Western Kittitas County Groundwater Study, Washington

A proposal prepared by the U.S. Geological Survey for Washington State Department of Ecology

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Background — The surface waters in the Yakima River basin, located in central Washington (fig. 1), are considered over allocated, with junior surface-water users having their entitlements 'prorated' in below average runoff years. Since 1945, at least 14 percent of the time junior users have been prorated. In turn, since about 1960, new water demands have been met by the use of groundwater, and almost all of these uses hold a later priority date for withdrawals than the surface-water users. As a result, in 2007 a private organization in Kittitas County submitted a petition to the Washington State Department of Ecology (WaDOE). The petition requested WaDOE to unconditionally withdraw future appropriations of groundwater in Kittitas County until sufficient information is known about potential effects from groundwater withdrawals on the more senior surface-water rights and streamflow. WaDOE rejected the unconditional withdrawal, and started to negotiate a Memorandum of Agreement (MOA) with Kittitas County. As part of this MOA, it was determined that a groundwater study would be conducted to (1) define the hydrogeology of the study area, (2) provide information regarding groundwater occurrence and availability, (3) describe the potential extent of groundwater and surface water continuity, and (4) determine the potential for impairment resulting from groundwater withdrawal. The area for study was determined to be the western (upper) part of Kittitas County that mainly consists of the bedrock-floored, upland area (fig. 2) because the groundwater resources for the remaining part of the county are currently being analyzed as part of a basin-wide water availability study being conducted by the U.S. Geological Survey (USGS). As of

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October 2010, an emergency rule is in effect that establishes a withdrawal from appropriation of all unappropriated groundwater in the western Kittitas County (Washington Administrative Code 173-539A-010).

Description of Study Area

Location and Setting

The Yakima River basin, located in central Washington (fig. 1), has a drainage area of about 6,200 mi^2 and produces a mean annual unregulated streamflow (adjusted for regulation) of about 5,600 ft^3/s (about 4,055,000 acre-feet) and a regulated streamflow of about 3,600 ft^3/s (about 2,606,000 acre-feet). The basin includes three of Washington State's Water Resources Inventory Areas (numbers 37, 38, and 39), parts of three counties (Kittitas, Yakima, and Benton Counties), part of the Yakama Nation lands, and four ecoregions (Omernik, 1987; Cuffney and others, 1997).

The headwaters are on the upper, humid east slope of the Cascade Range, where the mean annual precipitation is more than 100 inches. The basin ends at the confluence of the Yakima and Columbia Rivers in the low-lying, arid part of the basin, which receives about 6 inches of precipitation per year. There are eight major rivers and numerous smaller streams tributary to the Yakima River (fig. 1), the largest tributary being the Naches River. Most of the precipitation falls during the winter in the form of snow in the mountains, especially within the study area. The mean annual precipitation over the entire basin is about 27 inches (about 12,000 ft^3/s or 8.7 million acre-feet). The spatial pattern of mean annual precipitation resembles the pattern of the basin's highly variable topography. Altitudes in the basin range from 400 to nearly 8,000 feet. The difference between the mean annual precipitation and mean annual unregulated streamflow

indicates that about 6,400 ft^3/s or about 4.6 million acre-feet of water is lost to evapotranspiration under natural conditions.

Within the Yakima River basin, the study area underlies about 860 mi^2, of which 77 percent is underlain by bedrock. For the remaining part of the study area, unconsolidated sediments underlie 17 percent and basalt of the Columbia River Basalt Group (CRBG) underlies 6 percent (fig. 3). U.S. Forest Service lands occupy about 67 percent of the study area (fig. 4). The average elevation in the study area is about 3,620 ft and ranges from 1,730 to 7,960 ft. Mean annual precipitation in the study area is on the order of 80 inches. Based on streamflow for the Yakima River at Cle Elum, the area generates about 2,200 ft^3/s of unregulated runoff (4.4 $ft^3/s/mi^2$) and 1,700 ft^3/s of runoff under regulated conditions. The three U.S. Bureau of Reclamation (Reclamation) operated reservoirs in the study area account for about 78 percent of the total surface-water storage in the basin.

Overview of the Geology and Hydrogeology

The study area is located on the eastern slopes of the Cascade Range where the Cascade Mountain physiographic province begins to transition into the Columbia Plateau physiographic province (Meyers and Price, 1979). The western margin of the Columbia Plateau contains the Yakima Fold Belt subprovince where the study area is located. This region is highly folded and faulted and is underlain by various consolidated rocks, ranging in age from Paleozoic to Tertiary, and unconsolidated materials and volcanic rocks of Quaternary age (figure 3). The headwater areas in the Cascade Range within western Kittitas County include metamorphic, sedimentary, and intrusive and extrusive igneous rocks—the bedrock. The remaining parts of Kittitas County are composed of basalt lava flows of the CRBG with some discontinuous,

weakly consolidated sediments. The bedrock areas abut and intercalate with the CRBG. The sedimentary basins in Kittitas County are underlain by unconsolidated basin-fill composed of lacustrine and alluvium deposits that are in places more than 1,000 feet thick in the Kittitas basin and up to 700 ft thick in the Roslyn basin that is in the study area (Jones and others, 2006); wind-blown deposits occur locally along the lower valley sides.

Basin-fill deposits are important for groundwater occurrence in Kittitas County. The basin-fill sediments, such as gravel, sand, silt, and clay, were eroded from the Cascade Range and from the east-west-trending anticlinal ridges that were formed from the buckling of the basalt sequence during mid- to late-Miocene time. Much of the sediments are part of the Ellensburg Formation. This formation underlies, intercalates, and overlies the basalts along the western edge, and, excluding the Roslyn basin, composes most of the thickness of the consolidated deposits in the basinal areas, which are narrow to large-open synclinal basins.

The deposition of a thick, upper sequence of sand, gravel, and some fine materials is the result of erosion by glacial ice and transport by meltwater streams. Damming of large lakes by glacial ice during the Pleistocene epoch resulted in the deposition of silt and clay beds in parts of the uplands, in particular, unit 2 in the Roslyn basin (Jones and others, 2006). Thus, the unconsolidated materials in the basinal areas are abutting and interbedded with the bedrock and basalt range from Miocene to Holocene in age.

The study area contains a complex assortment of Quaternary to Paleozoic bedrock units (Vaccaro and others, 2009). These units were subdivided into eight surficial hydrogeologic units on the basis of age and rock type (Vaccaro and others, 2009; see plate 2). The vertical

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extent of this complex mélange of units was not mapped as part of the ongoing USGS Yakima study.

Problem — Baseflows in the tributary streams in the western portion of Kittitas County are important in the late summer and fall when demands on these streams peak. The ongoing USGS Yakima study indicates that groundwater and surface water are interconnected in the Yakima River basin, however the hydrogeologic framework and the potential impacts of groundwater withdrawals on tributary streamflow in the bedrock system were not investigated.

Objectives — The objectives for the groundwater study have been defined by a joint effort of Kittitas County, WaDOE, and other parties. These objectives are to: (1) define the hydrogeology of the study area, (2) provide information regarding groundwater occurrence and availability, (3) describe the potential extent of groundwater and surface water continuity in the study area, and (4) determine the extent of potential impairment resulting from well use.

The objectives of this study are being met using a phased approach with four phases. The first phase includes (1) project planning, coordination, and outreach, (2) gathering, compiling, documenting, and assessing available data, (3) initial collection of readily available data, and (4) conducting readily achievable work elements that provide information for meeting the objectives. The second phase, an initial conceptual model of the groundwater flow system will be developed based on the information from Phase 1. The third phase consists of data collection activities to support the following work elements: (1) analyzing water rights, (2) mapping and characterizing hydrogeologic units to the extent possible within the data limitations, (3) mapping groundwater levels, (4) estimating groundwater use, (5) developing updated estimates of groundwater recharge, and (6) constructing water budgets for selected subbasins. Together,

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these items provide the information for describing the groundwater-flow system (occurrence and availability) and provide the building blocks for (1) constructing the hydrogeologic framework and (2) estimating the extent of groundwater and surface water continuity and potential impairment. The reason for the phased approach has been outlined by WaDOE as, "The need for these phases is dictated by the desire of the County and Ecology to do public outreach to stakeholders, and the potential limitations that available data and information may impose on the completion of the Project. In addition, a phased approach will facilitate the information-sharing and decision-making processes" (T. Mackie, Washington State Department of Ecology, written commun., 2010). Therefore, the project will include outreach efforts to be conducted by the USGS, WaDOE, and Kittitas County.

Relevance and Benefits — The study addresses most issues identified in the Water Resources Discipline's strategic plan and the Washington Water Science Center's priority program opportunities for meeting the Nation's needs. These issues include tools for managing the Nation's watersheds effectively and improving simulation tools for transference to others. The assessment of availability and sustainability of America's water, and estimating effects of land-use and management alternatives on quantity and providing such information for National assessments also are important issues. These issues and the study address river-basin simulation and groundwater withdrawal effects on surface water. Last, the USGS is a neutral scientific party for providing information, and is building partnerships to solve important problems that are common in the Nation.

Approach — Understanding the interaction of groundwater and surface water is essential to water resource managers. Management of one component of the hydrologic system, such as a stream or an aquifer, commonly is only partly effective because each hydrologic component is

in continuing interaction with other components (Winter and others, 1998). Data collection, watershed characterization, and assessment of the water resources of western Kittitas County need to be conducted on a basin-wide scale and all major components of the water budget examined.

The broad approach begins with developing a project website and a QA/QC plan to facilitate communication and establish consistent methods between project partners and stakeholders. Hydrologic and hydrogeologic data will be compiled and collected and the data will be entered into the National Water Information System (NWIS) database. Geospatial data will be compiled and entered in a newly created Geographic Information Systems (GIS) based database. These data will be evaluated to characterize the flow system for the basin. The specific tasks needed to complete the study are presented below. A project timeline and budget are given at the end of this document. The project duration is expected to be 3 years.

Phase 1 Development of work plans and project planning, data compilation, initial data collection, and update existing watershed models

Task 1.1 Develop work plan for study and project coordination - The coordination between the project entities and stakeholders will begin in Phase 1. An initial public meeting will be held to: (1) explain the project and design, (2) develop a method for coordination of data collection, and (3) help determine availability of data and their sources.

The initial work plan is this document. A more detailed plan for selected work elements will be developed during the first stage of the project to improve the coordination and supply information for the other parties.

Task 1.2 Develop and populate project website - A USGS project website will provide descriptions of the Kittitas groundwater study objectives and study methods, periodic project progress updates, project reports, and other products. The website also may contain links to project data and results. The website will be hosted and maintained by the USGS for the duration of the project.

Task 1.3 Compile and document available data - There are many sources of available data, including USGS, Reclamation, U.S. Forest Service, WaDOE, Washington State Department of Health (WaDOH), Washington State Department of Transportation, Yakama Nation, and local well drillers and water purveyors, and the form of these data varies from digital GIS data-layers to paper copies. Sources of pertinent data will be identified and contacted. Some data compilation has been completed or is ongoing by the USGS Yakima study. The WaDOE has conducted hydrogeologic analyses for water budget neutral determinations and completed much work on identifying the location and associated surface-water rights through the adjudication process. The USGS uncoded and older well logs and WaDOE well logs will be examined in the process in order to plan for developing a database and the field inventory. Wells that are part of the ongoing USGS study will be identified for inclusion in the field inventory and to identify areas where wells need to be inventoried.

Current and historical available water-use information will be obtained from the WaDOE, the WaDOH, and water purveyors located within the study area.

A project database(s) for storage, evaluation, and analysis of available geospatial information for the study area will be established using a combination of GIS, and data management and analysis software. The databases will integrate the above described

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information from multiple sources, and will be continually populated with new data as they become available. Final GIS data will be made available through the project web page. Pertinent well information either compiled or collected during the study will be input into NWIS. Some data will need to be digitized to be brought into a GIS. The GIS data will be projected using the State Plane south zone Lambert projection. All data will be checked for accuracy in accordance with the USGS Washington Water Science Center quality assurance plan (Drost, 2005).

Task 1.4 Evaluate and assess data and develop plans to collect additional data - Currently available data will be evaluated for relevance and accuracy. Additional data that are necessary to meet study objectives will be identified. The need for additional data will be guided by information required to characterize the water resources of western Kittitas County. Additional data needs also will address data gaps identified by study partners and technical questions from the partners and stakeholder group members. Results of this task will be integrated with Phase 2 work.

Additional data needs identified as part of the work element will be prioritized and a plan will be developed to collect the data. Possible additional data for the categories identified in Phase 3 may include: geochemical data, groundwater levels, streamflow, and information pertaining to hydrogeologic units and hydraulic properties.

Task 1.5 Coordinate Public outreach - Essential to the study, and to be started in Phase 1, is the coordination between project partners and stakeholders. The USGS, WaDOE, and Kittitas County will conduct a public outreach effort for the length of the study. The purpose

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of this public outreach effort is to inform stakeholders about the study progress and present preliminary data and interim results during periodic public presentations.

Phase 2 Development of an initial conceptual model of the groundwater-flow system - An initial conceptual model of the groundwater flow system will be developed during this phase. Information pertaining to hydrogeologic units, horizontal and vertical movement of water, hydraulic head variations, water budgets, and hydraulic characteristics will be tabulated from published literature, data gathered in Phase 1 and the results from the USGS Yakima study. Available geochemical information also will be analyzed for developing a conceptual model. The initial conceptual model will be used to help guide the collection of selected data.

Phase 3 Development of the hydrogeologic framework

Task 3.1 Compile and map water-right information - The location of surface-water and groundwater rights in the study area are important for understanding potential impairment. A water-right file was obtained from WaDOE by the USGS Yakima study team in 2006. WaDOE will provide to the USGS an updated water-right file that will contain the following information: (1) name for the permit, (2) maximum withdrawal in cubic feet per second and acre-feet per year, (3) the location of the point-of-diversion (POD), (4) the adjudication subbasin number and list of the names and GIS-delineations of subbasins associated with that number, (5) the name of the source, for example, Teanaway River or spring, and (6) the priority date. The USGS will analyze this file to identify rights in the study area. The actual location of the right will be estimated using the information from the file and detailed maps of streams; this work will need to be completed because the POD in many cases identify the quarter-quarter section which does not place the right directly on a

stream. For springs, the center of the most detailed location information from the file will be used as the location of the spring.

Surface-water rights, by subbasin, will be compiled for inclusion into the subbasin water budgets and for comparison with streamflow and estimated pumpage. Distance between surface-water rights and existing wells also will be calculated. Where possible, a location on a stream will be identified that is an estimate of where a water-right spring's outflow would drain to.

As part of the USGS Yakima study, groundwater rights were associated with individual rights. A file of groundwater rights and associated wells in the study area will be sent to WaDOE in order to have these associations verified.

Task 3.2 Estimate the hydraulic characteristics of hydrogeologic units - The hydraulic characteristics of the hydrogeologic units are important for understanding the groundwater-flow system at various scales. They provide information for understanding relations between the groundwater and the surface-water resources, for defining movement of water in and between units, and for understanding recharge/discharge relationships, including transit times.

The principal characteristics to be analyzed include lateral and vertical hydraulic conductivity, storage coefficient, specific yield, and streambed conductance. The information from drillers' logs, existing aquifer tests, compilations done in previous studies (for example, Vaccaro and others, 2009), and any published groundwater model investigations will be compiled and analyzed as part of this element. For the non-basalt bedrock types, a literature search will be conducted to find information on the hydraulic

characteristics of similar rock types. To the extent possible, the spatial variability of the information will be analyzed. The published information for vertical hydraulic conductivity will be analyzed in detail to gain some understanding of the potential range in the values to help understand the connectivity between hydrogeologic units. The characteristics of fractures and faults also will be analyzed to the extent possible. Although not strictly a hydraulic characteristic, well yields, by rock type and or hydrogeologic unit will be compiled and mapped. Anomalous well yields related to subsurface artifacts left over from coal mining in the study area will also be evaluated.

Additional data collection may be necessary to adequately define aquifer properties of the groundwater system and thus, the hydrogeologic framework. If needed, this work would be conducted as early as possible to ensure availability of results for inclusion in the description of the hydrogeologic framework (Task 3.10); however, the funds required for this potential work are uncertain and are not included in the proposal budget. The need for aquifer tests will be evaluated in Phase 1 and this work would be: (1) limited to those areas where existing data are insufficient to adequately characterize major aquifers and aquitards and (2) contracted, if additional funding becomes available, by WaDOE or Kittitas County to a private vendor with local experience.

Task 3.3 Develop maps of surficial hydrogeology and hydrogeologic units - The interpretation of the hydrogeologic framework of western Kittitas County will be based primarily on existing maps of surficial geology and the lithologic information from drillers' logs. Previous investigators have studied the hydrogeology and surficial aquifers of the study area at a regional scale (Jones and others, 2006; Vaccaro and others, 2009). Using these previous investigations and existing data, major hydrogeologic units will be identified

and maps of the surficial geology, including bedrock differentiation, and refined total sediment thickness, with 2 to 3 cross sections will be constructed.

Task 3.4 Collect groundwater-level data and construct maps of groundwater levels, if data availability permits – A well-records inventory and field inventory of wells will be conducted to locate wells suitable for the establishment of a groundwater-level monitoring network. A synoptic water-level measurement will be conducted and a monthly monitoring network of wells will be established and operated. A subset of the monthly monitoring network will be instrumented with continuous water-level recorders (1) to provide areal and vertical coverage of the major aquifers in the study area, (2) to better evaluate groundwater and surface-water interactions, and (3) to document groundwater levels away from major withdrawal areas. The monitoring network could be expanded or extended in time if more funding becomes available.

Data permitting, groundwater-level maps for major hydrogeologic units in the study area will be constructed based on data collected during this study and supplemented by historical data and reported water levels. Such maps would provide information about groundwater flow directions, and horizontal and vertical gradients. A preliminary look at water levels reported by drillers in many wells indicates a very complex system with multiple controls such as faults and variations/changes in rock types.

Task 3.5 Estimate reaches that receive groundwater discharge for selected streams - Stream baseflow measurements will be made to delineate gaining and losing stream reaches. Baseflow measurement sites will augment the USGS and Reclamation streamflow-gaging stations currently operating in the study area and earlier synoptic streamflow measurements

summarized by Magirl and others (2009). Historical data from four WaDOE gaging stations will be analyzed to determine if they provide additional information on streamflow gains or losses. Measurements will be made once during the low-flow season. Areas of groundwater discharge to streams will be refined using fiber-optic distributed temperature sensing and thermal profiling methods described by Vaccaro and Maloy (2006).

Task 3.6 Obtain estimates on the age and source of water to wells, springs, and streams – Hydrochemical data compiled as part of Task 1.2 will be analyzed to develop an initial conceptual model of the source of water and if possible, potential ages of water. This information will provide a background for designing a sampling network. To obtain information on the potential range in groundwater ages, carbon-14 samples will be taken from selected springs and wells in different bedrock units, and the confined unit in the Roslyn basin (Jones and others, 2006). To ascertain younger ages, SF_6 (sulphur fluoride) will be analyzed from samples from springs, creeks, and wells. Stable isotope samples will be taken to provide information on the source of water. Samples may be from springs, creeks, wells, snowmelt, pore water in the root zone, and rainfall. Excluding the snowmelt and pore-water samples, data collection will occur during the April-May period and during the July-September low-flow period. For snowmelt and pore-water collection, collectors will be designed and deployed in October of FY12. Snowmelt samples will be collected based on the weather and samplers checked once a month. Pore-water samples will be gathered on a monthly basis. All samples will also be analyzed for common ions.

Task 3.7 Update estimates of groundwater pumpage – The growth of exempt wells in Kittitas County and concern over the possible infringement of the groundwater withdrawals on senior water right-holders require a thorough assessment of total groundwater pumpage.

Using data collected in previous studies and as part of Task 1.2, groundwater pumpage estimates will be extended from the work of Vaccaro and Sumioka (2006) for years 2001 through 2010. Exempt water use will be estimated using WaDOE well logs and previous investigations, land use datasets, census records, tax-parcel information, and average per capita water use. All available data for WaDOH class A and B systems will be obtained and analyzed.

Task 3.8 Modify watershed models - The existing USGS Precipitation-Runoff Modeling System (PRMS; Leavesley and others, 1983) models (Mastin and Vaccaro, 2002) that are in the USGS Modular Modeling System (Leavesley and others, 1996) will be modified to account for bedrock-sediment contacts for streamflow nodes, updated to simulate current climatic conditions, and converted to a Window-based system.

Task 3.9 Use existing models to update estimates of potential groundwater recharge - Recharge is an important control on the flow system and is an important component of management activities--from conservation practices to fishery restoration to groundwater availability. For this study, recharge is considered to derive from direct precipitation, snowmelt, applied irrigation water, and canal losses. Groundwater gains from streamflow losses are not treated as part of the recharge component. The gains from streamflow will be estimated from the seepage runs, analysis of streamflow records, and groundwater-model simulations from the USGS Yakima study.

The water-budget components calculated from the existing USGS watershed models will be used to estimate recharge. The watershed models (described above) include all of the bedrock areas (fig. 5). For the remaining lowland area with large-scale human activities, the

daily water-budget model, a deep percolation model (DPM; Bauer and Vaccaro, 1987; Vaccaro, 2007), constructed as part of the USGS Yakima study for the Roslyn basin will be used (fig.5).

Task 3.10 Construct water budgets for selected subbasins – Water budgets provide a means for evaluating availability and sustainability of a water supply and a basis for assessing how a change in one part of the hydrologic cycle may affect other aspects of the cycle (Healy and others, 2007). For understanding groundwater in bedrock terrains, the most important factor is understanding a water balance (A. Shapiro, written comunn., U.S. Geological Survey, 2008). To construct water budgets, the existing USGS PRMS and DPM models (Tasks 3.8 and 3.9) will be employed. The PRMS model includes 12 subbasins (fig. 5) that cover the complete study area (Mastin and Vaccaro, 2002). The watershed model currently operates using climate data input for the period of water years 1950 through 2005. The model calculates numerous hydrologic water-budget components, including unregulated streamflow. The streamflow is calculated at the outlet for each subbasin and at several accumulation locations. The DPM model (fig. 5) includes about 52 square miles surrounding the Roslyn basin, and its area was based on the most intensely developed part within the watershed modeled area.

Although it is not known at this time which water-budget components will be constructed for a subbasin, at least several can be identified. These are, precipitation, streamflow, evapotranspiration, and water leaving the roots zone (potential recharge). Groundwater availability for each subbasin will be evaluated. In addition to the groundwater component, the PRMS model calculates the surface-water and subsurface–water components of the streamflow, and thus, these components can be included in the subbasin water budget.

Available observed regulated streamflow also will be included in the water budgets. For each watershed, ranges and median values of components will be presented.

Task 3.11 Describe the hydrogeologic framework – The hydrogeologic framework integrates all existing and new information collected and compiled as part of this study and addresses objectives 1 and 2. Applicable information from the ongoing USGS Yakima study will be incorporated into the description of the framework. The framework will include a description of the flow system, sources of water, areas of groundwater discharge, importance of water-budget components relative to groundwater pumpage, and potential relations between groundwater and surface water. The framework provides the basics for assessing the potential extent of groundwater and surface water continuity in the study area (objective 3). The description of the hydrogeologic framework will be included in the report produced in Phase 4.

Task 3.12 Assess flow capture and sensitivities – Several approaches will be used to assess streamflow capture. Also of importance is assessing the sensitivity of streamflow capture to the uncertainties in the hydrogeologic framework and data availability. The possible approaches are listed below.

1. Calculate the potential capture zones for different hydrogeologic settings using radial flow models (Reilly, 1984; Reilly and Harbaugh, 1993; Johnson and others, 2001; Samani and others, 2004).

2. Calculate potential streamflow depletion by nearby pumping wells (Barlow, 2000; Reeves, 2008).

3. Test sensitivity of streamflow changes to pumping rates and relations to hydrogeologic units and their characteristics.

The results from 1-3 above, when analyzed in conjunction with the hydrogeologic framework, will allow for the description of the potential streamflow capture by groundwater pumping in the study area (objective 3).

Phase 4 Documentation and presentation of the study results - An understanding of the interaction between the aquifers and surface water will be based on the interpretations of existing and newly collected information (Phase 1 - 3). The documentation of the study results will include a description of (1) the hydrogeology of the study area (objective 1), (2) groundwater occurrence and availability (objective 2), (3) the extent of groundwater/surface water continuity in the study area (objective 3), and (4) the extent of potential impairment by well use (objective 4). The information will provide a conceptual understanding of the hydrologic processes of western Kittitas County for future water management planning and decisions.

A report summarizing the hydrogeology and flow system of the study area will be prepared and published by September 2013.

Budget — The project will cost $1,035,000 over three fiscal years (FY 2011-2013). Project costs will be shared by the Washington State Department of Ecology and USGS. The budget covers all salary and other expenses to support the objectives and approach detailed above. Tasks can be expanded to investigate important flow system characteristics if additional funds become available.

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Funding Sources

Agency	FY 2011	FY 2012	FY 2013	Total
USGS	$ 20,000	$ 150,000	$165,000	$ 335,000
Ecology	$ 370,000	$ 165,000	$165,000	$ 700,000
Total	$ 390,000	$ 315,000	$330,000	$ 1,035,000

Timelines and Report Products — The USGS will prepare and publish a USGS Science Investigations Reports by September 2013. The USGS Publication Service Center will provide illustration, editorial, and publishing services. A project website will be maintained by the USGS for the duration of the study. A detailed timeline for the project is provided in the table below.

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Timelines:

Federal Fiscal Year	2011				2012				2013			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4
PHASE 1: Development of work plans and project planning, data compilation, and initial data collection												
Task 1.1 Develop work plan for study and project coordination	X											
Task 1.2 Develop and populate project website	X	X										
Task 1.3 Compile and document available data	X	X	X									
Task 1.4 Evaluate and assess data and develop plans to collect additional data		X	X	X								
Task 1.5 Coordinate Public outreach	Ongoing effort				Ongoing effort				Ongoing effort			
PHASE 2: Development of an initial conceptual model of the groundwater-flow system				X	X							
PHASE 3: Development of the hydrogeologic framework												
Task 3.1 Compile and map water-right information				X	X	X						
Task 3.2 Estimate the hydraulic characteristics of hydrogeologic units					X	X						
Task 3.3 Develop maps of hydrogeologic units						X	X	X				
Task 3.4 Collect groundwater-level data and construct maps of groundwater levels				X	X	X	X	X	X	X		
Task 3.5 Estimate reaches that receive groundwater discharge for selected streams				X		X			X			
Task 3.6 Obtain estimates on the source and age of water to wells, springs, and streams				X	X	X	X	X	X			
Task 3.7 Update estimates of groundwater pumpage					X	X						
Task 3.8 Modify watershed models			X	X								
Task 3.9 Use existing models to update estimates of potential groundwater recharge								X	X			
Task 3.10 Construct water budgets for selected subbasins									X	X		
Task 3.11 Describe the hydrogeologic framework									X	X		
Task 3.12 Assess flow capture and sensitivities										X		
PHASE 4: Documentation and presentation of the study results											X	X

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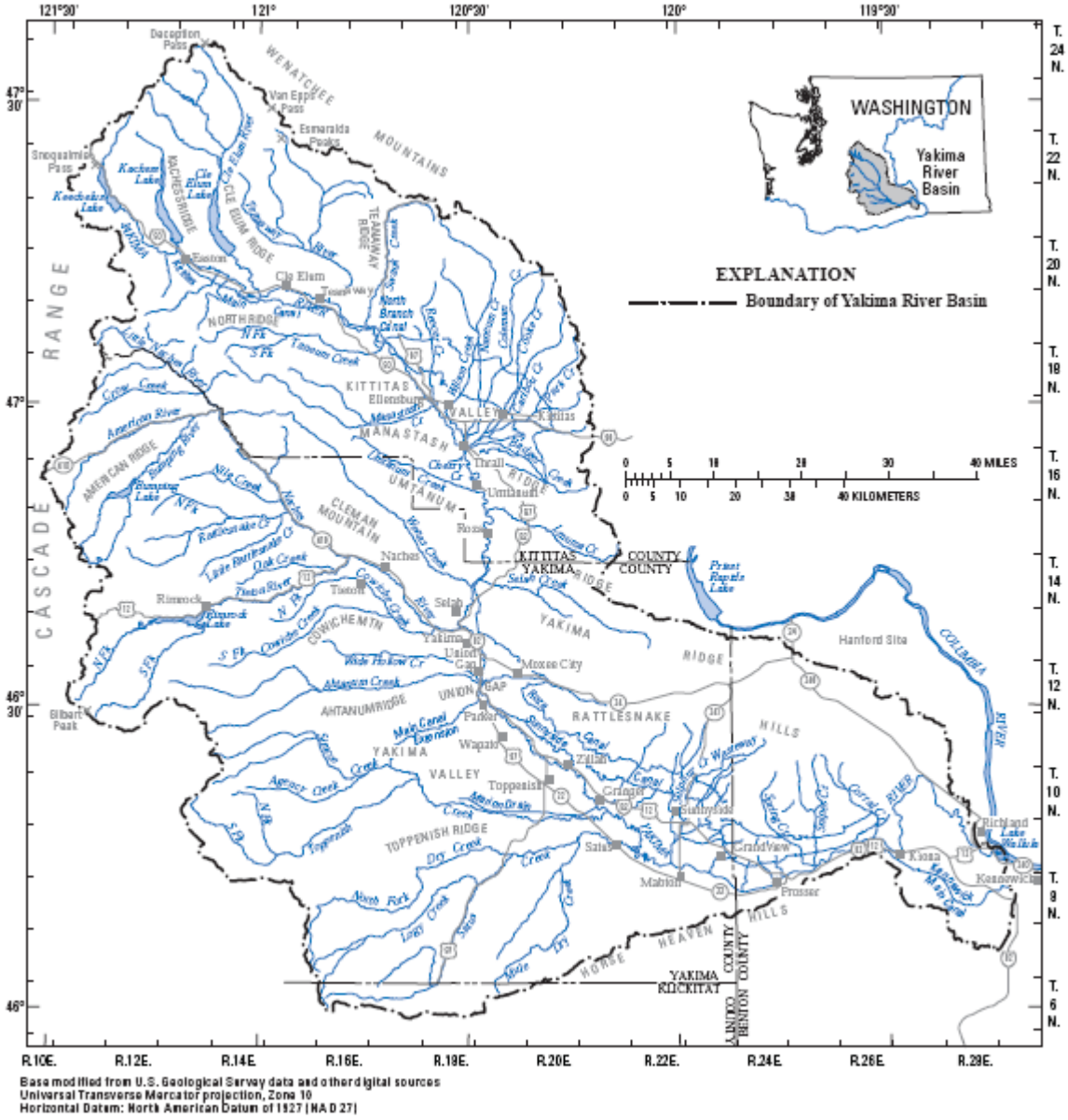

Figure 1. Yakima River basin, Washington.

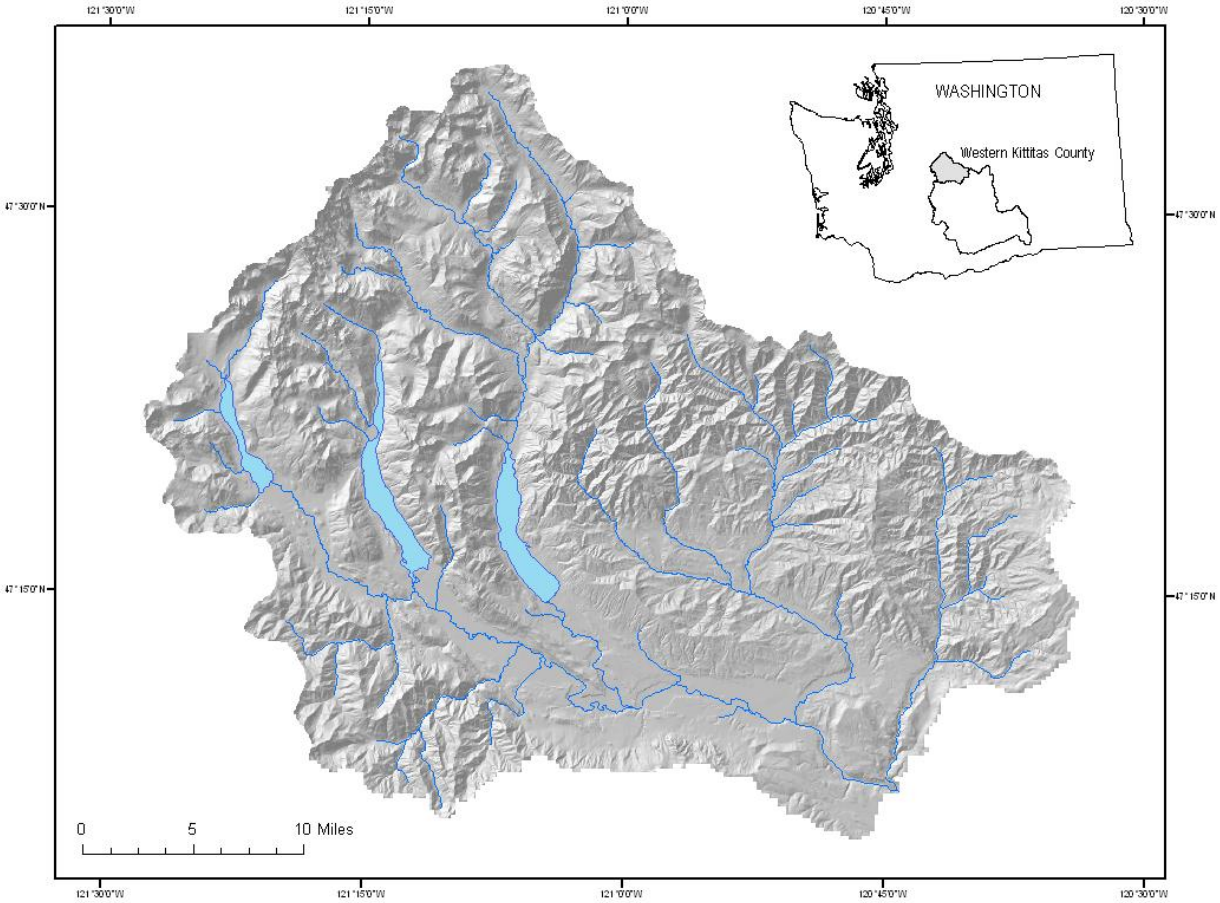

Figure 2. Western Kittitas County study area, Washington.

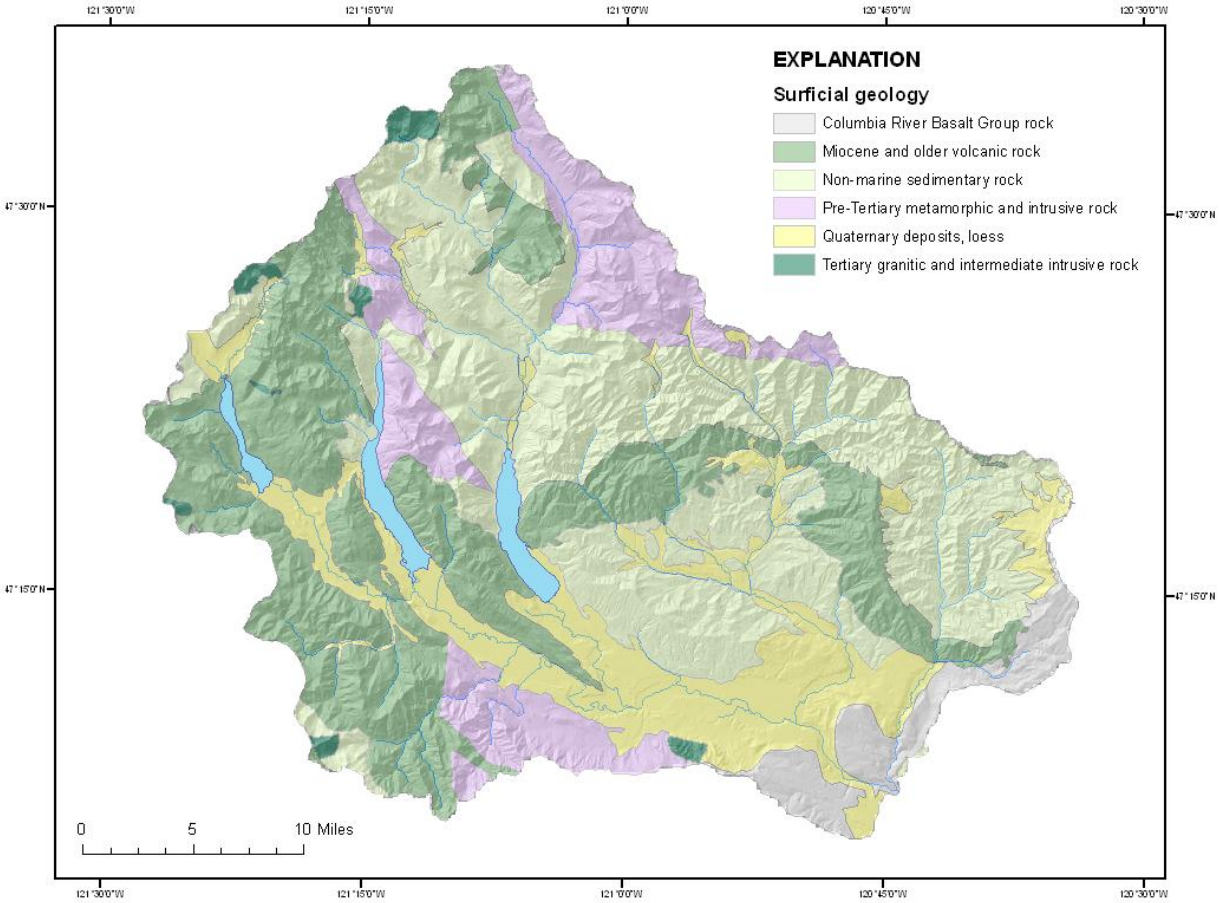

Figure 3. Simplified surficial geology of western Kittitas County study area, Washington.

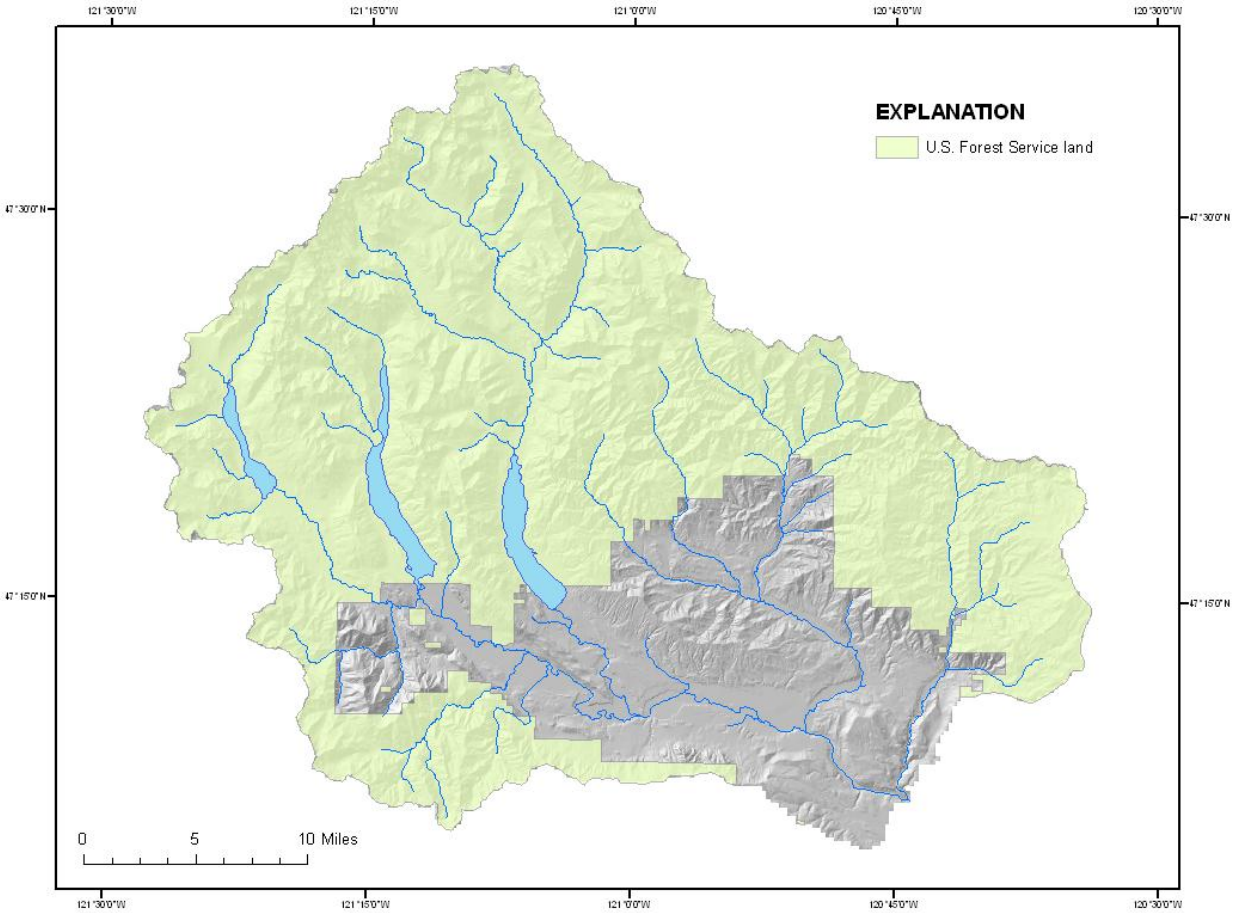

Figure 4. U.S. Forest Service land in western Kittitas County study area, Washington.

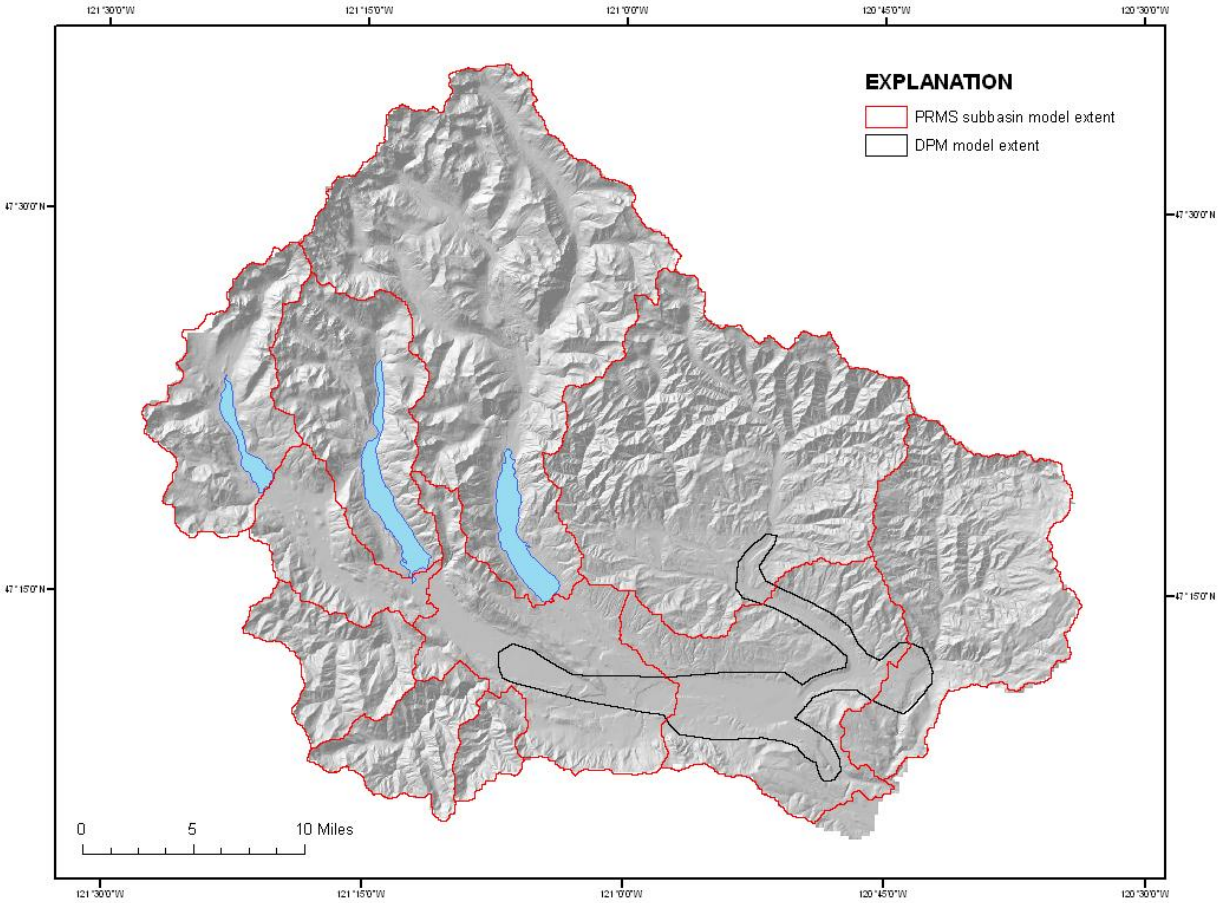

Figure 5. PRMS and DPM model extent in western Kittitas County study area, Washington.