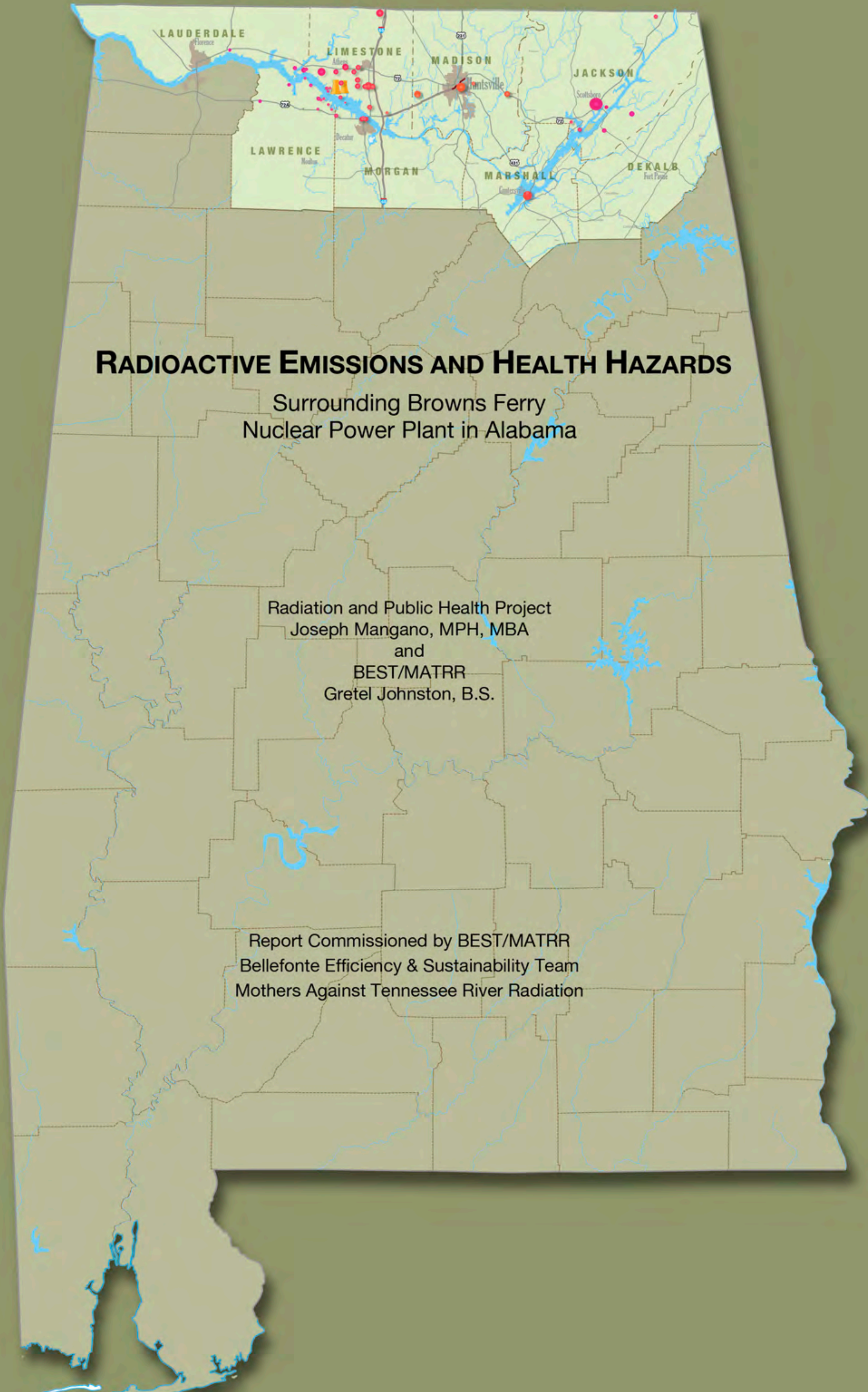



# Radioactive Emissions and Health Hazards

## Surrounding Browns Ferry Nuclear Power Plant in Alabama

Radiation and Public Health Project
Joseph Mangano, MPH, MBA
and
BEST/MATRR
Gretel Johnston, B.S.

Report Commissioned by BEST/MATRR
Bellefonte Efficiency & Sustainability Team
Mothers Against Tennessee River Radiation

# Radioactive Emissions and Health Hazards

## Surrounding Browns Ferry

## Nuclear Power Plant in Alabama


Radiation and Public Health Project
Joseph Mangano, MPH, MBA

and

BEST/MATRR
Gretel Johnston


June 4, 2013

Report Commissioned by BEST/MATRR
A Chapter of the Blue Ridge Environmental Defense League

Bellefonte Efficiency & Sustainability Team
Mothers Against Tennessee River Radiation

MATRR.ORG


Cover Design by Roy Simmons


Digital ISBN: 0-9620343-7-1
Pbk ISBN 0-9620343-6-3
LCCN: 2013941018

Candel Publishing, LLC
P.O. Box 158
Scottsboro, AL 35768
candel.net

# Table of Contents

# List of Acronyms

| | |
|---|---|
| BEST | Bellefonte Efficiency & Sustainability Team |
| BREDL | Blue Ridge Environmental Defense League |
| BWR | Boiling Water Reactor |
| CRB | Control Rod Blades |
| GE | General Electric |
| MATRR | Mothers Against Tennessee River Radiation |
| NCI | National Cancer Institute |
| NPP | Nuclear Power Plant |
| NRC | U.S. Nuclear Regulatory Commission |
| PWR | Pressurized Water Reactor |
| RPHP | Radiation and Public Health Project |
| TVA | Tennessee Valley Authority |

# Gratitude

We are grateful to BEST/MATRR members and donors who have made this report possible, and especially to the Blue Ridge Environmental Defense League and the organizers of the Know Nukes Ya'll Summit, who generously donated legacy funds from the Summit to help support our local efforts. And special thanks go to our BEST Radiation Monitoring Project Manager, Garry Morgan, who called for local citizen radiation monitoring for many years, then with Lou Zeller's assistance, Garry equipped, organized and implemented systematic monitoring of areas near and downwind of Browns Ferry, creating videos and a graphic users manual to help empower other communities to monitor as well. The Tennessee Valley is fortunate to have Garry Morgan's concern, expertise and energy working for its citizens.

## List of Tables



## List of Illustrations

[page deliberately blank]

# *EXECUTIVE SUMMARY*

The Browns Ferry Nuclear Plant in northern Alabama runs three of the five operating nuclear reactors in the state. Nearly 1 million persons live within 50 miles of the plant.

Potential harm to local residents from Browns Ferry can be expressed in various ways:

1. Browns Ferry stores massive amounts of high-level radioactive waste, mostly in pools of water that must be constantly cooled to avoid a meltdown. **Browns Ferry has the 2nd largest waste storage of 71 U.S. nuclear power plants**.

2. Browns Ferry reactors have been closed for more than one year on six separate occasions due to mechanical problems, more than any U.S. nuclear plant. **The longest shutdown in the U.S. occurred at Browns Ferry 1, from 1985 to 2007.**

3. The 1975 near-miss accident at Reactor Unit 1 is considered the worst mishap at a U.S. nuclear power reactor, aside from the Three Mile Island meltdown; yet, Browns Ferry still does not comply with the fire safety regulations created after its 1975 fire.

4. **A 1982 federal estimate of 60,000 radiation poisoning cases and 3,800 cancer deaths per meltdown to a reactor core would be greater today**, due to higher population and effects beyond the 1982 study's geographic limits.

5. Amounts of tritium and beta-emitting radiation in drinking water near Browns Ferry are substantially greater than in Montgomery, which is far from nuclear plants.

6. Citizen-based monitoring has found higher levels of radioactivity (air, water, and land) close to, downwind, and downriver from Browns Ferry, and highest after rain events.

7. **Infant mortality in the seven closest downwind counties from Browns Ferry is 22.3% above U.S. rate, a steady increase from the early 1990s**, when it was below U.S. rate. The excess is 40.3% for Hispanics and 32.6% for whites.

8. **Since Browns Ferry's startup in the mid-1970s, the local mortality rate (all causes) steadily rose from 1.7% to 20.5% above U.S. rate.** Significant excesses exist for both genders, all ages, whites, and nearly all major causes.

Data presented in this report suggests a possible link between Browns Ferry emissions and elevated health risks. This finding is particularly important at this time, as the plant's three reactors approach 40 years in operation. Aging reactors have corroding parts, which can increase the risk of a meltdown and of larger routine releases. Officials and the public should understand patterns of radioactive contamination near the plant, along with local health trends, to ensure that decisions are made that best protect public health.

[page deliberately blank]

# I. *INTRODUCTION*

## A. BRIEF HISTORY OF NUCLEAR POWER IN ALABAMA

The discovery of nuclear fission, or creation of high energy by splitting uranium atoms, was first used for military purposes, i.e. the atomic bombs in Japan during World War II. Soon after, other uses of the fission process were introduced. One of these was the creation of electric power from the heat generated by fission. The "Atoms for Peace" speech given at the United Nations by President Dwight Eisenhower in 1953 opened the door for the development of reactors that would produce electricity, and the first reactor began operating at Shippingport, near Pittsburgh, PA in 1957.

Hundreds of reactors were proposed by electric utilities, who were interested based on the potential to produce clean and cheap energy. In 1974, the U.S. Atomic Energy Commission predicted that the nation would have 1,200 reactors by the turn of the century. In Alabama, formal applications were made by utility companies for 13 reactors in the state. Five (5) of these are in operation; all others were cancelled, except for Bellefonte 1, which is still being planned (Table 1).

**TABLE 1**

**NUCLEAR POWER REACTORS IN ALABAMA**

| Reactor | City/Town | Announced | **Startup** |
|---|---|---|---|
| Browns Ferry 1 | Decatur | 6/17/66 | 8/17/73 |
| Browns Ferry 2 | Decatur | 6/17/66 | 7/20/74 |
| Browns Ferry 3 | Decatur | 6/22/67 | 8/ 8/76 |
| Joseph M. Farley 1 | Dothan | 5/13/69 | 8/ 9/77 |
| Joseph M. Farley 2 | Dothan | 6/30/70 | 5/ 8/81 |
| Barton 1 | Clanton | 1/ 1/72 | |
| Barton 2 | Clanton | 1/ 1/72 | |
| Barton 3 | Clanton | 1/ 1/74 | |
| Barton 4 | Clanton | 1/ 1/74 | |
| Bellefonte 1 | Scottsboro | 1/ 1/70 | |
| Bellefonte 2 | Scottsboro | 1/ 1/70 | |
| Bellefonte 3 | Scottsboro | 9/ 1/05 | |
| Bellefonte 4 | Scottsboro | 9/ 1/05 | |

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

The U.S. Nuclear Regulatory Commission (NRC) has never refused a license extension request and has granted 20-year license extensions, after the initial 40-year licenses expire, for 75 of the 104 U.S. reactors, including the five reactors in Alabama. Nuclear power in Alabama has been producing over 25% of the state's electricity in recent years.
(Source: U.S. Nuclear Regulatory Commission, Information Digest, various years, www.nrc.gov.)

## B. RADIOACTIVE WASTE STORED AT NUCLEAR PLANTS

To produce electricity, nuclear power reactors split uranium-235 atoms, generating high energy that is transformed into electrical power. This splitting process, known as fission, also produces over 100 chemicals not found in nature. These chemicals are the same as those found in the large clouds of fallout after above-ground atomic bomb tests.

Fission products, 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 affect various organs. Cesium seeks out the muscles (including the heart and reproductive organs), iodine attacks the thyroid gland, and strontium attaches to bone. Each causes cancer after breaking cell membranes and damages cell DNA creating mutations, and is especially harmful to the fetus, infant, and child. Some decay quickly (Iodine-131 has a half life of 8.05 days), while others remain for long periods (Strontium-90 has a half life of 28.7 years and Cesium-137 of 30 years, meaning it remains radioactive for over 300 years).

Most of the radioactivity produced in reactors is contained within the reactor building and stored as high-level waste in deep pools of water that must be constantly cooled. At Browns Ferry and other aging plants, the pools are becoming full and have no dedicated backup power. Only about 20% of the waste nationally has been transferred to safer above-ground outdoor casks. **As of the end of 2010, Browns Ferry maintained 1,932 metric tons of waste on site, the second largest of 71 U.S. nuclear plants.** The amount of radioactivity at the plant (**314,140,400 curies**), the $5^{th}$ highest in the U.S., is equivalent to several times more than that released by the 1986 Chernobyl meltdown, and hundreds of times more than releases from atomic bombs at Hiroshima and Nagasaki in 1945. The list of U.S. nuclear plants with the largest amounts of high-level waste is given in Table 2:

**TABLE 2**

**U.S. Nuclear Power Plants (Total = 71)**
**With Largest Amounts of High-Level Nuclear Waste, As of December 2010**

| Plant | State | Metric Tons | Curies |
|---|---|---|---|
| 1. Dresden | IL | 2,146 | 350,380,400 |
| **2. Browns Ferry** | **AL** | **1,932** | **314,140,400** |
| 3. Nine Mile Point | NY | 1,865 | 355,269,600 |
| 4. Millstone | CT | 1,709 | 445,230,400 |
| 5. Palo Verde | AZ | 1,674 | 360,032,400 |
| 6. Salem/Hope Creek | NJ | 1,659 | 216,050,800 |
| 7. Peach Bottom | PA | 1,554 | 254,072,600 |
| 8. Edwin I. Hatch | GA | 1,446 | 237,432,400 |
| 9. D.C. Cook | IL | 1,433 | 286,914,600 |
| 10. San Onofre | CA | 1,423 | 315,932,400 |

Source: Alvarez, Robert *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 and debate, the federal government designated Yucca Mountain in Nevada as a permanent waste site, despite considerable opposition. In 2010, the Obama administration stopped all expenditures for building the inadequate site, and assembled a panel to further consider options for long term waste storage. Some experts believe a permanent repository will never open, leaving existing nuclear plants like Browns Ferry to maintain the waste indefinitely.

## C. MARK I REACTOR DESIGN FAULTS

The Browns Ferry GE Mark I Boiling Water Reactors, the same model as Fukushima, had serious enough design flaws that three General Electric (GE) nuclear engineers working on the system publicly resigned their positions in 1976, citing dangerous shortcomings in the GE Mark I design. In 1986, top Nuclear Regulatory Commission (NRC) safety official, Harold Denton, stated that the WASH 1400 Safety Study revealed a 90% probability of the Mark I containment failing in the case of a significant malfunction, resulting in retrofit torus vent pipe installations for all Mark I's allowing the control operator to release unfiltered radiation into the atmosphere to save containment. (Source: Gunter, Paul; "Hazards of Boiling Water Reactors in the United States," NIRS, 1996 and 2011.)

## D. BROWNS FERRY AGING ISSUES

During their first 10 to 15 years of operation, all three Browns Ferry Reactors had poor operational records with high numbers of SCRAMs (emergency nuclear reactor shutdowns), which thermally shock reactor containment structures, causing weakening, premature aging and metal fatigue of the reactor pressure vessels. Altogether, the three reactors have suffered over 270 emergency SCRAMs. The reactors are now reaching their 40 design-basis life span, but NRC extended their operating license for 20 more years – despite a 1993 NRC report which confirmed "age-related degradation in Boiling Water Reactors will damage or destroy vital safety related components inside the reactor vessel before the forty year license expires." It was determined that the reactor vessel cracks were the result of the deterioration of Type 304 Stainless Steel due to exposure to chronic radiation, heat, corrosive chemistry, and fatigue.

After 20 year over design-basis license extensions were granted by the NRC, GE issued warnings about control rods cracking, then inspected Browns Ferry and found cracking of the rods necessary for shutting down the reactor for SCRAMs or refueling. In addition, according to an Associated Press Investigative Report in 2011, "The AP found proof that aging reactors have been allowed to run less safely to prolong operations. As equipment has approached or violated safety limits, regulators and reactor operators have loosened or bent the rules."; and, "Last year, the NRC weakened the safety margin for acceptable radiation damage to reactor vessels — for a second time. The standard is based on a measurement known as a reactor vessel's "reference temperature," which predicts when it will become dangerously brittle and vulnerable to failure." (Source: AP report by Jeff Donn, "Safety Rules Loosened for Aging Nuclear Reactors," June 20, 2011, http://www.nbcnews.com/id/43455859/ns/us_news-environment/t/safety-rules-loosened-aging-nuclear-reactors/#.UYp50JVs3S8; and, NRC, Licensee Event Reports search of BFN SCRAMSs; https://lersearch.inl.gov/Entry.aspx.)

## E. BROWNS FERRY LONG-TERM SHUT DOWNS

A 2006 Union of Concerned Scientists Report listed 51 instances when a U.S. nuclear reactor closed for over one year before restart. **Six year-long (or more) outages occurred at Browns Ferry – the largest number of any U.S. nuclear plant** (Table 3). Three shutdowns of over one year occurred at Peach Bottom PA and Sequoyah TN. The 22-year shut down at Browns Ferry 1, from 1975 to 2007, was by far the longest in the U.S., while the plant also has the 2nd and 3rd longest shut downs ever.

**TABLE 3**

**BROWNS FERRY SHUT DOWNS OF ONE YEAR OR LONGER**

| REACTOR | DATE SHUT | DATE OPEN | |
|---|---|---|---|
| Browns Ferry 1 | 3/22/75 | 9/24/76 | |
| Browns Ferry 1 | 3/19/85 | 6/ 2/07 | **1st Longest in U.S.** |
| Browns Ferry 2 | 3/22/75 | 9/10/76 | |
| Browns Ferry 2 | 9/15/84 | 5/24/91 | **3rd Longest in U.S.** |
| Browns Ferry 3 | 9/ 7/83 | 11/28/84 | |
| Browns Ferry 3 | 3/ 9/85 | 11/19/95 | **2nd Longest in U.S.** |

Source: Union of Concerned Scientists, *Unlearned Lessons of Year-plus Reactor Outages*, 2006

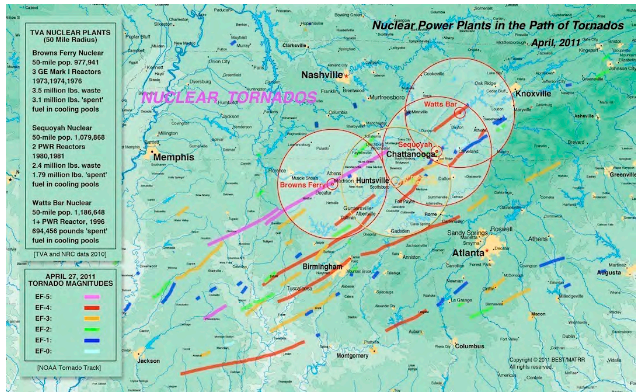
## F. BROWNS FEERY I FIRE - 1975

On March 22, 1975, a fire broke out at Browns Ferry Unit 1 when a worker set a cable seal on fire with a candle. The fire caused significant damage to the cable room, burning about 1600 cables, and threatened the entire reactor unit, almost resulting in a core boiloff/meltdown accident, before it was extinguished seven hours later. The U.S. Nuclear Regulatory Commission made multiple changes to its fire prevention regulations after the incident, but Browns Ferry is still not in compliance (37 years later) with the regulations its own fire was responsible for creating, and the NRC has allowed the negligence. **The 1975 incident at Browns Ferry 1 is considered by many to be the most serious accident of any U.S. nuclear power reactor, with the exception of the Three Mile Island partial core meltdown in 1979.**

It seems worthy of note that David Dinsmore Comey (on whom the U.S, Environmental Protection Agency (EPA) bestowed its First Annual Environmental Quality Award in 1974 "for services that have immeasurably improved the design and safety review of nuclear reactors") writing in 1976 about the Browns Ferry fire said, "Every nuclear plant in the country uses a cable spreader room below its control room. Despite requirements for separation and redundancy of reactor protection and control systems, every reactor has been permitted to go into operation with this sort of configuration which lends itself to a single failure's wiping out all redundant systems." Source: David Dinsmore Comey, "The Fire at Brown's Ferry Nuclear Power Station," in *Not Man Apart*, Friends of the Earth, California, 1976, http://www.ccnr.org/browns_ferry.html

## G. TORNADO EVENTS OF 2011

The Tennessee Valley is in what locals call a tornado corridor, since the area periodically suffers the destruction of major tornados and they seem to return along familiar pathways. On April 27, 2011, fifteen EF-4 and EF-5 tornados crossed the southeastern U.S. (see Appendix 2) and one Category EF-5, the strongest tornado known to man, destroyed a row of incoming power towers right next to Browns Ferry Nuclear Power Plant, cutting power to the plant for seven days. Given over three million pounds (with over 314 million curies) of highly radioactive fuel is stored in pools requiring constant power for coolant circulation and raised 40 feet in the air with only sheet metal roofing overhead, this was a serious near-miss event. All but one line of incoming power was lost to the plant, and despite TVA reports to the public that all emergency systems performed as designed, numerous incidents occurred that were serious enough to require Event Reports (Nos. 46793, 46801, 46805) to the Nuclear Regulatory Commission (NRC). What they revealed was worthy of note:



*Nuclear and Tornados Map* (see Appendix 2)

1.) Only 12 of the required 100 off-site Emergency Sirens were functional on April 27.

2.) Two of eight Emergency Diesel Generators failed that day, one for the fire pump and one for the security station and sirens. A third generator was shutdown the next day – totaling a 37.5% failure rate for emergency backup power.

3.) On that day, a Main Steam Isolation Valve indicator failed on Unit 3 – so operators could not tell if the valve had closed as it should during the reactor emergency shutdown.

4.) On that day, April 27, hours after Unit 1 automatically shut down due to loss of the electrical grid, it received a second automatic shut down signal due to a low water level inside the reactor vessel. TVA later explained the operating crew was "distracted," allowing the water level to boil down too low for safe reactor cooling.

5.) On April 28, an electrical part failure on Unit 1 initiated an automatic closer of Shutdown Cooling emergency valves. Power was restored after 47 minutes.

6.) On May 2, Unit 1 received an 'A' Emergency Generator output breaker trip, resulting in loss of Shutdown Cooling. Power was restored after 57 minutes.

## H. 'RED FINDING' FOR BROWNS FERRY NUCLEAR PLANT

Nuclear Regulatory Commission inspectors were on-site reviewing existing safety issues when the tornados hit in 2011, and NRC issued Browns Ferry a rare 'Red Finding' (only four have ever been issued in nuclear history) for unrelated problems just eleven days after the tornados hit, a finding that still stands two years later. A 'Red Finding' is NRC's worst rating, the most severe rating possible before a plant is shut down and forced into its decommissioning stage. The 'Red Finding' was given because of extended safety performance deficiencies and missed testing opportunities for a significantly degraded coolant injection valve, which meant an entire system could not be counted on to cool the reactor core, potentially leading to core damage. The faulty reactor cooling valve was found to have been inoperable for 18 months before the problem was discovered, and a jerry-rigged work-around was initially attempted to address the problem. A Professional Reactor Operator Society article also noted: "TVA provided incomplete and inaccurate information in a letter to the NRC. . . [which] referenced 18 valves. . . a Severity Level III violation." Source: Bob Meyer, "Most Significant NRC findings of 2012," Professional Reactor Operator Society, Feb.3, 2013, http://nucpros.com/content/most-significant-nrc-findings-2012

### I. Control Room Fire - 2012

In January of 2012, Unit 3 control room operators noticed smoke and a flame under an annunciator panel. According to the Professional Reactor Operator Society, "The cause of the event was a failed power supply. An overcurrent was caused by an aged capacitor that had not received preventative maintenance to address its service life." The signifcance of this fire is that there had been three similar warning events of power failure in an annuciator panel – twice in 2008 and again in 2009, but the aged equipment was not monitored by the TVA or the NRC. Source: Professional Nuclear Reactor Operator Society "Browns Ferry Nuclear Plant, Unit 3 LER: Annunciator Panel Power Supply Fire in Unit 3 Control Room," July 9, 2012, http://www.nucpros.com/content/browns-ferry-nuclear-plant-unit-3-ler-annunciator-panel-power-supply-fire-unit-3-control-roo

### J. Ongoing Radioactive Leaks and Releases

There have been sixteen reportable radioactive leaks at Browns Ferry Nuclear Power Plant (see Appendix 3), in addition to the routine radioactive releases. In 2010, a worker discovered an open test valve at Condensate Storage Tank 5, where 1,000 gallons of radioactively contaminated water had leaked, at concentrations of 2 million picocuries per liter which is 100 times the EPA drinking water contamination limit. So far, TVA reports drinking water test sites have not exceeded EPA limits. Sources: Jeff Donn, "Radioactive tritium leaks found at 48 US nuke sites," AP, June 21, 2011,http://www.nbcnews.com/id/43475479/ns/us_news-environment/t/radioactive-tritium-leaks-found-us-nuke-sites/#.UX7Aa5Vs3S8; and Union of Concerned Scientists, "Groundwater Events Sorted by Location," September 29, 2010, http://www.ucsusa.org/assets/documents/nuclear_power/Groundwater-Events-Sorted-by-Location.pdf (See Appendix 3)

## *II. Health Hazards Posed by Reactor Meltdowns*

### A. Description

Much of the health concern posed by nuclear reactors focuses on major meltdowns. The radioactivity in a reactor core and waste pools must be constantly cooled by water, or the fuel will heat uncontrollably, causing a huge release of radioactivity. This release can be caused by mechanical failure (like at Chernobyl in 1986, when safeguard redundancy was deliberately shut off during testing), by an act of nature (like 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), according to the *Medical Encyclopedia of the National Library of Medicine* (Radiation Sickness, http://www.nlm.nih.gov/medlineplus/ency/article/000026.htm). In addition, a large number of bomb survivors in the two cities developed cancers over the next several decades; thyroid and breast cancer had the greatest excesses. (Source: Thompson DE et al. Cancer Incidence in Atomic Bomb Survivors. Part II: Solid Tumors, 1958-1987. Radiation Effects Research Foundation, Hiroshima Japan, 1994).

## B. Estimates of Casualties

If a meltdown resulting in large scale releases of radioactivity from the reactor core or the waste pools occurred at Browns Ferry, there would be no vaporizing of humans. However, many would suffer from acute radiation poisoning (in the short term) and cancer (in the long term). In 1982, the Sandia National Laboratories submitted estimates to Congress for each U.S. nuclear plant in the case of core meltdown. Estimates for Browns Ferry are given in Table 4.

**TABLE 4**

**Estimated Deaths/Cases of Acute Radiation Poisoning and Cancer Deaths Near Browns Ferry, Following a Core Meltdown [1982]**

| Type of Effect | Unit 1 | Unit 2 | Unit 3 |
|---|---|---|---|
| Deaths, Acute Radiation Poisoning | 18,000 | 18,000 | 18,000 |
| Cases, Acute Radiation Poisoning | 42,000 | 42,000 | 42,000 |
| Cancer Deaths | 3,800 | 3,800 | 3,800 |

Note: Acute radiation poisoning cases and deaths calculated for a radius of 20 miles from the plant, cancer deaths calculated for radius 30 miles from the plant. Source: 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.

The Sandia figures are known as CRAC-2 (Calculation of Reactor Accident Consequences). **CRAC-2 estimated casualties for a core meltdown per Browns Ferry Units 1, 2, or 3 are 60,000 cases of acute radiation poisoning (18,000 fatal) and 3,800 cancer deaths**. Estimates would be much larger today, since the local population has grown since 1982 when the calculations were made, and people beyond a 20 mile radius from the plant will also suffer adverse health consequences. Estimated costs from a meltdown after each unit ($67.3 billion, $69.1 billion, and $73.0 billion in 1980 dollars) would also be far greater today due to inflation. In the seven north Alabama counties immediately downwind of Browns Ferry (DeKalb, Jackson, Lawrence, Limestone, Madison, Marshall, and Morgan), the population grew 47.7%, from 534,059 to 788,777 from 1980 to 2010.

Concerns about meltdowns near Browns Ferry are well founded. According to the 2010 Census, there are nearly 1 million residents living within 50 miles of Browns Ferry – up 11.0% from a decade earlier (Table 5):

**TABLE 5**

**2010 Population and Change from 2000**
**By Distance from Browns Ferry**

| Distance | 2010 Population | % Ch. From 2000 |
|---|---|---|
| 10 miles | 39,930 | +12.3% |
| 20 miles | 196,318 | +14.8% |
| 50 miles | 977,941 | +11.0% |

Source: Bill Dedman, NBC News. "Nuclear Neighbors: Population Rises Near US Reactors", April 4, 2011

Despite the 1975 fire accident just two years after the plant began operating, Browns Ferry reactors may have become more vulnerable to a meltdown from mechanical failure in recent years because of their aging parts, and are decidedly more vulnerable to a meltdown from a terrorist attack. Finally, the March 2011 meltdown at four reactors in Fukushima, Japan is a reminder that these disasters can also occur from an act of nature.

## *III. RADIOACTIVITY RELEASED FROM BROWNS FERRY*

### A. OFFICIAL RADIOACTIVE RELEASES INTO THE ENVIRONMENT

Radionuclides created by fission disintegrate, releasing energy as they try to regain stability, and a curie is a unit of radioactivity corresponding to $3.7 \times 10^{10}$ disintegrations per second. Utilities operating nuclear power plants are required to submit annual reports on radioactive releases to the federal government. From 1970-1993, the Brookhaven National Laboratories collected and disseminated data for each nuclear plant on airborne emissions of "Iodine-131 and effluents," or those radioactive chemicals with a half life of at least eight days, and most likely to enter the food chain and the body.

In this period, the three Browns Ferry reactors emitted 1.70 curies of Iodine-131, which is relatively typical of U.S. reactors. This total represents about 15% of the 14.20 official total from the 1979 Three Mile Island partial core meltdown. Comparisons of all U.S. plants were halted after 1993 by the U.S. government. (Source: Brookhaven National Laboratory *Radioactive Materials Released from Nuclear Power Plants*, NUREG/CR-2907, annual reports)

More recent data on radioactive emissions into the environment include the years 2000 through 2009, by quarter, for most U.S. reactors. The information is available online, but it is very resource-intensive to rank reactors and plants, since one must analyze each reactor's data. The data, posted by federal regulators, includes several types of airborne emissions, including fission and activation gases, iodine-131, particulates (half life over eight days), and tritium. The web site, operated by the U.S. Nuclear Regulatory Commission, also provides quarterly measurements of several types of liquid emissions, including dissolved/entrained gases, fission/activation products, and tritium. (Source: U.S. Nuclear Regulatory Commission, Effluent Database for Nuclear Power Plants, www.reirs.com/effluent).

An examination of the quarterly emission levels database, reveals a number of omissions and limitations in the data that make helpful analyses difficult, namely:

1. For the 10-year period, liquid releases are given only for 2005, 2007, 2008, and 2009

2. For the 10-year period, airborne releases are not given for 2006

3. For airborne releases of fission and activation gases, almost all of the quarterly measurements after 2003 are given as "N/D" (not detectable)

4. For liquid releases of fission/activation products, the number of curies from 2008 to 2009 jumped from 0.0114 to 34.8200, a 3054 times higher jump (which seems not likely)

5. Also for liquid releases of fission/activation products, the number of curies in the last three quarters of 2009 was 10.1, 10.1, and 10.1, respectively; the chance of these three being exactly equal is almost zero, and suggests these data are rough estimates

6. In 2008, while Browns Ferry emitted its highest amount of airborne tritium in the decade, it emitted its lowest amount of liquid tritium

*TVA Photographs of Browns Ferry, Fair usage for Non-profit science and health report.*

Without any further explanation from the Tennessee Valley Authority (TVA), which operates the plant and makes measurements, and the U.S. Nuclear Regulatory Commission (NRC), which regulates the TVA and publishes measurements, these unusual results have no obvious explanation. Because of these and other limits, precaution should be taken when analyzing these data for patterns and trends. Perhaps the most complete and most reliable type of radiation measure data is the airborne levels of tritium, a gas found in much greater amounts than many chemicals in reactors, and thus easier to measure.

Table 6. provides the quarterly and annual environmental releases of tritium from Browns Ferry 1, 2, and 3. All figures are given in curies.

**TABLE 6**

**Quarterly Airborne Releases of Tritium, 2000-2009
From Browns Ferry Nuclear Plant, in Curies**

| Year | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr | TOTAL |
|---|---|---|---|---|---|
| 2000 | 8.25 | 12.00 | 16.40 | 11.90 | **48.55** |
| 2001 | 19.50 | 9.22 | 14.80 | 15.30 | **58.82** |
| 2002 | 31.00 | 13.20 | 10.60 | 63.80 | **121.70** |
| 2003 | 25.80 | 38.30 | 22.90 | 22.90 | **109.90** |
| 2004 | 23.60 | 10.30 | 12.00 | 8.61 | **54.51** |
| 2005 | 13.20 | 14.90 | 10.10 | 5.57 | **43.77** |
| 2006 | No data | No data | No data | No data | ----- |
| 2007 | 1.90 | 14.30 | 11.30 | 7.13 | **34.63** |
| 2008 | 21.40 | 56.00 | 76.30 | 30.20 | **183.90** |
| 2009 | 39.10 | 19.20 | 19.50 | 17.70 | **95.50** |

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

In the decade, there are periods of increase and decline, from an annual low of 34.63 curies (in 2007) to a high of 183.90 curies (in 2008). There are even "hot" and "cold" quarters that sometimes follow one another. For example, there was a large increase from 10.60 to 63.80 curies from 3rd to 4th quarter 2002, before a decline back to 25.80 in 1st quarter 2003.

While acknowledging the limits of the data, Browns Ferry can be ranked among the 65 operating nuclear power plants in the U.S. In 2008, the year of its highest recorded airborne tritium emissions, Browns Ferry had the 8th highest amount in the nation:

**TABLE 7**

**U.S. Nuclear Power Plants (Total = 65 operational)
With Largest Airborne Tritium Released, 2008**

| Plant | State | Curies |
|---|---|---|
| 1. Palo Verde | AZ | 1715.1 |
| 2. Brunswick | NC | 296.2 |
| 3. Salem | NJ | 278.9 |
| 4. Harris | NC | 259.7 |
| 5. Catawba | SC | 258.7 |
| 6. D. C. Cook | MI | 242.7 |
| 7. McGuire | NC | 226.4 |
| **8. Browns Ferry** | **AL** | **183.9** |

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

| Curies of Tritium Released in Liquid Effluents | | |
|---|---|---|
| Statistical Summary for 2003 | PWR | BWR |
| Total | 40,600 | 665 |
| Minimum | 0.1 | 0 |
| Maximum | 2,080 | 174 |
| Average | 725 | 27.7 |
| Number of Data | 56 | 24 |

An NRC example of typical annual liquid releases from nuclear power plants. Source: U.S. Nuclear Regulatory Commission, FAQs About Liquid Radioactive Releases, http://www.nrc.gov/reactors/operating/ops-experience/tritium/faqs.html#affect (Note: The EPA allows 20,000 picocuries per liter in drinking water, and one picocurie equals 0.000000000001 curie or one trillionth of one curie.)

## B. Official Radioactivity Levels in the Environment

Nuclear power plants release tritium into the environment via routine and accidental releases into the air and water. The U.S. Environmental Protection Agency 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 is called "Envirofacts," can be accessed at http://iaspub.epa.gov/enviro/erams_query_v2.simple_query, and covers measurements taken since 1978.

There are nine Alabama locations in the EPA web site. Two are relatively close to Browns Ferry. One is Muscle Shoals in Colbert County, about 20 miles west of the plant, and the other is Scottsboro, about 70 miles east of the plant, in Jackson County. Each of these locations contains periodic measurements of various types of radioactivity in drinking water, beginning in 1978.

Unfortunately, many measurements for some types of radioactivity are given as negative numbers. A single measurement has an error range, meaning that there is a 95% chance that the true concentration of radioactivity is within that range. Sometimes, when levels are relatively low, the number falls below zero, although the true number is a low, but positive value. Analyzing data with many negative numbers is not helpful; types of radioactivity in drinking water with many values below zero include Iodine-131 and gross alpha (sum of all radioactive chemicals emitting alpha particles).

However, measurements of other types of radioactivity show most or all positive values. Table 8 summarizes the results for (annual) gross beta and (quarterly) tritium in drinking water, for Muscle Shoals, Scottsboro, and also Montgomery (a "control" location, far from any reactor). Gross beta is given for the period 1978-2013, while tritium is given for 1996-2013 (from 1978-1995, only measurements to the nearest hundred were reported for tritium).

**TABLE 8**

**Tritium and Gross Beta in Drinking Water, in Picocuries per Liter**
**Muscle Shoals, Scottsboro, and Montgomery AL, 1978-2013**

| Indicator | Muscle Shoals | Scottsboro | Montgomery |
|---|---|---|---|
| **Tritium (quarterly), 1996-2013** | | | |
| Measurements | 66 | 66 | 60 |
| Average | **88.52** | **78.53** | **11.08** |
| High Measurement | 574 | 295 | 151 |
| Number < Zero | 9 | 10 | 25 |
| Average (assume negative numbers equal zero) | **90.97** | **84.53** | **25.42** |
| **Gross Beta (annual), 1978-2013** | | | |
| Measurements | 34 | 33 | 34 |
| Average | **1.94** | **1.73** | **1.63** |
| High Measurement | 2.67 | 2.99 | 3.07 |
| Number < Zero | 0 | 0 | 0 |

Note: EPA allows 20,000 picocuries in our drinking water. One picocurie is one trillionth of a curie. Source: U.S. Environmental Protection Agency. Radnet: Envirofacts, http://iaspub.epa.gov/enviro/erams_query_v2.simple_query.

The tritium data in drinking water show both Muscle Shoals and Scottsboro have much greater levels than Montgomery (3-4 times more, or 7-8 times more, depending on whether negative numbers are counted as negative or zero). There were 66 measurements at both Muscle Shoals and Scottsboro, and 60 in Montgomery. The Muscle Shoals average is slightly above Scottsboro (+12.7%, or 88.52 vs. 78.53). **The highest single concentration of tritium in drinking water since 1996 was 574 picocuries per liter, in Muscle Shoals on October 11, 2012.**

The gross beta readings also show Muscle Shoals has a higher 1978-2013 average than Scottsboro and Montgomery. Muscle Shoals is the highest, or 19.0% above Montgomery (1.94 vs. 1.63 picocuries per liter). None of the 101 measurements in the three locations were less than zero.

While these data show relatively higher environmental levels closer to Browns Ferry, they are quite limited. Both tritium and gross beta are present in natural background radiation, and are not just produced by nuclear reactors; however, tritium is produced by and routinely released from nuclear power plants – and then there are the accidental releases (see Appendix 3). Identifying levels of individual anthropogenic (man made) radioactive chemicals only produced in reactors or atomic bombs, by using spectrographs or radiation spectral analyzers, would be much more helpful to understand the additional radioactivity that Browns Ferry adds to the environment.

In addition, testing at more sites, especially those closer than 20 miles from the plant, would also provide more useful information. Finally, more frequent tests could better identify patterns; for example, **readings such as the very high October 11, 2012 tritium in Muscle Shoals drinking water (574 pCi/l) might be identified if more than quarterly measurements were made.**

## C. RADIOACTIVITY IN THE ENVIRONMENT MEASURED BY CITIZENS

Because of the limitations of official measurements of environmental radioactivity, interested local citizens near Browns Ferry embarked on a program of measurements in October 2012. The group, Bellefonte Efficiency and Sustainability Team (BEST), a chapter of the larger Blue Ridge Environmental Defense League (BREDL). The group's mission includes empowering communities through environmental education in the Tennessee River Valley, encompassing the Browns Ferry, Sequoyah, and Watts Bar nuclear reactors.

Lou Zeller, BREDL's Executive Director and the project's Quality Assurance Officer, began the group's training using EPA standards; and BEST Monitoring Project Manager, Garry Morgan (retired U.S. Army Medical Department), expanded protocol to include Homeland Security standards and created the *BEST Radiation Monitoring Manual*.

BEST project methods are based on models developed in 2005 by Russian scientist Sergey Pashenko and American scientist Norm Buske and published in *A Citizen's Guide to Radiation Monitoring*; and also the BREDL/Shell Bluff Draft QAPP of July 3, 2012. BEST purchased a Geiger counter (Inspector™, manufactured by Southeast International) to measure the total of alpha, beta, gamma, and X-ray radiation in the air, water, and land.

Background levels were always established first, since a portion of environmental radioactivity is from natural sources (spectrographs are needed to identify radionuclides). Background levels, in Counts Per Minute (CPM), were 26 in water and 36 to 40 on land.

Although these are preliminary, several findings became clear in the first few months of BEST project operations that were not identified by measurements posted by NRC and EPA regulators on their websites.

**1. ELEVATED LEVELS CLOSE TO PLANT** Higher than background levels were generally found in locations close to Browns Ferry, i.e. those 1 to 10 miles from the plant's outer boundary. The high counts at these locations were about 125 CPMs, or 3-4 times above the background level of 36 to 40.

**2. ELEVATED LEVELS DOWNWIND OF PLANT** Higher levels of airborne and land-based radioactivity were documented at locations downwind (east) of Browns Ferry. Measurements upwind (west) showed minor difference with background levels.

**3. ELEVATED LEVELS DOWNRIVER OF PLANT** Measurements taken in the Tennessee River downriver from the plant were roughly 2 times greater than those taken from upriver locations.

**4. <u>HIGHEST LEVELS AFTER RAIN EVENT</u>** The highest levels of radioactivity occurred just after precipitation brought particles to earth. The highest readings observed by BEST members occurred in Scottsboro AL, 70 miles east of Browns Ferry. The team wiped droplets of precipitation from the hood of a car with a paper towel; the droplets were observed to be black. It is possible that radioactive particles, which are invisible, might be trapped in blackened soot particles. The team made minute-by-minute tests for one hour holding the Inspector™ counter just above the sample, and observed a high reading of 1602 CPM at twelve minutes (at least 40 times above background levels); also performing simple paper and aluminum tests confirming beta and gamma radiation.

**5. <u>HIGHEST LEVELS FOUND FAR FROM PLANT</u>** The fact that the highest levels detected thus far were from Scottsboro, 70 miles downwind of Browns Ferry, indicates a possibility that dispersion of radioactive emissions from nuclear plants may be an inconsistent result of wind and precipitation patterns, and may travel relatively long distances from a plant; however, the source can not be pin-pointed without spectrometers.

BEST has made their users manual available online at RadiationMonitors.blogspot.com and many of their field test operations can be viewed through a series of internet-based videos at RadiationVideos.blogspot.com. (Also see Appendix 5.)

## D. <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, one of dozens of radioactive chemicals found only in atomic bomb tests and nuclear reactor emissions. It is chemically similar to calcium, seeking out bone and teeth, and resides in the body for many years (half-life of 28.7 years), making it possible to test in-body levels. Sr-90 impairs and kills cells in the bone and bone marrow (in which the immune system defenses are built) making it a risk factor for all cancers.

The St. Louis study found that for children born in 1964, just after above-ground bomb testing ended, the average Sr-90 level was **50 times greater** than for those born in 1950, just before testing began. After above-ground atom bomb tests were banned, Sr-90 averages declined sharply (about 50% from 1964-1969) until the federal government discontinued the study in 1970. (Source: Rosenthal HL. 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 or DOE) operated a program measuring annual Sr-90 concentrations in the vertebrae of 100 healthy adults in San Francisco and New York City who had died in accidents. From 1965-74, after the Partial Test Ban Treaty reduced levels of fallout in diet, the average concentration of Sr-90 declined by 50% and at a lesser rate thereafter.
(Source: Klusek CS, Strontum-90 in Human Bone in the U.S., 1982. New York: Department of Energy Environmental Measurements Laboratory, 1982.)

The DOE terminated its 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) research group conducted a baby tooth study measuring Sr-90 levels, known as the Tooth Fairy Project. The study is patterned on the St. Louis effort, which provides historical data on Sr-90 levels in the U.S. **The RPHP tooth project represents the only study in the U.S. of in-body radioactivity for persons living near nuclear reactors.**

RPHP collected and tested nearly 5000 teeth, mostly from California, Connecticut, Florida, New Jersey, New York, and Pennsylvania. It found a consistent pattern of elevated Sr-90 (30 to 50% higher) in baby teeth living in counties closest to reactors, and a 49% rise in Sr-90 for children born in the late 1990s vs. the late 1980s. (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). Very few teeth from Alabama were collected and tested.

## *IV. HEALTH RISKS OF BROWNS FERRY*

### A. INTRODUCTION

Since the atomic era began in the 1940s, scientists have studied effects of exposures to man-made radioactivity. Elevated levels of illness and death are attributed to the Hiroshima and Nagasaki bombs; bomb tests in Nevada, the South Pacific, and the former Soviet Union; and the 1986 accident at the Chernobyl nuclear power plant. 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 a pelvic X-ray to a pregnant woman nearly doubled the chance the baby would die of cancer before age 10. (Source: Stewart AM, Webb J, and Hewitt D. A Survey of Childhood Malignancies. British Medical Journal, 1958;i:1495-1508).

Studies of low-dose exposures have addressed many diseases, but 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, and thus a damaged cell is most likely to cause harm. **There are at least 19 medical journal articles that identify elevated child cancer rates near different nuclear plants**, mostly power plants (see Appendix 1).

### B. DEFINING AREAS CLOSEST TO BROWNS FERRY

Defining which areas are most likely to be harmed by toxic emissions from Browns Ferry is an inexact process. The most affected are a result of proximity and downwind location, along with the source of food and water. The prevailing wind direction in the area is, similar to most of the continental U.S., from west to east (usually from the northwest in colder months and from the southwest in warmer months).

The seven Alabama counties closest to and downwind of Browns Ferry will be used for most analyses. These counties have a combined 2010 population of 788,867, including DeKalb (71,109), Jackson (53,227), Lawrence (34,339), Limestone (82,782), Madison (334,811), Marshall (93,109). The city of Huntsville is in Madison County. These counties are used because BEST citizens found the highest environmental radiation levels were detected in Scottsboro, 70 miles downwind. The map below shows monitored sites.


Map shows Browns Ferry and BEST radiation test sites. by Roy Simmons for BEST/MATRR

## C. BREAST CANCER MORTALITY NEAR BROWNS FERRY

RPHP's Jay Gould performed research on breast cancer near nuclear reactors. In his 1996 book *The Enemy Within*, Gould used National Center for Health Statistics data to show that women living within 100 miles of nuclear reactors are at the greatest risk of dying of breast cancer. (Source: Gould JM et al. The Enemy Within: The High Cost of Living Near Nuclear Reactors. New York: Four Walls Eight Windows, 1996).

Gould found that for most counties closest to Browns Ferry, the breast cancer death rate for white women rose substantially from the early 1950s to the late 1980s (Table 8). These include Limestone (+15%), Madison (+74%), and Morgan (+4%). The exception is Lawrence County (-37%). By contrast, rates for the U.S. only rose 1%.

**TABLE 9**

**Breast Cancer Mortality Rates, White Females and All Ages**
**Alabama Counties Closest to Browns Ferry Nuclear Plant, 1950-54 and 1985-89**

| | Rate/100,000 (Deaths) | | |
|---|---|---|---|
| County | 1950-54 | 1985-89 | % Change |
| Lawrence | 20.4 ( 8) | 12.9 ( 10) | - 37% |
| Limestone | 18.8 ( 11) | 21.7 ( 27) | +15% |
| Madison | 15.9 ( 20) | 27.6 ( 149) | +74% |
| Morgan | 16.6 ( 17) | 17.3 ( 50) | + 4% |
| U.S. | 24.4 (91932) | 24.6 (178868) | + 1% |

Source: National Center for Health Statistics, in *The Enemy Within*, Gould JM et al. New York: Four Walls Eight Windows, 1996. Rates age adjusted to 1950 U.S. Standard.

## D. <u>THYROID CANCER INCIDENCE</u>

Exposure to radioactive fission products constitutes a risk factor for all cancers. However, some cancers are considered more radiosensitive than others. One is childhood cancer, for reasons already explained. Another is thyroid cancer. One of the radioactive chemicals not found in nature, but produced only in atom bomb tests and nuclear reactor operations is radioisotopic iodine, which seeks out the thyroid gland when it enters the body, impairing and killing cells. Experts have not identified any true cause of thyroid cancer other than exposure to radioactive iodine; other risk factors, such as presence of another thyroid disorder, are not considered causes of the disease.

Thyroid cancer, of which radioactive iodine produced by nuclear power or bombs is the only known cause, is the fastest-rising type of cancer in the U.S., its rate having more than tripled from 1980 to 2009. The annual number of Americans diagnosed with the disorder has risen from 12,000 to 56,000 since 1991. While some contend that better diagnosis over time accounts for this increase, numerous researchers assert that there are other, still unknown factors. (Source: National Cancer Incidence, Surveillance, Epidemiology, and End Results program, http://www.seer.cancer.gov).

Because thyroid cancer is often treatable, and 97% of victims live more than five years after diagnosis, incidence is a much more useful measure of thyroid cancer than mortality. Table 10 lists the 10 Alabama counties (with at least 15 cases) with the highest 2005-2009 thyroid cancer incidence rates in the state:

**TABLE 10**

**Highest Thyroid Cancer Incidence**
**Alabama Counties, 2005-2009**

| County | Rate/100,000 | (Cases) |
|---|---|---|
| 1. Winston | 15.6 | ( 20) |
| 2. Walker | 12.4 | ( 45) |
| 3. Lauderdale | 11.7 | ( 55) |
| **4. Marshall** | **11.4** | **( 55)** |
| 5. Escambia | 10.7 | ( 20) |
| **6. Jackson** | **10.3** | **( 30)** |
| 7. Etowah | 9.7 | ( 55) |
| **8. Madison** | **9.3** | **(150)** |
| **9. Limestone** | **9.2** | **( 35)** |
| 10. Tuscaloosa | 9.1 | ( 75) |

Source: National Cancer Institute, State Cancer Profiles. www.statecancerprofiles.cancer.gov. Age Adjusted to 2000 U.S. Standard Population

Black spot denotes Browns Ferry


U.S. Census Bureau
www.census.gov

**Of the 10 Alabama counties with the highest thyroid cancer rates, four (4) are among the seven proximate/downwind counties in this analysis.** Among the four is Madison, with nearly one-half of the residents in the area. It appears that thyroid cancer in the area is higher than most Alabama counties.

## E. FEDERAL STUDIES OF CANCER NEAR U.S. NUCLEAR PLANTS

The federal government conducts no systematic tracking of disease and death rates among persons living near nuclear plants. The only large-scale federal study on cancer near nuclear reactors was a 1990 effort prepared by the National Cancer Institute (NCI), after Senator Edward M. Kennedy wrote to the National Institutes of Health director James Wyngaarden about an article on elevated leukemia rates near the Pilgrim plant in Massachusetts. NCI concluded there was no link between cancer risk and proximity to reactors, even though study methods have received criticism.

Browns Ferry was one of the 62 nuclear plants included in the NCI's 1990 study. The project analyzed cancer mortality in five-year periods before and after reactor startup in the period 1950 to 1984. It used the Standard Mortality Ratio (SMR), or the county rate divided by the U.S. rate, as a measure of mortality. The only cancer incidence (as opposed to mortality) data in the report was near reactors in Connecticut and Iowa, which were the only states with operating and reliable cancer registries before 1984.

The NCI selected Lawrence and Limestone counties as the "study" counties most proximate to Browns Ferry. Table 11 shows the change in SMR for all cancers before (1950-1973) and after (1974-1984) the startup of Browns Ferry.


**TABLE 11**

**Standard Mortality Ratio, All Cancers Combined
Lawrence and Limestone Counties, 1950-1973 and 1974-1984**

| Type of Cancer | Std. Mortality Ratio (Deaths) 1950-73 | 1974-84 | % Change |
|---|---|---|---|
| All+ | 0.78 (1497) | 0.91 (1230) | +17** |
| Leukemia | 0.98 ( 91) | 1.00 ( 55) | + 2 |
| Hodgkins Disease | 0.79 ( 18) | 1.17 ( 9) | +48 |
| Non-Hodgkins Lymphoma | 0.46 ( 24) | 0.75 ( 31) | +63 |
| Multiple Myeloma | 0.56 ( 13) | 0.66 ( 15) | + 9 |
| Stomach | 0.89 ( 132) | 0.58 ( 30) | - 35* |
| Colorectal | 0.58 ( 162) | 0.75 ( 135) | +29** |
| Liver | 0.84 ( 56) | 1.54 ( 31) | +83* |
| Trachea, Bronchus, Lung | 0.61 ( 189) | 1.00 ( 343) | +64* |
| Female Breast | 0.75 ( 131) | 0.79 ( 96) | + 5 |
| Thyroid | 0.71 ( 5) | 0.30 ( 1) | - 58 |
| Bone and Joint | 1.37 ( 20) | 1.20 ( 6) | - 12 |
| Bladder | 0.76 ( 42) | 0.76 ( 25) | 0 |
| Brain/Other Nervous Sys. | 0.97 ( 46) | 1.04 ( 36) | + 7 |
| Benign/unspecified neoplasms | 1.13 ( 7) | 1.40 ( 15) | +24 |

+Excluding Leukemia, * Significant at p<.05, ** Significant at p<.001
Source: Jablon S. et al. Cancer in Populations Living Near Nuclear Facilities. Washington DC: U.S. Government Printing Office, 1990.

Of the 15 types of cancer, the Standard Mortality Ratio (SMR) increased in 11; decreased in 3; and was unchanged in 1. The SMR increase for all cancers of 0.78 to 0.91, or from -22% to -9% below the U.S. rate, was highly significant at p<.001. Increases were also significant for colorectal, liver, and lung cancer.

In May 2009, the U.S. Nuclear Regulatory Commission published a notice in the Federal Register, announcing it was pursuing another 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 to conduct the study. The NAS has convened a panel to judge the feasibility of such a study, and to conduct and present it. There will be no public release of the study, whether or not it is completed, until at least 2015.

## F. INFANT MORTALITY

In 2000 and 2002, this author, Joseph Mangano, published articles for the Radiation Public Health Project showing that when nuclear power plants shut down, deaths of infants under one year and cancer cases of children under five years in local downwind counties decline rapidly immediately after shutdown. Sources: Mangano JJ. Improvements in local infant health after nuclear power reactor closing. Environmental Epidemiology and Toxicology 2000;2(1):32-36. Mangano JJ et al. Infant death and childhood cancer reductions after nuclear plant closings in the United States. Archives of Environmental Health 2002;57(1):23-32.

Because the developing fetus and infant are especially sensitive to harmful biological effects of radiation exposure, any change in health status from adding or removing environmental radioactivity will first be observed in the youngest.

Table 12 shows the change in the infant death rate in the seven Alabama counties closest to and downwind from Browns Ferry, from the two-year period 1973-1974 (as the plant was running at limited power) to the two year period 1975-1976 (as the plant was operating at full power).

**TABLE 12**

**Change in Local Infant Mortality, Age 0-1**
**Two Years Before 1973-74 and Two Years After 1975-76 Browns Ferry Startup**

| | Infant Deaths | | Live Births | | Deaths/1000 | | |
|---|---|---|---|---|---|---|---|
| Area | Before | After | Before | After | Before | After | % Ch |
| **7 Counties** | 287 | 271 | 15213 | 14604 | 18.87 | 18.56 | **- 1.6** |
| **United States** | 108357 | 98790 | 6296923 | 6311986 | 17.21 | 15.65 | **- 9.5** |

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Compares periods 1973-1974 and 1975-1976. Includes DeKalb, Jackson, Lawrence, Limestone, Madison, Marshall, and Morgan Counties.

The change in the death rate under one year in the seven counties closest to Browns Ferry was -1.6%, much less than the reduction in the United States (-9.5%). Even though the difference was not statistically significant, the change in local infant mortality supports studies showing the fetus and infant are more susceptible to radiation doses than adults. (See Appendix 1)

Another opportunity to evaluate changes after reactor startup was the re-start of Browns Ferry Unit 1 in June 2007, after 22 years of the reactor being offline (since 1985). The change in infant mortality in the two years after the Unit 1 reactor operated at full power (2008-2009) was also compared with the prior two years, for the same seven downwind counties: Lawrence, Limestone, Morgan, Madison, Marshall, Jackson, and DeKalb.

The local infant death rate fell just -0.4% after Browns Ferry Unit 1 re-start in 2007, compared to a nationwide decline of -4.9%. The Unit 1 restart infant mortality difference fell short of statistical significance. However, this followed the same pattern that was indicated when the plant began operating in the mid-1970s (Table 12).

With 43 years of infant mortality data available, it is possible to evaluate trends in local rates, compared to the U.S., over a long period of time. Table 13 shows the change in mortality among infants younger than one year for five-year periods, from 1968 to 2010. (The six-year period 1968-1973 is used to illustrate the period before Browns Ferry began operating; the two-year period 2009-2010 is used because it is the most current data available on the CDC web site as of spring 2013).

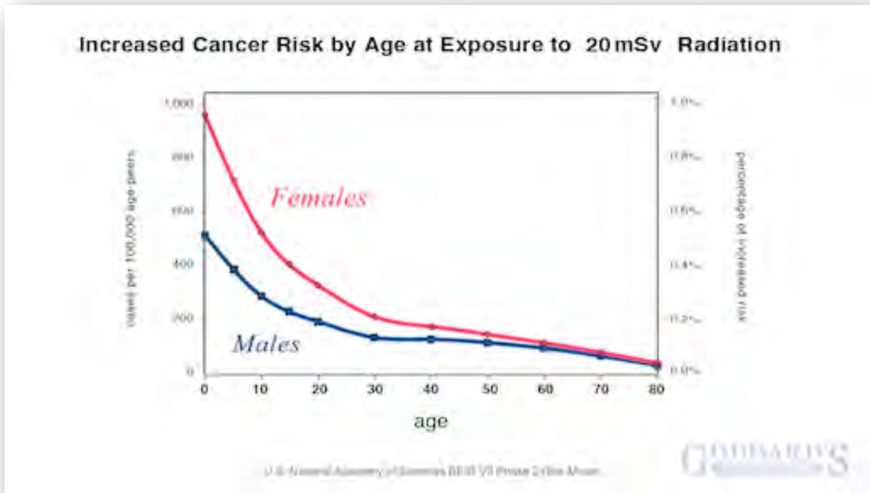
**TABLE 13**

**Infant Mortality, Age 0-1**
**Seven-County Area in Northern Alabama vs. U.S.**
**Five Year Periods, 1968-2010**

| | **Deaths/1000** | | | |
|---|---|---|---|---|
| Period | Local | U.S. | Local Deaths | **% Local vs. U.S.** |
| 1968-1973 | 20.99 | 19.71 | 1,084 | **+ 6.5** |
| **1974-1978** | 16.99 | 15.16 | 639 | **+12.1** |
| 1979-1983 | 12.73 | 12.05 | 501 | **+ 5.7** |
| 1984-1988 | 10.06 | 10.36 | 411 | **- 2.8** |
| 1989-1993 | 8.39 | 8.98 | 390 | **- 6.5** |
| 1994-1998 | 7.54 | 7.47 | 346 | **+ 0.8** |
| **1999-2003** | 7.76 | 7.14 | 352 | **+ 8.7** |
| **2004-2008** | 8.56 | 6.99 | 419 | **+22.6** |
| **2009-2010** | 7.80 | 6.42 | 154 | **+21.6** |

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Includes DeKalb, Jackson, Lawrence, Limestone, Madison, Marshall, and Morgan Counties.

After an initial jump in local vs. national infant mortality in the late 1970s, when Browns Ferry first began operating, the following years saw the local rate decline more rapidly, until it was below the U.S. But since the early 1990s, a steady increase has occurred in the local vs. national rate **(-6.5%, +0.8%, +8.7%, +22.6%, and +21.6%** for the latest two years available). With about 80 local infants dying each year in the seven counties, the numbers are large enough to merit further examination into potential reasons for this unexpected change, including exposure to emissions from Browns Ferry.




Source: National Academy of Sciences, *Biological Effects of Ionizing Radiation BEIR VII Phase 2 Report: Health Risks from Exposure to Low Levels of Ionizing Radiation*, National Academies Press, 2006, http://www.nap.edu/catalog/11340.html, (pg. 311), adjusted 100 mSv to 20 mSv by Ian Goddard according to BEIR instructions.

One way to further examine recent infant death rates is by race. Since 1999, the CDC web site classifies deaths into white non-Hispanics, black non-Hispanics, and white Hispanics, which make up nearly 100% of all deaths in the seven counties downwind of Browns Ferry. Table 14 shows local rates compared to the U.S. for each of these three racial/ethnic groups for the years 2004-2010, when local infant mortality was more than 20% greater than the U.S.

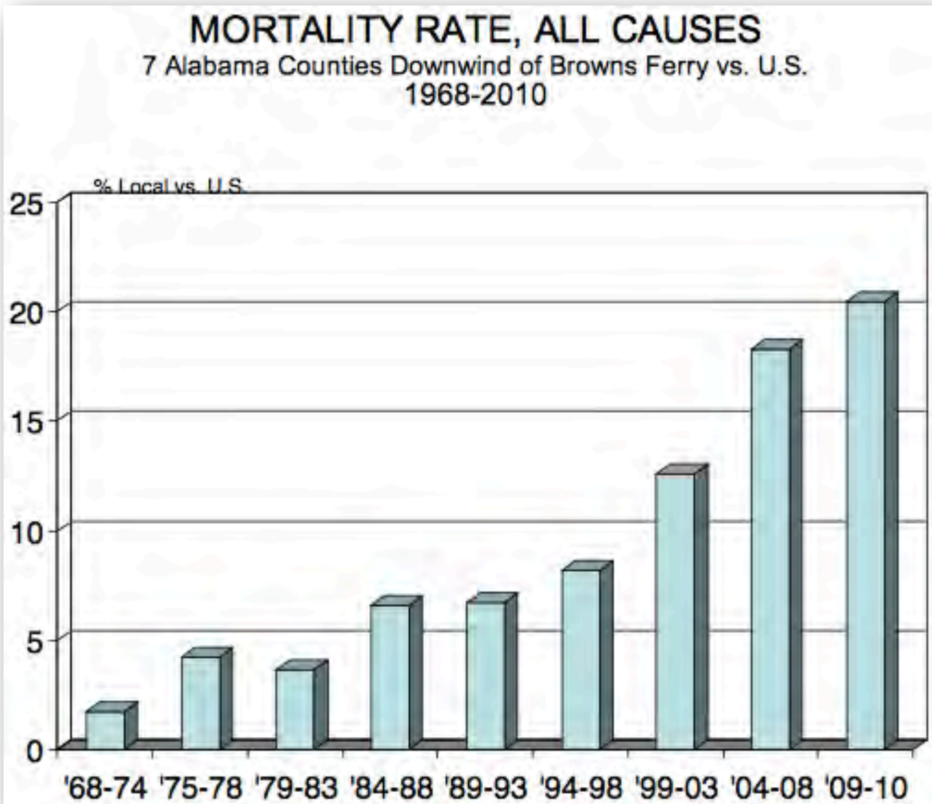
**TABLE 14**

**Infant Mortality, Age 0-1, By Race, 2004-2010**
**Seven-County Area in Northern Alabama vs. U.S.**

| Group | Deaths/1000 Local | Deaths/1000 U.S. | Local Deaths | % Local vs. U.S. |
|---|---|---|---|---|
| **White Hispanic** | 8.21 | 5.85 | 77 | **+40.3** |
| **White non-Hispanic** | 7.59 | 5.72 | 352 | **+32.6** |
| **Black non-Hispanic** | 12.71 | 13.46 | 135 | **- 5.6** |

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Includes DeKalb, Jackson, Lawrence, Limestone, Madison, Marshall, and Morgan Counties.

**Local 2004-2010 infant mortality rates for whites greatly exceeded the U.S., both for Hispanics (+40.3%) and non-Hispanics (+32.6%).** Both are statistically significant. The local rate for black non-Hispanics was actually 5.6% less than the nation, a non-significant difference.




## G. LOCAL MORTALITY RATE FROM ALL CAUSES

Another way to examine any potential health hazards from Browns Ferry radioactive emissions is to examine mortality. As mentioned, the U.S. Centers for Disease Control and Prevention maintains a data base on its web site of all deaths in the U.S. from 1968 to 2010, and adds the latest year's data annually.

Table 15 shows the local age-adjusted mortality rate compared to the U.S. rate for each five-year period beginning in 1968. The first period (1968-1974) is six years, as it represents the period before large-scale operations began at Browns Ferry, and the last period (2009-2010) is only two years pending the addition of future years. The table uses the seven closest counties located downwind (east) of the plant.

**TABLE 15**

**Mortality, All Causes Combined, All Ages**
**Seven-County Area in Northern Alabama vs. U.S.**
**Five Year Periods, 1968-2010**

| **Period** | Deaths/100,000 Local | Deaths/100,000 U.S. | Local Deaths | **% vs. US** | Expected | **Excess** |
|---|---|---|---|---|---|---|
| 1968-1974 | 1244.0 | 1222.8 | 26,426 | **+ 1.7** | - | - |
| 1975-1978 | 1113.1 | 1067.8 | 15,834 | **+ 4.2** | 15,438 | 396 |
| 1979-1983 | 1042.5 | 1005.9 | 21,079 | **+ 3.6** | 20,678 | 401 |
| 1984-1988 | 1043.4 | 978.5 | 23,883 | **+ 6.6** | 22,713 | 1170 |
| 1989-1993 | 990.6 | 927.9 | 25,836 | **+ 6.7** | 24,544 | 1292 |
| 1994-1998 | 965.4 | 892.5 | 28,650 | **+ 8.2** | 26,788 | 1862 |
| 1999-2003 | 968.6 | 860.3 | 31,515 | **+12.6** | 28,080 | 3435 |
| 2004-2008 | 939.0 | 793.7 | 34,234 | **+18.3** | 28,551 | 5683 |
| 2009-2010 | 901.9 | 748.3 | 14,405 | **+20.5** | 11,452 | 2953 |
| **Total 1975-2010** | **(36 years)** | | **195,436** | | **178,244** | **17,192 (8.8%)** |

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population. Includes DeKalb, Jackson, Lawrence, Limestone, Madison, Marshall, and Morgan Counties.

**In 1968-1974, largely before operations at Browns Ferry began, the local mortality rate was just 1.7% above the U.S. Thereafter, the gap steadily increased, until by 2009-2010, the local rate was 20.5% greater – the largest elevation in at least 43 years.**

Because the annual number of deaths in the seven counties is now over 7,000, this trend is highly significant. There is no obvious demographic change, such as race, ethnicity, age, or gender that explains such a dramatic difference. But while there are many potential factors that could contribute to this steady increase, exposure to emissions from Browns Ferry should be considered as one.

It is notable that a similar trend in local infant deaths occurred for all deaths, and that currently, local rates for both are more than 20% above the U.S. rate.

In 1999-2010, the most recent 12-year period, in which the greatest local-national gap in mortality rates was observed, it would be informative to examine the patterns for various demographic groups. Table 16 provides these data for four age groups, for racial/ethnic groups, and for each gender.

**TABLE 16**

**Mortality, All Causes Combined, All Ages**
**Seven-County Area in Northern Alabama vs. U.S.**
**By Race/Ethnicity, Gender, and Age Group, 1999-2010**

| | Deaths/100,000 | | | |
|---|---|---|---|---|
| Group | Local | U.S. | Local Deaths | % Local vs. U.S. |
| All Persons | 943.0 | 811.7 | 80,154 | **+16.2** |
| Race/Ethnicity | | | | |
| White non-Hispanic | 951.0 | 808.0 | 71,039 | **+17.7** |
| Black non-Hispanic | 1006.0 | 1042.5 | 8,198 | **- 3.5** |
| Gender | | | | |
| Males | 1128.9 | 971.1 | 40,132 | **+16.2** |
| Females | 799.9 | 687.9 | 40,022 | **+16.3** |
| Age at Death | | | | |
| 0-24 | 88.0 | 69.1 | 2,595 | **+27.4** |
| 25-44 | 192.0 | 152.7 | 4,745 | **+25.7** |
| 45-64 | 728.8 | 613.9 | 16,677 | **+18.7** |
| 65+ | 5482.0 | 4790.5 | 56,137 | **+14.4** |

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population.. Includes DeKalb, Jackson, Lawrence, Limestone, Madison, Marshall, and Morgan Counties.

In the 12-year period, the local age-adjusted mortality rate for all deaths was 16.2% above the U.S., based on 80,154 deaths. Local rates exceeded the nation for each age group, males and females, and white non-Hispanics. All local-national differences were statistically significant. The only demographic group in which the local rate was less than the U.S. was for black non-Hispanics (-3.5% lower). This group accounted for 10% of the deaths in the seven counties from 1999-2010. The low rate for all deaths for black non-Hispanics was similar to the low rate for infant deaths in this racial/ethnic group.

**Local death rates were especially high for young persons. The rates for persons who died at age 0-24 and 25-44 were 27.4% and 25.7% above the U.S., respectively.**

Another way to examine mortality patterns in the seven closest counties downwind from Browns Ferry is by cause of death. Table 17 compares local and national 1999-2010 age-adjusted mortality rates for the 11 most common causes, which account for 98% of deaths, plus all others combined.

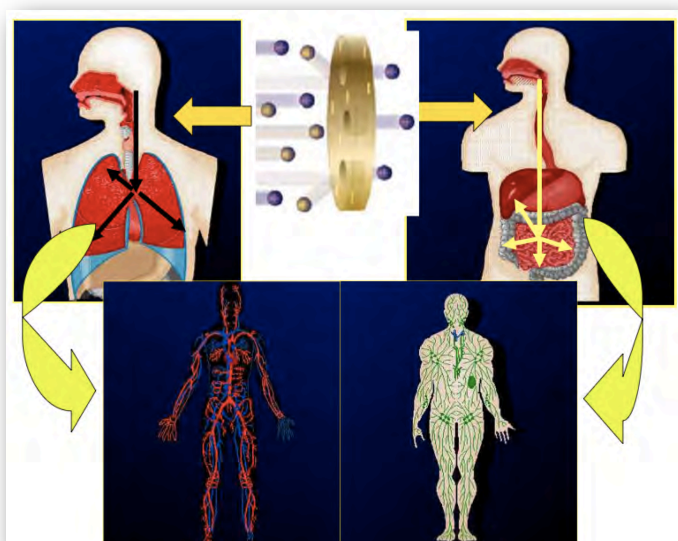
**TABLE 17**

**Mortality, Most Common Causes, All Ages**
**Seven-County Area in Northern Alabama vs. U.S., 1999-2010**

| Cause | Deaths/100,000 Local | Deaths/100,000 U.S. | Local Deaths | % Local vs. U.S. |
|---|---|---|---|---|
| All Persons | 943.0 | 811.7 | 80,154 | **+ 16.2** |
| Circulatory System | 354.0 | 289.0 | 29,511 | **+ 22.5** |
| Neoplasms | 199.7 | 190.5 | 17,865 | **+ 4.8** |
| Respiratory System | 95.8 | 78.4 | 8,079 | **+ 22.3** |
| Homicide, Suicide, Accidents | 68.2 | 57.6 | 5,922 | **+ 18.4** |
| Nervous System | 43.5 | 38.5 | 3,512 | **+ 13.0** |
| Endocrine, Nutr., Metabolic | 36.8 | 32.8 | 3,155 | **+ 12.4** |
| Digestive System | 31.6 | 29.0 | 2,778 | **+ 9.1** |
| Genitourinary System | 30.3 | 20.3 | 2,477 | **+ 49.5** |
| Infectious/Parasitic Diseases | 21.9 | 21.7 | 1,887 | **+ 0.9** |
| Mental/Behavioral Diseases | 23.3 | 25.1 | 1,817 | **- 7.0** |
| Signs and Symptoms | 19.7 | 11.1 | 1,625 | **+ 77.9** |
| All Other | 18.2 | 17.9 | 1,526 | **+ 1.6** |

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population.. Includes DeKalb, Jackson, Lawrence, Limestone, Madison, Marshall, and Morgan Counties.

The seven county mortality rate exceeded the U.S. rate for 11 of the above 12 categories. Of the 11 categories with excesses, 9 were statistically significant. The greatest excesses include signs and symptoms (+77.9%), genitourinary system disorders (+49.5%), circulatory system disorders (+22.5%), and respiratory system disorders (+22.3%).



Graphic Source: Antonietta M. Gatti et al, "Nanopathology: The Role of Micro and Nanoparticles in Biomaterial-induced Pathology", The European Commission, Project QLRT-2002-J47 (2002-2005), http://inchesnetwork.net/Fetal%20and%20embryological%20origin%20of%20diseases_Gatti.pdf

Analysts often point out that there may be limitations in geographic comparisons by cause of death. Categories are defined by the primary cause of death; in many cases, a decedent suffers from multiple disorders (such as heart disease and cancer). There are rules to define which cause is the primary cause, but they can be subject to interpretation by physicians completing death certificates and coders assigning a code to the primary cause of death. In other cases, a vague symptom might be assigned as the primary cause of death instead of a known disease entity; the seven-county death rate from signs and symptoms is nearly double that of the U.S. (19.7 vs. 11.1 deaths per 100,000 persons).

The local mortality rate from neoplasms, or cancers, is just 4.8% above the U.S. However, there is a possibility that a greater proportion of those local decedents who had cancer were assigned to another disease category than in the nation as a whole.

It is clear that the consistently high local death rates across various causes of death show an unusual pattern worthy of greater investigation, especially since the 1968-1974 local death rate was just 1.7% above the U.S, compared to the 2010 rate of 20.5%.

## H. CHILD CANCER INCIDENCE

Another health condition sensitive to radiation is childhood cancer. As mentioned, a dose of radiation causes much more genetic and cellular damage to the fetus, infant, and young child than the same exposure does to an adult. However, it is not possible to examine long-term trends in cancer incidence in Alabama, since the state cancer registry only began in 1996, and the latest available data are for cases diagnosed in 2009.

In the most recent available period (2005-2009), cancer incidence among children age 0-19 for each Alabama county with at least 15 cases in the five year period is provided on the internet. Rates for two of the four counties closest to Browns Ferry exceeded the Alabama rate of 15.2 cases per 100,000 per year; Limestone County (21.8) and Morgan County (16.7). Madison County's rate (12.4) was below the state; and no figures are calculated for all 50 states combined. Given limited data, a precise cause and effect relationship between Browns Ferry and local childhood cancer cannot be made or rejected. Nevertheless, there are 26 children a year who contract cancer in Browns Ferry's Limestone County and 42 kids a year who get cancer in downwind Madison County for yet unknown reasons. Source: National Cancer Institute, State Cancer Profiles. www.statecancerprofiles.cancer.gov and census.gov.

# *V. CONCLUSIONS AND RECOMMENDATIONS*

## A. CONCLUSIONS

This report has addressed patterns of radioactive emissions from the Browns Ferry Nuclear Power Plant, and potential links with adverse health effects among those living near or downwind of the plant. The plant has three of the five operating nuclear power reactors in Alabama. Nearly 1 million persons live within 50 miles of Browns Ferry.

The potential health consequences posed by Browns Ferry are massive. The plant contains 1,932 metric tons (containing 314,140,400 curies) of high-level radioactive waste, the highest of all U.S. nuclear plants except for Dresden IL. Most of this radioactivity is stored in deep pools of constantly-cooled water; loss of cooling water would result in a disastrous meltdown, which would poison many thousands of persons. A 1982 U.S. government panel estimated casualties from a core meltdown near all U.S. nuclear plants, and calculated 60,000 acute radiation poisoning and 3,800 cancer deaths per reactor near Browns Ferry. The numbers would be higher today because of increased population and additional casualties beyond the 20- and 30-mile limits of the study.

Browns Ferry has had a checkered safety record. The six shutdowns of at least one year is the highest number at any U.S. nuclear plant. The source of one of these shutdowns, the 1975 fire at Browns Ferry unit 1, is regarded by many as the most serious accident at a U.S. nuclear power plant other than the Three Mile Island partial meltdown. In addition, the 22-year outage at Browns Ferry 1 from 1985 to 2007 is easily the longest 'temporary' shutdown of any U.S. nuclear reactor.

The design of the Mark I reactor cooling pools at Browns Ferry are vulnerable to attacks by tornados as well as terrorists, since they are raised four stories in the air with no hardened overhead containment of these pools holding millions of pounds of highly enriched radioactive fuel in addition to nearly a million gallons of radioactive water. Browns Ferry is also one of the four nuclear power plant sites in history to receive a 'Red Finding' (the most severe short of plant shutdown) from the Nuclear Regulatory Commission in May, 2011 – a finding which still stands today.

While official measurements of radioactive emissions and environmental levels are often limited, some findings suggest that Browns Ferry is adding harmful radioactivity to the environment and food chain. For example, quarterly tritium levels taken since 1996 in drinking water at Muscle Shoals and Scottsboro were 3-4 times and 7-8 times greater than those in Montgomery, a control site far from any nuclear power plant.

Citizen-based monitoring, while only in operation for seven months, shows preliminary patterns indicating that Browns Ferry may be adding to environmental radioactivity levels, especially at downwind and downriver sites, and after rain events; however, spectrographic analyses of the offending radionuclides is required to determine specific identification of the radiation sources. BEST monitoring has recorded radiation levels from double to 40 times greater than background levels downwind and downriver from Browns Ferry, with only near background readings upwind and upriver. Since the highest levels recorded were found 70 miles downwind, early datum suggest the possibility that radioactivity from Browns Ferry may travel long distances before returning to earth.

The report also examined patterns of disease and death rates near Browns Ferry. For this purpose, the seven-county area immediately downwind (east) of the plant, with a population of about 800,000, was compared with the U.S. averages. Findings included:

1. Infant deaths changed little in the first two years after Browns Ferry startup in the 1970s, and the first two years after restart of Browns Ferry 1 in 2007.

2. The local infant death rate was below the U.S. in the late 1980s and early 1990s. However, the local rate has diverged steadily from the nation in the last decade (latest records are for 2010), until it has currently reached a level 22.3% above the U.S. These elevated infant death rates are even greater for whites (32.6%) and Hispanics (40.3%).

3. The mortality rate for all causes combined in the seven counties rose steadily from +1.7% above the U.S. in the early 1970s to +20.5% in the latest period (2009-2010). Elevated rates were observed for both genders, all age groups, whites (not blacks), and all major causes of death except for mental disorders.

4. Some of the highest current thyroid cancer rates in Alabama occurred in the seven-county area.

## B. <u>Recommendations</u>

This report has provided information about the potential adverse health consequences that the Browns Ferry nuclear facility poses to many thousands of local residents. Some questions have been raised, especially the steadily rising mortality rate in the closest downwind counties.

While these data should be taken seriously, they also need to be followed up with additional studies. Continued citizen-based monitoring of environmental radioactivity levels should be encouraged, and results should be considered by EPA, TVA and NRC officials, who are responsible for the health and safety surrounding nuclear power facilities, and therefore must consider and implement improvements in current methods of measuring emissions and environmental radioactivity emanating from Browns Ferry.

The unusual and steady rise in local death rates should be taken seriously by health officials, who need to conduct their own studies to examine potential causes – among them, toxic releases from Browns Ferry.

Continued operations of the Browns Ferry reactors, which are aging and are now reaching their original design-basis age limit of 40 years, should include a “report card” of emissions performance, for which that they have not been held accountable in the past, so that sound decisions can be made to best protect the public health.

## 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. *British Medical Journal,* 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. *British Medical Journal,* 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. *British Medical Journal,* 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. *British Medical Journal,* BMJ (Clinical Research Edition) 1987; 294(6572): 597-602.

## *Appendix 1*

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.

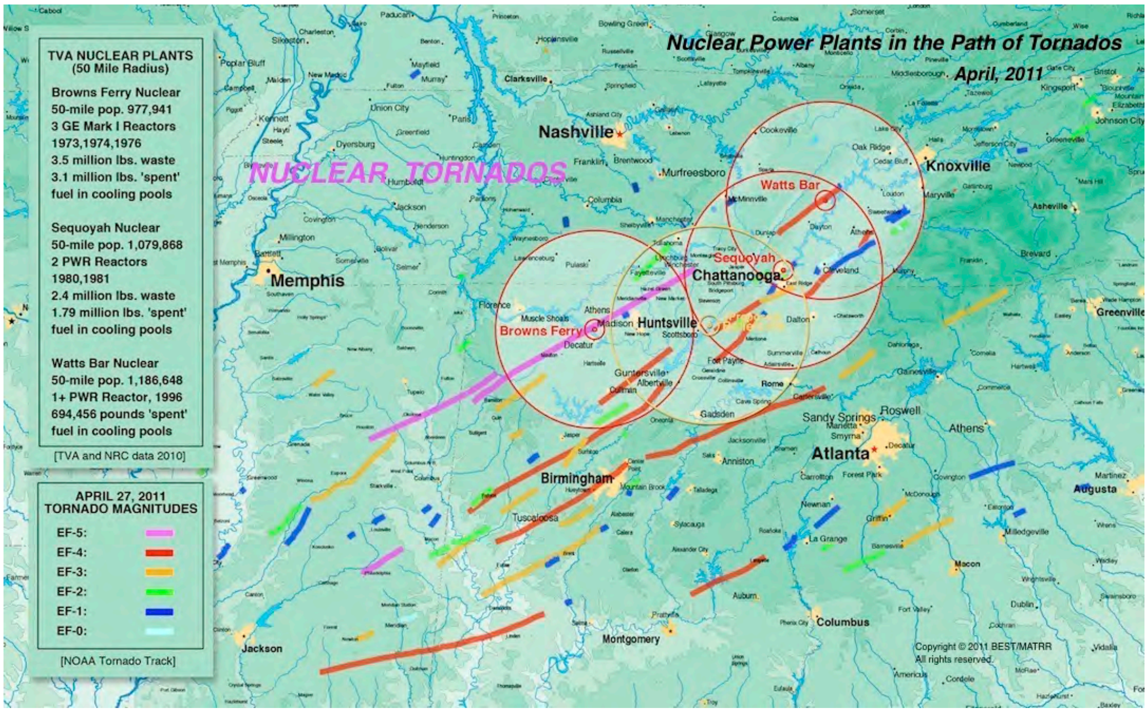
Mangano JJ, Sherman J, Chang C, Dave A, Feinberg E, Frimer M. Elevated childhood cancer incidence proximate to U.S. nuclear power plants. *Archives of Environmental Health* 2003; 58(2): 74-82.

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. *International Journal of Cancer* 2012; 131(5): E769-E780.

## APPENDIX 2: NUCLEAR POWER PLANTS IN THE PATH OF TORNADOS APRIL 27, 2011

50 Mile Radii of Nuclear Power Plants in the Tennessee Valley and 2011 Tornado Tracks




Sources: NOAA Tornado Tracks http://www.srh.noaa.gov/srh/ssd/mapping/; Bill Dedman, NBC News, "Nuclear Neighbors: Interactive Map," http://www.srh.noaa.gov/srh/ssd/mapping/; Pam Sohn, "Nuclear Waste Piling Up in Region," http://www.timesfreepress.com/news/2010/mar/22/nuclear-waste-piling-up-in-region/ Nuclear Tornados map created by Roy Simmons for BEST/MATRR, May 2011.

## APPENDIX 3: RADIOACTIVE LEAKS AT BROWNS FERRY NUCLEAR PLANT

Record of leaks and spills at TVA's Browns Ferry Nuclear Power Plant near Decatur, AL.

In chronological order, 1973 - 2010

Sources: Union of Concerned Scientists (UCS), "Groundwater Events Sorted by Location," September 29, 2010, http://www.ucsusa.org/assets/documents/nuclear_power/Groundwater-Events-Sorted-by-Location.pdf

### 1. 1973, October 19

Browns Ferry Unit 1 About 1,400 gallons of liquid radwaste of unknown, unanalyzed concentration was inadvertently discharge to the river due to personnel error. The liquid radwaste tank was intended to be placed in recirculation mode but was mistakenly placed in discharge mode.

**2. 1977, January 4**

Browns Ferry Unit 1 A leak in a residual heat removal heat exchanger allowed radioactive water to be released to the river at levels exceeding technical specification limits.

**3. 1978, July 15**

Browns Ferry Unit 1 After the unit was shut down for maintenance, the residual heat removal system was placed in operation to assist shut down cooling of the reactor vessel water. Workers determined that a residual heat removal heat exchanger had a tube leak and that radioactively contaminated water was being discharged to the Tennessee River "at a rate above permissible limits."

**4. 1983, January 16**

Browns Ferry Unit 3 A leaking tube in a residual heat removal heat exchanger allowed radioactive water from the reactor coolant system to be released to the river at levels exceeding technical specification limits.

**5. 2001, January 00**

Browns Ferry Unit 3 Tritium levels greater than baseline values were detected in an onsite monitoring well west of the Unit 3 condenser circulating water conduit in the radwaste loading area.

**6. 2005, March 00**

Browns Ferry Unit 1 A leak in a pipe elbow on the east side of the cooling tower and an overflow of the cooling tower basin caused by malfunction of the system level indicators resulted in radioactive contamination of the concrete pad and ground around the tower.

**7. 2005, March 00**

Browns Ferry Unit 2 A leak in a pipe elbow on the east side of the cooling tower and an overflow of the cooling tower basin caused by malfunction of the system level indicators resulted in radioactive contamination of the concrete pad and ground around the tower.

**8. 2005, March 00**

Browns Ferry Unit 3 A leak in a pipe elbow on the east side of the cooling tower and an overflow of the cooling tower basin caused by malfunction of the system level indicators resulted in radioactive contamination of the concrete pad and ground around the tower.

**9. 2005, November 00**

Browns Ferry Unit 1 Tritium levels greater than baseline values were detected in an underground cable tunnel between the intake structure and the turbine building. Samples taken in January 2006 identified gamma emitters in addition to tritium (beta emitter).

**10. 2005, November 00**

Browns Ferry Unit 2 Tritium levels greater than baseline values were detected in an underground cable tunnel between the intake structure and the turbine building. Samples taken in January 2006 identified gamma emitters in addition to tritium (beta emitter).

**11. 2005, November 00**

Browns Ferry Unit 3 Tritium levels greater than baseline values were detected in an underground cable tunnel between the intake structure and the turbine building. Samples taken in January 2006 identified gamma emitters in addition to tritium (beta emitter).

**12. 2006, February 00**

Browns Ferry Unit 1 A soil sample taken from underneath the radwaste ball joint vault (located outside the radwaste doors) indicated trace levels of cobalt-60 and cesium-137.

**13. 2006, February 00**

Browns Ferry Unit 2 A soil sample taken from underneath the radwaste ball joint vault (located outside the radwaste doors) indicated trace levels of cobalt-60 and cesium-137.

**14. 2006, February 00**

Browns Ferry Unit 3 A soil sample taken from underneath the radwaste ball joint vault (located outside the radwaste doors) indicated trace levels of cobalt-60 and cesium-137.

**15. 2008, January 05**

Browns Ferry Unit 3 The condensate storage tank overflowed due to failed tank level instrumentation. The spilled water flowed into the sump in the condensate piping tunnel, triggering a high level alarm that prompted workers to initiate the search that discovered the overflow condition. Some of the spilled water may have permeated through the pipe tunnel into the ground.

**16. 2010, April 07**

Browns Ferry Unit 3 Approximately 1,000 gallons of radioactively contaminated water leaked from Condensate Storage Tank No. 5 as workers were transferring water between condensate storage tanks. A worker conducting routine rounds observed water leaking from an open test valve near the top of CST No. 5.

## APPENDIX 4: REQUEST TO SUSPEND BROWNS FERRY OPERATING LICENSE

Blue Ridge Environmental Defense League

www.BREDL.org PO Box 88 Glendale Springs, North Carolina 28629 BREDL@skybest.com (336) 982-2691

October 7, 2011

Siva P. Lingam, Project Manager
Plant Licensing Branch 11-2
Division of Operating Reactor Licensing
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

**RE: § 2.206 Request for Action to Suspend GE Mark I Boiling Water Reactors Operating Licenses due to Flawed Primary Containment and Unreliable Back-up Electric Power Systems for Cooling Spent Fuel Pools**

Pursuant to 10 CFR § 2.206, the Blue Ridge Environmental Defense League ("BREDL" or "Petitioner") hereby submits written testimony regarding our June 7, 2011 joint petition request to the Nuclear Regulatory Commission for emergency enforcement action. The purpose of this request is to have NRC protect public health and safety through the prompt and thorough evaluation of safety problems at the Browns Ferry Nuclear Plant operated by the Tennessee Valley Authority near Athens, Alabama. BREDL is one of the co-petitioners ("Petitioners") to the Beyond Nuclear petition ("Petition") submitted on April 13, 2011. These remarks identify the enforcement action requested and the facts that BREDL believes are sufficient grounds for NRC to take enforcement action at Browns Ferry.

The Petitioners request that the NRC immediately suspend the operating licenses of General Electric (GE) boiling-water reactor (BWR) Mark I units to ensure that public health and safety is not unduly jeopardized. The Petition focuses on the unreliability of the GE BWR Mark I containment system to mitigate a severe accident and the lack of emergency power systems to cool high density storage pools and radioactive reactor fuel assemblies.

Esse quam videre

Two items recommended by the NRC for further review; specifically, the possible overheating of radioactive fuel pools during an emergency and the loss of power such as the recent tornado-caused black outs. The GE Mark I irradiated fuel pools are located at the top of the reactor building and currently do not have backup power if offsite and onsite electrical power were lost simultaneously. Other petition items accepted by the NRC for review are: 1) the failure of the Mark I to prevent radioactive contamination of the atmosphere and ocean, 2) failure of the hardened vent system to cope with a severe accident and 3) the threats posed by rising river water at reactors located in flood plains.

**Background**

On April 13, 2011, Beyond Nuclear filed a petition for an enforcement action under 10 CFR 2.206. On April 19, 2011, the Petition Review Board denied the request for immediate action only. On or about June 7 BREDL and others submitted copetitioners requests. The PRB held a public meeting June 8. Over 3,000 co-petitioner requests were received by the NRC following the June 8 public meeting. On August 16, 2011, the Petitioners were informed of the Petition Review Board's decision to accept in part the petition for review.

**Enforcement action requested**

The Petition seeks to suspend the operation of the General Electric Mark I Boiling Water Reactors, which are almost identical to the Fukushima reactors that melted down in Japan. Petitioners ask that the Mark I reactors cease operations until several emergency actions are taken including: 1) that the NRC revoke the 1989 prior approval for all GE Mark I operators to voluntarily install the same experimental hardened vent systems on flawed containment structures that the Fukushima catastrophe demonstrates to





have a 100% failure rate and; 2) that the agency immediately issue Orders requiring all U.S. Mark I operators to promptly install dedicated emergency back-up electrical power to ensure reliable cooling systems for the densely packed spent fuel pools. The GE BWR fuel pools are located at the top of the reactor building and currently do not have backup power if offsite and on-site electrical power were lost simultaneously.

Further, BREDL seeks the following specific actions: 1) NRC should order TVA to evaluate pressure suppression containment venting to determine whether the Browns Ferry Nuclear Plant should be allowed to continue operation. 2) NRC should issue an order to TVA to inspect control rod blades at Browns Ferry and not merely rely on the suggestion in an Information Notice; and 3) The NRC should order TVA to eliminate the existing unsafe irradiated fuel storage system at Browns Ferry and move the fuel to hardened storage in concrete structures.

In accordance with 10 CFR 2.202(e)(1), these orders would involve the modification of a part 50 license and are backfits; therefore, the requirements of § 50.109(a)(5) are to be followed; i.e., "The Commission shall always require the backfitting of a facility if it determines that such regulatory action is necessary to ensure that the facility provides adequate protection to the health and safety of the public and is in accord with the common defense and security." TVA is subject to the Commission's jurisdiction.

**Facts Supporting Enforcement Action**

- ***Reactor Containment***

The GE Mark I reactor was badly designed. To correct a fundamental flaw, pressure suppression containments systems were added to these plants in order to prevent high



pressures inside the reactor containment building during an accident. To do this, the direct torus vent system was designed to release steam—unfiltered and radioactive—directly to the atmosphere. Banning such dangerous pressure suppression methods and substituting safer dry containments was proposed by a few principled nuclear engineers, but their advice fell on deaf ears because it would, "[M]ake unlicensable the GE and Westinghouse plants now in review."[1] Today, some principled engineers persist in this quest to turn the NRC back from the dark side of promoting nuclear power to regulating it. This year, Arnold Gundersen stated the case most eloquently to the Advisory Committee on Reactor Safeguards:

Everyone sitting on the ACRS today knows that the pressure suppression

> containments on General Electric BWR's were inadequate when they were first designed. As a result of that design inadequacy, boiling water reactor containment vents were added in 1989 to prevent containment overpressurization. Currently there are 23 Mark 1 containment systems in operation. All 23 Mark 1's have vents that were added as a Band-Aid fix. It is time for the ACRS to evaluate containment venting to determine whether or not it any of these reactors be allowed to continue operation. [2]

The nuclear disaster at Fukushima Dai-ichi lends an urgency to the immediate question: What will it take to convince the NRC to prevents a similar disaster in the United States? Germany, when faced with the issue of providing energy with adequate protection to the health and safety of the public and in accord with the common defense and security said *no* to the nuclear power program in its entirety.

Further, it is just plain wrong to posit, as the NRC does, that no radioactive leaks are associated with the GE Mark I reactor pressure suppression containments systems. To avoid exceeding the primary containment pressure limit, that is what they are designed to

---

1 Note from Joseph M. Hendrie to John F. O'Leary, September 25, 1972.
2 Statement of Arnold Gundersen, Advisory Committee on Reactor Safeguards Subcommittee on Fukushima, Official Transcript of meeting of May 26, 2011, NRC HQ, Rockville, MD, ADAMS Accession No. ML11147A075



do in an accident. Based on his post-Fukushima findings, Gundersen served up crow to the committee:

> In December of 2010 I wrote to you again notifying you of a significant amount of additional information about containment failures and flaws because at the October 2010 ACRS meeting, the NRC staff informed the ACRS that the NRC's calculations assume that there is zero leakage in the Mark 1 design. Each time I have contacted you, the containment integrity data has been rebuffed and ignored. The accidents at the Fukushima Mark 1 BWR reactors have confirmed my belief that leakage of a nuclear containment cannot be based upon the assumption of a leakage rate of zero used by the NRC. This week, Tokyo Electric Power Company (TEPCO) has finally acknowledged that all three of the Fukushima Mark 1 containment systems are leaking significant radiation into the environment, and at least Units 1 and 2 began leaking on the first day of the accident. Unfortunately, the possibility of such containment failures, to which I have alerted you for the past six years, have been proven correct.[3]

If indeed United States were unable to license nuclear plants without pressure suppression containment Band-Aids, then perhaps Germany's example is correct. The NRC should order TVA to evaluate pressure suppression containment venting to determine whether the Browns Ferry Nuclear Plant should be allowed to continue operation.

- ***Control Rod Cracks***

Plant inspections done by the manufacturer indicate that the Browns Ferry Nuclear Plant suffers from cracking of the control rods necessary for shutting down the reactor. Based on this information, the manufacturer predicts that the control rods will fail sooner. An NRC Information Notice (IN) issued in June 2011 states:

> The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees that GE Hitachi Nuclear Energy (GEH) has discovered severe cracking in Marathon control rod blades (CRBs) near the end of their nuclear lifetime limits in an international BWR/6. As a result of investigations into the cracking, GEH has determined that the design life of

---

3 Statement of Arnold Gundersen, Advisory Committee on Reactor Safeguards Subcommittee on Fukushima, Official Transcript of meeting of May 26, 2011, NRC HQ, Rockville, MD, ADAMS Accession No. ML11147A075





> certain Marathon CRBs may be less than previously stated and is revising the end-of-life depletion limits of these CRBs. The NRC expects that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems.[4]

Not only did 100% of the control rods inspected suffer from cracking, the damage was more widespread and more serious than previously known. The Information Notice continued:

> In August 2010, GEH, as part of its surveillance program to monitor Marathon CRB performance, visually inspected four discharged CRBs at an international BWR/6 and found cracks on all four CRBs. The cracks were much more numerous and had more material distortion than those observed in previous inspections of Marathon CRBs. The cracks were also more severe in that they

resulted in missing boron-carbide capsule tube fragments from two of the inspected CRBs.[5]

The list of suspect plants includes Browns Ferry 1, 2 and 3 and sixteen more GE Mark I BWRs: Cooper, Dresden 2 and 3, Duane Arnold, Fitzpatrick, Hatch 1 and 2, Monticello, Nine Mile Point 1, Oyster Creek, Peach Bottom 2 and 3, Pilgrim, Quad Cities 1 and 2, and Vermont Yankee.[6] Based on this evidence, 83% of the GE Mark I reactors in the United States are likely operating with cracked control rod blades.

Analysis of the missing fragments found in two of the four control rods inspected uncovered no negative effects on plant performance; however, to make this finding at Browns Ferry or the other affected plants would require individual reactor testing.

Browns Ferry was TVA's first nuclear power plant. The initial design life-span of nuclear plants is 30 to 40 years. All three Browns Ferry units are approaching the forty-year mark: Unit 1 began commercial operation on August 1, 1974, Unit 2 on March 1, 1975 and Unit 3 on March 1, 1977. NRC renewed the operating licenses for all three

4 NRC Information Notice 2011-13: Control Rod Blade Cracking Resulting in Reduced Design Lifetime, June 29, 2011, ADAMS Accession No. ML111380019
5 *Id.*
6 The other four listed in the IN are Clinton, Grand Gulf, Perry and River Bend.



Browns Ferry reactors in May 2006, allowing TVA to continue operating them until 2033, 2034, and 2036, respectively. The new information regarding control rod cracks came after the renewal.

Control rod mismanagement was involved in at least two major nuclear accidents, at the Argonne Low Power Reactor and Chernobyl. The history of Chernobyl is familiar; less well known are events at Argonne, where the improper withdrawal of the control rod mechanism at the Army's experimental reactor in Idaho caused an explosion which killed three operators and released 1100 curies of fission products into the atmosphere.[7] In four milliseconds this small reactor went from 200 kilowatts power to 20 million kilowatts.[8] Although the NRC Information Notice includes no specific enforcement, it does point to the NRC's expectation that plant operators will act to avoid control rod problems caused by these flaws. NRC should issue an order to TVA to check these components and not merely rely on the IN suggestion.

• ***Irradiated Fuel Pool Danger***

TVA stores Browns Ferry's radioactive fuel rods in pools on upper levels of the plant. Over 1,415 metric tons of irradiated fuel in three pools is covered by a heavy metal sheet buildings on a concrete pad above the plant. As with most plants, water in the fuel pools is circulated by electric pumps. If the plant is scrammed and off-site power and electric back-ups fail, the fuel would heat the water, turning it to steam.

The area above the spent fuel pool is not designed to withstand high winds from tornadoes and hurricanes. As stated by an NRC spokesman, "The design of the Browns

---

7 Horan, J. R., and J. B. Braun, 1993, *Occupational Radiation Exposure History of Idaho Field Office Operations at the INEL*, EGG-CS-11143, EG&G Idaho, Inc., October, Idaho Falls, Idaho (retrieved 10/6/11 from Wikipedia).
8 Steve Wander (editor) (February 2007) "Supercritical" *System Failure Case Studies* (NASA) **1** (4). http://pbma.nasa.gov/docs/public/pbma/general/sl1_sfcs.pdf (retrieved 10/6/11 from Wikipedia)

Esse quam videre



Ferry spent fuel pool has blowout panels. In case of a tornado where you have differential pressure across the wall, the panels would blow off and minimize any damage."[9]

On April 27, 2011 tornadoes knocked out TVA's electric power transmission lines in Mississippi and northern Alabama, causing an emergency and automatic cold shutdown of the Browns Ferry Nuclear Plant. The plant was forced to rely on diesel backup power for seven days.

> One NRC inspector told the audience that those containments were upgraded for assaults such as that on the heels of the Sept. 11, 2001, terrorist attacks. But David Lochbaum, a former TVA nuclear engineer and a former NRC training instructor, took that answer to task. "That's not accurate," said Lochbaum, a Chattanoogan who now works for the Union of Concerned Scientists. "It may be reassuring, but it's not accurate." The 9/11 changes "were only about airplanes," not multiple problems such as what the tornadoes caused or could

have caused if one had made a direct hit on the plant, he said. [10]

The NRC should order TVA to eliminate the existing unsafe irradiated fuel storage system and move the fuel to hardened storage in concrete structures.

• ***Need for Action Indicated by Record of Violations***

During the last few years, TVA has compiled an unenviable record of compliance at Browns Ferry.

On May 9, 2011, the NRC issued to TVA a violation (EA-11-018) for failure to implement an In-Service Training program for its engineers at Browns Ferry. More than a training exercise, this management failure led to an operational failure in which the RHR loop II subsystem was unable to fulfill its safety function due to a failure of LPCI

---

9 NRC Region II Administrator Victor McCee, "Tornado Concerns Raised At Browns Ferry Nuclear Plant" WHNT-TV, Huntsville, AL, May 31, 2011, retrieved 10/6/11 from http://www.whnt.com/news/whnttornado- concerns-raised-at-browns-ferry...
10 "Regulators say TVA's Browns Ferry Nuclear Plant safe to operate" *Times-Free Press* October 4th, 2011



Outboard Injection Valve. The malfunctioning valve was not discovered for a year and a half. The violation was of Red Significance. The system is necessary for reactor core cooling during accidents and the valve failure left that system inoperable, potentially leading to core damage had an accident involving a certain series of events occurred.

On April 19, 2010, NRC issued Notice of Violations (EA-09-307) to TVA at Browns Ferry for failure to meet the requirements of 10 CFR 50, Appendix R, III.G, fire protection of safe shutdown capability. The violations were of Yellow and White Significance. There were multiple examples of TVA not providing fire protection capable of limiting damage to the plant. In 1974 a worker using a candle to check for air leaks started a fire that disabled safety systems at Browns Ferry Nuclear Plant.

On May 12, 2004, NRC issued to TVA a Notice of Violation (EA-04-063) for Severity Level III violations at Browns Ferry. Numerous problems in the Long-Term Torus Integrity Program were cited for failures to perform numerous weld repairs; omission of welds requiring repair; and failure to verify the location of repaired welds.

## *Appendix 4*

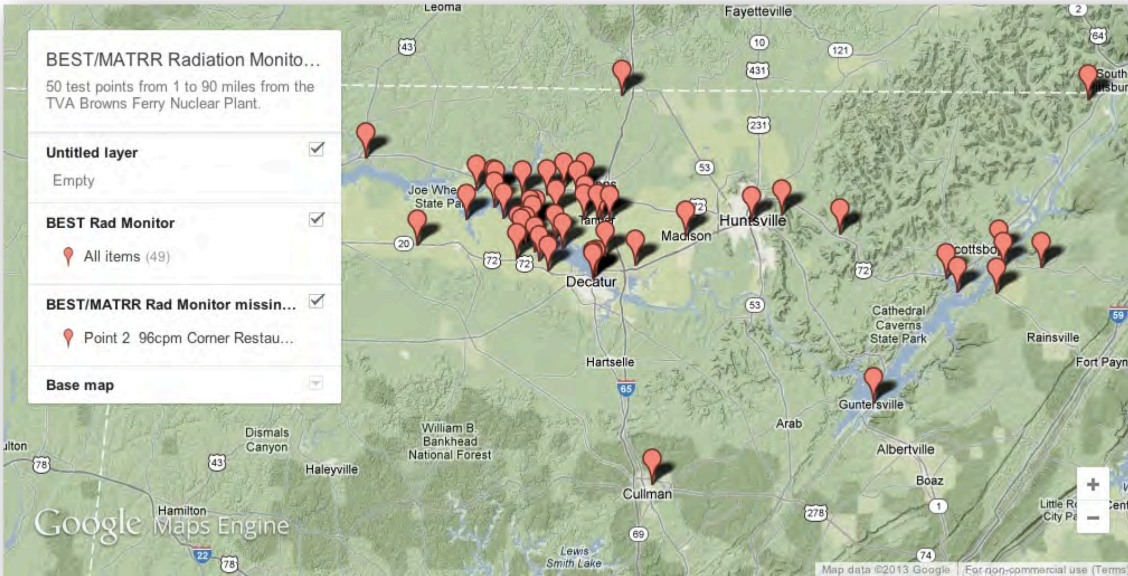
These violations support our request that regulatory action by the NRC is necessary to ensure that operations at Browns Ferry provide adequate protection to the health and safety of the public and are in accord with the common defense and security.

Respectfully submitted,

Louis A. Zeller
Blue Ridge Environmental Defense League
PO Box 88
Glendale Springs, NC 28629
bredl@skybest.org
www.BREDL.org

Esse quam videre

## Appendix 5: BEST Radiation Monitoring Test Sites




As of publication, June 2013, the BEST/MATRR Radiation Monitoring Project had established 50 field test sites around Browns Ferry Nuclear Power Plant, and had recorded readings of radiation counts per minute (CPM) at each of the sites, some multiple times and under varying weather conditions. Test sites circled the plant and worked outward to determine plume paths. The distances range from under one mile to over 90 miles from the plant, and the readings on the Inspector™ geiger counter ranged from backgrounds of 32 to over 1600 CPM.

BEST/MATRR is a chapter of the Blue Ridge Environmental Defense League (BREDL), whose Executive Director, Lou Zeller, began group project training using EPA protocols and is BEST monitoring project Quality Assurance Officer. The Project Manager, Garry Morgan, is retired from the Army Medical Department with experience and training in Radiation Protection, Nuclear, Biological and Chemical Decontamination and Emergency Response in military and civilian medical care settings. Mr. Morgan expanded the training and procedures to include Department of Defense, Department of Homeland Security and State of Alabama Department of Health Radiation Control protocols.

BEST/MATRR Radiation Monitoring Project information and downloadable copies of *A Citizen's Guide to Monitor Radioactivity,* and our intended companion manual, *BEST Radiation Monitoring Manual* are available online at http://RadiationMonitors.blogspot.com. In addition, BEST project director, Garry Morgan, recorded several videos of field tests which are also available online at http://RadiationVideos.blogspot.com. The above map of BEST Radiation Monitoring Test Sites, also created by Morgan, may be viewed online using an interactive Google map showing CPM readings at https://mapsengine.google.com/map/edit?mid=zUriF2xNKAQ4.kc_DIj9TCDyM

## BIBLIOGRAPHY


Alvarez, Robert *Spent Nuclear Fuel Pools in the U.S.: Reducing the Deadly Risks of Storage*, Institute for Policy Studies, May 2011; http://www.ips-dc.org/reports/spent_nuclear_fuel_pools_in_the_us_reducing_the_deadly_risks_of_storage

Brookhaven National Laboratory *Radioactive Materials Released from Nuclear Power Plants*, NUREG/CR-2907; http://pbadupws.nrc.gov/docs/ML0414/ML041450170.pdf

Centers for Disease Control and Prevention, http://wonder.cdc.gov.

Comey, David Dinsmore "The Fire at Brown's Ferry Nuclear Power Station," in *Not Man Apart*, Friends of the Earth, California, 1976, http://www.ccnr.org/browns_ferry.html

Donn, Jeff "Radioactive tritium leaks found at 48 US nuke sites," AP, June 21, 2011,http://www.nbcnews.com/id/43475479/ns/us_news-environment/t/radioactive-tritium-leaks-found-us-nuke-sites/#.UX7Aa5Vs3S8

Donn, Jeff "Safety Rules Loosened for Aging Nuclear Reactors," June 20, 2011; http://www.nbcnews.com/id/43455859/ns/us_news-environment/t/safety-rules-loosened-aging-nuclear-reactors/#.UYp50JVs3S8

Dedman, Bill "Nuclear Neighbors: Population Rises Near US Reactors", NBC News, April 4, 2011; http://www.nbcnews.com/id/42555888/ns/us_news-life/t/nuclear-neighbors-population-rises-near-us-reactors/?ns=us_news-life

Environmental Protection Agency, Radnet Search "Envirofacts," covers measurements taken since 1978, http://iaspub.epa.gov/enviro/erams_query_v2.simple_query

Gatti, Antonietta M. et al, "Nanopathology: The Role of Micro and Nanoparticles in Biomaterial-induced Pathology", The European Commission, Project QLRT-2002-J47 (2002-2005), http://inchesnetwork.net/Fetal%20and%20embryological%20origin%20of%20diseases_Gatti.pdf

Gould JM et al. *The Enemy Within: The High Cost of Living Near Nuclear Reactors*, New York: Four Walls Eight Windows, 1996.

Gunter, Paul "Hazards of Boiling Water Reactors in the United States," Nuclear Information Research Service (NIRS) March, 1996, updated by Michael Mariotte, NIRS.org, March 2011; http://www.nirs.org/factsheets/bwrfact.htm.

Jablon S. et al. Cancer in Populations Living Near Nuclear Facilities. Washington DC: U.S. Government Printing Office, 1990.

Klusek CS, Strontum-90 in Human Bone in the U.S., 1982. New York: Department of Energy Environmental Measurements Laboratory, 1982.

Lochbaum, David "Groundwater Events Sorted by Location," Union of Concerned Scientists, September 29, 2010, http://www.ucsusa.org/assets/documents/nuclear_power/Groundwater-Events-Sorted-by-Location.pdf

Lochbaum, David *Walking a Nuclear Tightrope: Unlearned Lessons of Year-plus Reactor Outages,* Union of Concerned Scientists, September 2006; http://www.ucsusa.org/nuclear_power/nuclear_power_risk/safety/walking-a-nuclear-tightrope.html

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

Mangano JJ. Improvements in local infant health after nuclear power reactor closing. Environmental Epidemiology and Toxicology 2000;2(1):32-36.

Mangano JJ et al. Infant death and childhood cancer reductions after nuclear plant closings in the United States. Archives of Environmental Health 2002;57(1):23-32.

*Medical Encyclopedia of the National Library of Medicine*, Medline Plus, "Radiation sickness," U.S. National Library of Medicine, National Institutes of Health, http://www.nlm.nih.gov/medlineplus/ency/article/000026.htm

Meyer, Bob "Most Significant NRC findings of 2012," Professional Reactor Operator Society, Feb.3, 2013, http://nucpros.com/content/most-significant-nrc-findings-2012

National Academy of Sciences, *Biological Effects of Ionizing Radiation BEIR VII Phase 2 Report: Health Risks from Exposure to Low Levels of Ionizing Radiation*, National Academies Press, 2006, http://www.nap.edu/catalog/11340.html

National Cancer Institute, Incidence, Surveillance, Epidemiology, and End Results program, National Institutes of Health, http://www.seer.cancer.gov

National Cancer Institute, State Cancer Profiles, National Institutes of Health, www.statecancerprofiles.cancer.gov.

Nuclear Regulatory Commission, Effluent Database for Nuclear Power Plants, www.reirs.com/effluent

Nuclear Regulatory Commission, FAQs About Liquid Radioactive Releases, http://www.nrc.gov/reactors/operating/ops-experience/tritium/faqs.html#affect

Nuclear Regulatory Commission, Information Digest, various years; www.nrc.gov.

Nuclear Regulatory Commission, Licensee Event Reports Search of BFN SCRAMSs; https://lersearch.inl.gov/Entry.aspx

Pashenko, Sergey and Buske, Norm *A Citizen's Guide to Radiation Monitoring,* ISAR: Resources for Environmental Activists, May 2005, http://www.radioactivist.org/ISAR%20final%20guide.pdf

Professional Nuclear Reactor Operator Society "Browns Ferry Nuclear Plant, Unit 3 LER: Annunciator Panel Power Supply Fire in Unit 3 Control Room," July 9, 2012, http://www.nucpros.com/content/browns-ferry-nuclear-plant-unit-3-ler-annunciator-panel-power-supply-fire-unit-3-control-roo

Rosenthal HL. Accumulation of Environmental 90Sr in Teeth of Children. Hanford Radiobiological Symposium, Richland WA, May 1969, 163-171.

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.

Stewart AM, Webb J, and Hewitt D. A Survey of Childhood Malignancies. British Medical Journal, 1958;i:1495-1508.

Thompson DE et al. Cancer Incidence in Atomic Bomb Survivors. Part II: Solid Tumors, 1958-1987. Radiation Effects Research Foundation, Hiroshima Japan, 1994, http://www.ncbi.nlm.nih.gov/pubmed/8127952

U.S. Census Bureau, Alabama Counties Map, www.census.gov

Zeller, Lou "§ 2.206 Request for Action to Suspend GE Mark I Boiling Water Reactors Operating Licenses due to Flawed Primary Containment and Unreliable Back-up Electric Power Systems for Cooling Spent Fuel Pools," Letter to Licensing Branch 11-2, NRC, Oct. 7, 2011.

# INDEX