NC STATE UNIVERSITY

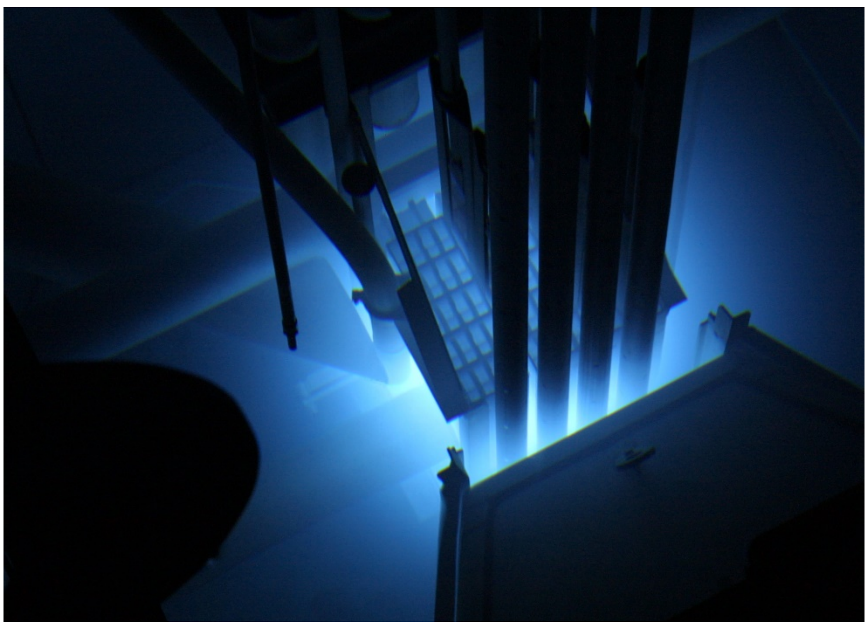
PULSTAR REACTOR

ENVIRONMENTAL

REPORT

NORTH CAROLINA STATE UNIVERSITY

RALEIGH, NORTH CAROLINA 27695



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1. INTRODUCTION

The PULSTAR reactor located on the North Carolina State University campus at Raleigh, North Carolina is a 1 MW, upgrading to 2 MW, pool type research reactor. It is used to support education at North Carolina State University (NCSU), various research endeavors, and specialized nuclear services to the industrial community and governmental agencies. The PULSTAR reactor has operated since 1972. Operations occur only as needed, typically during normal work days but occur around-the-clock for various periods of time. Continued operations are planned for many more years.

Typical reactor activities and experiments are associated with operation of the reactor and use of specialized irradiation facilities during reactor operation. These experiments and operations include neutron radiography, neutron activation analysis, positron/positronium lifetime spectroscopy, neutron powder diffraction, nuclear reactor operator training, and isotope production.

The PULSTAR reactor has been analyzed in accordance with licensing requirements for a non-power reactor by the US Nuclear Regulatory Commission (NRC). This includes a Safety Analysis Report (SAR)[1] which provides information on facility construction and operation, site characteristics, accidents, and engineered safety features. Environmental impact from operational activities and postulated accidents, and the impact of the environment on the facility as described in the SAR are summarized in this Environmental Report.

Requirements given in the PULSTAR reactor license include meeting federal regulations as given in the Code of Federal Regulations (CFR) and facility specific Technical Specifications (TS).[2] Compliance with applicable CFR and TS items is described in the SAR. Environmental concerns include compliance with requirements regarding airborne and liquid radioactive effluent, radioactive waste disposal, and radiation dose to members of the public from routine operations and postulated accidents. Compliance is achieved by use of design and engineered safety features and procedural controls. Design and engineered safety features include a ventilation/confinement system, shielding, the reactor building, a radiation monitoring system, and a reactor safety system. Procedural controls include a documented radiation protection program, emergency plan and procedures, operating procedures, maintenance and surveillance procedures, and environmental monitoring procedures.

2. FACILITY

The PULSTAR reactor is housed in Burlington Engineering Laboratories located on the North Carolina State University (NCSU) North campus. Figure 1 and Figure 2 depict the location of Burlington Engineering Laboratories with respect to the NCSU campus. Figure 3 depicts the general layout of Burlington Engineering Laboratories showing the location of the PULSTAR reactor and its associated external cooling system and ventilation stack. The PULSTAR reactor was constructed from 1968 to 1972 and was designed to blend with the existing adjacent NCSU campus structures. As designed, Burlington Engineering Laboratories essentially incorporates no conspicuous features that would identify the building as a nuclear reactor site.

The PULSTAR reactor external support facilities in the Burlington Engineering Laboratory complex include the cooling tower for heat dissipation, a 100 foot ventilation stack for exhaust ventilation, and underground power, water, natural gas and sewer utilities.

The reactor cooling tower is a typical air conditioning mechanical draft design and is located inside a brick screen cubicle as depicted in Figure 3. The brick screening improves the aesthetics for the cooling tower. Makeup water for the cooling tower is provided through underground connections to the municipal water system and thus provides no external features affecting the environment.

The 100 foot ventilation stack has existed at the Burlington Engineering Laboratories complex since the construction of first reactor at NCSU in 1952. When the PULSTAR was constructed, the stack was retrofitted with an internal concentric ventilation duct that handles the PULSTAR ventilation exhaust. Hence, with the exception of painting, the stack has retained the same visual appearance since the early 1950s. The NCSU campus has several high structures in the immediate vicinity of the reactor stack, including a boiler exhaust stack on Yarbrough Drive (approximately 100 feet tall) and several multistory buildings such as the D.H. Hill Library with 11 floors.

The reactor is shielded by water and thick concrete walls. Additional shielding is provided by the reactor building which has thick, solid, concrete exterior walls. A radiation monitoring system is used to monitor radiation levels inside the reactor building and the ventilation system. Other important operational parameters and systems are monitored, e.g. water level in the reactor pool, ventilation system operational status, and the reactor safety system.

3. ENVIRONMENTAL EFFECTS OF SITE PREPARATION AND FACILITY CONSTRUCTION

Construction of the Burlington Engineering Laboratory complex which houses the PULSTAR reactor occurred on the NCSU North campus in the vicinity of several other large university buildings. Construction did not produce a significant effect on the terrain, vegetation, wildlife or nearby waters, etc. The societal, economic and aesthetic impact of the Burlington Engineering Laboratories complex is no greater than that of any similar university structure.

4. ENVIRONMENTAL EFFECTS OF FACILITY OPERATION

The PULSTAR reactor generally operates five days per week with an annual average of approximately 1200 full power hours per year. Reactor staffing is generally limited to one shift with the exception of occasional experiments where multi-shift operations occur. Figure 4 depicts the reactor operation history during the period from 1996 through 2015[3] at a full power level of 1 MW. In the past few years, operations have increased to meet user demand. Future operations at 2 MW are planned.

The thermal plume produced by the cooling tower in support of the PULSTAR reactor has not produced a noticeable effect on the environment. The PULSTAR cooling tower was sited adjacent to a much larger cooling tower used for the Burlington Engineering Laboratories air conditioning system. The latter cooling tower was removed when the BEL changed over to the campus chilled water system. None of the cooling towers have had observable effects on the environment. Excessive drift and/or fog have not occurred with the operation of the PULSTAR cooling tower. The heat dissipation rate is equivalent to HVAC systems for typical commercial buildings. The reactor cooling tower uses, on average, approximately 500 gallons of water per MW·h of operation.

Radioactive liquid effluents are collected, mixed, filtered, sampled, analyzed and in stored in three fiberglass waste tanks located on the reactor site. Liquid waste is verified to meet local, state and federal regulations prior to discharge to the sanitary sewer. Figure 5 summarizes the radioactive liquid waste releases that have occurred in the last 20 years of PULSTAR reactor operation[3]

The routine release of radioactive gaseous effluents is primarily ^{41}Ar generated during the operation of the PULSTAR reactor which is produced by the neutron activation of air. The ^{41}Ar release is kept As Low As Reasonably Achievable (ALARA) by design, using engineered safety features and operating procedures. For example, the ventilation stack reduces radiation dose by atmospheric dispersion, and minimizing air volume in experimental and reactor systems limits ^{41}Ar production. Radiation dose inside and outside the reactor facility from ^{41}Ar releases have been well below established federal limits. Figure 6 provides information on ^{41}Ar releases that have occurred in the past 20 years of PULSTAR Reactor operation.[3]

Radioactive solid waste includes contaminated items (e.g. filters, resin beads, experimental equipment) and consumable materials (e.g. paper and plastic items). Radioactive solid waste is transferred to the NCSU broad scope radioactive materials license and then packaged and shipped in accordance with federal regulations to an approved disposal facility. All radioactive solid waste to date meets the regulatory definition of low level waste. Radioactive solid waste data is shown in Figure 7.[3]

An environmental monitoring program is in place for monitoring radioactivity releases from the PULSTAR reactor. This program is implemented by the NCSU Radiation Safety Division. Monitoring of external radiation dose, airborne particulates, surface and ground water, milk, and vegetation are performed. No radioactive releases attributable to reactor operation have been detected.[3]

A Radiation Protection Program[4] is in place and monitors the PULSTAR reactor for external radiation dose, radiation shield integrity, radioactive contamination, and radioactive effluent. Areas within the facility generally meet regulatory limits for members of the public. Areas within the BEL and reactor site boundary meet regulatory limits.

Operation of the reactor at 2 MW will not cause a significant increase in radiation levels or effluent. This is a result of recently upgraded radiation shielding and experimental systems.

The reactor fuel is owned by the US Department of Energy,[5] not NCSU. Arrangements for transport and transfer or disposal of reactor fuel are made with the US Department of Energy and US Nuclear Regulatory Commission in accordance with applicable regulations. A quality assurance program for radioactive material shipments of this type is in place as required by federal regulations.[6]

A maintenance and surveillance program is in place to maintain, repair, test, and verify that reactor systems are operational and capable of performing their intended function. To operate the reactor, reactor systems and the radiation monitoring systems required by TS must be operational.

There are no releases of potentially harmful chemical substances associated with the PULSTAR reactor operation. However, small amounts of a corrosion inhibiting and biocide additives for the cooling tower system are released as part of the cooling tower blowdown and evaporative losses. The cooling tower water may also contain dissolved solids which accumulate as a result of the continuing evaporation from the tower.

Hazardous materials used at the PULSTAR reactor are similar to those used in other laboratory equipped buildings at NCSU. The use of hazardous chemicals in support of research endeavors is controlled through the NCSU Environmental Health and Safety organization. Specifically, this organization provides the researcher with a means of disposing hazardous chemicals to avoid using the sanitary sewer system and general guidelines on the handling and hazards associated with various chemicals. Applicable state, federal and local laws and regulations are met. With the exception of the trace amounts of cooling tower chemical releases, the PULSTAR reactor does not generate chemical waste that impacts the environment.

5. ENVIRONMENTAL EFFECTS OF ACCIDENTS

No accidental releases have occurred in the operating history of the PULSTAR reactor. Postulated accidents including failure of an experiment, loss of reactor pool water, loss of cooling, and credible damage to the reactor fuel with associated fission product release result in doses well below 10 CFR Part 100 limits, well within US EPA protective action guides, and have been analyzed to be within 10 CFR Part 20 limits for members of the general public. Should the reactor fuel be completely uncovered by water, reactor fuel damage would not occur since the reactor fuel would be sufficiently cooled by air circulation[1]. An automatic reactor shutdown (scram) occurs for any of the following:

1. overpower condition
2. low reactor coolant flow
3. low reactor pool level
4. high reactor pool temperature

In addition, by facility procedures, if higher than normal radiation levels are indicated by radiation monitoring instrumentation, the reactor operator shuts down the reactor. If a radiation monitor exceeds a designated level based on the SAR, TS, and Emergency Plan[7], the ventilation system filters the air prior to exhaust. As analyzed in the SAR, radiation doses from accidents are negligible with respect to the environment.

Also as analyzed in the SAR, there are no adverse effects or accidents that affect the reactor facility associated with the surrounding area or environment; e.g. adverse weather, site geology or hydrology, air or vehicle traffic, rail roads, or activities associated with academia, industry, commerce, public facilities and events, or residential housing.

6. UNAVOIDABLE EFFECTS OF FACILITY CONSTRUCTION AND OPERATION

The unavoidable effects of continued operation of the PULSTAR reactor involve the materials used in construction that cannot be recovered and use of reactor fuel (fissionable material). No adverse impact on the environment is expected from either of these unavoidable effects.

7. ALTERNATIVE TO CONSTRUCTION AND OPERATIONS OF THE FACILITY

There are no suitable alternatives to the capabilities and benefits provided by operating a nuclear research reactor facility. The capabilities provided via the reactor facility include the training of nuclear engineering students in reactor operation, production of radioisotopes, and the use of irradiation facilities and neutron beams in support of research an extension activities.

8. LONG TERM EFFECTS OF FACILITY CONSTRUCTION AND OPERATION

The long-term consequences of the continued operation of the PULSTAR reactor are considered to be beneficial via the contributions to scientific knowledge and education. Considering the relatively small capital investment associated with the construction of the PULSTAR reactor and its resulting small impact on the environment, very little irreversible and irretrievable commitment is associated with the facility.

9. COSTS AND BENEFITS OF FACILITY AND ALTERNATIVES

The original cost of the PULSTAR reactor, excluding the Burlington Engineering Laboratory building, was less than one million dollars. The benefits include but are not limited to basic research support, training and education, and providing specialized testing of materials used in industry. There exists no alternative device that can reasonably provide this range of activities.

10. CONCLUSIONS

Potential effects from the continued operation of the PULSTAR reactor on the environment, including esthetics, noise, community and impact on local flora and fauna are negligible.

Based on the PULSTAR reactor documentation and this Environmental Report, it is concluded that no significant environmental impact is associated with the re-licensing of the PULSTAR reactor.

11. REFERENCES

[1] North Carolina State University PULSTAR Reactor, *Safety Analysis Report*.

[2] North Carolina State University PULSTAR Reactor, *R120 Facility License-Appendix A: Technical Specifications*, <date TBD>.

[3] North Carolina State University PULSTAR Reactor, *Annual Operating Reports.*

[4] North Carolina State University PULSTAR Reactor, *Radiation Protection Program.*

[5] Department of Energy (DOE) Research Reactor Infrastructure Program Contract No.78287.

[6] North Carolina State University PULSTAR Reactor, *Quality Assurance Program for Packaging and Transportation of Radioactive Material* (docket no. 71-0331), https://www.nrc.gov/docs/ML1523/ML15233A073.pdf.

[7] North Carolina State University PULSTAR Reactor, *Emergency Plan*, Revision 10.

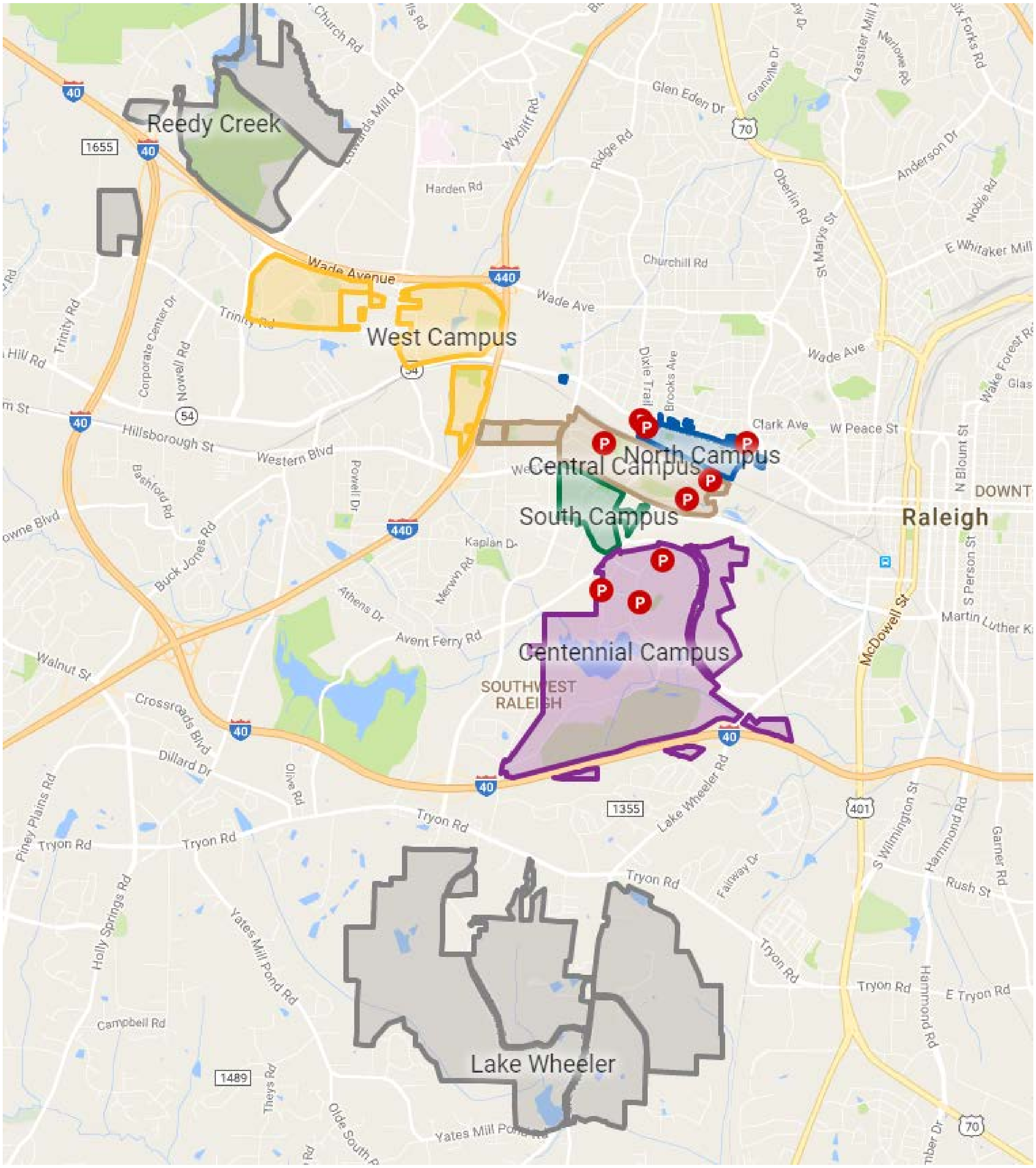

Figure 1 – North Carolina State University Campus Map

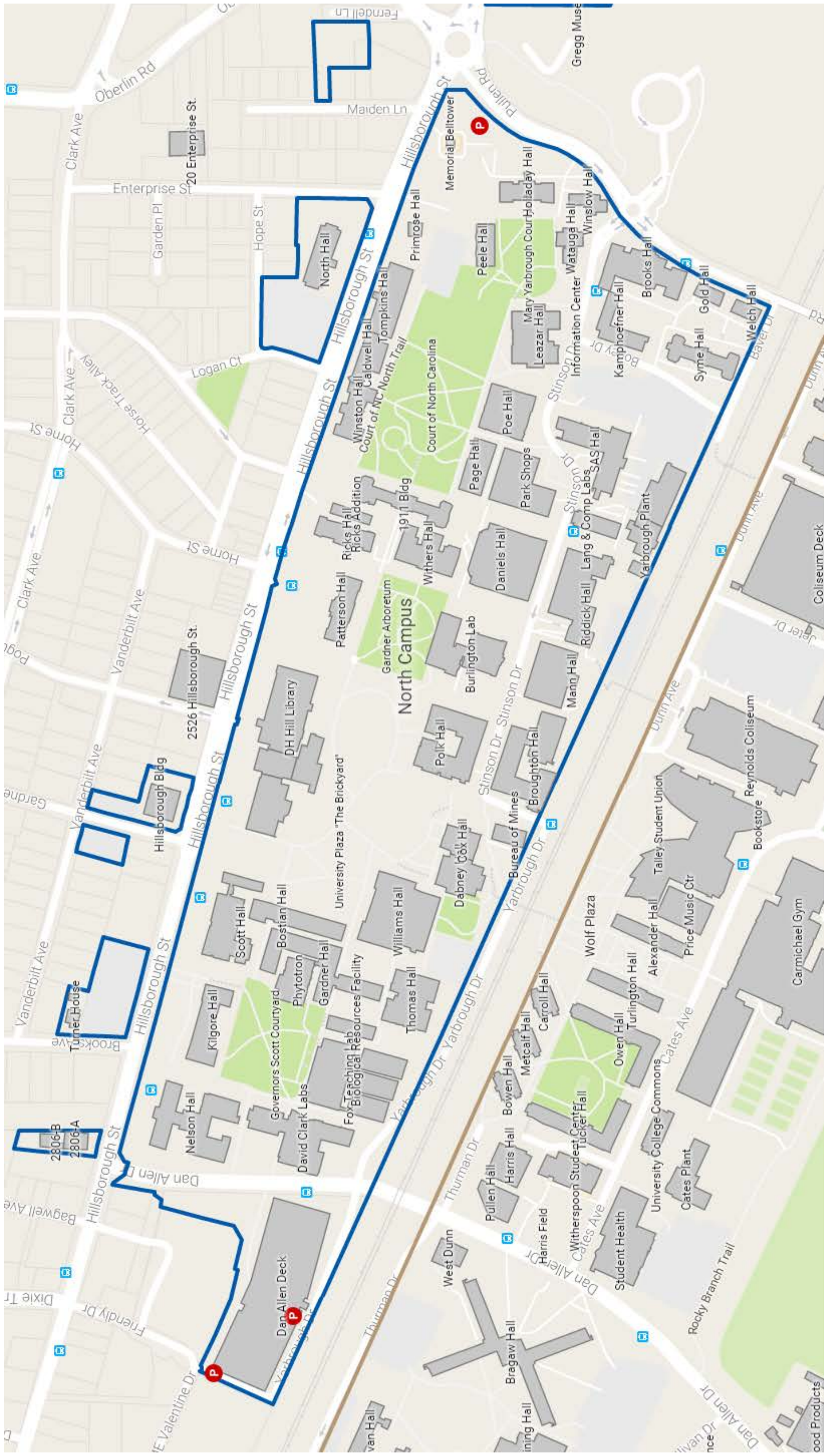

Figure 2 – North Carolina State University North Campus Map

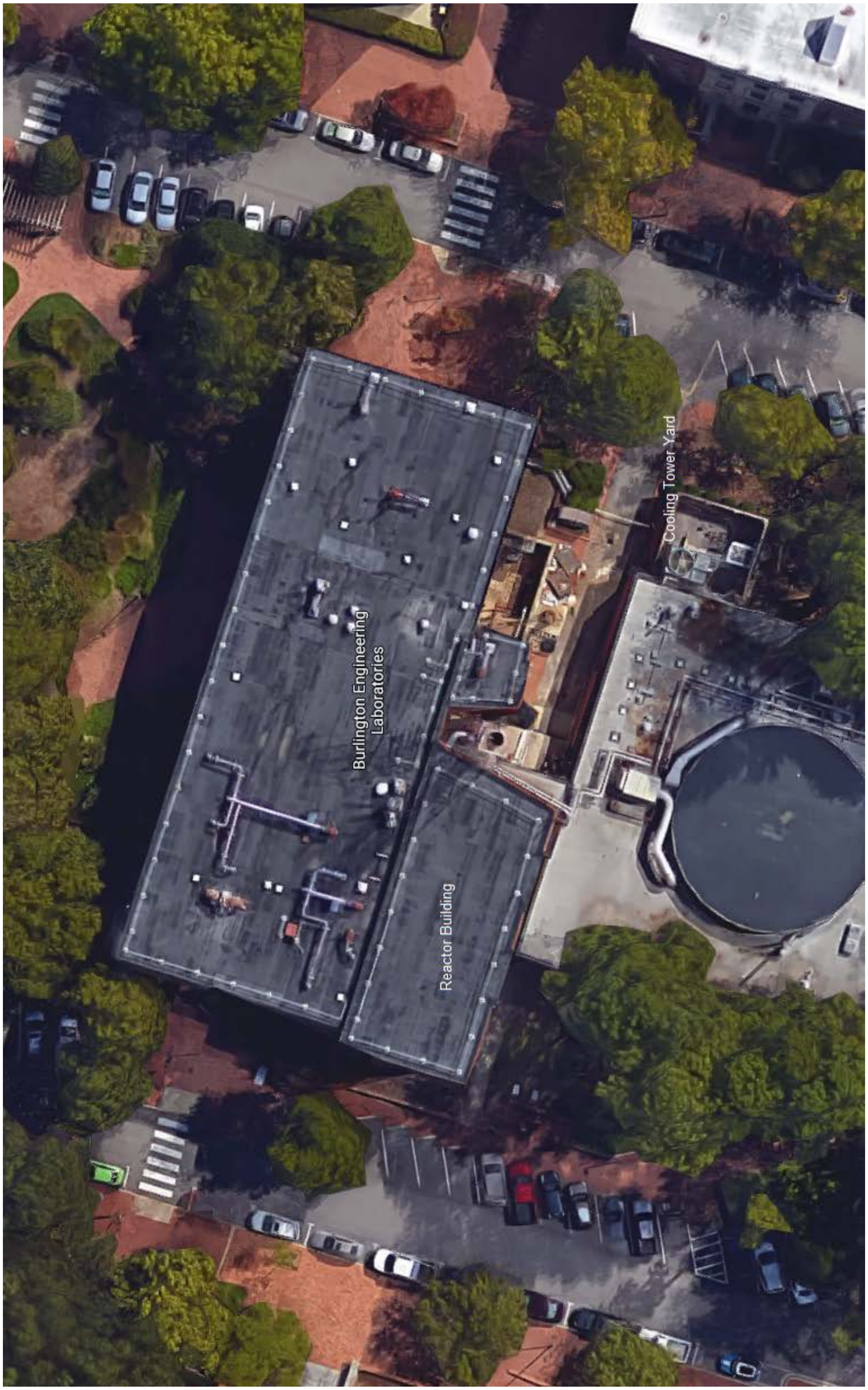

Figure 3 – Burlington Engineering Laboratory and PULSTAR Reactor Building

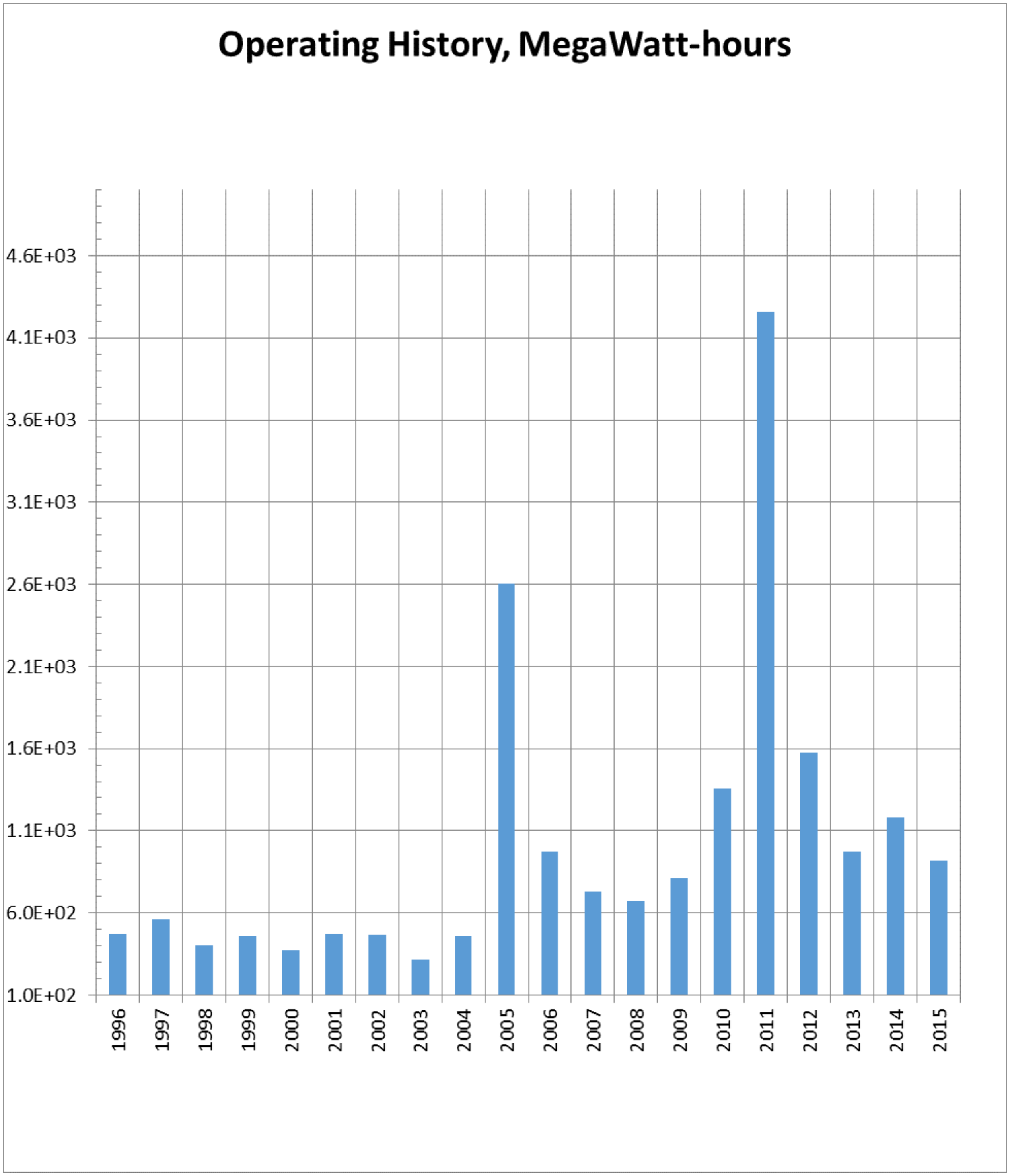

Figure 4 – Operating History for the PULSTAR Reactor Facility – 1996 – 2015

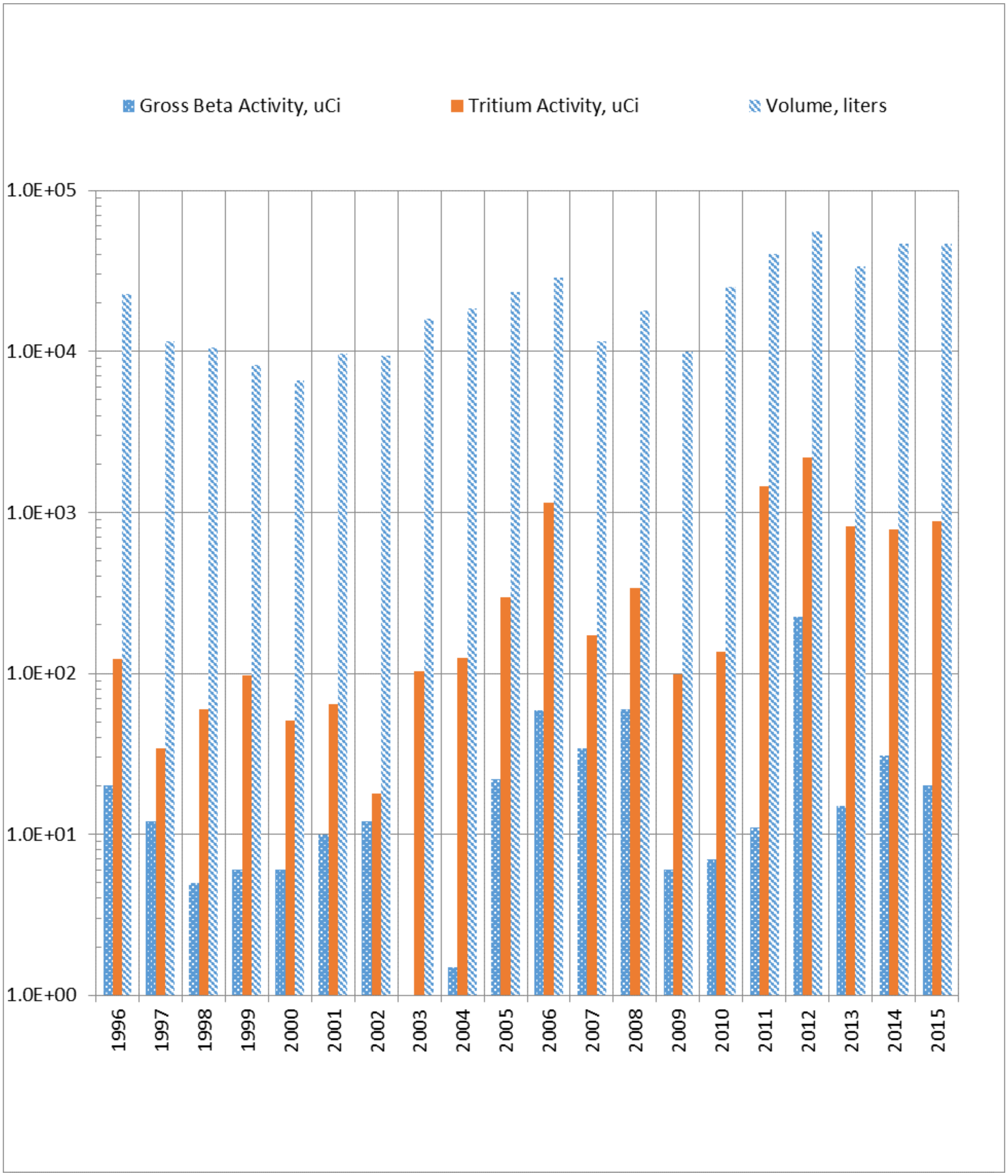

Figure 5 – Liquid Effluent History for the PULSTAR Reactor Facility – 1996 – 2015

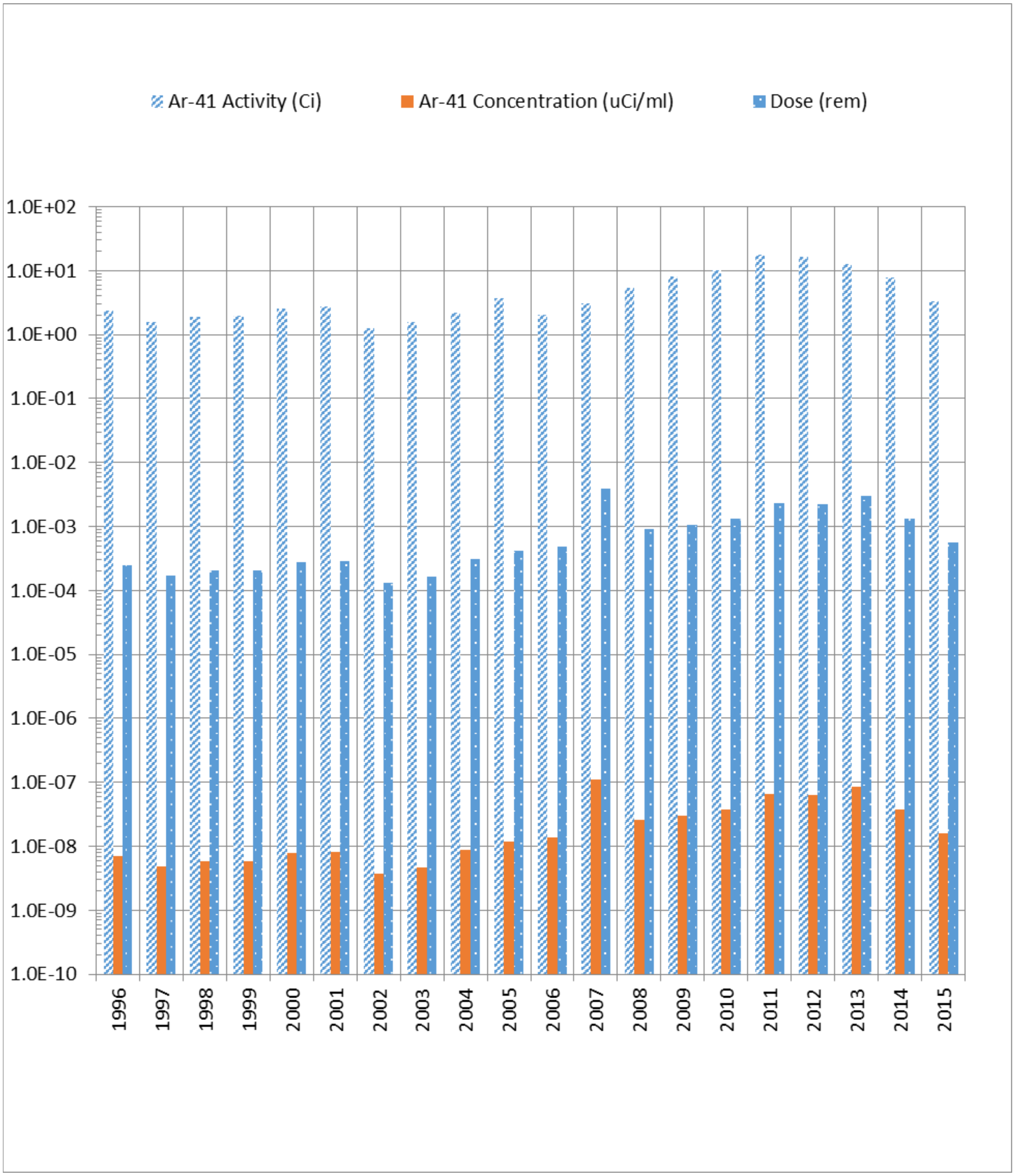

Figure 6 – Air Bourne Effluent History for the PULSTAR Reactor Facility – 1996 – 2015

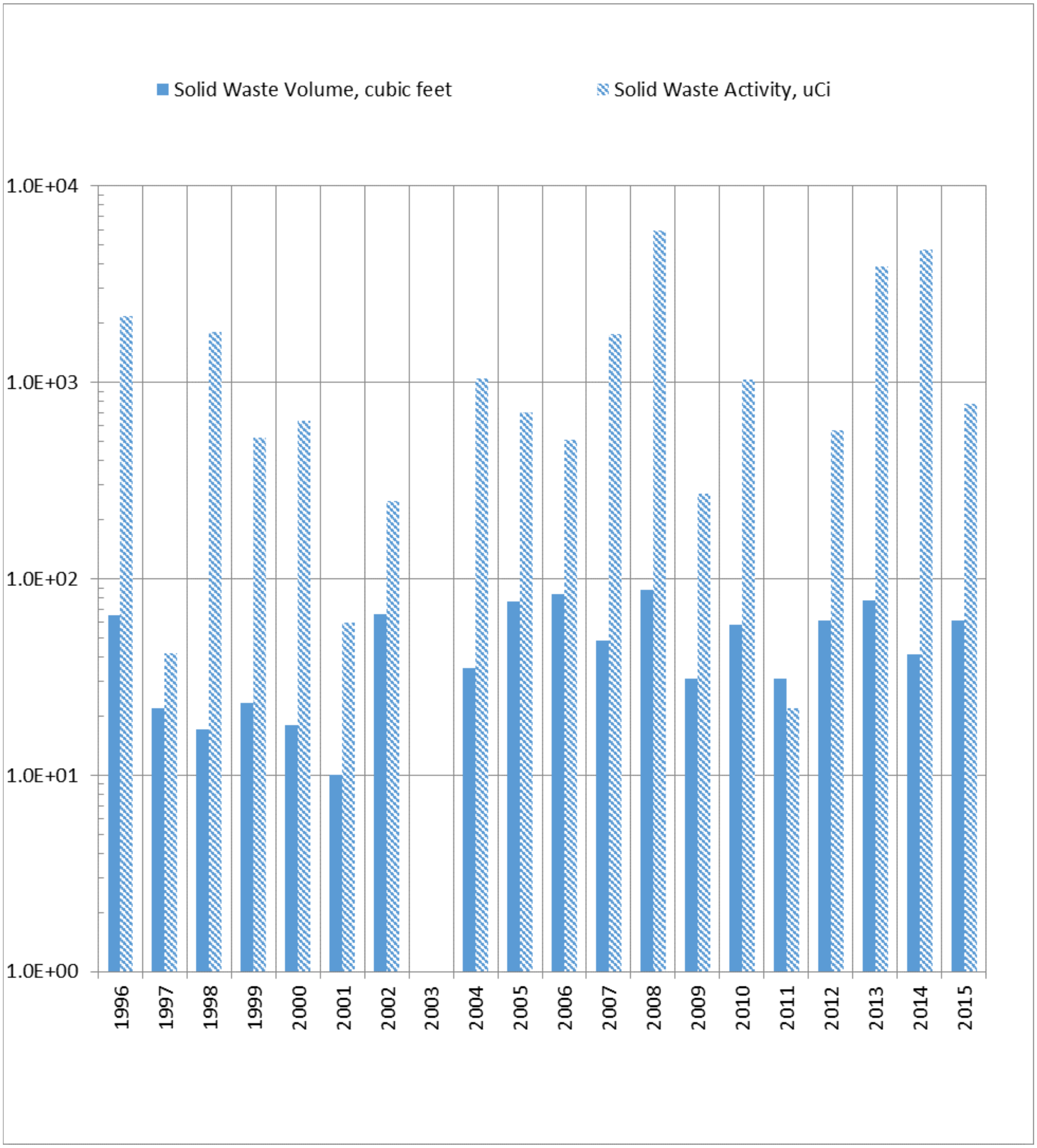

Figure 7 – Solid Radioactive Waste History for the PULSTAR Reactor Facility – 1996 – 2015