TEXAS INSTRUMENTS INCORPORATED ATTLEBORO FACILITY
BUILDING INTERIORS REMEDIATION
DRAINAGE SYSTEM CHARACTERIZATION

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LIMITATIONS / INCONSISTENCIES

(1) SOME MDFs HAVE BEEN RECALCULATED.

(2) ONLY DRAIN LINES IN AFFECTED AREAS WERE PRESENTED IN FINAL REPORT. THIS DOCUMENT LOOKS AT AREAS ADJACENT TO AFFECTED AREAS / LOGICAL SAMPLING POINTS.

(3) SOME INVENTORIES WERE RECALCULATED

(4) TABLE 1 DOES NOT DISTINGUISH BETWEEN VC AND CI SAMPLES

(5) INVENTORY CALCULATIONS IN THIS REPORT ARE FOR U-235 ONLY.

1.0 INTRODUCTION

A radiological investigation of the subsurface drains servicing the affected areas of Buildings 4 and 10 at the Texas Instruments Incorporated (TI) Attleboro Facility was performed by Roy F. Weston, Inc. (WESTON), from 11 to 21 September 1995. Affected areas had been previously defined as part of the Building Interiors Remediation Project described in the *Supplement to the 1992 Remediation Plan*. The radiological characterization was conducted to determine the distribution, concentration and inventory of uranium-234, -235 and -238 in the drainage system as a result of historical nuclear material processing activities. Affected areas within these buildings at the TI Attleboro Facility are illustrated in Figures 1 and 2.

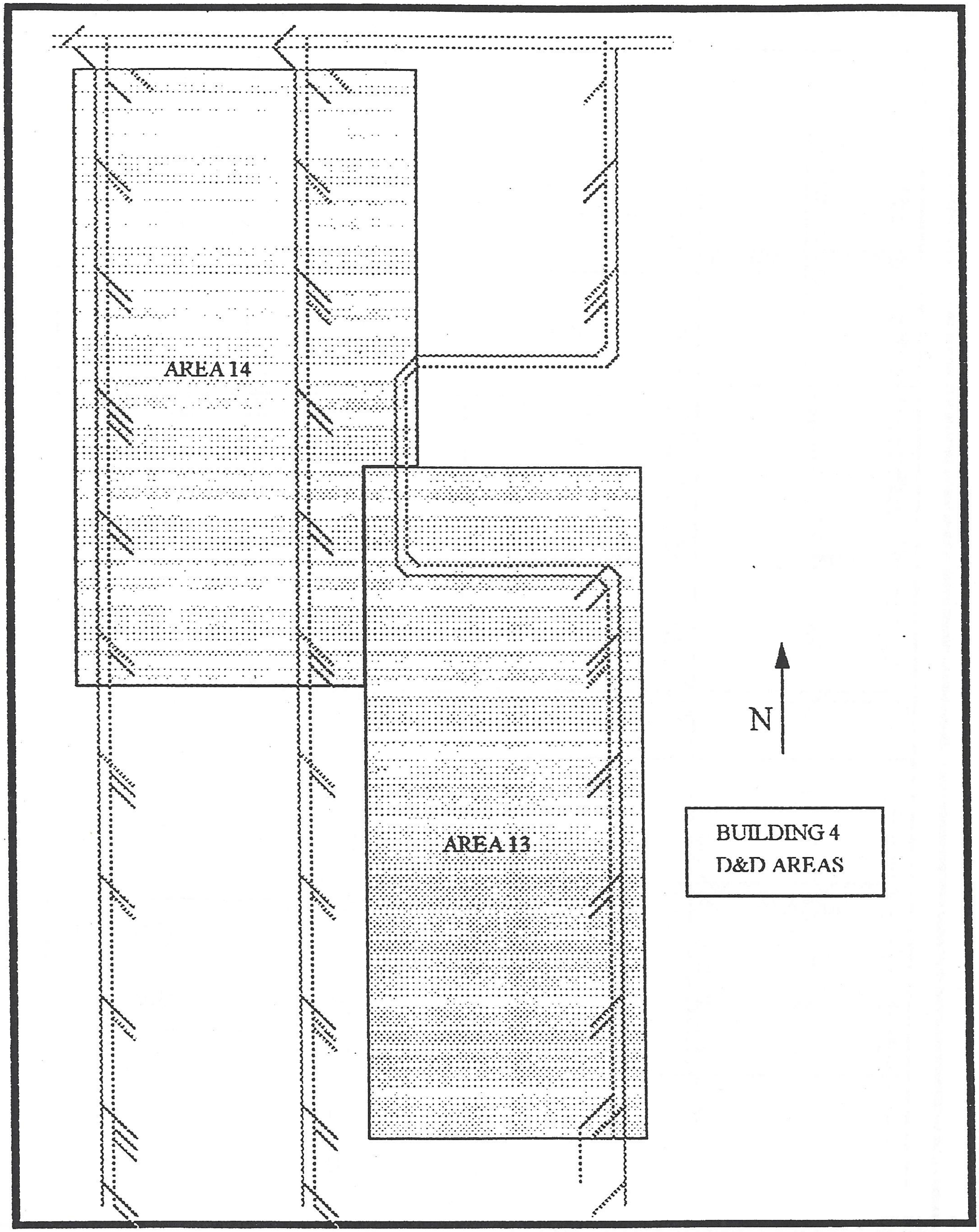
The drainage system investigation included two primary assessment efforts and the collection of pipe scale and/or other residue samples through direct access to the main lines. Direct-reading field radiological instrumentation was used to identify radioactive material inventory within "feed" lines originating at the concrete floor slab surface. Direct reading measurements were used as supplemental information in recommending pipes for removal or attempted decontamination. Isotopic uranium analyses of residue samples were processed to determine the residual mass of uranium-235 contained in the drainage system.

The drainage system investigation was performed immediately after the Pilot-Scale Interiors Remediation Project and prior to the Full-Scale Interiors Remediation Project. An aggressive investigation schedule was implemented in support of Nuclear Regulatory Commission (NRC) license termination and to assess the potential for inadvertent exposures to non-radiological workers performing routine drainage system maintenance and the potential for inadvertent criticality from relocation and/or disturbance of highly enriched and concentrated uranium.

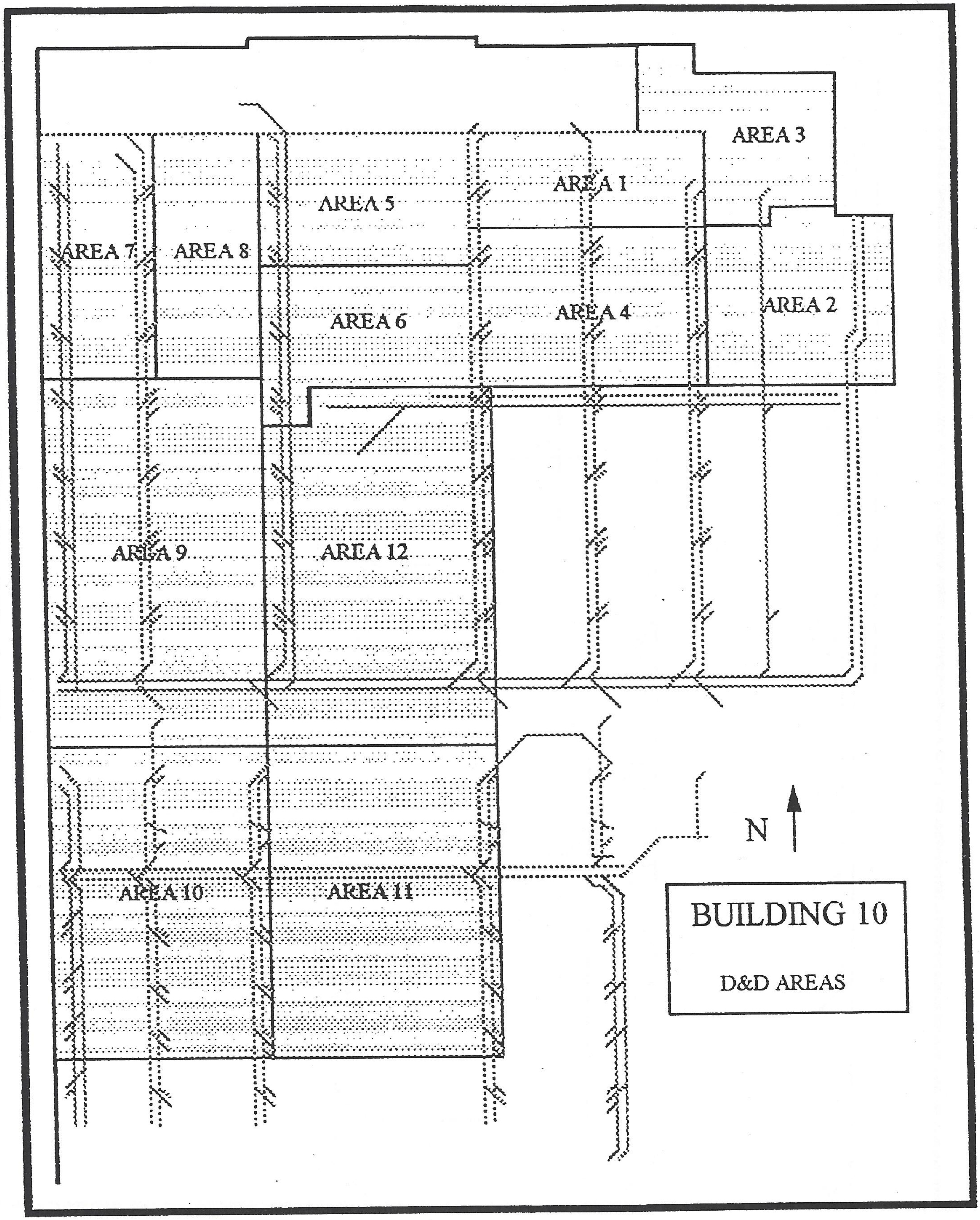
1.1 Drainage System Description

Buildings 4 and 10 drainage systems consist of 4-inch vitreous clay (VC) and 4, 5, and 6-inch cast-iron (CI) lines (referred to as "arterial lines") located 2 to 3 feet below facility grade. These lines, which run from north to south or south to north, lines typically flow into east-west lines of 6 to 12-inches in diameter (referred to as "main lines"). Floor penetrations (referred to as "feeder lines") are typically 4-inches in diameter and may be encountered at various locations above the subsurface drainage system. Conversations with TI personnel have indicated that the VC lines accepted flow from floor drains, while the CI lines accepted flow from roof drains. These personnel also have indicated that there have been historical instances of "cross-routing" between these systems. This document uses the terms "drain" and "line" interchangeably.

Figu . Building 4 Subsurface Drainage Sys



Fi 2. Building 10 Subsurface Drainage tem



1.2 Pilot-Scale Findings

The pilot-scale remediation was performed from June to August 1995. This study area included the Caged Area (Areas 1 and 4 on Figure 2) and the Screen Print Room (Area 7 on Figure 2). Based on the information collected during remediation activities, it was determined that the soil and pipes posed a potential safety concern and that the soil and pipes required excavation and removal under radiological controls. It also was determined that other drain lines within the affected areas of Buildings 4 and 10 should be surveyed for significant accumulation of concentrated radioactive material prior to the execution of full-scale remediation activities through the facilities.

1.2.1 Caged Area (Areas 1 and 4)

After a feed line floor penetration servicing an overhead roof drain was sampled, elevated readings were identified and investigated. The feed line was excavated to a depth of 3 feet, where it attached to a 4-inch CI main line. After the excavated lines were broken and removed, a small uranium rod of approximately 5 inches in length and 1/2 inch in diameter was identified and retrieved. While retrieving this rod, it was noted that the surrounding soil and pipes also exhibited elevated radiological measurements.

In addition to the 4-inch CI, a 4-inch VC line was identified at this location. Both pipes were opened and found to contain from 50-90 percent sediment and residue blockage. The pipe contents and surrounding soils were sampled and analyzed for total and isotopic uranium concentrations. Total uranium concentrations in the pipe sediments were 53,000 picocuries per gram (pCi/g) and 1,517 pCi/g for the CI and VC lines, respectively. The CI line and surrounding soils exhibited a uranium-235 concentration of 2,000 pCi/g and enrichment to 33 percent by weight, indicating that highly enriched uranium was leaking from the line into nearby soils. Approximately 5 feet of the CI line and several cubic yards of surrounding soil were removed during remediation activities. The remaining lines and soil will be removed during the remediation of Areas 5 and 6.

Near-surface recirculation piping ranging from 2 to 4 inches in diameter was frequently located near the slab surface in the Caged Area. Radiological surveys of this piping typically indicated marginal surface contamination on the interiors of the pipes, typically ranging from less than 3000 disintegration per minute (dpm)/100 cm^2. If surveys detected above background surface concentrations or if the pipe could not be readily opened for survey, it was disposed of as radioactive debris. Approximately 60 to 70 feet of this piping was disposed of in this manner.

1.2.2 Screen Print Room (Area 7)

During contaminated concrete removal at the north side of the Screen Print Room (Area 7), the initiation point of a 4-inch VC main line was encountered. This line exhibited surface contamination levels (on the pipe interior) as high as

1,000,000 dpm/100 cm^2, although did not contain a visible accumulation of residue. Approximately 15 feet of line was removed until surface contamination levels within the pipe were reduced to background levels. Minor soil contamination was noted near the initiation point of the line and excavated. Soil concentrations were 71.6 and 9.8 pCi/g in soils near the initiation point and line removal termination point, respectively. In contrast to the Caged Area, the Screen Print Room uranium enrichment indicated previous use of depleted uranium.

2.0 MATERIALS AND METHODS

Materials and methods used in the drainage system investigation were applied to two primary programs: sampling and analyses of residue contained within main lines, and radiological measurements within the interiors of arterial and feed lines accessible at or near the floor grade.

2.1 Sampling and Analysis of Pipe Residue

The radioactive material inventory was developed through sampling 13 subsurface locations of CI and VC lines. After available TI "as-built" diagrams were reviewed, these locations were selected based on historical information and/or suspected transfer of contaminated material to these lines. Radiological survey data from previous investigations and removal actions (undertaken in the pilot program) were used to identify potential routes of transfer through the facility. In general, one CI and one VC line were present at each location (except at location 4). If selected locations were blocked by stationary equipment or stock, alternate representative locations were identified. The final 15 sampling locations within Buildings 4 and 10 are shown on Figures 3 and 4, respectively.

At each sampling location, concrete was removed and soil was excavated to just below pipe level. The excavation was monitored with radiological instrumentation. A section of each pipe was cut open, allowing access into the pipes. After pipes were opened, a sample of the sediment or other residue in the pipe was collected and submitted for isotopic and/or total uranium analyses. The sedimentation and buildup within pipes was variable and was typically greater in the CI lines. Some VC lines had clean surfaces that would not yield a sample. Based upon direct observation, field personnel recorded the percentage blockage in the line. Lines with little or no buildup were typically rated at 5 to 10 percent blockage. Several VC pipes were not sampled due to liquid backup, pressurization, or leaking water.

2.2 Use of Direct Reading Radiological Instrumentation

Direct reading radiological instrumentation was used for both feed drain and main drain line surveys. The location of feed drain survey points is identified on Figures 3 and 4. Main drain line surveys were performed at several of the 15 locations identified on Figures

3 and 4. All radiological instrumentation information (serial numbers, calibration certificates, and function check results) are maintained onsite within the TI Nuclear Decommissioning Project file system.

2.2.1 Feed Drain Surveys

As part of the drain line investigation, characterization personnel used a specialized Bicron 1-inch by 1-inch sodium iodide gamma scintillator, coupled to a Ludlum Model 2221 Scaler/Ratemeter operating in ratemeter mode. The background count rate of this system ranged from 1,200 to 2,500 counts per minute (cpm) over the site work areas.

Many of the feed drain lines were open or had readily removable plugs or caps. Field personnel passed the detector through these lines until blockage or directional changes were encountered. The maximum detector response was recorded. The 1-inch by 1-inch detector is sensitive to the low-energy x-ray emissions associated with enriched and/or depleted uranium accumulations.

Prior to use of the aforementioned 1-inch by 1-inch sodium iodide system, a Ludlum Model 44-1 beta scintillator/Model 2221 scaler/ratemeter was used in 8 to 10 feed lines. Although the geometry of this system is not optimal for detecting large accumulations in or around pipes, it is adequate for identifying contaminated scale within the line.

2.2.2 Arterial and Main Drain Line Surveys

After excavating, breaking and sampling the several lines at locations 1 to 15, a Ludlum Model 133-2-1 waterproof Geiger-Mueller (GM) "peanut probe" detector was "snaked" through the line with a flexible rod and long-distance cable. The use of the probe identified any significant blockage in the main lines and identified large accumulations of radioactive materials within the drain lines or in the surrounding soils.

The Model 133-2-1 GM detector was linked to a Ludlum Model 2221 Scaler /Ratemeter operating in ratemeter mode. The background count rate of this system ranged from 15 to 20 cpm. The Model 133-2-1 has limited relative response capabilities when measuring enriched uranium due to the low energy x-rays and limited beta emission rate associated with the isotopic abundance of highly enriched uranium. For this reason, readings above background were assessed as potentially indicating a significant accumulation of enriched uranium.

The probe was snaked through the pipe in both directions from the access opening. Elevated detector measurements were noted at varying distances away from the access point. The terminal entry distance in each direction was recorded, and blockage or direction changes noted.

Figure 3. Building trusive Sampling and Feed Line Meas ent Locations

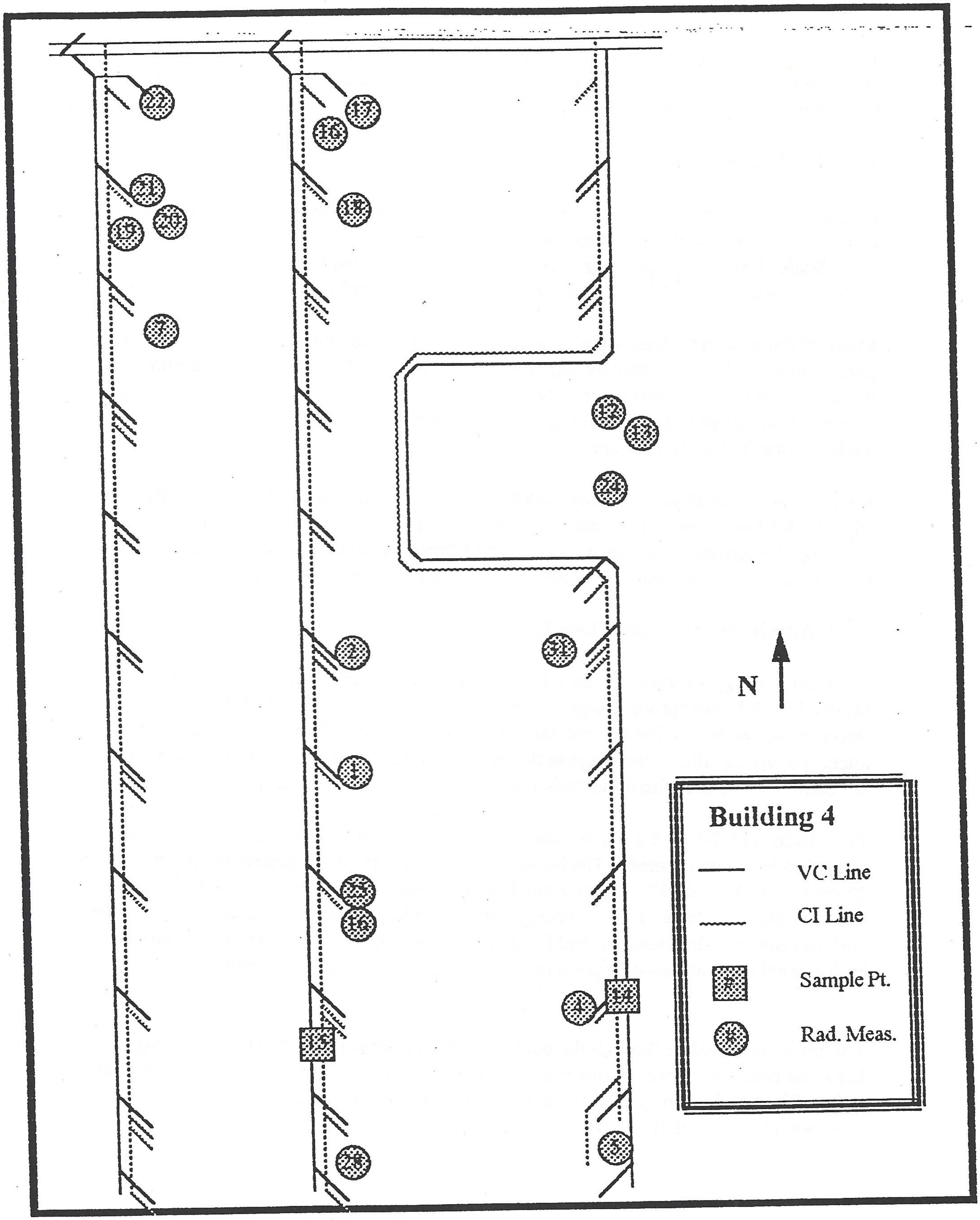
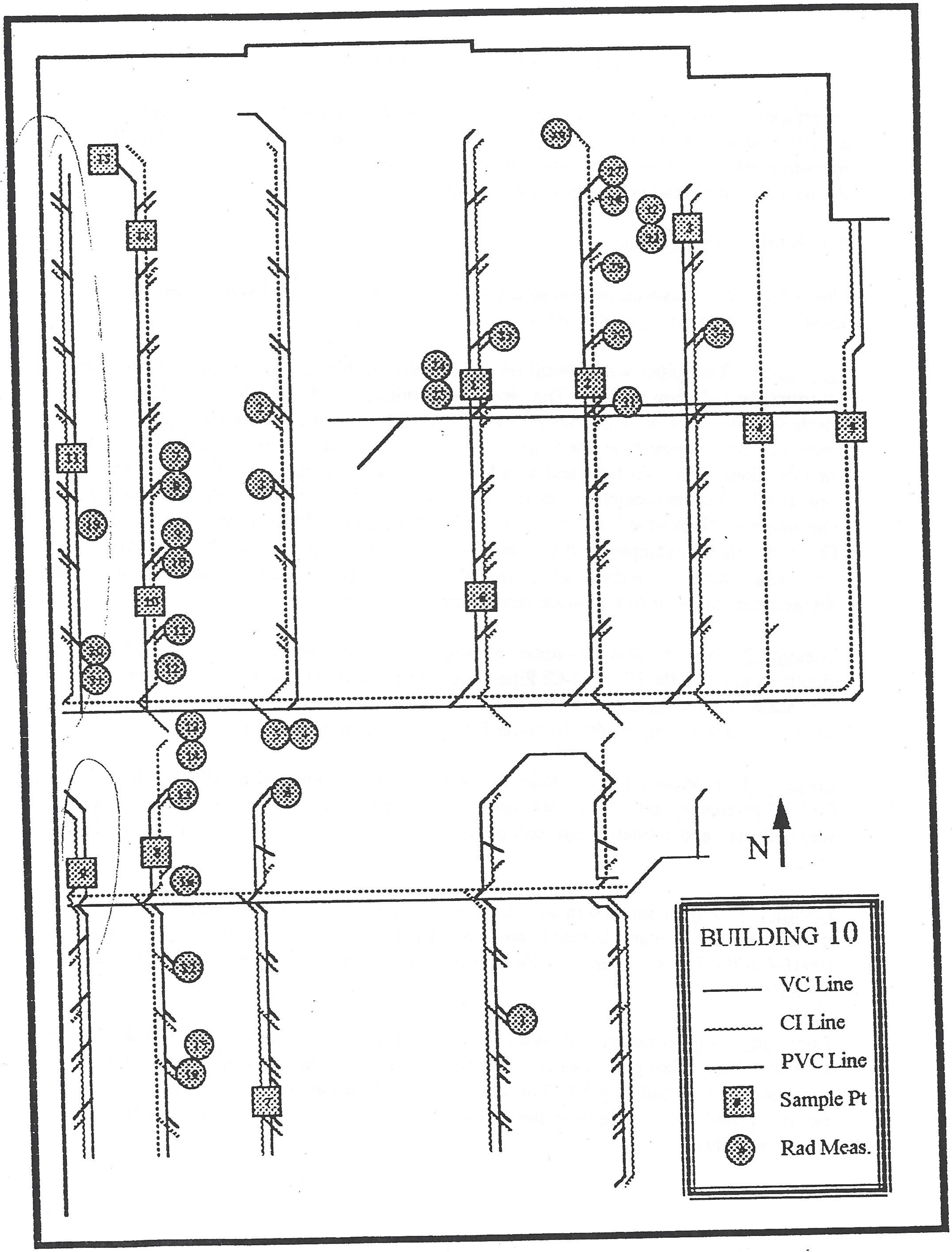


Figure 4. Buildin. .0 Intrusive Sampling and Feed Line M urement Locations



3.0 INVESTIGATION FINDINGS

Investigation findings include physical descriptions of the lines based on intrusive sampling activities, analytical results for samples collected in the drain lines, direct radiological measurements of the feed drain lines, total uranium and fissile material inventory, and a discussion of potential criticality considerations.

3.1 Physical Descriptions

The following discussions pertain to any or all main lines identified and opened at locations 1 to 15 on Figures 3 and 4.

Location 1 - Two pipes were identified and sampled at this location during the Pilot-Scale Interiors Remediation Project. The pipes are identified as 0815-04-4C-BSS-00-CI Pipe Inside and 0815-04-4C-BSS-00-VC Pipe Inside. During pilot investigations, high readings from the pipe feed line were noted and the pipe was excavated and removed to the main lines. The 4-inch CI and 4-inch VC pipes were opened; a small rod (5 inches long and 1/2-inch in diameter) was removed. Significant sediment buildup was identified. The sediment blocked at least 90 percent of the CI pipe and 50 percent of the VC pipe. This sediment was sampled and shipped for isotopic uranium analysis. It should be noted that these findings were the basis for the WESTON recommendation to perform drain line characterization prior to full -scale remediation activities.

Location 2 - Pipe location 2 includes a 4-inch CI pipe and 5-inch VC pipe. The CI pipe is identified as 0830-04-3D-BSS-CI Pipe Inside. There was very little buildup other than pipe scale, but a sample was collected and submitted for isotopic uranium analysis. The VC pipe was not sampled due to water flow and leakage in the area.

Location 3 - Pipe location 3 includes one 4-inch CI pipe identified as 0830-01-3B-BSS-00-CI Pipe Inside, and a 5-inch VC line. Very little residue was noted, but a scale sample was collected and submitted for isotopic uranium analysis. The VC line had no residue to sample.

Location 4 - Pipe location 4 included a 4-inch CI pipe that was independent of the traditional drain scenario in that it was alone and not parallel with a VC pipe. A sample (0916-02-2D-BSS-00-West Iron Pipe) was collected and submitted for isotopic uranium analysis.

Location 5 - Pipe location 5 includes an 8-inch CI pipe identified as 0916-02-2D-BSS-00-East Iron Pipe. This pipe is an arterial line for a large number of roof drains on the northeast part of Building 10. The VC line at this location was leaking water and could not be opened. A sample from the CI line was collected and submitted for isotopic uranium analysis.

Location 6 - Pipe location 6 was chosen due to its downgradient location from the accumulation of enriched uranium identified at location 1. Two pipes (0915-12-4E-BSS-00-Iron Pipe, a 5-inch CI; 0915-12-4E-BSS-00-Clay Pipe, a 4-inch VC) had very little amounts of sediment, but sample scrapings were collected and submitted for isotopic uranium analysis.

Location 7 - Pipe location 7 was the only accessible point to the line due to facility stock and surrounding structures. The corresponding samples are from a 5-inch CI pipe identified as 0914-10-6J-BSS-00-Iron Pipe and a 4-inch VC pipe identified as 0914-10-6J-BSS-Clay Pipe.

Location 8 - Pipe location 8 is located against the west wall of Building 10 near the 4 -10 connector. The samples are from a 4-inch CI pipe identified as 0913-10-8H-BSS-00-CI Inside and a 4-inch VC pipe identified as 0913-10-8H-BSS-00-VC Inside.

Location 9 - Pipe location 9 has two pipes, a 4-inch CI pipe identified as 0913-10-7G-BSS-00-CI Inside and a 4-inch VC pipe identified as 0913-10-7G-BSS-00-VC Pipe.

Location 10 - Pipe location 10 is at the end of a pipe with known contamination. The two pipes sampled were a 6-inch CI pipe identified as 0912-09-7F-BSS-00-CI Pipe and a 4-inch VC pipe identified as 0912-09-7F-BSS-00-VC Pipe.

Location 11 - Pipe location 11 is at a point in a line just outside of the old Screen Print Room. The two lines sampled here were a 4-inch CI pipe identified as 0914-09-8D-BSS-00-Iron Pipe and a 4-inch VC pipe identified as 0914-09-8D-BSS-00-Clay Pipe.

Location 12 - Pipe Location 12 is a 4-inch VC pipe identified as 0728-07-8B-BSS-00-Wall at a point where it starts to run parallel with a wall. There was very little material at this point but a sample was taken and submitted for isotopic uranium analysis.

Location 13 - Pipe location 13 is in the same pipe as is in locations 10 and 12. It is a 4-inch VC pipe designated 0728-07-8B-BSS-00-Pipe. The pipe had approximately 1/2 inch of sediment built up inside of it.

Location 14 - Pipe location 14 is in Building 4 near the Lewis Mill. The two pipes accessed included a 5-inch CI pipe identified as 0919-13-2F-BSS-East Iron Pipe and a 4-inch VC pipe identified as 0919-13-2F-BSS East Clay Pipe. Both of the lines were 50 percent blocked with sediment buildup.

Location 15 - Pipe location 15 is also in Building 4 near the Lewis Mill. The two pipes here are also a 5-inch CI (0919-15-3F-BSS-West Iron Pipe) and a 4-inch VC pipe (0919-15-3F-BSS-00-West Clay Pipe). The CI line was 30 percent blocked with sediment and the VC line was 10 percent blocked with sediment buildup.

3.2 Sampling Analytical Results

Pipe scale and residue samples were packaged and shipped to TMA Eberline, Oak Ridge, for isotopic uranium analysis using the EML U-02 (Modified) procedure. All shipments were transported using chain-of-custody forms. Copies of these forms are maintained in the WESTON project files. Table 1 includes the reported results of uranium-234, -235, and -238 concentrations, respectively, as collected in any or all lines sampled at locations 1 through 15. The final column of the table presents the total uranium activity of the drain line residue as the sum of the isotopic uranium concentrations.

Table 1 also presents the calculated isotopic abundance by weight using the formula:

$$W\% = (SA_{U} / A_{U}) / \{(SA_{U\text{-}234} / A_{U\text{-}234})\ (SA_{U\text{-}235} / A_{U\text{-}235})\ (SA_{U\text{-}238} / A_{U\text{-}238})\} * 100$$

where:

$W\%$ = weight percentage of the uranium isotope
SA_{U} = specific activity of the uranium isotopes (pCi/g)
A_{U} = concentration of the uranium isotopes (pCi/g)
$SA_{U\text{-}234}$ = specific activity of uranium-234 (pCi/g)
$A_{U\text{-}234}$ = concentration of uranium-234 (pCi/g)
$SA_{U\text{-}235}$ = specific activity of uranium-235 (pCi/g)
$A_{U\text{-}235}$ = concentration of uranium-235 (pCi/g)
$SA_{U\text{-}2358}$ = specific activity of uranium-238 (pCi/g)
$A_{U\text{-}2358}$ = concentration of uranium-238 (pCi/g)

The highest uranium-235 enrichments (and concentrations) occur in the VC and CI arterial lines running from the north end of the Caged Area (under the main walkway) between sample locations 1 and 6. The enrichment in the CI line is relatively constant at 33 to 34 weight percent (w%), with an approximately ten-fold dilution in total uranium concentration between locations 1 and 6, from 53,000 - 5,900 pCi/g. The lowest total uranium concentrations and uranium-235 enrichments were identified in samples taken from locations 14 and 15 within Building 4.

Locations 4 and 5 accessed lines that had previously supported assay laboratories associated with nuclear material manufacturing activities. Sampling and visual observation confirmed that there was little to no accumulation of residue in these lines. Analytical data for both CI lines indicated a total uranium concentration of approximately 500 pCi/g in the thin layer of scale.

Table 1. Analytical Results From Pipe Residue Samples

Pipe Location Number	U-234 Conc. (pCi/g)	U-234 Enrmt. (w%)	U-235 Conc. (pCi/g)	U-235 Enrmt. (w%)	U-238 Conc. (pCi/g)	U-238 Enrmt. (w%)	Total U (pCi/g)
1	50600	0.29%	2000	33.13%	624.7	66.58%	53224.7
	935.5	0.01%	53	1.53%	529.2	98.46%	1517.7
2	400.8	0.10%	16.5	11.46%	19.8	88.45%	437.1
3	10.5	0.02%	0.8	4.25%	2.8	95.73%	14.1
4	444.2	0.06%	30.4	12.49%	33.1	87.45%	507.7
5	437.4	0.05%	21.4	7.12%	43.4	92.83%	502.2
6	128	0.18%	4.2	17.37%	3.1	82.45%	135.3
	5629	0.35%	193	34.72%	56.1	64.93%	5878.1
7	41.3	0.03%	1.4	3.19%	6.6	96.78%	49.3
	12.6	0.02%	2.6	12.23%	2.9	87.75%	18.1
8		NA	13[1]	NA	NA	NA	NA
		NA	1.8[1]	NA	NA	NA	NA
9	467	0.04%	20.5	4.69%	64.8	95.28%	552.3
	25.7	0.08%	1.1	10.23%	1.5	89.69%	28.3
10	127.5	0.03%	5.4	3.41%	23.8	96.57%	156.7
	18.5	0.00%	0.84	0.37%	34.9	99.62%	54.24
11	794.5	0.06%	36.4	8.55%	60.5	91.39%	891.4
	11.9	0.03%	1.5	12.06%	1.7	87.91%	15.1
12	12.1	0.00%	1.6	0.43%	58.1	99.57%	71.8
13	4.7	0.01%	0.15	0.47%	4.9	99.52%	9.75
14	6.1	0.01%	0.32	0.91%	5.4	99.08%	11.82
	7.4	0.02%	0.32	3.01%	1.6	96.96%	9.32
15	14.6	0.03%	0.33	1.93%	2.6	98.04%	17.53
	4.3	0.02%	0.33	3.53%	1.4	96.45%	6.03

[1] Sample results reported only for uranium-235.

3.3 Direct Measurement Results

Feed drain surveys and main line "snaking" are presented below.

3.3.1 Feed Drain Surveys

Feed drain measurements were performed based on the accessibility of the feed ports to the main lines. The background count rate of the 1-inch by 1-inch detector/Model 2221 Scaler/Ratemeter ranged from 1,200 to 2,500 cpm for Building 4 and 1,700 to 2,500 cpm for Building 10. As surveys were performed, it was determined that the approximate "in-pipe" background count rate ranged from 2,500 to 3,500 cpm. This background is slightly elevated due to the geometry effects associated with surveying a closed pipe. In several instances a Model 2221/Model 44-1 beta scintillation system was utilized for feed line measurements. The typical background of this system ranged from 60 to 80 cpm.

Drain head surveys from Buildings 4 and 10 are presented in Tables 2 and 3, respectively. The location numbers may be referenced to Figures 3 and 4.

Table 2. Feed Drain Surveys in Building 4.

Location Number	Pipe Matrix	CPM Above Background	Comments
1	CI	NA	Capped
2	VC	4,100	
3	CI	3,000	
4	VC	NA	Filled In
5	VC	2,700	
6	VC	2,100	
7	CI	2,100	
8	CI	3,500	
9	VC	5,600	
10	VC	4,300	
11	CI	3,200	
12	VC	4,300	
13	VC	3,900	
15	Concrete	4,000	At South Roll-up Door Building 4
16	CI	18,000	
17	VC	20,000	
19	CI	3,100	
20	CI	3,500	
21	CI	3,000	
22	CI	2,900	
23	VC	6,200	
24	VC	5,600	
25	VC	16,000	
26	VC	5,400	
27	CI/VC	5,200	Two Pipes Side By Side
28	CI	3,000	
29	VC	5,500	
30	VC	7,100	
31	VC	5,600	

Feed lines at locations 16, 17, and 25 exhibit gamma count rates approximately five to six times background. These feed lines will probably be removed during future decontamination activities in Building 4.

Table 3. Building 10 Feed Drain Surveys

Location Number	Pipe Matrix	Counts Per Minute (CPM)	Comments
1	CI	6,200	
2	CI	3,600	
3	VC	7,700	
4	CI	3,800	
5	VC	26,000	
6	VC	6,500	
7	VC	6,700	
8	CI	3,700	
9	CI	3,200	
10	VC	6,300	
11	VC	6,600	
12	CI	7,500	
13	VC	7,000	
14	CI	3,700	
15	VC	6,000	
16	CI	3,300	
17	CI	3,300	
18	VC	6,600	
19	VC	6,000	
20	CI	2,800	
21	CI	3,000	
22	CI	3,500	
23	VC	99[1]	B Scint
24	VC	309[1]	Pipe Line
25	CI	491[1]	Pipe Line
26	VC	150[1]	Pipe Line
27	VC	166[1]	
28	CI	113[1]	
29	CI	71[1]	
30	CI	92[1]	
31	CI	91[1]	
32	CI	143[1]	
33	CI	88[1]	
34	CI	98[1]	

[1]Measurements performed with beta scintillator.

The measurement performed at location 5 indicated gamma count rates in excess of ten times background. Subsequent sampling indicated small pieces of uranium metal around the feed port. This feed line was decontaminated in association with Area 9 activities.

Measurements performed at locations 10 to 14 indicated gamma count rates of approximately two to three times background. Several of these feed lines were removed during decontamination activities in Areas 9 and 10.

3.3.2 Main Drain Surveys

Table 4 presents radiological measurements collected with the GM peanut probe at various distances away from the pipe access point. Readings are designated with a cardinal compass designation; the distance is given in feet. Table 4 also presents the terminal distance of snake penetration, which typically resulted from a pipe directional change or line blockage.

Table 4. Arterial/Main Drain Line Surveys

Location	Direction	Max CPM	Distance (ft)	Direction	Max CPM	Distance (ft)
3 - CI	North	20-25	10	South	20-25	20
4 - CI	North	15-20	20	South	45	17
5 - CI	North	20-25	20	South	25-30	20
6 - CI	North	30-35	20	South	20-25	12
6 - VC	North	30-35	20	South	15-20	12

Measurements along the CI and VC lines between locations 1 and 6 confirm the presence of elevated uranium concentrations in and near the pipe. For the VC and CI lines, count rates decrease in the southerly direction. Measurements along the CI line associated with sample location 5 are inconclusive. A maximum measurement of 45 cpm in the southerly direction of the CI line at sample location 4 indicates the potential for subsurface accumulation of radioactive material.

3.4 Inventory Assessment

The discovery of drain lines containing high enrichment/concentrated uranium were discovered during the pilot-scale program. Consequently, it was necessary to calculate the mass of residual nuclear material contained in the entire drainage system. Inventory assessment was based upon the visual inspection of lines and associated estimates of percentage blockage, isotopic uranium concentrations associated with each residue sample, the length and diameter of each pipe section represented by a sample, and estimated density of scale or sediment. Based upon the following methodology, the residual nuclear material content has been estimated for all arterial and main lines under affected areas.

3.4.1 Grouping of Pipe Lengths to Representative Sampling Points

Table 5 contains a grouping of all lines associated with each sample collected during intrusive investigation activities. Each group contains a series of pipe lengths and associated diameters, as delineated on Figures 5 and 6. Each group was logically constructed based upon direction of flow and proximity to similar operations. Since all 6 to 12-inch main lines were not disturbed during the investigation, it was necessary to group these lines with arterial lines most likely exhibiting similar concentrations and blockage.

3.4.2 Calculation of Mass of Material Within Pipe Groups

For each group of pipe lines, the total mass of residue in each section (for lines of varying diameter) is calculated as a function of the interior volume, percentage blockage and density of residue. The calculations use the following equation:

$$M_R = (pi/d^2) * L * \%B * D_R$$

where:

M_R = mass of residue in section of line (g)
d = diameter of line section (cm)
L = length of line section (cm)
%B = percent blockage in line section (unitless)
D_R = density of residue (g/cm^3)

For each group presented in Table 5, the mass of residue is summed over all included sections. The lines associated with locations 1 and 6 contain the largest quantities of residue in Building 10. All other lines contain less than 10 percent blockage, resulting in reduced residue mass. Lines associated with location 15 in Building 4 exhibit 30 to 50 percent blockage and the largest associated residue mass.

3.4.3 Calculation of Uranium-235 Mass

The mass of residue for each group presented in Table 5 is multiplied by the uranium-235 concentration (shown in Table 1) associated with each sample location and drain line (VC or CI) to yield total uranium-235 activity. This activity is divided by the specific activity of uranium-235 (2.6 E-6 pCi/g) to yield the uranium-235 mass in grams. Table 5 presents the uranium-235 mass associated with all pipe sections in each group.

The CI line associated with locations 1 and 6 contains approximately 284 grams of uranium-235, which is approximately 98 percent of the Building 10 total of 295 grams. The Building 4 inventory has a significantly lower total of 0.3 grams, although the lack of information for location 15 lines could result in additional inventory.

Table 5.

Pipe Location Number	TI Number	Sample Location (pipes)	Diameter (inch)	Length (feet)	Additional Length (feet)	Blockage	Volume Built Up (cc)	U-235 Conc (pCi/g)	Mass U-235 (grams)	Pipe Location Number
1	25	0815-04-4C-BSS-00-CI PIPE	4	80	0	0.90	177920	2000	271.0	1
	26	0815-04-4C-BSS-00-VC PIPE	4	100	0	0.5	123556	53	5.0	
2	34	0830-04-3D-BSS-00-CI PIPE	4	80	0	0.05	9884	16.5	0.1	2
			5	60	0	0.05	11583	16.5	0.1	
			6	10	35	0.05	2780	16.5	0.0	
			8		40					
	n/a	VC PIPE	4		75					
3	35	0830-01-3B-BSS-00-CI PIPE	4	130	-35	0.05	16062	0.8	0.0	3
	n/a	VC PIPE	4		95					
4	56	0916-02-2D-BSS-00-WEST IRON PIPE	4	80	0	0.1	19769	30.4	0.5	4
			5	40	0	0.1	15444	30.4	0.4	
			6	15	0	0.1	8340	30.4	0.2	
5	55	0916-02-2D-BSS-00-EAST IRON PIPE	4	120	-120	0.1	29653	21.4	0.5	5
			6	40	-40	0.1	22240	21.4	0.4	
			8	150	-55	0.1	148267	21.4	2.4	
	n/a	VC PIPE	6		95					
6	51	0815-12-4E-BSS-00-CLAY PIPE	4	50	0	0.3	37067	4.2	0.1	6
	52	0815-12-4E-BSS-00-IRON PIPE	5	60	0	0.3	69500	193	10.2	
			6	10	0	0.3	16680	193	2.5	
7	47	0814-10-6J-BSS-00-CLAY PIPE	4	65	10	0.05	8031	1.4	0.0	7
	n/a	VC PIPE (2 untested pipes)	4		150					
	48	0814-10-6J-BSS-00-IRON PIPE	5	20		0.05	3861	2.6	0.0	
			6	45		0.05	12510	2.6	0.0	
	n/a	CI PIPE (2 untested pipes)	4		75					
			6		50					
			8		35					
8	n/a	0913-10-7G-BSS-00-VC INSIDE	4	25		0.075	4633	13	0.0	8
	n/a	VC PIPE (untested pipe)	4	25	20					
	n/a	0913-10-7G-BSS-00-CI INSIDE	4	25		0.075	4633	1.8	0.0	
	n/a	CI PIPE (untested pipe)	4	45	35					
Between 7,8 & 9	n/a	VC PIPE (main)	8		30					Between 7,8 & 9
			10		35					
	n/a	CI PIPE (main)	12		65					
9	40	0813-10-8H-BSS-00-VC INSIDE	4	25		0.1	6178	20.5	0.1	9
	41	0813-10-8H-BSS-00-CI INSIDE	4	25		0.1	6178	1.1	0.0	

Table 5.

Pipe Location Number	TI Number	Sample Location (*pipes*)	Diameter (inch)	Length (feet)	Additional Length (feet)	Blockage	Volume Built Up (cc)	U-235 Conc (pCi/g)	Mass U-235 (grams)	Pipe Location Number
10	37	0813-09-7F-BSS-00-VC INSIDE	4	130		0.1	32125	5.4	0.1	10
	36	0813-09-7F-BSS-00-CI INSIDE	4	10		0.1	2471	0.84	0.0	
			5	20		0.1	7722	0.84	0.0	
			6	40		0.1	22240	0.84	0.0	
			8	30		0.1	29653	0.84	0.0	
11	49	0814-09-8D-BSS-00-CLAY PIPE	4	150		0.1	37067	36.4	1.0	11
	50	0814-09-8D-BSS-00-IRON PIPE	4	150		0.1	37067	1.5	0.0	
12	19	0728-07-8B-BSS-00-WALL	4	20		0.05	2471	1.6	0.0	12
13	20	0728-07-8B-BSS-00-PIPE	4	8		0.1	1977	0.15	0.0	13
Pipes Not Tested Or Accounted For	n/a	VC PIPE (main)	6		100					Pipes Not Tested Or Accounted For
			8		55					
			10		65					
	n/a	CI PIPE (main)	8		40					
			10		60					
			12		120					
	n/a	VC PIPE (pipe under wall)	4		170					
	n/a	CI PIPE (pipe under wall)	4		80					
			5		60					
			6		10					
	n/a	PVC PIPE	4		210					
14	57	0919-13-2F-BSS-00-EAST CLAY PIPE	4	280		0.5	345956	0.32	0.1	14
	58	0919-13-2F-BSS-00-EAST IRON PIPE	5	250		0.5	482640	0.32	0.1	
			6	30		0.5	83400	0.32	0.0	
15	59	0919-13-3F-BSS-00-WEST CLAY PIPE	4	220		0.1	54365	0.33	0.0	15
	60	0919-13-3F-BSS-00-WEST IRON PIPE	5	175		0.3	202709	0.33	0.1	
			6	45		0.3	75060	0.33	0.0	
Other Pipes In Bldg 4	n/a	VC PIPE (main)	6		40					Other Pipes In Bldg 4
			8		70					
	n/a	CI PIPE (main)	10		70					
			12		40					
	n/a	VC PIPE (west)	4		200					
	n/a	CI PIPE (west)	6		200					
	n/a	VC PIPE (north 3)	4		210					
	n/a	CI PIPE (north 3)	5		210					
				2883	2855		5738.0 Total Feet of Pipe			

Figure 5. Buildi Pipe Grouping for Uranium-235 Inve y Development

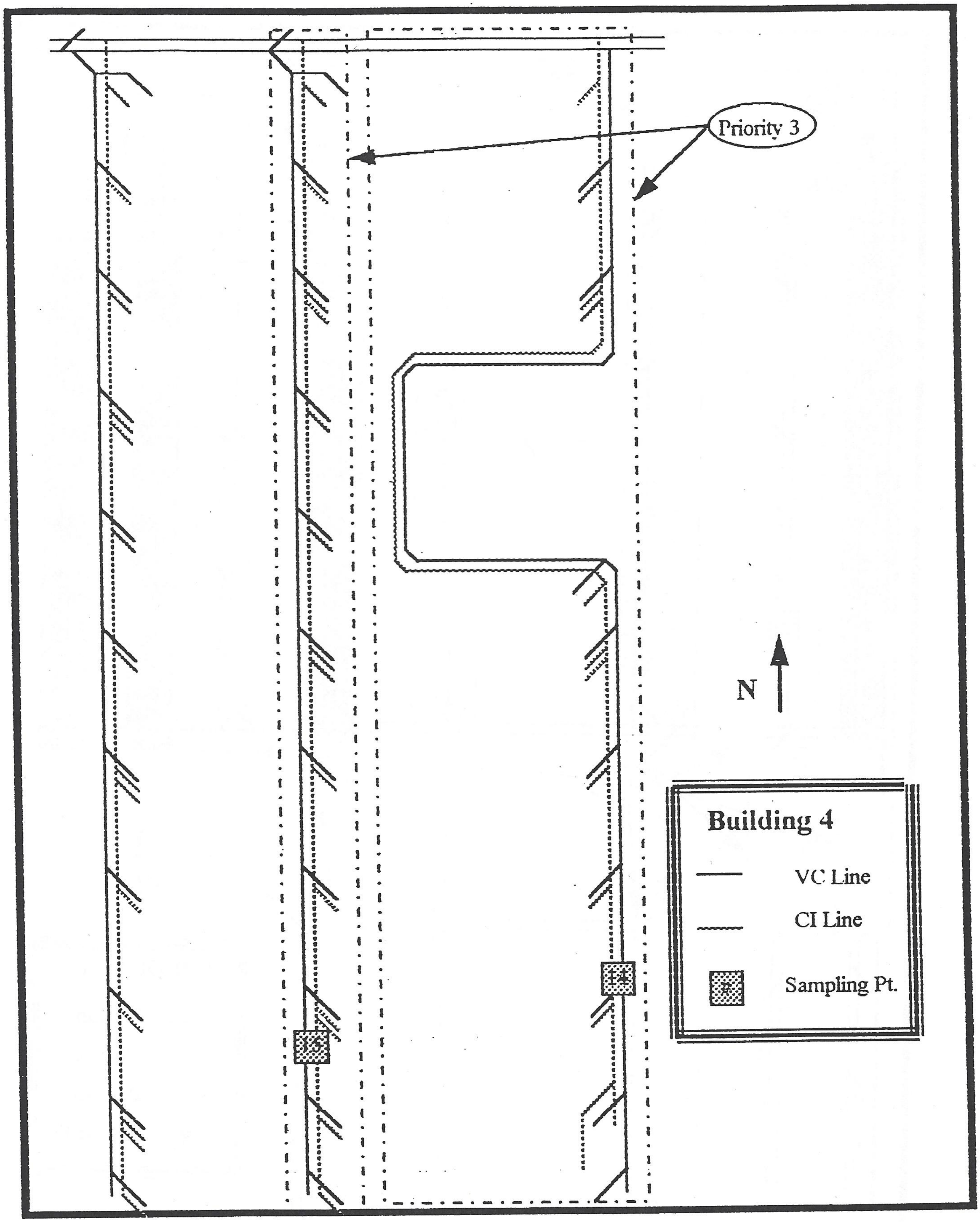
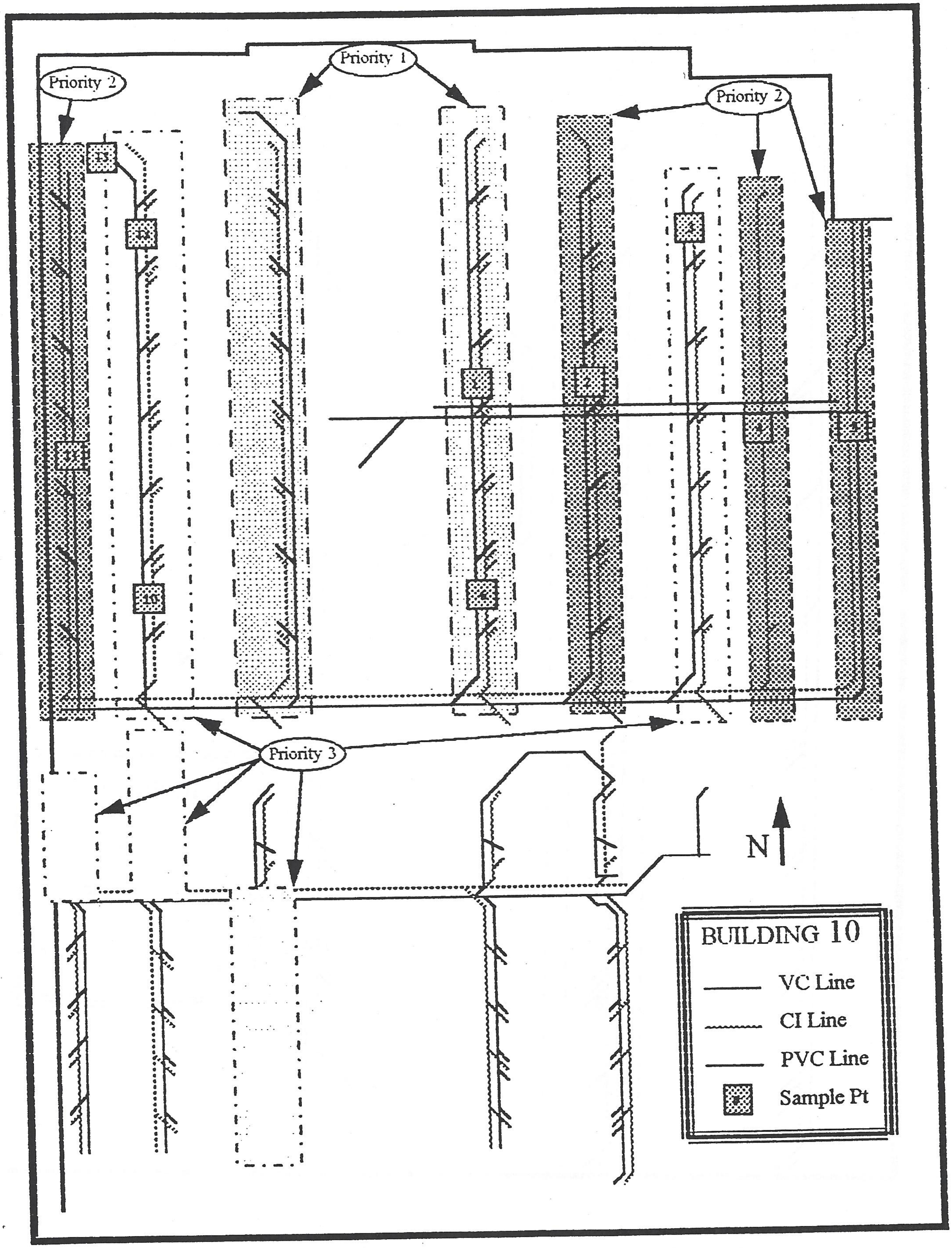


Figure 6. Building 10 Pipe Grouping for Uranium-235 Inventory Development



3.5 Criticality Concerns

The identification of uranium-235 enrichments as high as 34 percent by weight at concentrations exceeding 2000 pCi/g (in 4-inch CI lines) warranted the consideration of inadvertent criticality concerns. These inadvertent concerns could be the result of accumulation of fissile materials in subsurface traps, drain lines, or other collection points. A criticality assessment was performed for two scenarios probably encountered during remediation activities. The assessment scenarios addressed a drain line geometry of typical length packed with highly enriched uranium, and a packed drain line surrounded by highly contaminated soil in a hemispherical geometry. All criticality calculations were performed using the SCALE 4.1 code that contains KENO V.a. The constituents of soil (e.g., silicon, aluminum, calcium) used in calculations were derived from national or eastern United States averages.

3.5.1 Criticality Scenario #1 - *20-foot Length of 5-inch Diameter Pipe Filled with Soil Containing 80 Percent Enriched Uranium*

This scenario was assessed under the assumption that the pipe containing the uranium is stainless steel (wall thickness of approximately 0.25 inches). Two material content conditions within the pipe were assessed, the first consisting of pure uranium metal (80 percent enriched) and the second a mix of 80 percent uranium metal and 20 percent water. The calculation of k-effective was performed for a variety of bounding materials including concrete, vacuum, and water.

Given the aforementioned geometry and content conditions, the k-effective never exceeds 0.9. Therefore, an inadvertent criticality is not considered a possibility, given the field conditions.

3.5.2 Criticality Scenario #2 - *Leakage of Uranium from Pipe into Soil - Hemispherical Geometry*

This scenario was developed to determine the radius of contamination for a pipe and underlying soil. This radius will result in an inadvertent criticality given varying concentrations of highly enriched uranium. The scenario was modeled after conditions encountered during the pilot study in which a pipe had leaked in a hemispherical pattern below a drain line carrying enriched uranium waste. The critical radius was calculated for soil concentrations of 1,000,000 pCi/g, 100,000 pCi/g, and 10,000 pCi/g, respectively.

For a soil concentration of 1,000,000 pCi/g the surrounding soil must consist almost entirely of enriched uranium (density 19.1 g/cm^3). The underlying soil hemisphere was assumed to be surrounded by clean soil. A soil hemisphere radius of 18 cm yields an average k-effective of 1.

At a soil concentration of 100,000 pCi/g, a soil hemisphere radius of 45 cm yields an average k-effective of approximately 1.

At a soil concentration of 10,000 pCi/g, no criticality will occur for any radius. The average k-effective value was calculated to be less than 0.85 for a soil hemisphere radius of 1,000 meters.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

HANDLING AND TREATMENT OF EXISTING LINES

As a result of the drainage system investigation, three categories of lines have been developed. Categories have been developed to define the type and extent of remedial action required and potential magnitude of health hazard due to intrusion by an untrained worker performing maintenance. Figures 5 and 6 present groupings of drain lines by the following categories which are described as:

PRIORITY 1 - Priority 1 lines require complete removal due to significant uranium concentrations in or around sections of the line. Potential hazards to untrained workers performing routine maintenance warrant the removal of this material by decontamination workers operating under the protocol of the current building decommissioning effort. The total uranium concentration of material in these lines ranges from 10,000 to 50,000 pCi/g. Priority 1 lines are encountered in Building 10 only, and are designated on Figure 6. Both "sets" of priority 1 lines include a 4-inch VC and 5-inch CI, and are routed from a north to south direction on either side of the former Health and Safety and 509 Departments. These lines bound Areas 5, 6, and 12. The set of lines bounding this area to the west terminate at the Beckhart wire drawing machine, while the set of lines to the east feeds into 8-12" main lines servicing other areas of Building 10.

PRIORITY 2 - Priority 2 lines require a cleaning effort to remove pipe scale and some sediment, typically exhibiting total uranium concentrations of 500 to 1000 pCi/g. These lines could pose a minor hazard to untrained workers performing routine maintenance operations; any intrusive actions should be performed with qualified radiological protection oversight. Priority 2 lines are encountered in Building 10 only, and appear to have serviced the laboratory wing and eastern sections of the former HFIR project. These lines are comprised of both CI and VC of varying diameter and are located in and around decontamination areas 2, 3, 7, 9, and 10 of Building 10.

PRIORITY 3 - Priority 3 lines contain little or no detectable radiological contamination, and would not require substantial decontamination or other special handling during the Building Interiors Project. These lines would pose little or no hazard to untrained workers performing routine maintenance operations or intrusive actions. Typical total uranium concentrations in these CI and VC lines range from background to 500 pCi/g. Although these lines contain some residue or scale exceeding the 30 pCi/g total uranium cleanup criteria, averaging of the thin layer usually results in a significantly lower uranium concentration when averaged over the mass of the entire pipe. This relationship is noted in "dilution factors" contained in Table 6. All lines within Building 4 are classified as Priority 3.

Table 6. Pipe mass dilution factors.

Inner Dia (in)	0.05 Blockage	0.1 Blockage	0.25 Blockage	0.5 Blockage
Cast Iron				
4	0.09	0.16	0.33	0.49
5	0.11	0.20	0.38	0.55
6	0.13	0.23	0.43	0.60
8	0.17	0.29	0.50	0.67
10	0.16	0.28	0.49	0.66
12	0.19	0.32	0.54	0.70
Vitreous Clay				
4	0.08	0.14	0.29	0.45
5	0.10	0.17	0.35	0.51
6	0.11	0.21	0.39	0.56
8	0.15	0.26	0.47	0.64
10	0.14	0.25	0.45	0.62
12	0.17	0.29	0.50	0.67

CRITICALITY

Based on the existing drainage system configuration, uranium-235 concentrations and physical form of residue, an inadvertent criticality is not considered a credible possibility. However, criticality scenarios should be modified if new data indicate a change in the projected maximum enrichments and concentrations, or significant collection points are identified in the drainage system. Given the mass of uranium-235 available, the cleaning of Priority 2 lines will not result in the accumulation of pressure wash water potentially achieving inadvertent criticality.

4.2 Recommendations

The recommendations with respect to remediation of the drainage systems are as follows:

1) Complete removal of designated Priority 1 paired lines and any contaminated soils that are encountered. Replacement with new lines per TI specifications.

2) Application of cleaning methods to Priority 2 lines. The sequence will proceed with line photography and initial survey, high-pressure line cleaning and liquid retention, and

resurvey of the lines. Priority 3 lines should be subject to this procedure as schedule and cost factors allow. Implementation of these procedures would be in accordance with the principle of reducing contamination and potential exposures to as low as reasonable achievable.

4.3 Limitations

Pilot-scale findings demonstrated that uncharted contaminated near-surface equipment recirculation and transfer piping may be encountered. This piping is typically identified through thorough investigation of concrete slabs above or near former equipment pads, subsurface features including sumps, and surface/subsurface trenches. These procedures will be used during full-scale characterization and decontamination operations to ensure that these features are included/validated.