

**Stratigraphic and structural controls of ground water  
flow in the Pahsimeroi Basin, Idaho: Insights from  
geophysical data**

**Report prepared for the Bureau of Land Management**

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**Technical Report BSU CGISS 06-01  
Boise State University Department ID# 693G106123 (6FE15CCIX0002)  
30 September, 2006**

## Summary

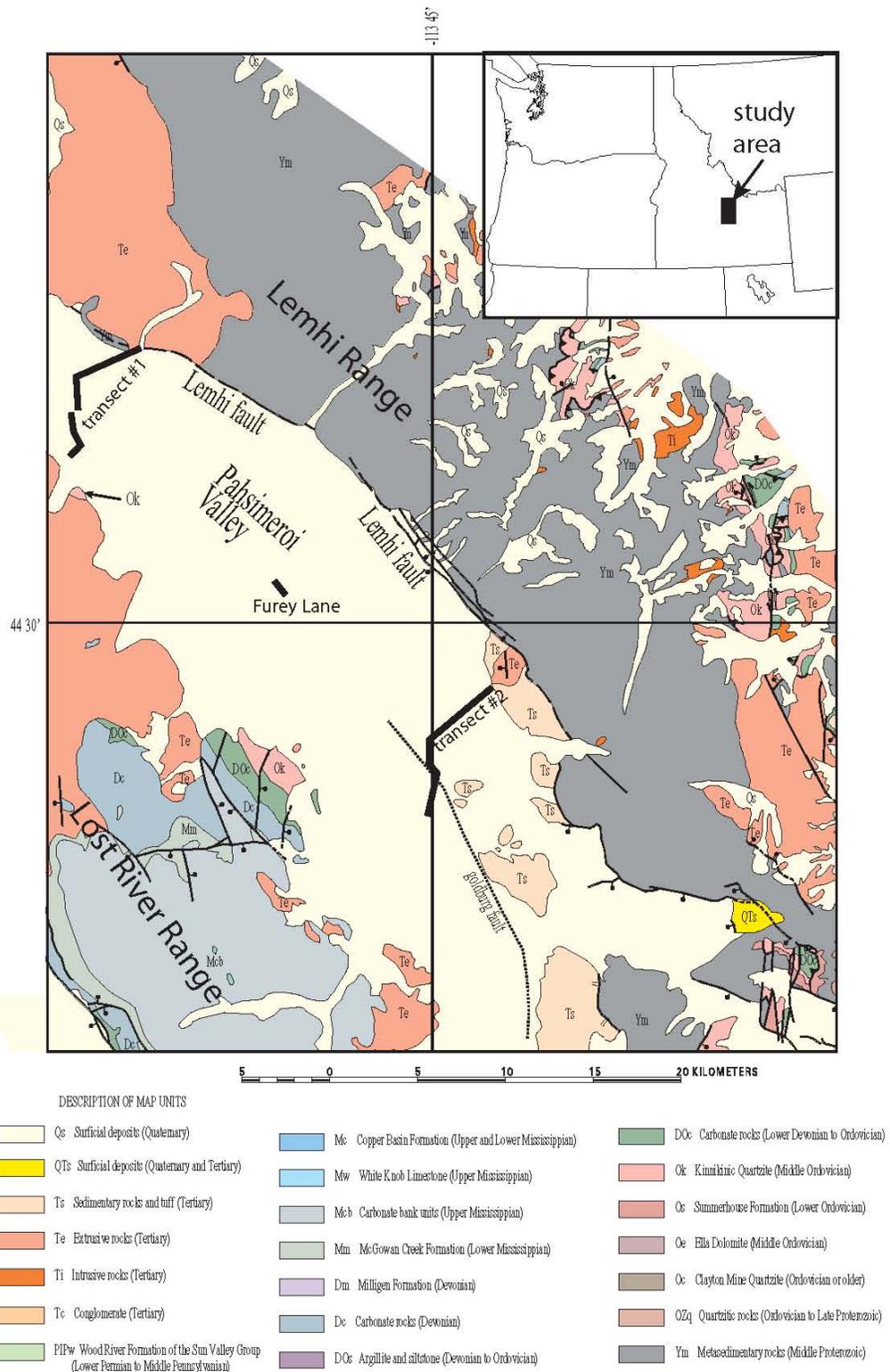
This report summarizes the results from a seismic reflection survey in the Pahsimeroi Valley, Idaho conducted September, 2005. We acquired approximately 20 km of seismic data along two cross-basin transects and an axial seismic line at Furey Lane to identify whether subsurface geologic and tectonic conditions influence surface and ground water flow. Additionally, we invert existing gravity data from the valley to estimate basin geometry and depths. Based on gravity and seismic data, we can divide the physiographic Pahsimeroi Valley into three basin segments. The relatively deep and symmetric central basin depocenter is filled with folded and faulted Tertiary strata with a thin cover of unconsolidated Quaternary fill. In contrast, the northern portion of the Pahsimeroi Basin contains a significantly greater amount of unconsolidated Quaternary deposits over shallow bedrock. Gravity data suggest the southern Pahsimeroi Basin is shallow, but we do not further report on the southern reaches of the valley in this report.

Assuming basement rocks act as a relatively impermeable boundary to ground water flow, the northward shallowing and narrowing of the Pahsimeroi basin north of Furey Lane would restrict ground water flow and force ground water to the surface. Along our northern transect at Downton Lane, we interpret bedrock at depths less than 300 m across most of the basin. In contrast, bedrock depths approach 2 km in the south central portion of the basin. This decrease in volume of basin sediments coupled with an increase in downgradient water supply may explain the gaining reaches of the Pahsimeroi River north of Furey Lane.

Along our southern transect at McCoy Lane, we identify the active northwest-trending Goldburg normal fault in the center of the basin. This fault is mapped in the Donkey Hills to the south and aligns with 10 km of surface springs and a gaining reach of the Pahsimeroi River. We hypothesize water from the Doublesprings drainage flows northeast from the Lost River Range into alluvial fan deposits below the Pahsimeroi Valley until water reaches the Goldburg fault. Here, a positive head and decreased permeability of older rocks in the footwall of the fault forces groundwater to the surface. Once the ground water surfaces, the water joins the main channel of the Pahsimeroi River north of McCoy Lane.

## Introduction

Numerous gaining and losing reaches of the Pahsimeroi River coupled with limited water and competing water rights has prompted a comprehensive assessment of the Pahsimeroi aquifer. This study summarizes newly collected seismic data and integrates existing gravity data. The purpose of our study is to identify major geologic and tectonic boundaries that may control or influence surface and ground water flow within the Pahsimeroi Valley. We collected two 10 km long northeast-southwest oriented transects across the Pahsimeroi Valley along with one short axial seismic survey to image and characterize basin strata (Figure 1). In this report, we first describe the geologic and physiographic setting of the Pahsimeroi Valley. We then describe geophysical data acquisition and processing methods used during our study. Lastly, we interpret the geophysical data and combine with ongoing studies on surface water and ground water flow to identify how the geologic and tectonic setting may help explain the hydrogeologic setting in the Pahsimeroi Valley



**Figure 1. Geologic map of the Pahsimeroi Valley and adjacent areas (modified from Wilson and Skipp, 1994 and Janecke, 1992). Seismic transects and fault boundaries are also included.**

## **Geologic and Tectonic Setting**

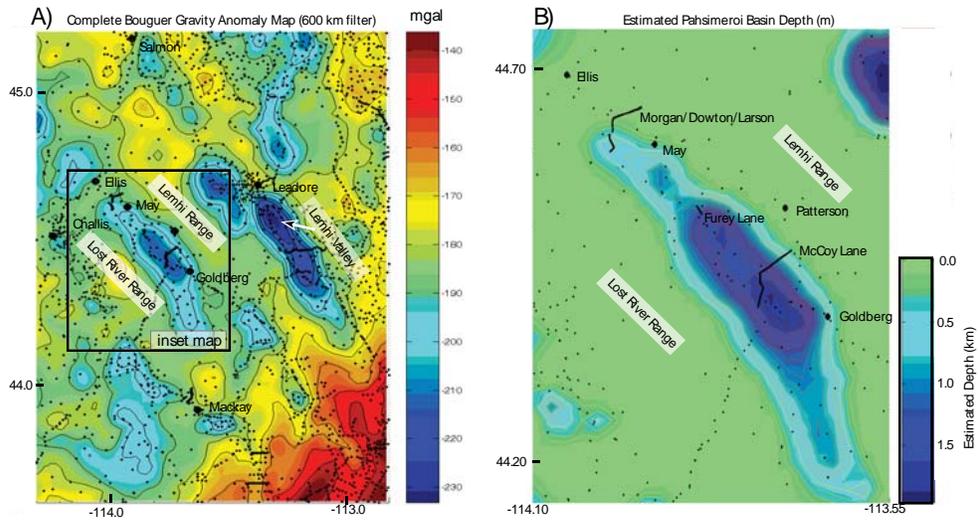
The 50 km long Pahsimeroi Valley is approximately 15 km wide in the central portion of the valley and narrows along the northern reaches. The valley trends northwest-southeast and is bound by Quaternary faults along the eastern basin margin (e.g., Crone and Haller, 1991; Janecke, 1993). The Lost River Mountain Range lies southwest of the valley and the Lemhi Mountain Range lies to the northeast (Figure 1). The Pahsimeroi River flows north through the central valley with portions of the river gaining water from subsurface flow, while other portions of the river losing water to subsurface flow. The Pahsimeroi River flows into the Salmon River near the town of Ellis, Idaho.

The Pahsimeroi Valley is comprised of unconsolidated fluvial and alluvial deposits shed from the adjacent mountains, glacial deposits, and overbank river deposits. Beneath the permeable Quaternary valley fill lie Tertiary sedimentary rocks, 50 Ma Challis volcanic rocks, Paleozoic sedimentary rocks, and Precambrian metasedimentary rocks. The Challis volcanic rocks are a series of rhyolitic volcanic flows and tuffs that cover large parts of east-central Idaho, including portions of the Pahsimeroi Valley (Figure 1). These volcanic rocks may act as impermeable barriers to fluid flow. Paleozoic sediments consist of predominantly limestone and dolomite. Although the Paleozoic rocks may be relatively impermeable, fracture and dissolution derived fluid flow may be significant. The Precambrian basement rocks are metamorphosed gneiss and schist that can be considered relatively impermeable.

The Pahsimeroi Valley and adjacent areas are part of the Basin and Range Province of eastern and central Idaho. Multiple phases of geologic deformation have shaped the areas surrounding the Pahsimeroi Valley (e.g., Janecke, 1992; 1993). During and after deposition of Challis volcanic rocks, northwest-southeast oriented extension initiated. Approximately 46-48 Ma, a rotation from northwest-southeast oriented extension to the present-day northeast-southwest extension occurred (Janecke, 1992). Thus, northwest-southeast oriented normal faults control basin evolution and many regional physiographic features.

### ***Gravity Data***

To provide an estimate of basin geometry, we contour the complete Bouguer gravity data (Bankey et al., 1985; Figure 2A). A change in gravity values from surface gravity measurements reflects a change in density of underlying strata. Material that occupies mountain ranges of the Basin and Range generally is denser than material that fills the basins (e.g., Okaya and Thompson, 1985). Estimates for density values of the Pahsimeroi Basin materials are as follows: unconsolidated late Quaternary alluvial and fluvial sediments (2.0-2.2 g/cc); Tertiary volcanoclastic and sedimentary rocks (~2.5 g/cc); Tertiary andesitic volcanic rocks (2.3–2.6 g/cc); Paleozoic and older sedimentary and metasedimentary rocks (~2.8 g/cc). Assuming a two-layer model of basin fill strata overlying more dense bedrock, we invert the gravity data to define the general shape and depth of the Pahsimeroi Basin (Saltus and Jachens, 1995). Figure 2B shows the estimated basin depths where we assume a basin/range density contrast of 0.3 g/cc (Okaya and Thompson, 1985). Our inversion suggests the Pahsimeroi Basin is a relatively symmetric northwest-trending basin that is less than 2.0 km deep. Transect #2 is located immediately north of the deepest portion of the basin; Transect #1 is located where bedrock shallows.



**Figure 2. A) Complete Bouguer gravity anomaly map for the region with a box around the Pahsimeroi Valley. B) Contour map of basin depths estimated from gravity data Contour interval = 100 m.**

Although the assumption of a two-layer density model oversimplifies the actual configuration of geologic materials below the Pahsimeroi Valley, the first order shape and depth of the basin is evident. Geologic (Janecke, 1993; Wilson and Skipp; 1994) and seismic (see below) data support the gravity-based depth estimates of nearly 2 km near Transect #2. Here, Tertiary strata overlie Paleozoic and older rocks (2.5 g/cc over 2.8 g/cc) with a negligible influence of thin overlying Quaternary strata. Although data points are sparse near Transect #1,



**Figure 3. Seismic source along Morgan Creek alluvial fan.**

the gravity data suggest the basin is very shallow. Here, borehole (DeVol et al., 2002) and seismic (see below) data suggest bedrock sits upon unconsolidated Quaternary sediments. Under this scenario, the relative density contrast between bedrock and unconsolidated fill may be greater than the above assumption (closer to 0.5 g/cc), thus Figure 2B may overestimate bedrock depths along the northern portions of the valley, consistent with estimates from seismic data placing bedrock at approximately 300 m depth below Downton Lane.

## **Seismic Methods**

We acquired approximately 20 km of seismic reflection data along 5 profiles using a 200 kg rubber band accelerated weight drop (Figure 3). We acquired all seismic data with a 5 m source and receiver spacing along paved and gravel valley roads. We recorded 120 channels using 10 Hz geophones to provide a maximum offset of 600 m. Due to permitting restrictions, we did not produce source soundings within 100 m of the Pahsimeroi River. Acquisition parameters were designed to image strata in the upper one km using seismic reflection methods. Additionally, we used the first-arrival refraction information to estimate refractor depths and velocities to estimate depth to water table. These estimated depths are provided above all seismic reflection images. Processing steps included velocity analysis, bandpass filters, static corrections, and post-stack migration. We converted seismic sections to depth using average velocity values obtained from processing the data.

### **Transect #1**

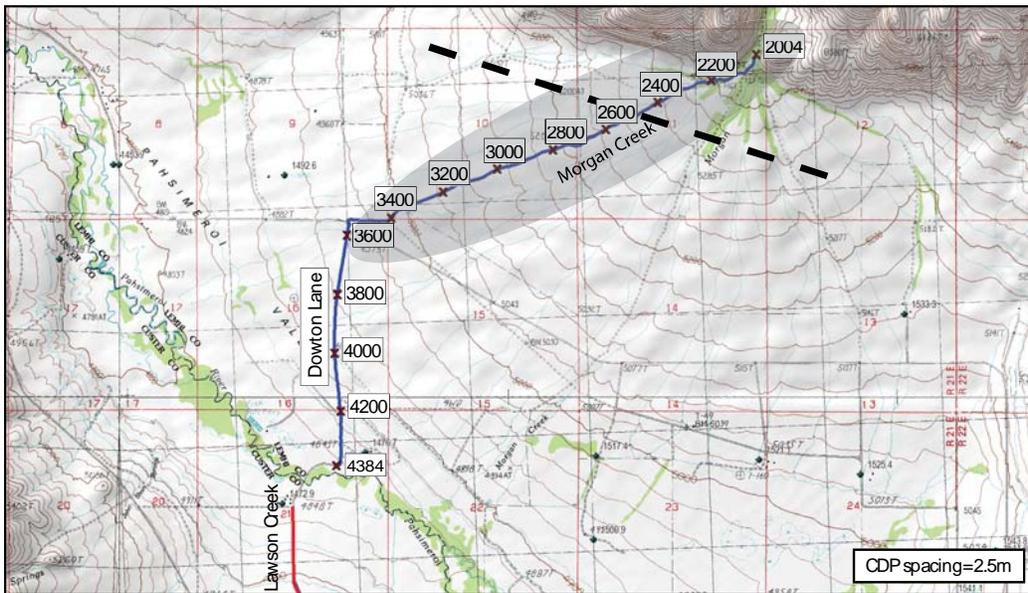
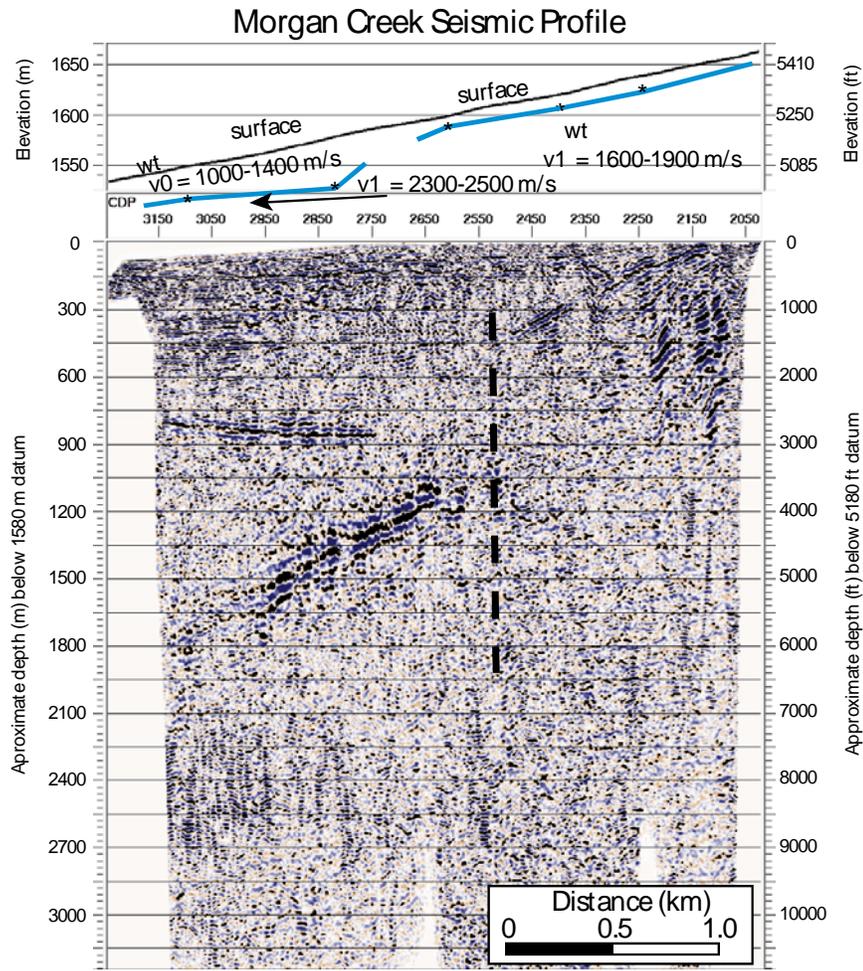
Transect #1 is located along the northern reaches of the Pahsimeroi Valley (Figure 1). Gravity data suggest the basin is only a few hundred meters deep along this transect, in contrast to the deep portions of the Pahsimeroi Basin southeast of Furey Lane (Figure 2). Nearby borehole data suggest the upper few hundred meters contains coarse-grained fluvial sediments derived from the Pahsimeroi River (DeVol et al., 2002). Transect #1 consists of three profiles along the northern portion of the Pahsimeroi Valley. The eastern profile crosses the Morgan Creek alluvial fan and ends at Farm to Market Road (Figure 4). Profile 2 begins at Farm to Market Road and proceeds south along Downton Lane to the intersection of the Pahsimeroi River (Figure 5). The third profile begins 100 m south of the Pahsimeroi River, extends south along Downton Lane and southwest along Lawson Creek (Figure 6).

### **Morgan Creek profile**

The 3.0 km long Morgan Creek profile begins at the boundary between the Lemhi Range and the Pahsimeroi Valley at Morgan Creek (Figures 1 and 4). The profile extends southwest down the Morgan Creek alluvial fan and terminates at the intersection of Downton Lane and Farm to Market Road. The profile begins at approximately 1660 m elevation and ends at approximately 1540 m elevation.

Figure 4 shows the Morgan Creek seismic profile with surface topography and seismic refraction derived water table elevation. Velocities above 1500 m/s for unconsolidated sediments are considered water saturated, therefore we interpret the water table within 50 m of the surface along the length of the profile. Paleozoic meta-sediments and a thin layer of Tertiary volcanic rocks outcrop near CDP 2200 (Wilson and Skipp, 1994; Figure 1) and alluvial fan and fluvial deposits comprise near-surface deposits south and west of bedrock outcrops. Near-surface refraction velocities change near CDP 2700 with slower head wave velocities occupying the upper reaches of Morgan Creek and faster head wave velocities are closer to the basin center. Generally, finer grained saturated and unconsolidated sediments contain velocities that range from 1600-1900 m/s compared to more coarse-grained materials that contain velocities from 2200-2900 m/s. Therefore we interpret a coarsening of near-surface deposits near the base of the Morgan Creek fan.

The stacked seismic section shows a continuous ~30 degree west-dipping package of reflectors from CDP 2000-2500. We interpret the top reflector in this package as top of Paleozoic bedrock. At CDP 2500, the reflectors terminate and a reflector with nearly identical dip then



**Figure 4. Morgan Creek (A) elevation profile with depth to water table based on refraction data. Stars represent locations of refraction analysis. (B). Unmigrated seismic profile with approximate depths relative to a 1580 m datum. (C) Topographic map with station locations and inferred fault location.**

appears at ~1000 m depth. Because we cannot confidently identify the age equivalent strata across the fault, we interpret a near-vertical normal fault with a minimum displacement of 500 m. Coincident with the inferred normal fault, we identify a change in water table depths and lithologies. This lithology and depth change may reflect recent fault activity and may also act as a conduit for vertical fluid flow. From CDP 2700 to 3200, strata dip eastward less than 5 degrees. We interpret the strong-amplitude reflector at 750-850 m depth to represent top of Tertiary or older basement rocks.

### **Downton Lane Profile**

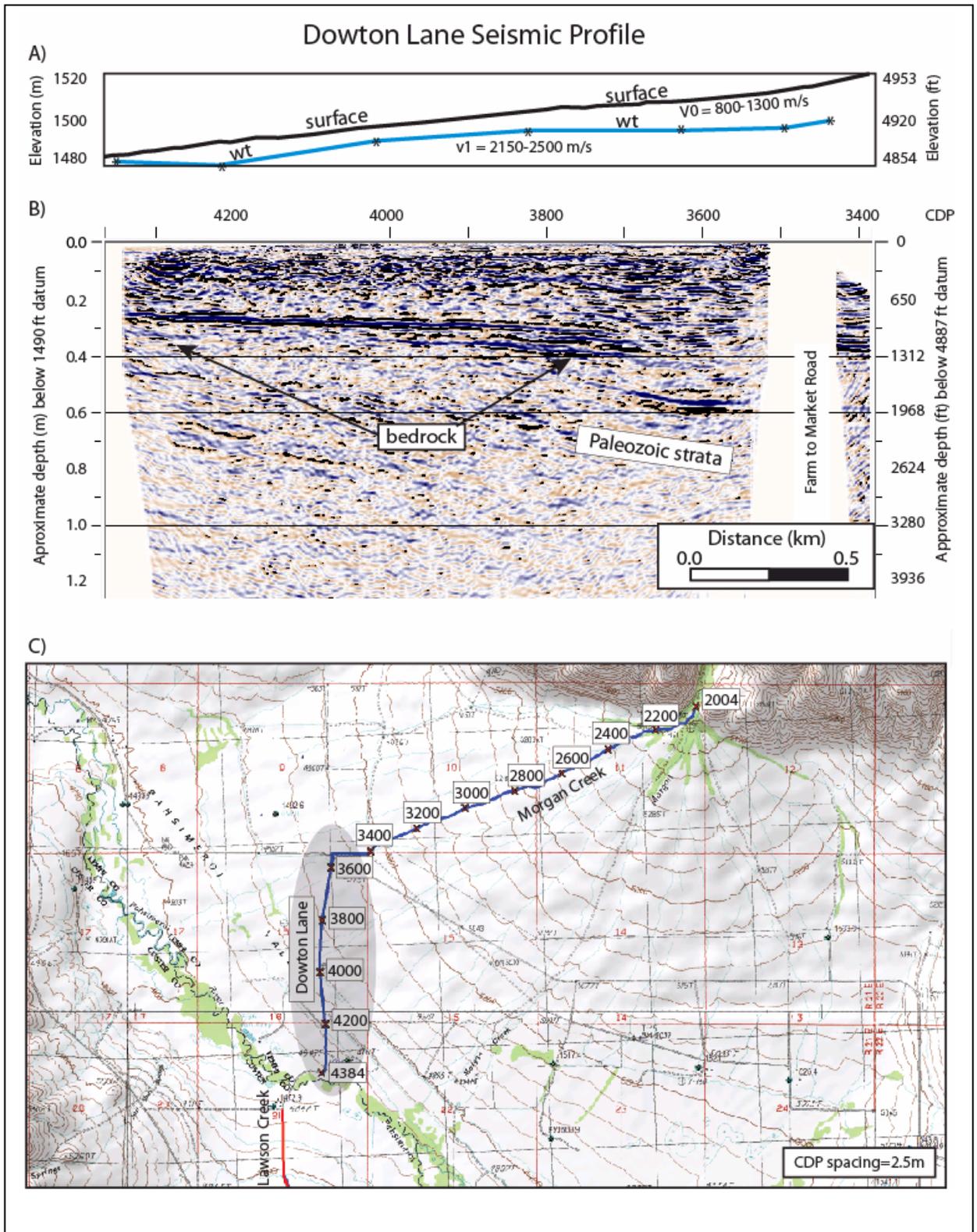
Immediately southwest of the Morgan Creek profile, we acquired the 2.25 km long Downton Lane profile (Figure 5). Well logs affiliated with the Pahsimeroi fish hatchery adjacent to Downton Lane show mostly gravel in the upper 150 m below land surface with a few clay lenses at depth. Our refraction analysis shows high seismic velocities affiliated with coarse-grained water saturated deposits within 20 m of the surface the length of the profile. As the profile approached the Pahsimeroi River, the water table shallows to surface elevations.

The most prominent reflector on the Downton Lane profile is a strong east-dipping reflector at approximately 300 m depth (Figure 5). We interpret this strong amplitude planar reflector as the top of Tertiary bedrock, likely Challis volcanic rocks. Due to the reflectors consistent and flat nature and the presence of coarse-grained fluvial sediments above, we infer an eroded top to the rock layer below Downton Lane. Along the northeastern portion of this profile, the strong amplitude reflector fades and we observe dipping strata at increased depths. Because we observe east-dipping strata below the sediment/rock contact with diminished amplitudes affiliated with this reflector, we infer either a thin layer of Tertiary volcanic rocks above older (Paleozoic/Precambrian) strata that thins or disappears entirely below Farm to Market Road and farther east along the Morgan Creek fan. Our interpretation is consistent with bedrock maps that show a thin layer of Tertiary volcanic rocks overlying Paleozoic and Precambrian rocks (Figure 1). The materials that occupy bedrock below Downton Lane may be important since carbonate dissolution in Paleozoic rocks may influence ground water flow.

### **Lawson Creek Profile**

The 2.75 km long Lawson Creek profile begins 100 m southwest of the Pahsimeroi River along Downton Lane and west along a dirt road that parallels Lawson Creek (Figure 6). The surface elevation rises approximately 60 m while the seismic refraction derived water table grades from surface elevations to approximately 20 m below land surface along the western portions of the profile.

The seismic reflection stack shows a prominent continuous reflector that ranges in depth from 50-250 m depth. The reflector is identical in character and depth to the bedrock reflector identified along the Downton Lane seismic profile. Challis volcanic rock exposures and Paleozoic strata are mapped in the adjacent hills (Wilson and Skipp, 1994), therefore we interpret unconsolidated coarse-grained sediments overlying Tertiary volcanic rocks and Paleozoic and older strata below. The continuous nature of the bedrock reflector and the inferred volcanic rock layer suggests a relatively impermeable boundary relative to overlying sediments.



**Figure 5. A) Downton Lane elevation, refraction, and seismic profile. Stars represent locations of refraction analysis. B) seismic profile, and C) topographic map showing CDP locations.**

# Lawson Creek Seismic Profile

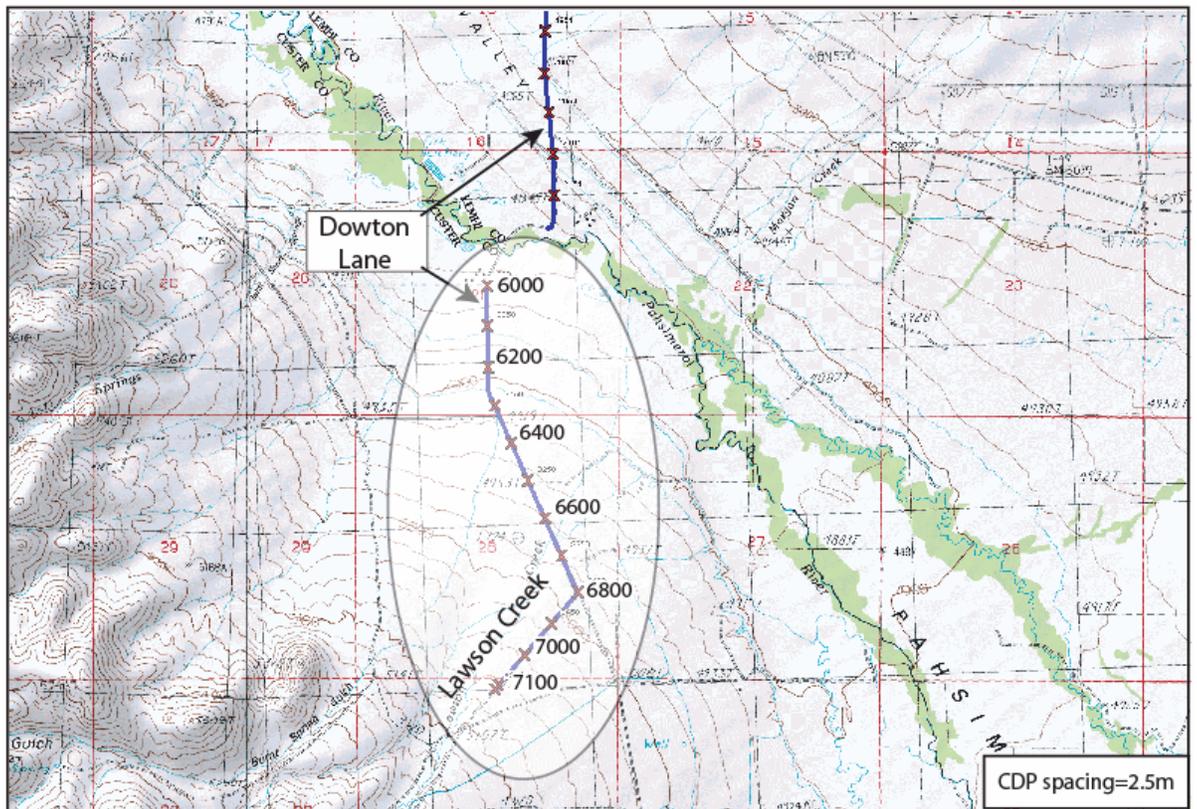
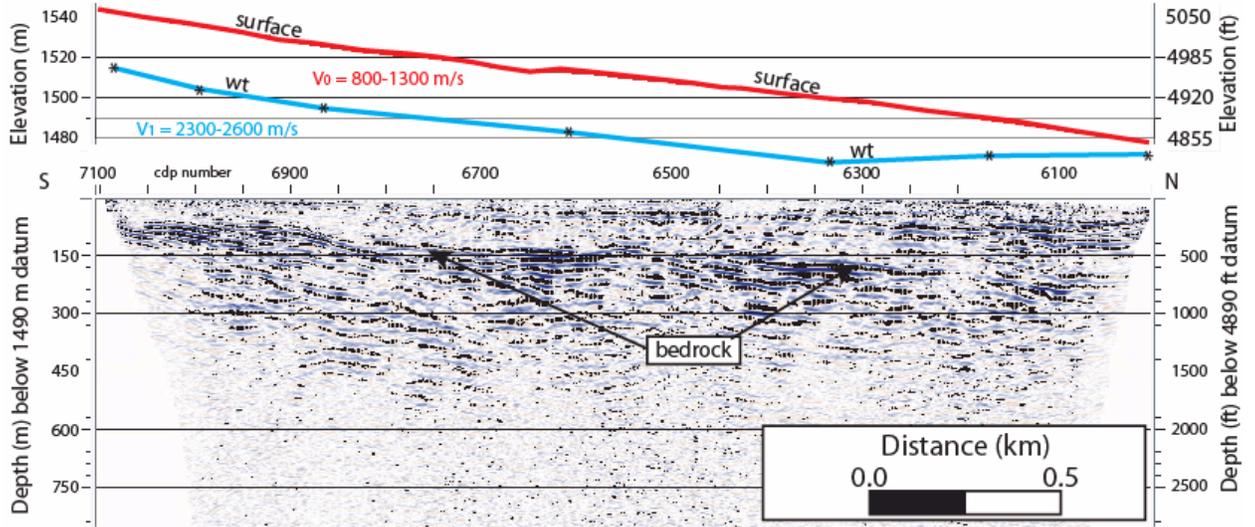


Figure 6. Lawson Creek elevation and refraction and seismic reflection profiles. Stars represent locations of refraction analysis. Below is the topographic map with line location.

## **Transect #2**

### **McCoy Lane Profile**

The 10 km long McCoy Lane profile begins from the northeast at the intersection of Farm to Market Road and McCoy Lane (Figures 1 and 7). The profile extends southwest along McCoy Lane, south across the Pahsimeroi River, and extends southwest approximately 1.75 km up the alluvial fan beyond the termination of McCoy Lane at Pahsimeroi Valley Road. The Pahsimeroi River splits into two channels upgradient from McCoy Lane with the western channel containing continuous surface flow along mapped springs while the eastern channel loses water for much of the year to subsurface flow (Figure 7). The surface elevation change is approximately 100 m across the profile with springs associated with the west channel of the Pahsimeroi River approximately 2 km west of the main river channel.

Our seismic refraction results suggest the depth to a high-velocity refractor (2300-2600 m/s) varies considerably along the profile (Figure 7). Along the northeast portions of the profile, we interpret depths from 50-90 m below surface levels. Along the south central portion of the profile, the high-velocity refractor appears at depths less than 10 m and along the very southern end of the profile, refractor depths approach 100 m. Refractor velocities are consistent with coarse-grained saturated sediments measurements and depths are consistent with water well measurements. The location of saturated sediments near the surface is consistent with the location of mapped springs along the western river channel of the Pahsimeroi River (Figure 7).

The seismic image from McCoy Lane clearly shows reflections from the upper one km. Reflections below one km are not clearly imaged due to acquisition parameters and seismic source strength. However, a few key reflectors appear to depths approaching 2 km, consistent with gravity measurements that place basin depths at approximately 1.8 km along the south-central portion of McCoy Lane (Figure 2). The seismic character changes laterally across the profile. The northeast portions of the profile show dominantly northeast-dipping strata in the upper one km with apparent dips decreasing at shallower depths. The northeast-dipping strata unconformably lie below a near flat-lying reflector from surface elevations to ~100 m depth. Additionally, a deep reflector dipping southwest ~15 degrees along the northeast portions of the profile contrasts with the northeast dipping character of the basin. We do not image the southwest-dipping reflector beyond ~3 km or below ~1.5 km depth. This may be due to acquisition settings where deeper targets are not imaged or from geologic complexities in the basin.

We interpret the shallowest reflector that crosses the eastern half of the profile (upper 100 m) as the base of Quaternary unconsolidated sediments (Qs). These sediments are affiliated with alluvial and fluvial processes and are mapped throughout the valley. Immediately below Qs, we interpret the northeast-dipping angular unconformity as the top of Tertiary sedimentary rocks (Ts). We base this interpretation on nearby exposures of Tertiary strata with similar dips (Janecke, 1992; Wilson and Skipp; 1994; Figures 1 and 7). With the thinning of Qs along the central portion of the profile, we interpret Ts at depths less than 30 m. This interpretation is consistent with surface exposures of Ts southeast of the profile (Figure 7). We associate the southwest dipping basal reflector as a low angle normal fault that Janecke (1992) termed the Donkey fault. Janecke (1992) hypothesized that this fault that appears in the adjacent Donkey Hills was active during Oligocene and has since rotated from high angle to its present low angle dip. An increase in dip with depth of Ts units suggests the Donkey Hill fault was active during Tertiary deposition.

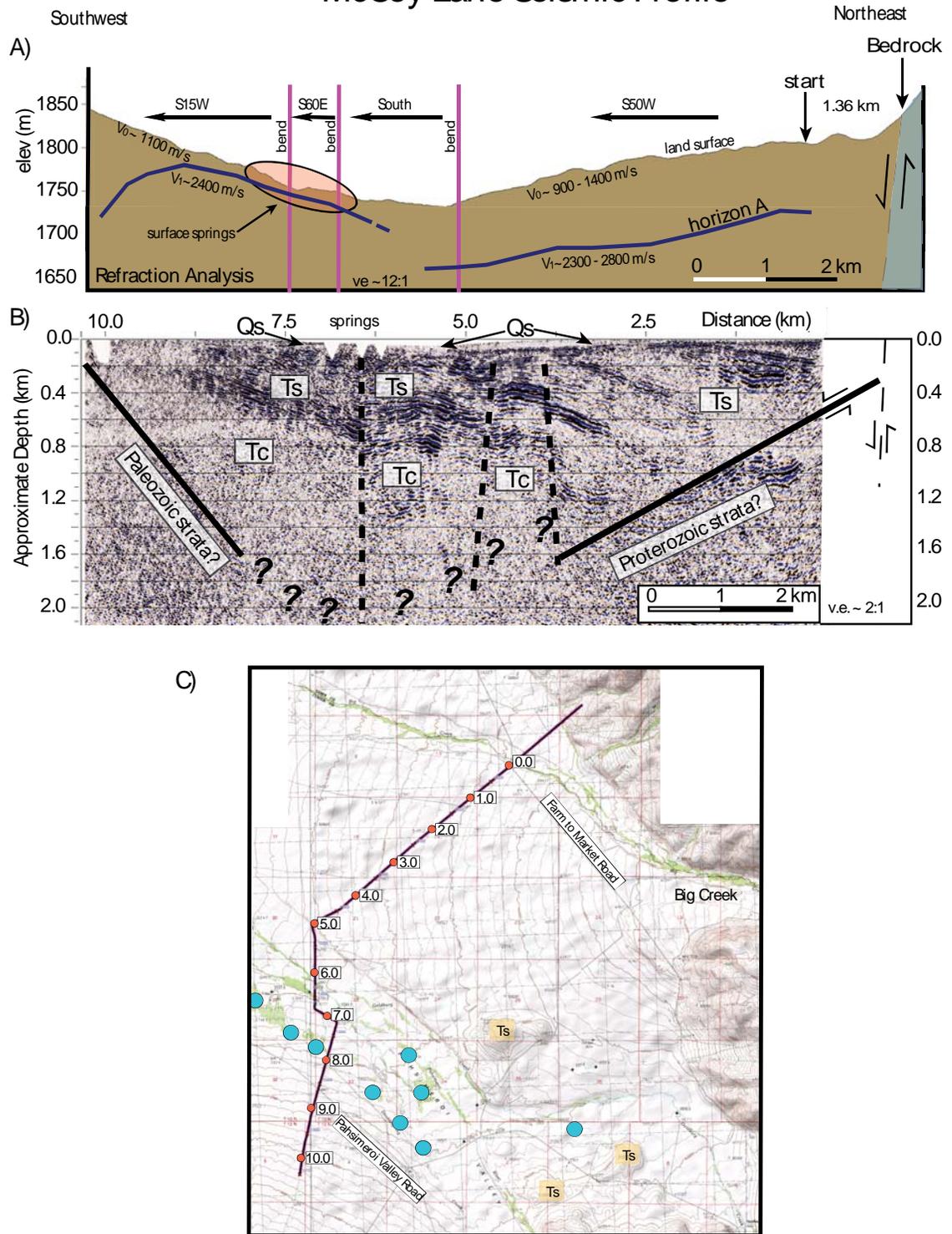
The central portion of Transect #2 between 3-7 km distance shows arcuate and offset reflectors that suggest deformed and faulted Tertiary strata extend from the very near surface to more than one km depth. The faults along the central portion of the profile do not cut Qs, suggesting they may not be active or act as conduits for vertical fluid flow. However, the fault at 6.5 km distance corresponds with northeast-dipping reflectors adjacent to folded and faulted strata. This fault also offsets very shallow strata where surface springs and the western channel of the Pahsimeroi River appear. The line of surface springs extends more than 10 km with an approximately N45W trend (Figure 7). We term this fault the Goldberg fault based on Janecke (1992) interpretation of the active Goldberg strand of the Lemhi fault extending into the central portion of the basin north from the Donkey Hills (Figure 1). The diffuse nature of reflections on the downthrown side of the Goldberg fault may be related to the change in line orientation with respect to structural dip, a rotation of nearly 45 degrees. The contact between Qs and older Tertiary strata is difficult to identify, thus the amount of vertical offset across the Goldberg fault is difficult to assess. However, we believe the location of the surface springs with respect to the fault location suggest the fault may significantly influence fluid flow.

### ***Furey Lane***

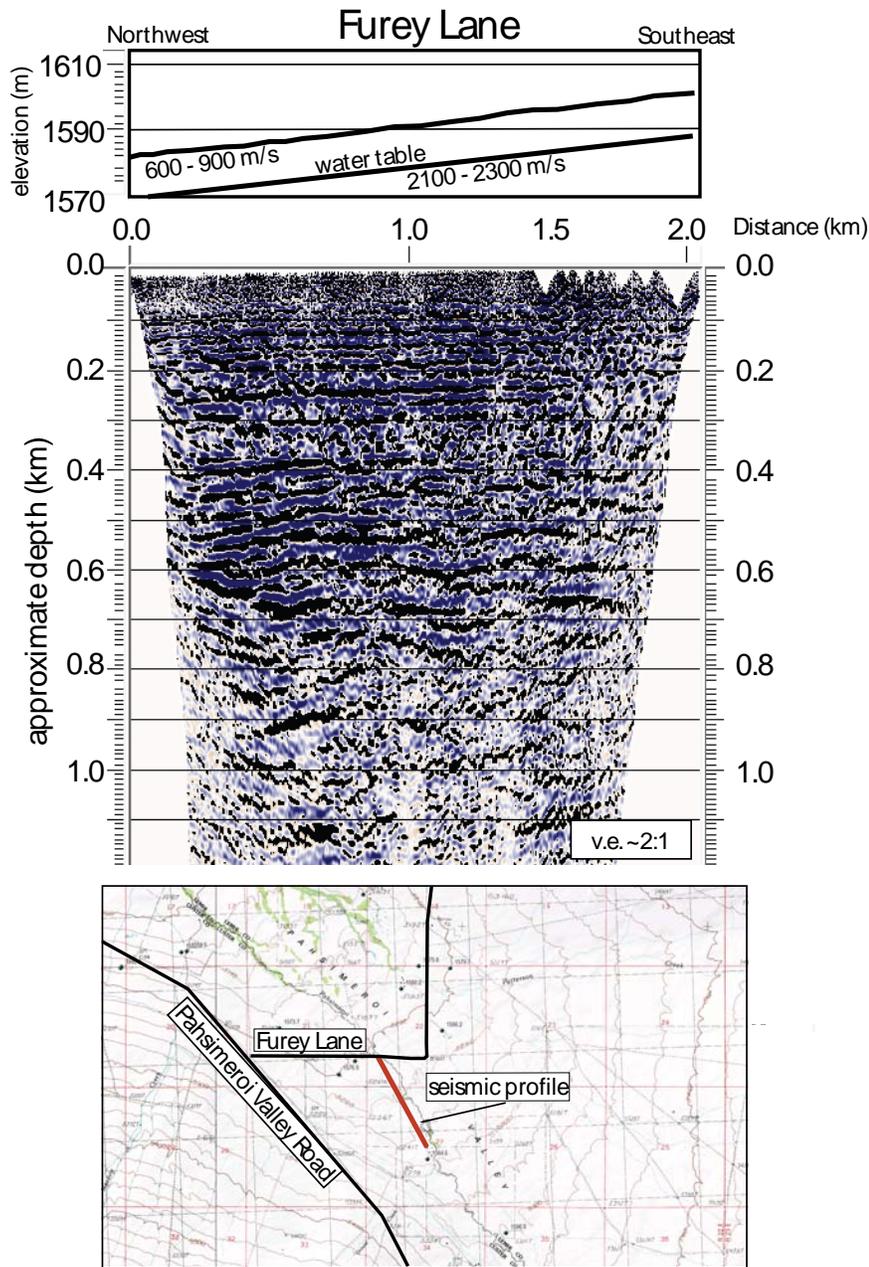
The 2.0 km long Furey Lane profile is oriented northwest-southeast and was designed to image strata in the central portion of the basin parallel to the direction of flow for the Pahsimeroi River (Figures 1 and 8). Furey Lane is located along a losing stretch of the Pahsimeroi River that is dry much of the year. Immediately downgradient, the river flows again where springs are present (Figure 8). The surface elevation rises approximately 10 m across the profile and seismic refraction-derived water table depths mimic surface elevations approximately 12-14 m below land surface.

The seismic reflection data show flat-lying strata to depths that exceed 1.0 km (Figure 8). The large velocity contrasts observed along Transects #1 and #2 in the upper few hundred meters do not appear below on this profile. This suggests that the Furey Lane seismic profile has imaged a package of flat-lying Quaternary and Tertiary strata no obvious barriers or conduits to ground water flow. This interpretation is supported by the gravity data where Furey Lane appears near the northern portion of the Pahsimeroi Basin depocenter with estimated basin depths from 1.2-1.5 km. Southwest dipping strata along the northwest portion of the profile at depths greater than 0.6 km may be related to shallowing bedrock depths.

# McCoy Lane Seismic Profile



**Figure 7. Seismic transect #2 along McCoy Lane. A) Elevation profile and refraction layer velocities and depths. B) Migrated depths seismic reflection section with interpretation. C) Topographic map of line location (black line) with distance markers (km), Tertiary outcrops in the basin, and location of springs (circles).**



**Figure 8. Furey Lane elevation water table profile, seismic reflection section, and topographic map with line location.**

## Discussion and Conclusions

Gravity data from the Pahasimeroi Valley show the simplified shape of the Pahasimeroi Basin. We observe a basin that approaches 2 km depth near the central portion of the valley and very shallow depths to bedrock both to the south and north of the basin depocenter. With the exception of the west channel of the Pahasimeroi River near Transect #2, the Pahasimeroi River loses surface water nearly the entire length of the river until north of Furey Lane (J. Williams, personal comm.). North of Furey Lane, the basin shallows more than 1.0 km and decreases in

width. This transition from losing to gaining river stretches north of Furey Lane may be simply explained by the decreased depths of relatively impermeable bedrock, the basin narrowing, and an increase in ground water entering the downgradient system from adjacent mountains; thus ground water flow is restricted and volume increases.

The exception to the bedrock configuration defining surface and ground water flow is the gaining stretch of the Pahsimeroi River along the western river channel near Transect #2. Here, we identify an active fault based on seismic and geologic mapping (Janecke, 1992) that corresponds in orientation and location with a line of surface springs that feed the Pahsimeroi River (Figure 1). The gaining reach at Transect #2 also corresponds to the location of the drainage and alluvial fan associated with the Doublesprings Pass. We hypothesize that surface water fed from Doublesprings pass is lost within the associated alluvial fan. The ground water travels along northeast-dipping Quaternary and Tertiary strata until ground water reaches the Goldburg fault. Here, Tertiary and younger strata are juxtaposed against older less permeable rocks to the northeast where the groundwater is forced to the surface along the permeable fault boundary. Within near surface Quaternary sediments, the water fans out laterally to appear on the surface as a distributed zone of springs. This fanning of water below the surface is additionally supported by the seismic refraction results that suggest shallow water saturated sediments are distributed over approximately 4 km west of the main channel of the Pahsimeroi River, yet the Goldburg fault appears on the seismic data as a single fault strand. Further evidence to support the springs fed by water from the Doublesprings drainage is water temperatures are ~ 4° C colder at the springs compared to water in the Pahsimeroi River (B. Whittier, personal comm.).

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