Proposal to Trace Groundwater at Malad Gorge Springs

By Neal Farmer IDWR

Background and Objective:

The new ESPAM being developed by IDWR will increase time discretization resolution to a monthly basis but to do this efficiently more information is needed about recharge and discharge from the aquifer. Dye tracer tests directly quantify numerous hydrologic parameters and flow regime characteristics verse other techniques such as measuring groundwater levels and spring flow rates which are indirect methods to characterize changes. Physical parameters compliment tracer tests and vice versa during analysis stage of a study. The effectiveness of Fluorescein dye to trace canal water leakage down to the aquifer has been demonstrated at the "W-canal Site" northeast of Wendell where it was determined that the time of travel from land surface down to the aquifer (150 feet) was defined at 4 weeks but interpreted to be about 3 weeks.

Fluorescein was first synthesized by Adolf von Baeyer in 1871. It is a green colored dye that is the most commonly used dye for both surface and groundwater tracing studies. It is certified by ANSI/NSF for Standard 60 potable water and approved by the EPA as noted by a copy of the certification located in the appendix. Sodium Fluorescein (Acid Yellow 73 – CAS # 518-47-8) can be detected in a fluorometer at very low concentrations of 0.1 ppb even in water containing a high percentage of natural background fluorescence such as canal water, rivers or even raw sewage. Dye tracing may also be used for the analysis of blood circulation within various parts of the human or animal body. For example, fluorescent angiography, a technique of analyzing the circulation in the retina is used for diagnosing various eye diseases. With modern fluorometers, capable of tracking single fluorescent molecules, it is possible to track migrations of single cells tagged by a fluorescent molecule (see Fluorescein in biological research) (Wikipedia.com). Tests will be designed with the goal to achieve a dye concentration at the sample sites ranging between 0.1-100 ppb which is well above the lab equipment detection limit and well below the visual detection limit of the unaided eye at 1,000 ppb.

Fluorescent dyes make excellent tracers for a variety of reasons, including:

1. They are water soluble.
2. They are highly detectable (some below 1 part per trillion).
3. They are inexpensive.
4. They are fairly stable in a normal water environment.
5. They have been used successfully for tracing for over 100 years.
6. They are not naturally found in aquifer systems and therefore no background interference like other tracers can be like bromide.
7. They have extremely low toxicity ratings. The absence of toxicity from Fluorescein is documented as noted in the following reference by Smart (1984).

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Figure 1. Concentrated Fluorescein dye illuminated with a UV light (Wikipedia.com)

The type of tracer selected for a tracer test is dependent on many factors. One such factor includes the purpose of the study. For example, if information such as the velocity of the ground water, porosity, and the dispersion coefficient are of interest, then a conservative tracer should be used. Other factors include type of medium, available funds, the stability of the tracer, detectability of tracer, difficulty of sampling and analysis (availability of tracer, ease of sampling and availability of technology for analysis), physical/chemical/biological properties of tracer and public health considerations (Davis et. al., 1985). Various components go into the design of a tracer test. For tracer tests at springs in the Thousand Springs area, the following components were considered and evaluated: the conceptual design, down gradient receptors such as humans, aquaculture industry and endangered species, transient hydrologic barriers such as canal recharge, selection of initial mass of tracer or its concentration, observation wells, sampling schedule and locations, and monitoring.

The transport of a conservative tracer is primarily controlled by advection and dispersion. Advection is the movement of the solute due to general ground water motion. The rate of the flowing ground water can be evaluated based on Darcy's Law. Tracer migration due to advection is assumed to occur at the same rate as the average linear velocity of the ground water (Fetter, 2001). It is important to realize that not all solute will travel at the same rate as the ground water. Some solute will move slower than the mean velocity and some will move faster than the mean velocity. This mechanical mixing together with ionic diffusion results in hydrodynamic dispersion and spreading of the solute. It is known that dispersivity is scale-dependent (Davis et.al., 1985), meaning that values of longitudinal dispersivity generally increase with increasing distance between the injection point and sampling locations (i.e. dispersivity increases as the plume migrates down gradient) (Anderson and Woessner, 1992). In fractured, non-soluble aquifers, Leibundgut and Wernli (1986) estimated about 1% of the dye introduced is recovered (Aley, 2002) but from a tracer study performed in a basalt perched aquifer under the Bell Rapids Irrigation District in Twin Falls county by Dallas (2005) up to 28% of the dye was recovered.

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Location and Site Conditions

Most spring locations from Crystal Springs downstream to Malad Gorge will likely have groundwater flowing through basalt related rock types which includes pillow rubble zones. Use of Fluorescein as a tracer is appropriate for this type of geology that exhibits fracture and conduit flow characteristics. The well targeted for dye release at Malad Gorge State Park is located in the 'Picnic Area' as shown (central right side) in Figure 2 with a green circle. Sample locations are noted as red numbers.

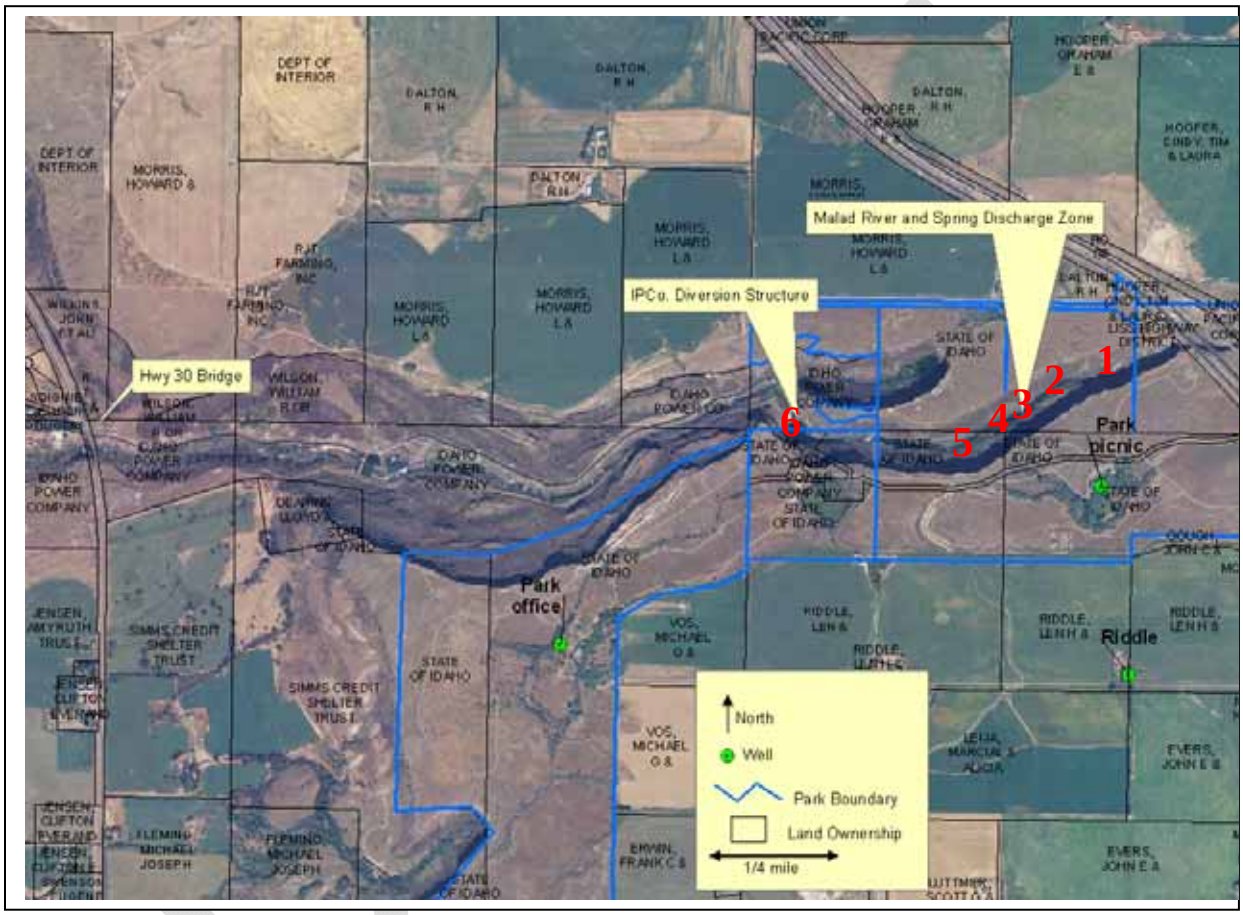

Figure 2. Location of Malad Gorge and Park Picnic Well (noted by green circle). Sample locations are noted with red colored numbers.

Geologic Conditions and Subsurface Conceptual Flow Model

Water will initially follow the easiest flow paths horizontally along basalt contact zones that are highly transmissive with possible 'conduit' type of flow path characteristics. In tandem but at a slower rate, water will also flow through fractures in the massive portion of the basalt from the overlying flow contact zone. Approximate horizontal groundwater flow velocities may be inferred from dye tracer tests by Farmer (2001) and Dallas (2005) in a basalt flow 200 feet in

elevation beneath the Bell Rapids Irrigation District in Twin Falls County. The range of horizontal groundwater velocities obtained from these studies are listed in Tables 1 and 2.

The well drilling report shows open hole (10 inch diameter?) with no casing below 21 feet and there is broken basalt within the saturated zone of the aquifer (Figure 3). Water level in the well on November 15, 2007 was 185 feet below land surface but the dye will be released into the upper level of the broken basalt at 212 feet below land surface. Figure 4 shows the conceptual 2-D model for conditions and dye transport to the springs and river. It is about 1,000 feet between the well and the nearest springs.

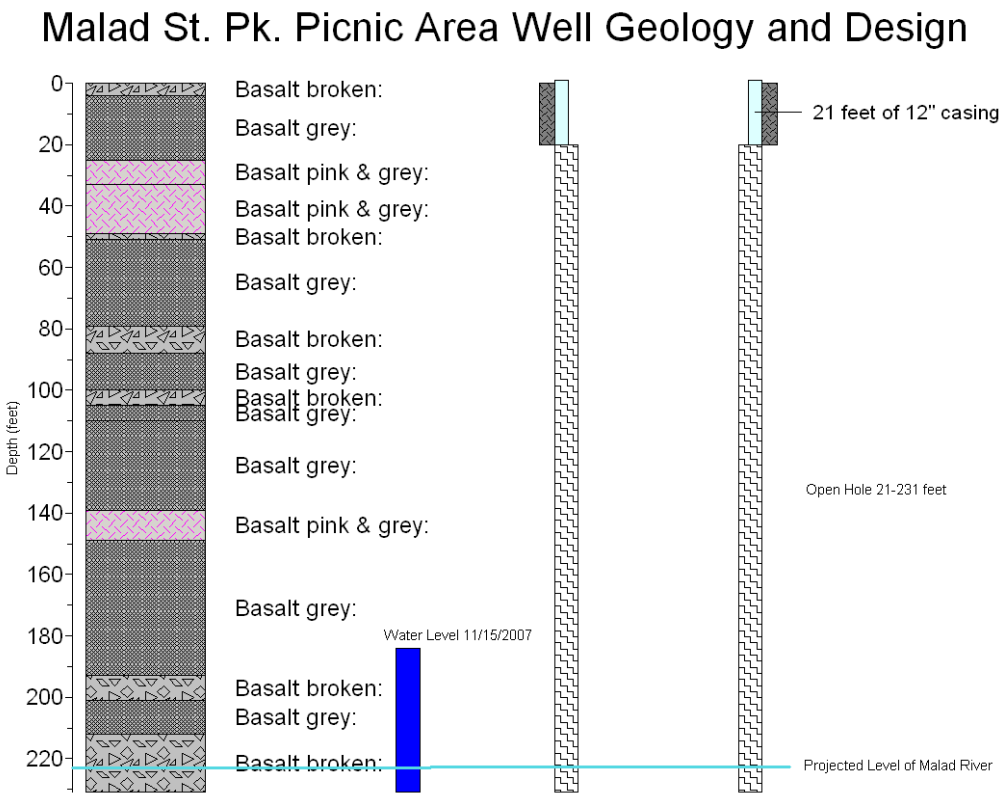

Figure3. Geology and well construction for the Malad Gorge Park picnic area well.

Test	Sampling Point	Distance (m)	First Arrival (days)	Time of Peak (days)	Maximum Tracer Velocity (m/day)	**Average Tracer Velocity (m/day)**
NPS-7-2003	Well NPS-2	337.4	7	17	48.20	19.85
	Well NPS-3	331.3	5	25	66.26	13.25
	Well NPS-6	272.5	5	12	54.50	22.71
	1984 spring	463.0	17	25	27.24	18.25
	1991 W. Fork spring	547.7	25	39	21.90	14.04
	1991 E. Fork spring	547.7	12	20	45.64	27.39

Table 1. Table of groundwater velocity results from Dallas (2005).

Test	**Average Linear GW Flow Velocity (feet/day)**	Maximum Linear GW Flow Velocity (feet/day)
Well NPS-2-97	140	230
Well NPS-6-98	75	160
Well NPS-3-99	48	150

Table 2. Table of groundwater velocities from Farmer (2001).

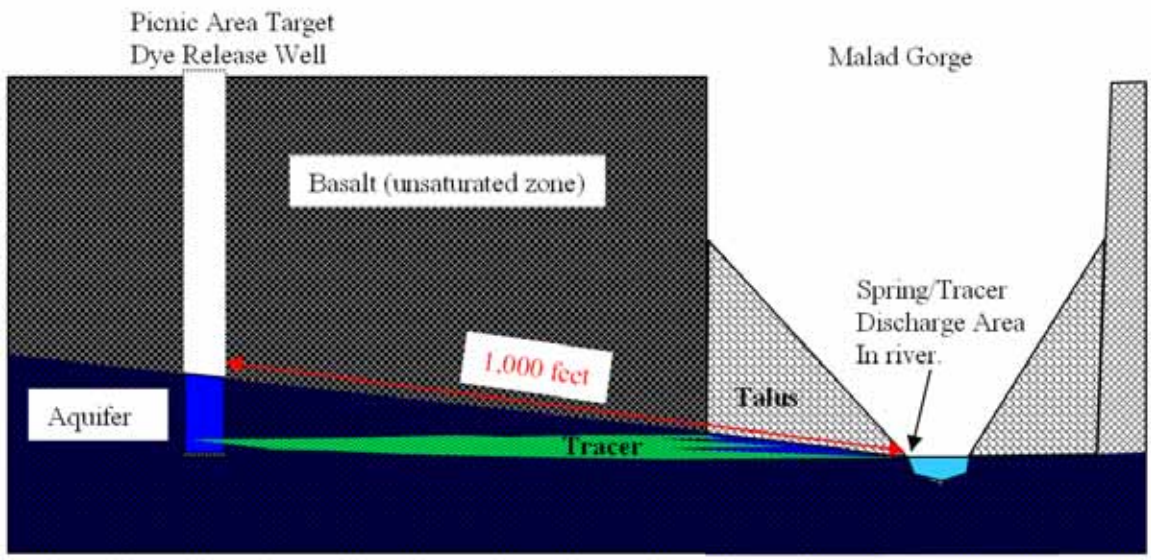

Figure 4. Conceptual 2-D cross section model of the tracer test at Malad Gorge.

Based on the shape of the dye tracer break through curves from Farmer (2001) and Dallas (2005) the full plume of dye may take several months to completely pass through but the initial break through of dye is estimated at 7 days. It is anticipated the regional aquifer will dilute the dye concentrations to low levels before the dye discharges from the springs into the river. It is estimated there is 750 gallons of water in the borehole of the well and the initial concentration of the dye in the well will be approximately 180 ppm (1.5 pounds of dye) resulting in a resurgent concentration at the springs ranging from 1-100 ppb. It is optimal to remove the pump and deploy a 'dye mixing pump' for at least 3 days after dye release to allow it to flow towards the springs. The original pump can be re-installed and turned back on after this period and the well flushed of dye by simply pumping water. Another advantage to this site is there are no wells in between the springs and the dye release well.

Proposed Approach to Trace Fluorescein Dye at Malad Gorge State Park

A USGS field and lab procedural report by James Wilson (1986), a thesis by Dallas (2005) and recommendations by The Ozark Underground Laboratory Handbook by Tom Aley, along with personal experience will be used as guidance for detailed project implementation. Based on my experience and review of the literature in the appendices, it is both viable and feasible to trace groundwater flow at Malad Gorge State Park with the following procedure:

1. **Establish 6 monitoring locations** and deploy [2] charcoal packets at each location along with collecting [1] 50 ml water samples. Sample site number [1] will be located as far up the river as reasonably possible give the geology and hazards with the goal of placing the sample site up stream of any potential dye discharge. Sample sites [2,3,4,5] will be located at large spring discharge areas on the south side of the river with the goal to determine which spring discharge the most dye. Sample site [6] will be at Idaho Power Co. diversion structure and functions as a downstream integrated sample that will be exposed to all dye passing through the river. This will provide the concentration in the river as a whole and serve as a backup in case dye discharges from other unknown springs besides the locations of sample sites [2,3,4,5].

2. **Collect 2 'rounds' of samples (both charcoal and water) prior to injection** of dye from all sampling locations on a weekly basis to evaluate natural background fluorescence and remove this background level from the data. IDWR and IPCo. will provide staff for this task.

3. **Inject a solution of 1.5 pounds of Fluorescein dye** mixed with 3 gallons of potable water directly into well water through plastic tubing at the 212 foot depth level. The amount of dye is based on literature review and past tracer tests performed within a basalt aquifer as noted in the appendix documents (Dallas 2005; Farmer and Larson, 2001;
    - Thomas Aley states on page 13 of the 2002 Tracer Handbook "*There is no credible standard equation for estimating dye quantities needed for groundwater tracing work.*" and on page 14 "*We seldom use less than one pound of any of the dyes for any particular dye introduction. In Karst areas, most dye introductions use one to five pounds of the selected dye except where the dye is introduced into wells, borings, or backhoe pits. When dye introductions are made into these man-made locations, dye quantities are most commonly in the range of five to ten pounds for Fluorescein or eosine and ten to twenty pounds of rhodamine WT. Groundwater tracing in non-karst areas typically requires two or three times more dye than in karst areas.*"

    The existing pump will need to be pulled out and a 12 volt mixing pump deployed. The mixing pump will need to be operated continuously for several days until 90% of the dye has flowed out of the well. Then the mixing pump will be removed and the original pump lowered back into the well. The mixing pump will need a steady 110 volt power outlet from the restroom facilities connected to a converter for a 12 volt supply to the mixing pump. After the test is over the well can be disinfected and tested for bacteria.

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4. **Sampling frequency** will change with time. During the first two week period samples will be collected twice per week then weekly there after for another 4 weeks. Then frequency decreased to bi-weekly for another month. After this time period the data will be evaluated and a decision made if additional samples need to be collected. The total test period will be approximately 12 weeks as noted below in the table and IDWR and IPCo. will provide staff for this task.

Week	# of Locations	Total # of water samples	Total # of charcoal samples	Notes
-1	6	6	12	Pretest sampling for background
0	6	6	12	Pretest sampling then dye release date
0.5	6	6	12	
1	6	6	12	
1.5	6	6	12	
2	6	6	12	
3	6	6	12	
4	6	6	12	
5	6	6	12	
6	6	6	12	
7				No sampling
8	6	6	12	
9				No sampling
10	6	6	12	
11				No sampling
12	6	6	12	
		78	**156**	**Total # of samples**

5. **Analyze samples** by two methods. IDWR staff will perform the 'in-house' method with a calibrated lab fluorometer model TD-700 made by Turner Designs or a La Motte brand "Smart Spectro" Spectrophotometer. The TD-700 was used by Dallas (2005) which is located at the IDWR office in Boise. The "Smart Spectro" is also located at Boise IDWR. Periodically, a few samples should be mailed to Ozark Underground Labs (OUL) to be analyzed with their equipment for additional QA/QC. The samples will be selected from the first arrival of dye, maximum peak concentration and one during the recession of the dye breakthrough curve. All water samples will be retained and stored in a refrigerator until the test is completed.

6. **QA/QC** will be attained by submitting 3 water samples and 3 charcoal packets to a laboratory from the site with the highest concentration determined by the fluorometer. The three time periods from this one site will be from the peak concentration, first arrival and mid-recession. Then the water sample and charcoal packet from the peak concentration from each additional location will be also sent off to the lab for a total of 7 samples (each having both a water sample and charcoal packet) submitted to the lab. A blank water sample will be tested during each analysis using a fluorometer. Natural background fluorescence will be determined by collecting and analyzing two rounds of samples from each location prior to dye injection to provide a baseline.

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7. **Date analysis and report writing** will be performed at the end of the test discussing and describing the results and recommendations for future actions. Copies will be made available.

Biological Considerations

Fluorescein is non-toxic, biologically degrades and photo degrades when exposed to ultraviolet light. A literature search has been made to ensure that biological risks to humans, human food sources, and aquatic species such as fish, snails and Daphnia are taken into consideration for the test design and there is no known adverse effects anticipated given the project design. Dye tracing has been performed at locations with endangered species (snails and shellfish), human food sources (trout farms), and salmon spawning beds for over half a century with the approval of the U.S. Fish and Wildlife Service, state agencies and other private and non-profit organizations (Aley, 2008).

Human

Human health and safety are addressed from the MSDS sheets provided in the appendices. The dye is EPA certified to conform to the ANSI/NSF Standard 60 for use in potable public water supplies as set forth by the Clean Water Act (see a copy of the certification in the appendices) up to 10 ppb. Smart (1984) states "Persistent dye concentrations in tracer studies should not cause problems provided they are below 100 ppb". The pump will be turned on and the system flushed until the water is colorless. The water will be tested for residual dye and continued flushing if levels are above 10 ppb. The resurgent concentrations from the springs and in the river will not be a risk to humans since there is no exposure or consumption of this water.

Snails

Endangered and non-endangered snails were considered by seeking professional recommendations and information. Tom Aley has performed numerous dye tracer tests at locations where endangered snails are present with the blessing of the U.S. Fish and Wildlife Service (Aley, 2008). A literature search was performed and numerous snail experts contacted about the potential risk as noted from copies of emails in the appendix. I spoke with Dr. John Stark who is the director and a professor at Washington State University about snails and his opinion was that the dye should not pose a problem to snails if the concentration is below 300.0 ppm. John Stark is an ecotoxicologist who specializes in ecological risk assessment of threatened and endangered species (see Daphnia section below).

Fish

Two potential issues, native or indigenous populations and commercial production are addressed in regards to fish. Dye tracing has been approved by federal regulatory agencies and performed in streams and rivers for over half a century at locations that include sensitive environments and endangered species such as in Salmon spawning beds with no problems or issues (Aley, 2008). Resurgent dye concentrations are expected to be very low ranging from 0.1-100 ppb from the springs and diluted after mixing with additional river water near the spring area above the upper IPCo. diversion structure. Even more dilution will occur downstream from more spring discharge into the river where it is anticipated concentrations of dye will be at or below the minimum detection limits. As a precaution, samples will be

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collected at the upper diversion structure to monitor concentrations in the river. The endemic species of Shoshone Sculpin are present in the lower Malad River below the Highway 30 Bridge (Bowler, 1992 and personal communication with Malad Gorge staff, 2008). The dye is expected to be below detection limits by the time it flows through this section from the effects of dilution, biological degradation, ultraviolet light degradation, and absorption onto concrete and rock substrate.

Daphnia

Daphnia are small, planktonic crustaceans, between .2 and 5 mm in length (Figure 5). *Daphnia* are members of the order Cladocera, and are one of the several small aquatic crustaceans commonly called water fleas because of their saltatory swimming style (although fleas are insects and thus only very distantly related). They live in various aquatic environments ranging from acidic swamps to freshwater lakes, ponds, streams and rivers (Wikipedia, 2008).

Figure 5. Photo of Daphnia crustacean (Wikipedia, 2008).

Dr. John Stark was contacted by IDWR staff (personal communication) and discussed the risk of Fluorescein dye to both snails and Daphnia. Dr. Stark is an ecotoxicologist who specializes in ecological risk assessment of threatened and endangered species. He runs the WSU Salmon toxicology research laboratory and has recently started work on the effects of pesticides on endangered butterfly species. Stark is also a population modeler and has developed population-level risk assessments based on matrix models and differential equation models.

John D. Stark
Director, WSU Puyallup Research & Extension Center
and Professor, Ecotoxicology Program
7612 Pioneer Way
Puyallup, WA 98371-4998

http://entomology.wsu.edu/Profiles/stark.html

Phone: (253) 445-4519
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Dr. Stark provided a professional paper (Walthall and Stark, 1999) that addresses the risk of dyes to Daphnia and the research paper concluded there is little or no issues with dye concentrations below 337 (278±403) mg/liter (ppm) and the resurgent dye concentration is expected to be several orders of magnitude less in concentration within the range of 0.1-100 ppb.

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List of Supplies and Equipment Needed for Implementation of One Dye Test

(most equipment will be a one time cost and therefore subsequent supply cost may be about half of this total cost)

Item #	Description	Estimated Cost
1	IDWR in-kind contribution fluorometer TD700 ($5,000)	0
2	IDWR in-kind contribution fluorometer Smart Spectro ($2,000)	0
3	Dye (2 pounds + shipping)	100
4	Bulk 500 per case 50 mL screw top vials	100
5	Charcoal packets (200)	100
6	Wash bottles	20
7	Laboratory wipes	20
8	Laboratory soapless cleaner and brushes	20
9	Black sharpie markers	20
10	"Blue Ice" packs	50
11	Aqua ammonia (29%)	100
12	Isopropyl alcohol (70%)	100
13	OUL lab analysis (7 samples @ $40 ea)	280
14	Mixing pump 12 volt (Abyss Model)	1,155
15	110 volt AC to 12 volt DC converter for pump	355
16	250 feet of 3/8" polytubing	50
17	Bacteria tests and disinfection	40
18	Pull existing pump	700
19	Miscellaneous items (tape, string, tarp, funnel, buckets, etc.	50
	Subtotal $	**3260**

Quantity	DESCRIPTION Include make, model, color, etc.	Cat. #	Estimated Amount
1	Pyrex 1000 beakers starter set	EG-34502-90	26.48
1	NALGENE ® polypropylene volumetric flask, 100 mL	**K-06108-20**	25.50
1	NALGENE ® polypropylene volumetric flask, 250 mL	**K-06108-40**	32.00
1	NALGENE ® polypropylene volumetric flask, 500 mL	**K-06108-50**	38.00
1	NALGENE ® polypropylene volumetric flask, 1000 mL	**K-06108-60**	48.50
1	PYREX ® Brand 5580 Volumetric Flask; 2000 mL	**K-34560-12**	74.00
1	Pyrex ® Brand 3022 cylinder; 10 mL	**K-34593-01**	15.50
1	Pyrex ® Brand 3022 cylinder; 100 mL	**K-34593-04**	24.50
1	Pyrex ® Brand 3022 cylinder; 250 mL	**K-34593-05**	43.00

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1	Pyrex ® Brand 3022 cylinder; 500 mL	**K-34593-06**	54.00
1	Volumetric Pipettes, Class B pipettes, 20mL	**K-25561-24**	15.00
1	Volumetric Pipettes, Class B pipettes, 25mL	**K-25561-26**	15.00
1	Volumetric Pipettes, Class B pipettes, 50mL	**K-25561-32**	19.00
1	Pipette Controllers , filler, 50 mL capacity	**K-24805-10**	16.50
1	NALGENE ® polypropylene Erlenmeyer flask, 1000 mL (package of 2)	**K-06109-50**	46.50
1	NALGENE ® polypropylene Erlenmeyer flask, 2000 mL (package of 2)	**K-06109-60**	58.00
1	Nalgene ® economy low-density polyethylene wash bottle, 250 mL (package of 6)	**EW-62304-30**	22.50
1	Microflex ® Ultra One ® Latex Gloves; size, medium (box of 50)	**EW-86231-91**	11.50
1	Potassium hydroxide, flakes c.p. (1kg)	**EW-88247-49**	47.90
1	TEST TUBE BRUSH, 10"L X 3/4" DIAMETER, PACK OF 12 (package of 12)	**EG-84550-52**	29.50
1	Small neck bottle brush - 16-1/2"L x 3/4" to 2" dia - 1 each	**EG-84550-76**	11.75
1	Burette brush, 16-1/2"L x 1/8 to 3/4" diameter, pack of 12 (package of 12)	**EG-84550-61**	35.00
1	Ohaus ® High-Performance Hand-Held Balance	**K-11013-51**	148.00
1	NALGENE ® Unwire™ half rack for 25-mm tubes, blue	**K-06738-83**	17.00
	Cole-Parmer 625 East Bunker Court Vernon Hills, Illinois 60061 Phone: 1-800-323-4340 Fax: 1-847-247-2929 E-Mail: info@Coleparmer.com www.coleparmer.com		
	Estimated shipping		100
		Sub Total	**$975**

20% Contingency for unforeseen costs…….…… $847

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Total Supplies & Equipment: about $5, 082

- IDWR in-kind staff cost (1 day per week for 16 weeks) = $3,200
- IDWR in-kind travel cost (16 trips @ 180 miles ea @ $0.475/mile) = $1,368

Total IDWR In-kind = $4,568

*(note that IDWR in-kind costs are a maximum estimate and might decrease because of combined travel with other dye test sampling, sample analysis with other tests, etc.)

Facilities Needed

A lab environment will be needed for the duration of the test to prepare calibration standards, test and store samples. A sink, bench with electrical outlet, refrigerator, and deionized water will need to be available at this work area. The state of Idaho Agriculture Department or State Lab may have a small work area available. I will need assistance from management to secure a work area. If we can not find a work area at another facility we can still proceed with the project but tests will need to be done here in the office at IDWR which will be less convenient but workable.

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Appendix of Information Used for Proposed Implementation

1. Certification of Approval for use in Potable Water & Safety Reference
2. Material Safety Data Sheet for Fluorescein
3. Flourometric Facts Bulletin - Fluorescein
4. Technical Data Bulletin
5. USGS Report (title page only) "Fluorometric Procedures for Dye Tracing"
6. Groundwater Tracing Handbook by Thomas Aley
7. Reference: Groundwater Tracer Tests at Hagerman Fossil Beds N.M. 2001
8. Reference: Hydrologic Study of the Deer Gulch Basalt 2005
9. Reference: Tracer Tests in Columbia River Basalts 1998
10. Resume of Thomas Aley – author of Groundwater Tracing Handbook by Ozark Underground Laboratory.
11. Amount of dye verses distance for two tracer tests in basalt.
12. Email correspondence
13. List of References

TO PLACE AN ORDER OR FOR TECHNICAL ASSISTANCE CONTACT US AT:
1-800-394-0678
Kingscote Chemicals • 3334 S. Tech Boulevard • Miamisburg, Ohio 45342
Phone (937) 886-9100 • Fax (937) 886-9300
E-mail: sales@brightdyes.com • www.brightdyes.com

CERTIFIED TO MEET EPA STANDARDS
BRIGHT DYES
This is a Certification that these products conform to the ANSI/NSF Standard 60 for potable water as set forth by the EPA in The Clean Water Act.
NSF
* Official Listing as Certified by NSF detailed on back of certification

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A Review of the Toxicity of Twelve Fluorescent Dyes Used for Water Tracing
P.L. Smart

Abstract

Toxicological information is reviewed for twelve fluorescent dyes used in water tracing, Fluorescent Brightener 28, Tinopal CBS-X, Amino G Acid, Diphenyl Brilliant Flavine 7GFF, Pyranine, Lissamine Yellow FF, Fluorescein, Eosine, Rhodamine WT, Rhodamine B, Sulphorhodamine B and Sulphorhodamine G. Mammalian tests indicate a low level of both acute and chronic toxicity. **However,**

only three tracers could be demonstrated not to provide a carcinogenic or mutagenic hazard. These were Tinopal CBS-X, **Fluorescein** and Rhodamine WT. Rhodamine B is a known carcinogen and should not be used. In aquatic ecosystems, larval stages of shellfish and algae were the most sensitive. Persistent dye concentractions in tracer studies should not cause problems provided they are below 100 µg/l.

http://www.caves.org/pub/journal/PDF/V46/v46n2-Smart.htm

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BRIGHT DYESMATERIAL SAFETY DATA SHEET
FLT YELLOW/GREEN LIQUID CONCENTRATE
PAGE 1 OF 3

MSDS PREPARATION INFORMATION

PREPARED BY:	T. P. MULDOON (937) 886-9100
DATE PREPARED:	1/01/05

PRODUCT INFORMATION

MAUNFACTURED BY:	KINGSCOTE CHEMICALS 3334 S. TECH BLVD. MIAMISBURG, OHIO 45342
CHEMICAL NAME	NOT APPLICABLE
CHEMICAL FORMULA	NOT APPLICABLE
CHEMICAL FAMILY	AQUEOUS DYE PRODUCT

HAZARDOUS INGREDIENTS

NONE PER 29 CFR 1910.1200

PHYSICAL DATA

PHYSICAL STATE	LIQUID
ODOR AND APPEARANCE	YELLOW/GREEN, WITH NO APPARENT ODOR
SPECIFIC GRAVITY	APPROXIMATELY 1.05
VAPOR DENSITY (mm Hg @ 25 ° C)	~23.75
VAPOR DENSITY (AIR =1)	~0.6
EVAPORATION RATE (Butyl Acetate = 1)	~1.8
BOILING POINT	100 degrees C (212 degrees F)
FREEZING POINT	0 degrees C (32 degrees F)
pH	8.0 OR ABOVE
SOLUBILITY IN WATER	HIGHLY SOLUBLE

FIRE HAZARD

CONDITION OF FLAMMABILITY	NON-FLAMABLE
MEANS OF EXTINCTION	WATER FOG, CARBON DIOXIDE, OR DRY CHEMICAL
FLASH POINT AND METHOD	NOT APPLICABLE
UPPER FLAMABLE LIMIT	NOT APPLICABLE
LOWER FLAMABLE LIMIT	NOT APPLICABLE
AUTO-IGNITION TEMPERATURE	NOT APPLICABLE
HAZARDOUS COMBUSTION PRODUCTS	NOT APPLICABLE
UNUSUAL FIRE HAZARD	NOT APPLICABLE

EXPLOSION HAZARD

SENSITIVITY TO STATIC DISCHARGE	NOT APPLICABLE
SENSITIVITY TO MECHANICAL IMPACT	NOT APPLICABLE

REACTIVITY DATA

PRODUCT STABILITY	STABLE
PRODUCT INCOMPATIBILITY	NONE KNOWN
CONDITIONS OF REACTIVITY	NOT APPLICABLE
HAZARDOUS DECOMPOSITION PRODUCTS	NONE KNOWN

TOXICOLOGICAL PROPERTIES

SYMPTOMS OF OVER EXPOSURE FOR EACH POTENTIAL ROUTE OF ENTRY:

INHALLATION, ACUTE	NO HARMFUL EFFECTS EXPECTED.
INHALATION, CHRONIC	NO HARMFUL EFFECTS EXPECTED.
SKIN CONTACT	WILL TEMPORARILY GIVE SKIN A YELLOW/GREEN COLOR.
EYE CONTACT	NO HARMFUL EFFECTS EXPECTED.
INGESTION	URINE MAY BE A YELLOW/GREEN COLOR UNTIL THE DYE HAS BEEN WASHED THROUGH THE SYSTEM.
EFFECTS OF ACUTE EXPOSURE	NO HARMFUL EFFECTS EXPECTED
EFFECTS OF CHRONIC EXPOSURE	NO HARMFUL EFFECTS EXPECTED
THRESHOLD OF LIMIT VALUE	NOT APPLICABLE
CARCINOGENICITY	NOT LISTED AS A KINOWN OR SUSPECTED CARCINOGEN BY IARC, NTP OR OSHA.
TERATOGENICITY	NONE KNOWN
TOXICOLOGY SYNERGISTIC PRODUCTS	NONE KNOWN

PREVENTATIVE MEASURES

PERSONAL PROTECTIVE EQUIPMENT

GLOVES	RUBBER
RESPIRATORY	USE NISOH APPROVED DUST MASK IF DUSTY CONDITIONS EXIST.
CLOTHING	PROTECTIVE CLOTHING SHOULD BE WORN WHERE CONTACT IS UNAVOIDABLE.
OTHER	HAVE ACCESS TO EMERGENCY EYEWASH.

PREVENTATIVE MEASURES (CONT.)

ENGINEERING CONTROLS	NOT NECESSARY UNDER NORMAL CONDITIONS, USE LOCAL VENTILATION IF DUSTY CONDITIONS EXIST.
SPILL OR LEAK RESPONSE	CLEAN UP SPILLS IMMEDIATELY, PREVENT FROM ENTERING DRAIN. USE ABSORBANTS AND PLACE ALL SPILL MATERIALS IN WASTE DISPOSAL CONTAINER. FLUSH AFFECTED AREA WITH WATER.
WASTE DISPOSAL	INCINERATE OR REMOVE TO A SUITABLE SOLID WASTE DISPOSAL SITE, DISPOSE OF ALL WASTES IN ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.
HANDELING PROCEDURES AND EQUIPMENT	NO SPECIAL REQUIREMENTS.
STORAGE REQUIREMENTS	STORE AT ROOM TEMPERATURE BUT ABOVE THE FREEZING POINT OF WATER.
SHIPPING INFORMATION	KEEP FROM FREEZING

FIRST AID MEASURES

FIRST AID EMERGENGY PROCEDURES

EYE CONTACT	FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES. GET MEDICAL ATTENTION IF IRRITATION PERSISTS.
SKIN CONTACT	WASH SKIN THOROUGHLY WITH SOAP AND WATER. GET MEDICAL ATTENTION IF IRRITATION DEVELOPS.
INHALATION	IF DUST IS INHALED, MOVE TO FRESH AIR. IF BREATHING IS DIFFICULT GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.
INGESTION	DRINK PLENTY OF WATER AND INDUCE VOMITING. GET MEDICAL ATTENTION IF LARGE QUANTITIES WERE INGESTED OR IF NAUSEA OCCURS. NEVER GIVE FLUIDS OR INDUCE VOMITING IF THE PERSON IS UNCONSCIOUS OR HAS CONVULSIONS.

SPECIAL NOTICE

ALL INFORMATION, RECOMMENDATIONS AND SUGGESTIONS APPEARING HEREIN CONCERNING THIS PRODUCT ARE BASED UPON DATA OBTAINED FROM MANUFACTURER AND/OR RECOGNIZED TECHNICAL SOURCES; HOWEVER, KINGSCOTE CHEMICALS MAKES NO WARRANTY, REPRESENTATION OR GUARANTEE AS TO THE ACCURACY, SUFFICIENCY OR COMPLETENESS OF THE MATERIAL SET FORTH HEREIN. IT IS THE USER'S RESPONSIBILITY TO DETERMINE THE SAFETY, TOXICITY AND SUITABILITY OF HIS OWN USE, HANDLING, AND DISPOSAL OF THE PRODUCT. ADDITIONAL PRODUCT LITERATURE MAY BE AVAILABLE UPON REQUEST. SINCE ACTUAL USE BY OTHERS IS BEYOND OUR CONTROL, NO WARRANTY, EXPRESS OR IMPLIED, IS MADE BY KINGSCOTE CHEMICALS AS TO THE EFFECTS OF SUCH USE, THE RESULTS TO BE OBTAINED OR THE SAFETY AND TOXICITY OF THE PRODUCT, NOR DOES KINGSCOTE CHEMICALS ASSUME ANY LIABILITY ARISING OUT OF USE BY OTHERS OF THE PRODUCT REFERRED TO HEREIN. THE DATA IN THE MSDS RELATES ONLY TO SPECIFIC MATERIAL DESIGNATED HEREIN AND DOES NOT RELATE TO USE IN COMBINATION WITH ANY OTHER MATERIAL OR IN ANY PROCESS.

END OF MATERIAL SAFETY DATA SHEET

Bulletin No. 103
Fluorescein

INTRODUCTION

Fluorescein was the first fluorescent dye used for water tracing work[1] and is still used for qualitative (visual) studies of underground contamination of wells. In recent years, Rhodamine WT has almost completely replaced fluorescein for flow measurements[2] and circulation, dispersion, and plume studies[3]. Nonetheless, fluorescein has a role in such studies, and can be used for masking, hydraulic model studies, and underground water studies.

ADVANTAGES

Fluorescein has the following advantages over other tracer dyes:

- Its low sorption rate is far better than Rhodamine B, and comparable to Rhodamine WT.
- It has a temperature coefficient of only –0.36% per degree C, about one-eighth of the temperature coefficient of rhodamine dyes[2,4].
- It emits a brilliant green fluorescence, which gives an excellent visual or photographic contrast against the backgrounds normally encountered in water transport studies. Therefore it is easy to visualize the progress of an experiment.
- It is more aesthetic than the red dyes. This is psychologically important, especially in ocean areas subject to the blooms of certain dinoflagellates, called "red tides." Less public resistance will be encountered using a dye that does not resemble red tide[5].

DISADVANTAGES

Fluorescein has been replaced by other dyes, principally Rhodamine WT, for the following reasons:

- It is rapidly destroyed by sunlight. Reference 4 reports that a 50% loss occurred in three hours of sunlight exposure, with dye being held in an Erlenmeyer flask. Other tests in an flat, uncovered Pyrex dish showed an almost complete destruction in two hours[6].
- Many naturally occurring fluorescent materials have similar characteristics and thus interfere with measurement. When carefully chosen optical filters are used, the situation is better than that reported in Reference 4, but higher concentrations are required to overcome the effect of higher and more variable "blank" fluorescence.
- Fluorescein is more pH-sensitive than rhodamine dyes. Fluorescence drops very sharply at pH values below 5.5. For optimum results, pH should be between 6 and 10.

MASKING TECHNIQUES

In river, harbor, and ocean tests, fluorescein can be used to mask the objectionable color of the rhodamine dyes. Tests show that Fluorescein is an effective mask, subject to the following conditions[5]:

- The concentration of fluorescein should be at least five times that of the active ingredients in the Rhodamine B or Rhodamine WT concentrate.
- Where the receiving water is shallow, clear, and in full sunlight, the dyes must be dispersed quite rapidly. With slow dispersion, the photosensitive fluorescein will be destroyed before the masking effect is complete.
- Masking is subjective. Lower (hence less costly) amounts of fluorescein may be effective, depending on water clarity, bottom color, wave action, etc. Small scale addition of the mixed dyes to the receiving water should be made in advance

of a large scale test. This test should be made on a bright sunny day, if possible.

- Note that fluorescein is not the ingredient measured. The optical filter and light source in the fluorometer read only rhodamine dye[7].

HYDRAULIC MODEL STUDIES

Fluorescein may be used in hydraulic model studies in exactly the same way that Rhodamine WT is used (See Refs. 2 and 3 for details).

The major advantage of using fluorescein is its visibility; the green color can be seen as the test proceeds. The major disadvantage is fluorescein's light sensitivity. It can be destroyed by light entering the test area, both from windows and from indoor lights, especially fluorescent ones.

Containers used for dye destruction tests must be transparent to light at shorter wavelengths. Clear borosilicate glass baking pans are handy, since they transmit light at shorter wavelengths than window glass or the glass envelopes of fluorescent lamps.

Test samples must be at low concentrations (around 0.2 PPM) so that the fluorescein in the bottom of the pan is not protected from the incident light by absorption of the fluorescein in the top of the pan.

In certain cases, deliberate destruction of the fluorescein by sunlight may be a convenience instead of a problem. Hydraulic models often recycle water. With the very stable Rhodamine WT, the concentration of dye in the entire system will build up over a sequence of several tests, requiring replacement of the water. If a shallow holding tank can be placed outdoors, the degradation of fluorescein by sunlight may eliminate the need to replace the water.

UNDERGROUND WATER STUDIES

Fluorescein can be used quantitatively for underground tests, subject to limitations imposed by the higher background of naturally occurring fluorescent materials.

An advantage of fluorescein in underground studies is its light sensitivity. Should it reach an open receiving body of water, the color will be less of a problem because it will disappear rapidly in the sunlight.

FILTER AND LIGHT SOURCE SELECTION

Using fluorescein, the following light sources and filters are recommended (referenced part numbers are specific to Turner Designs products):

	10-AU-005
Optical Kit	10-086 (Lamp and all filters are included in this kit.)
Light Source	10-089 Blue Lamp
Reference	10-063
Excitation	10-105
Emission	10-109R-C

We have found that background fluorescence can be very high in natural systems with the fluorescein setup. In most cases, this background should be adequately suppressed using the 10-AU fluorometer. If, however, background cannot be suppressed, a mask (attenuator) may be added to the excitation filter holder to reduce its diameter and the amount of light scatter. Attenuation by a factor of 5 can be obtained with the 10-318R Attenuator Plate.

Fluorescein, known as "Acid Yellow 73", "Acid Yellow T", "DNC Yellow 7", etc., can be obtained from the following sources (addresses checked and confirmed June 1996):

Pylam Products Company, Inc.
1001 Stewart Avenue
Garden City, NY 11530
516/222-1750

Tricon Colors, Inc.
16 Leliarts Lane
Elmwood Park, NJ 07407
201/794-3800

LISSAMINE FF

The properties of uses of Lissamine FF are reported in Reference 9. Its spectral characteristics are similar to those of fluorescein, but it does not decompose as rapidly in sunlight. Use the fluorescein filters detailed above with Lissamine FF. Pylam Products (address shown above) offers

Lissamine FF as "Brilliant Acid Yellow 8G" or "Brilliant Sulphoflavine FFA".

REFERENCES

1) Dole, R. B., *Use of Fluorescein in the Study of Underground Waters*, USGS Water Supply Paper 160, 73-85 (1906).

2) *A Practical Guide to Flow Measurement*, monograph by Turner Designs, 845 W. Maude Avenue, Sunnyvale, CA 94086.

3) *Circulation, Dispersion, and Plume Studies*, monograph by Turner Designs, 845 W. Maude Avenue, Sunnyvale, CA 94086.

4) (0047) Feuerstein, D.L., Sellick, R.E., *Fluorescent Tracers for Dispersion Measurements*, Journal of Sanitary Engineering, ASCE 89 (SA4), 1-21 (1963).

5) (0031) Murakami, Ken, Water Quality Section, Water Quality Control Division, Public Works Research Institute, 5-41-7, Shimo, Kita-Ku, Tokyo, 115, personal communication.

6) Turner Designs Laboratory Tests conducted July 23, 1975.

7) "Filter Selection Guide" for Turner Designs Fluorometers, by Turner Designs, 845 W. Maude Avenue, Sunnyvale, CA 94086.

8) (0413) Smart, P.L., Laidlaw, I.M.S., An *Evaluation of Some Fluorescent Dyes for Water Tracing*, Water Resources Research, 13 (1), 15-33 (1977).

TURNER DESIGNS

845 W.Maude Ave. Sunnyvale, CA 94085 www.turnerdesigns.com

Telephone 408-749-0994 Toll Free 877-316-8049 Fax 408-749-0998

[redacted]

Division of Kingscote Chemicals

WATER TRACING DYE

FLT YELLOW/GREEN PRODUCTS

TECHNICAL DATA BULLETIN

Bright Dyes Yellow/Green products are specially formulated versions of Xanthene dye, certified by NSF International to ANSI/NSF Standard 60 for use in drinking water. This dye is the traditional fluorescent water tracing and leak detection material and has been used for labeling studies from the beginning of the century. It may be detected visually, by UV light and by appropriate fluoremetric equipment. Today it is most often used visually. This dye has been used by the military to mark downed pilots for search and rescue operations over large water bodies. Visually the dye appears yellow/green, depending on its concentration and under UV light as lime green.

Based on biochemical oxygen demand (BOD) studies, the dye is biodegradable with 65% of the available oxygen consumed in 7 days. The dye is resistant to absorption on most suspended matter in fresh and salt water. However, compared to Bright Dyes FWT Red products it is significantly less resistant to degradation by sunlight and when used in fluoremetry, stands out much less clearly against background fluorescence. As always the suitability of these products for any specific application should be evaluated by a qualified hydrologist or other industry professional.

General Properties	Tablets	Liquids	Powders
Detectability of active ingredient [1]	Visual <100 ppb	Visual <100 ppb	Visual <100 ppb
Maximum absorbance wavelength [2]	490/520 nm	490/520 nm	490/520 nm
Appearance	Orange convex 1.6cm diameter	Reddish, brown aqueous solution	Orange fine powder
NSF (Max use level in potable water)	6.0 ppb	10.0 ppb	1.0 ppb
Weight	1.35 gms ± 0.05		
Dissolution Time [3]	50% < 3 minutes 95% < 6 minutes		50% < 3 minutes 95% < 6 minutes
Specific Gravity		1.05 ± 0.05 @ 25° C	
Viscosity [4]		1.8 cps	
pH		8.5 ± 0.5 @ 25° C	

Coverage of Products	One Tablet	One Pint Liquid	One Pound Powder
Light Visual	605 gallons	125,000 gallons	1,200,000 gallons
Strong Visual	60 gallons	12,500 gallons	120,000 gallons

Caution: These products may cause irritation and/or staining if allowed to come in contact wit the skin. The use of gloves and goggles is recommended when handling this product, as with any other dye or chemical.

To our best knowledge the information and recommendations contained herein are accurate and reliable. However, this information and our recommendations are furnished without warranty, representation, inducement, or license of any kind, including, but not limited to the implied warranties and fitness for a particular use or purpose. Customers are encouraged to conduct their own tests and to read the material safety data sheet carefully before using.

[1] In deionized water in 100 ml flask. Actual detectability and coverage in the field will vary with specific water conditions.
[2] No significant change in fluorescence between 6 and 11 pH.
[3] (One tablet, 1 gram of powder), in flowing deionized water in a 10 gallon tank.
[4] Measured on a Brookfield viscometer, Model LV, UL adapter, 60 rpm @ 25° C.

Kingscote Chemicals, 3334 S. Tech Blvd., Miamisburg, Ohio 45342
Telephone: (937) 886-9100 Fax: (937) 886-9300 Web: www.brightdyes.com

Techniques of Water-Resources Investigations
of the United States Geological Survey

Chapter A12

FLUOROMETRIC PROCEDURES FOR DYE TRACING

By James F. Wilson, Jr., Ernest D. Cobb,
and Frederick A. Kilpatrick

BOOK 3

APPLICATIONS OF HYDRAULICS

Revised 1986

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DRA

The Ozark Underground Laboratory's

GROUNDWATER TRACING HANDBOOK

A handbook prepared for the use of clients and colleagues of the Ozark Underground Laboratory
2002

Thomas Aley

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Ground Water Tracer Tests at the Hagerman Fossil Beds National Monument

Neal Farmer[1] and Isaac Larsen[2]

Technical Report

January 2001

[1]Ground Water Geologist, U.S. Department of the Interior, National Park Service, Hagerman Fossil Beds National Monument, Hagerman, Idaho.

[2]Geology Student, Department of Geology, Carleton College.

United States Department of the Interior
National Park Service

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HYDROLOGIC STUDY OF THE DEER GULCH BASALT IN HAGERMAN

FOSSIL BEDS NATIONAL MONUMENT, IDAHO

A Thesis

Presented in Partial Fulfillment of the Requirements for the

Degree of Masters of Science

with a

Major in Hydrology

in the

College of Graduate Studies

University of Idaho

by

Kathryn Dallas

January 2005

Major Professor: Dr. James Osiensky

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GROUND WATER TRACER STUDIES IN COLUMBIA RIVER BASALT

A Thesis

Presented in Partial Fulfillment of the Requirements for the

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Robin E. Nimmer

December, 1998

Major Professor: Dr. Dale R. Ralston

PERSONAL DATA

Born September 8, 1938 in Steubenville, Ohio. U.S. Citizen. Married, two adult children.

EDUCATION

University of California, Berkeley. B.S. in Forestry (1960).

University of California, Berkeley. M.S. in Forestry with emphasis in forest influences and wildland hydrology. (1962).

University of California, Berkeley. Department of Geography (1962-1963); emphasis in hydrology and geology.

University of Arizona, Tucson. Department of Watershed Management (1963-1964); emphasis in wildland hydrology.

Southern Illinois University, Carbondale. Department of Geography (1972-1973). Emphasis in hydrology and geology.

PROFESSIONAL CERTIFICATION & REGISTRATION

Professional Hydrogeologist, Certificate Number 179, American Institute of Hydrology, Board of Registration. Granted 1983.

Certified Forester, Society of American Foresters. Granted 1996.

Professional Geologist, State of Arkansas Registration Number 1646. Issued 1991.

Professional Geologist, State of Kentucky Registration Number 1541. Issued 1994.

Registered Geologist, State of Missouri Registration Number 0989. Issued 1998.

Professional Geologist, State of Alabama Registration Number 1089. Issued 2003.

PROFESSIONAL SOCIETY MEMBERSHIPS

American Institute of Hydrology
Association of Ground Water Scientists and Engineers
Society of American Foresters
Missouri Consulting Foresters Association
National Speleological Society

HONORS AND AWARDS

1960. Pack Prize in Forestry. University of California.
1961. Membership in Xi Sigma Pi, honorary forestry society.
1972. Award for outstanding performance, United States Forest Service.

1972. U.S. Forest Service nominee for the American Motors Conservation Award.
1973. Lester B. Dill Award for significant contributions to speleology. Mississippi Valley-Ozark Region of the National Speleological Society.
1977. Chairman's Conservation Award. Mississippi Valley-Ozark Region of the National Speleological Society.
1979. J Harlan Bretz Award for outstanding contributions to the study of speleology in the state of Missouri. Missouri Speleological Survey.
1981. Outstanding Service to Education Award. Phi Delta Kappa honorary educational fraternity for southwest Missouri.
1981. Fellow. National Speleological Society.
1988. In The Name of Science Award. Springfield, Missouri Public Schools. In recognition of outstanding service and dedication to science.

EMPLOYMENT HISTORY

1973 to Present. Director and President, Ozark Underground Laboratory, Protem, Missouri. Conducts or directs consulting and contract studies in hydrogeology, cave and karst related issues, and natural resource management of karst regions.

1966 to 1973. Hydrologist, United States Forest Service. Winona, Missouri and Springfield, Missouri. Directed the Hurricane Creek Barometer Watershed study, which assessed the interactions of land use and ground water hydrology in a forested karst area. Directed Grey Hollow study. Conducted "trouble shooting work" in Missouri, Arkansas, Wisconsin, Utah, Illinois, and Indiana. Left government service as GS-12.

1964 to 1965. Chief Hydrologist, Toups Engineering, Inc., Santa Ana, California. Duties included basic data collection and analysis for plaintiffs in Santa Ana Basin adjudication and similar work for defendants in San Gabriel Basin adjudication; these were both ground water basin adjudication suits. Directed technical work on ground water basin management and artificial recharge.

1963 to 1964. Teaching Assistant, Department of Watershed Management, University of Arizona, Tucson. Aerial photogrammetry and photo interpretation.

1963. Researcher, grant from Office of Naval Research, U.S. Navy, through Department of Geography, University of California, Berkeley. Conducted field studies on the origin and hydrology of caves in Jamaica, Haiti, and the Dominican Republic. Responsible for all field work. Work resulted in 3 publications.

1960 to 1963. Teaching Assistant and Research Assistant, School of Forestry, University of California, Berkeley. Teaching in aerial photogrammetry, photo interpretation, and forest influences. Research assistant in the same fields.

SUMMARY OF EXPERIENCE

39 years of professional experience in ground water and surface water hydrology, pollution control investigations, and land management issues with particular emphasis on soluble rock landscapes. The following projects are representative examples.

1. Hydrologic studies for land management and spring protection with particular emphasis on soluble rock regions. Numerous studies of this type have been conducted for local, state, and federal agencies in Missouri, Arkansas, Alabama, Kentucky, Illinois, Tennessee, Alaska, and Wyoming.

2. Expert witness testimony on pollution potential of underground injection of hazardous wastes into deep-lying soluble rocks in Oklahoma.

3. Expert witness testimony in ground water and surface water hydrology in Missouri, Arkansas, Oklahoma, Kansas, California, Alabama, Maryland, and Indiana.

4. Expert witness testimony on riverbank stability problems in Missouri before U.S. Senate Committees at request of Senator John Danforth of Missouri.

5. Member of 6-member review panel on the adequacy of testing to determine radionuclide migration from a radioactive waste disposal site at the Idaho National Engineering Laboratory, Idaho. Served as the only hydrogeologist on the panel.

6. Member of 6-member expert hydrogeology panel on hydrological issues associated with the St. Louis Airport Radioactive Waste Site.

7. Chairman of a 4-member "blue ribbon" panel established by the U.S. Forest Service to assess the significance of cave and karst resources in southeastern Alaska. The panel also assessed the extent to which land management activities were adversely impacting the resources.

8. Hydrologic consultant to St. Charles County, Missouri on clean-up of radioactive wastes at Weldon Spring Site, a former Atomic Energy Commission processing facility. Advised on actions to protect county well field from radioactive contaminants dumped in an abandoned quarry.

9. Ground water tracing in soluble rock landscapes, and delineation of recharge areas for spring systems. Work conducted in Missouri, Arkansas, Oklahoma, Indiana, Illinois, Kentucky, Tennessee, Alabama, Florida, Georgia, Texas, Maryland, Pennsylvania, New York, West Virginia, Arizona, Oregon, California, Wyoming, and Alaska. Ground water tracing in fractured rock landscapes in New Hampshire, Alabama, New Mexico, Minnesota, Idaho, Utah, and Washington. Ground water tracing in unconsolidated geologic units in New York, Massachusetts, Florida, North Carolina, South Dakota, Missouri, Arkansas, California, Oregon, Washington, Alaska, and British Columbia (Canada).

10. Hydrogeologic investigations of groundwater impacts from pipeline corridors. Missouri, Oklahoma, and Texas.

11. Ground water tracing investigations at mines in West Virginia, Pennsylvania, Missouri, Utah, Colorado, Montana, Irian Jaya Indonesia, and Peru.

12. Hydrologic investigations to determine sources of pollutants which caused fish kills at commercial fish farms in Missouri and Arkansas.

13. Hydrogeologic site investigations (and sometimes testimony) on municipal landfills with emphasis on site suitability and probability of ground water contamination. 21 sites in Arkansas, Missouri, Wisconsin, and Alabama.

14. Hazardous waste remediation investigations with emphasis on hydrogeology. Sites in Missouri, Arkansas, Kentucky, Pennsylvania, Maryland, Alabama, Tennessee, and California. Second opinion review of projects in Missouri, Kansas, and New York.

15. Impacts of food processing wastes on surface and ground water quality. Various projects in Arkansas and Missouri.

16. Hydrologic investigations of petroleum pollution of wells. Multiple sites in Missouri, Arkansas, and North Carolina.

17. Assessment of the hydrologic impacts of proposed geothermal energy development on the Santa Clara Indian Reservation, New Mexico.

18. Investigations on the extent and sources of sewage contamination in about 100 springs at Eureka Springs, Arkansas. Work involved the delineation of recharge areas for most of these springs and the identification of sewer line segments which had the greatest leakage problems.

19. Hydrogeologic hazard area mapping for proposed sewer line corridors in a sinkhole plain area south of Mammoth Cave, Kentucky. Work included hydrologic recommendations for minimizing exfiltration and monitoring strategies.

20. Hydrogeologic mapping of Greene County, Missouri to identify areas where sinkhole flooding and serious ground water contamination could result from land development.

21. Assessment of impacts of proposed highways on springs, caves, and endangered cave-dwelling species, Arkansas, Missouri, Indiana, Virginia, and West Virginia. Similar work for airports in Missouri and Arkansas, and for coal-fired power plants in Missouri and Arkansas.

22. Identification and delineation of rare, threatened, and endangered animal species' habitats in caves and ground water systems. Studies in Arkansas, Missouri, Oklahoma, Tennessee, Alabama, and Illinois.

23. Health and safety assessment of Harrison's Crystal Cave, Barbados.

24. Health and safety assessment of natural radiation as encountered in caves open to the public in the United States. Development of industry standards.

25. Various microclimate, hydrologic, biologic, interpretive, and management investigations of caves in Missouri, Arkansas, Tennessee, Kentucky, New Mexico, Arizona, California, Wyoming, Oregon, Alaska, British Columbia, New Zealand, and Australia.

26. Evaluation of 19 sites for designation as National Natural Landmarks; sites are in Indiana, Missouri, Arkansas, Iowa, Ohio, and New Mexico.

27. Assessment of hydrologic impacts of rock quarries. Multiple sites in Missouri, Arkansas, Maryland, Illinois, Alabama, and Alaska.

28. Assessment of the impacts of deep mining on regional hydrology. Missouri.

29. Preparation of sole-source aquifer designation petition. Missouri.

30. Delineation of wellhead protection zones for public ground water supplies in Arkansas, Missouri, Alabama, South Dakota, New Hampshire, Maryland, and Florida.

31. Feasibility study for creation of a national-scale American Cave and Karst Museum.

32. Instructor in numerous professional short-courses. These have included:

1) over 20 four-day courses in karst hydrogeology and groundwater monitoring sponsored by the Association of Ground Water Scientists and Engineers and by Environmental Education Enterprises;

2) two courses on groundwater site investigation techniques for health department professionals in Washington State; and

3) courses on land management in karst terrains for resource managers in West Virginia, Indiana, Kentucky, Tennessee, Missouri, Arkansas, Utah, Idaho, Oregon, Washington, Alaska, and New Mexico.

PUBLICATIONS

1. _____. 1962. Analytical review of Gurnee, Russell; Richard Anderson; Albert C. Mueller; and Jose Limeras. 1961. Barton Hill Project; a study of the hydrology of limestone terrain. National Speleological Society Bulletin. Vol. 23, Part I. 30p. Review in Cave Notes, Vol. 4:4, pp. 32-33.

2. _____. 1963. Water balances for limestone terrain. *Cave Notes*, Vol. 5:3, pp. 17-22.

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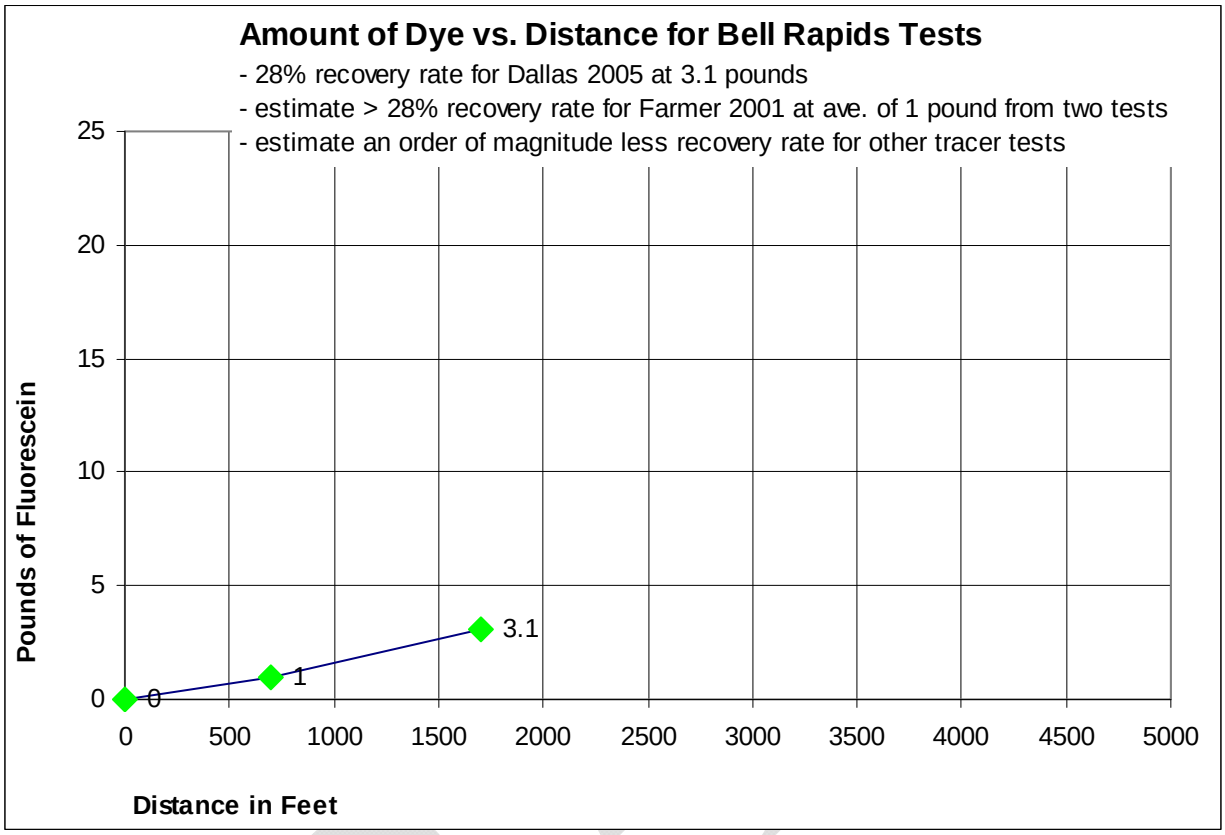
Amount of Dye vs. Distance for Bell Rapids Tests
- 28% recovery rate for Dallas 2005 at 3.1 pounds
- estimate > 28% recovery rate for Farmer 2001 at ave. of 1 pound from two tests
- estimate an order of magnitude less recovery rate for other tracer tests
Pounds of Fluorescein
25
20
15
10
5
0
0
1
3.1
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance in Feet

DRAFT

EMAIL

-----Original Message-----
From: Kris, Michy (PIRSA) [mailto:Kris.Michy@saugov.sa.gov.au]
Sent: Sunday, November 09, 2008 4:30 PM
To: Farmer, Neal
Subject: Re: Snails and fluorescent dye

I think you would have better success searching for the information in America, rather than Australia. I don't know if the species mentioned are native to America, or introduced, but they have "American" names.

I did a quick Google search about freshwater snails and the Australian Museum comes up several times, so the following link could provide a starting point:

http://www.amonline.net.au/invertebrates/staff/ponder.htm

-----Original Message-----
From: Farmer, Neal [mailto:Neal.Farmer@idwr.idaho.gov]
Sent: Sat 08/11/2008 05:56
To: PIRSA:Ruralsolutions
Subject: Snails and fluorescent dye

Greetings,

I trying to find out if the dye Fluorescein has any harmful effects on freshwater snail species in particular:

Snake River physa

Bliss Rapids snail

Idaho Springsnail

Do you know of any scientific literature or sources that would discuss this topic?

Neal Farmer
Special Projects Coordinator
Idaho Department of Water Resources
208-287-4836

DRAFT

From: System Administrator
Sent: Sunday, November 09, 2008 12:42 PM
To: Farmer, Neal
Subject: Undeliverable: Please forward to POC - Snails and Fluorescent dye topic

Your message did not reach some or all of the intended recipients.

Subject: Please forward to POC - Snails and Fluorescent dye topic
Sent: 11/7/2008 12:33 PM

The following recipient(s) could not be reached:

kwalt@frank.mtsu.edu on 11/9/2008 12:42 PM
Could not deliver the message in the time limit specified. Please retry or contact your administrator.
<a025.idwr.state.id.us #4.4.7>

From: cgnorton@stkate.edu [mailto:cgnorton@stkate.edu]
Sent: Saturday, November 08, 2008 3:13 PM
To: Farmer, Neal
Subject: Re: Snails and fluorescent dye

Neal -
I did a brief search, and found very little, mostly examples of using the dye to stain microscopic samples or nerve cells. You might try contacting Rob Dillon - he has a web site on Freshwater Gastropods of NA and knows alot about snails in general.

His email is: Rob Dillon <dillonr@cofc.edu>

Sorry I couldn't be more helpful.

Cindy Norton
Dr. Cynthia G. Norton
Endowed Professor in the Sciences
Professor of Biology and Women's Studies
College of St. Catherine
2004 Randolph Ave.
St. Paul, MN 55105
651-690-6631
_____
Soon to be St. Catherine University, as of June 1, 2009

"You will do foolish things, but do them with enthusiasm." Colette

DRAFT

From: Mark Dybdahl [mailto:dybdahl@wsu.edu]
Sent: Friday, November 07, 2008 12:41 PM
To: Farmer, Neal
Subject: Re: Snails and Fluorescent dye

Neal

I can't help you. I am not sure. My guess is there would be no effect. I could do a literature search if you need help with that.

Mark

Greetings,

I'm trying to find out if the dye Fluorescein has any harmful effects on freshwater snail species in particular:

Snake River physa
Bliss Rapids snail
Idaho Springsnail

Do you know of any scientific literature or sources that would discuss this topic?

Neal Farmer
Special Projects Coordinator
Idaho Department of Water Resources
208-287-4836

- -

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Reference and Sources of Information

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   "Hi Neal this is Tom Aley with the Ozark Underground Lab. I'm working in Washington State today – you can probably reach me in the morning on my cell phone 417-251-1520. Fluorescein is not going to cause you any problems. We are sending you a journal review from the mid-80's where they looked at biological impacts of Fluorescein and as I recall no problems at all - with the blessings of U.S. Fish and Wildlife Service - we have used Fluorescein in a number of traces to delineate the recharge area for the federally endangered tumbling creek cave snail. The genus of it is antropia. The cave in which they are located also has populations of fisa jirina. No problems with those. I've traced a lot to salmon streams and salmon spawning streams in Alaska. No problems there. It's not going to color fish flesh or anything like that and we've done lots of tracing in coastal Washington from on-site sewage systems in the marine shellfish beds again no concerns there."

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