

NORTH CAROLINA STATE UNIVERSITY

**DEPARTMENT
OF
ENVIRONMENTAL HEALTH & SAFETY**

RADIATION PROTECTION OFFICE

**ENVIRONMENTAL RADIATION SURVEILLANCE
REPORT**

**FOR THE PERIOD
JULY 1, 1993 - JUNE 30, 1994**

PREPARED BY

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Attachment A

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1. INTRODUCTION

The Environmental Radiation Surveillance Program exists to provide routine measurements of the university environment surrounding the PULSTAR Reactor. The specific objectives of this program include:

- 1) Providing information that assesses the adequacy of the protection of the university community and the public-at-large;
- 2) Meeting requirements of regulatory agencies;
- 3) Verifying radionuclide containment in the reactor facility;
- 4) Meeting legal liability obligations; and
- 5) Providing public assurance and acceptance.

2. AIR MONITORING (TABLES 2.1, 2.2, AND 2.3; FIGURES 2a THROUGH 2e)

Figures 2a through 2e show bar graphs of gross beta activity (fCi/cubic meter vs. week number). The highest gross beta activity observed was 53.0 fCi m^{-3} at the Broughton station during the week of 08/10/93. The annual campus average was 17.4 fCi m^{-3} . Instances of missing data for a monitor station are due to pump and electric motor malfunctions.

Table 2.2 lists LLD values for several gamma emitters which would be indicative of fission product activity. No gamma activity due to any of these radionuclides was detected.

Table 2.3 lists regulatory limits, alert levels, and average background levels for airborne radioactivity.

TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

| <u>SITE</u> | <u>DIRECTION</u> ¹ | <u>DISTANCE</u> ² (meters) | <u>ELEVATION</u> ³ (meters) |
|------------------|-------------------------------|--|---|
| BROUGHTON | SOUTHWEST | 125 | -17 |
| DAVID CLARK LABS | WEST | 500 | -18 |
| LIBRARY | NORTHWEST | 192 | +11 |
| RIDDICK | SOUTHEAST | 99 | -14 |
| WITHERS | NORTHEAST | 82 | -6 |

¹DIRECTION-DIRECTION FROM REACTOR STACK

²DISTANCE-DISTANCE FROM REACTOR STACK

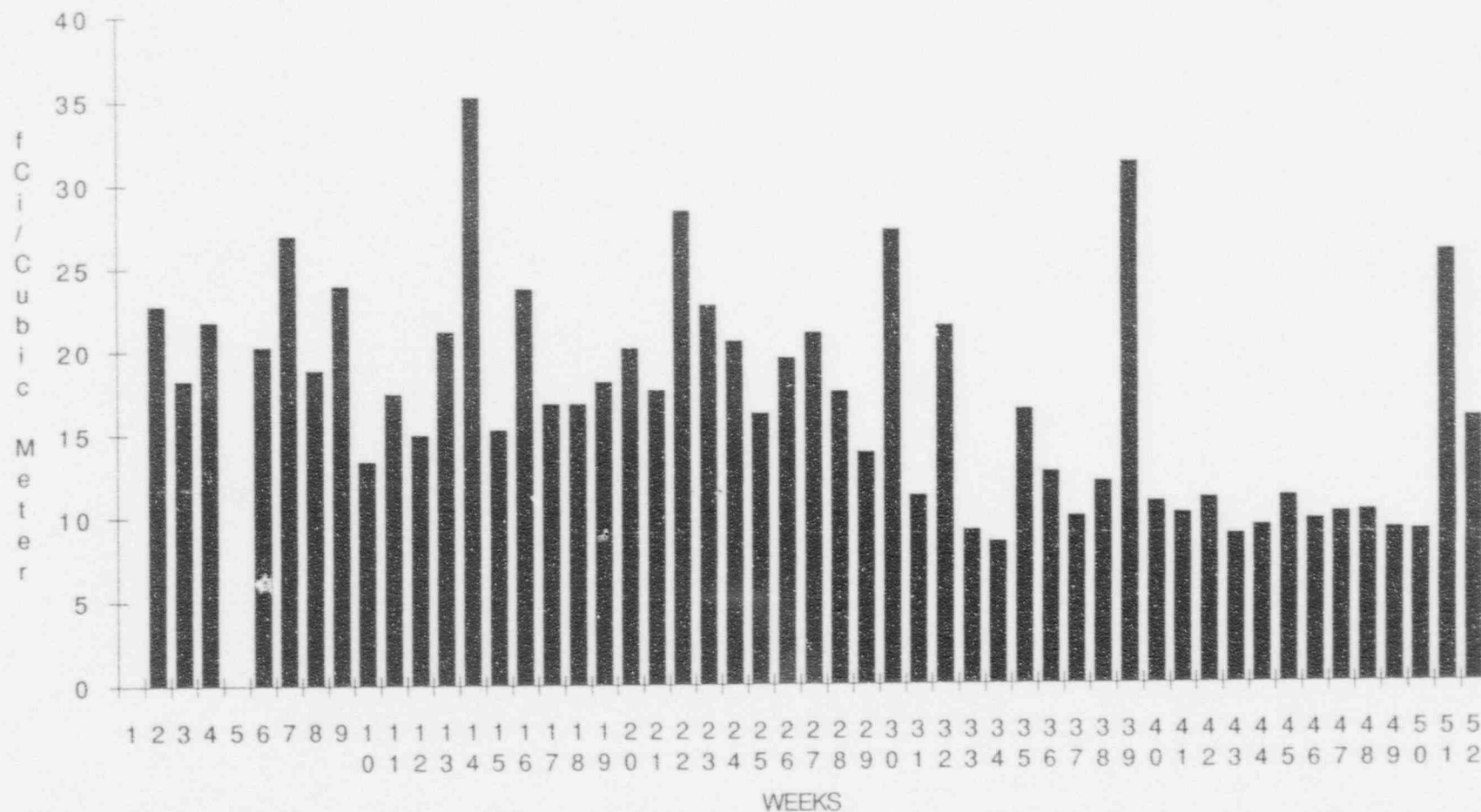
³ELEVATION-ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

FIGURE 2a

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fCi/CUBIC M
ALERT LEVEL=500 fCi/CUBIC M
LLD~1 fCi/CUBIC M

CLARK



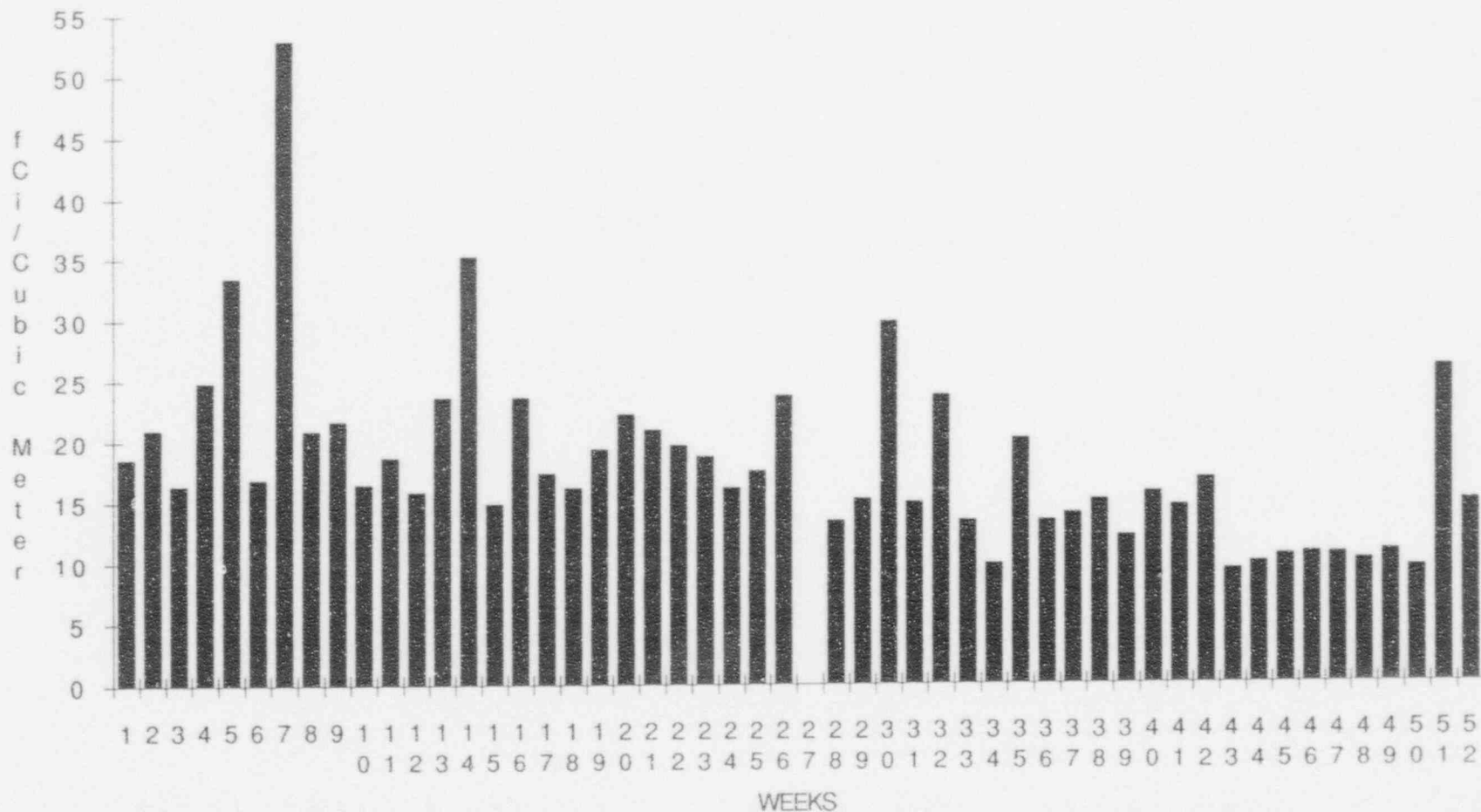
WEEK NUMBER FROM JUNE 29, 1993 THROUGH JUNE 23, 1994
JUNE 29 BEGINS AT WEEK #1

FIGURE 2 b

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fCi/CUBIC M
ALERT LEVEL=500 fCi/CUBIC M
LLD~1 fCi/CUBIC M

BROUGHTON



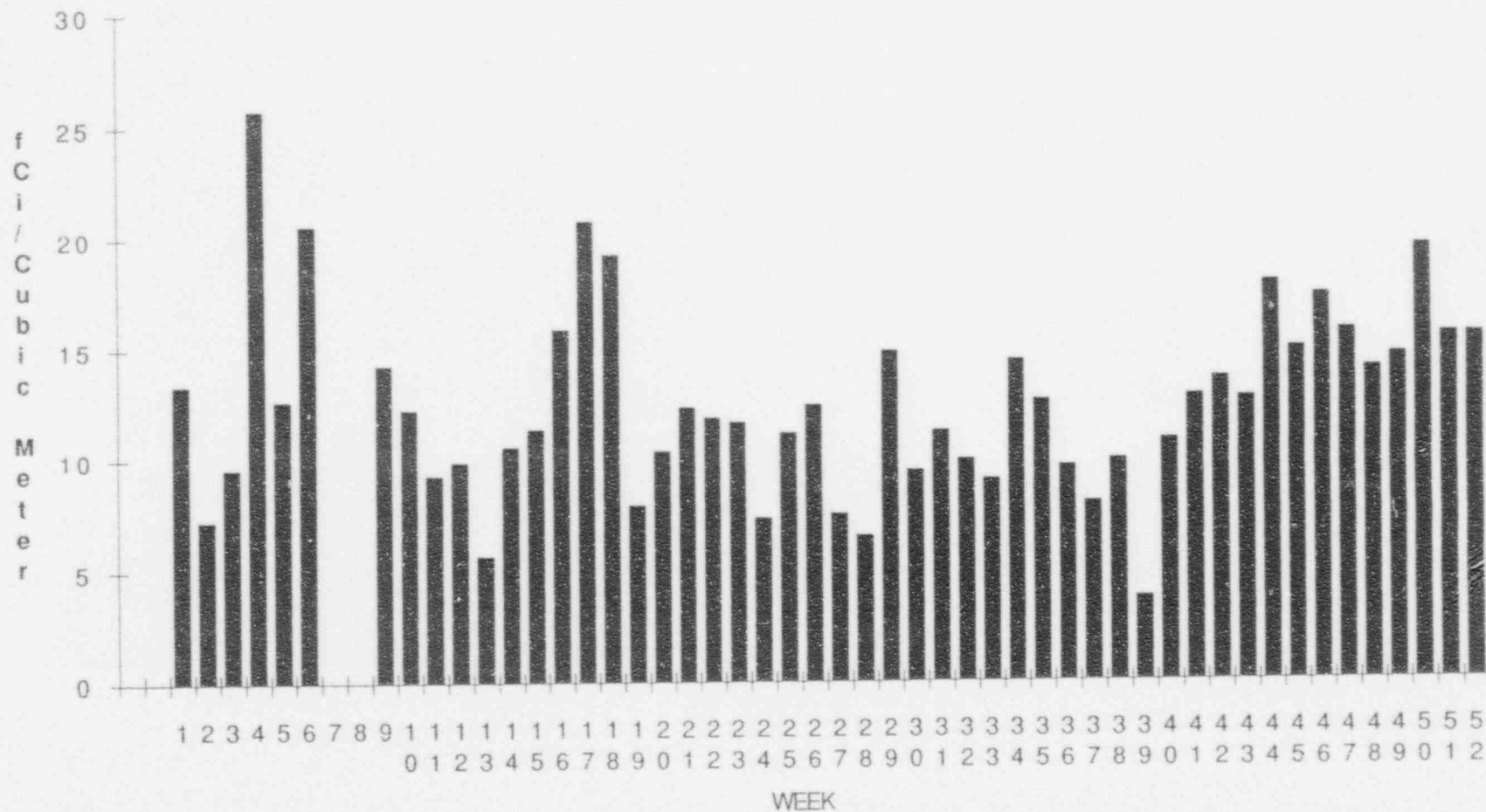
WEEK NUMBER FROM JUNE 29, 1993 THROUGH JUNE 28, 1994
JUNE 29 BEGINS AT WEEK #1

FIGURE 2c

AIRBORNE CROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fCi/CUBIC M
ALERT LEVEL=500 fCi/CUBIC M
LLD=1 fCi/CUBIC M

RIDDICK



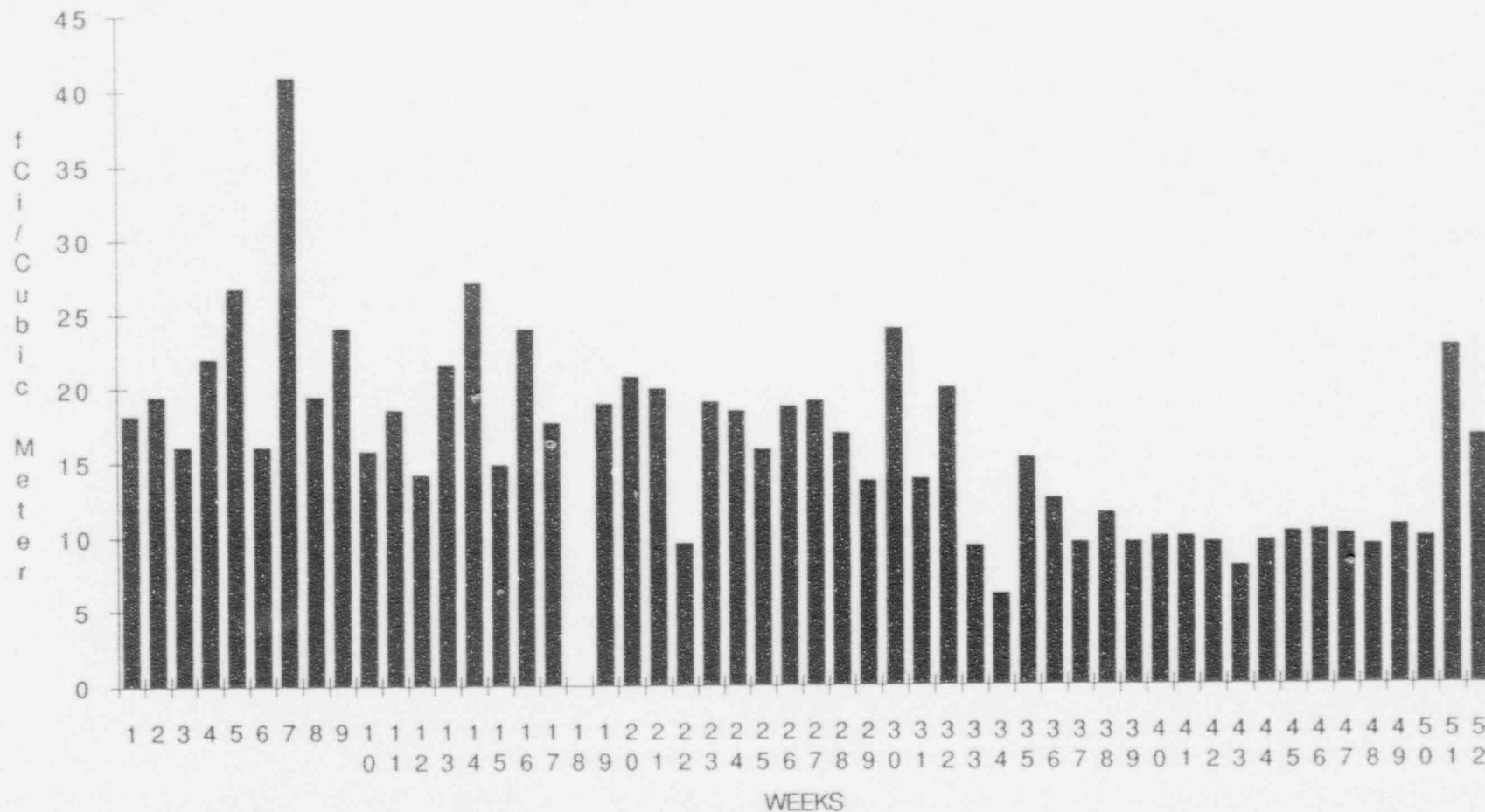
WEEK NUMBER FROM JUNE 29, 1993 THROUGH JUNE 28, 1994
JUNE 29 BEGINS AT WEEK #1

FIGURE 2d

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fci/CUBIC M
ALERT LEVEL=500 fci/CUBIC M
LLD~1 fci/CUBIC M

WITHERS

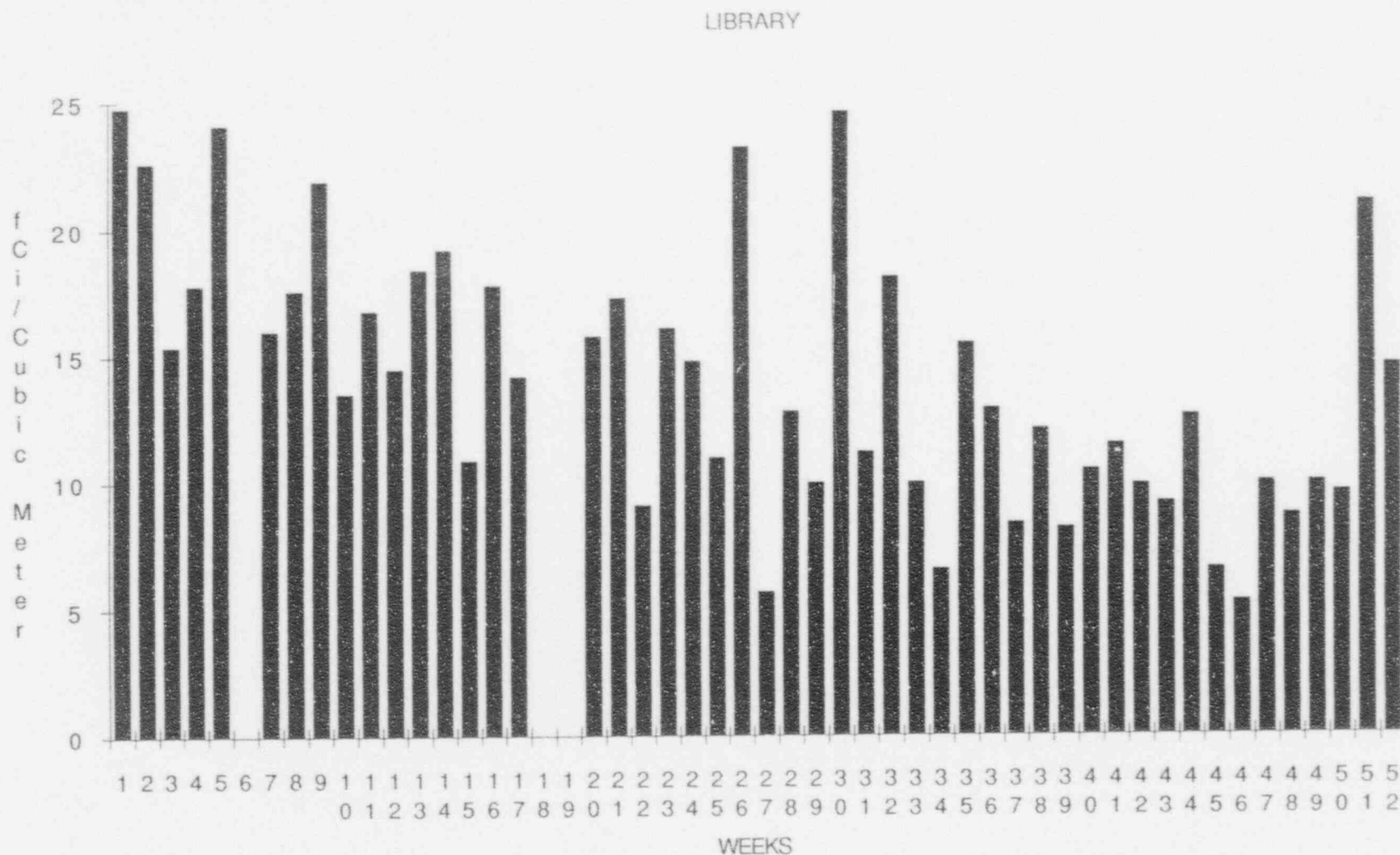


WEEK NUMBER FROM JUNE 29, 1993 THROUGH JUNE 28, 1994
JUNE 29 BEGINS AT WEEK #1

FIGURE 2e

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULAROTY LIMIT=1000 fci/CUBIC M
ALERT LEVEL=500 fci/CUBIC M
LLD~1 fci/CUBIC M



WEEK NUMBER FROM JUNE 29, 1993 THROUGH JUNE 28, 1994
JUNE 29 BEGINS AT WEEK #1

TABLE 2.2

| TABLE 2.2 AERIALY TRANSPORTED GAMMA ACTIVITY | | | | | (fCi m E-3) | | | | |
|--|-------|-------|-------|-------|-------------|--------|--------|--------|--------|
| | | | | | NUCLIDES | | | | |
| SAMPLING PERIOD | Co-57 | Co-60 | Nb-95 | Zr-95 | Ru-103 | Ru-106 | Cs-137 | Ce-141 | Ce-144 |
| 1993 | | | | | | | | | |
| 06/29 - 07/06 | 0.19 | 0.35 | 0.39 | 0.62 | 0.39 | 2.86 | 0.32 | 0.53 | 1.59 |
| 07/06 - 07/13 | 0.19 | 0.39 | 0.32 | 0.59 | 0.35 | 2.94 | 0.32 | 0.46 | 1.66 |
| 07/13 - 07/20 | 0.13 | 0.38 | 0.25 | 0.42 | 0.24 | 2.09 | 0.24 | 0.29 | 1.17 |
| 07/20 - 07/28 | 0.17 | 0.29 | 0.24 | 0.38 | 0.23 | 2.21 | 0.24 | 0.29 | 1.35 |
| 07/28 - 08/03 | 0.29 | 0.52 | 0.45 | 0.68 | 0.39 | 3.62 | 0.42 | 0.52 | 2.22 |
| 08/03 - 08/10 | 0.18 | 0.32 | 0.3 | 0.49 | 0.31 | 2.41 | 0.29 | 0.4 | 1.45 |
| 08/10 - 08/19 | 0.14 | 0.24 | 0.2 | 0.34 | 0.2 | 1.68 | 0.19 | 0.26 | 1.07 |
| 08/19 - 08/24 | 0.33 | 0.55 | 0.5 | 0.68 | 0.43 | 3.83 | 0.47 | 0.57 | 2.49 |
| 08/24 - 08/31 | 0.21 | 0.35 | 0.32 | 0.42 | 0.29 | 2.48 | 0.27 | 0.37 | 1.64 |
| 08/31 - 09/07 | 0.14 | 0.26 | 0.23 | 0.4 | 0.23 | 1.84 | 0.21 | 0.3 | 1.09 |
| 09/07 - 09/15 | 0.13 | 0.19 | 0.2 | 0.33 | 0.2 | 1.54 | 0.17 | 0.27 | 0.96 |
| 09/15 - 09/21 | 0.17 | 0.32 | 0.28 | 0.46 | 0.27 | 2.33 | 0.24 | 0.35 | 1.35 |
| 09/21 - 09/29 | 0.14 | 0.24 | 0.21 | 0.34 | 0.21 | 1.94 | 0.21 | 0.27 | 1.09 |
| 09/29 - 10/05 | 0.32 | 0.58 | 0.22 | 0.67 | 0.2 | 1.81 | 0.46 | 0.55 | 2.45 |
| 10/05 - 10/12 | 0.17 | 0.32 | 0.26 | 0.39 | 0.25 | 2.16 | 0.24 | 0.32 | 1.32 |
| 10/12 - 10/18 | 0.19 | 0.27 | 0.3 | 0.54 | 0.32 | 2.36 | 0.26 | 0.49 | 1.49 |
| 10/18 - 10/27 | 0.12 | 0.22 | 0.16 | 0.28 | 0.17 | 1.61 | 0.16 | 0.22 | 0.94 |
| 10/27 - 11/03 | 0.25 | 0.47 | 0.35 | 0.68 | 0.38 | 3.29 | 0.37 | 0.51 | 2.01 |
| 11/03 - 11/10 | 0.19 | 0.33 | 0.26 | 0.48 | 0.28 | 2.47 | 0.27 | 0.37 | 1.53 |
| 11/10 - 11/16 | 0.31 | 0.51 | 0.44 | 0.75 | 0.42 | 4.08 | 0.45 | 0.6 | 2.37 |
| 11/16 - 11/23 | 0.18 | 0.35 | 0.28 | 0.48 | 0.29 | 2.21 | 0.24 | 0.42 | 1.44 |
| 11/23 - 11/30 | 0.12 | 0.21 | 0.16 | 0.28 | 0.17 | 1.44 | 0.17 | 0.24 | 0.92 |
| 11/30 - 12/07 | 0.17 | 0.28 | 0.24 | 0.39 | 0.23 | 2.24 | 0.23 | 0.32 | 1.34 |
| 12/07 - 12/16 | 0.14 | 0.23 | 0.29 | 0.49 | 0.37 | 1.91 | 0.19 | 0.6 | 1.11 |
| 12/16 - 12/23 | 0.11 | 0.22 | 0.28 | 0.48 | 0.35 | 1.8 | 0.15 | 0.57 | 1.08 |
| 12/23 - 12/30 | 0.22 | 0.37 | 0.4 | 0.64 | 0.46 | 2.79 | 0.31 | 0.65 | 1.67 |

ALL DATA IN TABLE 2.2 ARE LLD VALUES.

TABLE 2.2 1993-1994

| TABLE 2.2 AERIALY TRANSPORTED GAMMA ACTIVITY | | | | (fCi m E-3) | | | | | |
|--|-------|-------|-------|-------------|----------|--------|--------|--------|--------|
| | | | | | NUCLIDES | | | | |
| SAMPLING PERIOD | Co-57 | Co-60 | Nb-95 | Zr-95 | Ru-103 | Ru-106 | Cs-137 | Ce-141 | Ce-144 |
| 1994 | | | | | | | | | |
| 12/30 - 01/04 | 0.21 | 0.36 | 0.36 | 0.62 | 0.41 | 2.69 | 0.32 | 0.63 | 1.71 |
| 01/04 - 01/11 | 0.2 | 0.37 | 0.3 | 0.52 | 0.38 | 2.71 | 0.29 | 0.53 | 1.58 |
| 01/11 - 01/18 | 0.18 | 0.32 | 0.27 | 0.46 | 0.29 | 2.26 | 0.27 | 0.39 | 1.44 |
| 01/18 - 01/25 | 0.24 | 0.44 | 0.34 | 0.6 | 0.36 | 3.03 | 0.33 | 0.51 | 1.87 |
| 01/25 - 02/01 | 0.18 | 0.28 | 0.28 | 0.46 | 0.28 | 2.38 | 0.28 | 0.37 | 1.42 |
| 02/01 - 02/10 | 0.15 | 0.24 | 0.21 | 0.34 | 0.22 | 1.74 | 0.2 | 0.3 | 1.16 |
| 02/10 - 02/15 | 0.24 | 0.47 | 0.36 | 0.68 | 0.37 | 3.08 | 0.37 | 0.47 | 2 |
| 02/15 - 02/25 | 0.13 | 0.24 | 0.24 | 0.42 | 0.25 | 1.96 | 0.19 | 0.35 | 1.07 |
| 02/25 - 03/01 | 0.32 | 0.61 | 0.57 | 0.88 | 0.54 | 4.55 | 0.47 | 0.77 | 2.48 |
| 03/01 - 03/08 | 0.18 | 0.32 | 0.28 | 0.47 | 0.26 | 2.53 | 0.28 | 0.33 | 1.46 |
| 03/08 - 03/15 | 0.2 | 0.34 | 0.29 | 0.48 | 0.25 | 2.75 | 0.28 | 0.37 | 1.51 |
| 03/15 - 03/22 | 0.22 | 0.36 | 0.33 | 0.55 | 0.3 | 3.11 | 0.35 | 0.42 | 1.74 |
| 03/22 - 03/30 | 0.2 | 0.32 | 0.35 | 0.65 | 0.38 | 2.96 | 0.31 | 0.61 | 1.53 |
| 03/30 - 04/05 | 0.31 | 0.57 | 0.69 | 1.1 | 0.81 | 4.3 | 0.43 | 1.3 | 2.4 |
| 04/05 - 04/12 | 0.19 | 0.32 | 0.4 | 0.65 | 0.47 | 2.56 | 0.29 | 0.75 | 1.53 |
| 04/12 - 04/19 | 0.3 | 0.51 | 0.52 | 0.96 | 0.63 | 4.05 | 0.44 | 0.96 | 2.34 |
| 04/19 - 04/27 | 0.26 | 0.37 | 0.4 | 0.71 | 0.42 | 3.3 | 0.36 | 0.69 | 2.02 |
| 04/27 - 05/03 | 0.32 | 0.51 | 0.53 | 0.85 | 0.52 | 4.34 | 0.48 | 0.77 | 2.56 |
| 05/03 - 05/10 | 0.25 | 0.43 | 0.38 | 0.62 | 0.37 | 3.21 | 0.4 | 0.48 | 1.96 |
| 05/10 - 05/17 | 0.27 | 0.45 | 0.53 | 0.92 | 0.63 | 3.69 | 0.41 | 0.1 | 2.19 |
| 05/17 - 05/24 | 0.21 | 0.37 | 0.31 | 0.56 | 0.29 | 2.73 | 0.31 | 0.38 | 1.56 |
| 05/24 - 05/31 | 0.22 | 0.38 | 0.35 | 0.55 | 0.3 | 3.08 | 0.33 | 0.45 | 1.83 |
| 05/31 - 06/07 | 0.21 | 0.37 | 0.29 | 0.49 | 0.3 | 2.81 | 0.32 | 0.39 | 1.7 |
| 06/07 - 06/14 | 0.2 | 0.34 | 0.32 | 0.55 | 0.28 | 2.56 | 0.28 | 0.45 | 1.59 |
| 06/14 - 06/21 | 0.16 | 0.27 | 0.23 | 0.44 | 0.23 | 2.1 | 0.25 | 0.33 | 1.3 |
| 06/21 - 06/28 | 0.16 | 0.26 | 0.24 | 0.41 | 0.23 | 1.99 | 0.22 | 0.33 | 1.21 |

ALL DATA IN TABLE 2.2 ARE LLD VALUES.

TABLE 2.3 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR
AIRBORNE RADIOACTIVITY (fCi m⁻³)

| <u>NUCLIDE</u> | <u>REGULATORY LIMIT</u> | <u>ALERT LEVEL</u> | <u>AVERAGE N.C. BACKGROUND LEVEL</u> |
|----------------|-----------------------------|------------------------|--|
| GROSS ALPHA | 20 | 10 | 4 |
| GROSS BETA | 1000 | 500 | 100 |
| Cs-137 | 5 x 10 ⁵ | 10 | 2 |
| Ce-144 | 2 x 10 ⁵ | 100 | 0 |
| Ru-106 | 2 x 10 ⁵ | 30 | 0 |
| I-131 | 1 x 10 ⁵ | 10 | 0 |

Reference: Environmental Radiation Surveillance Report 1986-88, State of N.C.
Radiation Protection Section

3. MILK (TABLE 3.1)

Milk samples are collected each month from the Campus Creamery and the Lake Wheeler Road Dairy. Previously, samples were obtained from the Randleigh Dairy Farm but it is no longer operational.

The FDA's Preventive Action Guide (PAG) for I-131 is 1.5×10^4 pCi/liter for infants. All analyses during this period show activities at least three (3) orders of magnitude below the PAG.

The analyses are performed in duplicate and the higher value is reported in each case.

TABLE 3.1 I-131 IN COWS' MILK ($\text{pCi liter}^{-1} \pm 2 \sigma$) LLD $\sim 3 \text{ pCi liter}^{-1}$

| <u>DATE</u> | <u>pCi liter⁻¹</u> | |
|----------------|-------------------------------|---------------------|
| | <u>CAMPUS CREAMERY</u> | <u>LAKE WHEELER</u> |
| JULY 1993 | ≤ 3.0 | ≤ 3.0 |
| AUGUST 1993 | ≤ 3.0 | ≤ 3.0 |
| SEPTEMBER 1993 | ≤ 3.0 | ≤ 3.0 |
| OCTOBER 1993 | ≤ 3.0 | ≤ 3.0 |
| NOVEMBER 1993 | ≤ 3.0 | ≤ 3.0 |
| DECEMBER 1993 | ≤ 3.0 | ≤ 3.0 |
| JANUARY 1994 | ≤ 3.0 | ≤ 3.0 |
| FEBRUARY 1994 | ≤ 3.0 | ≤ 3.0 |
| MARCH 1994 | ≤ 3.0 | ≤ 3.0 |
| APRIL 1994 | ≤ 3.0 | ≤ 3.0 |
| MAY 1994 | ≤ 3.0 | ≤ 3.0 |
| JUNE 1994 | ≤ 3.0 | ≤ 3.0 |

4. SURFACE WATER (TABLES 4.1 AND 4.2)

Table 4.1 gives the gross alpha and beta activities for water from Rocky Branch at points where it enters (ON) and exits (OFF) the campus. The LLD values for gross alpha and beta activities are $\sim 0.4 \text{ pCi liter}^{-1}$ and $\sim 0.4 \text{ pCi liter}^{-1}$, respectively. For gross alpha activity the Alert Level is 5 pCi liter^{-1} and the Regulatory Limit is $15 \text{ pCi liter}^{-1}$. For gross beta activity the Alert Level is $12.5 \text{ pCi liter}^{-1}$ and the Regulatory Limit is $50 \text{ pCi liter}^{-1}$. Samples with gross alpha or beta activities exceeding these Alert Levels would require gamma analysis to identify the radionuclides present. The LLD values in Table 4.2 are for the second quarter of 1994.

TABLE 4.1 GROSS ALPHA AND BETA ACTIVITY IN SURFACE WATER ($\text{pCi liter}^{-1} \pm 2 \sigma$)

*LLD _{α} $\sim 0.4 \text{ pCi liter}^{-1}$ LLD _{β} $\sim 0.4 \text{ pCi liter}^{-1}$

| <u>DATE</u> | <u>LOCATION</u> | <u>pCi liter⁻¹</u> | |
|---------------------|-----------------|-------------------------------|-----------------------|
| | | <u>GROSS ALPHA</u> | <u>GROSS BETA</u> |
| THIRD QUARTER 1993 | ON | < 0.4 | 0.8 ± 0.3 |
| | OFF | < 0.4 | < 0.4 |
| FOURTH QUARTER 1993 | ON | < 0.6 | < 0.5 |
| | OFF | < 0.6 | < 0.5 |
| FIRST QUARTER 1994 | ON | < 0.3 | 1.4 ± 0.4 |
| | OFF | < 0.3 | 1.3 ± 0.3 |
| SECOND QUARTER 1994 | ON | < 0.3 | 1.4 ± 0.4 |
| | OFF | < 0.3 | 1.3 ± 0.4 |

*LLD VALUES ARE DETERMINED QUARTERLY

TABLE 4.2 LOWER LIMITS OF DETECTION FOR SEVERAL GAMMA EMITTERS IN
SURFACE WATER FROM NCSU ERSI ANALYSIS

| <u>NUCLIDE</u> | <u>LLD (pCi liter⁻¹)*</u> |
|----------------|--------------------------------------|
| Co-60 | 0.4 |
| Zn-65 | 0.7 |
| Cs-137 | 0.3 |
| Cs-134 | 0.4 |
| Sr-85 | 0.4 |
| Ru-103 | 0.3 |
| Ru-106 | 3.0 |
| Nb-95 | 0.4 |
| Zr-95 | 0.5 |

*LLD VALUES ARE FOR THE 2ND QUARTER OF 1994

5. VEGETATION (TABLE 5.1 and 5.2)

Table 5.1 gives gross beta activities for grass samples collected on the NCSU Campus. The reported activities are all below the Alert Level of 20 pCi gram⁻¹. Table 5.2 lists LLD values for several gamma emitters. No gamma activity due to any of these radionuclides has been observed in campus vegetation. The beta and gamma activities are reported as pCi per gram of green vegetation.

TABLE 5.1 GROSS BETA ACTIVITY IN CAMPUS VEGETATION *LLD ~ 0.5 pCi g⁻¹

| <u>SAMPLE DATE</u> | <u>SAMPLE LOCATION</u> | <u>(pCi g⁻¹ ± 2σ)</u> |
|--------------------|------------------------|----------------------------------|
| DECEMBER 1993 | NORTH CAMPUS | 2.8 ± 0.1 |
| DECEMBER 1993 | SOUTH CAMPUS | 2.7 ± 0.1 |
| DECEMBER 1993 | EAST CAMPUS | 2.7 ± 0.1 |
| DECEMBER 1993 | WEST CAMPUS | 4.4 ± 0.2 |
| APRIL 1994 | NORTH CAMPUS | 2.7 ± 0.1 |
| APRIL 1994 | SOUTH CAMPUS | 2.6 ± 0.1 |
| APRIL 1994 | EAST CAMPUS | 2.8 ± 0.1 |
| APRIL 1994 | WEST CAMPUS | 2.7 ± 0.1 |

*LLD values are determined semiannually

Table 5.2

LLD VALUES FOR GAMMA EMITTERS IN VEGETATION

| <u>NUCLIDE</u> | <u>LLD (pCi gram⁻¹)*</u> |
|----------------|-------------------------------------|
| Co-60 | 0.01 |
| Zn-65 | 0.02 |
| Cs-137 | 0.01 |
| Cs-134 | 0.01 |
| Sr-85 | 0.01 |
| Ru-103 | 0.01 |
| Nb-95 | 0.01 |
| Zr-95 | 0.02 |

*LLD VALUES ARE FOR THE 2ND QUARTER OF 1994

6. THERMOLUMINESCENT DOSIMETERS (TLDs) (TABLE 6.1)

TLD analysis is contracted to Teledyne Isotopes for determination of ambient gamma exposures. The dosimeters are CaSO_4 doped with dysprosium and have a manufacturer-stated sensitivity of $0.5 \pm 0.15 \text{ mR}$ (90% C.L.). Exposures are integrated over a three-month period at each of the five air monitor stations listed in Table 2.1 and also at the top of the PULSTAR Reactor stack. A control station is located in 214 David Clark Laboratories. Table 6.1 gives the data for these seven (7) sampling locations.

The observed exposures are those expected to be produced by background radiations in this area of North Carolina. The data of Table 6.1 agrees well with the state-wide average exposure rate of $\sim 18 - 20 \text{ mR}$ per quarter year.

TABLE 6.1 ENVIR. TLD EXP.

| TABLE 6.1 ENVIRONMENTAL TLD EXPOSURES (mR/QUARTER YEAR $\pm 2\sigma$) | | | | | | | | | | |
|--|--------------------|----------------|--|----------------|----------------|----------------|----------------|--|--|--|
| DATE | WITHERS | RIDDICK | BROUGHTON | LIBRARY | DAVID CLARK | PULSTAR STACK | CONTROL | | | |
| 04/07/93 - 07/07/93 | 14.5 \pm 1.2 | 21.6 \pm 1.7 | 16.4 \pm 1.5 | 16.8 \pm 3.3 | 14.5 \pm 2.0 | 13.5 \pm 0.3 | 15.7 \pm 2.3 | | | |
| 07/07/93 - 09/29/93 | 1 ^a 1.6 | 20.2 \pm 1.6 | 15.3 \pm 1.2 | 16.3 \pm 1.5 | 11.6 \pm 1.3 | 12.1 \pm 1.0 | 14.2 \pm 1.8 | | | |
| 09/29/93 - 01/11/94 | 11.1 \pm 1.6 | 18.8 \pm 2.3 | 13.3 \pm 1.2 | 12.2 \pm 2.5 | 10.2 \pm 1.7 | 15.4 \pm 0.9 | 11.3 \pm 2.5 | | | |
| 01/11/94 - 04/04/94 | 14.2 \pm 1.1 | 19.0 \pm 5.6 | 13.5 \pm 3.0 | 14.5 \pm 2.2 | 11.4 \pm 0.7 | 14.3 \pm 0.7 | 14.9 \pm 1.6 | | | |
| 04/04/94 - 06/27/94 | | | DATA NOT YET AVAILABLE FOR THESE DATES | | | | | | | |
| THIS DATA WAS UNAVAILABLE FOR INCLUSION IN THE 1992-93 REPORT | | | | | | | | | | |

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory of the Radiation Protection Office has participated in the U. S. EPA Environmental Laboratory Intercomparison Studies Program during this reporting period. The objective of this program is to provide laboratories performing environmental radiation measurements with unknowns to test their analytical techniques. The results of the intercomparison studies are given in Tables 7.1 a-g. All samples are analyzed in triplicate and reported as an average value with an experimental sigma (1s).

Appendix 1 gives an explanation of the quantities listed in the tables and an example calculation.

TABLE 7.1a GROSS ALPHA ACTIVITY AIR FILTER - INTERCOMPARISON STUDY
- 27 AUGUST 1993

The known value for gross alpha activity is 19.0 pCi/filter with an expected laboratory precision of 5.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

ALPHA

| Lab | Res. 1 | Res. 2 | Res. 3 | Exper. Sigma | Rng anal (R + SR) | Average | Normalized deviation (grand-avg) (known) | |
|-----|--------|--------|--------|-----------------|----------------------|---------|---|-------|
| QA | 17.0 | 19.0 | 18.0 | 1.00 | 0.236 | 18.00 | -0.69 | -0.35 |

STATISTICAL SUMMARY OF 204 PARTICIPANTS

| <u>Statistic</u> | <u>Respondents</u> | <u>Non-outliers</u> |
|--|--------------------|---------------------|
| Mean | 20.35 | Grand Avg 20.00 |
| Std. Dev. | 4.67 | 3.27 |
| Variance | 21.78 | 10.70 |
| % Coef. of Var. | 22.93 | 16.36 |
| % deviation of mean from known value | 7.13 | 5.24 |
| Norm. dev. of mean from known value | 0.29 | 0.30 |
| Median | 19.67 | 19.67 |
| % deviation of median from known value | 3.51 | 3.51 |
| Norm. dev. of median from known value | 0.14 | 0.20 |

TABLE 7.1b GROSS BETA ACTIVITY AIR FILTER - INTERCOMPARISON STUDY -
27 AUGUST 1993

The known value for gross beta activity is 47.0 pCi/filter with an expected laboratory precision of 5.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

BETA

| <u>Lab</u> | <u>Res. 1</u> | <u>Res. 2</u> | <u>Res. 3</u> | <u>Exper.</u> <u>Sigma</u> | <u>Rng anal</u> <u>(R + SR)</u> | <u>Average</u> | <u>Normalized deviation</u> <u>(grand-avg)(known)</u> | |
|------------|---------------|---------------|---------------|-------------------------------|------------------------------------|----------------|--|------|
| QA | 51.0 | 49.0 | 49.0 | 1.15 | 0.236 | 49.67 | 0.12 | 0.92 |

STATISTICAL SUMMARY OF 189 PARTICIPANTS

| <u>Statistic</u> | <u>Respondents</u> | <u>Grand Avg</u> | <u>Non-outliers</u> |
|--|--------------------|------------------|---------------------|
| Mean | 49.86 | 49.32 | |
| Std. Dev. | 7.82 | 4.62 | |
| Variance | 61.22 | 21.38 | |
| % Coef. of Var. | 15.69 | 9.37 | |
| % deviation of mean from known value | 6.07 | 4.93 | |
| Norm. dev. of mean from known value | 0.36 | 0.50 | |
| Median | 49.00 | 49.00 | |
| % deviation of median from known value | 4.26 | 4.26 | |
| Norm. dev. of median from known value | 0.26 | 0.43 | |

TABLE 7.1c ^{137}Cs ACTIVITY AIR FILTER INTERCOMPARISON STUDY -
27 AUGUST 1993

The known value for Cesium-137 activity is 9.0 pCi/filter with an expected laboratory precision of 5.0 (1s, 1 determination).

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^{137}Cs

| <u>Lab</u> | <u>Res. 1</u> | <u>Res. 2</u> | <u>Res. 3</u> | <u>Exper. Sigma</u> | <u>Rng anal (R + SR)</u> | <u>Average</u> | <u>Normalized deviation (grand-avg)(known)</u> | |
|------------|---------------|---------------|---------------|---------------------|--------------------------|----------------|--|------|
| QA | 10.00 | 10.00 | 10.00 | 0.00 | 0.000 | 10.00 | 0.00 | 0.35 |

STATISTICAL SUMMARY OF 189 PARTICIPANTS

| <u>Statistic</u> | <u>Respondents</u> | <u>Non-outliers</u> |
|--|--------------------|---------------------|
| Mean | 10.36 | Grand Avg 10.00 |
| Std. Dev. | 2.98 | 1.62 |
| Variance | 8.89 | 2.63 |
| % Coef. of Var. | 28.80 | 16.22 |
| % deviation of mean from known value | 15.07 | 11.16 |
| Norm. dev. of mean from known value | 0.45 | 0.62 |
| Median | 10.00 | 10.00 |
| % deviation of median from known value | 11.11 | 11.11 |
| Norm. dev. of median from known value | 0.34 | 0.62 |

TABLE 7.1d GROSS ALPHA ACTIVITY IN WATER - INTERCOMPARISON STUDY
-28 JANUARY 1994

The known value for gross alpha activity is 15.0 pCi/liter with an expected laboratory precision of 5.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS ALPHA

| <u>Lab</u> | <u>Res. 1</u> | <u>Res. 2</u> | <u>Res. 3</u> | <u>Exper.</u> <u>Sigma</u> | <u>Rng anal</u> <u>(R + SR)</u> | <u>Average</u> | <u>Normalized deviation</u> <u>(grand-avg)(known)</u> | |
|------------|---------------|---------------|---------------|-------------------------------|------------------------------------|----------------|--|-------|
| CA | 12.0 | 14.0 | 13.0 | 1.00 | 0.236 | 13.00 | -0.26 | -0.69 |

STATISTICAL SUMMARY OF 253 PARTICIPANTS

| <u>Statistic</u> | <u>Respondents</u> | <u>Grand Avg</u> | <u>Non-outliers</u> |
|--|--------------------|------------------|---------------------|
| Mean | 14.38 | | 13.75 |
| Std. Dev. | 5.97 | | 4.25 |
| Variance | 35.68 | | 18.08 |
| % Coef. of Var. | 41.55 | | 30.92 |
| % deviation of mean from known value | - 4.15 | | - 8.32 |
| Norm. dev. of mean from known value | - 0.10 | | - 0.29 |
| Median | 13.00 | | 13.00 |
| % deviation of median from known value | - 13.33 | | - 13.33 |
| Norm. dev. of median from known value | - 0.33 | | - 0.47 |

TABLE 7.1e GROSS BETA ACTIVITY IN WATER - INTERCOMPARISON STUDY
-28 JANUARY 1994

The known value for gross beta activity is 62.0 pCi/liter with an expected laboratory precision of 10.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS BETA

| Lab | Res. 1 | Res. 2 | Res. 3 | Exper. Sigma | Rng anal (R + SR) | Average | Normalized deviation (grand-avg)/(known) | |
|-----|--------|--------|--------|-----------------|----------------------|---------|---|------|
| CA | 69.0 | 70.0 | 71.0 | 1.00 | 0.118 | 70.0 | 2.40 | 1.39 |

STATISTICAL SUMMARY OF 253 PARTICIPANTS

| Statistic | Respondents | Grand Avg | Non-outliers |
|--|-------------|-----------|--------------|
| Mean | 56.86 | | 56.14 |
| Std. Dev. | 15.85 | | 14.15 |
| Variance | 251.07 | | 200.24 |
| % Coef. of Var. | 27.87 | | 25.21 |
| % deviation of mean from known value | - 8.29 | | -9.45 |
| Norm. dev. of mean from known value | - 0.32 | | -0.41 |
| Median | 57.67 | | 57.67 |
| % deviation of median from known value | -6.99 | | -6.99 |
| Norm. dev. of median from known value | -0.27 | | -0.31 |

TABLE 7.1f TRITIUM IN WATER - INTERCOMPARISON STUDY - 5 NOVEMBER 1993

The known value for tritium activity is 7398.0 pCi/liter with an expected laboratory precision of 740.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

³H

| Lab | Res. 1 | Res. 2 | Res. 3 | Exper. Sigma | Rng anal (R + SR) | Average | Normalized deviation (grand-avg)/(known) |
|-----|--------|--------|--------|-----------------|----------------------|---------|---|
| CA | 5018.0 | 5441.0 | 4652.0 | 394.84 | 0.630 | 5037.00 | -5.10 -5.53 |

STATISTICAL SUMMARY OF 220 PARTICIPANTS

| Statistic | Respondents | Grand Avg | Non-outliers |
|--|-------------|-----------|--------------|
| Mean | 7017.15 | | 7215.65 |
| Std. Dev. | 1320.54 | | 574.68 |
| Variance | 1743826.64 | | 330256.18 |
| % Coef. of Var. | 18.82 | | 7.96 |
| % deviation of mean from known value | - 5.15 | | - 2.46 |
| Norm. dev. of mean from known value | - 0.29 | | - 0.32 |
| Median | 7209.00 | | 7259.50 |
| % deviation of median from known value | - 2.55 | | - 1.87 |
| Norm. dev. of median from known value | - 0.14 | | - 0.24 |

TABLE 7.1g TRITIUM IN WATER - INTERCOMPARISON STUDY - 4 MARCH 1994

The known value for tritium activity is 4936.0 pCi/liter with an expected laboratory precision of 494.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

³H

| | | | | Exper. | Rng anal | | Normalized deviation | |
|-----|--------|--------|--------|--------|----------|---------|----------------------|------|
| Lab | Res. 1 | Res. 2 | Res. 3 | Sigma | (R + SR) | Average | (grand-avg)/(known) | |
| CA | 5110.0 | 5097.0 | 5130.0 | 16.62 | 0.039 | 5112.33 | 0.94 | 0.62 |

STATISTICAL SUMMARY OF 179 PARTICIPANTS

| Statistic | Respondents | Grand Avg | Non-outliers |
|--|-------------|-----------|--------------|
| Mean | 4923.89 | | 4844.97 |
| Std. Dev. | 1142.70 | | 477.67 |
| Variance | 1305770.15 | | 228168.29 |
| % Coef. of Var. | 23.21 | | 9.86 |
| % deviation of mean from known value | - 0.25 | | -1.84 |
| Norm. dev. of mean from known value | - 0.01 | | -0.19 |
| Median | 4823.33 | | 4819.00 |
| % deviation of median from known value | - 2.28 | | -2.37 |
| Norm. dev. of median from known value | - 0.01 | | -0.24 |

8. CONCLUSIONS

The data obtained during this period do not show any fission product activities. The observed environmental radioactivity is due primarily to radon progeny, primordial radionuclides (e.g., K-40) and those radionuclides (e.g., Be-7) which originate in the upper atmosphere as the result of cosmic ray interactions. These facts justify the conclusion that the PULSTAR Reactor facility continues to operate safely and does not release fission product materials into the environment.

9. ACKNOWLEDGMENTS

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APPENDIX 1

The vertical columns in Tables 7 are identified as columns 1-8 from left to right.

| | |
|------------------|--|
| Column 1: | Laboratory identification code (e.g., QA). |
| Columns 2, 3, 4: | Laboratory results given in triplicate. |
| Column 5: | Standard deviation (1s) of the experimental results. |
| Column 6: | Normalized range value in "mean range + standard error of the range". |
| Column 7: | Average value of the triplicate analysis. |
| Column 8: | Normalized deviation from the grand average value of all laboratories expressed in σ_m units. |
| Column 9: | Normalized deviation from the known value expressed in σ_m units. |

The following example calculation gives a set of data, the mean value, the experimental sigma, and the range. These statistics provide measures of the central tendency and dispersion of the data.

The normalized range is computed by first finding mean range, R , the control limit, CL , and the standard error of the range, σ_R . The normalized range measures the dispersion of the data (precision) in such a form that control charts may be used. Control charts allow one to readily compare past analytical performance with present performance. In the example, the normalized range equals 0.3 which is less than 3 which is the upper control level. The precision of the results is acceptable.

The normalized deviation is calculated by computing the deviation and the standard error of the mean, σ_m . The normalized deviation allows one to measure central tendency (accuracy) readily through the use of control charts. Trends in analytical accuracy can be determined in this manner. For this example, the normalized deviation is -0.7 which falls between +2 and -2 which are the upper and lower warning levels. The accuracy of the data is acceptable.

Finally, the experimental error of all laboratories, the grand average, and the normalized deviation from the grand average are calculated in order to ascertain the performance of all the laboratories as a group. Any bias in methodology or instrumentation may be indicated by these results.

EXAMPLE CALCULATIONS

Experimental data:

Known value = μ = 3273 pCi ³H/liter urine on September 24, 1974

Expected laboratory precision = σ = 357 pCi/liter

| Laboratory | Sample | Result |
|------------|----------------|----------------|
| D | x ₁ | 3060 pCi/liter |
| D | x ₂ | 3060 pCi/liter |
| D | x ₃ | 3240 pCi/liter |

Mean = \bar{x}

$$\bar{x} = \frac{\sum_{i=1}^N x_i}{N} = \frac{9360}{3} = 3120 \text{ pCi/liter}$$

where N = number of results = 3

Experimental sigma = s

$$s = \sqrt{\frac{\sum_{i=1}^N (x_i)^2 - \frac{\left(\sum_{i=1}^N x_i\right)^2}{N}}{N - 1}}$$

$$s = \sqrt{\frac{(3060)^2 + (3060)^2 + (3240)^2 - \frac{(3060 + 3060 + 3240)^2}{3}}{2}}$$

$$s = 103.9 \text{ pCi/liter}$$

Range = r

$$r = | \text{maximum result} - \text{minimum result} |$$

$$r = | 3240 - 3060 | = 180 \text{ pCi/liter}$$

Range Analysis (RNG ANLY)*

Mean range = \bar{R}

$$\bar{R} = d_2 \sigma$$

where $d_2^{**} = 1.693$ for $N = 3$

$$= (1.693) (357)$$

$$\bar{R} = 604.4 \text{ pCi/liter}$$

Control limit = CL

$$CL = \bar{R} + 3\sigma_R$$

$$= D_4 \bar{R}$$

where $D_4^{**} = 2.575$ for $N = 3$

$$= (2.575) (604.4)$$

$$CL = 1556 \text{ pCi/liter}$$

Standard error of the range = σ_R

$$\sigma_R = (R + 3\sigma_R - \bar{R}) \div 3$$

$$= (D_4 \bar{R} - \bar{R}) \div 3$$

$$= (1556 - 604.4) \div 3$$

$$\sigma_R = 317.2 \text{ pCi/liter}$$

Let range = $r = w\bar{R} + x\sigma_R = 180 \text{ pCi/liter}$

Define normalized range = $w + x$

for $r > \bar{R}$, $w = 1$

$$\text{then } r = w\bar{R} + x\sigma_R = \bar{R} + x\sigma_R$$

$$\text{or } x = \frac{r - \bar{R}}{\sigma_R}$$

$$\text{therefore } w + x = 1 + x = 1 + \frac{r - \bar{R}}{\sigma_R}$$

*Rosenstein, M., and A. S. Goldin, "Statistical Techniques for Quality Control of Environmental Radioassay," AQCS Report Stat-1, U.S. Department of Health Education and Welfare, PHS, November 1964.

**From table "Factors for Computing Control Limits," Handbook of Tables for Probability and Statistics, 2nd Edition, The Chemical Rubber Co., Cleveland, Ohio, 1968, p. 454.

$$\text{for } r \leq R, \quad x = 0$$

$$\text{then } r = w\bar{R} + x\sigma_R = w\bar{R}$$

$$\text{or } w = \frac{r}{\bar{R}}$$

$$\text{therefore } w + x = w + 0 = \frac{r}{\bar{R}}$$

$$\text{since } r < \bar{R}, (180 < 604.4)$$

$$w + x = \frac{180}{604.4}$$

$$w + x = 0.30$$

Normalized deviation of the mean from the known value = ND

Deviation of mean from the known value = D

$$D = \bar{x} - \mu$$

$$= 3120 - 3273$$

$$D = -153 \text{ pCi/liter}$$

Standard error of the mean = σ_m

$$\sigma_m = \frac{\sigma}{\sqrt{N}}$$

$$= \frac{357}{\sqrt{3}}$$

$$\sigma_m = 206.1 \text{ pCi/liter}$$

$$ND = \frac{D}{\sigma_m}$$

$$= \frac{-153}{206.1}$$

$$ND = -0.7$$

Control limit = CL

$$CL = (\mu \pm 3\sigma_m)$$

Warning Limit = WL

$$WL = (\mu \pm 2\sigma_m)$$

Experimental sigma (all laboratories) = s_t (See Figure 2)

$$s_t = \sqrt{\frac{\sum_{i=1}^N (x_i)^2 - \frac{\left(\sum_{i=1}^N x_i\right)^2}{N}}{N - 1}}$$

$$= \sqrt{\frac{162639133 - \frac{(49345)^2}{15}}{14}}$$

$$s_t = 149 \text{ pCi/liter}$$

Grand average = GA

$$GA = \frac{\sum_{i=1}^N x_i}{N}$$

$$= \frac{49345}{15}$$

$$GA = 3290 \text{ pCi/liter}$$

Normalized deviation from the grand average = ND'

Deviation of the mean from the grand average = D'

$$D' = \bar{x} - GA$$

$$= 3120 - 3290$$

$$D' = -170 \text{ pCi/liter}$$

$$ND' = \frac{D'}{\sigma_m}$$

$$= \frac{-170}{206.1}$$

$$ND' = -0.8$$