Partnerships are Key for a Decade of Stream Restoration on the Tongass National Forest

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In 2007 the Tongass National Forest completed a watershed restoration project on Sal Creek, a little-known stream on northeast Prince of Wales Island. Project planning had been in the works for several years, and the type of work that occurred was not unusual as far as watershed restoration projects go. What was unusual at the time was that the Forest Service did not do the work alone. Instead, the Forest and conservation groups collaborated on what would become the first of many public/partner restoration projects on the Tongass over the next decade. This collaboration would eventually lead to partners becoming more involved and having a greater voice in the management of the nation’s largest National Forest.

The Tongass National Forest is known for its towering old-growth forest and diverse wildlife. In addition to the Fish and Wildlife program, the Forest Service also manages a number of programs aimed at protecting and preserving these natural resources.

Figure 1: An excavator removes a 40 year old log culvert on an abandoned logging road in the Sal Creek watershed (2007).
forests, annual rainfall that can exceed 200 inches, and abundant wild salmon runs that number into the tens of millions. At nearly 17 million acres (similar in size to West Virginia), the Tongass is our largest National Forest. The Tongass comprises the vast majority of the southeast Alaska panhandle and surrounds virtually every community with federal public lands. With a history steeped in Native Alaska Tlingit, Haida, and Tsimshian cultures, a post-War timber boom that dominated the region for decades, a vibrant commercial fishing and processing industry, and an outfitter and guide industry growing in prominence, local residents and communities share a deep connection to the forests, streams, and oceans that surround them.

But the Tongass is also known for a complicated history involving timber harvest and its effects on salmon. From the 1950’s to the 1990’s old growth timber harvest, made possible by several long-term contracts between the U.S. Forest Service and local pulp mills, was the region’s predominant economic driver. At the time, logging practices did not provide the protections for salmon or their habitat as they do today, and many watersheds were dramatically changed as managers sought to fulfill the timber contracts. Needless to say, many watersheds were left with lingering problems.

However, in spite of the problems in some locations, the majority of watersheds on the Tongass are largely intact and produce millions of wild salmon that return to southeast Alaska every year to spawn and rear in thousands of miles of streams. Salmon provides important income, directly accounting for about 1 in every 10 jobs and $1 billion in annual economic activity in southeast Alaska. For others, wild salmon are an important food source where alternative protein can be expensive or unavailable. But for most everyone in the region, salmon are integral to their culture and way of life; it’s safe to say that virtually everyone in southeast Alaska can relate some aspect of their life to salmon (Figure 2).

Sal Creek

Sal Creek is not an especially unique watershed by southeast Alaska standards. With about 3 of its 8 miles of perennial stream containing salmon, and draining 4,500 acres, its only development includes a few miles of logging road and decades-old clear-cuts. Logging in Sal Creek ended in 1972 and used most of the traditional harvest methods of the time. To expedite the logging, roads were constructed on its floodplain, crossing many tributaries (Figure 1). Its massive spruce and hemlock trees were pulled across the stream or down from the hillsides creating paths of soil disturbance and erosion that facilitated the rapid growth of red alder (*Alnus rubra*; Figure 3, Figure 7) rather than slower growing conifer. And many of the naturally occurring logjams and other wood features that shaped the stream and made it so productive for salmon were removed to expedite the harvest and, reflecting thinking of the time, to improve fish passage. In the ensuing decades, the logging roads became overgrown with small trees, and culverts and bridges became plugged with debris, potentially blocking salmon migration to upstream spawning and rearing areas. It would be generations before large trees naturally fell into the stream to create salmon habitat—managers realized that Sal Creek could benefit from accelerated recovery with restoration.

In 2004, the Tongass began an effort to identify watersheds with streams affected by historic logging practices. The Cobble Landscape Assessment, as it became known, inventoried every conceivable forest management issue covering 20 distinct watersheds across some 18,000 acres of northeast Prince of Wales Island. Recognizing the backlog of impairments and the significant opportunity to improve salmon habitat health and function, watershed restoration quickly became a primary focus in the project area. Wildlife habitat,
sedimentation and erosion, landslides, future timber harvest, and recreation also became part of the conversation and National Forest staff identified droves of secondary projects that could benefit forest resources and the people that use them.

As the focus on Sal Creek began to take shape, biologists, silviculturists, engineers, and foresters descended on its streams, forests, and roads to evaluate improvement potential. Culverts and road surfaces were evaluated for fish passage and chronic erosion problems. Riparian forests dense with red alder were surveyed for their potential to be converted back to conifer. In Sal Creek, numerous surveys were completed to determine the extent and rate of channel instability and movement. Habitat surveys developed for southeast Alaska by research scientists at the U.S. Forest Service’s Pacific Northwest Research Station showed where salmon habitat was degraded and where logjams and large trees would be most beneficial. Finally, the abundance and relative fitness of its juvenile salmonid population was measured with crews of local students and members of the Youth Conservation Corps with the goal of evaluating the effects of restoration projects on the salmon (Figure 4).

Managers soon recognized that Sal Creek’s salmon habitat would not improve, and may actually continue to decline, without the addition of trees and wood to the channels and floodplains. They also knew this would be a larger than normal project and require expertise and funding not available locally. As plans to reconstruct sections of Sal Creek using engineered logjams were being developed, organizations outside the agency were paying close attention and were excited to lend a hand. In 2005 The Nature Conservancy contacted the Forest and expressed interest in assisting with the project. Soon after (in 2006) The Nature Conservancy and the Tongass established the first of many public-private partnerships to restore salmon habitat and watershed conditions. The following year Trout Unlimited, with funding of its own, awarded a contract to a local restoration contractor to complete the work at Sal Creek. This process initiated a model that gave non-governmental organizations the ability to perform work on public lands which would be followed several more times across the Tongass.

From 2006 to 2007, nearly 400 whole trees were placed in Sal Creek creating dozens of distinct logjams over nearly 3 miles of stream (Figure 5). Over 2 miles of abandoned logging roads and some 28 culverts and bridges were obliterated to reconnect salmon to tributary streams. Additionally, over 350 acres of riparian and upland forest were treated with pre-commercial thinning techniques to enhance the growth of conifer trees near the stream and improve wildlife habitat.

Over the two years partners leveraged nearly $300,000 and pioneered new ways to accomplish work. Soon after the success of Sal Creek, local and national organizations, including The Wilderness Society, Audubon and
the Sitka Conservation Society, started voicing support for this new way of project planning and implementation. Perhaps more importantly, this process illustrated that managers could accomplish more with limited public resources by collaborating with partners in on-the-ground projects instead of making decisions and implementing projects alone. The Sal Creek restoration project paved the way for collaborative, partnership-based projects on the Tongass, and many more projects like it would soon become a reality.

Ten Years Later and the Era of Partnerships

Since Sal Creek, the Tongass and its partners have completed 22 restoration projects in 11 watersheds in much the same fashion (Figure 6), and another 27 projects were completed by the Forest Service on their own. The Nature Conservancy helped complete projects in the Harris, Twelve-Mile, Dog Salmon, Staney and Snipe Creek watersheds on Prince of Wales Island, and the Saginaw, Kadake, and Shelikof Creek projects on other islands. Trout Unlimited helped complete work on the Sitkoh River on Chichagof Island and on Starrigavan Creek on Baranof Island. Funding has come largely through partners via the National Forest Foundation, National Fish and Wildlife Foundation, Alaska Sustainable Salmon Fund, NOAA’s Pacific Salmon Recovery Fund, as well as the Forest Service and other federal sources. Many of the projects have also gained national attention with Harris River being awarded the U.S. Forest Service’s

Figure 5: A restoration site on Sal Creek before the project in 2006 (left), and after in 2009 (right). Note the same red alder tree located right of center in both photos.

Figure 6: Locations of stream restoration projects implemented in the last decade on the Tongass National Forest.
Rise to the Future award in 2012, and both the Twelvemile and Shelikof Creek Projects being named as “Waters to Watch” by the National Fish Habitat Partnership in 2014, and 2017, respectively.

Today, the Tongass continues to collaborate with its partners on a variety of projects, including a robust Forest-wide restoration monitoring project, social media campaigns, and working more closely with local and tribal organizations. These initial projects, however, helped solidify valuable partnerships between local managers and the conservation groups charged with protecting and conserving salmon and the streams that support them, as well as local businesses and individual stakeholders that rely on Tongass fisheries. Partners and interested members of the public now sit on Forest planning committees or represent their particular interests in collaborative meetings. For example, the Tongass’ newest Forest Plan, which is based on the unanimous recommendations of a Federal Advisory Committee comprised of a diverse group of southeast Alaskans, included specific new conservation provisions for high-value fisheries watersheds identified by Trout Unlimited as the Tongass-77, as well as conservation priority areas identified by The Nature Conservancy and the Audubon Society. And while challenges remain, as they inevitably will for land managers overseeing an area as large and diverse as the Tongass, the Sal Creek restoration project and those like it remain a model for how land managers and the public can work together to improve National Forest System lands and their resources far into the future.

**Additional Information**

**Harris River Restoration:**
- Forest Service
- Nature Conservancy
- Trout Unlimited

**Sitkoh River Restoration**

**Shelikof Creek Restoration**

**Twelvemile Creek Restoration**

**Gandláay Háanaa Restoration**

**Other Restorations**

**Management Implications**

- Partner collaboration takes time to develop and requires frequent and effective communication at all levels, between and among all parties.
- Partners can leverage funding and other limited resources, communicate the progress or success of projects, and be a vital link to stakeholders of public land resources.
- Planning projects at larger landscape scales allows more thorough integration between different types of projects (i.e. recreation, wildlife, etc), and may be better able to capture the needs of resources that move between boundaries, such as salmon and wildlife.
- A robust monitoring plan is important for evaluating both the results of individual projects, as well as how well restoration programs and partner collaborations are working. Such a program also provides a means of communicating with partners, managers, and stakeholders.

**Figure 7:** Aerial imagery of the Sal Creek restoration project reach (phase 1), in 1971 (immediately after harvest) and in the spring of 2004. Note the red alder, a deciduous tree, along the stream in 2004 before leaf emergence.
Direct technical assistance from applied scientists at the National Stream and Aquatic Ecology Center is available to help Forest Service field practitioners with managing and restoring streams and riparian corridors. The technical expertise of the Center includes hydrology, fluvial geomorphology, riparian plant ecology, aquatic ecology, climatology, and engineering. If you would like to discuss a specific stream-related resource problem and (if needed) arrange a field visit, please contact a scientist at the Center or David Levinson, the NSAEC program manager.

Roughness in channels and floodplains is a fundamental characteristic of stream corridors, with increased flow resistance due to heterogeneity positively associated with ecological health. A spreadsheet tool for resistance coefficient selection in natural channels has been updated by the National Stream and Aquatic Ecology Center. This tool assists practitioners with selecting flow resistance coefficients for stream channels. Such coefficients are needed to quantify roughness for hydraulic modeling, stream assessments, stream restoration design, geomorphic analyses, and ecological studies. This Excel spreadsheet is available for download from the Center’s tools webpage, with documentation provided in technical summary report TS-103.1.

The National Riparian Core Protocol: A Riparian Vegetation Monitoring Protocol for Wadeable Streams of the Conterminous United States, has been published and is available as a General Technical Report through Treesearch. This effort, developed with the leadership of the National Stream and Aquatic Ecology Center, provides “guidance on sampling riparian vegetation and guidance on sampling riparian vegetation and physical characteristics along wadeable stream channels and their associated floodplains and valley bottoms.”

Abstract: Riparian areas are hotspots of biological diversity that may serve as high quality habitat for fish and wildlife. The National Riparian Core Protocol (NRCP) provides tools and methods to assist natural resource professionals in sampling riparian vegetation and physical characteristics along wadeable streams. Guidance is provided for collecting basic information on riparian vegetation composition and physical structure in fluvial riparian ecosystems. The NRCP provides a foundation to assess the characteristics and condition of channels and riparian vegetation at a single point in time or in response to changes in land- and water-use activities, including restoration, or natural processes through time.
Decommissioning Unpaved Forest Roads: Alternatives and Effectiveness

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Increased runoff, sediment production and sediment delivery from unpaved roads are a major concern for National Forests. Key issues are the large number of such roads, their substantial impacts on runoff and erosion, and limited funds for maintenance. Unpaved roads typically have infiltration rates of less than 5 mm/hr, so even low or moderate intensity rainstorms can generate Horton (infiltration-excess) overland flow (Figure 8; Ramos-Scharrón and LeFevor 2016). The low infiltration rates and lack of surface cover make unpaved roads highly susceptible to surface erosion by rainsplash, sheetwash, and rilling or gullying. In hilly areas road cut-slopes can further increase runoff by intercepting subsurface flow and converting this to road surface runoff (Wemple and Jones, 2003), which further increases road surface erosion. The concentrated runoff from roads is a particular concern when the runoff and sediment are delivered to a stream, wetland, or lake, with potential adverse effects on water quality and aquatic habitat. Stream crossings also can be a major source of sediment if a culvert fails by plugging or excessive runoff, which results in erosion of the stream crossing, potential diversion of the stream down the road, and/or the creation of rills and gullies as the diverted water flows back to the stream. Roads are also a major cause of landslides in sloping terrain due to the increase in pore pressures from road surface runoff, reduction in hillslope strength due to the cut-slope, and increased loading due to the fill-slope (Ochiai and Sidle, 2006).

In many National Forests there are numerous legacy roads that are no longer needed and may be adversely affecting other resources, such as wildlife and ecosystem services. Road decommissioning is a common tool to reduce or eliminate the adverse effects of roads. Decommissioning techniques range from simply closing a road to traffic to complete removal by ripping, re-contouring, and revegetating (Switalski et al., 2004; Weaver et al., 2015). In addition to treating the road surface it is critical to remove culverts and associated road fills to prevent crossing failures. An intermediate approach is to rip the roadbed with a bulldozer or other machines to reduce surface compaction and increase infiltration (Luce, 1997; Weaver et al., 2015).

This article summarizes current information on the short- and long-term effects of three decommissioning treatments on infiltration, road surface erosion, and road-stream connectivity. We draw upon our recent research in the Arapaho-Roosevelt National Forest where we conducted plot-scale rainfall simulations, measured segment-scale sediment production using sediment fences, and conducted pre- and post-treatment surveys of 12 km of unpaved roads that were decommissioned in early fall 2013. To maximize utility we also present results from other studies and take a process-based approach to help the reader adapt the information to their specific conditions. The three treatments discussed here include road closures, ripping, and ripping plus mulching.

Figure 8: Overland flow on the road surface due to a low infiltration rate. Road runoff also can be enhanced by the exfiltration of water from a cut-slope. Note the small fill-slope failure caused by the road surface runoff and the suggestion of older cut-slope failures on the left-hand side of the picture. Photo courtesy of Drew Coe.
Effectiveness of Road Closure, Ripping, and Ripping plus Mulching

Road Closure
Road closure is the simplest and least costly decommissioning technique, but how much and how quickly does closing an unpaved road reduce surface runoff and erosion? A study in Idaho showed that the saturated hydraulic conductivity of an abandoned road after 30 years with no traffic was still only 7-28 mm (0.3-1.1 inches) per hour (Foltz et al., 2009), which is much lower than the typical value of 40-80 mm/hr for an undisturbed forest. Our rainfall simulation experiments on 1 m² plots showed that the infiltration rate for roads closed to traffic for at least 25 years rapidly declined to only 5 mm/hr (Figure 9; Sosa-Pérez and MacDonald, 2017a). Higher infiltration rates could be expected where there is more rapid vegetative regrowth, as root growth and increased biological activity will help reduce soil compaction. However, in peninsular Malaysia a logging road that had been abandoned for 40 years still had a saturated hydraulic conductivity that was only 9% of the value from adjacent hillslopes (Ziegler et al., 2007).

While road closure does not rapidly restore infiltration rates, closure is relatively effective at reducing road surface erosion. Rainfall simulations on an abandoned road in Idaho with 98% ground cover yielded a mean sediment concentration that was only 14% of the value from a similar road that had been subjected to logging traffic two years earlier (Foltz et al., 2009). At the road segment scale median sediment production rates from unpaved roads with no traffic were 6-10 times lower than segments with either low or high traffic (Sosa-Pérez and MacDonald, 2017b).

Figure 9: Mean infiltration rates over time for closed roads, closed roads with 80 passes of an OHV, ripped roads, and ripped roads with mulch (n=4 for each treatment). Rainfall was applied on 1 m² plots for 45 minutes at 45 mm (1.8 inches) per hour (modified from Sosa-Pérez and MacDonald, 2017a).

There are two main reasons for the much lower sediment production from abandoned or closed roads. First, the surface cover shifts from bare soil (and rocks) to litter and live vegetation. This cover will largely eliminate rainsplash, which is a dominant source of sediment on unpaved roads (Ziegler et al., 2000). Any surface cover also helps slow overland flow, which will reduce particle detachment and sediment transport capacity. The amount of surface cover is arguably the predominant control on surface erosion at the hillslope scale (Larsen et al., 2009; Robichaud et al., 2013). Second, the elimination of traffic greatly reduces the supply of readily-erodible fine sediment because it eliminates the crushing of larger particles by passing vehicles. The passage of vehicles also can pump the finer particles to the surface where they can be more readily eroded by rainsplash and sheetwash (Reid and Dunne, 1984). Our rainfall simulations showed that just 80 passes of an OHV caused a three-fold increase in sediment production (Sosa-Pérez and MacDonald, 2017a).

Ripping
Ripping is the breaking of the road surface by pulling metal tines through the soil with a bulldozer (Figure 10; Luce, 1997; Weaver et al., 2015). Typically there are three vertical tines spaced about 0.7 m (30 inches) apart, and this creates a furrow and ridge topography (Figure 11) without turning over the soil. In some cases the tines have a lateral “wing” at the end to help break up the subsurface compaction. Our data show that ripping can slightly increase the amount of bare soil (Figure 11a, b).

The effectiveness of ripping is controversial in terms of its persistence and the extent to which it may channel surface runoff to create rills or gullies. In Idaho ripping initially decreased the bulk density to 1.50 Mg/m³ and increased the hydraulic conductivity from 8 to 30 mm/hr, but after 90 mm of simulated rainfall the bulk density increased back up to 1.70 Mg/m³ and the hydraulic conductivity dropped by half to 15 mm/hr (Luce, 1997). On the Payette National Forest the surface cover was only...
8-27% three years after ripping and the saturated hydraulic conductivity was only 9 mm/hr (Foltz et al., 2007). We also found that infiltration rates on ripped roads dropped to less than 10 mm/hr after about 30 minutes of simulated rainfall (Figure 9; Sosa-Pérez and MacDonald, 2017a), with more infiltration in the furrows. In our rainfall simulations mean sediment production from the

Figure 10: A bulldozer with three winged metal tines used for ripping skid trails (left). A close up of a winged tine (right); for scale the black and white squares are 2 x 2 cm. Photos courtesy of Will Olson.

Figure 11: Typical road segments one year after decommissioning. a) Segment with 4% slope that was only ripped. The road surface shows evidence of erosion, but all of the eroded sediment was trapped in the furrows created by the ripping. b) Segment with 9% slope that was only ripped, showing much more eroded, transported, and deposited sediment. c) and d) Road segments that were ripped and mulched showing much less erosion due to the combination of the mulch, greater vegetative regrowth, and greater wood cover compared to the segments that had only been ripped.
ripped plots was 72 g/m², and this was 40% higher than the closed roads (Figure 12). Since sediment production did not decline over time and was strongly correlated to runoff (R²=0.67, p<0.0001), we infer that sediment production from the ripped plots was not supply limited (unlike the closed roads) (Sosa-Pérez and MacDonald, 2017a). At the road segment scale we found that only three of the 19 ripped segments generated measurable amounts of sediment, and each of these segments were exceptionally long and/or steep (Sosa-Pérez and MacDonald, 2017b). Our road survey showed that most segments had some evidence of surface erosion after ripping—especially the steeper segments—although most of the runoff and sediment was trapped in the furrows (Figure 11a, b).

### Ripping plus Mulching

There are fewer studies and relevant field data on the effectiveness of ripping plus mulching for road decommissioning. Our study showed that after nearly a year and an exceptionally large storm the mulched segments averaged less than just 30% bare soil, and this was significantly less than the segments that had only been ripped (Figure 11a and b, versus c and d; Sosa-Pérez and MacDonald, 2017b). In our rainfall simulations mulching significantly increased infiltration compared to just ripping, but the infiltration rate on the mulched plots continued to decline and by 45 minutes the infiltration rate was only 20 mm per hour (Figure 9; Sosa-Pérez and MacDonald, 2017a).

Mulching was much more beneficial in terms of reducing mean sediment production from 72 g/m² for the ripped plots to only 16 g/m². However, mean sediment production from the mulched plots did slowly increase over time, indicating a decreasing effectiveness of mulch for reducing sediment production at the plot scale (Figure 12; Sosa-Pérez and MacDonald, 2017a). Mulch effectiveness also was evident at the road segment scale, as none of the nine ripped and mulched segments generated and delivered measurable amounts of sediment to the sediment fences.

The same general results and principles for road decommissioning should also apply to ripping skid trails. Unpublished results indicate that rilling can develop on ripped skid trails in burned areas once slopes exceed about 5-8% (Demirtas, 2017), which is similar to the threshold where we identified extensive rilling on roads after a fire (Sosa-Pérez and MacDonald, 2016). The placement of logging slash or mulch can reduce sediment production and rilling depending on the percent surface cover, amount of ground contact, and the amount and intensity of rainfall and snowmelt.

### Road-Stream Connectivity

Prior to decommissioning our road survey documented that 55% of the 185 road segments had a sediment plume, but the mean plume length was only 13 m. These generally short plume lengths can be attributed to the low mean annual precipitation of 460 mm and the relatively gentle mean hillslope gradients of 11% (Sosa-Pérez and MacDonald, 2017b). Thirty percent of the road length was within 10 to 100 m of a stream, but only 10% of the segments (12% of the total road length) had sediment plumes that could be traced to within 5 m of a stream (“connected”).

After ripping or ripping plus mulching only 11 segments had any new deposition on a pre-existing sediment plume, but in each case the segments had been subjected to illegal OHV traffic that flattened the ridges and furrows. This reduced the on-segment storage capacity and allowed the runoff and sediment to flow off the road segment (Sosa-Pérez and MacDonald, 2017b). After decommissioning only four segments (2% of the total road length) were connected to the stream, and the mean length of the sediment plumes for these segments was only 7 m. The short plume lengths and limited connectivity indicate that the primary control on
road-stream connectivity is the proximity of a road to the stream. Overall, we found that ripping was effective in trapping much of the sediment on the road surface due to the ridge-and-furrow topography, but this trapping efficiency will most probably decrease over time depending on the amount and intensity of rainfall versus the rate of vegetative regrowth.

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References


Management Implications

- Decommissioning options range from simply closing a road and removing culverts to ripping or full eradication. Treatment choice is largely a function of objectives and cost.
- Road closure can rapidly reduce sediment production because the elimination of traffic and increase in surface cover greatly reduces the supply of readily-erodible fine sediment. In contrast, compaction and the associated low infiltration can persist for decades. Slope failures can continue to be an issue due to the persistent hydrologic effects of the road along with the instability associated with cut-slopes and fill-slopes. To be effective road closure must include the removal of culverts and road fills.
- Ripping does not fully restore the roadbed to a properly functioning hydrologic condition and increases the supply of readily erodible fine sediment. Mulching after ripping increases the infiltration rate, reduces road surface erosion, and can facilitate vegetative regrowth. Mulching is particularly beneficial on steeper segments.
- The effects of ripping and mulching on skid trails is similar to unpaved roads, but in burned areas ripping can induce rilling when off-contour gradients exceed about 5-8%.
- Ripping, or ripping and mulching, are generally effective in reducing road-stream connectivity, and most of the residual connectivity is due to road segments in close proximity to a stream.
Mid-Winter Drought Update: La Niña Impacts Snowpack Conditions Across the West

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Mid-winter snowpack across the West reflects the impacts of the current La Niña pattern on the storm track, which has shifted further north than average this winter. As shown in Figure 13, snowpack conditions across much of the Great Basin and Southwest remain well-below normal as of mid-February. Based on SNOTEL snowpack data, the region of below-normal snow water equivalent extends from Oregon through California, Nevada, most of Utah, and the Southwest. The worst snowpack conditions are currently across basins in Arizona and New Mexico, which have 10-50% of normal this winter.

Spring streamflow and runoff forecasts reflect the below-normal snowpack, with a majority of the river basins of the Great Basin and Southwest forecasted to be below 50% of the 1981-2010 average.

In contrast, there are above normal mid-winter snowpack conditions in northern Wyoming, western Montana, central and northern Idaho, and most of Washington. Snowpack >150% of median extends from greater Yellowstone northward across western Montana.

The latest U.S. Drought Monitor has Severe to Extreme drought (D2-D3) across a broad area of the central and western US; from Missouri extending westward to Nevada. Moderate to Severe drought (D1-D2) conditions are also present over southern California, and in eastern Montana and the Dakotas.

Figure 13: Snow water equivalent as a percent of median (1981-2010) for the Western U.S. Graphic courtesy of the USDA NRCS National Water and Climate Center (for the end of day 2/19/2018).