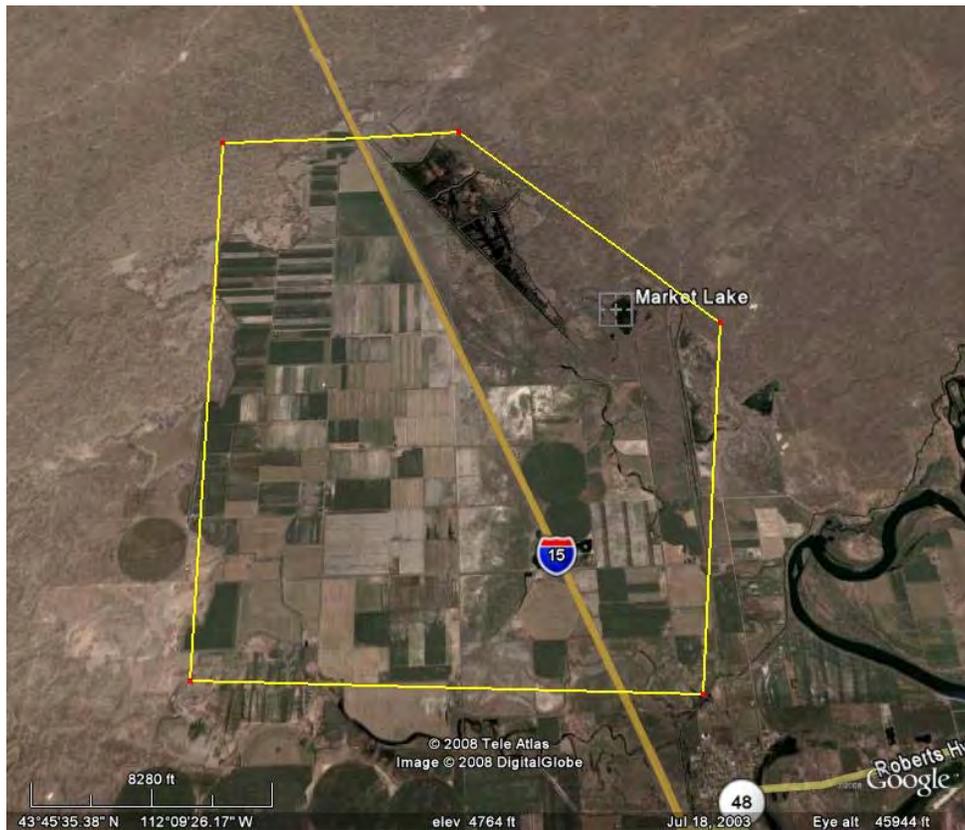


# Arsenic Occurrence in Ground Water in the Market Lake Area, Idaho

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## Abstract

This report presents the results and an evaluation of the data from a ground water quality study conducted from January through April 2008, near the town of Roberts, in Jefferson County, Idaho. The objective of the study was to evaluate the results from a previous study by Rocky Mountain Environmental Inc. (2006), which concluded that elevated arsenic concentrations reported in several domestic wells northwest of Roberts in the Market Lake area are from natural sources and are not further impacted by sand and gravel operations in the area.

Three sampling events were conducted from January 2008 through April 2008. Eight domestic wells, a pond from a previous sand and gravel operation, and a flowing artesian well were sampled to evaluate ambient arsenic concentrations in the study area. Domestic wells included shallow sandpoint wells less than 40 feet deep and deeper wells greater than 100 feet that penetrated through the alluvium and into the deeper basalt bedrock.

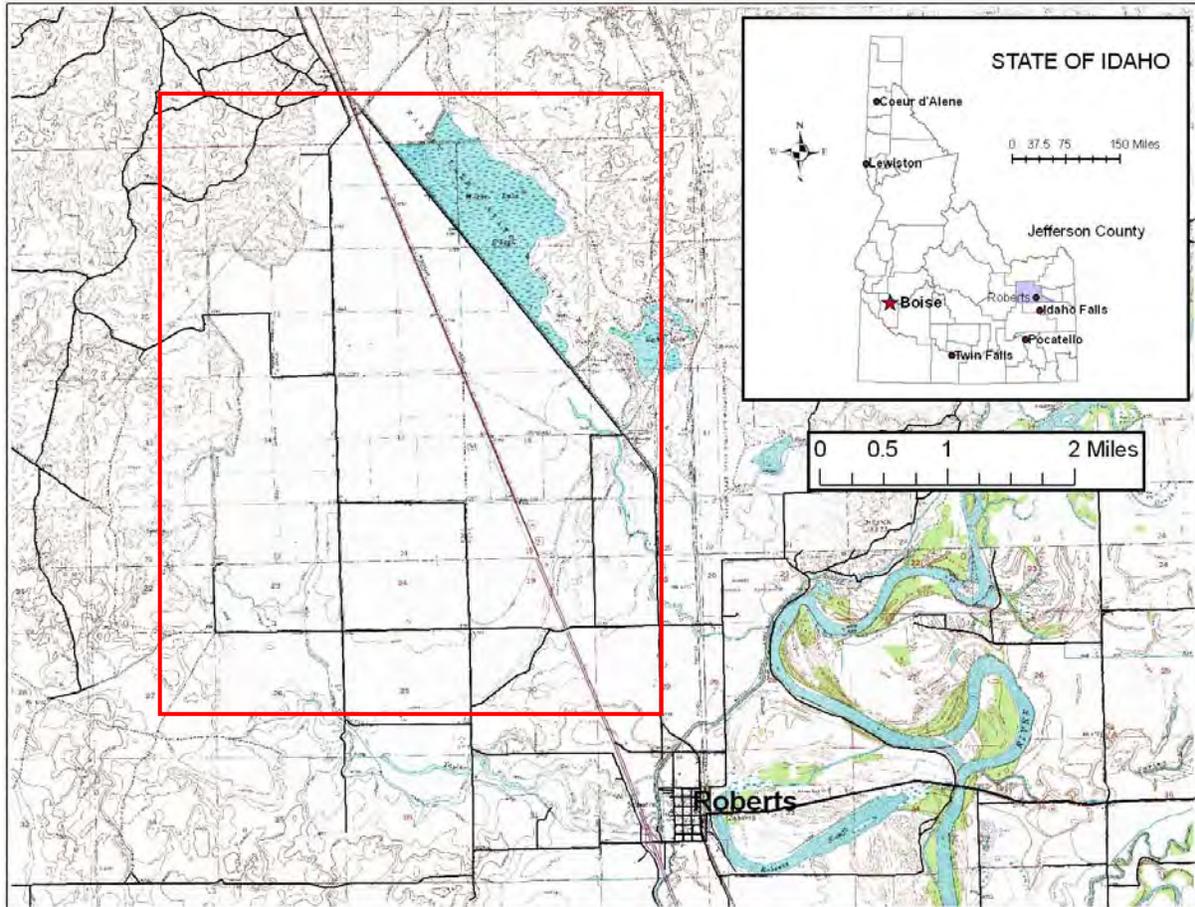
Ground water flow direction in the study area is generally toward the southwest, which is consistent with flow directions identified in the Snake River Plain Aquifer (SRPA). However, it's likely that local flow directions vary due to stratigraphic variation. The study area is encompassed by the Mud Lake – Market Lake barrier, consisting of saturated sedimentary deposits which form a low permeability zone within the highly transmissive SRPA. As a result, ground water tends to flow comparatively slower across this zone in contrast to the surrounding basalts of the SRPA. The stratigraphic variation creates an artesian component in the area which appears to bring deeper ground water up into the lacustrine sedimentary units.

Arsenic, the primary constituent of concern, was identified in all the samples collected for this study. All but one of the eight domestic wells sampled contained arsenic at concentrations greater than the Idaho Drinking Water Standard of 0.010 mg/l. An unused flowing artesian well also contained arsenic at concentrations above the Idaho Drinking Water Standard. Analytical data indicate that most wells in the area have low dissolved oxygen, and are high in iron, manganese, sulfate, sulfide, and arsenic. Arsenic concentrations in the shallow wells vary. The old gravel pit pond, located just east of Interstate 15, had arsenic concentrations above the drinking water standard.

Major ion results show evidence that the water chemistry varies significantly among the pond, the shallow aquifer, and the deeper aquifer. The deeper wells exhibited low dissolved oxygen levels (below 1 mg/L), while the shallow wells averaged dissolved oxygen concentrations of 1.2 mg/L. The oxygen isotope samples indicate a distinct recharge history for the deeper water (below 100 feet), shallow water (less than 40 feet), and the pond. Despite this different recharge history, arsenic concentrations are elevated in most of the shallow wells, all the deep wells, and the pond. The 2008 DEQ study concluded that elevated arsenic concentrations are present at all sampled depths, both up-gradient and down-gradient of the former gravel pit.

# Introduction

The objective of the study performed by the Idaho Department of Environmental Quality (DEQ) is to evaluate ambient arsenic ground water concentrations in the Roberts, Idaho area (Figure 1) in an effort to determine if elevated arsenic concentrations in the area are naturally occurring or if they may have been impacted by local sand and gravel operations.



**Figure 1.** Location map for Market Lake arsenic study area.

The study was prompted by a report produced by Rocky Mountain Environmental Associates Inc. (RME), dated August 11, 2006 (Rush, 2006), which intended to provide information on the potential impact of sand and gravel operations proposed by Walters Ready Mix of Rexburg, Idaho. The report indicated that several domestic wells in the area contain arsenic concentrations above the Idaho Drinking Water Standard (IDWS) of 0.010 mg/L. Residents also expressed concern that sand and gravel operations in the area were exacerbating the problem. The report concluded that the operation of a proposed gravel pit in the area would not cause arsenic concentrations to elevate in domestic water wells, nor would gravel pit operations negatively impact pre-existing arsenic contamination in the ground water.

This study was conducted to evaluate the RME report and to gather additional data over an expanded area. This was accomplished by reviewing available hydrogeological data, sampling eight domestic wells, an existing pond from a previous gravel operation in the area, and a flowing artesian well in the Market Lake Wildlife Management Area (MLWMA). Three sampling events were conducted, one in January, a second in March and the final event in April 2008. While the primary constituent of concern is arsenic, other parameters including anion/cations, additional metals, and the isotopes of oxygen, deuterium, and tritium were analyzed and evaluated in an effort to identify potential ground water source areas.

Concern over the potential effects of long-term, chronic exposure to arsenic in drinking water has prompted the U.S. Environmental Protection Agency (EPA) to reduce the drinking water standard for arsenic from 50 parts per billion (ppb) to 10 ppb, effective January 26, 2006. The standard applies to most public drinking water systems in Idaho. There is no regulatory oversight of private domestic well in Idaho so these well owners are not required to comply with the new arsenic standard. The Idaho Ground Water Quality Rule has established the Maximum Contaminant Level (MCL) for arsenic at 0.050 mg/L.

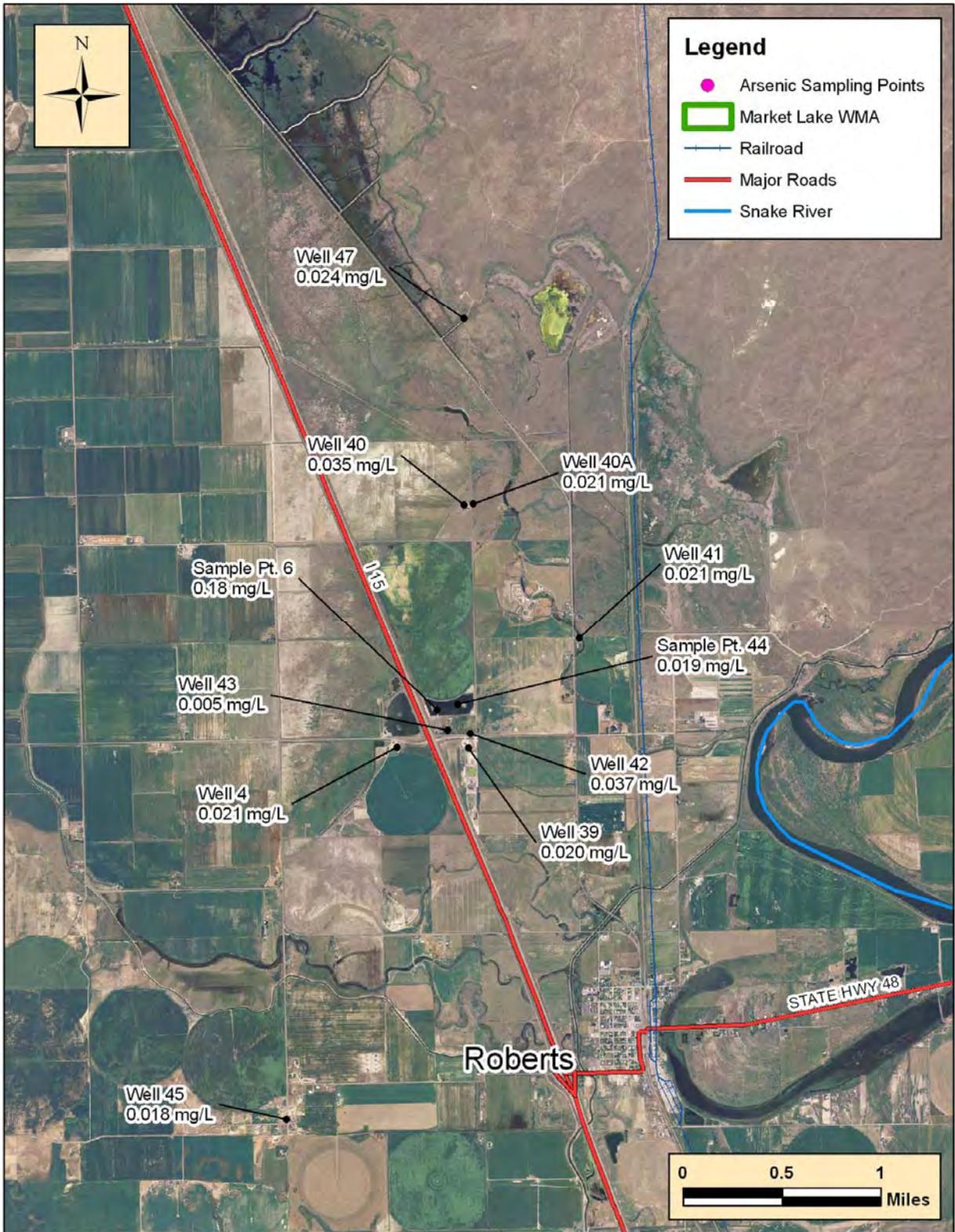
### ***Study Area Description***

The town of Roberts is located approximately 12 miles north of Idaho Falls along Interstate 15, on the Eastern Snake River Plain (ESRP). The study was focused on an area where several residential wells are located approximately two miles north-northwest of Roberts in Sections 19 and 20, Township 5 North, Range 37 East (T5N, R37E, S19 and S20), and extended north and east to the MLWMA. Another domestic well approximately two miles west of Roberts in the low-lying basalt ridges was sampled, and a flowing well on the MLWMA was sampled.

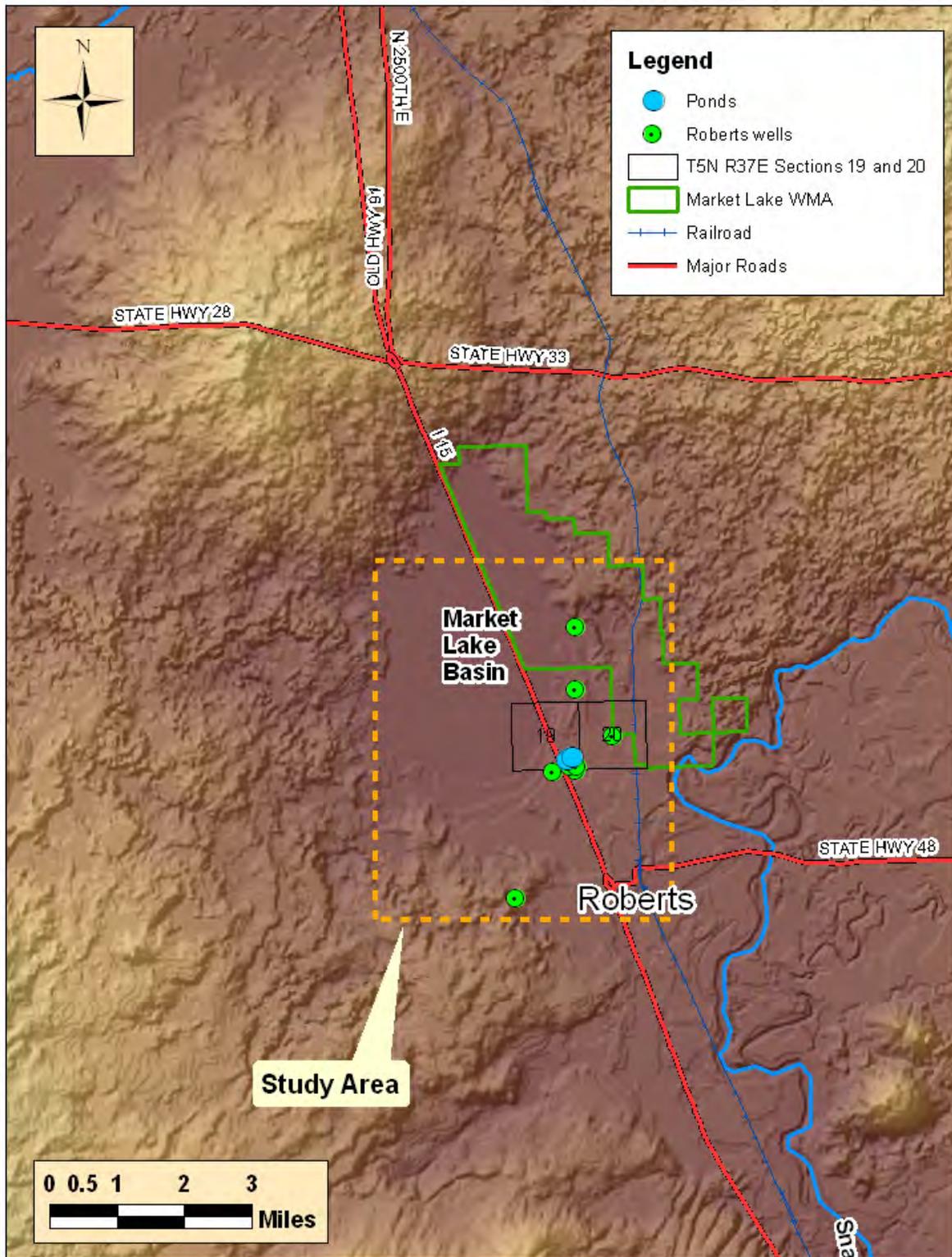
### **Location and Topography**

The study area is located on the ESRP, northwest of Roberts, Idaho, and is mostly enclosed by the Market Lake Basin (MLB) (Figure 3). The MLB is a small basin lying just west of the confluence of the Henry's Fork and South Fork of the Snake River. The MLB measures approximately 6 square miles and is surrounded to the northwest and south by low-lying basalt flows which encroach on the basin (IDWR, 2001). The study area is open to the Snake River to the southeast and is bounded by the Market Lake Wildlife Management Area to the northeast (Figure 2). The most prominent topographic feature in the area is the Menan Buttes which rise approximately 300 to 400 feet above the surrounding terrain. The MLB is separated from the larger Mud Lake basin by a low topographic rise only a few tens of feet high. The Mud Lake basin lies approximately

The topography in the Market Lake basin slopes from south to north, in contrast to the southwesterly slope of the regional land surface. The local northerly slope within the basin is probably a remnant of the original slope of the alluvial fan that originated from the South Fork of the Snake River and spread outward to the west in a classical fan-shaped deposit. The land surface elevation at the southern edge of the Market Lake basin is approximately 4,775 feet while the land surface elevation on the northern part of the basin is about 4,760 feet.



**Figure 2.** Study area and sampling points with average arsenic concentrations in milligrams per liter (mg/L).



**Figure 3.** Study area showing relief in the area of the Market Lake basin and wells and ponds sampled for this study. The green outline is the boundary of the Market Lake Wildlife Management Area.

## Surficial Geology

The surficial geology of the Market Lake area has been shaped by three major events. These are regional and localized subsidence, basaltic volcanism, and climatic cycles that controlled glaciation in the mountains east of the current Snake River Plain.

The ESRP is considered a regional subsiding basin related to the Yellowstone hotspot. The down warp is caused by loading associated with the passage of the North American plate over the Yellowstone hotspot. Localized subsidence on portions of the ESRP, based on high-precision leveling surveys, show evidence of a broad region of subsidence in and around the Market Lake area (Pelton, 1991; Reilinger et al., 1977). Subsidence of 2-3 mm/yr (1959-1967) just north of Market Lake is documented. Recent studies (Blair and Link, 2000; Blair, 2001), suggest localized fault-related subsidence has had an impact in the Market Lake area as well.

Basaltic volcanism controls the basic drainage patterns on the ESRP by constructing topographic barriers. This is evidenced by the low-lying ridges encompassing the MLB, Menan Buttes to the east, and the Little Grassy Butte lava flow to the north. These eruptive features have historically diverted the Henry's Fork and caused re-occurring lacustrine sedimentation in the Market Lake area (Allison, 2001).

Climatic cycles during the Pleistocene Period created several glacial episodes in the mountains east of the Snake River Plain. Glacial melt water streams interacted with changing volcanic topography to develop lakes in the Market Lake area. An increased sediment load in glacial fed streams caused the South Fork Snake River to dam the Henry's Fork. These glacial melt waters caused the Henry's Fork to flood or rapidly aggrade and fill the MLB with sediment (Allison, 2001). Additional lacustrine sediments were deposited in the MLB when the Snake River aggraded a terrace across Little Grassy Butte and Kettle Butte lava flows (Scott, 1982).

## Soils

Soils in the study area are transitional as the Snake River and its tributaries have meandered across the current and ancestral flood plain, and the Market Lake Basin was inundated as a result of cyclic climatic conditions and localized volcanism. Grain size generally decreases from east to west across the basin as fluvial sediments consisting of mostly sand, trend to lacustrine clays. According to Allison (2001), four distinct soil types are recognized in the study area; from east to west these include:

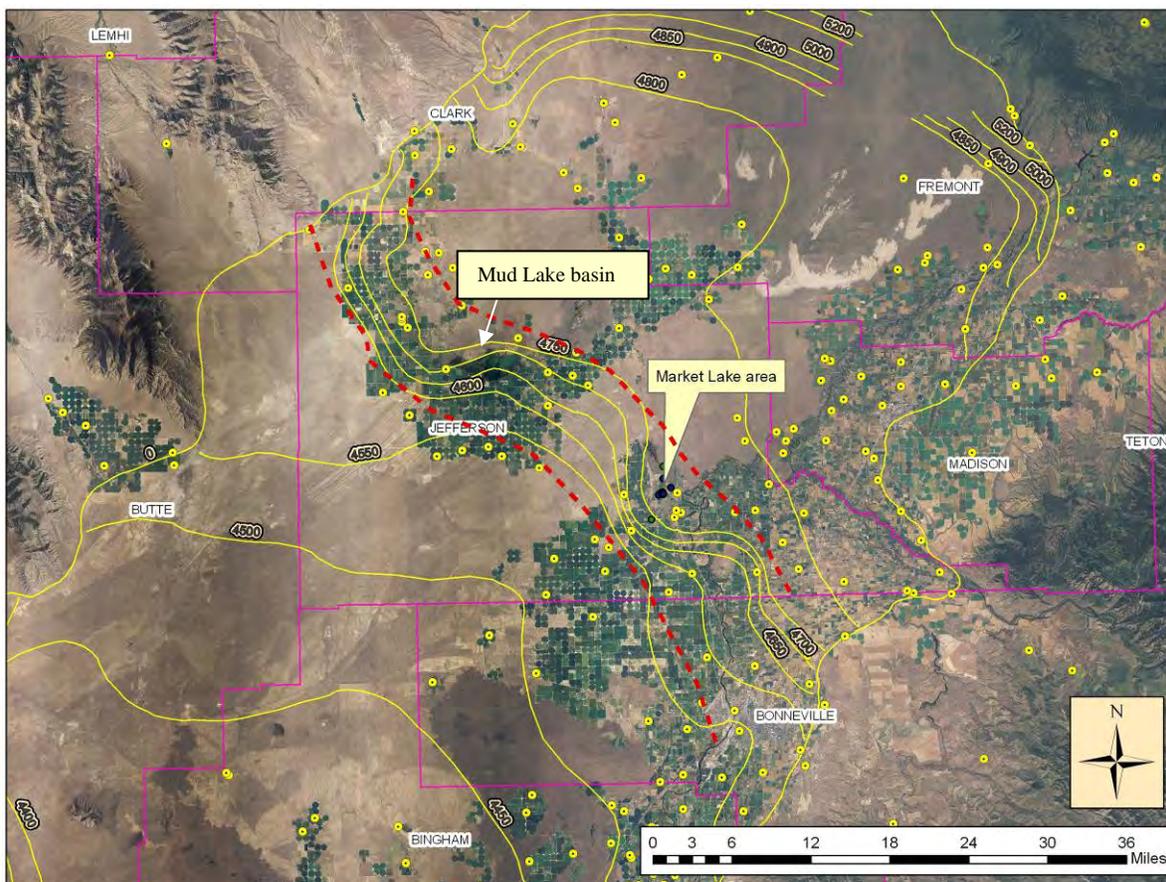
- The modern floodplain of the Snake River and tributaries: Light brown silt and fine-grained, subrounded quartz sand, locally contains rounded quartzite pebbles in fine sand matrix. Laminated to massive; may incorporate reworked alluvial gravels near Roberts.
- Volcanic lithic sand: black to tan, medium-grained to granule, subangular, poorly-sorted volcanic lithic sand. Quartz grains are generally more rounded and finer-grained than lithic. Thick packages of planar and trough crossbeds, scour surfaces, and fining upward sequences are common. Unit fines westward and becomes more volcanic-rich toward Market Lake.
- Lakeshore sand: black, medium to coarse-grained, subangular, poorly-sorted volcanic lithic sand. Becomes finer-grained toward Market Lake, becoming silty with medium-grained volcanic lithic fragments. Pinches out into the silt and clays of Market Lake.

- Lacustrine clay of Market Lake: gray, hard laminated clay, surface is mudcracked; eastern boundary of unit is a gradational contact with fine sands of the Lakeshore Sand. Depth of clays range from 1 meter near basalt flows on the edge of the basin to 2-3 meters in the center of the basin.

## Hydrogeology

Crosthwaite (1973) discussed a low permeable hydrologic barrier to the movement of ground water within the study area. This barrier, termed the Mud Lake – Market Lake barrier (barrier), extends from northwest of Mud Lake to southeast of Market Lake through the study area.

Crosthwaite summarized that northeast and southwest of the barrier (Figure 4), where the water-table gradients are low (5 to 10 feet per mile), a very permeable basalt is the principal water-bearing formation. At the barrier, where water table gradients are steep (30 to 60 feet per mile), the principal water-bearing formations are less permeable clays, silts, sands, and some gravel. As the water moves laterally through the barrier, it percolates downward through the sedimentary beds. As a result, depth to ground water increases toward the southwest. After irrigation began in the Market Lake area in the early 1900s, percolation of irrigated water caused an expansion of the perched water table in the sediments, thus increasing the volume of saturated sediments.



**Figure 4.** Ground water contours (in yellow) and approximate location of the Mud Lake – Market Lake Barrier, as indicated by dashed red lines (from Crosthwaite, 1973). Yellow symbols show location of wells with water level elevations used to generate the contours.

Northeast of the study area, well logs show basalt flows with interbedded sedimentary deposits. The alluvium which is at the surface west of the Henry's Fork is overlain by basalt of the Little Grassy Butte flow and underlain by earlier basalt flows west of the river. The alluvium pinches out near Market Lake. West of Market Lake, the lakebeds associated with the Terreton Basalts occur at the surface and thick lenses of sediments occur to depth.

The barrier signifies a change in geology across several miles of the Snake River Plain Aquifer (SRPA). Up-gradient of the barrier, the aquifer predominantly consists of sediments interbedded with numerous basalt flows. At the eastern edge of the barrier, these basalt flows pinch out, permeability decreases and ground water is forced to flow through less- transmissive, fine-grained sediments. Down-gradient from the barrier, sedimentary deposits pinch out and the principal water-bearing formations are basalt once again. As a result, the barrier acts as a transition zone from a sedimentary/basaltic sequence to a basaltic sequence (Crosthwaite, 1973). The significance of this feature to the study area is that the increased travel time through the sediments causes the ground water to remain in contact with basin sediments for an extended period of time. Borings in the western portion of the MLB (Allison, 2001) indicate significant amounts of organic material in the sediments which may create reducing conditions, raising the pH level, which, in conjunction with the extended ground water residence time, could generate a greater capacity to dissolve and mobilize additional compounds and metals.

For the purposes of this study ground water is discussed in terms of shallow and deep zones. Shallow ground water is considered to extend to depths of 40 feet below land surface, while deep ground water is considered to be greater than 40 feet below land surface. The distinction between shallow and deep ground water was mainly based on the depths of the wells available for sample collection. Three wells with depths ranging from 21 to 34 feet and one pond are representative of shallow ground water, while six wells ranging in depth from 100 to 200 feet are representative of deep ground water.

Well 47, located within the MLWMA (Figure 2) is a flowing well that was sampled during the project. The casing elevation of this well is about 4,755 feet. The total depth of the well was measured by DEQ at 176 feet below the top of the casing. When the well was sampled on April 23, 2008, the discharge was estimated at about 100 gallons per minute (gpm). When the well was visited on October 22, 2008, the flow was estimated at about 20 gpm. The flowing condition at this well may reflect the wells location within an area of steep water table gradient where westward moving ground water in permeable basalt encounters the less transmissive lake bed sediments in the Market Lake area. Also, the well is located in the bottom of a drain ditch. The top of the well casing is about five feet below the surrounding land surface and the elevation of the top of the casing is approximately the same as the water surface elevation in nearby ponds within the MLWMA; the low elevation of the casing may also contribute to the flowing condition at this well.

## ***Ground Water and Surface Water Chemistry***

### **Analytical Methods**

Table 1 lists laboratory analytical methods, preservatives, and holding times for ground water and pond samples collected during the study. Holding times and preservative requirements were

met with the exception of sulfide analysis. Sulfide analysis was conducted on water from the same sample container used for the major ion analysis; this container was not preserved with zinc acetate as recommended for the analytical method listed in Table 1.

**Table 1.** Analytical methods, preservatives and holding times for samples collected during the sample events.

Matrix	Parameter	Analytical Method	Preservative	Holding Time
Water	Total Dissolved Solids	EPA 160.1	4° C ± 2° C	28 days
Water	NO <sub>2</sub> +NO <sub>3</sub> -N	EPA 300.0	4° C ± 2° C	48 hours
Water	Chloride, Sulfate	EPA 300.0	4° C ± 2° C	28 days
Water	Alkalinity	SM2320 B	4° C ± 2° C, tightly capped	48 hours
Water	Total Dissolved Solids	EPA 160.1	4° C ± 2° C	28 days
Water	Ca, Mg, Na, K	EPA 200.8	4° C ± 2° C	28 days
Water	Fe, Mn, As	EPA 200.8	4° C ± 2° C	28 days
Water	NH <sub>3</sub> – N	EPA 350.1	4° C ± 2° C	28 days
Water	<sup>15</sup> N	TP11	Freeze samples	Unlimited if frozen
Water	<sup>18</sup> O	TP13	None	None
Water	Deuterium	TP04	None	None
Water	Sulfide	SM4500-S <sup>2</sup> -F	See note	See note

**Sulfide analysis** – recommended preservatives are zinc acetate and pH adjustment with sodium hydroxide to a pH >9.0. Preservatives were not available at the time of sample collection so sulfide analysis was conducted on an unpreserved chilled sample.

In an effort to distinguish relationships between the surface water, the shallow ground water and deep ground water, samples were collected to characterize the water chemistry in the study area. Field parameters (Table 2, page 18) were collected for each sample and anions and cations (Table 3, page 19) were analyzed for the majority of the samples for two of the three sampling events. Arsenic was analyzed in each sample throughout the study. Secondary drinking water standard metals including iron and manganese were analyzed for one event (Table 4, page 21). The stable isotopes of oxygen and deuterium were analyzed during two sample events and tritium was analyzed at seven wells for one sampling event (Table 5, page 22).

### Field Parameters

Field parameters, including pH, specific conductance, temperature, and dissolved oxygen (DO) were recorded during each sample event. Plots of well depth vs. specific conductance and well depth vs. DO do not show any variation with depth. The most notable field parameter feature was the low DO levels found in most of the deeper ground water samples. DO concentrations from samples collected in the deeper zone were all less than 1.0 mg/L, indicating an oxygen-deficient or anaerobic environment. Of the three shallow wells, Well 40 showed very low DO levels, while Well 43 averaged 1.3 mg/L and Well 40a had a DO value of 4.6 (Table 2). The pH level in wells deeper than 100 feet averaged approximately 8.24, consistent with a more anaerobic aquifer. Field parameters for the pond samples varied as the pond was sampled twice beneath an ice cover and once after the ice melted. The most prominent feature of the pond

water was the high pH level, which averaged approximately 9.8. The combination of high pH and low DO appears to be commonly associated with elevated arsenic concentrations in the MLB.

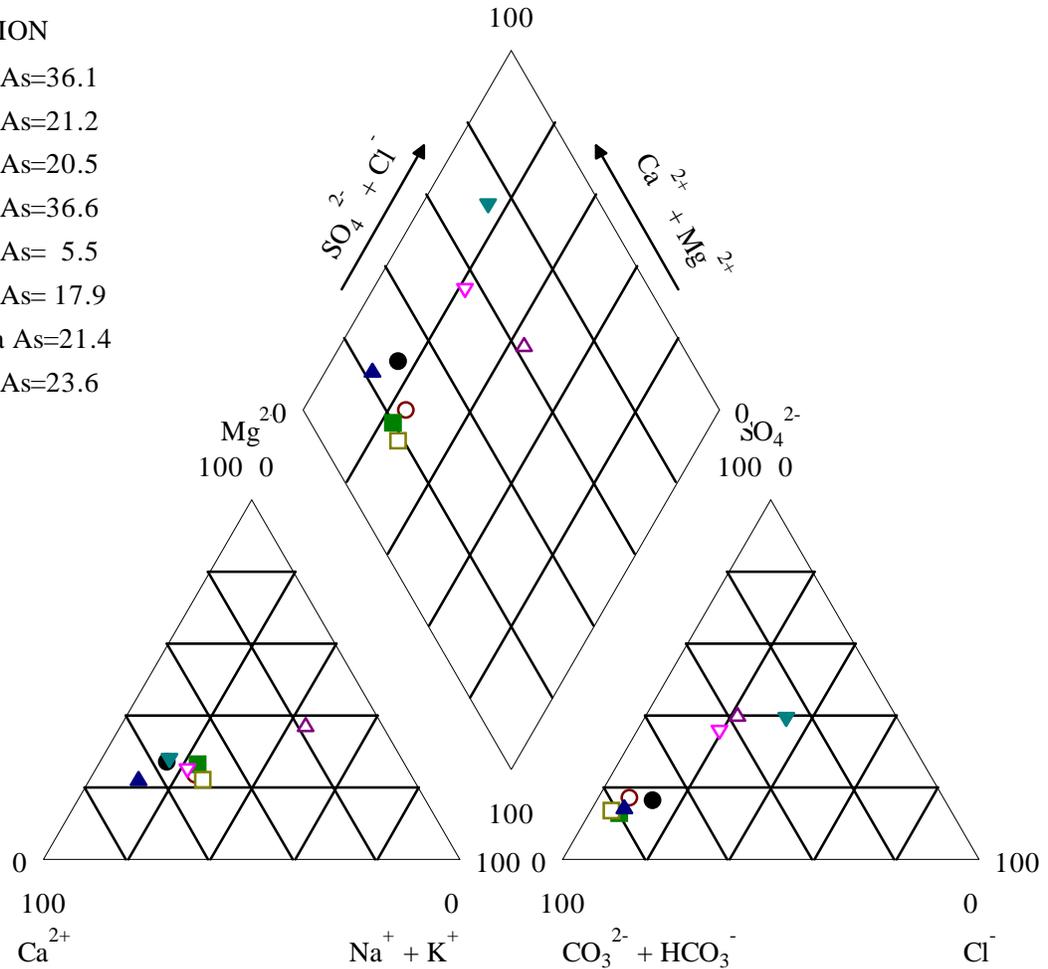
### **Anion/Cation Analysis**

Anion/cation analyses were performed to help identify potential sources of recharge and similarities in the water chemistry within the study area. Samples were collected in six domestic wells, at an old gravel pond, and from a flowing well located in the MLWMA. Figure 5 presents a Piper trilinear diagram of the water chemistry of the domestic wells, the pond, and the artesian well. The results (Table 23 and Figure 5) show a distinct chemistry difference in the pond water compared to the ground water. The pond water showed elevated concentrations of chloride, sodium, sulfate, and potassium. The shallow wells showed elevated concentrations of calcium and nitrogen compared to the deeper wells; however, Well 40 showed higher concentrations of magnesium (Mg), sodium (Na), chlorine (Cl), sulfate, nitrate and sulfide than the other shallow wells.

Results from the anion/cation analyses provide a good line of evidence indicating that water chemistry varies significantly among the pond, the deeper aquifer, and the shallow water wells. Results from the January 15, 2008 sampling event of most wells and the April 15, 2008 samples from wells 40a and 47 are displayed in a Piper diagram (Figure 5). Water chemistry indicates that there is no connection between the pond (DEQ 44) and well 43 (DEQ 43) located approximately 100 yards south of the pond. The Piper diagram shows that deep wells (4, 39, 41, 42, 45 and 47) have very similar water chemistry with the exception of well 47, the flowing artesian well. Well 47 had a higher percentage of chloride and sulfate compared to the other deep wells. The reason for this difference is unknown.

#### EXPLANATION

- DEQ 40 As=36.1
- DEQ 04 As=21.2
- DEQ 41 As=20.5
- DEQ 42 As=36.6
- ▲ DEQ 43 As= 5.5
- △ DEQ 44 As= 17.9
- ▼ DEQ 40a As=21.4
- ▽ DEQ 47 As=23.6



**Figure 5.** Piper diagram, showing water chemistry for shallow and deep wells and the pond.

### **Isotope Results**

Samples were analyzed for the isotopes of oxygen and deuterium ( $^{18}\text{O}$  and  $^2\text{H}$ ), in order to consider the ratio between these two isotopes and what it may mean in this study, and for tritium, the presence of which provides further information, depending on its concentration.

### **Oxygen and Deuterium Background**

The stable isotope ratios of oxygen and deuterium in atmospheric water vapor are subject to changes that begin when water evaporates from the ocean. Oxygen and deuterium isotope ratios continue to evolve as an air mass moves inland and the water vapor condenses to form precipitation. Oxygen and deuterium isotope ratios in precipitation can vary for different storm events in a particular area and for summer versus winter storm events from the same area. Isotope ratios can also vary for storm events that occur at different latitudes and at differing altitude and/or temperature conditions. Once precipitation infiltrates and enters the ground water system, further changes in oxygen and deuterium ratios are limited because evaporative processes are no longer active. Seasonal isotopic variations in the recharged water become

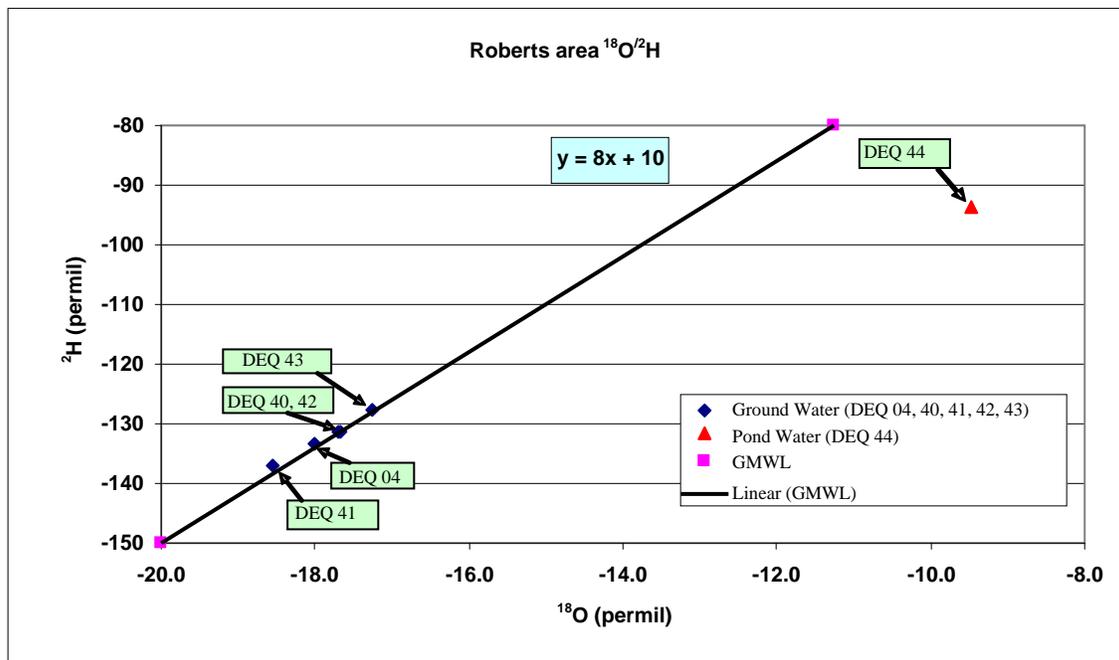
dampened out once the water enters an aquifer. Oxygen and deuterium results are often compared to the Global Meteoric Water Line (GMWL) which describes the worldwide relationship between oxygen and deuterium in worldwide fresh surface waters. The equation describing a best fit line for these data is:

$$\delta H = 8\delta^{18}O + 10 \text{ o/oo SMOW (Craig, 1961)}$$

### Oxygen and Deuterium Results

Figure 6 shows a plot of oxygen versus deuterium for samples collected in the Roberts area as part of this study. The isotopic results for the pond samples show significant evaporation of this source, resulting in a plotting position in the upper right area of the graph. Because of this unique signature, oxygen and deuterium isotopes can serve as a useful indicator that nearby shallow and deeper aquifer wells are not impacted by the pond.

Table 5 presents the results of the isotope samples. The results indicate two signatures, one distinct signature for the pond (DEQ 44) and a second signature for wells 4, 40, 41, 42 and 43. Isotope results from the pond sample indicate that this surface water body has undergone significant evaporation resulting in water with a higher proportion of the heavier isotopes of oxygen and deuterium. This distinct isotopic signature can serve as an excellent tracer and should be detectable in nearby wells if water were migrating from the pond to the wells. Shallow well 43 is about 500 feet south of the pond but the pond isotopic signature was not detected in the well, an indication that ground water is moving from east to west in the area in accordance with the flow direction shown on the potentiometric map (Figure 4).



**Figure 6.** Plot of oxygen versus deuterium results

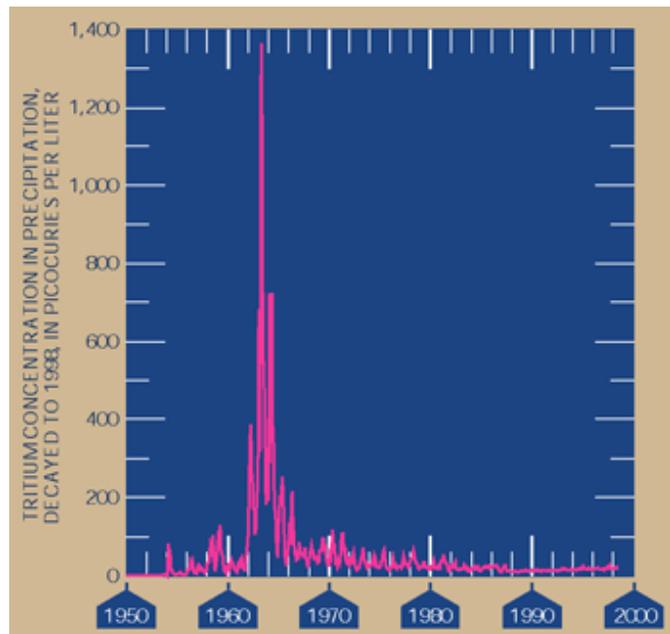
## Tritium Background

The following discussion is summarized from Cook and Herczeg (2000) and U.S. Geological Survey sources (<http://toxics.usgs.gov/definitions/tritium.html>). Tritium is the common name for hydrogen-3 ( $^3\text{H}$ ), which is a radioactive isotope of hydrogen. Like ordinary hydrogen ( $^1\text{H}$ ) and deuterium ( $^2\text{H}$ ), tritium has a single proton in its nucleus. Unlike ordinary hydrogen, deuterium and tritium have neutrons in their nucleus. Deuterium has one neutron in its nucleus and is stable, while tritium's nucleus contains two neutrons and is unstable. Tritium decays spontaneously to helium-3 ( $^3\text{He}$ ) through ejection of a beta particle (essentially a high-energy electron). The half-life of tritium is about 12.32 years.

The tritium content of water is usually expressed in tritium units (TU), where one tritium unit represents 1 tritium atom in 1,018 hydrogen atoms. In picocuries per liter, 1 TU is approximately 3.19 picoCuries per liter (pCi/L). Tritium occurs in very small quantities naturally, being produced in the upper atmosphere by cosmic rays. Natural (pre-nuclear age) levels of tritium in precipitation are on the order of 1 to 5 TU. Atmospheric nuclear-weapons testing during the 1950s and 1960s introduced relatively large amounts of tritium into the atmosphere that can be detected in ground water that was recharged during this period.

## Using Tritium to Date the Age of Ground Water

Tritium can be used to estimate whether ground water has been recharged before or after 1953; 1953 marks the onset of much of the U.S. atmospheric weapons testing program. Tritium in the atmosphere quickly combines with water vapor, which can subsequently condense to form precipitation (rain, hail, sleet, or snow). The amount of tritium in infiltrating precipitation that subsequently becomes ground-water recharge is controlled primarily by the quantity of tritium in the atmosphere when the precipitation formed, plus the length of time it takes water to move from the land surface to the water table. Because tritium decays with a half-life of 12.32 years, ground water that does not contain detectable tritium is inferred to have infiltrated into the subsurface prior to 1953. Conversely, ground water that contains detectable tritium is inferred to contain at least some water that infiltrated after 1953.



Tritium concentrations in the atmosphere. [Image from USGS Circular 1213](#)

## Tritium Results

Samples for tritium analysis were collected from seven wells during the April 2008 sample event. The results, listed in Table 5 show that five of the seven samples had tritium levels that

ranged from 23 to 34 pCi/L (7 to 11 TU). These tritium results are consistent with the tritium concentration in modern surface water. Two samples had tritium levels of 4 and 7 pCi/L (1 and 2 TU). These results are considered to represent water that infiltrated prior to the onset of atmospheric weapons testing in 1953, and as such, this water has been isolated from recent recharge. Well 41, which had a tritium level of 1 TU has a total depth of 200 feet. Well 47, which had a tritium level of 1 TU is a flowing well and is also located in the eastern, up-gradient part of the study area. A driller's log is not available for Well 47, but the well depth was measured at 176 feet by DEQ. There is no agricultural land east (up-gradient) of well 47 and limited agricultural land east of well 41. Tritium concentrations in wells west of these two wells may represent infiltration of modern day irrigation water, while ground water at wells 41 and 47 may represent water that entered the flow system prior to the onset of atmospheric weapons testing.

Wells 4, 39, and 42 had tritium levels of 34, 26, and 25 pCi/L, respectively (11, 8, and 8 T.U., respectively). These wells range in depth from 100 to 120 feet, according to drillers' logs. Elevated tritium at these wells could be due to infiltration of irrigation water which has a modern tritium signature.

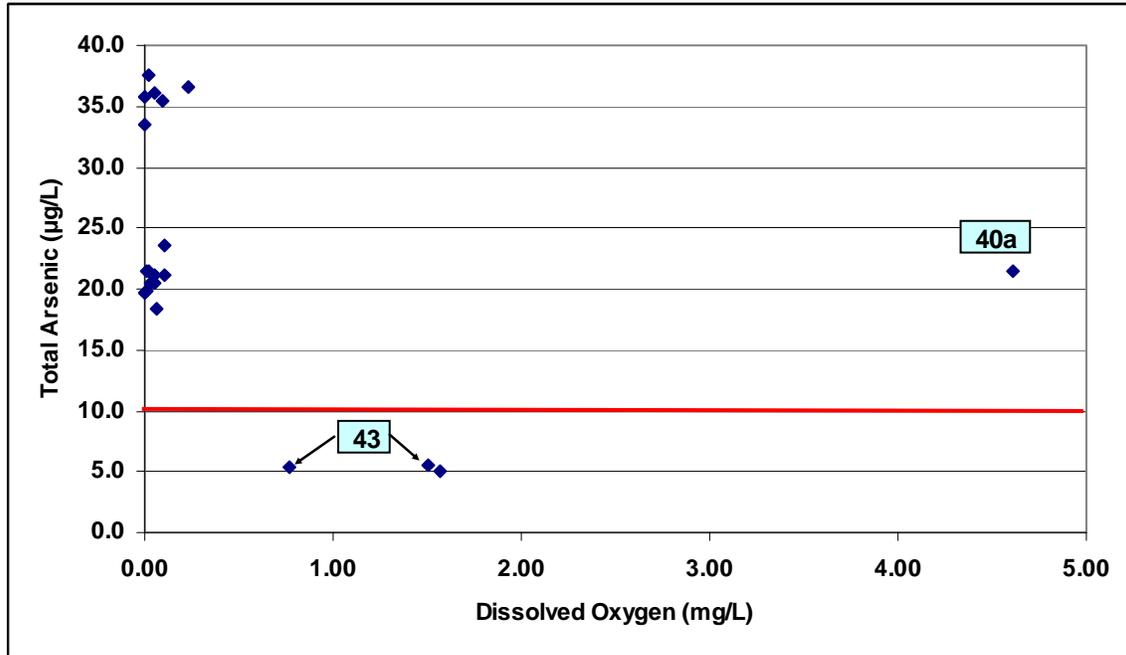
Tritium results are consistent with the conceptual model of the basin, in that regional ground water moving west encounters the low-permeability Market Lake sediments. The ground water flow velocity within these lacustrine sediments is likely slower than within the regional flow system resulting in a longer residence time for ground water within the sediments.

### ***Arsenic and Other Constituents With Secondary Drinking Water Standards***

Arsenic was identified in every sample collected during this study. Concentrations were higher than the drinking water standard (DWS) of 0.010 mg/L in all samples except those collected from the shallow domestic Well 43 (Table 4). Arsenic concentrations in the pond averaged 0.0185 mg/L. The average arsenic concentrations in wells 100 feet and deeper averaged 0.027 mg/L, while concentrations in the shallow wells varied from 0.032 mg/L in the shallow wells 40 and 40a, to 0.005 mg/L in shallow well 43. The arsenic concentration in the flowing artesian well was 0.024 mg/L. This well lies up-gradient from the residences and is considered to best represent background ambient conditions for deep ground water in the area.

The average arsenic concentrations indicate that elevated arsenic concentrations are the norm in this area, as are low dissolved oxygen concentrations (Figure 7). Well 43 was the only well with arsenic concentrations below the DWS. The fact that arsenic concentrations in the three shallow wells vary as they do is likely a function of where the well is completed in the lacustrine deposits. It is anticipated that arsenic concentrations may be higher in the finer-grained sediments of the old Market Lake bed, due to the longer ground water residence time and anaerobic conditions within these sediments. However, the analytical data from the sampling events show that elevated arsenic is present in wells that produce water from both the lacustrine sediments and underlying basalt units that are 100 to 200 feet deep. Based on these data, there do not appear to be any units that would provide arsenic-free water within the basin.

Total iron and manganese, which have secondary DWS of 0.300 mg/L and 0.050 mg/L, respectively, were analyzed for during the April 2008 sampling event. Results indicate that iron and manganese exceeded the secondary DWS in wells 40, 40a, 4, 41, 42, 39, and the flowing well (47). Elevated iron and manganese concentrations in Market Lake ground water is probably an area-wide condition, especially in the deeper ground water, indicating that ambient concentrations of these metals will commonly exceed the secondary drinking water standard.



**Figure 7.** Plot of arsenic concentrations vs. dissolved oxygen for ground water samples collected by DEQ.

## Conclusions

The objective of the study was to determine if elevated arsenic concentrations in the Roberts area are naturally occurring or if anthropogenic sources of arsenic could be identified. To accomplish this, three sampling events were completed over a period of four months, from several ground water wells and one pond.

Analytical results indicate that elevated arsenic concentrations above the DWS are naturally occurring throughout the study area. Deep wells, greater than 40 feet, all had elevated arsenic concentrations, averaging 0.027 mg/L, or almost three times the DWS. Arsenic concentrations in shallow wells varied with location and depth. Seven of the eight domestic wells sampled in the area contained arsenic concentrations greater than the DWS.

Based on the analytical results, literature search, and conversations with residents in the area, it appears that elevated arsenic concentrations in the study area are naturally occurring and that impacts from anthropogenic sources are negligible. Lines of evidence to support these conclusions include:

- All of the wells greater than 100 feet in depth within the study area had elevated arsenic concentrations as well as elevated iron and manganese concentrations.
- Wells 40 and 40a, completed in the shallow lacustrine/fluvial sediments, had elevated arsenic, iron, and manganese concentrations. Therefore, it is concluded that elevated concentrations of arsenic and metals (iron and manganese) are not limited to a single zone of saturation. This may be attributed to anaerobic conditions within the aquifer and long ground water residence times in the low permeability sediments. The lacustrine sediments may contain elevated, naturally occurring arsenic but this condition was not evaluated as part of this study.
- The flowing artesian well within the Market Lake Wildlife Management Area is considered to be an up-gradient well based on flow patterns throughout the area. The cation water chemistry of this well is nearly identical to other shallow and deep wells in the study area; the anion water chemistry is similar to a pond sample and a shallow well (well 40a).
- The only sample that meets the Idaho Drinking Water Standard for arsenic was from shallow Well 43 (average 0.0053 mg/L), which is approximately 25 feet deep. This well is located approximately 100 yards south of an existing gravel quarry pond, which has elevated arsenic concentrations (average 0.0185 mg/L), and approximately 200 yards west of Well 42 (average 0.0365 mg/L), a deep well with the highest average arsenic concentrations in the study area. Water chemistry strongly suggests that there is no hydraulic connection among Well 43, the pond, and the deep ground water.
- Low dissolved oxygen, no or low nitrate concentrations, detections of ammonia and hydrogen sulfide, and elevated iron and manganese all point to a ground water environment with anoxic conditions that favor the release of arsenic from sediments. This particular geochemical environment indicates that elevated arsenic observed in ground water is not from surficial or anthropogenic sources.
- Previous analytical results in the Idaho Department of Water Resources (IDWR, 2007) database indicate elevated arsenic concentrations in the Roberts area with generally decreasing concentrations west and southwest of the Market Lake lacustrine deposits.

This may indicate that ground water southwest of the Market Lake barrier exists in a more transmissive environment characteristic of the Snake River Plain Aquifer where the aquifer is aerobic and contains arsenic concentrations below the DWS.

## **Recommendations**

As a result of this study, it has become apparent that elevated concentrations of arsenic and other constituents with secondary drinking water standards are present in the Roberts area, and that residents are concerned about their drinking water. It is also likely that additional residents outside of this study area have elevated concentrations of arsenic and/or secondary drinking water constituents in their ground water. Therefore, the following recommendations are made:

- Further investigation should be undertaken, to more thoroughly define the extent of this naturally occurring arsenic. The most likely area of investigation lies to the east of the Market Lake area.
- Also, cores obtained from wells drilled as part of a Masters Thesis conducted in the Market Lake area should be evaluated to determine whether the lacustrine sediments present in the Market Lake basin contain arsenic concentrations above background levels. These cores have been in storage at the Idaho State University. Selected portions of these core samples could be evaluated using the Department's XRF unit (X-Ray Fluorescence).
- Consideration should be given to a water testing event where private domestic well owners from the area can submit water samples for arsenic analysis. This information could be used in an expanded sampling program to determine the areal extent of ground water with elevated arsenic.

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**Table 2.** Field parameters for Roberts area samples collected from January through April, 2008.

DEQ ID	Sample Date	Sample Time	Well Depth (ft)	Field Parameters			
				pH (units)	Sp Cond (uS/cm)	Temp (deg C)	D.O. (mg/L)
40	1/15/2008	13:03	34	7.45	506	10.7	0.05
40	3/10/2008	16:55	34	7.85	645	10.7	0.00
40	4/23/2008	16:06	34	8.16	656	10.9	0.00
40a	4/24/2008	8:45	21	8.09	775	8.6	4.61
4	1/15/2008	10:05	120	7.74	312	8.8	0.11
4	3/11/2008	10:00	120	8.93	392	7.6	0.02
4	4/23/2008	15:10	120	8.20	398	7.3	0.01
41	1/15/2008	12:25	200	7.75	290	9.3	0.03
41	3/11/2008	11:13	200	9.06	373	9.6	0.05
41	4/23/2008	15:45	200	8.51	375	9.8	0.01
42	1/15/2008	11:25	100	7.33	292	11.8	0.23
42	3/10/2008	15:23	100	7.59	374	11.8	0.09
42	4/23/2008	18:30	100	8.49	377	12.1	0.02
43	1/15/2008	10:45	25	6.77	312	14.0	1.50
43	3/10/2008	16:40	25	7.67	377	12.5	1.57
43	4/23/2008	14:20	25	7.97	413	11.8	0.77
44	1/15/2008	14:00	Pond	9.65	469	3.7	3.73
44	3/11/2008	8:40	Pond	10.19	688	3.4	0.70
44	4/24/2008	8:15	Pond	9.56	614	6.8	10.73
39	3/10/2008	17:50	120	7.76	403	10.7	0.00
39	4/23/2008	14:44	120	8.17	425	11.0	0.05
45	3/11/2008	10:40	101	8.61	1130	9.4	0.06
6	1/15/2008	14:45	Pond	9.68	483	3.5	5.34
47	4/23/2008	18:00	176	8.98	360	9.2	0.11

**Table 3.** Laboratory results for Roberts area samples collected during the period January through April, 2008.

DEQ ID	Sample Date	Sample Time	Well Depth (ft)	Laboratory Parameters												
				Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	CO3 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	SO4 (mg/L)	TDS (mg/L)	Alkalinity (mg/L, as CaCO3)	NO2+NO3-N (mg/L)	Sulfide H2S (mg/L)	NH3-N (mg/L)
40	1/15/2008	13:03	34	85.8	25.2	24.3	5.16	0	318	34.3	58.2	471	261	1.33		
40	3/10/2008	16:55	34	78.6	23.8	22.8	4.90									
40	4/23/2008	16:06	34							35.4	60.4	469		1.97	0.111	<b>0.05</b>
40a	4/24/2008	8:45	21	94.9	29.3	28.8	6.76	0	71	51.5	80.3	558	58	5.14	0.117	<b>0.05</b>
4	1/15/2008	10:05	120	46.5	12.8	22.7	5.14	0	195	10.8	35.5	292	160	<b>0.01</b>		
4	3/11/2008	10:00	120	44.3	12.7	22.8	5.16									
4	4/23/2008	15:10	120							11.2	36.4	286		0.035	0.0765	0.175
41	1/15/2008	12:25	200	47.6	15.4	23.1	5.25	0	206	10.6	26.1	297	169	<b>0.01</b>		
41	3/11/2008	11:13	200	39.8	13.5	20.2	4.57									
41	4/23/2008	15:45	200							11.1	27.0	274		<b>0.01</b>	0.0775	0.219
42	1/15/2008	11:25	100	42.9	11.3	23.6	5.10	0	256	9.7	33.0	208	210	<b>0.01</b>		
42	3/10/2008	15:23	100	40.4	10.8	22.6	4.95									
42	4/23/2008	18:30	100							10.1	34.0	279		<b>0.01</b>	0.0749	0.15
43	1/15/2008	10:45	25	60.3	12.4	10.6	2.84	0	221	12.4	32.4	303	181	<b>0.00</b>		
43	3/10/2008	16:40	25	55.7	11.8	10.1	2.64									
43	4/23/2008	14:20	25							8.1	36.0	279		0.55	0.113	<b>0.05</b>
44	1/15/2008	14:00	Pond	24.9	29.9	57.1	18.60	0	149	49.7	122.0	433	122	<b>0.01</b>		
44	3/11/2008	8:40	Pond	25.7	31.8	60.2	19.40									
44	4/24/2008	8:15	Pond							44.4	103.0	442		<b>0.01</b>	0.078	<b>0.05</b>
39	3/10/2008	17:50	120	49.8	13.4	23.5	5.30									
39	4/23/2008	14:44	120							13.0	39.6	300		<b>0.01</b>	0.0756	0.183

DEQ ID	Sample Date	Sample Time	Well Depth (ft)	Laboratory Parameters												
				Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	CO3 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	SO4 (mg/L)	TDS (mg/L)	Alkalinity (mg/L, as CaCO3)	NO2+NO3-N (mg/L)	Sulfide H2S (mg/L)	NH3-N (mg/L)
45	3/11/2008	10:40	101	86.1	29.0	139.0	6.81									
6	1/15/2008	14:45	Pond	25.1	30.2	57.9	18.20	0	150	50.0	124.0	453	123	<b>0.01</b>		
47	4/23/2008	18:00	176	39.2	11.1	16.4	4.73	0	45	11.5	29.2	281	37	<b>0.01</b>	0.0753	0.16

**Table 4.** Arsenic, iron and manganese results for samples collected in the Roberts area, January through April 2008.

DEQ ID	Sample Date	Sample Time	Well Depth (ft)	Total As mg/L	Total Fe mg/L	Total Mn mg/L
40	1/15/2008	13:03	34	0.0361		
40	3/10/2008	16:55	34	0.0335		
40	4/23/2008	16:06	34	0.0358	0.365	0.581
40a	4/24/2008	8:45	21	0.0214	0.453	0.083
4	1/15/2008	10:05	120	0.0212		
4	3/11/2008	10:00	120	0.0214		
4	4/23/2008	15:10	120	0.0199	0.898	0.371
41	1/15/2008	12:25	200	0.0205		
41	3/11/2008	11:13	200	0.0205		
41	4/23/2008	15:45	200	0.0214	0.511	0.267
42	1/15/2008	11:25	100	0.0366		
42	3/10/2008	15:23	100	0.0354		
42	4/23/2008	18:30	100	0.0375	0.817	0.380
43	1/15/2008	10:45	25	0.0055		
43	3/10/2008	16:40	25	0.0050		
43	4/23/2008	14:20	25	0.0054	0.295	0.001
44	1/15/2008	14:00	Pond W	0.0179		
44	3/11/2008	8:40	Pond W	0.0190		
44	4/24/2008	8:15	Pond W	0.0190	0.214	0.009
39	3/10/2008	17:50	120	0.0197		
39	4/23/2008	14:44	120	0.0212	0.833	0.501
45	3/11/2008	10:40	101	0.0184		
6	1/15/2008	14:45	Pond E	0.0181		
6	3/11/2008	8:45	Pond E	0.0188		
47	4/23/2008	18:00	176	0.0236	0.553	0.387

**Table 5.** Oxygen, deuterium and tritium isotope results for samples collected in the Roberts area January through April, 2008.

DEQ ID	Sample Date	Sample Time	Well Depth (ft)	Isotopes		
				<sup>18</sup> O (per mil)	<sup>2</sup> H (per mil)	Tritium (pCi/L)
40	1/15/2008	13:03	34	-17.7	-131	
40	3/10/2008	16:55	34			
40	4/23/2008	16:06	34	-18.0	-133	26 ± 6
40a	4/24/2008	8:45	21	-17.2	-127	
4	1/15/2008	10:05	120	-18.0	-133	
4	3/11/2008	10:00	120			
4	4/23/2008	15:10	120	-18.0	-133	34 ± 6
41	1/15/2008	12:25	200	-18.6	-137	
41	3/11/2008	11:13	200			
41	4/23/2008	15:45	200	-18.5	-136	4 ± 6
42	1/15/2008	11:25	100	-17.7	-131	
42	3/10/2008	15:23	100			
42	4/23/2008	18:30	100	-17.7	-129	25 ± 7
43	1/15/2008	10:45	25	-17.3	-128	
43	3/10/2008	16:40	25			
43	4/23/2008	14:20	25	-17.2	-128	23 ± 6
44	1/15/2008	14:00	Pond	-9.5	-94	
44	3/11/2008	8:40	Pond			
44	4/24/2008	8:15	Pond	-11.1	-100	
39	3/10/2008	17:50	120			
39	4/23/2008	14:44	120	-18.0	-132	26 ± 7
45	3/11/2008	10:40	101			
6	1/15/2008	14:45	Pond	-9.6	-93	
47	4/23/2008	18:00	176	-18.6	-136	7 ± 5