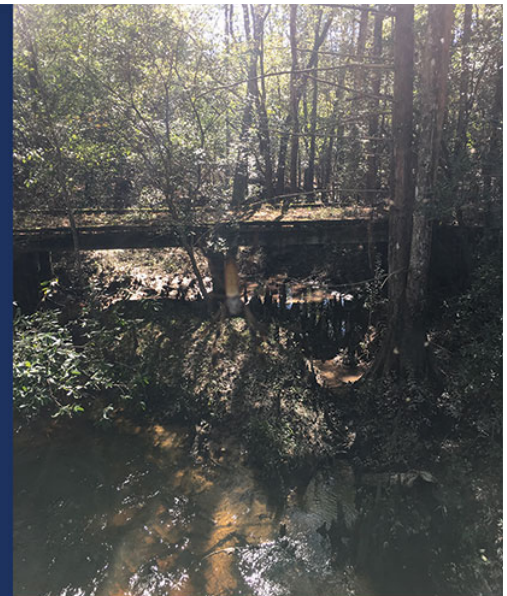
Salmon Test Site Radiological Monitoring



Annual Report

2018

Salmon Test Site
Lamar County, Mississippi

Analytical Results for the Quarterly Sampling
Study of Selected Wells
And Other Surface Samples

January 2018 - December 2018

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Abbreviations and Notations

AEC	- U.S. Atomic Energy Commission
DOE	- U.S. Department of Energy
ERDA	- Energy Research and Development Administration
EPA	- U.S. Environmental Protection Agency
NCRP	- National Council on Radiation Protection and Measurements
HMC	- Half Moon Creek
HMCOP	- Half Moon Creek Overflow Pond
IT	- International Technologies Corporation
L	- Liter
LLD	- Lower Limit of Detection
LTHMP	- Long-Term Hydrological Monitoring Program
Dup	- Duplicate
NA	- Not applicable
ND	- No data provided
NS	- No sample collected
NSD	- Sample collected by DRH; Broken during transport to DRH
pCi/L	- Picocuries per liter = 10^{-12} curies per liter
PWGZ	- Pond West of Ground zero
SGZ	- Surface Ground Zero
^{3}H	- Tritium
^{137}Cs	- Cesium-137
E-7	- Equipment Well #7
HMH-#	- Hydrological Monitoring Holes- 1 through 16
HM-L,-L2	- Hydrological Monitoring Well - Local Aquifer
HM-S	- Hydrological Monitoring Well - Surficial Aquifer
HM-1	- Hydrological Monitoring Well - Aquifer 1
HM-2a	- Hydrological Monitoring Well - Aquifer 2a
HM-2b	- Hydrological Monitoring Well - Aquifer 2b
HM-3	- Hydrological Monitoring Well - Aquifer 3
HT-#	- Hydrological Test Well -2c, -4, -5
SA#-##-X	- Source Area 1 to 5 – sequential well number - Aquifer

Preface

This report compiles the data from the January and October quarterly monitoring of the Salmon Test Site (STS), formerly called the Tatum Salt Dome Test Site (TSDTS), in Lamar County, Mississippi. There was no annual sampling done in 2018 just the routine quarterly sampling done by the Mississippi State Department of Radiological Health.

The analytical results identify tritium as the only radionuclide identified above the DRH lower limit of detection and not routinely found at those levels in environmental samples. However, no tritium level above the EPA drinking water standard (20,000 pCi/L) was detected in a potable (i.e., suitable for drinking) water source. Additionally, the overall tritium concentration continues to decrease consistent with radioactive decay and dilution in the absence of new sources of significant tritium activity.

DOE transferred the surface site to the State of Mississippi on December 15, 2010, renaming it the Jamie Whitten Forest Management Area. During 2010, 360 tree samples were taken and analyzed in preparation for this transfer. The Mississippi Forestry Commission now manages the site.

Validity of Information

The Division of Radiological Health (DRH), Environmental Monitoring Laboratory is using DOE's Mixed Analyte Performance Evaluation Program (MAPEP) for its laboratory proficiency testing. As a participant in this program, DRH analyzes unknown, simulated environmental samples provided by MAPEP and reports its results directly to them.

In most cases covered by this report, DRH and Navarro shared either duplicate or split samples. Some of the data reflect instances when samples were neither split nor duplicated. In many cases, sample results are less than the Lower Limit of Detection (LLD) for the analytical technique and equipment. For example, for tritium the LLD is approximately 300 picocuries per liter (pCi/L) during routine DRH analysis, and 300 to 400 pCi/L for the contract lab's analysis. Concentrations that fall below the LLD are reported "<LLD".

The contract lab performs some analyses using a "Tritium Enrichment" technique, in which tritium is concentrated by electrolysis. This data can be noted by numbers expressed in quotes, in a fashion similar to: "94.7 ± 6.44", and are generally less than 300 pCi/L as samples showing higher results during routine analysis are not enriched.

Background Information
The Salmon Test Site, Tritium, and the Role of the Division of Radiological Health

The Salmon Test Site (STS) is located in the piney woods area of the gulf coastal plain near Hattiesburg, Mississippi (Fig. 1). The salt dome at STS is an almost circular dome, 1500 meters (5000 feet) in diameter. The salt is 460 meters (1500 feet) below the ground surface. The salt in the dome is 90% NaCl (commonly called halite) and 10% $CaSO_4$ (commonly called anhydrite).

Project Dribble and Project Miracle Play

During the 1960s the Department of Defense and the U.S. Atomic Energy Commission (AEC) conducted Projects Dribble and Miracle Play in the geological structure known as the Tatum Salt Dome in Lamar County, Mississippi. Project Dribble consisted of two nuclear detonations, and the Miracle Play series consisted of two methane and oxygen gas explosions. All four of the shots were a part of the Department of Defense's Vela-Uniform Project. The STS test cavity contains fission and activation products from the detonations (Fig. 2).

Detonations, Nuclear

The first detonation at STS was the Salmon Event. It occurred on October 22, 1964. Its yield was estimated at the time to be 5.3 ± 0.5 kilotons. Note: Some intra-office correspondence indicates a yield closer to 8 kilotons, which may have been determined from later calculations. A search of the scientific literature has not confirmed this higher value. The device was detonated at a depth of 826 meters (2710 feet) below surface ground zero (SGZ) and created a cavity in the salt 17 meters (55 feet) in radius.

The second detonation was the Sterling Event; originally to be detonated in a mined cavity on the site. However, failure of two separate attempts to set a large diameter casing to the salt forced a change in plans. The device was placed in the cavity formed by the Salmon Event, and detonated on December 3, 1966. It was calculated to have a 380-ton yield.

Detonations, Non-Nuclear

Two methane/oxygen gas detonations took place in the original Salmon/Sterling cavity. These were called, collectively, "Miracle Play." The first shot, February 2, 1969, was called Diode Tube and was estimated to have a 315-ton TNT-equivalence. The second shot, Humid Water, detonated April 19, 1970, also had a 315-ton TNT-equivalence.

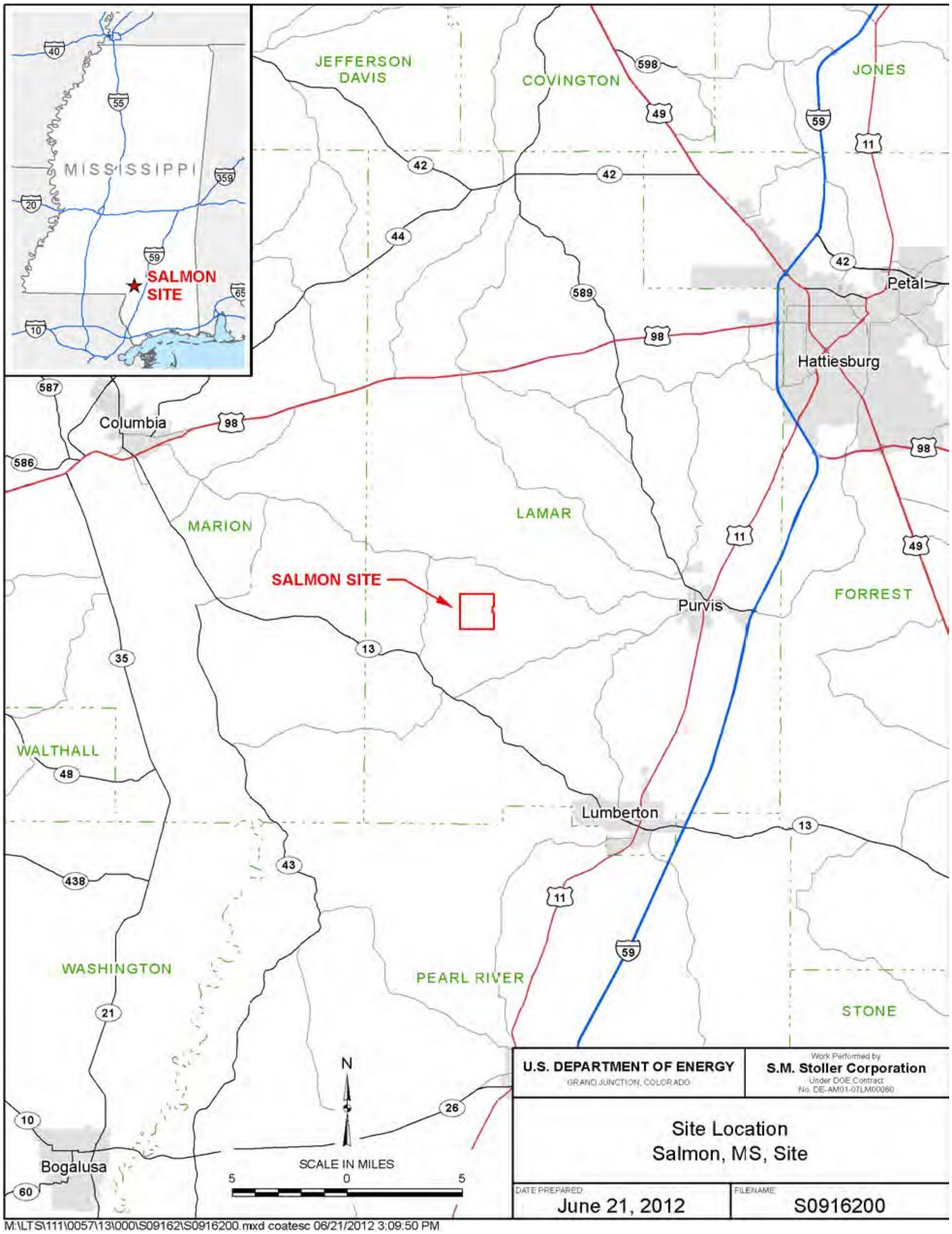

Figure 1, Location Map

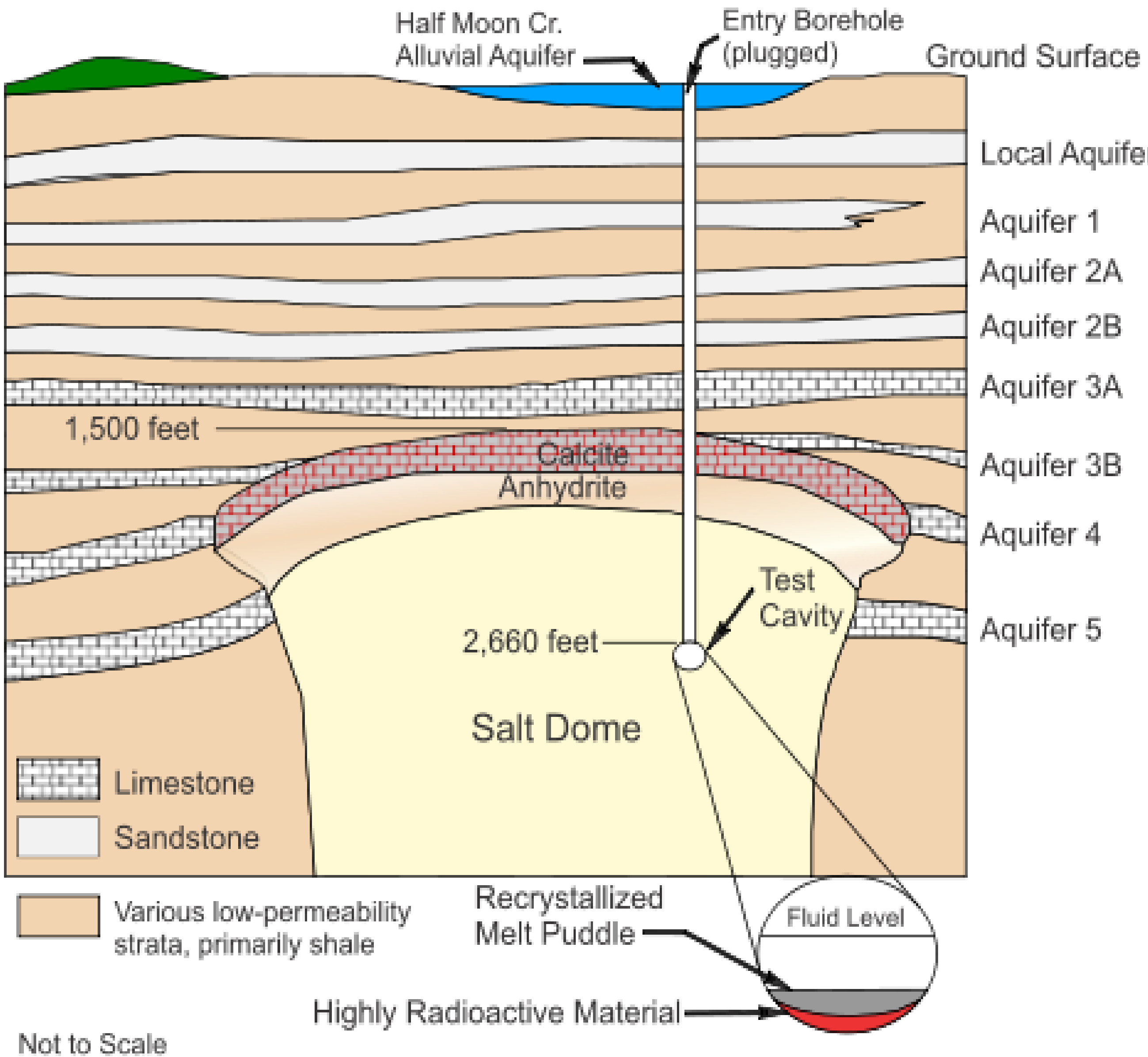

Figure 2, Test Cavity and Aquifers at the Salmon Test Site

Other Site Activities

In preparation for the second nuclear shot and the following gas shots, a plant to process and store radioactive liquids, gases, and solids was built onsite near SGZ. This facility, known as the Bleeddown Plant, processed some of the soil and drilling mud, and all of the liquids and gases.

From March through July of 1965, Aquifer 5 was injected with 7600 liters (2000 gallons) of 15% hydrochloric acid in water solution through Well HT-2 (Fig. 2). This acidic solution effectively dissolved the formation within the Cook Mountain Limestone aquifer near the wellbore, allowing more efficient injection of the wastewater. Following this, 1,279,000 liters (337,900 gallons) of contaminated water were injected. At sampling, this water contained 38 curies of beta-gamma emitters and 3253 curies of tritium. A last injection of 340,700 liters (90,000 gallons) of fresh water was made at 414 kPa (60 psi).

Site Decommissioning/Decontamination Limits

AEC contractors from Las Vegas, Nevada conducted the site cleanup from May 1971 through June 1972. Reports indicated that even though locally inclement conditions hampered the clean-up effort, the site was left radiologically "clean," consistent with the following limits imposed by the AEC as final clean up criteria:

Surface Water	300,000	pCi/liter tritium
Soil	1,000	pCi/gram tritium
	10	pCi/gram beta-gamma emitter
	1	pCi/gram alpha emitters

The Division of Radiological Health of the Mississippi State Department of Health has been directly involved with STS projects of the Atomic Energy Commission, the Energy Research and Development Administration (ERDA) and the Department of Energy since early 1974.

The reason for the involvement of the Division was the potential for accidental release of waste injected into deep formations (note the fact that radioactively contaminated water had begun surfacing from AEC monitoring well HT-2m). Division activities also address our concerns regarding the potential impact by intentional or natural incursions into the cavity on groundwater onsite and offsite. The isotope of concern has been tritium. In September 1974, an *ad hoc* committee was formulated at the request of the Division to assist in the evaluation of U. S. Government activities at the then Tatum Salt Dome Test Site. That committee was the Tatum Salt Dome Advisory Committee.

The Division has been involved only with the radiological matters at the STS. It has also acted as a state clearinghouse for distribution of information received from the various federal agencies involved with the Salmon Project. From 1974 to 1990, the Division unofficially acted as the coordinator for Mississippi's involvement at the STS. In 1990, the Mississippi Department of Environmental Quality (MDEQ) became the official coordinator for clean-up activities at STS, and in 2000, that responsibility was officially transferred to the Mississippi State Department of Health.

Due to the possibility of further radiological contamination from HT-2m, the Division had personnel assigned onsite during the HT-2m plugback in August 1975, and the reconditioning of wells HT-1 and Ascot Oil Co. No. 2 Bass Well near Baxterville. The Division also performed tritium analyses on sample splits taken by EPA during the 1975 Salmon operations. Sampling frequency was increased after the HT-2m plugback.

During the April 1977 sample collection period, the EPA collected some special soil and water samples in the area east of surface ground zero (SGZ) and west of the Half Moon Creek Overflow. The Division did not receive samples from that particular soil and water sampling. In July 1977, the Division was apprised of the fact that EPA detected significant levels of tritium in the samples collected in April. A monitoring program was developed to determine the areal and vertical extent, and magnitude of the tritium contamination. From that time until 2010, radiological samples collected by EPA or the Division were, with few exceptions, splits or duplicates shared between the agencies.

During September and October 1977, representatives of the Division and the Mississippi State Geological Survey (now incorporated into MDEQ) assisted EPA in the collection of soil and water samples from some 130 hand-augered holes in the area of SGZ. The Division of Radiological Health analyzed splits of the water samples.

After analysis of the data, members of the Tatum Salt Dome Advisory Committee and other interested members of state government determined that additional hand-augered wells should be drilled and a series of shallow water table monitoring holes emplaced. One hole was to be drilled and a well completed in the local aquifer in the SGZ area. Water samples and soil samples collected during the drilling of PS-3 were split with the Division and analyzed for tritium. For various reasons, monitor well PS-3 was never completed.

In September 1978, a meeting of the Tatum Salt Dome Advisory Committee discussed NVO-200, "Special Study-Tatum Dome Test Site-Final Report," and the role of the Department of Energy, Nevada Operations Office, with respect to future activities at STS. The Committee determined that the incomplete PS-3 was of no use and should be completed or preferably replaced.

In October 1978, the Mississippi Mineral Resources Institute (MMRI), at the request of State Senator Dale Ford, asked that the Division prepare a synopsis of DRH activities and radioassay results relative to the Tatum Salt Dome (TSD). The information supplied by DRH and Mississippi State Geological Survey (MSGS) and compiled by MMRI showed the geohydrology of the TSD was highly uncertain. There was a question concerning the dome's integrity and the cavity status itself was in doubt.

A Technical Advisory Committee to Senator Ford and the Senate Oil and Gas Committee had a DRH staff member as a representative. Representatives from MSGS and MMRI constituted the remainder of the committee. The input of the DRH representative concerned only radiological matters. DOE and the Technical Committee conducted several meetings between December 6, 1978, and January 19, 1979. On January 19, 1979, the DOE committed to performing an extensive re-evaluation of the status of the STS in general, with a focus on water and game pathways to man.

Surface Ground Zero (SGZ) Well Depths

In 1979, a group of wells reaching the aquifers (Fig. 2) above the dome were drilled, developed, and pumped. One of the original SGZ wells, PS-3 at 43.3 meters (142 feet), was plugged. Current well depths are as follows:

HM-S	Surficial Aquifer	9 meters (30 ft.)
HM-L	Local Aquifer	62.2 meters (204 ft.)
HM-L2	Local Aquifer	61 meters (200 ft.)
HM-1	Aquifer 1	126 meters (415 ft.)
HM-2a	Aquifer 2a	164 meters (537 ft.)
HM-2b	Aquifer 2b	213 meters (700 ft.)
HM-3	Aquifer 3	267 meters (875 ft.)

REECo Pit

Between 1977 and 1979, during the augering program to collect soil samples and their subsequent analyses, the results indicated notable levels of tritium near the SGZ area. At that time, another area onsite was identified that had not previously shown tritium results. This location was some 640 meters (2100 feet) from SGZ (Fig. 3). A literature search indicated that this location had been a disposal pit for the Reynolds Electrical and Engineering Company (REECo). This resulted in the addition of three monitoring points within the old pit to the Long Term Hydrologic Monitoring Program.

Tritium levels at this pit were unremarkable until 1983, when the level increased from the 1000-2000 pCi/L range to approximately 12,000 pCi/L at one location. In 1984, levels returned to the previous range of values.

DRH requested information from the U.S. Department of Energy about the use of the pit in January 1984. Their response identified the pit as a borrow pit, originally used to fill in other excavations and then for storage of drilling mud. During decommissioning and site cleanup, the pit was used for the disposal of noncombustible materials and uncontaminated tools and equipment. They described the pit as filled to capacity, the area filled-in and grass planted.

Over the years, this pit has eroded and now has a gully 3.7 to 4.6 meters (12 to 15 feet) deep in places. The erosion exposed bricks and concrete fill. Water flows through the pit during high rainfall months. A natural spring is present at one end of this pit; based upon continued sampling, it does not appear to have ever been contaminated by tritium. Cows and wildlife have been observed using this spring for water. Water flows through the pit, emptying into a small brook somewhat distant from the pit; it also appears to be uncontaminated, beyond any contribution from the pit water.

Senator Trent Lott's Requests

During the fall of 1989, Senator Trent Lott asked DOE to address concerns regarding security needs at SGZ and assess contaminants at the REECo pits. He also asked DOE to perform an epidemiological cancer study in Lamar County, and evaluate the adequacy of their exchange of information with residents in the STS area. As a result, DOE increased the amount of information it makes available to area residents and performed an environmental study of site conditions. The cancer study was conducted but was inconclusive.

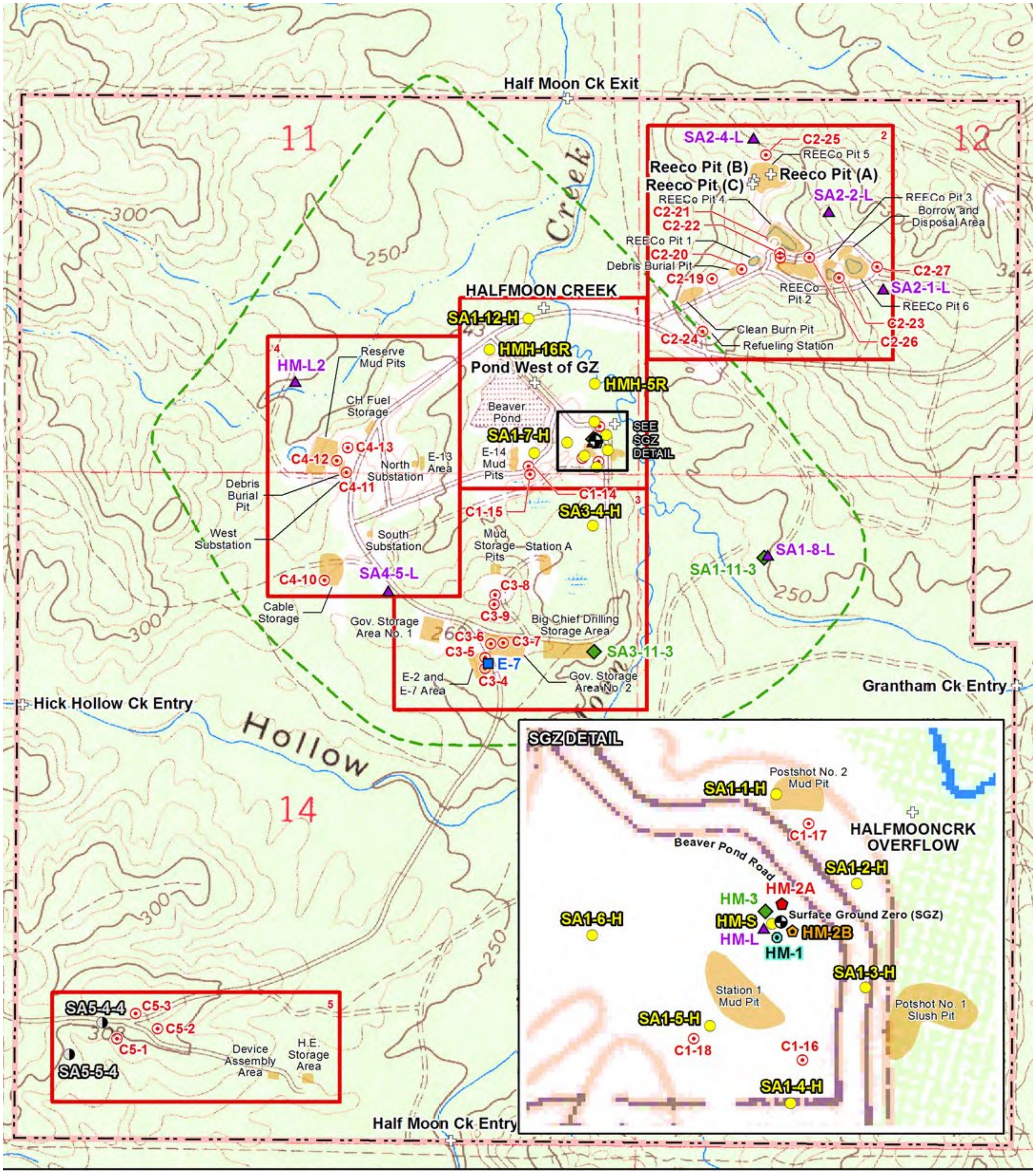

Figure 3, SGZ Downhole Wells and Other Onsite Sample Locations

New Wells on the Salmon Test Site

From the late summer 1995 until January 1997, 29 new wells were drilled, 15 shallow wells (less than 18 meters [59 feet]) and 14 deep wells of varying depth (50.3 to 640 m [165 to 2100 ft]). These wells were drilled both to detect contamination and to characterize the direction of water flow in the aquifers around the Tatum Salt Dome. These wells are the SA# series wells and are a part of the annual sampling. During the 1998 annual sampling of the shallow wells, SA1-1-H well produced tritium analyses results greater than 30,000 pCi/L. This well samples the Half Moon Creek alluvium and is not a potable water source. In December 1998, 70 shallow holes were direct-pushed to repeat the September/October 1977 special study. Division staff and IT Corporation took duplicate water samples.

In early 2002, four more wells were drilled while many of the earlier wells were plugged and abandoned as part of the Restoration Plan. This left the Long Term Hydrological Monitoring Program (LTHMP) with 28 wells (12 shallow and 16 deep) and 6 surface-water sampling points. In late 2007, all but the two deepest wells were converted to low flow pumps.

Private Wells, Community Water Supplies and Offsite Monitoring

Since March 1980, the annual joint sampling, by the responsible Federal Agency and the Division of Radiological Health, has included private and public supply wells (Fig. 4). The specific public water supplies sampled are Baxterville, Lumberton, Purvis, and Hub Water Association.

During the 1990 annual joint sampling of private wells, the offsite monitoring was expanded to include, not only water, but also meat, milk, vegetables and other food products for human consumption. Its intent was to examine the various pathways by which tritium, as well as other radionuclides, could be ingested.

During the 2002 Annual joint sampling, EPA and DRH notified residents that individual private well samples would no longer be collected. This was because the DOE had provided assistance to the county for the installation of public water lines to supply all area residents. The offsite sampling was reduced to the collection of samples from area creeks, ponds and public water suppliers (Table 2).

In 2009, the DOE unilaterally discontinued offsite sampling, but added sampling points for water entering and leaving the site.It is DRH's intention to continue to sample water from Baxterville, N. Lumberton, Purvis and Hub Water Association.

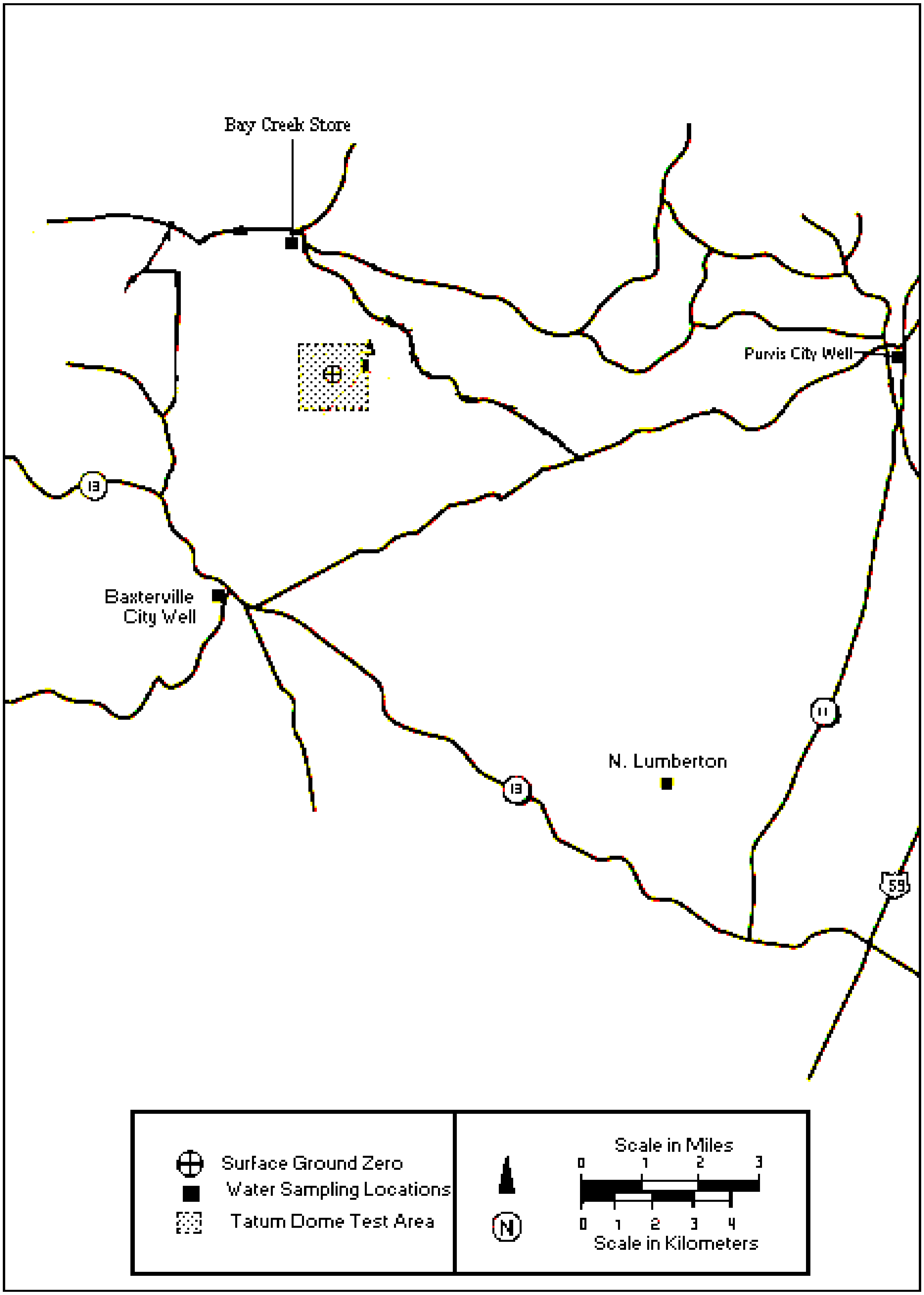

Figure 4, Some of the Offsite Sampling Locations

The Study Currently Underway At Salmon

During the November 1983 annual sampling, a number of monitored locations had elevated levels of tritium. A number of explanations were discussed, including the most likely explanation that it was due to the dry conditions onsite. Tritium concentration tends to be high during drier months of the year (usually summer and fall) due to less water saturation by rainfall. To evaluate this hypothesis, or assist in the development of a more effective one, an automated rain gauge was installed near the site on February 12, 1992 to accurately measure rainfall. Either DRH or EPA measured rainfall into the year 2000. Weather monitoring has ended at the site, the eight years of data having confirmed the theory sufficiently.

After the April 1984 sampling, a "special study" was begun by the Division of Radiological Health with the concurrence of DOE. This study focused on the HMH Series, the Overflow Pond near SGZ, Half Moon Creek, the Pond West of Ground Zero (Beaver Pond), HM-S, and the REECo Pit (Fig. 3 and 5). Samples were collected monthly in an ongoing study of tritium levels.

Results of this program have been quite consistent, with a definite trend downward for tritium concentrations (Fig. 6). The sampling frequency was reduced to quarterly when the April 1990 cooperative sampling results did not show a reversal of this trend.

In February of 2002, the HMH series were plugged and abandoned as part of the Site Restoration Plan. Wells that are more reliable replaced three of these holes and several had already become redundant with the SA# series wells.

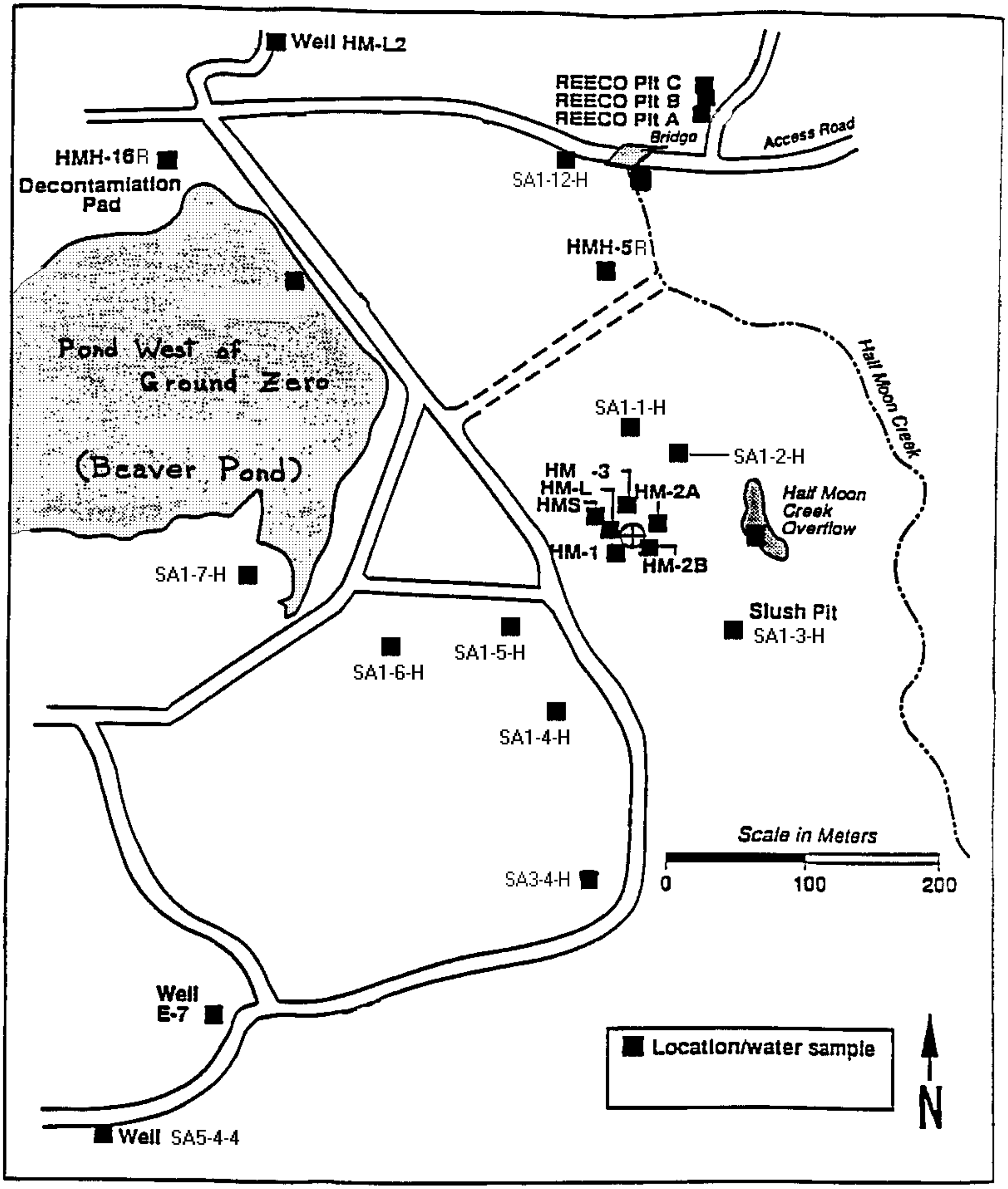

Figure 5, Onsite Sampling Location

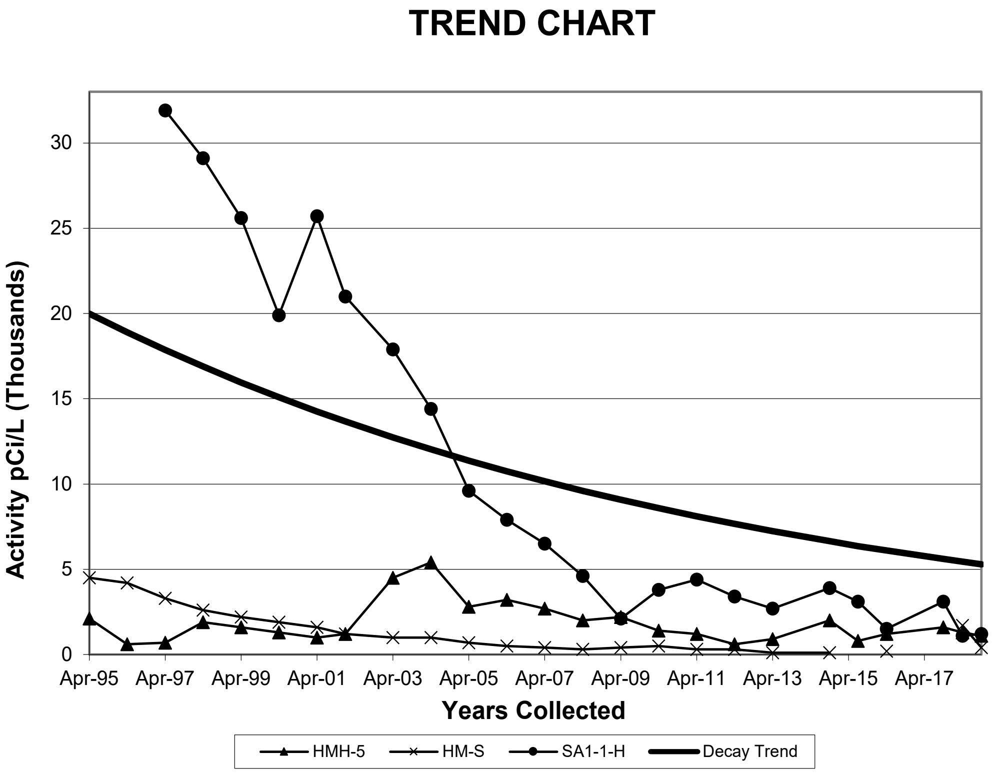

Figure 6, Tritium Trend Chart for Selected Sample Points. NOTE: The spike in the HMH-5 data at April 2003 is from the replacement well HMH-5R that is 20 ft deeper than the original 10ft hole.

Tritium

Since the start of the STS environmental monitoring program, tritium has been the principal radionuclide of concern.

Tritium is a naturally occurring radioactive form of hydrogen that is produced in the atmosphere when cosmic rays collide with air molecules. As a result, tritium is found in very small or trace amounts in groundwater throughout the world. It is also a byproduct of the production of electricity by nuclear power plants. Tritium emits a weak form of radiation, a low-energy beta particle similar to an electron. The tritium radiation does not travel very far in air and cannot penetrate the skin.

Tritium is almost always found as tritiated water and primarily enters the body when people eat or drink food or water containing tritium or absorb it through their skin. People can also inhale tritium as a gas in the air. Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the soft tissues. Half of the tritium is excreted within approximately 10 days after exposure. About 10 percent of the dose from any tritium exposure comes from the small fraction of the exposure that the body retains as organically bound tritium (ICRP-30, 1979). Everyone is exposed to small amounts of tritium every day, because it occurs naturally in the environment and the foods we eat. Workers in federal weapons facilities; medical, biomedical, or university research facilities; or nuclear fuel cycle facilities may receive increased exposures to tritium.

The NRC agrees with national and international radiation protection regulatory agencies that any exposure to radiation could pose some health risk. This risk increases with exposure in a linear, no-threshold manner. Lower levels of radiation therefore have lower risks. The health risks include increased occurrence of cancer. Since it is assumed that any exposure to radiation could pose some health risk, it makes sense to keep radiation doses as low as reasonably achievable - known as ALARA. The NRC's radiation dose limits and ALARA requirements minimize the health risk and ensure that no individual exceeds federal health and safety standards.

The NRC sets dose limits for radiation workers and the general public well below the levels of radiation exposure that cause health effects in humans – including a developing embryo or fetus. The effects of high doses and high dose rates are well understood. Public health research, however, has not established health risks at low doses and low dose rates – below about 10,000 mrem.

The EPA's authority under the Safe Drinking Water Act sets federal limits for drinking water contaminants. Water suppliers must provide water that meets these standards, called maximum contaminant levels. Some states have adopted the EPA's drinking water standards as legally enforceable groundwater protection standards. These standards are often used in assessing laboratory test results of water from private wells.

The EPA's dose-based drinking water standard of 4 mrem per year is based on a maximum contaminant level of 20,000 picocuries per liter for tritium. If other similar radioactive materials are also present in the drinking water, the annual dose from all the materials combined shall not exceed 4 mrem per year. This standard was expected to be exceeded only in extraordinary circumstances (EPA, 1975; EPA, 1976b).

In 1991, EPA used improved calculations to conclude a tritium concentration of 60,900 pCi/L would yield a 4 mrem per year dose. However, EPA kept the 20,000 pCi/L value for tritium in its latest regulations.

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[1] U.S.NRC Backgrounder on Tritium, Radiation Protection Limits, and Drinking Water Standards

Safe Drinking Water Standards for Radioactive Materials

The United States Environmental Protection Agency has established maximum contaminant levels in the Safe Drinking Water Regulations: "The average annual concentration of beta particle-emitting man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than four milliRem per year." Twenty thousand picocuries per liter (20,000 pCi/L) of tritium in "finished" drinking water if taken internally at the rate of two liters per day for a year, equals the average annual concentration assumed to produce a total body dose equivalent of four milliRem per year.

The groundwater in some aquifers at the STS is non-potable (i.e., due to its brackish nature not suitable for drinking or cooking); therefore, this standard does not apply directly to them. However, the Mississippi Department of Environmental Quality does apply the drinking water standard to all Mississippi water sources.

In the absence of any other more appropriate standards, it has also been applied to tritium concentrations in game, fish and vegetation samples. The part that naturally occurring tritium plays in this report is difficult to determine. Members of the DRH staff have estimated that any amount of tritium that might possibly be detected in offsite wells will be quite small and was probably produced from natural causes and/or the atmospheric testing of nuclear weapons.

The Mississippi State Department of Health and other regulatory agencies continue to urge the responsible federal agencies to establish standards for such other environmental components and contaminants that they have not promulgated.

Tritium Analysis

During the 2018 quarterly samplings, onsite locations were sampled for tritium analyses only. These analyses identified locations onsite that were above background.

Study of Select Wells and Surface Water

During the April 1985 routine sampling, representatives of EPA, DOE, and DRH decided to continue the special study that began in April 1984 and was to terminate in October of 1985. Beginning with the April 1986 data, the DRH has continued this sampling study of the HMH Series, sharing split or duplicate samples with EPA. Also included in this study are other samples: from the HM-S Well, Half Moon Creek, Half Moon Creek Overflow Pond, and Pond West of Ground Zero, and three sampling points along the REECo borrow pit gully. By agreement with DOE, many of the HMH-# wells were discontinued as of April 1999 and will no longer be sampled. In February 2002, the HMH-# wells were plugged and abandoned. Replacing HMH-5 and 16 were HMH-5R and 16R, and SA1-1-H was added to the quarterly sampling to make up for HMH-1 and 2. In early 2010, DOE discontinued funding for the analysis of the EPA duplicates, so they are no longer sent.

The REECo pit sample points may not be available due to lack of water during dry months. Analytical results are detailed below.

Table 1. Study of the HMH Series and Surface Water

HMH Series

(All Results are in pCi/L ± 2 Sigma Error for Tritium)

Date	HMH-5R	HM-S	SA1-1-H
01-10	1200±264	<LLD	786±210
04-10	1380±286	<LLD	1140±252
10-17	1260±259	<LLD	2540±450

Surface Water

(All Results are in pCi/L ± 2 Sigma Error for Tritium)

Date	REECo Pit Point A	REECo Pit Point B	REECo Pit Point C
01-10	<LLD	<LLD	<LLD
04-10	<LLD	<LLD	<LLD
10-17	<LLD	<LLD	<LLD

Date	HMC	HMCOP	PWGZ
01-23	<LLD	<LLD	<LLD
04-10	<LLD	<LLD	<LLD
10-17	<LLD	<LLD	<LLD

Appendix

Please send questions or comments concerning information contained in this report to the following address:

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Jackson, MS 39215-1700

Mississippi State Department of Health