Oregon Water Resources Department Memorandum

Date: 30 May 2018

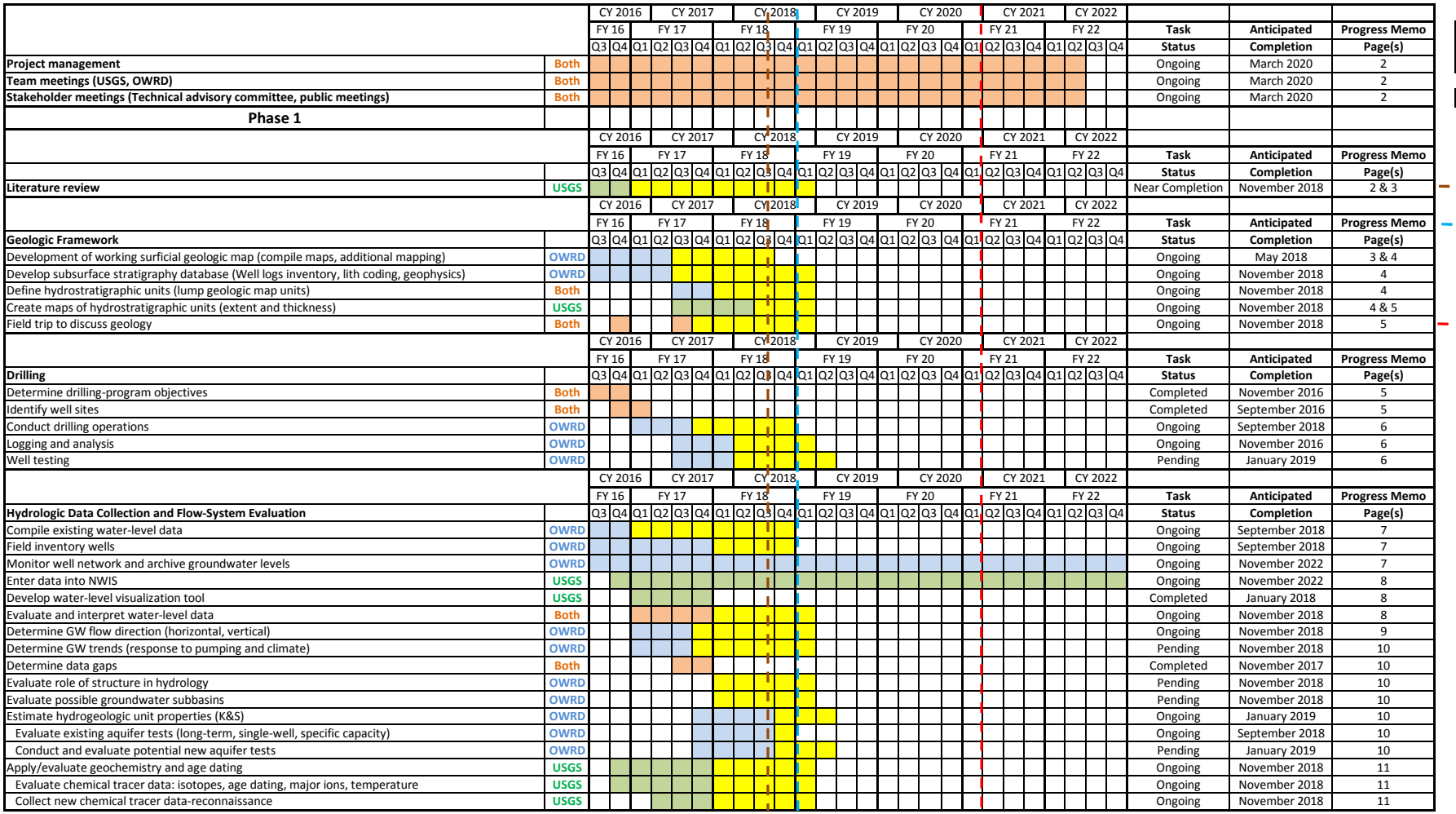
From: Gerald H. Grondin -- Hydrogeologist, OWRD Groundwater Section

To: Justin Iverson -- Manager, OWRD Groundwater Section

Subject: Harney Basin Groundwater Study Gantt Chart Implementation Update Summary

This one-page memo and attached annotated Gantt Chart provides a summary update on the progress of implementing the Harney Basin groundwater study Gantt Chart for Phase 1. A longer (17-page) memo attached behind the annotated Gantt Chart provides a fuller update of each Gantt Chart task progress status (completed, ongoing, yet to be completed, and the anticipated completion date) and how each task was or is being accomplished with the intent of helping increase understanding and answer questions of interested parties. It addresses each Gantt Chart task in the same order as the Gantt Chart. The page number(s) for each task in the longer memo is noted in the annotated Gantt Chart. For this memo, the summary GW study progress update is:

- The Harney Basin rule (OAR 690-512) was adopted by the Water Resources Commission on 14 April 2016 and the rule became effective on 15 April 2016. The rule mandates a GW study and report.
- The Harney Basin GW study work plan was finalized in December 2016 and released to the public in January 2017. The GW study technical team started work in spring 2016 in anticipation of the study.
- The Harney Basin GW study work plan Gantt Chart begins on 1 April 2016 and ends 1 October 2022.
  - Most Phase 1 tasks (primarily field work and data analyses) are charted to occur from 1 April 2016 to 1 October 2018.
  - Phase 1 tasks charted to continue beyond 1 October 2018 relate to ongoing GW level measurements and report writing. The rule mandates completing the report by the end of 2020.
- The Harney Basin GW study progress has benefited from additional resources and concurrent studies.
- Nearly all Phase 1 tasks charted to end by October 2018 are anticipated to end within October 2018.
- Phase 1 tasks charted to end by October 2018, but likely extending beyond that deadline are:
  - Completion of surface water seepage runs that require late summer to fall low flow conditions. An incomplete fall 2017 seepage run was conducted at targeted stream segments. The remaining seepage runs at other targeted stream segments and redoing part of the fall 2017 seepage run is needed to complete the seepage run task. Field work is anticipated to occur in fall 2018, and data analyses completion is anticipated by late fall 2018.
  - Conducting strategic aquifer tests during the non-irrigation season (November to March) to best determine and analyze groundwater response to specified pumping. Other Gantt Chart tasks and unforeseen circumstances precluded conducting the tests during the November 2017 to March 2018 period. Instead, the tests and analyses are expected to occur from November 2018 to March 2019.
- The Harney Basin GW study technical effort revealed a need for 2 additional tasks:
  - Surveying well measuring point elevations at most “synoptic” wells to gain better precision in water level elevations for the potentiometric (water table) map. This is needed to accurately determine groundwater gradients and flow directions. Planning and conducting the effort is anticipated to be completed no later than September 2018.
  - Adding water chemistry to the OWRD groundwater database including the ability to receive vetted (QA/QC) formatted data from various sources, input data, retrieve data, and graph data. Discussions have begun and a summer 2018 completion may be possible.


CY 2016
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Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
Task
Anticipated
Progress Memo
Status
Completion
Page(s)
Project management Both Ongoing March 2020 2
Team meetings (USGS, OWRD) Both Ongoing March 2020 2
Stakeholder meetings (Technical advisory committee, public meetings) Both Ongoing March 2020 2
Phase 1
Literature review USGS Near Completion November 2018 2 & 3
Geologic Framework
Development of working surficial geologic map (compile maps, additional mapping) OWRD Ongoing May 2018 3 & 4
Develop subsurface stratigraphy database (Well logs inventory, lith coding, geophysics) OWRD Ongoing November 2018 4
Define hydrostratigraphic units (lump geologic map units) Both Ongoing November 2018 4
Create maps of hydrostratigraphic units (extent and thickness) USGS Ongoing November 2018 4 & 5
Field trip to discuss geology Both Ongoing November 2018 5
Drilling
Determine drilling-program objectives Both Completed November 2016 5
Identify well sites Both Completed September 2016 5
Conduct drilling operations OWRD Ongoing September 2018 6
Logging and analysis OWRD Ongoing November 2016 6
Well testing OWRD Pending January 2019 6
Hydrologic Data Collection and Flow-System Evaluation
Compile existing water-level data OWRD Ongoing September 2018 7
Field inventory wells OWRD Ongoing September 2018 7
Monitor well network and archive groundwater levels OWRD Ongoing November 2022 7
Enter data into NWIS USGS Ongoing November 2022 8
Develop water-level visualization tool USGS Completed January 2018 8
Evaluate and interpret water-level data Both Ongoing November 2018 8
Determine GW flow direction (horizontal, vertical) OWRD Ongoing November 2018 9
Determine GW trends (response to pumping and climate) OWRD Pending November 2018 10
Determine data gaps Both Completed November 2017 10
Evaluate role of structure in hydrology OWRD Pending November 2018 10
Evaluate possible groundwater subbasins OWRD Pending November 2018 10
Estimate hydrogeologic unit properties (K&S) OWRD Ongoing January 2019 10
Evaluate existing aquifer tests (long-term, single-well, specific capacity) OWRD Ongoing September 2018 10
Conduct and evaluate potential new aquifer tests OWRD Pending January 2019 10
Apply/evaluate geochemistry and age dating USGS Ongoing November 2018 11
Evaluate chemical tracer data: isotopes, age dating, major ions, temperature USGS Ongoing November 2018 11
Collect new chemical tracer data-reconnaissance USGS Ongoing November 2018 11
USGS Lead
OWRD Lead
Joint Effort
Extended Time
CY = Calendar Year
FY = Fed Fiscal Year
June 2018
Phase 1 Report Begin Writing, Review & Publish Period 1 Oct 2018
Phase 1 Report Deadline 31 Dec 2020

		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022						
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22				Task	Anticipated	Progress Memo
Hydrologic Budget		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	**Status**	**Completion**	**Page(s)**
Estimate GW discharge to wells (transient)	OWRD																											Ongoing	November 2018	12 to 14
Estimate GW use	OWRD																											Ongoing	November 2018	12 to 14
Link GW use to wells	OWRD																											Ongoing	November 2018	12 to 14
Link wells to hydrogeologic units	Both																											Ongoing	November 2018	12 to 14
Assign water use to wells	OWRD																											Ongoing	November 2018	12 to 14
Determine period of use	OWRD																											Ongoing	November 2018	12 to 14
Estimate GW discharge to streams	USGS																											Ongoing	November 2018	15
Seepage runs	Both																											Ongoing	November 2018	15
Hydrograph analysis	USGS																											Ongoing	November 2018	15
Evaluate alternate potential methods of estimating discharge to streams	Both																											Ongoing	November 2018	15
Estimate GW discharge to springs, lakes, wetlands	USGS																											Ongoing	November 2018	15 & 16
Compile existing data	USGS																											Ongoing	November 2018	15 & 16
Collect new measurements	Both																											Ongoing	November 2018	15 & 16
Estimate ET loss	USGS																											Ongoing	November 2018	15 & 16
Recharge (transient)	USGS																											Ongoing	November 2018	16 & 17
Review literature	USGS																											Ongoing	November 2018	17
Determine appropriate approach (SWB,PRMS, mass-balance, water-level response)	USGS																											Ongoing	November 2018	18
Implement recharge analysis	USGS																											Ongoing	November 2018	18
From precipitation	USGS																											Ongoing	November 2018	18
From irrigation	USGS																											Ongoing	November 2018	18
From surface water (streams, canals)	USGS																											Ongoing	November 2018	18
Determine mountain front recharge component	USGS																											Ongoing	November 2018	18
Evaluate possible interbasin flow	USGS																											Ongoing	November 2018	18
		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022						
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22				Task	Anticipated	Progress Memo
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	**Status**	**Completion**	**Page(s)**
Write report to synthesize understanding of groundwater-flow system	Both																											Pending	November 2020	18 & 19

USGS Lead
OWRD Lead
Joint Effort

Extended Time

CY = Calendar Year
FY = Fed Fiscal Year

1 June 2018

Phase 1 Report Begin Writing, Review & Publish Period 1 Oct 2018

Phase 1 Report Deadline 31 Dec 2020

Oregon Water Resources Department Memorandum

Date: 30 May 2018

From: Gerald H. Grondin -- Hydrogeologist, OWRD Groundwater Section

To: Justin Iverson -- Manager, OWRD Groundwater Section

Subject: Harney Basin Groundwater Study Gantt Chart Implementation Update

This memo provides an update on the progress of implementing the Harney Basin groundwater study Gantt Chart for Phase 1 with each chart item annotated. The following should be noted for context:

- The Harney Basin rule (OAR 690-512) was adopted by the Water Resources Commission on 14 April 2016 and the rule became effective on 15 April 2016.
- The Harney Basin GW study work plan was finalized in December 2016 and released to the public in January 2017. The GW study technical team started work in spring 2016 in anticipation of the study.
- The Harney Basin GW study work plan Gantt Chart begins on 1 April 2016 and ends 1 October 2022.
  - Most Phase 1 tasks (primarily field work and data analyses) are charted to occur from 1 April 2016 to 1 October 2018. Phase 1 activities charted to extend beyond 1 October 2018 relate to continued GW level measurements and report writing. The rule mandates completing a peer reviewed report by the end of 2020.
  - Phase 2 tasks are charted to occur from 1 October 2018 to 1 April 2022. These tasks primarily relate to the GW modeling effort.
- The first synoptic GW level measurements were conducted in March 2016 at an incomplete set of wells (147 wells). The set was completed in fall 2017 (230 wells).
- The first quarterly GW level measurements were conducted in April 2016 at an incomplete set of wells. The set was completed in fall 2017 (120 wells) and revised to 109 wells in April 2018.
- Other technical work commenced during spring 2016 or later.
- The Harney Basin GW study implementation progress has significantly benefited from the following additional resources and/or concurrent activities for other studies:
  - Erick Burns, and others (USGS) who are currently investigating regional groundwater and subsurface heat flow in the California, Idaho, Oregon, and Washington volcanogenic terrains.
  - David Sherrod (USGS) for previous and current geologic mapping in the Harney Basin.
  - Mark Ferns, Bob Houston, and Jason McCluaghry (Oregon DOGAMI) for previous and current geologic mapping in the Harney Basin.
  - Jonathan LaMarche (OWRD) for leading Harney Basin GW study surface water hydrology work.
  - Jordan Beamer (OWRD) for leading OWRD part of Harney Basin GW study evapotranspiration work.
  - Harmony Burright (OWRD) for leading facilitation of Harney GW SAC and other public outreach.
  - Halley Barnett (UW MS student and OWRD intern, now volunteer) for data entry of historic and current data (water levels and chemistry, well lithology and specific capacity, other), well-log ties, field assistance, and MS project related to Warm Springs Valley springs and nearby wells.
  - Kiri Hargie (PSU MS student) for MS thesis project related to water temperature and chemistry at Harney Basin springs and wells.
  - JR Johnson & Dally Swindlehurst (OWRD), Angie Ketscher & Karen Moon (Harney Watershed Council), and Crane School for GW level measurements and chemistry and/or owner contacts.
  - Additional contributing resources may occur.

General for Both Phase 1 & Phase 2

		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022			
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22			
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Project management	Both																										
Team meetings (USGS, OWRD)	Both																										
Stakeholder meetings (Technical advisory committee, public meetings)	Both																										

1. Project Management: Ongoing. OWRD & USGS are actively managing their portion of the Harney Basin GW study with internal scheduled and ad-hoc meetings, debriefings, coordination, and resource assessments.

2. USGS-OWRD Team Meetings: Ongoing. OWRD & USGS Harney Basin GW study technical staff conduct technical team meetings at least quarterly prior to each Harney GW SAC meeting and have conducted additional meetings to debrief and update each other, assess study implementation progress, assess pending short-term and long-term study tasks, evaluate data collected and additional data needed, discuss ongoing and pending data analyses, and assess available versus needed resources to complete study tasks. The additional meetings have occurred as needed and/or as ad-hoc opportunities allow. Many of the quarterly meetings have included the OWRD Harney GW SAC facilitator and on occasion various OWRD technical staff and/or OWRD management. The USGS provides an OWRD liaison desk and cubical to the OWRD team lead who attempts to work at the USGS one-day per week and be available for ad-hoc discussions as field work and in-Salem work tasks allow.

3. Stakeholder Meetings: Ongoing. Regular quarterly Harney GW SAC meetings are occurring and will continue to occur throughout the duration of the Harney Basin GW study. Future town hall meetings are anticipated to occur as OWRD, USGS, and the Harney GW SAC agree that vetted data analyses and/or results have progressed sufficiently for greater public consumption, review, comment, and feedback. Raw data is available via OWRD and USGS databases and data viewing tools as soon as the data is entered into the USGS and/or OWRD databases and the data quality is confirmed. Other public meetings such as Place Based Planning, Harney Watershed Council, OWRD management, OWRD rule making, and others are independent of the Harney Basin GW study, but are anticipated to contribute useful information to the study.

Phase 1: Literature Review

		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022			
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22			
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Literature review	USGS																										

1. Literature Review: Largely completed.
   - Completed:
     - OWRD and USGS have conducted extensive searches to identify, collect, list, and review numerous published and unpublished technical reports, articles, and raw data relevant to the Harney Basin GW study.
     - Currently, more than 80 items of the OWRD literature list can be electronically downloaded at via the OWRD web page for picking-up (downloading) files from OWRD at:

       http://filepickup.wrd.state.or.us/files/studies/harney_gw_study/Selected_References/

       (Some documents are not posted due to copyright considerations)

- Currently, seven items of the OWRD literature list can be electronically downloaded via the OWRD web page for the Malheur Lake Basin at:

  http://www.oregon.gov/owrd/Pages/Place/Malheur_Lake_Basin.aspx#Groundwater_Study

- Currently, six items of the USGS literature list can be electronically downloaded at via the USGS Harney Basin Groundwater Study site:

  https://www.usgs.gov/centers/or-water/science/harney-basin-groundwater-study?qt-science_center_objects=3#qt-science_center_objects

- Yet to be Completed:
  - Both OWRD and USGS continue to discover and receive additional literature leads as the Harney Basin GW study progresses.
  - Both OWRD and USGS need to maintain a centralized regularly updated literature list. Reference management software (Zotero) accessed via the Oregon State Library may be an option.
  - Provide public access to a regularly updated list of all references (bibliography) compiled by OWRD and the USGS via the USGS Harney GW study web-site and the OWRD Malheur Lake Basin web site.
  - Create an OWRD link to the USGS Harney GW study web-site within the "USGS-OWRD Cooperative Studies" sub-section within the OWRD "Ground Water Studies and Publications" web-page found at:

    http://www.oregon.gov/owrd/pages/gw/gw_pubs.aspx#USGS_OWRD_Cooperative_Studies

Phase 1: Geologic Framework

		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022			
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22			
Geologic Framework		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Development of working surficial geologic map (compile maps, additional mapping)	OWRD																										
Develop subsurface stratigraphy database (Well logs inventory, lith coding, geophysics)	OWRD																										
Define hydrostratigraphic units (lump geologic map units)	Both																										
Create maps of hydrostratigraphic units (extent and thickness)	USGS																										
Field trip to discuss geology	Both																										

1. Develop Surficial Geologic Map: Ongoing
   - Completed:
     - DOGAMI has completed four geologic maps in the Harney Basin (1:24,000 scale): Harney Quad, Devine Ridge South Quad, Devine Ridge North Quad, and Crane Quad. They are currently under review to be published through the USGS STATEMAP program.
     - PSU geology MS students have completed one geologic map in the Harney Basin (1:24,000 scale), the Telephone Butte Quad, to be published through the USGS EDMAP program.
     - OWRD nearly completed a surficial geologic map of 12 geologic units for the Harney Basin. It is a compilation of published and unpublished geologic maps of varying geologic detail. The 12 geologic units reflect similar geologic properties, origin, and likely hydraulic properties. Until very recently, these geologic units were being used to define subsurface hydrostratigraphic units.
     - USGS (Sherrod & Keith) recently completed and published (publicly released on 30 March 2018) a compiled surficial geologic map for the Harney Basin independent of the Harney GW study OWRD surficial geologic map compilation effort. The USGS compiled geologic units reflect geologic age, composition, hydrogeologic grouping and lithologic pattern. A Preliminary review indicates the USGS map and the OWRD map are very similar.

- ✓ Consequently in March 2018, the OWRD and USGS Harney GW study technical staff agreed to adopt the Sherrod & Keith compiled surficial geologic map given: Sherrod's extensive geologic experience in the basin, the logic of the compiled geologic units, the completed map is peer reviewed and now published, and the map's current use by other USGS projects.
- ✓ Previously noted geologic mapping by DOGAMI and PSU and direct field observations by OWRD and USGS staff will be used to refine the Sherrod and Keith map as necessary when defining subsurface hydrostratigraphic units.

- Yet to be Completed:
  - DOGAMI plans to conduct additional geologic mapping of the Poison Creek Quad and one other quad during the summer of 2018 under the USGS STATEMAP program.
  - PSU geology MS students are funded to conduct additional geologic mapping of the Calamity Butte Quad under the USGS EDMAP program.

2. <u>Develop Subsurface Stratigraphy Database:</u> Mostly Completed
   - Completed:
     The OWRD Groundwater database references 2689 Harney Basin wells. Of these:
     - The OWRD Groundwater database contains 2685 Harney Basin wells with water well reports.
     - The OWRD Groundwater database contains lithology-coding for 2468 Harney Basin wells.
     - The OWRD Groundwater database notes geophysics data is available for analyses for 4 Harney Basin wells, exploration wells for oil and gas.
     - The OWRD Groundwater database notes 32 candidate Harney Basin wells suitable for possible geophysical logging.
   - Yet to be Completed:
     - Possible geophysical logging of several strategically located candidate Harney Basin wells yet to be identified to aid distinguishing sub-surface geologic-hydrostratigraphic units and identify the depth to a predominant extremely low hydraulic permeability zone in the valleys and uplands.
     - Complete analyses of existing and any new geophysical logs.
     - Completion is anticipated to occur in November 2018.

3. <u>Define Hydrostratigraphic Units:</u> Ongoing
   - Started:
     - Relating geologic units of the OWRD compiled surficial geologic map to the lith-coding for each lith-coded Harney Basin well in the OWRD Groundwater database began in 2017.
     - Currently, the map's 12 "lumped" geologic units reflecting similar geologic properties, origin, and likely hydraulic properties has been related to lith-coding for 343 of the 2468 lith-coded Harney Basin wells.
   - Restarting:
     - Relating geologic units of the Sherrod & Kieth (USGS) compiled surficial geologic map based on geologic age, composition, hydrogeologic grouping and lithologic pattern to the lith-coding for each lith-coded Harney Basin well in the OWRD Groundwater database.
     - Completion is anticipated to occur by November 2018.

4. <u>Create Maps of Hydrostratigraphic Units (extent and thickness):</u> Begin Spring 2018
   - Creating hydrostratigraphic maps depend upon completing the defining of hydrostratigraphic units.
   - The current challenge is to distinguish different hydrostratigraphic units with depth below land surface in the main valley areas given their description on water well reports is often similar. Efforts to distinguish the units with depth have begun and will continue. The effort has and will include:

- Aerial and vertical distribution of fine versus coarse grained sediments using the lith-coding for each lith-coded Harney Basin well in the OWRD Groundwater database.
- Aerial and vertical distribution of hydraulic properties using available specific capacity, pump test, and aquifer test data along with well construction data in the OWRD Groundwater database.

- Completion is anticipated to occur by November 2018.

5. Conduct Geology Field Trips: Ongoing
   - Completed:
     - Geologic field trip of Donner und Blitzen valley for Harney Basin GW study technical team members led by David Sherrod (USGS)
     - Multiple geologic field trips for Harney Basin GW study technical team members (individual and group) of different DOGAMI geologic mapping (1:24,000 scale) in upland areas adjacent to Harney Valley led by DOGAMI's Mark Ferns, Bob Houston, Jason McCluaghry, and student intern.
     - Geologic field trip of Harney Basin volcanic tuff deposits for the Harney GW SAC and interested public led by DOGAMI's Bob Houston.
   - Yet to be Completed:
     - Additional geologic field trips for Harney Basin GW study technical team members of ongoing DOGAMI geologic mapping to assimilate additional geologic information as it becomes available.
     - Completion is anticipated to occur in November 2018.

Phase 1: Drilling

		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022			
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22			
Drilling		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Determine drilling-program objectives	Both																										
Identify well sites	Both																										
Conduct drilling operations	OWRD																										
Logging and analysis	OWRD																										
Well testing	OWRD																										

1. Determine Drilling Program Objectives: Completed
   - Primary Objectives:
     - Obtain detailed sub-surface geologic data at key locations.
     - Obtain hourly or bi-hourly groundwater level data representing groundwater at different depth in different geologic units and/or different water bearing zones within the same geologic unit at key locations where high frequency time-series groundwater level data is needed to:
       - Provide groundwater level data in areas where the data is sparse, or
       - Provide groundwater level data in likely groundwater recharge or discharge areas, or
       - Assess groundwater level seasonal and long-term trend in areas of high groundwater use, or
       - Assess the relationship between groundwater at different depths or different geologic units, or
       - Assess the relationship between groundwater and surface water and/or evapotranspiration.
   - Additional Objectives
     - Obtain aquifer test data.
     - Obtain groundwater chemistry data

2. Identify Well Sites: Completed
   - General areas were identified using the drilling program objectives.
   - Specific site locations were identified based upon site accessibility and securing site access agreements.

3. Conduct Drilling Operations: Ongoing
   - Completed:
     - Lawen (June 2015): 2 wells (shallow & deep)
     - Virginia Valley (October 2016): 2 wells (shallow & deep)
     - Sunset Valley (November 2016): 2 wells (shallow & deep)
     - Weaver Springs (December 2016): 2 wells (shallow & deep)
     - Chain Lakes (June 2017): 1 well
   - Yet to be Completed:
     - OSU Agricultural Research Station: 3 wells (very shallow, shallow, deep)
     - Completion is anticipated to occur by September 2018.

4. Logging and Analysis: Ongoing
   - Completed:
     - Geologist collection, description and maintaining a written log of well cutting samples or well core samples representing 10-foot well depth increments except where driller lost fluid circulation.
     - Geologic analysis of the samples collected.
     - Data entry of written log into the OWRD Groundwater database.
   - Yet to be Completed:
     - Geologist collection, description and maintaining a written log of well cutting samples of OSU Agricultural Research Station wells to be drilled.
     - Geologic analysis of the samples collected from OSU Agricultural Research Station wells.
     - Geophysical logging of selected deep wells.
     - Data entry and analysis of the geophysical data.
     - Completion is anticipated to occur by November 2018.

5. Well Testing: Pending
   - Pending:
     - Collection of water chemistry samples dependent on small diameter pump availability.
     - Use of wells in the vicinity of irrigation wells as aquifer test observation wells.
   - Anticipated Completion:
     - Water chemistry collection: September 2018.
     - Use as aquifer test observation wells: January 2019.

Phase 1: Hydrologic Data Collection and Flow System Evaluation

		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022			
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22			
Hydrologic Data Collection and Flow-System Evaluation		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
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Field inventory wells	OWRD																										
Monitor well network and archive groundwater levels	OWRD																										
Enter data into NWIS	USGS																										
Develop water-level visualization tool	USGS																										
Evaluate and interpret water-level data	Both																										
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Determine data gaps	Both																										
Evaluate role of structure in hydrology	OWRD																										
Evaluate possible groundwater subbasins	OWRD																										
Estimate hydrogeologic unit properties (K&S)	OWRD																										
Evaluate existing aquifer tests (long-term, single-well, specific capacity)	OWRD																										
Conduct and evaluate potential new aquifer tests	OWRD																										
Apply/evaluate geochemistry and age dating	USGS																										
Evaluate chemical tracer data: isotopes, age dating, major ions, temperature	USGS																										
Collect new chemical tracer data-reconnaissance	USGS																										

1. Compile Existing Water-Level Data:
   - Completed:
     - Collected published and unpublished historic groundwater level data.
     - Entered well information inventory into OWRD Groundwater database.
     - Entered historic groundwater level data into OWRD Groundwater database.
     - Collect and enter new OWRD groundwater level data into OWRD Groundwater database.
   - Yet to be Completed:
     - Enter Harney Watershed Council groundwater level data into OWRD Groundwater database.
     - Completion depends upon:
       - Creating well information inventory for OWRD Groundwater database.
       - Entering well information inventory into OWRD Groundwater database.
       - Training watershed council representative on OWRD Groundwater database protocols.
     - Anticipated completion is September 2018.

2. Field Inventory Wells:
   - Completed:
     - Historic USGS field inventory of Harney Basin water level wells for previous studies:
       - Inventory sheets are in USGS Oregon Water Science Center files.
       - Inventory data is in USGS NWIS database and shared with OWRD Groundwater database.
     - OWRD field inventory of current groundwater study water level wells:
       - Inventory sheets are in OWRD Groundwater Section files.
       - Inventory data is in OWRD Groundwater database and shared with USGS NWIS database.
   - Yet to be Completed:
     - Harney Watershed Council groundwater level wells (about 80 wells), need owner access permission.
     - OWRD watermaster quarterly wells (about 20 wells), need owner access permission.
     - Elevation survey of well measuring points to improve groundwater level elevation precision.
       - This task is not part of original work plan, but determined essential for study data analyses.
       - See details under item 7 below: "Determine Groundwater Flow Direction" within the "Yet to be completed" sub-section.
     - Anticipated completion is September 2018.

3. Monitor Well Network and Archive Groundwater Levels:
   - Completed:
     - Synoptic Groundwater level measurement wells: 231 wells.
     - Quarterly Groundwater level measurement wells: 120 wells.
     - Re-evaluated Quarterly Groundwater level measurement wells:
       - Revised to 109 wells (May 2018)
       - Assessed continued need for wells showing duplicate data: 13 wells dropped.
       - Assessed adequacy of study area coverage and well depth coverage: 2 wells added.
     - Recorder Groundwater level measurement wells: 19 wells.
   - Yet to be Completed:
     - Add 3 OSU Agricultural Research Station wells to be drilled to current 19 recorder wells.
     - Incorporate Harney Watershed Council groundwater level well network: about 80 wells.
     - Future Harney quarterly groundwater level measurements from present through 2022 or later.
   - Anticipated completion is November 2022.

4. Enter Data into NWIS:
   - Completed:
     - All OWRD Groundwater database data is shared with USGS NWIS database.
     - OWRD-USGS data sharing complete through February-March 2018 groundwater level synoptic.
   - Ongoing:
     - Spring 2018 groundwater level synoptic data (anticipate data share in April 2018).
     - Future Harney quarterly groundwater level measurements from present through 2022 or later.
   - Anticipated completion is November 2022.

5. Develop Water-Level Visualization Tool:
   - Completed:
     - USGS:
       - Harney Basin water level mapper approved and released to public in February 2018.
       - Harney Basin water level mapper can be found via USGS web-page at:

         https://or.water.usgs.gov/projs_dir/harney_gw/

     - OWRD:
       - OWRD statewide Groundwater Site Information System released to public in November 2017.
       - OWRD statewide Groundwater Site Information System via OWRD web-page at:

         http://apps.wrd.state.or.us/apps/gw/gw_info/gw_info_report/Default.aspx

   - Ongoing:
     - USGS maintenance of Harney Basin water level mapper through 2022.
     - OWRD maintenance of statewide Groundwater Site Information System in perpetuity.
     - Future Harney quarterly groundwater level measurements from present through 2022 or later.

6. Evaluate and Interpret Water-Level Data:
   - Completed:
     Initial "Greater Harney Valley Area" groundwater level trend assessment was completed in June 2015.
     - Initial finding of definite long-term groundwater level decline in Weaver Springs area and Crane-Buchanan corridor area.
     - Initial finding of possible to likely long-term groundwater level decline in other "Greater Harney Valley Area" vicinities.
     - Initial finding of total permitted groundwater use possibly to likely exceeding the capacity of the groundwater resource.
   - Pending:
     - Updating graphs of groundwater level data (individual wells and well groupings).
     - Systematic analyses of the groundwater level data graphs:
       - Groundwater level trend analyses (seasonal and long-term).
       - Groundwater level trend versus climate trend analyses.
       - Groundwater level trend versus location, well depth, and/or hydrostratigraphic unit analyses.
       - Groundwater level data trend versus groundwater use and/or groundwater budget analyses.
       - Groundwater level data trend versus nearby surface water (GW - SW interaction).
       - Groundwater level data trend in uplands versus valleys.
   - Anticipated completion is November 2018.

7. Determine Groundwater Flow Direction (Horizontal, Vertical):
   - Completed:
     Preliminary potentiometric (water table) map was completed in September 2016.
     - Primary data was from spring 2016 synoptic groundwater level data at 147 wells.
     - Supplemental data to provide "control" in data gap areas came from:
       - April 2016 quarterly groundwater level data.
       - Other available groundwater level data.
       - Mapped spring elevation data.
     - Map was used to:
       - Identify well coverage gaps that needed to be filled.
       - Identify areas where groundwater level differences needed explanation.
       - Compare to previous groundwater level maps by Piper and others (1939) and Leonard (1970).
       - Gain an initial sense of the current potentiometric (water table) surface and GW flow directions.
   - Yet to be Completed:
     - Create potentiometric (water table) map based primarily upon February-March 2018 synoptic groundwater level data related to 207 wells with static groundwater level measurements and any available supplemental data from:
       - Harney Watershed Council groundwater level wells.
       - Permit condition wells.
     - Need to conduct well measuring point elevation surveying at up to 199 candidate wells to increase the precision of elevation values for the potentiometric map.
       - Needed in areas where groundwater elevation differences are less than the precision of current elevation values.
       - This task is not part of original work plan, but determined essential for map and data analyses.
       - The work is contracted with DOGAMI Oregon Lidar Consortium to survey as many of the 199 wells as possible within 2 field weeks maximum, one week in June and one week in July using survey grade GPS units.
       - The surveying well prioritization strategy is:
         + Survey wells located outside areas with completed Lidar coverage (see attached map).
         + Survey wells within areas of Lidar coverage developing or in progress.
         + Survey wells within areas of existing Lidar coverage.
     - Systematic analysis of potentiometric map:
       - Note - explain groundwater level change since Piper and others (1939) and Leonard (1970).
       - Note - explain areas where groundwater level differences occur.
       - Note - explain current potentiometric (water table) surface and areal GW flow directions.
       - Note - explain current vertical GW flow directions (upward, downward, none) by area.
       - Note - explain areas of groundwater recharge and discharge.
       - Note - explain areas of identified geologic structure influence on groundwater flow.
       - Note - explain areas of identified hydrostratigraphic unit change on groundwater flow.
       - Note - explain groundwater flow in uplands versus valleys.
       - Note - explain occurrence or absence of groundwater sub-basins.
     - Systematic analysis of updated groundwater level data graphs (individual wells and well groupings).
       - Note - explain current vertical GW flow directions (upward, downward, none) by area.
       - Note - explain areas of groundwater recharge and discharge.
       - Note - explain areas of identified geologic structure control influence.
       - Note - explain areas of identified hydrostratigraphic unit change influence.
       - Note – define and explain occurrence or absence of groundwater sub-basins considering all available and pertinent physical and chemical data.
   - Anticipated completion is November 2018.

8. Determine Groundwater Trends (Response to Pumping and Climate):
   - See previous item 6 ("Evaluate and Interpret Water-Level Data"), "Pending."
   - Anticipated completion is November 2018.

9. Determine Data Gaps:
   - See previous item 7 ("Determine Groundwater Flow Direction (Horizontal, Vertical"), "Completed."
   - Completed.

10. Evaluate Role of Structure in Hydrology:
   - See previous item 7 ("Determine Groundwater Flow Direction (Horizontal, Vertical"), "Yet to be Completed."
   - Anticipated completion is November 2018.

11. Evaluate Possible Groundwater Sub-Basins:
   - See previous item 7 ("Determine Groundwater Flow Direction (Horizontal, Vertical"), "Yet to be Completed."
   - Anticipated completion is November 2018.

12. Estimate Hydrogeologic (Hydrostratigraphic) Unit Properties:
   - Ongoing:
     Compile and assess existing aquifer property test data and/or analyses from:
     - Previous studies.
     - OWRD water right permit pump test program.
     - Driller pump tests reported on water well reports (well logs).
     - Available miscellaneous tests.
   - Yet to be Completed:
     - New aquifer property tests: Conduct non-irrigation season (1 November to 28 February) tests.
       - Prioritize areas for conducting tests.
       - Single pumping well with observation wells (preferably unused, instrumented wells).
       - Possibly multiple pumping wells with observation wells (preferably unused, instrumented wells).
     - Systematic analysis of aquifer property test data (existing and new):
       - Determine aquifer transmissivity-hydraulic conductivity from aquifer property test data.
       - Determine aquifer storage coefficient from aquifer property test data
       - Graph and analyze aquifer property values versus well open interval depth.
       - Graph and analyze aquifer property values versus hydrostratigraphy.
       - Graph and analyze aquifer property values derived from specific capacity data versus:
         + Single well aquifer test data.
         + Single pumping well with observation well(s) data.
         + Multiple pumping wells with observation well(s) data.
       - Map and analyze aquifer property values versus location and open interval depth.
   - Anticipated Completion:
     - September 2018 for existing aquifer property test data.
     - January 2019 for non-irrigation season (1 November to 28 February) aquifer property tests.

13. Apply/Evaluate Geochemistry and Age Dating (water chemistry data and analyses):
    - Ongoing:
        - Some historic (published and unpublished) Harney Basin spring and well water chemistry data has been entered into the USGS NWIS database.
        - Current Harney Basin groundwater study spring and well water chemistry data is being entered into the USGS NWIS database.
        - Current PSU MS student thesis spring and well water chemistry data currently resides with student.
        - Preliminary graphing and analyses of chemistry data to assess possible water source(s), age, mixing, change along suspected flow path(s), areal differences, and data gaps.
    - Yet to be Completed:
        - Additional (strategic) spring and well water chemistry sampling by USGS.
        - Possible future (spring 2018 - fall 2019) well water chemistry sampling by Oregon DEQ initiated independently of the Harney Basin groundwater study:
            - May add chemistry of interest to the Harney Basin groundwater study.
            - Will electronically store data in publically accessible EPA STORET and DEQ Ambient Water Quality Monitoring System (AWQMS) database.
            - Will electronically share data with the Harney Basin groundwater study as it become available.
        - Add water chemistry data entry, storage, retrieval, and analysis capability to the OWRD groundwater database.
        - Obtain and complete data entry of historic, current, and future water chemistry (USGS, PSU, DEQ, and other) into the USGS NWIS and/or OWRD groundwater database.
        - Systematic analysis of historic and current spring and well water chemistry data (stable isotope, radiometric, major ions, trace elements, and possibly other chemistry) to possibly determine water source(s), age, mixing, change along identified flow path(s), areal differences, and relationship to hydrostratigraphic units using various Harney Basin GW study produced graphs and/or maps.
    - Anticipated completion is November 2018.

Phase 1: Hydrologic Budget

		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022			
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22			
Hydrologic Budget		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Estimate GW discharge to wells (transient)	OWRD																										
Estimate GW use	OWRD																										
Link GW use to wells	OWRD																										
Link wells to hydrogeologic units	Both																										
Assign water use to wells	OWRD																										
Determine period of use	OWRD																										
Estimate GW discharge to streams	USGS																										
Seepage runs	Both																										
Hydrograph analysis	USGS																										
Evaluate alternate potential methods of estimating discharge to streams	Both																										
Estimate GW discharge to springs, lakes, wetlands	USGS																										
Compile existing data	USGS																										
Collect new measurements	Both																										
Estimate ET loss	USGS																										
Recharge (transient)	USGS																										
Review literature	USGS																										
Determine appropriate approach (SWB,PRMS, mass-balance, water-level response)	USGS																										
Implement recharge analysis	USGS																										
From precipitation	USGS																										
From irrigation	USGS																										
From surface water (streams, canals)	USGS																										
Determine mountain front recharge component	USGS																										
Evaluate possible interbasin flow	USGS																										

1. Estimate Groundwater Discharge to Wells (Transient):
   - Completed:
     - 850 wells with a water well report (well-log) in the Malheur Lake Administrative Basin correlated to:
       - One or more of 784 "valid" (non-cancelled) Oregon groundwater rights found in the OWRD groundwater database.
       - One or more of 1145 of 1514 points of diversion (POD) wells total associated with the 784 "valid" Oregon groundwater rights found in the OWRD groundwater database. Many of the 369 non-correlated POD wells have wells yet to be constructed or have no water well reports.
     - Note: 883 of the 1514 POD wells noted above are associated with Oregon groundwater rights that include a water measuring device (totalizing flow meter) condition (requirement).
   - Yet to be Completed:
     - Complete correlation of Harney Basin wells to permitted and/or certificated Oregon groundwater rights in the OWRD groundwater database.
     - Estimate Groundwater Use:
       - Irrigation use:
         + Obtain location of irrigation wells (Township/Range-section, tax lot, and/or GPS) and date of irrigation well completion from OWRD databases.
         + Determine the hydrostratigraphic unit(s) each irrigation well taps.
         + Determine and reconcile annual time series of spatial coverage of primary and supplemental irrigation place of use (POU) acreage (developed and undeveloped) for each groundwater right using OWRD water right digital data and digital maps and satellite imagery.
         + Determine annual time series of water use for each developed surface water and groundwater related POU for 25 years (1991 to 2016) using evapotranspiration (ET) analyses utilizing 4 approaches [ET unit approach, Landsat-vegetation index (VI) approach, Operational simplified surface energy balance model (SSEBop) approach, and Mapping Evapotranspiration at high Resolution using Internalized Calibration (METRIC) approach] using a combination of various satellite imagery and on-ground data [latent & sensible heat flux, ambient air temperature & humidity, wind speed & direction, net radiation, soil temperature & heat flux, and precipitation, vegetation, water right, and other data] to estimate monthly, seasonal, and annual net ET and total ET.
         + Contrast and/or constrain ET based irrigation water use estimate(s) with other irrigation estimation methods based upon OWRD surface water and groundwater right allowable rate and duty data (maximum allowable usage), available well flow meter data (actual usage for some POU acreage), OSU-USDA Harney Basin crop demand, Harney Placed Based Planning agriculture sub-committee analysis-information, and/or other methods to be identified.
         + Assign 100% groundwater use to POU acreages with primary groundwater right only.
         + Assign 100% surface water use to POU acreages with primary surface water right only.
         + Assign surface water usage versus groundwater usage for each POU acreage with primary surface water right and supplemental groundwater right for each year based upon surface water right priority date related to each POU and the watermaster log of priority date based surface water regulation for each year.
         + Determine water source and assign water usage to any developed acreage with no approved, non-cancelled water right.
       - Municipal Use:
         + Obtain location of municipal wells (Township/Range-section, tax lot, and/or GPS) and date of irrigation well completion from OWRD databases.
         + Determine hydrostratigraphic unit tapped by each municipal well.

- Obtain recorded-reported municipal well pumping time series data in OWRD groundwater and water use databases and/or directly from each municipality.
- Obtain municipal wastewater effluent discharge to evaporation pond time series data.
- Obtain data or determine time series for any possible precipitation and/or runoff inflow to evaporation pond.
- Determine time series for municipal wastewater effluent seepage to subsurface versus evaporation using ET analyses for open water.
- Conduct calculations to determine time series for net municipal groundwater use.
- Contrast and/or constrain municipal water use estimate(s) with groundwater right allowable rate and duty data (maximum allowable usage).

- Industrial Use:
  - Obtain location of industrial wells (Township/Range-section, tax lot, and/or GPS) and date of irrigation well completion from OWRD databases.
  - Determine hydrostratigraphic unit tapped by each Industrial well
  - Obtain any available recorded-reported well pumping time series data for any independent (non-municipal supported) industrial wells noted in the OWRD groundwater and water use databases and/or directly from each industry. If data is not available, use industry derived estimates for similar sized industry.
  - Obtain any available independent industrial wastewater effluent discharge to evaporation pond time series data. If data is not available, use industry derived estimates for similar sized industry.
  - Obtain data or determine time series for any possible precipitation and/or runoff inflow to evaporation pond.
  - Determine time series for independent industry wastewater effluent seepage to subsurface versus evaporation using ET analyses for open water.
  - Conduct calculations to determine time series for net independent industry groundwater use.
  - Contrast and/or constrain independent industrial water use estimate(s) with groundwater right allowable rate and duty data (maximum allowable usage).
- Community Water System Use:
  - Obtain location of community water system wells from Oregon Health Authority Drinking Water Program and/or OWRD databases.
  - Determine hydrostratigraphic unit tapped by each community water system well.
  - Determine community water system well water usage based upon any available recorded-reported time series data in OWRD groundwater and water use databases, or from Oregon Health Authority Drinking Water Program (reported usage and/or usage used for well-head protection calculations), and/or directly from each community water system.
  - Identify the presence, determine the size, and determine the water needed for any green space supported by a community water system based upon any available recorded-reported seasonal water use data, domestic use determinations (see next groundwater use sub-section, “Domestic Use”), and or studies applicable to the Harney Basin conditions.
  - Determine community water system wastewater effluent discharge to septic system and/or evaporation pond based upon any available time series data and/or any wastewater effluent discharge studies (DEQ, EPA, other) applicable to the Harney Basin conditions.
  - Contrast and/or constrain community water system use estimate(s) with any available groundwater right allowable rate and duty data (maximum allowable usage) and/or any community water system water usage studies applicable to the Harney Basin conditions.

- Domestic Use:
  - Obtain location of active rural residential dwellings (Township/Range-section, tax lot) and date of dwelling becoming active from Harney County records.
  - Obtain location of domestic wells (Township/Range-section, tax lot, and/or GPS) and date of domestic well completion from OWRD databases.
  - Determine hydrostratigraphic unit tapped by each domestic well.
  - Determine domestic well water usage based upon any available recorded-reported time series data in OWRD groundwater and water use databases, municipal water use data, domestic water usage studies applicable to the Harney Basin conditions, Harney GW SAC domestic sub-committee analysis-information, and/or other methods to be identified.
  - Identify the presence, size, and water needed for any green space supported by a domestic well based upon any available recorded-reported seasonal water use data, domestic use analyses, studies applicable to the Harney Basin conditions, Harney Placed Based Planning domestic sub-committee analysis-information, and/or other methods to be identified.
  - Determine domestic wastewater effluent discharge to septic system based upon any available time series data and/or any domestic wastewater effluent discharge studies (DEQ, EPA, other) applicable to the Harney Basin conditions.
  - Contrast and/or constrain domestic well water usage estimate(s) with any available groundwater right allowable rate and duty data (maximum allowable usage), driller estimated well yield recorded on water well report, and/or any domestic well water usage studies applicable to the Harney Basin conditions.
- Livestock Use:
  - Obtain location of livestock wells (Township/Range-section, tax lot, and/or GPS) and date of livestock well completion from OWRD databases.
  - Determine hydrostratigraphic unit tapped by each livestock well.
  - Identify active versus inactive livestock wells
  - Identify livestock wells used seasonally versus year-round.
  - Identify livestock wells with automated shutoff versus continuous pumping.
  - Determine hydrostratigraphic unit tapped by each livestock well.
  - Determine livestock well water usage based upon U.S. BLM, U.S. FWS, and other available records, any livestock water use demand studies by USDA, ODA, OSU, and others applicable to Harney Basin conditions, Harney Placed Based Planning livestock sub-committee analysis-information, and/or other methods to be identified.
  - Contrast and/or constrain livestock well water usage estimate(s) with any available groundwater right allowable rate and duty data (maximum allowable usage), driller estimated well yield recorded on water well report, and/or any livestock well water usage studies applicable to the Harney Basin conditions.

- Link Groundwater Use to Wells:
  See discussion in previous sub-section: "Estimate Groundwater Discharge to Wells (Transient)"
- Link Wells to Hydrogeologic (Hydrostratigraphic) Units:
  See discussion in previous sub-section: "Estimate Groundwater Discharge to Wells (Transient)"
- Assign Water Use to Wells:
  See discussion in previous sub-section: "Estimate Groundwater Discharge to Wells (Transient)"
- Determine Period of Use:
  See discussion in previous sub-section: "Estimate Groundwater Discharge to Wells (Transient)"

- Anticipated completion is late November 2018.

2. Estimate Groundwater Discharge to Streams:
   - Completed:
     - Seepage Run Segments:
       - Silvies River (fall 2017):
         - Filemile Dam to Greenhouse Road.
       - Silver Creek (fall 2017):
         - Wickiup Creek (Claw Creek) confluence to Nicoll Creek (gage station) confluence.
         - Dry Mountain Ranch reach from ranch north side to ranch south side.
       - Poison Creek (fall 2017):
         - Below Wilson Creek confluence to Hwy 20.
       - Rattlesnake Creek (fall 2017):
         - Above Fort Harney to south of Fort Harney.
   - Yet to be Completed:
     - Seepage Run Segments:
       - Silvies River:
         - River gage station (ID 10393500) to Fivemile Dam.
         - Revisit Hotchkiss Road to Greenhouse Road segment.
         - Possibly a segment above Malheur Lake.
       - Silver Creek:
         - A segment above and/or below Moon Reservoir.
         - Revisit Dry Mountain Ranch segment from ranch north side to ranch south side.
       - Donner und Blitzen River:
         - Fish Creek confluence to river gage station (ID 10396000) above Frenchglen.
       - Possibly Kiger Creek.
       - Possibly Cucamonga Creek.
     - Hydrograph Analyses:
       - Identify recorder and or quarterly measurement wells in the vicinity of surface water that have a completion depth less than 200 feet and/or casing and seal depth less than 200 feet.
       - Obtain available stream gage data from OWRD databases.
       - Compare-analyze graphs for possible relationships.
     - Evaluate Alternate Potential Methods of Measuring Discharge to Streams:
       - Installing and monitoring temporary nested shallow drive-point "wells" of varying depth at targeted locations is under consideration, but well rules may preclude.
       - Installing and monitoring temporary streambed seepage devices at targeted locations is under consideration.
     - Determine groundwater discharge to streams and groundwater recharge from streams using the above measurements and analyses.
   - Anticipated completion is November due to conditions needed for field measurements.

3. Estimate Groundwater Discharge to Springs, Lakes, Wetlands:
   - Completed:
     - Compile Existing Data:
       - 102 published and unpublished springs inventoried in OWRD groundwater database, including date(s) of discharge measurement(s). Note: 10 of the springs are outside the Harney Basin.
       - Digital map coverage of 46 Harney Basin springs.
     - Collect New Measurements:
       - 7 Warm Springs Valley springs measured by OWRD hydrologist & UW MS student (part of the 102 springs inventoried in OWRD groundwater database).
       - Other Harney Basin springs measured and/or sampled by PSU MS student.

- Obtain and review published and unpublished USGS and/or U.S. FWS literature and data related to water budgets for Harney Basin lakes and wetlands.

- Yet to be Completed:
  - Compile Existing Data:
    - Add Harney Basin springs measured and/or sampled by PSU MS student to springs inventoried in OWRD groundwater database.
    - Add to the OWRD groundwater database the spring discharge measurement data for the 102 published and unpublished springs inventoried in OWRD groundwater database and for the other Harney Basin springs measured and/or sampled by PSU MS student.
    - Add to the OWRD groundwater database available spring water chemistry data for the 102 published and unpublished springs inventoried in OWRD groundwater database and for the other Harney Basin springs measured and/or sampled by PSU MS student.
  - Estimate Evapotranspiration (ET) Loss:
    - Analyze USGS and/or U.S. FWS literature and data related to water budgets for Harney Basin lakes and wetlands.
    - Conduct evapotranspiration (ET) analyses utilizing 4 approaches using a combination of various satellite imagery and on-ground data [latent & sensible heat flux, ambient air temperature & humidity, wind speed & direction, net radiation, soil temperature & heat flux, and precipitation, vegetation, water right, and other data] to estimate monthly, seasonal, and annual net ET and total ET from irrigated land, grassland, wetland, marsh, and groundwater recharge areas:
      + ET unit approach.
      + Landsat-vegetation index (VI) approach.
      + Operational simplified surface energy balance model (SSEBop) approach.
      + Mapping Evapotranspiration at high Resolution using Internalized Calibration (METRIC) approach.
  - Determine groundwater discharge to springs, lakes, and wetlands, and determine and groundwater recharge from lakes and wetlands using surface water inflow-outflow data and ET analyses.
- Anticipated completion is November 2018.

4. <u>Recharge (Transient):</u>
   - Completed:
     - Literature Review.
     - Identify Groundwater Recharge Analysis Approaches Potentially Appropriate for the Harney Basin:
       - Modified Maxey-Eakin Approach:
         + An empirical model that estimates groundwater recharge as a function of precipitation.
         + Input data includes: time-series precipitation data and measured or estimated surface water discharge from the uplands to the valley floor.
         + Output includes: mean annual total water available for groundwater recharge or surface runoff and net upland groundwater recharge.
       - Soil Water Balance (SWB) Method:
         + A non-empirical model.
         + Input data includes: spatially variable precipitation and temperature data, soils data (hydrologic soil group and soil-water capacity), land-use classifications (vegetation type), and surface water data (surface water discharge measurements and base-flow estimates).
         + Output includes: spatially variable and time transient groundwater recharge estimates.

        - Recharge from Streamflow Losses (Mass Balance Method):
            - Recharge is estimated as a residual of the surface water budget.
            - Input data includes: measured and estimated mean annual surface water discharge from the uplands to the valley floor, mean annual evapotranspiration (ET) from surface water irrigation, and mean annual surface water discharge to the valley lakes.
            - Output includes: groundwater recharge from streamflow loss to the valley basin fill.
        - Precipitation-Runoff Modeling System (PRMS):
            - This method evaluates the impacts of various combinations of precipitation, climate, and land use on streamflow, sediment yields, and general basin hydrology. A basin's response to normal and extreme rainfall and snowmelt can be simulated to evaluate changes in water-balance relationships, flow regimes, flood peaks and volumes, soil-water relationships, sediment yields, and groundwater recharge.
            - Input data includes: precipitation and air temperature data, solar radiation data, streamflow and sediment data, and topography, soil, and vegetation data.
            - Output includes: surface water discharge, annual and monthly potential and actual evapotranspiration (ET), and surface water gain and/or loss from/to groundwater.
        - Water-Level Response Method:
            - Identify recorder and/or quarterly measurement wells with data showing possible response to precipitation events and/or surface water changes at streams, lakes, or fields.
            - Obtain available precipitation or surface water data from gages and/or estimates.
            - Compare-analyze groundwater level graphs to surface water and precipitation graphs for possible relationships.
            - Determine the component of groundwater level change in response to precipitation events and/or surface water changes.
            - Calculate recharge rate and/or volume responsible for observed groundwater level changes using analytic and/or numerical methods, hydraulic property values (aquifer, streambed, and/or soil), groundwater level versus surface water level differences, and/or other data.
- Yet to be Completed:
    - Implement Recharge Analysis (recharge from precipitation, surface water, and irrigation):
        - Modified Maxey-Eakin Approach: ongoing
        - Soil Water Balance (SWB) Method: ongoing
        - Recharge from Streamflow Losses (Mass Balance Method): ongoing
        - Evapotranspiration (ET) Analyses: ongoing
    - Determine Mountain Front Recharge Component.
        - Conduct seepage runs: ongoing
            - At perennial streams and intermittent runoff streams discharging from the uplands.
            - At multiple stream sites: above the upland mouth, at or near the upland mouth, on and/or below the valley alluvial fan adjacent to the upland, at the confluence with another surface water body or note where the stream's flow within the valley ceases.
        - Water- Level Response Method applied to mountain front vicinity sites.
- Anticipated completion is November 2018.

5. Review Literature:
    - See previous item 4 ("Recharge (Transient)"), "Completed."
    - Completed.

6. Determine Appropriate Approach (SWB, PRMS, Mass-Balance, Water-Level Response):
   - See previous item 4 ("Recharge (Transient)"), "Completed."
   - See sub-section: "Identify Groundwater Recharge Analysis Approaches Potentially Appropriate for the Harney Basin".
   - Completed.

7. Implement Recharge Analysis:
   - See previous item 4 ("Recharge (Transient)"), "Yet to be Completed."
   - Anticipated completion is November 2018.

8. Determine Mountain Front Recharge Component:
   - See previous item 4 ("Recharge (Transient)"), "Yet to be Completed."
   - Anticipated completion is November 2018.

9. Evaluate Possible Interbasin Flow:
   - Completed:
     - Preliminary potentiometric (water table) map in September 2016 based on spring 2016 (March 2016) groundwater level synoptic measurements at 147 wells and supplemental non-synoptic data.
     - Preliminary map raises possibility of interbasin groundwater flow.
   - Yet to be Completed:
     - Potentiometric (water table) map based on late-February-early-March 2018 synoptic groundwater level measurements at 207 wells with static groundwater level measurements and any available supplemental data. Map completion needs well measuring point elevation surveying at up to 199 candidate wells to increase the precision of elevation values for the potentiometric map.
     - Determine groundwater flow direction at Harney Basin boundaries, particularly groundwater flow across the basin boundary to or from adjacent basins. Flow direction determination needs well measuring point elevation surveying at up to 199 candidate wells to increase the precision of elevation values that form the basis for assessing groundwater flow directions.
     - Calculate interbasin groundwater flow using analytic and/or numerical methods, observed hydraulic gradients, and available hydraulic aquifer property values.
   - Anticipated completion is November 2018.

Phase 1: Write Report to Synthesize Understanding of Groundwater Flow System

		CY 2016		CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022			
		FY 16		FY 17				FY 18				FY 19				FY 20				FY 21				FY 22			
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Write report to synthesize understanding of groundwater-flow system	Both																										

1. Write Report to Synthesize Understanding of Groundwater Flow System:
   - Anticipated Beginning: October-November 2018
     - Anticipate writing draft of various report sections to begin independently as various analyses progress and/or near completion.
     - Anticipate revising drafts as subsequent analyses become available, subsequent report sections are written, and "internal" Harney Basin groundwater study technical staff peer reviews occur.
     - Discuss preliminary results-findings at public meetings and receive feedback.
     - Revise draft as needed based upon feedback.

- Anticipated Completion of Peer Review Draft: September 2019
  - Submit draft to professional technical hydrogeologic peer reviewers.
  - Revise draft as needed based upon peer review feedback.
  - Revise draft as needed based upon preliminary numerical groundwater modeling effort begun for Harney Basin groundwater study Phase 2.
- Anticipated Completion of Final Report by December 2020

Harney Basin

Synoptic GW Level Wells
199 Candidates for
Well MP Elevation Surveying

Oregon Water Resources Department
May 2018

Explanation

Candidate Wells for Well MP Elevation Surveying and Lidar Coverage in the Harney Basin

- Harney_Selected_Wells_for_Well_MP_Elevation_Surveying
- DOGAMI_OLC_Lidar_Projects_Completed_03_13_2018
- DOGAMI_OLC_Lidar_Projects_in_Progress_03_13_2018
- DOGAMI_OLC_Lidar_Projects_Developing_03_13_2018
- Other_Completed_Lidar_Projects_03_13_2018
- Harney_Basin

Software: ESRI ArcMap ver. 10.3.1
Source File: S:\groups\gwater\grondin\areas\Harney_valley\arcview \Harney_Valley_Field_Work_Map\ Harney_Valley_Field_Work_Map_17_well_MP_elev_survey_2018.mxd

Oregon Lambert Projection, NAD 83 (EPSG# 2992)

This product is for informational purposes and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information.

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