Mosier Well Evaluation Report

Prepared for:

The Wasco County Soil and Water Conservation District

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1.0 Introduction and Background

The Wasco County Soil and Water Conservation District (SWCD) contracted GSI Water Solutions, Inc. (GSI), in October 2013 to assess the feasibility of repairing potentially commingling wells located within a portion of the lower Mosier Creek watershed, and to prioritize the assessed wells for repair. This report summarizes the results of the assessment, which included the following work components: desktop and field assessments of individual wells, an evaluation of repair feasibility based on the field assessments, cost estimates for repair or replacement of assessed wells, prioritization of assessed wells for repair, and general recommendations for future work to address the impacts of commingling wells in the area. The assessment work summarized in this report focused on wells located within “Zone 1,” an area defined by the U.S. Geological Survey (USGS) as the most vulnerable to commingling in a cooperative study with the Mosier Watershed Council (MWC) and SWCD (USGS Scientific Investigation Report 2012-5005, Burns et al., 2012). Zone 1 is located within the Mosier Oregon Water Resources Department (OWRD) administrative area, which was established to prohibit future groundwater appropriations other than for exempt uses because of groundwater level declines in the area. The original focus area for this assessment currently is being refined on the basis of consultation with OWRD’s staff and observations made during this project to aid in prioritizing future well assessment and repair work. Figure 1-1 is a map showing the general setting of the Mosier area, the Zone 1 area, and OWRD administrative area boundaries.

1.1 Background

Groundwater from aquifers hosted by basalt flows of the Columbia River Basalt Group (CRBG), and to a minor extent the sediments of the Dalles Formation, is the primary water supply for rural domestic, irrigation, and municipal uses in the Mosier Creek watershed. Beginning in the 1970s, groundwater usage in the watershed increased significantly with drilling of new wells, primarily for irrigation and domestic uses. OWRD has documented rapid rates of water level declines in the basalt aquifers, particularly since the 1970s (Lite and Grondin, 1988). In response to the water level declines, OWRD delineated an administrative area in 1988 and withdrew the Pomona and Priest Rapids aquifers from further appropriation other than for exempt uses. Despite the withdrawal of the aquifers, water level declines continued to occur at similar rates, with total declines of 150 to 200 feet recorded in some wells. Stakeholders in the Mosier area have identified declining water levels and the consequent threat to a stable supply of water as the highest priority concern within the watershed because of the almost exclusive reliance on groundwater for potable supply in the area.

Several entities have completed studies since Lite and Grondin (1988) to evaluate potential causes and impacts of water level declines in the Mosier area, and ways to mitigate the declines. The most recent studies leading up to the well assessment work described in this report and their primary conclusions are:

- Evaluation of long-term water-level declines in basalt aquifers near Mosier, Oregon (Burns, et al, 2012), in USGS Scientific Investigations Report (SIR) 2012–5002. This study used a numerical groundwater flow model to conduct predictive uncertainty analyses. The primary conclusion of the flow simulation results was that commingling wells are a significant and likely dominant cause of observed declines in the Mosier area. USGS delineated three areas of differing vulnerability to potential impacts from commingling wells, termed, from highest to lowest
vulnerability, Zones 1 through 3, and identified 26 potentially commingling wells within Zone 1 from an inventory of wells completed by Kienle in 1995.

- Mosier Aquifer Recovery Feasibility Study (GSI, et al., 2011), prepared for the MWC and SWCD under a grant from OWRD’s Water Conservation, Reuse, and Storage Grant Program. This study evaluated the feasibility of methods to halt and potentially reverse water level declines, including artificial recharge techniques and repair of commingling wells. The study concluded that artificial recharge has limited utility unless commingling wells are repaired, and identified conceptual techniques and costs for repair of typical wells found in the Mosier area.

In 2013, the SWCD funded this assessment with the overall objective of developing an implementation plan for beginning to address commingling wells, starting with a list of potentially commingling wells located in Zone 1, the highest area identified by USGS as the most vulnerable to impacts from commingling. The initial specific objectives of this work included:

1. Determine whether any of the 26 wells in Zone 1 can be eliminated from further consideration based on existing information.
2. Evaluate whether individual wells, not eliminated on the basis of existing information, currently are commingling or have the potential to commingle aquifers.
3. Determine whether each commingling well can be repaired, and, if so, how the repair should be completed, and the approximate cost for the repair.

The scope of the assessment, as it related to the first objective, was modified somewhat on the basis of observations during the assessment and communications with OWRD and SWCD staff members. The remainder of this report includes a brief summary of the hydrogeology of the aquifers in the Mosier area, and describes the general approach and methods used to accomplish the objectives of the assessment, the results of the assessment work, conclusions and recommendations for repair of the assessed wells, and recommended priorities for future assessment and repair work.

1.2 Hydrogeology

A brief summary description of the hydrogeology of the Mosier area of relevance to the well assessment project is provided in this section. The reader is referred to Lite and Grondin (1988); Kienle (1995); Tolan and Lite (2008); Lite (2013); Burns, et al. (2012); and GSI, et al. (2011) for more detailed descriptions of the geology and hydrogeology of aquifers in the Mosier area.

The Mosier area is underlain by flood basalts of the CRBG. The base of the Pomona basalt flow, two flows comprising the Priest Rapids basalt (Lolo [upper] and Rosalia [lower]) and flowtops of upper portion of the Frenchman Springs basalt host the principal basalt aquifers that wells in the Mosier area target for groundwater production. The Selah Interbed, consisting of alluvial sediments deposited between eruptions of the flows of the Priest Rapids basalt and the single flow of the Pomona basalt, is present within a portion of the study area. The Quincy/Squaw Creek Interbed is present at varying thicknesses between Frenchman Springs and Priest Rapids basalts. Clastic alluvial sediments and volcaniclastic deposits of the Dalles Formation overlie the CRBG flows. A small portion of the study area is covered with Quaternary fluvial sediments consisting of catastrophic Missoula Flood deposits and modern alluvium.
Geologic structures, including folds and faults, commonly act as boundaries to groundwater flow in the basalt aquifers. The Mosier Syncline (downwarped fold) and Rocky Prairie Thrust Fault (Figure 1-2) are the most relevant structural features for the purposes of this assessment and prioritizing wells for future assessment and repair. A description of the other structures can be found in Burns, et al. (2012); GSI, et al. (2011); and Lite (2013). Figure 1-2 illustrates the distribution of geologic units and structures within the study area.

Structural control on paleo-drainage development and basalt flow emplacement affects the distribution and hydraulic characteristics of both sedimentary and basalt aquifers within the study area. Lite and Grondin (1988) and Lite (2013) noted that the permeability of the Pomona and Priest Rapids aquifers is greatest near the axis of the Mosier Syncline. Higher permeability in the aquifers correlates with the presence of sedimentary interbeds, indicating that paleo-drainage development within the syncline exerted a strong influence on the development and distribution of permeability within both sediments and basalt flows (Lite, 2013). The axis of the syncline is the topographic low point of the basalt aquifer system and the Rocky Prairie thrust fault limits northward flow in the basalt aquifers. These characteristics, coupled with generally higher permeabilities associated with the syncline axis, create conditions that result in greater potential for impacts caused by wells that cross-connect aquifers. Figure 1-3 is a schematic north-south cross-section through the lower Mosier Creek watershed that illustrates the primary geologic units and structures referenced in this report.

2.0 Approach and Methods

2.1 General Approach
The general approach to the project was to complete a desktop assessment to identify wells that potentially connect two or more aquifers, and complete a field assessment of those wells to evaluate repair feasibility and prioritize each of the field-assessed wells for repair/replacement. A basic premise behind this approach is that each well that is open to two or more aquifers has the potential to commingle those aquifers, whether flow between aquifers is occurring, or more than one aquifer currently is saturated within the well. The rationale behind this premise is that this group of wells likely actively commingled aquifers in the past, before water levels declined sufficiently to equilibrate between aquifers or dewater an aquifer. As high-priority wells are repaired, recovery of water levels could result in renewed commingling in these wells, if left unrepaired. Therefore, all wells open to two or more aquifers were retained for future consideration; the presence of active commingling became the basis for assigning a higher priority for repair/replacement. Key elements of the approach to the well assessments included:

1. A desktop assessment, using readily available information, to determine whether the potential for commingling could be eliminated before field assessment based on well construction and interpretation of the geologic logs.
2. Outreach and coordination with well owners to gain access to wells and to address the owners’ needs and concerns during the well assessments.
3. Establishing contingency measures to provide an alternate supply of potable water to domestic users during the assessments, and minimize the chances for interruptions in supply.
4. A field assessment to verify well construction, assess the condition of the well, and examine for indications of the presence and rate of vertical flow in the borehole.
5. Review the field assessment data to evaluate repair feasibility and costs, and prioritize the assessed wells for repair/replacement.
6. Communicate the results of the assessments to SWCD and the community.

2.2 Methods
The well assessment project focused initially on a list of 26 wells within Zone 1 that USGS identified as potentially commingling. In preparation for this project, SWCD updated the list with the names of current well owners, addresses, and contact information. Fourteen additional wells were identified within the Zone 1 area during the course of the desktop assessments and field assessments through interviews with well owners and OWRD staff members. These wells were added to the list of potentially commingling wells and desktop assessments were completed for each well.

An arbitrary integer identifier was assigned to each well assessed during this project. These numbers are used throughout this report to maintain confidentiality of individual well owners.

Desktop Assessment
The initial step of the desktop assessment was to identify and acquire information regarding wells within Zone 1 and other areas in the Mosier Creek watershed. The USGS provided information from the field assessments completed during the cooperative study with the MWC and SWCD, including video surveys for eight wells and geophysical surveys for six of the eight wells. Six of the wells videoed by the USGS were on the original Zone 1 list; three of these were determined to not be commingling. Ken Lite of OWRD provided input to the project team in reviewing and developing consensus geologic unit contact interpretations, identifying and verifying well locations and well histories, and discussing conceptual model interpretations. The remainder of the desktop assessment included the following steps:

- Merged the well data tabulated for previous studies (e.g., USGS) with the well database created for aquifer recovery feasibility project (GSI, et al., 2011).
- Reviewed the OWRD well report for each Zone 1 well and compared the information with merged tabulated well data to verify completeness and accuracy.
- Updated the database with interpretations of geologic unit contacts on the basis of driller’s log descriptions, available geochemistry and approximate geologic unit elevations from published USGS and OWRD information and well videos. The locations and geologic log interpretations for each well were reviewed in collaboration with Ken Lite of OWRD.
- Compared geologic unit contact depths with casing and seal depths to verify the potential for the well to commingle aquifers.
- Developed an initial assessment priority on the basis of well construction, geologic units open to the well, and proximity of the well to the axis of the Mosier Syncline. Wells for which available information indicated were not open to two or more aquifers were eliminated from further consideration; outreach to well owners to obtain access for field assessment was initiated for the remaining wells on the list.
Well Owner Outreach and Access

Outreach to owners of Zone 1 wells was initiated by MWC, first with an appeal to well owners to provide access to their wells during an MWC informational meeting on October 15, 2013, followed by direct contact with individual owners to solicit participation. A well access agreement was developed by the project team and SWCD to clearly establish the terms of access and responsibility for expenses and liability. After an access agreement was developed, the project team followed up with calls to well owners who had indicated interest in participating to further explain the process, review the access agreement, and set up an initial site visit to assess logistics. Eight well owners provided access to 10 wells for field assessment.

Field Assessments

Field assessment methods focused on (1) maintaining a sanitary potable water supply for the residence during assessment of domestic wells, (2) completing assessment of irrigation wells before frost control and irrigation seasons, and (3) obtaining a high quality video. Well videos were conducted by the project team on 10 wells for this phase of the project. The general procedures for each field assessment included the following steps:

- Installed the temporary water supply and filled with water pumped from the domestic well; also filled a water truck with water from the well to flush the well.
- Disconnected and removed the pump, and inspected the pump, column, and wiring for wear and worked with the well owner to replace worn parts before reinstallation.
- Flushed the well and ran the video survey. Each video survey started by zeroing the camera at the ground surface. The camera then was advanced down to water within the well at a slow rate to observe the condition of the casing, other well construction details, and discernible geologic contacts. The camera then was advanced below the water surface and stopped periodically (typically every 10 feet) to use the side view capability to look for particulate movement suggestive of vertical flow. The rate of movement across the pre-measured field of view of the camera was noted, to provide a general rate of flow within the borehole.
- Disinfected the well and reinstalled the pump and column.
- Reconnected the pumping system and confirmed proper operation before demobilizing from the site.

Interpretation and Prioritization

Data from the desktop and field assessments were evaluated to assess the presence and relative degree of vertical borehole flow, and to confirm well construction details. Video surveys for 13 wells were reviewed and evaluated, 10 from this phase of the assessment and three from USGS. The assessed wells were prioritized for repair/replacement based on the following criteria:

- Whether more than one aquifer in the well was saturated, resulting in a complete connection between aquifers
- Observed vertical flow indicating active commingling
• Semi-quantitative assessment of the rate of flow between aquifers
• The proximity of the well to the axis of the Mosier Syncline

The feasibility of applying repair methods to each of the wells assessed for this project was evaluated on the basis of compliance with OWRD well construction standards in Oregon Administrative Rules (OAR) 690-200-220, the ability to provide the user with their accustomed well capacity, and locally available contractor capabilities. Potential methods for repairing wells used the methods initially identified in GSI, et al. (2011) as a starting point. The applicability of these methods was assessed and updated on the basis of additional feedback from well contractors and OWRD’s staff. Two potentially feasible repair options were identified for several wells that are open to more than one fully saturated water-bearing zone.

3.0 Results

3.1 Evaluation of Commingling Potential

The initial evaluation of the commingling potential of the 40 wells identified within Zone 1 involved a desktop assessment of well construction and geologic information from well logs, and consultation with OWRD’s staff. Twenty-eight wells were determined to potentially commingle aquifers based interpretation of geologic units penetrated by the borehole, the most recent recorded water level in the well, and the presence and location of a well seal. Twelve of the 40 wells were eliminated from further consideration during the desktop assessment. Table 3-1 summarizes available well construction and geologic information compiled as part of the desktop assessment for wells shown in Figure 3-1.

Field assessments were completed on 13 of the 28 wells retained for further evaluation: 10 as part of this project and 3 were evaluated by USGS in 2005. Table 3-2 summarizes observations from field-assessed wells and well videos available from USGS. The general locations of the wells assessed for this project are shown in Figure 3-2. Figure 3-3 provides a schematic summary of well construction, water level, and aquifers for the 28 potentially commingling wells. Appendix A includes a summary of field assessment information and well construction as-builts for each assessed well.

Conceptual Setting

Evaluation of well assessment data in the context of the hydrogeologic framework of the lower watershed helps explain field observations and provides a tool for predicting the potential for active commingling in wells based on well construction and location. Current groundwater levels in many wells within the study area are at a similar elevation of approximately 300 feet above mean sea level (msl), based on well assessments completed in this study and OWRD groundwater level monitoring data (OWRD, 2014). The 300-foot msl groundwater elevation generally represents a composite of groundwater elevations in all aquifers within the Zone 1 area, providing a potential opportunity to predict whether active commingling is occurring in a given well within Zone 1. For example, the assessment results show that the basal water-bearing unit hosted by the Pomona basalt generally is unsaturated where it occurs at an elevation of more than 300 feet. Similarly, the Priest Rapids aquifer is unsaturated where the base is at an elevation of more than 300 feet. Figure 3-4 shows an idealized schematic cross-section illustrating this concept and identifies the general areas within the study area where saturated and unsaturated sections of the Pomona, Priest Rapids, and Frenchman Springs appear
to be located relative to the current composite groundwater elevation and geologic unit contact elevations.

**Evaluation of Individual Wells**

Review of desktop and field assessment results revealed two basic circumstances in the Zone 1 wells evaluated for this project: (1) current static water levels are below one or more of the aquifers exposed in the well (e.g., the lower Pomona or upper Priest Rapids), essentially hydraulically "disconnecting" aquifers within the well; and (2) two or more aquifers are still saturated allowing the possibility of vertical movement between the two. Figure 3-4 shows the open intervals of each of the Zone 1 wells assessed for this project relative to saturated portions of the different aquifer units within the study area. The following characteristics were noted for the wells in which the static water level was below one or more aquifers exposed in the well:

- Eight wells are open to the aquifers hosted by the Pomona and Priest Rapids basalts, but the current static water level is below the base of the Pomona aquifer. These wells were likely commingling when groundwater levels were higher, but commingling ceased after groundwater levels dropped below the bottom of the Pomona Basalt aquifer. Although not currently commingling, these wells have the potential to commingle again if groundwater levels in either aquifer recover in the future.
- Three wells are open to the Pomona, Priest Rapids, and Frenchman Springs basalt aquifers, but only the Priest Rapids and Frenchman Springs aquifers are still saturated. Consequently, the Pomona aquifer has been decoupled from the others in these wells because of water level declines and a commingling pathway exists only between the Priest Rapids and Frenchman Springs basalt aquifers.
- One well is open to the Priest Rapids and Frenchman Springs basalt aquifers, but only the Frenchman Springs is saturated, precluding active commingling at present.

Thirteen of the wells in which two or more of the aquifers are still saturated were field-assessed as part of this project or by USGS. Nine of the 13 well video surveys indicated some form of active commingling occurring in the well, with most indicating a relatively low rate of vertical flow. Of the nine well video surveys indicating commingling, vertical flow observed in three wells consisted of cascading water entering an open portion of the well above the static groundwater level. In the remaining six wells, water movement from a lower water-bearing zone to an upper zone was observed below the static groundwater level. Vertical flow rates estimated from the video surveys were less than 1 gallon per minute (gpm) to 12 gpm. Flow was not observed in video surveys of 4 of the 13 field-assessed wells.

**3.2 Well Repair or Replacement Prioritization**

This section summarizes general criteria for prioritizing wells for future repair efforts to maximize benefits derived from well repair/replacement work and ranks the repair/replacement priority for the specific subset of wells that were field-assessed for this project. General criteria for prioritizing well assessment and repair derive from the current understanding of the hydrogeologic framework in the Mosier area, and do not consider well ownership or access issues. Clearly, accessibility for assessment and repair will be an overriding factor in determining whether and when a given well can be addressed. However, the general criteria are useful for focusing well owner access outreach and prioritizing repair
dollars because repairs based solely on accessibility may provide only marginal hydraulic benefit in the form of water level improvements.

**General Criteria**

A prioritization scheme for well repair/replacement should target the greatest reduction in flow between aquifers with the minimal amount of well repairs or replacements. Based on the observed similarity of groundwater level decline rates and groundwater elevations among wells historically monitored within the study area (Burns, et al., 2012), an apparent hydraulic connection between most wells currently exists. This means that repairing or replacing a subset of commingling wells should induce water level changes that may in turn increase commingling flow at wells that are not repaired or replaced, particularly those located in closer proximity to the axis of the syncline (i.e., the bottom of the aquifer system, in the northern portion of Zone 1). This observation indicates that all similarly constructed wells in a given area should be repaired or replaced to maximize the benefit, and, therefore, grouping wells based on location within the study area and well construction, starting with those in closest proximity to the synclinal axis, appears to be an effective prioritization scheme.

Previous reports have indicated that wells interconnecting the Pomona and Priest Rapids aquifers appear to have been a primary source of commingling within the study area (Lite and Grondin, 1988; Kienle, 1995; and Jervey, 1996), particularly in the lower part of the syncline where pressure differentials between the Pomona and Priest Rapids aquifers may have been as much as 100 pounds per square inch (psi) (231 feet) (GSI, et al., 2011). Based on field assessments and review of USGS well videos, wells open to the Pomona and Priest Rapids aquifers with groundwater levels above the base of the Pomona aquifer (Wells 17, 19, 29, 30, and 31) were actively commingling in most cases (with the exception of Well 19, in which a large portion of the lower borehole collapsed). These observations suggest that focusing well repairs and replacements of wells open to the Pomona and Priest Rapids aquifers within the lower portion of the study area, below an elevation where the composite groundwater level is above the bottom of the Pomona aquifer (Figure 3-4), should be the highest priority of the Zone 1 wells. In general, wells open to both the Frenchman Springs and Priest Rapids aquifers located in the lower portion of the study area should be the next highest priority for repair.

**Repair Priority of Field-Assessed Wells**

The wells assessed for this project, representing a subset of the wells located within the Zone 1 area, were prioritized relative to each other for repair and replacement.

**Pomona – Priest Rapids:** Active commingling between the Priest Rapids and Pomona aquifers is occurring in Wells 17, 29, 30, and 31 at rates of between 2 and 12 gpm. These wells are the highest priority for repair/replacement. Commingling does not appear to be occurring or consists at this time of minor cascading flow in wells open to both the Pomona and Priest Rapids aquifers where the groundwater level is currently below the base of the Pomona aquifer (Wells 6, 7, 11, and 35). These wells likely historically commingled the two aquifers, but as groundwater levels declined in the study area, the Pomona aquifer has become unsaturated and commingling ceased. Repair or replacement of these wells does not appear to be a high priority at this time. However, should groundwater levels recover to a point where the base of the Pomona aquifer becomes re-saturated as well repairs or replacements are completed nearby, repair of these wells would be required in the future to sustain recovery of groundwater levels.
Priest Rapids – Frenchman Springs: Commingling flow from the Frenchman Springs to the Priest Rapids aquifers is occurring at approximate rates of less than 1 gpm to 7 gpm in Wells 3, 5, and 38. These wells generally are located in the upper portion of the study area, where pressure differentials between these aquifers are less than the lower portion of the study area. Repair or replacement of these wells is a lower priority than similarly constructed wells located lower in the study area, and actively commingling wells completed in the Priest Rapids and Pomona aquifers.

Glaciofluvial Deposits – Pomona: Field assessment of a single well open to the Glaciofluvial Deposits and the Pomona aquifer (Well 26) indicates that some commingling appears to be occurring based on vertical flow observed in the video survey. However, determination of the commingling pathway was not possible. Based on general observations of composite groundwater levels within the basalt aquifers, it is likely that flow pathway is from the Pomona aquifer to the Glaciofluvial Deposits in the lowest portions of the study area where this well is located. Based on this one observation, this well and other similarly constructed wells may result in commingling between these aquifers. The priority of repair or replacement of these wells is relatively low; however, it may become important in wells where flow from the Pomona aquifer to the overlying sediments is occurring in the lowest portions of the study area.

3.3 Well Repair Feasibility and Costing

The criteria for determining the feasibility of repairing commingling wells include: (1) the repair must eliminate commingling, (2) the repaired well must retain the ability to produce water from the well at an accustomed rate and duration, and (3) the repair must be readily implementable using expertise and tooling of contractors who work in the region.

The relative productivity and available drawdown in each aquifer at a given location is uncertain and will require evaluation before implementing an individual well repair or replacement, particularly for irrigation wells where a higher yield is required. If these criteria cannot be met, well replacement was assumed to be necessary. For this assessment, the ability to produce water at an accustomed rate and duration assumes aquifer yield is adequate and is based mostly on whether the post-repair borehole diameter would be large enough to accommodate a pump system capable of yielding an adequate rate and pressure.

Repair feasibility was evaluated on the basis of available information from the well assessments, and does not guarantee that implementation of a repair will be successful. A contingency should be established for each attempted repair in the event that unexpected difficulties prevent a successful repair and a well needs to be decommissioned and replaced.

Commingling Well Repair Methods

OWRD water well repair standards are defined by rule under OAR, Chapter 690, Division 215 (OAR 690-215) and are applicable to the well repair options described in this section. Any well repair that does not meet standards outlined in these rules would require a special standard (as defined in OAR 690-200-0021) subject to approval by OWRD’s well construction compliance staff. Repair methods described in this section are based on similar methods described in GSI, et al. (2011), which were developed through discussions with OWRD’s staff and were reconfirmed with OWRD’s well construction staff for this report. However, OWRD’s staff recently confirmed that repairs using a smaller annular dimension are
allowed using certain grouting techniques, and that this will increase the likelihood that repair of some smaller-diameter wells will be feasible.

Repairs to eliminate aquifer interconnection in many wells will require casing and sealing large sections of the well that currently either do not have an adequate seal or are completely open to multiple aquifers. Repair of most wells requires selecting an aquifer to retain and sealing off the other(s). Aquifer selection generally is determined by whether the aquifer can produce the needed well capacity during the long term. For non-exempt wells, the water right providing authorization for use of the well may dictate which aquifer the well is required to use and should be checked before implementing repair.

Repair methods identified as best suited to meet the objectives involve perforating existing casing where not sealed, installing a smaller-diameter casing, and installing a full-length cement seal between the smaller-diameter casing and borehole/outer casing. This method provides a reliable and effective repair, but also results in a reduced well diameter. Consequently, where the upper aquifer within an open well interval is capable of supplying water at an adequate rate and pressure, the most cost-effective alternative repair would be to install a grout plug in the lower portion of a commingling well.

As described in GSI, et al. (2011) report, other well repair techniques, including overdrilling, split seals, and packers, generally were evaluated, but were not considered feasible because they were excessively costly or there was uncertainty about their ability to eliminate aquifer interconnection.

Where potentially feasible, methods and costs for sealing either the lower or upper aquifer in a well are provided. Well decommissioning and replacement costs also are provided for each well. A general summary of well repair methods that could meet the well repair objectives previously described is provided below, and illustrated in Figure 3-5.

**Upper Borehole Repair:** In general, this repair targets sealing one or more aquifers in the upper portion of the well such as (1) the Pomona Basalt aquifer and overlying sediments to produce water only from the Priest Rapids Basalt aquifer, or (2) sealing through the overlying sediments, and Pomona and Priest Rapids basalt aquifers to target the Frenchman Springs. This proposed repair would be to perforate the existing, unsealed casing; extend a smaller-diameter casing from the surface; and place a continuous grout seal behind the new casing to seal through the existing casing or open borehole across all overlying aquifers open in the well. OWRD rules (OAR 690-210-0150(1) (a-c)) require a minimum 2-inch-nominal-diameter difference between the permanent casing and the borehole (e.g., 6-inch casing inside existing 8-inch casing or borehole) when grout is installed from the bottom of the casing (typically using a “grout shoe”).

Note that this differs from the repair feasibility evaluation in GSI, et al. (2011), which assumed a minimum 4-inch-nominal-diameter difference would be required to achieve a repair acceptable to OWRD, limiting the repair feasibility primarily to 8-inch-diameter wells.

Several potential issues could prevent use of this repair method at individual wells, including: borehole misalignment preventing installation of the casing string, the 2-inch borehole size reduction does not allow installation of a pump of adequate size, and caved borehole walls or pinchpoints do not allow grout flow throughout the outside of the new casing to the surface to provide a fully penetrating seal. In these cases, decommissioning and replacement of the well may be the only viable option for elimination of commingling.
Specific steps for implementation of this repair include:

1. Perforate existing casing below the location of the current seal (requires special standard).
2. Install inner casing 2 inches smaller-diameter than outer casing and borehole, and set within fine-grained portion of the Selah Interbed for wells targeting development of the Priest Rapids Basalt aquifer or within the Quincy/Squaw Creek Interbed for wells targeting development of the Frenchman Springs aquifer.
3. Place fine sand from the well bottom to just below the bottom of the interior casing to prevent grout migration.
4. Pressure grout the annulus between the casing and the borehole to land surface.
5. Remove fine sand and residual grout, and develop the well.

**Lower Borehole Repair:** In wells open to the Frenchman Springs (e.g., Wells 3, 5, and 38) and Priest Rapids aquifer and the target aquifer of the repaired well is the Priest Rapids basalt aquifer, a grout plug may be used to seal the Frenchman Springs aquifer to eliminate aquifer interconnection between these two aquifers, assuming that the Priest Rapids is sufficiently productive and the static water level provides enough available drawdown to achieve the desired pumping rate.

**Commingling Well Replacement**

Should repair of a commingling well prove to be infeasible or too costly, remediation of commingling at that location would involve decommissioning the existing well and installing a new well designed to prevent commingling. Decommissioning of the existing commingling well generally consists of filling the well with a cement grout from the bottom of the well to the land surface and is described by OWRD well abandonment rules (OAR 690-220). Wells with casings will require removal of the casing before placement of cement grout. If casing removal is not possible, ripping or perforating the casing before placement of cement grout is permitted (OAR 690-220-0040). Additionally, abandonment of wells under artesian pressure requires pressurized application of cement grout as described in OAR 690-220-0070. Figure 3-5 shows the general process for well abandonment.

A new well intended to replace an existing commingling well would be designed to produce water from a single aquifer. Typically, this is accomplished by setting a casing smaller in diameter (typically a minimum of 4 inches smaller-diameter) than the borehole, followed by installation of a grout seal between the casing and the borehole at each aquifer encountered during the drilling process. Drilling then continues at the nominal interior diameter of the casing used and is repeated at each aquifer until the target aquifer is reached. Practically, for the purposes of completing a 6-inch well in the Priest Rapids aquifer within the study area, this process would entail the following: (1) drill 10-inch upper borehole through the Dalles Formation and Pomona basalt and terminate the boring within a fine-grained section of the Selah Interbed, where present; (2) install a 6-inch production casing in the upper borehole and cement the casing in place with a full-length seal; and (3) drill below the cemented casing into the Priest Rapids aquifer and complete the well. Additional casing strings and grouting steps, which would require a wider initial boring diameter, may be required to target the Frenchman Springs.

A similar process also would be used to target the Pomona aquifer, but the upper borehole and sealed casing would terminate in the upper portion of the Pomona flow and the lower borehole would terminate at the base of the Pomona flow within the productive zone above the Selah Interbed. Good
examples of wells constructed by this process include the City of Mosier’s Well #4 (WASC 51497), which was drilled in 2006, or WASC 51793, which was drilled in 2010. Both of these wells are cased and sealed down to the target aquifer to prevent aquifer interconnection between the target aquifer and the overlying aquifers encountered during the drilling process. Figure 3-5 illustrates the construction process to complete a well as described above.

Effective well design and installation to replace a commingling well, or in the case of new construction requires several key decisions, including: selection and identification of casing and seal depths, and selection and identification of the target production aquifer. A process for making the latest pertinent information and resources available to facilitate those decisions will be the best insurance for implementing commingling well repairs and preventing installation of additional commingling wells.

Well Repair and Replacement Cost Estimates
Cost estimates applicable to each well repair option and various well replacement configurations were based on some general assumptions mostly applicable to Zone 1. These assumptions include:

- The lowest aquifer open to an existing well is the likely target for well repairs and new well construction, which in many cases is the Priest Rapids Basalt aquifer. Although the relative productivity of the Priest Rapids Basalt aquifer is high in many locations within the Zone 1 area, the ability to produce accustomed rates of water, particularly for irrigation supply, is not certain and likely will need to be assessed further on an individual well basis.
- Pump removal and installation costs are not included in the total cost.
- A 10 percent contingency is included in all costs presented.
- Costs reflect understanding of market conditions in June 2014 based on consultation with Person Pump and Well Drilling, based in Goldendale, Washington, and confirmed by comparison with unit costs for similar work in the Willamette Valley. Actual costs at the time of repair or replacement is conducted will depend on current economic conditions, which are sensitive to market demand, labor, fuel, and materials costs.

Table 3-3 summarizes costs for well repair options and well replacement for the 13 wells assessed during this project. The costs presented in Table 3-3 are approximate and are based on the assumptions outlined above, as well as material and labor costs at the time these estimates were prepared (June 2014).

Decommissioning costs vary primarily because of the depth of the well and potential volume of cement needed. Some boreholes may require greater volumes of cement to seal off highly permeable zones, which would significantly increase the cost. Review of individual well videos should be completed before initiating a decommissioning to identify potentially permeable zones where methods to minimize cement loss should be employed, such as pre-conditioning to reduce the borehole wall permeability and cementing in lifts.
4.0 Conclusions and Recommendations

4.1 Conclusions
The occurrence and rate of commingling, particularly between the Priest Rapids and Pomona aquifers, correlates strongly with proximity to the axis of the Mosier Syncline. Groundwater levels have declined below the base of the Pomona basalt and portions of the Priest Rapids basalt except in lowest part of the syncline. Further, commingling appears to have resulted in a composite groundwater level of approximately 300 feet msl in the lower portion of the basin. Understanding the relationship between the elevation of aquifer contacts and this composite groundwater level provides a basis for predicting which wells may be commingling, and prioritizing wells for assessment and repair. Shallow aquifers in wells located in closer proximity to the axis of the syncline are more likely to be saturated and actively commingling with deeper, higher pressure aquifers.

Nearly all of the wells located in the lower portion of Zone 1, near the axis of the syncline where the static water level is above the base of the Pomona aquifer, are actively commingling. The wells assessed for this project were prioritized for repair/replacement on the basis of whether they were actively commingling aquifers, which aquifers were involved, the rate of commingling, and proximity to the axis of the Mosier Syncline. The assessed wells were placed in three priority groupings for repair/replacement based on whether they are actively commingling, which generally correlates to proximity to the syncline, and which aquifers are exposed in the wells. The highest priority grouping for repair/replacement are wells located in closer proximity to the axis of the syncline and are actively commingling. Within this group, wells open to the Priest Rapids and Pomona basalts are the highest priority, followed by those open to the Frenchman Springs and Priest Rapids basalts. Second are those commingling, but located in the upper portion of Zone 1. Of the 13 wells fully assessed for this project, 10 appear to be actively commingling at approximate rates of 1 to 7 gpm. The preliminary prioritization for repair or replacement of the wells assessed for this project is shown in Table 3-3 (Overall Priority).

One or more potentially feasible repair options were identified for most wells on the basis of the assessments. However, it is possible that unexpected conditions encountered during implementation of a repair may require decommissioning and replacement. Consequently, repair work should include contingencies in the event the repair cannot be completed as designed and the well needs to be decommissioned and replaced.

Cost estimates for repairs and well replacement were developed for each of the assessed wells. Sealing the lower aquifer generally would be the lowest cost option, but in most cases would be the least feasible because the potential to obtain the desired yield may be less in many cases. Sealing the upper borehole is more costly and potentially of somewhat higher risk, but would be more likely to result in obtaining the desired yield.

Additional, undocumented wells likely are present in Zone 1, based on the observations of residences in the area that are not associated with any documented well. SWCD has authorized work to identify potentially undocumented wells within Zone 1 by correlating tax lots with documented well locations and identifying those tax lots with existing residences that are not associated with an known well.
4.2 Recommendations
The recommended next steps are for SWCD to consider target two objectives: (1) begin to implement repair of wells, starting with a pilot repair project to verify assumptions and findings of this work, and (2) focus efforts on the accessing and repairing wells that will provide the greatest benefit toward recovery of groundwater levels in the area, namely commingling wells in closest proximity to the axis of the syncline. To these ends, we recommend the following:

- **Prioritize identifying all wells to attempt to obtain access to wells in the lower areas of the Zone 1.** This work would involve correlating locations of known existing wells with developed tax lots and identifying residential tax lots that are not served by the City of Mosier and for which documentation of a known well at the property is lacking. This work would include:
  - Complete desktop assessments of newly identified wells, as information allows.
  - Conduct outreach to owners of newly identified wells, starting with those within the lower portions of the syncline.
  - Develop a system for continued outreach to well owners identified within the higher priority area.
  - Prioritize obtaining access to assess wells located in the lower syncline as SWCD is able. Similarly focus on repairing wells in closer proximity to the syncline that are found to be actively commingling.

- **Complete one or two pilot repair projects wells to evaluate the most efficient ways to execute a repair and to measure repair benefits.** The pilot repair should target an actively commingling well that would involve working through one or more potentially complicating issues, such as (1) an actively commingling well, (2) an irrigation well, (3) evaluating whether the target aquifer can provide sufficient yield, and (4) sealing off the upper aquifer. Implementation would include the following steps:
  1. Verify the yield of the target aquifer under current water level conditions by conducting a short-term test of the water-bearing zone using an inflatable packer and pump system.
  2. Review the video survey to verify key assumptions, and conduct a new survey, as needed, to clarify the results of the initial survey.
  3. Complete final design and implementation of the repair.
  4. Test the well to verify the effectiveness of the repair.
References


