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ENVIRONMENTAL MONITORING
AT AMES LABORATORY

Calendar Year 1976

Milo D. Voss

AMES LABORATORY, USERDA
IOWA STATE UNIVERSITY
AMES, IOWA

Date of Transmittal : April 1977

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ENVIRONMENTAL MONITORING AT AMES LABORATORY

Calendar Year 1976

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Environmental Monitoring at Ames Laboratory:

Calendar Year 1976

ABSTRACT

This is an annual report summarizing the effluent and environmental monitoring program at the Ames Laboratory of the United States Energy Research and Development Administration.

Earlier reports in this series concerned only environmental radioactivity and were each entitled "Survey of Environmental Radioactivity". The report for 1973 included some information on effluents, both radioactive and non-radioactive, with an assessment of the radiation dose to the public.

The 1974 report was the first in the present series of reports. An inventory of the radioactive materials and certain chemicals released to the environment is included. A summary of the radioactivity found in the environment is presented. An estimate of the radiation dose to the public resulting from the operations of the Ames Laboratory is stated.

The environmental program was modified in July of 1976.

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1. Summary

The results and conclusions from the Ames Laboratory environmental monitoring programs for the Ames Laboratory Research Reactor (ALRR) are presented in this report. The major areas of radiological monitoring were ALRR effluent air, environmental air, effluent water and environmental water. Effluent and environmental water were also monitored for chemical constituents which could be present from ALRR operations.

Air sampling showed that the isotopes detectable by gamma analyses in the ALRR stack effluent were lower in concentration than isotopes in the environmental air samples. Therefore, ALRR operations did not contribute anything to the particulate gamma activity in the atmosphere. Radioisotopes that were above background in the stack were radioactive hydrogen (H-3 or tritium) and radioactive argon (Ar-41). The average individual dose from Ar-41 and H-3 at the exclusion fence was estimated to be 3.42 mRem and the estimated dose to the entire population within a 50 mile radius of the ALRR was 91.8 man-Rem. These values are 0.7% and 0.09%, respectively, of the doses derived from the concentration guides (1).

In the liquid released from the ALRR complex, H-3 was the predominant isotope. With respect to the percentage of the concentration guide value, H-3 was a factor of 10 higher than any other constituent. Before stream dilution the average individual dose from H-3 was 1.1% of the dose derived from the concentration guide. After mixing in the receiving stream the potential dose was not more than 0.03% of the dose derived from the concentration guide (1).

The ALRR was operated during calendar 1976 under an interim National Pollutant Discharge Elimination System (NPDES) permit issued by the Environmental Protection Agency. The pH of the effluent was outside the

the lower limit of 6.0 in two (pH 2.9 and 3.1 respectively) of 475 samples (NPDES permit requires 12 samples). The highest pH value observed in Onion Creek downstream from the ALRR effluent was 9.0. All remaining NPDES conditions were satisfied. The final NPDES permit which will become effective July 1, 1977 will have an effluent limit for hexavalent chromium. Ames Laboratory is presently meeting the instream limits for hexavalent chromium set by the State of Iowa. Samples taken in Onion Creek downstream from the ALRR effluent confluence point averaged 0.02 mg/l in hexavalent chromium, 40% of Iowa's standard. The maximum discharge limit for Fecal Coliform is 400 counts/100 ml. One of the 12 samples collected was 1000 counts/100 ml which exceeded the limit. The non-radiological impact of ALRR operations on Onion Creek and subsequent streams is negligible.

The environmental monitoring program was changed on July 1, 1976. The changes which were made are shown in Appendix D, Tables D1 and D2. The changes were made in order to improve the cost effectiveness of the program and in accord with the minimal impact of the ALRR on the surrounding environment. Media and sites which had shown no previous impact or correlation with reactor operations were eliminated. A new site was added, and the media and sites which could show impacts were retained. The data for the entire year, both for the early and modified program, have been included. The changes were subject to consideration and agreement with Chicago Operations Office of ERDA.

II. Ames Laboratory Facilities and Locality

The facilities of the Ames Laboratory include offices, laboratories, warehouses and service buildings located among university buildings on the campus of Iowa State University (I.S.U.) in Ames, Iowa. In addition to the facilities on campus, the Ames Laboratory Research Reactor (ALRR) together with a waste handling-decontamination facility and an office-warehouse is located on a 40 acre site approximately (Figure 1, page 31) 1.5 miles (2.4 Km) northwest of the I.S.U. campus (Figure 2) and 3 miles (4.8 Km) west and north of downtown Ames (City Hall). The site of the ALRR is about 1,000 feet (305 m) above sea level and is enclosed by an exclusion fence at 700 feet (213 m) or more centered on the reactor. The nearest non-residential building (I.S.U.) is about 800 feet (244 m) east of the reactor and the nearest residential lot is about 1250 feet (381 m) south of the ALRR.

Ames is located in central Iowa where the Squaw Creek and Skunk River come together (Figures 3 and 4). The land is gently rolling "swell and swale". The flat upland is only a little greater than 100 feet (30.5 m) above the river flood plain. The general area is about 900 feet (274 m) above sea level. The City of Ames covers 16.4 square miles (42.5 Km²). The I.S.U. student population of about 19,000 is included in the Ames population numbering 40,000.* The major portion of Iowa State University and parts of Ames lie within a 2 mile (3.2 Km) radius of the Ames Laboratory Research Reactor. Within the 2 mile (3.2 Km) circle the land usage is 33% residential (Ames and I.S.U.), 25% wooded, and 42% agricultural.

The climatology of the area is temperate and continental subject to wide seasonal range in temperature, precipitation and winds. The average

*From 1970 census

annual temperature is 49°F (9.4°C). The average annual precipitation is 32 inches (81.3 cm): 90% rain, 10% snow, with small amounts of sleet and hail.

In the colder months the winds are mostly from the northwest sector averaging 18-20 miles/hours (29-32 Km/hour); in the warmer months winds are from the southeast sector averaging 12-14 miles/hour (19-23 Km/hour).

One characterization of winds is the fraction of time the wind blows from a certain direction. In the Ames area, the variations of a given wind direction between the least time or frequency and the greatest time is about a factor of two.

The average wind speed at 10 feet (3 m) above the ground is estimated as 9 miles/hour (4.0 m/sec) and at 100 feet (30.5 m) it is 13 miles/hour (5.8 m/sec).

An inversion is an atmospheric condition which limits the upward rise of effluents from ventilation and smokestacks. This condition occurs in varying degrees about 290 times per year with an average duration of 14 hours.

The sources of water supply for Ames and Iowa State University are sand and gravel aquifers lying within two buried bedrock valleys, the Squaw and the Skunk. Water is pumped for storage and distribution from a number of wells which are 100-130 feet (30.5-39.6 m) deep. The City of Ames pumped $1,949 \times 10^6$ gallons (7.4×10^9 liters) from the well field in 1976. In addition, Iowa State University pumped 405×10^6 gallons (1.5×10^9 liters) in the same period, making the total pumped from the well field $2,354 \times 10^6$ gallons (8.9×10^9 liters). Surface water contributes to the recharge of the system as water is pumped from the wells. The travel

time of water from the Skunk River to the well area is estimated at one year. The contribution to the recharge from Squaw Creek is less than that from the Skunk River. Recharge water from Squaw Creek passes through absorbing and filtering material, a mixture of clay, silt and sand which lies over the waterbearing sand and gravel.

The surface streams of particular interest to the Ames Laboratory are the Onion Creek Gulch, Onion Creek, Squaw Creek and the Skunk River. Onion Creek and Onion Creek Gulch are intermittent and non-classified streams. Squaw Creek and the Skunk River are classed as B, fresh warm water, and thus protected for wildlife, fish, aquatic and semi-aquatic life and secondary contact recreation. The classifications have been established by the Iowa Water Quality Commission. The Skunk River is changed to a Class C, protected raw water source of potable water supply, at the point of withdrawal at Oskaloosa, Iowa, 85 river miles (137 Km) downstream from Ames.

The area around Ames is generally rural with farming producing important yields of corn, soybeans, and wheat. The neighboring towns (Figure 3) are mostly small communities.

<u>City</u>	<u>Population*</u>	<u>From Ames</u>
Nevada	5,000	7 miles (11 Km) east
Ankeny	9,000	22 miles (35 Km) south
Boone	12,500	13 miles (21 Km) west
Story City	2,100	14 miles (23 Km) north

The capitol of Iowa, Des Moines, population 201,400* lies 30 miles (48 Km) south of Ames. Fort Dodge, 31,000*, one of our sampling locations, lies 43 miles (69 Km) northwest of Ames (Figure 4).

*From 1970 census

The total population within a circle of 50 mile (80 Km) radius is 590,500*.

The Ames Laboratory Research Reactor is fueled with uranium-235, with circulating heavy water as the coolant and moderator. The primary coolant, heavy water (D_2O), is circulated through the reactor in a closed system with a heat exchanger. The secondary heat removal system uses city supplied softened water circulated through the heat exchanger and an open cooling tower.

The reactor operates at 5,000 kilowatts thermal power level on a continuous schedule. The reactor produces up to 10^{14} neutrons/cm²/sec in various experimental facilities. The principal uses of the reactor are the production of fission products which are separated and studied, the irradiation of crystals for the study of structures and energy levels by neutron diffraction, the irradiation of materials, especially metals, for the study of radiation effects, the production of radioisotopes which are used in a variety of tracer studies, and activation of elements in materials for analytical studies.

The waste disposal/decontamination facility houses a decontamination booth and special sinks with systems for complete collection of the cleanings, a solid waste compactor, tank storage for liquids (water) with filtration and ion exchange processing systems, and evaporation and distillation systems. The output of this facility is clean equipment for re-use, Class C or better water for release to the environment; and packaged solid waste for shipment to a radioactive waste burial site.

*From 1970 census

The laboratories associated with the reactor and those in the Ames Laboratory complex on the Iowa State University campus that use radioactivity have relatively small amounts of radioactivity at any one time. The majority of the work deals with tracer studies employing relatively small amounts of radioisotopes (Ca-45, Cl-36, Co-60, Fe-59, Hf-175, Mn-54 and others). Waste from these experiments is collected and disposed of as radioactive waste.

The principal potential sources for release of radioisotopes and chemicals to the environment are the research reactor and the waste disposal/decontamination facility. Liquids released on the I.S.U. campus Ames Laboratory facilities are handled through the sanitary sewer system. Liquid and solid radioactive wastes in these facilities are collected and taken to the reactor site waste disposal facility for processing. Airborne releases are eliminated or minimized by experiment system design or source limitation. The liquid and solid contaminated wastes generated at the reactor site are transferred to the waste disposal facility for processing. Irradiated air systems of the reactor are filtered before release and are monitored. The liquid effluents from the reactor site are monitored at a single outfall site where all such wastes are released.

The effluent monitoring pertaining to these facilities and the environmental monitoring are presented in this report.

III. Definition of Terms

Average Average as used in this report is the arithmetical mean of all sample results. The activity of a sample was set equal to zero when the count rate was less than background. When the count rate was less than the detection limit, which is a function of the minimum detectable activity (4) (but greater than the instrument background) the calculated activity was used in averaging. No yearly average is the mean of the monthly averages.

Confidence Limits The confidence limits given in Table 1 indicate the accuracy of the particular value based on considerations of the count rate, count time and background, not on the distribution of sample values (4). The limits in this table have been derived for and are applicable only to the value which is stated for each media. The values used in Table 1 are typical yearly averages which appear in each media type group; that is, air, water, and bottom sediment.

Table 1
95% Confidence Limits

<u>Media Type</u>	<u>Sample Size</u>	<u>Count Time</u>	<u>Average Activity ($\pm 2\sigma$)</u>
<u>Beta</u>			
Air	152 m ³	50 min	0.098 (± 0.0094) $\times 10^{-12}$ $\mu\text{Ci/ml}$
Water	1	30 min	6.07 (± 1.35) $\times 10^{-9}$ $\mu\text{Ci/ml}$
Bottom Sediment	4 g	30 min	10.33 (± 0.71) $\times 10^{-6}$ $\mu\text{Ci/ml}$
<u>Alpha</u>			
Air	Same as Beta		0.0027(± 0.0037) $\times 10^{-12}$ $\mu\text{Ci/ml}$
Water			0.59 (± 0.76) $\times 10^{-9}$ $\mu\text{Ci/ml}$
Bottom Sediment			0.66 (± 0.26) $\times 10^{-6}$ $\mu\text{Ci/ml}$
<u>Tritium</u>			
Water			2.08 (± 0.50) $\times 10^{-6}$ $\mu\text{Ci/ml}$

Average Tritium Counting Efficiency = 23%

Detection Limit The minimum detectable activity (limit) is defined as that activity which, in the same counting time, yields a count which is more than the instrument background count by three times the standard deviation of the background count (4).

The detection limit is a value of radioactivity per unit volume or mass based on the sample volume or mass, the counting procedure, and the minimum detectable activity. The detection limit is stated in Table 2 for each media.

Table 2
Detection Limits, Radiological

	Air 10^{-15} Ci/ml	Water 10^{-9} Ci/ml	Bottom Sediment 10^{-9} Ci/g
Beta	4.80	1.00	250.
Alpha	3.20	0.39	100.
Tritium	--	500	--
Ag-110m	0.32 (0.13)*	0.30 (0.13)	22.4 (8.81)
Ba-140	0.93 (0.38)	0.92 (0.38)	65.6 (25.8)
Ba-137	1.46 (1.23)	1.71 (1.20)	154. (82.8)
Ce-141	0.95 (0.18)	0.13 (0.17)	16.3 (15.1)
Ce-144	0.58 (0.72)	0.66 (0.67)	65.3 (48.6)
Co-60	0.31 (0.14)	0.37 (0.15)	30.0 (9.6)
Cs-137	0.22 (0.15)	0.27 (0.15)	23.1 (10.4)
La-140	0.36 (0.27)	0.39 (0.26)	38.3 (18.2)
Nb-95	0.18 (0.13)	0.26 (0.13)	23.3 (8.9)
Ru-103	0.16 (0.13)	0.19 (0.13)	17.5 (8.8)
Ru-106	3.86 (2.75)	4.68 (2.70)	385. (173.)
Sb-124	0.93 (0.14)	0.95 (0.13)	27.4 (9.2)
Sb-125	2.75 (0.41)	2.80 (0.40)	72.4 (27.4)
Zn-65	0.54 (0.25)	0.52 (0.24)	37.6 (17.1)
Zr-95	0.36 (0.26)	0.43 (0.25)	40.3 (17.3)

*All values in parentheses were used after changing to a more efficient Ge(Li) detector.

With respect to the gamma detection limits, typical counting times were 1333.3 minutes (333.3*). Samples volumes for air and water were 1.50×10^{10} ml and 2.2×10^4 ml, respectively. Sample mass for bottom sediment averaged 400 grams.

The non-radiological detection limits are shown in Table 3. Values less than the detection limits can be obtained. However, the values will be significantly less accurate since more judgement on the part of the analyst is needed.

Table 3
Detection Limits, Non-Radiological

Chloride	2.5 mg/l
Hexavalent Chromium	0.05 mg/l
Zinc	0.1 mg/l
Flow	1 l/min
BOD	0.25 mg/l
Fecal Coliform	1 organism/100 ml

High All highs given in this report are individual sample highs.
 Low All lows given in this report are individual sample lows.
 NDA No detectable activity.

IV. Radiological Monitoring Program

The Ames Laboratory radiological program monitors effluent (air particulate and water), environmental air particulate, river and well water and precipitation in the Ames area. Gamma analysis is generally performed on composites of samples collected over a month, quarter or the entire year. The samples are analyzed using a Nuclear Data 4096 Channel Gamma spectrometer with a high resolution Ge(Li) detector. A computer program based on ICPEAX (5) is used to determine peak energies and areas based on a gaussian fitting routine.

Individual samples are submitted to gross beta and alpha analysis. This provides an indication of the activity of the sample within 3 weeks. All alpha and beta determinations are made in a 3 inch gas proportional Sharp Low Betamatic System. The activity concentration is calculated using the following equation:

$$\text{Activity Concentration} = \frac{(\text{Counts/Time}) - \text{Background}}{(\text{Counter Efficiency})(\text{Volume})(2.22 \times 10^6 \text{ dpm}/\mu\text{Ci})} \quad (1)$$

Self-absorption was not considered. As such, the results are easily compared to other samples and to previous years. Since the alpha and beta determination is basically a screening process, this purpose is served equally as well without self-absorption corrections.

The tritium activity is determined on a 5 ml sample using a dioxane-naphthalene cocktail and a Beckman Scintillation Counter. The tritium activity concentration is also calculated using Equation 1.

A. Effluents

Air

Stack air particulate samples are collected on 2 inch (5 cm) Whatman #41 filter paper using a Gast pump with a flow rate of 3 CFM (5 liters per minute) from a sample point near the top of the ALRR stack (Figure 1). Comments describing the stack sampling program are as follows: (1) The air sampler system as operated in this sampling program, produces a particulate collection efficiency of >97% using the above filter paper, (2) Sampling is continuous with the filters being changed every working day, (3) both sample and stack flow rates are recorded, (4) gross beta and alpha activity is determined with the Sharp System after a seven day holding period, (5) gamma analysis is performed on quarterly composites of the daily samples. The Ar-41 is continuously monitored with readings taken hourly during reactor operations. The Ar-41 detector, a geiger mueller type, is calibrated twice a year. The H-3 effluent is an estimate based on the loss of primary coolant for the year and its average H-3 concentration.

The activity concentration in the ALRR stack for 1976 is shown in Table 4. The stack volume for 1976 was 2.18×10^{14} ml.

Table 4
ALRR Stack Effluent
($\mu\text{Ci/ml}$)

<u>Isotope</u>	<u>Concentration</u>
Gross Beta	5.15×10^{-14}
Gross Alpha	1.89×10^{-16}
Ar-41	3.68×10^{-6}
Be-7	7.67×10^{-14}
Ce-141	4.83×10^{-16}
Ce-144	4.38×10^{-16}
Co-60	5.10×10^{-16}
Cs-137	3.60×10^{-16}
H-3	1.72×10^{-6}
Nb-95	4.90×10^{-16}
Zr-95	3.36×10^{-16}

Water

Water samples are collected twice daily, except weekends and holidays from the ALRR outfall, discharge point for the ALRR complex (Site 2R, Figure 1). Alpha and beta activity is determined by evaporating a 1 liter sample into a 3 inch aluminum planchet and counting in a Sharp Low Betamatic. Tritium is determined on a 5 ml sample with a Beckman Scintillation Counter and dioxane-naphthalene cocktail. The tritium (H-3) discharge concentration range was from 0.03% to 66% of the concentration guide with an overall average of 1.28%. Gamma scan analyses were performed on monthly composites of the morning outfall samples, AM, and afternoon samples, PM. The concentration guides (CG's), based on radiation dose to individuals in uncontrolled areas, are shown in Appendix A. See Appendix B, Table B7 for a monthly summary of the outfall results. A summary for 1976 is shown in Table 5.

Table 5
Radioactivity in the ALRR Outfall
($\mu\text{Ci/ml}$)

	Number of Samples	Average Concentration	% CG	High	Low
Gross Beta, 10^{-9}	488	6.41	0.21	22.7	NDA
Gross Alpha, 10^{-9}	488	0.08	0.28	1.98	NDA
H-3, 10^{-6}	48/	38.4	1.28	1987.0	0.90
Co-60, 10^{-9}	composites	0.060	0.0002	0.47	NDA
Cs-137, 10^{-9}	composites	0.041	0.0002	0.61	NDA

Liquid radioactive waste is sampled and treated on a batch basis. Alpha and Beta activities are determined by evaporating a 100 ml sample and counting. Equation 1 with self-absorption corrections is used to calculate the alpha and beta activity concentration. Self-absorption corrections are employed because an absolute activity concentration is desired for waste discharge and the sample residue is small, less than 0.1 g, making the corrections relatively low. The tritium activity

concentration is determined on a 1 ml sample. The gamma analysis is performed on the residue of an evaporated 3 liter sample. All radioactive waste generated at the laboratories located on the I.S.U. campus is collected, evaporated and disposed of as solid waste. The radioactivity in liquid waste released to the environment in 1976 is shown in Table 6.

The average outfall flow rate for 1976 was 67 liters per minute. This yields a total volume for 1976 of 3.5×10^{10} ml. Table 6 concentrations reflect the total isotopic amount divided by the total volume. The concentration guides, based on radiation dose to individuals in uncontrolled areas, is shown in Appendix A.

Table 6

Liquid Radioactive Waste Released to the Environment

<u>Isotope</u>	<u>Amount, μCi</u>	<u>Concentration, $\mu\text{Ci/ml}$</u>	<u>% CG</u>
Gross Beta	13.60	3.92×10^{-10}	1.3×10^{-2}
Gross Alpha	0.89	2.53×10^{-11}	8.4×10^{-2}
Ag-110m	0.67	1.90×10^{-11}	6.3×10^{-6}
Ce-141	0.214	6.09×10^{-12}	6.8×10^{-6}
Ce-144	1.11	3.13×10^{-11}	3.1×10^{-4}
Co-60	0.962	2.72×10^{-11}	9.5×10^{-5}
Cs-137	0.938	2.65×10^{-11}	1.3×10^{-4}
H-3	1.43×10^6	4.13×10^{-6}	1.4
Nb-95	0.818	2.32×10^{-11}	2.3×10^{-5}
Ru-103	0.213	6.04×10^{-12}	7.5×10^{-7}
Sb-124	3.43	9.78×10^{-11}	4.8×10^{-4}
Sb-125	0.306	7.52×10^{-12}	2.5×10^{-6}
Zr-95	0.407	1.16×10^{-11}	1.9×10^{-5}

In monitoring effluent from the I.S.U. campus facilities, the Ames Water Pollution Control Plant (Site 11R, Figure 3) effluent is sampled weekly and a composite sludge sample is processed monthly. The effluent liquid is treated the same as a river or outfall sample. The sludge sample is mixed and a 100 ml portion is filtered. After drying, the filter paper is ashed and both portions are counted for gross beta and alpha activity. Gamma analysis is performed on a composite of the year's samples. The tritium concentration is not determined on the sludge samples.

Table 7

Radioactivity in the Water Pollution Control Plant Samples (11R)

($\mu\text{Ci/ml}$)

	<u>Number of Samples</u>	<u>Beta, 10^{-9}</u>	<u>% CG</u>	<u>Alpha, 10^{-9}</u>	<u>% CG</u>	<u>Number of Samples</u>	<u>Tritium, 10^{-6}</u>	<u>% CG</u>
Plant Effluent (Site 11R)	53					50		
Average		11.8	0.39	0.14	0.46		2.60	0.086
High		21.3		0.48			10.1	
Low		NDA		NDA			1.06	
Sludge Soluble	12							
Average		33.2		1.30			Not Determined	
High		46.4		6.60				
Low		23.9		NDA				
Sludge Insoluble	12							
Average		103.		15.1			Not Determined	
High		190.		28.8				
Low		45.5		6.01				

The result of gamma analyses on the Ames sludge shows no detectable gamma activity other than natural occurring radionuclides.

B. Environmental

Air Samples

Air samples are collected from two different locations at the Ames Laboratory on a daily (except weekends) basis for the purpose of monitoring the particulate radioactivity content of the atmosphere. The sites are located at the ALRR weather tower site (Site 1A, Figure 1) and the roof of Spedding Hall (Site 2A, Figure 2). Samples are collected over a 24 hour period, held for 7 days to allow short-lived activities to decay and then analyzed. Samples are collected on Whatman #41 3 inch (7.62 cm) diameter filter paper using a Gast pump with a flow rate of 4.1 CFM (116 liters per minute). The samples are placed directly in a Sharp Low Betamatic three inch gas proportional system and counted for gross alpha and beta activity. The filter papers are then retained until a composite sample for 90 days is collected. The composite sample is then analyzed for specific gamma emitting isotope content using a Ge(Li) detector/4096 channel analyzer. The isotopic activity that was detectable on the 1976 composites is summarized in Table 8 and shown quarterly in Appendix B, Tables B2 and B4. The gross beta and alpha activity is summarized in Table 9 and shown monthly in Appendix B, Tables B1 and B3. The Alpha High concentration shown, as well as the fission isotopes listed in Table 8, are due to fallout from atmospheric nuclear testing received during the fourth quarter monitoring period.

Table 8
Gamma Analysis of Air Samples
(10^{-15} $\mu\text{Ci/ml}$)

<u>Isotope</u>	<u>ALRR--Site 1A</u>		<u>Spedding Hall--Site 2A</u>	
	<u>Ave</u>	<u>% CG</u>	<u>Ave</u>	<u>% CG</u>
Be-7	163.	4.1×10^{-4}	126.	3.2×10^{-4}
Ce-141	5.20	1.1×10^{-4}	4.57	9.3×10^{-6}
Ce-144	1.74	8.7×10^{-4}	1.71	8.6×10^{-4}
Cs-137	0.501	1.2×10^{-4}	0.576	1.2×10^{-4}
Nb-95	7.03	2.3×10^{-4}	6.65	2.2×10^{-4}
Ru-103	4.40	1.5×10^{-4}	3.80	1.3×10^{-4}
Zr-95	3.03	3.0×10^{-4}	2.90	2.9×10^{-4}

Table 9
Radioactivity in Air
(10^{-12} $\mu\text{Ci/ml}$)

	<u>Number of Samples</u>	<u>Beta</u>	<u>% CG</u>	<u>Alpha</u>	<u>% CG</u>
ALRR--Site 1A	237				
Average		0.051	0.05	0.0021	10.5
High		0.571		0.0343	
Low		0.003		NDA	
Spedding Hall-- Site 2A	218				
Average		0.065	0.07	0.0025	12.5
High		1.70		0.0371	
Low		0.006		NDA	

Precipitation Samples

Precipitation samples are collected on an "as it happens basis" near the weather observation tower on the ALRR Site. The samples are evaporated to dryness and counted for gross alpha and beta activity. A 5 ml sample is used for tritium analysis. Gamma analysis is performed on a quarterly composite. The monthly and quarterly data are presented in Appendix B, Tables B20 and B21, and summarized in Table 10. The total number of samples for 1976 was 12.

Table 10
Radioactivity in Precipitation
($\mu\text{Ci/ml}$)

	<u>Average</u>
Beta	16.3×10^{-9}
Alpha,	1.74×10^{-9}
Ba-140,	3.08×10^{-9}
Be-7	11.1×10^{-9}
Ce-141	2.27×10^{-9}
Cs-137	2.74×10^{-9}
La-140	166.3×10^{-9}
Nb-95	3.83×10^{-9}
Ru-103	3.43×10^{-9}
Zr-95	1.94×10^{-9}
H-3	2.11×10^{-6}

River Water Samples

River water samples are collected weekly and analyzed for tritium activity and gross alpha and beta activity. Samples are obtained from Onion Creek (Site 3R, 4R, Figure 2,6), the first flowing creek in the flow route of the ALRR drainage system, and the Skunk River (Site 11R, Figure 3,7) downstream from both the ALRR drainage system and the Ames Pollution Control Plant. In addition, samples (Clear Creek) are obtained from outside the ALRR flow route. This constitutes a control site and is numbered nine in the data. Samples are obtained whenever possible. At times the creeks are completely dry in the late summer and fall and frozen solid in the winter. If water is flowing under the ice, a sample is obtained by chopping through the ice. If there is an unusually large amount of

suspended material in the sample, the sample is filtered and the soluble and insoluble portions are counted separately; otherwise, the one liter sample is evaporated to near dryness and transferred to a planchet. The planchets are placed directly in the Sharp System for counting. Tritium is determined with a 5 ml sample using liquid scintillation. Gamma analysis is performed on quarterly composites of the weekly samples. The sample results are summarized in Table 11.

Table 11
Radioactivity in River Water
($\mu\text{Ci/ml}$)

	<u>Number of Samples</u>	<u>Beta 10^{-9}</u>	<u>% CG</u>	<u>Alpha 10^{-9}</u>	<u>% CG</u>	<u>Number of Samples</u>	<u>Tritium 10^{-6}</u>	<u>% CG</u>
<u>Downstream</u>								
<u>Sites 4R, 6R, 8R</u>								
Soluble	77					77		
Ave		5.82	0.194	0.53	1.8		2.33	0.078
High		18.3		1.80			24.5	
Low		NDA		NDA			0.294	
Insoluble	0					0		
<u>Upstream</u>								
<u>Sites 1R, 3R, 5R, 7R</u>								
Soluble	102					102		
Ave		4.61	0.153	0.492	1.7		2.26	0.085
High		23.3		2.10			5.67	
Low		0.493		NDA			0.243	
Insoluble	1							
Ave		9.64		0.961				
High		9.64		0.961				
Low		9.64		0.961				
<u>Control</u>								
<u>Sites 9R, 10R</u>								
Soluble	50					50		
Ave		5.37	0.18	0.464	1.5		2.11	0.070
High		17.5		1.62			5.60	
Low		NDA		NDA			0.676	
Insoluble	0							

Gamma analysis for River Sites 1R, 3R, 4R, 8R, 10R yielded no detectable isotopes other than naturally occurring radionuclides.

Pond Water

Pond water samples are collected monthly from three sites (Figure 3): The George Todd site (1P) four miles (6.4 Km) northeast of the ALRR; the Izaak Walton League site (2P) three miles (4.8 Km) east of the ALRR; and the Kelley site (3P) six miles (9.6 Km) south of the ALRR. The sample size is one liter and is handled in the same manner as the river water samples. Gamma analysis on yearly composites, 6 samples, yielded no detectable isotopes other than naturally occurring radionuclides. The yearly data are presented in Appendix B, Table B18, and summarized in Table 14.

Table 14
Radioactivity in Pond Water
($\mu\text{Ci/ml}$)

	<u>Number of Samples</u>	<u>Beta 10^{-9}</u>	<u>% CG</u>	<u>Alpha 10^{-9}</u>	<u>% CG</u>	<u>Tritium 10^{-6}</u>	<u>% CG</u>
Average	21	6.92	0.17	0.372	1.2	1.82	0.061
High		15.0		1.08		3.63	
Low		1.58		NDA		1.12	

Well Water Samples

Well water samples are obtained monthly from City of Ames wells (1W, Figure 7), Iowa State University (I.S.U.) campus wells (2W, Figure 6), and from a privately owned farm well (Martin) at a location two miles north of the ALRR. The sample size is one liter and is handled in the same manner as the river water samples. No gamma activity was observed on the yearly composites of the well samples. The yearly data are presented in Appendix B, Table B19, and summarized in Table 15.

Table 15
Radioactivity in Well Water Samples
($\mu\text{Ci}/\text{ml}$)

	<u>Number of Samples</u>	<u>Beta 10^{-9}</u>	<u>% CG</u>	<u>Alpha 10^{-9}</u>	<u>% CG</u>	<u>Tritium 10^{-6}</u>	<u>% CG</u>
Average	30	4.52	0.15	0.274	0.91	1.79	0.596
High		6.94		0.841		3.46	
Low		2.43		NDA		0.964	

Bottom Sediment

Bottom sediment samples are obtained at or near the river water and pond water sites on a quarterly basis. Samples are analyzed for gross alpha and beta activity. A one-liter sample is obtained from the top 2-3 inches (5-8 cm) of bottom sediment in a semi-quiescent area. The sample is mixed thoroughly and a 3-4 gram counting sample is prepared. The counting samples are dried thoroughly in an oven and then counted directly in the Sharp System. The results for 1976 are shown in Table 16 and Table B23.

Table 16
Radioactivity in Bottom Sediments
(10^{-6} $\mu\text{Ci}/\text{g}$)

	<u>Number of Samples</u>	<u>Ave</u>	<u>Beta High</u>	<u>Low</u>	<u>Ave</u>	<u>Alpha High</u>	<u>Low</u>
Ponds	6	9.57	13.2	7.15	0.633	0.961	0.135
Downstream sites 2R,2F, 4R,6R,8R	11	7.59	9.55	6.84	0.304	0.691	0.120
Upstream sites 1R,3R, 5R,7R	10	7.33	8.71	5.88	0.291	0.631	0.120
Control sites 9R,10R	5	6.91	8.86	5.08	0.279	0.405	0.060

Gamma analysis of the bottom sediment samples (200-600 grams) yielded detectable amounts of Cs-137. At Site 2R detectable amounts of Ag-110m, Ce-144, Cs-137, Co-60, Nb-95, Ru-103, and Zr-95 were found. The presence of these isotopes, with the exception of Cs-137, occurred only at this site and is probably due to ALRR operations. These isotopes were not found in samples from Site 2F or at any other point downstream.

C. Impact

From the effluent data it has been shown that the contribution to the environmental radioactivity in air from Ames Laboratory operations consisted principally of radioactive argon, Ar-41, and tritium, H-3.

Applying principles of meteorological diffusion to the stack effluent, particularly section 3-5.5.4, Long-period Average Concentration of "Meteorology and atomic energy 1968", USAEC (5) the estimates have been made for the radiation dose at the exclusion fence. The man-Rem dose for the population within a 50 mile (80 Km) radius of the reactor has been estimated using a cylindrical diffusion volume with a 50 mile (80 Km) radius and a height of 1,000 feet (305 m). The height used in the 1974 report was 2,000 feet (610 m).

Average Individual Dose at Fence Line for 1976

	Millirem
Ar-41	3.39
H-3 (tritium)	0.032
TOTAL	3.42

The 50 mile Man-Rem Dose for 1976 (590,500 population)

	Man-Rem
Ar-41	2.5
H-3 (tritium)	89.3
TOTAL	91.8

The concentration guide value for an average dose taken as 0.5 Rem/3 = 0.17 Rem yielded 100,385 man-Rem for the population within 50 miles (80 Km). Thus the man-Rem dose, derived from the concentration guide, due to Ames Laboratory operation was .0009 or 0.09% of the Radiation Protection Standard.

Using the concentration guide value of 500 mRem for an individual at the exclusion fence, the ratio was 0.007, 0.7% of the Radiation Protection Standard.

The apparent reversal in the Ar-41 and H-3 doses under the two conditions above was due to the decay of Ar-41 during the diffusion time to distribute the Ar-41. The models for the fence line case and the 50 mile (80 Km) radius case were also different. The doses were based on the relationship of the concentration guide level exposure to the radiation protection standard in ERDA Manual Chapter 0524.

There are no realistic models for the exposure due to the concentrations of radionuclides in the streams. Based on the H-3 released as waste during 1976 in the outfall, Table 6, before stream dilution, the average individual dose was 1.1% of the dose derived from the concentration guide. After mixing in the receiving stream the potential dose was not more than 0.03% of that derived from the concentration guide. H-3 has the highest percentage of the concentration guide, by a factor of 10, of any of the radioactive waste constituents shown in Table 6.

V. Non-Radiological Monitoring Program

A. Effluents

Effluent water samples are collected twice daily at the ALRR outfall. A Beckman pH Meter is used to determine the pH of each sample. The effluent temperature is determined daily with a standard mercury centigrade thermometer when the first sample is obtained. This thermometer, -20°C to 110°C in 1°C increments, has been checked for accuracy against a 0°C to 50°C in 0.1°C increments laboratory thermometer. The flow rate is determined daily by measuring the time needed to fill a container of known volume.

Weekly effluent samples are collected for chloride, hexavalent chromium and zinc measurements. The hexavalent chromium and zinc determinations are made as soon after sampling as time permits usually within one to two days. The hexavalent chromium and zinc analyses are performed with a Hach DR Colorimeter using Hach's procedures and chemicals. Hach's hexavalent chromium analysis is based on the 1,5-Diphenylcarbohydrazine method (7). The zinc analysis is based on the Zincon method (7). The chloride determination is performed after a number of samples have been collected. The chloride determination is a Hach Chemical Company procedure based on the mercuric nitrate method (7).

The 5 day biochemical oxygen demand (BOD) and fecal coliform analysis are performed monthly. The BOD sample is a flow weighted mixture of several samples taken throughout the day. The procedures in Standard Methods (3) are followed for the BOD determination. The fecal coliform sample is a grab sample taken in a sterile glass bottle. The membrane filter technique employing gridded membrane filter paper and sterile M-FC broth ampoules from Millipore is used for the fecal coliform determination.

A summary of the non-radiological effluent data is shown in Table 17.

A monthly breakdown of these results appears in Appendix C.

Table 17
Non-Radiological Effluent Results
1976

	<u>Number of Samples</u>	<u>Average</u>	<u>High</u>	<u>Low</u>
Chlorides	48	674 mg/l	3604 mg/l	30 mg/l
Chromium (hexavalent)	48	.35 mg/l	1.75 mg/l	0.1 mg/l
Zinc	44	.08 mg/l	.35 mg/l	0.0 mg/l
pH	475	7.8	9.0	2.9
Temperature	240	21.6°C	30°C	8°C
Flow	191	67 l/min	750 l/min	5 l/min
Biochemical Oxygen Demand (5 day)	11	1.71 mg/l	2.5 mg/l	.95 mg/l
Fecal Coliform	12	180 /100 ml	1000 /100 ml	2 /100 ml

B. Environmental (Non-Radiological)

The hexavalent chromium concentration and pH were determined for samples from Sites 3R (Upstream) and 4R (Downstream) (Figure 2). The sampling and analytical procedures were as described previously. Sites 3R and 4R were dry 7 out of the 12 months in 1976, therefore, a limited number of analysis could be performed. The summary for 1976 is shown in Table 18 with a monthly breakdown in Appendix C.

Table 18

Non-Radiological Environmental Results

	<u>Number of Samples</u>	<u>Average</u>	<u>High</u>	<u>Low</u>
Site 3R--Upstream				
Chromium (hexavalent)	16	0.02 mg/l	0.025 mg/l	0.0 mg/l
pH	17	8.0	8.9	7.0
Site 4R--Downstream				
Chromium (hexavalent)	16	0.02 mg/l	0.05 mg/l	0.00 mg/l
pH	17	8.0	9.0	7.4

C. Impact (Non-Radiological)

The year 1976 was a very dry year for the Ames area. The stream (Onion Creek) that receives the effluent from the ALRR was dry and non-flowing for seven out of twelve months in 1976. The discharge water from the ALRR was absorbed into the ground before it reached Onion Creek. From the ALRR discharge point to Onion Creek is a distance of one half mile (.8 Km).

When samples were available from Onion Creek analysis showed that ALRR was not affecting the water quality. The average upstream and downstream hexavalent chromium concentrations were the same. pH values above and below the ALRR confluence were the same.

All ALRR effluent samples were within the NPDES (Table A2) effluent limits with the exception of three. Of the 475 pH samples, two were below the lower limit of pH 6.0. One out of 12 fecal coliform samples exceeded the NPDES limit of 400 counts per 100 ml. The highest temperature recorded during 1976 was 30°C which is 5°C within NPDES limits. The BOD averages were 1.71 mg/l and .149 Kg/day which are 6% and 24% respectively of the NPDES permit

limitations. The yearly average of 180 fecal coliform bacteria per 100 ml is 90% of the discharge limit. Zinc in the ALRR effluent averaged .08 mg/l and .009 Kg/day, these numbers are 8% and 15% for the discharge permit limits. The 1976 average concentration of hexavalent chromium was .35 mg/l in the ALRR effluent. When sampling was possible, the hexavalent chromium concentration (.02 mg/l) in Onion Creek was the same for both upstream and downstream samples. Ames Laboratory has until July of 1977 to comply with the NPDES limitation of .05 mg/l concentration of hexavalent chromium and work is underway in order to meet the deadline.

The non-radiological impact of ALRR operations on Onion Creek and subsequent streams is negligible. Of the 1021 analyses performed relative to NPDES effluent limitations only three were not within stated guidelines. In terms of the Iowa standards, considering that Onion Creek is a non-classified stream and that the standards applied were instream, class C sources of potable water, the ALRR site is not detrimental in any way to Onion Creek and subsequent streams.

Table 19
Sample Site Location

AIR

<u>Figure Reference</u>	<u>Map Symbol</u>	
1,5	1A	The on-site monitoring station is located approximately 400 feet (122 m) south of the reactor.
2,6	2A	The off-site monitoring station is located on the Spedding Hall roof approximately one mile (1.6 Km) southeast of the reactor.

RIVER AND BOTTOM SEDIMENT

<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
1,2,5,6	1R	1-DD-U	This on-site sampling point is located just above the mixing zone of the outfall in Onion Creek Gulch.
1,2,5,6	2R	Outfall	This site is the outfall and is listed as such. The bottom sediment sample is just below the outfall point in Onion Creek Gulch.
1,2,5,6	2F	Fence	Site is approximately 300 feet (91 m) downstream from outfall point at Reactor site boundary fence.
2,6	3R	3-On-U	This site is in Onion Creek upstream from confluence with Onion Creek Gulch.
2,6	4R	4-On-D	Site is approximately 1000 feet (305 m) downstream from confluence point in Onion Creek.
2	5R	5-Sq-U	Site is in Squaw Creek upstream from the confluence with Onion Creek.
2	6R	6-Sq-D	Site is in Squaw Creek downstream from the Onion Creek confluence.
3	7R	7-Sk-U	Site is in the Skunk River upstream from the Squaw Creek confluence.
3,7	8R	8-Sk-D	Site is in the Skunk River downstream from the Squaw Creek confluence.
2,6	9R	9-CC	This control site is located outside the flow pattern of ALRR effluent in Clear Creek.

Table 19 Continued

RIVER AND BOTTOM SEDIMENT - Continued

<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
3	10R	10-DM	This control site is located approximately 15 miles (24 Km) west of the reactor in the Des Moines River.
3,6	11R	11-Sk-S	This is a sample of the Ames Water Pollution Control Plant effluent.

WELLS

3,6	1W	City	The water wells for the City of Ames are all located east of Squaw Creek. The location indicated is the water treatment plant.
2,6	2W	I.S.U.	The Iowa State University wells are located west of Squaw Creek.
2,6	3W	Martin	The Martin site is a private farm well located two miles (3.2 Km) north of the ALRR.

Figure 1: Ames Laboratory Research Reactor Site Plan. Map drawn to scale.

Figure 2: Environmental Sampling Sites within Two Miles (3.2 Km) of ALRR.
Map drawn to scale.

Figure 3: Environmental Sampling Sites within Sixteen Miles (25.7) Km of ALRR. Map drawn to scale.

Figure 5: Ames Laboratory Research Reactor Site Plan. Map drawn to scale. (Modified)

Figure 6: Environmental Sampling Sites within Two Miles (3.2 Km) of ALRR. Map drawn to scale. (Modified)

VII. References

1. ERDAM 0524, "Standards for Radiation Protection".
2. Iowa Departmental Rules, "Water Quality Standards", Chapter 16, February 12, 1974.
3. "Standard Methods for the Examination of Water and Wastewaters", 13th Edition, 1971 American Public Health Association, New York, New York 10019.
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7. Hach Chemical Company, Ames, Iowa 50010

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APPENDIX A. Applicable Standards

The radionuclide concentration standards for air and water applicable to ALRR operations are the Concentration Guides (CG's) given in Chapter 0524 of the ERDA Manual (1). A summary of the concentration guides is given in Table A1. The most restrictive (uncontrolled area) Chapter 0524 Table II value, soluble or insoluble, is reported in Table A1.

Table A1
Concentration Guides (CG's)

	In Water ($\times 10^{-9}$ μ Ci/ml)	In Air ($\times 10^{-12}$ μ Ci/ml)
Alpha	30	0.02
Beta	3,000	100
Ag-110m	30,000	300
Ar-41	--	40,000
Ba-140	20,000	1,000
Be-7	2,000,000	40,000
Ce-141	90,000	5,000
Ce-144	10,000	200
Co-60	30,000	300
Cs-134	9,000	400
Cs-137	20,000	500
H-3	3,000,000	200,000
La-140	20,000	4,000
Na-22	30,000	300
Nb-95	100,000	3,000
Ru-103	80,000	3,000
Sb-124	20,000	700
Sb-125	30,000	900
Zn-65	100,000	2,000
Zr-95	60,000	1,000

Ames Laboratory has received authorization to discharge into the drainage ditch, a tributary of Onion Creek, under the National Pollutant Discharge Elimination System (NPDES). The interim NPDES effluent limitations applicable for 1976 are specified in Table A2.

Table A2
NPDES Interim Effluent Limitations

	Concentration		Quantity	
	Daily Avg.	Daily Max.	Daily Avg.	Daily Max.
Temperature	---	35°C	---	---
Biochemical Oxygen Demand (5 day)	30 mg/l	45 mg/l	0.6 Kg/day	0.8 Kg/day
Fecal Coliform (organisms/100 ml)	200	400	---	---
Zinc	1 mg/l	2 mg/l	0.06 Kg/day	0.12 Kg/day
pH	not less than 6.0 nor greater than 10.0			

Chapter 16 of the Iowa Department of Environmental Quality Rules, "Water Quality Standards" adopted February 12, 1974, provides instream guidelines for chlorides, hexavalent chromium, and turbidity. Chlorides and hexavalent chromium for Class C water, raw water source of potable water, should not exceed 250 mg/l and 0.05 mg/l, respectively, in the stream at the point of withdrawal. The turbidity of any receiving stream should not be increased by more than 25 Jackson turbidity units.

APPENDIX B. Radiological Results for Specific Sites

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Table B1
Air Site 1A, On-Site Station
(10^{-12} $\mu\text{Ci/ml}$)

	Number of Samples	Beta	Alpha
Jan	18	0.018	0.0010
Feb	15	0.025	0.0015
Mar	23	0.022	0.0017
Apr	21	0.027	0.0012
May	20	0.029	0.0014
Jun	20	0.028	0.0023
Jul	20	0.027	0.0009
Aug	20	0.037	0.0011
Sep	21	0.028	0.0008
Oct	21	0.119	0.0039
Nov	20	0.153	0.0044
Dec	18	0.094	0.0051
Total	237		
Average		0.051	0.0021
High		0.571	0.0343
Low		0.003	NDA

Table B2
Gamma Analysis Air Site 1A
On-Site Station
(10^{-15} $\mu\text{Ci/ml}$)

Quarter	Be-7	Ce-141	Ce-144	Cs-137	Nb-95	Ru-103	Zr-95
1	93.6	NDA	NDA	NDA	NDA	NDA	NDA
2	216.0	NDA	1.72	1.05	NDA	NDA	NDA
3	196.0	NDA	1.37	0.52	NDA	NDA	NDA
4	145.0	20.8	3.88	0.43	28.1	17.6	12.1
Average	163.0	5.20	1.74	0.50	7.03	4.40	3.03

Table B3
Air Site 2A, Off-Site Station
(10^{-12} $\mu\text{Ci/ml}$)

	Number of Samples	Beta	Alpha
Jan	16	0.024	0.0024
Feb	14	0.029	0.0016
Mar	21	0.027	0.0016
Apr	17	0.028	0.0017
May	14	0.028	0.0019
Jun	19	0.027	0.0017
Jul	20	0.030	0.0012
Aug	20	0.032	0.0017
Sep	17	0.024	0.0009
Oct	19	0.223	0.0056
Nov	22	0.169	0.0049
Dec	19	0.094	0.0044
Total	218		
Average		0.065	0.0025
High		1.700	0.0371
Low		0.005	NDA

Table B4
Gamma Analysis Air Site 2A
(10^{-15} $\mu\text{Ci/ml}$)

Quarter	Be-7	Ce-141	Ce-144	Cs-137	Nb-95	Ru-103	Zr-95
1	95.2	NDA	NDA	0.42	NDA	NDA	NDA
2	113.0	NDA	1.34	1.02	NDA	NDA	NDA
3	160.0	NDA	0.98	0.42	NDA	NDA	NDA
4	134.0	1.83	4.53	0.45	26.6	15.2	11.6
Average	126.0	4.57	1.71	0.58	6.65	3.80	2.90

Table B5
ALRR Stack Effluent
(10^{-12} μ Ci/ml)

	Number of Samples	Beta	Alpha
Jan	19	0.023	0.0014
Feb	18	0.0393	0.0023
Mar	23	0.0366	0.0026
Apr	19	0.0397	0.0021
May	20	0.0400	0.0014
Jun	21	0.0416	0.0016
Jul	21	0.0337	0.0009
Aug	20	0.0695	0.0018
Sep	21	0.0353	0.0010
Oct	21	0.1150	0.0024
Nov	20	0.0919	0.0026
Dec	19	0.0498	0.0027
Total	242		
Average			0.0019
High		0.665	0.0226
Low		0.008	NDA

Table B6
Gamma Analysis ALRR Stack Effluent
(10^{-15} μ Ci/ml)

Quarter	Be-7	Ce-141	Ce-144	Co-60	Cs-137	Nb-95	Ru-103	Zr-95
1	45.4	NDA	NDA	2.04	NDA	NDA	NDA	NDA
2	95.0	NDA	NDA	NDA	1.02	NDA	NDA	NDA
3	106.0	NDA	1.75	NDA	0.42	0.49	NDA	0.39
4	60.6	1.93	NDA	NDA	NDA	1.49	2.66	0.96
Average	76.7	0.48	0.44	0.51	0.36	0.49	3.35	0.34

Table B7
ALRR Outfall Activity (Map Site 2R)
($\mu\text{Ci}/\text{ml}$)

	Number of Samples	Beta 10^{-9}	Alpha 10^{-9}	Co-60 10^{-9}	Cs-137 10^{-9}	Number of Samples	Tritium 10^{-6}
Jan AM	20	6.79	0.03	NDA	NDA	20	7.38
PM	18	7.28	0.07	NDA	NDA	18	7.39
Feb AM	20	8.13	0.06	NDA	NDA	20	6.60
PM	20	8.10	0.04	0.21	NDA	20	6.03
Mar AM	23	6.45	0.02	NDA	NDA	23	4.60
PM	23	7.27	0.03	NDA	0.22	23	5.03
Apr AM	21	6.61	0.18	NDA	NDA	20	105.07
PM	21	6.33	0.16	NDA	NDA	21	8.10
May AM	20	4.90	0.05	NDA	NDA	20	6.38
PM	20	5.30	0.05	0.27	NDA	20	5.39
Jun AM	21	6.80	0.13	NDA	NDA	21	100.49
PM	21	6.99	0.06	NDA	NDA	21	7.44
Jul AM	20	6.43	0.07	NDA	NDA	20	22.18
PM	20	6.88	0.11	NDA	NDA	20	15.13
Aug AM	21	5.63	0.07	NDA	NDA	21	4.79
PM	20	6.30	0.10	NDA	NDA	20	6.10
Sep AM	21	6.47	0.11	NDA	NDA	21	237.75
PM	20	6.63	0.12	0.47	0.61	20	337.43
Oct AM	21	6.69	0.21	NDA	NDA	21	4.47
PM	21	6.73	0.07	NDA	0.14	21	4.46
Nov AM	20	5.57	0.12	0.15	NDA	20	3.75
PM	20	6.12	0.09	NDA	NDA	20	3.84
Dec AM	19	4.11	0.01	0.22	NDA	19	4.32
PM	17	4.92	0.04	NDA	NDA	17	4.67
Total	488					487	
Average		6.41	0.08	0.06	0.04		38.43
High		22.70	1.98	0.47	0.61		1987.0
Low		NDA	NDA	NDA	NDA		0.90

Table B8
River Site 1R
Upstream, Onion Creek Gulch (Drainage Ditch) (1-DD-U)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	0	Site Dry		0	
Feb	0	Site Dry		0	
Mar	3	1.98	0.04	3	3.94
Apr	4	1.76	0.24	4	3.38
May	4	1.07	0.12	4	4.28
Jun	5	1.52	0.08	5	6.06
Total	16			16	
Average		1.54	0.13		4.47
High		2.66	0.60		13.50
Low		0.49	NDA		2.83

Table B9
River Site 3R
Upstream, Onion Creek (3-On-U)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	1	7.61	0.30	1	2.47
Feb	2	9.28	0.75	2	2.67
Mar	5	6.54	1.11	5	2.69
Apr	4	3.95	0.66	4	1.27
May	4	2.83	0.26	4	1.95
Jun	5	4.63	0.55	5	1.74
Jul	4	4.04	0.59	4	1.35
Aug	0	Site Dry		0	
Sep	0	Site Dry		0	
Oct	0	Site Dry		0	
Nov	0	Site Dry		0	
Dec	0	Site Dry		0	
Total	25			25	
Average		5.01	0.64		1.93
High		13.87	2.40		5.67
Low		1.30	NDA		2.43

Table B10
River Site 4R
Downstream, Onion Creek (4-On-D)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	0			0	
Feb	2	4.55	0.75	2	1.98
Mar	4	4.97	0.89	4	2.53
Apr	4	4.73	0.62	4	1.57
May	4	2.96	0.26	4	2.13
Jun	4	4.00	0.51	4	7.23
Jul	5	5.78	0.75	5	1.44
Aug	0	Site Dry		0	
Sep	0	Site Dry		0	
Oct	0	Site Dry		0	
Nov	0	Site Dry		0	
Dec	0	Site Dry		0	
Total	23			23	
Average		4.55	0.62		2.83
High		10.27	1.20		24.48
Low		1.58	NDA		0.37

Table B11
River Site 5R
Upstream, Squaw Creek (5-Sq-U)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	4	4.63	0.17	4	1.39
Feb	4	3.55	0.48	4	2.25
Mar	5	7.92	0.66	5	2.65
Apr	4	5.43	0.86	4	1.26
May	4	4.29	0.51	4	1.96
Jun	4	5.79	0.89	4	2.28
Total	25			25	
Average		5.53	0.59		1.90
High		14.86	1.56		4.71
Low		2.66	NDA		0.56

Table B12
River Site 6R
Downstream, Squaw Creek (6-Sq-D)
($\mu\text{Ci/ml}$)

<u>Soluble Portion</u>					
	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	4	3.78	0.14	4	2.11
Feb	4	3.39	0.39	4	2.04
Mar	5	8.02	0.65	5	2.59
Apr	4	5.19	0.92	4	1.70
May	4	4.37	0.29	4	1.88
Jun	3	5.90	0.88	3	1.56
Total	24			24	
Average		5.44	0.56		2.02
High		14.95	1.80		4.46
Low		1.94	NDA		0.80

Table B13
River Site 7R
Upstream, Skunk River (7-Sk-U)
($\mu\text{Ci/ml}$)

<u>Soluble Portion</u>					
	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	4	6.08	0.39	4	2.21
Feb	4	4.85	0.26	4	2.03
Mar	5	10.40	1.01	5	2.55
Apr	4	7.15	0.89	4	1.40
May	4	5.28	0.32	4	1.97
Jun	4	6.48	0.72	4	1.86
Total	25			25	
Average		6.85	0.61		1.96
High		23.24	2.58		3.93
Low		3.56	NDA		0.69

Table B14
River Site 8R
Downstream, Skunk River (8-Sk-D)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	3	9.40	0.10	3	2.41
Feb	3	7.79	0.30	3	2.23
Mar	3	9.34	0.52	3	2.42
Apr	2	10.98	1.20	2	0.94
May	2	0.81	0.48	1	2.01
Jun	3	6.73	0.54	3	3.96
Jul	2	4.62	0.51	2	1.98
Aug	3	4.87	0.16	3	1.68
Sep	3	8.83	0.04	3	2.28
Oct	1	11.26	0.30	1	2.03
Nov	0	Site Dry		0	
Dec	0	Site Dry		0	
Total	25			25	
Average		7.40	0.39		2.28
High		18.33	1.56		10.09
Low		NDA	NDA		0.30

Table B15
River Site 9R
Control, Clear Creek (9-CC)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	1	5.45	NDA	1	3.55
Feb	1	5.68	0.36	1	2.21
Mar	4	5.05	0.26	4	2.21
Apr	4	3.96	0.89	4	1.78
May	3	2.03	NDA	3	2.41
Jun	4	3.54	0.63	4	1.66
Jul	4	3.98	0.39	4	1.41
Aug	0	Site Dry		0	
Sep	0	Site Dry		0	
Oct	0	Site Dry		0	
Nov	0	Site Dry		0	
Dec	0	Site Dry		0	
Total	21			21	
Average		3.87	0.42		1.96
High		5.99	1.26		4.54
Low		0.68	NDA		0.68

Table B16
River Site 10R
Control, Des Moines River (10-DM)
($\mu\text{Ci/ml}$)

<u>Soluble Portion</u>					
	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	4	6.59	0.18	4	
Feb	4	5.53	0.30	4	2.17
Mar	5	7.89	0.45	4	2.16
Apr	4	8.23	0.87	4	
May	4	5.92	0.36	4	2.83
Jun	4	6.68	0.74	4	2.06
Total	25			25	
Average		7.98	0.59		
High		17.46	1.62		5.60
Low		NDA	NDA		1.21

Table B17
River Site 11R
Ames Water Pollution Control Plant Effluent (11-Sk-S)
($\mu\text{Ci/ml}$)

<u>Soluble Portion</u>					
	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	4	14.38	0.03	4	2.93
Feb	4	15.09	0.09	4	2.77
Mar	4	8.84	0.03	4	2.55
Apr	4	11.09	0.30	4	2.45
May	4	9.09	0.12	5	3.26
Jun	4	7.25	0.08	3	2.17
Jul	5	10.15	0.13	5	1.80
Aug	4	10.99	0.23	4	1.97
Sep	5	12.23	0.12	5	4.26
Oct	4	16.06	0.23	4	3.07
Nov	4	13.84	0.18	4	2.29
Dec	5	12.42	0.14	5	1.58
Total	51			50	
Average		11.77	0.14		2.60
High		21.32	0.48		10.14
Low		NDA	NDA		1.06

No detectable gamma activity.

Table B18
Radioactivity in Wells
($\mu\text{Ci/ml}$)

Site	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Tritium, 10^{-6}
City	12	4.30	0.31	2.10
Martin	10	5.34	0.18	1.67
I.S.U.	8	3.91	0.34	1.61
Total	30			
Average		4.52	0.28	1.79
High		6.94	0.84	3.47
Low		2.43	NDA	0.96

No detectable gamma activity.

Table B19
Radioactivity in Ponds
($\mu\text{Ci/ml}$)

Site	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Tritium, 10^{-6}
Kelly	7	3.28	0.36	1.46
Todd	7	7.50	0.52	2.02
Walton	7	10.00	0.24	1.99
Total	21			
Average		6.92	0.37	1.82
High		15.00	1.08	3.63
Low		1.56	NDA	1.13

No detectable gamma activity.

Table B20
Radioactivity in Precipitation
($\mu\text{Ci/ml}$)

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	0			0	
Feb	1	19.19	2.22	1	3.45
Mar	1	9.18	0.83	1	3.99
Apr	3	4.81	0.87	3	1.00
May	2	4.10	0.79	2	2.36
Jun	1	5.10	0.22	1	0.90
Jul	1	4.93	0.32	1	1.33
Aug	1	2.18	0.43	1	2.04
Sep	0			0	
Oct	1	28.23	4.51	0	
Nov	1	104.3	8.13	1	6.79
Dec	0			0	
Total	12			11	
Average		16.31	1.74		2.11
High		104.3	8.13		6.79
Low		2.09	NDA		0.09

Table B21
Gamma Analysis of Precipitation
($10^{-9} \mu\text{Ci/ml}$)

Quarter	Volume (liters)	Ba-140	Be-7	Ce-141	Cs-137	La-140	Nb-95	Ru-103	Zr-95
1	2.31	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA
2	11.0	NDA	NDA	NDA	NDA	NDA	NDA	NDA	NDA
3	1.92	NDA	NDA	NDA	8.98	NDA	NDA	NDA	NDA
4	0.930	12.3	44.2	9.09	1.99	665.0	15.2	13.7	7.74
Average		3.08	11.1	2.27	2.74	166.3	3.83	3.43	1.94

Table B22
Radioactivity in Bottom Sediment
($\mu\text{Ci/g}$)

Site	Number of Samples	Beta, 10^{-6}	Alpha, 10^{-6}
<u>Upstream</u>			
1-DD-U	3	7.15	0.32
3-On-U	3	6.84	0.13
5-Sq-U	2	7.53	0.29
7-Sk-U	2	7.33	0.29
Total	10		
Average		7.34	0.29
High		8.71	0.67
Low		5.89	0.12
<u>Downstream</u>			
Outfall	2	8.34	0.44
2F-DD-D	1	7.80	0.23
4-On-D	3	6.55	0.19
6-Sq-D	2	7.29	0.24
8-Sk-D	3	7.59	0.38
Total	10		
Average		7.60	0.30
High		9.55	0.69
Low		5.23	0.11
<u>Control</u>			
9-CC	3	5.72	0.29
10-DM	2	6.91	0.27
Total	5		
Average		6.19	0.28
High		8.86	0.41
Low		5.08	0.06
<u>Ponds</u>			
Kelley	2	11.01	0.75
Todd	2	9.80	0.74
Walton	2	7.91	0.41
Total	6		
Average		9.57	0.63
High		13.19	0.96
Low		7.15	0.14

Table B23
Gamma Analysis of Bottom Sediment
(10^{-9} $\mu\text{Ci/gm}$)

Upstream Site	Number of Samples	Cs-137	Downstream Site	Number of Samples	Cs-137	
1-DD-U	2	15.7	Outfall	4	93.4	
3-On-U	4	5.50	2F-DD-D	3	63.4	
5-Sq-U	2	13.70	4-On-D	4	17.4	
7-Sk-U	2	29.10	6-Sq-D	2	7.05	
			8-Sk-D	4	36.45	
Total	10			17		
Average		13.9			46.7	
High		52.2			207.0	
Low		22.0			14.1	
Control Site			Pond Site			
9-CC	4	25.5	Kelley	4	596*	
10-DM	2	93.4	Todd	2	152.0	
			Walton	2	83.6	
Total	6			8		
Average		48.1			357.0	
High		139.0			2220.0	
Low		24.1			47.9	
Outfall	Ag-110m	Ce-144	Co-60	Nb-95	Ru-103	Zn-95
Average	31.3	225	55.1	41.3	9.05	20.6
High	80.8	544	157.0	165.0	36.2	82.2
Low	44.2	357	63.3	165.0	36.2	82.2

*This site average includes a sample anomaly observed in the first quarter sediment analysis. A resample of the site and one 100 feet (30.5 m) from this sample point could not reproduce the high reading indicated in the pond site summary.

APPENDIX C. Non-Radiological Results for Specific Sites

Table C1
Chemical Analysis
ALRR Outfall (Map Site)

	Number of Samples	Average mg/l		
		Cl ⁻	Cr ⁺⁶	Zn ⁺²
Jan	4	1054	0.45	0.12
Feb	4	991	0.64	0.17
Mar	5	1112	0.26	0.12
Apr	4	166	0.09	0.07
May	3	307	0.16	0.05
Jun	5	325	0.44	0.04
Jul	3	539	0.09	0.05
Aug	4	1025	0.23	0.13
Sep	5	753	0.11	0.06
Oct	4	597	0.70	0.05
Nov	3	667	0.15	0.03
Dec	4	381	0.77	0.05
Total	48			
Average		674	0.35	0.08
High		3604	1.75	0.35
Low		30	0.01	0.00

Table C2
pH and Temperature
ALRR Outfall (Map Site)

	pH				Temperature, °C			
	Number	Ave	High	Low	Number	Ave	High	Low
Jan	38	8.0	8.7	6.8	20	18	25	8
Feb	40	7.8	9.0	6.8	20	20	24	15
Mar	44	7.9	8.5	6.5	24	20	24	16
Apr	40	7.9	8.9	6.5	21	20	24	17
May	39	7.7	8.2	6.4	19	21	22	18
Jun	43	7.3	8.2	6.8	22	22	28	19
Jul	40	7.4	8.5	6.3	20	27	29	22
Aug	39	7.9	8.6	6.8	20	27	30	23
Sep	39	7.9	8.5	6.3	20	26	28	24
Oct	38	7.9	8.2	7.4	19	23	27	20
Nov	40	7.9	8.6	7.2	19	20	25	13
Dec	35	7.6	8.8	2.9	17	17	23	10
Total	475				240			
Average		7.8				22		
High		9.0				30		
Low		2.9				8		

Table C3
Flow, Biochemical Oxygen Demand and Fecal Coliform Count
ALRR Outfall (Map Site)

Flow, l/min					BOD		Fecal Coliform	
	Number	Ave	High	Low	Number	mg/l	Number	Counts/100 ml
Jan	10	48	60	8	1	1.6	1	40
Feb	8	40	120	5	1	1.5	1	2
Mar	9	80	231	10	1	2.3	1	94
Apr	13	117	750	8	1	1.0	1	49
May	18	83	375	12	1	2.5	1	384
Jun	22	83	500	8	1	2.1	1	340
Jul	20	62	273	10			1	1000
Aug	20	26	167	12	1	2.0	1	30
Sep	20	81	375	16	1	2.5	1	65
Oct	18	57	273	24	1	1.0	1	15
Nov	17	50	231	7	1	1.4	1	84
Dec	16	69	187	11	1	1.0	1	55
Total	19				11		12	
Average		67				1.71		180
High		750				2.5		1000
Low		5				1.0		2

Table C4
pH and Cr⁺⁶ Concentrations
Onion Creek, Upstream (3R) and Downstream (4R)

	pH			Cr ⁺⁶ , mg/l		
	Number of Samples	Upstream Site 3R	Downstream Site 4R	Number of Samples	Upstream Site 3R	Downstream Site 4R
Jan	dry			dry		
Feb	dry			dry		
Mar	3	8.2	8.3	3	0.02	0.02
Apr	3	8.4	8.4	3	0.02	0.02
May	4	7.9	7.8	4	0.02	0.02
Jun	4	7.7	7.8	4	0.02	0.02
Jul	3	8.2	8.2	3	0.01	0.03
Aug	dry			dry		
Sep	dry			dry		
Oct	dry			dry		
Nov	dry			dry		
Dec	dry			dry		
Total	17			17		
Average		8.0	8.0		0.02	0.02
High		8.9	9.0		0.025	0.05
Low		7.0	7.4		0.0	0.0

APPENDIX D. Environmental Monitoring Program Sample Changes

Table D1
Sample Points Prior to July 1, 1976

AIR

<u>Figure Reference</u>	<u>Symbol</u>	
1	1A	The on-site monitoring station is located approximately 400 feet south of the reactor.
2	2A	The off-site monitoring station is located on the Spedding Hall roof approximately one mile southeast of the reactor.

RIVER AND BOTTOM SEDIMENT

<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
1,2	1R	1-DD-U	This on-site sampling point is located just above the mixing zone of the outfall in Onion Creek Gulch.
1,2	2R	Outfall	This site is the outfall and is listed as such. The bottom sediment sample is just below the outfall point in Onion Creek Gulch.
2	3R	3-On-U	This site is in Onion Creek upstream from confluence with Onion Creek Gulch.
2	4R	4-On-D	Site is approximately 1000 feet downstream from confluence point in Onion Creek.
2	5R	5-Sq-U	Site is in Squaw Creek upstream from the confluence with Onion Creek.
2	6R	6-Sq-D	Site is in Squaw Creek downstream from the Onion Creek confluence.
3	7R	7-Sk-U	Site is in the Skunk River upstream from the Squaw Creek confluence.
3	8R	8-Sk-D	Site is in the Skunk River downstream from the Squaw Creek confluence.
2	9R	9-CC	This control site is located outside the flow pattern of ALRR effluent in Clear Creek.
3	10R	10-DM	This control site is located approximately 15 miles west of the reactor in the Des Moines River.
3	11R	11-Sk-S	This is a sample of the Ames Water Pollution Control Plant effluent.

Table D1 Continued

SOIL & VEGETATION

The 24 soil and vegetation sampling sites consists of six groups. Each succeeding group is further away from the ALRR, Group 1 being the nearest to the reactor. Four sites, each in a different direction (northwest, northeast, southwest, southeast) make up each group.

	<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
Group 1:	1,2	1S	1S-SE1	Soil site, southeast
	2	2S	2S-SW1	Soil site, southwest
	1	3S	3SV-NW1	Soil and vegetation site, northwest
	1	4S	4S-NE1	Soil site, northeast
Group 2:	2	5S	5S-SE2	Soil site, southeast
	2	6S	6S-SW2	Soil site, southwest
	2	7S	7S-NW2	Soil site, northwest
	2	8S	8S-NE2	Soil site, northeast
Group 3:	2	9SV	9SV-SE3	Soil and vegetation site, southeast
	2	10SV	10SV-SW3	Soil and vegetation site, southwest
	2	11SV	11SV-NW3	Soil and vegetation site, northwest
	2	12SV	12SV-NE3	Soil and vegetation site, northeast
Group 4:	2	13SV	13SV-SE4	Soil and vegetation site, southeast
	2	14S	14S-SW4	Soil site, southwest
	2	15SV	15SV-NW4	Soil and vegetation site, northwest
	2	16S	16S-NE4	Soil site, northeast
Group 5:	3	17SV	17SV-SE5	Soil and vegetation site, southeast
	3	18S	18S-SW5	Soil site, southwest
	3	19SV	19SV-NW5	Soil and vegetation site, northwest
	3	20S	20S-NE5	Soil site, northeast

Table D1 Continued

	<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
Group 6:	3	21SV	21SV-SE6	Soil and vegetation site, southeast
	3	22SV	22SV-SW6	Soil and vegetation site, southwest
	3	23S	23S-NW6	Soil site, northwest
	3	24SV	24SV-NE6	Soil and vegetation site, northeast

PONDS AND WELLS

<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
3	1P	Todd	The George Todd pond site is located four miles northeast of the ALRR.
3	2P	Walton	The Izaak Walton League pond site is located three miles east of the ALRR.
3	3P	Kelley	The Kelley pond site is located six miles south of the ALRR.
3	1W	City	The water wells for the City of Ames are all located east of Squaw Creek. The location indicated is the water treatment plant.
2	2W	I.S.U.	The Iowa State University wells are located west of Squaw Creek.
2	3W	Martin	The Martin site is a private farm well located two miles north of the ALRR.

Table D2
Sample Points after July 1, 1976

AIR

<u>Figure Reference</u>	<u>Map Symbol</u>	
1,5	1A	The on-site monitoring station is located approximately 400 feet (122 m) south of the reactor.
2,6	2A	The off-site monitoring station is located on the Spedding Hall roof approximately one mile (1.6 Km) southeast of the reactor.

RIVER AND BOTTOM SEDIMENT

<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
1,2,5,6	1R	1-DD-U	This on-site sampling point is located just above the mixing zone of the outfall in Onion Creek Gulch.
1,2,5,6	2R	Outfall	This site is the outfall and is listed as such. The bottom sediment sample is just below the outfall point in Onion Creek Gulch.
1,2,5,6	2F	Fence	Site is approximately 300 feet (91 m) downstream from outfall point at Reactor site boundary fence.
2,5,6	3R	3-On-U	This site is in Onion Creek upstream from confluence with Onion Creek Gulch.
2,5,6	4R	4-On-D	Site is approximately 1000 feet (305 m) downstream from confluence point in Onion Creek.
3,7	8R	8-Sk-D	Site is in the Skunk River downstream from the Squaw Creek confluence.
2,5,6	9R	9-CC	This control site is located outside the flow pattern of ALRR effluent in Clear Creek.
3,6	11R	11-Sk-S	This is a sample of the Ames Water Pollution Control Plant effluent.

Table D2 Continued

WELLS

<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
3,6	1W	City	The water wells for the City of Ames are all located east of Squaw Creek. The location indicated is the water treatment plant.
2,6	2W	I.S.U.	The Iowa State University wells are located west of Squaw Creek.
2,6	3W	Martin	The Martin site is a private farm well located two miles (3.2 Km) north of the ALRR.