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Consulting in Hydrogeology

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Memorandum

Date: June 30, 2014

To: Rick Noll, Project Manager, Spokane Conservation District

From: Laura Strauss, LG, LHg, Northwest Land & Water, Inc. (NLW)

Re: Results for West Plains and Lower Hangman Creek sampling and analysis of groundwater samples to supplement the previous WRIA 54/56 Hydrogeologic Investigations

Introduction

In 2010 and 2012, Spokane Conservation District (SCD) constructed monitoring wells in intermediate and deep basalt aquifers of WRIA 54 and 56. These aquifers supply water for domestic, industrial, commercial, and agricultural needs and will continue to be the sole source of water for growing population. Sampling and analysis of groundwater from the monitoring wells following well construction (2010 and 2012) indicate "old" water on the order of thousands of years to greater than 10,000 years in WRIA 56 and 21,000 years in West Plains of WRIA 54. From a water resource perspective, the significance of "old" water is the potential limitation on how much and at what rates groundwater can be developed as a long-term, reliable water supply source.

SCD contracted NLW to sample and analyze C-14 (groundwater age), stable isotopes, and routine constituents from 7 of the 11 monitoring wells and 13 water supply wells. Results from the monitoring wells were compared to results from samples collected in 2010 or 2012 or provide results for monitoring wells that did have age data due to budget constraints that limited the number of C-14 and tritium analyses. Due to budget constraints, MW-11 was not sampled in 2012 and MW-2 was not analyzed for C-14 and tritium in 2010

The sampling, analysis, and reporting would follow the sample protocols and quality assurance protection plan (QAPP) that was implemented in 2010 and 2012 was updated and used for this project.

The results from these samples provide insights about the potential sustainability of groundwater supplies, particularly if the results are understood in the context of long-term trends in groundwater storage. The sampling at supply wells required coordination with local purveyors and made use of existing pumping equipment and sampling ports.

This memorandum documents the work conducted to sample the wells and summarize and analyze the data. The tasks to conduct the work are described in the contract with SCD under Ecology Grant G1400597. This memorandum serves as a supplement to the report dated June 30, 2012, entitled *West Plains (WRIA 54) & Lower Hangman Creek Watershed (WRIA 56) Hydro-*

geologic Characterization & Monitoring Well Drilling Final Report, referred to herein as the 2012 report. The 2012 report was an addendum to an earlier report (NLW, 2011). References are made to the 2012 report for all background information about analytes and methodology.

Sampling & Analysis

Samples were analyzed for field parameters, routine chemistry, stable isotopes ^{18}O, D, and ^{13}C, and radioactive isotopes of tritium and ^{14}C. A list of the wells sampled is given below in **Table 1** with the lithology of the unit in which the well was completed. Well locations are shown on **Figure 1**.

Samples were collected and analyzed using the same methodology and laboratories as described in the 2012 report and the QAPP that was updated from the 2012 investigation.

Table 1. Summary of wells sampled in 2014

Well/Sample Name	Lithology	Well depth
Airforce Base Well 2 (AFB-2)	basalt	400
Airforce Base Well 7 (AFB-7)	unconsolidated deposits	230
Airway Heights Well 9 (AH-9)	unconsolidated deposits	255
Airway Hts Parkwest Well	basalt	301
Cheney Well 1 (C-1)	basalt	525
Four Lakes off Craig Rd (FL)	basalt	775
Freeman School	basalt/basement	215
Medical Lake Well (ML) at Lehn Rd	basalt/basement	964
Medical Lake Well (ML) at Hallet Rd	basalt	440
Reardan SR-2	basalt	452
Rockford Well 5	basalt	270
428174	basement	346
Tekoa S04	basalt	303
MW-1	basalt	137
MW-2	basalt	276
MW-5	basalt	357
MW-6	basalt	224
MW-7	basalt	360
MW-8	basalt	370
MW-11	basalt	240

Results

Laboratory analytical results are summarized in **Table 2a** for monitoring wells and **Table 2b** for water supply wells.

Stable isotopes of ^{18}O and deuterium are plotted with the local MWL on **Figure 2** and ^{14}C is plotted against ^{18}O and tritium on **Figure 3**. Data from the same monitoring well from a previous investigation is included on the graphs using the same color and shape as used to represent 2014 data, but is indicated as hollow while all 2014 data is indicated as a solid symbol. Samples collected from shallow wells are indicated with squares, deep wells with triangles, and deep wells over 400 feet depth with a circle. Graphs indicate similar trends as shown on the corresponding graphs in the 2012 report.

Stable Isotopes

^{18}O and D are plotted with the local meteoric water line (MWL) and previous monitoring well data on **Figure 2**. The data are consistent and indicate a range in the elevation of precipitation recharge. The data plot closely to the local MWL for southwestern Idaho, as did the 2010 and 2012 samples. The quality assurance data were reviewed, and all standards and duplicates fell within the acceptable criteria. The 2014 data indicate:

Well 428174 has the lightest isotopic signature; it is completed in basement rock near the downgradient edge of the basin.

AFB-7, has the heaviest isotopic signature and is completed in paleochannel deposits.

The monitoring well data is slightly heavier for 2014 data than for earlier data except for MW-1 and MW-2, yet all monitoring well data falls along the local meteoric water line.

The majority of the samples suggest mixing of low- and high-elevation precipitation.

Carbon-14 & Carbon-13

The ^{14}C and ^{13}C results are reported as “apparent” or “measured” ages, which range from 1420 years to 21,690 years; $\delta\ ^{13}C$ ranges from –14.4 to –20.9 permil. Groundwater age is shown on **Figure 1**.

As discussed in the Characterization Report (NLW, 2011), the data indicate that the groundwater is enriched (heavier) in ^{13}C relative to typical soil gas, suggesting that carbon mass transfer has occurred since the water infiltrated through the soil zone. The 2012 report concluded that a lack of correlation between $\delta^{13}C$ and bicarbonate suggests that volcanic glass dissolution and carbon dioxide degassing are responsible for enriching the groundwater in $\delta\ ^{13}C$ relative to an assumed soil gas of about -22 permil rather than dissolution of carbonate (Appendix C; NLW, 2011). The lower graph on **Figure 3** indicates this mechanism, just as is indicated on similar Figure 6-4 in the Characterization Report and explained in that report. This same mechanism is assumed for the 2014 samples because they are from the same groundwater systems. Therefore, the reported age is assumed to represent “actual” groundwater age as was done in the previous investigations.

Ten of 20 wells have groundwater age greater than 10,000 years, including samples from wells located near the West Plains basin “rim”, i.e. the upgradient edge of the watershed. Only three samples have ages less than 2,000 years. In general, groundwater ages for samples from deeper wells are older than samples from shallow wells.

Tritium

Tritium results range from 0 to 3.82 TU (**Table 2**). Twelve of 20 samples contain tritium at concentrations that exceed the error, indicating that they contain at least some groundwater that was recharged within the last 60 years. All of the five samples with tritium concentrations greater than 1 TU are from shallow wells and have relatively heavy isotopic signatures.

Figure 3 shows the relationship between tritium, ^{14}C, and ^{18}O. Low concentrations of tritium (<1 TU) are detected in samples with a ^{14}C age ranging from 2,600 to more than 20,000 years, indicating that the oldest water is mixing with some recently recharged groundwater. In the absence of mixing, samples with ages over 60 years would have no detectable tritium. The tritium data indicates mixing is a significant mechanism in the groundwater system.

Comparison of 2014 Data to Earlier Results

Table 3, below, compares 2014 results with results from corresponding wells from earlier investigations.

Five monitoring wells sampled in 2014 have age data for corresponding wells from earlier investigations. For each of these, the 2014 ^{14}C age is slightly older than results from 2010 or 2012, ranging from 440 years for MW-7 to 990 years for MW-1; similarly tritium is less in 2014 samples, indicating less contribution from recent water.

Six monitoring wells sampled in 2014 have 18O/D data for corresponding wells from earlier investigations. For all but MW-1 and MW-2, the 2014 data are slightly heavier, however, the differences are relatively small and the significance is unclear.

Table 3. Comparison of Well Data

Sample	^{13}C (per-mil)	^{14}Cage (years)	^{18}O (per-mil)	Deuterium (permil)	Tritium (TU)
2014 MW-1	-19.3	15,720	-17.5	-133.1	0
2010 MW1_137	-16.1	14,730	-16.1	-128.2	0.03
2014 MW-2	-19.7	10,910	-16.3	-126.5	0
2010 MW2_276	NA	NA	-15.9	-123.8	NA
2014 MW-5	-18.8	8,230	-15.2	-119.3	0.11
2010 MW5_355	NA	NA	-15.4	-120.4	NA
2010 BH5-501	-15.6	7,670	NA	NA	0.03
2014 MW-6	-20.3	6,390	-15.9	-121.3	0.04
2010 MW6_224	-15.7	5,870	-15.8	-123.1	0.12
2014 MW-7	-19.6	10,540	-15.8	-123.3	0.29
2012 MW-7	-14.5	10,100	-16.2	-126.0	0.61
2014 MW-8	-19.0	4,650	-16.1	-126.2	0
2012 MW-8	-15.5	3,880	-16.6	-127.2	0.52

Interpretation

In general, groundwater from many of the wells is quite old; presence of tritium and the stable isotopic signature also suggests mixing of old water with young, recently recharged groundwater.

The sample with the oldest age, 21,690 years, is from Well 428174 that occurs near the downgradient edge of the groundwater basin, furthest from the basin rim where much of the recharge occurs.

Groundwater from the Reardon, Medical Lake, Four Lakes, and Cheney wells is over 9,000 years old, and each of these wells is located relatively near the basement rim, the probable location of the majority of groundwater recharge for these wells. These old ages for relatively short travel distances suggest a long residence time and that removal of groundwater at relatively significant rates could result in "mining" groundwater with minimal replenishment.

The occurrence of detectable tritium with old ^{14}C age indicates the groundwater is a mixture of old and young water and suggests that the old water contribution is significantly older than the apparent age of the sample because the sample age has been diluted with young water.

The sample with the youngest age, 1,420 years, is from shallow well AFB-7; it is completed in the paleochannel deposits which are expected to contain relatively younger, more recently recharged groundwater. This is consistent with the conceptual groundwater flow model described in the 2010 and 2012 reports.

Explanations for specific results are given below:

- Rockford Well, which is closer to the mountain recharge area than MW-1, is younger than MW-1; this is consistent with what is expected because MW-1 has a longer flow path.

- MW-2 has a longer flow path compared to Tekoa which is directly upgradient from MW-2, yet MW-2 has a younger age than Tekoa, suggesting that MW-2 is recharged in part from infiltration of Hangman Creek water, as discussed in the 2012 report.

- MW-11 is completed about 120 feet above MW-7, directly below the paleochannel deposits, and is 7,000 years younger than MW-7 indicating that there is a fairly strong separation between the shallow and deep groundwater systems in the Marshall gravel pit area. .

- AFB-7, Airway Heights 9, and Airway Heights Parkwest have the youngest groundwater age, the heaviest isotopic signature, and the greatest tritium. AFB-7 and Airway Heights 9 are completed in unconsolidated paleochannel deposits. These results suggest local, relatively recent, low-elevation precipitation recharging the highly permeable groundwater system within the unconsolidated deposits.

- Wells that contain tritium in 2010 and 2012, and did not contain tritium or contained less tritium in 2014 may indicate that they are pumping a smaller percentage of young, recently recharged water and that risk of "mining" groundwater is greater. However, for samples that had detectable tritium in 2010 or 2012 and none in 2014, results may alternatively indicate that some young water may have been introduced into the intermediate/deep aquifer groundwater during the drilling process.

Recommendations

Recommendations are made below to improve understanding of the local and regional groundwater resource and assist water managers in decision-making to sustainably develop groundwater in WRIAs 54 and 56.

1. SCD and SC should develop a list of candidate wells to sample and analyze in the future for the same parameters of this study. This work should target spatial gaps (in map view and vertically) where groundwater geochemical characteristics and age data are needed.

2. Groundwater monitoring wells or existing wells should be also be constructed and/or instrumented to collect long-term water level data in areas of anticipated future groundwater development and/or areas where "groundwater mining" appears to be occurring.

3. Sample constructed monitoring wells two years or more after their installation for wells that had initial samples with detectable tritium and old ^{14}C age, to identify if mixing is due to natural conditions or occurred temporarily during drilling.

References

Northwest Land & Water, 2011. Hangman Creek Watershed (WRIA 56) Hydrogeologic Characterization & Monitoring Well Drilling. Prepared for Spokane County Conservation District, June 1, 2011.

Northwest Land & Water, 2012. West Plains (WRIA 54) & Lower Hangman Creek Watershed (WRIA 56) Hydrogeologic Characterization & Monitoring Well Drilling Final Report, An Addendum to: Hangman Creek Watershed (WRIA 56) Hydrogeologic Characterization & Monitoring Well Drilling Final Report, June 30, 2012.

Table 2a. Summary of Water Quality Data for 2014 Groundwater Samples from Select Monitoring Wells

Constituent	Units	MW 1	MW 2	MW 5	MW 6	MW 7	MW 8	MW 11
Field								
Conductivity, field	umhos/c	not meas	280	346	307	242	161	398
Oxygen, Dissolved	mg/l	not meas	1U	1U	1U	1U	7	1U
pH field	std. units	not meas	6.94	7.49	7.16	7.21	7.63	7.33
Temperature, deg C	deg C	not meas	16.3	17	12	15.5	17.7	
Physical								
Conductivity	umhos/c	294						414
pH	std. units	7.46						
Total Dissolved Solids	mg/L	179	150	168	170	142	112	267
Isotopes								
carbon-13	permil	-19.3	-19.7	-18.8	-20.3	-19.6	-19	-19
Carbon-14, years	years	15720+/- 30	10910+/- 30	8230+/- 30	6390+/- 30	10540+/- 30	4610+/- 30	3470+/- 30
Deuterium	permil	-133.1	-126.54	-119.32	-121.33	-123.3	-126.23	-118.77
O-18	permil	-17.5	-16.33	-15.22	-15.91	-15.82	-16.11	-15.26
Tritium	TU	-0.03+/-0.09	-0.04+/-0.09	0.11+/-0.09	0.04+/-0.09	0.29+/-0.09	-0.04+/-0.09	2.76+/-0.09
Trace Metals								
Iron	mg/L	0.334	0.126	0.0264	1.15	0.016	0.01U	0.0172
Manganese	mg/L	0.0235	0.023	0.017	0.177	0.0171	0.001U	0.0898
Routine Constituents								
Alkalinity as Bicarbon	mg/L	144	128	108	140	106	66	138
Ammonia-nitrogen	mg/L	0.02	13.6	0.02	0.02	0.02	0.02	0.02U
Calcium	mg/L	20	19.6	28.4	29.4	22.3	14.1	41.8
Chloride	mg/L	2.71	2.21	28.4	1.79	1.69	0.703	21.6
Magnesium	mg/L	14.7	11.1	13.5	10.5	9.8	6.89	12.7
NO3/N	mg/L	0.1U	0.1U	0.1U	0.1U	0.1U	0.49	0.644
Potassium	mg/L	3.46	3.23	1.89	2.9	2.89	2.19	3.55
Silica (SiO2) fused	mg/L	56.5	48.2	42.2	58.9	51.8	46	41.7
Silicon	mg/L	26.4	22.5	19.7	27.5	24.2	21.5	19.5
Sodium	mg/L	16.8	19.5	13.8	13.1	11.6	6.29	23.5
Sulfate	mg/L	8.39	4.76	10.1	4.06	6.39	3.08	40.1

Table 2b. Summary of Water Quality Data for 2014 Groundwater Samples from Select Water Supply Wells

Constituent	Units	428174	AFB-2	AFB-7	Freeman Sch.	Four Lakes	Cheney Well 1	Airway Hts Parkwest	Airway Hts 9	Medical Lake Lehn Rd	Medical Lake Hallet	Reardon SR 2	Rockford Well 5	Tekoa
Field														
Conductivity, field	umhos/c	not meas	252	397	372	239	351	304	429	316	288	288	330	283
Oxygen, Dissolved	mg/l	not meas	1U	4.5	3.5	1U	1U	3.5	5	1U	1U	1U	1.5	5.5
pH field	std. units	not meas	7.1	7.64	6.43	7.05	7.7	6.88	7.52	7.39	7.22	7.71	6.72	8.22
Temperature, deg C	deg C	not meas	13.6	11.5	13.9	15.2	16.9	12.6	10	15	16	16.6	14.3	14
Physical														
Conductivity	umhos/c	280	245	384	357	223	339	266	419	277	280	279	294	258
pH	std. units													
Total Dissolved Solids	mg/L	112	180	166	232	142	190	186	236	182	156	178	194	133
Isotopes														
carbon-13	permil	-16.6	-17.9	-16.6	-20.9	-18.8	-16.4	-17.1	-19.5	-15.5	-17.1	-15.3	-16.6	-19.6
Carbon-14, years	years	21690+/- 30	4200+/- 30	1420+/- 30	2630+/- 30	10670+/- 30	9410+/- 30	1490+/- 30	1470+/- 30	13540+/- 30	11710+/- 30	12920+/- 30	11550+/- 30	14620+/- 30
Deuterium	permil	-137.82	-121.98	-112.34	-125.56	-128	-126.92	-114.55	-113.52	-134.7	-131.47	-134.51	-125.36	-126.22
O-18	permil	-17.66	-15.77	-14.54	-16.29	-16.39	-16.55	-14.88	-14.67	-17.38	-17.13	-17.61	-16.59	-16.59
Tritium	TU	0.92+/-0.09	2.24+/-0.09	3.82+/-0.09	-0.03+/-0.09	0.36+/-0.09	0.21+/-0.09	3.01+/-0.1	4.03+/-0.13	0.19+/-0.09	0.2+/-0.09	-0.08+/-0.09	-0.01+/-0.09	0.03+/-0.09
Trace Metals														
Iron	mg/L	1.01	0.0181	0.141	0.01U	0.142	0.0622	0.01U	0.01U	0.106	0.125	0.0778	0.498	0.0115
Manganese	mg/L	0.0798	0.00747	0.00171	0.001U	0.0107	0.0187	0.00609	0.001U	0.0206	0.0134	0.0324	0.0576	0.00569
Routine Constituents														
Alkalinity as Bicarbon	mg/L	142	90	162	172	100	166	109	182	126	122	130	140	128
Ammonia-nitrogen	mg/L	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02
Calcium	mg/L	18.7	18.3	39.9	29.6	15.1	20.9	26.9	42.7	19.9	19.7	21	18.5	20.8
Chloride	mg/L	2.52	7.24	11.1	2.73	2.23	3.41	6.19	10.5	3.31	2.73	2.76	2.66	2.36
Magnesium	mg/L	10.9	7.72	11.7	12.9	2.85	14	8.87	9.94	8.12	8.97	8.56	11.9	14.3
NO3/N	mg/L	0.1U	0.706	1.69	1.1	0.1U	0.1U	1.79	2.44	0.1U	0.1U	0.1U	0.1U	0.1U
Potassium	mg/L	1.5	1.9	2.87	4.44	2.85	2.48	1.03	2.86	2.22	1.72	1.28	2.89	3.19
Silica (SiO2) fused	mg/L	20.9	39.6	21.6	49.6	45.4	47.7	33.8	25.5	41.1	39.2	37.7	40.2	33
Silicon	mg/L	9.75	18.5	10.1	23.2	21.2	22.3	15.8	11.9	19.2	18.3	17.6	18.8	15.4
Sodium	mg/L	18.1	10.4	6.31	12.4	12.8	18.3	4.58	12.9	18.3	15.4	15.4	12.7	15.5
Sulfate	mg/L	3.54	19.6	15.7	6.66	10.7	8.55	11.1	9.06	11.8	15.5	9.96	8.8	4.99

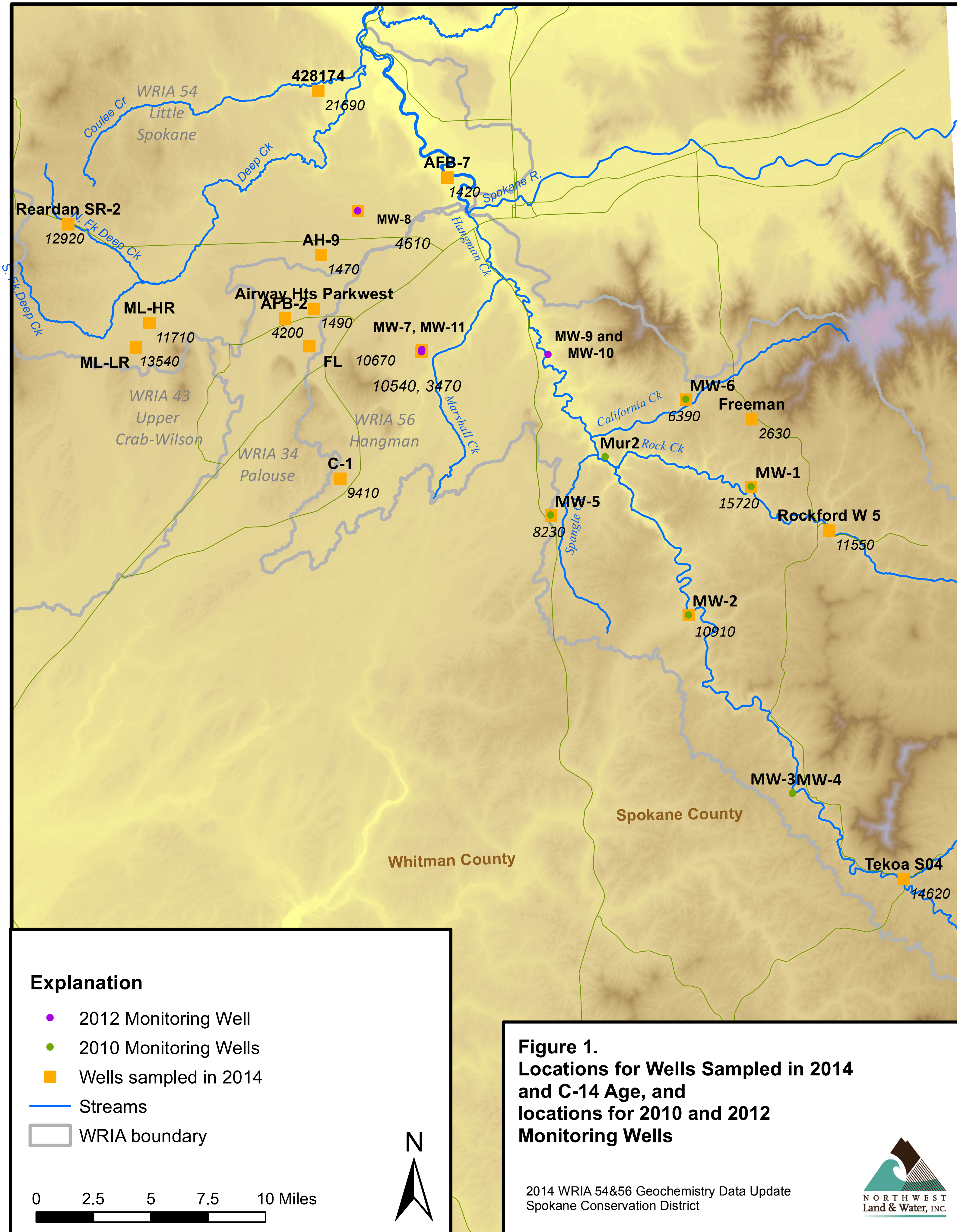

Figure 1.
Locations for Wells Sampled in 2014 and C-14 Age, and locations for 2010 and 2012 Monitoring Wells

2014 WRIA 54&56 Geochemistry Data Update
Spokane Conservation District

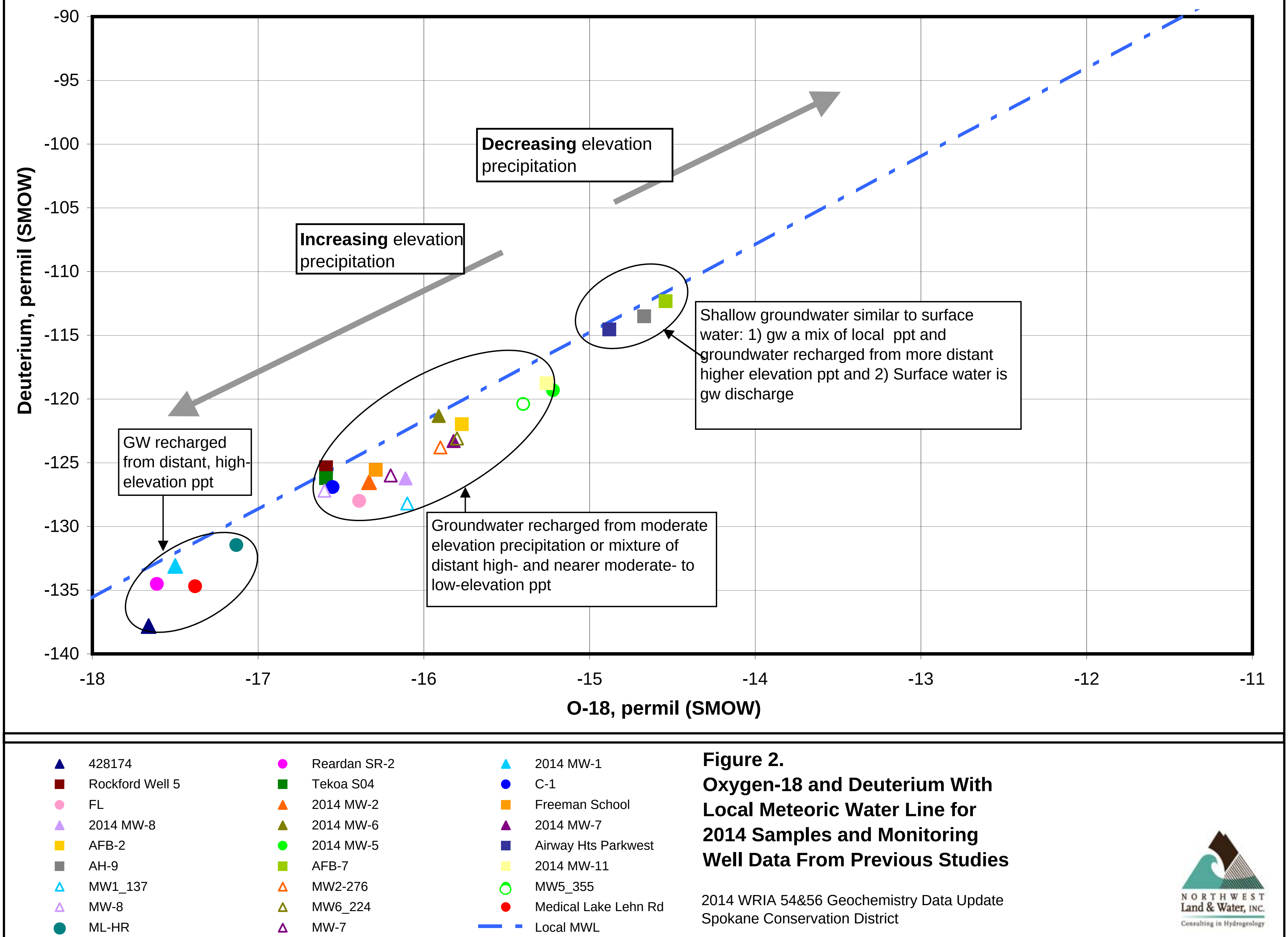

Figure 2.
Oxygen-18 and Deuterium With Local Meteoric Water Line for 2014 Samples and Monitoring Well Data From Previous Studies

2014 WRIA 54&56 Geochemistry Data Update
Spokane Conservation District

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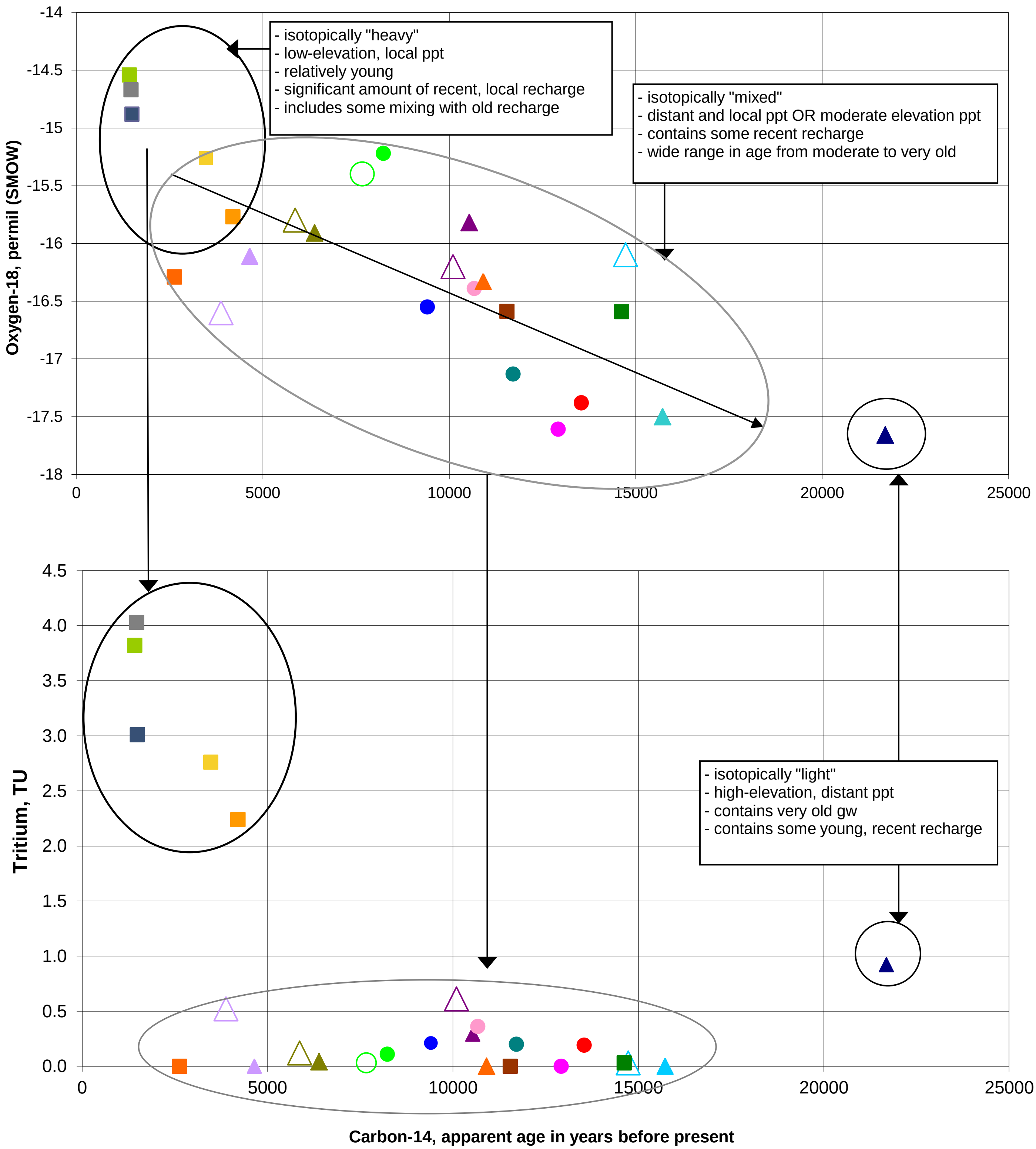

△MW1_137
△MW-8
▲2014 MW-2
▲2014 MW-7
▲428174
●ML-HR
●C-1
■AFB-2
■AH-9
○BH5_501
△MW-7
●2014 MW-5
▲2014 MW-8
●Reardan SR-2
■Rockford Well 5
●FL
■AFB-7
△MW6_224
◆2014 MW-1
▲2014 MW-6
■2014 MW-11
●Medical Lake Lehn Rd
■Tekoa S04
■Freeman School
■Airway Hts Parkwest

Figure 3
Oxygen-18, Carbon-14, and Tritium in 2014 Samples and MW Data From Previous Studies

2014 WRIA 54&56 Geochemistry Data Update
Spokane County Conservation District

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