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SAVANNAH RIVER LABORATORY QUARTERLY REPORT

JULY - SEPTEMBER 1975

HYDROGEOCHEMICAL AND STREAM SEDIMENT RECONNAISSANCE - EASTERN UNITED STATES

NATIONAL URANIUM RESOURCE EVALUATION PROGRAM

MASTER

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Savannah River Laboratory
Aiken, South Carolina 29801

PREPARED FOR THE U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION UNDER CONTRACT AT(07-2)-1

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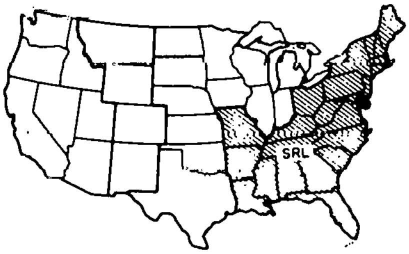
FOREWORD

This progress report is the third in the DPST-75-138 series summarizing accomplishments, status, and program of the Savannah River Laboratory (SRL) contribution to the National Uranium Resource Evaluation (NURE) program. The results and conclusions reported here are preliminary; formal reports on specific topics will be issued when appropriate.

The NURE program was begun in the spring of 1973 to stimulate commercial uranium exploration in an attempt to meet the rapidly increasing national demand for uranium. This program was established to evaluate domestic uranium resources in the continental United States and to identify areas favorable for uranium exploration. The Grand Junction Office of the Energy Research and Development Administration (ERDA) is responsible for administering and coordinating NURE program efforts. Inputs to the NURE program come from ERDA prime contractors, ERDA-sponsored research and development, the uranium industry, U.S. Geological Survey (USGS), U.S. Bureau of Mines (BuMines), other government agencies, and independent sources.

In 1975, SRL accepted responsibility for hydrogeochemical and stream sediment reconnaissance surveys of twenty-five states in the eastern United States. Oak Ridge Gaseous Diffusion Plant (ORGDP), Los Alamos Scientific Laboratory (LASL), and Lawrence Livermore Laboratory (LLL) have accepted responsibility for similar reconnaissance surveys in the rest of the continental United States including Alaska. Variations in uranium and pathfinder elements in surface and underground waters and stream sediments will be systematically determined as guides for uranium search.



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STATUS AND PROGRAM

HIGHLIGHTS OF FIRST QUARTER FY-1976

Field Data and Sample Collection

- Design and fabrication of field equipment were completed.
- Equipment of SRL design currently in use includes two types of sediment samplers, a pressure filtration system, a fission foil package and field evaporator, and a backpack that converts into a field work table.
- Types of samples and field measurements to be obtained were defined and field procedures were written.
- Sample identification procedures were defined.
- Sixteen hundred orientation sites were selected and marked on topographic maps.
- Field concentration of dissolved solids using ion exchange resin was developed. A batch system using specially prepared mixed cation and anion resin was shown to give 99.9% recovery of uranium in 15 minutes.
- A "pre-orientation" study was completed to define quantitatively components of variability. Preliminary statistical treatment indicates that sieve size, stream size, and geographic location are highly significant factors. Variability due to personnel is not significant if good technique is used. However, carefully planned sampling procedures are required to minimize variability.
- Orientation studies are in progress in six states. Sampling was completed in the Texas Coastal Plain, Georgia Piedmont, and the North and South Carolina Blue Ridge, and is under way in the North Carolina Inner Piedmont, Slate Belt, and Triassic. Approximately 1000 of an anticipated 1600 sites were sampled, producing about 4000 samples and over 10,000 onsite measurements.

Laboratory Analyses

- A "Class 100" clean receiving laboratory was installed and is operational. Sample preparation procedures are being developed.

- The Pilot Scale Reactor Activation Facility (PSRAF) was installed in a production reactor and is operational. The facility is capable of performing multi-element analyses on 80 samples per day (2-shift operation). Sensitivity for uranium dissolved in water is 0.6 ppb.

- The ^{252}Cf facility was upgraded from 25 mg to ∿100 mg ^{252}Cf, and moderator design was improved for greater efficiency. The facility became operational in July and has been used for rock analyses in screening potential orientation study sites. Sensitivity for uranium is about 0.5 ppm, and up to 50 elements can be analyzed at the 10 ppm level.

- Evaluation of uranium fluorimetry, automated fission-track recording, and freeze-drying concentration techniques is in progress.

Data Management, Analysis, and Interpretation

- Detailed design of the SRL-NURE data file was completed, and programming is in progress.

- A digitizing tablet for automatically entering map information and a 35-mm microfilm camera and enlarger system for producing computer-generated map overlays were ordered.

- Formats for field data sheets for orientation studies were defined.

PROGRAM FOR FY-1976

The proposed program for the rest of FY-1976 is summarized in Figure 1. Details are given below.

Field Data and Sample Collection

Second Quarter FY-1976

- Complete major orientation sampling; begin evaluation of seasonal effects on hydrogeochemistry of uranium.
- Complete variability study, including interpretation of results and identification of sampling procedures leading to lowest variability.
- Begin correlation of orientation data.
- Make initial contacts with potential subcontractors and local universities.
- Begin publishing results of orientation studies.
- Evaluate existing radiological well data for South Carolina.

Third Quarter FY-1976

- Continue evaluation of seasonal effects.
- Identify necessary field measurements and types of samples for wide area sampling; define procedures.
- Order necessary field equipment and supplies for wide area survey.
- Begin development of detailed geological models from orientation data.
- Identify useful hydrogeochemical indicators and means to correct for local geology (geologic controls).
- Detail sample collection program for wide area survey.
- Evaluate cost-effectiveness of well-sampling and utility to overall program.

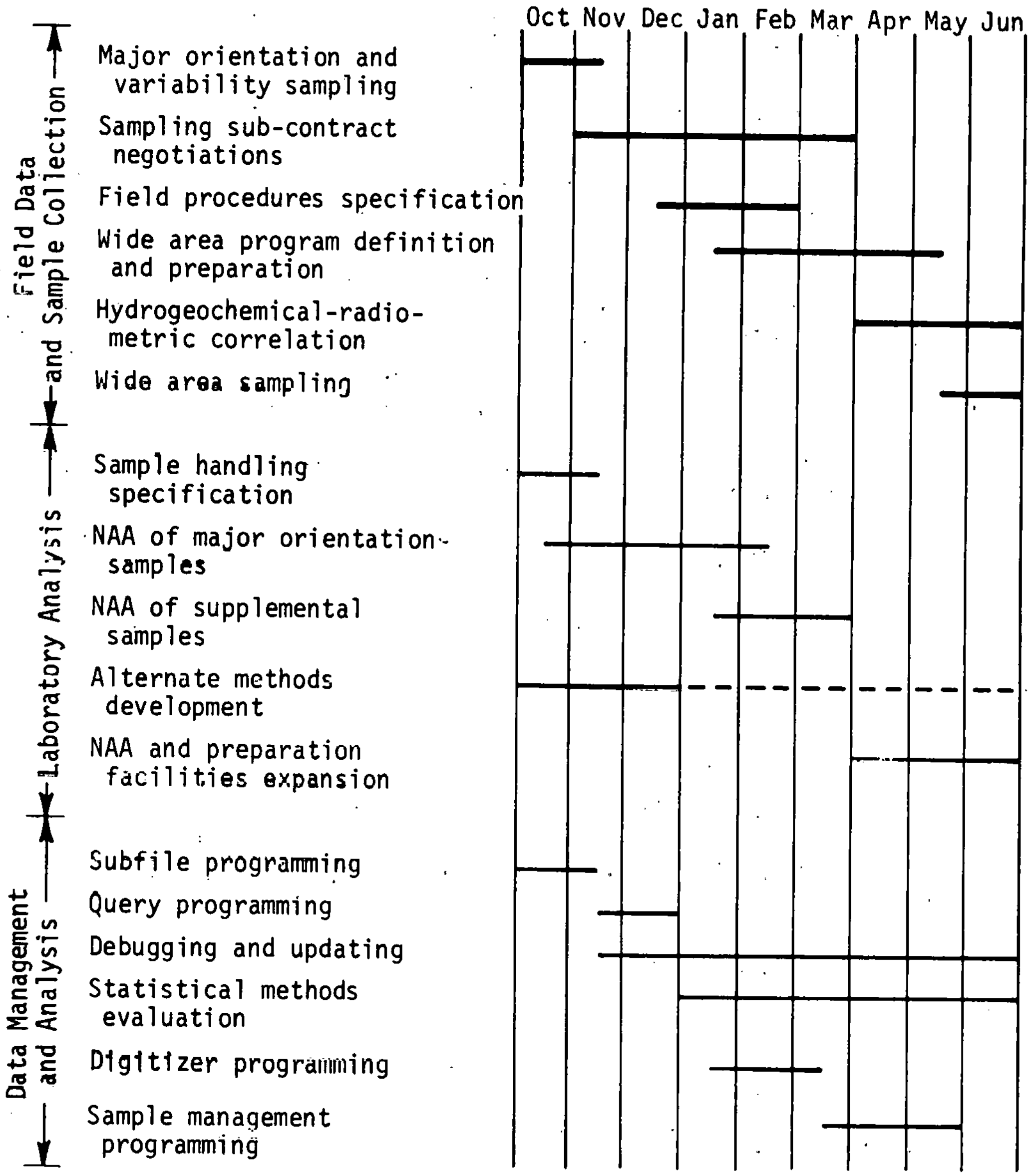


FIGURE 1. Main Program Items for FY-1976

Fourth Quarter FY-1976

- Complete determination of size and intensity of halos for each province.
- Complete specifying sites for surface water collection.
- Define sampling pattern for ground water sample collection.
- Begin correlation of hydrogeochemical data with ERDA aeroradiometric data.
- Complete writing contracts and begin wide area sampling.
- Complete development of geological models.

Laboratory Analyses

Second Quarter FY-1976

- Specify sample receiving, preparation, cataloging, and storage procedures.
- Continue evaluation of backup and quality control techniques, including fluorimetric, freeze-drying, and automated fission-track recording techniques.
- Complete debugging of data reduction programs.
- Begin analysis of orientation samples in Pilot Scale Reactor Activation Facility (PSRAF).
- Define design criteria for upgrading PSRAF; specify data acquisition system and components of pneumatic transport system.

Third Quarter FY-1976

- Complete neutron activation analysis of major orientation samples.

Fourth Quarter FY-1976

- Expand clean facility as required based on orientation study experience.
- Begin expansion of PSRAF capacity from 10,000 to 60,000 samples per year.
- Begin analyzing wide area samples in PSRAF.

Data Management, Analysis, and Interpretation

Second Quarter FY-1976

- Define procedures to correct input errors.
- Complete writing programs for creation of subfiles and for initial interrogation of the data file.
- Complete programming for input of spectral data tapes.

Third Quarter FY-1976

- Begin input of sampling and geological data using digitizing tablet.
- Begin evaluation of computer-generated microfiche for producing overlays.
- Complete initial programming for statistical and mathematical enhancement of anomalies and evaluate with synthetic data.
- Complete programming to interface the data file with the SRL JOSHUA computational system including selection, extraction, and reformatting. (This will be required for detailed interrogation of the data file.)
- Refine program for creating subfiles.

Fourth Quarter FY-1976

- Evaluate automated site selection.
- Continue evaluations of statistical and mathematical methods using authentic data.

FIELD DATA AND SAMPLE COLLECTION

PROGRAM FORMULATION AND PLANNING

The fundamental strategy of the SRL hydrogeochemical program is to maximize the likelihood of finding areas favorable for commercial uranium exploration. The approach is to develop techniques to locate anomalies in surface water, stream sediments, and ground water which may indicate deposits of commercial interest.

The orientation studies now in progress are designed to identify the most effective hydrogeochemical, computational, and analytical techniques for use in the reconnaissance survey.

DEVELOPMENT OF FIELD TECHNOLOGY

Field Analytical and Sampling Equipment

After several modifications, the final design and fabrication of two types of stream sediment samplers have been completed. Both types of sediment samplers have been field-tested and issued to all orientation sampling teams.

The drag sampler consists of a stainless steel tube with an attached bail, band clamp, and removable drill bag (Figure 2). The attachment point of the bail was carefully selected to force the sampling element down into the sediment as the bail rope is pulled. A drill-cloth bag for collecting ore samples (Hutchinson Bag Corporation, Hutchinson, Kansas) was selected from the many available types of bags because of its high wet-strength and extremely tight weave. After the cotton threads become wet, this bag will retain even clay-sized sediments. The cloth of the bag contains no sizing or other additives which might contaminate the sample.

The drag sampler was designed primarily for sampling sand or silt sediments. It is thrown slightly across- and downstream and then dragged upstream against the flow. This technique keeps even very fine silt in the bag and effectively integrates the mid-channel of the stream. (Supporting data are given under the "Variability Study" section.)

The spring-loaded ("clam shell") sampler (Figure 3) is constructed of 6061 aluminum alloy with a stainless-steel reinforced lip. The spring-loaded lid is larger than the lower

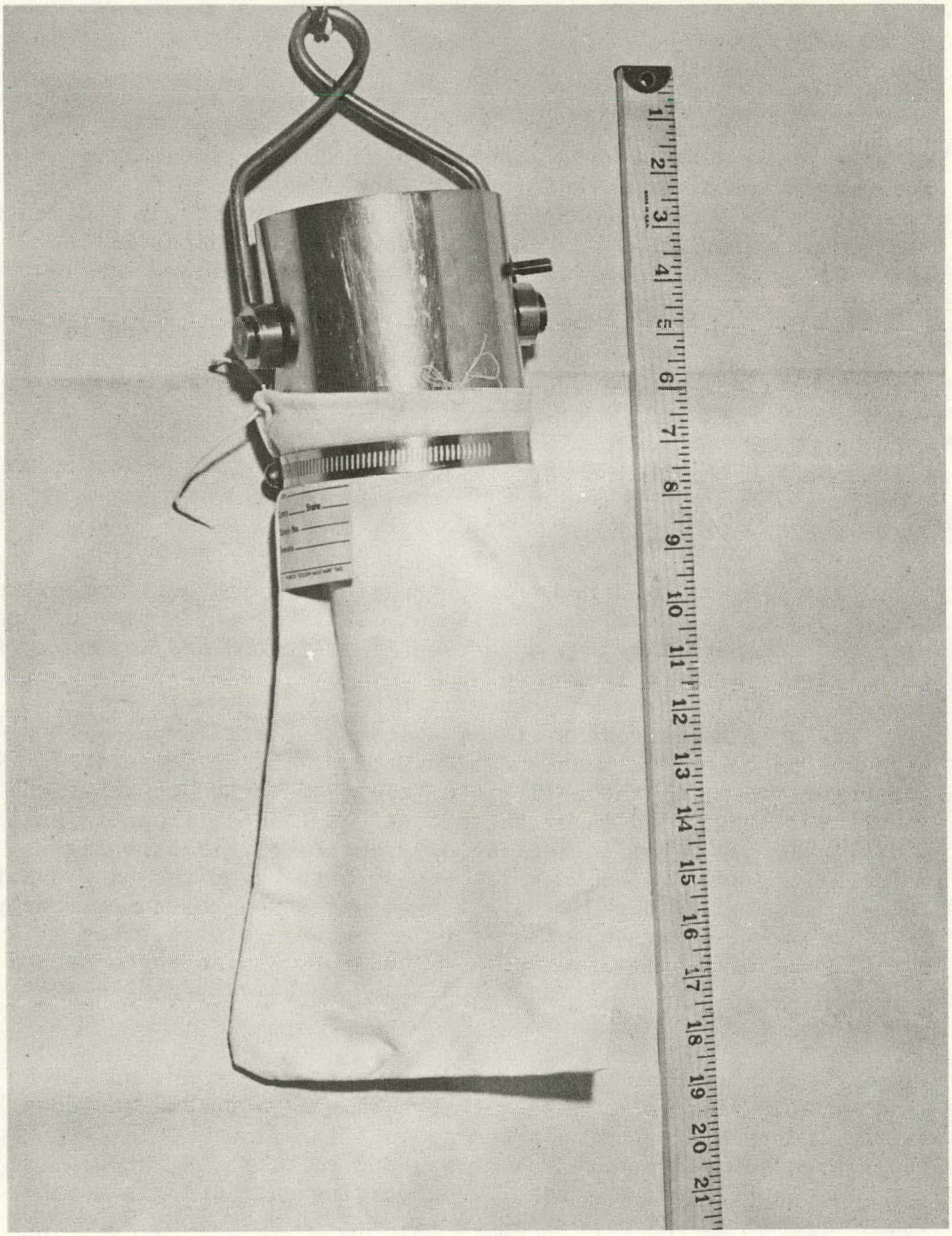


FIGURE 2. Drag Sediment Sampler

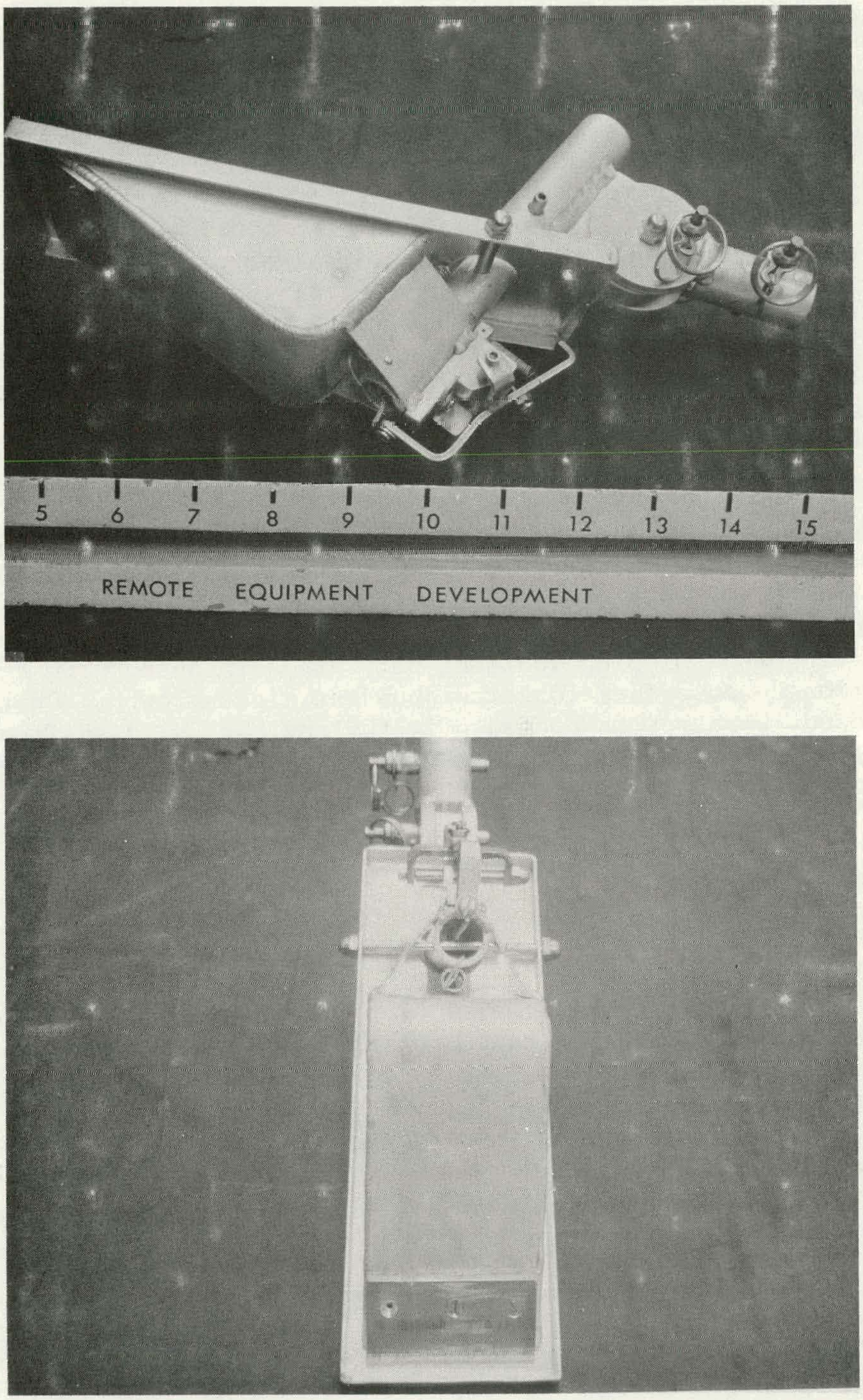


FIGURE 3. Spring-Loaded Sediment Scoop Sampler

scoop lip and has an overhanging edge. This allows the lid to seal the sediment sample in the lower scoop without loss of fines, even in fast-flowing streams. The "clam shell" scoop can be extended up to 12 feet by attaching hollow six-foot fiberglass poles, which double as walking staffs. The attachment angle of the scoop can be varied from 90° to 180° for use under conditions ranging from clay through silt and sand to rocky bottoms.

To reduce the weight of sediment that an orientation team must carry to base camp, each gross sediment sample is wet-screened at the sampling site. (This practice saves up to 50 pounds per team daily.) The -40 mesh sediment is collected in the bottom pan and is recovered from the water by pouring through a wet drill sample bag and squeezing dry. The moist sediment is then scooped out of the cloth bag and packaged in a special high wet-strength Kraft paper envelope (Skyline Labs, Inc., Wheat Ridge, Colorado) for transportation to the laboratory for analysis. The envelope is very strong, lightweight, and noncontaminating and allows the sample to continue drying without mildew or algae growth. These envelopes were specifically designed for packaging sediment for geochemical surveys. Polyethylene bags were evaluated for storing and shipping sediment but were eliminated from consideration because they fostered abundant algae growth. On the other hand, porous spun-bonded polyethylene bags allowed fines to escape. These specially processed envelopes appeared to offer the best combination of porosity with retention of fines.

The field filtration system being used in orientation studies consists of a two-liter aluminum reservoir lined with polytetrafluoroethylene which is pressurized to 40 psig with a fluorocarbon gas (Figure 4). All surfaces in contact with the water except the polycarbonate filter are polytetrafluoroethylene. *Nuclepore* 0.8 μm filters (General Electric Company, Schenectady, New York) are used because they are inert, lightweight, and vary less than 10 mg in weight. (These properties are important because suspended solids collected on the filter membrane will be analyzed directly by activation analysis.) In general, one liter of filtered water can be obtained in 1 to 5 minutes, and a second liter can be recovered in an additional 10 to 30 minutes.

Because of their light weight and compactness, *Mini Spec 20*® spectrophotometers (Bauch and Lomb, Rochester, New York) are being used for field analysis. Detailed procedures have been defined for analyzing phosphate, nitrate, ammonia, and sulfate. Total alkalinity is determined by titration. With a day's practice, the entire sequence of analyses can readily be completed by one worker in 20 minutes.

The *Mini Spec 20*® and the pressure filtration assembly are attached to a specially designed, high-strength, aluminum sheet

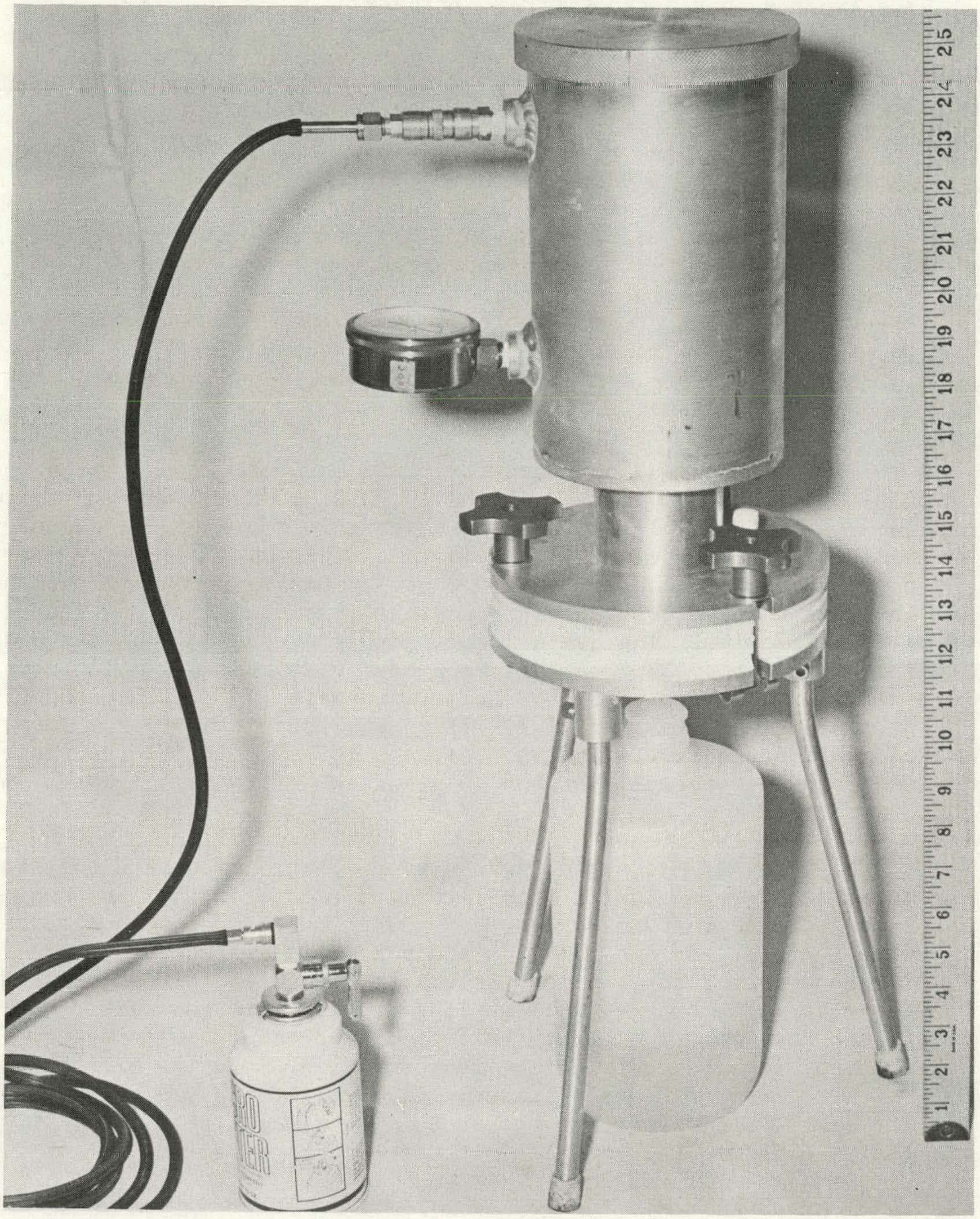


FIGURE 4. Filtration Assembly

constructed on a backpack frame (Figure 5). The aluminum sheet can be swung up from the backpack and made into a field work table using the frame itself and a detachable tripod as legs (Figure 6). The total weight including the backpack is 30 pounds.

The *Martek Mark V®* (Martek Instruments, Inc., Newport Beach, California) and the *Hydrolab* (Hydrolab Corp., Austin, Texas) water quality analyzers were used in orientation studies. Martek Instruments, Inc. modified the *Mark V®* to measure Eh as well as pH, specific conductivity, dissolved oxygen, and temperature. The *Martek* unit was selected for cross-country use because it is considerably smaller and lighter. The *Hydrolab* unit was more rugged and stable in extended use. The *Martek Mark V®* is carried in a backpack along with the sediment sampling and screening equipment and support gear. This backpack and gear weighs 31 pounds.

Ion-selective electrodes for field use were investigated for determination of CO_3^{2-}, PO_4^{3-}, SO_4^{2-}, and NO_3^-. Only the nitrate ion electrode (Model 93-07, Orion Research, Cambridge, Massachusetts) was judged satisfactory for field use. The lower limit for nitrate determination is about 10^{-5}M (0.6 ppm). Data given by the vendor indicate that interferences from other ions should not constitute a major problem. The overall accuracy is expected to be $\geqslant \pm 30\%$. The nitrate ion electrode gave reproducible readings, which were stable within five minutes. Calibrations at 10^{-3}, 10^{-4}, and 10^{-5}M NO_3^- made two days apart fell within 5 mV of one another. The slope is not quite Nernstian: between 10^{-4} and 10^{-3}M, the slope was 62 mV per decade; between 10^{-4} and 10^{-6}M, the slope was 54 mV per decade.

Carbonate, phosphate, and sulfate electrodes were unsatisfactory. They were slow to stabilize, and the potential would unexpectedly shift 20 mV or so to a new voltage level when electrodes were taken out of one solution and placed in another or after standing unused for a time. Once a stable potential was reached, the electrodes behaved well as long as they were maintained wet and in the same solution. But the abrupt, unpredictable change, coupled with the poor initial response time, make the electrodes unsuited for field application. All three of these electrodes have the same (Pb^{2+}) basis for response. The kind of behavior observed is typical and probably not subject to correction at the present state of the art.

Fission-track techniques were further developed for determination of 0.001 to 1.0 ppb uranium. In the field, a 50 $\mu\ell$ sample of water is spotted onto a piece of 10-μm-thick polycarbonate foil held between two concentric plastic rings (Figure 7) and evaporated using a specially designed "oven" employing a standard hand warmer. Fission foil samples were collected at all

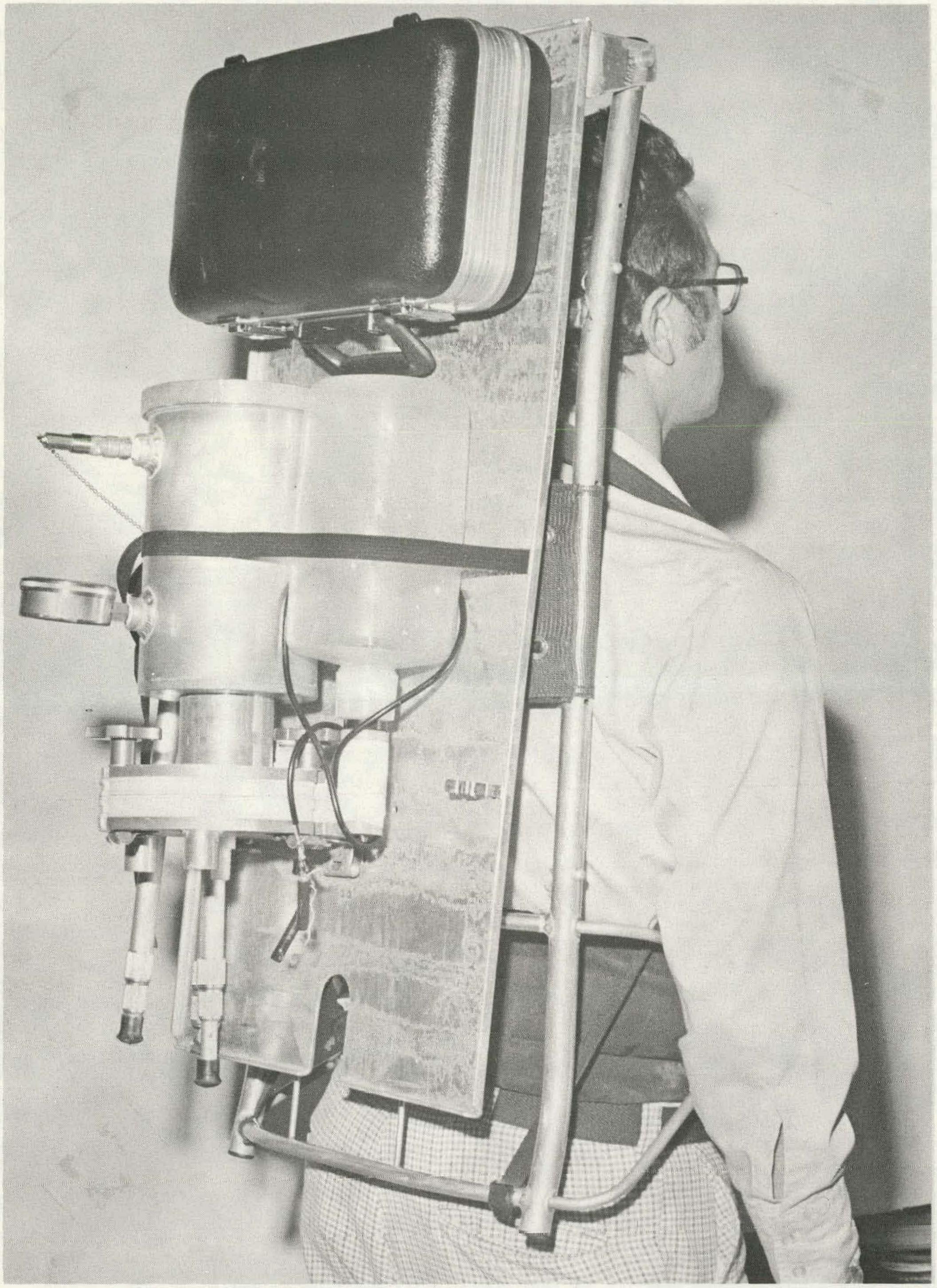


FIGURE 5. Backpack for Spectrophotometer and Filter Apparatus

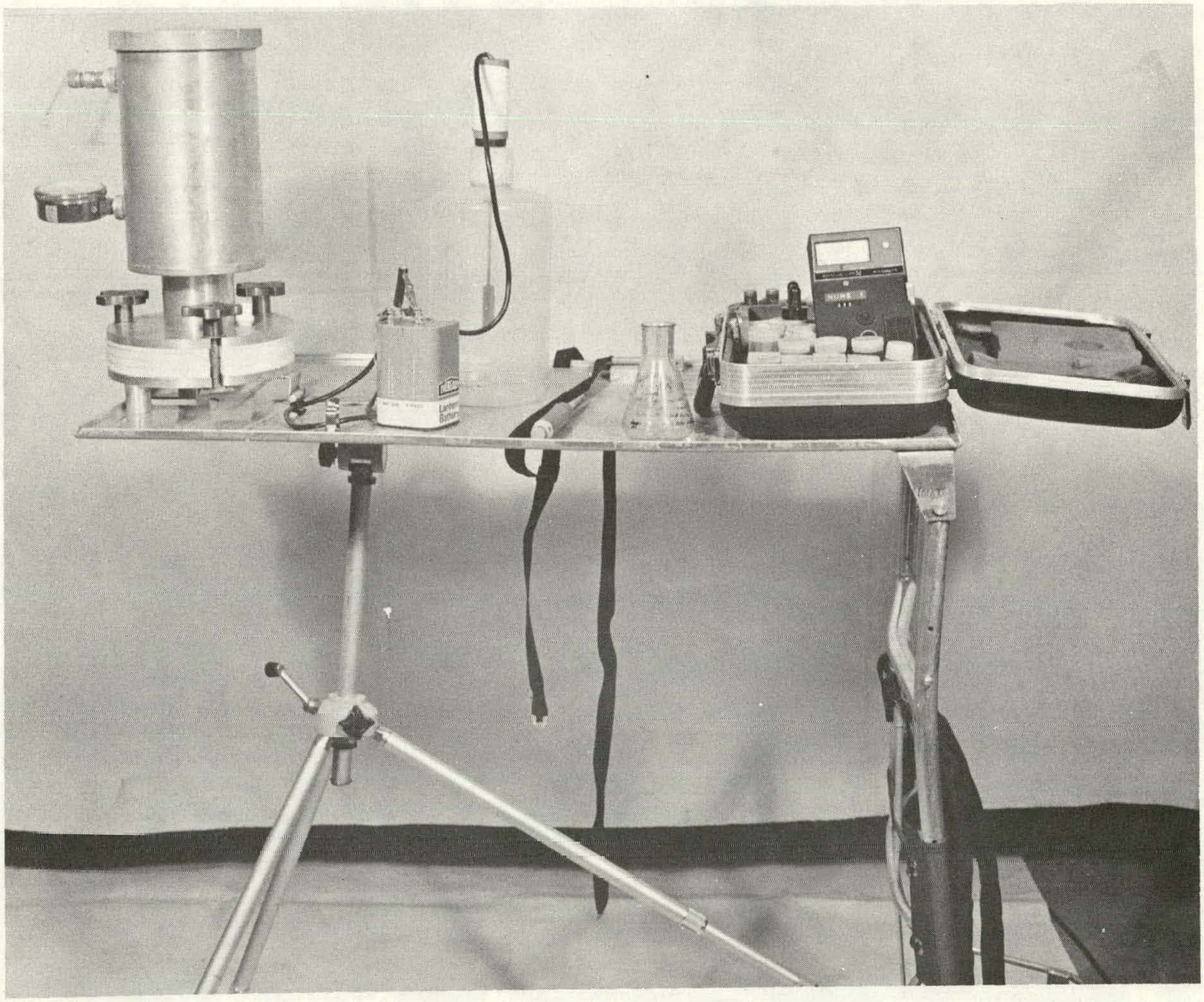


FIGURE 6. Field Work Table

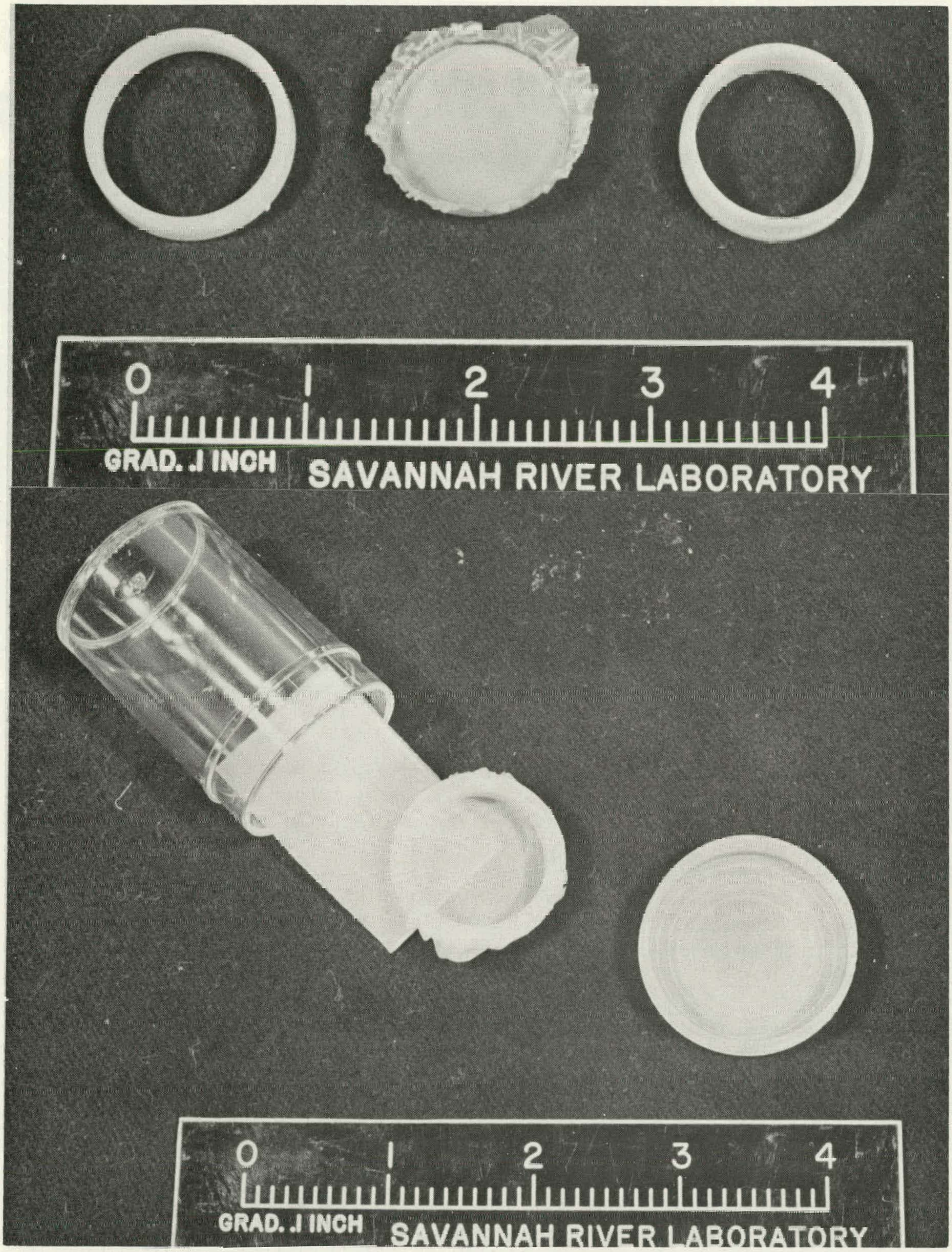


FIGURE 7. Fission Foils Adaptable for Semi-Automated Counting

orientation sites to be used as backup samples to the concentrated samples collected on ion-exchange resin.

Ion Exchange Concentration

The detection limit for uranium in the SRL neutron activation analysis facility is about 0.6 ppb. Discussions with outside agencies and limited experimental data indicate that detection limits as low as 0.01 ppb dissolved uranium may be required to recognize uranium dispersion halos under some geological conditions. Uranium must be concentrated 50- to 100-fold to achieve 0.01 ppb sensitivity. Field concentration using ion exchange is being developed to achieve this sensitivity.

Initial uranium extraction tests were run in ion exchange columns with filtered water from a stream containing 1 to 2 ppb of dissolved uranium. Uranium analyses were done by fission-track counting. Four types of columns were tested, each of which was 1 cm in diameter and 10 cm long. Columns were filled with 200 to 400 mesh cation and anion exchange resins, and mixtures of the two resins. Up to 99% recovery of uranium was observed, but flows through all of the columns were quite slow. Even under a 10-foot head two to five hours were required to pass a liter of water through each column. The slow flow probably renders columns impracticable for routine field use.

A more promising approach is batch equilibration using mixed anion and cation exchange resins. In this method, 10 grams of a stoichiometric mixture of cation resin (H^+ form) and anion resin (OH^- form) are simply stirred with a liter of water. As cations and anions are absorbed, H^+ ions and OH^- ions are released from the resin and react to form water. All ions are removed from solution under the driving force of neutralization. For this procedure to achieve satisfactory concentration of ions for neutron activation analysis, the following conditions must be met:

- Impurities in the resin should not interfere with neutron activation analysis of important elements.
- The resins must have sufficient capacity to remove all of the ions from solution.
- The volume of resin must be reducible to 10 ml or less to fit into a NAA irradiation capsule (rabbit).
- Virtually all of the ions in solution must be absorbed by the resin within 30 minutes.

Samples of specially purified *AG 50 W × 8*, 100 to 200 mesh cation exchange resin (H^+ form) and *AG 1 × 8*, 100 to 200 mesh anion exchange resin (OH^- form) were obtained from Bio-Rad Laboratories (Richmond, California). Trace analyses obtained on the cation resin are shown in Table 1. The anion resin was converted >90% to the OH^- form, but trace analyses have not yet been obtained. The measured capacity of the cation resin was 2.49 meq/g and that of the anion resin was 1.44 meq/g based on the weight of the damp, as-received material. A stoichiometric mixture will therefore contain 63% anion resin and 37% cation resin by weight. One gram of this mixed resin will have a capacity of about 0.9 meq.

TABLE 1. Analysis of Cation Resin

Element	*Concentration, ppm*	
Mn	0.005	±0.001
Ba	0.218	±0.048
K	0.900	±0.330
Cl	3.64	±0.74
Na	1.12	±0.23
I	0.026	±0.006
Br	0.046	±0.010
Th	<0.021	
U	<0.0053	

The bulk densities of the damp, as-received cation and anion resins were 0.80 g/ml and 0.75 g/ml, respectively. When a stoichiometric mixture of these resins is shaken with water, the volume increases greatly because of the adherence of cation and anion resin particles to each other. When a 10-g sample of mixed resin was shaken with water and allowed to stand, it settled to a volume of about 50 ml. However, oven-drying at 100° to 115°C reduced the volume to 7.4 ml, small enough to fit easily into a 10-ml NAA irradiation capsule.

Preliminary tests with ^{233}U tracer to follow the rate of sorption of uranium on mixed resin showed about 99% of the uranium was sorbed in 15 minutes on 1 g of resin from 100 ml of solution containing up to 6 meq/l of salts. Sorption of ions was determined by measuring the specific conductance of solutions initially containing salts likely to be found in natural waters. In a typical example, 1 liter of water containing 1.5×10^{-3}M $CaCl_2$ and 1.5×10^{-3}M Na_2SO_4 was agitated with 10 g of mixed resin. The initial conductivity, 700 µmhos/cm, was reduced to 0.5 µmhos/cm in 15 minutes. This reduction in conductivity corresponds to the removal of 99.9% of the ions under conditions in which the resin is about 70% saturated with ions other than H^+ and OH^-. To avoid overloading the resin, field teams have been instructed to treat only 500 ml of water if conductivity is 500 to 1000 µmhos/cm, and 100 ml if conductivity exceeds 1000 µmhos/cm.

Samples of the mixed resin were irradiated with a ^{60}Co gamma source. Extrapolated results of these tests indicated that after 3 hours irradiation in the PSRAF, approximately 15 psig pressure should build up in the capsule. Other tests have shown that no measurable distortion of the capsule or leakage of sealed capsules occurred even at 45 psig. Since current plans call for a maximum of 30 minutes of irradiation, no problems are anticipated from resin degradation.

VARIABILITY STUDIES

A "pre-orientation" study was undertaken to define factors affecting variability. Variables are summarized in Table 2.

For those who wish to perform their own statistical analyses, the data from a nearly complete factorial experiment of 384 items are given in Appendix A, along with a listing of replicate analyses.

In a preliminary analysis of the data, the position in the stream from which the sample was taken was considered a random variable. This was not strictly true, because the sample positions were selected in an orderly fashion; i.e., toward left bank, toward right bank, upstream, and downstream and were purposely selected to give the widest possible variance. However, none of the other variables were random, so this one was selected as random, and its mean square or variance was taken as a measure of the error in an analysis of variance.

The raw data were transformed by the relation:

$$y = \ln X,$$

where X is the original value of uranium concentration in ppm.

TABLE 2. Variables in Pre-Orientation Study

A. Method of Sampling

"Clam-shell" Sampler (composite of five scoops)
Drag Sampler

B. Sampler

Chemist
Technician

C. Sieve Size

60 - 80
80 - 100
-100

D. Stream Size

Large
Small

E. Geographic Location

Edgefield, SC (barren)
Barnwell, SC (barren)
Laurel Creek, GA (U-bearing)
Spruce Pine, NC (U-bearing)

F. Sampling Location in Stream

1-4

This transformation was made because variance throughout the table is more nearly constant for the transformed values. Thus, errors of the values are a constant fraction of the value rather than an additive constant in terms of ppm. The gross analysis of variance appears in Table 3.

TABLE 3. Gross Analysis of Variance

Source	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*
Between Position	167.62	95	1.76
Within Position	115.29	288	0.40
Total	282.91		

The "Within Position" numbers are calculated from the transformed values for the 96 sets. The sums of squares between positions was divided into quantities attributed to the main factors and all of their interactions. Factors are tabulated in Table 4. Neither the factor "method" nor the factor "sampler" is significant at the 95% level. All other factors and several interactions are highly significant. Each significant interaction includes "location" as one of the factors. These interactions mean that the effect of sieve size and stream size are not independent of location. In an extreme example, uranium concentration might be highest in the fine fraction in one location (e.g., if uranium is adsorbed to clay) but highest in intermediate fractions at another location (perhaps in a placer deposit).

TABLE 4. Factors Contributing to Variance

Source[a]	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*	*Factor*[b]
A	1.43	1	1.43	3.56
B	0.90	1	0.90	2.25
C	61.08	2	30.54	76.3
D	8.50	1	8.50	21.2
E	29.46	3	9.82	24.5
AB	0.61	1	0.61	
AC	0.22	2	0.11	
AD	0.16	1	0.16	
AE	0.79	3	0.26	
BC	0.54	2	0.27	
BD	0.37	1	0.37	
BE	3.41	3	1.14	2.84
CD	0.64	2	0.32	
CE	34.09	6	5.68	14.2
DE	6.82	3	2.27	5.68
ABC	0.51	2	0.25	
ABD	0.04	1	0.04	
ABE	0.97	3	0.32	
ACD	0.07	2	0.04	
ACE	0.24	6	0.04	
BCD	0.13	2	0.07	
BCE	0.58	6	0.10	
CDE	9.17	6	1.53	3.82
ADE	1.14	3	0.38	
BDE	2.50	3	0.83	
ABCD	0.16	2	0.08	
ABCE	0.92	6	0.15	
ABDE	0.72	3	0.24	
ACDE	0.43	6	0.07	
BCDE	0.27	6	0.04	
ABCDE	0.79	6	0.13	
Error	115.29	288	0.40	
Total	282.91	383		

a. A = Method
B = Sampler
C = Sieve Size
D = Stream Size
E = Geographic Location

b. Significant 90% level: F = 2.73
Significant 95% level: F = 3.89

The variation from position-to-position in a stream is significantly greater than the analytical error. For the 15 pairs of replicates that represent only analytical error, the variance or the mean sum of squares is 0.032. This is very much smaller than the 0.40 mean sums of squares used as the error in Table 4. The practice of taking samples at each of the four widely differing positions at a sampling point produces a value with a large statistical error. Either more samples will be required at each sampling point or a carefully specified procedure will be required for selecting the sampling positions.

Table 5 should provide the reader with a feel for the variation in the observed values. The table should be self-explanatory. For example, the two entries under "Method" are "Bag" and "Clam Shell," along with their mean values and their variances. A more complete treatment of these data is in progress. For example, the complete statistical analysis will establish what fraction of the duplicate sediment samples taken in the orientation study must be analyzed by neutron activation analysis for quality assurance purposes.

TABLE 5. Observed Values in Variance Study

Item	*Mean*	*Variance of the Mean*
Method		
Bag	1.38	0.0043
Clam Shell	1.25	0.0033
Sampler		
A	1.36	0.0042
B	1.27	0.0033
Sieve Size		
60	0.90	0.0046
80	1.19	0.0042
100	1.85	0.0048
Position		
1	1.15	0.0061
2	1.19	0.0091
3	1.57	0.0069
4	1.35	0.0077
Stream		
Small	1.46	0.0045
Large	1.17	0.0029
Location		
Edgefield	1.07	0.0017
Laurel Creek	1.69	0.0079
Spruce Pine	1.48	0.0028
Barnwell	1.03	0.0154

The "pre-orientation" sites will be resampled to determine the contribution of seasonal change to variability. In addition, multiple samples will be taken in mid-stream to determine to what degree variability due to stream position can be reduced by following careful procedures.

ORIENTATION STUDIES

Nine orientation studies are in progress in Georgia, Pennsylvania, North Carolina, South Carolina, Tennessee, and Texas. These localities were selected to represent a variety of potential uranium deposits in the eastern United States. Table 6 summarizes these studies and sampling sites, which are discussed briefly below.

1. *Georgia Piedmont Site*

Preliminary samples were collected at the Moye uraniferous pegmatite in Lamar County, Georgia, by Professor Robert Carpenter, University of Georgia, and a student assistant. This pegmatite was only 60 m^2 at the surface and was selected as a "point source" of uranium. Selected hand samples assayed 0.25 wt % uranium as uraninite. Sediment samples from the mid-channel of the stream that were screened into -20 to +80, -80 to +230, and -230 NBS mesh fractions, and rock and soil samples from the pegmatite and nearby area were submitted to Atomic Energy of Canada, Ltd. (Ottawa, Canada) for delayed neutron activation analysis of uranium.

TABLE 6. Summary of Orientation Studies

Location	*Type*	*Principal Uranium Mineral*	*Sampling Sites*	*Status*
1. GA Piedmont	Pegmatite	Uraninite	100	Sampling completed
2. PA Plateau	Sandstone	Uranophane	200	Contracted
3. NC Blue Ridge	Pegmatite and Disseminated	Samarskite and Uraninite	530	Sampling completed
4. NC Inner Piedmont	Disseminated Placer	Monazite	200	Sampling in progress
5. NC Slate Belt, Triassic	Black Shale	-	100	Sampling in progress
6. NC Coastal Plain	Black Shale/ Sandstone	-	100	Contracted
7. SC Blue Ridge	Unknown	-	60	Sampling completed
8. TN Plateau	Black Shale	-	75	Sampling completed
9. TX Coastal Plain	Sandstone	Pitchblende	89	Sampling completed

The -230 mesh sediment fraction varied randomly from 10 to 30 ppm uranium over the entire area. However, the deposit was clearly indicated in the -20 to +80 and the -80 to +230 mesh fractions taken in the immediate vicinity of the pegmatite. In the -20 to +80 fraction, regional background averaged 1.3 ppm, while sediment in the small stream containing the pegmatite averaged 11.7 ppm. The "halo" was at least 0.3 mi, at which point the small stream joined a much larger stream.

The "halo" size was not defined in the -80 to +230 fraction. Within 0.3 miles of the deposit, values ranged from 28 to 97 ppm; average 64 ppm. In an adjacent fork and upstream from the deposit, values averaged 10 ppm, while over a mile downstream (in the major stream) values averaged 25 ppm.

We consider these results encouraging, though far from definitive, and have sampled 50 additional surface sites and 50 ground water sites. Analyses are pending.

2. *Pennsylvania Plateau Site*

McCauley[2] describes a number of uranium occurrences in organic-rich sandstones in Sullivan and Columbia counties. These occurrences are in the Devonian Catskill Formation and should serve as models for similar Paleozoic deltaic deposits of the Appalachians. A contract has been let for 200 sample localities in 400 square miles of this area. Sampling is expected to begin in early October and to be completed by late October 1975.

3. *North Carolina Blue Ridge Sites*

A number of uranium occurrences are known in the Spruce Pine-Grandfather Mountain area of western North Carolina. Professor Paul Ragland of the University of North Carolina and a student assistant have completed a field study in this area and have suggested three drainage basins for hydrogeochemical sampling. Two of the basins are within the Spruce Pine pegmatite district and contain uraniferous columbo-tantalite (samarskite). The third basin is in the Grandfather Mountain window and is characterized by uraninite and secondary minerals disseminated in phyllonite zones.[3]

Analyses of rock samples collected in this study indicate that thorium is the primary contributor to radioactivity at the Grandfather Mountain window site, whereas ^{40}K, thorium, and uranium contribute to radioactivity at the Spruce Pine sites. A ground scintillometer survey along roads, major streams, and trails with readings at approximately 0.4 mile spacings revealed only one major source of radioactivity in each of the three basins. A statistical analysis of scintillometer data indicated that background levels correlate well with mapped geologic units. Anomaly threshold values were selected at $\overline{X} + 2\sigma$ for each rock type, and maps were prepared outlining zones of anomalous radioactivity.

A contract was let for approximately 530 surface and ground water samples in the Spruce Pine-Grandfather Mountain area. Sampling was completed by late September 1975.

4. *North Carolina Inner Piedmont*

High uranium monazite (up to 2.3 wt % U_3O_8) occurs in the Inner Piedmont of North Carolina and South Carolina.[4] An area has been selected near Shelby, North Carolina, which spans portions of Inner Piedmont, Kings Mountain, and Charlotte geologic belts, and which should provide adequate sampling of the reported uraniferous monazites.

A contract has been let for 200 samples from this area. Sampling is in progress and should be completed by mid-October 1975.

5. *North Carolina Slate Belt-Triassic Basin*

An area has been selected in Moore County, North Carolina, where mafic and felsic volcaniclastic rocks of Cambrian (?) age are adjacent to, and provided material for, Triassic sandstones, siltstones, and carbonaceous shales. Gold mineralization in the area is apparently associated with volcanic activity, and copper mineralization may be related to Triassic faulting.

Field work is in progress to sample 50 surface and 50 ground water sites in this area. This area and the one in the North Carolina Coastal Plain (see below) were selected to provide hydrogeochemical data on areas in which ERDA and U. S. Geological Survey aeroradiometric results are available.

6. *North Carolina Coastal Plain*

An area has been selected in Johnston and adjacent counties of North Carolina where felsic volcanic slates of Cambrian age are in contact with fluvial sandstones and organic-rich estuarine shales of Cretaceous age. The drainage patterns and weathering conditions are such that a mechanism of secondary uranium enrichment can be envisioned, in which circulating ground water contacts the organic-rich shale.[5]

A contract has been let to sample 50 surface and 50 ground water sites in this area. Sampling should be completed by late October 1975.

7. South Carolina Blue Ridge

A davidite occurrence on Laurel Creek in Rabun County, Georgia, was discussed in the previous report as a potential orientation study area. Preliminary sampling of stream sediments yielded up to 46 ppm uranium, but a ground scintillometer survey failed to reveal concentrations of radioactive material at the Georgia site. The area was rejected in favor of the Oconee County, South Carolina, area where an Atomic Energy Commission (AEC) compilation of uranium occurrences[7] included a site with up to 0.16 wt % U_3O_8.

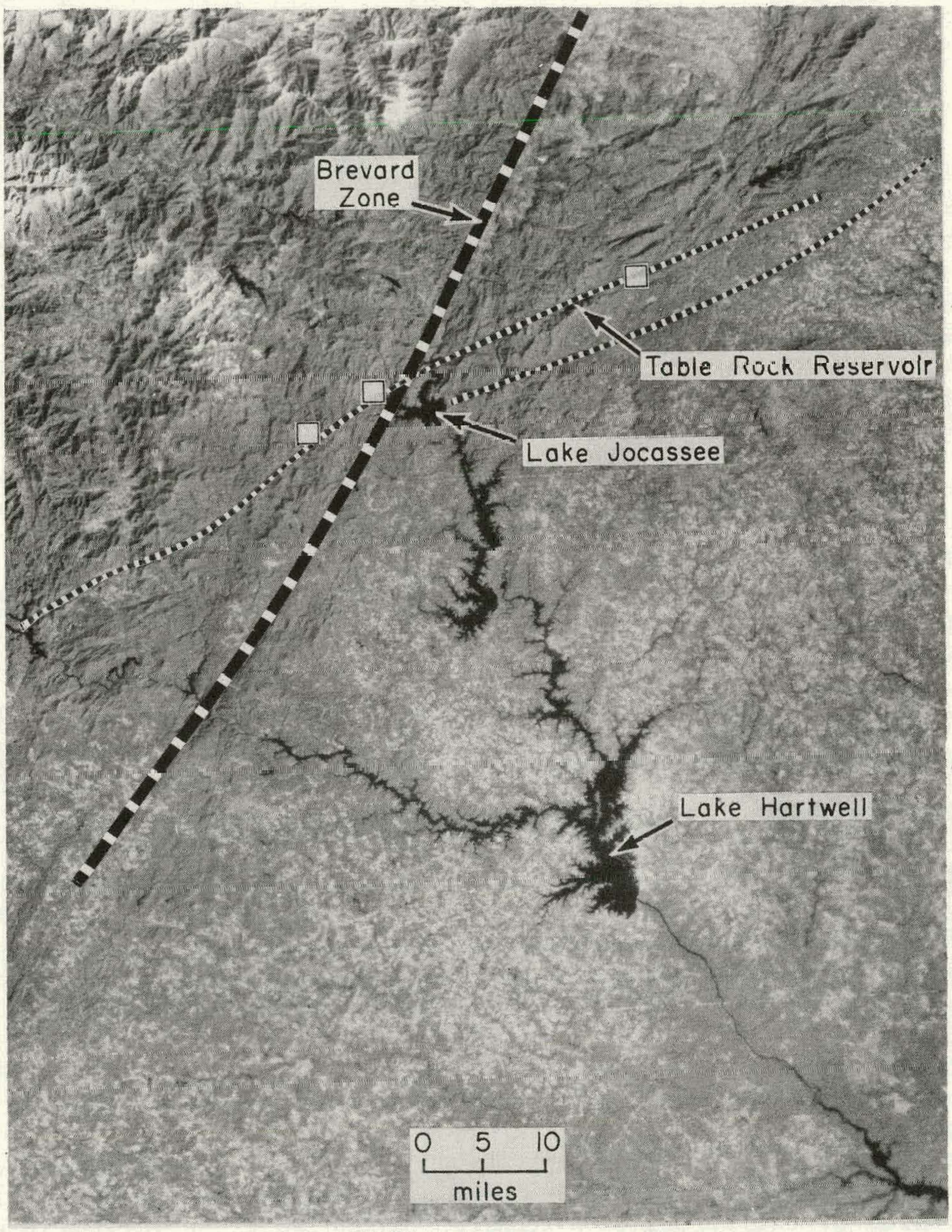
A ground scintillometer survey in this area was conducted by SRL personnel. Background counts ranged from 300 to 800 cpm total gamma. Three areas yielded count rates above 2500 cpm. Count rates at the reported uranium locality were above 50,000 cpm in a small trench. The high count rate areas fall along a line approximating the regional strike of the Brevard Belt and other geologic units in this region. Samples were taken which contain up to 1 wt % thorium and 400 ppm uranium.

Professor R. D. Hatcher of Clemson University has furnished SRL with a detailed geologic map of the Tamassee quadrangle.[8] "Hot" spots found in our scintillometer survey are along the unconformable contact between the Toxaway gneiss and overlying units; they may represent fossile monazite placers.

Another explanation for the distribution of radioactivity in this area can be inferred from satellite infrared imagery (Figure 8). A pronounced lineament observable on ERTS imagery of the study area connects the deposit with a davidite occurrence in Rabun County, Georgia, and a torbernite-molybdenite locality in Greenville County, South Carolina. We will attempt to judge whether there is a genetic relation between the uranium occurrence and the observed lineament. Fifty surface sites were sampled in the area of the deposits. Only ten ground water samples were obtained because the area is remote and few wells exist.

8. Tennessee Plateau

Professor Robert Carpenter of the University of Georgia and a student assistant have collected 220 stream sediment samples from streams crossing four outcrops of the Chattanooga Shale in Central Tennessee. An AEC and USGS report[10] indicates uranium concentrations of 10 to 500 ppm in this formation.



▪▪▪▪ Lineation on ERTS Image
☐ Reported Uranium Occurrence

FIGURE 8. ERTS Photograph of Brevard Fault Area

9. *Texas Coastal Plain*

Sampling of water and stream sediments was conducted in the Karnes City-Kosciusco area, Texas, in conjunction with Oak Ridge Gaseous Diffusion Plant (ORGDP) personnel. This area was selected because it contained a classic roll-front deposit that had been drilled but not yet mined and because a wealth of geological and hydrogeochemical information exists on the area.[8,11]

Professor Robert Carpenter of the Department of Geology, University of Georgia, a consultant of SRL, accompanied the teams for the first two days of field work. Professor Carpenter assisted the teams in making initial contacts in the area. Negotiations with *Chevron Oil* and *Conoco*, major mineral lease holders in the area, and with the many land owners who permitted the teams access to surface sampling sites and wells were essential to the successful completion of this sampling operation.

Sampling sites were preselected and marked on the 7.5 minute topographic maps supplied to the sampling teams. Thirteen sites were sampled on the San Antonio River and Cibolo Creek, and twenty-six tributary streams (twenty-three of which were dry) across the deposit zones were sampled. The SRL team attempted to obtain a well water sample within each one square mile grid segment in the vicinity of the deposit and in designated background areas. A total of 50 well-water samples were obtained covering several geological formations (updip, in, and downdip) of the deposit zone.

The pH of surface waters in the area was fairly constant (range 7.5 to 8.5; average 8.0) while ground waters varied greatly (range 6.2 to 9.1; average 7.7). Similarly, conductivity of surface waters was fairly constant (1100 to 2300 μmho/cm; average 1500) while ground waters varied widely (540 to 8900 μmho/cm; average 3500). Total alkalinity, conductivity, pH, and sulfate ion and phosphate ion concentrations were measured both in the field and in the laboratory up to six weeks later. Values remained relatively constant, normally changing less than 15%.

At each orientation study site in Areas 1-8, the following samples were collected: 10 cc of filtered water in an irradiation capsule; suspended solids from two liters of water; a fission foil with residue from 50 μℓ of filtered water; 10 g of resin with dissolved solids from one liter of filtered water; and two composite mid-stream sediment samples, one from each sampler. In the Texas study, an additional 100 cc of water were collected for later tests, but no resin was used because of the high salinity of the water. In addition to the samples, measurements and observations were made as outlined in Appendix B.

SAMPLE PREPARATION

Analyses of field samples will seek to determine quantitatively as little as 5 ng of uranium. To assure dependable analyses, resin packages and fission foils were assembled in clean facilities before being sent into the field. Before neutron activation analysis (NAA), solid samples will be loaded into irradiation capsules ("rabbits") and the capsules will be cleaned under "Class 100" conditions (less than 100 particles per cubic foot of air). A special clean receiving laboratory has been set up and is operational. Current efforts are aimed at developing efficient operating procedures for the receiving laboratory. Work is also in progress to determine the most effective means of immobilizing solid samples in capsules and of minimizing argon interference. Argon, present at a low level in air, is easily activated and is an interference in NAA for some elements at trace concentrations.

NEUTRON ACTIVATION ANALYSIS

Pilot Scale Reactor Activation Facility (PSRAF)

Installation of the PSRAF in a production reactor at SRP is complete. This facility was described schematically in a previous report.[6]

All components of the facility were operationally tested and perform as anticipated. Computer programs for the PDP-9 data acquisition system and the microprocessor system controller were written and are operational. Calibration of individual components and of the total activation analysis system are in progress. Preliminary data indicate the following operating characteristics:

- Thermal neutron flux: nominal 2×10^{12} $n/cm^2/s$.
- Fast neutron flux (E_n>7.5MeV): nominal 1×10^8 $n/cm^2/s$.
- Sample volume: 10 cm^3 maximum
- Transport times: less than 1.5 sec for about 90 ft and sending pressures of about 10 psig.
- Irradiation temperature: 30°C maximum, with 15 gpm of 24°C cooling water and 75 CFH of ambient cooling air.
- Delayed neutron detector: about 40% efficient for 0.4 to 0.9 MeV neutrons (the energy range of the delayed neutron emitting fission products of interest).

- GeLi detectors: greater than 10% efficient (relative to a 3" x 3" NaI detector), with less than 1.75 keV resolution at 1332 keV.
- Natural uranium detection limit (signal-to-noise ratio equals 1) is 0.6 ppb in 10 ml aqueous solution.
- U/Th delayed neutron discrimination ratio is 600/1.
- Anticipated capacity: 80 samples per day (assuming two shift operation).

The data reduction programs were written and are being debugged. Specific yields for gamma-active, neutron-capture products are being determined by irradiations of known solutions. These yields are input to the data reduction programs to develop detection limits for each element. The accuracy of these values will be confirmed by comparison with analyses of NBS and USGS rock, steel, etc. Standard multi-element analyses of orientation study samples will begin in early October and should be substantially complete by February 1976.

SRL Californium Activation Facility

Installation of four sources totalling approximately 100 mg of ^{252}Cf is complete, and the californium activation analysis facility is operational. Flux mapping has verified the improved detection sensitivities resulting from the H_2O/D_2O moderator annulus.[6] The calculated interference-free detection sensitivities are listed in Table 7. Absolute calibration of the system is continuing with the analysis of NBS and USGS solid and liquid standards.

A dual, automatic, delayed neutron/high resolution/gamma-ray detection system is now operational. This system will permit sensitive uranium and pathfinder element analysis with the facility unattended. The experimentally measured uranium detection limit is ∿500 ppb for 10 cc of liquid or 15 g of solid samples. Sample analysis time is about 10 min/sample at the 1 ppm level for natural uranium.

A procedure was developed to determine natural uranium in solid matrices in the presence of larger quantities of thoria. Samples containing 1 ppm uranium and 60 ppm thorium gave equal delayed neutron counting response. In support of orientation studies, rock samples from Oconee County, South Carolina, were analyzed. The facility will continue to be used in screening orientation rock samples and to provide backup for the PSRAF.

TABLE 7. Detection Sensitivities for ^{252}Cf NAA Facility

Detection Limit, ppm	*Element*
<0.001	Eu, Dy
0.001 - 0.01	Mn, In, ^{129}I, Ir, Au, Lu, Ho, Sm, Re, ^{239}Pu
0.01 - 0.1	Na, Sc, Co, Ga, Br, Ag, Sb, I, Cs, La, Pr, Tm, Yb, Ta, W, Pt, As, Se
0.1 - 1.0	Ar, K, Cr, V, Cu, Cd, Ce, Nd, Gd, Tb, Er, Hf, Hg, Ge, Sr, natural U
1.0 - 10	Cl, Zn, Mo, Ru, Rh, Pd, Te, Ba, Os
10 - 100	F, Mg, Al, Ti, Ni, Sn, Rb, Y
100 - 1000	Ca, Fe, Zr
>1000	Pb, O, S

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a. Based on 100 counts in photopeak from 15% efficient Ge(Li) detector. 10-gram sample is assumed. The lowest detection limit for each element was selected from one of the listed regimes.

No.	*Irradiation Time*	*Decay Time*	*Count Time*	*Cycles*
1	6 sec	1 sec	6 sec	50
2	1 hr	5 min	30 min	1
3	1 day	1 hr	30 min	1
4	7 days	1 hr	30 min	1

b. Based on the 25% efficiency of the delayed neutron detector.

OTHER ANALYTICAL TECHNIQUES

Alternatives to neutron activation analysis of resin-concentrated dissolved uranium are also being evaluated. Fluorimetric techniques and fission-track analyses appear to be most promising. A fission foil package and a field evaporator have been developed (see Field Technology section). The present effort is concerned with developing an automated reader. Spark counting, a promising technique conducive to automation, is being pursued.[12-15]

Alternative concentration techniques are also being tested for use with NAA. One potentially useful technique is freeze-drying. A freeze drier has been purchased (Virtis Company, Gardiner, New York), and current work is aimed at developing a suitable collection package.

Development of followup techniques such as mineralogical identification of micron-sized particles has been deferred until the need for this type of followup is better defined.

INPUT

Field cards were produced in the format substantially as planned earlier.[6] Cards were printed on "polypaper" (Nalgene Corporation, Rochester, New York) to avoid mildewing and mutilation on handling. Samples of surface and ground water cards are given in Appendix B.

A 36-in. × 48-in. *Summagraphics* Model HW12 digitizing tablet (Summagraphics, Inc., Fairchild, Connecticut) is being evaluated for entering sample locations and geological information into the data base. The system is expected to be operational in late February 1976. Until then, sample locations will be entered manually, but there will be no satisfactory way to enter geological data.

DATA FILE FORMAT

General Characteristics of the SRL-NURE Hydrogeochemical Data File

The hydrogeochemical data file will ultimately become too large to maintain as a random access file. The most practical means of storage is as a sequential tape file. Because different types of information will be read into the file at different times, frequent updating will be required. Similarly, data analysis will require frequent interrogation of the file to extract sub-files upon which the analyses will be run. To reduce the number of times the complete file must be read into the computer, a program is being written to update and query the file simultaneously (Figure 9). The "query" part of the program will write selected records into JOSHUA modules[16] for analysis. JOSHUA is an operating system which provides the data handling services required to accomplish extensive, iterative, scientific calculations on a large semi-permanent data base. JOSHUA contains a number of modules for performing mathematical operations on the data, such as regression analysis.

File Structure

The file structure that is being developed for the hydrogeochemical program will be very general for two reasons:

- It is not certain at this stage what data will be required.
- The program is interlaboratory, and the file structure may be used by others with similar but not identical data requirements.

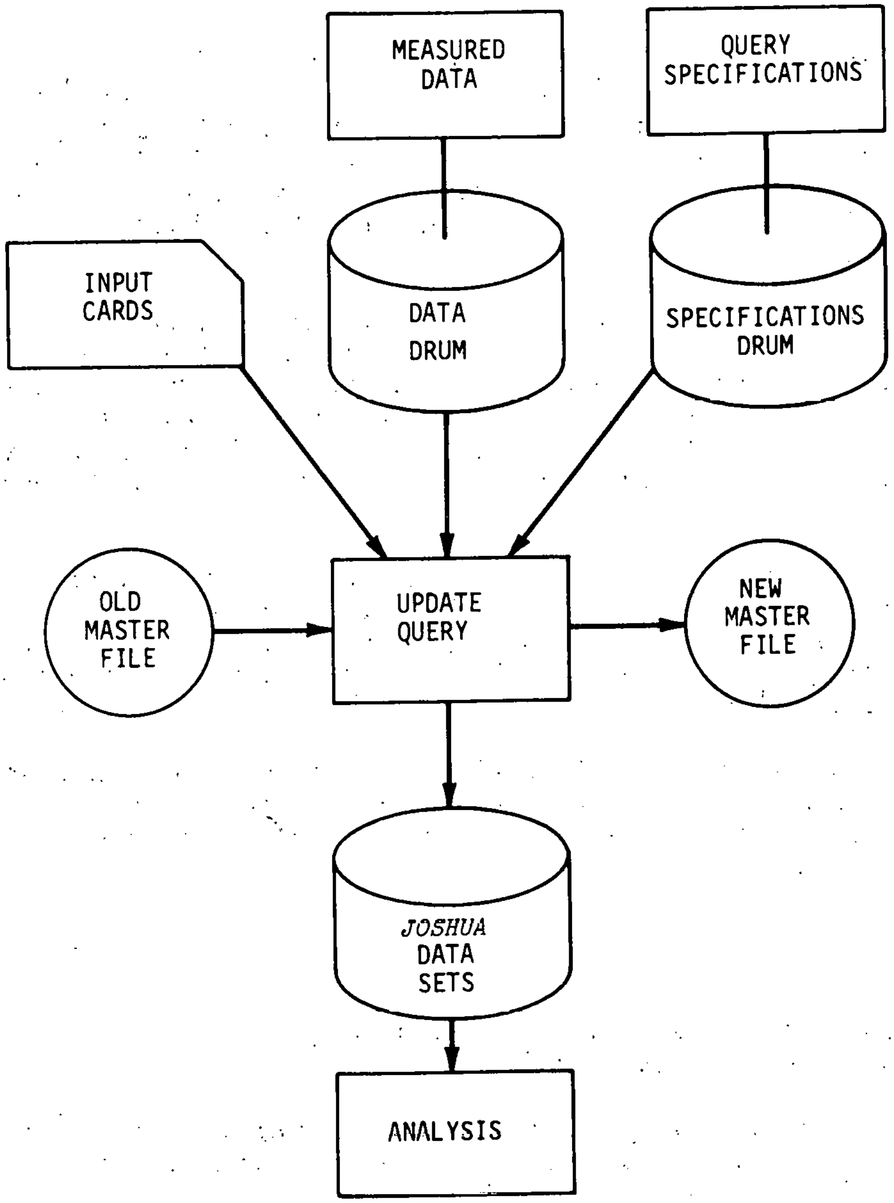


FIGURE 9. Hydrogeochemical Data Processing

Data Types

The four major types of data to be collected in the program arc:

- site location
- site description
- sample description
- measured results

There will be several types of sites (stream, well, etc.) each having its own descriptive data. There will be several types of samples (water, filtrate, sediment, etc.) and preparation methods, each having its own descriptive data. And there may be several types of measurements (neutron activation, gamma activity, etc.), each resulting in a list of elemental or isotopic concentrations.

These data fall into a natural structure. We can compose a record which contains all data for a site with the site name as the record name. The collection of these records is a file. Each record consists of segments. Each segment consists of a Header portion (control and accounting information), and a Data portion. This organization is called the Physical File Structure (Figure 10).

While segments are physically stored in a linear fashion, they logically can be viewed as a hierarchal structure (Figure 11). Each segment (in the Header portion) points to the next segment at the same level (brother) and to the first segment at the next lower level (son).

When we compare this logical structure with the four major collections of NURE data, each collection becomes a level of the hierarchy. Two typical record structures are illustrated in Figures 12 and 13.

Segment Types

Seven types of segments are required (Table 8). Other types can be added as the need arises.

There may be multiple occurrence of a segment type within the same level (e.g., multiple water samples, multiple measurements on the same sample).

TABLE 8. Segment Definition

Segment Type	*Segment Description*
1	Site Location
2	Stream Site Description
3	Ground Water Site Description
4	Water Sample
5	Suspended Solids Sample
6	Sediment Sample
7	Measurement

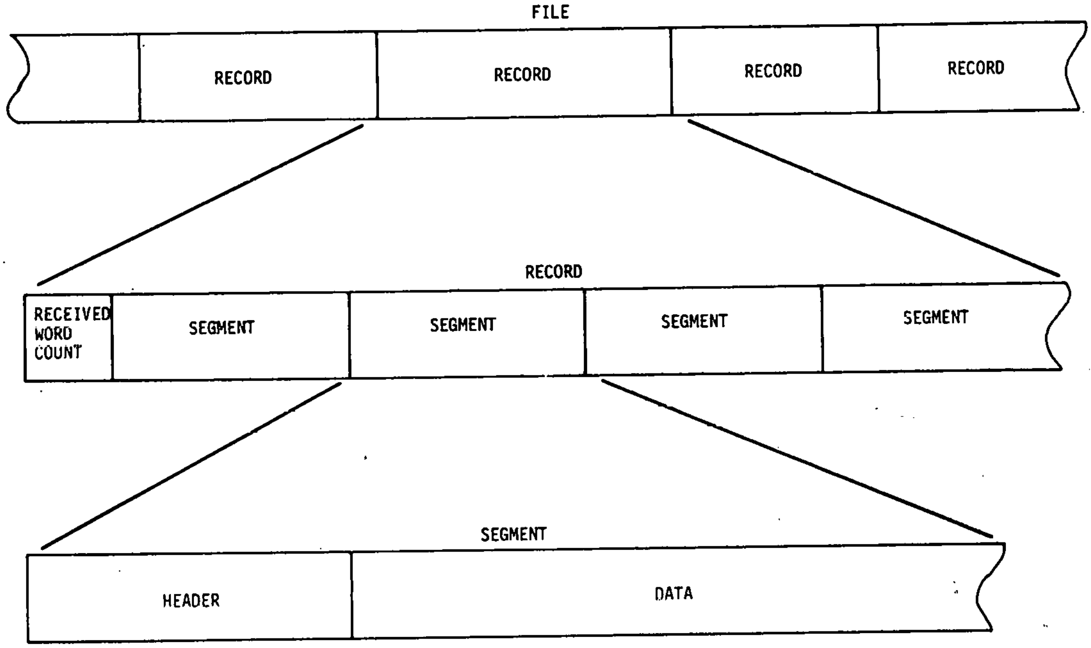


FIGURE 10. Physical File Structure

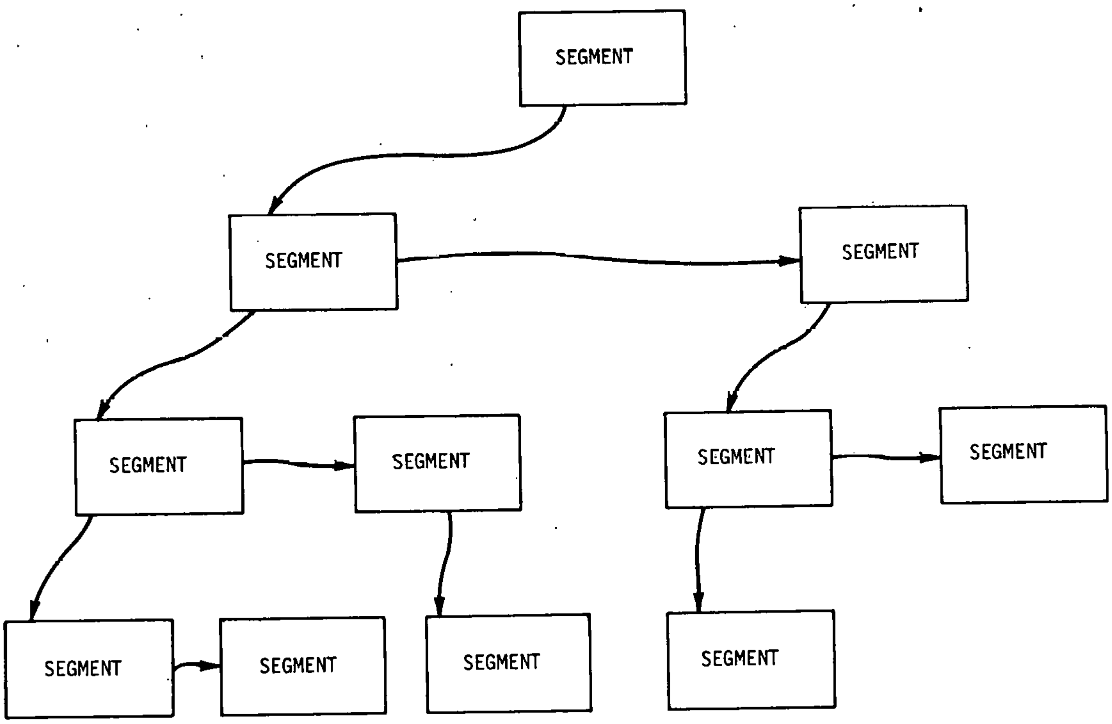


FIGURE 11. Logical Record Structure

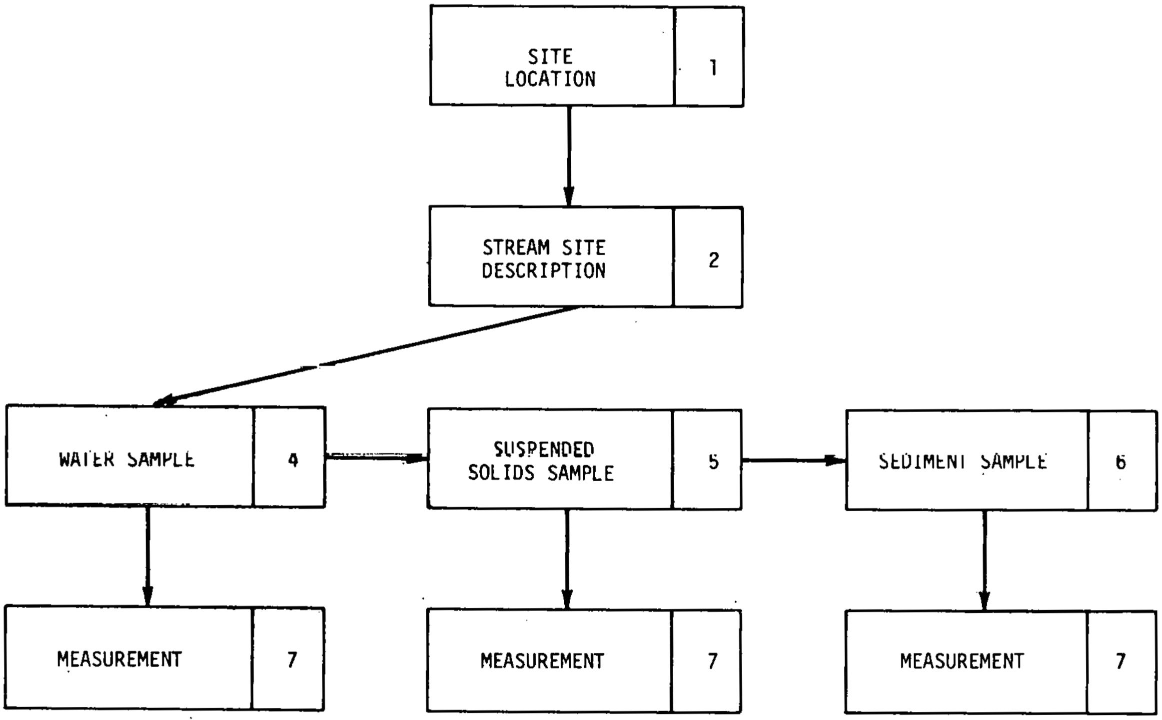


FIGURE 12. Typical Record Structure for Stream Site

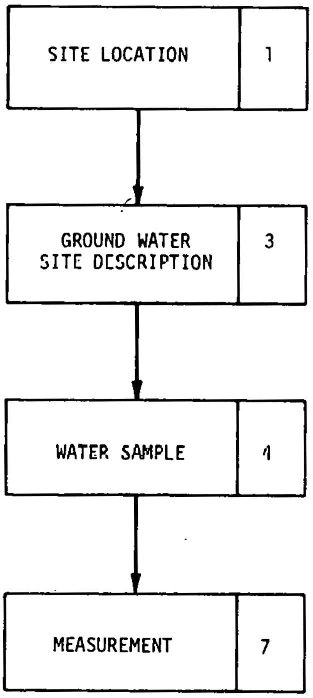
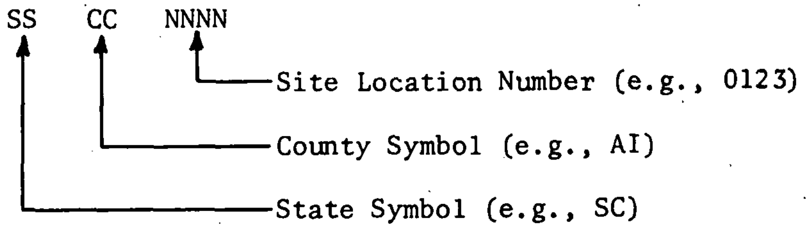


FIGURE 13. Typical Record Structure for Ground Water Site

Segment Names

Each segment has an 8-character name qualifier. The site location name qualifier is the record name. This name is of the form:



The name qualifiers for the remaining levels are arbitrary, but they must be unique within a given level of a sub-tree.

The concatenation of the name qualifiers uniquely references a segment and is the segment name. For example:

SCAI0123.STREAM

SCAI0123.STREAM.WATER

SCAI0123.STREAM.WATER.NAA

references the left-most segments in the lower levels of Figure 12.

In some cases, the segment name qualifier implies the segment type (e.g., STREAM implies Segment Type 2). This is because only one occurrence of that segment type is allowed. When multiple segments of the same type occur, the name qualifiers must be different (e.g., WATER1, WATER2, WATER3 are name qualifiers for three occurrences of Segment Type 4).

Data Element Names

If S is a concatenated segment name, and E is the name qualifier of a data element in S, then S.E is the complete data element name. If the element has multiple occurrences in the segment, then the occurrence number can be appended to complete the name.

Formal versus Informal Names

The formal naming structure is essential for organizing the data into records and maintaining the data. However, it may be cumbersome for use by people preparing input data. A shorthand or informal naming convention may be used to identify input. Any informal naming convention is acceptable provided that it can be translated by tables, algorithms, and implication into the formal name structure. An example of formal and informal segment names is given in Figure 14.

The preceding file structure should be adequate for both the orientation studies and for the wide area survey. Initial data are expected to be available from the orientation studies in October 1975. Processing codes should be available soon thereafter. A reasonable goal is to have updating capability by mid-November, and query capability by late December. Many of the data analysis programs are already available in "CRASS" (Correlation, Regression Analysis Subsystem); others are being developed.

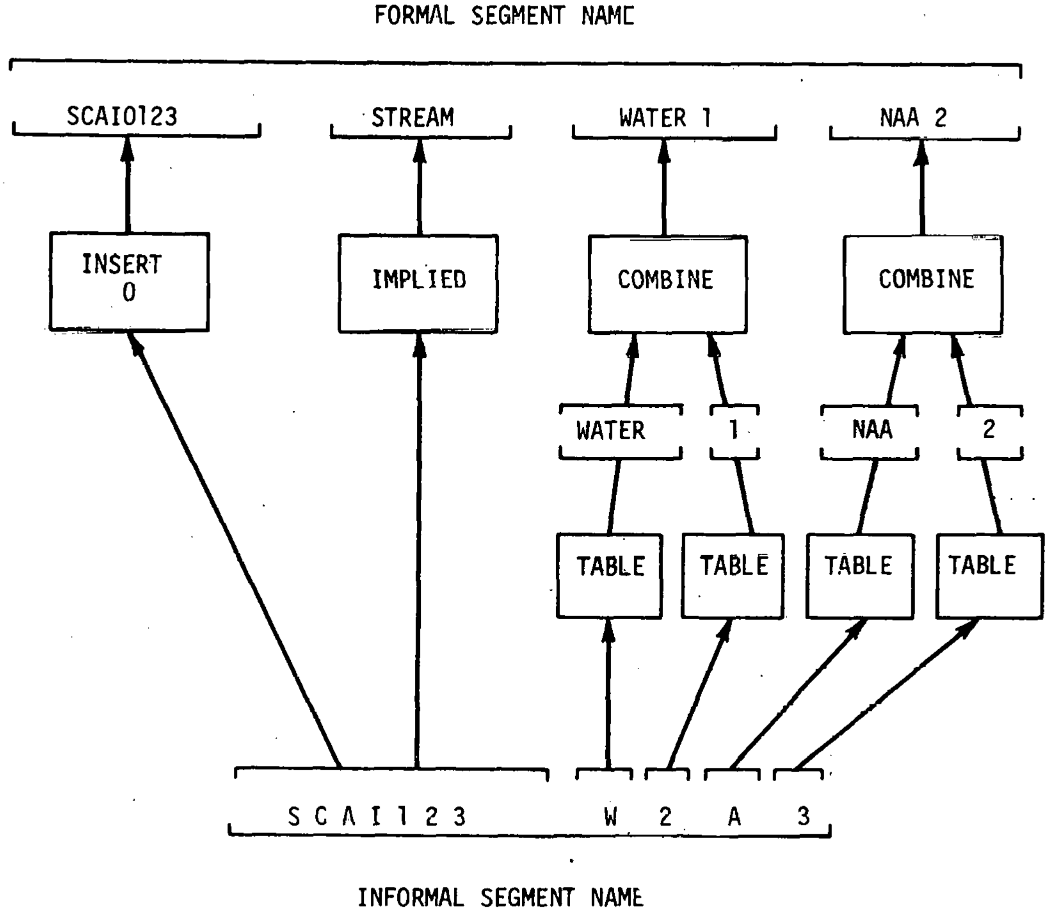


FIGURE 14. Examples of Formal and Informal Segment Names

ANALYSIS AND OUTPUT

Studies are in progress to determine the feasibility of using computer-generated microfilms to produce maps on which are plotted concentrations or uranium or other pathfinders. It appears to be feasible to produce the desired maps by enlarging 35-mm microfilm to the size of 1:250,000 maps, providing the resolution of the microfilm will satisfy our needs. Microfilm-generated overlays would then be used in conjunction with the proper transparencies or "reproducibles" to produce the desired map. "Reproducibles" are available from the U. S. Geological Survey, Reston, Virginia.

A 35-mm microfilm camera and enlarging equipment for producing overlays are on order. These will be evaluated with "reproducibles" to determine the feasibility of presenting data in this manner. Presenting data as microfilm-generated overlays allows the flexibility of producing maps at SRL or at outside agencies.

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APPENDIX A. Raw Data from Pre-Orientation Studies

TABLE A-1.

A. Edgefield, South Carolina, Small Stream

		Uranium, ppm			
	Sieve	*Sampler No. 1*		*Sampler No. 2*	
Location	*Size*	*Bag*	*Clam*	*Bag*	*Clam*
1	60	3.24	3.26	3.32	3.32
	80	3.15	4.00	4.92	5.39
	100	1.86	4.41	3.82	4.19
2	60	2.98	2.12	1.93	3.08
	80	4.55	2.63	2.44	NA
	100	6.04	6.19	5.91	2.20
3	60	3.38	2.95	2.81	2.81
	80	3.77	5.18	3.13	4.67
	100	5.41	3.88	4.72	5.79
4	60	3.03	2.01	7.97	9.15
	80	5.39	2.06	3.88	4.32
	100	6.82	2.19	6.16	5.80

B. Edgefield, South Carolina, Large Stream

		Uranium, ppm			
	Sieve	*Sampler No. 1*		*Sampler No. 2*	
Location	*Size*	*Bag*	*Clam*	*Bag*	*Clam*
1	60	1.79	2.02	1.86	NA
	80	1.82	2.25	1.91	1.85
	100	1.89	1.98	2.12	2.18
2	60	1.91	1.96	2.58	2.05
	80	2.44	2.16	2.21	2.20
	100	2.52	2.40	2.25	2.25
3	60	NA	3.44	2.09	2.61
	80	2.53	3.28	2.93	2.44
	100	2.45	2.13	2.32	2.12
4	60	2.00	2.83	2.04	1.83
	80	2.36	3.86	2.36	2.09
	100	2.12	4.38	2.33	2.14

TABLE A-2.

A. Laurel Creek, Georgia, Small Stream

		Uranium, ppm			
	Sieve	*Sampler No. 1*		*Sampler No. 2*	
Location	*Size*	*Bag*	*Clam*	*Bag*	*Clam*
1	60	3.86	5.00	3.33	2.78
	80	3.72	6.66	5.10	4.02
	100	4.50	9.22	7.87	8.83
2	60	12.4	10.6	3.41	2.25
	80	26.7	13.8	4.47	3.31
	100	46.7	29.8	7.45	6.39
3	60	13.6	11.6	7.08	6.58
	80	21.0	17.4	6.58	10.0
	100	21.4	22.6	12.8	13.1
4	60	8.18	2.29	4.01	2.74
	80	21.6	2.69	2.99	3.18
	100	22.6	5.56	4.58	5.09

B. Laurel Creek, Georgia, Large Stream

		Uranium, ppm			
	Sieve	*Sampler No. 1*		*Sampler No. 2*	
Location	*Size*	*Bag*	*Clam*	*Bag*	*Clam*
1	60	3.57	1.54	5.76	8.86
	80	4.05	2.02	8.68	13.5
	100	9.93	5.25	18.2	25.0
2	60	1.56	4.87	1.32	1.02
	80	2.45	5.60	1.64	1.38
	100	4.77	13.5	4.89	1.94
3	60	3.93	1.56	1.29	1.08
	80	8.63	3.02	2.18	1.04
	100	15.2	3.99	7.24	3.98
4	60	1.32	2.30	2.36	1.64
	80	3.83	3.22	7.65	3.11
	100	15.8	7.32	15.1	6.04

TABLE A-3.

A. Spruce Pine, North Carolina, Small Stream

		Uranium, ppm			
	Sieve	*Sampler No. 1*		*Sampler No. 2*	
Location	*Size*	*Bag*	*Clam*	*Bag*	*Clam*
1	60	NA	3.65	4.18	4.80
	80	NA	4.23	3.56	4.33
	100	NA	5.41	5.10	6.41
2	60	3.51	3.32	4.03	3.84
	80	3.77	3.90	4.85	4.03
	100	5.92	4.83	4.63	4.81
3	60	3.14	4.50	5.69	3.09
	80	3.26	3.71	5.96	3.06
	100	5.01	5.27	8.56	5.41
4	60	3.82	3.56	4.03	3.19
	80	3.96	3.59	4.04	3.75
	100	7.23	6.19	5.44	5.42

B. Spruce Pine, North Carolina, Large Stream

		Uranium, ppm			
	Sieve	*Sampler No. 1*		*Sampler No. 2*	
Location	*Size*	*Bag*	*Clam*	*Bag*	*Clam*
1	60	1.12	1.55	1.81	1.72
	80	2.23	1.57	2.48	2.79
	100	4.66	3.59	5.22	5.12
2	60	1.85	1.39	8.72	4.52
	80	4.00	1.16	10.6	5.60
	100	4.73	4.07	13.0	7.22
3	60	5.81	5.84	4.76	4.27
	80	5.42	4.69	3.89	4.40
	100	6.14	7.85	6.32	6.87
4	60	6.06	6.61	1.45	4.16
	80	19.4	12.3	2.24	3.44
	100	16.7	14.9	3.76	7.02

TABLE A-4.

A. Barnwell, South Carolina, Small Stream

		Uranium, ppm			
	Sieve	*Sampler No. 1*		*Sampler No. 2*	
Location	*Size*	*Bag*	*Clam*	*Bag*	*Clam*
1	60	0.56	0.44	0.37	1.10
	80	0.99	4.11	0.88	2.65
	100	4.24	15.0	5.14	1.32
2	60	0.83	0.84	0.37	1.37
	80	1.03	1.56	0.32	3.65
	100	13.6	27.4	2.89	17.7
3	60	0.82	2.61	4.41	1.76
	80	1.85	1.32	12.0	1.84
	100	17.0	30.4	99.0	28.6
4	60	1.75	0.24	0.58	1.42
	80	18.0	0.72	1.03	2.77
	100	52.3	12.6	21.9	10.5

B. Barnwell, South Carolina, Large Stream

		Uranium, ppm			
	Sieve	*Sampler No. 1*		*Sampler No. 2*	
Location	*Size*	*Bag*	*Clam*	*Bag*	*Clam*
1	60	1.50	0.61	1.19	1.21
	80	3.30	1.09	5.41	1.46
	100	7.32	4.94	8.77	3.98
2	60	0.74	0.44	0.70	1.08
	80	2.19	0.88	1.13	3.17
	100	8.84	3.92	4.42	6.22
3	60	8.04	2.96	5.79	2.04
	80	4.37	3.43	2.35	3.70
	100	21.0	5.95	10.3	7.14
4	60	1.62	1.96	1.82	2.49
	80	1.67	1.24	1.19	1.83
	100	4.76	3.35	5.28	3.62

TABLE A-5.

Multiple Analyses

Replicates

1.79	1.90
5.00	5.89
3.57	1.63
5.69	5.55
2.96	2.88
2.06	2.49
2.25	1.93
6.58	7.77
2.79	1.94
4.37	3.93
18.0	12.3
4.72	4.96
15.1	13.4
5.12	5.91
5.41	5.70

Quadruplicate

5.16, 4.57, 5.83, 5.12

APPENDIX B. Field Data Sheets

Ground Water Sampling Sheet - Front Face

GROUND WATER SAMPLING CARD

SITE CODE NUMBER	DATE	TIME	TEAM NO.	LATITUDE	LONGITUDE	WELL OR SPRING	DEPTH OF WELL IN FEET
1 2 3 4 5 6 7 8	9 10 11 12 13 14	15 16 17 18	19 20 21	22 23 24 25 26 27 28	29 30 31 32 33 34 35	36	37 38 39 40

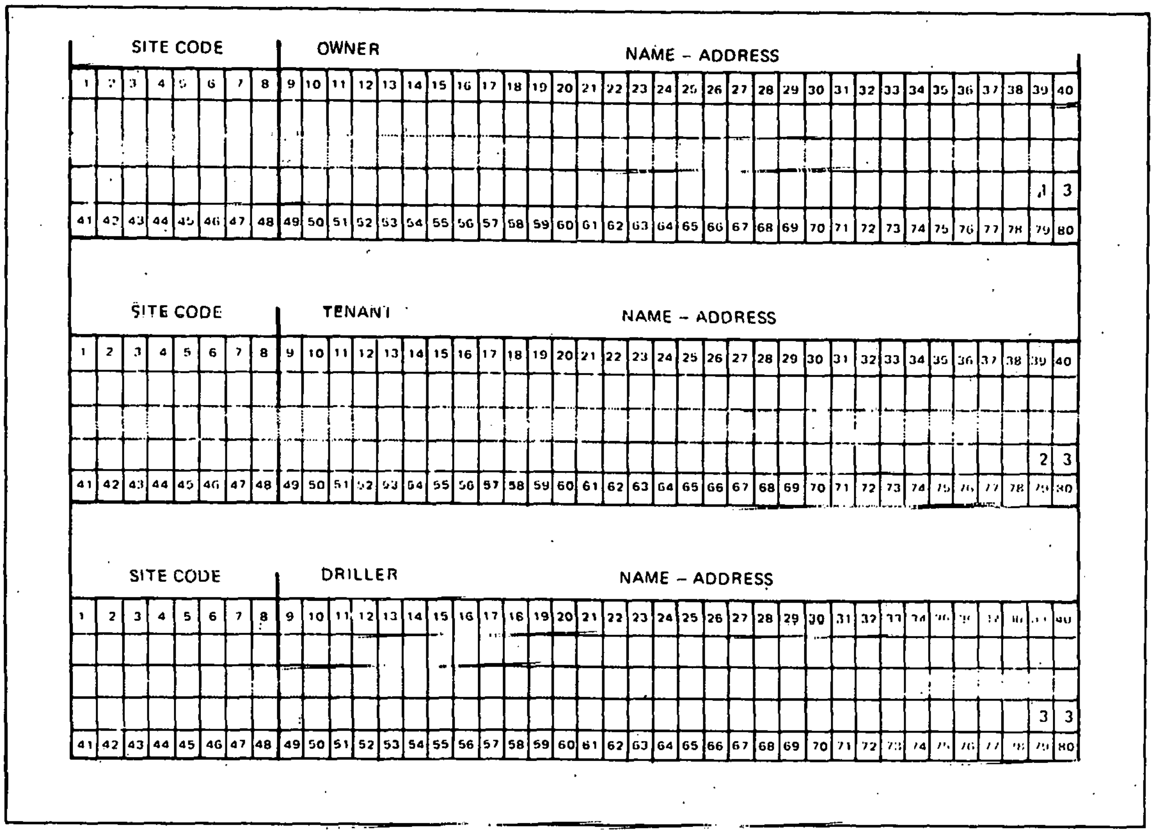
LENGTH OF SCREEN, FEET	AGE OF WELL, YEARS	AGE OF PIPES, YEARS	FORMATION (First six consonants)	TYPE OF WELL	CASING?	CLASSIFICATION	WHERE SAMPLE TAKEN	PIPE COMPOSITION	TREATMENT (List up to three)	USE	APPEARANCE	ODOR	ACTIVITIES (List up to five)	FREQUENCY OF USE			
																0	3
41 42 43	44 45 46	47 48 49	50 51 52 53 54 55	56	57	58	59	60	61 62 63	64	65	66	67 68 69 70 71	72	73 74 75 76 77 78	79	80

FIELD ANALYSIS DATA CARD

SITE CODE NUMBER	pH	Eh MILLIVOLTS	TEMP °C	SPECIFIC COND µmhos/cm	DISSOLVED O_2 mg/l	SPARE
1 2 3 4 5 6 7 8	9 10 11 12 13	14 15 16 17 18	19 20 21 22 23	24 25 26 27 28 29	30 31 32 33 34	35 36 37 38 39 40

SULFATE % TRANSMISSION	PHOSPHATE % TRANSMISSION	NITRATE % TRANSMISSION	AMMONIA % TRANSMISSION	ALKALINITY DROPS H_2SO_4	Ml OF WATER IN FILTRATE	Ml OF WATER PER 10 g RESIN	SPARE	
								2
41 42 43	44 45 46	47 48 49	50 51 52 53	54 55 56	57 58 59	60 61 62 63	64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79	80

Ground Water Sampling Sheet - Reverse Face



SITE CODE | **OWNER** | **NAME – ADDRESS**

1 2 3 4 5 6 7 8 | 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

1 3

41 42 43 44 45 46 47 48 | 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

SITE CODE | **TENANT** | **NAME – ADDRESS**

1 2 3 4 5 6 7 8 | 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

2 3

41 42 43 44 45 46 47 48 | 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

SITE CODE | **DRILLER** | **NAME – ADDRESS**

1 2 3 4 5 6 7 8 | 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

3 3

41 42 43 44 45 46 47 48 | 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Stream Sampling Sheet

STREAM SAMPLING CARD

SITE CODE NUMBER	DATE	TIME	TEAM NO.	LATITUDE	LONGITUDE	BASIN CODE NUMBER
1 2 3 4 5 6 7 8	9 10 11 12 13 14	15 16 17 18	19 20 21	22 23 24 25 26 27 28	29 30 31 32 33 34 35	36 37 38 39 40

1

41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

WIDTH	MAXIMUM DEPTH	VELOCITY	SHAPE	BOTTOM TYPE	ERODED OR DEPOSIT	WATER LEVEL	VEGETATION	RELIEF	STAIN	ACTIVITIES (List up to five)	WATER SAMPLE LOC.	SED SAMPLE LOC.	COLOR	WEATHER	RECENT RAIN	SPARE
STREAM																

FIELD ANALYSIS DATA CARD

SITE CODE NUMBER	pH	Eh MILLIVOLTS	TEMP °C	SPECIFIC COND µmhos/cm	DISSOLVED O_2 mg/l	SPARE
1 2 3 4 5 6 7 8	9 10 11 12 13	14 15 16 17 18	19 20 21 22 23	24 25 26 27 28 29	30 31 32 33 34	35 36 37 38 39 40

2

41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

SULFATE % TRANSMISSION	PHOSPHATE % TRANSMISSION	NITRATE % TRANSMISSION	AMMONIA % TRANSMISSION	ALKALINITY DROPS H_2SO_4	Ml OF WATER IN FILTRATE	Ml OF WATER PER 10 g RESIN	SPARE