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# REPORT ON HEALTH STATUS OF RESIDENTS

# IN SAN LUIS OBISPO AND SANTA BARBARA COUNTIES

# LIVING NEAR THE DIABLO CANYON NUCLEAR REACTORS

# LOCATED IN AVILA BEACH, CALIFORNIA


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**TABLE OF CONTENTS**

## EXECUTIVE SUMMARY

The two Diablo Canyon nuclear power reactors (Diablo Canyon) in San Luis Obispo (SLO) County are aging. They began operation in 1984 and 1985, respectively.

They are the only California nuclear power reactors still operating to produce electricity, after the San Onofre reactors were closed in June 2013. In 2010, 465,521 people lived within 50 miles of the plant.

As of 2010, the Diablo Canyon nuclear power plant held 1126 metric tons of high-level radioactive waste, containing more radioactivity than that released during the Chernobyl disaster of 1986. Diablo Canyon emitted more highly-toxic liquid tritium into the environment than any U.S. plant during the late 2000s.

A 2013 study by the Union of Concerned Scientists concluded that the discovery of "a previously unknown earthquake fault line running as close as 2,000 feet from Diablo Canyon's two reactors…could cause more ground motion during an earthquake than the plant was designed to withstand. Since this new fault was discovered, the NRC [Nuclear Regulatory Commission] has not demonstrated that the reactors meet agency safety standards."

Average radioactive Strontium-90 (Sr-90) levels in baby teeth from San Luis Obispo and Santa Barbara counties were 30.8% greater than the Sr-90 levels in all California baby teeth tested. In the state of California, Sr-90 levels in baby teeth rose steadily, increasing 50.2% in children born in the late 1990s vs. the late 1980s. Nuclear power plants are the only current source of Sr-90 emissions into the environment.

**Major findings about local health patterns include:**

1. Since the Diablo Canyon nuclear power plant opened in the mid-1980s, San Luis Obispo County has changed from a relatively low-cancer to a high-cancer county.

2. Due to increases in the San Luis Obispo County cancer rate during 2001-2010, an additional 738 people were diagnosed with cancer.

3. Cancer incidence in San Luis Obispo County rose from 0.4% below to 6.9% above the average for the state of California during the time period of 1988-1990 to 2003-2010. The current cancer rate is the highest of all 20 counties in southern California.

4. After Diablo Canyon began operating, significant rapid increases occurred for the incidence of thyroid and female breast cancer in San Luis Obispo County, both highly radiosensitive cancers.

5. After Diablo Canyon began operating, infant mortality in San Luis Obispo County rose significantly.

6. After Diablo Canyon began operating, child/adolescent cancer mortality in the county rose rapidly.

7. Melanoma incidence in San Luis Obispo County soared from 3.6% above to 130.2% above the state incidence rate during the period from 1988-1990 to 2003-2010, and is now the highest of all California counties.

8. Cancer mortality for people of all ages in San Luis Obispo County rose from 5.1% below to 1.4% above California from 1988-1990 to 2008-2010, making SLO the 25th highest county in the state (up from 43rd highest).

9. The ratio of babies born at very low-weight (below 3 pounds, 4 ounces) rose 45.0% higher in the 9 San Luis Obispo County zip codes closest to Diablo Canyon, versus the other more distant 10 county zip codes.

10. The ratio of all-cause mortality rose 47.9% higher in the 9 San Luis Obispo County zip codes closest to Diablo Canyon, versus the other more distant 10 county zip codes.

11. In the 10 zip code areas in Santa Barbara County closest to Diablo Canyon, there was a greater rise in the rates of infant mortality (61.7%), low weight births (40.2%) and total mortality (19.1%), than in the 5 zip codes areas in the city of Santa Barbara, located approximately 90 miles from the reactors.

12. The major findings of this report show increases in various rates of disease and death in San Luis Obispo County, as compared to the state of California, since the 1980s (before plant startup and during its early years of operation). This includes increases in infant mortality, child/adolescent cancer mortality, cancer incidence for all ages (especially thyroid, female breast, and melanoma), and cancer mortality for all ages.

**Conclusions and Recommendations:**

While many factors can affect disease and death rates, the official public health data presented in this report suggest a probable link between the routine, federally-permitted emissions of radioactivity from the Diablo Canyon nuclear power plant and elevated health risks among those infants, children and adults living closest to the reactors.

These findings strongly suggest that federally-permitted radiation releases pose a health risk to the public, especially to people living near Diablo Canyon in California.

These data also correspond with earlier studies showing significant declines in local disease and death rates after the shutdown of the Rancho Seco nuclear power plant in Sacramento County in 1989.

This report should be followed by additional health studies and shared with elected officials and local citizens so that the public health implications of nuclear power are fully understood, especially as aging reactors continue to operate.

## I. Introduction

**A. Background.** Two nuclear power reactors are located at the Diablo Canyon plant in Avila Beach in San Luis Obispo County, California. The Diablo Canyon nuclear power plant (Diablo Canyon) is owned and operated by Pacific Gas & Electric (PG&E).

These reactors achieved initial criticality and began creating radioactivity on April 29, 1984 and August 19, 1985, respectively. (U.S. Nuclear Regulatory Commission, www.nrc.gov). The two Diablo Canyon nuclear units are rated to produce 1122 and 1118 megawatts of electricity, respectively, somewhat larger than the average U.S. reactor.

In 1969, the California State Assembly endorsed a plan to eventually build 63 nuclear power reactors throughout the state. (Mangano JJ, Mad Science: The Nuclear Power Experiment, New York: OR Books, 2012). From 1958 to 1975, a total of 15 reactors were formally proposed to the U.S. Atomic Energy Commission and its successor, the U.S. Nuclear Regulatory Commission (NRC).

Of these, eight (8) were cancelled, and seven (7) were completed and operated. Diablo Canyon nuclear units 1 and 2 are the only two reactors still operating in the state, after the two San Onofre nuclear units were permanently closed by Southern California Edison on June 7, 2013. Table 1 lists these reactors with information about their status.

**Table 1**
**Nuclear Power Reactors in California**

| Reactor | County | Announced | Startup | Shutdown |
|---|---|---|---|---|
| Humboldt Bay 3 | Humboldt | 2/18/58 | 2/16/63 | 7/2/76 |
| Rancho Seco | Sacramento | 8/21/67 | 9/16/74 | 6/7/89 |
| San Onofre 1 | Orange | 1/17/63 | 3/27/67 | 11/30/92 |
| San Onofre 2 | Orange | 1/27/70 | 7/26/82 | 6/7/13 |
| San Onofre 3 | Orange | 1/27/70 | 9/16/83 | 6/7/13 |
| Diablo Canyon 1 | San Luis Obispo | 11/20/66 | 4/29/84 | |
| Diablo Canyon 2 | San Luis Obispo | 2/18/68 | 8/19/85 | |
| Bodega Bay | Sonoma | 1962 | | |
| Bolsa Island 1 | Orange | 9/1/67 | | |
| Bolsa Island 2 | Orange | 9/1/67 | | |
| Mendocino 1 | Mendocino | 1972 | | |
| Mendocino 2 | Mendocino | 1972 | | |
| Malibu | Los Angeles | 1/1/60 | | |
| Sundesert 1 | Riverside | 6/1/75 | | |
| Sundesert 2 | Riverside | 6/1/75 | | |

Source: U.S. Nuclear Regulatory Commission, www.nrc.gov.

The Diablo Canyon plant is nearing 30 years of operations since startup. Like all older reactors in the U.S., some of Diablo Canyon's components have aged and corroded, increasing the chances for leaks, and possibly even a catastrophic system failure and core meltdown.

Diablo Canyon's two reactor units began operations in 1984 and 1985, respectively. Four replacement steam generators were installed in 2009 and the reactor vessel heads were replaced in 2009-2010.

American reactors were originally designed to operate no more than 40 years, so Diablo Canyon can be considered in its twilight, unless PG&E is granted a 20-year license extension by the U.S. Nuclear Regulatory Commission (NRC).

A recent report by the Union of Concerned Scientists concluded that the discovery of "a previously unknown earthquake fault line running as close as 2,000 feet from Diablo Canyon's two reactors…could cause more ground motion during an earthquake than the plant was designed to withstand. Since this new fault was discovered, the NRC has not demonstrated that the reactors meet agency safety standards." (Union of Concerned Scientists, Seismic Shift: Diablo Canyon Literally and Figuratively on Shaky Ground, Washington, DC, November 13, 2013).

According to an analysis by NBC News, which used 2010 Census data, 26,123 persons live within 10 miles of the plant, a 50.2% rise from a decade earlier. In addition, 465,521 persons live within 50 miles, an increase of 22.4%. (Bill Dedman, Nuclear neighbors: Population rises near US reactors, *msnbc.com*, April 14, 2011. Accessed on January 13, 2014 at http://www.msnbc.msn.com/id/42555888/ns/us_news-life/).

**B. <u>San Luis Obispo County</u>.** Diablo Canyon is located in San Luis Obispo (SLO) County, California. Its neighboring county, Santa Barbara County, lies to the southeast, downwind from the Diablo Canyon reactors.

San Luis Obispo County's population is currently 274,804 (2012 U.S. Census estimate), with the largest cities being San Luis Obispo (12 miles north of the plant), Paso Robles (31 miles north of the plant), and a small part of Santa Maria (15 miles southeast of the plant, with most of the remainder of the city in Santa Barbara County).

San Luis Obispo County's population grew rapidly from 1940 to 1990; the population is still rising, but at a much slower rate (Table 2):

**Table 2**
**Population, San Luis Obispo County, 1940 – 2012**

| Year | Population | % Change |
|---|---|---|
| 1940 | 33,246 | ---- |
| 1950 | 51,417 | +54.7% |
| 1960 | 81,044 | +57.6% |
| 1970 | 105,690 | +30.4% |
| 1980 | 155,435 | +47.1% |
| 1990 | 217,612 | +39.7% |
| 2000 | 246,681 | +13.6% |
| 2010 | 269,637 | + 9.3% |
| 2012 (est.) | 274,804 | + 9.5% |

Source: U.S. Bureau of the Census, www.census.gov, state and county quick facts.

The county includes 19 zip code areas, some of which overlap into other counties. The 2000 and 2010 populations of each of these zip code areas are given in Table 3.

**Table 3**
**Population, San Luis Obispo County**
**By Zip Code, 2000 and 2010**

| Zip | Principal Town/City | 2000 Pop. | 2010 Pop. |
|---|---|---|---|
| 93401 | San Luis Obispo | 27,034 | 28,033 |
| 93402 | Los Osos | 14,842 | 14,318 |
| 93405 | San Luis Obispo | 31,972 | 35,440 |
| 93420 | Arroyo Grande | 24,482 | 28,413 |
| 93422 | Atascadero | 29,532 | 31,375 |
| 93424 | Avila Beach | 797 | 1,261 |
| 93428 | Cambria | 6,515 | 6,314 |
| 93430 | Cayucos | 3,212 | 2,972 |
| 93432 | Creston | 1,193 | 1,384 |
| 93433 | Grover Beach | 13,099 | 13,162 |
| 93434 | Guadalupe | 5,724 | 7,110 |
| 93442 | Morro Bay | 10,891 | 10,789 |
| 93444 | Nipomo | 15,391 | 19,244 |
| 93445 | Oceano | 7,422 | 7,173 |
| 93446 | Paso Robles | 35,578 | 43,714 |
| 93449 | Pismo Beach | 8,562 | 7,657 |
| 93453 | Santa Margarita | 2,678 | 2,899 |
| 93461 | Shandon | 1,254 | 1,623 |
| 93465 | Templeton | 7,901 | 9,253 |
| TOTAL | | 248,079 | 272,134 |

Source: U.S. Bureau of the Census, http://www.zip-codes.comn/zip-code/93401/zip-code-93401-census-comparison.asp.

In Table 3, zip codes only partially in San Luis Obispo County are not included. Based on the fact that zip code areas do not always confirm to county lines, population totals are slightly higher than actual county population. (*See Appendix 2 and 3 for zip code maps for San Luis Obispo and Santa Barbara Counties*),

Certain demographic characteristics of San Luis Obispo County are presented in Table 4. These are important, since they may affect the health status of county residents.

**Table 4**
**Selected Demographic Characteristics**
**San Luis Obispo County vs. California**

| Characteristic | San Luis Obispo | California |
|---|---|---|
| 2012 population (est.) | 274,804 | 37,999,878 |
| 2010 population (actual) | 269,637 | 37,253,959 |
| 2010-2012 pop. Change | +1.9% | +2.0% |
| 2012 % pop. <18 yrs. | 18.3% | 24.3% |
| 2012 % pop. >65 yrs. | 16.2% | 12.1% |
| 2012 % pop. Female | 48.9% | 50.3% |
| 2012 % White non-Hispanic | 70.2% | 39.4% |
| 2012 % Hispanic | 21.5% | 38.2% |
| 2012 % Black | 2.3% | 6.6% |
| 2012 % Asian | 3.7% | 13.9% |
| 2012 % Other | 2.3% | 1.9% |
| 2008-12 % other than English Spoken at home, age 5+ | 17.3% | 43.5% |
| 2008-12 % HS grad., age 25+ | 89.5% | 81.0% |
| 2008-12 % Coll grad., Age 25+ | 31.5% | 30.5% |
| 2008-12 % < poverty | 13.7% | 15.3% |
| 2008-12 Median household income | $59,628 | $61,400 |

Source: U.S. Census Bureau. www.census.gov, state and local quick facts

In some ways, San Luis Obispo County can be considered a low-risk area for health problems. It has a much lower proportion of Hispanics than does the state of California as a whole (21.5% vs. 38.2%). Hispanics, many of whom are recent immigrants from other nations, tend to be of lower socioeconomic status. Both socioeconomic status and language barriers can limit knowledge of preventive health methods and access to health services.

But, the county also has a lower proportion of Asians than the state (3.7% vs. 13.9%). Asians tend to have higher socioeconomic status and lower rates of disease and death. Thus, the racial/ethnic mix may, or may not, affect county-state morbidity and mortality comparisons.

The county's adults are only slightly more educated than those in the state of California as a whole. The county poverty rate and median household income are nearly the same as the state, and will not affect any county-state comparisons of morbidity and mortality. This comparison does not show any clear indication that San Luis Obispo County morbidity and mortality rates will be higher or lower than the state of California due to demographic differences.

**C. Radioactive Waste.** To produce electricity, nuclear power reactors split uranium-235 atoms, generating high energy to heat water into steam that is transformed into electrical power via turbines. This atom-splitting process, known as fission, produces over 100 radioactive chemicals not found in nature. These radioactive chemicals are similar to those found in the fallout generated by above-ground atomic bomb tests during the Cold War years, which were banned in 1963 under the Nuclear Test Ban Treaty.

These chemicals, which take the form of gases and particles, include Cesium-137, Iodine-131, and Strontium-90. They are highly unstable atoms which emit alpha particles, beta particles, or gamma rays. When they enter the body, they can harm various organs. Cesium seeks out the muscle and soft tissue (including the heart and reproductive organs); iodine attacks the thyroid gland; and strontium attaches to teeth and bone and penetrates into bone marrow. Each of these radioactive isotopes raises cancer risk by breaking cell membranes and damaging cell DNA to create mutations−which are especially harmful to the fetus, infant, and child. Some isotopes decay and disappear quickly (Iodine-131 has a half life of 8.05 days), while others remain in the body for decades (Strontium-90 has a half-life of 28.7 years).

The high-level radioactivity produced by nuclear reactors is contained in fuel rods assemblies, located in the reactor core or stored underwater in spent fuel pools. At aging U.S. reactors, these spent pools are becoming full. At Diablo Canyon, approximately 67% of the spent fuel assemblies (each containing 200 or more fuel rods) are stored in the spent fuel pools, while the other 33% have been transferred to safer, above-ground, outdoor "dry cask" storage.

As of December 2010 **Diablo Canyon maintained 1,126 metric tons of radioactive waste on site** (19th highest of 65 U.S. nuclear plants). The 221,558,400 curies of radioactivity at the plant exceeds estimates of the 150,000,000 curies released by the April 26, 1986, Chernobyl explosions and meltdown in the former USSR, and is hundreds of times more than that released by the atomic bombs dropped on Hiroshima and Nagasaki Japan in 1945. A curie represents the disintegration of atomic particles, and is a standard measure of radioactivity. (Alvarez R., Spent Nuclear Fuel Pools in the U.S.: Reducing the Deadly Risks of Storage. Institute for Policy Studies, May 2011).

In 2002, after decades of investigation, the federal government designated Yucca Mountain in Nevada as a permanent hi-level waste storage site. But in 2010, the Obama administration stopped all expenditures for building the site, and assembled a panel to further consider options for long term waste storage. Some experts believe a permanent repository will never open, leaving the 100 U.S. existing nuclear plants, including Diablo Canyon, with the responsibility of maintaining large volumes of highly-toxic, high-level radioactive waste on-site, indefinitely.

## II. Health Hazards Posed by Reactor Meltdowns

**A. Description.** Much of the health concern posed by nuclear reactors focuses on meltdowns. The radioactive fuel rods in a reactor core and waste pools must be constantly cooled by water, or they will heat up rapidly, possibly leading to a loss of coolant, explosions and/or a main steam line rupture, resulting in a huge release of radioactivity. Meltdowns can be caused by mechanical failure/human error (as occurred at Chernobyl in 1986), by act of nature (as in the case of the earthquake/tsunami at Fukushima in 2011), or by an act of sabotage.

The experience at Hiroshima and Nagasaki demonstrated how exposure to high levels of radioactivity can harm humans. Those closest to the bombs were vaporized, literally melting from the intense heat. But many other victims who survived the initial blast developed acute radiation poisoning, marked by symptoms such as nausea, vomiting, diarrhea, skin burns, weakness, dehydration, bleeding, hair loss, ulcerations, bloody stool, and skin sloughing (falling off). In addition, unexpectedly large numbers of bomb survivors in the two cities developed cancers over the following decades; thyroid and breast cancer had the greatest excesses. (Thompson DE et al. Cancer Incidence in Atomic Bomb Survivors, Part II: Solid Tumors, 1958-1987, Radiation Effects Research Foundation, Hiroshima Japan, 1994).

Previous meltdowns have demonstrated that large numbers of casualties will result. In 2009, after the World Health Organization estimated that 9,000 lifetime cancer deaths would occur worldwide from Chernobyl, Russian researchers assembled a book that referenced 5,000 articles and reports not widely known in the West, most in Slavic languages.

**The team estimated that by 2004, Chernobyl had caused 985,000 deaths in the former Soviet Union and Europe.** Near Chernobyl, the research found elevated disease levels covering nearly all organ systems, including circulatory, endocrine, immune, respiratory, urogenital/reproductive, musculoskeletal, nervous, eye, and digestive systems. (Yablokov AV, Nesterenko VB, Nesterenko AV., Chernobyl: Consequences of the Catastrophe for People and the Environment, New York: New York Academy of Sciences, 2009).

Even the 1979 Three Mile Island accident near Harrisburg, PA, which was a partial meltdown with much lower radiation releases than Chernobyl, resulted in significant casualties. In the first five years after the disaster, the number of residents living within 10 miles diagnosed with cancer rose 64%, from 1,722 to 2,831. (Hatch MC et al., Cancer Near the Three Mile Island Nuclear Plant., American Journal of Epidemiology 1990, 132:3:397-412). In addition, the infant death rate in Dauphin County, PA, rose 54% in the two years after the meltdown (vs. the two years prior), and rose in 13 of 19 counties in the northeast direction, downwind from the nuclear plant. (Mangano JJ, Three Mile Island: Health Study Meltdown Bulletin of the Atomic Scientists, 2004, 60(5):30-35).

The catastrophe at Fukushima in March 2011 is so recent that very few studies on health consequences have been published. But already, scientists from Fukushima Medical University have found that 46% of 233,000 local children under age 18 have pre-cancerous thyroid nodules or cysts. (Fukushima Voice, 26 Thyroid Cancer Cases Confirmed in Fukushima Children: Preliminary Results of FY 2011-2013 Thyroid Ultrasound Examination, November 12, 2013, http://fukushimavoice-eng2.blogspot.com/2013/11/26-thyroid-cancer-cases-confirmed-in.html).

In addition, 75 children have been diagnosed with, or are suspected to have, thyroid cancer. (The Japan Times, Eight More Fukushima Kids Found with Thyroid Cancer, Disaster Link Denied, http://www.japantimes.co.jp/news/2014/02/07/nationaleight-more-fukushima-kids-found-with-thyroid-cancer-disaster-link-denied/#,UvUJ90nTkqQ). This total of 75 cancer cases compares to just two expected in a normal population of children. (National Cancer Institute. SEER Cancer Statistics Review, 1975-2010, http://www.seer.cancer.gov/csr/1975_2010/results_merged/sect_26-thyroid.pdf). The eventual casualties from Fukushima will take decades to manifest, but the totals will be extremely large, possibly on the order of those from Chernobyl.

**B. Estimates of Casualties.** If a meltdown resulting in large scale releases of radioactivity from the reactor core or the spent pools occurred at Diablo Canyon, many would suffer from acute radiation poisoning (short term) and cancer (long term). In 1982, the Sandia National Laboratories submitted estimates to Congress for each U.S. nuclear plant in the case of core meltdown. The Sandia figures are known as CRAC-2 (Calculation of Reactor Accident Consequences).

Within 17.5 miles of Diablo Canyon, 22,000 acute radiation poisoning cases (10,000 fatal) would be expected; and within 35 miles, 12,000 cancer deaths would occur. Estimates would be much larger today, since the local population has grown sharply since these calculations were made, which used 1980 census figures. The San Luis Obispo County population has nearly doubled since 1980 (Table 2). (Sandia National Laboratories, Calculation of Reactor Accident Consequences (CRAC-2) for U.S. Nuclear Power Plants, prepared for U.S. Congress, Subcommittee on Oversight and Investigations, Committee on Interior and Insular Affairs., November 1, 1982; published in New York Times and Washington Post the following day).

In a 2004 report, Dr. Edwin S. Lyman updated the CRAC-2 estimates for the case of the Indian Point nuclear power plant, located on the Hudson River, about 35 miles north of Times Square in New York City−an area with a much greater population density than that surrounding the Diablo Canyon reactors. The report presents the result of an independent analysis of the health and economic impacts of a terrorist attack at Indian Point which results in a core meltdown and in a large radiological release to the environment.

Dr. Lyman states, "We find that, depending on weather conditions, an attack could result in as many as 44,000 near-term deaths from acute radiation syndrome or as many as 518,000 long-term deaths from cancer among individuals within 50 miles of the plant. The report also estimated economic damages within 100 miles as great as $2.1 trillion with millions of people requiring permanent relocation." (Edwin S. Lyman, Ph.D., Chernobyl on the Hudson: The Health and Economic Impacts of a Terrorist Attack at the Indian Point Nuclear Plant, Union of Concerned Scientists, September 2004).

## III. ACTUAL RADIOACTIVITY RELEASED FROM DIABLO CANYON

**A. Official Radioactive Releases to the Environment**. The U.S. Environmental Protection Agency (EPA) sets "permissible limits" of radioactive emissions from reactors and radioactive concentrations in the environment near reactors. The U.S. Nuclear Regulatory Commission (NRC) mandates that all nuclear power plant operators issue annual reports on these emissions and environmental concentrations by type of radioactivity released.

For years, there have been concerns about these "permissible" limits, as many scientific papers have shown that all radiation exposures have a health risk. The National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation (BEIR) reached this conclusion in its 1990 and 2005 reports, based on hundreds of studies. The concern of many scientists and citizens is that "permissible" doses are not "safe" doses.

From 1973 to 1993, the Brookhaven National Laboratories collected and disseminated comparative data for each nuclear plant on airborne emissions of “Iodine-131 and effluents,” which are radioactive chemicals with a half life of at least eight days, and most likely to enter the food chain and the body.

During this period (which covers 1984-93, when the reactors operated), Diablo Canyon emitted $9.587^{-3}$ curies of I-131 and effluents, which was typical of U.S. reactors. Routinely-produced comparisons of all U.S. plants were halted after 1993 by the U.S. government. (Tichler J, Doty K, Lucadamo K., Radioactive Materials Released from Nuclear Power Plants, NUREG/CR-2907, Upton NY: Brookhaven National Laboratories, annual reports).

More recent data on radioactive emissions into the environment are posted on the NRC website for each year, from 2000 to 2009, by quarter, for most U.S. reactors. The data include several types of airborne and liquid emissions. (U.S. Nuclear Regulatory Commission, Effluent Database for Nuclear Power Plants, www.reirs.com/effluent).

These NRC emissions data have significant limitations. Comparisons of levels for all reactors and plants are not given, making the production of comparisons by reactor, or by nuclear plant, an extremely resource-intensive undertaking. Some years are missing for some reactors, and often the letters “ND” are given, indicating that the levels of radioactivity were “not detectable.”

Table 5 below shows annual amounts of five types of radioactivity (three airborne, two liquid) released from Diablo Canyon’s reactors for each year from 2000-2009. This table was constructed for this report, using the data provided on this NRC website. The data are reported in curies. A “curie” is a unit of radioactivity, corresponding to $3.7 \times 10^{10}$ disintegrations per second

**Table 5**
**Annual Releases, Various Types of Radioactivity**
**From Diablo Canyon, in Curies, By Year, 2000-2009**

| | Airborne | | Liquid | | |
|---|---|---|---|---|---|
| Year | Fission + Activation Products | Tritium | Dissolved + Entrained Gas* | Fission + Acti-vation Products | Tritium |
| 2000 | 25.32 | 221.1 | .002764 | .14860 | 1797 |
| 2001 | 39.36 | 220.2 | .001878 | .16040 | 1095 |
| 2002 | 30.48 | 306.7 | .012549 | .13230 | 1374 |
| 2003 | **133.92** | 246.2 | .014010 | .13960 | 913 |
| 2004 | 6.11 | 303.1 | .000475 | **.22060** | 1629 |
| 2005 | 0.93 | 245.9 | .001396 | .11830 | **2951** |
| 2006 | 0.28 | 235.5 | .007245 | .04668 | 1496 |
| 2007 | 1.61 | 203.7 | **.114176** | .05648 | **3204** |
| 2008 | 53.81 | 159.5 | **.249215** | .02891 | 2406 |
| 2009 | 12.69 | 196.2 | .016350 | .04317 | 2100 |
| 2000-04 | 235.19 | 1297.30 | .031676 | .80150 | 6808 |
| 2005-09 | 69.32 | 1046.30 | .388382 | .29354 | 12157 |

Source: U.S. Nuclear Regulatory Commission, Effluent Database for Nuclear Power Plants, www.reirs.com/effluent.

* Liquid emissions of dissolved and entrained gas not given for the following quarters: 1st quarter 2002, 3rd quarter 2004, 1st quarter 2005, and 3rd quarter 2006.

Annual trends in emission levels are highly irregular. **From the first to the second half of the 2000s, total emissions increased by more than 10 times for liquid dissolved and entrained gas, and nearly doubled for liquid tritium**.

During the same interval, decreases were observed for airborne and for liquid fission and activation products, along with airborne tritium. Certain years are observed to be much higher or lower than the norm, indicating that emissions follow "hot" or "cold" patterns, instead of a regular amount.

Table 6 below, which was prepared for this report, lists the plants with the highest emissions for three types of radioactivity in years in which Diablo Canyon had high release amounts.

**Table 6**
**U.S. Nuclear Plants with Greatest Emissions**
**Selected Types of Radioactivity and Selected Years, in Curies**

| Plant | State | Curies |
|---|---|---|
| 2002 AIRBORNE TRITIUM (of 61 U.S. plants) | | |
| 1. Palo Verde | AZ | 1666.5 |
| 2. Pilgrim | MA | 690.0 |
| 3. Salem/Hope Creek | NJ | 409.2 |
| **4. Diablo Canyon** | **CA** | **306.7** |
| 5. McGuire | NC | 261.9 |
| 2004 LIQUID FISSION AND ACTIVATION PRODUCTS (of 52 U.S. plants) | | |
| 1. Callaway | MO | .33940 |
| 2. Fort Calhoun | NE | .27634 |
| 3. Sequoyah | TN | .23870 |
| 4. Arkansas 1-2 | AR | .22648 |
| **5. Diablo Canyon** | **CA** | **.22060** |
| 2007 LIQUID TRITIUM (of 52 U.S. plants) | | |
| **1. Diablo Canyon** | **CA** | **3204** |
| 2. Sequoyah | TN | 1872 |
| 3. San Onofre | CA | 1817 |
| 4. McGuire | NC | 1633 |
| 5. Indian Point | NY | 1468 |

Source: U.S. Nuclear Regulatory Commission, Effluent Database for Nuclear Power Plants, www.reirs.com/effluent.

Diablo Canyon released the 4th highest amount of airborne tritium of 61 U.S. plants reporting data in 2002, and the 5th highest amount of liquid fission and activation products, of 52 plants reporting data in 2004. The plant also emitted the most liquid tritium into the environment in 2007, of 52 U.S. plants reporting data, with 3,204 curies; the next highest total was 1,872. Diablo Canyon totals for 2005, 2006, 2008, and 2009 appear to be among the highest in the U.S. for these years as well. **Diablo Canyon released more liquid tritium into the environment than any other U.S. nuclear plant in recent years**.

In summary, official NRC data on environmental releases of radioactivity from U.S. nuclear reactors are relatively limited. But the data that are available raise significant questions about the safety of Diablo Canyon, especially as its reactors age.

**B. <u>Official Radioactivity Levels in the Environment</u>.** The U.S. Environmental Protection Agency (EPA) makes levels of environmental radioactivity at various sites in the U.S. publicly available. Measurements in air, water, and milk are included. The web site, called "Envirofacts," can be accessed at http://oaspub.epa.gov/enviro/erams_query.simple_query, and covers measurements taken since 1978.

One of the stations in the EPA program is located at Diablo Canyon. Unfortunately, measurements are very limited, and only provided for radioactivity in surface water in the Pacific Ocean from 1978 to 1998. Furthermore, radioactivity levels for specific isotopes are very infrequent, and all measurements end in 1998 (for reasons unknown). The isotope with the largest number of measurements is tritium (H-3), with 76 readings.

The first 65 readings (1978-1995) for surface water in the Pacific Ocean near Diablo Canyon were given only to the nearest 100 (100, 200, etc.) picocuries per liter. Thus, the number "100" represents a reading in between 0 to 100. Only the final 11 measurements, available from 1995-1998, offer exact numbers. The highest number for the first 74 measurements was 500 (actually 400-500) picocuries of tritium per liter of water (October 9, 1979). However, the concentrations for the final two readings were 1,892 and 965 (September 29 and December 28, 1998), far greater than any measurement in the past 20 years. This finding strongly indicates that **there are "hot" periods of radioactive releases from Diablo Canyon.**

**C. <u>Radioactivity Levels in the Body</u>.** In the 1950s and 1960s, Washington University and the Greater St. Louis Committee for Nuclear Information collected 320,000 baby teeth, and tested them for levels of radioactive Strontium-90 (Sr-90), released only in atomic bomb tests and nuclear reactor emissions. The St. Louis study found that, for children born in 1964, just after above-ground bomb testing ended, the average Sr-90 level was about **50 times greater** than for those born in 1950, just before testing began. After above-ground atom bomb tests were banned in 1963, Sr-90 averages declined about 50% from 1964 to 1969. (Rosenthal H.L., Accumulation of Environmental 90Sr in Teeth of Children, Hanford Radiobiological Symposium, Richland WA, May 1969, 163-171).

From 1961-1982, the U.S. Atomic Energy Commission, later the U.S. Department of Energy, operated a program measuring Sr-90 concentrations in the vertebrae of 100 healthy adults in San Francisco and New York City who had died in accidents each year. (Klusek, CS, Strontum-90 in Human Bone in the U.S., 1982. New York: Department of Energy Environmental Measurements Laboratory, 1982). The Department of Energy terminated this program in 1982. Since then, the U.S. has been without a systematic government program of testing humans for radioactivity levels in their bodies.

From 1996 to 2006, the Radiation and Public Health Project (RPHP), a nonprofit research group conducted a baby tooth study measuring Sr-90 levels. The study was patterned on the St. Louis effort, which provided historical data on Sr-90 levels in the U.S. **To date, the RPHP study of Sr-90 in baby teeth remains the only analysis of in-body radioactivity for Americans living near nuclear reactors.**

RPHP collected and tested, at an independent laboratory, nearly 5000 baby teeth, mostly from California, Connecticut, Florida, New Jersey, New York, and Pennsylvania. It found a consistent pattern of elevated (30 to 50% higher) Sr-90 in baby teeth of children born in counties closest to nuclear power reactors, and a 49% rise in Sr-90 for children born in the late 1990s vs. the late 1980s. (Mangano, JJ et al., An unexpected rise in strontium-90 in US deciduous teeth in the 1990s, The Science of the Total Environment, 2003, 317:37-51).

**In California, the average Sr-90 level in baby teeth rose steadily, increasing 50.2% for children born in 1994-97 vs. children born in 1986-89**. The average increased from 93 to 139 millibecquerels of Sr-90 per gram of calcium (Table 7). The average Sr-90 levels had been falling since the mid-1960s (after the cessation and peak of above-ground atom bomb testing in 1963), when levels began to rise again in the 1980s and 1990s. **This rise in Sr-90 in teeth can only be due to a current source of radioactivity: relatively rare accidental releases of radioactivity, or routine, federally-permitted emissions of radioactivity, from all U.S. operating nuclear reactors, including Diablo Canyon**.

**Table 7**
**Average Strontium-90 Concentrations in Baby Teeth**
**In Millibecquerels Sr-90 per Gram of Calcium**
**California, Births 1982-1985 to 1994-1997**

| Birth Period | No. Teeth | Average Sr-90 | Std. Error |
|---|---|---|---|
| 1982-1985 | 12 | 104 | +/- 31 |
| 1986-1989 | 50 | **93** | +/- 14 |
| 1990-1993 | 53 | **112** | +/- 16 |
| 1994-1997 | 20 | **139** | +/- 32 |
| % Ch. 1986-1989 to 1994-1997 | | **+50.2%** | |

Source: Mangano JJ et al, An unexpected rise in strontium-90 in US deciduous teeth in the 1990s, The Science of the Total Environment, 2003:317:37-51.

The average of 93 for 1986-1989 births represented the end of a long decline since the mid-1960s, the peak of atmospheric atom bomb testing. But at the end of the 1980s, the decline changed to an increase, in California and elsewhere.

A substantial number of California baby teeth were collected from the two counties closest to Diablo Canyon. **The Sr-90 concentration in 50 baby teeth from San Luis Obispo and Santa Barbara counties−mostly San Luis Obispo County − was 127 millibecquerels per gram of calcium, or 30.8% greater than the Sr-90 levels of 97 millibecquerels in the 88 baby teeth from the rest of California**. (Mangano, JJ et al., An unexpected rise in strontium-90 in US deciduous teeth in the 1990s, The Science of the Total Environment 2003, 317:37-51).

## IV. HEALTH RISKS OF DIABLO CANYON

**A. Introduction.** Since the atomic era began in the 1940s, scientists have studied health effects of exposures to man-made radioactivity. Elevated levels of illness and death are attributed to the Hiroshima and Nagasaki bombs in Japan; to bomb tests in Nevada, the South Pacific, and the former Soviet Union; and to the 1986 accident at the Chernobyl nuclear power plant, also located in the former USSR. Research on effects of the 2011 meltdown at Fukushima, Japan is just emerging. Each of these involved relatively high levels of exposure to radioactivity.

In addition, researchers have addressed effects of relatively low doses of radioactivity. The first to document hazards of low-dose exposures was British physician Alice Stewart. In the 1950s, Stewart showed that pelvic X-rays to pregnant women nearly doubled the chance the baby would die of cancer before age 10. (Stewart AM, Webb J, and Hewitt D., A Survey of Childhood Malignancies. British Medical Journal, 1958, i:1495-1508).

Studies of low-dose exposures near nuclear reactors often focus on cancer in children. Radioactive chemicals are known to be more harmful to the young, particularly the developing fetus and infant. Body growth and cell division is most rapid early in life. Thus a damaged fetal or infant cell will replicate into other damaged cells before the cell can self-repair, more quickly than a damaged adult cell. **There are at least 19 medical journal articles that identify elevated child cancer rates near different nuclear sites, mostly nuclear power plants (Appendix 1).**

**B. 1990 Federal Study of Cancer Close to U.S. Nuclear Plants**. The federal government does not require health studies of populations living near nuclear plants. The only large-scale federal study on cancer near nuclear reactors was prepared by the National Cancer Institute (NCI) in 1990, after Senator Edward M. Kennedy wrote to National Institutes of Health director James Wyngaarden about an article on elevated leukemia rates near the Pilgrim plant in Massachusetts. The NCI concluded there was no link between cancer risk and proximity to reactors. (Jablon, S. et. al., Cancer in Populations Living Near Nuclear Facilities, Washington DC: U.S. Government Printing Office, 1990). Diablo Canyon was not included in this study, since the NCI only included nuclear plants operating before 1982.

The NCI study has been criticized for using *mortality data* for all 62 nuclear plants included in this research (the only available *incidence data* were near four plants in Connecticut and Iowa). Because of advances in medical treatment, many cases are successfully treated for some cancers, including the radiation-sensitive childhood cancer and thyroid cancer. Thus, mortality data are much less useful than incidence data. Another critique is that the latest data in the NCI study are for 1984, meaning the study is outdated. Finally, the study compared "study" counties (closest to nuclear plants) with "control" counties (distant from nuclear plants) – even though the control counties were often those *adjacent* to the county where a reactor was located. This methodology overlooks the fact that radiation does not abruptly stop at the county line.

In May 2009, the U.S. Nuclear Regulatory Commission published a notice in the *Federal Register*, announcing it was pursuing a new study of cancer near nuclear plants. After dropping its initial choice of subcontractor (Oak Ridge Associated Universities), the NRC selected the National Academy of Sciences (NAS) to conduct the study. The NAS has convened a panel to assess the feasibility of such a study, and to conduct and present it. However, there will be no public release of the study until at least 2016.

**C. <u>Defining Closest Areas</u>.**

Defining which areas are most likely to be harmed by toxic emissions from Diablo Canyon is difficult, since no data are available on how much radiation is actually taken up in human bodies, except for the RPHP study of Strontium-90 in baby teeth. The people most affected are usually those proximate and/or downwind from a nuclear plant. The prevailing wind direction in the Diablo Canyon area (near San Luis Obispo city) is from the northwest, which means that radiation releases are most likely to be dispersed toward the southeast, in the direction of southern San Luis Obispo County and northern Santa Barbara County.

The areas most likely to be affected by radioactive chemicals released by Diablo Canyon are:

1. San Luis Obispo County, in its entirety.

2. San Luis Obispo County, in those nine (9) zip code areas closest to the plant. These nine zip codes, which include areas roughly 15 miles from the plant, plus two proximate downwind zip code areas, include: 93401 (San Luis Obispo), 93402 (Los Osos), 93405 (San Luis Obispo), 93424 (Avila Beach), 93433 (Grover Beach), 93434 (Guadalupe), 93442 (Morro Bay), 93445 (Oceano), and 93449 (Pismo Beach).

3. Santa Barbara County, in those ten (10) zip codes in those northern (downwind) counties, closets to Diablo Canyon. These ten zip codes are 93117 (Goleta), 93427 (Buellton), 93429 (Casmalia), 93436 (Lompoc), 93437 (Lompoc), 93440 (Los Alamos), 93455 (Santa Maria), 93458 (Santa Maria), 93460 (Santa Ynez), and 93463 (Solvang).

The public health status indicators analyzed for this study include those which are most radiation-sensitive, including those affecting the fetus and infant, cancer rates, and mortality rates from all causes.

**D. <u>Child Mortality, Before and After Diablo Canyon Startup</u>.** As noted, Diablo Canyon's two reactors began operating in 1984 and 1985. Thus, it is logical to address the question of changes in local morbidity (disease) or mortality (death) rates before and after startup. The 1990 National Cancer Institute study of cancer near nuclear plants, which remains the only U.S. government analysis of nuclear plants in the U.S., used this methodology.

Pre-1984 (pre-startup) data are available on the U.S. Center for Disease Control and Prevention's web site (http://wonder.cdc.gov). The site provides annual data on mortality by county for each year from 1968 to 2010, making a before-and-after analysis possible.

This report examines changes in radiation-sensitive mortality measures in San Luis Obispo County vs. the State of California, comparing the "pre-startup" period of 1979-1983 to the "post-startup" period of 1984-2010. (Through this report the terms "State of California," "state" and "California" are used interchangeably. When used in comparison to populations living in SLO or Santa Barbara Counties (i.e., "verses" or "vs."), the terms "vs. the state" or "vs. California" refer to the relevant average data for the state as a whole.)

Infant mortality (deaths under one year per 100,000 live births) in San Luis Obispo County and California should be analyzed before and after Diablo Canyon startup, using the periods 1982-1983 vs. 1984-1985. The fetus and infant are most susceptible to radiation exposure, and health hazards are much more likely to have an immediate impact in these groups.

**In the first two years after Diablo Canyon startup vs. the prior two years, the local infant mortality rate increased 8.0%, from 36 to 41 deaths under age one, compared to a 3.2% decrease for California**. The county's infant death rate rose from -23.7 to -14.9% below the state rate−an increase of 11.5%. These differences are not statistically significant due to the small number of deaths involved. But this short-term change in a highly susceptible population (infants) suggests that long-term analyses of morbidity/mortality changes are merited. (U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov).

Data on long-term changes in county vs. state infant mortality, before and after Diablo Canyon startup, are available. Table 8 shows the difference during the five years immediately before startup (1979-1983) compared to all years after startup (1984-2010).

The period 1979-1983 was selected as the period before Diablo Canyon startup, since it more closely describes health status when the plant began operating. Table 8 also includes perinatal (<28 days) mortality. About two thirds of infant deaths occur in the first month of life.

**Table 8**
**Infant and Perinatal Mortality – Long Term Changes**
**Before and After Startup of Diablo Canyon**
**San Luis Obispo County vs. California, 1979-1983 vs. 1984-2010**

| | Deaths/100,000 Births (no. deaths) | | |
|---|---|---|---|
| Area | 1979-83 (before) | 1984-2010 (after) | % Change Rate |
| **INFANT MORTALITY (DEATHS < 1 YEAR)** | | | |
| San Luis Obispo | 761.31 ( 85) | 572.77 ( 403) | **- 24.8%** |
| California | 1038.74 (21493) | 666.21 (95403) | **- 35.9%** |
| County vs. State Rate | **-26.7%** | **-14.0%** | **+17.3%*** |

**PERINATAL MORTALITY (DEATHS < 27 DAYS)**

| | | | |
|---|---|---|---|
| San Luis Obispo | 447.83 ( 50) | 366.69 ( 258) | **- 18.1%** |
| California | 669.22 (13847) | 427.51 (60990) | **- 36.2%** |
| County vs. State Rate | **-33.1%** | **-14.2%** | **+28.2%**** |

Source: U.S. Centers for Disease Control and Prevention. http://wonder.cdc.gov.
* = significant at p<.03; ** = significant at p<.02.

The SLO County decrease in infant mortality was just 24.8%, compared to a 35.9% drop for California. This difference is statistically significant (p<.03), due to the large number of infant deaths (403) in San Luis Obispo County during the first 27 years of reactor operations. The local infant mortality rate was 26.7% below the state rate for the period 1979-1983, but climbed to just 14.0% below thereafter.

The county decrease in perinatal mortality was also much less than the state's (-18.1% vs. -36.2%). This difference was also statistically significant at p<.02. The pre-startup county rate was 33.1% below the state, but since has been just 14.2% less. **Infant mortality in San Luis Obispo County, which was far below the California rate before Diablo Canyon began operating, is now approaching the California rate.**

A final observation about infant mortality is how the San Luis Obispo County rate compares to the state by ethnicity. The 2004-2010 San Luis Obispo County infant death rate for white non-Hispanics (Caucasian) is 15.4% below that of California, but 0.6% above the state for white Hispanics. From 1999-2000 to 2009-2010, the number of white Hispanic births in the county jumped 48%, from 1,307 to 1,933. If the trend of more white Hispanic births with infant death rates above the state continues, the county's infant death rate, well below the state for decades, may soon draw even with California.

Probably the most commonly-used measure of adverse health consequences resulting from exposure to radiation is childhood cancer. As mentioned, radioactive chemicals from nuclear reactors are all carcinogenic; exposures at the youngest ages are most harmful; and damage to DNA structure in cells can create mutations leading to cancer. The periods before and after Diablo Canyon startup were again selected as 1979-1983 and 1984-2010. In the pre-startup period, the San Luis Obispo cancer death rate age 0-24 was 39.5% below the state. Thereafter, the local rate had closed the gap to only 17.7% less, which was of borderline significance (p<.07, where p<.05 is significant).

In the most recent eight-year period (2003-2010), the San Luis Obispo County rate was just 3.9% below the state (3.46 vs. 3.60 per 100,000 population). **Similar to infant mortality, child/adolescent cancer mortality, which was far below the state before Diablo Canyon began operating, is now approaching the state rate.**

## V. OTHER HEALTH STATUS TRENDS – SAN LUIS OBISPO COUNTY

**A. All-Age Cancer Incidence.** Starting in 1988, the California Cancer Registry (Registry) began producing complete data for all cancer cases in the state. While it is, therefore, not possible to analyze cancer incidence trends before and after the startup of Diablo Canyon in 1984-85, it is feasible to review changes in cancer incidence during the most recent 23-year period, from 1988 to 2010. The Registry currently is complete through 2010.

The California Registry makes county-specific cancer incidence rates available on its web site, by year. The number of cases involved is large: over 155,000 Californians (including over 1,400 residents of San Luis Obispo County) are diagnosed with cancer each year.

Table 9 displays county and state age-adjusted cancer incidence trends for all cancers combined. The earliest three-year period 1988-1990 is used as a baseline, as Diablo Canyon had only been operating a few years at that time, limiting the effect that radiation exposure would have had on cancer deaths.

For radiation-induced cancer the time frame between exposure, illness and death often takes years, even decades. Therefore, the data for following two decades (1991-2000 and 2001-2010) are also provided, in order to examine local cancer incidence rates as Diablo Canyon ages and cumulative exposures to radioactivity grow.

**Table 9**
**All-Cancer Incidence, All Ages, Ethnicity, and Genders**
**San Luis Obispo County vs. California**
**1988-1990 vs. 1991-2000 and 2001-2010**

| | Cases/100,000 Persons (no. Cases) | | |
|---|---|---|---|
| Period | San Luis Obispo | California | % Co. vs. State |
| 1988-1990 | 462.81 ( 2,956) | 464.85 ( 339,919) | **- 0.4%** |
| 1991-2000 | 471.45 (11,658) | 471.43 (1,290,707) | **+ 0.0%** |
| 2001-2010 | 464.95 (13,933) | 441.54 (1,478,853) | **+ 5.3%**** |
| 2003-2010 | 468.01 (11,421) | 437.97 (1,196,782) | **+ 6.9%**** |

Source: California Cancer Registry, http://www.cancer-rates.info/ca/index.php. Rates adjusted to 2000 U.S. standard population.
** = Significant at p<.00001.

In the baseline (1988-1990) period, the county rate was 0.4% below that of California. In the decade following, that figure was virtually unchanged (0.0%). But in the most recent decade (2001-2010), the San Luis Obispo County rate was 5.3% **greater** than the state, a highly significant change due to the large number of cases. **If the San Luis Obispo County cancer rate had equaled the state cancer rate in 2001-2010, as it had previously, then 738 fewer persons would have been diagnosed with cancer.**

In 2003-2010, the county incidence rate exceeded the state by 6.9%, also statistically significant. This finding shows that the gap between San Luis Obispo and California cancer incidence is still growing.

The unexpected rise in San Luis Obispo County cancer incidence in the past decade can be further examined for the most radiation-sensitive types of cancer. While radiation exposure increases risk for all cancers, studies of Hiroshima and Nagasaki survivors found that the greatest risk occurred for thyroid and female breast cancer.

Table 10 provides similar analyses for these two types of malignancy, comparing incidence for the past two decades with the 1988-1990 baseline period.

**Table 10**
**Thyroid and Female Breast Cancer Incidence, All Ages, Ethnicity, and Genders**
**San Luis Obispo County vs. California**
**1988-1990 vs. 1991-2000 and 2001-2010**

| | Cases/100,000 Persons (no. Cases) | | |
|---|---|---|---|
| Period | San Luis Obispo | California | % Co. vs. State |
| Thyroid Cancer | | | |
| 1988-1990 | 4.35 ( 27) | 5.15 ( 4,258) | **- 15.5%** |
| 1991-2000 | 5.67 ( 133) | 5.98 ( 18,112) | **- 5.5%** |
| 2001-2010 | 9.65 ( 262) | 9.50 ( 33,505) | **+ 1.6%*** |
| Female Breast Cancer | | | |
| 1988-1990 | 120.19 ( 396) | 128.74 ( 50,979) | **- 6.6%** |
| 1991-2000 | 138.64 ( 1,772) | 131.91 (195,961) | **+ 5.1%**** |
| 2001-2010 | 129.60 ( 2,004) | 123.65 (225,555) | **+ 4.8%**** |

Source: California Cancer Registry, http://www.cancer-rates.info/ca/index.php. Rates adjusted to 2000 U.S. standard population.
** = Significant at p<.001; * = Significant at p<.04.

Thyroid cancer incidence in San Luis Obispo County was 15.5% below the state in 1988-1990. In the next two decades, the gap closed, first to just 5.5% below, then to 1.6% above the state, a statistically significant increase. Thyroid cancer is rising in California and in all areas of the U.S., but is rising especially rapidly in San Luis Obispo County.

Female breast cancer in the county was 6.6% below the state in the baseline period of 1988-1990. In the decades following, the county was higher than the state, first by 5.1% then by 4.8%, both of which were statistically significant. **The particularly rapid rises in breast and thyroid cancer are yet another suggestion that radiation exposure from Diablo Canyon is a factor in higher San Luis Obispo cancer rates.**

**As Table 11 shows, San Luis Obispo has the highest 2003-2010 cancer incidence rate of the 20 most southern counties in the state of California** (i.e., those counties located below 37' North latitude). These counties account for 69.1% of the cancer cases in the state (827,450 of 1,196,782).

**Table 11**
**All-Cancer Incidence, All Ages, Ethnicity, and Genders**
**20 Counties in the Southern Portion of California**
**County vs. State Rates, 2003-2010**

| County | No. Of Cases | Cases/100,000 | % Co. vs. State |
|---|---|---|---|
| **1. San Luis Obispo** | **11,421** | **468.01** | **+ 6.9%** |
| 2. Santa Cruz | 9,057 | 454.77 | + 3.8% |
| 3. San Diego | 102,976 | 454.30 | + 3.7% |
| 4. Ventura | 27,801 | 450.50 | + 2.7% |
| 5. Santa Barbara | 14,906 | 445.45 | + 1.7% |
| CALIFORNIA | 1,196,782 | 437.97 | ----- |
| 6. Orange | 97,366 | 435.77 | - 0.5% |
| 7. Santa Clara | 55,166 | 432.91 | - 1.2% |
| 8. Kern | 21,768 | 430.83 | - 1.4% |
| 9. San Bernardino | 53,342 | 430.42 | - 1.7% |
| 10. Riverside | 65,408 | 429.24 | - 2.0% |
| 11. San Benito | 1,569 | 427.83 | - 2.3% |
| 12. Fresno | 25,658 | 424.74 | - 3.0% |
| 13. Monterey | 12,355 | 423.02 | - 3.4% |
| 14. Merced | 6,485 | 422.63 | - 3.5% |
| 15. Los Angeles | 297,428 | 422.43 | - 3.5% |
| 16. Madera | 4,532 | 421.40 | - 3.8% |
| 17. Kings | 3,521 | 409.38 | - 6.5% |
| 18. Tulare | 11,089 | 408.92 | - 6.6% |
| 19. Inyo-Mono | 1,249 | 402.51 | - 8.1% |
| 20. Imperial | 4,353 | 387.25 | - 11.6% |

Source: California Cancer Registry, http://www.cancer-rates.info/ca/index.php. Rates adjusted to 2000 U.S. standard population.

**The 2003-2010 San Luis Obispo incidence rate for melanoma was the highest of all California counties, or +130.2% greater than the state (46.85 vs. 20.35 per 100,000 persons)**, which is significant based on the large number of cases diagnosed among county residents (983). The county rate was only 3.6% above the state in the baseline period of 1988-1990, but has risen steadily since. As with any type of cancer, melanoma may have multiple causes, including excess sun exposure. But, because a number of California counties are situated on the Pacific Ocean, where residents are more likely to spend time outdoors in the sun, this very high rate is still unusual, suggesting other carcinogens (including radiation from Diablo Canyon) may also be a factor.

**B. Childhood Cancer Incidence**. Another indicator of changes in health status in San Luis Obispo County since the startup of Diablo Canyon is childhood cancer incidence. As mentioned, childhood cancer has been the most-studied health outcome near nuclear reactors (see Appendix 1).

Table 12 provides incidence rates for San Luis Obispo County and California for cancer incidence age 0-19 during the 24-year period 1988-2011. Because childhood cancer is relatively rare (annual cases in the county range from 4 to 15), the 3-year baseline period 1988-1990 does not contain enough cases (18) in San Luis Obispo County to be reliable. Instead, the 7-year period 1988-1994 serves as the "baseline," and 1995-2011 as the "after" period.

**Table 12**
**Childhood Cancer Incidence Age 0-19, All Ages, Ethnicity, and Genders**
**San Luis Obispo County vs. California, 1988-1994 vs. 1995-2011**

| | Cases/100,000 Persons (no. Cases) | | % County |
|---|---|---|---|
| Period | San Luis Obispo | California | vs. State |
| 1988-1994 | 12.43 ( 50) | 15.85 ( 9,992) | **- 21.5%** |
| 1995-2011 | 17.12 ( 186) | 16.56 (28,928) | **+ 3.4%*** |

Source: California Cancer Registry (personal correspondence January 27, 2014). * = Significant at p<.01.

**The San Luis Obispo County child cancer rate jumped from 21.5% below the state to 3.4% above the state after 1988-1994, a statistically significant change.** A total of 236 county children age 0-19 were diagnosed with the disease in the past 24 years. This finding adds further credence to the hypothesis that radioactive releases from Diablo Canyon harmed humans, especially as the plant aged and cumulative doses in bodies rose. **Had the San Luis Obispo County childhood cancer rate stayed 21.5% below the state rate, 47 fewer children would have developed cancer.**

**C. All-Age Cancer Mortality**. The California Cancer Registry also provides data for mortality for persons of all ages, for each year from 1988 to 2010. While the CDC data include deaths as far back as 1968, it is not necessary to establish a long period of time as a baseline. The lag between exposure and cancer death for most local residents would take at least several years, as most are adults who are less susceptible to radiation than are the very young.

Similar to cancer incidence, this report will use 1988-1990 (just after Diablo Canyon startup) as a baseline, and compare cancer mortality with future rates. Table 13 compares San Luis Obispo County rates with those of California for 1988-1990 and the two decades following.

**Table 13**
**All Cancer Mortality, All Ages, Ethnicity, and Genders**
**San Luis Obispo County vs. California**
**1988-1990 vs. 1991-2000 and 2001-2010**

| | Deaths/100,000 Persons (Deaths) | | | Co. rank |
|---|---|---|---|---|
| Period | San Luis Obispo | California | % Co. vs. State | (of 47) |
| 1988-1990 | 193.20 ( 1236) | 203.67 (144,714) | **- 5.1%** | **43** |
| 1991-2000 | 184.20 ( 4589) | 191.74 (512,921) | **- 3.9%** | **37** |
| 2001-2010 | 164.47 ( 5061) | 166.43 (545,776) | **- 1.2%**** | **31** |
| | | | | |
| 2010 | 163.92 ( 563) | 154.83 ( 56,124) | **+ 5.9%*** | **16** |

Source: California Cancer Registry, http://www.cancer-rates.info/ca/index.php. Rates adjusted to 2000 U.S. standard population.
** = Significant at p<.01; * = Borderline Significant at p<.08.

San Luis Obispo County has consistently had a cancer mortality rate below the state. In 1988, it had the 43rd highest of 47 California counties and county groups. But **the county cancer mortality rate (compared to California) rose steadily from -5.1% (late 1980s) to -3.9% (1990s) to -1.2% (2000s)**, a statistically significant increase. In fact, the county's cancer death rate was +5.9% above the state in 2010 (borderline significant), the last year for which complete data are available.

## VI. HEALTH STATUS TRENDS -ZIP CODES CLOSEST TO DIABLO CANYON

**A. Infant Health – Closest vs. More Distant Zip Codes and vs. State.** As mentioned, the fetus, infant, and young child are far more sensitive to a given dose of radiation than are adults. Thus, any adverse effects to persons living near Diablo Canyon should be detectable using measures of fetal and infant health.

One of these measures is babies who die before age one, known commonly as infant mortality. Another measure is the proportion of babies born below normal weight, or "low weight births," defined as 2,500 grams (5 pounds, 8 ounces). Those born at less than 1,500 grams (3 pounds, 4 ounces) are classified as "very low weight births."

The California Department of Public Health makes available on its web site zip code-specific numbers of births and numbers of deaths under one year, plus numbers of babies born below 2,500g and 1,500g. Such data are available for each year from 1989 to 2011. While no data before Diablo Canyon startup (1984/1985) are available, 23-year patterns and trends can be analyzed by zip code.

San Luis Obispo's 19 zip code areas are at various distances from the Diablo Canyon nuclear power plant, located in Avila Beach, California, on the Pacific Ocean. Of the 19, nine (9) are roughly 15 miles or less from the plant (including two proximate downwind zip code areas), while the other ten (10) are more distant.

One way of assessing any possible effects of emissions from Diablo Canyon is to compare these two areas: those "closest" (or "proximate") vs. those "more distant" (or "farther") from the nuclear power plant. It should be noted that, while some of these zip code areas overlap slightly into other counties, these 19 zip code areas roughly approximate San Luis Obispo County. (Please refer to San Luis Obispo and Santa Barbara County zip code maps in Appendix 2 and 3 and to nine closest zip codes closest listed in Section IV-C above.)

Tables 14, 15, and 16 present the changes in infant mortality, and in low weight/very low weight births, for those babies born 1989-1991 (baseline period) to 2004-2011 (most recent period), for the nine (9) closest zip code areas, for the 10 more distant other county zip code areas, and for California. These other 10 zip codes are an "underexposed" control group, while California serves as an "unexposed" control group.

**Table 14**
**Change in Infant Mortality, San Luis Obispo County, 1989-1991 to 2004-2010**
**Nine (9) Most Proximate Zip Codes to Diablo Canyon vs. 10 Other Zip Codes/California**

| | Live Births | | Deaths < 1 Yr. | | % Deaths < 1 Yr. | | |
|---|---|---|---|---|---|---|---|
| Zip Codes | 1989-91 | 2004-10 | 1989-91 | 2004-10 | 1989-91 | 2004-10 | % Ch. |
| 9 Proximate | 4032 | 7531 | 25 | 35 | 0.620 | 0.465 | |
| 10 Distant | 5062 | 9613 | 34 | 55 | 0.672 | 0.572 | |
| California | 1792697 | 3612670 | 14336 | 19356 | 0.800 | 0.536 | |
| Proximate/Distant Ratio | | | | | **0.923** | **0.812** | **- 12.0** |
| Diablo Canyon/California Ratio | | | | | **0.775** | **0.869** | **+12.1** |

Sources: California Department of Public Health, http://www.cdph.ca.gov/data/statistics (Diablo Canyon data), and U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov (California data).

**Table 15**
**Change in Low Weight Births, San Luis Obispo County, 1989-1991 to 2004-2011**
**Nine (9) Most Proximate Zip Codes to Diablo Canyon vs. 10 Other Zip Codes/California**

| | Live Births | | Births <2500 g | | % Births <2500 g | | |
|---|---|---|---|---|---|---|---|
| Zip Codes | 1989-91 | 2004-11 | 1989-91 | 2004-11 | 1989-91 | 2004-11 | % Ch. |
| 9 Proximate | 4032 | 8555 | 198 | 523 | 4.910 | 6.113 | |
| 10 Distant | 5062 | 13332 | 283 | 794 | 5.590 | 5.956 | |
| California | 1783362 | 4315701 | 105,111 | 294,077 | 5.863 | 6.814 | |
| Proximate/Distant Ratio | | | | | **0.878** | **1.026** | **+16.9*** |
| Diablo Canyon/California Ratio | | | | | **0.837** | **0.897** | **+ 7.2** |

Source: California Department of Public Health, http://www.cdph.ca.gov/data/statistics.
*= significant at p<.01

**Table 16**
**Change in Very Low Weight Births, San Luis Obispo County, 1989-1991 to 2004-2011**
**Nine (9) Most Proximate Zip Codes to Diablo Canyon vs. 10 Other Zip Codes/California**

| | Live Births | | Births <1500 g | | % Births <1500 g | | |
|---|---|---|---|---|---|---|---|
| Zip Codes | 1989-91 | 2004-11 | 1989-91 | 2004-11 | 1989-91 | 2004-11 | % Ch. |
| 9 Proximate | 4032 | 8555 | 24 | 105 | 0.595 | 1.227 | |
| 10 Distant | 5062 | 13332 | 35 | 131 | 0.691 | 0.983 | |
| California | 1783362 | 4315701 | 18299 | 50854 | 1.026 | 1.178 | |
| Proximate/Distant Ratio | | | | | **0.861** | **1.248** | **+45.0**** |
| Diablo Canyon/California Ratio | | | | | **0.580** | **1.042** | **+79.7**** |

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Source: California Department of Public Health, http://www.cdph.ca.gov/data/statistics.
** significant at p<.00001

Infant mortality changes in the 9 proximate zip codes to Diablo Canyon yields mixed results. While the ratio to the 10 other county zip codes decreased over time by 12.0%, the ratio to California rose by 12.1% over time.

The change in the ratio of low-weight births in the 9 most proximate zip codes increased against both the 10 other county zip codes (16.9%) and the state (7.2%). The 16.9% figure was statistically significant.

The change in the ratio of very low-weight births in the 9 most proximate zip codes was 45.0% more than the other 10 county zip codes and 79.7% more than California, both statistically significant changes. **The 1989-1991 rate of very low-weight births (under 1,500 grams) in the zip codes closest to Diablo Canyon was less than the rate in more distant zip codes and in the state. But, by 2004-2011, the rate of very low-weight births in the San Luis Obispo County zip codes closest to the Diablo Canyon reactors exceeded the rate in both the more distant county zip codes and in the state of California.**

**B. <u>All-Cause Mortality – Closest vs. More Distant Zip Codes and State</u>.** Another means of assessing health status in the population near Diablo Canyon is that of mortality. The California Department of Public Health also provides annual numbers of deaths by zip code and by age group, for each year from 1989 to 2010. However, age-specific populations, which are needed to compute mortality rates, are only available for the 2000 and 2010 censuses. Thus, a review of changes over this 11-year period will be undertaken below.

Table 17 provides statistical data on the changes in total mortality rates for the nine (9) closest zip codes to Diablo Canyon, for the other more distant 10 zip codes in the county, and for California. The two-year periods 2000-2001 and 2009-2010 are used, and use populations from the 2000 and 2010 U.S. Censuses, respectively, as the denominator in calculating rates.

**Table 17**
**Change in Mortality, All Ages**
**San Luis Obispo County, 2000-2001 to 2009-2010**
**Nine (9) Most Proximate Zip Codes to Diablo Canyon vs. 10 Other Zip Codes/California**

| | Number of Deaths | | Deaths/100,000 Pop. | | |
|---|---|---|---|---|---|
| Zip Codes | 2000-01 | 2009-10 | 2000-01 | 2009-10 | % Ch. |
| 9 Proximate | 1749 | 1891 | 660.50 | 620.97 | |
| 10 Distant | 2961 | 2408 | 1041.76 | 661.70 | |
| California | 463595 | 466748 | 785.50 | 651.08 | |
| Proximate/Distant Ratio | | | **0.634** | **0.938** | **+47.9**** |
| Diablo Canyon/California Ratio | | | **0.841** | **0.954** | **+13.4**** |

Source: California Department of Public Health. http://www.cdph.ca.gov/data/statistics. Rates adjusted to the 2000 U.S. standard population.
** significant at p<.00001

Death rates in the nine (9) zip codes most proximate to Diablo Canyon were initially below the more distant 10 zip codes in San Luis Obispo County. But the gap closed sharply during the decade. **For persons of all ages, the mortality ratio of closest to distant zip code areas jumped 47.9%, from 0.634 to 0.938 during the period 2000-01 to 2009-10**. Because over 2,000 county residents die each year, this change was highly significant at p<.00001. The gap between the nine (9) zip codes and California also closed, as the ratio rose 13.4%, statistically significant.

## VII. HEALTH STATUS TRENDS – SANTA BARBARA COUNTY

**A. Infant Health – Closest vs. More Distant Zip Codes and State.** This report also covers health status patterns in Santa Barbara County, which is located to the southeast of, and adjacent to, San Luis Obispo County.

The Santa Barbara County 10 zip code areas that are closest to and downwind/southeast of Diablo Canyon (see section IV-C) are compared with the five (5) Santa Barbara County zip code areas comprising the city of Santa Barbara, which is located approximately 90 miles from the plant. These five zip codes are 93101, 93103, 93109, 93110, and 93111.

The hypothesis is that increases in disease and death rates in the 10 zip code areas nearest Diablo Canyon will be greater than in Santa Barbara city proper and in the state of California, which received much lower exposure to radioactive releases from the nuclear plant. Again, the population most vulnerable to radioactive emissions are the fetus and infant.

Tables 18, 19, and 20 provide spatial comparisons for infant mortality, low birth weight and very low birth weight between 1989-1991 and 2004-2011, in the Santa Barbara County zip code areas closest to (10 zip codes) and more distant from (5 zip codes) Diablo Canyon.

**Table 18**
**Change in Infant Mortality, Santa Barbara County, 1989-1991 to 2004-2010**
**Zip Codes Proximate to Diablo Canyon vs. Santa Barbara City/California**

| | Live Births | | Deaths < 1 Yr. | | % Deaths < 1 Yr. | | |
|---|---|---|---|---|---|---|---|
| Zip Codes | 1989-91 | 2004-10 | 1989-91 | 2004-10 | 1989-91 | 2004-10 | % Ch. |
| 10 Proximate | 6950 | 25092 | 42 | 119 | 0.604 | 0.438 | |
| 5 S. Barbara | 4764 | 8264 | 34 | 30 | 0.847 | 0.320 | |
| California | 1792697 | 3612670 | 14336 | 19356 | 0.800 | 0.536 | |
| Proximate/S. Barbara Ratio | | | | | **0.847** | **1.370** | **+61.7**** |
| Proximate/California Ratio | | | | | **0.756** | **0.818** | **+ 8.2** |

Sources: California Department of Public Health, http://www.cdph.ca.gov/data/statistics (Diablo Canyon data). U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov (California data).
** significant at p<.0001.

**Table 19**
**Change in Low Weight Births, Santa Barbara County, 1989-1991 to 2004-2010**
**Zip Codes Proximate to Diablo Canyon vs. Santa Barbara City/California**

| | Live Births | | Births <2500 g | | % Births <2500 g | | |
|---|---|---|---|---|---|---|---|
| Zip Codes | 1989-91 | 2004-11 | 1989-91 | 2004-11 | 1989-91 | 2004-11 | % Ch. |
| 10 Proximate | 6950 | 27149 | 319 | 1653 | 4.590 | 6.089 | |
| 5 S. Barbara | 4764 | 9374 | 231 | 430 | 4.849 | 4.587 | |
| California | 1783362 | 4315701 | 105111 | 294077 | 5.863 | 6.814 | |
| Proximate/S. Barbara Ratio | | | | | **0.947** | **1.327** | **+40.2**** |
| Proximate/California Ratio | | | | | **0.783** | **0.894** | **+14.2**** |

Source: California Department of Public Health. http://www.cdph.ca.gov/data/statistics.
**= significant at p<.0001

**Table 20**
**Change in Very Low Birth Weights, Santa Barbara County, 1989-1991 to 2004-2010**
**Zip Codes Proximate to Diablo Canyon vs. Santa Barbara City/California**

| | Live Births | | Births <1500 g | | % Births <1500 g | | |
|---|---|---|---|---|---|---|---|
| Zip Codes | 1989-91 | 2004-11 | 1989-91 | 2004-11 | 1989-91 | 2004-11 | % Ch. |
| 10 Proximate | 6950 | 27149 | 59 | 255 | 0.849 | 0.939 | |
| 5 Distant | 4764 | 9374 | 32 | 81 | 0.672 | 0.864 | |
| California | 1783362 | 4315701 | 18299 | 50854 | 1.026 | 1.178 | |
| Proximate/S. Barbara Ratio | | | | | **1.263** | **1.087** | **- 13.9** |
| Proximate/California Ratio | | | | | **0.827** | **0.797** | **- 3.6** |

Source: California Department of Public Health, http://www.cdph.ca.gov/data/statistics.

The change in ratio for the 10 Santa Barbara County zip code areas closest to Diablo Canyon, vs. Santa Barbara city rose 61.7% for infant deaths and 40.2% for low weight births, both highly significant. Increases also occurred vs. the state of California, 8.2% for infant deaths and 14.2% for low birth weight, with only the 2nd being significant. For very low weight births, the ratios declined over time (13.9% vs. Santa Barbara city and 3.6% vs. the state, neither statistically significant).

**B. All-Cause Mortality – Closest vs. More Distant Zip Codes and State.** Changes in age-adjusted mortality rates from 2000-2001 to 2009-2010 for the areas described above were also analyzed, and presented in Table 21.

**Table 21**
**Change in Mortality, All Ages, Santa Barbara County, 2000-2001 to 2009-2010**
**Zip Codes Proximate to Diablo Canyon vs. Santa Barbara City/California**

| | Number of Deaths | | Deaths/100,000 Pop. | | |
|---|---|---|---|---|---|
| Zip Codes | 2000-01 | 2009-10 | 2000-01 | 2009-10 | % Ch. |
| 10 Proximate | 2283 | 2530 | 655.58 | 608.33 | |
| 5 S. Barbara | 1446 | 1324 | 700.27 | 545.80 | |
| California | 463595 | 466748 | 785.50 | 651.08 | |
| Proximate/S. Barbara Ratio | | | **0.936** | **1.115** | **+19.1**** |
| Proximate/California Ratio | | | **0.835** | **0.934** | **+11.9**** |

Source: California Department of Public Health, http://www.cdph.ca.gov/data/statistics. Rates adjusted to the 2000 U.S. standard population.
** significant at p<.00001

The change in total mortality in the 10 Santa Barbara County zip code areas closest to Diablo Canyon exceeded those of Santa Barbara city and California, by 19.1% and 11.9%, respectively. Both increases were statistically significant, because of the large number of deaths involved: 2,530 residents of the 10 Santa Barbara County zip codes closest to Diablo Canyon died in 2009 and 2010. Both increases are statistically significant.

## VIII. CONCLUSIONS AND RECOMMENDATIONS

**A. Conclusions.** This report reviews information on radioactivity produced by the Diablo Canyon nuclear reactors, and on the potential and actual health threats posed by the reactors' carcinogenic chemicals. A meltdown−and subsequent release of enormous amounts of radioactivity from the reactor core or spent fuel pools−would be catastrophic. Thousands would suffer and die from radiation poisoning and cancer, and large areas of San Luis Obispo County could become uninhabitable for decades.

Diablo Canyon is an aging nuclear power plant that has been operating for nearly 30 years, increasing the chances of corrosion, component failure and radiation leaks over time. In addition, Diablo Canyon is located near multiple fault lines, placing the plant at risk for earthquakes and for possible ground motion beyond the design basis of the plant.

The actual consequences of radioactivity routinely emitted into the environment by the operation of the Diablo Canyon nuclear plant pose a serious contemporary health concern. While official data make it difficult to calculate the exact amount of radioactive releases and levels in air, water, soil, and food, any dose of radioactivity is known to pose a health risk, especially to the fetus, infant and young. Moreover, certain types of radioactivity, such as liquid tritium, were released in greater amounts by Diablo Canyon than by other U.S. nuclear plants.

This is the first known analysis of local health status patterns and trends near the Diablo Canyon nuclear power plant. The statistical information presented test the hypothesis that morbidity and mortality rates in areas close to nuclear plants will elevate over time.

The major findings of this report show increases in various rates of disease and death in San Luis Obispo County, as compared to the state of California, since the 1980s (before plant startup and during its early years of operation). This includes increases in infant mortality, child/adolescent cancer mortality, cancer incidence for all ages (especially thyroid, female breast, and melanoma), and cancer mortality for all ages.

In addition, official vital statistics show that certain morbidity or mortality rates are rising more rapidly in the nine (9) zip code areas in San Luis Obispo County closest (under 15 miles) from Diablo Canyon, vs. the other 10 zip codes in the county, and vs. the state of California. These health status indicators include babies born at very low weight (below 3 pounds, 4 ounces) and all-cause mortality.

Another unusual pattern of rising morbidity and mortality occurred in the 10 zip code area in Santa Barbara County closest to Diablo Canyon. Compared to the five more distant zip codes comprising Santa Barbara city, located 90 miles from the nuclear plant, these closer 10 zip codes experienced a 61.7% greater rise in infant mortality, and a 40.2% greater rise in low weight births, during the time period 1989-1991 to 2004-2011. In addition, in these 10 Santa Barbara County zip codes, the total mortality rate increased 19.1% from 2000-2001 to 2009-2010.

These findings strongly support the hypothesis that elevated radioactivity in the environment −and hence in the diet−is a factor in the rising morbidity and mortality rates in affected populations living near Diablo Canyon.

They also support three studies that document reduced local disease and death rates after a nuclear plant shuts down. Each of these studies focused on Sacramento County, California, the site of the Rancho Seco reactor (closed 1989), and were presented in peer-review journal articles. Two of these studies include short-term analyses of the very young, including infant deaths and cancer cases under age 5. (Mangano, J.J., Improvements in Local Infant Health After Nuclear Power Reactor Closing, Journal of Environmental Epidemiology and Toxicology, 2000, 2(1):32-26; and Mangano J.J. et al., Infant Death and Cancer Reductions After Nuclear Plant Closing in the U.S. Archives of Environmental Health, 2002, 57(1):23-31).

Last year, a third report documented long-term decreases in cancer incidence of all ages in the decades following the closure of the Rancho Seco nuclear plant. (Mangano JJ and Sherman JS, Long-Term Local Cancer Reductions Following Nuclear Plant Shutdown, Biomedicine International, 2013, 4(1):3-16).

While many factors can affect morbidity and mortality rates, the data presented in this report strongly suggest a link between emissions from Diablo Canyon and elevated health risks to those most sensitive to radiation exposure.

This information should be followed by additional health studies. It should be shared with government officials and with local citizens so that the public health implications of operating Diablo Canyon and other aging nuclear reactors are fully understood.

**B. <u>Recommendations</u>.** This study presents evidence of significant adverse health impacts from the Diablo Canyon nuclear reactors on local residents in San Luis Obispo and Santa Barbara counties. It provides the basis for the following recommendations:

- Further studies should be conducted into the relationship between local radioactivity releases and local health status, especially for the time period after 2010 given the number of unusually elevated mortality and incidence rates observed in the late 2000s.

- The unexpected and steady rise in local morbidity and mortality rates, and in cancer rates, especially those in young persons, should be taken seriously by local, state and national officials.

- Information on a potential radiation-cancer link should be considered by the U.S. Nuclear Regulatory Commission in its environmental review of utility applications to renew and extend the licenses of aging nuclear power plants in California and across the U.S.

## APPENDIX 1
## JOURNAL ARTICLES (19) THAT IDENTIFY ELEVATED LEVELS OF CHILDHOOD CANCER NEAR NUCLEAR PLANTS

Sharp L, McKinney PA, Black RJ. Incidence of childhood brain and other non-haematopoietic neoplasms near nuclear sites in Scotland, 1975-94. Occupational and Environmental Medicine 1999; 56(5): 308-314.

Busby C, Cato MS. Death rates from leukaemia are higher than expected in areas around nuclear sites in Berkshire and Oxfordshire. BMJ 1997; 315(7103): 309.

Black RJ, Sharp L, Harkness EF, McKinney PA. Leukaemia and non-Hodgkin's lymphoma: incidence in children and young adults resident in the Dounreay area of Carthness, Scotland in 1968-91. Journal of Epidemiology and Community Health 1994; 48(3): 232-236.

Draper GJ, Stiller CA, Cartwright RA, Craft AW, Vincent TJ. Cancer in Cumbria and in the vicinity of the Sellafield nuclear installation, 1963-90. BMJ 1993; 306(6870): 89-94.
43.

Goldsmith JR. Nuclear installations and childhood cancer in the UK: mortality and incidence for 0-9 year-old children, 1971-1980. The Science of the Total Environment 1992; 127(1-2): 13-35.

Kinlen LJ, Hudson CM, Stiller CA. Contacts between adults as evidence for an infective origin of childhood leukaemia: an explanation for the excess near nuclear establishments in west Berkshire? British Journal of Cancer 1991; 64(3): 549-554.

Ewings PD, Bowie C, Phillips MJ, Johnson SA. Incidence of leukemia in young people in the vicinity of Hinkley Point nuclear power station, 1959-86. BMJ 1989;299(6694): 289-293.

Cook-Mozaffari PJ, Darby SC, Doll R, Forman D, Herman C, Pike MC, Vincent T. Geographical variation in mortality from leukemia and other cancers in England and Wales in relation to proximity to nuclear installations, 1969-78. British Journal of Cancer 1989; 59(3): 476-485.

Roman E, Beral V, Carpenter L, Watson A, Barton C, Ryder H, Aston DL. Childhood leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities in relation to nuclear establishments in the vicinity. BMJ (Clinical Research Edition) 1987; 294(6572): 597-602.

Forman D, Cook-Mozaffari P, Darby S, Davey G, Stratton I, Doll R, Pike M. Cancer near nuclear installations. Nature 1987; 329(6139): 499-505.

Heasman MA, Kemp IW, Urquhart JD, Black R. Childhood leukemia in northern Scotland. Lancet 1986; 1(8475): 266.

Gunay U, Meral A, Sevinir B. Pediatric malignancies in Bursa, Turkey. Journal of Environmental Pathology, Toxicology, and Oncology 1996; 15(2-4): 263-265.

McLaughlin JR, Clarke EA, Nishri ED, Anderson TW. Childhood leukemia in the vicinity of Canadian nuclear facilities. Cancer Causes and Control 1993; 4(1): 51-58.

Viel JF, Pobel D, Carre A. Incidence of leukaemia in young people around the La Hague nuclear waste reprocessing plant: a sensitivity analysis. Statistical Medicine 1995; 14(21-22): 2459-2472.

Hoffmann W, Dieckmann H, Schmitz-Feuerhake I. A cluster of childhood leukemia near a nuclear reactor in northern Germany. Archives of Environmental Health 1997; 52(4): 275-280.

Zaridze DG, Li N, Men T, Duffy SW. Childhood cancer incidence in relation to distance from the former nuclear testing site in Semipalatinsk, Kazakhstan. International Journal of Cancer 1994; 59(4): 471-475.

Mangano JJ, Sherman J, Chang C, Dave A, Feinberg E, Frimer M. Elevated childhood cancer incidence proximate to U.S. nuclear power plants. Archives of Environmental Health 2003; 58(2): 74-82.

Spix C, Schmiedel S, Kaatsch P, Schultze-Rath R, Blettner M. Case-control study on childhood cancer in the vicinity of nuclear power plants in Germany 1980-2003. European Journal of Cancer 2008; 44(2); 275-284.

Sermage-Faure C, Laurier D, Goujon-Bellec S, Chartier M, Guyot-Goubin A, Rudant J, et al. Childhood leukemia around French nuclear power plants – the Geocap study, 2002-2007. Int J Cancer 2012; 131(5): E769-E780.

# APPENDIX 2 – ZIP CODE MAP, SAN LUIS OBISPO COUNTY, CALIFORNIA

**APPENDIX 3 – ZIP CODE MAP, SANTA BARBARA COUNTY, CALIFORNIA**