Long Term Agro-Ecosystem Research Network (LTAR)
Great Basin Floristic Province

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INTRODUCTION/SUMMARY

Intermountain sagebrush steppe plant communities in the Great Basin and Columbia Plateau are considered to be among the most endangered ecosystems in the United States. The human population in this area is expanding at the highest rate in the nation and major sociological and ecological changes are occurring from urbanization, changing technology and land use, climate change, limited water resources, altered fire regimes and invasive species. Large scale vegetation type conversion is adversely affecting water resources and watershed function, native plant biodiversity, wildlife habitat, and forage for both native herbivores and livestock. Land managers across this region are struggling just to maintain, let alone improve, the ecological condition of these systems and the services that they provide for a growing number of diverse user groups (Chambers et al. 2008).

The Intermountain western United States has high spatial variability in soils, weather, vegetation and topography, but a relatively low density of environmental monitoring systems when compared to less complex ecosystems in other regions of the country. The entire Great Basin floristic province is severely under-represented among national ecological monitoring networks such as Ameriflux, the Critical Zone Observatory (CZO) system, and the National Ecological Observatory Network (NEON), and is the only major eco-region in the nation that does not have a Long-Term Ecological Research (LTER) site (Map, Appendix 2). The existing LTAR network has only 4 sites in the 11 western states and only 1 site in the Intermountain region: Pullman, WA, which is primarily involved in agricultural cropping systems in Washington, northern Idaho and northcentral Oregon. Three other LTAR sites in the western US represent Sonoran and Chihuahuan desert (Southwest Watershed Research Center, Tucson and Jornada Experimental Range, Las Cruces) and Central Plains (Rangeland Resources Research Unit, Fort Collins, Nunn CO/Cheyenne WY). This under-represented ecosystem covers over 600,000 km^2 in Nevada, Oregon, Idaho, Utah and California. This area comprises 7.5% of the contiguous US land area, and over 44% of the 5 contributing states.

The Northwest Watershed Research Center (NWRC) in Boise, Idaho and the Eastern Oregon Agricultural Research Center (EOARC) in Burns, Oregon have been conducting ecological and hydrologic research at multiple locations within the Great Basin and Columbia plateau for over 50 years (Map Appendix 2). NWRC and EOARC maintain long-term monitoring programs at the Reynolds Creek Experimental Watershed (RCEW) and Northern Great Basin Experimental Range (NGBER), and have developed successful partnerships with federal and state agencies, and regional universities for technology transfer to both public and private land managers. The Boise and Burns ARS units have provided leadership for major regional, national and global research and technology-transfer programs including the Sagebrush-Steppe Treatment Evaluation Project (Sage-STEP), Conservation Effects Assessment Project (CEAP), Ecologically Based Invasive Plant Management (EBIPM) program, Great Basin Research and Management Partnership (GBRMP), GEWEX Americas Prediction Project (GAPP), and received significant external research support from NRCS, USDA, BLM, NASA, NSF and NOAA. These two ARS research locations are uniquely suited to provide the core leadership and organizational infrastructure for a Great Basin Floristic Province addition to the Long Term Agro-Ecosystem Research (LTAR) network.

The mission of NWRC is to provide knowledge and technology for management of semi-arid rangeland watersheds; to quantitatively describe the hydrologic processes and interactive influences of climate, soils, vegetation, topography, and management on rangeland systems; to develop information, simulation models, and tools that can be used by action agencies and producers in determining optimum management strategies; and to maintain long-term databases for scientific applications. This mission is implemented through two closely integrated CRIS projects contributing to the USDA-ARS Pasture, Forage, and Rangeland Systems (NP215) and Water Availability and Watershed Management (NP211) National Research Programs.

The mission of the Burns-ARS unit is to develop agricultural and natural resource strategies that maintain or enhance intermountain forests and shrub steppe ecosystems for the benefit of present and future generations. To achieve this mission, research focuses on rangeland ecology and management,

restoration, and environmentally compatible livestock systems. The Burns-ARS unit, in collaboration with Oregon State University, forms the Eastern Oregon Agricultural Research Center (EOARC). The Burns-ARS unit contributes directly to the USDA-ARS Pasture, Forage, and Rangeland Systems (NP215) and Crop Protection and Quarantine (NP304) National Research Programs.

INFRASTRUCTURE CAPACITY - CORE LOCATIONS

Northwest Watershed Research Center and Reynolds Creek Experimental Watershed

The Northwest Watershed Research Center (NWRC) was established in Boise Idaho in 1959 with a mandate from Congress to establish a research watershed to study processes related to water supply, seasonal snow cover, soil freezing, erosion, water quality, and regional flooding. As part of this initial mission, NWRC established the 239 km^2 Reynolds Creek Experimental Watershed (RCEW) about 90 km southwest of Boise. In subsequent years, NWRC expanded its core research mission to include the hydrologic and ecological effects of landscape-scale disturbance from wildfire and invasive weeds, and rangeland restoration.

The early emphasis at RCEW was landscape-scale characterization of precipitation, stream discharge and sediment, and snow depth and density. Continuous records for these core data start between 1961 and 1965 (Table 1). A comprehensive resource inventory was initiated for RCEW in 1965 with detailed mapping of the geology, soils and vegetation (Stephenson 1977). In its first appearance in the scientific press, RCEW was described as an "outdoor laboratory" for long-term hydrologic research, a mission that continues to this day (Robins et al. 1965; Slaughter et al. 2001; Marks 2007; Reba et al. 2011). The research mission at RCEW subsequently evolved to include more detailed study of weather impacts on hydrologic processes, long-term evaluation of environmental gradients in a changing climate, experimental evaluation of landscape-scale management practices (e.g., prescribed fire, grazing, juniper control), and use of remote sensing and simulation models for spatial and temporal extrapolation. The longevity, intensity and breadth of hydrologic data at RCEW provide unique opportunities for hydrologic model evaluation and comparison, direct testing of hypotheses related to scaling issues, and assessment of potential climate-change impacts. In 1974, Stephenson and Freeze published what is generally regarded as the first, physically-based hillslope hydrology model using data collected in the RCEW for verification (Stephenson and Freeze 1974). These data have subsequently contributed to development, testing and validation of numerous process-based hydrologic and ecological models including USLE, MUSLE, WEPP, SPUR, SPAW, SHAW, ERYHM, SHE, ERMiT and RHEM.

RCEW is the only ARS watershed where snow is the principal precipitation input affecting both the timing and amount of stream-flow. Much of the current hydrologic research at RCEW emphasizes models that were developed by NWRC personnel to characterize and predict snow accumulation and melt and resulting stream-flow as affected by topography, vegetation and landscape scale management. RCEW is also a test-bed for assessing landscape-scale effects of fire, invasive weeds and grazing on overland flow and soil erosion processes, tools for hydrologic risk assessment, and hydrologic linkages with rangeland productivity and health. RCEW has also been a test-bed for new instrumentation for environmental monitoring including: evaluation of diverse rain gauge technology, snow measurement in windy environments; and procedures for evaluating stream flow in cold conditions. More recent work includes innovative research in both aerial and terrestrial LiDAR applications, utilization of geophysical measurements such as ground penetrating radar and electromagnetic induction for snow monitoring and soil mapping, satellite monitoring of livestock movement and behavior patterns, use of unmanned aerial vehicles for remote sensing, spatially extensive measurement of soil temperature with fiber optic cable, direct measurement of canopy-scale CO_2 and water flux in complex terrain and over snow, and measurement of intermediate scale soil water content from cosmic ray attenuation. RCEW has always been at the forefront of automated monitoring technology and the majority of environmental measurements at RCEW are telemetered daily for efficient quality control and database access.

RCEW combines a varied landscape representative of the Intermountain region with a strong support structure, laboratory space and housing facilities. At 239 km^2, RCEW is large enough to capture

critical landscape variability in soil type, topography and vegetation typical of the region. RCEW encompasses an environmental gradient extending from low-elevation salt-desert shrub to rugged mountainous terrain dominated by subalpine vegetation. Environments and vegetation types along this gradient typify those found throughout nine western states of the U.S. and in many other rangeland areas of the world. Long-term grazing exclosures were established in the mid-1960s in all major vegetation types and periodically sampled for temporal changes in vegetation production and species composition, diversity and richness. Vegetation production, composition, LAI, and rangeland health have also been monitored at sites associated with numerous long-term studies and modeling efforts. Livestock grazing is the predominant land-use on RCEW. The watershed is also typical of the predominant land-ownership pattern (77% public, 23% private) and management scenario (multiple-use grazing) for the bulk of the western United States. As with most of the Intermountain west, the predominant precipitation input to the system is upper-elevation snow, which is the principal source of irrigation water for the regional agriculture industry and the main driver for electricity production in the region.

Typical of this mountainous region, elevation ranges from about 1000 msl to over 2000 msl. There is a corresponding range in climatic conditions, with mean annual precipitation ranging from less than 250 mm/yr to more than 1000 mm/yr and mean annual temperature ranges from 4°C to 9.5°C in the upper and lower elevations, respectively. The temperature range is especially critical because it spans the rain/snow transition elevation. Thus, precipitation at the highest elevations in the watershed is about 80% snow, while that in the lower elevations is more than 80% rain. This has important implications for model testing and development, as the precipitation form largely governs hydrologic response, and for assessing global change impacts as the transition elevation rises.

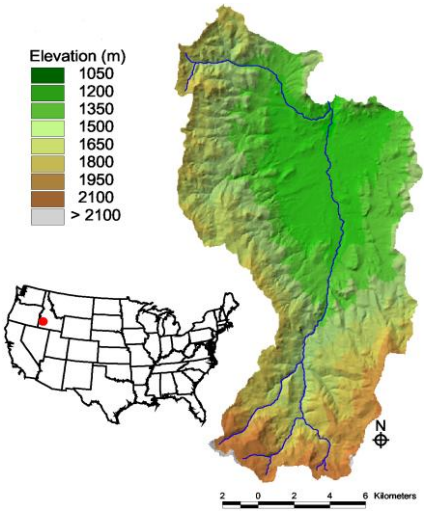

Figure 1 The Reynolds Creek Experimental Watershed, located in southwest Idaho. Perennial streams are shown above. Almost all stream flow generation is from elevations greater than 1650 m.

The geology of the RCEW is predominantly basalt, with significant portions of granite, lacusterine sediments and welded tuff. Consistent with the climatic and geologic variability, there is also a wide range of soils in the RCEW. Plant communities associated with Wyoming big sagebrush, mountain big sagebrush, low sagebrush, aspen and Douglas fir are found within RCEW. Since these plant communities are extensive throughout the region, we can extend research results well beyond the borders of the watershed.

The scientific infrastructure is designed to facilitate ecohydrologic research at a variety of scales and complexities by monitoring basic processes such as precipitation and runoff, and by providing fundamental information, such as detailed soil survey, at a range of scales and in a variety of environments. Thus, within the RCEW, along with core data, runoff is measured at scales ranging from small plots, to small "micro" (1 to 2 ha) watersheds, to small subwatersheds (12 – 50 ha) to much larger subwatersheds (1500 to 5500 ha), to the entire RCEW (239,000 ha).

Maintenance of a remote research watershed of the scale of RCEW requires a substantial effort.

At the base of the watershed, NWRC maintains a field station which serves several critical functions. First, there is a facility for maintaining vehicles and other equipment. Second, the facility provides the base from which fundamental data collection and instrument repair occur. Third, the field station headquarters is a data collection hub that receives telemetry from 84 different sites across the watershed that are then transmitted daily to the Boise laboratory. Fourth, it provides a safety net for field personnel by maintaining radio contact for emergency services, and providing other logistical support for year-round watershed operations. Finally, RCEW headquarters provides accommodations for up to 15 people. The location also has meeting room and laboratory space, and wireless internet access. Additional accommodations are available at the Reynolds Mountain cabin near the top of the watershed that sleeps five. There are currently eight graduate students working on thesis projects based on field research at the RCEW and in each of the past two years, have spent more than 100 student nights at the watershed. The relationship between NWRC personnel and students includes basic logistical support, formal advising on committees and serving as the primary research adviser. Eleven students have obtained degrees, mostly PhD's, in the past 10 years with an NWRC scientist as primary research advisor.

Eastern Oregon Agricultural Research Center and Northern Great Basin Experimental Range

Burns-ARS owns and manages the 6500 ha Northern Great Basin Experimental Range (NGBER) approximately 56 km from Burns, OR. NGBER has supported a +200 beef cow herd since 1935. The NBGER is comprised of 54 different soil types and has vegetation community types largely representative of the Great Basin and Columbia Plateau. These include three subspecies of big sagebrush, two species of low sagebrush, silver sagebrush, annual grass, crested wheatgrass and juniper dominated plant communities.

In 1936, large grazing exclosures were established at the NGBER and have been continually maintained to provide long-term evaluations of grazing effects. Research facilities at NGBER include plots instrumented to collect a wide variety of environmental data, multiple weather stations (including a permanent NOAA weather station), rain-out shelters for growing plants in controlled environments, plant and soil processing facilities, housing for temporary employees and visiting scientists and a conference center for extension activities. The NGBER also has corrals, a feedlot, livestock scales, and squeeze-chutes for beef cattle research. Infrastructure at the Burns-ARS headquarters location at the EOARC near Burns is a cooperative with Oregon State University and includes 256 ha of pastureland (primary flood irrigated hay meadows), three dry labs for processing vegetation and soil samples, a 1000 ft^2 indoor growing facility, a 3-season greenhouse, a seed-coating research lab, plant and soil drying facilities, and a wet lab with equipment to analyze plant, animal, and soil samples. The seed-coating research lab is the only one in the nation dedicated to developing seed-coating technologies for improving rangeland restoration. The Burns-ARS headquarters also have a bunkhouse and two houses available for visiting researchers and collaborators. The Burns headquarters also include a full shop, several large equipment storage sheds, research feedlots, livestock handling corrals and buildings, and research scales and livestock chutes. The Burns-ARS field support equipment includes a backhoe, bulldozer, large loader, large and small forklifts, several tractors, three rangeland drills, prescribed fire equipment including fire suppression trucks, herbicide application equipment, semi-truck with livestock and flatbed trailers, dump truck, many 4 X 4 pickup trucks and passenger vehicles, heavy equipment trailers for towing behind pickups, two UTVs, and many ATVs.

Data Richness and Availability - RCEW

The data richness, which may be thought of as the scientific infrastructure of the RCEW, is remarkable relative to any other comparable research site in terms of the longevity, intensity and breadth of the data collected. In 2001, NWRC published a groundbreaking series of papers describing the core data collected at RCEW between 1961 and 1996 (Hanson et al. 2001; Marks 2001; Marks et al. 2001; Pierson et al. 2001; Seyfried et al. 2001a; Seyfried et al. 2001b; Slaughter et al. 2001). All data are current and available thru WY2012, resulting in more than 50 years of comprehensive watershed data. Data reports have subsequently been published for a number of other ARS watersheds in Texas, Ohio, Arizona,

Pennsylvania and Georgia. A summary of the NWRC core data is provided in Table 1. It includes an extensive precipitation monitoring network, three meteorological stations with co-located soil water and soil temperature profiles strategically located along an elevation gradient, a network of weirs monitoring stream flow and sediment concentration over a range of scales, a snow course network designed to describe snow accumulation and melt at eight locations across the watershed, and snow pillows. In addition, spatial data, such as the digital elevation model, original vegetation, geology and soil inventory maps and subsequent remote sensing classifications, are described in the series (Seyfried et al. 2001c).

Table 1. Summary of Reynolds Creek Experimental Watershed Data Collection

Parameter:	Measured Value:	# of Stations			Years of Record:	Data Interval:
		1975	1996	2013		
Precipitation	shielded precipitation	53	17	28	1962-2013	Breakpoint (bp),[1]
	unshielded precipitation	53	17	26	1962-2013	15 min
Snow	snow course SWE	8	8	8	1961-2013	bi-weekly
	snow pillow SWE	1	1	2	1961-2013	15 min
	snow depth			32	1994-2013	15 min
Daily Climate	T_{max} and T_{min}	3	3	32	1964-2013	Daily
(evap- summer only)	pan evaporation	3	3	1	1974-2006	Summer
Weather	air temperature	3	5	38	1981-2013	15 min
	humidity	3	5	36	1981-2013	
	solar radiation	3	5	32	1981-2013	
	thermal radiation			5	1995-2013	
	wind speed & direction	3	4	32	1981-2013	
	barometric pressure	3	3	6	1981-2013	
	heat flux			8	2002-2013	
	surface & canopy temp			3	2003-2013	
Eddy Correlation	H, L_vE, H_2O, C-flux, R_n (4 component)			5	2002-2013	10 Hz & 30 min avg
Sap Flux	heat dissipation			12	2010-2013	Hourly
Soil Lysimeter	lysimeter water content	4			1976-1991	Hourly
Snowmelt lysimeter	water flux		8	6	1982-2013	Hourly
Neutron Probe	soil water (various depths)	18	14	35	1970-2013	bi-weekly
Soil Moisture	% water (various depths)			32	2000-2013	Hourly
Soil Temperature	soil temp (various depths)	5	5	32	1981-2013	Hourly
DTS Snow & Soil Temperature	distributed temperature (various depths)			2 km	2010-2013	Hourly
Ground Water	GW head	34	12	9	1968-2013	Hourly
Discharge & Sediment	stream discharge	13	8	10	1963-2013	bp,[2] 15 min
	suspended sediment	3	3	9	1965-2013	event-based
Stream Temperature	water temperature at the weir			4	2000-2013	Hourly
Vegetation	production, LAI and cover			3	2009-2013	Semiannually

In the years following 1996, the monitoring network at the RCEW has greatly expanded, and all data are now available from the NWRC ftp site (ftp.nwrc.ars.usda.gov). NWRC is also in the process of updating both the meta-data descriptions and the on-line database to include both site and GIS data layers corresponding to the entire 50+ year period of record. The additions to the RCEW monitoring network are described in relatively recent publications (Flerchinger et al. 2008; Marks 2007). In response to the need to enhance the utility of physically-based models in the complex, mountainous terrain of RCEW, the network of meteorological stations has been expanded from 3 stations in 1996, to 33 in 2011 (Figure 2). There has been a similar expansion of ecohydrologic monitoring on the landscape, with additions of 2 weirs, 32 snow depth sites (ultrasonic), 5 eddy covariance stations, 20 soil moisture and temperature locations, 10 groundwater monitoring wells, 32 continuously monitored soil water and temperature profiles (usually to bedrock), 20 neutron probe monitoring sites and stream temperature at four locations. New, 1-m resolution LiDAR digital elevation data has been obtained from an aerial survey in 2007. Plant production, LAI and cover are now monitored annually at three sites in the watershed. In addition, intensive snow surveys are conducted on different watersheds (Reynolds Mountain East, Upper Sheep Creek and South Mountain) in most years. The large expansion of instrumentation that occurred after 1996 was achieved both by extending the exiting extensive monitoring network and by initiating new, in-depth studies of ecohydrological processes. This expansion was mostly associated with the addition of meteorological stations to existing precipitation gauge sites. In addition, soil water content and temperature and snow depth are now monitored continuously at all precipitation gauge sites.

Four intensively studied subwatersheds are illustrated in Figure 2. The Reynolds Mountain East (RME) subwatershed has been the focus of snow research for many years. Data collected there have been instrumental in the development and enhancement of the ISNOBAL model and more recent linkage with subsurface models, particularly PHIM and also SEM. Eddy covariance measurements of water vapor and CO_2 flux have been collected at three locations, one over sagebrush, one over aspen and one under the aspen canopy. In addition, three climate stations, supplemented by tripod weather stations, help characterize the site weather. Other data include soil water content, groundwater level, snow depth and stream-flow. These data are described in a recent publication (Reba et al. 2011) and are publically available via ftp. Recent winter field experiments include a combination of LiDAR, ground penetrating radar and detailed surveys for quantifying distributions of snow water equivalent and fiber optic cable for distributed temperature sensing.

Upper Sheep Creek (USC) has been a site for model testing and development since its inception in the early 1970's. The current high intensity of instrumentation is related to the recent prescribed fire to investigate the impacts of fire on stream-flow and water quality in mountain catchments. Eddy covariance measurements of water vapor and CO_2 flux are measured over sagebrush and aspen vegetation (before and after fire). In addition, soil water content and temperature are monitored throughout the watershed to bedrock. Data from USC have been critical for a number of modeling studies, most recently focused on the SHAW model. A summary and analysis of data collected at USC was recently published (Chauvin et al. 2011). In addition, new instrumentation in the form of fiber optic distributed temperature sensing and cosmic ray soil moisture observing systems, are currently under evaluation at USC.

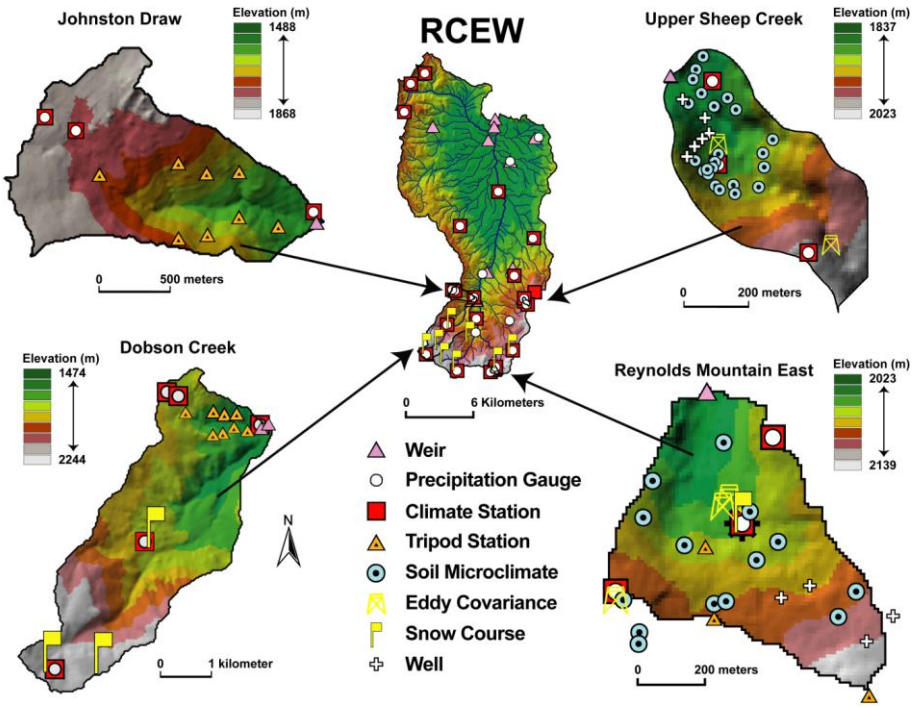

Figure 2. Instrumentation at the RCEW.

The Johnston Draw (JD) subwatershed is notable for the ecohydrolgical gradients it contains. The elevation range spans the rain/snow transition elevation, and much of the watershed is made up of steep north or south facing slopes. Current research at JD focuses on two issues critical in mountainous terrain: 1) simulation of hydrology, particularly input driven snow melt and stream-flow generation, across the rain/snow transition elevation, and 2) quantification of slope and aspect effects on soil water and temperature. These issues are especially interesting as we observe the migration of the rain/snow transition elevation to higher elevations with global climate change. For this study, a weir was installed in 2001 at which time the basin was also supplemented with additional meteorological stations. The "Tripod Station" triangles in Figure 2 represent sites with air temperature, wind speed and direction, relative humidity, snow depth and soil water and temperature from 5 cm to bedrock. Johnston draw is also part of the larger RCEW prescribed fire program.

The Dobson Creek subwatershed is an example of a site that is much less intensively instrumented, but where principles that have been established at smaller scales can be applied and tested at larger, more practical scales that necessarily have a wider range of conditions. In addition, a prescribed fire site, the Breaks, is located immediately adjacent to Dobson Creek.

Data collected at the RCEW have been used in over 450 manuscripts addressing a wide variety of topics. Because of the unique combination of long-term data collection, co-located weather snow, soil and stream flow measurements and the relatively large elevation gradient, the RCEW data (Figure 3) provide a unique window into the effects of climate change, which are explored in a few recent publications (Nayak et al. 2010; Chauvin et al. 2011; Seyfried et al. 2011).

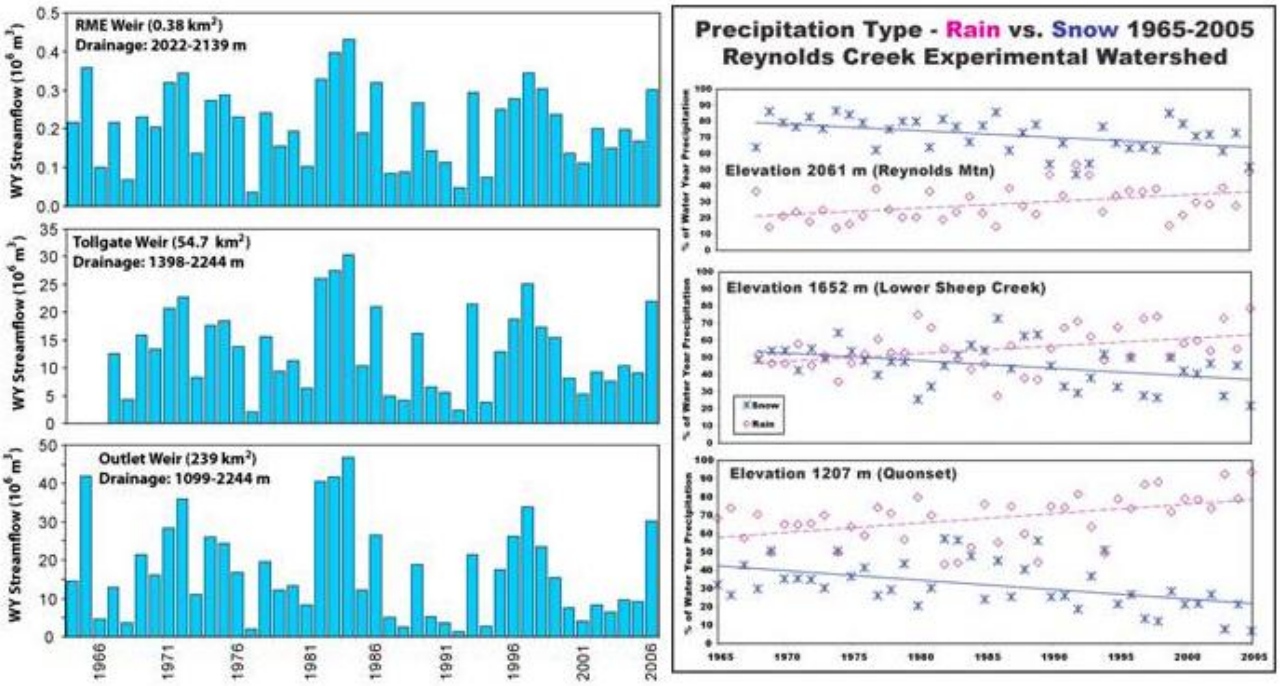

Figure 3. From 1965 to 2005, annual stream-flow totals show no trend. However, air temperature has increased approximately 2°C (not shown), resulting in precipitation form transition from snow to rain at all elevations, and earlier runoff in the spring.

Virtually all data collected at the RCEW are available upon request. Most of the data are accessible either via the Hydrological Information System sponsored by the National Science Foundation or the local ftp site. Data made available to the general public have undergone at least two levels of processing. In the first level, data are made serially complete and obvious errors flagged. In the second level, more subtle issues such as instrument drift or calibration error are addressed. Forcing data are "filled in" at this level where needed to facilitate their use in ecohydrologic models. The second level of data quality requires a considerable time investment resulting in a time lag between data collection and posting. Currently all data through 2012 are processed at level II and will be on the ftp site this year. In general, data are made available as soon as they are processed.

RCEW is part of several additional data collection networks including: NASA Soil Moisture Active Passive (SMAP) network; NSF Consortium of Universities for the Advancement of Hydrologic Science (CUASHI) Water and Environmental Research System (WATERS) test bed site; NRCS Soil Climate Analysis Network (SCAN); NOAA Climate Reference Network (CRN); Changing Cold Regions Network (CCRN); and the National Atmospheric Deposition Program (NADP) network.

Data Richness and Availability - NGBER

The Burns-ARS maintains multiple long-term datasets. One of the most valuable is livestock exclosures established in 1936 and untreated since that time. The exclosures provide a significant historical resource demonstrating changes in plant communities and soils for over 70 years and can be used to evaluate the long-term influence of management practices and climate (e.g. Sneva et al. 1984; Ponzetti and McCune 2001; Liston et al. 2003; Davies et al. 2010). The Burns-ARS also maintains long-term climatic data at the NGBER and had a permanent NOAA weather station installed in 2003. The

Burns-ARS, in cooperation with Oregon State University, maintains long-term beef cattle numbers, performance, and forage use at the NGBER. The Burns-ARS also maintains other long-term studies of the effects of juniper control (21 yrs old) (Bates et al. 2005), interaction between burning and grazing (19 yrs old) (Davies et al. 2009), plant functional group removal (15 yrs old) (Boyd and Svejcar 2011), prescribed burning cut juniper (15 yrs old) (Bates and Svejcar 2009), prescribed burning of juniper encroached aspen stands (14 yrs old) (Bates et al. 2006), and variability across the Wyoming big sagebrush alliance (11 yrs old) (Davies et al. 2006, 2007). The Burns-ARS unit is also implementing additional long-term studies including evaluations of restoration practices in annual grass-invaded rangelands, wildlife important shrub establishment post-juniper control, responses of sagebrush communities to wildfires and prescribed burns, and impacts of mechanical brush control in sagebrush communities. These studies are currently between 5-7 years old and the Burns-ARS staff is committed to continuing these studies to obtain long-term data.

The data from the NOAA weather station at the NGBER (OR Riley 10WSW) is available online to the general public at http://www.ncdc.noaa.gov/crn/report. Additional data is available in published manuscripts, experiment station reports, and progress reports that are available online at http://oregonstate.edu/dept/eoarc/publication. More detailed data are available by request.

Geographic Coverage at Various Scales

RCEW: The RCEW and associated research sites lie within the mountain agroecosystem. They are imbedded within the HUC-2 watershed draining into the Snake River and eventually the Columbia River. The landscapes are representative of typical sagebrush dominated, mountainous rangelands found throughout the Great Basin floristic region, within National Ecological Observatory Network (NEON) domain #15. It includes southern Idaho, eastern Oregon, central Washington, most of Nevada, western Utah and parts of Wyoming and Montana.

The data collected at the RCEW are consistent with and highly complementary of data collected by NSF funded networks, the LTER (Long-term Ecological Research), NEON and CZO (Critical Zone Observatory). In all cases, the physical, abiotic data collected at RCEW is similar to that collected at the other network sites, but in terms of measurement intensity and longevity, the RCEW data far exceeds those other network sites in general. For example, most NEON sites have an eddy covariance flux tower at the core to their measurement protocol. Some have been collecting data for as long as two years. There are five such towers in the RCEW that have been collecting data for almost 10 years. In other respects, especially biogeochemical data, those other sites have a more intensive data collection/monitoring network. RCEW is, therefore, well positioned to provide critical abiotic baseline data for a variety of research topics relevant to the missions of the three NSF networks. In particular, RCEW provides a unique location to examine the impacts of global climate change given the long record of climate, soil and stream-flow data.

NGBER: The Burns-ARS unit is located within the Pacific Agro-ecosystem and also maintains research projects in the Mountain Agro-Ecosystem. The Burns-ARS unit is located in the HUC-2 Pacific Northwest Region Watershed and also conducts research in Great Basin and California Regions. The Burn-ARS unit is centrally located in the Great Basin (Domain #15) of the National Ecological Observatory Network (NEON). The NGBER is one of only two ARS-owned experimental rangeland in the Pacific Agro-ecosystem and the Great Basin floristic province. The NGBER consists of five sagebrush community types, juniper woodlands, annual grass-invaded rangelands, and crested wheatgrass seedings. These plant communities are the dominant vegetation throughout much of the Great Basin and sagebrush ecosystem in Oregon, California, Nevada, Utah, Idaho, Colorado, and Wyoming. The research conducted by both the Burns and Boise-ARS locations occurs primarily in the Major Land Resource Areas (MLRAs) 11, 23, 24, and 25. This research, however, is relevant to MLRAs 7, 8, 12, 13, 26, 27, 28B, 32, 34A, 34B, and 35. The NGBER is largely representative of the 62 million hectare sagebrush ecosystem.

Satellite, Regional and International Research Locations and Networks

***South Mountain (SM) Juniper Hydrology Watersheds, the Owyhee Juniper Mountain Project Area, and the Owyhee Uplands Management Area*:** Four watersheds in western Owyhee County, Idaho were instrumented in 2007 by NWRC and EOARC to monitor and telemeter hourly weather, stream-flow and suspended sediment. In addition to general hydrologic and ecologic modeling infrastructure, these basins will be used to test the hydrologic impacts of juniper on the timing and amount of stream-flow, deposition and redistribution of snow, and ecological recovery of sagebrush/bunchgrass steppe after mechanical and prescribed-fire treatment of invasive juniper. The South Mountain watersheds are part of a larger juniper restoration science and management project in southwestern Idaho that includes the Juniper Mountain Project Area (JMPA). The JMPA is part of a BLM initiative established in 2004 to treat 1150 km^2 of juniper infested rangeland. EOARC and NWRC have an extensive background in juniper ecology and management and are working with BLM to develop and implement strategies to deal with this issue which affects over 36,000 km^2 of rangeland in the northern Great Basin. RCEW, SM and JMPA are all part of the 40,000 km^2 Owyhee Uplands Management Area that BLM is using to develop a coordinated remote sensing strategy for management of federal lands in the Great Basin. NWRC collaborative research in remote sensing at RCEW, SM and the JMPA have contributed to this project and assisted in evaluation of LiDAR, Landsat and hyperspectral remote sensing data.

***Boise River Basin and Dry Creek Experimental Watershed**:* NWRC is working with the US Bureau of Reclamation (USBR) to apply physically-based snow models to the 2150 km^2 Boise River basin (BRB) in an effort to improve water supply forecasts under rapidly warming climate conditions. While NWRC scientists have been working in the BRB for more than a decade, they are now beginning to transfer research models to real-time water management schemes. NWRC scientists are working with faculty from Boise State University, Utah State University and the University of Syracuse in the Dry Creek Experimental Watershed (DCEW), which is in the mountain drainage just above the City of Boise, to assess the impact of the rain snow transition on this major urban area of Idaho.

***Boise Foothills East Management Area*:** BFE-MA is a 240 km^2 area just north of Boise Idaho that is a key field domain for scientific and management collaboration between ARS, Boise State University, Idaho State University, the University of Idaho, Utah State University, USFS Rocky Mountain Research Station, Idaho Department of Fish and Game, BLM and the city of Boise. The BFE-MA is one of the most heavily utilized recreational areas in southern Idaho, contains a key Wildlife Management Area, and is a complex mixture of state, federal, city and private land ownership. Key concerns of the city of Boise are the danger of wildfire and potential for catastrophic flooding. NWRC is using this area as a test-bed for development of microclimatological supplements for NRCS Ecological Site Descriptions, has conducted remote sensing research using multiple sensor platforms, and is conducting field research in rangeland restoration and hydrologic risk assessment.

Snake River Birds of Prey National Conservation Area: This 2000 km^2 area was established by the Bureau of Land Management in 1993 for the conservation, protection and enhancement of raptor populations and habitat. Both raptor and prey species in this area are threatened by the increasing frequency and size of wildfires over the last 30 years, the proliferation of introduced annual weeds, and the disappearance of habitat-critical sagebrush-bunchgrass plant communities. This area is a critical test-bed for rangeland restoration activities, and ARS and BLM have a Memorandum of Understanding (MOU) to use this area for research and outreach activities. This area includes NWRC-operated meteorological instrumentation, is a principal field location for the ARS EBIPM program, and has a collaborator working group that includes ARS, BLM, USGS, USGS, Idaho National Guard, several NGO groups, and 3 regional universities.

Sierra Nevada Hydrologic Observatory: This includes research watersheds in the southern Sierra Nevada of California, which are up to two orders of magnitude larger than and represent a much broader range of conditions than those at RCEW. The American River Basin (5500 km^2) involves a joint project with UC on greatly expanded environmental monitoring and modeling, while the Marble Fork of the Keweah (153 km^2) and the Tulomne River (1200 km^2) basins involve collaborations with UC, Cal Tech, and NASA on simulation modeling to extend LiDAR measurements of the seasonal snow cover depth to

a volume of stored snow water equivalent (SWE) to improve water supply forecasts. These locations provide an opportunity for NWRC to extend models and methods to different environments and scales.

Changing Cold Regions Network (CCRN)*:* This network, established by the Canadian Global Institute for Water Security located at the University of Saskatchewan, is a follow to the GEWEX research conducted jointly between NWRC and Canadian scientists over the past decade. It involves a transect of watersheds along the spine of the western mountains from the Arctic Tundra down to the Mexican border (more than 5000 km) to evaluate how climate warming will impact snowcover and water supply for ecosystems, urban and manufacturing in western North America. This network will facilitate joint research and shared results between Canadian and US scientists.

Dischma Basin, Switzerland*:* The Dischma (52 km^2), just above Davos, Switzerland is the focus of joint modeling and research between Swiss and NWRC scientists on simulating snow deposition and melt for improved representation of snow processes in models designed to provide water supply forecasts. It provides evaluation of NWRC models and methods in an environment very different from the RCEW and Great Basin conditions.

Ecologically Based Invasive Plant Management Projects: The EBIPM program was established in 2009 as an ARS Areawide project that includes diverse collaboration at field and demonstration sites throughout the floristic Great Basin. This program develops and promotes a practical, science based management approach to the restoration of millions of hectares of rangeland that have been disturbed by invasive annual weeds. The EBIPM program (http://www.ebipm.org/) is a principal technology transfer outlet for rangeland restoration research by ARS, four universities, six public agencies and 12 private producers.

The Sagebrush Steppe Treatment Evaluation Project (SageSTEP; http://www.sagestep.org/): is a Great Basin regional experiment evaluating methods of sagebrush steppe restoration. Project treatments for evaluating mechanical, chemical and fire effects on invasive juniper and annual weeds were implemented between 2005 and 2010 and are subsequently undergoing long-term monitoring for post-treatment effects. NWRC was responsible for hydrologic monitoring and modeling for this program and continues to use this network of field sites for core validation of disturbance effects on soil erosion, and testing of models for rangeland health and hydrologic risk assessment.

Agriculture and Food Research Initiative (AFRI) rangeland seedling establishment projects: EOARC and NWRC were awarded Rangeland Research Program (RRP) grants in 2011 and 2012 to develop a systems approach to seedling establishment on degraded rangeland. These studies include 15 field sites across the northern sagebrush steppe in Oregon, Nevada and Idaho to evaluate the ecological processes driving seedling recruitment in these systems. All of these sites include meteorological and soil instrumentation to characterize and model seedbed microclimate. These projects also include development and enhancement of regional weather datasets and evaluation of Global Climate Model (GCM) output for seasonal forecasting applications for rangeland restoration. Although these grants were designed to support regional rangeland applications, they also provide a useful framework for any distributed hydrologic or ecological modeling application and are complimentary to additional collaborative projects with NRCS (CEAP and Ecological Site Description Programs), USGS (Powell Center Cheatgrass Working Group and Land Treatment Digital Library) and ARS (EBIPM and ARS watershed network applications).

Five Creeks Rangeland Restoration Project**:** is a 78,000 ac rangeland restoration project on Steens Mountain in southeastern Oregon administered by the Bureau of Land Management. The project involves prescribed burning encroaching western juniper to restore sagebrush steppe plant communities. EOARC scientists are evaluating different methods to accelerate the recovery of sage-grouse habitat and livestock forage production after juniper is controlled. EOARC is also evaluating how plant community response to prescribed burning varies by plant community and site characteristics.

Northern Great Basin Wyoming Big Sagebrush Project**:** is a +10 year research project evaluating variation in Wyoming big sagebrush communities across the Northern Great Basin. This includes 35 permanent sites located throughout southeastern Oregon that are sampled yearly by EOARC scientists. This includes determining the influence of climate on plant community productivity and yearly

variability in vegetation cover and habitat values.

***Otley Ranch*:** Burns-ARS has been evaluating the effects of juniper control projects on the Otley Ranch site since 1992. This has included prescribed burning and cutting western juniper to restore sagebrush steppe. Vegetation characteristics, soil variables, and, in collaboration with Boise-ARS, erosion and runoff risk have been measured at this site.

***Sheldon and Hart Mountain National Refuges*:** The Sheldon and Hart Mountian National Refuges comprise over 750,000 ac in southeastern Oregon and northern Nevada. EOARC has a long history of conducting research on both refuges. Burns-ARS is evaluating the impacts of wild (feral) horses on riparian areas and uplands on Sheldon at five sites since 2007. Burns-ARS is determining the impacts of fire and mechanical treatments on biodiversity, forage production, soil nutrient availability and wildlife habitat in mountain big sagebrush plant communities on Hart Mountain.

PRODUCTIVITY

The current scientific staff of the NWRC is six Category 1 scientists with varied and complimentary natural resource backgrounds: Hydrology, Hydraulic Engineering, Soil Science, Plant Physiology and Range Science. Two Category 3 scientists provide modeling, GIS and database support and two post-doctoral research associates and a cadre of field technicians provide dedicated support for NWRC and RCEW field infrastructure. This group is highly productive, both in terms of peer reviewed journal articles (total of 545 refereed publications by NWRC scientists), science/management partnerships, and technology transfer. Current NWRC scientists have published an average of >4 refereed publications per year since 2007. Several example technologies and products including: *Isnobal*, a stand-alone, physically-based, spatially distributed snow accumulation and melt model that has also been incorporated into the Penn State Hydrologic Model (PHIM); *SHAW*, a stand-alone energy balance model that simulates plant water uptake, soil water movement, groundwater recharge, and soil temperature that has also been coupled with a variety of distributed hydrologic and crop management models, such as WEB-DHM, Snobal, IBIS, the Root Zone Water Quality Model, and WeedTurf; *RHEM*, Rangeland Hydrology and Erosion Model developed in collaboration with the ARS Southwest Watershed Research Center (Tucson), the ARS Great Basin Rangeland Research Unit (Reno) and Natural Resources Conservation Service (NRCS) and implemented through the NRCS/ARS Conservation Effects Assessment Project (CEAP); *ERMiT*, Erosion Risk Management Tool cooperatively developed with the Forest Service, Rocky Mountain Research Station and used by Interagency Burned Area Emergency Response (BAER) Teams; *Clark ATS*, The Clark Animal Tracking System (ATS), GPS-based method for detailed spatial and temporal monitoring of animal activities under a wide array of remote conditions; *EBIPM*, The Ecologically Based Invasive Plant Management program is a regional research and demonstration program designed to assist land managers in designing effective strategies to restore rangelands that have been degraded by wildfire and have a proliferation of introduced annual weeds; *SEM*, Soil Ecohydrology Model, which simulates soil water status, groundwater recharge and estimates vegetation production. These accomplishments have been facilitated by considerable amounts of outside funding over the past decade. NWRC scientists have consistently attracted over $300,000/year from a variety of sources including NRCS, USDA-AFRI, BLM, Interagency Joint Fire Sciences Program, NASA, NSF, and NOAA. Technology transfer of models, products and tools has been facilitated through collaboration with the ARS EBIPM program, NRCS CEAP, Sagebrush Steppe Treatment Evaluation Program (SageSTEP), USGS Land Treatment Digital Library (LTDL), and Joint Fire Sciences (JFS) Science Delivery Project.

The Burns-ARS unit is a highly productive unit with seven permanent CAT 1 Scientists covering Range Science, Ecology and Agronomy. Since 2007, Burns-ARS scientific staff averaged ~5 peer-reviewed journal articles per scientist per year. All published manuscripts are posted online at the Eastern Oregon Agricultural Research Centers (EOARC) website (http://oregonstate.edu/dept/eoarc/publication). Among the many honors achieved by its current scientists include one ARS Distinguished Senior Scientist of the Year, one ARS Pacific West Area Scientist of the Year, three Society for Range Management Outstanding Achievement Awards, and three Society for Range Management Outstanding

Young Range Professional Awards. Burns-ARS scientists have also implemented and maintained the Ecologically Based Invasive Plant Management Program, an ARS area-wide educational and research program spanning 6 western states and included 27 partners. It received the Award for Excellence in Technology Transfer by the Federal Laboratory Consortium for Technology Transfer in 2012 and a national ARS technology transfer award in 2013.

PARTNERSHIPS

NWRC and EOARC work in partnership with a wide variety of stakeholders and collaborators including federal and state agencies, over 25 universities around the world, private landowners and permittees, and non-governmental organizations. Some current examples include:

Private land owners. Livestock production is the primary agricultural commodity in much of the Great Basin and Intermountain West. Both NWRC and EOARC work closely with livestock ranchers, and the Bureau of Land Management to ensure that research is meeting their needs.

Bureau of Land Management (BLM). BLM is the largest landowner at RCEW and in the Great Basin floristic province in general. BLM also manages key satellite research locations including the Snake River Birds of Prey National Conservation Area, Boise Foothills East Management Area, Owhyee Uplands Area, Juniper Mountain research locations and AFRI field sites. BLM is a full partner in the NWRC/EOARC prescribed fire and juniper management research programs and a significant cooperator in the EBIPM, SageSTEP, CEAP and JFS programs. EOARC and NWRC have >150 research sites on BLM administered lands in Oregon, Nevada, Utah, and Idaho.

Bureau of Reclamation (USBR). USBR is a partner with NWRC on application of physics-based *iSnobal* model to understand how climate warming has and will impact water supply forecasts from the region. NWRC is working directly with operational forecasters to provide products and tools that can be used for this purpose. Regional instrumentation and monitoring will be evaluated, and either improved or augmented to support this joint research effort.

Natural Resources Conservation Service (NRCS). Current cooperative research with the NWRC is directed towards the development of snow modeling approaches that the agency may use for snowmelt forecasting across the western USA. NWRC participates in the SCAN program and has done fundamental research on the soil water sensors used in that program. In addition, NWRC and EOARC are participating in several major Conservation Effects Assessment Project (CEAP) activities including development and validation of the RHEM model, cold-season hydrologic model enhancement of the SWAT and AGWA models, and evaluation of prescribed-grazing, invasive plant, and rangeland seeding Conservation Practice Standards. Five scientists from the Burns and Boise-ARS units were requested to write chapters for the NRCS Rangeland Conservation Effects Assessment Project. Burns-ARS scientists have also written an NRCS guide for managing exotic annual grasses. The Burns-ARS unit is collaborating with NRCS in Arizona, Montana and the Yellowstone National Park to evaluate seed coating and agglomerations to restore degraded lands.

United States Fish and Wildlife (USFWS). The Burns-ARS has long history of partnering with the US Fish and Wildlife Refuges. The Sheldon-Hart Refuge Complex in Oregon and Nevada has partnered with the Burns-ARS to evaluate the impacts of feral horses on riparian and rangeland plant communities and to determine the impacts of burning and mowing on mountain big sagebrush communities. The Malheur National Wildlife Refuge has partnered with the Burns-ARS to investigate diversifying crested wheatgrass seedings. The partnerships with US Fish and Wildlife Refuges have provided in-kind support, funding, and land for Burns-ARS to conduct research projects. This partnership has also resulted in the Burns-ARS contributing to the management plans of the Malheur, Sheldon-Hart, and Tule Lake Refuges.

United States Geological Survey (USGS). NWRC is working on a number of cooperative projects with USGS Forest and Rangeland Ecosystem Science Center (FRESC), Land Treatment Digital Library (LTDL), Powell Center Cheatgrass Working Group, the Great Basin Landscape Conservation Cooperative (GBLCC) and the North Central Climate Science Center (NC-CSC). Cooperative projects include development of mechanistic species distribution models for annual weed distributions as they

may be affected by climate change; assessment of climatological controls of seeding success on BLM land in the Great Basin that has been disturbed by wildfire and invasive annual weeds; development of microclimatological tools for rangeland restoration applications; and testing and validation of seasonal forecasting applications for fall planting of native grass and shrub species in the Great Basin.

United States Forest Service - Rocky Mountain Research Station (USFS-RMRS). NWRC and RMRS were instrumental in development of the Great Basin Research and Management Partnership (GBRMP) which has now been formalized with an MOU to include ARS, RMRS, NRCS, USF&WS, NPS, USGS, NIFA, NASA and 6 regional university cooperators. GBRMP exists to facilitate communication and collaboration between science and management organizations to address critical issues facing the Great Basin in the areas of climate change, invasive plants, water resources, and urbanization. NWRC and RMRS have collaborated in extensive research in the areas of rangeland restoration, watershed hydrology and remote sensing, and were key participants in regional science and management programs such as SageSTEPand Bromus REEnet.

National Aeronautics and Space Administration (NASA). RCEW is a recognized NASA Calibration/Validation site and has been a site for NASA research for more than 20 years primarily related to remote sensing of soil water. RCEW has been a calibration/validation site for the AMSR project for about ten years and is currently one of the SMAP locations to be used for the upcoming launch. NWRC scientists are working with NASA scientists from JPL on the Airborne Snow Observatory program involving by-weekly LiDAR overflights combined with NWRC simulation model estimates of snow density to provide SWE volume updates to water supply forecasters in California and Colorado.

The Sagebrush Steppe Treatment Evaluation Project (SageSTEP). SageSTEP is a federally-funded research program designed to evaluate chemical, mechanical and fire treatments for control of cheatgrass and pinyon/juniper encroachment. The project includes collaborators from five universities, six federal agencies and one non-profit organization in six states. NWRC was responsible for the hydrologic component of the SageSTEP program and to develop modeling tools to assess the environmental impacts of both juniper encroachment and control treatments on Great Basin rangelands.

The Nature Conservancy (TNC). The NGBER and TNC partner to address many threats to the sagebrush steppe ecosystems. TNC has a permanent full time and a term employee at the Burns-ARS headquarters. TNC and NBGER are collaborating on improving seeding technologies, control and revegetate exotic annual grass invaded rangelands, and post-fire management to improve sagebrush habitats.

Oregon Department of Fish and Wildlife (ODFW). NGBER and ODFW have collaborated to determine rangeland management effects of wildlife habitat. ODFW have supported research conducted by NGBER to evaluate methods to improve sage-grouse habitat in crested wheatgrass seedings and improve shrub establishment.

University/ARS Cooperative Projects: **Idaho State University,** remote sensing; **University of Idaho,** hydrologic modeling, remote sensing, sensor development; **University of Syracuse**, **Utah State University** and **Boise State University**, remote sensing, hydrology, soil microbiology, grazing; **Oregon State University**, EOARC/OSU co-located, rangeland management, restoration, grazing, fire; **University of Alaska Fairbanks**, livestock distribution and grazing behavior; **Cornell University**, grazing and animal behavior; **University of Reading** (England), snow hydrology; **Pennsylvania State University** and **Duke University**, hydrologic modeling and snow hydrology; **University of Texas**, bedload transport **University of California, Santa Barbara, UC Berkeley** and **UC Merced**, remote sensing, instrument development, snow hydrology; **University of California, Sierra Field Station**, grazing, riparian management, restoration; **Edinburgh University** (Scotland) snow hydrology and remote sensing; **University of Saskatchewa**n (Canada), snow hydrology; **Brigham Young University, University of Nevada**, restoration, seed coating technologies.

ARS Cooperators: **Southwest Watershed Research Center**, Tucson, AZ: development of the RHEM model, improvement and testing, including integration of NWRC *iSnobal* snow model, into large-scale CEAP assessment tools, and conducting watershed inter-comparison studies between RCEW and Walnut Gulch Experimental Watershed; **Great Basin Rangeland Research Unit**, Reno, NV: CEAP

activities related to predicting rangeland productivity in the sagebrush steppe and applications of RHEM for juniper and cheatgrass dominated ecosystems; **US Sheep Experiment Station**, Dubois, ID: grazing animal effects on water quality at stream crossings; **Forage and Range Research Laboratory** in Logan, UT: Ecologically Based Invasive Plant Management Program, evaluation and testing of alternative plant materials for rangeland restoration; **Jornada Experimental Range** in Las Cruces, NM: development of microclimatic supplements for NRCS Ecological Site Descriptions. ARS-Burns is cooperating with ARS locations in New Mexico, Mandan, Miles City, and Boise to evaluate seed coating and agglomoration technology for improving rangeland restoration success. NWRC is a principal contributor to a number of multi-location projects that take advantage of the network of ARS watershed locations including: Comparison of eddy covariance flux measurements of water vapor and CO_2 in different environments; Discovery of convergence of eco-hydrologic patterns at different watershed locations; evaluation of climate change effects on water resources; Comparison of regional variability in soil microclimate.

Outreach: EOARC and NWRC conduct extensive outreach to teachers, students, extension and management personnel. Burns-ARS and OSU co-host rangeland and beef field days to transfer technology to livestock producers and land managers. This partnership also conducts outreach projects, which include a rangeland camp for high school students, 2nd grade field trips to the EOARC, scientific discovery field trips for 5th and 6th graders, and numerous extension programs. NWRC hosts an annual "Into the Watershed" program in cooperation with the University of Idaho, which focuses on science education of high school teachers and an Owyhee Hydrology Field Camp which provides outdoor science education for rural high school students. The EBIPM program has both science and outreach/extension/demonstration elements and has held numerous workshops, field trips and demonstrations at field sites throughout the Great Basin. The annual EBIPM field school has been held in Oregon, Idaho, Nevada and Utah and over 2000 land managers have attended EBIPM workshops and presentation. The EBIPM website (www.ebipm.org) hosts a variety of management tools, user guides and videos for assistance in invasive plant management. In addition, 7000 user-support guidelines and 1500 videos for implementing EBIPM have been distributed.

SUMMARY

The Eastern Oregon Agricultural Research Center in Burns, Oregon and the Northwest Watershed Research Center in Boise, Idaho, have been conducting ecological and hydrologic research, at multiple locations within the Great Basin and Columbia plateau for over 50 years. In the last 15 years, this has included a number of significant collaborative projects between the locations. The data collected, and research conducted have contributed significantly to the management of Great Basin systems for sustainable soil, vegetation, animal and water resources. These two research units have complementary strengths in hydrology, soil science, vegetation and grazing animal management and they have historically leveraged these strengths to address cross-disciplinary issues of invasive weed management, landscape-scale ecological disturbance, climate change impacts, and agricultural and natural-resource sustainability. Both groups have developed extensive collaborative relationships with regional university, agency and non-governmental organizations and have participated in significant regional science and management initiatives related to the Intermountain western United States. The LTAR domain proposed here represents one of the largest and most imperiled ecosystems in the United States, and one that is uniformly under-represented by existing national cooperative monitoring networks. The proposed Great Basin LTAR would significantly enhance the existing LTAR network, and has generated interest and support from a broad range of educational, science and management organizations (Appendix 1).

Appendix 1: Institutional Support

ARS has operated RCEW since 1959, and USDA has conducted research at NGBER for over 70 years. The institutional commitment to these long-term research sites has paid off in numerous publications that would not have been possible without long-term records and sustained programs of both research and management. Current issues of climate change, sustainability in disturbed environments, landscape-scale management and point-to-regional scaling of science and management applications could not be addressed effectively from locations with a shorter-duration record. These long-term data, wide-spread partnerships and collaboration, and the productivity of unit scientists provide strong evidence for significant contributions from the Boise and Burns ARS units to the LTAR network.

Statement of Support from Andrew C. Hammond, USDA-ARS-PWA Area Director

From: Laird, Veronica **On Behalf Of** Hammond, Andrew
Sent: Thursday, March 21, 2013 3:42 PM
To: Pierson, Fred
Cc: Hammond, Andrew; Whalen, Maureen; PWA-Acting.AsstAD; Roman, Trish; Laird, Veronica; Svejcar, Tony
Subject: Support for Participation in Support of LTAR

Because a strength of ARS research is the ability to conduct long-term research and a core area of ARS's research mission is natural resources and environment, I support the participation of the ARS, Northwest Watershed Research Center, Boise, Idaho, and the Range and Meadow Forage Management Research Unit, Burns, Oregon, in ARS's Long-Term Agro-Ecosystem Research Network (LTAR) contingent on annual appropriations and the research priority setting process.

ANDREW C. HAMMOND
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November 11, 2011

Dr. Fred Pierson
Research Leader
USDA-ARS, Northwest Watershed Research Center
800 Park Blvd., Suite 105
Boise, ID 83712

Dear Dr. Pierson:

This letter is to express the University of Idaho's strong support for the Northwest Watershed Research Center and its proposal for inclusion in the LTAR effort of the ARS. The office in Boise has been a strong partner with the University over the past decade, especially with research efforts at Reynolds Creek in southern Idaho. Our faculty have benefited from the extensive instrumentation in the watershed and have developed complementary research efforts that we feel benefit the research for that site. Our students have benefited greatly from the expertise of the ARS scientists working there and the opportunities to develop research projects with the large amounts of data available to them. Our faculty and students also greatly benefited from the opportunities for interdisciplinary research that is critical for understanding the complexity of environmental change. Reynolds Creek is an extraordinary example of a successful, long-term, highly instrumented watershed that would be a prime site in LTAR.

Reynolds Creek also is important to the University's plan for networking research sites throughout Idaho and the region. We are developing complementary instrumentation in many of the University forest and range properties to be able to develop regional scale models and data sets that will aid management objectives. There are other ARS properties (e.g., Dubois, Kimberly) that are important to this network development as well as Forest Service research areas. Reynolds Creek clearly is the model for instrumentation and interdisciplinary research and education and we are attempting to build these same capabilities in other areas.

The University is confident that the partnership with ARS will continue to get stronger and is very interested in developing additional research and educational programs. Experience in other regions has demonstrated the high value of integrated federal and academic scientific teams and we feel that is the case at Reynolds Creek. We believe we can expand those opportunities and involvement with LTAR is a prime example of achieving that objective.

Sincerely,

John K. McIver
Vice President for Research and Economic Development

Eastern Oregon Agricultural Research Center
Oregon State University
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T 541-573-8900 | F 541-573-3042 | http://oregonstate.edu/dept/eoarc/

March 29, 2013

Dr. Tony Svejcar
Research Leader
USDA-ARS
Burns, OR 97720

RE: Support for the Long Term Agro-Ecosystem Research Network

Dear Dr. Svejcar,

This letter is in support of the effort to include ARS units in Burns and Boise into the Long Term Agro-Ecosystem Research Network (LTAR). Given our strong working relationships and shared vision, we see this effort as a potential benefit to both of our organizations. The general focus of the LTAR and the inclusion within a larger network fits well in our overall mission.

The opportunity to advance research on sustainable livestock production has been a major emphasis at Oregon State University. The LTAR would provide a major opportunity to fit that work within a larger context. Our customers are very supportive of this kind of work, and the Eastern Oregon Agricultural Research Center also provides an educational environment for students from OSU, other universities within the region, and for students from cooperating universities in Brazil.

The inclusion of our research organization within the LTAR framework holds many potential benefits and we are excited about the potential opportunities.

Sincerely,

David Bohnert
Director
Eastern Oregon Agricultural Research Center - Burns
Office Phone: 541-573-8910
Email: dave.bohnert@oregonstate.edu

United States Department of Agriculture

NRCS
Natural Resources Conservation Service
National Water & Climate Center
1201 NE Lloyd Blvd., Suite 802
Portland, OR 97232

Date: March 26, 2013

Dr. Fred Pierson
Research Leader
USDA-ARS Northwest Watershed Research Center
800 Park Blvd, Suite 105
Boise, ID 83712

Dear Dr. Pierson:

This letter is intended to provide strong support of your joint proposal with the ARS Burns location for inclusion in the ARS Long-Term Agro-ecosystem Research Network.

The NRCS National Water and Climate Center (NWCC), in Portland, Oregon, is responsible for both data collection and management for the SNOTEL and SCAN systems. We utilize these data to prepare water supply forecasts, as well as climate and drought assessments for the western US. In the western US, water is the limiting resource for agriculture, ecosystems, as well as urban and industrial development. The importance of water from western mountain snowcovers cannot be overstated, and the potential for climate warming to have a substantial impact on this critical resource should not be underestimated.

Historically the NWCC has relied upon ARS scientists from the Northwest Watershed Research Center (NWRC) and the Reynolds Creek Experimental Watershed (RCEW) facilities and data to provide a scientific foundation for our operational programs and products. NWRC scientists collaborate directly with our staff to evaluate and validate our forecasting and assessment tools. We rely upon the depth of NWRC expertise and access to RCEW facilities and data to evaluate new and innovative instrumentation and measurement approaches. These evaluations were critical to the development of the NRCS SCAN network and modernization of the SNOTEL network. Collaborations involving the development and evaluation of simulation models are particularly important. Rapidly changing climate limits the utility of statistical methods, requiring development of more robust simulation models. The future of water supply forecasts in the west will be based on collaborative efforts between ARS and NRCS to develop the next generation of simulation utilities and tools. On behalf of the NWCC I look forward to working with this group in the future and strongly support acceptance of their current proposal.

Sincerely,

MICHAEL L. STROBEL, Director
NWCC, Portland, OR

Helping People Help the Land

Mike Pellant
Great Basin Restoration Initiative Coordinator
BLM, 1387 S. Vinnell Way
Boise, ID 83709
Phone 208-373-3823 (Fax-3850)
Email "mpellant@blm.gov"

March 20, 2013,

Dr. Fred Pierson
Research Leader
USDA-ARS Northwest Watershed Research Center

Dear Dr. Pierson,

This letter is in support of your joint proposal with the ARS Burns location for inclusion in the ARS Long-Term Agro-ecosystem Research Network.

I am currently a Rangeland Ecologist and coordinator of the BLM Great Basin Restoration Initiative (GBRI). GBRI was initiated in 1999 after a disastrous wildfire season (almost 2 million acres of public lands were burned) to restore diversity and stability on degraded rangelands and woodlands. I have been active in the science and management of rangelands in the Great Basin for over 20 years and have cooperated extensively with both NWRC and the Burns research unit through both local and regional research and management initiatives such as the Sagebrush Steppe Treatment Evaluation Project (SageSTEP), the Ecologically Based Invasive Plant Management (EBIPM) program, the Great Basin Research and Management Partnership (GBRMP), Bromus REENet, the USGS Powell Center Cheatgrass Working Group, and several regional NIFA-AFRI projects.

Previous collaborations with NWRC have resulted in 38 refereed journal articles and book chapters and numerous conference proceedings concerning germination ecophysiology, seedbed microclimate, weather and climate applications for resource management, juniper ecology and management, prescribed fire, and remote sensing of rangeland plant species. The proposed Great Basin LTAR will greatly assist regional science and management programs designed to address problems with introduced annual weeds, woody plant encroachment into sagebrush/bunchgrass habitat, water resources planning and rangeland erosion.

These investigators and their large network of collaborators have a great deal of research experience in these areas of study, but also have a long history of effective collaboration and technology transfer to the management community. I look forward to working with this group in the future and strongly support acceptance of their current proposal.

Mike Pellant

Great Basin Restoration Initiative Coordinator

United States Department Agriculture | Forest Service | Rocky Mountain Research Station Albuquerque Lab | 333 Broadway SE, Suite 115 Albuquerque, NM 87102-3497 Ph: 505-724-3660

File Code: 2500/4000
Date: March 25, 2013

Fred Pierson
Research Leader
USDA-Agricultural Research Service
Northwest Watershed Research Center
800 Park Blvd., Suite 105
Boise, ID 83712

Dear Dr. Pierson:

This letter is to express the USDA Forest Service Rocky Mountain Research Station's (RMRS) strong support for the Great Basin Floristic Province LTAR proposal submitted by the Northwest Watershed Research Center and Eastern Oregon Agricultural Research Center. The ARS office in Boise has been a partner with several RMRS scientists. I lead a Grassland, Shrubland and Desert Ecosystems Science Program (GSD) with researchers located in Boise, Moscow, Reno and Provo who specialize in restoration, seed ecology, invasive species, and nursery science. I believe LTAR status will enhance our respective ability to provide better opportunities for both continued and new collaboration, particularly in the research areas of native plants materials development, hydrology, soil science, climate change, and networked long-term research.

Current collaboration with RMRS includes hydrologic research with scientists at our Boise Aquatics Sciences Laboratory; Remote sensing and soil erosion modeling research with scientists in our Moscow Forestry Sciences Laboratory; Rangeland restoration research with GSD scientists, Nancy Shaw in Boise and Jeanne Chambers in Reno; and across the board collaboration with RMRS as part of SageSTEP; the Great Basin Research and Management Partnership (GBRMP); and the Great Basin Consortium. We are hoping that LTAR status will increase collaboration given that LTARs are identified as research locations that are open and available to leverage long-term databases and infrastructure. RMRS experimental ranges and forests in Utah and Idaho may also be valuable contributions toward future networking with this proposed LTAR.

As the incoming executive committee chair for the GBRMP, I view this proposed LTAR as an opportunity to increase Great Basin partnerships in research and science delivery. I believe the future of USDA research, particularly in the current budget environment, depends on innovative cross-agency partnerships, sharing of resources, and integrated science for getting critical work done. We need to work together to meet requests from customers who have increasingly complex problems needing research solutions. Please support this proposal.

Sincerely,

Deborah M. Finch
Science Program Manager

The Nature Conservancy
Protecting nature. Preserving life.™

The Nature Conservancy in Oregon
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Bend, OR 97702

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nature.org

March 29, 2013

Dr. Tony Svejcar
USDA-ARS-EOARC
67826-A, HWY 205
Burns, OR 97720

Dr. Svejcar,

I am writing in support of the Great Basin Floristic Province - Long Term Agro-Ecosystem Research Network (LTAR).

The Nature Conservancy is a non-profit conservation organization whose mission is to conserve the lands and waters on which all life depends to leave a sustainable world for future generations. Maintenance of healthy ecosystems and restoration of degraded habitats is central to our mission. Challenges posed by urbanization, changing technology and land use, climate change, limited water resources, altered fire regimes and invasive species are significant barriers to achieving our mission and we recognize that they severely hinder the ability of rangelands to provide ecosystem services, and sustain agricultural economies.

The Nature Conservancy is working with many rangeland stakeholders to address conservation priorities and ecosystem threats in Oregon and other western states. These collaborative efforts extend from local cooperative weed management to statewide planning and project implementation on both public and private lands. We have been privileged to work with USDA-ARS scientists on a variety of cooperative projects and consider the research and monitoring they conduct to inform adaptive management to be crucial in resolving the complex challenges facing Great Basin ecosystems. The opportunity to establish an LTAR network site in the intermountain sagebrush-steppe offers potential for a much needed investment in research infrastructure. This need is recognized across interest groups and issues. A very timely example can be found in the final USFWS Conservation Objectives Team report recommending research priorities for the Greater sage-grouse. (http://www.fws.gov/nevada/highlights/news_releases/2013/032513_cot_nr.pdf)

While many stakeholders do recognize the need for expanded research investments, very few entities have the ability to conduct or coordinate research efforts and findings. The Nature Conservancy strongly supports including the Burns/Boise ARS units in the LTAR and stands ready to collaborate with the network.

Sincerely,

Garth Fuller
Eastern Oregon Conservation Director
The Nature Conservancy

UNIVERSITY OF SASKATCHEWAN
Global Institute for Water Security

Global Institute for Water Security
National Hydrology Research Centre
11 Innovation Boulevard
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March 27, 2013

Dr. Fred Pierson
Research Leader
USDA-ARS Northwest Watershed Research Center

Dear Dr. Pierson,

I am pleased to provide my strong support for your joint proposal with the ARS Burns location for inclusion in the ARS Long-Term Agro-ecosystem Research Network.

The Global Institute for Water Security (GIWS), University of Saskatchewan, was created to provide the organizational structure through which the Canada Excellence Research Chair (CERC) in Water Security can realize its stated goals, and is funded by a federal-provincial-university partnership with base funding of $30 M over seven years. The GIWS primarily has four research theme areas, namely Climate Change and Water Security, Land Water Management and Environmental Change, Sustainable Development of Natural Resources and Socio-hydrology (http://www.usask.ca/water), and a key focus is on the Saskatchewan River Basin (SRB), which is located in one of the most extreme and variable climates of the world. The basin is a critically-important water resource for the Prairie Provinces of Canada, includes regionally and globally-important biomes, and represents many of the major challenges faced by water resources world-wide. The Global Energy and Water Exchanges (GEWEX) initiative of the World Climate Research Program has now approved the SRB Project, developed by the GIWS with its national and international research partners, as an initiating Regional Hydroclimate Project (RHP), one of ten regional GEWEX projects in the world and currently the only one of its kind in North America.

University of Saskatchewan faculty have been actively collaborating with ARS scientists from the Northwest Watershed Research Center (NWRC) and working at the Reynolds Creek Experimental Watershed for over a decade. Collaborations have involved remote sensing validation efforts as part of the NASA CLPX, comparative analysis of Canadian and US sites through the North American GEWEX program, and development of measurement technologies and process-based simulation models through the US NSF WATERS program. These collaborative efforts have evolved from informal meetings at workshops and symposia a decade ago to the present extensive cross-border exchanges of students, postgraduate scientists, and principal faculty. This has thus far resulted in more than a dozen advanced degrees (combined US and Canadian), more than 30 jointly authored peer reviewed journal publications, and an extensive exchange of

measurement techniques, instrumentation technology, and simulation models. Working together across an international border has provided insight to conditions along the entire North American Cordillera from the Mexican border to the Arctic under rapidly warming climate conditions. This has not only benefited everyone involved professionally, but has resulted in real advances to mountain and cold regions natural resources and hydrologic science.

In an effort to better understand how a warmer climate is likely to impact ecosystems and water resources in western Canada, the GIWS is currently leading the Changing Cold Region Network (CCRN) funded by the Natural Science and Engineering Research Council (NSERC) through their Climate Change and Atmospheric Research program to integrate climate and land-surface process observations and modeling in the region of the Saskatchewan and the MacKenzie River basins. The network consists of 36 leading researchers from Canada and 15 international scientists, including USDA researchers. Unofficially, the CCRN includes the Reynolds Creek Experimental Watershed as a key US component. We see great potential for collaboration in the diagnosis, modelling and prediction of environmental change and in large regional scale analysis. Hence we would very much like to formalize this connection and hope that inclusion of RCEW in the USDA LTAR network will facilitate this. It is clear that climate-driven changes that are occurring in RCEW are an early warning to what we may expect in Canada.

On behalf of the GIWS, the University of Saskatchewan, and CCRN, I look forward to working with ARS scientists from NWRC in the future and strongly support acceptance of their current proposal.

Professor Howard Wheater, FREng
Canada Excellence Research Chair in Water Security
Director, Global Institute for Water Security

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, CA 94035-1000

Reply to Attn of: SGE/239-15

TO: Fred Pierson

FROM: David Bubenheim, Ph.D., Biospheric Science Branch

SUBJECT: Long-Term Agro-ecosystem Research (LTAR) Network Proposal

I would like to express my support for your proposal to become part of the Long-Term Agro-ecosystem Research (LTAR) Network. The teaming of ARS Burns and ARS Boise provides unique access to quantitative watershed data and expertise regarding an area of the country not well represented on a regional scale.

You know that I have been working with the USDA-ARS and USDA-NRCS regarding science issues in the Great Basin, particularly at the landscape scale. Establishment of the LTAR presence would significantly strengthen the science infrastructure of the Great Basin. As the NASA representative to the Great Basin Research and Management Partnership (GBRMP) organization I recognize the distinct contributions to be made to the Great Basin as well as broader relevance to ecosystem research.

The limited focus on Great Basin issues and the potential scientific benefits of enhanced research efforts has been a topic of discussion within NASA. The LTAR you are proposing would provide a solid partner for focused studies in the area. I am excited by the possibilities and assure you that I personally would be enthusiast to collaborate.

Sincerely,

David Bubenheim

Great Basin LCC
LANDSCAPE CONSERVATION COOPERATIVE

March 29, 2013

Fred Pierson
Research Leader
USDA-Agricultural Research Service
Northwest Watershed Research Center
800 Park Blvd., Suite 105
Boise, ID 83712

Dear Mr. Pierson,

This letter is to support the proposal for a Great Basin Floristic Province – Long Term Agro-Ecosystem Research Network. The mission of the great Basin Landscape Conservation Cooperative (GB LCC) is to enhance the understanding of the effects of changing climate and other natural and human impacts across the region and to promote the coordination of science-based actions to enable human and natural communities to respond and adapt to those conditions. Based on surveys in our Great Basin Climate Forums, we know that a majority of resource managers in the Basin use weather and climate data in their decision-making on a weekly or bi-weekly basis. Establishing an LTAR network in the Great Basin would allow us to better inform resource managers and agribusiness about changing climate, likely changes in drought frequency and in general, better inform their decision-making. As the Science Coordinator for the GB LCC I currently interact with investigators from both the EOARC and the NWRC programs. I am a member of the Great Basin Research and Management Program Board and on the Northwest and Southwest Climate Science Center Science review Teams; all of which would be stakeholders for, and engaged in collaborations with, the proposed LTAR. On behalf of the Great Basin LCC I strongly support this proposal.

Sincerely,

Todd E. Hopkins

Todd E. Hopkins, Ph.D.
Science Coordinator
Great Basin Landscape Conservation Cooperative
1340 Financial Blvd, Reno, NV 89502

University of Nevada, Reno

March 21, 2013

Dr. Fred Pierson, Research Leader
USDA-Agricultural Research Service
Northwest Watershed Research Center
800 Park Blvd., Suite 105
Boise, ID 83712

Dear Dr. Pierson:

I am writing on behalf of the University of Nevada, Reno, to express our support of the proposal by the Northwest Watershed Research Center and Eastern Oregon Agricultural Research Center to include their Great Basin programs within the Long Term Agro-Ecosystem Research Network supported by ARS.

In my capacity as Director of UNR's Academy for the Environment, Director of the Great Basin Cooperative Ecosystem Studies Unit, and Executive Committee member of the Great Basin Research and Management Partnership, I have had many interactions with the people and programs supported by ARS. Through these interactions, I have come to greatly respect the programs supported by these two research centers and find their proposal very compelling.

The Great Basin faces many serious resource management challenges that can only be met successfully through multi-institutional, cooperative research and management programs. Unfortunately, support for the development of needed research and infrastructure has lagged behind these significant needs. The establishment of a Great Basin-focused LTAR would be a significant step towards the enhancement of our collective research capacity in this rapidly developing, but fragile, ecoregion of our country.

As Director of the Great Basin CESU, I work with our federal (including ARS) and non-federal partners to meet the following objectives:

- Provide research, technical assistance and education to federal land management, environmental and research agencies and their potential partners;
- Develop a program of research, technical assistance and education that involves the biological, physical, social, and cultural sciences needed to address resources issues and interdisciplinary problem-solving at multiple scales and in an ecosystem context at the local, regional and national level; and
- Place special emphasis on the working collaboration among federal agencies and universities and their related partner institutions.

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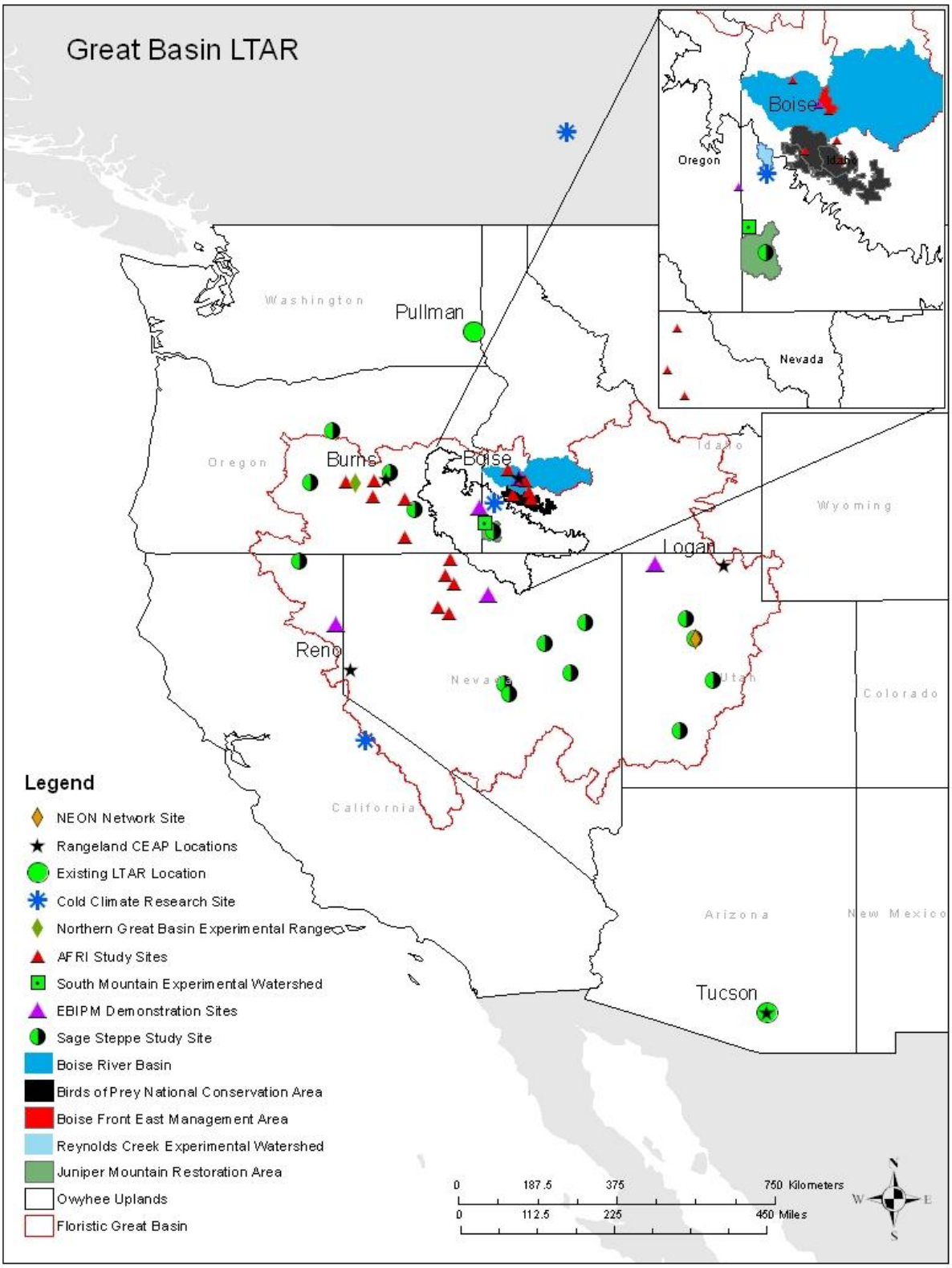
My experiences working with researchers involved with SageSTEP, Nevada's NSF-EPSCoR Climate Change Program and the GB-RMP have convinced me that cooperative, long-term research programs are needed to successfully address the enormous issues we face in the Great Basin. I believe the establishment of a Great Basin LTAR, would make a significant and immediate contribution to the management of the imperiled ecosystems in the Great Basin.

I am fully supportive of this initiative and hope that ARS supports their application to join the LTAR. Terrific opportunities for innovative, collaborative programs are emerging and this effort would be well positioned to lead the way on many critical issues.

Sincerely,

Michael W. Collopy
Assistant Vice President for Research

Appendix 2 - Great Basin Floristic Province LTAR map



Appendix 3
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