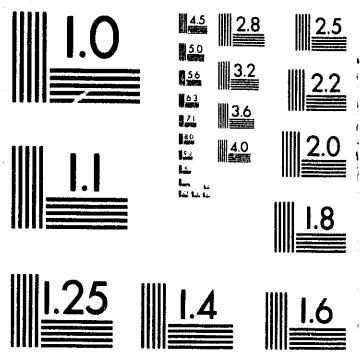

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0

1 of 1

Y/TS-1005

COMPARISON OF RESULTS OF TWO DYE-TRACER TESTS AT THE CHESTNUT RIDGE SECURITY PITS, Y-12 PLANT, OAK RIDGE, TENNESSEE

P. M. Goldstrand
Environmental Sciences Division
Oak Ridge National Laboratory

J. Haas
EIC Laboratories
111 Downey St.
Norwood, MA 02062

January 1994

Prepared for and in cooperation with the Environmental Management Department
Health, Safety, Environment, and Accountability Organization

Oak Ridge Y-12 Plant
Oak Ridge, Tennessee 37831

managed by
MARTIN MARIETTA ENERGY
SYSTEMS, INC.

for the
U.S. DEPARTMENT OF ENERGY
under contract
DE-AC05-84OR21400

CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

Personnel from Martin Marietta Energy Systems, Inc. (Energy Systems) manage a closed hazardous waste disposal unit, the Chestnut Ridge Security Pits (CRSP), located on the crest of Chestnut Ridge near the Y-12 Plant, Oak Ridge, Tennessee. To investigate the discharge of groundwater from CRSP to springs and streams located along the flanks and base of Chestnut Ridge, an initial dye-tracer study was conducted during 1990. A hydraulic connection was inferred to exist between the injection well (GW-178) on Chestnut Ridge and several sites to the east-northeast, east, and southeast of CRSP. A second dye-tracer study was conducted in 1992 to verify the results of the initial test and identify additional discharge points that are active during wet-weather conditions. No definitive evidence for the presence of dye was identified at any of the 35 locations monitored during the second dye study.

Although interpretations of the initial dye test suggest a hydraulic connection with several sites and CRSP, reevaluation of the spectrofluorescence data from this test suggests that dye may not have been detected during the initial test. A combination of relatively high analytical detection limits during the initial test, and high natural background interference spectral peaks observed during the second test, suggest that high natural background emission spectra near the wavelength of the dye used during the initial test may have caused the apparently high reported concentrations.

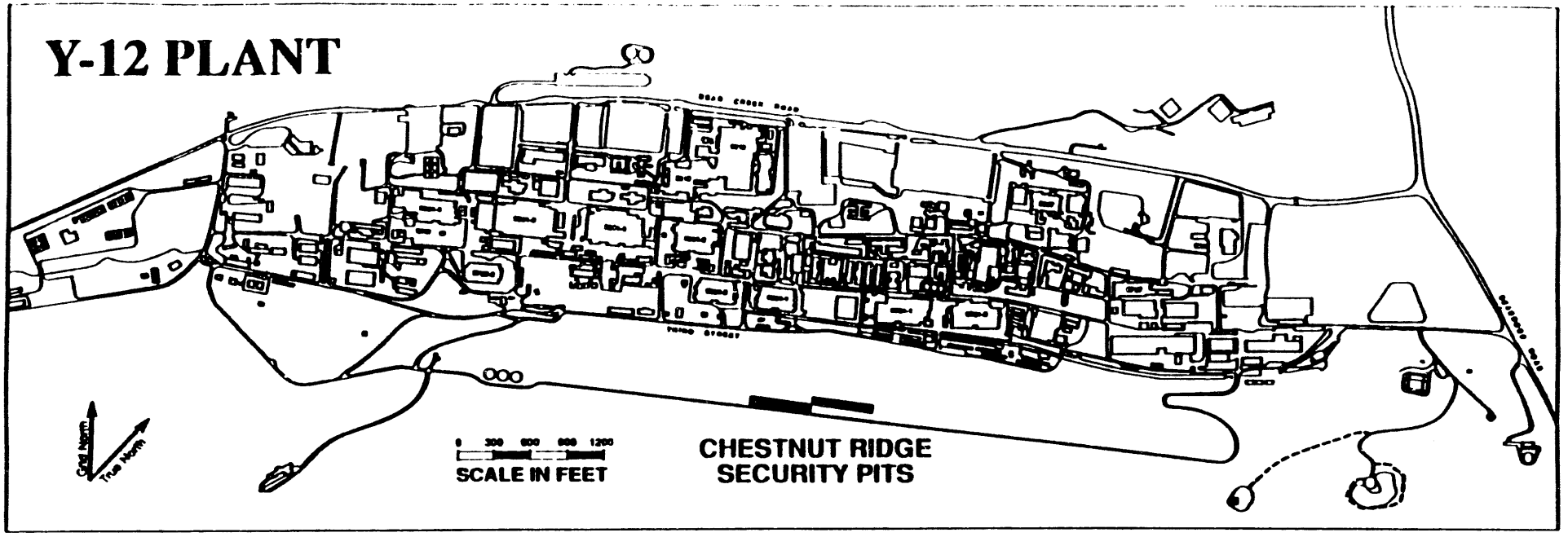
The results of these two tests do not preclude that a hydraulic connection exists; dye may be present in concentrations below the analytical detection limits or has yet to emerge from the groundwater system. The dye injection well is not completed within any significant karst features. Dye migration therefore, may be within a diffuse, slow-flow portion of the aquifer, at least in the immediate vicinity of the source well. In addition, low-flow conditions occurred during both dye studies and the dyes may not have yet emerged at the monitoring sites or may have emerged at springs not monitored.

1. INTRODUCTION

Two different dye-tracer tests have been performed at the Chestnut Ridge Security Pits (CRSP) hazardous waste disposal unit at the U.S. Department of Energy, Oak Ridge Y-12 Plant (Fig. 1.1). These tests were designed to delineate the general flow directions and groundwater flow rates as part of the groundwater quality assessment monitoring program at this site. The initial dye-tracer test was performed during the period of July to October, 1990 (Geraghty and Miller, Inc., 1990). Based on the results of the first test, the existence of hydraulic connections were inferred between the injection well and eight sampling sites to the east-northeast, east, and southeast of CRSP. To comply with the recommendations made to the Tennessee Department of Environment and Conservation staff, a second dye-tracer study was conducted from March to August of 1992 to verify the results of the initial dye-tracer study. The second test was also designed to identify additional discharge points active during wet-weather conditions and obtain qualitative data on the minimum travel times. However, no definitive evidence for the presence of dye was identified at any of the sampling locations during the second dye test (Science Applications International Corp., 1992a). This document is a follow-up report for both tests that summarizes the field and analytical methods and compares the results and interpretations of each test to clarify the discrepancies between the tests.

1.1 CHESTNUT RIDGE SECURITY PITS FACILITY DESCRIPTION

The CRSP are a series of subsurface landfills used from 1973 to 1988 for the disposal of solid and liquid wastes associated with the production processes at the Y-12 Plant. The



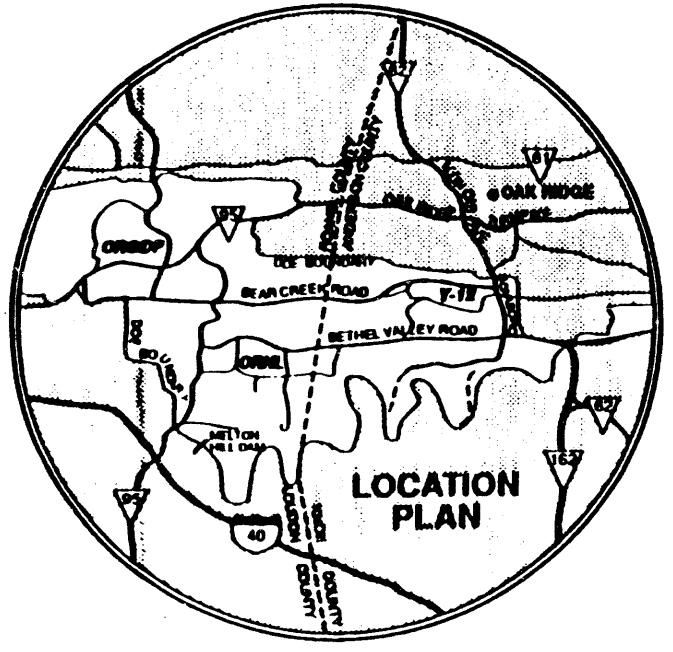


Fig. 1.1 Location map of Chestnut Ridge Security Pits.

CRSP consists of two, waste disposal, trench areas located along the crest of Chestnut Ridge, south of the Y-12 Plant (Fig. 1.1). Both hazardous and nonhazardous waste were deposited in the CRSP. Hazardous waste disposal ceased in 1984 and the facility was closed and capped in accordance with an approved Resource Conservation and Recovery Act Closure Plan in June 1989 (Dames and Moore, 1989).

Detailed waste inventories are classified, but an unclassified inventory of materials buried at the pits includes: acids, fiberglass, beryllium, biological waste, debris, heavy metals, inorganic, organic, thorium, and uranium (Energy Systems, 1984). Of the 3,950 tons of material deposited at the CRSP, uranium represents 44 percent, ferrous material 13 percent, thorium 11 percent, debris 10 percent, and other inorganic material 10 percent. Minor amounts of lithium hydride, deuterium, zirconium, alcohols, and chlorinated solvents are also present (Energy Systems, 1988).

1.2 GEOLOGY AND HYDROGEOLOGY

The CRSP are situated in the soil overlying the Cambrian Copper Ridge Dolomite. The Copper Ridge Dolomite is the basal formation of the Knox Group and consists of massive-to thinly-bedded, locally chert-rich dolostone with abundant stylolites (King and Haase, 1987). Strike of bedding is generally from N 55-65^{0}E and dips are approximately 45^0 to the southeast.

The potentiometric surface reflects surface topography, resulting in a groundwater divide at the crest of Chestnut Ridge in the vicinity of the CRSP. To the north of Chestnut Ridge, the hydraulic gradient is high in response to the steep topographic slope from the ridge to Bear Creek Valley (BCV). Southward the hydraulic gradient is low, generally following the slightly more subdued topography of the upper Knox Group. While groundwater movement is largely controlled by fractures and dissolution channels within the bedrock, the area does not appear to have a well developed karst conduit system (Science Application International Corp., 1992b). Thus, the bedrock aquifer may be predominantly a diffuse, slow-flow system.

A limited spring and seep survey was conducted prior to the initial test, identifying a number of springs and surface streams that may receive their discharge waters from Chestnut Ridge. Four main areas were surveyed as possible dye discharge sites: (1) Upper East Fork Poplar Creek (UEFPC), north of CRSP; (2) BCV, north and west of CRSP; (3) South Chestnut Ridge (SCR); and (4) Scarboro Creek, to the east and along strike with Chestnut Ridge (Fig. 1.2).

2. METHODS

2.1 FIRST DYE-TRACER TEST

The objectives of the first dye-tracer test were to determine groundwater flow directions in the saturated zone below Chestnut Ridge in the vicinity of the CRSP and identify

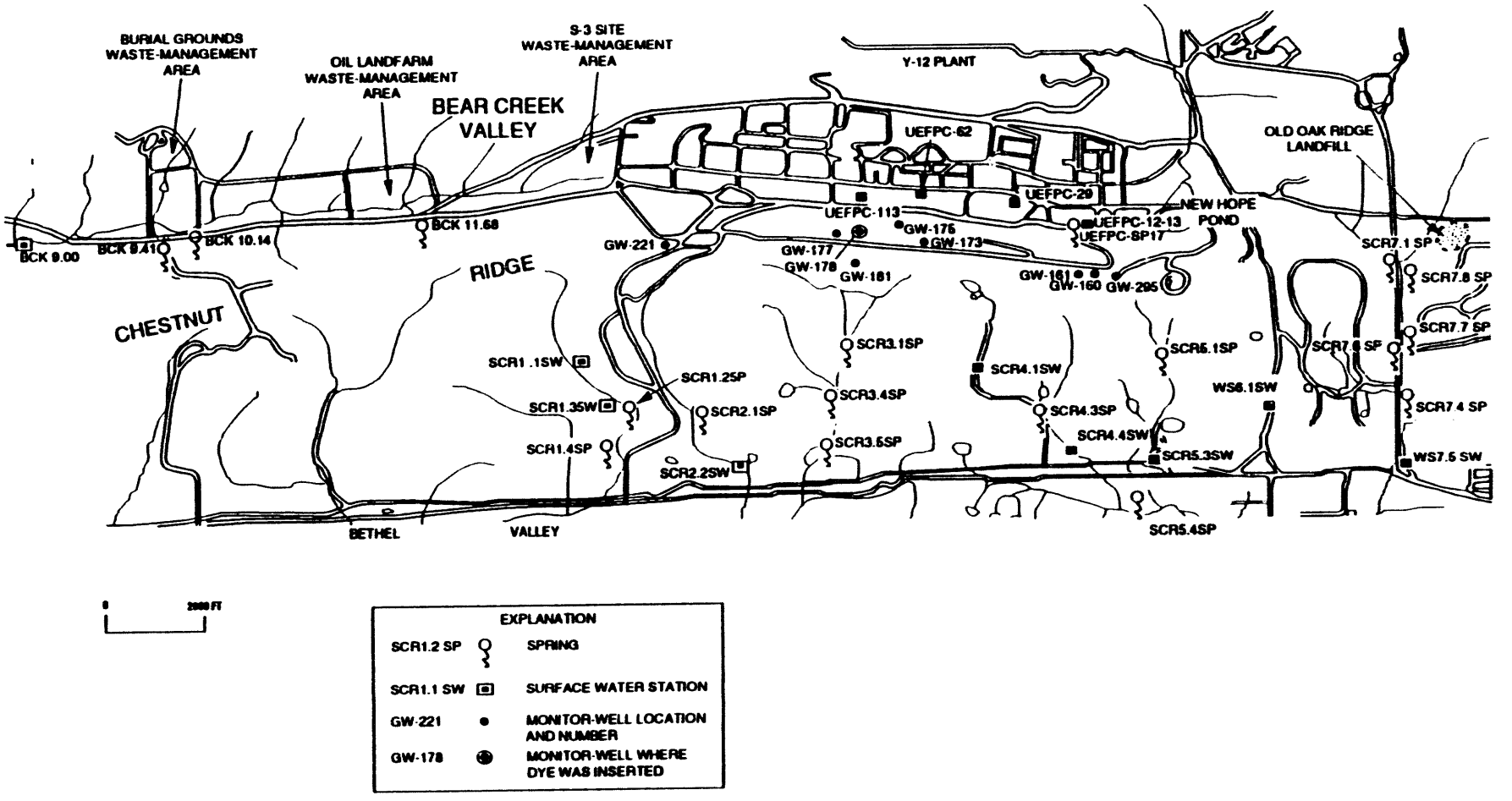


Figure 1.2: Monitoring stations for initial dye-tracer study.

some of the natural groundwater discharge points originating from the CRSP area (Geraghty and Miller, Inc., 1990). The injection well (GW-178) is screened between 1,008 and 1,019 ft above mean sea level, with a total depth of 133 ft below the ground surface (King et al., 1991). During construction of this well, several solution cavities were encountered (from approximately 43 to 83 ft), but no cavities were encountered in the screened interval from 122 to 132 ft. Only two "possible" fractures are believed to occur within the screened interval (Geraghty and Miller, Inc., 1987). Personnel from Geraghty and Miller, Inc. (1990) conducted a recharge test on this well in which one well-casing volume (approximately 29.6 gal) of potable water discharged to the groundwater system over a "few hours"; no quantitative hydraulic conductivity values are given.

Sixteen springs, fifteen surface water sites, and eight groundwater monitoring wells were selected for monitoring the presence of dye (Fig. 1.2). Three weeks prior to insertion of the dye, charcoal detectors were installed at each site to monitor the natural background fluorescence. Dye detectors consisted of 10 grams of reagent-grade, activated charcoal placed within a nylon stocking and suspended in the water of the sample site by a "Quinlan Gumdrop" (Geraghty and Miller Inc., 1990). The gumdrop consisted of a 6-inch diameter concrete block, into which a wire is embedded for the attachment of the detector. Twice during the three weeks of background monitoring, the detectors were collected and analyzed for background fluorescence. All but three sites had background fluorescence below the analytical detection limit of 1 ppb (Table 2.1).

Table 2.1: Initial dye-tracer monitoring sites, background concentrations and dye detection (Geraght and Miller, Inc., 1990).

SITE	TYPE[1]	BACKGROUND (ppb)	DYE DETECTION
GW-160	W	<1	negative
GW-161	W	<1	negative
GW-295	W	<1	negative
GW-173	W	<1	negative
GW-175	W	<1	positive
GW-177	W	<1	negative
GW-178	W	<1	negative
GW-181	W	<1	negative
BCK-9.00	SW	<1	possible
BCK-9.41	SP	<1	negative
BCK-10.14	SP	1.1 ± 0.2	possible
BCK-11.68	SP	<1	negative
UEFPC-113	SW	<1	positive
UEFPC-62	SW	<1	positive
UEFPC-29	SW	<1	positive
UEFPC-17	SP	1.3 ± 0.4	possible
UEFPC-12/13	SW	<1	positive
SCR-1.1	SW	<1	negative
SCR-1.2	SP	<1	negative
SCR-1.3	SW	<1	negative
SCR-1.4	SP	<1	negative
SCR-1.5	SW	<1	negative
SCR-2.1	SP	<1	negative
SCR-2.2	SW	<1	negative
SCR-3.1	SP	<1	negative
SCR-3.4	SP	<1	negative
SCR-3.5	SP	<1	negative
SCR-4.1	SW	<1	negative
SCR-4.3	SP	<1	negative
SCR-4.4	SW	<1	negative
SCR-5.1	SP	<1	positive
SCR-5.3	SW	<1	negative
SCR-5.4	SP	<1	positive
SCR-7.1	SP	<1	positive
SCR-7.4	SP	<1	negative
SCR-7.6	SP	<1	negative
SCR-7.7	SP	<1	negative
SCR-7.8	SP	<1	negative
WS-6.1	SW	<1	negative
WS-7.5	SW	2.6 ± 1.0	possible

1 W = groundwater monitoring wells; SW = surface stream; SP = spring

Ten kilograms of sodium fluorescein powder were mixed with 20 gal of water and injected into monitoring Well GW-178 on July 11, 1990. Dye injection was preceded and followed by slugs of 1,000 gal of potable water (Geraghty and Miller, Inc., 1990). During the test, each detector was collected weekly by Energy Systems personnel and analyzed at the Y-12 analytical laboratory using full chain-of-custody procedures. Detectors were stored in 250-milliliter amber jars at 4^0C until analyzed. To prevent cross-contamination during collection of detectors in the field, protective clothing was changed at each site where technicians had contact with spring or surface water. New detectors were handled using clean latex gloves during each exchange. At each detector location, an aliquot of water was sampled and tested for temperature, pH, and specific conductance, with each instrument calibrated with a standard before the measurements were taken. Throughout the test several detectors were lost, probably due to predation or other natural causes (Geraghty and Miller, Inc., 1990).

Elution of possible absorbed dye from the activated charcoal was done using a standard 100-ml aliquot of "Smart solution" of 25% distilled water, 25% NH_4OH, and 50% 1-propanol (Geraghty and Miller, Inc., 1990). Geraghty and Miller, Inc. (1990) do not note if the samples were washed prior to elution. Two aliquots of the supernatant solution were decanted into a clean cuvette and analyzed in a Perkin Elmer 650-S spectroflorophotometer. One aliquot of supernatant solution was analyzed after 1 hour of elution, another analyzed after 24 hours of elution. A representative spectrum band above and below the emission peak for fluorescein was scanned. The spectrum was

interpreted at the midpoint of the fluorescein peak, and was determined by scanning the representative wavelength range in nanometers (nm) of the excitation peak of the dye (490 nm) and scaling across the abscissa to the specific wavelength. A peak height of 0.30 cm was calculated to be equivalent to 1 ppb at the nominal instrument setting and used as the detection limit.

Apparent concentrations above background levels or detection limits were reported for those eluted in the "Smart solution" for either 1 hour or 24 hours. Copies of the spectrographs (for Weeks 2 to 9 after dye insertion) show that some samples had an increase in fluorescence between the 1-hour and 24-hour analyses, whereas several other samples show the opposite affect. Some samples showed no fluorescence during one analysis and fluorescence in another.

Four types of quality assurance samples were analyzed: calibration samples, reagent blank samples, instrument blank samples, and spiked dye recovery samples (Geraghty and Miller Inc., 1990). Instrument calibrations were performed each week and each time the instrument was restarted or readjusted. Serial dilution of batch dye with reagent-grade water was analyzed in concentrations of <5 ppb, 5-10 ppb, 50-100 ppb, and 500-1,000 ppb, using sensitivity factors of 10, 3, 1, and 0.1, respectively. The resulting plot for concentration in the range of 1 to 50 ppb showed a close linear relationship (Geraghty and Miller, Inc., 1990). The slope of this line was calculated for three calibration analyses and used as a conversion factor for reading within the specified

concentration, sensitivity, and response ranges. For concentrations of 50 ppb or less the conversion factor was 3.77 (Geraghty and Miller, Inc., 1990). Three calibration samples were analyzed for each concentration range with a duplicate of at least one sample analyzed. Reagent blank samples were prepared using reagents, charcoal, "Smart solution", and glassware to be used during the test. The reagent blanks were analyzed only at the beginning of the study and show no fluorescence above the detection limit. Spiked samples were prepared by suspending a detector in water collected from UEFPC for 6 days. Water from UEFPC was used so the affects of natural, background-producing substances would be observed. A known concentration of dye was added after the 6 days and left in the water for an additional 24 hours, after which the detector was removed and analyzed. Results indicate that the spiked samples show that the amount of dye recovered from the activated charcoal ranged between only 8 and 12 percent (Geraghty and Miller, Inc., 1990).

2.2 SECOND DYE-TRACER TEST

The rational for the second dye-tracer test was three-fold: to more completely delineate the groundwater flow directions, provide qualitative data on dye concentrations at the discharge points related to the CRSP recharge area, and verify the results of the initial test (Science Applications International Corp., 1992b). Furthermore, the initial dye-tracer test was begun during the low-flow season which could have hindered the transport of the dye, thus the second test was designed to compare the results between high-flow and low-flow periods.

Additionally, the presence of an old landfill (Fig. 1.2) may have been a possible source of interference at two of the monitoring sites (SCR7.1SP and WS7.5SW) of the initial dye test. Also, the relatively high analytical detection limit (1 ppb) and natural background interferences make it difficult to distinguish a 1 ppb baseline from a true peak concentration of 2 to 5 ppb (Science Applications International Corp., 1992b).

For verification of the first dye test results, the same injection well was used for the second test (GW-178). However, a few of the sampling locations used during the first test were considered excessive and eliminated (Science Applications International Corp., 1992b). Lack of funds prevented greater coverage of the area. The monitoring sites for the second dye-tracer test were limited to 5 groundwater wells, 11 surface water sites, and 19 springs (Fig. 2.1; Table 2.2). Wells GW-232 and GW-561 were added to monitor possible groundwater flow to the east and south, respectively. Well GW-734 was completed in a large cavity within the Maynardville Limestone, which could provide information on possible flow to the northeast, and was added to the dye sampling stations after background testing was completed.

Four weeks of background sampling were completed prior to dye injection (Table 2.2). Data gaps in some background locations occur due to loss of detectors from predation, equipment failure, or natural processes. This problem was alleviated by the placement of rebar and back-up anchors in high-flow

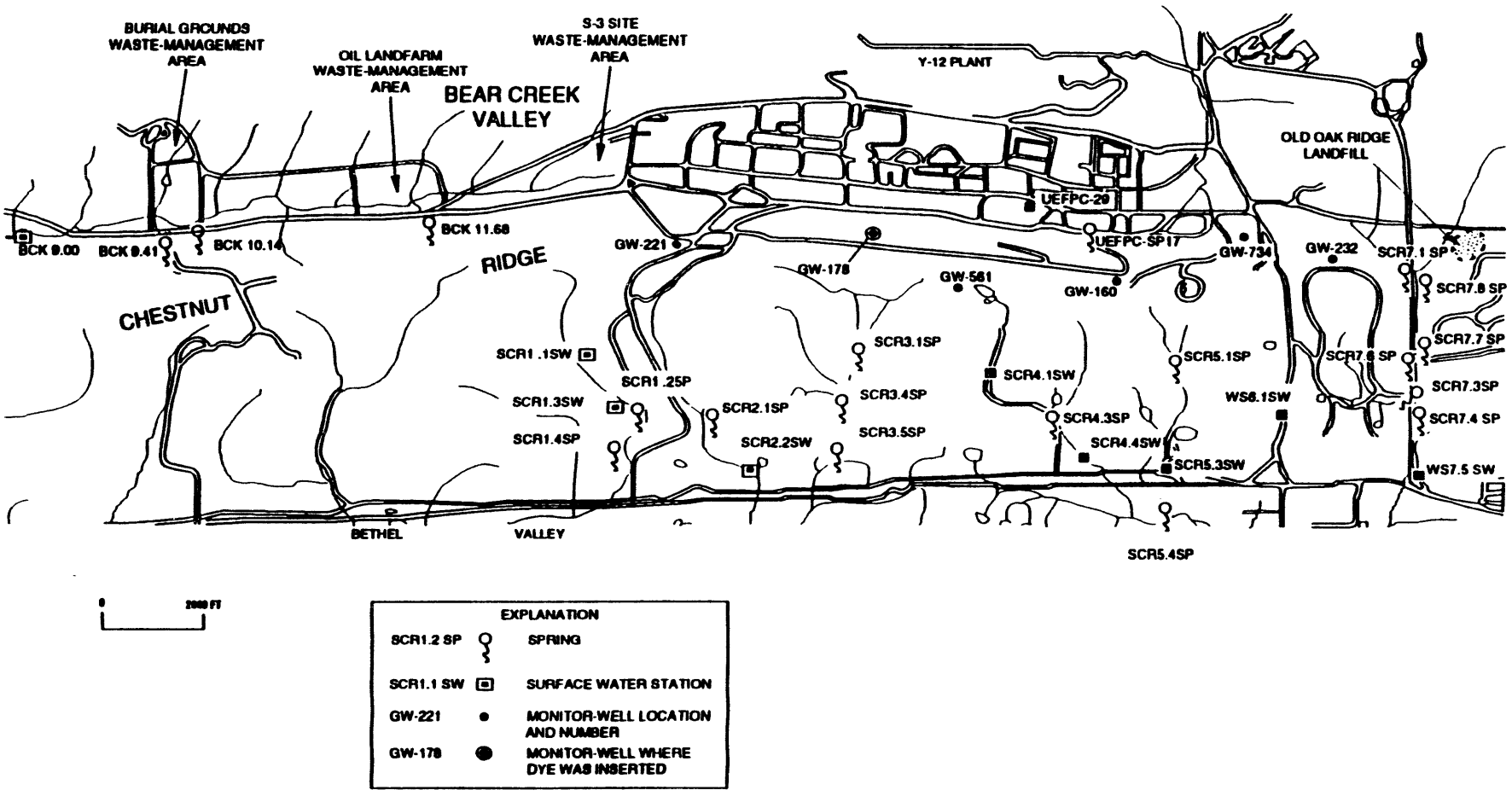


Figure 2.1: Monitoring stations for second dye-tracer study.

Table 2.2: Second dye-tracer test monitoring sites, background concentrations and weekly analyses.

FLUOR

Week	BCK-9.00	BCK-9.41	BCK-10.14	BCK-11.68	SCR-1.5S	SCR-1.4SP	SCR-1.3S	SCR-1.2SP	SCR-1.1S	SCR-2.2S	SCR-2.1SP	SCR-3.5SP
-4	0.075	0.029	31.2	0.04	0.06	0.067	0.15	0.067	0.03	0.021	0.086	0.018
-3	0.027	0.021	32.3	0.046	0.15	0.043	0.12	0.038	0.05	0.03	0.038	0.032
-2	0.025	0.027	15.6	0.023	0.046	0.021	0.055	0.027	0.035	0.018	0.019	
-1	0.04	0.032	0.8	0.029		0.023	0.032	0.043	0.033	0.038	0.026	0.026
0												
1	0.024	0.027	17.6	0.022	0.1	0.023	0.04	0.035	0.03	0.043	0.024	0.038
2	0.075	0.021	15.8	0.038	0.067	0.024	0.06	0.035	0.03	0.032	.15*	0.06
3	0.024	0.032	12.6	0.024	0.15	0.027	0.035	0.06	0.046	0.075	0.029	0.026
4	0.03	0.025	11.5	0.021	0.06	0.04	0.03	0.043	0.035	0.038	0.025	0.027
5	0.021	0.032	15.7	0.023	0.086	0.029	0.04	0.06	0.032	0.019	0.036	0.025
6	0.032	0.029	14.9	0.021	0.06	0.029	0.02	0.029	0.06	0.024	0.04	0.046
7	0.043	0.021	32.7	0.033	0.06	0.035	0.05	0.06	0.043	0.023	0.075	0.023
8	0.033	0.024	32.1	0.05	0.1	0.025	0.046	0.1	0.043	0.023	0.043	0.022
9	0.075	0.024	31	0.029	0.086	0.032	0.1	0.075	0.055	0.019	0.075	0.024
10	0.032	0.038	42.2	0.033	0.075	0.029	0.06	0.086	0.046	0.019	0.033	0.024
11	0.043	0.04	43.9	0.06	0.1	0.026	0.12	0.15	0.032	0.02	0.05	0.024
12	0.075	0.04	42.9	0.075	0.075	0.033	0.15	0.12	0.04	0.021	0.043	0.023
13	0.086	0.02	41.3	0.055	0.075	0.026	0.067	0.15	0.15	0.024	0.055	0.032
14	0.06	0.043	21.7	0.043	0.075	0.04	0.055	0.05	0.043	0.02	0.06	0.03
15	0.5	0.046	32.7	0.12	0.1	0.027	0.15	0.075	0.025	0.021	0.038	0.025
16	0.06	0.025	31	0.05	0.06	0.027	0.1	0.046	0.075	0.02	0.035	0.035
17	0.05	0.12	25.2	0.046	0.12	0.06	0.086	0.075	0.086	0.03	0.086	0.075
18	0.055	0.046	17.3	0.033	0.046	0.05	0.067	0.12	0.06	0.022	0.086	0.023
MEAN	0.04175	0.02725	19.975	0.0345	0.0853333	0.0385	0.08925	0.04375	0.037	0.02675	0.04225	0.0253333
STD	0.023	0.0046	14.88	0.0104	0.056	0.0197	0.055	0.01687	0.0089	0.009	0.03	0.007
M+3STD	0.11075	0.04105	64.615	0.0657	0.2533333	0.0976	0.25425	0.09436	0.0637	0.05375	0.13225	0.0463333

RWT (ppb)

Week	BCK-9.00	BCK-9.41	BCK-10.14	BCK-11.68	SCR-1.5S	SCR-1.4SP	SCR-1.3S	SCR-1.2SP	SCR-1.1S	SCR-2.2S	SCR-2.1SP	SCR-3.5SP
-4	0.79	0.23	1.04	0.31	0.87	0.52	0.94	0.62	0.74	0.88	0.69	0.75
-3	0.86	0.28	0.86	0.32	0.86	0.41	0.97	0.81	0.87	0.78	0.58	0.8
-2	1.19	0.36	1.13	0.38	0.56	0.49	0.53	0.75	0.54	0.54	0.7	
-1	1.02	0.26	1.54	0.31		0.82	0.84	0.4	0.41	0.59	0.7	0.75
0												
1	0.82	0.23	0.98	0.47	0.82	0.33	0.83	0.92	0.43	0.57	0.85	0.54
2	0.96	0.1	0.83	0.2	0.62	0.28	0.26	0.56	0.54	0.57	0.5	0.59
3	1.02	0.21	0.75	0.18	0.78	0.32	0.77	0.33	0.64	0.62	0.62	0.71
4	0.87	0.22	1.08	0.14	0.45	0.36	0.68	0.52	0.47	0.14	0.7	0.31
5	0.51	0.23	0.88	0.2	0.64	0.21	0.55	0.71	0.48	0.16	0.7	0.36
6	0.81	0.1	1.14	0.41	0.5	0.34	0.95	0.43	1.02	0.2	1.06	0.33
7	0.79	0.15	1.02	0.21	0.63	0.27	0.63	0.33	0.46	0.24	0.91	0.3
8	1.26	0.08	1.14	0.19	0.48	0.18	0.35	0.4	1.15	0.26	0.62	0.28
9	1.27	0.14	1.42	0.3	0.66	0.28	0.86	0.82	0.93	0.24	1.51	0.79
10	0.64	0.16	2.61*	0.15	0.7	0.09	0.65	0.56	1.11	0.23	0.58	0.27
11	0.68	0.08	1.42	0.25	0.62	0.14	0.52	0.35	1.51	0.22	0.3	0.19
12	0.69	0.17	1.86	0.45	0.76	0.27	0.81	1.12	0.97	0.14	0.38	0.59
13	1.66*	0.11	1.07*	0.28	1.34*	0.09	1.46*	1.27*	1.82*	0.32	0.87	0.66
14	0.034	0.12	1.67*	0.33	0.72	0.11	0.88	0.97	0.94	0.29	0.53	0.23
15	1.21	0.2	1.23*	0.54	0.83	0.26	1.55*	1.12*	0.63	0.38	1.74*	0.86
16	0.75	0.22	0.98	0.46	1.47*	0.21	0.92	0.68	1.24*	0.45	0.82	0.75
17	0.87	0.024	2.23*	0.51	1.7*	0.51	0.93	0.92	1.74*	0.33	0.73	0.83
18	1.32*	0.19	2.04*	0.45	1.7*	0.77	1.08*	1.27*	1.6*	1.55*	0.5	1.01
MEAN	0.965	0.2825	1.1425	0.33	0.7633333	0.56	0.82	0.645	0.64	0.6975	0.6675	0.7666667
STD	0.178	0.0556	0.288	0.0336	0.176	0.1794	0.201	0.1815	0.2047	0.1596	0.0585	0.0288
M+3STD	1.499	0.4493	2.0065	0.4308	1.2913333	1.0982	1.423	1.1895	1.2541	1.1763	0.843	0.8530667

Table 2.2: Second dye-tracer test monitoring sites, background concentrations and weekly analyses (continued).

FLUOR

Week	SCR-3.4SP	SCR-3.1SP	SCR-4.4S	SCR-4.3SP	SCR-4.1S	SCR-5.4SP	SCR-5.3S	SCR-5.1SP	WS-4.1SW	WS-7.5SW	SCR-7.4SP	SCR-7.3SP	SCR-7.6SP
-4	0.029	0.026	0.018	0.024	0.027	0.027	0.032	0.033	0.024	0.03	0.023	0.086	0.06
-3	0.038	0.043	0.019	0.05	0.04	0.035	0.03	0.12	0.03	0.043	0.024	0.035	0.086
-2	0.021	0.024	0.025	0.035	0.032	0.024	0.029	0.025	0.02	0.033	0.014	0.032	0.06
-1	0.029	0.032	0.029	0.029	0.04	0.05	0.033	0.035	0.024	0.05	0.024	0.038	0.055
0													
1	0.021	0.032	0.023	0.2*	0.033	0.04	0.05	0.029	0.019	0.05	0.024	0.055	0.04
2	0.033	0.03	0.032	0.05	0.06	0.06	0.055	0.032	0.019	0.032	0.018	0.026	0.067
3	0.06	0.046	0.075	0.043	0.026	0.05	0.032	0.046	0.017	0.046	0.03	0.021	0.055
4	0.022	0.035	0.015	0.035	0.03	0.06	0.029	0.027	0.019	0.032	0.021	0.022	0.029
5	0.02	0.033	0.022	0.046	0.032	0.026	0.033	0.025	0.018	0.06	0.023	0.021	0.033
6	0.025	0.035	0.033	0.075	0.026	0.038	0.025	0.05	0.021	0.03	0.024	0.023	0.067
7	0.029	0.032	0.021	0.1	0.067	0.067	0.046	0.055	0.04	0.04	0.022	0.033	0.043
8	0.024	0.043	0.025	0.05	0.022	0.05	0.03	0.033	0.021	0.03	0.024	0.019	0.032
9	0.025	0.035	0.022	0.067	0.05	0.021	0.038	0.033	0.022	0.055	0.025	0.022	0.1
10	0.029	0.025	0.02	0.055	0.023	0.01	0.035	0.05	0.021	0.038	0.038	0.017	0.032
11	0.029	0.026	0.022	0.05	0.05	0.038	0.075	0.03	0.043	0.035	0.023	0.024	0.067
12	0.032	0.033	0.022	0.046	0.028	0.067	0.029	0.023	0.019	0.1	0.032	0.024	0.067
13	0.025	0.038	0.026	0.055	0.027	0.046	0.025	0.035	0.023	0.06	0.021	0.023	0.086
14	0.027	0.035	0.021	0.029	0.06	0.06	0.055	0.046	0.055	0.022	0.038	0.046	0.055
15	0.029	0.024	0.022	0.05	0.026	0.067	0.035	0.032	0.021	0.043	0.029	0.04	0.035
16	0.029	0.035	0.022	0.021	0.035	0.038	0.038	0.021	0.026	0.015	0.022	0.023	0.12
17	0.023	0.086	0.05	0.12	0.05	0.12	0.055	0.04	0.046	0.15	0.027	0.033	0.2
18	0.04	0.038	0.025	0.043	0.032	0.043	0.03	0.027	0.024	0.12	0.029	0.055	0.12
MEAN	0.02925	0.03125	0.02275	0.0345	0.03475	0.034	0.031	0.05325	0.0245	0.039	0.02125	0.04775	0.06525
STD	0.0069	0.0085	0.0052	0.0113	0.00639	0.0116	0.00188	0.0447	0.0041	0.0091	0.00485	0.0256	0.014
M+3STD	0.04995	0.05675	0.03835	0.0684	0.05392	0.0688	0.03664	0.18735	0.0368	0.0663	0.0358	0.12455	0.10725

RWT

Week	SCR-3.4SP	SCR-3.1SP	SCR-4.4S	SCR-4.3SP	SCR-4.1S	SCR-5.4SP	SCR-5.3S	SCR-5.1SP	WS-4.1SW	WS-7.5SW	SCR-7.4SP	SCR-7.3SP	SCR-7.6SP
-4	0.75	0.51	0.49	0.62	0.32	0.88	0.72	0.44	0.24	1.31	0.33	0.32	0.33
-3	0.85	0.51	0.83	0.74	0.55	1.44	0.79	0.56	0.47	0.88	0.33	0.67	0.46
-2	0.28	0.41	0.56	0.74	0.33	0.51	0.74	0.54	0.31	1.35	0.46	0.42	0.65
-1	0.53	0.51	0.93	0.7	0.61	0.83	1.28	0.54	0.9	1.02	0.43	0.67	0.77
0													
1	0.68	0.84	0.49	0.8	0.37	0.82	0.87	0.25	0.61	1.14	0.35	0.47	0.36
2	0.51	0.52	0.5	1	0.64	0.83	1.09	0.51	0.27	0.98	0.3	0.37	0.49
3	0.32	0.53	0.33	0.54	0.31	0.6	0.32	0.27	0.22	0.86	0.17	0.7	0.49
4	0.25	0.26	0.35	0.36	0.23	0.82	0.41	0.21	0.12	0.92	0.18	0.27	0.41
5	0.23	0.39	0.23	0.42	0.33	0.72	0.68	0.15	0.18	0.51	0.23	0.28	0.23
6	0.24	0.27	0.25	0.37	0.28	1.18	0.73	0.24	0.17	0.41	0.23	0.38	0.5
7	0.38	0.26	0.16	0.43	0.27	0.54	0.41	0.3	0.21	0.56	0.27	0.18	0.57
8	0.36	0.23	0.11	0.55	0.26	0.66	0.41	0.2	0.07	0.93	0.2	0.47	0.2
9	0.47	0.34	0.42	0.62	0.28	2.38*	0.35	0.34	0.12	0.97	0.2	0.24	0.47
10	0.15	0.47	0.2	0.55	0.09	0.03	0.26	0.24	0.12	0.6	0.25	0.17	0.21
11	0.12	0.3	0.19	0.78	0.37	0.59	0.13	0.21	0.13	..42	0.14	0.5	0.41
12	0.33	0.33	0.19	0.78	0.52	1.57	0.37	0.5	0.21	0.56	0.17	0.49	0.33
13	0.25	0.67	0.12	0.27	0.31	1.8*	0.61	0.38	0.21	0.75*	.89*	0.21	0.4
14	0.23	0.29	0.59	0.27	0.11	1.16*	0.37	0.35	0.59	0.8	0.4	0.69	0.57
15	0.12	0.51	1.72*	1.14*	0.35	1.12	0.58	0.47	0.41	1.13*	0.92	0.97*	0.63
16	0.26	0.34	0.41	0.36	0.44	1.35*	0.26	0.28	0.22	1.37	0.14	0.55	0.34
17	0.62	0.62	0.59	0.73*	0.37	1.68*	1.32*	0.83	0.56	2.5*	0.47	0.59	0.35
18	0.51	.4*	1.09	0.68	0.31	1.62*	0.58	0.26	0.78*	2.14*	0.55	0.47	0.41
MEAN	0.6025	0.485	0.7025	0.7	0.4525	0.915	0.8825	0.52	0.48	1.14	0.3875	0.52	0.5525
STD	0.253	0.05	0.211	0.05656	0.149	0.386	0.266	0.054	0.296	0.227	0.0675	0.1779	0.1956
M+3STD	1.3615	0.635	1.3355	0.86968	0.8995	2.073	1.6805	0.682	1.368	1.821	0.59	1.0537	1.1393

Table 2.2: Second dye-tracer test monitoring sites, background concentrations and weekly analyses (continued).

FLUOR

Week	SCR-7.7SP	SCR-7.8SP	SCR-7.1SP	UEFPC-SP	UEFPC-29	GW-232	GW-561	GW160	GW-221	GW-734
-4	0.038	0.12	0.03	0.032	0.02		0.04	0.15	0.026	
-3	0.03		0.055	0.024	0.029	0.035	0.024	0.032	0.021	
-2	0.025	0.027	0.032	0.02	0.029	0.022	0.021	0.033	0.021	
-1	0.018	0.15	0.029	0.021	0.025		0.015	0.033	0.019	
0										
1	0.05	0.038	0.027	0.023	0.025	0.026	0.032	0.055	0.04	0.04
2	0.06	0.2*	0.04	0.021	0.035	0.021	0.022	0.046	0.029	0.032
3	0.2*	0.029	0.038	0.026	0.021	0.03	0.033	0.075	0.033	0.026
4	0.04	0.06	0.086	0.024	0.02	0.025	0.04	0.03	0.029	0.025
5	0.036	0.033	0.03	0.029	0.023	0.027	0.038	0.06	0.032	0.022
6	0.06	0.038	0.05	0.023	0.043	0.024	0.027	0.06	0.023	0.086
7	0.043	0.078	0.038	0.026	0.02	0.038	0.026	0.068	0.023	0.033
8	0.043	0.032	0.075	0.022	0.035	0.035	0.033	0.75	0.026	0.1
9	0.063	0.055	0.086	0.024	0.024	0.025	0.026	0.1	0.021	0.035
10	0.033	0.075	0.032	0.019	0.015	0.027	0.025	0.15	0.03	0.021
11	0.055	0.06	0.055	0.021	0.019	0.033	0.026	0.067	0.029	0.025
12	0.06	0.04	0.067	0.021	0.033	0.033	0.035	0.043	0.025	0.025
13	0.055	0.035	0.043	0.027	0.03	0.025	0.033	0.038	0.027	0.026
14	0.06	0.038	0.1	0.022	0.026	0.022	0.023	0.043	0.026	0.026
15	0.06	0.035	0.1	0.032	0.026	0.027	0.05	0.067	.03	0.025
16	0.043	0.046	0.067	0.038	0.04	0.026	0.05	0.075	0.023	0.024
17	0.086	0.2	0.1	0.029	0.027	0.026	0.05	0.06	0.024	0.03[illegible]
18	0.2	0.032	0.086	0.04	0.03	0.032	0.06	0.15	0.026	0.024
MEAN	0.02775	0.099	0.0365	0.02425	0.02575	0.0285	0.025	0.062	0.02175	
STD	0.0084	0.0641	0.01239	0.0054	0.0042	0.0092	0.01067	0.0586	0.00298	
M+3STD	0.05295	0.2913	0.07367	0.04045	0.03835	0.0561	0.05701	0.2378	0.03069	

RWT

Week	SCR-7.7SP	SCR-7.8SP	SCR-7.1SP	UEFPC-SP	UEFPC-29	GW-232	GW-561	GW160	GW-221	GW-734
-4	0.53	0.44	0.41	1.44	5.44		0.19	0.21	0.2	
-3	0.4		0.62	1.24	5.2	0.42	0.18	0.17	0.1	
-2	0.33	0.31	0.61	0.65	0.82	0.5	0.15	0.21	0.11	
-1	0.51	0.47	0.94	1.04	3.76	0.17	0.21	0.083	0.16	
0										
1	0.58	0.47	1.07	1.35	1.36	0.44	0.33	0.11	0.14	0.15
2	0.55	0.33	0.78	0.83	2.16	0.77	0.15	0.09	0.08	0.23
3	0.53	0.49	0.21	0.49	2.97	0.11	0.11	0.04	0.1	0.072
4	0.31	0.27	0.24	0.57	3.18	0.2	0.13	0.11	0.14	0.12
5	0.49	0.13	0.63	1.02	2.4	0.06	0.15	0.1	0.09	0.17
6	0.49	0.16	0.33	0.93	3.73	0.14	0.19	0.09	0.08	0.1
7	0.24	0.14	0.46	0.99	1.14	0.07	0.29	0.03	0.06	0.09
8	0.48	0.16	0.3	1.31	2.7	0.15	0.07	0.04	0.04	0.04
9	0.3	0.18	0.31	1.1	2.72	0.16	0.2	0.1	0.08	0.09
10	0.22	0.39	0.33	1.37	4.74	0.04	0.09	0.05	0.1	0.07
11	0.23	0.13	0.53	0.87	3.58	0.08	0.05	0.06	0.05	0.07
12	0.34	0.35	0.27	1.65	2.74	0.19	0.12	0.07	0.25	0.1
13	0.34	0.35	0.67	2.21*	3.09	0.03	0.07	0.03	0.18	0.16
14	0.23	0.18	0.22	1.41*	9.3	0.08	0.11	0.05	0.2	0.04
15	0.16	0.47	1.12	1.3	7.8	0.45	0.14	0.09	0.16	0.1
16	0.31	0.2	0.58	0.92	5.61	0.28	0.12	0.1	0.16	0.16
17	0.36	0.37	0.73	1.51*	7.19	0.26	0.19	0.12	0.1	0.42
18	0.65	0.55	0.89	1.51*	7.5	.97*	0.21	0.04	0.12	0.24
MEAN	0.4425	0.4066667	0.645	1.0925	3.805	0.3633333	0.1825	0.16825	0.1425	
STD	0.0943	0.085	0.2191	0.3571	2.123	0.172	0.025	0.0598	0.0464	
M+3STD	0.7254	0.6616667	1.3023	2.1038	10.174	0.8793333	0.2575	0.34765	0.2817	

streams, and encasement of all detectors within stainless steel cages.

Two dyes were injected into Well GW-178 on March 13, 1992. The two dyes used for the second test were Rhodamine WT (RWT), a red dye, and Calcofluor White (FB28), an optical brightener (Science Applications International Corp., 1992a, 1992b). Prior to dye injection, a primer slug of 836.6 gallons of water was gravity fed into Well GW-178 at a flow rate 52 gal/hour. Next, 22.2 gallons of RWT (20% solution) and a mixture of 20 kg of liquid FB28 and 40 gallons of potable water were injected into the well. Post dye injection was followed by a chaser slug of 1,000 gallons of potable water. Flow rates for the chaser slug were much slower than the preinjection primer slug. For the 5 days after dye injection, flow rates increased slightly from 12 to 15.6 gal/hour.

Approximately one month into the second dye-tracer test, GW-178 was mistakenly purged of 40 gallons of water by K-25 Sampling and Environmental Support Department personnel. Analysis of the purged water indicate that approximately 28 g of FB28 and 11 g of RWT were removed. Compared to the 20 kg of each dye injected into GW-178, only an estimated 0.14% of FB28 and 0.06% of RWT were removed from the well. The purged water was not reinducted into GW-178, however, the well was scrubbed and potable water was jetted through the screen to clear any possible obstructions or clogging of the screen and sand pack, and a total of 292.4 gallons of potable water was added to provide a positive hydraulic

head.

Two different dye detectors were used during the second test: charcoal detectors (like those used in the first test) for absorption of RWT dye, and cotton detectors for absorbtion of FB28 dye. Both types of detectors were enclosed within a nylon-mesh packet. The thread used to sew the packets was found to be fluorescent and caused a false fluorescence at the location were the thread contacted the cotton. Visual screening of the cotton detectors under a long-wave, ultraviolet lamp prior to spectrofluorometer analyses allowed for the identification and isolation of these false fluorescent areas.

Field methods, measurements, and quality control were the same as those outlined for the initial dye-tracer test. To avoid cross-contamination between sampling sites, field equipment was decontaminated between sites using a solution of 5% bleach and de-ionized water. Gloves were either decontaminated or disposed of between sites. All decontamination was performed downgradient, but as close as practicable, to the sample site to avoid contamination of the field vehicle and restrict the transport of dye from the vicinity of the sample site.

In the laboratory, both the cotton and charcoal detectors were washed for approximately 5 minutes under distilled water to remove silt and organic debris. Charcoal samples, standards, serial dilutions, and laboratory blanks were all stored

in a refrigerator until analyzed, at which time all were removed together to insure temperature equilibration between all solutions. Charcoal detectors were eluted in a beaker of 30 ml "Smart solution" consisting of a 5:2:3 mixture of 1-propanol, concentrated NH_4OH, and distilled water. Charcoal samples were not dried prior to elution in the extraction "Smart solution", as suggested in the Work Plan (Science Applications International Corp., 1992b), because the dried charcoal effervesced considerably in the extraction solution producing more fine particles, which elevated background scattering during spectrofluorometry.

Samples were analyzed using a synchronous scanning spectrofluorometer (Perkin Elmer LS-50). At the beginning and end of each day of sample analyses, three standards of each dye (100 ppt, 1 ppb, 10 ppb) were used as a calibration for the day. A laboratory blank was analyzed each day to ensure that the eluant solution was not contaminated. To check for field and transportation contamination, a field blank was also analyzed. Throughout the second dye-tracer test, no contamination was noted from the field or laboratory blanks (Science Applications International Corp., 1992a). One charcoal sample in every 20 samples was split and analyzed to check the precision of the instrument, no significant differences were noted. The reader is referred to Science Applications International Corp. (1992a) for split sample data. One in every 10 cotton samples was measured using three consecutive scans to validate the instrument precision. Cotton detectors were also visually scanned for fluorescence under a long-wave ultraviolet

lamp.

3. COMPARISON OF FIRST AND SECOND DYE-TRACER TEST RESULTS

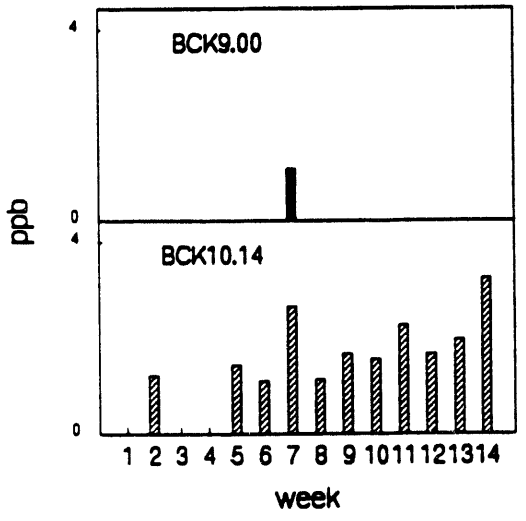
3.1 FIRST DYE-TRACER TEST RESULTS AND INTERPRETATIONS

During the first dye-tracer test, a positive result or inferred presence of dye, was considered to be any concentration above the analytical detection limit (1 ppb) at those localities where no previous fluorescence baseline (background) was observed. A "possible" result was based on a concentration at sites above the observed background fluorescence at that site. Eight sites were identified as having positive results, suggesting hydraulic connections with GW-178. These sites include: SCR-5.4SP, SCR-5.1SP, SCR-7.1SP, UEFPC-113, UEFPC-62, UEFPC-29, UEFPC-12/13 and GW-175 (Table 3.1). A possible connection was inferred to exist between GW-178 and Sites BCK-10.14SP, BCK-9.00SW, UEFPC-SP17, and WS-7.5SW (Table 3.1).

In BCV, one surface water (BCK-9.00) and one spring (BCK-10.14) site were identified as having dye detected. The BCK-9.00 had possible dye detected during the eighth week after injection, but at levels slightly above the detection limit (Fig. 3.1). The BCK-10.14 had apparent fluorescence concentrations above the background fluorescence of 1.1 ppb (Table 3.1) in 11 of the 15 weeks monitored, with its highest concentration of 3.24 ppb during Week 15 (Fig. 3.1).

Table 3.1: Initial dye-tracer monitoring sites with fluorescence peak concentrations exceeding the 1 ppb analytical detection limit.

week	BCK9.00	BCK10.14	UEFPC-113	UEFPC-62	UEFPC-29	UEFPC-SP17	UEFPC-12/13	SCR5.1SP	SCR5.4SP	SCR7.1SP	WS7.5SW	GW-175
2						1.58					3.32	
3		1.21									1.92	
4			1.55	3.02	1.85		5.5		1.13		3.54	
5									1.17			
6		1.43				1.73				1.43	4.52	1.28
7		1.09							1.51		7.09	
8	1.09	2.64			1.09	2.68		1.21	1.32		12.82	
9		1.13				2.6			2.45		9.05	
10		1.66										
11		1.55										
12		2.26		1.4	1.47	1.51	1.28					
13		1.66			1.21		1.09				2.71	
14		1.96		1.13	1.43		1.06				2.19	
15		3.24									1.36	



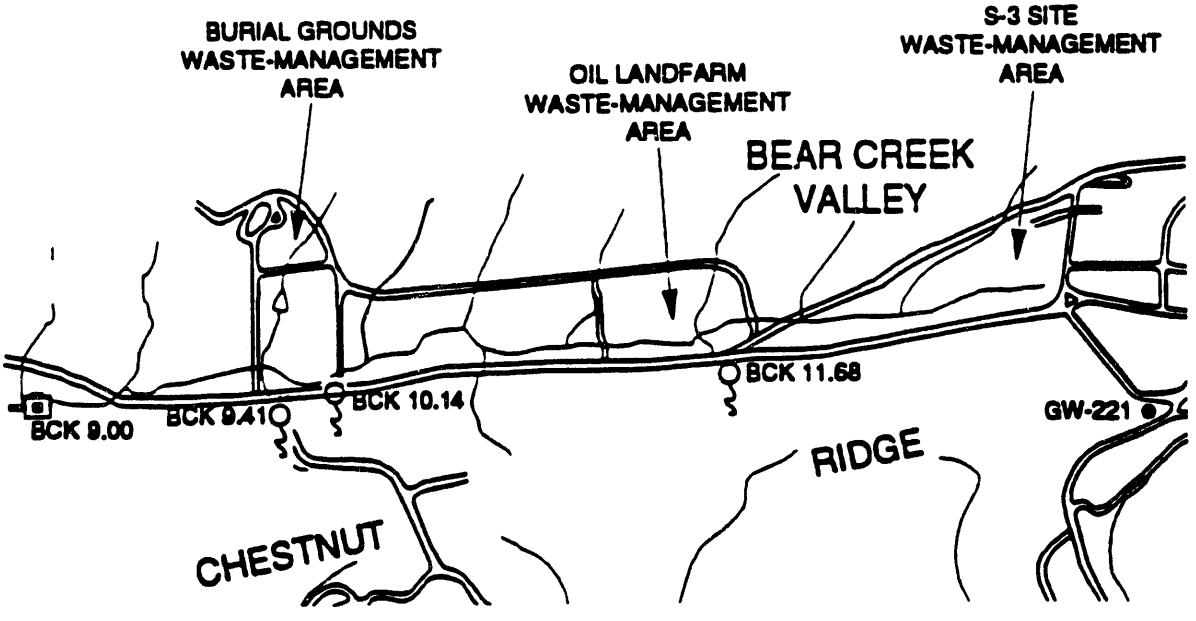


Figure 3.1: Initial test monitoring sites in Bear Creek Valley with fluorescein concentrations reported above the detection limit (1ppb) for BCK-9.00 and background fluorescence (1.1 ppb) for BCK-10.14.

All the monitoring sites in UEFPC were interpreted to have had positive dye detection at least once during the initial test (Fig. 3.2). The UEFPC-SP17 was the only spring monitored in UEFPC and had apparent fluorescence concentrations above the 1.3 ppb background fluorescence during the second week after dye injection (Fig. 3.2). Most of the observed concentrations were below 2 ppb, with slightly higher concentrations at UEFPC-12/13 and UEFPC-62 during Week 4 and at UEFPC-SP17 during Weeks 8 and 9 (Fig. 3.2).

Two springs within the same drainage (SCR-5.1SP and SCR-5.4SP) had apparent fluorescence concentrations above the analytical detection limit (Fig. 3.3; Table 3.1). Most of the apparent concentrations were slightly above the detection limit, with the highest concentration of 2.45 ppb during Week 9 in SCR-5.4SP (Fig. 3.3). Also, Well GW-175 had apparent fluorescence concentrations slightly above the detection limit during Week 6 (Fig. 3.3; Table 3.1).

Along Scarboro Creek, two sites were interpreted as having dye present (Fig. 3.3). Spring SCR-7.1SP had an apparent concentration slightly above the detection limit during Week 6 (Fig. 3.3; Table 3.1). The surface stream monitoring site, WS-7.5SW, had the highest background fluorescence (2.6 ppm) of all the sites monitored during the initial test (Table 2.2) and had the highest concentrations of any site during this test (Fig. 3.3).

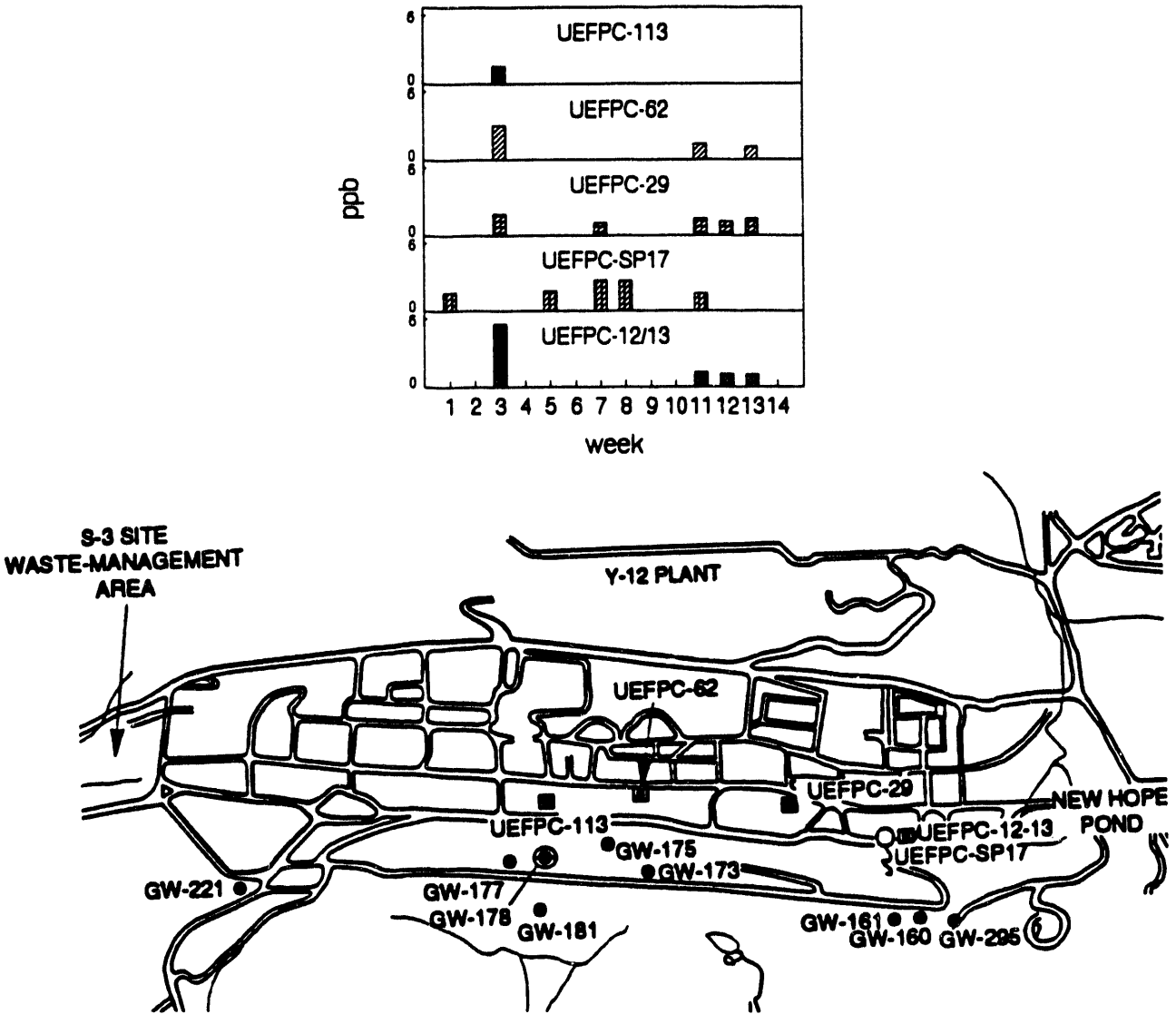


Figure 3.2: Initial test monitoring sites in UEFPC with fluorescein concentrations reported above the detection limit (1ppb) for UEFPC-113, UEFPC-62, UEFPC-29, UEFPC-12/13 and background fluorescence (1.3 ppb) for UEFPC-SP17.

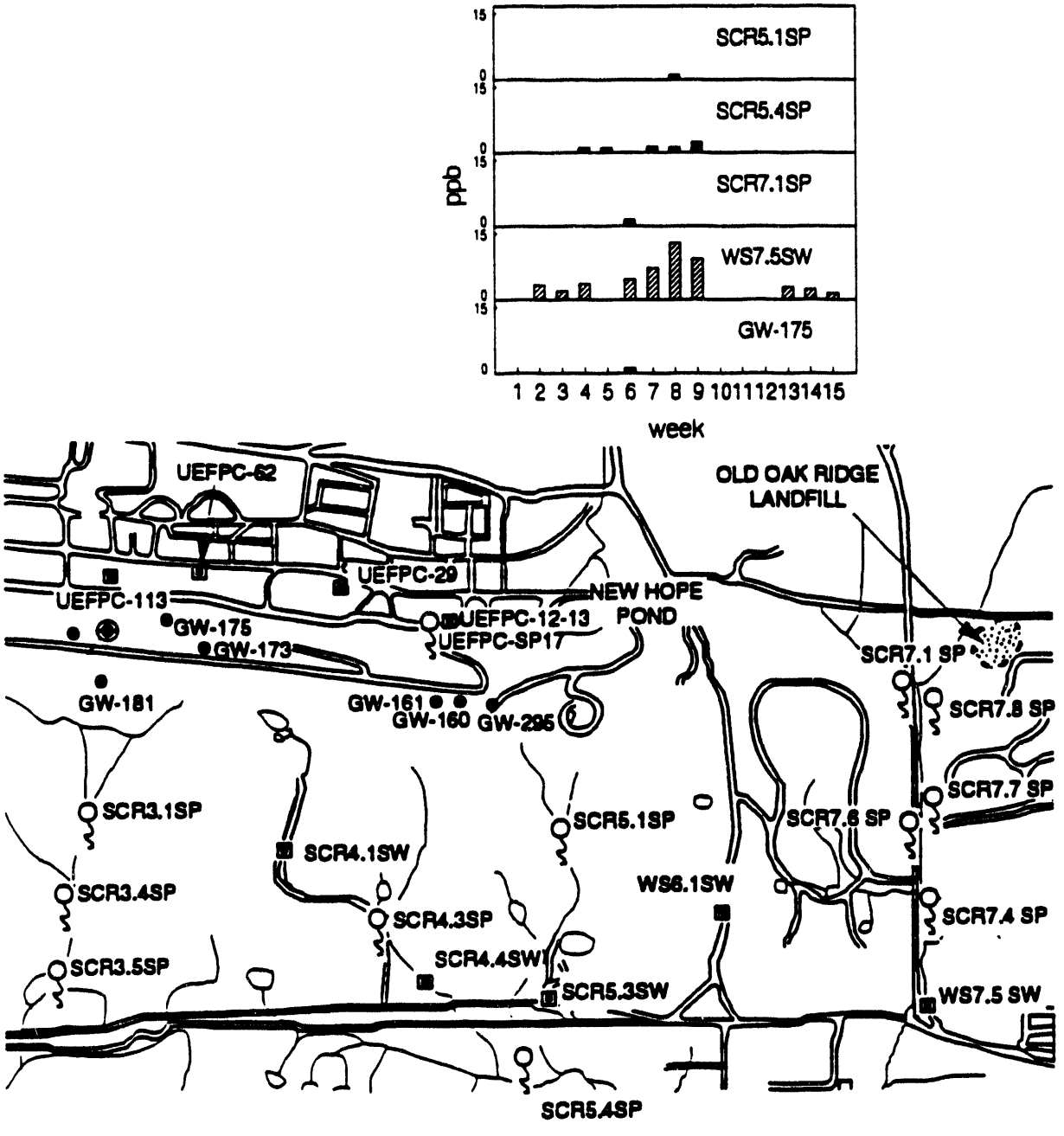


Figure 3.3: Initial test monitoring sites on south Chestnut Ridge with fluorescein concentrations reported above the detection limit (1ppb), and at Scarboro Creek with fluorescein concentrations reported above the detection limit (1ppb) for SCR-7.1SP and background fluorescence (2.6 ppb) for WS-7.5SW.

Specific conductivity data measured in the field were evaluated using the method of Shuster and White (1971) to determine whether springs monitored during the initial test were fed by diffuse flow, conduit flow, or a combination of diffuse and conduit flow (Geraghty and Miller, Inc., 1990). The premise of Shuster and White (1971) is that in slow, diffuse-flow systems recharge waters chemically equilibrate within the system and chemical and physical variability will be low. In rapid, conduit-flow systems, large volumes of water can be carried to springs in pulses resulting in high physical and chemical variability between baseflow and flood conditions (Shuster and White, 1971). The coefficient of variation (CV) (standard deviation divided by the mean, multiplied by 100) of the specific conductivity was used to infer whether a spring was fed by conduit flow, diffuse flow, or combinations of both (Geraghty and Miller, Inc., 1990). Table 3.2 presents the calculated CV of specific conductivity and proposed flow types for springs monitored during the initial tracer tests (Geraghty and Miller, Inc., 1990). Ten of the eighteen springs were believed to represent conduit flow and all of the springs where fluorescence was noted are from these conduit-type springs (Tables 3.1 and 3.2).

3.2 SECOND DYE-TRACER TEST RESULTS AND INTERPRETATIONS

In contrast to the first dye-tracer test, except for two locations (discussed below) where fluorescence spectra were present during background monitoring, no unequivocal dye spectral peaks where observed during the second test. The mean

Table 3.2: Coefficient of variation of specific conductance for the initial dye-tracer test (Geraghty and Miller, Inc., 1990).

SPRING	COEFFICIENT OF VARIATION OF SPECIFIC CONDUCTIVITY	FLOW TYPE
SCR-1.4SP	9%	BOTH
SCR-1.2SP	8%	BOTH
SCR-2.1SP	15%	CONDUIT
SCR-3.5SP	9%	BOTH
SCR-3.4SP	6%	BOTH
SCR-3.1SP	4%	DIFFUSE
SCR-4.3SP	16%	CONDUIT
SCR-5.4SP	10%	CONDUIT
SCR-5.1SP	10%	CONDUIT
SCR-7.4SP	4%	DIFFUSE
SCR-7.6SP	5%	BOTH
SCR-7.7SP	6%	BOTH
SCR-7.8SP	10%	CONDUIT
SCR-7.1SP	11%	CONDUIT
UEFPC-SP17	20%	CONDUIT
BCK-11.68	11%	CONDUIT
BCK-10.14	20%	CONDUIT
BCK-9.41	14%	CONDUIT

<5% = diffuse flow/ slow flow
5 to 10% = Both conduit and diffuse flow
>10% = Conduit flow/ quick flow

plus 3 standard deviations above the calculated background fluorescence concentration for each site was used as a criteria to infer possible low-level dye detection. For a complete analysis of the second dye-tracer results the reader is referred to Science Applications International Corp. (1992a).

During background testing, a rhodamine-like spectral peak was noted at UEFPC-29SW and continued to be detected throughout the test at this location in apparent concentrations as high as 9.3 ppb (Table 2.2). For several years prior to and during the second dye test, Rhodamine B dye was used to test drains within the Y-12 facility, and it is believed that it is this dye that persistently caused the rhodamine-like spectral peaks at UEFPC-29SW.

Spectral peaks denoting the presence of optical brightener were observed during background monitoring and continually throughout the second test at Station BCK-10.14SP, with apparent concentrations as high as 43.9 ppb. The presence of an optical brightener at BCK10.14SP is unclear; however, industrial and domestic effluent such as detergent and antifreeze can cause FB28-like fluorescence. Data personnel at from Geraghty and Miller, Inc. (1989) indicate that this spring is hydraulically connected to Bear Creek. Thus, it is possible that BCK-10.14SP is receiving nearby optical brightener input from either the Oil Landfarm or Burial Grounds Waste-Management areas which has migrated into Bear Creek.

In BCV, spectral peaks in the range of FB28 and above the mean +3 standard deviation criteria were observed at BCK-9.00, BCK-9.41, and BCK-11.68 (Fig. 3.4; Table 3.3). Fluorescence peaks in the range of RWT and above the detection criteria were observed only at BCK-11.68 (Fig. 3.4). The possible presence of both FB28 and RWT fluorescence above the detection criteria occurred only at one site (BCK-11.68) during the same weeks (Weeks 12 and 15); however, total possible concentrations were extremely low (< 0.6 ppb).

In the SCR-1 drainage, apparent FB28 concentrations above the detection criteria was observed at SCR-1.2SP and SCR-1.1SW (Fig. 3.5; Table 3.3). Apparent RWT concentrations above the detection criteria occurred only during Week 11 at SCR-1.1SW (Fig. 3.5). No correlation is apparent in this drainage for both the dyes being present at the same time. If FB-28 were present in this drainage, concentrations were less than 0.2 ppb. High natural background fluorescence was observed at this surface water site during 4 of the 18 weeks of the test; thus, it is unclear if the RWT fluorescence during Week 11 is a low RWT tracer concentration, or related to a high natural background in the stream.

In the SCR-2 drainage, possible FB28 concentrations above the detection criteria was observed once at SCR-2.2SW and possible RWT above the detection criteria was observed at SCR-2.1SP (Fig. 3.5; Table 3.3). In the surface waters of SCR-2.2SW, RWT spectral peaks were absent and if FB28 were present,

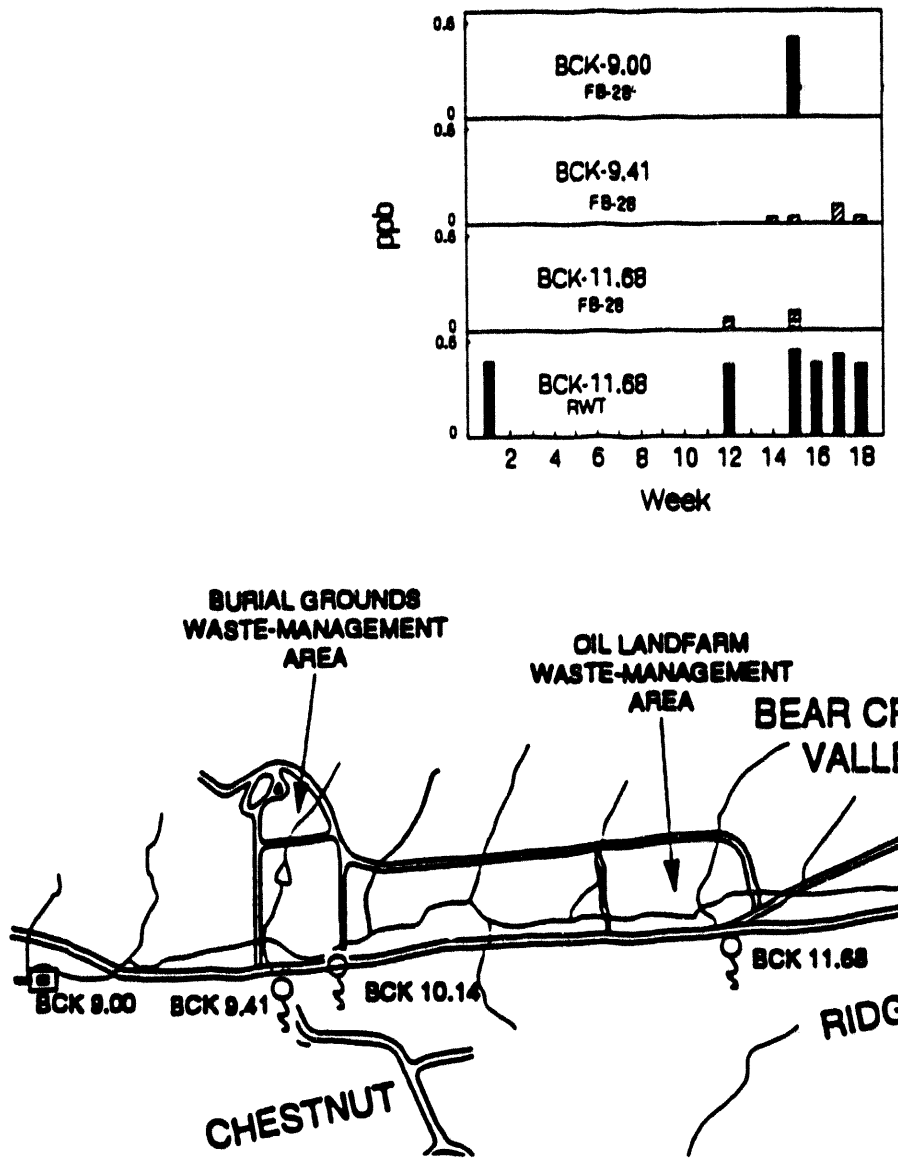


Figure 3.4: Second test monitoring sites in BCV with fluorescence concentrations above the detection criteria.

Table 3.3: Second dye-tracer monitoring sites with RWT and/or FB28 apparent concentrations above the background mean plus 3 standard deviations.

FLUOR

Week	BCK-9.00	BCK-9.41	BCK-10.14	BCK-11.68	SCR-1.5S	SCR-1.3S	SCR-1.2SP	SCR-1.1S	SCR-2.2S	SCR-2.1SP	SCR-3.5SP	SCR-3.4SP
1												
2										.15*	0.06	
3									0.075			0.06
4												
5												
6											0.046	
7												
8							0.1					
9												
10												
11							0.15					
12				0.075			0.12					
13							0.15	0.15*				
14		0.043										
15	0.5	0.046		0.12								
16								0.075				
17		0.12						0.086			0.075	
18		0.046					0.12					

RWT (ppb)

Week	BCK-9.00	BCK-9.41	BCK-10.14	BCK-11.68	SCR-1.5S	SCR-1.3S	SCR-1.2SP	SCR-1.1S	SCR-2.2S	SCR-2.1SP	SCR-3.5SP	SCR-3.4SP
1				0.47						0.85		
2												
3												
4												
5												
6										1.06		
7										0.91		
8												
9										1.51		
10			2.61*									
11								1.51				
12				0.45								
13	1.66*				1.34*	1.46*	1.27*	1.82*		0.87		
14												
15				0.54		1.55*				1.74*	0.86	
16				0.46	1.47*							
17			2.23*	0.51	1.7*			1.74*				
18			2.04*	0.45	1.7*		1.27*	1.6*	1.55*		1.01	

* = interference peaks

Table 3.3: Second dye-tracer monitoring sites with RWT and/or FB28 apparent concentrations above the background mean plus 3 standard deviations (continued).

FLUOR

Week	SCR-3.1SP	SCR-4.4S	SCR-4.3SP	SCR-4.1S	SCR-5.4SP	SCR-5.3S	SCR-5.1SP	WS-6.1SW	WS-7.5SW	SCR-7.4SP	SCR-7.6SP	SCR-7.7SP	SCR-7.1SP
1			0.2*			0.05							
2				0.06		0.055						0.06	
3		0.075										0.2*	
4													0.006
5													
6			0.075									0.06	
7			0.1	0.067		0.046		0.04					
8													0.075
9						0.038						0.063	0.006
10										0.038			
11						0.075		0.043				0.055	
12									0.1			0.06	
13												0.055	
14				0.06		0.055		0.055		0.038		0.06	0.1
15												0.06	0.1
16						0.038					0.12		
17	0.006	0.05	0.12		0.12	0.055		0.046	0.15		0.2	0.064	0.1
18									0.12		0.12	0.2	0.006

RWT

Week	SCR-3.1SP	SCR-4.4S	SCR-4.3SP	SCR-4.1S	SCR-5.4SP	SCR-5.3S	SCR-5.1SP	WS-6.1SW	WS-7.5SW	SCR-7.4SP	SCR-7.6SP	SCR-7.7SP	SCR-7.1SP
1	0.84												
2			1										
3													
4													
5													
6													
7													
8													
9					2.38*								
10													
11													
12													
13	0.67												
14													
15		1.72*	1.14*							0.92			
16													
17							0.83		2.5*				
18									2.14*				

Table 3.3: Second dye-tracer monitoring sites with RWT and/or FB28 apparent concentrations above the background mean plus 3 standard deviations (continued).

FLUOR

Week	UEFPC-SP	UEFPC-29	GW-232	GW-561	GW160	GW-221
1						
2						
3						0.033
4						
5						0.032
6		0.043				
7						
8					0.75	
9						
10						
11						
12						
13						
14						
15						
16		0.04				
17						
18	0.04			0.06		

RWT

Week	UEFPC-SP	UEFPC-29	GW-232	GW-561	GW160	GW-221
1				0.33		
2						
3						
4						
5						
6						
7				0.29		
8						
9						
10						
11						
12						
13	2.21*					
14						
15						
16						
17						
18			.97*			

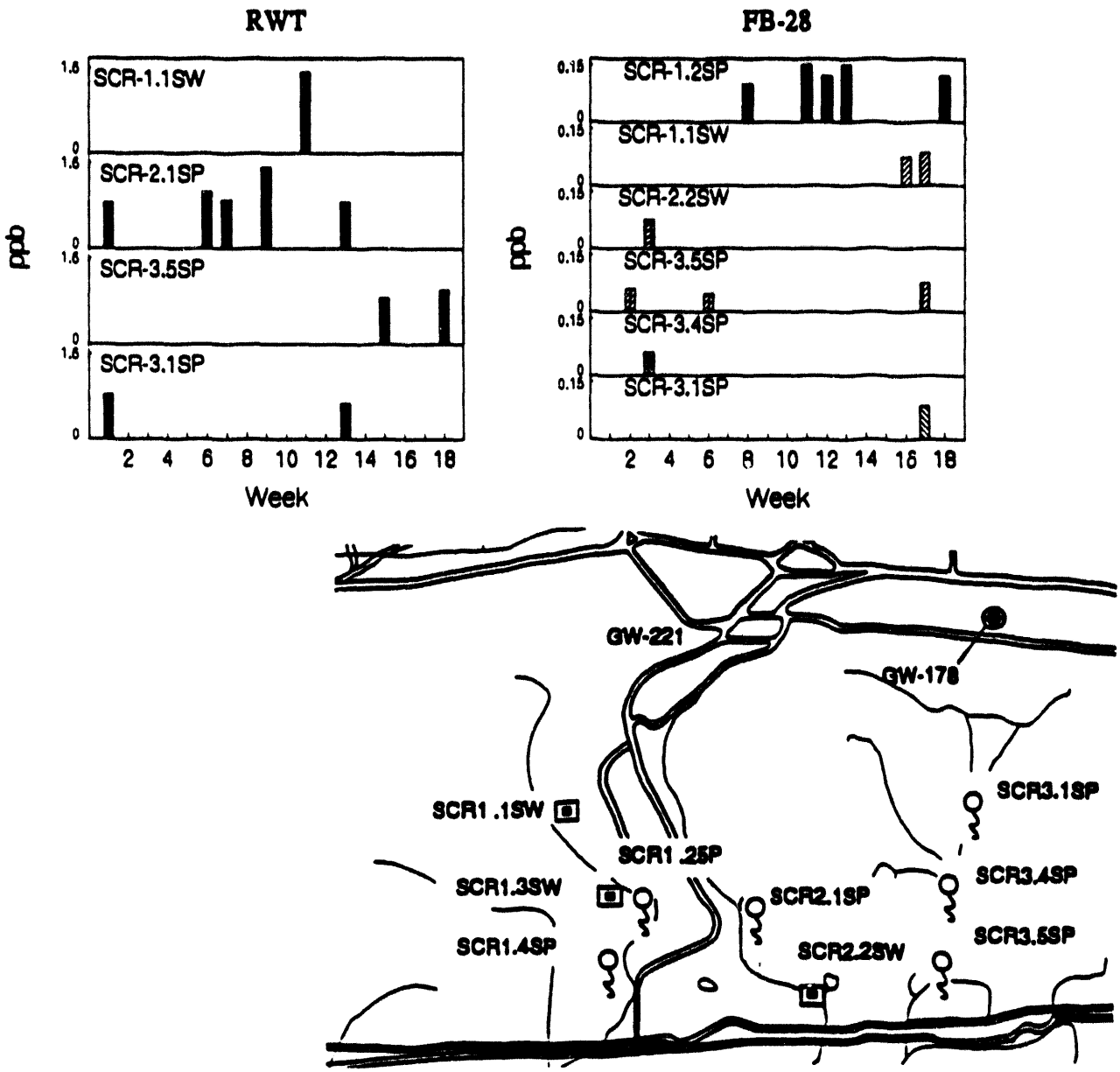


Figure 3.5: Second test monitoring sites in SCR-1, SCR-2, and SCR-3 drainages with fluorescence concentrations above the detection criteria.

concentrations did not exceed 0.075 ppb. No apparent FB28 was identified at site SCR2.1SP, and if RWT was present, concentrations did not exceed 1.51 ppb.

Apparent FB28 concentrations above the detection criteria in the SCR-3 drainage occurred at Sites SCR-3.5SP, SCR-3.4SP, and SCR-3.1SP (Fig. 3.5; Table 3.3). Possible RWT concentrations above the detection criteria was observed at SCR-3.5SP and SCR-3.1SP (Fig. 3.5; Table 3.3). Fluorescence peaks in the range of both FB28 and RWT were observed at SCR-3.1SP, but not during the same week. No apparent correlation is present between sites in this drainage, and if the dyes were present in this drainage, RWT concentrations were below 1.01 ppb and FB-28 concentrations did not exceed 0.086 ppb.

In the SCR-4 drainage, possible FB28 spectral peaks were observed at Sites SCR-4.4SW, SCR-4.3SP, and SCR-4.1SW (Fig. 3.6; Table 3.3). Apparent RWT concentrations above the detection criteria were present during Week 2 at SCR-4.3SP (Fig. 3.6). The possible presence of RWT and FB-28 in SCR-4.3SP did not coincide temporally. If the dyes were present in this drainage, concentrations of RWT were 1.0 ppb or less and FB-28 concentrations were 0.075 ppb or less.

Apparent FB28 concentrations above the detection criteria in the SCR-5 drainage were observed at SCR-5.4SP and SCR-5.3SW (Fig. 3.6; Table 3.3). A possible

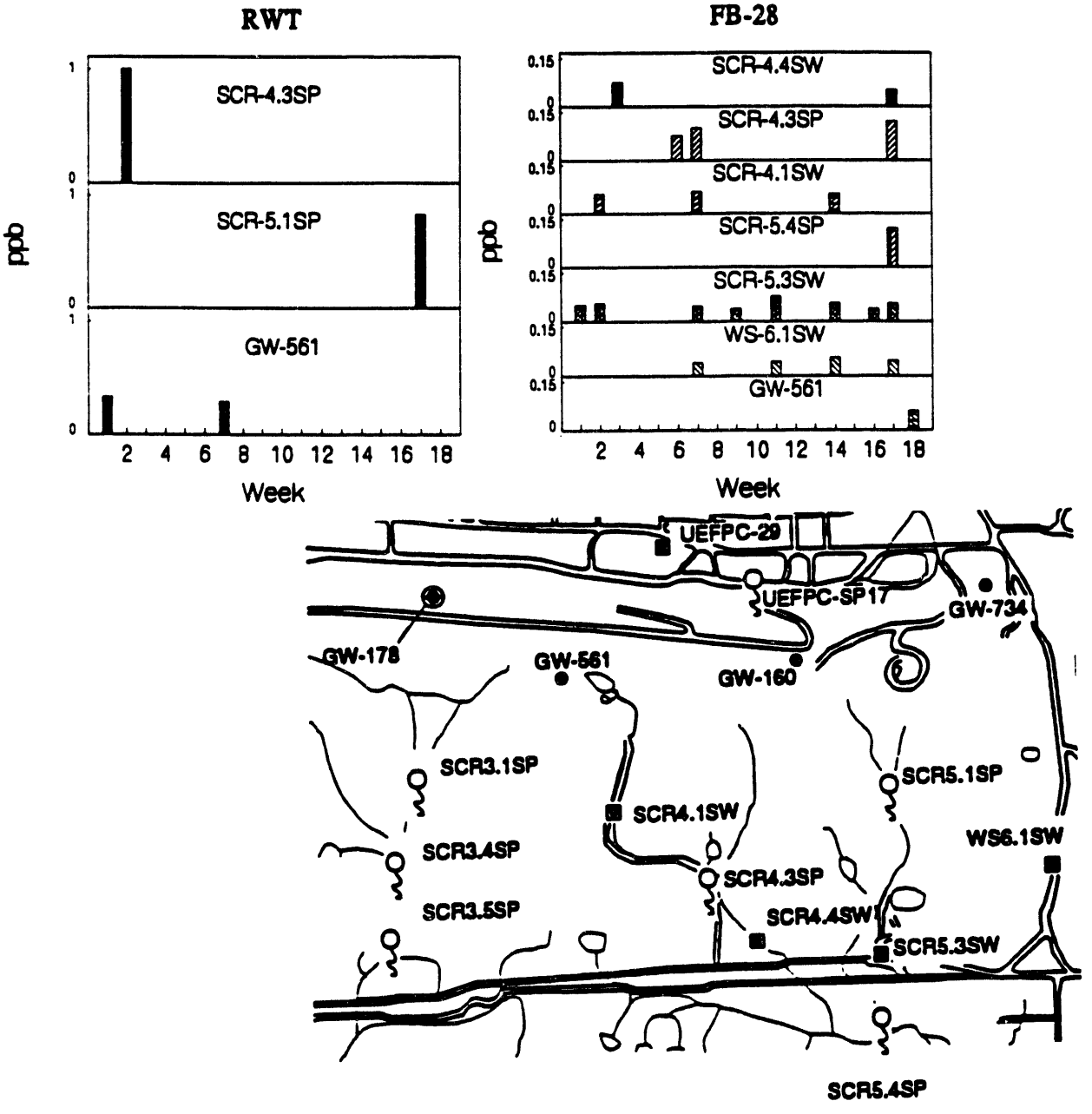


Figure 3.6: Second test monitoring sites in SCR-4, SCR-5, and WS-6 drainages and Well 561 with fluorescence concentrations above the detection criteria.

RWT spectral peak was observed only at SCR-5.1SP during Week 17 (Fig. 3.6). There is no apparent correlation between the two dyes in this drainage. If FB28 were present, it was in low concentrations (0.12 ppb or less).

At the surface water Location WS-6.1 only FB28 was possibly detected at concentrations at or below 0.055 ppb (Fig. 3.6; Table 3.3). No spectral peaks in the range of RWT were observed above the detection criteria at this site.

Along Scarboro Creek, apparent FB28 concentrations above the detection criteria were observed at SCR-7.1SP, SCR-7.4SP, SCR-7.6SP, SCR-7.7SP, and WS-7.5SW (Fig. 3.7; Table 3.3). Spectral peak in the range of RWT were only observed at SCR-7.4SP during week 15 (Fig. 3.7). The apparent FB28 and RWT spectral peaks do not appear at the same time within SCR-7.4SP but occur within a week of each other. Possible correlations for FB28 may occur between SCR-7.1SP, SCR7.6SP, SCR-7.7SP, and WS-7.5SW for Weeks 17 and 18 and SCR-7.1SP, and SCR-7.7SP for Weeks 14 and 15. However, if FB-28 and RWT were present, concentrations did not exceed 0.2 ppb and 0.92 ppb, respectively.

In the area of UEFPC, apparent FB28 concentrations above the detection criteria were reported from UEFPC-SP17 and UEFPC-29SW (Fig. 3.8; Table 3.3). No apparent RWT concentration above the detection criteria were reported from this area. If FB28 dye was present in UEFPC, concentrations were 0.04 ppb or less.

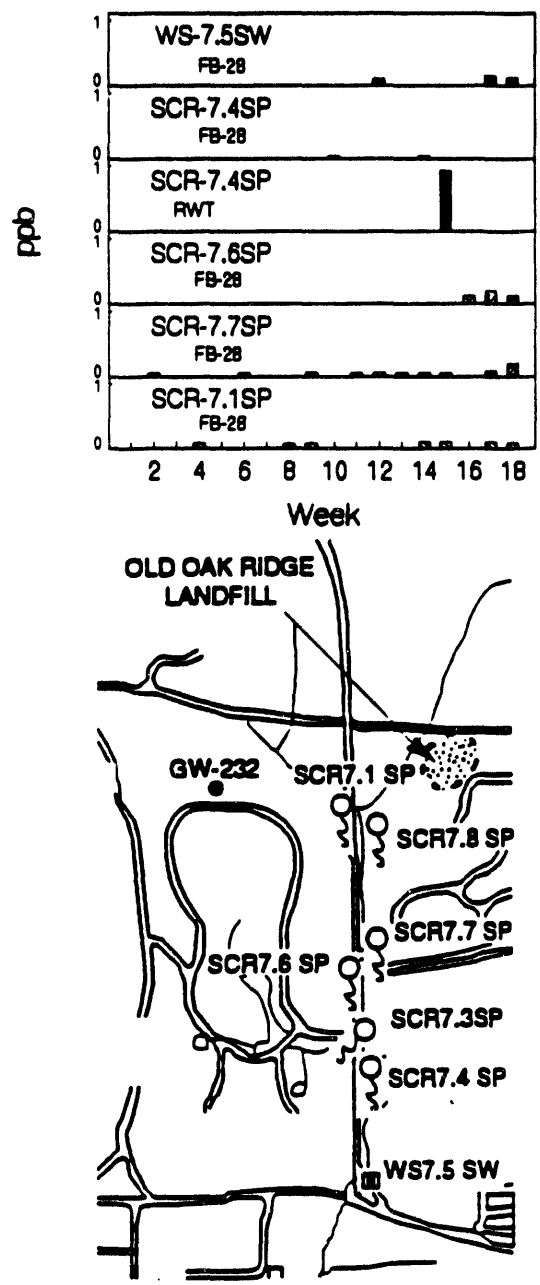


Figure 3.7: Second test monitoring sites in SCR-7 and WS-7 drainages with fluorescence concentrations above the detection criteria.

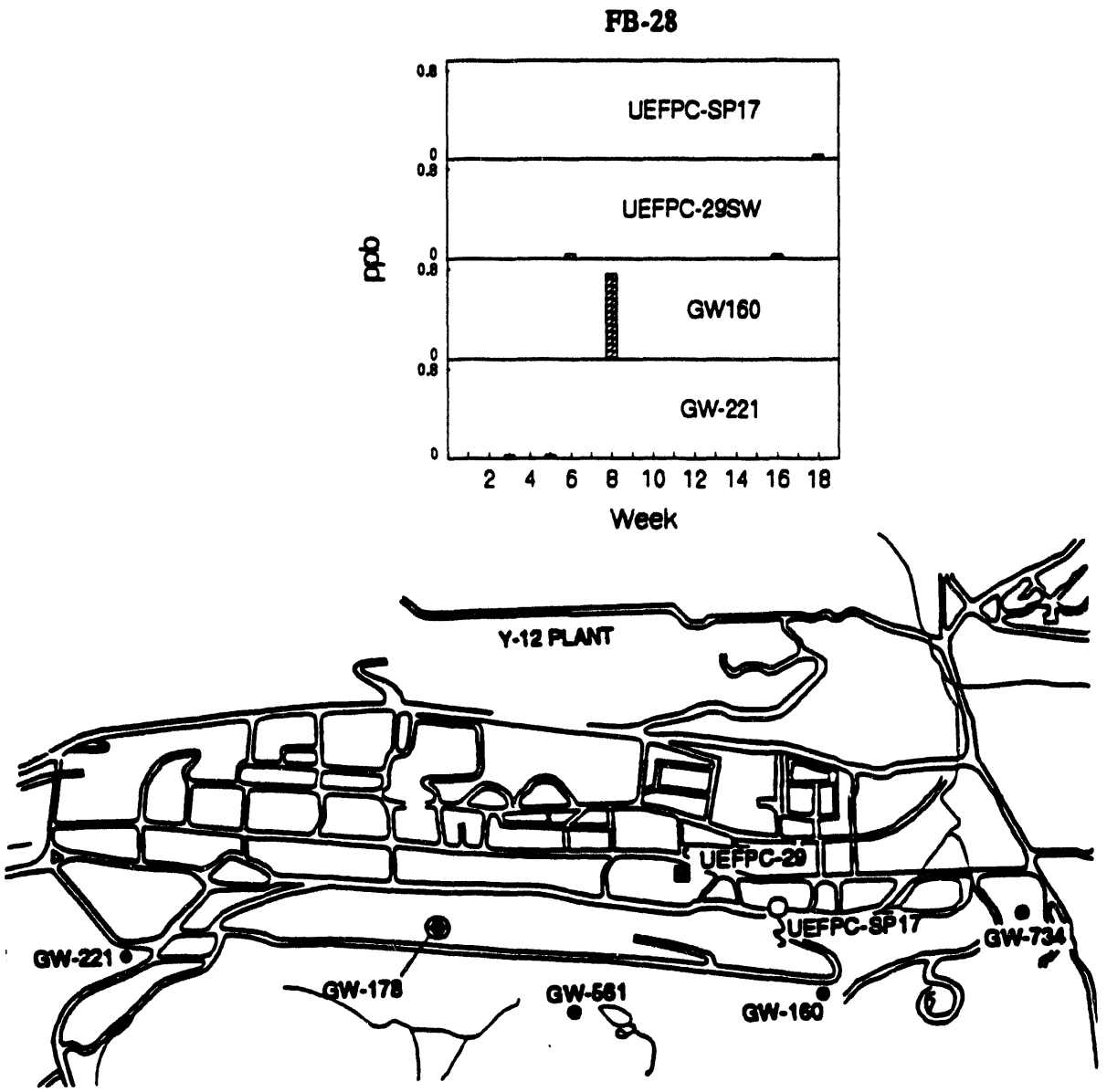


Figure 3.8: Second test monitoring sites in the UEFPC drainage and Wells 160 and 221 with fluorescence concentrations above the detection criteria.

Within the groundwater monitoring wells, apparent FB28 concentrations above the detection criteria were observed in GW-561 (Fig. 3.6), GW-160 (Fig. 3.8), and GW-221 (Fig. 3.8). Although no background analyses were available on GW-734, an apparent elevated FB28 concentration appears at Week 8 (Table 2.2). The possible presence of RWT in concentrations above the detection criteria was observed in GW-561 during Weeks 1 and 7. Within this groundwater well, the possible presences of both dyes did not occur at the same time. If the dye were present in these wells, concentrations did not exceed 0.75 ppb.

During the last two weeks of the second test (Weeks 17 and 18), a large number of sites show fluorescence concentrations above the detection criteria, and these elevated concentrations correspond to an increase in rainfall at that time (Science Applications International Corp., 1992b). It is possible that with the increase in rainfall, dye was flushed from the karst system and detected at those locations. However, if dye was flushed from the karst system the concentrations for both dyes were below 1 ppb (Table 2.2).

Two dyes were used to enhance detection, under the premise that both dyes should travel along the same pathways and should be detected together. The presence of two different dyes at a monitoring site would alleviate uncertainties related to natural background fluorescence. However, during the second dye-tracer test only 2 sites showed spectral peaks in the range of both FB28 and RWT

in apparent concentrations above the detection criteria (BCK-11.68 during Weeks 12 and 15, and SCR-3.1SP during Week 17). One possible explanation why both dyes may not move at the same rates is that although both dyes have high adsorption rates when in contact with organic compounds such as humus, the adsorption rate of RWT is higher than many dyes when in contact with limestone and kaolinite (Smart and Laidlaw, 1977). It may be possible that movement of the RWT dye has been inhibited and concentrations decreased by adsorption within the aquifer to rock, clay, and organic matter.

An analyses of the coefficient of variation of specific conductivity was complete for the data collected during the second test for the same springs analyzed during the first test to compare results (Table 3.4). For the second test, the coefficient of variation of the specific conductivity suggests that all but one spring (SCR-7.6SP) are fed by conduit-flow. In all but one location (UEFPC-SP17), the coefficients of variation were larger during the second test than the first (Tables 3.2 and 3.4). The difference between these data may be related to different sampling techniques, equipment calibration, or seasonal variations. However, the differences between these two results are significant and suggest that, for these two data sets, the coefficient of variation of specific conductivity is unreliable in determining if these springs are discharged through diffuse-flow systems, conduit-flow systems, or a combination of both types.

Table 3.4: Coefficient of variation of specific conductance for the second dye-tracer test.

SPRING	COEFFICIENT OF VARIATION OF SPECIFIC CONDUCTIVITY	FLOW TYPE
SCR-1.4SP	19%	CONDUIT
SCR-1.2SP	16%	CONDUIT
SCR-2.1SP	25%	CONDUIT
SCR-3.5SP	18%	CONDUIT
SCR-3.4SP	15%	CONDUIT
SCR-3.1SP	15%	CONDIUT
SCR-4.3SP	33%	CONDUIT
SCR-5.4SP	31%	CONDUIT
SCR-5.1SP	23%	CONDUIT
SCR-7.4SP	11%	CONDUIT
SCR-7.6SP	8%	BOTH
SCR-7.7SP	15%	CONDUIT
SCR-7.8SP	15%	CONDUIT
SCR-7.1SP	10%	CONDUIT
UEFPC-SP17	14%	CONDUIT
BCK-11.68	14%	CONDUIT
BCK-10.14	25%	CONDUIT
BCK-9.41	23%	CONDUIT
SCR-7.3SP*	20%	CONDUIT

<5% = diffuse flow/ slow flow
5 to 10% = Both conduit and diffuse flow
>10% = Conduit flow/ quick flow

* Spring not monitored during first dye-tracer test.

4. DISCUSSION

4.1 COMPARISON OF BOTH TESTS

Two dye-tracer tests conducted on Chestnut Ridge during 1990 and 1992 to provide information on possible karst system discharge locations from Chestnut Ridge have proved inconclusive. Interpretations of the first dye-tracer test suggest that dye was detected in at least eight monitoring locations and may have been detected in four other sites (Geraghty and Miller, Inc., 1990). In contrast, data from the second dye test indicate that, except for the two sites where fluorescence was present during background monitoring, no dye was definitely detected. Both tests used the same injection well, monitored approximately the same sites, and collected data for approximately the same amount of time. Several factors, such as field or analytical methods, may be responsible for the discrepancy between the two tests.

Field and analytical methods, measurements, and quality control were generally the same for the first test as those outlined for the second dye-tracer test. During the initial tracer test, the dye was eluted from the activated charcoal using a standard 100-ml aliquot of "Smart solution" consisting of a 1:1:2 mixture of distilled water, NH_4OH, and 1-propanol. During the second test the charcoal detectors were eluted in 30-ml of a 3:2:5 mixture of distilled water, NH_4OH, and 1-propanol. The smaller volume of eluant solution used during the second test

would increase the overall concentration, allowing better recovery and detection of dye if it were present.

Experiments on the washing times of the charcoal detectors were conducted after the second test, and results indicate that a two-hour wash under tap water prior to the extraction procedure significantly reduced background interference. During the second test, detectors were washed for five minutes. Personnel from Geraghty and Miller, Inc. (1990) do not note if the samples of the first test were washed prior to elution.

The first dye-tracer test used Sodium Fluorescein (Acid Yellow 73), a green fluorescence dye. A disadvantage of this dye is that natural background fluorescence (i.e., from fulvic acid extracted from the soil) in the green region of the spectrum can mask the fluorescein emission peak (Smart and Laidlaw, 1977). Thus, natural background fluorescence in the green part of the spectrum may make it difficult to note the presence of low concentrations of fluorescein or discern a natural background spectral peak from a dye peak.

The relatively high analytical detection limit (1 ppb) of the first test make it difficult to distinguish between the presence of dye and possible high natural background interference. During spectrofluorometric analysis, the known excitation and emission wavelengths of the dye are scanned, where the peak height

represents the concentration. However, if other fluorescence material is present, they will produce their own spectral peaks. Fluorescence is additive, so that the tail of one spectral peak can produce an apparently high spectral peak (and concentration) in another adjacent wavelength (Smart and Smart, 1991). During the second test, large interference peaks occurred at several monitoring locations. These interference peaks occurred at about 500 nanometers (nm) and the tails of this peaks gave anomalously high spectral peaks in the fluorescence range for Rhodamine WT (at 550 nm). These same elevated natural background peaks at 500 nm could also affect the spectra in the range of fluorescein from the initial test, with excitation and emission peaks at 490 and 520 nm, respectively. Figure 4.1 is a spectrograph showing a natural background interference at an intensity of 3.1 (approximately equivalent to 10 ppb) at about 500 nm and a smaller RWT peak at 550 nm corresponding to a 2 ppb concentration. The tailing effects of this 10 ppb interference peak could completely mask and cause apparently high concentrations in the excitation range of fluorescein at 490 nm (Fig. 4.1). In this hypothetical example, where no true fluorescein dye is present, the high natural background peak would give an apparent fluorescein concentration of approximately 10 ppb.

A comparison of those locations considered to have had "positive" and "possible" dye detection during the first test and those locations with interference background noted during the second test suggest that background interference

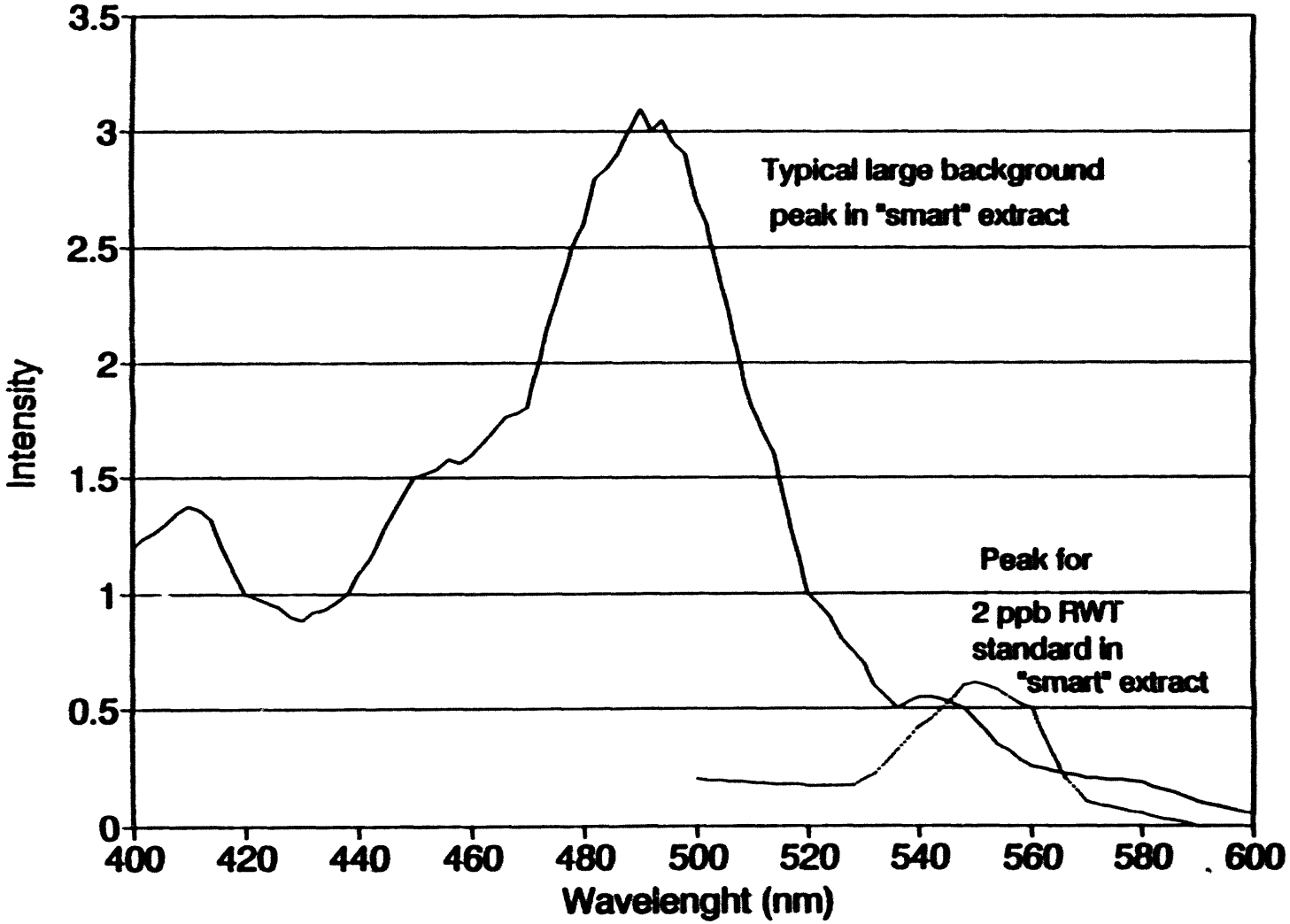


Figure 4.1: Schematic diagram of the possible effects of interference fluorescence spectral peaks on concentration values with natural background fluorescence peak at about 500 nm and a 2 ppb RWT excitation peak at 550 nm. The high background peak could give an apparent fluorescein signature in the range of 490 nm.

could have affected results for some of these sites in the initial test. Table 3.1 shows those locations and concentrations that exceeded the detection limit of 1 ppb during the initial test. Locations UEFPC-113, UEFPC-62, UEFPC12/13, and GW-175 were not monitored during the second test and are not discussed. Locations BCK-9.00 and BCK-10.14 had elevated background peaks for one to four weeks, which resulted in anomalously high apparent RWT concentrations between 1.07 and 2.61 ppb during the second test. Figure 4.2 shows the fluorescein concentrations from the initial test, with respect to the apparent RWT concentrations related to the background interference from the second test, at the Bear Creek sites. The highest background concentrations for each location recorded during the second test are noted by the bar labeled "BG" at the right side of Figure 4.2. It is conceivable that high background interference peaks in the 500 nm range gave anomalously high concentrations in the range for fluorescein (490 nm).

The UEFPC-29 had rhodamine detected throughout the second tracer test related to Rhodamine B dye being used at the Y-12 Plant. Thus, it is likely, though uncertain, if natural interference fluorescence had affected the results of the initial test at that site. The UEFPC-SP17 had two weeks of high background interference that produced apparent elevated RWT concentrations between 1.41 and 2.21 ppb (Fig. 4.3). As with the Bear Creek monitoring sites, the initial test concentrations for UEFPC-SP17 could be a result of high natural background

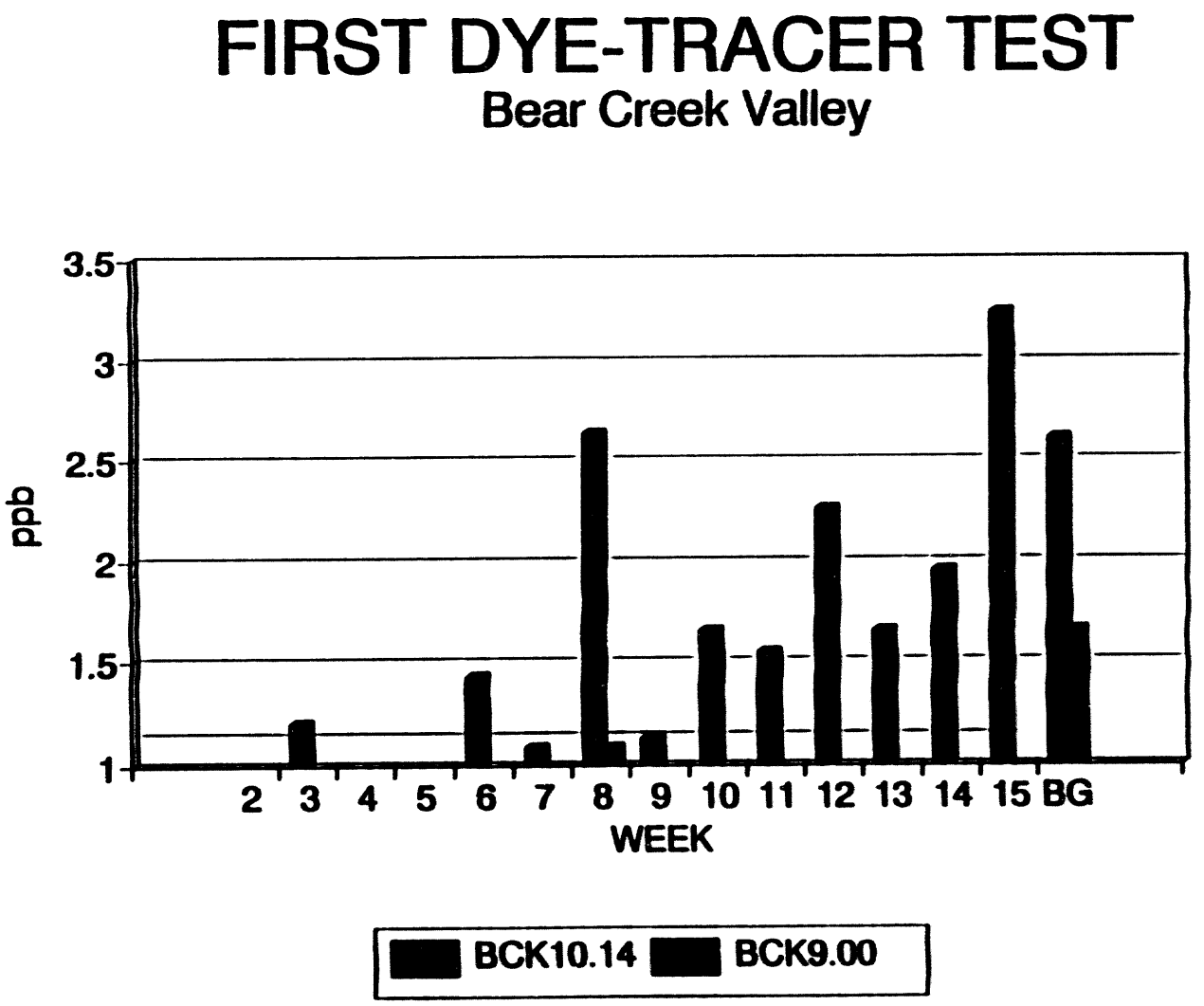


Figure 4.2: **Initial test monitoring sites in Bear Creek Valley with fluorescein concentrations reported above the detection limit (1ppb) for BCK-9.00 and background fluorescence (1.1 ppb) for BCK-10.14. BG = apparent RWT concentrations at 550 nm related to background interference at 500 nm.**

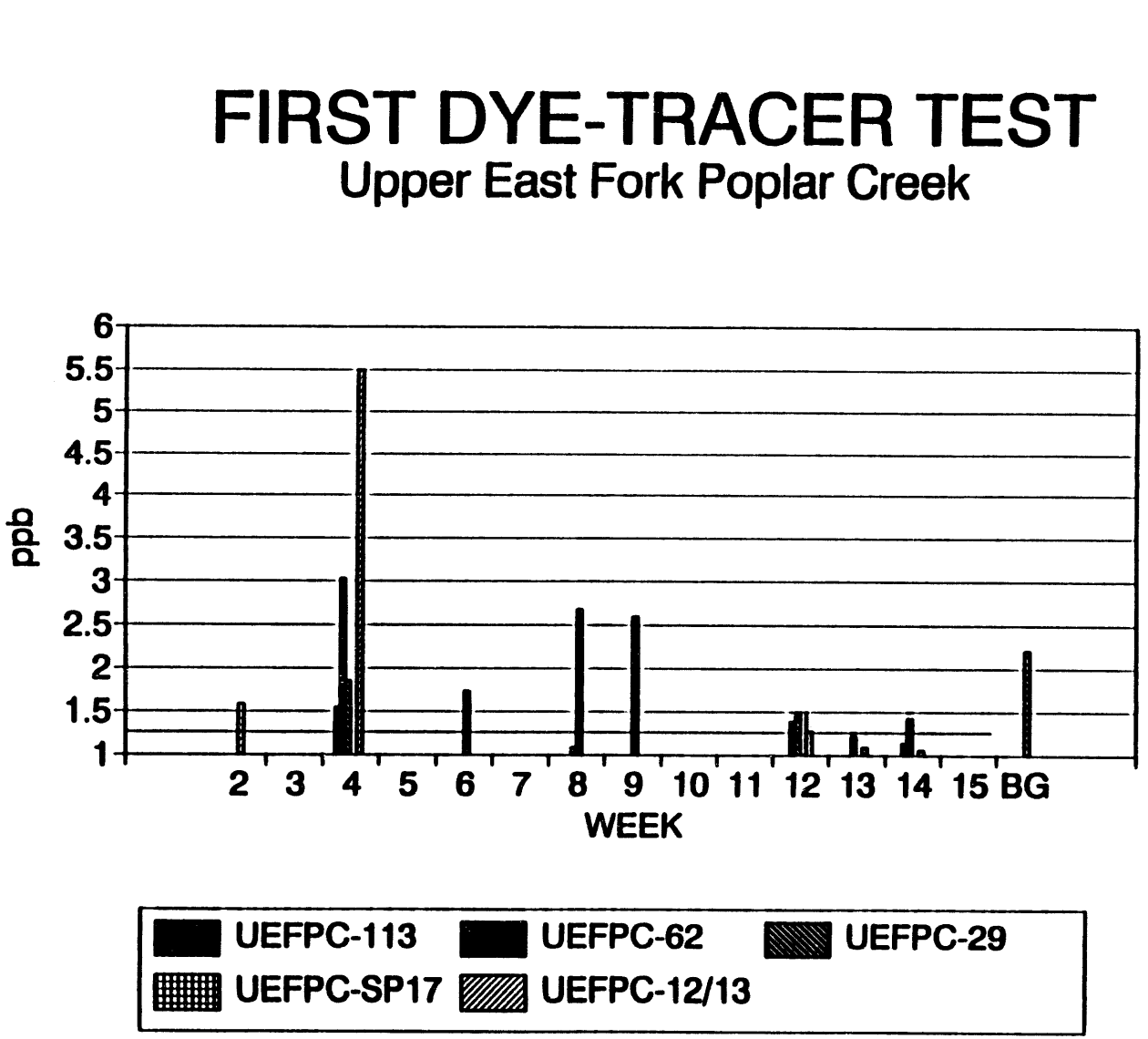


Figure 4.3: **Initial test monitoring sites in UEFPC with fluorescein concentrations reported above the detection limit (1ppb) for UEFPC-113, UEFPC-62, UEFPC-29, UEFPC-12/13 and background fluorescence (1.3 ppb) for UEFPC-SP17. BG = apparent RWT concentrations at 550 nm related to background interference at 500 nm.**

fluorescence (Fig. 4.3).

Both SCR-5.1SP and SCR-7.1SP had no detected interference peaks during the second test, but SCR-5.4SP had four peaks which gave RWT an apparent concentration between 1.16 and 2.38 ppb. The apparent fluorescein noted at the SCR Sites during the initial test could be artifacts of high background fluorescence in the 500 nm range (Fig. 4.4).

The WS-7.5SW did have two interference peaks during the second test, but at much lower apparent concentrations than those reported during the first test (Fig. 4.5). Personnel from Science Applications International Corp. (1992b) suggest that a closed municipal landfill, upgradient of SCR-7.1SP and WS-7.5SW, is a possible source of the fluorescein detected at these sites.

Additionally, there is no apparent correlation between the estimated minimum travel velocities between the first and second dye tests, as well as between the minimum travel velocities on the RWT and FB-28 dyes in the second test. Table 4.1 lists the estimated minimum travel velocities between the injection well and the sampling sites where the possible detection of dye was noted. These estimates assume the most direct pathway and are calculated for the first week in which concentrations exceeded the detection limit or criteria. The difference between travel velocities of the first and second tests could be a result of different

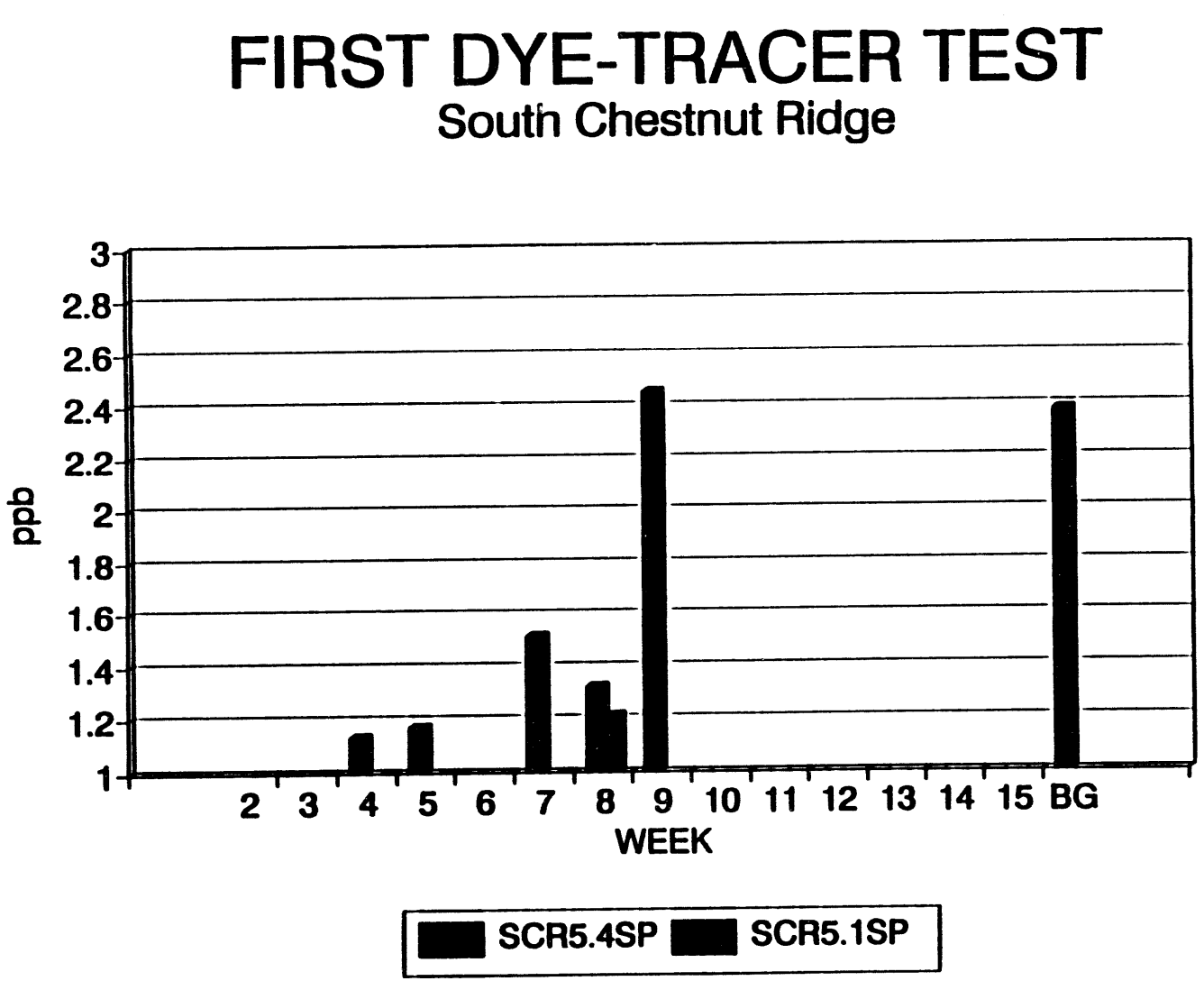


Figure 4.4: **Initial test monitoring sites on south Chestnut Ridge with fluorescein concentrations reported above the detection limit (1ppb). BG = apparent RWT concentrations at 550 nm related to background interference at 500 nm.**

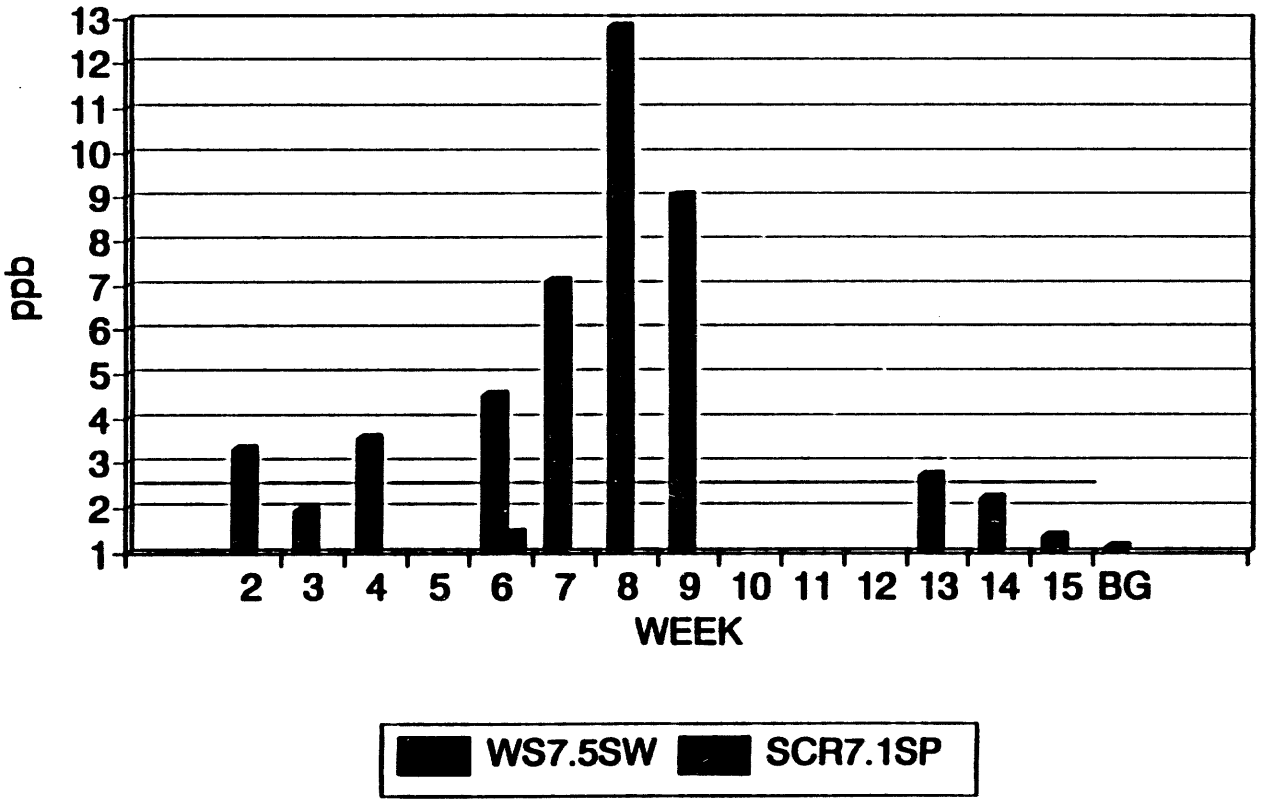


Figure 4.5: **Initial test monitoring sites at Scarboro Creek with fluorescein concentrations reported above the detection limit (1ppb) for SCR-7.1SP and background fluorescence (dotted line at 2.6 ppb) for WS-7.5SW. BG = apparent RWT concentrations at 550 nm related to background interference at 500 nm.**

amounts of precipitation between tests; however, the mean precipitation during the second test was only slightly lower (0.16 inches) than on the first test (Fig. 4.6). Therefore, travel velocities during the second test should be approximately equal to those of the initial test. However, in all but one of the initial test sites, the estimated travel velocities were significantly greater than those of the second test (Table 4.1). Theoretically, both the RWT and FB28 dyes should travel the same pathway and at the same velocity within the aquifer; however, the apparent travel velocities for these two dyes differ significantly where both spectral peaks were observed at the same location (Table 4.1). For example, at BCK-11.68SW, FB-28 had an estimated travel velocity of 109 ft/day whereas at the same location, RWT had an estimated velocity of 1314 ft/day.

4.2 CONCLUSIONS

The conclusion is that both dye-tracer tests conducted at the CRSP have not yet provided information on any hydraulic connections with the surrounding areas. If dye was indeed present at the monitoring locations, it occurred in such low concentrations that it was difficult to distinguish any possible dye fluorescence peaks from natural background fluorescence. There are several reasons that dye was not detected: inappropriate injection well, affects of the CRSP cap, abnormally low precipitation, adsorption of dye within the matrix of the aquifer, slow travel times for the dye, or deep migration of groundwater.

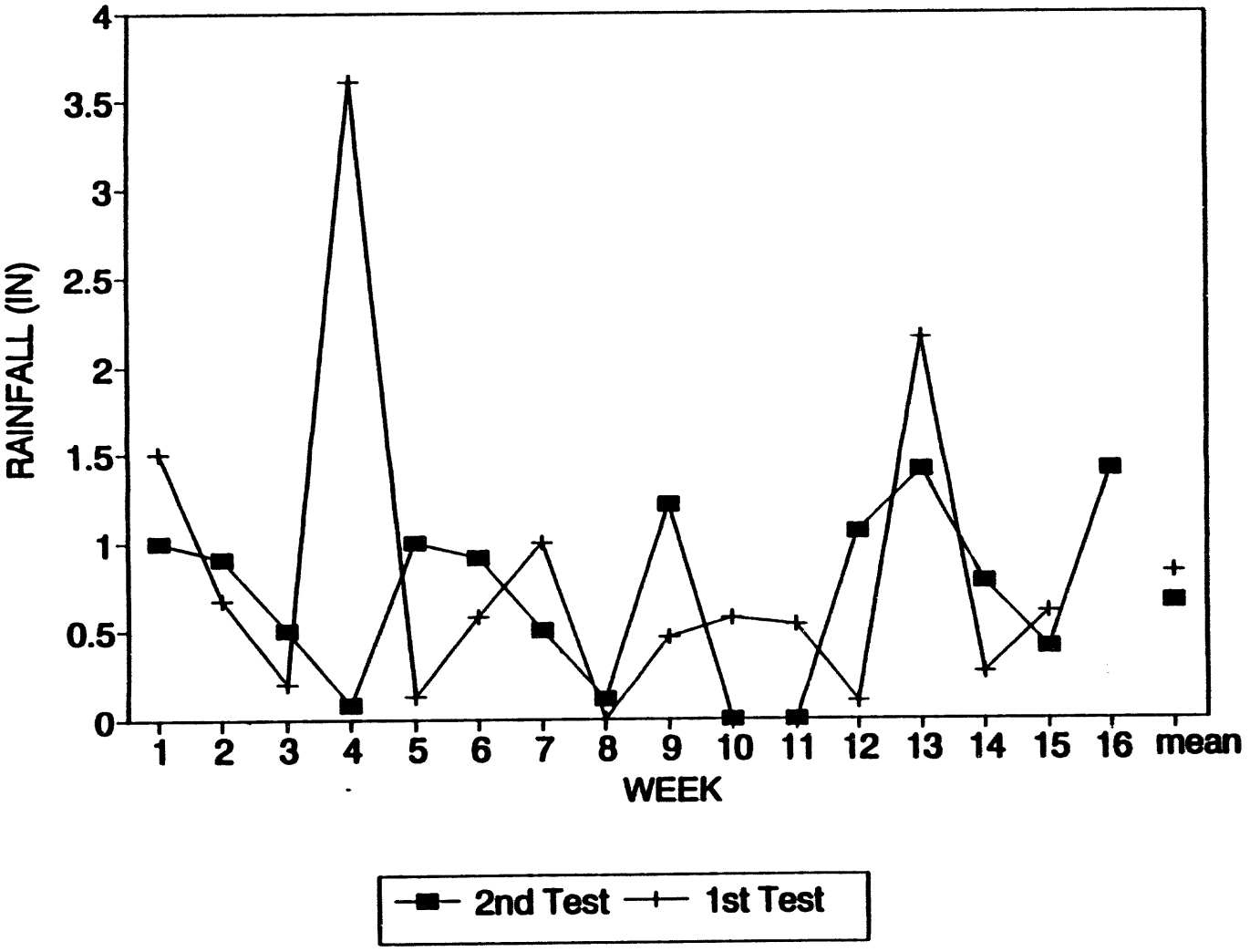


Figure 4.6: Comparison of weekly rainfall (in inches) during weeks after dye injection for the first and second dye-tracer tests. The mean rainfall for 15 weeks after dye injection for both tests is shown at the right to the figure.

Table 4.1: Estimated minimum travel velocities of dyes for the first and second dye-tracer tests. Estimates are based on the most direct path between the injection well and sampling sites and the first apparent dye detection.

Site	FIRST TEST Minimum velocity (ft/day)	SECOND TEST Minimum velocity (ft/day)	
		FB-28	RWT
BCK-9.00SW	321	171	
BCK-9.41SP		173	
BCK-10.14SP	660		
BCK-11.68SW		109	1314
SCR-1.1SW		61	87
SCR-1.2SP		109	
SCR-2.1SP			750
SCR-2.2SW		271	
SCR-3.1SP		21	357
SCR-3.4SP		171	
SCR-3.5SP		357	47
SCR-4.1SW		250	
SCR-4.3SP		77	232
SCR-4.4SW		309	
SCR-5.1SP	112		53
SCR-5.3SW		1000	
SCR-5.4SP	285	65	
SCR-7.1SP	240	368	
SCR-7.4SP		157	105
SCR-7.6SP		97	
SCR-7.7SP		786	
WS-6.1SW		179	
WS-7.5SW	843	139	
UEFPC-113	36		
UEFPC-62	71		
UEFPC-29SW	114	71	
UEFPC-17SP	286	32	
UEFPC-12/13	125		
GW-160		82	
GW-221		161	
GW-561		14	750

4.2.1 Inappropriate Injection Well

The construction of the injection well (GW-178) may inhibit groundwater recharge into a karst system. Although several solution cavities were encountered during the drilling of this well, they were cased off and only two "possible" fractures are believed to occur within the screened interval. It is possible that the fractures within the screened interval only allow groundwater and dye access to diffuse, slow-flow portions of the system rather than the conduit, quick-flow portion.

During injection of the primer slug for the second test, GW-178 had a flow rate of 52 gal/hour. However, during injection of the chaser slug, flow rates had slowed to between 12 and 15.6 gal/hour. Ideally, a dye test would provide an instantaneous slug of dye to enter the groundwater system. However, because the injection was not completed for several days, the dyes slowly diffused into the groundwater system. Personnel from Geraghty and Miller, Inc. (1990) gave no indication that the injection rates during the initial test varied, although no quantitative data is provided.

4.2.2 Affects of the CRSP Cap

The CRSP were capped with a multilayer, low-permeability cap in 1988 (HSW Environmental Consultants, Inc., 1992), which may retard recharge on the crest of Chestnut Ridge in the vicinity of the injection well (which is located slightly north of the CRSP capped area). Infiltration of recharge water falling on Chestnut

Ridge should be impeded by this low permeability cap. However, piezometric surface maps for times before and after cap construction indicate that GW-178 is located within a groundwater high on Chestnut Ridge, and that the cap has had little or no affect on the piezometric surface (Shevenell and Goldstrand, in press). Thus, it appears that the CRSP cap has not affected groundwater flow in the injection well area.

4.2.3 Low Precipitation

The initial dye test was conducted during the low-flow season (July to October, 1990). The second test was planned to coincide with the historical wet season of the Oak Ridge Reservation (ORR). Rainfall data for the last 30 years indicate that the peak average annual precipitation for the ORR area generally occurs between December and March (Science Applications International Corp., 1992a). During the second test, measured precipitation was approximately 25 percent lower than the 30-year average rainfall for the first 10 to 14 weeks of the test (Science Applications International Corp., 1992a). As a result, one well and several of the springs and stream monitoring stations were dry or at low flow conditions during part of the second dye-test (Table 4.2). This low seasonal rainfall may have lowered the baseline flow allowing dye to remain in storage until increased baseline flow conditions, or perhaps migrated to deeper karst systems (Science Applications International Corp., 1992a). During the last four to eight weeks of the monitoring period, baseline flow increased to normal-or high-flow

Table 4.2: Dry to low flow conditions during the second dye-tracer test (Science Applications International Corp., 1992a).

STATION	WEEKS	FLOW TREND
GW-561	13-18	WELL DRY
BCK-9.00SW	8-13	LOW FLOW
BCK-10.14SP	5-7	LOW FLOW
BCK-11.68SP	5-7	LOW FLOW
SCR-2.1SP	5-17	INTERMITTED LOW FLOW
SCR-2.2SW	4-18	DRY
SCR-3.1SP	5-7	LOW FLOW
SCR-3.4SP	5-7	LOW FLOW
SCR-4.1SW	5-15	LOW FLOW TO NEARLY DRY
SCR-4.4SW	5-6	LOW FLOW
SCR-7.1SP	5-9	STAGNANT TO LOW FLOW

conditions (Science Applications International Corp., 1992a).

4.2.4 Adsorption of Dye

It is possible, that in conjunction with low flow conditions, RWT and fluorescein dyes were lost to adsorption within the matrix. Both RWT and fluorescein have high adsorption rates when in contact with organic compounds such as humus (Smart and Laidlaw, 1977). Additionally, RWT has a relatively high adsorption rate to inorganic materials such as kaolinite and limestone (Smart and Laidlaw, 1977). Thus, during the low-flow conditions of the initial test and the first part of the second test, the dyes may have adsorbed on the matrix of the aquifer.

4.2.5 Slow Travel Times

As noted above, the injection well monitors a more diffuse, slow-flow system rather than a conduit-or quick-flow system. The screened interval does not contain solution features and may not monitor a well-connected flow system. During the second test, several days were needed to accomplish injection of the chaser slug. Ideally, an instantaneous slug of dye and chaser should be injected into the groundwater system. The slow flow into the groundwater system after dye injection probably resulted in lower dye concentrations throughout the system (Science Applications International Corp., 1992a).

4.2.6 Deep Migration

Karst aquifers may have multiple flow paths which are, in part, dependent on baseline flow conditions. As noted above, the first dye-tracer test and the first part of the second dye-tracer test occurred during low-flow conditions. It may be that the dyes migrated to slightly deeper levels beneath Chestnut Ridge during the low-flow conditions and have not yet emerged. It is also possible that the injection site is not connected with any of the monitoring sites and may be connected with a deeper-flow system not yet recognized.

5. SUMMARY

Two dye-tracer tests conducted on Chestnut Ridge do not definitively prove that a hydraulic connection occurs between GW-178 and the monitoring sites surrounding CRSP. Although initial interpretations of the first dye test suggest a hydraulic connection with several sites, the relatively high analytical detection limits during the first test, and the high interference background peaks observed during the second test, indicate that dye was not detected during the second test and may not have been actually detected during the initial test. High natural background in the range of the fluorescein spectra may have caused the apparently high reported concentrations of dye during the initial study. However, one monitoring site during the initial test (WS-7.5SW) appears to have had fluorescein present, but it is unclear if this indicates a hydraulic connection with

CRSP or is derived from a closed landfill site upgradient of that location.

The results of these two tests do not preclude that a hydraulic connection exists; dye may be present in concentrations below the analytical detection limits or has not yet emerged. The injection well is not screened within any significant karst features and dye migration may be within a diffuse, slow-flow aquifer. Also, low-flow conditions occurred during both tests and the dyes may not have yet emerged at the monitoring sites, or they may have emerged at springs other than those monitored.

Recommendations for future dye-tracer tests are provided in Science Applications International Corp. (1992a) and include: (1) baseline monitoring (at least eight week long) prior to tests, (2) baseline monitoring for specific interference peaks in the spectral range of of the dyes to be used during the tests, (3) selection of an injection well that intersects known karst features, (4) complete a specific capacity test on the injection well prior to the test, (5) conduct the test during high flow conditions, (6) consider the uses of inorganic tracers, (7) QA assessment of analytical methods to minimize interferences, and (8) new and improved analytical method should be considered. In addition to these recommendations, a year-long study should be conducted on selected wells and springs to determine the seasonal variability of natural background fluorescence.

6. REFERENCES

Energy Systems. 1984. Inventory of Disposals Conducted in the Chestnut Ridge Security Pits, Y-12 Plant, Oak Ridge, Tennessee (Y/TS-191).

Energy Systems. 1988. Revised RCRA Closure Plan for the Chestnut Ridge Security Pits, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee. (Y/TS-391).

Fetter, C.W. 1988. Applied Hydrogeology. MacMillan Publishing Company, New York, 592 p.

Geraghty and Miller, Inc. 1987. Monitor-well documentation report for the 1987 drilling program at the Y-12 Plant. (Y/SUB/87-00206C/20).

Geraghty and Miller, Inc. 1989. Tracer study of the Hydrologic System of Upper Bear Creek, Y-12 Facility, Oak Ridge, Tennessee. (Y/SUB/89-00206C/4).

Geraghty and Miller, Inc. 1990. A Study of Groundwater Flow from Chestnut Ridge Security Pits Using a Fluorescent Dye Tracer: Preliminary Results. (Y/SUB/90-00206C/6).

HSW Environmental Consultants. 1992. Groundwater Quality Assessment for the Upper East Fork Poplar Creek Hydrogeologic Regime at the Y-12 Plant; 1991. (Y/SUB/92-YP507C/2/P1).

King, H. L., and Haase, C. S. 1987. Subsurface-controlled Geologic Maps for the Y-12 Plant and Adjacent Areas of Bear Creek Valley (ORNL/TM-10112).

King, H. L., Haase, C. S., and Harrington, B. K. 1991. Updated Subsurface Data Base for Bear Creek Valley, Chestnut Ridge, and Parts of Bethel Valley on the U.S. Department of Energy Oak Ridge Reservation (Y/TS-735).

Mull, D. S., Smoot, J. L., and Lieberman, T. D. 1988. Dye Tracing Techniques Used to Determine Groundwater Flow in a Carbonate Aquifer System. Near Investigations Report 87-4174.

Science Applications International Corp. 1992a. Final Report of the Second Dye-Tracer Test at the Chestnut Ridge Security Pits, Y-12 Plant, Oak Ridge, Tennessee (Y/SUB/93-99928C/Y10/1).

Science Applications International Corp. 1992b. Workplan for the Second Dye-Tracer Test at the Chestnut Ridge Security Pits, Y-12 Plant, Oak Ridge, Tennessee (Y/TS-831).

Shevenell, L. A., and Goldstrand, P. M. In Press. Effectiveness Evaluation of Three RCRA Caps at the Y-12 Plant, Oak Ridge, Tennessee. (Y/TS-891).

Shuster, E. T., and White W. B. 1971. Seasonal Fluctuations in the Chemistry of Limestone Springs: A Possible Means for Characterizing Carbonate Aquifers. Journal of Hydrology, V. 14, p. 93-128.

Smart, P. L., and Laidlaw, I. M. S. 1977. An Evaluation of Some Fluorescent Dyes for Water Tracing, Water Resources Research, V. 13, No. 1, p. 15-33.

Smart, C. C., and Smart, P. L. 1991. Correction of Background Interference and Cross-Fluorescence in Filter Fluorometric Analysis of Water-Tracer Dyes. Proceedings of the Third Conference on Hydrogeology, Ecology, Monitoring, and Management of Groundwater in Karst Terranes: U.S. EPA and the Association of Groundwater Scientists and Engineers, p. 475-491.

DISTRIBUTION

DEPARTMENT OF ENERGY
G. W. Bodenstein (2)
W. G. McMillan

HEALTH, SAFETY ENVIRONMENT
AND ACCOUNTABILITYORGANIZATION
W. K. Jago
S. B. Jones
E. B. Rundle
S. W. Wiley (2)
File - EMD - RC

ENVIRONMENTAL RESTORATION PROGRAM
M. J. Norris
V. J. Brumback
J. A. Hodgins

UNIVERSITY OF TENNESSEE
R. M. Evans
B. W. McMaster

UNIVERSITY OF NEVADA, RENO
P. M. Goldstrand
L. A. Shevenell

EIC LABORATORIES
J. Haas

QUINLAN AND ASSOCIATES
J. F. Quinlan

ENVIRONMENTAL SCIENCES DIVISION
R. B. Clapp
R. B. Dreier
T. O. Early
D. D. Huff
J. M. Loar
D. D. Rhew
W. E. Sanford
R. R. Turner
D. Watson

ENERGY DIVISION
R. H. Ketelle
R. R. Lee

WASTE MANAGEMENT DIVISION

K. D. Delius
C. W. Hutzler
J. E. Stone

HSW
J. R. Walker

SCIENCE APPLICATIONS
INTERNATIONAL CORPORATION
D. W. Combs
D. Keefer

A. K. Lee/DOE-OSTI (2)
Y-12 Central Files

DATE
FILMED
5/16/94
END