plan approval (CPA) application (Tetra Tech, 2012a, 2012b), the proposed Salem Harbor Redevelopment (SHR) Project involves construction and operation of a new state-of-the-art combined cycle natural gas-fired electric generation facility and related structures and infrastructure on a +/- 20-acre portion of the +/- 65-acre Salem Harbor Generating Station site. The facility will be a 630 MW nominal natural gas-fired electric generation facility with "quick start" capability. During the summer, the facility will be capable of generating an additional 62 MW, for a total of 692 MW. SHR Project components include two quick-start natural gas turbine generators, two steam turbine generators, two heat recovery steam generators with pollution control equipment, administrative/warehouse/shops space, a water treatment facility, electric power step-up transformers, an ammonia storage tank, two to three water tanks, two air-cooled condensers, and other accessory structures.

Briefly (see Tetra Tech, 2012a, 2012b, for additional details), the SHR Project will utilize clean burning natural gas in dry low-nitrogen oxide (NO_x) turbine combustors, in combination with selective catalytic reduction (SCR) technology to reduce NO_x emissions from the turbine generator units. Advanced combustor design and good combustion practices will be used to reduce carbon monoxide (CO) and volatile organic compound (VOC) emissions. A catalytic oxidation system will reduce CO emissions and also provide some reduction of VOCs.

1.2 Tetra Tech's Air Dispersion Modeling Analysis of SHR Project Stack Emissions

The DEIR describes the air dispersion modeling that was conducted for pollutant emissions from the project's stacks, predicting short-term and annual average impacts for United States Environmental Protection Agency (US EPA) criteria air pollutants (*e.g.*, $PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, and lead)[2], and for 24 air toxics (Tetra Tech, 2012a). In its air quality modeling and impact analysis, Tetra Tech compared maximum modeled SHR Project air impacts to health-protective ambient air quality standards (*e.g.*, the US EPA National Ambient Air Quality Standards (NAAQS) and air toxics guidelines (*e.g.*, the Massachusetts Department of Environmental Protection [MADEP] Allowable Ambient Limits [AALs] and 24-hour Threshold Effects Exposure Limits [TELs]) to assess the potential health impacts of SHR Project air emissions. Both the US EPA NAAQS and MADEP ambient air limits are intended to be protective of adverse health effects among members of the general population, including potentially susceptible individuals. Isopleth maps of the maximum modeled air concentrations indicate that, in some cases and for certain pollutants and averaging times, the highest air concentration impacts are expected over water, in Salem Harbor or the open ocean, rather than in populated areas of Salem or neighboring communities. For example, the maximum modeled concentration for 1-hour NO_2 is expected in the harbor. In addition, while the highest predicted concentration of annual $PM_{2.5}$ is expected over land, there are other upper-range $PM_{2.5}$ impacts predicted to occur only over the ocean.

[2] PM = particulate matter (less than 2.5 μm in size [$PM_{2.5}$]; less than 10 μm in size [PM_{10}]); NO_2 = nitrogen dioxide; SO_2 = sulfur dioxide; CO = carbon monoxide.

To evaluate potential public health impacts from the SHR Project criteria air pollutant emissions, we relied on an approach that compared maximum modeled cumulative concentrations to the health-based NAAQS. For non-criteria air pollutants (*i.e.*, air toxics), we conducted an inhalation risk assessment to predict the likelihood of chronic non-cancer and cancer health risks. These risk assessment calculations supplement, rather than replace, Tetra Tech's comparison of their air modeling results to the MADEP ambient air toxic guidelines. Because of the health-protective nature of the AALs and TELs,[3] comparison to these limits is an appropriate methodology for determining whether there is a potential risk to public health due to stack emissions of air toxics from the SHR Project. As such, we have verified the Tetra Tech analysis of air toxics, which is reproduced in Table 1.1 below. AALs and TELs were obtained from MADEP (1995). The results of the Tetra Tech analyses for both criteria air pollutants and air toxics are discussed in more detail in Sections 2.1 and 2.2.

Table 1.1 Comparison of Maximum Modeled Ambient Air Impacts of Air Toxics from SHR Project Stack Emissions to MADEP Air Pollutant Guidelines

Pollutant	Project 24-hour Impacts *vs.* TEL		Project Annual Impacts *vs.* AAL		Impact as % of MADEP Criterion	
	Modeled Impact (µg/m^3)	MADEP TEL (µg/m^3)	Modeled Impact (µg/m^3)	MADEP AAL (µg/m^3)	24-hr (%)	Annual (%)
Arsenic	0.000048	0.003	0.000005	0.0003	1.590	1.656
Chromium (tot.)	0.001320	1.36	0.000039	0.68	0.097	0.006
Chromium (VI)	0.000238	0.003	0.000007	0.0001	7.941	7.039
Copper	0.00018	0.54	0.00002	0.54	0.034	0.004
Lead	0.00017	0.14	0.000012	0.07	0.122	0.018
Nickel	0.00058	0.27	0.00005	0.18	0.216	0.029
Cadmium	0.000242	0.003	0.000027	0.001	8.069	2.724
Mercury	0.00006	0.14	0.000006	0.07	0.040	0.009
Beryllium	0.000003	0.001	0.0000003	0.0004	0.264	0.074
Selenium	0.00003	0.54	0.0000007	0.54	0.005	0.0001
Vanadium	0.00051	0.27	0.00006	0.27	0.187	0.021
Formaldehyde	0.215064	2.0	0.006429	0.8	10.75	0.804
Acetaldehyde	0.048926	2	0.000678	0.5	2.446	0.136
1,3-Butadiene	0.001761	1.2	0.000015	0.003	0.147	0.488
Benzene	0.075227	1.74	0.000514	0.12	4.323	0.428
Naphthalene	0.009474	14.25	0.000067	14.25	0.066	0.0005
Sulfuric Acid	0.458684	2.72	0.015315	2.72	16.863	0.563
Ethylbenzene	0.013521	300	0.000394	300	0.005	0.0001
Propylene oxide	0.315089	6	0.001661	0.3	5.251	0.554
p-Dichlorobenzene	0.000264	122.61	0.000030	0.18	0.0002	0.017
o-Dichlorobenzene	0.000264	81.74	0.000030	81.74	0.0003	0.00004
Toluene	0.083765	80	0.001812	20	0.105	0.009
Xylenes	0.046515	11.80	0.000878	11.80	0.394	0.007
Ammonia	1.140820	100	0.033211	100	1.141	0.033

[3] As stated by MADEP (MADEP, 1990), both the TELs and AALs are intended to be protective of adverse health effects among members of the general population, including potentially susceptible individuals. For example, MADEP (http://www.mass.gov/dep/air/community/qatox.pdf) states that the AALs "are based on potential known or suspected carcinogenic and toxic health properties of individual compounds. Safety factors are incorporated into the AALs to protect sensitive people and children, and to account for other exposure pathways, like food, soil, and water. For cancer risk, AALs denote the concentration of a carcinogen associated with a one in a million excess cancer risk over a lifetime of exposure. For non-cancer benchmarks, the concentration represents the value likely to present no appreciable risk of adverse noncancer effects with long-term continuous inhalation."

Table 1.1 shows that maximum modeled air quality impacts from the SHR Project stack air toxics emissions are well below both the 24-hour TELs and annual-average AALs, indicating an absence of potential public health risk from SHR Project stack emissions of non-criteria air pollutants. Importantly, safety factors are incorporated into the TELs and AALs to protect sensitive people and children, and to account for other exposure pathways. In order to further verify that the SHR Project emissions would not increase non-cancer and cancer risks to the area population, as described in Section 2.2 below, Gradient calculated Hazard Quotients (HQs) and Excess Lifetime Cancer Risks (ELCRs) to quantify non-cancer and cancer health risks, respectively.

In Table 1.1, and throughout this HRA, the SHR Project contributions to air concentrations in nearby communities are given in units of micrograms per cubic meter ($\mu g/m^3$). It is helpful to consider the size of this measurement unit and appreciate that a microgram represents an extremely tiny concentration. A cubic meter of air ($1\ m^3$) is a volume of about a yard by a yard by a yard, and the air in this volume weighs 1.2 kg or 1,200 grams (about 2⅔ pounds). A gram is about 1/28th of an ounce (*i.e.*, about 28 grams in an ounce), and a microgram is one-millionth of a gram, or one-billionth of a kilogram. Thus, a concentration of 1 $\mu g/m^3$ corresponds to a weight of a substance floating in the air that is about one-billionth of the weight of the air surrounding it. A concentration of 1 part in one billion (ppb) is a very tiny amount of material, because one ppb is like the weight of a single (6") human hair (0.0001 oz.) relative to the weight of a 3-ton SUV (100,000 oz.), or the lapse of one second in a time span of 32 years. Since there are about 310 million people in the US, finding an impurity present at the level of 1 ppb would be more difficult than finding one single specific individual among the population of 310 million people. That is, at 1 ppb you would have to examine about 999,999,999 chunks of clean air before you could be assured of finding the one piece of particulate at the 1 ppb concentration level. Another helpful comparison might be that of carbon dioxide (CO_2), which is a trace-gas constituent of the outside air, and which we all breathe in at a ambient concentration of 714,000 $\mu g/m^3$. In comparison, typical background annual-average levels of airborne particulate ("$PM_{2.5}$") in the Lynn area are about 7.3 $\mu g/m^3$ (See Table 2.1, below).

1.3 HRA Organization

Our HRA includes three key components, namely an evaluation of the potential for human health risks of SHR Project stack air quality impacts (Section 2), an assessment of potential health risks for an ammonia accidental release scenario (Section 3), and an evaluation of baseline health status in the Salem area (Section 4). Importantly, our evaluation of potential human health risks of SHR Project stack air quality impacts contains multiple components, including:

- a public health evaluation of SHR Project criteria air pollutant stack emissions (Section 2.1);
- an assessment of chronic inhalation non-cancer and cancer health risks from SHR Project air toxics stack emissions (Section 2.2); and
- an acute (short-term) exposure evaluation for respiratory irritants (Section 2.3).

For each of these human health risk assessment components, we made determinations regarding the acceptability of the SHR Project impacts by relying upon two standard types of acceptability criteria, namely: 1) comparison with health-based benchmarks (*e.g.*, the primary NAAQS, the US EPA regulatory lifetime-cancer-risk range of 10^{-6} to 10^{-4}, HQ calculation, *etc.*), and 2) the comparison of incremental SHR Project impacts with ubiquitous, background levels of these pollutants in ambient air. Implicit in our determinations is the fundamental toxicology principle that, although elevated doses of any compound can be harmful, sufficiently low, yet non-zero levels of exposure can be considered innocuous and protective of public health, or of sufficiently low risk so as to be acceptable.

The societal acceptability of a non-zero level of risk is consistent with the fact that risk to health and life accompanies all parts of our everyday existence. To live and breathe is to be at risk for disease, injury, and death. Whatever we do, or fail to do, we encounter risk. A short drive to the grocery store entails some risk. Walking or bicycling the same distance is likely to pose an even greater risk. You may jog or exercise to improve your health, but these activities may also endanger it in unanticipated ways. Most accidental injuries and deaths occur in our homes. All of our activities entail risk, and when we act to eliminate or reduce one risk, we likely increase or create another risk. Most of the risks we face are (or seem) very small, and when we are asked to make judgments about how to avoid risks by changing our behavior, expending effort, or spending our money, we must ask ourselves whether our actions are reducing our overall risk. Would the time, effort, and expense be better spent on addressing some other potential danger? Health risk assessment is a quantitative process that helps answer this question.

Health risk assessment is a formalized, quantitative process whereby one can numerically estimate the probability of whether certain exposure levels to specific "chemicals of concern" might lead to an adverse health outcome, such as cancer. As noted by the Presidential/Congressional Commission on Risk Assessment and Risk Management, risk assessment relies on scientific observations regarding the relationship between exposure and effects, as well as inferences and assumptions, in order to determine what levels of exposure carry acceptable risks (CRARM, 1997). For cancer, the result of a risk assessment is an upper bound estimate on the probability of getting cancer, given the concentrations measured or estimated to be present, the toxicity of the chemicals, and the degree of exposure assumed, often accompanied by a description of the uncertainty in the overall assessment and in each of its components (US EPA, 1995, 2000a). While uncertainty is inherent in a risk assessment, conservative assumptions are common in risk assessment, *i.e.*, assumptions are made so that calculated risks represent overestimates of potential risks. Given such assumptions, and their associated safety factors, it should be recognized that calculated risks are upper-bound and hypothetical in nature. Hypothetical risks are risks that are not known to actually occur, but which are estimated from assumptions regarding exposure and toxicity. Known risks, sometimes referred to as "actuarial risks," have known probabilities based on actual data (*e.g.*, deaths, accident rates, hospitalizations, ER visits).

In order to put calculated hypothetical health risks from ambient or project-specific pollutant exposures into perspective, it is helpful to consider how these risks compare to overall health risks faced by the general public. Of the U.S. population (nearly 315 million people[4]), about 2.4 million people die every year (CDC, 2010). Of the annual U.S. deaths:

- heart and vascular disease are responsible for about one third of all deaths, and
- cancer deaths are responsible for about one quarter.

Thus, for the population generally, our lifetime risk of dying from cardiovascular disease is about 1 in 3, and for dying from cancer is about 1 in 4. These proportions of deaths from cardiovascular disease and cancer are roughly stable over time and from place to place in the U.S. Only a proportion of the individuals developing cancer die of the disease. In the U.S., the baseline chances of developing invasive cancer (cancer incidence) sometime during one's life are as follows:

- 45% for men, and

[4] http://www.census.gov/population/www/popclockus.html

- 38% for women (Siegel *et al.*, 2012)

or, 41.5% as an average for both sexes, which can be expressed as a lifetime odds of 1 in 2.4. By comparison, the upper limit of US EPA's acceptable lifetime cancer risk range is 1 in 10,000, about 4,200-fold lower than baseline for all of us. As we describe in Section 2.2, hypothetical lifetime excess cancer risks associated with maximum modeled SHR Project impacts are several orders of magnitude smaller than even US EPA's range, – *i.e.*, in the range of about 1 in 10,000,000,000 to 4 in 100,000,000.

For estimating the likelihood of non-cancer effects from intake of chemicals, exposure concentrations are compared to so-called reference concentrations (RfCs). For example, chronic RfCs are concentrations set low enough (through the use of uncertainty factors [UFs] and margins of safety), such that lifetime exposure is not anticipated to result in any adverse health effect, even for sensitive subpopulations such as children, the elderly, or individuals with pre-existing disease. It is important to keep in mind that RfCs are set to levels many-fold lower than those levels of exposure which have actually been demonstrated to have a potentially adverse health effect.

2 Human Health Risk Evaluation of SHR Project Stack Air Emissions

2.1 Evaluation of SHR Project Stack Criteria Air Pollutant Emissions

Elevated levels of common ambient air pollutants, such as PM, NO_2, SO_2, have been statistically linked with increased risk of cardiorespiratory health outcomes, including asthma symptoms, emergency room visits and hospital admissions for respiratory illnesses, and premature mortality. To address potential health concerns from these and other common ambient air pollutants (termed criteria air pollutants, and including PM, NO_2, SO_2, CO, ozone, and lead), the Clean Air Act directs US EPA to develop NAAQS that "accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in the ambient air" (US Congress, 1970, as cited in US EPA, 2011a).

Compliance with the primary NAAQS is designed to assure, with an adequate margin of safety, a lack of significant public health risks. Because the primary NAAQS are solely health-based, they are not adjusted for factors such as technological feasibility, or costs and benefits. By incorporation of a margin of safety, the NAAQS are set to address both uncertainties in the state of the science and the possibility of additional harms that might be identified in the future. Furthermore, the NAAQS are intended to be protective of the health of sensitive subpopulations, such as people with pre-existing disease (*e.g.*, cardiovascular diseases or asthma), children, and the elderly. Similarly, the NAAQS are established to be protective of both short-term health effects and long-term health effects by defining the averaging time for the standards. These averaging times vary from 1 hour to 1 year, with the 1-hour standards intended to be protective of potential short-term effects, and the annual average standards intended to be protective of potential long-term health effects. In Section 2.3, we focus on potential health impacts of short-term (acute) NO_2 and SO_2 exposures.

The NAAQS reflect the current understanding of the health effects literature because the Clean Air Act requires US EPA to periodically review and, if appropriate, revise existing criteria and standards every five years. The NAAQS review process is extensive and involves various US EPA offices as well as the external scientific community, various stakeholder groups, and the public. In particular, the Clean Air Scientific Advisory Committee (CASAC) – a congressionally mandated independent panel of non-government scientists and technical experts selected from the medical, academic, and research communities – plays a key role in reviewing the current status of health effects research and recommending whether revisions to criteria and standards are necessary. Although the NAAQS are periodically reviewed and updated, this does not mean that prior NAAQS were not health protective. Instead, changes in standards such as the NAAQS may reflect increased margins of safety rather than an increased expectation of serious, adverse health effects. Judgments on what constitutes an adequate margin of safety can change as the state of the science evolves and the understanding and manner of dealing with uncertainties changes. For example, as part of the recent review of the PM standards, US EPA broadened its health analyses to address developmental effects and susceptible populations such as people with lower socioeconomic status (US EPA, 2011a).

For our HRA, Gradient compared the cumulative impacts (maximum modeled SHR project-related concentrations plus monitored background levels) of the criteria air pollutants with the current health-protective NAAQS to assess the likelihood of potential health effects associated with SHR Project criteria air pollutant stack emissions. The results, as shown in Table 2.1, indicate that cumulative impacts are well below the health-protective NAAQS for the criteria air pollutants that will be emitted by the proposed SHR Project. In fact, the maximum modeled SHR Project concentrations are generally a small fraction of background concentrations. Therefore, emissions of criteria air pollutants from the SHR Project stack emissions are expected to have no significant impacts on human health risks, including on local community rates of cardiovascular and respiratory diseases.

Table 2.1 Criteria Air Pollutant Levels, Both Maximum Modeled Project-Specific Impacts and Cumulative Impacts, Compared to the US EPA NAAQS

Pollutant	Averaging Period	Maximum Modeled [a] (μg/m³)	Monitored Background [b] (μg/m³)	Cumulative Impact [c] (μg/m³)	NAAQS (μg/m³)
SO_2	1-hr	1.1	57.6	58.7	195
	3-hr (secondary)	1.2	60.3	61.5	1300
	24-hr	0.7	31.4	32.1	none [d]
	Annual	0.04	5.6	5.64	none [d]
CO	1-hr	439	1030	1469	40,000
	8-hr	213	687	900	10,000
NO_2 [e]	1-hr	44.3	82.3	126.6	188
	Annual	0.6	19.3	19.9	100
PM_{10}	24-hr	5.4	35	40.4	150
$PM_{2.5}$	24-hr	4.4	19.2	23.6	35
	Annual	0.5	7.3	7.8	12 [f]
Lead	Rolling 3 mo.	<0.00017	NR	NA	0.15
	Quarterly	NA	0.01	NA	NA

Notes:

NO_2 = nitrogen dioxide, PM_{10} = particulate matter <10 micrometers, $PM_{2.5}$=particulate matter <2.5 micrometers, NR = not reported, NA = not applicable, SIL = significant impact level.

(a) Maximum modeled SHR Project concentrations as reported in Table 6-9 of the Comprehensive Plan Approval Application (Tetra Tech, 2012b). As explained in Tetra Tech (2012b), these maximum facility impact concentrations used for the determination of significant impact areas are based on the 5-year average of the 1st highest values occurring in each year for 24-hour and annual $PM_{2.5}$ concentrations and 1-hour SO_2 and NO_2 concentrations, while the concentrations for the other pollutants and averaging periods are based on the maximum predicted concentrations over 5 years of meteorological data.

(b) Background concentrations as reported in Tables 2-1 and 6-5 of the Draft Environmental Impact Report (Tetra Tech, 2012a). As discussed in Tetra Tech (2012a), background concentrations are based on 2009-2011 measurements; CO, NO_2, and $PM_{2.5}$ background concentrations are for measurements from the closest state and local ambient air monitor in Lynn (about 5.9 miles southwest of the site), while SO_2, PM_{10}, and lead are for measurements from the ambient air monitor on Harrison Avenue in Boston (about 17 miles southwest of the site) due to the absence of data for these pollutants at the closer Lynn monitor. For shorter-term averaging times, background concentrations are generally the maximum second highest value over the three years, or in the case of $PM_{2.5}$, 1-hr NO_2, and 1-hour SO_2, the average of the 98th or 99th (for SO_2) percentile values. For longer-term averaging times, background concentrations are the maximum in any averaging period over the three years, except for $PM_{2.5}$, which is based on the average.

(c) Maximum modeled SHR Project concentrations plus monitored background levels.

(d) Revoked by US EPA in 2010 (US EPA, 2010a).

(e) For 1-hr NO_2, a cumulative impact assessment that considered other regional sources of this NAAQS pollutant was also conducted by Tetra Tech for 5-year averages of the 8th highest daily maximum concentrations occurring in each year (Tetra Tech, 2012a, 2012b). When the impacts of two MADEP-provided interacting sources were combined with the SHR Project impacts (for a total of 102.6 μg/m³ of which 7.9 μg/m³ was attributable to the SHR Project), the total project plus background level was reported as 184.9 μg/m³ (Tetra Tech, 2012a, 2012b).

(f) The new $PM_{2.5}$ annual average NAAQS was recently (on Dec. 14, 2012) revised downward to 12 μg/m^3. The previous value (1997-2012) was 15 μg/m^3.

Table 2.1 uses maximum modeled SHR Project-related concentrations that represent the highest predicted airborne exposure concentration increments to criteria air pollutants for a single location, including in some cases locations that are within the harbor and/or over the ocean. As such, they would not be representative of the time- and spatially-averaged exposures that would be anticipated as an individual moves among different locations (*e.g.*, home, workplace, stores, *etc.*) within a community. As the first step in assessment of the impact of SHR Project stack air emissions, Tetra Tech (2012a) used air dispersion modeling to estimate criteria air pollutant concentrations and compared project maximum predicted impact concentrations to their respective significant impact levels (SILs) that have been adopted by US EPA and MADEP. SHR Project maximum predicted impact concentrations were below the SILs for all criteria air pollutants and averaging periods with the exception of 24-hr PM_{10}, 24 hour and annual $PM_{2.5}$, and 1-hr NO_2. For these three criteria air pollutants, Tetra Tech conducted an additional NAAQS compliance assessment that considered SHR Project maximum predicted impact concentrations plus ambient background representing contributions from other air pollutant sources.

We note that several NAAQS have been revised to more stringent levels in recent years. In particular, US EPA completed its review of the NO_2 and SO_2 NAAQS about two years ago, adding 1-hour NAAQS for both pollutants (US EPA, 2010a, 2010b). Most recently, US EPA (2012a) completed its review of the PM NAAQS, issuing a final rule on December 14 that changed the $PM_{2.5}$ annual NAAQS from 15 μg/m^3 to a level of 12 μg/m^3. US EPA decided to retain the 24-hour $PM_{2.5}$ standard of 35 μg/m^3 without any change. These recommendations are based on epidemiological studies that have reported associations between health effects (including cardiovascular disease effects) and PM levels below the prior annual $PM_{2.5}$ NAAQS of 15 μg/m^3. US EPA also retained the 24-hour PM_{10} standard of 150 μg/m^3. As shown in Table 2.1, predicted cumulative impacts for maximum modeled SHR Project concentrations fall below the revised $PM_{2.5}$ NAAQS (and the 24-hour PM_{10} NAAQS) promulgated by US EPA.

To provide additional perspective regarding our conclusion that even the maximum modeled SHR Project impacts are expected to pose insignificant public health risks, it is important to note that, for all of us, exposure to criteria air pollutants comes from multiple sources, including primarily long-distance transport from upwind sources, local stationary sources and mobile sources (*e.g.*, from cars and buses), as well as from indoor sources (*e.g.*, at home or in an office). Because people spend a majority of their time in indoor environments, indoor sources of air pollutants are major contributors to daily exposures. Studies have shown that indoor concentrations of air pollutants are often greater than outdoor concentrations because pollutants from indoor sources can remain confined within the home over extended periods of time. Indoor sources of criteria air pollutants include cooking, natural gas combustion, home-heating combustion, candles, cleaning activities, and cigarette smoke. As shown in Table 2.2, cooking and cleaning activities can result in elevated short-term $PM_{2.5}$ impacts ranging from 10 to 100 μg/m^3 (Long *et al.*, 2000).

Table 2.2 Average Short-term Peak $PM_{2.5}$ Impacts During Various Cleaning, Cooking, and Other Activities in Boston Area Homes

Activity	$PM_{2.5}$ Concentration ($\mu g/m^3$)
Baking (electric)	15
Baking (gas)	101
Toasting	54
Broiling	29
Sautéing	66
Stir-frying	37
Frying	41
Dusting	23
Vacuuming	7
Cleaning with Pine Sol	11
Walking vigorously over carpet indoors	12
Burning candles	28

To help provide perspective on how exposures to the maximum modeled SHR Project impacts compare to everyday incremental (*i.e.*, on top of typical background) exposures associated with common voluntary activities, we calculated equivalent exposures to $PM_{2.5}$ and NO_2 for several typical everyday activities. These comparisons are presented in Table 2.3. The results show that the exposure that would be received from a full year of breathing ambient air with $PM_{2.5}$ and NO_2 concentrations at the levels of the maximum modeled SHR Project stack air emissions impacts is equivalent to short durations of everyday $PM_{2.5}$ and NO_2 exposures from common indoor and outdoor activities (*e.g.*, driving a car, mowing the lawn, cooking).

Table 2.3 Comparison of Equivalent Exposures to Criteria Air Pollutants for Everyday Activities Compared to Maximum Modeled Concentrations from the SHR Project Stack Air Emissions

Project-related Concentration	Type of Impact	Approximate Equivalent Exposure
$PM_{2.5}$ $\mu g/m^3$		
0.5	Maximum modeled annual impact	15 minutes per day in a car[a] 10 times per year lawn mowing for 30 minutes each time[b] 15 minutes per day in the kitchen while baking with a gas oven[c]
NO_2 $\mu g/m^3$		
0.6	Maximum modeled annual impact	17 minutes per week cooking with a gas stove and oven[d] 8 minutes of oven cleaning per week[d] 11 minutes per day in a car[a]

Notes:
(a) Average in-vehicle concentrations ($PM_{2.5}$ = 48 $\mu g/m^3$, NO_2 = 41.7 ppb) from Zhu *et al.* (2008) and Riediker *et al.* (2003), respectively.
(b) Average personal $PM_{2.5}$ exposure level (936 $\mu g/m^3$) for lawn mowing activities from Baldauf *et al.* (2006).
(c) Average whole-house $PM_{2.5}$ concentrations (50 $\mu g/m^3$) for cooking activities with a gas stove or gas oven from Wallace *et al.* (2004).
(d) Average NO_2 concentrations for cooking a full meal using gas (191 ppb) and for gas oven cleaning activities (403 ppb) from ARCADIS (2001).

In conclusion, the predicted maximum modeled impacts from SHR Project stack air emissions are not expected to contribute significantly to the ubiquitous background levels of criteria air pollutants we all experience. Importantly, the cumulative impacts (SHR Project impacts + background) are well below the health-protective NAAQS and are thus not expected present significant risk to the health of residents in the area, including people pre-existing with cardiovascular or respiratory disease. To provide additional perspective, we demonstrated in Table 2.3 that cumulative year-long exposures to maximum modeled SHR Project $PM_{2.5}$ and NO_2 impacts are equivalent to those doses received from short durations of everyday common activities.

2.2 Chronic Non-cancer and Cancer Health Risks from SHR Project Stack Air Toxics Emissions

To assess the potential for adverse health effects from SHR Project stack air toxics emissions, we calculated chronic inhalation non-cancer and cancer health risks associated with maximum modeled SHR Project stack impacts in accordance with standard risk assessment protocols, including guidelines provided in the US EPA Risk Assessment Guidance for Superfund (RAGS) Part F, Supplemental Guidance for Inhalation Risk Assessment (US EPA, 2009a). These chronic risk calculations are intended to supplement the Tetra Tech comparisons of maximum modeled annual average SHR Project impacts with the MADEP AALs, which are themselves health-based ambient air standards intended to be protective of both threshold and non-threshold effects from long-term (annual) exposures. Based on the finding that no SHR Project maximal impacts were above AALs, with most being two or more orders of magnitude less than the corresponding AAL, the Tetra Tech analysis provided evidence that SHR Project stack emissions would not be expected to lead to non-cancer or cancer health effects for residents in nearby neighborhoods.

We estimated HQs and ELCRs to further assess the likelihood of potential non-cancer and cancer health effects, respectively, among individuals with hypothetical maximum chronic inhalation exposures to project emissions. The HQ expresses the result of dividing the project-predicted maximum concentration by a health-protective concentration to which a continuous exposure over a lifetime would not be expected to harm health. Importantly, these risk calculations utilize alternative health-based benchmarks for non-cancer and cancer endpoints other than the Massachusetts AALs. Specifically, we relied upon chronic dose-response values recommended for use in inhalation risk assessments of HAPs available from the US EPA Office of Air Quality Planning and Standards (OAQPS).[5] As stated on the OAQPS Air Toxics Website (US EPA, 2012b), OAQPS developed a priority scheme for selecting the recommended chronic dose-response values, with US EPA RfCs and Unit Risks (URs) from US EPA's Integrated Risk Information System (IRIS) being the preferred values for assessing non-cancer and cancer health outcomes, respectively. As defined by US EPA, an RfC is "an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (US EPA, 2012c). US EPA defines a UR as "the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/L in water, or 1 $\mu g/m^3$ in air." With inhalation URs being upper bound values, US EPA acknowledges that actual cancer risk is likely to be lower, and could be as low as zero, in particular for the numerous air toxics (*e.g.*, acetaldehyde, ethylbenzene, naphthalene) included in the cancer risk assessment based on their classification as probable carcinogens, but which lack sufficient data to establish them as proven human carcinogens (US EPA, 2012d).

For substances lacking current IRIS assessments, OAQPS selected alternative dose-response values from the following sources (in ranked order of preference): 1) Agency for Toxic Substances and Disease Registry (ATSDR) chronic inhalation Minimal Risk Levels (MRLs)[6] (ATSDR, 2012; available only for noncancer effects); 2) California EPA (CalOEHHA, 2012) Chronic Reference Exposure Levels (RELs)[7]

[5] http://www.epa.gov/ttn/atw/toxsource/table1.pdf.
[6] http://www.atsdr.cdc.gov/mrls/index.html.
[7] http://www.oehha.org/air/allrels.html.

and URs;[8] and 3) toxicity factors from the US EPA Health Effects Assessment Summary Tables (US EPA, 1997).[9] No toxicity factors were available for two compounds (copper and total chromium) although neither is expected to contribute significantly to non-cancer health risks due to either the very low predicted concentrations (total chromium) or their low inhalation toxicity (copper). Appendix A summarizes the toxicity factors that were used in our risk calculations. Furthermore, we were able to calculate HQs and ECLRs for chromium IV, which is the form of chromium associated with potential cancer risk (US EPA, 2000b).

In general, each of the dose-response values used in our risk assessment was developed by US EPA or other regulatory agencies (*e.g.*, CalEPA, ATSDR) following a comprehensive process that considered the weight of the toxicological evidence and that typically utilized multiple safety and UFs. For example, in deriving RfCs from Lowest-Observed-Adverse-Effect-Levels (LOAELs) and/or No-Observed-Adverse-Effect-Levels (NOAELs) from either human epidemiology or laboratory animal toxicology studies, US EPA typically divides these concentrations by multiple UFs to account for potential uncertainties (including inter- and intra-species differences in sensitivity, insufficient study durations, use of a LOAEL instead of a NOAEL, and data deficiencies) to arrive at a final RfC. Such health-based benchmarks are set low enough to assure safety, rather than to represent a threshold above which an adverse effect might be expected. That is, the levels are derived to over predict rather than under predict potential health effects and are thus considered to contribute to the "conservative" (*i.e.*, health-protective) nature of the risk assessment process.

Consistent with US EPA inhalation risk assessment guidance (US EPA, 2009a), we calculated time-adjusted exposure concentrations as follows:

$$\text{Time-adjusted exposure} = \frac{(EPC*ET*EF*ED)}{AT}$$

Where:

EPC	=	Exposure point concentration (Tetra Tech annual-average maximum modeled SHR Project impacts, $\mu g/m^3$)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
AT	=	Averaging time (hours)

For non-cancer risks, the averaging time (or total period of interest) is equivalent to the exposure duration. For cancer risks, the standard averaging time is a lifetime, or 613,200 hours to represent a 70-year lifetime.

Table 2.4 summarizes the Tetra Tech maximum modeled annual average air modeling predictions for SHR Project stack air emissions at a variety of locations (receptors) selected to reflect the topographical features in the Salem area surrounding the site. We used these maximum concentrations as the exposure point concentrations (EPCs) in our inhalation risk calculations. These values were provided by Tetra Tech based on its air dispersion modeling analysis in the DEIR (Tetra Tech, 2012a). Table 2.4 also contains estimates of existing background concentrations for a limited subset of air toxics measured at the

[8] http://www.oehha.ca.gov/air/hot_spots/pdf/CPFs042909.pdf.
[9] http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2877.

air toxics monitor at the water treatment plant in Lynn, MA (approximately 7 miles from the proposed SHR Project site) and Harrison Avenue in Boston (approximately 18 miles from the proposed SHR Project site). Measured background levels of pollutants in Boston are between 1.7 times (mercury) and 386 times (selenium) higher than maximal SHR Project impacts. All measured background concentrations of VOCs in Lynn were higher than the annual average SHR Project impact; background concentrations were from 276 times (ethylbenzene) to 1,623 times (1,3-butadiene) higher in background air compared with SHR Project emissions.

Table 2.4 Maximum Modeled Annual Average SHR Project Stack Air Emission Impacts and Background Air Toxics Concentrations

Pollutant	Annual Average SHR Project Impact, μg/m³	Measured Background, Mean Concentration, [a] μg/m³ (max meas. concentration)
Arsenic	0.000005	0.00042 (0.00126)
Chromium (total)	0.000039	0.00226 (0.00323)
Chromium (VI)	0.000007	--
Copper	0.00002	--
Lead	0.000012	0.00303 (0.01040)
Nickel	0.00005	0.00141 (0.00432)
Cadmium	0.000027	0.00013 (0.00290)
Mercury	0.000006	0.00001 (0.00002)
Beryllium	0.0000003	0.00001 (0.00012)
Selenium	0.0000007	0.00027 (0.00085)
Vanadium	0.00006	--
Formaldehyde	0.006429	--
Acetaldehyde	0.000678	--
1,3-Butadiene	0.000015	0.024 (0.062)[b]
Benzene	0.000514	0.355 (0.607)[b]
Naphthalene	0.000067	--
Sulfuric Acid	0.015315	--
Ethylbenzene	0.000394	0.109 (0.308)[b]
Propylene oxide	0.001661	--
p-Dichlorobenzene	0.000030	--
o-Dichlorobenzene	0.000030	--
Toluene	0.001812	0.671 (2.736)[b]
Xylenes	0.000878	0.334 (0.964)[b]
Ammonia	0.033211	--

Notes:
(a) Source: MADEP (2012). Geometric means for 2011 monitoring data are provided, with maximum detected concentrations in parentheses; unless otherwise noted, background data are for the Boston ambient monitor on Harrison Avenue.
(b) Data for the Lynn (MA) ambient monitor.

Table 2.5 below summarizes the exposure assumptions used for the highly conservative exposure scenario considered for our health risk calculations, namely that of an off-site resident present continuously (24/7) at the location of maximum modeled annual average SHR Project impacts. As shown in Table 2.5, we assumed that a resident was present 24 hours a day, 365 days a year, for the standard assumed residential duration of 30 years at the location of maximum modeled annual average SHR Project impacts. This continuous-resident scenario has a higher exposure frequency and duration than other potential receptors (*e.g.*, schoolchildren, office workers), meaning that this scenario is designed to yield risk estimates that are highly conservative (*i.e.*, that would be overestimates for other potential receptors). In addition, our health-protective scenario assumes that indoor pollutant concentrations due to the SHR Project air emissions are identical to ambient (outdoor) predicted pollutant concentrations; this is a highly conservative assumption for the particulate phase pollutants (*e.g.*, metals) and reactive pollutants (formaldehyde, acetaldehyde), where indoor concentrations of outdoor-derived contributions of these pollutants can be substantially reduced compared to the corresponding outdoor concentrations (US EPA, 2009b; Seaman *et al.*, 2007; Salthammer *et al.*, 2010). Table 2.6 summarizes the estimated time-adjusted exposure concentrations calculated using these conservative assumptions.

Table 2.5 Exposure Assumptions for the Off-site Resident Scenario

Input	Value
EPC	Varies by pollutant (see Table 2.4)
ET	24 hours/day
EF	365 days/year
ED	30 years
AT	262,800 hours (nc); 613,200 (ca)

Notes:
nc = non-cancer health effect analysis.
ca = cancer health effect analysis.

Table 2.6 Estimated Time-Adjusted Exposure Concentrations for Assessing Non-Cancer and Cancer Risks, Using Maximal SHR Project Stack Air Impacts and Monitored Background Air Toxics Concentrations in Lynn and Boston, MA

Pollutant	For Calculating HQs		For Assessing Cancer Risks	
	Maximum Modeled SHR Project Impact (µg/m³)	Monitored Background (µg/m³)	Maximum Modeled SHR Project Impact (µg/m³)	Monitored Background (µg/m³)
Arsenic	5.00E-06	4.20E-04	2.14E-06	1.80E-04
Chromium (total)	3.90E-05	2.26E-03	1.67E-05	9.68E-04
Chromium (VI)	7.00E-06	--	3.03E-06	--
Copper	2.00E-05	--	8.57E-06	--
Lead	1.20E-05	3.03E-03	5.14E-06	1.29E-03
Nickel	5.00E-05	1.41E-03	2.14E-05	6.04E-04
Cadmium	2.70E-05	1.30E-04	1.16E-05	5.57E-05
Mercury	6.00E-06	1.00E-05	2.57E-06	4.28E-06
Beryllium	3.00E-07	1.00E-05	1.29E-07	4.28E-06
Selenium	7.00E-07	2.70E-04	3.00E-07	1.15E-04
Vanadium	6.00E-05	--	2.57E-05	--
Formaldehyde	6.43E-03	--	2.76E-03	--
Acetaldehyde	6.78E-04	--	2.91E-04	--
1,3-Butadiene	1.50E-05	2.43E-02	6.43E-06	1.04E-02
Benzene	5.14E-04	3.55E-01	2.20E-04	1.52E-01
Naphthalene	6.70E-05	--	2.87E-05	--
Sulfuric Acid	1.53E-02	--	6.60E-03	--
Ethylbenzene	3.94E-04	1.09E-01	1.69E-04	4.65E-02
Propylene oxide	1.66E-03	--	7.12E-04	--
p-Dichlorobenzene	3.00E-05	--	1.29E-05	--
o-Dichlorobenzene	3.00E-05	--	1.29E-05	--
Toluene	1.81E-03	6.71E-01	7.77E-04	2.88E-01
Xylenes	8.78E-04	3.34E-01	3.76E-04	1.43E-01
Ammonia	3.32E-02	--	1.42E-02	--

Notes:
-- = Data not available.

Using the time-adjusted exposure concentrations in Table 2.6, we estimated chronic inhalation non-cancer health risks by calculating HQs according to the following equation (US EPA, 2009a):

$$Hazard\ Quotient = \frac{Exposure\ Concentration\ (\frac{\mu g}{m^3})}{RfC\ (\frac{\mu g}{m^3})}$$

For cancer risks, we estimated theoretical incremental ELCRs by combining time-adjusted exposure concentrations and URs according to the following equation (US EPA, 2009a):

$$Cancer\ Risk = Exposure\ Concentration\ \left(\frac{\mu g}{m^3}\right) x\ Unit\ Risk\ [\ \left(\frac{\mu g}{m^3}\right)^{-1}\ ]$$

Calculated HQs and ELCRs are summarized in Tables 2.7 and 2.8, respectively. As shown in Table 2.7, all HQs calculated for an off-site resident exposed to maximum modeled SHR Project stack air impacts are far below an HQ of 1,[10] ranging from 3.5×10^{-8} for selenium to 0.0037 for sulfuric acid. The overall summed hazard index (HI) of 0.08 is also well below 1, indicating that estimated chronic exposures to maximum modeled SHR Project stack air impacts are not expected to result in non-cancer health risks. In addition, Table 2.8 shows that all estimated ELCRs are well below the regulatory cancer risk range of 10^{-6} to 10^{-4} that is considered to be acceptable by US EPA (US EPA, 1990), with ELCRs ranging from 1.9×10^{-10} for 1,3-butadiene to 3.6×10^{-8} for chromium VI. The overall summed cancer risk of 1.1×10^{-7} is also below the US EPA regulatory *de minimis* level, further supporting an absence of significant cancer risk from worst-case chronic exposures to maximum modeled SHR Project stack air impacts.

[10] US EPA (2006) states that HQs of less than one indicate that an estimated exposure for an individual is considered to be without significant non-cancer health risk. However, because RfCs are not direct estimators of risk but are instead reference points for gauging potential effects that incorporate protective assumptions in the face of uncertainty, US EPA documents (US EPA, 2006) state that exceedances of the RfC (*i.e.*, HQs exceeding one) do not necessarily suggest a likelihood of adverse health effects. In other words, the HQ is not a measure of the probability that adverse effects will occur and is not likely to be proportional to risk. An HQ greater than one is interpreted as an indication that there is the potential for adverse health effects and that additional evaluation of chronic non-cancer risks is warranted.

Table 2.7 Non-Cancer Hazard Quotients (HQs) with and without the SHR Project

Pollutant	Project-specific HQs for Maximum Annual Average SHR Project Stack Air Impacts	HQs w/o Project (*i.e.*, Background)	HQs with Project (*i.e.*, Background + Maximum SHR Project Impact)
Arsenic	3.3E-04	2.8E-02	2.8E-02
Chromium (total)	--	--	--
Chromium (VI)	7.0E-05	--	--
Copper	--	--	--
Lead	8.0E-05	2.0E-02	2.0E-02
Nickel	5.6E-04	1.6E-02	1.6E-02
Cadmium	2.7E-03	1.3E-02	1.6E-02
Mercury	2.0E-05	3.33E-05	5.3E-05
Beryllium	1.5E-05	5.0E-04	5.2E-04
Selenium	3.5E-08	1.4E-05	1.4E-05
Vanadium	6.0E-04	--	--
Formaldehyde	6.6E-04	--	--
Acetaldehyde	7.5E-05	--	--
1,3-Butadiene	7.5E-06	1.2E-02	1.2E-02
Benzene	1.7E-05	1.2E-02	1.2E-02
Naphthalene	6.7E-07	--	--
Sulfuric Acid	1.5E-02	--	--
Ethylbenzene	3.9E-07	1.1E-04	1.1E-04
Propylene oxide	5.5E-04	--	--
p-Dichlorobenzene	3.8E-08	--	--
o-Dichlorobenzene	--	--	--
Toluene	3.6E-07	1.3E-04	1.4E-04
Xylenes	8.8E-06	3.3E-03	3.4E-03
Ammonia	3.3E-04	--	--

Notes:
-- = Data not available.

Table 2.8 Estimated Excess Lifetime Cancer Risks (ELCRs) with and without the SHR Project

Pollutant	Project-specific Cancer Risks for Maximum Annual Average SHR Project Stack Air Impacts	Cancer Risks w/o Project (*i.e.*, Background)	Cancer Risks with Project (*i.e.*, Background + Maximum SHR Project Impact)
Arsenic	9.2E-09	7.7E-07	7.8E-07
Chromium (total)	--	--	--
Chromium (VI)	3.6E-08	--	--
Copper	--	--	--
Lead	--	--	--
Nickel	--	--	--
Cadmium	2.1E-08	1.0E-07	1.2E-07
Mercury	--	--	--
Beryllium	3.1E-10	1.0E-08	1.1E-08
Selenium	--	--	--
Vanadium	--	--	--
Formaldehyde	3.6E-08	--	--
Acetaldehyde	6.4E-10	--	--
1,3-Butadiene	1.9E-10	3.1E-07	3.1E-07
Benzene	1.7E-09	1.2E-06	1.2E-06
Naphthalene	9.8E-10	--	--
Sulfuric Acid	--	--	--
Ethylbenzene	4.2E-10	1.2E-07	1.2E-07
Propylene oxide	2.6E-09	--	--
p-Dichlorobenzene	--	--	--
o-Dichlorobenzene	--	--	--
Toluene	--	--	--
Xylenes	--	--	--
Ammonia	--	--	--

Notes:
-- = Data not available.

For those air toxics measured at the Lynn or Boston air toxics monitors, risks were also calculated using estimates of existing background air toxics levels based on the measurement data from the local monitor (*i.e.*, without SHR Project), and for the sum of the maximum modeled SHR Project stack air impacts and existing background air toxics levels (*i.e.*, with SHR Project). As shown in Tables 2.7 and 2.8 and Figures 2.1 and 2.2 below, estimated HQs and ELCRs estimated from background levels alone are almost identical to those calculated for both background and project impacts together. This is particularly illustrated by Figures 2.1 and 2.2, which show no significant differences between the "with SHR Project" and "without SHR Project" calculated risks. In other words, it is expected that even maximum modeled SHR Project stack air quality impacts will have only a negligible impact on chronic inhalation non-cancer and cancer health risks in nearby communities.

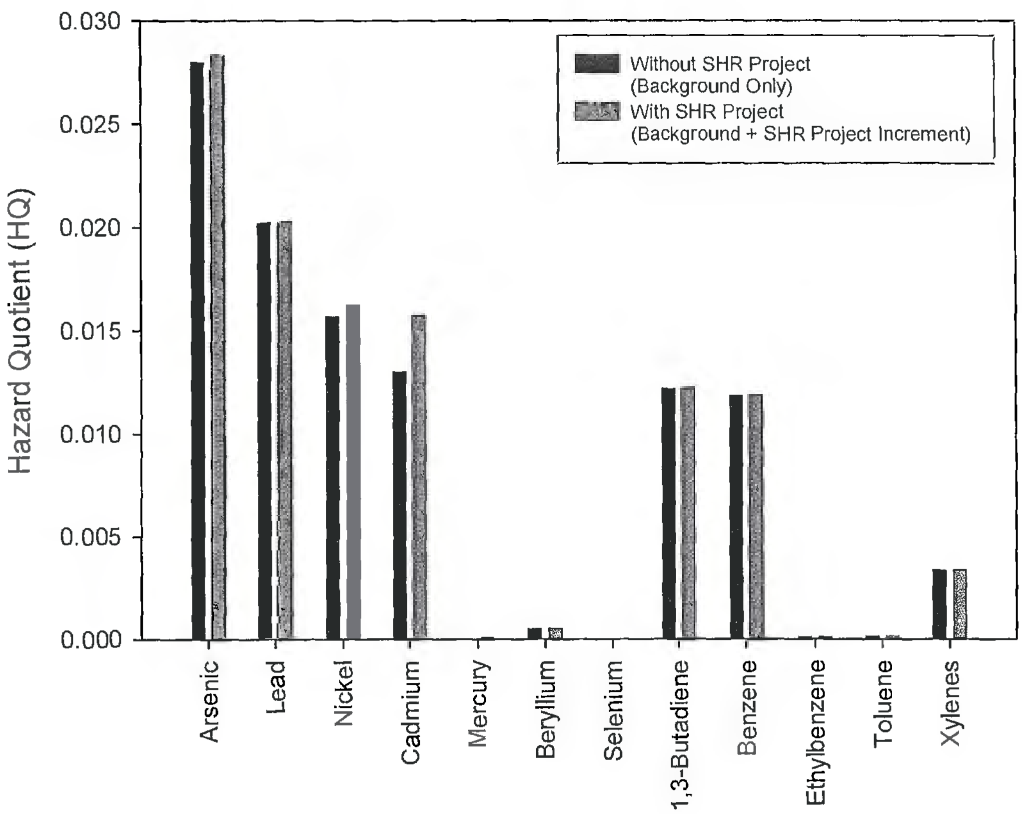

Figure 2.1 Non-cancer Hazard Quotients (HQs) with and without the SHR Project Maximum Modeled Stack Air Impacts

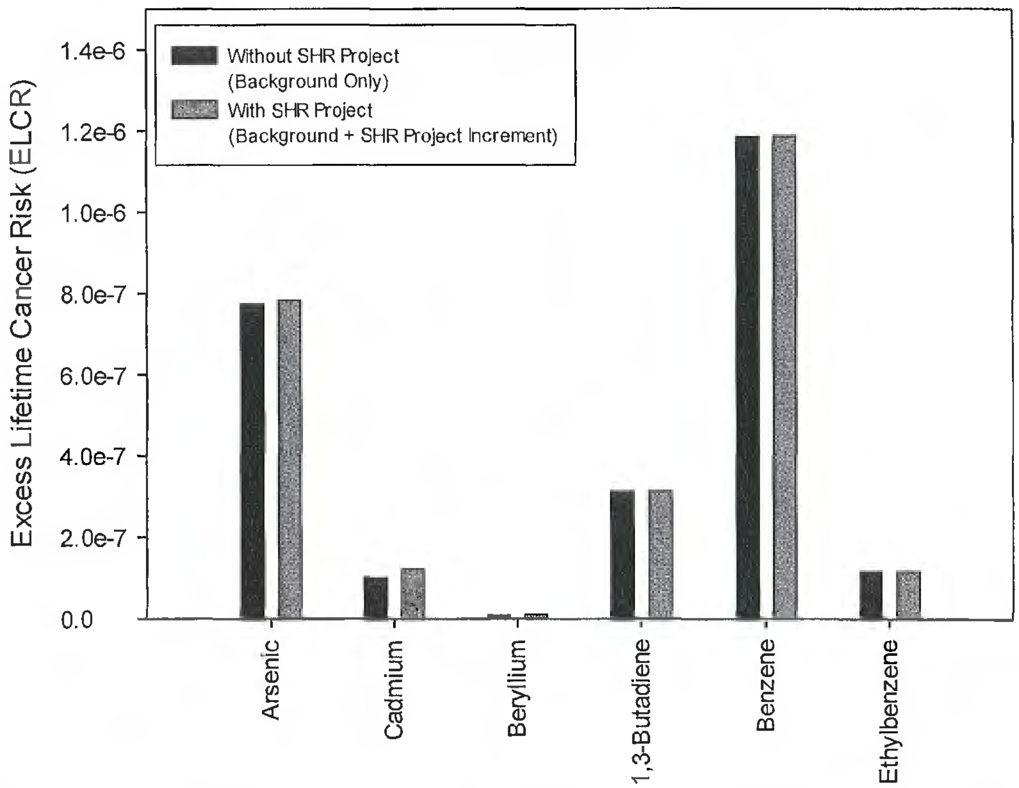

Figure 2.2. Excess Lifetime Cancer Risks (ELCRs) with and without the SHR Project Maximum Modeled Stack Air Impacts

2.3 Acute (Short-term) Exposure Evaluation for Respiratory Irritants

Two of the criteria air pollutants (NO_2 and SO_2), at sufficiently high exposure levels, are known to be respiratory irritants and thus may be associated with acute respiratory effects among asthmatics. Thus, we conducted an acute exposure evaluation as a supplement to the prior (Section 2.2) chronic inhalation risk assessment.[11] For both of these air pollutants, we principally relied upon the recently promulgated 1-hour NAAQS that incorporate the current evidence for acute effects to short-term NO_2 and SO_2 exposures (US EPA, 2010a, 2010b). Regarding NO_2, US EPA indicates that "current scientific evidence links short-term NO_2 exposures, ranging from 30 minutes to 24 hours, with an array of adverse respiratory effects including increased asthma symptoms, more difficulty controlling asthma, and an increase in respiratory illnesses and symptoms."[12] Regarding SO_2, US EPA states that "current scientific evidence links short-term exposure to SO_2, ranging from five minutes to 24 hours, with a range of adverse respiratory effects including narrowing of the airways that can cause difficulty breathing (bronchoconstriction) and increased

[11] Note that several air toxics included in the Tetra Tech (2012a) air quality impact analysis, including acetaldehyde, formaldehyde, and sulfuric acid, are also known to be respiratory irritants at sufficiently high exposure levels. However, they are not included in this acute exposure evaluation as projected emissions of these air toxics by the SHR Project are minimal.
[12] From the US EPA NO_2 Fact Sheet available at: http://www.epa.gov/airquality/nitrogenoxides/pdfs/20100122fs.pdf.

asthma symptoms. These effects may be important for asthmatics at elevated ventilation rates (*e.g.*, while exercising or playing)."[13] Furthermore, US EPA has concluded that "studies also show a connection between short-term exposure to [both pollutants] and increased visits to emergency departments and hospital admissions for respiratory illnesses, particularly in at risk populations including children, the elderly, and asthmatics." Therefore, in 2010, US EPA set a new 1-hour average NO_2 standard at the level of 100 parts per billion (ppb) [equivalent to 188 $\mu g/m^3$].[14] Similarly, US EPA revised the primary SO_2 standard to a new 1-hour average level of 75 ppb [equivalent to 195 $\mu g/m^3$].[15] These 1-hour US EPA standards are intended to protect against the adverse health effects associated with short-term NO_2 and SO_2 exposures, including respiratory effects in sensitive populations such as asthmatics.

The maximum predicted concentrations of these pollutants were also compared with Acute Exposure Guideline Levels (AEGLs). The US EPA Office of Solid Waste (OSW) recommends a hierarchal approach for establishing acute inhalation exposure criteria that are protective of the general public from short-term discomfort or mild adverse health effects (US EPA, 2005), and AEGLs are the preferred values in the OSW hierarchal approach based on: 1) their applicability to a 1-hour exposure period for protection of the general public, and 2) the high level of documentation and associated review.

The AEGLs are developed by the National Advisory Committee for Acute Exposure Guidelines for Hazardous Substances (NAC) to represent threshold exposure limits for the general public, including sensitive subpopulations (NRC, 2001). Members of the NAC include US EPA scientists as well as scientists from other governmental and regulatory agencies. AEGLs are subjected to a comprehensive review process that includes both public and peer review components.[16] AEGLs are typically developed for three levels of severity (AEGL-1, AEGL-2, and AEGL-3) for exposure periods ranging from 10 minutes up to 8 hours (for 10-minute, 30-minute, 1-hour, 4-hour, and 8-hour exposure periods) to be protective of toxic effects of varying degrees of severity, including both non-cancer and cancer health effects.

The AEGL-1 values are used in this assessment, as they represent the lowest exposure thresholds that are protective of mild health effects such as discomfort and irritation.

As defined on the US EPA AEGLs web page (US EPA, 2012e), the AEGL-1 is:

> the airborne concentration (expressed as parts per million or milligrams per cubic meter (ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

US EPA (2012e) states that airborne concentrations below the AEGL-1 may "produce mild and progressively increasing but transient and non-disabling odor, taste, and sensory irritation or certain asymptomatic, non-sensory effects." The AEGL-1 is intended to be protective of the general population including infants and children, the elderly, asthmatics, and other susceptible individuals. This assessment

[13] From the US EPA SO_2 Fact Sheet available at: http://www.epa.gov/airquality/sulfurdioxide/pdfs/20100602fs.pdf

[14] Compliance with the 1-hour standard will be assessed by evaluating the 3-year average of the 98th percentile of the annual distribution of daily maximum 1-hour average concentrations.

[15] Compliance with the 1-hour standard will be assessed by evaluating the 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour average concentrations.

[16] The current listing of finalized, interim, and proposed AEGLs is available on the US EPA website at: http://www.epa.gov/oppt/aegl/ (US EPA, 2012e).

utilizes AEGL-1 values where available in either final, interim, or proposed form for the airborne chemicals of interest.

In addition to the 1-hr AEGL-1 acute reference values, we also compared maximum modeled 1-hour concentrations to acute toxicity factors developed by the CalEPA Office of Environmental Health Hazard Assessment (OEHHA). An acute REL[17] is defined as "an exposure that is not likely to cause adverse health effects in a human population, including sensitive subgroups, exposed to that concentration for one hour on an intermittent basis." Acute RELs are developed for potential non-cancer health impacts associated with routine, short-term exposures and are based on the most sensitive, relevant, adverse health effect reported in the toxicological literature. They are specifically developed to protect the most sensitive individuals in the population through use of margins of safety. Thus, acute RELs are typically based on very mild health effects that include eye, nose, or throat irritation.

As shown in Table 2.9, maximum modeled SHR Project 1-hour impacts for NO_2 and SO_2, as well as estimates of cumulative impact levels (maximum modeled 1-hour + ambient background) are well below relevant acute reference values. Relevant acute reference values include the 1-hour health-protective NAAQS that were specifically designed to address asthma and respiratory diseases, as well as the AEGL-1 values and the RELs established by the California EPA.

Table 2.9 Maximum Acute Impacts of Potential Respiratory Irritants Relative to Acute Reference Values

Pollutant	Maximum Modeled SHR Project 1-hour Concentrations (μg/m^3)[a]	Estimated 1-hour Cumulative Impact Levels (μg/m^3)[b]	Acute (1-hour) Reference Value (μg/m^3)		
			NAAQS[c]	REL[d]	AEGL-1[e]
Nitrogen dioxide	44.3	126.6[f]	188	470	940
Sulfur dioxide	1.1	58.7	195	660	520

Notes:

(a) Maximum modeled SHR Project 1-hour concentrations for NO_2 and SO_2 from Table 6-9 of Tetra Tech (2012b, p 6-8).

(b) From Table 2.1.

(c) National Ambient Air Quality Standard (http://www.epa.gov/air/criteria.html) (US EPA, 2011b).

(d) Acute Reference Exposure Levels from CalEPA OEHHA (http://oehha.ca.gov/air/allrels.html ; acute averaging time = 1 hour) (US EPA, 2011b).

(e) US EPA. (2012e). Acute Exposure Guideline Levels (AEGLs) Program. Available at: http://www.epa.gov/oppt/aegl/

(f) For 1-hr NO_2, a cumulative impact assessment that considered other regional sources of this NAAQS pollutant was also conducted by Tetra Tech for 5-year averages of the 8th highest daily maximum concentrations occurring in each year (Tetra Tech, 2012a, 2012b). When the impacts of two MADEP-provided interacting sources were combined with the SHR Project impacts (for a total of 102.6 μg/m^3 of which 7.9 μg/m^3 was attributable to the SHR Project), the total project plus background level was reported as 184.9 μg/m^3 (Tetra Tech, 2012a, 2012b).

In conclusion, the maximum modeled 1-hour NO_2 and SO_2 concentrations for SHR Project stack air impacts, as well as cumulative impact levels (maximum modeled 1-hour + ambient background), are well below the health-based standards developed specifically to be protective of acute health impacts. Therefore, air emissions of these respiratory irritants from the SHR Project are not expected to contribute to acute health effects, including respiratory irritation and asthma exacerbation, even at maximum modeled concentrations.

[17] http://www.oehha.ca.gov/air/allrels.html (CalOEHHA, 2012).

3 Analysis of Worst-Case Accidental Ammonia Release

3.1 Aqueous Ammonia Storage and Transfer Specifications

As discussed in Tetra Tech (2012b), the SHR Facility will use a 19% solution of aqueous ammonia for its selective catalytic reduction (SCR) systems, which are pollution control devices located in the turbine heat recovery steam generators for reduction of NO_x emissions. The 19% aqueous ammonia will be stored in an above-ground 34,000 gallon steel tank. The storage tank will be a vertical cylindrical tank, with a diameter of 12 feet and a height of approximately 40 feet.

The aqueous ammonia storage tank will be constructed in accordance with the Massachusetts Department of Public Safety requirements for storage tanks greater than 10,000 gallons containing material other than water, including several design features intended to mitigate potential impacts of an accidental ammonia release. The tank will have single wall construction, which provides for more effective monitoring and reparability than a double wall tank. The tank, as well as ammonia transfer pumps, valves, and piping will be located within a concrete containment structure (dike) designed to contain 110% of the volume of the tank. The dike will be 23 feet by 19 feet and have 12 foot walls to provide the necessary containment. The dike will be constructed so that the floor of the dike will be 4 feet below grade and the top of the dike walls will be 8 feet above grade. In order to minimize the exposed surface area of any aqueous ammonia that enters the diked area, passive evaporative controls (polyethylene balls or equivalent) will be installed to reduce the surface area by 90%. In order to further mitigate the potential impacts of an accidental ammonia release, the entire tank and diked area will be located within an enclosure 60 feet long, 40 feet wide, and 40 feet high. The walls of the structure will be fully sealed, and the only ventilation for the structure will be by means of roof vents. The dike wall and enclosure surrounding the tank will thus decrease the risk of damage to the tank caused by accidental vehicle contact.

Transfer from ammonia delivery trucks to the storage tank will take place within a contained concrete storage tank unloading pad with drainage design, such that any spills during ammonia delivery will drain into the diked containment area. Delivery trucks will be required to have fast-acting shutoff valves in the unlikely event that a leak or other problem should arise. A hose from the top of the tank connected back to the truck will return displaced vapor to the truck, or an equivalent method for control of transfer losses will be used. The storage tank will be equipped with level monitoring instrumentation that will be continuously monitored in the control room. In the event that the tank level approaches an overfill condition during filling, a high level alarm will sound, initiating an immediate response to the situation.

3.2 Tetra Tech (2012b) Worst-case Ammonia Spill Modeling

Given that ammonia in aqueous solution is volatile, an accidental release of this material would result in some release of ammonia to the ambient air. Therefore, Tetra Tech (2012b) performed a worst-case accidental release scenario to evaluate the potential health impacts of such a release. As described in Tetra Tech (2012b), the release scenario assumed a release of the entire contents of the tank into the diked containment area, and conservatively evaluated the air quality impacts of such a release at the nearest projected controlled access perimeter (PCAP) (approximately 230 feet from the ammonia storage area).

The ammonia emissions resulting from a hypothetical worst-case release scenario were calculated using the Areal Locations of Hazardous Atmospheres (ALOHA) model, which demonstrates that no locations outside the PCAP would be exposed to concentrations above 25 ppm. This model was developed by the US EPA and the National Oceanic and Atmospheric Administration, and is included as a prescribed technique under the US EPA Risk Management Program (RMP) guidance. ALOHA model inputs are summarized in Tetra Tech (2012b).

The ALOHA model results indicate a steady state release rate of ammonia from the diked area (within the enclosure) of 1.23 pounds per minute. The enclosure will mitigate the release of ammonia to the atmosphere, since the exchange of enclosure air with outdoor air is controlled by the building ventilation design. The enclosure will be designed with an air exchange rate of 4, meaning that the flow rate of outdoor air into and out of the enclosure per hour will be four times the enclosure volume. For the ammonia enclosure design, an air exchange rate of 4 means that the volume of enclosure air exhausted to the atmosphere will be 914 actual cubic feet per minute (acfm). If the diked area releases ammonia at 1.23 pounds per minute, after about 45 minutes (if the release is not controlled) the ammonia concentration in the enclosure will be near equilibrium and the release rate of ammonia from the enclosure roof will approach 1.23 pounds per minute. In actuality, ammonia sensors in the enclosure will alert plant staff to a problem, and action to control a release to the dike can be taken before significant ammonia accumulates in the diked area.

In order to conservatively evaluate potential offsite consequences of an ammonia release, a continuous release of ammonia of 1.23 pounds per minute from the enclosure roof was evaluated with the AERMOD dispersion model. This is the same dispersion model used for the evaluation of air quality impacts from the facility exhaust stacks. As described in Tetra Tech (2012b), the same AERMOD inputs and databases used for the stack modeling were used for the ammonia release analysis. A dense modeling receptor network at and near the PCAP was used to assess the maximum offsite ammonia concentrations. The enclosure exhaust parameters used were a 40 foot release height, from a roof vent with an area of 1 square foot exhausting 914 acfm at ambient temperature.

3.3 Health Evaluation of Worst-case Model-predicted Ammonia Air Concentrations

Predicted 1-hour maximum concentrations at the PCAP and nearby locations were evaluated in terms of the US EPA AEGL-1 and AEGL-2 values and the American Industrial Hygiene Association (AIHA) Emergency Response Planning Guideline Level 1 (ERPG-1) and Level 2 (ERPG-2) values. As previously discussed in Section 2.3, AEGL-1 values are generally based on mild odor, taste, and sensory irritation or certain asymptomatic, non-sensory effects. As defined on the US EPA AEGL website (US EPA, 2012e), an AEGL-2 is defined as "the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape." Parallel to the AEGL-1, an AIHA ERPG-1 is defined as the maximum airborne concentration below which nearly all individuals could be exposed to for up to one hour without experiencing other than mild transient health effects and/or a clearly defined objectionable odor. Parallel to the AEGL-2, an ERPG-2 is defined as the maximum airborne concentration which it is believed that nearly all individuals could be exposed to for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair the ability to take self-directed protective action.

Table 3.1 presents the results of the predicted 1-hour maximum concentrations of ammonia in the event of a worse case release from the storage tank. The results in Table 3.1 are shown for the northern PCAP (worst-case PCAP value), the west PCAP (worst-case aside from north PCAP), the East PCAP, the South Essex Sewerage District (SESD), and the nearest residence to the ammonia storage area (Fort Avenue, just east of Memorial Drive). As shown in Table 3.1, the AERMOD modeling results indicate that in the event of a hypothetical worst-case release, maximum hourly ammonia concentrations would be less than the lowest relevant acute exposure guideline values, namely the ERPG-1 level of 25 ppm, at all locations outside of the PCAP.

Table 3.1 Summary of Worst-Case Release Scenario for Ammonia

Location	Distance From Ammonia Storage Enclosure (feet)[a]	Ammonia Concentration (Maximum Hourly Value in ppm)[a]	AEGL-1 (ppm)[b]	AEGL-2 (ppm)[b]	ERPG-1 (ppm)[c]	ERPG-2 (ppm)[c]
Power Plant North PCAP	230	24.5	30	160	25	150
Power Plant West PCAP	360	14.3	30	160	25	150
Power Plant East PCAP	470	4.9	30	160	25	150
Nearest Residence (Fort Avenue)	560	6.9	30	160	25	150
South Essex Sewerage District (SESD)	730	7.5	30	160	25	150

Notes:
(a) From Tetra Tech (2012b).
(b) From AIHA (2000).
(c) From US EPA (2012e).

Although the 1-hour maximum ammonia concentration predicted for the Power Plant North PCAP is very close to the ERPG-1 of 25 ppm, it is important to note that this exposure guideline is based on mild odor perception and/or mild irritation (AIHA, 2000), which are not equivalent to highly adverse health effects. Moreover, the area along the northern PCAP (where the 24.5 ppm concentration is predicted) is adjacent to the existing National Grid switchyard (which will remain in use as a switchyard). There will be no future public access inside this switchyard area. Thus, there are no residences or general public that would be subject to ammonia concentrations approaching 25 ppm.

In summary, findings from the Tetra Tech (2012b) worst-case accidental release modeling analysis thus support the adequate mitigation of potential human health impacts at and beyond the site PCAP by the proposed storage plans for aqueous ammonia, even in the event of a worst-case aqueous ammonia release.

4 Evaluation of Community Baseline Health Status

In accordance with the EFSB request that the project proponent consider the baseline health status of potentially affected communities, Gradient compiled and evaluated existing baseline health data for Salem. Where available, we also considered baseline health data for several neighboring communities, including Marblehead, Swampscott, Beverly, Peabody, and Manchester. Baseline health data include cancer statistics available from the Massachusetts Cancer Registry, statewide pediatric asthma surveillance data available from the Massachusetts Department of Public Health (MADPH), and asthma and cardiovascular hospitalization data available from the Massachusetts Community Health Information Profile (MassCHIP) website. We review these baseline health data in the following sections, and comment on whether project air emissions could be expected to augment risks for these diseases.

4.1 General Description of the City of Salem

Situated approximately 16 miles north of Boston, Salem is bordered by Swampscott and Lynn to the south, Peabody to the west, Beverly to the north, and Marblehead to the east. Salem's population is approximately 41,340 (based on 2010 census data). As stated in its Massachusetts Department of Housing and Community Development profile (Undated),[18] Salem occupies a land area of 18.05 square miles and has a population density of 4,703 per square mile.

Salem's population has a similar demographic makeup as Massachusetts as a whole. The percentage of residents under 18 years, under 5 years, and over 65 years is approximately the same as the statewide average. Based on 2010 population data provided by the United State Census Bureau, the majority of the population of Salem is white (81.5%); 4.9% are Black, and 15.6% Hispanic or Latino.

For many years, Salem was a trading, manufacturing, and retail center, but recently has been making a slow transition to a service-based economy. Salem relies upon tourism as a primary source of income; the town generated nearly $99 million from tourism in 2010. The city is home to Salem State College, the North Shore Medical Center, the Essex County District Superior and Probate Courts and Registry of Deeds, and the Peabody Essex Museum (City of Salem Finance Dept., 2011). The North Shore Medical Center is Salem's top employer, with 3,240 total employees, and Salem State University is the second largest employer, with about 1,506 employees (City of Salem, 2012). While there has been a decline in manufacturing jobs according to city reports, a much smaller proportion of Salem's initial employment base was comprised of manufacturing jobs when compared with the state as a whole or Essex County. In addition to the healthcare industry, the hospitality, food service, and entertainment industries currently employ a large number of people (Community Opportunities Group, 2005). As of 2005, Salem had approximately 27,149,592 square meters of residential land, 1,908,816 square meters of commercial land, and 999,755 square meters of industrial land (EOAF, 2005).

Directly to the north of Salem is the city of Beverly, which borders the Atlantic Ocean and has an industrial past. Although currently most of the top employers are healthcare and education related, the town still hosts a few manufacturing businesses (EOLWD, 2012a). The town of Marblehead is located to the east of Salem. While initially a fishing town, this community was home to a boom of shoe-making factories during the late 19th century. Currently, the largest employers in Marblehead are healthcare

[18] http://www.mass.gov/hed/docs/dhcd/profiles/258.doc

establishments, schools, and retail businesses (EOLWD, 2012b). Further north, the town of Manchester-by-the-Sea (Manchester) also began as a fishing community. The largest employers in Manchester are now educational, recreational, and retail establishments (EOLWD, 2012c). Swampscott lies just to the south of Marblehead and Salem, and Peabody borders Salem to the west. Swampscott also originated as a fishing community, and for a time it had a large tourism industry. Currently, over 30% of its jobs are in education or health, and almost 20% are in the leisure sector (Town of Swampscott, 2012). Peabody relied on its large leather industry from the late 18th century through the 1970s. Currently, there is one tannery still operating. It is also home to an industrial park developed in the mid-1980s, and a large retail industry (Peabody Historical Society and Museum, 2008).

4.2 Cancer Incidence

The Massachusetts Cancer Registry (which is part of MADPH) provides estimates of cancer incidence for each of the 351 cities and towns of Massachusetts (http://www.mass.gov/dph/mcr). With regard to local cancer rates, the report "Cancer Incidence in Massachusetts, 2004-2008" (MAEOHHS, 2011a) provides data for the five-year time period 2004-2008, including for 23 types of cancer, for all cancer types combined, and for both males and females. City and town rates are compared to the statewide-average incidence rate for each cancer, for each sex, and for each city and town (*e.g.*, a total of about 16,800 inter-comparisons). Because of the large number of comparisons, "statistically greater" or "statistically lower" cancer incidence rates can occur by random chance alone.

Salem is part of the Massachusetts Cancer Registry, and the most recent data can be found in the "Russell to Wales" section of the MADPH report (MAEOHHS, 2011b, p. 267).[19] MADPH reports that, within statistical confidence limits, Salem incidence rates for most cancers are about average. Salem rates are statistically above the state average for two cancer types: male leukemia (SIR[20] = 166) and male lung and bronchus cancer (SIR = 138). All other specific cancer types are comparable to the state incidence rates.

Marblehead cancer rates are similar to Massachusetts as a whole, with the exception of two cancer types. Male brain and other nervous system cancers are statistically significantly higher than the state rate (SIR = 281), and melanoma is significantly higher for both sexes (male SIR = 171; female SIR = 207). Female lung and bronchial cancer rates are significantly lower than for the state as a whole (SIR = 70). The combined rate for all types of cancer is not statistically different from the statewide rate for males or females (SIRs of 103 and 108, respectively).

For Manchester, female breast cancer and female melanoma rates are significantly elevated compared with the state (SIRs of 152 and 299, respectively); however, female lung and bronchial cancer rates are significantly below the state average (SIR = 39). Overall rates in males and females for all types of cancer are not significantly different than the state incidence rate (male SIR = 97; female SIR = 89).

In Swampscott, rates are statistically significantly above the state average for four cancer types: female bladder cancer (SIR = 193), female melanoma of the skin (SIR = 204), male leukemia (239) and male thyroid cancer (SIR = 252). However, it should be noted that all of these specific rates were based on

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[19] http://www.mass.gov/eohhs/docs/dph/cancer/registry-city-04-08-russel-wales.pdf

[20] As defined by MADPH (MAEOHHS, 2011b), the SIR (Standardized Incidence Ratio) is "an indirect method of adjustment for age and sex that describes in numerical terms how a city/town's cancer experience in a given time period compares with that of the state as a whole... An SIR of exactly 100 indicates that a city/town's incidence of a certain type of cancer is equal to that expected based on statewide average age-specific incidence rates... An SIR of more than 100 indicates that a city/town's incidence of a certain type of cancer is higher than expected for that type of cancer based on statewide average annual age-specific incidence rates... An SIR of less than 100 indicates that a city/town's incidence of a certain type of cancer is lower than expected based on statewide average age-specific incidence rates."

very small numbers of cases (8-19), which leads to less confidence in these estimates. The combined rate for all types of cancer was not statistically different from the statewide rate for males or females (SIRs of 100 and 107, respectively).

The city of Beverly has an incidence rate for all types of cancer that is not statistically different than the state as a whole (male SIR = 103; female SIR = 100). No specific cancer types are elevated in Beverly compared with the state incidence rate, while the male colon cancer rate (SIR = 63) and the male and female pancreatic cancer rates (male SIR = 42; female SIR = 47) are significantly below the state average.

Peabody is the only city in the Salem area with a statistically significantly increased cancer incidence for all sites compared with the statewide incidence (male SIR = 110; female SIR = 119). Peabody has a statistically significantly elevated incidence rate for male and female kidney and renal pelvis cancer (male SIR = 148; female SIR = 160), male and female leukemia (male SIR = 185, female SIR = 184), female lung and bronchial cancer (SIR = 138), and female non-Hodgkin lymphoma (SIR = 174).

In 1999, MADPH addressed public concerns regarding a possible role for emissions from the Salem Harbor Generating Station (SHGS) [the currently-operating coal-and-oil fired electric-power generating station located on the 65-acre site that will include the SHR Project] in cancer risk in the areas of Marblehead and Swampscott, MA. The 1999 MADPH cancer incidence report (MADPH, 1999), which included data for the years 1987-1994, indicated that Marblehead and Swampscott had significant elevations of certain types of cancer including breast cancer, leukemia, and melanoma. MADPH reviewed ambient air monitoring results, evaluated available information on historical SHGS emissions, conducted an air-dispersion-modeling analysis to identify specific geographic areas that were most impacted by historical SHGS emissions, and conducted a qualitative evaluation of the distribution of cancer cases in each town's census tracts over the years 1987-1994 relative to the geographic areas most impacted by SHGS emissions. In Marblehead, one of three census tracts had statistically significant increases in breast cancer (SIR 176, 95% CI: 133-128); however, this occurred in an area of Marblehead presumed to be less impacted by the SHGS emissions. Leukemia incidence in both sexes was significantly increased in census tracts 2031 and 2032 (SIR 203, 95% CI: 101-363; SIR 234, 95% CI: 101-461, respectively); however, these SIRs were based on a very small number of cases (n = 8 and n = 11) and the uncertainty of these estimates is reflected in the wide confidence intervals. Melanoma was also statistically significantly increased in tracts 2032 and 2033 (SIRs of 230 and 207, respectively). Again, these analyses were based on a small number of cases and generated wide confidence intervals. There were no cases of breast cancer, melanoma, or leukemia reported in the maximum impact locations along the northern border of Marblehead in the general vicinity of Cloutman's Point, Fluen Point, and Naugus Head (within census tract 2033). In addition, none of the individual census tracks in Swampscott had significantly elevated rates of any of the three cancer types. The report concluded that there was "no pattern of increased cancer incidence or geographic concentration of cases was observed in (census tracts) in Marblehead in the likely areas of maximum impact of emissions from the SHGS."

In summary, based on the above, and based on the negligible ELCRs calculated for maximum modeled SHR Project impacts (Section 2.2), it is not expected that SHR Project air emissions will have any impact on Salem cancer incidence rates, which in general are below statewide average rates. This same conclusion also applies to neighboring communities such as Marblehead, Swampscott, Beverly, and Manchester, which also have average incidence rates for most cancers and cancer incidence rates for all cancers combined that are below the statewide average rate or that are not statistically significantly elevated above the statewide average.

4.3 Asthma

Among Schoolchildren:

MADPH periodically surveys asthma prevalence in Massachusetts school populations and issues a report entitled "Pediatric Asthma in Massachusetts."[21] The four most recent MADPH reports cover the years 2005-2006 (MADPH, 2007), 2006-2007 (MADPH, 2009a), 2007-2008 (MADPH, 2010), and 2008-2009 (MADPH, 2012a). The reports cover many Massachusetts cities and towns, including Salem. Findings from each of the three reports include the following:

- In the 2005-2006 data, the statewide average school asthma prevalence was 10.6% (ranging among schools from 0% to 43.6%), and Appendix IV of the 2004-2005 report lists Salem as 11.1% and as "not statistically different" than the statewide average of other Massachusetts communities.
- In the 2006-2007 data, the statewide average school asthma prevalence was 10.8% (ranging among schools from 0% to 43.6%), and Appendix IV of the 2006-2007 lists Salem as 11.8% and "not statistically different" than the statewide average of other Massachusetts communities.
- In the 2007-2008 data, the statewide average school asthma prevalence was 10.85% (ranging among schools from 0% to a high of 46.15%), and Appendix IV of the 2007-2008 report lists Salem as 11.9% and as "not statistically different" than the statewide average of other Massachusetts communities.
- In the 2008-2009 data, the statewide average school asthma prevalence was 10.9% (ranging among schools from 0% to 75%), and Appendix IV of the 2008-2009 report lists Salem as 11.6% and as "not statistically different" than the statewide average of other Massachusetts communities.
- The three Salem schools located closest to the proposed SHR Project site, Bentley Elementary School, Salem Academy Charter School, and Carlton School, had pediatric asthma prevalence rates that were not statistically different compared to the statewide average prevalence for 2008-2009.

It is important to note MADPH's interpretation of these school-by-school pediatric asthma statistics, including in the most recent 2012 report of 2008-2009 data (MADPH, 2012a) which states:

> [Asthma] continues to affect more than 9.1% of Americans under the age of 18...and...[w]hile there was notable variation in reported asthma prevalence between schools (range of 0-75.0%), caution should be used when comparing school prevalence estimates. It is possible that some schools with either very high or very low prevalence may be impacted by methodological differences in reporting.

MADPH (2012a) then also identifies a number of separate factors that may play a role in asthma:

> It is also important to note that a higher prevalence of asthma at one school compared with another does not necessarily indicate environmental problems within that particular school. Pediatric respiratory symptoms have been associated with a number of factors

[21] http://www.mass.gov/eohhs/consumer/community-health/environmental-health/public-health-track/asthma-env/pediatric-asthma-surveillance-in-massachusetts.html

including exposures in the outdoor environment, exposures in the home environment, genetic factors, and lifestyle factors.

With regard to the possible role of industrial emission sources such as power plants and incinerators in asthma rates, notice should be taken of a Feb. 19, 2008 report by the MADPH on "Air Pollution and Pediatric Asthma in the Merrimack Valley." In this study, MADPH analyzed whether asthma in children was associated with major stationary (point) sources of air pollution. The main finding was that the prevalence of asthma was not associated with air pollution levels from stationary sources (MADPH, 2008). In fact, the geographic areas which received the highest fraction of air pollutants from stationary sources had the lowest asthma prevalence. The close proximity of high volumes of vehicle traffic was found to be associated with increased asthma.

Findings from the MADPH Merrimack Valley study are consistent with MADPH pediatric asthma data. Three cities in Massachusetts with large power plants, namely Salem, Somerset, and Sandwich, were reported to have pediatric asthma prevalence rates of 11.6%, 9.4%, and 8.8%, respectively in 2008-2009, and 11.9%, 11.5%, and 9.04%, respectively in 2007-2008 (MADPH, 2011, 2012a). The MADPH data show that these "power-plant" towns in fact have lower pediatric asthma rates than many rural, non-industrial Massachusetts communities, where the pediatric asthma rates are often higher: (average for 2005-2009: Clarksburg = 12%; Erving = 16.3%; Monson = 20.0%; Swansea = 13.8%). The pediatric asthma rates for Marblehead, Swampscott, Beverly, Manchester, and Peabody also fall below these rural communities.

Table 4.1 Reported Asthma Prevalence (%) in Schools by Community Comparison of Communities with Large Electric-Power Generating Plants to Rural Communities

	2005-2006	2006-2007	2007-2008	2008-2009	Average	
Power-plants communities:						
Salem	11.1	11.8	11.9	11.6	11.6	
Sandwich	6.74	8.75	9.04	8.8	8.3	
Somerset	11.4	12.4	11.5	9.4	11	
AVERAGE						**10**
Other subject cities:						
Marblehead	5.47	6.23	6.67	7.1	6.4	
Swampscott	9.23	9.59	9.23	8.5	9.1	
Beverly	8.61	9.8	11.0	9.7	9.8	
Manchester	9.32	10	12.1	11.7	11	
Peabody	9.3	9.55	9.71	9.77	9.6	
AVERAGE						**9.2**
Rural:						
Clarksburg	16.8	9.8	11.37	8.0	12	
Erving	15.2	17.7	14.9	17.3	16.3	
Monson	18.5	20.0	20.6	20.7	20.0	
Swansea	14.4	13.5	13.3	14.0	13.8	
AVERAGE						**15.53**

Among Adults:

The latest Massachusetts adult health statistics are provided in "A Profile of Health Among Massachusetts Adults, 2010: Results from the Behavioral Risk Factor Surveillance System," which summarizes several chronic health conditions including asthma. Generally, the "Central" and "Western" sections of Massachusetts have the highest adult asthma prevalence (17.7% and 18.2%, respectively, for people reporting that they "ever had asthma"). The Northeast region, which includes a large area of towns as far west as Dunstable and Westford, as far North as Amesbury and Salisbury, and as far south as Medford and Everett, had an overall prevalence rate of 15.6% for those reporting that they "ever had asthma" (MADPH, 2011a).[22] Another relevant report is "Burden of Asthma in Massachusetts" (MADPH, 2009). In the most current version of this report, the North Shore Community Health Network (which includes Salem, Marblehead, Manchester, Swampscott, and Peabody in addition to Danvers, Essex, Gloucester, Hamilton, Ipswich, Lynn, Lynnfield, Nahant, Rockport, Saugus, Topsfield, and Wenham) had an adult asthma prevalence of 10.2% for the years 2003-2007. This is not statistically different from the statewide five-year average annual prevalence of current asthma among adults of 9.8%

Overall, there is no expectation that operation of the SHR Project will affect asthma prevalence or hospitalizations among either schoolchildren or adults. This conclusion is supported by the results of our public health evaluation of criteria air pollutants from SHR Project stack emissions (Section 2.1), our assessment of chronic inhalation non-cancer and cancer health risks from SHR Project air toxics stack emissions (Section 2.2), and our acute (short-term) exposure evaluation for respiratory irritants (Section 2.3), all of which support the negligible impacts of SHR Project stack air emissions to both local air quality and potential health risks. In particular, maximum modeled SHR Project 1-hour concentrations of several respiratory irritants (NO_2 and SO_2) were shown to be far below health-based acute reference values that are developed to be protective of sensitive subpopulations including asthmatics.

4.4 Cardiovascular Disease

Epidemiologic studies of ambient air pollution have reported statistical associations between levels of various criteria air pollutants, and $PM_{2.5}$ in particular, measured at centrally located monitors and cardiovascular-related mortality and morbidity (*e.g.*, hospitalizations, emergency room visits). Although these statistical associations cannot establish that a "causal link" exists, it is important to examine cardiovascular health statistics for the City of Salem, which can be obtained from the MADPH MassCHIP database (http://www.mass.gov/dph/masschip). Table 4.2 below provides cardiovascular hospitalization and cardiovascular mortality data for Salem, showing little difference between age-adjusted rates of cardiovascular hospitalizations and mortality in Salem and statewide average rates (MADPH, 2012b).

[22] http://www.mass.gov/eohhs/docs/dph/behavioral-risk/report-2010.pdf

Table 4.2 Cardiovascular Mortality and Hospitalizations Statistics for Salem (2010)[a,b]

CV Health Outcome	CV Mortality		CV Hospitalization	
	Salem 3-yr Age-adjusted Rate	State 3-yr Age-adjusted Rate	Salem 3-yr Age-adjusted Rate	State 3-yr Age-adjusted Rate
Coronary Heart Disease	118.7	109.5	1092.2	1262.7
Acute Myocardial Infarction	20.9	32.3	176.6	194.9
Cerebrovascular Disease	35.7	35.0	262.1	237.8
All Circulatory System Diseases	223.6	215.7	1507.6	1577.8

Notes:

(a) All data obtained from MADPH MassCHIP website: http://www.mass.gov/dph/masschip (MADPH, 2012b).

(b) As explained on the MassCHIP website, age-adjusted rates expressed per 100,000 persons, with standardization using the 2000 US population as the standard population.

Given the small magnitude of even the maximum modeled SHR Project impacts on area $PM_{2.5}$ levels, it is not expected that SHR Project $PM_{2.5}$ emissions will contribute significantly to cardiovascular health risks in Salem. For example, the maximum modeled SHR Project annual average $PM_{2.5}$ impacts of 0.5 $\mu g/m^3$ are <0.7% of area background $PM_{2.5}$ levels, and also approximately 0.4% of the revised health-protective annual average $PM_{2.5}$ NAAQS (12 $\mu g/m^3$) recently finalized by US EPA.

5 Conclusions

Overall, our HRA for the SHR Project has demonstrated that maximum modeled air concentrations of specific substances associated with SHR Project stack air emissions would not be expected to contribute to significant health risks among potentially affected populations. Several separate lines of evidence from our health-risk analysis support our conclusion that the air emissions from the SHR Project are not expected to pose significant public health risks in the Salem area:

1. With regard to SHR Project criteria air pollutant stack emissions, the cumulative air concentrations (maximum modeled SHR Project impact plus existing background) are below the health-protective NAAQS for the criteria air pollutants of concern, which include SO_2, CO, NO_2, and PM (Table 2.1). Therefore, emissions of criteria air pollutants from the SHR Project are not expected to have significant impacts on human health (*e.g.*, asthma, cardiovascular and respiratory diseases) in nearby communities. Furthermore, as a matter of perspective, it is important to recognize one year of cumulative exposure to maximum modeled SHR Project $PM_{2.5}$ and NO_2 concentrations is equivalent to short durations of everyday exposures that we routinely receive during common indoor and outdoor activities such as cooking, yard work, or driving in a car (Table 2.3).
2. With regard to SHR Project non-criteria pollutant (*i.e.*, air toxics) stack air emissions, the maximum modeled ground-level air concentrations are below both the MADEP 24-hour TELs and the annual-average AALs, indicating that these concentrations cannot be expected to cause adverse health effects, even in sensitive populations (Table 1.1).
3. As a matter of perspective with regard to SHR Project air toxics emissions, measurements from the Lynn and Boston air toxics monitors show that maximum modeled SHR Project impacts for metals are between about 2-fold to >350-fold below measured background levels, while for VOCs, maximum SHR Project impacts are between 276-fold and >1,500-fold below measured background levels (Table 2.4).
4. Our quantitative HRA showed that all HQs, calculated for an off-site resident exposed to maximum modeled incremental SHR Project stack impacts, were well below unity (HQ = 1), with none being higher than HQ = 0.01. The overall summed HI for SHR Project stack emissions, which makes the health-protective assumption that all chemicals act *via* the same toxic-effect pathway, is also well below 1.0 (HI = 0.08). These results help assure that non-cancer health effects are not to be expected from SHR Project air toxics emissions (Table 2.7).
5. Our quantitative HRA showed that conservatively projected lifetime cancer risks for maximum modeled incremental SHR Project stack impacts were well below the 1 in 10,000 to 1 in 1,000,000 range considered to be acceptable by US EPA. The overall summed cancer risk was about 1 in 10,000,000, which is well below the US EPA's *de minimis* risk. The individual pollutant cancer risks were each even lower than the acceptable range, between about 1 in 10,000,000,000 to about 4 in 100,000,000. These results support an absence of any significant cancer risk from worst-case chronic exposures to maximum modeled SHR Project stack impacts (Table 2.8).
6. To examine the possibility of SHR Project emissions causing short-term respiratory irritation in sensitive populations such as asthmatics, we further examined maximum modeled 1-hr concentrations of NO_2 and SO_2. We compared SHR Project maximum modeled concentrations to

short-term exposure guidelines and standards, including the short-term NAAQS for SO_2 and NO_2 which are specifically designed to protect against asthma exacerbation and respiratory irritation. The results show that both the maximum modeled SHR Project 1-hour NO_2 and SO_2 concentrations, as well as estimates of cumulative impacts (maximum 1-hr + ambient background), are below the 1-hour health-protective NAAQS as well as other short-term exposure guideline levels.

7. Based on the results of an air modeling analysis performed by Tetra Tech for a worst-case accidental release scenario (Table 3.1), storage plans for aqueous ammonia at the proposed site adequately mitigate potential human health impacts of an accidental ammonia release.
8. Our review of community health data for Salem and nearby communities indicates that the Salem area generally has similar asthma, cardiovascular, and cancer rates compared with the state of Massachusetts. While isolated individual cancer sites are elevated in some communities, there were no patterns in elevations for the entire area that would suggest a shared environmental impact. In combination with the HRA results, it is unlikely that cancer rates will be affected by SHR Project activities.

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Appendix A

Chronic Non-Cancer and Cancer Inhalation Toxicity Factors

Table A.1 Chronic Non-Cancer Inhalation Toxicity Factors and Cancer Inhalation Unit Risk Factors Used in the SHR Project Assessment

Pollutant	Chronic Noncancer Inhalation Toxicity Factors		Chronic Cancer Unit Risk Factor	
	Value ($\mu g/m^3$)	Source	Value ($\mu g/m^3$)	Source
Arsenic	0.015	CAL	0.0043	IRIS
Chromium (total)	--	--	--	--
Chromium (VI)	0.1	IRIS	0.012	IRIS
Copper	--	--	--	--
Lead	0.15	EPA OAQPS	--	--
Nickel	0.09	ATSDR	--	--
Cadmium	0.01	ATSDR	0.0018	IRIS
Mercury	0.3	IRIS	--	--
Beryllium	0.02	IRIS	00024	IRIS
Selenium	20	CAL	--	--
Vanadium	0.1	ATSDR	--	--
Formaldehyde	9.8	ATSDR	0.000013	IRIS
Acetaldehyde	9	IRIS	0.0000022	IRIS
1,3-Butadiene	2	IRIS	0.00003	IRIS
Benzene	30	IRIS	0.0000078	IRIS
Naphthalene	100	IRIS	0.000034	CAL
Sulfuric Acid	1	CAL	--	--
Ethylbenzene	1000	IRIS	0.0000025	CAL
Propylene oxide	3	IRIS	0.0000037	IRIS
p-Dichlorobenzene	800	IRIS	--	--
o-Dichlorobenzene	--	--	--	--
Toluene	5000	IRIS	--	--
Xylenes	100	IRIS	--	--
Ammonia	100	IRIS	--	--

Notes:
-- = Tox value not available
IRIS = Integrated Risk Information System; ATSDR = US Agency for Toxic Substances and Disease Registry; CA = California EPA; EPA OAQPS = Environmental Protection Agency, Office of Air Quality Planning and Standards