Oregon Department of Environmental Quality

Issue Paper: Proposed pH Criteria Revisions for the Crooked River and Trout Creek Subbasins, Deschutes Basin, Oregon

Aquatic Life Use Updates Rulemaking

Background

DEQ is proposing to revise the water quality criteria for pH for the Crooked River and Trout Creek subbasins of the Deschutes River basin to reflect the criteria necessary to protect the aquatic life use and to be consistent with the pH criteria for other eastern and south-central Oregon basin waters. The current pH criteria for the Deschutes basin are the same as the criteria for waters in western Oregon and the Cascade Mountains. However, these two subbasins are in the eastern portion of the Deschutes basin and have hydrologic and geologic characteristics that result in higher natural pH levels similar to other eastern Oregon waters.

The purpose of the pH criteria is to protect aquatic life from impacts that may occur if the pH of the water is too low (acidic) or too high (basic). The criteria should be accurate so that they provide an appropriate target for permit limits, TMDLs and nonpoint source pollution reduction efforts. The proposed change in the upper pH limit from 8.5 to 9.0 standard units does not mean that efforts to control nutrient inputs and reduce nuisance algal growth should be curtailed. Rather it acknowledges that daily maximum pH levels up to 9.0 are protective of aquatic life and the revision will make the criteria for these subbasins consistent with basins in eastern and south-central Oregon, including the John Day, and Grande Ronde basins, which have the same salmon, steelhead, and trout species (see Figures 1 and 2 below).

Proposed Rule Amendment

DEQ proposes to amend *OAR 340-041-0135, Basin Specific Criteria (Deschutes): Water Quality Standards for this Basin*, to revise the pH criteria for the Crooked River and Trout Creek subbasins from 6.5 – 8.5 to 6.5 – 9, as shown in Appendix 1 below. The proposed pH standard language would be consistent with the language for the John Day and Grande Ronde basins, as shown below, which includes an action level of 8.7. See also the “Options Considered” section below.

The following is the current criteria language from the John Day and Grande Ronde basins:

> (1) pH (hydrogen ion activity). pH values may not fall outside the following range: all basin streams: 6.5–9.0. When greater than 25 percent of ambient measurements taken between June and September are greater than pH 8.7, and as resources are available according to priorities set by the Department, the Department will determine whether the values higher than 8.7 are anthropogenic or natural in origin.

Justification

Consistency with Similar Adjacent Basins

The Environmental Quality Commission adopted Oregon's current pH criteria in 1996. The pH criteria vary by region, with a range of 6.5 – 8.5 in coastal and Cascade streams, and 6.5 – 9.0 or 7.0 – 9.0 in most central and eastern Oregon streams (Figure 1). The 9.0 upper end of the pH range was adopted because it protects the aquatic life use, including salmonids (see further discussion below), and because naturally higher pH levels in eastern Oregon basins can rise above 8.5[1]. The criteria range for the Deschutes River Basin is currently the same as western Oregon and the Cascades Mountains. While much of the Deschutes watershed flow does originate as runoff of the Cascade Mountains, the Crooked River and Trout Creek subbasins are groundwater dominated and originate in the more arid ecoregion east of the Deschutes River, not from the Cascade Range. The Crooked River and Trout Creek subbasins are similar in geological, hydrological, and ecological character to the adjacent John Day basin and other central and eastern Oregon streams. Therefore, it is appropriate that the Crooked River and Trout Creek subbasins have pH criteria consistent with these similar eastern and central Oregon basins.

The similarities between the Crooked River and Trout Creek watersheds and other central and eastern Oregon watersheds are highlighted by EPA's ecoregion map, which accounts for ecology, landforms, soils, vegetation, climate, land use, wildlife, and hydrology[2]. The Crooked River and Trout Creek watersheds are primarily in the John Day/Clarno Uplands Level IV ecoregion[3]. (See Figures 3 and 4.) Most of the John Day basin is also in this ecoregion.

Protection of Aquatic Life

An upper pH criterion of 9.0, which is applied as a daily maximum, is protective of salmonid fishes according to multiple sources. The proposed pH criteria of 6.5 – 9.0 protects aquatic life according to EPA's recommended water quality criteria for pH[4]. In 1999, NOAA Fisheries completed a Biological Opinion that found no jeopardy for these criteria and EPA approved the criteria for several central and eastern Oregon basins. The literature reviewed in the Biological Opinion shows that impacts to invertebrates and to salmonids begin to occur when pH rises above 9 (i.e., 9.2 to 9.8) and that impacts to fish at these levels occur when they are exposed to the high pH water for more than 24 to 72 hours[5]. Therefore, because the upper criterion of 9.0 is applied as a daily maximum, there is a built-in margin of safety.

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[1] See Chapter 2, Oregon Department of Environmental Quality. 1995. Final Issue Paper: pH, Hydrogen Ion Concentration. Portland, OR. 44 pp.
[2] Omernik, J.M. and G.E. Griffith. 2014. Ecoregions of the conterminous United States: evolution of a hierarchical spatial framework. Environmental Management 54(6):1249-1266.
[3] https://www.epa.gov/eco-research/ecoregions. Visited January 4, 2022. See https://gaftp.epa.gov/EPADataCommons/ORD/Ecoregions/reg10/pnw_map.pdf for a copy of the map and legend.
[4] Quality Criteria for Water 1986. EPA, May 1, 1986.
[5] National Marine Fisheries Service. July 7, 1999. Biological Opinion on EPA Approval of Oregon Water Quality Standards.

When DEQ revised the pH criteria for basins in central and eastern Oregon in 1996, a technical advisory committee evaluated the available scientific information and data. The Technical Advisory Committee concluded that pH levels up to 9.0 protect aquatic life and that streams in the eastern region of the state can naturally reach pH values above 8.5. They noted that waters impacted by excessive algal growth could be distinguished by pH levels that rise above 9.0 and by large diel fluctuations in pH. Therefore, the committee recommended an increase in the upper end of the pH criteria range for eastern Oregon basins to 9.0. The committee also recommended that DEQ adopt an action level of pH 8.7 to trigger an evaluation of whether the higher pH levels result from anthropogenic sources.

The scientific literature confirms that pH levels between 6.5 and 9.0 are safe for fish and other freshwater aquatic life (Robertson-Bryan, Inc., 2004; Raleigh et al., 1984, Alabaster and Lloyd, 1982). Robertson-Bryan Inc, (2004) explains that the pH of water affects the physiological functions of aquatic organisms, including the exchange of ions with the water and respiration. The authors conclude that these important physiological processes operate normally in most aquatic biota under a relatively wide pH range of approximately 6-9 pH units. They add that in most lakes and ponds, diel pH fluctuations during the summer, when photosynthetic activity peaks, are generally less than 2 pH units. Diel fluctuations are less in streams; generally, 0.5-1.0 pH units. Unless diel fluctuations result in ambient pH that falls below 6 or is elevated above 9, they generally have no adverse impact on aquatic life (Robertson-Bryan, 2004).

Raleigh et al. (USFWS, 1984) discuss many of the important attributes of trout habitat and the development of a Habitat Suitability Index model. The report discusses pH only briefly and states that the precise pH tolerance and optimal ranges are not well documented for rainbow trout. The report summarizes that most trout populations can probably tolerate a pH range of 5.5 to 9.0, with an optimal range for growth of 6.5 to 8.0 (Hartman and Gill 1968; Behnke and Zarn 1976). Hartman and Gill (1968) surveyed trout distribution and habitat characteristics in western British Columbia, including Vancouver Island. Summer pH levels in streams with steelhead and cutthroat trout are predominantly in the 7 to 8.5 range, but do rise above 8.5, even in these streams that have high precipitation and are similar to western Oregon. The paper states that stream pH values did not bear obvious relationship to differences in trout distribution in their study and that their study should not be relied upon to understand the effects of pH and other limnological features on trout. It is not clear why the Raleigh paper cites Behnke and Zarn, 1976 as it does not provide information on the effects of pH on trout. The paper evaluates management of inland western trout, including one species found in Oregon, Lahontan cutthroat trout. The paper notes that Lahontan trout can tolerate higher alkalinity than other trout, which is likely the result of adaptation to their native habitats that include high alkalinity lakes.

Alabaster and Lloyd (1982) summarize of the effects of pH on fish as shown in Table 1 below. This review paper states that there is no definite pH range within which a fishery is unharmed and outside which it is damaged, but rather there is a gradual effect on growth and survival as the pH values are further removed from the normal range. The pH range which is not directly lethal to fish is 5-9; however, the toxicity of several common pollutants is markedly affected by pH changes within this range; increasing acidity or alkalinity may make ammonia, metals, or other substances more toxic. This is typically more of a concern with increasing acidity. In some cases, such as ammonia, aluminum and copper, the pH is accounted for within DEQ's water quality criteria for those substances. These substances should be controlled such that they are not toxic within the background chemistry, including pH, of the waterbody. Relatively little is known of the effects of alkaline discharges on fisheries, which may reflect the lesser concern about this as a problem. Laboratory data show that pH values between 9 and 10 may be harmful to some species of fish, and above 10 is harmful to most species. Typically, laboratory studies are conducted at constant rather than fluctuating pH.

Several references identify that pH values above 9.0, particularly above 9.5, can result in impacts to fish. Significant response between pH 8.5-9.0, and even in the range of 9.0-9.5, occurs where there is constant exposure for >24-48 hours. However, maximum pH values of 8.5 to 9.0 in the field are a temporary diurnal maximum (Wagner et al, 1997). While eastern Oregon has natural geologic background levels that reach 8.5 or slightly higher, the higher values are influenced by productivity and are not constant. (See the discussion below for additional information.)

Table 1. Summary of the Effects of pH Values on Fish (Alabaster and Lloyd 1982, p.39)

pH Range	Effect
6.5—9.0	Harmless to fish, although the toxicity of other poisons (e.g., ammonia, aluminum) may be affected by changes within this range.
9.0—9.5	Likely to be harmful to salmonids and perch if present for a considerable length of time.
9.5—10.0	Lethal to salmonids over a prolonged period but can be withstood for short periods. May be harmful to developmental stages of some species.
10.0—10.5	Can be withstood by roach and salmonids for short periods but lethal over a prolonged period.
10.5—11.0	Rapidly lethal to salmonids. Prolonged exposure to the upper limit of this range is lethal to carp, perch, goldfish, and pike.

Wagner et al. (1997) tested stress responses to hauling and stocking of hatchery fish. They found that mortality in the field (fish stocked into cages in reservoirs) occurred at pH levels greater than 9.3-9.4 and temperatures of 19.9-22.8°C after the fish had been transported by truck for 90 minutes. Laboratory and field tests indicated that pH values greater than 9.4 resulted in mortality, especially at higher temperatures. There was a significant stress response in the hauled fish when pH was 9.0 or greater. However, this would not be synonymous with in situ exposures as they are experienced by fish in their native habitats under the proposed criteria.

Witschi and Ziebell (1979) found there were impacts when hatchery fish that were acclimated to lower pH levels were released into waters above 9. Witschi and Ziebell (1979) observed only one death among 25 rainbow trout after 24-hour exposure to pH 9.0. When the pH was increased to 9.3, swimming and appetite decreased. However, acclimation (24 h) at pH 8.0 resulted in 100% survival of rainbow trout at pH levels as high as 9.7-9.9 in 96-hour tests (Murray and Ziebell 1984). In the field in eastern Oregon, the waters tend to be more basic, not uncommonly at 8.0 (Figure 5), so fish would likely be acclimated to these background levels.

EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS), Volume 2, states that short-term exposures of fish to high pH (~9.5) are rarely lethal to most fish species. However, prolonged exposure to pH between 9.5 and 10 can damage outer surfaces such as gills, eyes, and skin. Cypriniformes (e.g., minnows) often are less sensitive to high pH than Perciformes (e.g., perch). High pH also can affect the sensory epithelium of the fish olfactory system, making it difficult for fish to detect food, sex hormones or pheromones, alarm substances from conspecifics or toxic chemicals.

Sub-lethal impacts at pH 8.5-9.0 are associated with the facilitation of toxicity in other parameters (ammonia, metals) by pH rather than the direct impacts of pH. CADDIS acknowledges that an indirect effect to consider is its interaction with ammonia. As pH increases, unionized ammonia (NH_3), which is more toxic to aquatic life than the ionized form (NH_4^+), becomes the dominant form. DEQ's water quality criteria for ammonia, copper, and aluminum account for pH when determining toxicity and therefore exceedances for those pollutants. Therefore, if ambient pH is affecting the toxicity of ammonia or aluminum, this will result in a finding of impairment for those pollutants regardless of the criterion established for pH.

Background Conditions in the Crooked River and Trout Creek Subbasins

Waters in eastern Oregon tend to be more basic than those in the western part of the state. Eastern Oregon groundwater is typically somewhat basic (pH 7-8). Some springs have pH over 8 and even over 8.5. These pH values are a function of the weathering of volcanic material[6]. Soils in the Crooked River watershed have been characterized as having high amounts of exchangeable sodium, which results in soils with higher pH levels[7]. In the lower river (i.e., below Smith Rocks State Park), data from Opal Springs and from the Crooked River above Opal Springs, but in a reach influenced by multiple springs, show pH levels of 8.1 and 8.2 in May, August, and January (USGS National Water Information System). The Upper Crooked watershed contains high levels of bentonite, which forms in alkaline conditions. Analysis of bentonite in these areas indicates high levels of exchangeable sodium[8]. pH is not expected to exceed 9.0 due to natural conditions.

If waters start with a baseline pH of 8.0 to 8.2 and have lower flows, as is the case in the upper portions of the watershed, some amount of natural productivity may cause pH to rise above 8.5 as a daily maximum. Some amount of productivity is natural and needed to produce food for fish. In addition, if streams are relatively dilute (i.e., specific conductance < 100 uS/cm) with low buffering capacity, they are more susceptible to pH fluctuations from benthic respiration and photosynthesis[9].

Indicators that pH levels can occur as the result of background conditions rather than nutrient enrichment include: 1) higher median pH levels in the winter, not just during the growing season, and 2) smaller diel fluctuations than would be expected in waters with excessive algal growth. When maximum pH is in the range of 8.5 to 9.0 and it is due to productivity, pH levels during the growing season would be expected to fluctuate and be high for part of the day, likely

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[6] Pecoraino, G., D'Alessandro, W., Inguaggiato, S. (2015). The Other Side of the Coin: Geochemistry of Alkaline Lakes in Volcanic Areas. In: Rouwet, D., Christenson, B., Tassi, F., Vandemeulebrouck, J. (eds) Volcanic Lakes, pp219-237. Advances in Volcanology. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-36833-2_9

[7] Mayko, R. W., and G. K. Smith. 1966. Soil Survey: Prineville, Oregon Area. Soil Conservation Service, in cooperation with Oregon Agricultural Experimental Station. U.S. Department of Agriculture. 1966. 95 pp.

[8] Gray, J.J., R.P. Geitgey, and G.L Baxter. 1989. Bentonite in Oregon: Occurrences, Analyses, and Economic Potential. Special Paper 20. Oregon Department of Geology and Mineral Industries. Portland, OR. 36 pp.

[9] Stumm and Morgan, 1995. Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters.

in the afternoon. Grab samples for pH were for the most part taken between 7:00 am and 4:00 pm.

Figure 5 shows that there are pH levels above 8.5 at many locations in the upper Crooked River subbasin, above the city of Prineville. Figure 6 shows a monitoring site with diel data. pH gets close to or above 8.5 before the growing season (March) with little diel variation (<0.5). Figure 7 shows that as late as mid-November, minimum daily pH measurements did not fall below 8.0 and daily maximums still rise above 8.5 in the Crooked River above Ochoco Creek and above the city of Prineville. These data indicate that in some locations, the presence of pH levels close to or above 8.5 is likely due to geologic conditions combined with some productivity.

In other areas, pH does rise above 9 and diel swings are greater. Figure 8 shows sites in the Crooked River subbasin where 25% of the pH measurements between June and September exceed 8.7, the action value. The data at these sites identify a potential a concern and should be evaluated for anthropogenic nutrient loading and excessive algal growth.

Proposed Crooked River and Trout Creek Subbasins pH Criteria

DEQ proposes that the EQC adopt pH criteria for the Crooked River and Trout Creek subbasins of the Deschutes basin of 6.5 to 9.0, including the 8.7 action level[10]. The action level triggers a review to determine whether pH values consistently measured in the higher portion of the acceptable range (i.e., 8.7 – 9.0) are being cause by anthropogenic sources. The proposed pH criterion is the same as the current criteria for several Eastern Oregon basins as is shown in Appendix 1 below.

Although EPA's recommended criteria for pH is 6.5 to 9, Oregon has a pH standard of 6.5 to 8.5 for western Oregon basins. Waters in western Oregon generally maintain lower pH levels due to the geologic and hydrologic conditions. Therefore, pH levels above 8.5 are likely to result from excessive productivity or indicate anthropogenic sources and rather than natural background conditions. However, this is not the case in eastern Oregon, where background conditions can rise above 8.5 naturally, and the presence of excessive algal growth and anthropogenic sources is more likely indicated when pH rises above 9.0 as a daily maximum or where there are larger than normal diel fluctuations in pH. In addition, the available literature on the effects of pH on salmonids shows that impacts to fish, particularly fish acclimated to their native streams, do not occur until pH rises above 9.0 to 10.0, depending on the length of time the fish are to the high pH levels. The proposed criterion would apply as a daily maximum and, therefore, the criteria would be exceeded if pH rises above 9.0 and pH would approach 9.0 for only a portion of the day during the height of the summer growing season.

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[10] See Issue Paper, page 36 (3-2).

Impact of the Rulemaking

Water quality assessment and Total Maximum Daily Load (TMDL) development

Five waters are listed as impaired for pH in the Crooked River Basin in the 2022 Integrated Report based on the current criterion of 6.5 – 8.5. No waters are impaired in the Trout Creek Basin.

Under the new criteria, waterbodies would be listed as impaired if 10% of the samples exceed a pH of 9.0. DEQ evaluated the currently available data for the Crooked River subbasin to see which sites would exceed the revised criterion. Twelve sites had at least one pH value over 9.0 and 4 sites, two of which are within the Lake Billy Chinook reservoir, had enough exceedances to be listed as impaired.

DEQ expects to develop a TMDL for the Crooked River based on these listings and other water quality parameters, including chlorophyll-a, dissolved oxygen, and phosphorus[11,12]. Low dissolved oxygen (DO) concentrations or large diel fluctuations in DO also indicate nutrient and algal growth problems. The TMDL study will likely collect more diel pH data and will also evaluate whether the pH levels that exceed the action level of 8.7 are due to excessive algal growth caused by anthropogenic nutrient loading. It is important to ensure the water quality criteria are accurate and appropriate so that the TMDL establishes appropriate instream targets and allocations for nutrients and other pollutants to meet the criteria.

There are listings for ammonia, copper, and/or aluminum in the Crooked River subbasin as well. A change to the pH criteria will not affect these listings. The applicable criteria for these metals are based on the actual ambient pH levels, not the pH criteria values.

NPDES permitting

The only NPDES permitted facility that discharges into the effected subbasins is the City of Prineville Wastewater Treatment Facility, which discharges to the Crooked River. The facility currently has permit limits for pH ranging from 6.0 to 9.0.

Nonpoint source activities

The control of nutrient loading from nonpoint sources occurs by implementing best management practices. The revision of the pH criterion does not lessen the importance of reducing nutrient loading to prevent excessive algal growth from anthropogenic nutrient enrichment. This will remain important to protect and improve water quality at the site of the activity as well as to prevent nutrient loading to waters downstream.

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[11] State of Oregon Department of Environmental Quality TMDL Submission Schedule August 2022 Contact: Ryan Michie or Alex Liverman 700 NE Multnomah St, Suite 600 Portland, OR 97232

[12] Lower Deschutes, Crooked, Beaver - South Fork, and Trout Subbasins 17070303 - Beaver - South Fork Subbasin 17070304 - Upper Crooked Subbasin 17070305 - Lower Crooked Subbasin 17070306 - Lower Deschutes Subbasin 17070307 - Trout Subbasin Chlorophyll-a, Dissolved Oxygen, E. coli, Harmful Algal Blooms, pH, Phosphorus, Temperature Submitted by April 2030.

Figures

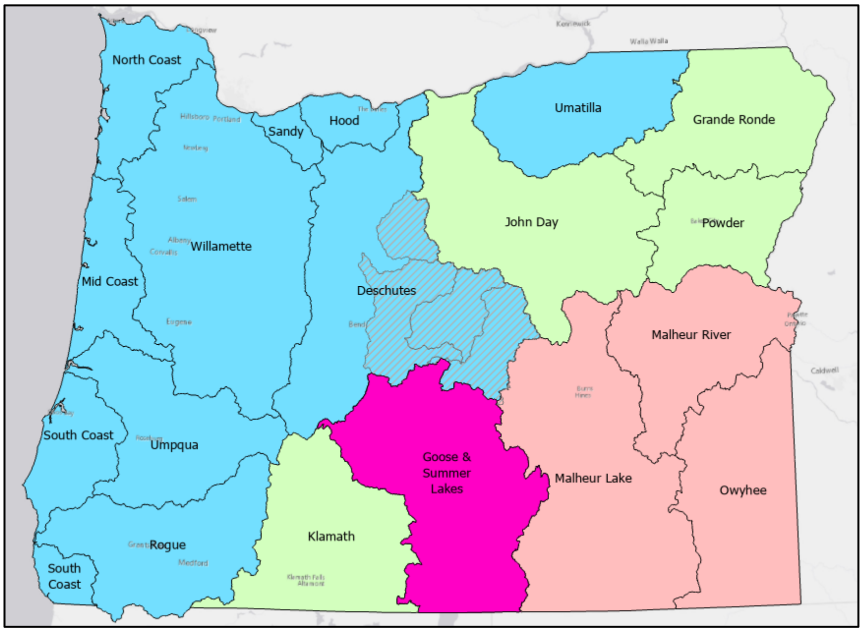


Figure 1. Current pH criteria by Oregon basin: 6.5-8.5 (blue), 6.5-9.0 (green), 7.0-9.0 (pink), 7.5-9.5 (bright pink). The area proposed for revision is hatched.

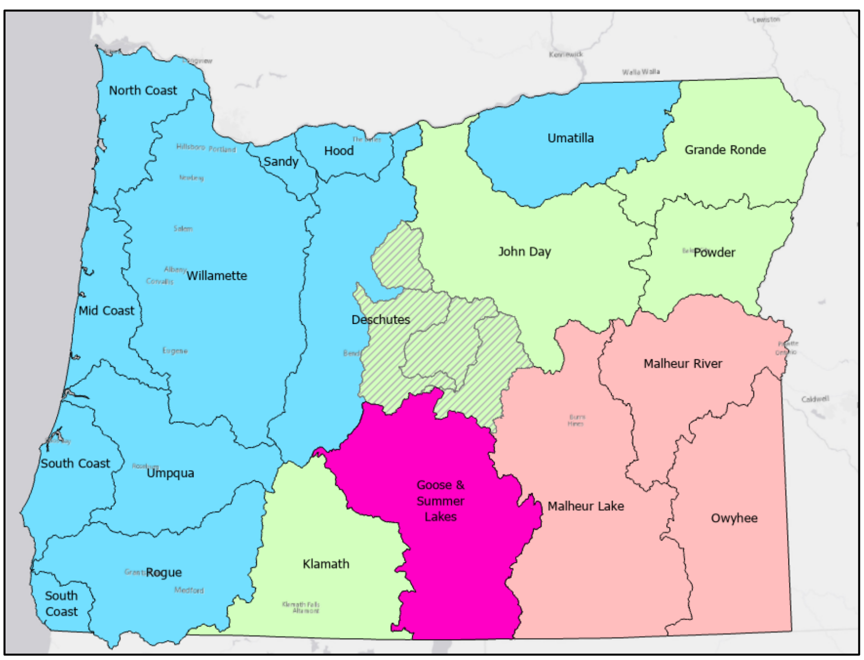


Figure 2. The area of proposed pH criteria revision is shown as hatched. The pH criteria are: 6.5-8.5 (blue), 6.5-9.0 (green), 7.0-9.0 (pink), 7.5-9.5 (bright pink).

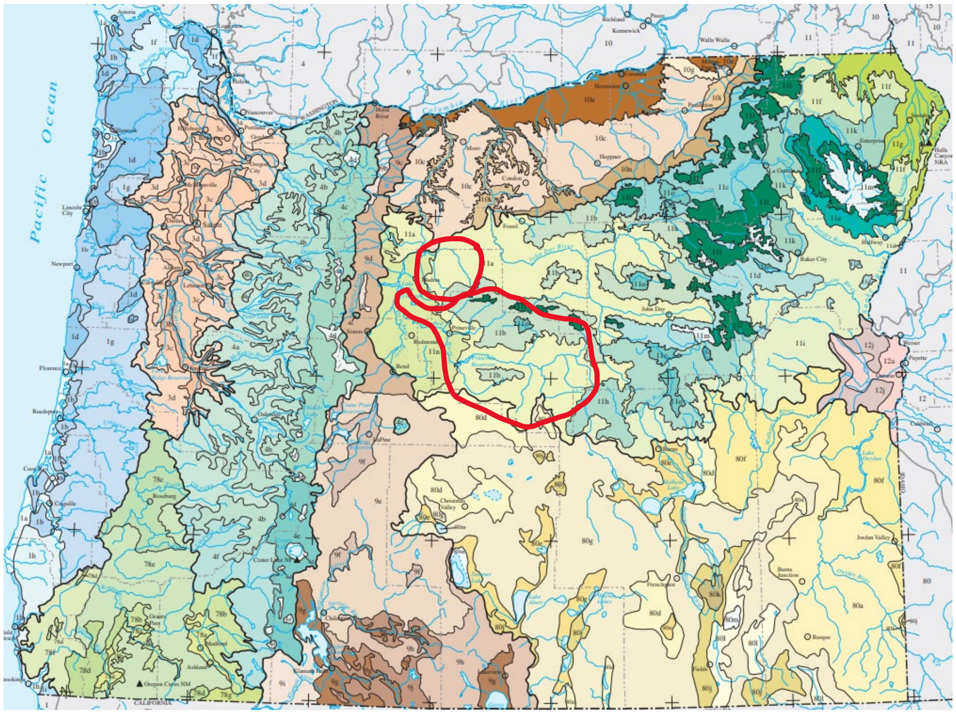


Figure 3. Eco-region map of Oregon showing differences between the Western Oregon and Cascades and eastern Oregon ecoregions. The Crooked River and Trout Creek subbasins (approximately circled in red) are part of John Day/Clarno Uplands Ecoregion (11a&b). https://www.epa.gov/eco-research/ecoregions

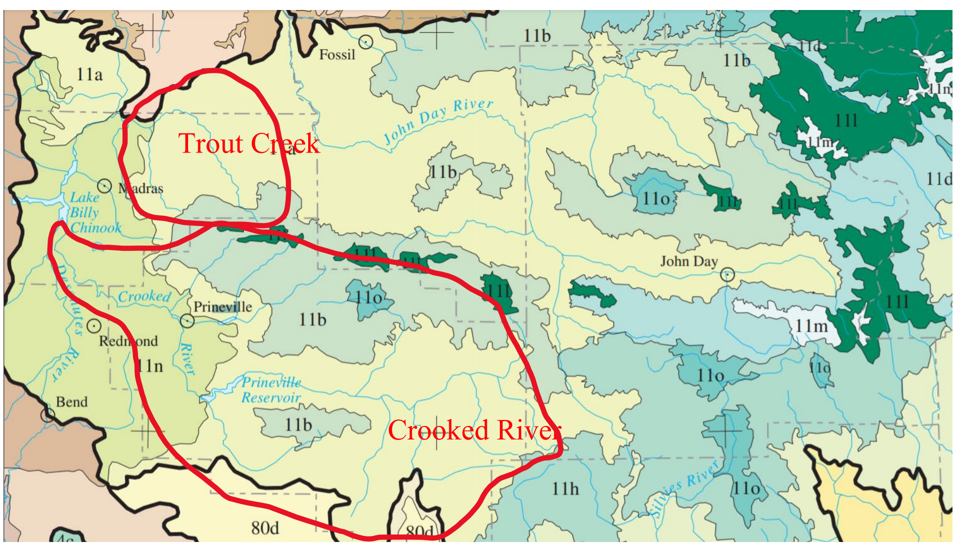


Figure 3. Zoomed-in ecoregion map highlighting ecoregions of Trout Creek and Crooked River basins (approximately outlined in red) within the John Day/Clarno Uplands Ecoregion (11a&b). https://www.epa.gov/eco-research/ecoregions

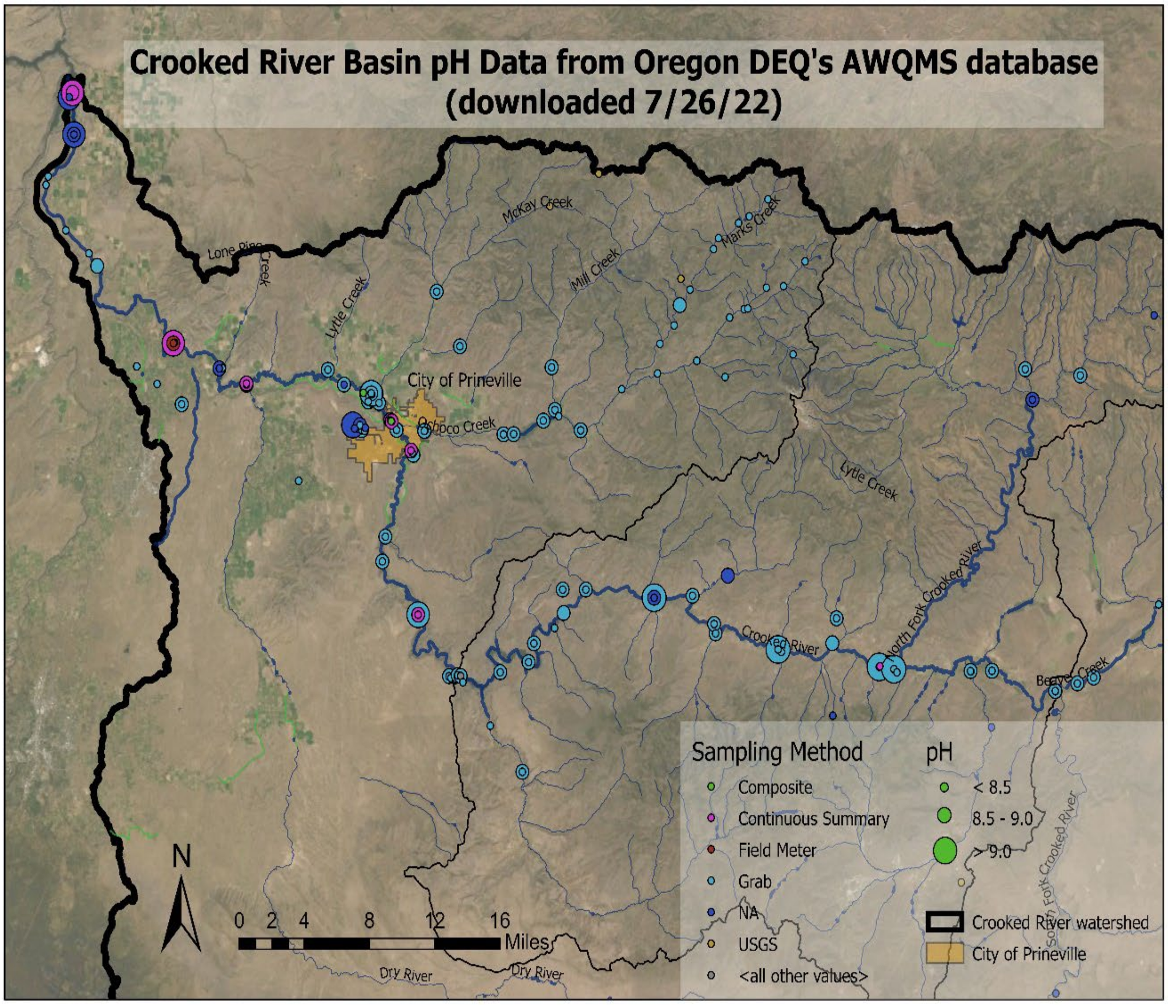


Figure 4. Crooked River subbasin pH data as of July 2022 (Oregon DEQ, Ambient Water Quality Monitoring System). The blue dots are locations of grab sample data, and the pink dots identify where there is some diel data. The size of the circle indicates the maximum pH level found at the site. The high values (i.e., >9.0) in the very lower part of the subbasin are in the Crooked River arm of Lake Billy Chinook rather than the free-flowing portion of the river.

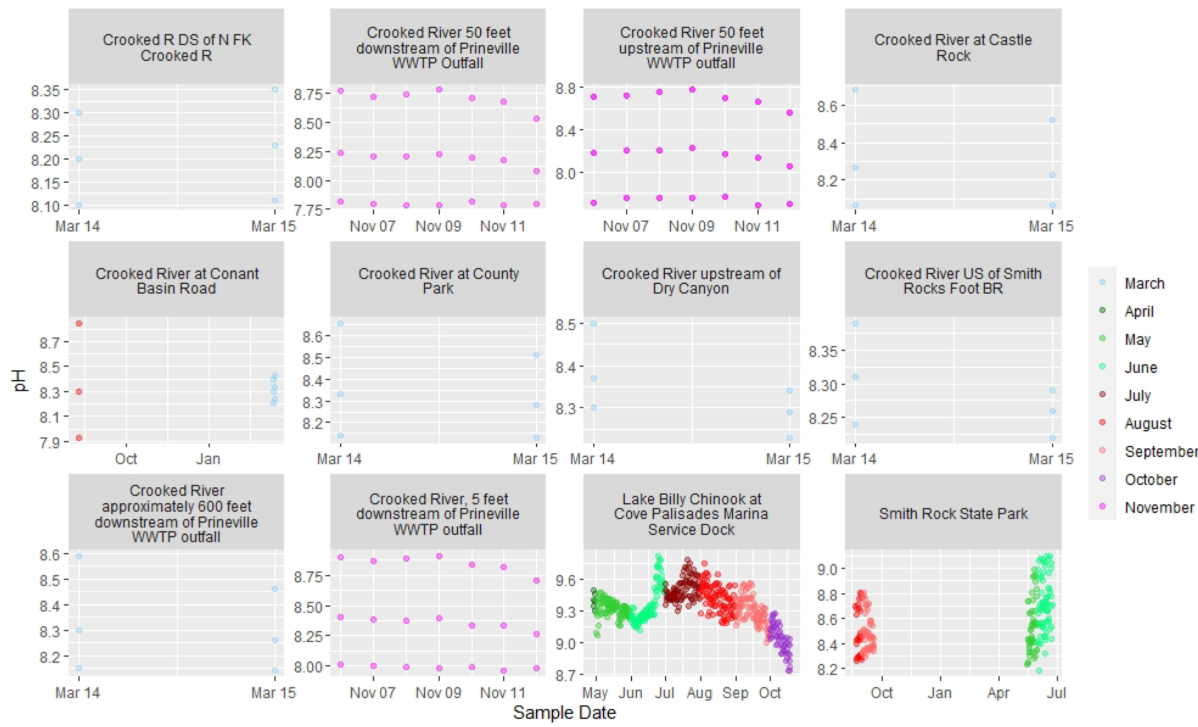


Figure 6. pH data from sites with diel monitoring. Data from AWQMS.

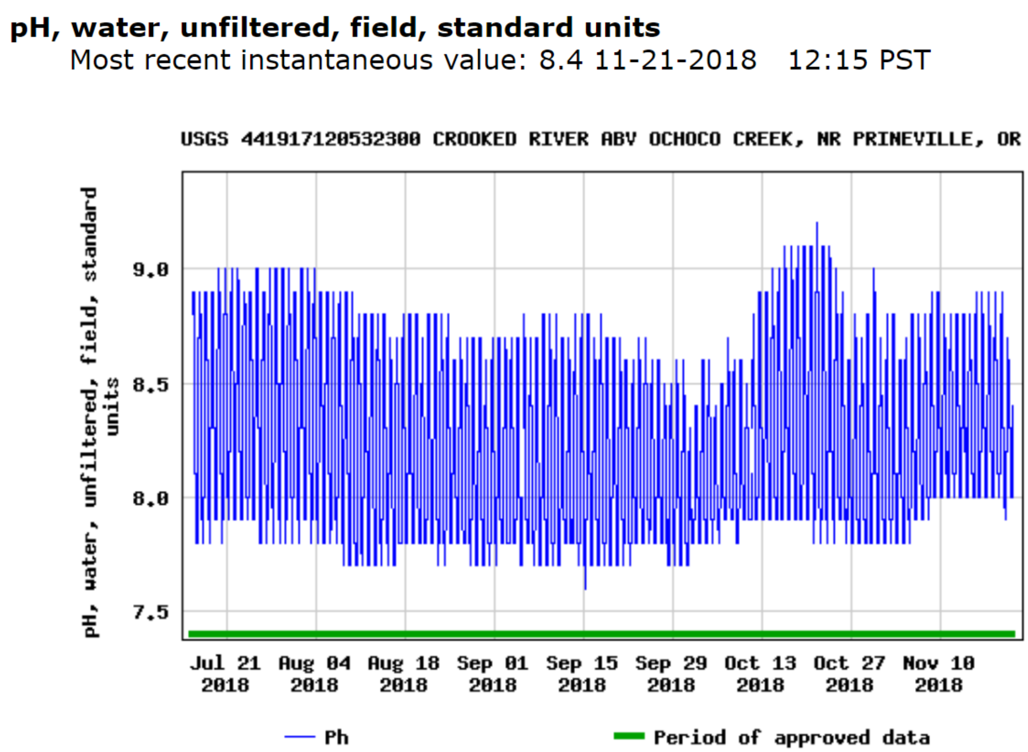
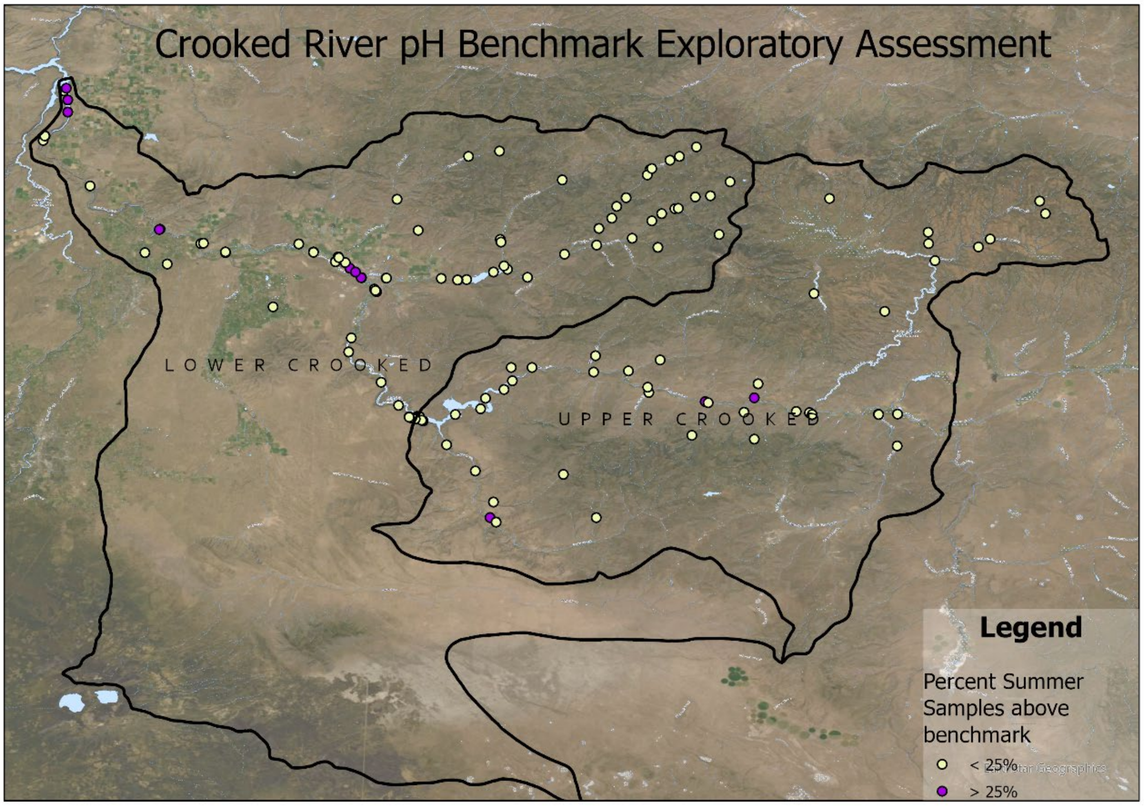


Figure 7. Diel pH data from Crooked River above Ochoco Creek, near Prineville (USGS Station 441917120532300). https://waterdata.usgs.gov/monitoring-location/441917120532300/#parameterCode=00400&startDT=2018-07-01&endDT=2018-12-01



This map shows the percentage of samples between June and September that are greater than pH 8.7. There is no data window applied to this analysis, data represents everything in AWQMS. Data pulled from AWQMS on 9/9/2022. Assessments were performed on a monitoring location basis.

Figure 8. Sites that would exceed the action value (at least 25% of the pH values from June through September exceed 8.7.)

Contact

Debra Sturdevant, Water Quality Standards Program
Debra.sturdevant@deq.oregon.gov
503-229-6691

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APPENDIX 1. Proposed Rule Amendment - Redline

340-041-0135

Basin-Specific Criteria (Deschutes): Water Quality Standards and Policies for this Basin

(1) pH (hydrogen ion concentration). pH values may not fall outside the following ranges:

(a) All other Basin streams ~~(~~except streams in the Crooked River and Trout Creek subbasins and the Cascade lakes~~)~~: 6.5~~–~~to 8.5;

(b) All streams in the Crooked River and Trout Creek subbasins: 6.5 to 9.0;

(c) Cascade lakes above 3,000 feet altitude: pH values may not fall outside the range of 6.0 to 8.5.

When greater than 25 percent of ambient measurements taken between June and September are greater than pH 8.7, and as resources are available according to priorities set by the Department, the Department will determine whether the values higher than 8.7 are anthropogenic or natural in origin.

APPENDIX 2.

Figure A-1. pH data from the upper Crooked River subbasin. Data from ODEQ’s WQMS database.

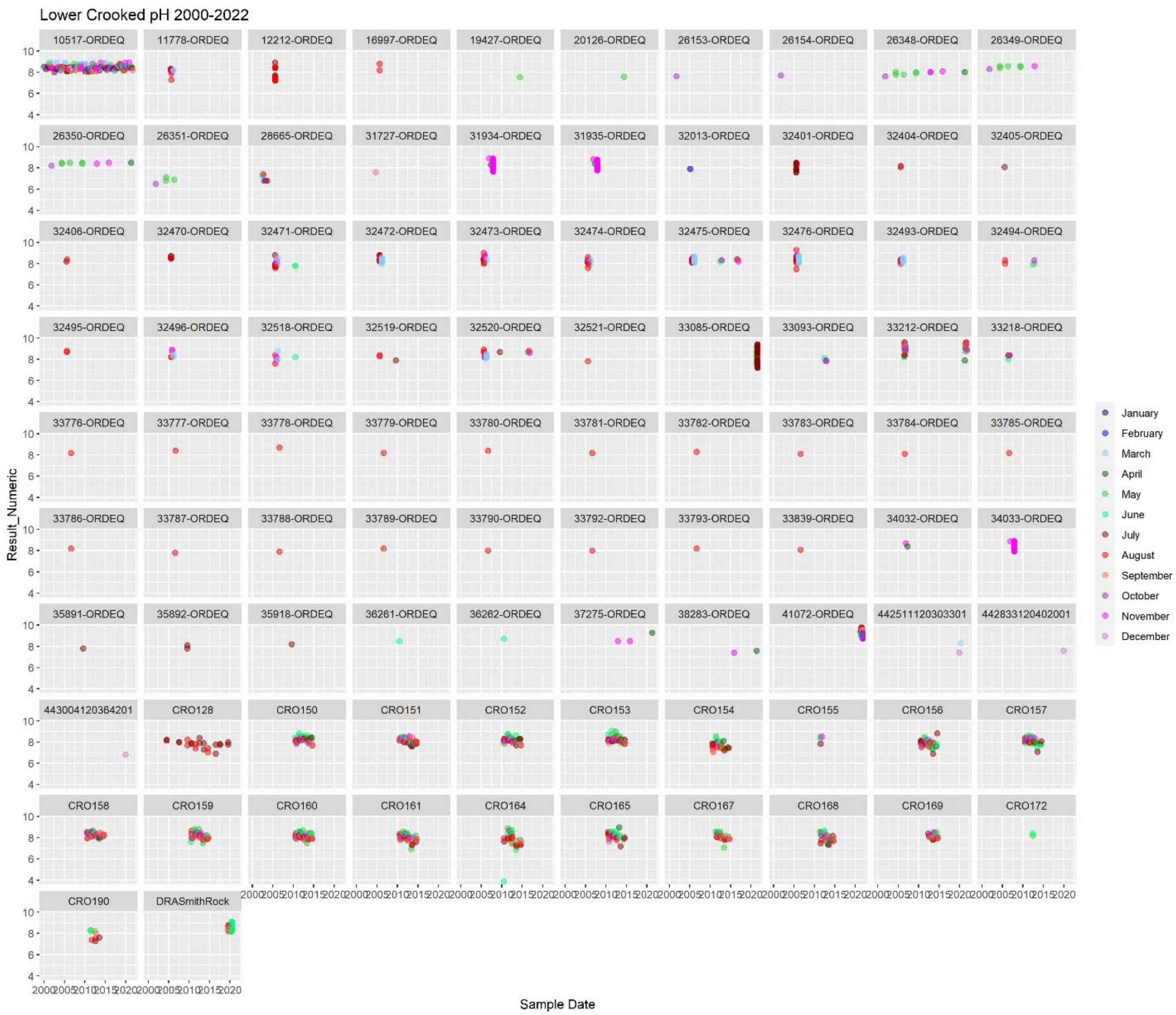

Figure A-2. pH data from the Lower Crooked River subbasin. Data from ODEQ's WQMS database.

ADDITIONAL REFERENCES

Alabaster and Lloyd, 1982. Water Quality Criteria for Freshwater Fish. JS Alabaster, Water Research Centre, Stevenage, UK, and R Lloyd, Ministry of Agriculture, Fisheries and Food, UK.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat Suitability Information: Rainbow Trout. U.S. Fish and Wildlife Service. FWS/OBS-82/10. 64pp.

Robertson-Bryan, Inc. 2004. Technical Memorandum: pH Requirements of Freshwater Aquatic Life. Elk Grove, CA

Wagner, 1997. Combined Effects of Temperature and High pH on Mortality and the Stress Response of Rainbow Trout after Stocking. Article *in* Transactions of the American Fisheries Society · November 1997