GROUNDWATER RESOURCE EVALUATION
Shangri La Water District
Walterville, Oregon

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EXECUTIVE SUMMARY

The Shangri-La Water District (SLWD) operates a water supply, storage, and distribution system to provide potable water to residents of the community of Shangri La, which is located in Lane County, Oregon approximately three (3) miles east of Springfield. A shallow well approximately 25 feet deep that is completed in alluvial materials deposited within the floodplain of the McKenzie river is used as the water source for the SLWD.

In 2009, fecal coliform bacteria was detected in the distribution system during routine testing of the district’s water. Coliform bacteria and the first detection of *E. coli* bacteria in well water were present in samples collected during routine sampling in May 2012. This resulted in further sampling of the water system in coordination with the Oregon Drinking Water Program (ODWP) and evaluation of the water supply, storage, and distribution system.

Branch Engineering, Inc. completed a final Water System Master Plan (WSMP) in 2014 that outlined options to address deficiencies in the SLWD system. This report was prepared as a supplement to the WSMP and presents an evaluation of the groundwater resources in the area and performance of wells operated at the project site.

The SLWD is located within Township 17 South, Range 1 West, Section 26 (Willamette Meridian). Twenty-eight records for wells constructed in this section have been compiled by the Oregon Water Resources Department (WRD), two (2) of which are associated with the SLWD. Review of the well logs identified five (5) wells which appear to solely draw water from shallow alluvial materials similar to the supply well for the SLWD. Estimated yields from these five (5) wells ranges between 20 and 150 gallons per minute (gpm) under various amounts of drawdown and testing timeframes. The low end of the estimated yields (i.e., 20 gpm) is slightly greater than the daily targeted production rate of 28,750 gallons cited in the WSMP. The yield for the SLWD well has been reported as 75 gallons per minute with two (2) feet of drawdown after 90 minutes of pumping.

Simulated annual recharge in the project area is estimated to range between seven (7) and 15 inches per year. Use of a recharge value of 11 inches per year over the 160 acre footprint of the SLWD results in a recharge value of approximately 147 acre-feet of water per year. The original water right permit allowing for use of 63 gallons per minute of groundwater represents approximately 69% of this estimated annual recharge value (i.e., based on 11 inches per year). At the low end of the simulated annual recharge (i.e., seven [7] inches per year) and groundwater extraction at the limit of the water right permit would represent approximately 108% of estimated recharge. However, actual groundwater extraction rates are lower than that permitted by the water right, and the
targeted production rate of 28,750 gallons per day cited in the WSMP represents approximately one-third the estimated recharge based on the low end of simulated annual recharge values (i.e., seven [7] inches per year).

An evaluation of water levels and aquifer response to pumping by both the potable water supply well and an irrigation well operated at the Shangri La community was performed during July 2015. The evaluation included collection of baseline water level data, installation of four (4) temporary piezometers, and collection of water level data from the piezometers and the irrigation well. A temporary piezometer identified as P1 was installed outside the well house approximately seven (7) feet from the potable water well. Temporary piezometers identified as P2 and P3 were located at radial distances of approximately 50 and 100 feet, respectively, to the northeast of temporary piezometer P1. Temporary piezometer P4 was installed approximately 25 feet from the irrigation well. The depth to water at temporary piezometers P1, P2, and P3 ranged between approximately nine (9) to 10 feet below land surface.

Changes in water levels (uncorrected for barometric effects) at temporary piezometers P1, P2, and P3 during the observation period between July 10 and 13, 2015, while the potable water well was operated normally (i.e., intermittently at a pumping rate of approximately 65 to 70 gpm) were on the order of 0.4 of a foot and were similar at all locations. Sudden but minor decreases and slower rebounds in water levels were observed at the temporary piezometers and may be reasonably attributed to aquifer response during active pumping of the potable water well and recovery during periods of no pumping. The similar magnitude and patterns of variation indicate a relatively large response area with likely superimposed influences from other sources (e.g., changes in surface water elevations/discharge rates).

The long operational period of the potable water well (e.g., multiple decades) supports the assumption of equilibrium conditions in the alluvial aquifer within the study area in response to groundwater pumping. The saturated thickness of aquifer between the surface of the water table (upper aquifer surface) and the bottom of the pumping well approaches 15 feet. The relatively minor response of the aquifer at short distances from the pumping well indicates there is sufficient groundwater to supply as currently operated. As presented in the WSMP, the majority (over 50%) of the water pumped from the supply well is lost from the system. The target production rate of 28,750 gallons per day presented in the WSMP equates to an average pumping rate of approximately 20 gpm, which is less than half the average pumping rate observed during the study. Based on the results of this study and anticipated significant reduction in water production, it is believed the currently existing well is capable of meeting long term demands.
An unused well was completed at the Shangri La community in 1984. This well is located in the same area as the existing potable and irrigation wells and has been proposed for use as an interim supply during planned upgrades to the SLWD system. It is further recommended that necessary changes in the water system be undertaken to allow this well be used as a backup well on an as-needed basis.
1.0 INTRODUCTION

The Shangri-La Water District (SLWD) operates a water supply, storage, and distribution system to provide potable water to residents of the community of Shangri La, which is located in Lane County, Oregon approximately three (3) miles east of Springfield (study area). A shallow well approximately 25 feet deep that is completed in alluvial materials deposited within the floodplain of the McKenzie river is used as the water source for the SLWD.

In 2009, fecal coliform bacteria was detected in the distribution system during routine testing of the district’s water. Coliform bacteria and the first detection of E. coli bacteria in well water were present in samples collected during routine sampling in May 2012. This resulted in further sampling of the water system in coordination with the Oregon Drinking Water Program (ODWP) and evaluation of the water supply, storage and distribution system.

Branch Engineering, Inc. completed a final Water System Master Plan (WSMP) in 2014 that outlined options to address deficiencies in the SLWD system. A copy of the final WSMP is presented in Appendix A of this report and the reader is referred to this document for information relevant to this report including project location and physical setting as well as information regarding the existing water system and options for upgrading the water supply system. This report was prepared as a supplement to the WSMP and presents an evaluation of the groundwater resource, information regarding response of the shallow alluvial aquifer to groundwater extraction, and discussion of existing wells associated with the SLWD with respect to meeting targeted long-term water supply needs. A service area and vicinity map for the SLWD is presented as Figure 1.1 in the final WSMP.

2.0 SCOPE OF WORK

A scope of work for additional evaluation of the groundwater resource at the study area was developed based on a conversation with Branch Engineering, Inc. personnel, review of the WSMP, meetings with Shangri La board members and stakeholders, and a brief site visit. Work tasks were grouped into two phases as outlined below.

2.1 Phase I Tasks

- Compile overview information regarding site location, physiographic setting, geologic and hydrogeologic setting, and stratigraphic units
- Compile and review construction and testing records available for wells in the area (i.e., well logs)
• Identify primary water-bearing zone(s)
• Characterize aquifer capacity (yield, transmissivity, etc.) based on available information
• Estimate recharge (precipitation infiltration)

2.2 Phase II Tasks
• Perform site specific investigation and evaluation of aquifer characteristics and groundwater resources underlying the site
• Obtain and review pumping data (supply vs. use)
• Establish baseline water level conditions over 3 – 5 days using datalogger and pressure transducers
• Install piezometers and perform aquifer tests to characterize lateral/vertical variability/heterogeneities
• Evaluate aquifer response around existing potable water and irrigation wells
• Preparation of report to document the information and findings of the groundwater resource evaluation.

3.0 BACKGROUND
3.1 Site Development and Water District
Development of the Shangri La community consists of single family residential properties that primarily occurred during the 1960s and 1970s. Most of the housing and related development is located on a steep hillside within the foothills of the Cascade Mountains (i.e., Western Cascades) east of Springfield, Oregon. The northernmost portion of the Shangri La community consists of 21 developed lots located within the McKenzie River floodplain. Access to the community is via Deerhorn Road off Highway 126. The community is not currently expanding nor are there plans for future additional development.

The potable water supply for the Shangri La community is provided by the SLWD. Primary components of the existing water system operated by the SLWD consist of one (1) shallow well, a pump deployed in the well, distribution piping, and two (2) storage reservoirs. Ancillary equipment includes chemical feed tanks and pumps (i.e., chlorine for disinfection and caustic soda [sodium hydroxide] and phosphate agents for corrosion
control), system controls, and meters. All elements of the SLWD system are located on-site (i.e., within property of the Shangri La community).

A single shallow well equipped with a single 7.5 horsepower pump is used as the potable water supply source for the SLWD. The well is located approximately 375 feet southeast of the south bank of the McKenzie River and 35 feet northwest of a slough that is seasonally connected with the McKenzie River. Testing of the well when constructed in 1971, and more recently in 2005, indicated a yield of 75 gallons per minute (gpm). However, it is reported that the pumping rate needs to be reduced during the summer months to prevent the pump from either pumping excessive sand and/or cavitation. Permit G-5533 was issued in 1975 in response to application G-5757 submitted in 1972 for appropriation of groundwater from the potable water well and allows for beneficial use of up to 63 gallons per minute (gpm) by the SLWD.

There is a very large discrepancy between volume of water produced at the well and that billed based on metered data at the residences serviced by the SLWD. The discrepancy is likely attributable to a combination of factors, including leakage in the system (e.g., piping and storage), inaccurate meters, and unknown or unaccounted for water use in the system. Average monthly water loss from March 2008 through December 2011 exceeded the water demand with an average of 61 percent of water produced being “lost”.

One (1) irrigation well connected to a separate distribution system serves 19 residential properties along the northern part of the Shangri La community. The irrigation distribution system is not connected to the domestic water supply system. Permit G-4419 (water right certificate) was issued in 1974 for appropriation of groundwater from the irrigation well and allows for beneficial use of up to 0.25 cubic feet per second (112 gpm) at the Shangri La community for supplemental irrigation and supplemental recreation.

3.2 Hydrogeology
3.2.1 Setting
The Willamette Basin is a drainage area encompassing 12,000 square miles of northwestern Oregon positioned between the Cascade Range on the east and Coast Range on the west.¹ Approximately 70 percent of Oregon’s population is located within the Willamette Basin, including residents of the Shangri La community.¹ Annual precipitation is high but varies in amount and form with location within the basin. Approximately 80 percent of total rainfall is received between October through March and

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only five (5) percent received in July and August. Since many surface water bodies (i.e., streams and rivers) have been administratively closed for new water appropriations during the summer months, groundwater is expected to be an increasingly important water source for meeting future demands.

3.2.2 Hydrogeologic Units

Bedrock underlying the area of Shangri La community has been assigned to a hydrogeologic unit referred to as the Basement Confining Unit (BCU) which includes both older marine and volcanic rocks of low permeability. In the study area the BCU is composed of volcanic and volcaniclastic rocks of the Western Cascade area. The BCU is characterized by low permeability, low porosity, and low well yield. Individual wells drawing groundwater from the BCU commonly have yields less than five (5) gallons per minute and are only sufficient for domestic uses.

In the southern part of the Willamette Basin the BCU is overlain by the Middle Sedimentary Unit (MSU) and Upper Sedimentary Unit (USU). Alluvial fan and braid-plain deposits form the bulk of the MSU in the southern Willamette Basin. It is commonly unconsolidated in the upper part and more compacted and cemented with depth. On driller’s well construction records the MSU is often described as cemented sand and gravel or conglomerate.

The USU primarily consists of unconsolidated sands and gravels of late Pleistocene and Holocene age. In the study area the USU represents channel gravels deposited in the floodplain of the meandering and anastomosing McKenzie River and are inset into older alluvial fan surfaces of the MSU. The thickness of the USU is commonly between approximately 20 and 40 feet. The USU is the most productive aquifer in the Willamette Basin and is characterized by high permeability, high porosity, and high well yield.

3.3 Review of Well Construction Records

3.3.1 Oregon Water Resource Database

The SLWD is located in the central part of section 26 of Township 17 South, Range 1 West (Willamette Meridian). Records for twenty-seven wells located within the section have been compiled by the Oregon Water Resources Department, one (1) of which is an application for a well identification tag and another of which was a dry hole that was not completed as a well (i.e., abandoned). A summary of the well records is presented in Appendix B. Copies of the well construction logs, two (2) of which are records for wells associated with the SLWD, are presented in Appendix C. Information included reported on these well construction records documents that the majority of the wells are completed in bedrock consisting of volcanic (e.g., basalt) and volcaniclastic (e.g., tuff, cinders) rocks. For the purpose of this review, wells within the area of interest were grouped according to
the type(s) of hydrogeologic unit(s) from which water is drawn (i.e., aquifer source). The specific groupings were alluvial (i.e., USU/MSU hydrogeologic unit), alluvial plus bedrock (i.e., USU/MSU and BCU hydrogeologic units), and bedrock only (i.e., BCU hydrogeologic unit). Information regarding the depth of the wells, units from which groundwater is drawn from, initial depth to water, static water level, and well yield is summarized in Table 1.

### Table 1. Summary of Construction, Water Level, and Well Testing Information

<table>
<thead>
<tr>
<th>Groundwater Source</th>
<th>Number of Wells</th>
<th>Total depth of well (feet)</th>
<th>Well seal depth (feet below surface)</th>
<th>Initial Depth to Water (feet below surface)</th>
<th>Static Water Level (feet below surface)</th>
<th>Well Testing Data (gpm/drawdown/test duration in hours)</th>
<th>Average pumping rate during test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial (USU/MSU)</td>
<td>5</td>
<td>25 – 30.5</td>
<td>18 – 20</td>
<td>20 - 25</td>
<td>1 - 13</td>
<td>17/NA/0.5 – 150/7/1</td>
<td>56</td>
</tr>
<tr>
<td>Hybrid (USU/MSU + BCU)</td>
<td>2</td>
<td>162, 165</td>
<td>19, 27</td>
<td>35, 125</td>
<td>3, 48</td>
<td>35/96/240, 13/117/1</td>
<td>24</td>
</tr>
<tr>
<td>Bedrock (BCU)</td>
<td>18</td>
<td>82 – 475 (dry hole)</td>
<td>6 - 78</td>
<td>30 - 300</td>
<td>7 - 132</td>
<td>3/509/4 – 60/260/1</td>
<td>16</td>
</tr>
</tbody>
</table>

It should be noted that classification of the groundwater sources involved interpretation of lithologic descriptions given on certain well logs as well as water level data. Though based on relatively limited data set for wells completed in the alluvial aquifer, information on the well logs indicates that the highest productivity (well yield) is associated with the alluvial aquifer and the lowest productivity is associated with the bedrock. In addition, the alluvial hydrogeologic units, and particularly the USU in the vicinity of the study area, are more readily recharged by direct communication with surface water (i.e., McKenzie River) than the underlying bedrock (i.e., BCU).

Review of the construction records identified only five (5) wells that appear to solely draw water from the alluvial aquifer. Estimated yields from these five (5) wells ranges between
20 and 150 gallons per minute (gpm) under various amounts of drawdown and testing timeframes. The lower end of the estimated yields (i.e., 20 gpm) is slightly greater than the daily targeted production rate of 28,750 gallons cited in the WSMP.

3.3.2 Construction Records for Wells at the Shangri La Community

3.3.2.1 Potable Water Well
The potable water well for the SLWD is associated with State Well Number 17/1W-26bd on the water well report and was later identified as Lane 911 by the Oregon Water Resources Department. A copy of the well record is included in Appendix C. The record documents construction of a well between April 28 and 30, 1971, using cable tool drilling methods and having borehole diameters of 14 inches from the surface to a depth of 20 feet and 10 inches in the depth interval of 20 to 25 feet, which is the total depth of the well. A cutting torch was used to cut 65 slots in the bottom five (5) feet of the 10 inch diameter casing having dimensions of approximately one-quarter (1/4) inch wide by six (6) inches long. The report notes placement of a gravel pack consisting of three-quarter (3/4) inch material in the depth interval of 20 to 25 feet. Based on the drilling method (cable tool) which involves alternately driving casing and bailing soil cuttings from the interior of the casing, it is considered probable that the casing is open at the bottom. Since the diameter of the perforated casing is the same as the borehole diameter the gravel pack may have been placed at the bottom of the well. A video inspection of the well in 2015 identified several feet of material at the base of the well. A well seal consisting of cement with bentonite was placed between the 10 inch diameter casing and outer borehole to a depth of 20 feet.

Soil materials encountered in the well borehole are described as top soil to a depth of two (2) feet, sand and gravel in the depth interval of two (2) to 16 feet (tight to 13 feet, loose 13 to 16 feet), loose large gravel between 16 and 18 feet, cemented sand and gravel in the depth interval of 18 to 20 feet, and loose sands and gravels from 20 feet to the total depth of 25 feet. The borehole was terminated in black basalt which may have been a boulder rather than bedrock based on the log of materials encountered in the borehole of an capped (unused) well located approximately 225 feet northeast of the potable water well (see 2.3.1.2 below).

Water was reported first encountered in the well at a depth of 20 feet which rose to a static level of eight (8) feet below land surface. A well test (flow test) involving pumping at a rate of 75 gpm for a period of 90 minutes that resulted in two (2) feet of drawdown was performed at the time of construction.
3.3.2.2 Capped Well
A well located approximately 225 feet northeast of the potable water well was installed for the SLWD during 1983 and 1984. The well is associated with State Well Number 17/1W-26bb on the water well report and was later identified as Lane 9974 by the Oregon Water Resources Department. A copy of the well record is included in Appendix C.

The record documents construction of a well to a total depth of 162 feet that was started on November 15, 1983 and completed on March 13, 1984, using cable tool drilling methods. The borehole diameter is 16 inches from the surface to a depth of 27 feet and 10 inches in the depth interval of 27 to 162 feet.

Soil materials encountered in the well borehole are described as top soil to a depth of three (3) feet, large gravel (>12") in the depth interval of three (3) to 10 feet, gravel and sand between 10 and 13 feet, gravel in the depth interval of 13 to 17 feet, clay and sand between 17 and 21 feet, cemented sand and gravel with clay in the depth interval of 21 to 35 feet, coarse sand and cobble between 35 and 39 feet, gravel with some clay between 39 and 49 feet, clay between 49 and 52 feet, interbedded hard clay with course sand in the depth interval of 52 and 70 feet, hard blue clay between 70 and 91 feet, gravel with some clay between 91 and 99 feet, basalt (broken) between 99 and 105 feet, blue clay between 105 and 106 feet, blue clay with gravel in the depth interval of 106 and 160 feet, and blue claystone between 160 and 162 feet. Although interpretive, it is considered probable that rock types described below a depth of 70 feet (e.g., blue clay, blue clay and gravel, blue claystone), and possibly 52 feet (i.e., interbedded hard clay with course sand), represent bedrock predominantly consisting of volcaniclastic deposits with some volcanic rock (i.e., broken basalt) that would be assigned to the BCU hydrogeologic unit. Description of the overlying lithologies are consistent with alluvial deposits of the MSU and USU.

A seal of cement with bentonite was placed with a tremie pipe to seal the well bore to a depth of 27 feet. The casing was perforated with slots one-quarter (1/4) inch wide by four (4) inches long in the depth intervals of 35 to 50 feet, 52 to 70 feet, and 90 to 105 feet. The well bore is open below a depth of 107 feet. No filterpack was used in construction of the well.

Water was reported first encountered in the well at a depth of 35 feet and rose to a static level of three (3) feet below land surface. A well test was performed at the time of construction which involved pumping at a rate of 35 gpm for a period of 10 days which

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2 The interval of cemented sand and gravel with clay reported for the depth interval of 21 to 35 feet may represent the upper portion of the MSU. Cemented alluvial materials were also reported in the well log for the potable water well in the depth interval of 18 to 20 feet.
resulted in 96 feet of drawdown. A temporary test pump was used for the well test and it is understood that the well has not been otherwise used since installed. The well is not currently equipped with a pump or connected to a power supply or water distribution system.

3.3.2.3 Irrigation Well
A well associated with an irrigation system is located approximately 115 feet southeast of the capped well (discussed in section 3.3.2.2). No construction record has been identified for the irrigation well. Based on the large diameter (approximately 24 inches) and depth (reported to be approximately 35 feet) of the well it is likely that it was installed using a large diameter auger boring machine, though other means of installing a “dug” well (e.g., shored excavation) are possible. The well is pumped essentially continuously during the irrigation season to provide water for irrigation and other water features (e.g., ponds, fountains) at 19 Shangri La properties located along the northern part of the development. Water not otherwise used for these purposes discharges to an elongate pond positioned between York Lane and Deerhorn Road.

Short term testing of the irrigation well has been performed by McKenzie Pump with different pumps under various pressures/flow rates. These well test records indicate the well was typically been at flow rates of approximately 205 to 245 gpm prior to replacement of the pump in 2015 due to failure. A temporary replacement pump that had been installed in May 2015 was operating at the time of this study. The well was tested at the time the temporary pump was installed at estimated flow rates of 128 to 188 gpm with drawdown approximately five (5) feet greater (18 feet depth pumping level) at the highest flow rate relative to the lowest flow rate (13 feet depth pumping level). Based on performance curves for the temporary replacement pump and pressures observed at the irrigation well when the well was being pumped the flow rate was approximately 140 gpm at the time of the study. Though approximate and not verified with calibrated flow meters, it should be noted that these flow rates exceed that allowed by the water right. Additional evaluation of the irrigation well involving measurement of actual pumping rates using a flow meter over an extended timeframe is planned.

3.4 Estimated Recharge and Water Budget
Simulated annual recharge in the Willamette Basin varies with precipitation patterns and ranges from seven (7) inches per year for the lowland area (e.g., Willamette Valley) where precipitation is less than 55 inches per year to over 40 inches per year in the upland areas of the Coast Range and Cascade Range where annual precipitation exceeds 100 inches per year.³ For the entire basin the average recharge for the 1996-1996 period was 22 inches per year. Annual recharge for the SLWD is estimated to range between seven (7)
and 15 inches per year.\(^3\) Use of a recharge value of 11 inches per year over the 160 acre footprint of the SLWD equates to a recharge value of approximately 147 acre-feet of water per year. The original water right permit allowing for use of 63 gallons per minute of groundwater represents approximately 69\% of this estimated annual recharge value. At the low end of the simulated annual recharge (i.e., seven [7] inches per year) groundwater extraction at the limit of the water right permit would represent approximately 108\% of estimated recharge. However, actual groundwater extraction rates are lower than that permitted by the water right, and the targeted production rate of 28,750 gallons per day cited in the WSMP represents approximately one-third the estimated recharge based on the low end of simulated annual recharge values (i.e., seven [7] inches per year). Additionally, the alluvial aquifer(s) are directly recharged by surface water (i.e., McKenzie River).

### 4.0 WELL AND AQUIFER TESTING

#### 4.1 Overview

Response of water levels to stress (pumping) was used to evaluate well performance and aquifer characteristics. The scope of testing involved the following:

- Collection of baseline water level data during normal operation of the irrigation and potable water wells,
- Installation of four (4) temporary piezometers identified as P1, P2, P3, and P4 to allow for collection of water level data at various distances from the irrigation and potable water wells,
- Collection of water level data around the potable water well during normal operation of the irrigation and potable water wells, and
- Collection of water level data to evaluate aquifer response to pumping at the irrigation well during recovery (pump off) and drawdown (pump on).

A site plan illustrating location of the irrigation and potable water wells, piezometers, and other site features is presented as Figure 1. Raw data is included on the electronic (i.e., Excel spreadsheet) files in Appendix D.

#### 4.2 Baseline Water Levels

On July 6, 2015, pressure transducers with data logging capabilities were deployed in the irrigation well and the pond/slough. Data logging was programmed to record water level

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data at six (6) minute intervals between five (5) PM on July 6 and 8:30 AM on July 10, 2015. A separate data logger was used to record barometric pressure at the same interval and time duration. Pumping from the irrigation well was suspended at approximately noon on July 9, 2015.

Since pressure transducers measure total pressure the transducers deployed beneath the water surface measure the combined hydrostatic (i.e., weight or pressure of water above the transducer) and barometric (i.e., atmospheric) pressures. Baseline monitoring data for the pond is presented in Figure 2 and baseline monitoring data for the irrigation well is presented in Figure 3. Submergence depth (i.e., water level height above the pressure transducer) is equivalent to 2.31 pounds per square inch as measured by the pressure transducer.

The graphs of time versus raw (or uncorrected) transducer submergence depth in the pond/slough and time versus barometric pressure plotted on Figure 2 illustrate a very similar pattern. This correlation shows that variation in the pressure data for the pond sensor (transducer) is primarily attributable to changes in barometric pressure. The graph of time versus pressure transducer measurements corrected for changes in barometric pressure plotted on Figure 2 illustrates a generally flat profile between July 6 and July 9, 2015 and an overall progressive increase in submergence depth of approximately one-tenth (0.1) of a foot during July 9 and 10 that flattens toward the end of the monitoring period.

A review of gauge height and discharge measurement for a gauging station on the McKenzie River below Leaburg dam (i.e., USGS station 14163150) indicates variations in these measurements (e.g., releases from upstream storage) during the baseline monitoring period but without a clear correlation with the pond/slough submergence data. However, as the USU has hydraulic connection with the McKenzie River in this area, water levels in the shallow aquifer are affected by river levels.

In the absence of other known influences, the rise in submergence depth observed during baseline monitoring period on July 9 and 10 is attributed to the suspension of pumping from the irrigation well (see below). Flattenning of the plot toward the end of the baseline monitoring period is interpreted to reflect the onset of more stabilized conditions.

Unlike the baseline plot of the pond/slough data, the graph of time versus raw (or uncorrected) and corrected transducer submergence depth in the irrigation well and time versus barometric pressure plotted on Figure 3 do not illustrate a pattern of covariance. This correlation shows that variation in the pressure data for the irrigation well sensor (transducer) is primarily attributable to pumping rather than barometric pressure. Essentially, the magnitude of the barometric pressure effects are small relative to those
associated with pumping. The plot also illustrates a rapid rebound of approximately four (4) feet in the irrigation well upon suspension of pumping and relatively rapid stabilization of water levels.

4.3 Water Levels Near Potable Water Well

On July 10, 2015, the four (4) temporary piezometers were installed at the Site. Each piezometer was installed to a depth of approximately 15 feet below land surface (BLS) and constructed with a screened interval in the depth interval of approximately 10 to 15 feet BLS. Temporary piezometer P1 was installed adjacent to the well house for the potable water well at a distance of approximately seven (7) feet from the potable water well. Temporary piezometers P2 and P3 were installed at distances of approximately 50 and 100 feet northeast, respectively, of temporary piezometer P1 (see Figure 1). Temporary piezometer P4 was installed west of the wellhouse for the irrigation well at a distance of approximately 30 feet from the well.

Pressure transducers with data logging capabilities were deployed in temporary piezometers P1, P2, and P3 on July 10, 2015. Data logging was programmed to record water level data at six (6) minute intervals between four (4) PM on July 10 and 10:18 AM on July 13, 2015. A separate data logger was used to record barometric pressure at the same interval and time duration. The irrigation well was not operated during this phase of testing.

A plot of submergence depths of sensors deployed in temporary piezometers P1, P2, and P3 versus time between July 10 and 13, 2015, is presented as Figure 4 and illustrate a very similar pattern at all three (3) locations. The pattern of submergence depths clearly reflect pumping at the potable water well as illustrated by relatively rapid changes when pumping started and ended. Specifically, initial rapid drawdown (decrease in submergence) follows the onset of pumping and is followed by a decreasing rate of change toward asymptotic values. When pumping is ceased rapid rebound (increased submergence) occurs and is followed by more gradual return toward equilibrium. The magnitude of drawdown follows the expected pattern of being greatest at the temporary piezometer closest to the pumping well (i.e., P1) and least at the temporary piezometer farthest from the pumping well (i.e., P3). The magnitude of drawdown during individual cycles correlates with a water level change of under approximately one-tenth (0.1) of a foot. The maximum difference between the minimum and maximum submergence depths at temporary piezometer P1 equates to four-tenths (0.4) of a foot of water level. An overall increasing trend in submergence depths was observed this phase of testing and is likely attributable to equilibration effects related to suspension of pumping at the irrigation well as a review of gauge height and discharge measurement for a gauging station on the
McKenzie River below Leaburg dam (i.e., USGS station 14163150) during this period did not indicate a significant variation (increase) in these measurements.

4.4 Irrigation Well
Pressure transducers with data logging capabilities were deployed in the irrigation well and temporary piezometer P4 on July 13, 2015. Data logging was programmed to record water level data at one (1) second intervals for a period of four (4) minutes beginning at 11:02 AM on July 13 and one minute intervals thereafter until 1:04 PM on July 13, 2015. A separate data logger was used to record barometric pressure at the same intervals and time durations. The irrigation well was turned on at the onset of this phase of testing. A depth-to-water measurement at the irrigation well of 10.99 feet below the elevation of the wellhouse pad was recorded approximately 15 minutes before pumping began. A depth-to-water measurement at the irrigation well of 12.95 feet below the elevation of the wellhouse pad was recorded approximately one (1) hour and 20 minutes after pumping began.

A plot of submergence depth of the sensor deployed in temporary piezometer P4 versus time during the test is presented as Figure 5. The plot illustrates a sharp decrease at the onset of pumping followed by slight rebound and then progressive decrease over time that does not appear to have stabilized at the termination of the test. The initial rebound is likely associated with development of backpressure in the discharge line and resultant decrease in pumping rate. The maximum magnitude of change recorded during the test was 0.053 psi or 0.12 of a foot. Based on recovery data recorded in the irrigation well during baseline monitoring a drawdown of approximately four (4) feet would be expected to develop in irrigation well with prolonged pumping.

4.5 Discussion
Data collected during testing was obtained during a period of several years of low rainfall for the region as well as the onset of the seasonal dry season. Due to this, as well as prolonged pumping from the irrigation well and normal operation of the potable water well, aquifer conditions at the time of this study are assumed to have achieved essentially equilibrium conditions.

Changes in water levels at the piezometers observed during testing were small relative to the saturated thickness of aquifer materials the potable water and irrigation wells draw from, as well as the magnitude of rebound from drawdown observed at the irrigation well during baseline monitoring. Highly similar drawdown and recovery patterns as well as essentially instantaneous change in response to normal operation of the potable water well (i.e., pumping cycles) was observed at temporary piezometers P1, P2, and P3 that span a distance of approximately 100 feet from the potable water well. This is most
consistent with the changes being at least partially reflective of pressure changes in the aquifer in response to pumping rather than completely attributable to physical dewatering of aquifer materials.

Data collected during testing indicate favorable well efficiencies and that groundwater extraction has not resulted in large areas of aquifer dewatering (i.e., cone of depression). For example, relative small changes in water levels were observed at relatively short distances from the potable water and irrigation wells during active pumping. Data collected during the study indicates that the higher and seasonally continuous rate of groundwater extraction from the irrigation well has a larger effect on water levels relative to the lower intermittent pumping from potable water well, though the degree of interference with the potable water well is small and is considered to be acceptable.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This groundwater resource evaluation was undertaken to supplement the Water System Master Plan through review of available information and acquisition and evaluation of sufficient site specific data to determine the adequacy of the existing water supply well. Specifically, the primary objective of the evaluation was to evaluate the adequacy of the existing potable water to supply the target quantity of water adopted in the master plan. A secondary objective was to evaluate the irrigation well with regard to pumping rates, construction, maintenance, and interference with the potable water well.

Data collected during this study does not indicate unacceptable (i.e., significant and widespread) effects on the shallow aquifer associated with operation of the existing potable water well for the SLWD. Water consumption is expected to significantly decrease after completion of planned upgrades to the SLWD distribution and storage system. Since the existing potable water well has been able to meet current and historic demands, and increases in future demand are not anticipated, deepening or alteration of the existing potable water well is not considered to be warranted in order to meet the targeted production of 28,750 gallons per day. However, normal maintenance activities such as removal of scale, biosolids/encrustations, and accumulated sediments should be expected. In order to reduce peak stress on the aquifer and minimize the potential for cavitation associated with excessive dewatering of the well, it is recommended that consideration be given to pump sizing and operation to spread demand over time through longer pumping periods at lower pumping rates (e.g., pumping cycles at approximately 40 gpm totaling approximately 12 hours per day rather than pumping cycles at approximately 60 gallons per minute totaling approximately (eight) 8 hours per day). Lower pumping
rates will also affect entrance velocities and potential mobilization of sediments into the well.

Somewhat limited irrigation well data generated during this study indicates that the irrigation well is capable of meeting production targets without causing unacceptable interference with the potable water well. It is understood that pump selection and well maintenance activities for the irrigation well is currently being undertaken. It is recommended that consideration be given to pump selection and operation in limits associated with the water right issued for the well.

6.0 LIMITATIONS

This report includes information provided by others and the accuracy of conclusions drawn from this information is inherently based on the accuracy of the information provided. The professional services of BB&A have been performed using the degree of care and skill ordinarily exercised, under similar circumstances, by reputable environmental research and consulting firms practicing in this or similar localities. No other warranty, express or implied, is made as to the professional advice in this report.

Based on our experience with similar investigations and within the limits of the scope of work, budgetary constraints, and physical limitations (i.e., number of available wells) of this project, data collected for this investigation is considered to be reasonably representative of subsurface aquifer conditions at the subject property. However, the results should only be considered as an indicator of site conditions and not as a guarantee of the subsurface aquifer conditions of areas not included in the investigation. The findings of this aquifer test should not be considered as scientific certainties, but rather as professional opinion based upon selected and limited data.

Sincerely,

BB&A ENVIRONMENTAL

Daniel Mumford, RG
Vice-President / Project Manager
FIGURES
Figure 2. Baseline Monitoring - Pond
Figure 3. Baseline Monitoring - Irrigation Well
Figure 4. Sensor Submergence - Temporary Piezometers P1, P2, and P3
Figure 5. P4 Submergence - Irrigation Well Test