Technical Proposal and Evaluation Criteria

Title: Analysis of seasonal groundwater dynamics for improved decision-support

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1. Executive summary

Due date: October 17, 2023
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The proposed work will enhance decision-support capabilities related to groundwater management in the Columbia Plateau Regional Aquifer System (CPRAS) in the Pacific Northwest. Improvements to existing modeling tools to improve the irrigation demand estimate, future climate simulations, and temporal resolution, as well as data collection efforts are the primary objectives from the NOFO that will be addressed herein. The U.S. Geological Survey (USGS) developed a model for the CPRAS that currently runs on an annual time step. The annual time step is beneficial for evaluating long-term changes in groundwater availability. However, the annual time step does not allow for an assessment of historical, and prediction of future, seasonal groundwater dynamics predominately related to summer pumping for irrigation. Parts of the CPRAS are well known for long-term groundwater declines related to irrigation pumping, especially in the Odessa Subarea. Additionally, municipal water systems in the study area have already experienced water shortages in the summer season that cannot be identified at the annual model time step or from the extensive groundwater monitoring conducted by the Washington State Department of Ecology (Ecology) that is mostly conducted in the spring when groundwater levels have rebounded from winter recharge. We propose to convert the model to run on a monthly timestep with improved irrigation demand estimates to better evaluate management decisions and climate scenarios that influence groundwater availability throughout the year. We will create and manage 47 new monitoring sites from contributed cost-share funds with co-located groundwater, soil moisture, and weather sensors that collect data on a sub-daily time step. These data will be used to calibrate and evaluate the improved model and will become part of existing networks to support water use decision making and research in the study area. The project will begin in April 2024 and will proceed through March 2026 for a total of two years. The project is *not* located on a Federal facility.

2. *Technical Project Description*

APPLICANT CATEGORY

We are a Category B applicant. We are acting in partnership with the Columbia Basin Conservation District (CBCD), a Category A entity (*see letter from K. Ribellia*). The CBCD is one of the key organizations for the Odessa Groundwater Replacement Project (OGWRP). They are already partners with PI for an existing U.S. Bureau of Reclamation project (#R20AP00123), participating in well monitoring activities. PI McLarty is also a partner on their recently funded Natural Resources Conservation Science (NRCS) Regional Conservation Partnership Program (RCPP) project. Her role is to coordinate groundwater monitoring efforts during implementation of CBCD's project. In the proposed work, we will partner with CBCD in three ways. First, we will work with them to identify water management scenarios in support of OGWRP implementation. They have current active projects including the RCPP and proposals under review to implement aspects of the OGWRP, specifically around delivery systems and on-farm infrastructure development. Second, we will work with CBCD to identify sites for the co-located monitoring stations. We will prioritize project sites within the OGWRP domain to monitor aquifer response to project implementation. Finally, CBCD is also submitting a proposal to the same program entitled, "Columbia Basin Groundwater Cooperative Interactive Web Application." Should both projects get funded, the data collected at our monitoring stations and modeling results will be uploaded in their web application and we will use their application as an avenue for results dissemination.

PROJECT GOALS

The overarching goal of the proposed work is to enhance a pre-existing regional groundwater flow model to evaluate seasonal groundwater dynamics. The existing model by Ely et al. (2014) runs on an annual timestep, which supports long-term historical evaluations of water level trends, but misses critical seasonal variability in groundwater demand and availability due mainly to irrigation pumping. The proposed work will build on an existing project to update the same model to run through 2020 instead of the current end date of simulations in 2007. Specific objectives in support of the overarching goal include:

1) Convert the model time step to monthly from annual.
2) Update the irrigation demand estimates.
3) Calibration and evaluation.
4) Scenario analysis.

DETAILED PROJECT DESCRIPTION

2.1. Data collection

Long-term data collection efforts provide crucial information about the status and sustainability of groundwater systems, and are required for calibration and validation of groundwater models (*Alley et al.*, 1999; *Taylor and Alley*, 2001). High temporal resolution data collected from pressure transducers provides critical information on the seasonality of groundwater dynamics. Figure 1a shows the location of existing sites with pressure transducers that are monitored by the Washington State Department of Ecology. The sites are clustered around the City of Spokane, the Palouse Basin and the Walla Walla Basin. The figure highlights limited transducer sites in the irrigated agricultural areas, including the groundwater-dependent Odessa Subarea and the Yakima Basin, two of the areas with the highest mean annual groundwater pumpage volumes in the study area (*Ely et al.*, 2014).

The seasonal variability of groundwater due to pumping can be significant. Drawdown levels occur during the pumping season throughout the study area, in some cases up to 30 feet during pumping (*Luzier and Burt*, 1974). The drawdowns occur rapidly after pumping begins and are widespread, which indicates strong confined conditions with low storage coefficients (*Wildrick*, 1985, 1991; *Covert*, 1995; *Porcello et al.*, 2009). Therefore, the vulnerability of individual users varies due to drawdown during pumping, causing both localized impacts at the site of pumping as well as distributed impacts as the cone of depression causes interference with neighboring wells. Figure 1b shows the seasonality of depth to groundwater at one of these sites from Figure 1a. The site is experiencing a declining trend over the period of record with distinct drops during the summer pumping season. This figure highlights the importance of capturing monthly groundwater dynamics to better understand historical, and predict future, groundwater availability during the pumping season.

The PI has established a stakeholder-driven groundwater monitoring network in Central and Eastern Washington funded by U.S. Bureau of Reclamation project #R20AP00123. The PI has partnered with seven conservation districts to conduct the monitoring following the Ecology

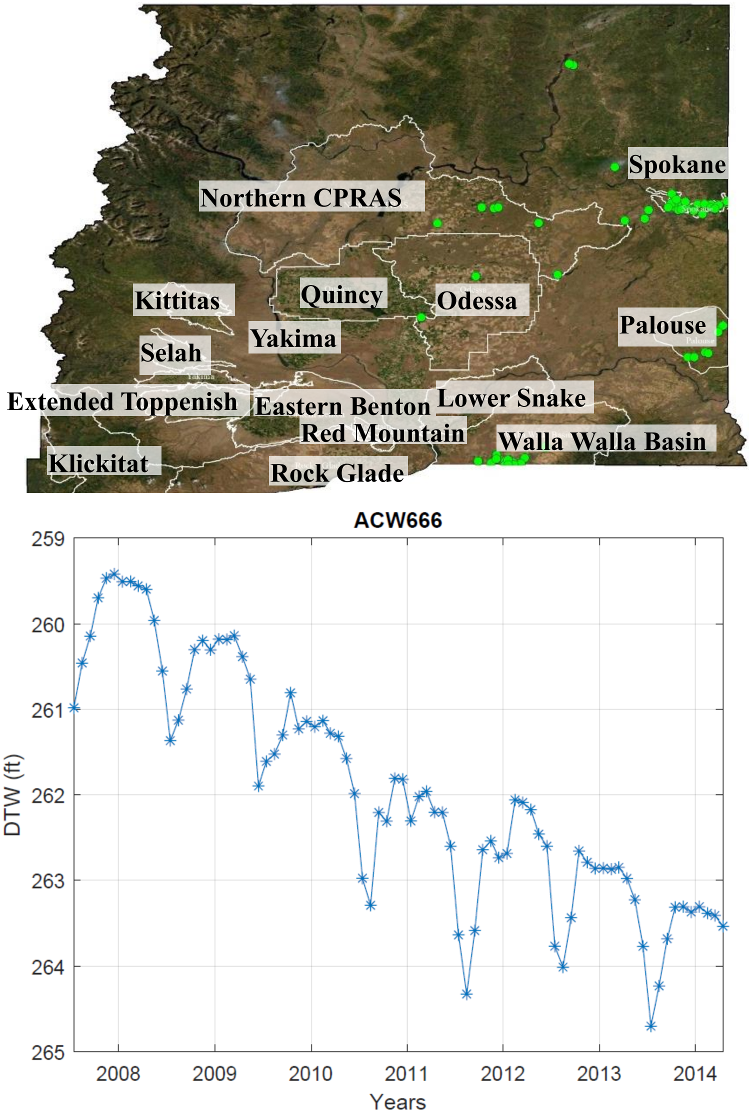

Figure 1. The top figure shows the location of pressure transducers (green dots) regularly monitored by the Washington State Department of Ecology in Eastern Washington. The white outlines correspond to the subarea boundaries from Hall et al. (2021). The bottom figure shows the depth to water (DTW) in feet on the y-axis for one pressure transducer site, aggregated to a monthly time step.

monitoring protocol, which began in 2021 and will continue through Spring 2024. Sites were prioritized within the study domain based on 1) irrigation and stock water wells screened in the deeper basalts and, 2) areas with a high density of permitted groundwater users but with limited recent monitoring sites.

Seven of the 31 sites monitored through that project contain pressure transducers to collect the highest accuracy and highest frequency observations. An additional 18 transducer sites are being added in the upcoming academic year from a recent seed grant (U.S. Geological Survey award #G21AP10598). Manual measurements are taken at all sites in the spring and fall. Fall measurements are taken to record the lowest value most impacted by pumping and the spring measurements are taken to represent the equilibrium level after winter recharge. The difference between these values indicates the maximum drawdown at each well location.

The proposed work will expand this monitoring effort to include additional sites and measurements. Cost-share funds (*see Letter of Funding Commitment from M. Rezac*) are included to establish 47 co-located sites to monitor groundwater, soil moisture, and weather. Groundwater will be monitored using pressure transducers to expand the number of sites with high accuracy and high temporal resolution groundwater data. The combination of the proposed sites and the PI's existing sites will nearly double the number of sites with continuous pressure transducer data when combined with the Ecology-monitored sites. The soil moisture sensors will monitor volumetric soil moisture content consistent with observations of soil moisture collected at over 100 sites by the AgWeatherNet. AgWeatherNet is a weather station network that provides data and decision-support for stakeholders, researchers, and policy-makers across the State of Washington and is managed at Washington State University (WSU). The weather stations monitor solar radiation, precipitation, relative humidity, air temperature, humidity, vapor pressure, barometric pressure, horizontal wind speed, wind gusts, wind direction, tilt, lightning strike counts, and the average lightning distance. Though not all the weather variables will be used in this project, the data will be made available for other uses (*see Data Management Practices*). The soil moisture and weather stations are manufactured by Meter Group. Meter Group is located in Pullman, WA and they teach a class each spring semester on how to use their instruments that the PhD student will enroll in.

2.2. Existing model

Groundwater flow dynamics in the CPRAS have been investigated through a series of USGS projects, which have produced several technical reports detailing the geology, data availability, and observationally inferred flow paths (*Snyder and Haynes*, 2010; *Burns et al.*, 2011). The major aquifer units, in order of shallowest to deepest, and also increasing thickness, are an overburden unit (surficial deposits, mean thickness 15 meters), the Saddle Mountain unit (a sparse deposit of volcanic and sedimentary deposits, mean thickness 90 m), the Wanapum basalt (basalt with sedimentary interbeds, mean thickness 100 m), and the Grande Ronde basalt (basalt with sedimentary interbeds, up to 4,000 m thick in places); all but the overburden are geologically classified as members of the Columbia River Basalt Group. The unconfined system is most abundant in the overburden unit, where modern sediments are accumulating on top of the basalt flows and scablands. The core of the basalt flows tends to be massive with some vertical fractures that can allow rapid movement of water, but there seem to be few vertical connections that directly link the unconfined system to the deeper confined layers.

The hydrogeologic properties of these units were estimated in previous work summarized by *Kahle et al*. (2011). The hydraulic conductivity was found to vary greatly and had a significant vertical anisotropy of up to 1000:1 in places (lateral conductivity is 1000 times higher than vertical) (*Ely et al.*, 2014), highlighting the focused nature of the deeper flow system. This hydrogeologic summary illustrates that the CPRAS system is not a simple aquifer. It is a highly complex, overlapping, multi-aquifer system where changes in the deeper confined system (*i.e.* from pumping) are not reflected by the shallow, water table aquifers.

The hydrogeologic data were compiled into a detailed numerical flow simulation to better understand the system's dynamics and allow for long-term forecasting (*Ely et al.*, 2014), which will be referred to as the "CPRAS model" hereafter. The cell-centered finite difference model was built around the USGS modular groundwater modeling framework MODFLOW-NWT (*Niswonger et al.*, 2011), which solves fully and partially saturated groundwater flow coupled to streamflow routing and anthropogenic water use packages. MODFLOW is the most widely used and tested groundwater model in the world with a development history of over four decades. The CPRAS model domain uses a uniform lateral grid with 3km square cells and a variable vertical discretization to efficiently capture the large-scale hydrogeologic units. The spatially variable groundwater flow equations are discretized on this grid and each cell contains unique values for the necessary parameters describing flow including porosity, hydraulic conductivity (permeability), and compressible storage coefficients.

The initial values of these parameters were set based on the previous work (*Burns et al.*, 2011) and refined during the calibration process, which was conducted over a transient period of record. The main input data to the model consists of streamflow, potential recharge (precipitation minus evaporation), irrigation return flows, and pumping rates; all of these were compiled as part of the efforts of *Kahle et al*. (2011), *Snyder and Haynes* (2010) and *Burns et al.* (2011). Unlike the hydraulic parameters, none of these values were adjusted during the calibration since they represent "known" quantities. The simulation results with the calibrated parameters exhibit good fit to the observation data scattered throughout the CPRAS system, meaning that the final hydraulic parameters provide the best possible description of the physical system.

2.3. Model refinements

2.3.1. Time step conversion to monthly resolution

The original transient simulation period for the CPRAS model was from 1900 to 2007. The model will be updated to run through 2020 as part of the 2026 Forecast Project (*see letter from T. Tebb and Section B.4*). We propose to convert the model from an annual to a monthly time step for the period 1985-2020, which requires an update to some of the model inputs. The primary model inputs include the spatial and temporal discretization, hydraulic parameters, boundary conditions, and stresses. Water-level altitudes, altitude changes, and errors are required for calibration and evaluation. The boundary conditions will remain as defined in the existing model, except for the location of some surface water features that will be updated in the Forecast Project. The existing hydraulic parameters will be used as the initial parameters that will be adjusted in the calibration process. The existing transient model has 90 stress periods beginning with a 1900-1919 period and continuing annually through the simulation period. The stress periods will be defined monthly for the updated model.

Recharge in non-irrigated grid cells is currently computed using a regression equation that estimates annual recharge as a function of annual precipitation (*Bauer and Vacaro*, 1990; *Kahle et al.*, 2011). The regression was derived from a deep-percolation model that evaluated changes in soil moisture, plant interception, and snowpack on a daily time step as a function of precipitation, temperature, streamflow, soils, land-use, transpiration, soil evaporation, snow accumulation, snowmelt, sublimation, and evaporation of intercepted moisture (*Bauer and Vaccaro*, 1987; *Kahle et al.*, 2011). The updated model will use the Recharge (RCH) MODFLOW package in conjunction with the original deep percolation model aggregated to a monthly timestep with updated inputs to simulate recharge in non-irrigated cells. Recharge in irrigated cells in the existing model is estimated as described next.

2.3.2. Irrigation crop water demand

We propose to update the representation of irrigation demand.

<u>*Existing irrigation demand*</u>

Irrigation demand is simulated in the existing CPRAS model for 1985-2007 using the spatially distributed Soil WATer (SOWAT) model (*Kahle et al.*, 2011). The SOWAT model is a soil-water balance model that was developed specifically for the existing CPRAS model. It calculates the change in soil moisture (*ΔSM*) based on precipitation (*PR*), irrigation application (*IR*), actual evapotranspiration (*ETa*), direct runoff (*DR*) and the groundwater flux below the modeled soil zone (*GF*) according to equation 1.

$$\Delta SM = PR + IR - ETa - DR - GF \qquad \text{Equation 1}$$

The *PR* and *ETa* in the existing model are climate inputs, with *PR* derived from the 4-km Parameter-elevation Regressions on Independent Slopes Model (PRISM) gridded monthly precipitation product, resampled to the 1-km grid-cell resolution of the SOWAT model. *ETa* was derived from remotely-sensed observations from the Advanced Very High Resolution Radiometer (AVHRR) sensor (pre-2000) and the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor (post-2000). The advantage of this method is it is based on observations of temperature from which *ETa* can be directly computed, instead of relying on empirical relationships between potential evapotranspiration and soil moisture. However, data availability for this approach necessitates a shift in data sources throughout the study period. The observation-based methodology also requires a shift in method for future simulations or coarse assumptions to predict future water demand.

The *DR* was calculated as the product of precipitation and a direct runoff fraction that determines infiltration excess runoff, but which does not account for saturation excess runoff. The direct runoff fraction was estimated to be a constant 7% throughout the study area. The *IR* is estimated based on the difference between the soil layer capacity and calculated soil moisture, divided by the irrigation efficiency. The irrigation efficiency in the existing model is the consumptive use requirement of crops divided by the volume of water diverted from surface water or pumped from groundwater. Irrigation efficiency is prescribed as 75% for groundwater. Irrigation efficiency for surface water was increased from 49% to 53% from 1985 to 2007. The *GF* is then computed as the sum of *SM* and *IR* minus the soil profile capacity. *SM* in each month is updated as the sum of soil moisture in the previous month and net infiltration minus *ETa*, where net infiltration is the difference between *PR* and *DR*.

<u>*Updated irrigation demand*</u>

The inputs to the SOWAT model will be modified in the proposed work and converted directly to the 3-km grid cell resolution of the CPRAS model. The precipitation data will be updated to the same GridMET (Abatzoglou, 2013) product used in the VIC-CropSyst simulations described next, to have consistency with that work. GridMET is available at ~4-km grid cell resolution and will be resampled to the CPRAS resolution. This product is available from 1979 – present.

The *IR*, *ETa*, and *DR* will be updated based on simulated values from the 2021 Forecast report (*Hall et al.*, 2021) using the coupled VIC-CropSyst model (*Malek et al.*, 2017). The model was run at 6-km grid-cell resolution and will be resampled to the 3-km CPRAS model grid. The output are available at a daily timestep and will be aggregated to monthly. VIC-CropSyst is a fully integrated model that couples the Variable Infiltration Capacity (VIC) (*Liang et al.*, 1994) land surface model with the CropSyst (*Stöckle et al.*, 2003) cropping systems model. VIC is a semi-distributed land-surface model that closes the energy and water budgets within individual grid cells, but does not simulate lateral fluxes. Heterogeneity in variables within a grid cell, such as land cover and saturated extent, are represented through semi-empirical relationships. CropSyst is a biophysically-based, multi-year, multi-crop model that runs at a daily/hourly time step to simulate soil water budgets, nutrient budgets (*e.g.*, N and P), C cycling, crop growth and yield, residue production, soil erosion, and user-defined management options including rotations, tillage, and irrigation scheduling through an entire growing cycle.

In the fully integrated coupling of VIC and CropSyst (termed "VIC-CropSyst"), VIC continues to model the basic water cycle by closing the water and energy budgets, but invokes CropSyst for area designated as cropland from the land cover dataset. In these cropland areas, VIC provides CropSyst with information on soil moisture availability, crop type, crop management, soil texture, and weather information. CropSyst uses that information, combined with crop specific phenologies to grow the crop, returning yield, biomass, transpiration, irrigation water demand, leaf area index, and plant water uptake by soil layer to VIC. VIC-CropSyst is has been developed and tested in the Columbia River Basin (*Adam et al.*, 2014; *Liu et al.*, 2014; *Stöckle et al.*, 2014). The coupled VIC-CropSyst model is already calibrated in the Columbia River Basin (CRB) using reconstructed natural streamflow to calibrate the soil parameters and crop yields reported mainly from the Washington Department of Agriculture to calibrate the crop parameters (*Adam et al.*, 2014; *Stöckle et al.*, 2014).

The VIC-CropSyst simulations used in the 2021 Forecast represent nine different irrigation types, including big gun, center pivot, drip, flood, furrow, rill, sprinkler, subsurface drip, and wheel line, each with unique parameters that represent the maximum available depletion of soil moisture, irrigation efficiency, and maximum capacity per day. The 2021 Forecast simulated ~80 different crops, including a variety of field crops, vegetables and fruits, pasture crops, and tree fruit and other perennial crops. Since the irrigation demand estimate already accounts for irrigation efficiency specific to each crop type and location, the *IR* variable will be directly updated in the SOWAT model with the irrigation demand from VIC-CropSyst.

ETa is a simulated output from VIC-CropSyst and varies daily in response to water availability and crop water demands specific the crop's phenological development at the current time step. This variable will be inputted directly into equation 1 after resampling to 3-km resolution. Surface and subsurface runoff are also simulated outputs from VIC-CropSyst. The surface runoff will be used to represent *DR* in equation 1 to be consistent with the definition of direct runoff from the SOWAT model. The *SM* and *GF* will be calculated following the methods in the SOWAT model, but with the updated *PR*, *ETa*, and *IR* values.

2.3.3. Irrigation water supply source

We propose to update the split between surface water and groundwater as the water supply source.

Existing water supply source

The existing model uses water rights information to determine the fraction of irrigation water being supplied by groundwater compared to surface water. The water rights information for Oregon was based on quarter-quarter acreages, which are about 40 acres in area, and the information for Washington was derived from Ecology's Water Rights Tracking System (WRTS). The fraction of groundwater use was increased for 1987, 1988, 1992-994, 2001 and 2005 to represent increased reliance on supplemental groundwater rights during drought when surface water is curtailed. April 1 – October 31 represented the irrigation season, corresponding with the season of use for the majority of irrigation water rights.

Updated water supply source

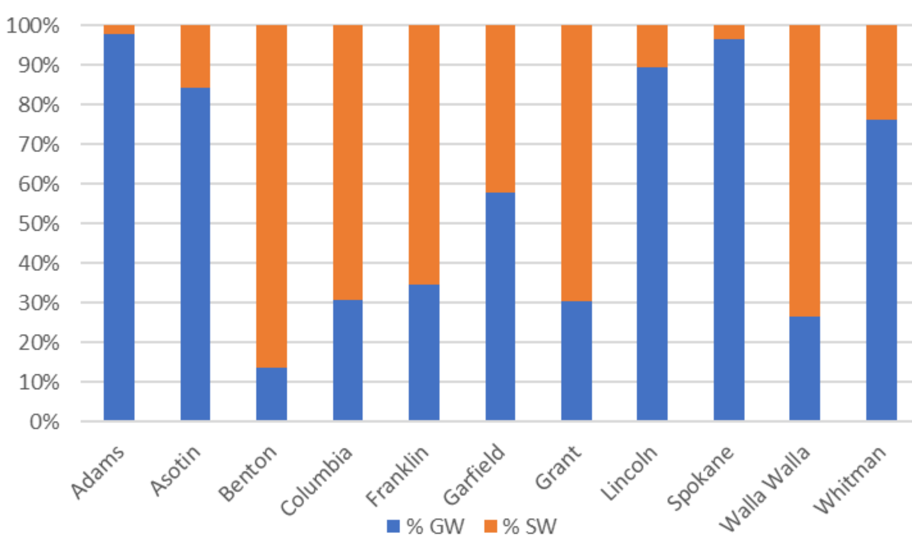

Figure 2. Percentage of surface water and groundwater rights permitted for use in Washington counties within the CPRAS domain.

Figure 2 shows the current split between surface water rights and groundwater rights currently permitted in some of the counties in Washington within the study area. The figure highlights the importance of spatially explicit water supply source fractions given the variability in water source dependency. The fraction of groundwater used to supply irrigation water will be updated through the full simulation period. The fraction will be adjusted for drought years as was done in the existing model, with the addition of 2015 as a drought year. The season of use will be determined based on the average season of use for the water rights within each grid cell.

2.4. Model calibration and evaluation

Ely et al. (2014) describe the calibration process of the existing model in detail. The transient calibration of the original model was conducted for a range of hydraulic properties including the horizontal and vertical hydraulic conductivities, storage coefficients as specific storage and specific yield, and drain conductance. The properties were calibrated for each main geologic unit, which were treated as homogeneous locally and vertically anisotropic. The original values for each property for each layer were derived from existing studies and perturbed within ranges considered reasonable and acceptable for the aquifer system. The calibration was conducted based on a comparison between simulated and observed hydraulic heads, first for steady state conditions and then for the transient model. The data sources originally used in the model exist at higher than annual temporal resolution, so they will be aggregated to the monthly time step. The input data sources used in the original USGS model are still actively collected but will require quality assurance checks before incorporation into the model framework at a monthly timestep; the sources are detailed by (*Kahle et al.*, 2011) and are all publicly available. The data collected from this project (Section 2.1) will also be incorporated used. The calibration and validation will be performed following the methods of the existing model using the Parameter ESTimation (PEST) software package (*Doherty*, 2015).

2.5. Scenario analysis

2.5.1. Future climate

Future scenarios will use the projected climate data by Abatzoglou & Brown (2012), which statistically downscales the results of 17 global climate models using the Multivariate Adaptive Constructed Analogs (MACA) method. This approach is consistent with the future VIC-CropSyst simulations from the 2021 Forecast. The future irrigation demand will be taken as model output from the future simulations in the 2021 Forecast. The future scenarios were modeled through 2085 based on the Representative Concentration Pathway (RCP, van Vuuren et al., 2014) scenarios 4.5 and 8.5. The RCPs were developed to evaluate varying potential impacts of climate change and socioeconomic scenarios. RCP 4.5 represents a future where the degree of radiative forcing is stabilizing with a CO_2 equivalent concentration of 650 ppm, while radiative forcing is increasing in RCP 8.5 with a CO_2 equivalent concentration of 1350 ppm. The future climate scenarios will be simulated with and without changes to pumping volumes and the fraction of irrigation demand met by groundwater versus surface water.

2.5.2. OGWRP implementation

Mendsaikhan (2022) used the existing CPRAS model to evaluate the spatial and temporal response to different groundwater pumping scenarios in the Odessa Subarea. She evaluated linear percent changes in pumping to be achieved between 2007 and 2050, a scenario of 2007 level pumping at a constant rate (no change), and 100% reduction in pumping all implemented in 2008 (extreme case). The 40%, 60%, 80%, and 100% reductions in pumping by 2050 showed statistically significant increases in composite hydraulic heads in the Odessa Subarea for the Grande Ronde layer only. The average increase in the Odessa Subarea was 46.3 ft by 2050 with a maximum increase of 132.0 ft. While the other layers did not show statistically significant changes, she notes the other scenarios and layers still have potentially meaningful results from a management perspective, for example an average simulated increase of 17.7 ft in the Grande Ronde if pumping is decreased by 20% by 2050 could still have positive implications for accessibility of groundwater based on existing well depths. Her results show that the largest increases in hydraulic head are along the western boundary of the Subarea where the majority of the pumping is, but the influence of the pumping changes move laterally outward, including into the eastern portion of the Subarea that is outside the region of OGWRP implementation.

The work by Mendsaikhan (2022) highlights the importance of evaluating both the spatial and temporal responses of the study area to different scenarios of OGWRP implementation. The proposed monthly evaluation will provide crucial insights to the growers in the area as well as to the municipal water systems that are reliant on groundwater in the area but are not part of the OGWRP explicitly. We propose to simulate different OGWRP implementation scenarios, in part informed by the Columbia Basin Conservation District, Lincoln County Conservation District and Ecology. The scenarios will implement pumping changes based on current and expanded implementation plans of the OGWRP.

2.5.3. Aquifer recharge

Numerous aquifer storage and recovery (ASR) are currently underway and planned in the study area, including projects scoped and implemented with the assistance of Aspect Consulting, the subaward partner in the proposed work. For example, Aspect is working with the City of Othello to implement ASR at their municipal well field. Gibson et al. (2018) qualitatively evaluated the potential to implement ASR across Washington State and found the injection potential equals 6400 million liters/day. This amount is equivalent to about 20% the capacity of Lake Roosevelt, the reservoir created behind the Grand Coulee Dam, over a full year. The highest concentration of viable sites from their study is in the proposed study area. A full aquifer recharge scenario will be evaluated based on implementation of all possible ASR sites indicated by Gibson et al. (2018) in addition to currently active and planned sites in the study area in Washington and Oregon.

2.5.4. Supplemental groundwater use during drought

Multiple types of water rights govern the way water can be used in the study area. Historically, the terms "supplemental" and "primary" have been most commonly, but inconsistently used. Supplemental rights referred to water that was stored to be used to *supplement* surface water, groundwater rights that were secondary and *supplemental* to primary surface water rights, and as *supplemental* water that added to other issued water rights. Now, the use of these terms has been clarified, but historical water rights records still maintain the supplemental status. Beginning with the drought declared in 2001, "emergency" or "standby/reserve" rights become available with a drought declaration to mitigate drought impacts (*Use of Terms that Clarify Relationships between Water Rights Program Guidance*, 2006). The State of Oregon also allows for emergency groundwater use when drought has been declared. A drought scenario will evaluate the impact of emergency groundwater use during declared drought years with and without supplemental rights.

2.5.5. Stakeholder-defined scenarios

Meetings with the Office of Columba River (OCR) within Ecology and the Columbia Basin (CBCD) and Lincoln County (LCCD) Conservation Districts will be used to develop stakeholder-defined management scenarios to evaluate with the improved model. The Forecast group also holds semi-annual "state caucus" meetings that are attended by representatives of each state agency that is relevant to the Forecast. The agencies include the Washington State Departments of Fish &Wildlife, Agriculture, Health, Commerce, and Natural Resources. Representatives from Ecology's Water Resources program also attend, as do representatives from relevant federal agencies as needed, including the U.S. Geological Survey. One example topic of interest that was identified by OCR at the Columbia River Policy Advisory Group meeting on October 5 is an assessment of multi-year drought impacts on groundwater levels.

3. __Project Location__

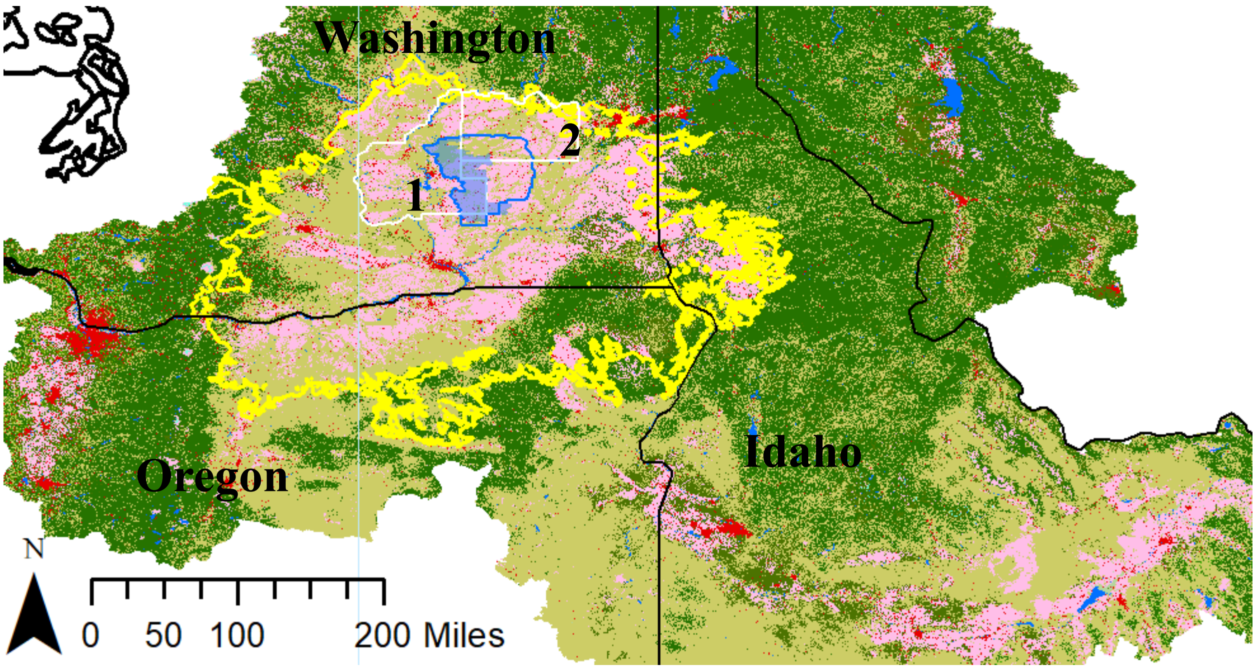

Figure 3. The figure shows the dominate landcover classes for the U.S. portion of the Columbia River Basin with the Columbia Plateau Regional Aquifer System (CPRAS) boundary in yellow. Cropland areas are shown in pink, highlighting that the largest agricultural region in the CRB sits within the CPRAS domain. The Columbia Basin (1) and Lincoln County (2), Conservation Districts are outlined in white. The Odessa Subarea is outlined in blue line and the subset of the Subarea that represents the Odessa Groundwater Replacement Program area is shaded in blue in the western portion of the Subarea.

The Columbia Plateau Regional Aquifer System (CPRAS) sits within the Columbia River Basin (CRB, Figure 3). The CPRAS is ~114,000 km^2 (~44,000 square miles). It is a complex, multi-layered aquifer system comprised primarily of groundwater with a median age of ~1000 years (*Jurgens et al.*, 2022). Surficial alluvial aquifers exist across parts of the CPRAS, but the largest groundwater storage capacity exists in three basalt layers, up to 4,800 meters thick. The agricultural regions overlying the aquifer support a multi-billion-dollar industry. About a quarter of irrigation water in the CRB is withdrawn from groundwater (*Vaccaro et al.*, 2015). The volume of groundwater pumpage has increased exponentially since the 1950s due to pumping for irrigation, jumping from less than 100,000 acre-feet across the aquifer in 1945 to over 1.4 million acre-feet by the most recent available measurement in 2007 (*Ely et al.*, 2014). The CPRAS is a "living laboratory" within which to study regional groundwater dynamics. The spatial scale is large enough to leverage remote sensing and is well-instrumented with *in situ* observations. The domain encompasses multiple natural and cultivated landscapes. The complexity of the subsurface, including well-mapped unconfined and confined groundwater layers, allows for a complete assessment of the integrated water column.

Groundwater has been declining at rates exceeding 10 feet/year in portions of the study area, especially in the Odessa Subarea (Figure 3), despite the requirement for state-issued permits to pump groundwater. This proves that simply “checking the box” of regulating use does not ensure sustainable conditions. Many wells in the Odessa are 800 to 1000 feet deep thus mitigation strategies such as low-cost passive aquifer recharge are ineffective. The Odessa Subarea was originally planned to be within the Columbia Basin Project area to receive Columbia River water for irrigation but was issued “temporary” groundwater permits in the early 1960s. Unmitigated groundwater declines could lead to annual losses of $630 million and 3,600 jobs due to lost potato production alone (*Bhattacharjee and Holland*, 2005). The severe declines and projected impacts led to the recent Odessa Groundwater Replacement Program (OGWRP) (*USBR*, 2012) to permanently convert groundwater to surface water users. However, voluntary participation in this program has been lower than anticipated, which is partially due to misconceptions about the cost/benefit tradeoffs for the project.

4. *Data Management Practices*

The data produced in this project include: 1) observation data collected at the proposed monitoring sites and 2) output from the updated model. The groundwater data collected by the pressure transducers will be publicly available through the Department of Ecology’s Environmental Information Management (EIM) System. The PI’s ongoing stakeholder-driven monitoring effort already has a unique study identification in EIM, COLBAS-GW-WSU-001, which stands for Columbia Basin Groundwater WSU 001. The newly collected data will be uploaded under this same ID. The soil moisture and weather data will be available through the AgWeatherNet weather station network managed at Washington State University (WSU). Landowners will be asked if they want the data collected at their sites to be part of the private station group with restricted access to their data or for their it to be available to AgWeatherNet users. Meter Group and AgWeatherNet are partners and use the same soil moisture and weather station equipment as is proposed. The existing flow model is publicly available. The updated model will be publicly available on GitHub, a cloud-based platform to support software development and version control.

5. *Evaluation Criteria*

A. Water Management Challenge

A.1. Description of the water management challenge

Groundwater modeling is a critical water resource tool to help Columba Basin water managers (e.g., irrigators, water systems, and individuals), more accurately forecast future groundwater supply and demand trends and evaluate potential solutions to mitigate declines in groundwater levels. The current CPRAS model is an available tool to help influence how water is used for the two areas of biggest water demand in the basin – drinking water and agriculture. Regionally, groundwater is the primary water supply source for a USGS-estimated 1.3 million people who rely on groundwater wells. Additionally, the CPRAS supports an estimated $6 billion per year agricultural industry. While surface water is the primary water source for basin agricultural operations, groundwater acts as a backup supply during drought. However, more severe and frequent periods of drought forecasted due to climate change put basin groundwater supplies in jeopardy.

The existing USGS groundwater model runs from 1900-2007 with annual timesteps and its utility to calculate risk-based climate scenarios is limited by historical groundwater inputs that don't reflect the current state of changing climate conditions in the Basin. The annual time step does not allow for the seasonal variability of groundwater pumping. Ecology funded work as part of the 2026 Columbia Basin Water Supply and Demand Forecast will include updating the model to simulate conditions through 2020 along with future scenarios to 2100 and it will evaluate modeled groundwater scenarios with and without climate change. However, the Ecology funding does not include funds to update agricultural pumping demands and return flow in the model based on agricultural and climate modeling results completed as part of the 2021 Supply and Demand Forecast, or to subdivide the model into interannual time steps. These new model inputs are key to reducing uncertainty in the groundwater model to provide a more reliable tool to inform management of scarce groundwater resources for communities, agriculture, and habitats in the Columbia Basin.

A.2. Concerns or outcomes if the challenge is not addressed

Declining groundwater has been a decades-long concern for the basalt aquifers in central and eastern Washington – with some areas experiencing as much as 10 feet annual declines. Absent an updated numerical groundwater model, Columbia Basin water managers will continue to face uncertainty in the reliability of groundwater sources during drought conditions and over long-term planning horizons. Improved forecasts of groundwater availability are needed to inform the studies, planning, design and construction of solutions that require decades to implement. Consequences of inaction to update the USGS model include decreased reliability under future climate and drought conditions. Rural groundwater dependent systems are disproportionately impacted by declining groundwater levels and drought conditions, from domestic wells to large agriculture and municipal systems. Curtailing water for junior water right holders in times of drought; or the drop of groundwater levels below pump intakes have negative but foreseeable impacts. Continued improvement of groundwater forecasting will be needed to support planning for water infrastructure improvements from the parcel scale of private well owners to regional water supply systems and Basin planning.

A.3. Explanation of how the project will address the challenge

Including updated pumping demand and recharge estimates based on modeling from the 2021 Forecast into the update of the existing USGS model to simulate conditions through 2020 will provide a more accurate starting point from which to evaluate the potential benefit from proposed projects, different water use scenarios, and risk-based climate scenarios Therefore, it is anticipated to give Columbia Basin water managers and policymakers a more reliable tool to anticipate drought impacts and climate change impacts on water resources. This work is also a large step forward towards integrating groundwater flow dynamics into the Forecast project.

Improving the existing groundwater flow model for the Basin is a step towards better forecasting of impacts that affect individuals and communities, and results in improved data for regional water management decisions. The positive results from this updated water management tool will likely show in outcomes like:

- Improved forecasts of declining aquifer levels during drought and normal years will help well owners understand the timing of future financial burdens related to lowering well pumps, drilling deeper wells, or implementing alternative water supplies.

- Improved groundwater modeling for future climate scenarios provides greater certainty in planning for challenging water management decisions. Predictions of aquifer responses under future climate and groundwater demand scenarios is critical to Basin planning and will help inform priority locations where groundwater dependent systems are at the greatest risk.
- Helping water managers accurately inform comprehensive growth and economic forecasts to plan where water can be sustainable sourced from for future community and business growth.

B. Project Benefits

The proposed project will enhance an existing tool and will create data products that will be made publicly available to water managers and researchers in the study area. The project benefits are directly linked to ongoing activities by the PI and stakeholder groups and can be used for additional future applications in management and research as needed.

B.1. Project need identification

The need for the project was identified following conversations with groundwater users, managers, and researchers in the study area as well as based on reviews of peer-reviewed literature, existing data availability, and reports. Serr et al. (2019) received 57 responses to a survey they sent out to 137 Group A water systems in Franklin, Grant, Lincoln, and Adams Counties in 2018. Of the water systems that responded, 13 reported having well decline or failure, especially in summer, five are already unable to meet annual water demand without water restrictions, and 35 are concerned about meeting demand in the next five to 15 years. The 2021 Forecast report identified integrated groundwater modeling as the first and only "high priority improvement" recommended for the 2026 report (*Hall et al.*, 2021). That recommendation included improvements in estimating the split between surface water and groundwater as a water supply source and the need to further expand groundwater monitoring.

The Washington State Drought Contingency Plan stated, "detection of short-term drought influences from longer-term ambient water level trends are hampered by the lack of wells with consistent long-term (more than 10 years) monthly water level measurement histories" (*Members of the Drought Contingency Planning Task Force*, 2018). This statement speaks directly to the need to evaluate groundwater dynamics on a monthly time step and to enhance monitoring capacity both with a higher spatial density of monitoring sites and with higher temporal sampling frequency to capture monthly dynamics, as is proposed.

B.2. Application of the tool

The Letters of Support and Partnership received by OCR, the Columbia Basin Conservation District, and the Lincoln County Conservation District (*see letters of support/partnership by T. Tebb, K. Ribellia, and E. Bowen*) all state these stakeholder partners' interest in the improved model and data collection efforts. The model results will go directly into the 2026 Forecast Report for use by OCR in informing water management and infrastructure decisions. The report is also publicly available and used by other state agencies, researchers, and practitioners. One of the goals of the scenario development with OCR, CBCD and LCCD is to create model simulations that can be most effectively and efficiently used by these partners to support their efforts to maintain and expand groundwater supply reliability. The key findings of the model results will be made publicly available and will be presented to different stakeholder groups in the region to maximize the utility of the results. For example, the scenario analyses will create maps of composite hydraulic heads for each aquifer layer in the region. The maps can be used to identify water systems that are already vulnerable to groundwater declines and the management scenarios that either enhance or diminish vulnerability. This is especially important for smaller systems that are impacted by regional dynamics but may not have resources to pursue water alternatives independently.

The collected data will be publicly available through existing data sharing for decision-support platforms. Future work by the PI and other researchers could further utilize these data to constrain model calibration efforts for land-surface models. Currently, these models adjust soil parameters that govern infiltration and runoff in the calibration process, but the calibration metrics are evaluated based on a comparison between simulated and observed streamflow. The monitoring locations can be leveraged in support of improved calibration of soil moisture. The groundwater data will also be available to the relevant agencies in each state that make decisions on water rights. These agencies directly use groundwater level observations to make decisions about water management in each state, often related to the issuance and management of water rights, including analyses of whether water rights decisions may impair existing water users. The groundwater level monitoring data is used to evaluate the long-term status of groundwater availability.

The Oregon Department of Water Resources and Washington's Ecology will both benefit directly from the drought scenarios. Both states allow for emergency groundwater pumping during drought, but an evaluation of the impact of the emergency pumping and of drought impacts on the aquifer system itself have yet to be fully explored. The drought scenarios will inform identification of regions vulnerable to drought that may or may not be experiencing vulnerability in average years.

B.3. Extent of benefits

The Department of Ecology will be the most direct user of the model results and data collection through the integration of the proposed work with the 2026 Forecast, which they are legislatively mandated to complete. The updated model will be made publicly available and can be used by other groundwater modeling efforts in the area including by hydrogeologists in private practice, the U.S. Bureau of Reclamation in analyzing groundwater-related infrastructure projects, the U.S. Geological Survey, and in research. The results can be directly used by different stakeholder groups, including the Odessa Groundwater Replacement Program (OGWRP) and Columbia Basin Sustainable Water Coalition (CBWSC). It is anticipated that these groups can use the scenario analyses to prioritize water management priorities and the acquisition of funds to support groundwater related infrastructure and institutional needs. The monthly timestep will identify "hot spot" areas that are vulnerable to summer drawdowns during irrigation and require more focused management than may have been previously known based on historical spring observations. Group A water systems are legislatively mandated to submit a Water System Plan to the Department of Health with a minimum 20-year planning period. However, not all water systems have met this requirement in the study area (Serr et al., 2019). Results from the future climate scenarios under different management decisions can be used to inform water system planning efforts.

B.4. Project complementarity

OCR is responsible for ensuring current and future water supply in the Columbia River Basin in Washington. Their mandate states they should "aggressively pursue the development of water supplies to benefit both instream and out-of-stream uses," (Revised Code of Washington 90.90.005) which encompasses water uses for communities, agriculture, endangered species, and the natural environment. The proposed work is planned in parallel with on-going efforts for the Washington State Long-Term Water Supply and Demand Forecast (“Forecast Project”) project funded by the Department of Ecology (“Ecology”). The Forecast Project is legislatively mandated by the Washington State Legislature (Revised Code of Washington 90.90.040) to provide an estimate of current and future water supply and demand in Eastern Washington. The Forecast Project results are used by state and local agencies to guide water management decisions such as water infrastructure development. The PI is the groundwater co-lead on the project in partnership with Aspect. The 2021 Forecast provided the first ever spatially distributed groundwater vulnerability assessment in Eastern Washington that explicitly accounts for aquifer heterogeneity. Planning for the 2026 Forecast is underway and will fund the current proposal team to update the model by Ely et al. (2014) to run through 2020, but it is beyond the scope of that project to include the updates proposed herein on irrigation demand and temporal resolution updates. The irrigation demand estimates and historical and future climate inputs for the proposed project will be updated to match the climate inputs for the Forecast project.

The proposed project complements another submission to the same Notice of Funding Opportunity by the Columbia Basin Conservation District. Their proposal, entitled, “Columbia Basin Groundwater Cooperative Interactive Web Application” seeks to develop a central repository for groundwater-related information in the study area. Should both their project and this one receive funding, we would work together as project partners to use their web platform as the primary data-sharing mechanism from this work. PI McLarty will also use that web platform to share groundwater observations and analyzed well log details from her current U.S. Bureau of Reclamation project (#R20AP00123). The data collected from PI’s existing grant will also be used for the calibration and validation efforts for the proposed model updates.

C. Project Implementation

C.1. Approach and methodology

MODFLOW is the most used groundwater flow model. The MODFLOW-based CPRAS model developed by the USGS is built on multiple years of effort to create a state-of-the-art modeling tool for this large regional aquifer system. The model itself continues to be used to support advanced understanding of the study area in both research and practice. The output from VIC-Cropsyst that will be used to improve historical and future irrigation demand estimates also allow for synthesis with the Forecast project. VIC-CropSyst is a one-of-its-kind integrated hydrology and cropping systems model. Most land-surface and hydrology models such as VIC only represent agricultural lands as a single crop type, often corn, and don’t account for crop mixes, agricultural management decisions, and changing water demand with phenological development.

The proposed model improvements will further enhance the utility of the model. The proposed monitoring sites build on existing monitoring networks with equipment that matches what is already being used in those networks. The proposed pressure transducers match those used by Ecology in their regular groundwater monitoring to contribute to a cohesive set of dynamic groundwater observations. The weather stations and soil moisture sensors also match those currently being deployed by the AgWeatherNet to again contribute to cohesive datasets in that network. A significant advance is the co-location of these three sensors together, which will allow for 1) improved calibration efforts of the proposed model and other hydrology and land surface models, 2) future research into how water budget dynamics scale from point observations to regional scales, accounting for subsurface heterogeneity, and 3) observation-based evaluation of historical water budget change.

C.2. Work plan

Task 1 – Data collection

Task 1.1. Site identification (Year1 Quarter1) – *Milestone: identify 47 sites for monitoring*

The project team will work with stakeholder partners and existing networks to identify sites for monitoring. The ideal site will have a well with a well log to identify local lithology, be used for irrigation, and have a separate monitoring port that the pressure transducer can be deployed separately from the pump.

Task 1.2. Site approvals (Y1Q2) – *Milestone: obtain signed agreements for monitoring*

Monitoring will only be conducted in locations where the landowner has agreed to participate in the project. The agreement includes acknowledgement of the data sharing plans and land access by the project team to establish and maintain the sites, and to conduct regular manual measurements.

Task 1.3. Site monitoring and maintenance (Y1Q3-Y2Q4) – *Milestone: continuous time series of observed data*

Each type of sensor has data logging capabilities that limit the need for manual measurements and frequent data download. However, site visits will occur monthly in the first year of the project by the PhD student and bi-monthly in the second year to ensure the sites are functioning. Manual measurements of groundwater will be collected at each site visit with an electric tape for additional validation and to support any corrections needed in processing the transducer data.

Task 2 – Model improvements

Task 2.1. Update model inputs (Y1Q1-Y1Q2) – *Milestone: complete processing of input data sets and model structure*

The postdoctoral scholar will initiate model development by defining the updated time step and stress periods for monthly simulations. The graduate student will assist the postdoctoral scholar in processing input climate data.

Task 2.2. Prepare irrigation demand and recharge estimates (Y1Q1-Y1Q2) – *Milestone: processed input fields for the RCH package*

The VIC-CropSyst output will be resampled and used to calculate soil moisture and the groundwater flux term in the SOWAT model for irrigated cells. The deep percolation model will be updated for non-irrigated cells. The estimated irrigated and non-irrigated recharge fluxes will be used in the RCH package.

Task 2.3. Prepare water supply source updates (Y1Q3) – *Milestone: gridded delineations of surface water versus groundwater rights for primary and supplemental uses*

The graduate student will evaluate historical water rights data from the county-scale already processed by PI McLarty's team to the grid cell resolution of the model. The gridded water rights data will be prepared to only account for primary surface water and groundwater rights and then separately to evaluated supplemental and standby/reserve rights used during drought.

Task 3 – Calibration and Validation

(Y1Q3-Y2Q2) – *Milestone: final set of calibrated model parameters.*

The postdoctoral scholar will initiate model calibration and validation efforts in collaboration with Aspect. The graduate student will be mentored in this space by the postdoctoral scholar and Aspect to complete these efforts.

Task 4 – Scenario analysis

Task 4.1. Development (Y1Q1-Y2Q2) – *Milestone: clearly defined model scenarios*

PI McLarty and Aspect will define the scenarios to evaluate with the updated model. Stakeholder meetings for this project and the Forecast project will be used to define the scenarios.

Task 4.2. Results (Y2Q3-Q4) – *Milestone: final products completed*

The results will be prepared according to the anticipated products described below. Products specific to the 2026 Forecast report will be finalized through that project following the completion of the proposed work.

Task 5 – Results dissemination

(Y2Q4) – *Milestone: completed dissemination activities*

Dissemination events with stakeholder groups will be completed in the final quarter of the project. Dissemination activities relevant to the 2026 Forecast will continue through that effort.

C.3. Anticipated products

Anticipated products include:

- Maps: Maps will be produced to represent the spatial distribution of different project results. These will include composite hydraulic head maps per aquifer layer and different years through the study time frame, including into the future, as well as additional maps of historical and predicted drawdown and vulnerability over stakeholder-informed time periods.
- Time series: Time series of depth to groundwater with associated trends, pumping under different scenarios, irrigation demand and water budget fluxes will be developed for different regions within the study area including for the Odessa Subarea.
- Observed data: time series data and associated metadata will be made publicly available as described in the Data Management Practices section.
- Model code: the updated model code will be made publicly available as described in the Data Management Practices section.

C.4. Project partners

- Washington State Department of Ecology Office of Columbia River (OCR, Letter by T. Tebb, Director). OCR has approved Forecast project funds to be used as a cost-share contribution by the lead applicant, WSU, and a subaward partner, Aspect Consulting. OCR will assist in scenario development and dissemination. Activities managed by OCR and underway through the Forecast project can be leveraged for the proposed work, for example the state caucus meetings. These meetings can be used to gain support for stakeholder-driven monitoring programs and to raise awareness for the importance of groundwater monitoring, modeling, assessment, and management. They will utilize project results on improved groundwater supply and demand estimates to inform water management decisions.
- Columbia Basin Conservation District (CBCD, Letter by K. Ribellia, Executive Director). The CBCD plays a pivotal role in supporting groundwater users to maintain water supply reliability and is the Category A partner for this proposal. They are a key organization for the Odessa Groundwater Replacement Program (OGWRP). They facility funding and engagement for stakeholders in their district and the larger OGWRP area, mostly for irrigators. CBCD and PI McLarty have an ongoing partnership around groundwater monitoring, through different funding efforts they each lead. CBCD will assist in identifying monitoring sites, scenario development, and results dissemination. The results dissemination will occur both through

stakeholder meetings and, if their proposal is funded in this same call, through their online web platform.

- Lincoln County Conservation District (LCCD, Letter by E. Bowen, Manager). LCCD has taken a lead role in organizing stakeholder efforts around groundwater supply reliability in the study area. They have their own long-term groundwater monitoring project to take monthly measurements at over 50 locations. They are also participants in PI McLarty's monitoring program and support data management efforts for that project. They have led efforts to coordinate water supply needs in the study area, particularly for local water purveyors, in part as the lead organization for the development of the Columbia Basin Sustainable Water Coalition (CBSWC). Initial support for the Coalition was provided by a U.S. Bureau of Reclamation WaterSMART Planning Grant.

C.5. Staff experience

PI McLarty uses remote sensing, in-situ observations, and models to evaluate the status and dynamics of large aquifer systems. Her work is mostly located in the CPRAS region, High Mountain Asia, and Brazil, thus focusing on complex regions with subsurface heterogeneity. McLarty, in partnership with Turk and McClure, is the groundwater co-lead for the 2021 and 2026 Forecast projects. We developed a new groundwater vulnerability metric in the 2021 report that highlighted the importance of groundwater accessibility in defining vulnerability thresholds. Mclarty advised the PhD student who completed the extensive trends and vulnerability analysis for that report. She also advised N. Mendsaikhan on her master's thesis entitled, "The effects on groundwater resources from irrigation supply changes in the Odessa Subarea of the Columbia Plateau Aquifer," which analyzed different pumping scenarios using the existing CPRAS model. McLarty works closely with multiple conservation districts in the study area to implement stakeholder-driven community monitoring.

Subaward partner Jon Turk Jon Turk is licensed hydrogeologist with over 20 years of experience assessing surface water-groundwater interactions, and conjunctive management to balance source water supplies and water quality. Turk has provided technical, regulatory, and legislative consultation for water system and regional water supply planning, reclaimed water, and aquifer storage and recovery. His work utilizes a variety of modeling platforms to assess complex water resource systems for both capacity and water quality considerations. Turk recently managed a broad team of technical experts to support Washington Department of Natural Resources' (DNR) objectives of updating drought forecasts and impacts across all DNR managed lands. He also worked as Aspect's project manager and co-leader of the groundwater module for 2021 Forecast. Turk managed Aspect's project across all elements of the Forecast and led the technical analyses for the integration of groundwater data into the Forecast, including critical declining aquifer level trends and legislative report production.

Subaward partner Seann McClure provided support for both the 2016 and 2021 Forecast reports. His other work in the region includes groundwater modeling and conceptual model development in support of ASR, aquifer testing, and hydrogeologic study support for groundwater replacement. With 14 years of professional experience in Washington State geology and hydrogeologic characterization and modeling, McClure is skilled in field investigation techniques and analysis, hydrogeologic conceptual model development, and numerical modeling and calibration. He is proficient with the model calibration code PEST, numerical modeling codes MODFLOW, SURFACT, SEAWAT, and MT3DMS, and the coding language Python. His experience includes constructing and calibrating new groundwater models as well as updating and adapting existing large regional models.

The postdoctoral scholar will lead the model development activities in the first project year. The top qualifications that will be used in the hiring process are 1) experience with MODFLOW and 2) experience with PEST. An understanding of hydrogeology in the Pacific Northwest would be beneficial, but not mandatory. The ideal PhD student will have experience with programming languages and modeling, preferably with Python and/or Fortan, and have an interest in groundwater. The student could have a background in hydrology, geology, or data science. The student should also be interested in, and ideally have experience with, field work to help manage the monitoring sites.

D. Dissemination of Results

Results from the project will be disseminated through multiple pathways. Processed results from the proposed work will be made available through an online project page for the 2026 Forecast, managed by the State of Washington Water Research Center housed at WSU. The 2021 Forecast made all data available that was used for the final project in the form of an ArcGIS story map. The same is currently planned for the 2026 project. The results will also be incorporated into the 2026 Forecast products, including a legislative report, a detailed technical report, informational flyers and publicly available PowerPoint presentations. The Forecast project team also regularly meets with partner state agencies and the Columbia River Policy Advisory Group, both to assist in prioritizing project directions and for progress reports and dissemination of results. Results will be presented to the academic community at the 2025 American Geophysical Union Fall Meeting. Dissemination will also occur in partnership with the Columbia Basin and Lincoln County Conservation Districts in their roles as point organizations for the OGWRP and Columbia Basin Sustainable Water Coalition.

E. Presidential and Department of the Interior Priorities

Executive Order 14008: *Tackling the Climate Crisis at Home and Abroad* is the primary Biden-Harris Administration priority that will be supported in the proposed work. Specifically, the order calls for using science to lead to action in support of clean water protections. Section 211 identifies the need to develop “Climate Action Plans and Data and Information Products to Improve Adaptation and Increase Resilience,” including for the efficient use of water. Section 216 identifies the goal of conserving at least 30 percent of our nation’s waters by 2030. The improved model developed herein will improve the science-based understanding of 1) how much water is available in the CPRAS on a monthly timestep, 2) how water availability will change under future climate conditions, and 3) management strategies that can be used to achieve the President’s directive to conserve water supplies.

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Office of Columbia River
1250 West Alder St., Union Gap, WA 98903-0009 • 509-575-2490

October 12, 2023

Attn: Nathan Moeller (CPN-7309)
Bureau of Reclamation
Columbia-Pacific Regional Office
1150 N. Curtis Road
Boise, Idaho 83706

RE: Letter of Support for “Analysis of seasonal groundwater dynamics for improved decision-support”

Dear Bureau of Reclamation Review Panel:

On behalf of the Washington State Department of Ecology (Ecology), the Office of Columbia River (OCR), I am writing in support of Principal Investigator (PI) McLarty’s proposal entitled, “Analysis of seasonal groundwater dynamics for improved decision-support.”

The proposed work will directly benefit OCR by expanding on the Columbia River Basin Long-Term Water Supply and Demand Forecast (Forecast) we are funding under legislative mandate. The mission of OCR is to “to aggressively seek new water supplies for both instream and out-of-stream benefits in the greater Columbia River Basin of Eastern Washington.” In addition to meeting our legislative mandate, the Forecast project is used by OCR to gain a greater understanding of when and where eastern Washington State will face future vulnerabilities, providing information needed to address future water supply and water management challenges, including investments in water supply projects that support future needs of Washington’s water users.

PI McLarty leads the groundwater efforts for the 2026 Forecast project. The monthly groundwater model simulations with improved irrigation demand estimates would directly support our legislative mandate by enhancing the robustness of our groundwater supply estimates. The seasonal evaluation of groundwater dynamics will support our decision-making with respect to groundwater management. We will work with PI McLarty to develop management scenarios for the project to support our decision-making needs.

Thank you for your consideration.

Sincerely,

G. Thomas Tebb, L.H.G, L.E.G.
Director, Office of Columbia River

GT:ce(231011)

Lincoln County
Conservation District

October 11, 2023

Bureau of Reclamation
Columbia-Pacific Regional Office
1150 N. Curtis Road
Boise, Idaho 83706
Attn: Nathan Moeller (CPN-7309)

Re: Letter of Support and Partnership for "Analysis of seasonal groundwater dynamics for improved decision-support"

Dear Bureau of Reclamation Review Panel:

On behalf of the Lincoln County Conservation District, I am writing in support for PI McLarty on her proposal entitled, "Analysis of seasonal groundwater dynamics for improved decision-support," and we agree to the content of the application.

As the lead organization for the Columbia Basin Sustainable Water Coalition, we take an active role in supporting water supply reliability with a focus on mitigating groundwater declines for municipal and small water systems, in raising awareness, and planning on their behalf. We will work with PI McLarty to develop water management scenarios that focus on the needs of the water systems we work with and the growers in our county. We will also work with her to utilize our multi-year groundwater monitoring data to support calibration and validation efforts, while also identifying new monitoring site locations.

Thank you for your consideration.

Sincerely,

Elsa Bowen

Elsa Bowen
District Manager
Lincoln County Conservation District
Cell: 509-209-1911

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Budget Narrative

a. Personnel

FEDERAL REQUEST:
Alexandra McLarty, Assistant Professor, will be the Principal Investigator and responsible for overseeing project implementation. She will directly supervise the PhD student and postdoctoral scholar in model development, calibration and evaluation, and scenario analysis. She will be the main point of contact with stakeholder participants including the Columbia Basin and Lincoln County Conservation Districts and the Department of Ecology's Office of Columbia River (OCR). She is the groundwater module lead for OCR's Long-Term Water Supply and Demand Project and will facilitate integration between the model developments from that project and the proposed work. Her salary is $12,263.75/month. One summer month per project year at 100% effort is included (Year 1: $12,264, Year 2: $12,755, Total: $25,019).

Postdoctoral Scholar ("postdoc"): A postdoc is included in the first project year for 12 months based on a monthly salary of $5,833, for a total in Year 1 only of $69,996. The postdoc will lead the model enhancements and will initiate the calibration and evaluation process. The postdoc will assist the PI in mentoring the graduate student, particularly as it pertains to the modeling efforts. The postdoc will ideally have experience with the MODFLOW groundwater flow model.

Graduate Student: A fulltime PhD student is included in each project year as a research assistant based on a salary of $26,202 in Year 1 and $27,250 in Year 2. The student will collect and process the additional data needed to move to a monthly timestep and to re-calibrate model parameters. The student will work with the PI to develop the model scenarios. The student will work with the PI and postdoc to become familiar with the model in Year 1 and will complete remaining calibration and evaluation activities in Year 2. The student will run and analyze different model scenarios. The student will present project findings at the American Geophysical Fall Meeting in December 2025.

NON-FEDERAL REQUEST:
Alexandra McLarty, Assistant Professor, will cost-share a portion of funds from the Department of Ecology's Long-Term Water Supply and Demand Forecast (Forecast) project (see Letter of Funding Commitment from T. Tebb). As the groundwater lead for that project, McLarty is responsible for overseeing model development to extend the same model from the proposed work with simulations to 2020. The in-kind contribution is a portion of the Forecast project that overlaps with the proposed work. It includes 1.5 summer months in Year 1 ($18,396) and 0.5 summer months in Year 2 ($6,377) for a total in-kind contribution of $24,773.

Graduate Student: In-kind contribution for a graduate student on the Forecast project will be included fulltime in Year 1 (26,727) and for half of Year 2 ($13,898). The student will conduct the model development to extend the model simulation period to 2020, working both with the PI and the subaward partners, Aspect Consulting. The student will attend project meetings with the Department of Ecology, other relevant state agencies, and stakeholders.

b. Fringe Benefits

FEDERAL REQUEST:
Washington State University's fringe benefits rate is 31.2% for faculty, 35.2% for postdoctoral scholars, and 15.4% for graduate students. The Qualified Tuition Reduction (QTR) for the PhD student is included as a fringe benefit at $14,097 in Year 1 and $14,661 in Year 2. The faculty benefits in Year 1 ($3830) and Year 2 ($3983) sum to $7813 in total. The postdoc benefits in Year 1 are $24,622. The graduate student benefits in Year 1 ($4028) and Year 2 ($4189) sum to $8217 in total.

NON-FEDERAL REQUEST:
Washington State University's fringe benefits rate at the time the project was budgeted for the cost-share contribution was 32.4% for faculty and 15.4% for graduate students. The Qualified Tuition Reduction (QTR) for the PhD student is included as a fringe benefit at $14,065 in Year 1 and $7314 in Year 2. The faculty benefits in Year 1 ($5959) and Year 2 ($2066) sum to $8025 in total. The graduate student benefits in Year 1 ($4108) and Year 2 ($2136) sum to $6244 in total.

c. Travel

FEDERAL REQUEST:
The budget includes $4600 in Year 1 and $4700 in Year 2 for travel expenses. The Year 1 travel consists of 12 driving trips to meet with stakeholder partners at the Office of Columbia River and with the partner conservation districts, and to set up the monitoring sites. The Year 2 travel includes bi-monthly (six total) trips to meet with stakeholder partners and to visit the monitoring cites. The budget is based on an estimated round trip distance of 290 miles at the current federal mileage rate of 65.5 cents per mile. The Year 2 budget also attendance to the American Geophysical Union Fall Meeting in 2025 to present project findings. The 2025 Fall Meeting will be in New Orleans, LA. Roundtrip airfare from Pullman, WA is estimated to be $700. The lodging and meals & incidental rates for New Orleans is $162 and $74 per day, respectively, according to the U.S. General Services Administration per day with attendance budgeted for the five days of the meeting ($650 lodging and $370 M&IE total). The registration rate is $725 for a full member. The cumulative budget for attendance at AGU is $2450.

NON-FEDERAL REQUEST:
The Forecast budget includes $2000 in Year 1 and $1000 in Year 2 for travel expenses to fly to Seattle, WA from Pullman, WA to work in person with the subaward partners, Aspect Consulting. The trips are budgeted based on $355 round trip airfare, an average of $204/night lodging and $79/day for meals & incidental in Seattle, WA for a three-day visit. Two visits are included in Year 1 during model development and one visit in Year 2 during calibration.

d. Equipment

Not requested.

e. Supplies

FEDERAL REQUEST:
A student computer is requested for $2100 in Year 1.
Publication costs are requested for $4000 in Year 2.

NON-FEDERAL REQUEST:
$200,690 in equipment is included as a cost-share contribution from the PI's start-up funds in Year 1. The costs include a total of $4270 per monitoring site for a total of 47 sites. The budget for each monitoring site is based on $227 for a TEROS 12, 5-meter soil moisture sensor from Meter Group, $1,624 for an ATMOS 41, 5-meter weather station from METER Group, and $2,419 for a pressure transducer equipment set. The budget included for the TEROS 12 and ATMOS41 is from an equipment quote from METER Group. The budget for the pressure transducer set is from an equipment quote from Geotech Environmental Equipment, Inc. for Seametrics devices. The quote includes a PT2X 50PSIA cableless transducer, a cableless BaroSCOUT barometric pressure transducer, a USB communication kit, and an educational discount. The PT2X was chosen based on its narrower diameter compared to other pressure transducers to better fit in study wells.

f. Contractual

***Subaward*:**

FEDERAL REQUEST

A subaward in the amount of $44,974 will be made to Aspect, Geosyntec, a consulting company, to provide support for subdividing the model into sub-annual time steps and updating groundwater pumping demand, including guidance on model updates, troubleshooting assistance, QA/QC, assistance with workplan development and reporting, and related project administration.

Costs are based on the following standard billing rates and hours for subrecipient consultant staff:

Year 1:		
Associate Hydrogeologist	$274/hr. x 47	$12,878
Project Professional	$224/hr. x 69	$15,456
Senior Staff Professional	$178/hr. x 3	$534
Coordinator 3	$128/hr x 8	$11,024
	Year 1 Total:	$29,892
Year 2:		
Associate Hydrogeologist	$288/hr. x 21	$6,048
Project Professional	$235/hr. x 34	$7,990
Senior Staff Professional	$187/hr. x 2	$374
Coordinator 3	$134/hr x 5	$670
	Year 2 Total:	$15,082

Standard billing rates in Year 2 are estimated based on an assumed 5% increase over standard 2024 rates.

The subaward includes $8,715.63 for personnel salaries, $6,805.16 for fringe benefits, and $14,371.20 for indirect costs in Year 1, and $4,397.47 for personnel salaries, $3,433.54 for fringe benefits, and $7,250.99 for indirect costs in Year 2. Salary costs, fringe benefit costs, and indirect costs are based on Aspect, Geosyntec's Overhead Rate which is calculated as a percentage of Direct Labor Cost and produced as part of 2022 FAR Compliance Rate Calculation - Single Combined audited annually by an independent CPA firm:

- Aspect, Geosyntec's total audited Overhead rate is 242.97%.
- Aspect, Geosyntec's Indirect rate is 164.89%.
- Aspect, Geosyntec's Fringe Benefits are 78.08%. Below is the breakdown of Fringe Benefits, since it exceeds the 35%.

Annual Fringe Benefits	
Compensated Leave	25.67%
Group Insurance	26.31%
Other Employee Benefits	2.75%
Payroll Taxes	15.03%
Pension and Post-Employment Benefit	7.26%

Recruiting Incentive	1.06%
Total	78.08%

g. Construction

Not requested.

h. Other

NON-FEDERAL REQUEST

Aspect, Geosyntec will cost-share a portion of funds from the Department of Ecology funded Long-Term Water Supply and Demand Forecast (see Letter of Funding Commitment from J. Turk). The referenced work will include support for extending the time frame simulated by the CPRAS groundwater model to 2020, including guidance on model updates, trouble shooting assistance, QA/QC, and assistance with workplan development and reporting. Initial planning work will begin in fall 2023 and the project will continue through 2026.

The total cost share commitment is valued $50,016 and is based on the following travel, and Aspect, Geosyntec average standard billing rates and hours for subrecipient consultant staff:

Associate Hydrogeologist	$279/hr. x 44	$12,276
Project Professional	$228/hr. x 153	$34,884
Travel	$952/trip x 3	$2,856

Standard average billing rate is averaged over 2 years and based on estimated 2024 standard billing rates, an assumed 5% increase in 2025, and that 66% of the work will be completed in 2024 and 33% of the work will be completed in 2025.

The standard rate x time costs include $13,750.47 for salaries, $10,736.37 for fringe benefits, and $22,673.16 for indirect costs. Salary costs, fringe benefit costs, and indirect costs are based on Aspect, Geosyntec's Overhead Rate which is calculated as a percentage of Direct Labor Cost and produced as part of 2022 FAR Compliance Rate Calculation - Single Combined audited annually by an independent CPA firm:

- Aspect, Geosyntec's total audited Overhead rate is 242.97%.
- Aspect, Geosyntec's Indirect rate is 164.89%.
- Aspect, Geosyntec's Fringe Benefits are 78.08%. Below is the breakdown of Fringe Benefits, since it exceeds the 35%.

Annual Fringe Benefits	
Compensated Leave	25.67%
Group Insurance	26.31%
Other Employee Benefits	2.75%
Payroll Taxes	15.03%
Pension and Post-Employment Benefit	7.26%
Recruiting Incentive	1.06%
Total	78.08%

Travel costs are for 3 trips from Seattle to Pullman for one person for in-person collaboration and include airfare, vehicle rental, two nights of hotel fees per trip, and per-diem based on GSA rates and published prices.

j. Indirect Costs

FEDERAL REQUEST
The Washington State University indirect cost rate is federally negotiated at 53% for on-campus research (a copy of the agreement is appended to this budget narrative). The cognizant agency is the Department of Health and Human Services (Helen Fung; 415-437-7820). The 53% rate is applied to a MTDC base of $229,601 for a total indirect cost of $121,689, split between Year 1 ($91,500) and Year 2 ($30,188).

NON-FEDERAL REQUEST
The Washington State University indirect cost rate is federally negotiated at 26% for off-campus research (a copy of the agreement is appended to this budget narrative). The cognizant agency is the Department of Health and Human Services (Helen Fung; 415-437-7820). The 26% rate is applied to a MTDC base of $82,667 for a total indirect cost of $21,493, split between Year 1 ($14,869) and Year 2 ($6,624).