2006
Radiological Watershed Study:
Teton, Henry's Fork, and Portneuf Rivers

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Introduction

In order to accurately monitor the effects of the Idaho National Laboratory (INL) on the environment in southeast Idaho, it is essential to understand the general radiological components of surface water in watersheds throughout the region. Many studies have been done to characterize ground water and surface water near the INL, but information is lacking for the surrounding watersheds. With background radiological data from watersheds surrounding the INL, it will be possible to determine the nature and extent of any major releases or deposition events as a result of INL operations in the future. In light of the new INL mission focused on nuclear research, it is imperative that we proactively obtain the necessary background data. This research also helps fulfill the mission of the Department of Environmental Quality Division of INL Oversight (DEQ-INL) to perform independent sampling, which is often difficult to do on the INL itself because of access restrictions and lack of surface water in most years.

Objective

The objective of this study was to establish background levels of radiological constituents in surface water and in-stream sediment surrounding the INL in order to help assess any future INL impact on the environment.

Background

The Henry's Fork of the Snake River (Henry's Fork), Teton River, and Portneuf River watersheds (Figure 1) were chosen based on their proximity to the INL, their differing physical characteristics, and possible anthropogenic inputs.

Henry's Fork of the Snake River Watershed

The Henry's Fork watershed is located approximately 60 miles northeast of the INL. The watershed, which is part of the greater Yellowstone ecosystem, sits between the Snake River Plain and the Yellowstone Plateau. The four sample sites in the Henry's Fork watershed are located on Duck Creek, Hotel Creek, Robinson Creek, and the Warm River. Duck Creek originates in the Henry's Lake Mountains, while Hotel Creek comes out of the eastern Centennial Mountains. Robinson Creek has its origin in Yellowstone National Park, just inside the park border in Idaho. The Warm River system has its source at the foot of the east side of Snow Creek Butte, south of Moose Creek Plateau.

Teton River Watershed

The Teton River watershed is approximately 70 miles directly east of the INL. The Teton, Snake River, and Big Hole Mountains surround this watershed. The Teton Mountains are the youngest mountains in the Rocky Mountain range, at 10 million years old. The Snake River Mountains are on the southern edge of the watershed and the Big Hole Mountains on the west side. The four sample sites in the Teton watershed are located on Teton Creek, Darby Creek, Fox Creek, and the Teton River. Three of these creeks—Teton Creek, Darby Creek, and Fox Creek—originate on the western slope of the Teton Mountains. The Teton River sample location is found at the northern end of the valley before the river enters the Teton River Canyon. Water at this location most likely originates from all three mountain ranges.

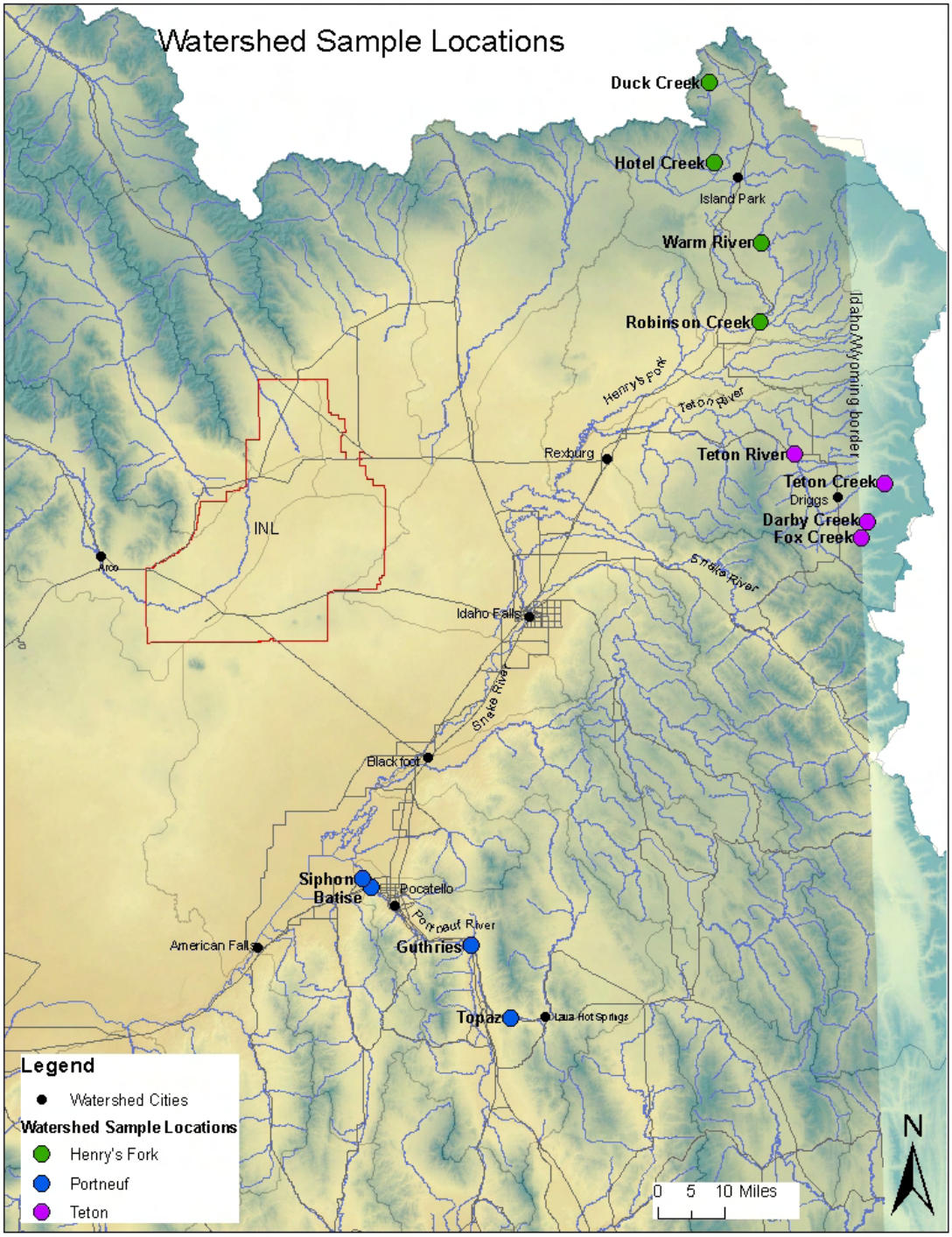

Figure 1. Watershed sample site locations.

Portneuf River Watershed

The Portneuf River watershed is located approximately 50 miles southeast of the INL. This watershed is different from the Teton and Henry's Fork watersheds, as it is under more industrial pressure and the influence of physical control structures. Each of the four sample sites in the Portneuf watershed is located on the Portneuf River (Figure 1). Topaz is the uppermost site, while Siphon is the lowest site, located downstream from Pocatello. The Guthries site is generally referred to as "above marsh." The Portneuf River originates in the Chesterfield Range and the Portneuf Range. After the Portneuf River leaves the Portneuf Valley, it is flanked on both sides by the Caribou National Forest as it flows toward Pocatello and then into the American Falls Reservoir.

Methods

The data collected from these watersheds was compared, understanding that the Portneuf River watershed may have anthropogenic inputs of radiological contaminants from mining operations not associated with the INL. In each of these watersheds, four separate sites were sampled to ensure statistical significance. Surface water samples were collected as grab samples at all 12 sites once in the spring and again in late summer in order to have representative results for high flow and base flow. Water samples were analyzed[1] for gross alpha and gross beta radioactivity, tritium, enriched tritium (lower detection level), cesium-137 (Cs-137), strontium-90 (Sr-90), radium-228 (Ra-228), radium (Ra-226), lead-210 (Pb-210), and potassium-40 (K-40) (Table 1). Additionally, these samples were analyzed for common ions, aluminum, and iron (Table 2).

At the Henry's Fork and Teton sample sites, in-stream sediment samples were taken at each location only in the summer, because in the spring there were no accessible depositional areas. The Portneuf locations have sediment samples for both spring and fall. The sediment samples were analyzed for lead-210, radium-226, radium-228, potassium-40, and cesium-137. At each sample site, field parameters such as pH, dissolved oxygen, and conductivity were measured using a Hydro Lab.

[1] A detailed explanation of the radiological methods can be found in an Idaho State University dissertation by Masoud Beitollahi (2007) entitled "Radiological Evaluation of the Lower Portneuf River with Emphasis on TENORM."

Table 1. Radiological methods.

Analysis	Analytical Method	Minimum Detectable Concentration
Watershed Study		
Gross alpha and beta radioactivity	EPA-900 - Gas-flow proportional counting	3-4 pCi/L[a] gross alpha, 1.5-2 pCi/L gross beta
Sr-90 in water	Chemical precipitation with carrier and analyzed by gas flow proportional counter.	~0.01 pCi/L for 1000 minute count
Cs-137 in water	Counting by germanium detector gamma spectroscopy after use of scavenging agent (AMP) to improve MDA[b] by concentrating cesium from larger sample into smaller more efficient counting geometry.	~0.1-0.3 pCi/L for 20-liter sample. MDA is inversely proportional to increased sample volume. Volume can be increased by a factor of 10 in some cases.
Tritium	EPA 906-Liquid scintillation	120-150 pCi/L
Enriched tritium	HASL-300 3H-02-RC electrolytic enrichment and liquid scintillation	8-12 pCi/L
Pb-210 in water	Co-precipitation followed by direct counting gamma spectrometry	~9 pCi/L
Ra-226 in water	Co-precipitation followed by gamma spectrometry and determination by indirect gamma peak	~1.3 pCi/L
Ra-228 in water	Co-precipitation followed by gamma spectrometry and determination by indirect gamma peak	~4 pCi/L
Pb-210 in sediment	Modified HASL-300, alternate counting geometry. Direct measurement by gamma spectrometry	~680 pCi/kg[c]
Ra-226 in sediment	Modified HASL-300, alternate counting geometry. Determination by INDIRECT measurement by gamma spectrometry	~100 pCi/kg
Ra-228 in sediment	Modified HASL-300, alternate counting geometry. Determination by INDIRECT measurement by gamma spectrometry	~210 pCi/kg
K-40 in sediment	Modified HASL-300, alternate counting geometry. Direct measurement by gamma spectrometry	~800 pCi/kg
Cs-137 in sediment	Modified HASL-300, alternate counting geometry. Direct measurement by gamma spectrometry	~ 50 pCi/Kg

[a] pCi/L – picocuries per liter
[b] MDA – minimum detectable activity
[c] pCi/kg – picocuries per kilogram

Table 2. Non-radiological methods.

Analysis	Analytical Method	Minimum Detectable Concentration (mg/L)
Watershed Study		
Alkalinity	SM 2320 B	1
Chloride	EPA 300.0	2
Sulfate	EPA 300.0	2
Calcium	EPA 200.7	0.1
Magnesium	EPA 200.7	2
Potassium	SM 3111B	0.1
Sodium	SM 3111B	0.1
Aluminum	EPA 200.7	2
Iron	EPA 200.7	20

Results

Water Samples

General water quality parameters are shown in Table 3. In general, pH increased in summer samples, with the exception of three locations in the Portneuf watershed. Water temperatures increased at all sites except Robinson Creek and Warm River, which both have large contributions from ground water. At the other two Henry's Fork sites, temperature increased very little. Dissolved oxygen decreased at all Teton and three of four Portneuf sites. Dissolved oxygen increased at the Henry's Fork sample locations. Specific conductance increased at all locations.

Table 3. Field parameters for sample locations.

Location	Date	Time	pH	Air Temp. (°C)	Water Temp. (°C)	Dissolved Oxygen (mg/L)	Turbidity (NTU[a])	Specific Cond. (ms/cm [b])	Discharge (cfs[c])
Portneuf Watershed (spring)									
Topaz	5/15/06	9:40	8.35	20	11	9.58	64.9	0.438	na
Above Marsh	5/15/06	10:40	8.7	20	12	9.17	98.7	0.433	735
Batise	5/15/06	12:00	8.2	20	11	7.46	57.13	0.4115	1209
Siphon	5/15/06	12:45	8.5	20	11	6.99	39.1	0.473	na
Teton Watershed (spring)									
Teton Creek	6/5/06	10:15	7.58	na	4	11.45	7.34	0.085	na
Darby	6/5/06	11:30	7.82	na	5.4	10.85	3.54	0.133	na
Fox	6/5/06	11:50	7.78	na	5.9	10.6	21.4	0.142	na
Teton River	6/5/06	1:30	7.65	na	14.2	9.1	5.79	0.219	na
Henry's Fork Watershed (spring)									
Robinson Creek	6/15/06	3:30	7.56	na	17.42	7.87	na	0.069	na
Warm River	6/15/06	2:15	6.5	na	16.83	7.89	na	0.050	na
Duck Creek	6/15/06	11:30	7.1	na	6.7	9.3	na	0.159	na
Hotel Creek	6/15/06	12:45	7.07	na	7.18	9.23	na	0.043	na
Portneuf Watershed (summer)									
Topaz	8/14/2007	10:00	8.17	21	16.85	7.5	8.9	0.705	na
Above Marsh	8/14/2007	1:15	8.21	21	16.85	7.89	7.5	0.6685	164.09
Batise	8/14/2007	2:15	8.38	36	18.6	7.398	5.6	0.6425	72.82
Siphon	8/14/2007	2:45	7.49	27	14.73	7.86	1.4	0.733	na
Teton Watershed (summer)									
Teton Creek	7/31/2006	10:00	7.65	na	7.5	10.3	na	0.116	60.35
Darby	7/31/2006	11:00	8.06	na	7.2	10.1	1.07	0.156	28.11
Fox	7/31/2006	12:00	8.07	na	7.8	9.9	0.87	0.165	17.59
Teton River	7/31/2006	1:15	7.99	na	15.7	9.14	na	0.296	331
Henry's Fork Watershed (summer)									
Robinson Creek	8/25/2006	3:00	8.33	na	16.17	9.39	na	0.115	na
Warm River	8/25/2006	1:34	7.2	na	15.02	8.97	na	0.051	na
Duck Creek	8/25/2006	11:15	8.01	na	8.94	9.38	na	0.208	na
Hotel Creek	8/25/2006	12:10	8.39	na	8.39	9.46	na	0.065	na

[a] NTU – nephelometric turbidity unit
[b] ms/cm² – microsiemens per centimeter
[c] cfs – cubic feet per second

Common ions, aluminum, and iron, along with the coinciding averages, are reported in Table 4 and Table 5. In general, magnesium, sodium, potassium, chloride, sulfate, and alkalinity concentrations increased in the summer samples. Aluminum and iron both declined slightly in the summer samples. In the Portneuf and Teton watersheds, calcium concentrations did not have a clear correlation between spring and summer. Calcium concentrations in the Henry's Fork watershed increased at each sampling location.

Table 4. Common ion concentrations for spring and summer sampling.

Sample Location	Calcium (mg/L)		Magnesium (mg/L)		Sodium (mg/L)		Potassium (mg/L)		Chloride (mg/L)	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Portneuf Watershed										
Topaz	74	77	19	30	12	29	3.9	8.6	13.4	35.9
Above Marsh	83	58	19	30	13	29	3.8	6.2	14.4	44.2
Batise	62	58	17	27	15	33	3.6	6.9	18.7	43.8
Siphon	61	66	18	26	20	44	4.2	7.5	23.3	47.6
Average	70	65	18	28	15	34	3.9	7.3	17.5	42.9
Teton Watershed										
Teton Creek	24	26	5.6	6.6	0.4	0.5	0.4	0.4	<2	<2
Darby Creek	34	34	10	10.4	0.3	0.4	0.3	0.3	2.12	<2
Fox Creek	42	36	10	10.3	0.3	0.4	0.5	0.4	2.09	<2
Teton River	48	52	10	16	1.2	1.8	1.1	0.8	2.16	2.59
Average	37	37	8.9	10.8	0.6	0.8	0.6	0.5	2.12	2.14
Henry's Fork Watershed										
Duck Creek	30	36	7.6	10	1.3	2.2	0.9	1.4	<2	<2
Hotel Creek	6.2	9.3	2.4	3.4	1.5	1.9	0.7	0.8	<2	<2
Warm River	5.6	5.3	1.6	1.4	3.8	4.4	2.2	2.4	<2	2.04
Robinson Creek	7.1	9.6	1.7	2.1	7.1	15	1.4	2.1	3.7	8.16
Average	12.2	15.1	3.3	4.2	3.4	5.9	1.3	1.7	2.4	3.55

Table 5. Sulfate, alkalinity, aluminum, and iron concentrations for spring and summer sampling.

Sample Location	Sulfate (mg/L)		Alkalinity ($CaCo_3$) (mg/L)		Aluminum (mg/L)		Iron (mg/L)	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Portneuf Watershed								
Topaz	17.4	37.8	191	300	2	0.24	1.8	0.25
Above Marsh	17.7	31.7	184	249	2.8	0.11	2.6	0.11
Batise	16.4	35.3	173	239	1.9	0.13	1.7	0.13
Siphon	24.5	64.2	183	235	1.6	0.11	1.4	0.11
Average	19.0	42.3	183	256	2.1	0.15	1.9	0.15
Teton Watershed								
Teton Creek	2.05	4.35	73	86	0.27	<0.1	0.25	0.01
Darby Creek	2.05	4.19	113	124	0.1	<0.1	0.08	<0.1
Fox Creek	<2	2.88	120	130	0.51	<0.1	0.53	<0.1
Teton River	3.55	8.16	143	186	0.22	<0.1	0.25	0.04
Average	2.41	4.90	112	132	0.28	<0.1	0.28	0.06
Henry's Fork Watershed								
Duck Creek	<2	4.24	94	121	0.7	0.24	0.73	0.28
Hotel Creek	<2	<2	25	38	0.54	0.11	0.48	0.18
Warm River	<2	<2	24	23	0.19	<0.1	0.24	0.12
Robinson Creek	<2	2.32	32	49	0.11	<0.1	0.17	0.04
Average	<2	2.64	44	57.8	0.4	0.14	0.41	0.16

Radionuclide concentrations in water are reported in Tables 6 through 14. There were no detections of gross alpha radioactivity. Not surprisingly though, there were gross beta detections. The Portneuf samples had four detectable gross beta results in the spring and four in the summer. Each of the summer results was two to three times greater than the spring result from the same site. The Teton samples had one gross beta detection in the spring and one at a different location in the summer, with no clear increasing or decreasing trend for the Teton. The Henry's Fork samples had two gross beta detections in the spring but none in the summer. All gross beta results were at very low levels and within the range of concentrations observed for naturally occurring radioactivity. Strontium-90 was not detected in any of the water samples.

Table 6. Gross alpha concentrations in spring and summer water samples.

Sample Locations	Gross Alpha Concentrations[1] (pCi/L)							
	Spring		±2SD[2]	MDC[3]	Summer		±2SD	MDC
Portneuf Watershed								
Topaz	-4.4	U	2.7	5.0	0.1	U	3.5	6.0
Above Marsh	-2.9	U	3.3	6.0	-0.3	U	3.0	5.2
Batiste	-3.9	U	2.6	4.8	3.5	U	3.1	5.0
Siphon	-3.0	U	2.7	4.9	-6.6	U	3.6	6.7
Teton Watershed								
Teton Creek	0.2	U	1.3	2.2	0.5	U	1.2	2.0
Darby	-0.7	U	1.7	2.9	-4.0	U	1.5	3.3
Fox	-4.5	U	2.0	3.9	-2.1	U	1.5	2.8
Teton River	0.9	U	1.7	2.8	-0.6	U	2.2	3.8
Henry's Fork Watershed								
Robinson Creek	0.2	U	0.9	1.5	-1.7	U	1.2	2.1
Warm River	0.4	U	0.8	1.4	-2.7	U	1.0	2.0
Duck Creek	-1.8	U	1.8	3.2	-1.2	U	1.7	3.0
Hotel Creek	-0.1	U	0.7	1.2	-2.7	U	1.0	2.0

[1] U – non-detect
[2] ± 2 SD – plus or minus two standard deviations
[3] MDC – minimum detectable concentration

Table 7. Gross beta concentrations in spring and summer water samples.

Sample Locations	Gross Beta Concentrations[1] (pCi/L)							
	Spring		±2SD[2]	MDC[3]	Summer		±2SD	MDC
Portneuf Watershed								
Topaz	1.8		1.0	1.7	9.5		1.3	1.7
Above Marsh	3.5		1.2	1.8	6.8		1.1	1.6
Batiste	3.5		1.1	1.7	8.9		1.2	1.6
Siphon	3.9		1.1	1.7	6.6		1.2	1.8
Teton Watershed								
Teton Creek	0.9	U	0.9	1.5	2.3		0.9	1.4
Darby	0.2	U	0.9	1.5	-0.6	U	0.8	1.5
Fox	1.3	U	1.0	1.6	0.5	U	0.8	1.4
Teton River	2.7		0.9	1.4	0.6	U	0.9	1.5
Henry's Fork Watershed								
Robinson Creek	1.4		0.8	1.3	0.9	U	0.9	1.4
Warm River	1.5		0.8	1.3	0.9	U	0.9	1.4
Duck Creek	0.2	U	0.9	1.5	1.2	U	0.9	1.5
Hotel Creek	0.7	U	0.8	1.3	-0.7	U	0.8	1.4

[1] U – non-detect
[2] ± 2 SD – plus or minus two standard deviations
[3] MDC – minimum detectable concentration

Table 8. Strontium-90 concentrations in spring and summer water samples.

Sr-90 Concentrations[1] (pCi/L)				
Sample Location	**Spring**		**Summer**	
Portneuf Watershed				
Topaz	<0.035	U	<0.022	U
Above Marsh	<0.036	U	<0.030	U
Batiste	<0.033	U	<0.025	U
Siphon	<0.035	U	<0.023	U
Teton Watershed				
Teton Creek	<0.034	U	<0.034	U
Darby	<0.022	U	<0.032	U
Fox	<0.028	U	<0.047	U
Teton River	<0.033	U	<0.031	U
Henry's Fork Watershed				
Robinson Creek	<0.052	U	<0.042	U
Warm River	<0.047	U	<0.062	U
Duck Creek	<0.051	U	<0.024	U
Hotel Creek	<0.050	U	<0.042	U

[1] U – non-detect

None of the single samples had detectable results for cesium-137. When the single samples were combined into a single composite sample for each watershed, small amounts of cesium-137 were detected. Each of the watersheds had higher cesium-137 concentrations in the summer than in the spring.

Table 9. Cesium-137 concentrations in spring and summer water samples.

Sample Locations	Cs-137 Concentrations [1] (pCi/L)							
	Spring		**± 2 SD[2]**	**MDC[3]**	**Summer**		**± 2 SD**	**MDC**
Portneuf Watershed								
Topaz	0.02	U	0.07	0.12	0.06	U	0.07	0.11
Above Marsh	0.00	U	0.08	0.14	0.03	U	0.09	0.15
Batiste	0.02	U	0.09	0.15	0.04	U	0.07	0.12
Siphon	0.01	U	0.09	0.16	0.02	U	0.07	0.11
Portneuf Combo.	0.016		0.006	0.009	0.061		0.007	0.007
Teton Watershed								
Teton Creek	0.04	U	0.04	0.12	0.08	U	0.10	0.17
Darby	0.03	U	0.08	0.14	0.03	U	0.07	0.12
Fox	0.01	U	0.07	0.12	0.04	U	0.08	0.14
Teton River	0.02	U	0.06	0.11	0.06	U	0.08	0.13
Teton Combo.	0.007	U	0.005	0.008	0.018		0.005	0.008
Henry's Fork Watershed								
Robinson Creek	0.01	U	0.08	0.13	0.03	U	0.10	0.16
Warm River	0.01	U	0.08	0.13	0.14	U	0.12	0.19
Duck Creek	0.03	U	0.13	0.21	0.02	U	0.08	0.13
Hotel Creek	0.00	U	0.08	0.14	0.03	U	0.09	0.15
Henry's Fork Combo.	0.019		0.006	0.008	0.070		0.004	0.007

[1] U – non-detect
[2] ± 2 SD – plus or minus two standard deviations
[3] MDC – minimum detectable concentration

There were no standard method tritium detections. Samples that did not yield detectable tritium using the standard liquid scintillation analysis method were reanalyzed using an electrolytic enrichment process to concentrate the tritium in the sample prior to reanalysis by liquid scintillation. This procedure reduces the MDC to less than 25 pCi/L, which is within the expected range for background tritium levels. There were detectable results at each sample location for enriched tritium. Enriched tritium results from each of the Henry's Fork sample sites increased from spring to summer. Neither the Portneuf nor the Teton results had any clear correlation between seasons.

Table 10. Tritium concentrations in spring and summer water samples, standard method.

Sample Locations	Tritium Concentrations[1] (pCi/L)							
	Spring		± 2SD[2]	MDC[3]	Summer		± 2SD	MDC
Portneuf Watershed								
Topaz	-60	U	80	130	-50	U	90	150
Above Marsh	-40	U	80	130	20	U	80	130
Batiste	60	U	80	120	-80	U	80	140
Siphon	-60	U	80	130	60	U	80	130
Teton Watershed								
Teton Creek	-30	U	80	130	70	U	80	130
Darby	0	U	80	130	-60	U	80	140
Fox	-30	U	80	130	0	U	80	130
Teton River	-30	U	80	130	10	U	80	130
Henry's Fork Watershed								
Robinson Creek	-80	U	80	140	90	U	80	130
Warm River	-40	U	80	140	50	U	80	130
Duck Creek	-30	U	80	140	-60	U	80	140
Hotel Creek	-40	U	80	140	60	U	80	130

[1] U – non-detect
[2] ± 2 SD – plus or minus two standard deviations
[3] MDC – minimum detectable concentration

Table 11. Enriched tritium concentrations in spring and summer water samples.

Sample Locations	Enriched Tritium Concentrations (pCi/L)					
	Spring	±2SD[1]	MDC[2]	Summer	±2SD	MDC
Portneuf Watershed						
Topaz	28	6	9	19	7	11
Above Marsh	9	3	5	18	8	12
Batiste	31	6	7	17	7	11
Siphon	21	5	7	23	7	11
Teton Watershed						
Teton Creek	25	5	7	30	8	11
Darby	30	6	8	25	7	9
Fox	26	5	7	30	8	11
Teton River	18	5	7	22	6	9
Henry's Fork Watershed						
Robinson Creek	24	8	12	45	7	9
Warm River	41	8	11	56	9	12
Duck Creek	18	7	10	31	7	10
Hotel Creek	25	7	11	38	8	10

[1] ± 2 SD – plus or minus two standard deviations
[2] MDC – minimum detectable concentration

There were no detectable concentrations of the natural radionuclides lead-210, radium-226, or radium-228 in any of the water samples.

Table 12. Lead-210 concentrations in spring and summer water samples.

Sample Location	Lead-210 Concentrations[1] (pCi/L)							
	Spring		± 2 SD[2]	MDC[3]	Summer		± 2 SD	MDC
Portneuf Watershed								
Topaz	3.05	U	5.54	9.43	-2.54	U	3.81	8.00
Above Marsh	3.73	U	4.03	8.38	-0.11	U	3.93	8.22
Batiste	0.16	U	3.11	7.08	0.56	U	6.91	9.06
Siphon	0.43	U	3.41	9.60	2.96	U	7.26	8.89
Teton Watershed								
Teton Creek	-0.62	U	3.08	8.33	1.39	U	5.91	9.46
Darby	3.35	U	7.09	9.27	-0.03	U	3.94	8.22
Fox	3.35	U	2.89	9.03	4.25	U	2.91	9.11
Teton River	-0.99	U	3.70	6.11	0.29	U	3.95	8.38
Henry's Fork Watershed								
Robinson Creek	4.42	U	3.21	9.76	3.68	U	7.25	9.68
Warm River	2.77	U	3.58	9.35	3.70	U	7.17	9.24
Duck Creek	2.50	U	4.02	8.43	1.38	U	6.79	9.24
Hotel Creek	0.42	U	7.60	8.89	0.98	U	6.71	9.43

[1] U – non-detect
[2] ± 2 SD – plus or minus two standard deviations
[3] MDC – minimum detectable concentration

Table 13. Radium-226 concentrations in spring and summer water samples.

Sample Location	Radium-226 Concentrations[1] (pCi/L)							
	Spring		± 2 SD[2]	MDC[3]	Summer		± 2 SD	MDC
Portneuf Watershed								
Topaz	0.67	U	0.58	1.30	0.30	U	0.71	1.24
Above Marsh	1.14	U	1.06	1.30	0.55	U	0.76	1.24
Batiste	0.44	U	0.52	1.00	0.85	U	0.71	1.32
Siphon	0.83	U	0.33	1.24	0.66	U	0.66	1.30
Teton Watershed								
Teton Creek	1.21	U	0.48	1.30	0.42	U	0.54	1.19
Darby	0.20	U	0.81	1.35	1.21	U	0.70	1.24
Fox	0.58	U	0.52	1.22	0.59	U	0.66	1.24
Teton River	0.50	U	0.87	1.19	0.29	U	0.93	1.32
Henry's Fork Watershed								
Robinson Creek	0.98	U	0.61	1.27	0.21	U	0.75	1.22
Warm River	0.35	U	0.96	1.22	0.55	U	0.67	1.22
Duck Creek	-0.48	U	0.18	1.32	0.17	U	0.69	1.27
Hotel Creek	1.03	U	0.73	1.30	0.87	U	0.69	1.24

[1] U – non-detect
[2] ± 2 SD – plus or minus two standard deviations
[3] MDC – minimum detectable concentration

Table 14. Radium-228 concentrations in spring and summer water samples.

Sample Location	Radium-228 Concentrations[1] (pCi/L)							
	Spring		± 2 SD[2]	MDC[3]	Summer		± 2 SD	MDC
Portneuf Watershed								
Topaz	-0.62	U	1.39	3.70	2.02	U	1.37	3.70
Above Marsh	1.38	U	1.16	4.16	1.05	U	1.00	4.03
Batiste	2.93	U	1.84	3.70	1.95	U	1.38	4.46
Siphon	1.16	U	1.01	3.84	2.07	U	2.76	3.97
Teton Watershed								
Teton Creek	-0.61	U	0.28	3.32	1.16	U	1.11	3.87
Darby	0.98	U	1.34	3.62	-1.44	U	0.95	4.70
Fox	1.96	U	1.32	3.49	2.11	U	1.39	4.92
Teton River	2.45	U	3.12	4.41	1.04	U	0.97	3.70
Henry's Fork Watershed								
Robinson Creek	2.08	U	2.70	4.76	1.08	U	0.97	3.27
Warm River	3.90	U	2.12	4.81	2.01	U	1.39	3.59
Duck Creek	1.99	U	1.35	3.19	0.76	U	2.58	4.24
Hotel Creek	2.08	U	1.37	5.22	0.29	U	0.95	3.65

[1] U – non-detect
[2] ± 2 SD – plus or minus two standard deviations
[3] MDC – minimum detectable concentration

Sediment Samples

Samples from each location were analyzed for the natural radionuclides lead-210, radium-226, radium-228, and potassium-40 and also cesium-137, which is human-made. All of the natural radionuclides were detectable at each sample location. Radionuclide concentrations in sediment are reported in Tables 15 through 17.

Lead-210 and radium-226 are both members of the uranium-238 decay series. Radium-228 is a member of the thorium-232 decay series. Neither potassium-40 nor cesium-137 is part of a decay series. This information is important in order to know which concentration ranges to compare the results with.

Results for lead-210 and radium-226 can both be compared with the range of 0.2-1.6 picocuries per gram (pCi/g) for uranium-238 in all rocks and an average soil concentration of 0.6 pCi/g (Eisenbud and Gesell 1997). Half of the lead-210 results fall just above this range, which is not surprising because lead-210 concentrations in sediments can be enriched from the decay of radon-222 present in the atmosphere and subsequently deposited on the earth. All of the radium-226 results fall within this range and are close to the average concentration of 0.6 pCi/g for soil.

Concentrations for radium-228 can be compared to the range of 0.2-2.2 pCi/g for thorium-232 in all rocks and an average soil concentration of 1.0 pCi/g (Eisenbud and Gesell 1997). All of the results for radium-228 fall within this range.

Table 15. Lead-210 and radium-226 concentrations in sediment samples.

Location	Sample Date	Season	Pb-210 (pCi/g)			Ra-226 (pCi/g)		
			Concentration	± 2 SD[1]	MDC[2]	Concentration	± 2 SD	MDC
Portneuf Watershed								
Topaz	06/22/06	spring	1.31	0.43	0.65	0.48	0.06	0.08
Topaz	08/18/06	summer	0.93	0.46	0.73	0.59	0.07	0.09
ABV Marsh	06/22/06	spring	1.04	0.41	0.64	0.52	0.55	0.07
ABV Marsh	09/22/06	summer	1.67	0.46	0.68	0.33	0.05	0.07
Batiste	06/22/06	spring	1.62	0.43	0.60	1.13	0.07	0.07
Batiste	09/01/06	summer	0.78	0.37	0.62	0.45	0.05	0.07
Siphon	06/22/06	spring	1.70	0.43	0.61	1.05	0.07	0.07
Siphon	09/01/06	summer	1.70	0.46	0.66	0.77	0.07	0.09
Teton Watershed								
Teton Creek	07/31/06	summer	2.08	0.46	0.60	1.60	0.09	0.08
Darby	07/31/06	summer	1.86	0.23	0.62	0.68	0.04	0.10
Fox	ns[3]	ns	ns	ns	ns	ns	ns	ns
Teton River	07/31/06	summer	1.71	0.52	0.77	0.92	0.09	0.11
Henry's Fork Watershed								
Robinson Creek	08/29/06	summer	1.74	0.51	0.75	1.05	0.08	0.09
Hotel Creek	08/29/06	summer	0.57	0.40	0.62	0.38	0.04	0.06
Duck Creek	08/29/06	summer	1.44	0.47	0.71	0.73	0.73	0.09
Warm River	08/29/06	summer	3.19	0.71	0.97	1.54	0.11	0.11

[1] ± 2 SD – plus or minus two standard deviations
[2] MDC – minimum detectable concentration
[3] ns – not sampled

Table 16. Radium-228 concentrations in sediment samples.

Sample Location	Sample Date	Season	Radium- 228 (pCi/g)		
			Concentration	± 2 SD[1]	MDC[2]
Portneuf Watershed					
Topaz	06/22/06	spring	0.78	0.14	0.20
Topaz	08/18/06	summer	0.72	0.14	0.20
ABV Marsh	06/22/06	spring	0.56	0.10	0.15
ABV Marsh	09/22/06	summer	0.46	0.10	0.16
Batiste	06/22/06	spring	1.08	0.12	0.16
Batiste	09/01/06	summer	0.51	0.11	0.16
Siphon	06/22/06	spring	0.87	0.11	0.15
Siphon	09/01/06	summer	1.04	0.16	0.22
Teton Watershed					
Teton Creek	07/31/06	summer	1.66	0.14	0.17
Darby	07/31/06	summer	0.75	0.07	0.22
Fox	ns[3]	ns	ns	ns	ns
Teton River	07/31/06	summer	1.70	0.17	0.24
Henry's Fork Watershed					
Robinson Creek	08/29/06	summer	2.07	0.18	0.21
Hotel Creek	08/29/06	summer	0.72	0.10	0.15
Duck Creek	08/29/06	summer	1.03	0.15	0.21
Warm River	08/29/06	summer	2.26	0.22	0.28

[1] ± 2 SD – plus or minus two standard deviations
[2] MDC – minimum detectable concentration
[3] ns – not sampled

The background concentration range for potassium-40 is 2-41 pCi/g for all rocks, with an average soil concentration of 11 pCi/g (Eisenbud and Gesell 1997). All of the potassium-40 results fall with this range.

Cesium-137 was detected at most of the sample sites. Cesium-137 was deposited into the environment from fallout during the weapons testing era, and to a much lesser extent from the Chernobyl nuclear power plant accident. Scientific studies (Beck and Bennett 2002, NCRP 2006) have been performed to determine deposition inventories of cesium-137 throughout the country. Based on these studies, it is possible to determine what concentrations should still be in the soil. Estimated concentrations of fallout in near-surface soil for southeast Idaho range from 0.08-1.34 pCi/g. Concentrations greater than 1.34 pCi/g would suggest an additional source of Cs-137 or some other concentrating mechanism in the resulting sediments. All detectable sediment concentrations for this study fall within or below the estimated background concentration range of 0.08-1.34 pCi/g for near-surface soil.

Table 17. Potassium-40 and cesium-137 concentrations in sediment samples.

Sample Location	Sample Date	Season	K-40 (pCi/g)			Cs-137 (pCi/g)			
			Concentration[1]	± 2 SD[2]	MDC[3]	Concentration		± 2 SD	MDC
Portneuf Watershed									
Topaz	06/22/06	spring	11.47	0.82	0.73	0.05		0.02	0.03
Topaz	08/18/06	summer	11.34	0.86	0.83	0.06		0.02	0.03
ABV Marsh	06/22/06	spring	7.56	0.62	0.60	0.03	U	0.02	0.03
ABV Marsh	09/22/06	summer	6.43	0.55	0.58	0.03		0.01	0.02
Batiste	06/22/06	spring	15.22	0.89	0.60	0.07		0.01	0.02
Batiste	09/01/06	summer	8.07	0.62	0.60	0.02	U	0.02	0.02
Siphon	06/22/06	spring	14.58	0.89	0.59	0.06		0.02	0.03
Siphon	09/01/06	summer	14.31	0.97	0.81	0.09		0.02	0.04
Teton Watershed									
Teton Creek	07/31/06	summer	30.85	1.55	0.61	0.11		0.02	0.03
Darby	07/31/06	summer	12.20	0.45	0.84	0.26		0.02	0.04
Fox Creek	ns[4]	ns	ns	ns	ns	ns		ns	ns
Teton River	07/31/06	summer	15.65	1.06	0.91	0.10		0.03	0.04
Henry's Fork Watershed									
Robinson Creek	08/29/06	summer	34.56	1.78	0.78	0.02	U	0.02	0.04
Hotel Creek	08/29/06	summer	18.90	1.08	0.56	0.15		0.01	0.02
Duck Creek	08/29/06	summer	26.69	1.45	0.77	0.27		0.03	0.04
Warm River	08/29/06	summer	32.40	1.78	1.02	0.08		0.03	0.05

[1] U – non-detect
[2] ± 2 SD – plus or minus two standard deviations
[3] MDC – minimum detectable concentration
[4] ns – not sampled

Summary

The results of this sampling project show that there are no additional radiological impacts to the areas sampled in these particular watersheds, above expected background concentrations. This information will be helpful to assess any future INL impacts to the environment. Sampling in other watersheds may be planned in the future in order to obtain a complete picture of the radiological concentrations in the environment around southeast Idaho.

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