June 23, 2023

Oregon Department of Environmental Quality
700 NE Multnomah St., STE 600
Portland, OR 97232

Via email to: aquaticlife.2022@deq.oregon.gov; emil.hnidey@deq.oregon.gov

Re: Input on Aquatic Life Use Rulemaking (Notice of Proposed Rulemaking filed 4/27/23 regarding Amendments to Water Quality Standards)

Dear Members of the Environmental Quality Commission, Director Feldon, and DEQ Staff,

Trout Unlimited (TU) is a non-profit organization dedicated to the conservation of cold-water fish (such as trout, salmon, and steelhead) and their habitats. Our organization has more than 350,000 members and supporters nationwide, including over 3,500 members in Oregon. TU's mission is to bring together diverse interests to care for and recover rivers and streams so our children can experience the joy of wild and native trout and salmon.

TU held a seat on the rulemaking advisory committee (RAC) for the Aquatic Life Use rulemaking, and participated in all RAC discussions. Department of Environmental Quality (DEQ) staff were receptive to RAC member input and good communicators throughout the process, and we greatly appreciate the time and effort those staff committed to this effort.

Trout Unlimited supports *most* of the proposed updates included in this rule package. However, we are very concerned about the proposed change to less stringent pH criteria for the Crooked River and Trout Creek, and request that the Environmental Quality Commission not approve the proposed change in pH water quality standards for those streams.

Please accept the following detailed comments on the Aquatic Life Use rule package:

1. **TU supports the map updates that will apply more stringent temperature and dissolved oxygen criteria.**

The temperature and dissolved oxygen standards that apply in a waterbody depend upon the designated beneficial uses and "aquatic life uses" of the waterbody. In many instances, temperature and dissolved oxygen criteria will change to a more stringent standard under this rulemaking to reflect updated information on when and where certain coldwater fish species are distributed on the landscape. TU appreciates and supports that.

DEQ last updated its maps that determine where its temperature standards apply (the so-called "fish maps") in 2003. In the two decades since, fish passage has been restored on some streams, species have been re-introduced to certain watersheds, state and federal biologists have collected new data on when and where fish species are distributed, and mapping technology has significantly improved.

TU appreciates and supports updates to fish maps that will result in more stringent temperature standards applying. As part of this update, we also recognize and acknowledge that some information gathered and studies conducted over the past 20 years will result in *less* stringent standards applying in some areas under this rulemaking (e.g., if recent studies have shown that bull trout do *not* inhabit a stream that fish managers believed them to inhabit years ago). That is part of the give-and-take of relying on best available science, and we can accept those results where the data supports it.

There are a few updates and changes in temperature standards that we wish particularly support. Salmon and steelhead were re-introduced above the Pelton Round Butte hydroelectric complex in the Deschutes River after the existing fish maps were created. Accordingly, DEQ proposes that temperature standards change in portions of the Deschutes River, Crooked River, and Whychus Creek from an 18°C (64.4 F) maximum temperature standard to 16°C (60.8 F) (due to a recategorization on the fish maps from "Salmon and Trout Rearing and Migration" aquatic use to "Core Cold Water Habitat" designation). Similarly, state and federal agencies successfully re-established a bull trout population in the upper Clackamas River in recent years. Now, DEQ proposes that portions of the upper Clackamas will change from a 16°C (60.8 F) standard to 12°C (53.6 F) (formerly considered "Core Cold Water Habitat," now being reclassified as "Bull Trout Spawning and Juvenile Rearing" habitat). The Aquatic Life Use rulemaking proposes similar changes to more stringent temperature standards in the Umpqua and Grande Ronde River basins. All of these are important and scientifically-supported revisions.

DEQ has never conducted a rulemaking on the aquatic life use subcategories associated with the dissolved oxygen (DO) standards. Rather, since 1996, DEQ has applied DO criteria as specified in memos to the Environmental Protection Agency (EPA). The Aquatic Life Use rulemaking will designate DO standards in DEQ's rules for the first time. This should result in some waterbodies receiving more stringent DO designations (such as portions of the Deschutes and Crooked Rivers and Whychus Creek, which DEQ proposes to change from a 6.5 mg/L dissolved oxygen criterion to a more protective 8.0 gm/L standard, due to a recategorization from "Cool Water Aquatic Life" use to "Cold Water Aquatic Life" use). As stated above with regard to the temperature rules, TU believes these dissolved oxygen proposals are important and scientifically-defensible.

2. **TU has reservations about the proposed resident trout spawning maps that narrow the scope of certain stringent dissolved oxygen standards, but we believe DEQ proposes a reasonable approach to filling in gaps moving forward.**

Oregon's dissolved oxygen regulations provide that certain DO criteria apply in "active spawning areas used by resident trout species" and "where resident trout spawning occurs . . ."[1] This language raises the important and difficult issue of exactly where resident trout spawn in Oregon. DEQ has determined that under the prior implementation of this rule, the agency was somewhat over-inclusive in its designation of resident trout spawning areas.[2] During the RAC process, DEQ proposed options for narrowing its designation. Some of these options would have over-corrected for the issue and entirely removed watersheds that host wild trout (such as the Long Tom River, the Deschutes upstream of Bend, and the entire Owyhee River basin) from the resident trout spawning maps. TU appreciates that DEQ is moving forward with an option that maps all known resident trout spawning habitats based on an extensive literature search and close collaboration with ODFW. Nevertheless, there will still be data gaps.

We understand that the agencies will continue working together to fill data gaps in certain geographies, particularly including eastern Oregon and the Willamette River basin. That is a reasonable approach and

[1] OAR 340-041-0016(1).
[2] *See* RAC Meeting Materials for December 16, 2022.

we appreciate ODFW's efforts to support DEQ's data needs in that process. As DEQ moves forward with narrowing and reviewing resident trout spawning areas, TU recommends that the agency apply the precautionary principle and apply the resident trout spawning designation if it's reasonably likely that an area is used for spawning but not officially recognized as such by the literature or ODFW.

3. **TU disagrees with the proposed change to less stringent pH criteria for the Crooked River and Trout Creek because DEQ has not shown that high pH in these basins is natural in origin, the agency's justification differs from the approach that experts applied to a similar pH update in the 1990s, the proposed "action level" will not be effective, and the change leaves no margin of safety for listed fish species.**

The upper limit for pH in the Crooked River and Trout Creek is currently 8.5 pH units. That 8.5 standard has applied to those basins since 1947.[3] Numerous waterbody segments in the relevant area are listed as impaired for pH. This rule package proposes to change the pH criteria upward to 9.0, which would remove at least some of these segments from the 303(d) list, as summarized in the following chart that DEQ distributed during the RAC process:[4]

Table 1. Potential impact of pH criteria change to water quality impairments for pH in Crooked River Basin

Waterbody/Segment	2022 Category	Potential impact of proposed revision to pH standard
Crooked River/ Dry Creek to Lone Pine Creek	5 (Impaired)	Delisting, or might trigger action level of 8.7
Crooked River/Lone Pine Creek to Opal Springs	5 (Impaired)	Delisting, or might trigger action level of 8.7
Horse Heaven Creek/ Bonnieview Dam to confluence with Crooked River	No data	n/a; additional data is needed
North Fork Crooked River/ confluence with Johnson Creek and Howard Creek to Deep Creek	3 (Insufficient information);	n/a; additional data is needed
South Fork Crooked River/ confluence with Crooked River to Twelvemile Creek	5 (Impaired)	2 impaired (based on earlier data ; new data would be needed to delist)

DEQ presented the pH criteria change for the Crooked River and Trout Creek to RAC members as an administrative correction.[5] TU disagrees that DEQ has shown that this standard—which has applied for nearly 80 years—is an error or oversight that warrants fixing.

[3] DEQ, June 1995, Technical Advisory Committee, Policy Advisory Committee, TAC pH Subcommittee, *Final Issue Paper: pH Hydrogen Ion Concentration 1992-1994 Water Quality Standards Review* at page 1-5 ("The Oregon State Sanitary Authority adopted a statewide criterion on 6.5-8.5 pH units in 1947. In 1967, the Sanitary Authority revised the statewide criteria to 7.0-8.5 pH units. The present criteria in basin form were adopted by the EQC in 1976.") (hereinafter, the "1995 Issue Paper") (available in Attachment 1).
[4] DEQ, *WORKING DRAFT: pH Criteria revisions for Crooked River and Trout Creek* (version distributed as materials for second RAC Meeting).
[5] *Id.* (stating that the rulemaking would "*correct* the pH criteria for the Crooked River and Trout Creek sub-basins to make them consistent with other eastern Oregon basins.").

a. Portions of the Crooked River and Trout Creek are designated critical habitat for middle Columbia summer steelhead and bull trout, and poor water quality is a well-documented issue in these basins.

The Crooked River is a tributary to Lake Billy Chinook and the Deschutes River upstream of the Pelton Round Butte hydroelectric complex. Its lower reach (between Lake Billy Chinook and the Highway 97 bridge) is designated critical habitat for bull trout.[6] Beginning in 2007, summer steelhead have been reintroduced to the Crooked River above the dams in connection with the FERC relicensing for the Pelton Project; the reintroduced summer steelhead are designated as a nonessential population under section 10(j) of the Endangered Species Act.[7] Accordingly, there is no designated critical habitat for steelhead in the Crooked.

Trout Creek enters the Deschutes below the dams, and includes designated critical habitat for both bull trout[8] and middle Columbia River steelhead.[9]

The Crooked River has many water quality issues, which are compounded by the frequent low streamflow conditions in summer and fall. As one example: in 2022, there was a fish kill in the Crooked due to curtailed releases from Bowman Dam.[10] After that low streamflow event, ODFW estimated that—in the period between June 2022 and October 2022—redband trout populations declined by more than 20% and whitefish populations declined by more than 80%.[11]

The following photo from the 2022 low-flow conditions demonstrate the conditions that native fish are dealing with in the Crooked:[12]

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[6] 75 Federal Register 63993 (October 18, 2010) (available at: https://ecos.fws.gov/ecp/species/8212#crithab).

[7] NOAA, *Proposed Issuance of an Endangered Species Act Section 10(a)(1)(B) Incidental Take Permit for the Deschutes Basin Habitat Conservation Plan, Oregon, and the U.S. Bureau of Reclamation's Continued Operation and Maintenance of the Deschutes Basin Project, Oregon*, NMFS Consultation No. WCRO-2020-03588 (October 18, 2022), at page 57 (available at: https://repository.library.noaa.gov/view/noaa/47627) (hereinafter the "Deschutes HCP BiOp").

[8] 75 Federal Register 63993.

[9] 70 Federal Register 52630 (September 2, 2005) (available at: https://www.fisheries.noaa.gov/action/designation-critical-habitat-12-evolutionarily-significant-units-west-coast-salmon-and); *see also* Deschutes HCP BiOp at page 71.

[10] ODFW, *Memorandum on Crooked River Low Flows 2022* (November 29, 2022 Draft) at page 7 ("Fish population monitoring conducted in June 2022 found fish populations to be healthy and estimated a Redband Trout population of 2,083 fish/mile and a Mountain Whitefish population of 6,950 fish/mile (Figure 5). Following low streamflows, sampling in October estimated a slight reduction in the Redband Trout population at 1,647 fish/mile and an estimated Mountain Whitefish decline of over 80% at 896 fish/mile.") (available at: https://www.dfw.state.or.us/fish/local_fisheries/deschutes/docs/Crooked_River_Low_Flow_Memo_20221129_v2.pdf); *id.*at 9 ("Following a water availability shortage and a curtailed irrigation season, the Crooked River downstream of Bowman Dam experienced six weeks of unprecedented low fall streamflows (10- cfs) in September-October 2022. Fish population monitoring near the end of the low-flow period documented overall survival of Redband Trout and Mountain Whitefish; however, density estimates (fish/mile) were reduced compared to before the drop in flows.")

[11] *Id.*

[12] *Id.* at 5.

Figure 2.Crooked River below Bowman Dam pictured at 175 cfs (August 16, 2022) and 10 cfs (September 22, 2022).

The Crooked River is a highly altered basin, with regard to both streamflow hydrography and land practices. The 1995 Issue Paper cautions that “most pH-related problems in the state are related to nonpoint source pollution, such as nutrient enrichment.”[13] TU agrees. In the Crooked and Trout Creek,

[13] 1995 Issue Paper at 4-2.

DEQ would need to show that pH exceeding 8.5 is natural in these streams and not a function of unchecked nonpoint source pollution before changing the criteria to a less stringent standard.

b. DEQ has not shown that pH exceedances in the Crooked River or Trout Creek basins are natural in origin.

We are concerned that this rule proposes changing the pH criteria for waterbodies where pH issues *very well may be* anthropogenic in origin, and not natural.

As a preliminary matter, based on DEQ's materials supporting this rule package, it appears that pH *under* 8.5 is natural in Trout Creek. The 2023 Issue Paper states that natural pH in eastern Oregon (ostensibly including the Crooked and Trout Creek) can rise above 8.5. Yet, the 2023 Issue Paper also provides that "[n]o waters are impaired [for pH] in the Trout Creek Basin".[14] If pH in Trout Creek does not currently exceed 8.5 (assuming DEQ is monitoring it), and Trout Creek is not on the 303(d) list for pH under the current criteria, then it seems pH is generally under 8.5 in that watershed under current conditions and pH above 8.5 in Trout Creek is not natural.[15] Accordingly, we do not follow DEQ's logic or purpose in relaxing the pH standard for Trout Creek. Moreover, if Trout Creek and Crooked River have the same geology—and therefore should have the same natural pH according to DEQ's 2023 Issue Paper—it's unclear why Trout Creek does not have the same extent of pH 303(d) listings as the Crooked.

In the Crooked River basin, DEQ argues that the geology is similar to eastern Oregon basins where natural pH exceeds 8.5, yet DEQ's analysis also demonstrates there are likely anthropogenic pH issues. For example, the 2023 Issue Paper explains that *under the new criteria*, there would still be sites in the Crooked with "enough exceedances to be listed as impaired."[16] Similarly, Figure 8 in the 2023 Issue Paper shows sites that would exceed the proposed 8.7 "action value," and notably, all but two of these are in the vicinity of Prineville and downstream (where most of the development, irrigated agriculture, industry, and modified streamflows occur in the basin).[17] Indeed, the analysis acknowledges that "data at these sites identify a potential [sic] concern and should be evaluated for anthropogenic nutrient loading and excessive algal growth."[18]

It's difficult to reconcile DEQ's reasoning that pH naturally exceeds 8.5 in the Crooked, but that there's also unnaturally high pH in the basin. DEQ's justification indicates that pH naturally exceeds 8.5 in the Crooked and that an appropriate maximum criteria of 9.0 should apply (with 9.0 presumably being the target for a future pH TMDL), while at the same time suggesting that elevated pH in the basin today could be anthropogenic and unnatural, warranting study and possibly 303(d) listing.

If DEQ cannot show that pH exceeding 8.5 is natural in the Crooked—and the Department has not compellingly done so here—then the precautionary, protective approach for water quality and native species is to not relax the water quality criteria for pH.

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[14] DEQ, *Issue Paper: Proposed pH Criteria Revisions for the Crooked River and Trout Creek Subbasins, Deschutes Basin, Oregon* at page 7 (2023) (available at: https://www.oregon.gov/deq/rulemaking/Pages/aquaticlife2022.aspx) (hereinafter, "2023 Issue Paper").

[15] TU queried DEQ's Ambient Water Quality Monitoring System (AWQMS) database for pH measurements in Mud Springs Creek, a tributary of Trout Creek. It appears all pH measurements from Mud Springs Creek were less than 8.5. *See* Attachment 2 (box plot of Mud Springs Creek AWQMS information for pH).

[16] 2023 Issue Paper at 7.

[17] *Id.* at 12.

[18] *Id.* at 6.

c. DEQ's review of pH standards in the 1990s applied the appropriate two-step analysis of: (1) whether exceedances in a basin were natural, and then (2) whether an increased pH standard would protect aquatic life. The pH justification for Crooked River and Trout Creek departs from that analysis and focuses on the second step only.

In the 1990s, DEQ assembled a technical advisory committee and policy advisory committee to review pH criteria standards in Oregon. Their 1995 Issue Paper demonstrates the appropriate approach to reviewing changes for pH criteria in eastern Oregon.

The 1995 Issue Paper starts by stating: "In developing a pH standard, it is necessary to be able to separate natural from anthropogenic effects. An underlying assumption in developing water quality standards is that the natural conditions represent the ideal and will provide for the greatest beneficial use."[19] We agree. This is why a maximum limit of 8.5 applies west of the Cascades; pH doesn't *naturally* exceed 8.5 west of the Cascades, and therefore a standard of 9.0 would be inappropriate there.[20]

When the 1990s advisory committee looked at this issue for eastern Oregon, they recognized that the Deschutes, Klamath, Grande Ronde, Umatilla, and John Day Basins had the highest percentage of pH violations in the state under then-applicable pH standards.[21] But that alone does not mean pH exceedances in those areas were natural. Rather, the assembled experts reasoned that exceedances in "*basins which have: (1) minimal nutrient enrichment, and (2) consistent violations in the upper portions of these watersheds where human impacts are minimal* would indicate that the current [then 8.5] pH standard may be near or below natural pH ranges in these watersheds."[22] The 1990s committees conducted a separate inquiry about whether an increased pH criteria of 9.0 would be protective of aquatic life.[23]

Ultimately, the 1995 Issue Paper experts recommended an increase to 9.0 pH criteria in *some* eastern Oregon basins only (*not including the Deschutes and its tributaries Trout Creek or Crooked River*), reasoning that the "technical subcommittee has a high level of certainty that pH exceedances in these basins are of natural origin, *and* a high degree of certainty that beneficial uses are fully protected at a pH of 9.0."[24]

DEQ has not provided any similar assurances about natural pH in the Crooked or Trout Creek in the current justification. Instead, the 2023 Issue Paper focuses on whether a 9.0 criterion would protect aquatic life.[25]

The bar for changing this standard is to *first* determine what level of pH in the waterbody is natural, and *second*, ask what standards would be protective of aquatic life. Our concern is that this rulemaking

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[19] 1995 Issue Paper at 2-1.
[20] *See* 2023 Issue Paper at 6 ("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.").
[21] *Id.* at 2-2.
[22] *Id.* at 2-3 (emphasis added).
[23] *Id.* at 1-6, 2-8 through 2-9, and 3-1.
[24] 1995 Issue Paper at 4-3 (emphasis added).
[25] 2023 Issue Paper at 1 (proposing the revision "to reflect the criteria necessary to protect aquatic life use and to be consistent with the pH criteria for other eastern and south-central Oregon basin waters."); *id.* ("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 [other basins in eastern Oregon having a maximum of 9.0 standard].").

focuses on the latter step only, which risks relaxing the pH standard in this portion of the Deschutes watershed to unnatural conditions.

d. The 2023 Issue Paper mischaracterizes the 1995 Issue Paper's recommendations about pH criteria increases in eastern Oregon; the 1995 Issue Paper recommended increasing the pH standard for certain basins that did *not include* the Crooked River or Trout Creek.

In the 1995 Issue Paper, DEQ's panel of outside technical and policy experts recommended increasing the pH criteria from 8.5 to 9.0 in *certain* eastern Oregon streams. The 2023 Issue Paper inaccurately summarizes that history, stating that "the committee recommended an increase in the upper end of the pH criteria range *for eastern Oregon basins* to 9.0."[26]

The 1990s advisory committee reviewed the pH standard for the Deschutes Basin and all of the other basins in central and eastern Oregon. However, the committee did *not* recommend that pH criteria for the Deschutes Basin (which includes the Crooked River and Trout Creek) be increased to 9.0. Rather, the 1995 Issue Paper recommended increasing the upper limit of pH criteria for *only* the John Day, Umatilla, Walla Walla, Grande Ronde, and Powder Basins.[27] Both the technical and policy advisory committees recommended raising the pH standard in those "several" basins only,[28] and DEQ staff incorporated and adopted those recommendations.[29]

The 1995 Issue Paper does not include a recommendation that the upper end of pH criteria for the Deschutes Basin (whether in whole, or in part) be increased to 9.0.

e. There is no margin of safety at pH 9.0 according to the 1995 Issue Paper and NOAA's 1999 Biological Opinion, contrary to DEQ's justification here.

The 2023 Issue Paper states: "because the upper criterion of 9.0 is applied as a daily maximum, there is a built-in margin of safety."[30]

That appears to be a departure from margin of safety analyses conducted on pH in eastern Oregon in the 1990s. NOAA's 1999 Biological Opinion on Oregon's water quality standards for dissolved oxygen, temperature, and pH states: "… a pH of 9.0 seems to be the cutoff for the start of adverse effects for some species of salmonids and their invertebrate food sources. Although significant mortality of listed and proposed species does not appear likely, *there is no reliable margin of safety at pH 9.0 . . .*"[31] Similarly, the 1995 Issue paper states: "the subcommittee must . . . state that there is *no reliable margin for error or safety at pH 9.0*."[32]

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[26] 2023 Issue Paper at 3.
[27] 1995 Issue Paper at 5-1, Table 5-1.
[28] *Id.*
[29] *Id.* at 5-2 ("The Department recommends that the pH criteria be changed as indicated in Table 5-1…"); *see also id.* at *Id.* at 5-2 (DEQ staff analysis in the 1995 recommendations, explaining that "evidence indicates that pHs up to 8.7 occur naturally and routinely *in the five Eastern Oregon basins under consideration.*") (emphasis added).
[30] 2023 Issue Paper at 2.
[31] NOAA, *Biological and Conference Opinion Approval of Oregon Water Quality Standards for Dissolved Oxygen, Temperature, and pH*, (July 7, 1999) at page 47 (emphasis added) (hereinafter, "NOAA's 1999 BiOP").
[32] 1995 Issue Paper at 4-3.

Relatedly, the 1990s advisory committee's point about risk and narrowed margin for error is still true and relevant to the proposed rule change: "Widening the acceptable range of pH may have the ramification of increased risk. As a corollary, the widening of a criteria may narrow the margin for error (e.g., error of measurement), thus increasing risk, even though the beneficial use is considered fully protected."[33]

If there is no margin of safety at pH 9.0, then DEQ should not assert otherwise and DEQ should not relax the relevant water quality standard for these watersheds that provide designated critical habitat for two listed salmonid species.

f. The proposed "action level" of 8.7 pH units is meaningless and ineffective because the rule language does not require DEQ to take any action other than studies.

The proposed rule language is as follows (noting, however, that the entire provision beginning with the words "When greater . . ." is *new* in this rule package, but not shown as such with red font in the 2023 Issue Paper):[34]

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.

Unfortunately, this proposed language does not require any action or consequence *if* DEQ determines that pH exceeding 8.7 is anthropogenic in origin. There appear to be 3 conditions to the determination described in this rule: (1) DEQ finding that 25% or more of ambient measurements between June and September exceed 8.7, (2) DEQ having resources available to conduct a study, and (3) a study being within the "priorities set by the Department . . ." If all of these conditions are met, then DEQ will only "determine whether the values higher than 8.7 are anthropogenic or natural in origin."

We question the value of this exercise (let alone its likelihood, based on agency workloads and resources). If DEQ proceeds with changing the pH criteria for Trout Creek and Crooked River—which TU opposes—then we would at least recommend that the rule language specify a consequence or result following the study. Examples would include expressly obligating DEQ to using 8.7 as the target pH criteria for a TMDL, or pursuing water quality restoration efforts as soon as reasonably practicable to remedy the increment of pH exceedance that *is* anthropogenic in origin.

NOAA has raised similar concerns about the exact type of pH action level proposed here, and we share those sentiments.[35]

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[33] *Id.* at 4-2.
[34] 2023 Issue Paper at 13.

g. Increasing the pH standard for the Crooked River and Trout Creek authorizes elevated pH inflows to Lake Billy Chinook and the Deschutes River, which will remain at a lower standard of 8.5.

Trout Creek and the Crooked River are tributaries to a waterbody (i.e., the Deschutes) that will maintain its more stringent 8.5 pH unit standard. If this rule change approved, our understanding is that this geography would be the only instance where a mainstem river in Oregon has more stringent pH criteria than its tributaries.[36] If the proposed change in pH criteria is approved—thereby ensuring a continued source of elevated pH in the Deschutes—we question whether pH issues in downstream areas could ever be fully addressed. For example, the mainstem Deschutes between the Pelton Regulating Dam and Warm Springs River is listed for pH, and a TMDL is not yet in place.[37] DEQ's analysis has not explained how this proposed change in pH criteria might affect watershed efforts in areas located downriver. If this change in pH criteria is approved, one could reasonably wonder whether a future review of pH standards might propose changing the pH standard for downstream areas of the Deschutes; TU sincerely hopes that will not occur.

h. The science on risks of elevated pH to native salmonids is stale, and there is evidence that pH in the range of 8.5-9.0 is not optimal for native fish species.

The 2023 Issue Paper conducts a relatively thorough assessment of scientific literature on elevated pH and its effects on fish. TU conducted a similar inquiry, and it is clear to us that the effects of pH in the range of 8.5-9.0 has not been thoroughly studied, especially in recent years. Nearly 30 years ago, the 1995 Issue Paper's authors acknowledged that "[t]he literature on the ecological effects of high pH . . . are largely dated, and are limited in numbers. This leaves a much more vague picture than at low pH of the value at which ecological impacts are felt."[38] This is still true.

Indeed, the generally accepted principle that pH 9.0 is protective of aquatic life dates back to a 1969 report on European freshwater fish, authored by the European Inland Fisheries Advisory Commission.[39] Presumably, that European Commission did not test the effects of high pH on some of the listed fish

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[35] NOAA's 1999 BiOp at page 47 ("Although the [8.7 pH action level] allows an investigation by ODEQ when greater than 25% of ambient measurements taken between June and September are greater than pH 8.7 to determine whether the values higher than 8.7 are anthropogenic or natural in origin, *the standard is worded so the investigation is optional*. Also, there is *no requirement for ODEQ to place the waterbody on the 303(d) list if it does an investigation and finds that the pH over 8.7 is anthropogenic in origin*.") (emphasis added).
[36] *See* 2023 Issue Paper at Figures 1 and 2.
[37] *See* EPA, How's My Waterway database, Deschutes River Assessment Unit ID: OR_SR_1707030603_05_102625 (available at: https://mywaterway.epa.gov/waterbody-report/OREGONDEQ/OR_SR_1707030603_05_102625/2022).
[38] 1995 Issue Paper at 4-3.
[39] *Id.* at 1-5 (reviewing the history of EPA's pH criteria guidance issued in 1976, and its upper lmit "obtained from only one reference (EIFAC 1969)"). *See also* EPA, *Quality Criteria for Water* (1976) at 340 ("A review of the effects of pH on freshwater fish has been published by the European Inland Fisheries Advisory Commission (EIFAC. 1969). The Commission concluded: 'There is no definite pH range within which a fishery is unharmed and outside which it is damaged, but rather, there is a gradual deterioration 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, and increasing acidity or alkalinity may make these poisons more toxic.'") (available at: https://www.epa.gov/sites/default/files/2018-10/documents/quality-criteria-water-1976.pdf); J.S. Alabaster, *Water Quality Criteria for Freshwater Fish*, 2nd ed. (1984) at 38 ("salmonid and some other species are harmed at values above 9.0 . . .").

present in the Crooked River or Trout Creek, such as bull trout and spring chinook salmon (let alone other aquatic species that are present and currently under consideration for ESA listings, such as the western ridged mussel (*Gonidea angulate*)).[40] The United States Fish & Wildlife Service reported almost 40 years ago that "[p]recise pH tolerance and optimal ranges are not well documented for rainbow trout. Most trout populations can probably tolerate a pH range of 5.5 to 9.0, with an *optimal range* of 6.5 to 8.0 . . ."[41] Unfortunately, the picture is not clearer today.

TU readily acknowledges that this rulemaking is not the time or forum for determining whether pH 9.0 is truly protective of aquatic life, or directing a study on how elevated pH might affect aquatic life in Oregon. We simply intend to highlight that the proposed change relaxes a water quality standard into a range that is close to lethal levels and which has not been closely reviewed in many years.

4. **Conclusion: Trout Unlimited supports the rule package except with regard to the proposed change in pH criteria. We encourage the Environmental Quality Commission to reject the proposed pH criteria change for Crooked River and Trout Creek.**

It is DEQ's responsibility to regulate and protect water quality for native fish. In instances of uncertainty, such as whether pH greater than 8.5 is natural in the Crooked or Trout Creek, TU urges DEQ to apply the precautionary principle and maintain the current water quality standard. Someday, DEQ will complete TMDL(s) for the Crooked—which we strongly support. We agree with DEQ's statement in the 2023 Issue Paper that "[i]t 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."[42] The crux of our concern in this rulemaking is that DEQ has not shown a relaxed pH standard of 9.0 (or a toothless action level of 8.7) is appropriate or consistent with natural conditions in the Crooked River or Trout Creek.

Trout Unlimited supports *most* of the proposed updates included in this rule package, but we request that the Environmental Quality Commission not approve the proposed change in pH water quality standards for the Crooked River and Trout Creek.

Thank you for considering these comments, and please let me know if you have any questions.

Sincerely,

James Fraser
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[40] *See* USFWS, *Western Ridged Mussel* (providing listing petition materials) (available at: https://www.fws.gov/species/western-ridged-mussel-gonidea-angulata).
[41] Robert F. Raleigh, USFWS, *Habitat Suitability Information: Rainbow* Trout (January 1984) at 7 (emphasis added).
[42] 2023 Issue Paper at 7.

Attachment 1

1995 Issue Paper

[*See following pages.*]

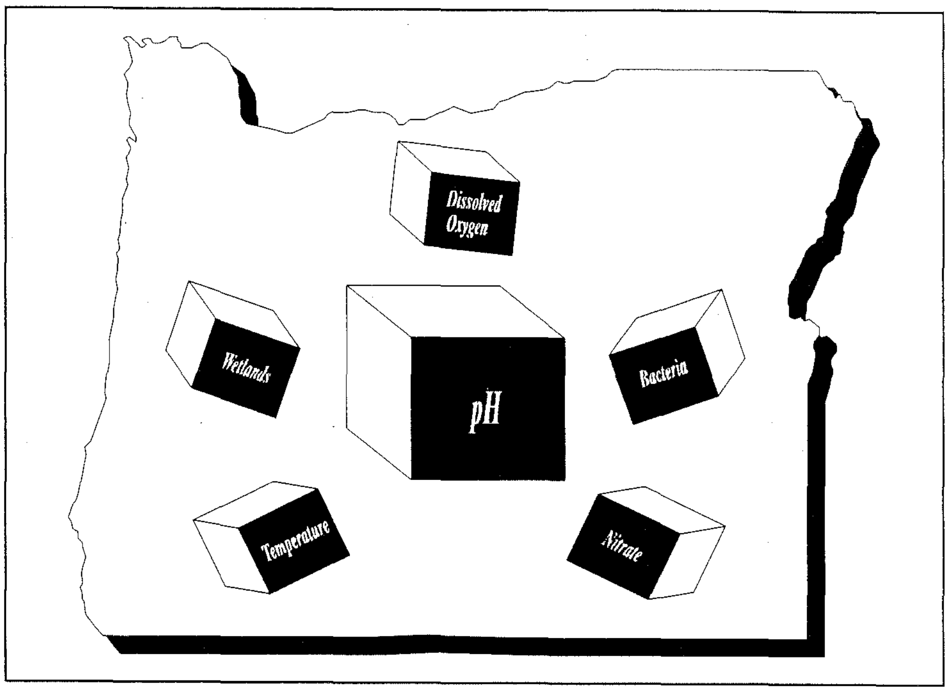
June 1995

FINAL ISSUE PAPER

pH

Hydrogen Ion Concentration

1992 – 1994 Water Quality Standards Review



State of Oregon

Technical Advisory Committee
Policy Advisory Committee
TAC pH Subcommittee

Department of Environmental Quality
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Portland, Oregon 97204

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INTRODUCTION

1.1 THE TRIENNIAL REVIEW

1.1.1 Purpose

The Department of Environmental Quality (DEQ) administers the federal *Clean Water Act* in the State of Oregon. Under Section 303 of the Act, DEQ is required to review Oregon's water quality standards at least once every 3 years. This process is commonly called the Triennial Water Quality Standards Review, or simply the Triennial Review. The scientific generalizations and data which support water quality and other pollution standards are constantly improving, and are becoming increasingly technical in nature. For example, the U.S. Environmental Protection Agency (EPA) issues technical guidance on an almost continual basis. The triennial review process keeps water quality standards abreast of constantly evolving scientific underpinnings and also in step with the state's changing needs.

Oregon's water quality standards are codified in the Oregon Administrative Rules (OAR) Chapter 340, Divisions 40 (groundwater) and 41 (surface water). The standards are presented in either narrative or numeric form. Narrative criteria define limits, often by stating that waters shall be maintained free from some condition. Numeric criteria require that concentrations or values of certain chemical or physical water characteristics, like temperature or dissolved oxygen, be maintained above or below specified levels. Some standards apply equally to all waterbodies in the state, while others are applied differently among the state's 19 basins.

A water quality standard, as defined by the *Clean Water Act*, has two elements. The first element is the beneficial uses of the state's water. Oregon's designated beneficial uses include:

- Public domestic water supply;
- Private domestic water supply;
- Industrial water supply;
- Irrigation water;
- Livestock watering;
- Anadromous fish passage;
- Salmonid fish rearing;
- Salmonid fish spawning;
- Resident fish & aquatic life;
- Wildlife & hunting;
- Fishing;
- Boating;
- Water contact recreation;
- Aesthetic quality;
- Hydropower; and
- Commercial navigation and transportation.

The second element is the specific numeric or narrative criterion or criteria which will provide sufficient water quality to protect that beneficial use.

Oregon's water quality standards

were last subjected to the triennial review process during the time period 1989 to 1991. DEQ initially developed issue papers for 14 water quality standards. As part of DEQ's public participation process, hearings were conducted in eight Oregon cities. Written public comments were also solicited. Subsequent to the public hearings and comment, the Environmental Quality Commission (EQC) approved rule adoption related to six standards:

- Antidegradation;
- Bacteria;
- Mixing zones;
- Toxic substances;
- Biological criteria; and
- Turbidity.

1.1.2 Process

The general overarching policy driving the water quality standards discussion is for "fishable and swimmable" waters and comes from the interim goals for the *Clean Water Act* (CWA). The general policy within the state has been and is for full protection of designated beneficial uses at all times and places. Technical and policy discussions began with this as a given. Each existing water quality standard was originally developed within this general policy framework. For the 1992–1994 Triennial Water Quality Standards Review, a Technical Advisory Committee (TAC) and subcommittees addressed the technical issues and a Policy Advisory Committee (PAC) addressed policy issues. This scheme was devised in order to isolate the technical discussion from the policy discussion as much as possible.

Technical Advisory Committee: Water quality standards are established using the best available scientific information within a public policy framework. Beginning with the 1992–1994 Triennial Review, DEQ decided to establish a Technical Advisory Committee for water quality standards. The committee is comprised of experts from academe and government agencies in complementary fields related to water quality criteria. For specific water quality standards, subcommittees with additional expertise were established. The role of the Technical Advisory Committee and its subcommittees is to help determine if new or additional information exists to warrant modification of the current water quality standards. The Committee then advises DEQ and the EQC on possible modifications to the standards.

The membership and affiliation of the Hydrogen Ion Concentration (pH) Subcommittee are shown in Table 1-1.

Policy Advisory Committee: In order to set the process within the appropriate public policy context, DEQ also established an analogous Policy Advisory Committee. The policy committee was drawn from academe, industry, and environmental advocacy groups to provide candid, critical, and constructive comments, advice, and recommendations. The major public policy issues for water quality standards are:

- The selection of the appropriate level of protection;
- The need to protect specific beneficial uses in specific seasons;
- The implementation and compliance difference between narrative and numeric standards;
- The timing of standards implementation in relation to the cost of compliance; and

Table 1-1: Membership and Affiliation of The Hydrogen Ion Concentration (pH) Subcommittee

NAME	AFFILIATION
Robert Baumgartner	Oregon DEQ
Greg McMurray, Ph.D (Cochair)	Oregon DEQ
Jan Miller	Unified Sewerage Agency
Peter Nelson, Ph.D (Cochair)	Oregon State University
Richard Petersen, Ph.D.	Portland State University
Greg Pettit	Oregon DEQ

- Establishing acceptable levels of risk.

1.2 EXISTING RULE

The existing criteria for pH are contained in OAR 340-41-(basin) (2)(d) — except for Walla Walla Basin which is OAR 340-41-685(2)(c) — and vary by basin as shown in Table 1-2. Basins of the state corresponding to the water quality standards are shown in Figure 1-1. The basic criterion for most waters of the state, including estuarine waters, is the range of 6.5–8.5 pH units. All marine waters and waters of the Columbia River are to be within the range of 7.0–8.5 pH units. The Snake River criterion is for the range of 7.0–9.0 pH units, and Goose Lake waters are to be maintained within the range of 7.5–9.5 pH units.

Natural variability outside the range of the criteria listed above and shown in Table 1-2 is accommodated by OAR 340-41-(basin)(3):

> *"Where the natural quality parameters of water of the (Basin) are outside the numerical limits of the above as-*

Table 1-2: Summary of Oregon pH Criteria

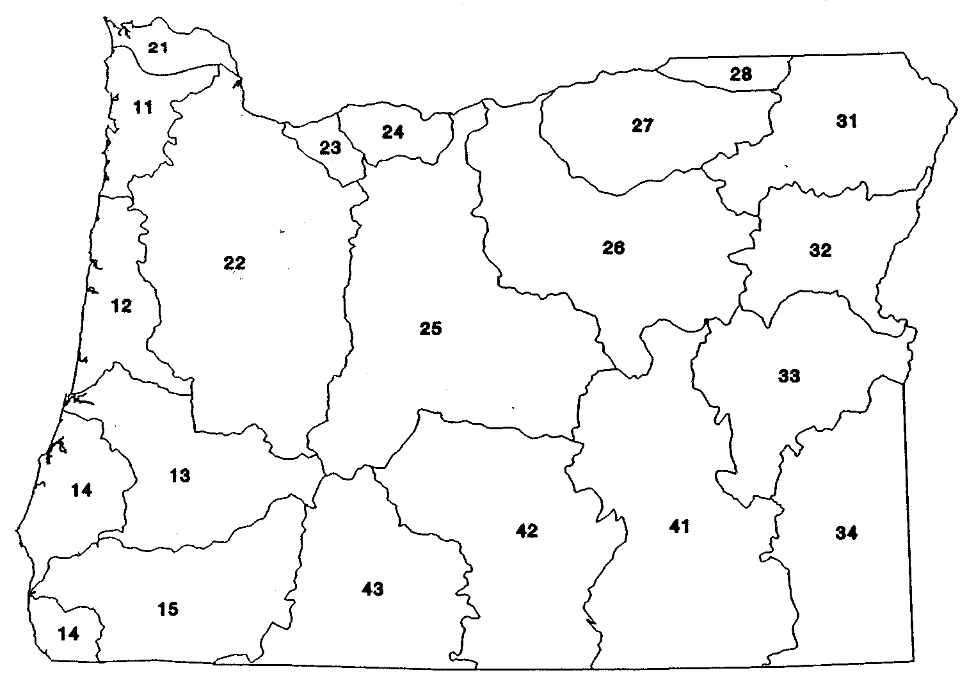
BASIN	MARINE	ESTUARINE	FRESHWATER	OTHER
North Coast – Lower Columbia Basin	7.0-8.5	6.5-8.5	6.5–8.5	NA
Mid Coast Basin	7.0-8.5	6.5-8.5	6.5–8.5	NA
Umpqua Basin	7.0-8.5	6.5-8.5	6.5–8.5	NA
South Coast Basin	7.0-8.5	6.5-8.5	6.5–8.5	NA
Rogue Basin	7.0-8.5	6.5-8.5	6.5–8.5	NA
Willamette Basin	NA	NA	6.5–8.5	7.0–8.5[a]
Sandy Basin	NA	NA	6.5–8.5	7.0–8.5[a]
Hood Basin	NA	NA	6.5–8.5	7.0–8.5[a]
Deschutes Basin	NA	NA	6.5–8.5	7.0–8.5[a]
John Day Basin	NA	NA	6.5–8.5	7.0–8.5[a]
Umatilla Basin	NA	NA	6.5–8.5	7.0–8.5[a]
Walla Walla Basin	NA	NA	6.5–8.5	NA
Grande Ronde Basin	NA	NA	6.5–8.5	7.0-9.0[b]
Powder Basin	NA	NA	6.5–8.5	7.0–9.0[b]
Malheur River Basin	NA	NA	7.0–9.0	NA
Owyhee Basin	NA	NA	7.0–9.0	NA
Malheur Lake Basin	NA	NA	7.0–9.0	NA
Goose and Summer Lakes Basin	NA	NA	7.0–9.0	7.5–9.5[c]
Klamath Basin	NA	NA	7.0–9.0	NA

LEGEND:

NA — Not applicable a — Columbia River b — Snake River c — Goose Lake

OREGON DRAINAGE BASINS

Basin No.	Basin
11,21	North Coast — Lower Columbia
12	Mid Coast
13	Umpqua
14	South Coast
15	Rogue
22	Willamette
23	Sandy
24	Hood
25	Deschutes
26	John Day
27	Umatilla
28	Walla Walla
31	Grande Ronde
32	Powder
33	Malheur River
34	Owyhee
41	Malheur Lake
42	Goose & Summer Lakes
43	Klamath



SA\Table\WH5409.5B

Figure 1-1: Water Quality Standards — Related Basins of Oregon

signed water quality standards, the natural water quality shall be the standard."

It should be noted that when natural variability causes values to fall outside the range of the pH criteria, there is no remaining assimilative capacity in the waterbody (i.e., no anthropogenic change will be allowed).

1.2.1 Purpose

The pH is a measure of the concentation (activity) of hydrogen, or hydronium, ions in water. It is expressed mathematically as:

$$pH = \log \frac{1}{(H^+)}$$

where H^+ is the amount of hydrogen ions in solution in moles per liter (Reid 1961). A pH value of 7 indicates neutrality, or an equal amount of H^+ and OH^-. Values from 0 to 7 indicate acid waters and from 7 to 14 indicate alkaline waters. Except for special cases like acid bog, natural waters generally fall within the range of 6.0 to 9.0 pH units, and the biota are likewise usually adapted within this range.

The purpose of the pH standard is the protection of aquatic life, principally salmonid or resident fish, which have historically been judged to be the most sensitive beneficial uses. The Oregon State Sanitary Authority adopted a statewide criterion of 6.5–8.5 pH units in 1947. In 1967, the Sanitary Authority revised the statewide criterion to 7.0–8.5 pH units. The present criteria in basin form were adopted by the EQC in 1976.

1.2.2 Technical Basis

The technical basis for the existing pH criteria was largely contained in the technical guidance on pH issued by EPA in 1976. The document recommended the pH ranges of 5.0–9.0 units for domestic water supplies, 6.5–9.0 for freshwater aquatic life, and 6.5–8.5 for marine aquatic life. The two bioassay references on freshwater fish cited by EPA showed a lower limit of about 6.5 for normal development. The upper limit of 9.0 was obtained from only one reference (EIFAC 1969). The larvae of aquatic insects were apparently more tolerant than fish.

The rate of change of pH was reported to be of importance in the toxicity of ammonia, but no attempt was made to relate this to the criterion of 6.5–9.0. Estuarine waters were given the same recommended range of pH 6.5–9.0, based on the vulnerability of adult fishes and oyster larvae. For marine waters substantially deeper than the euphotic zone, a range of 6.5–8.5 with a maximum change of 0.2 pH units was recommended, apparently based on the great buffering capacity of seawater (i.e., such a change would require the addition of a relatively great amount of strong acid or base).

1.3 CONCERNS WITH THE EXISTING RULE

1.3.1 Natural Range Versus Anthropogenic Effects

The existing pH criteria do not bracket the full range of apparent natural variability in pH within Oregon. During the period 1980-1990, the state experienced many technical violations of the criteria, both high and low (see Section 2.1.1, Table 2-2). Values of pH in some coastal streams during winter reached values in the range of 5.8–6.1. Conversely, values of pH in many interior streams reached values in the range of 9.3–9.7. Further, in the Cascade Lakes, about 10 percent of those studied have exhibited pH values below 6.5 (Nelson 1991). While a section of the standards allows for natural variability [OAR 340-41-(basin)(3)], the *Clean Water Act* requires the Department to demonstrate that the values outside the numeric standards are indeed due to natural variability and not to anthropogenic causes. Thus, the question of concern for the triennial review is whether the range of the numeric standard can be widened to account for more of the natural variability while still providing full protection of all beneficial uses.

Buffering Capacity: The capacity of water to neutralize acids or bases is generally called the buffering capacity. Buffering capacity is a natural characteristic which is closely related to alkalinity; alkalinity is related to basin geochemistry and varies between watersheds in Oregon. Although the present pH standard takes into account the generally higher natural pH ranges east of the Cascades, it does not directly take into account the differences in natural buffering capacity in the state. This results in a situation in which addition of a strong acid or base to two waterbodies protected by identical pH criteria could have vastly differing effects on pH, and consequently the aquatic biota.

Meteorological Effects: Rainwater without anthropogenic acids has a pH generally between 5.0 and 5.6 (NADP/NTN 1993). In areas with particularly high rainfall, primarily the Coast Range, which generally has between 60 and 120 inches per year (Taylor and Bartlett 1993), streams may be dominated by rainwater during the rainy season. In such cases, the pH of the streams may be largely reflective of the rainwater pH values. The numeric pH criteria should perhaps allow for these natural pH values.

1.3.2 Most Sensitive Beneficial Use

The 1976, EPA guidance was based largely on laboratory research conducted during the 1960s, and salmonid fish spawning and rearing were clearly thought to be the most sensitive beneficial uses. Since then, an enormous amount of laboratory, mesocosm, and field data on the vulnerabilities of all the aquatic biota to acidification has been collected under acid precipitation programs in North America and Europe. With various fish and amphibian species possibly to be listed as threatened or endangered in the Pacific Northwest, a reevaluation of the beneficial use most sensitive to pH seems advisable.

1.4 LITERATURE REVIEW

1.4.1 Classical Approach to Standard

The classical approach to pH standards has been to formulate numeric criteria which state a range of acceptable pH value. This acceptable range has been generally based on the application of laboratory experiments with fish and invertebrates to what is perceived as the most sensitive beneficial use. Since salmonid fry and eggs have been shown to be more sensitive to pH than are adults, salmonid spawning and rearing have been considered the most sensitive beneficial use.

Another aspect of the classical approach to pH standards is that the range of acceptable pH value is also based in part on the predictable variation in toxicity of other constituents with changes in pH. At the low pH end, toxicity of some metals, including aluminum, increases as acidity increases. Conversely, at high pH values, the toxicity of total ammonia increases as pH increases. These aspects of pH are discussed in Section 2.1.4, respectively.

1.4.2 Innovations

There have been no recent innovations in water quality standards for pH in the United States. Existing innovative water quality standards in other states are summarized in Section 1.4.5.

1.4.3 New Data

An enormous amount of new data related to pH and acid rain has been developed in North America and Europe over the past decade. In the United States, the body responsible for coordinating acid rain research has been the National Acid Precipitation Assessment Program (NAPAP). NAPAP has published a series of 27 technical reports in their *Acidic Deposition: State of Science and Technology* series. Report 13, *"Biological Effects of Changes in Surface Water Acid-Base Chemistry"* (Baker, et al. 1990) summarizes the results of laboratory bioassays, field bioassays, mesocosm experiments, whole-system manipulations, field surveys and long-term monitoring, for the most part conducted over the past 20 years. The following summary is based entirely on this report.

Mechanisms of pH Effect: The most important biological effect of elevated hydrogen ion concentration is probably direct toxicity due to effects on osmoregulation via the sodium transport system. Other factors and chemical constituents play an important role in the indirect toxic effects of pH. The solubility of aluminum increases with decreasing pH, and at pH values under 5.5 units, monomeric (i.e., free) aluminum can be toxic at concentrations as low as 10–50 μg/l. Dissolved organic carbon (DOC) may affect this relationship by complexing, and thereby reducing the availability of, the aluminum. In general, increasing concentrations of calcium tend to mitigate the toxicity of aluminum. Other base cations, including sodium, potassium and magnesium, may also tend to mitigate aluminum toxicity. In addition to aluminum, other metals may increase in toxicity or availability at low pH: these metals include manganese, zinc, copper, and cadmium.

The Microbial Community: Microbial communities are responsible for the breakdown of organic matter and nutrient regeneration. They comprise bacteria, fungi, yeasts, molds, protozoans and other microorganisms found in the water, on substrates and in sediments. A pH of 5.5 or so seems to be a threshold below which several effects on the microbial community may be observed. These include a decrease in the overall rate of decomposition and a decrease in the rate of nitrification. Bacterial density declines gradually between pH 7.0 and 5.0, and more rapidly between pH 5.0 and 3.0. Overall community respiration in lakes does not seem to be measurably affected by acidification.

Phytoplankton: The phytoplankton are microscopic algae which are responsible for most of the primary production in lakes and slower moving rivers. Phytoplankton species richness and diversity tend to decline with acidification, with shifts in species composition occurring between pH 6.0 and 5.0. Overall phytoplankton biomass and primary production appear to be less subject to change with decreasing pH. Phytoplankton may also be affected by changes in the availability of nutrients influenced by pH, but nitrogen cycling is most subject to acidification, whereas phosphorus is more likely to be the limiting nutrient in freshwater.

Zooplankton: The zooplankton are a taxonomically diverse group of small animals inhabiting the water column, filling the functional ecological niches of herbivores and predators. Some species of zooplankton have been demonstrated to be acid sensitive, whereas others have been shown to exhibit increased dominance under acidic conditions. Some studies have shown decreases in species richness, but other community measures are unclear. Zooplankton may also be affected indirectly by pH through its effects on the availability of food or predators.

Periphyton: The periphyton are attached forms of microscopic algae which are principally responsible for the primary production in faster moving streams. Periphyton respond similarly to acidification to the phytoplankton, with gradual decreases in species richness and shifts in community composition. However, some periphyton taxa, such as the bluegreen algae, have been shown to be acid sensitive, and other groups, such as the filamentous green algae, have been shown to increase in relative abundance during acidification.

Benthic Macroinvertebrates: Benthic macroinvertebrates are another taxonomically very diverse group, with the one common thread that they live within or on the substrate. They fill a variety of ecological niches. The community metrics of species richness, total biomass, diversity and density all decrease with decreasing pH. Some species of insects, crustacea and mollusks have been shown to be acid sensitive. Decreases in the range 7.0 to 6.0 may result in the loss of some species. Both direct and indirect pH toxicity as well as the indirect effects of food or predation level may affect the benthic community.

Fish: Fish have been subjected to a fairly comprehensive variety of research on acidification and pH-related impacts. Many studies show that acidification can cause the loss of acid-sensitive species and a decline in species richness. The effects of low pH are more pronounced at low concentrations of calcium; both the direct pH toxicity and that of aluminum result from osmoregulatory failure. Some fish species are sensitive to pH values as near neutral as 6.5 to 6.0, and many species of the cyprinid and dace families are sensitive in the range 6.0–5.5 pH units. Critical pH values for common species of fish range from about 6.2 to 4.6 pH units, with that for the common shiner at about 6.0, the smallmouth bass and rainbow trout at about 5.5, the white sucker at about 5.2, and the yellow perch at about 4.8 pH units.

Amphibians: Temporary ponds are very important to amphibians; 30 percent of all salamanders and 50 percent of all frogs in North America use them for breeding. In the areas surveyed (mainly the eastern United States), low pH may affect the sensitive species in 20 to 30 percent of the temporary ponds. The direct and indirect toxicity of pH to amphibians is dependent on species and life stage. The range of toxic pH to common amphibian species extends from 6.0 on the high end to about 3.5 on the low end.

Waterfowl and Mammals: The effects of low pH on waterfowl and mammals have been generally difficult to demonstrate. Piscivorous (fish eating) waterfowl and mammal species have been shown to be impacted by fish losses caused by acidification. Cadmium concentration increases in large mammalian herbivores, and elevated mercury concentrations in piscivorous waterfowl and mammals have also been observed.

The most important overall effects of low pH upon the biota are summarized in Table 1-3, taken from Baker, et al. (1990). These may be summarized by noting that only very slight changes have been documented with pH decreases from 6.5 to 6.0, but significant changes begin to occur when the pH is further reduced below 6.0.

1.4.4 EPA Guidance/Criteria/Recommendations

EPA has not issued technical guidance on pH since that included in the 1986 "Gold Book" (EPA 1986). This guidance was identical to that issued in the 1976 "Red Book" (EPA 1986). There are no plans at present for EPA to update or modify the existing guidance for pH criteria (David Sabock, personal communication). The existing guidance recommends numeric criteria designating an acceptable pH range of 6.5–9.0 units for freshwater and 6.5–8.5 units for marine waters.

Table 1-3: General Summary of Biological Changes Anticipated With Surface Water Acidification[a]

pH Range	General Biological Effects
6.5 to 6.0	Small decrease in species richness of phytoplankton, zooplankton, and benthic invertebrate communities resulting from the loss of a few highly acid-sensitive species, but no measurable change in community abundance or production. Some adverse effects (decreased reproductive success) may occur for highly acid-sensitive fish species (e.g., fathead minnow, striped bass).
6.0 to 5.5	Loss of sensitive species of minnows and dace, such as blacknose dace and fathead minnow; in some waters decreased reproductive success of lake trout and walleye, which are important sport fish species in some areas. Visual accumulations of filamentous green algae in the littoral zone of many lakes, and in some streams. Distinct decrease in the species richness and change in species composition of the phytoplankton, zooplankton and benthic communities, although little if any change in total community biomass or production. Loss of a number of common invertebrate species from the zooplankton and benthic communities, including zooplankton species such as *Diaptomus silicis*, *Mysis relicta*, *Epischura lacustris*; many species of snails, clams, mayflies, and amphipods, and some crayfish.
5.5 to 5.0	Loss of several important sport fish species, including lake trout, walleye, rainbow trout, and smallmouth bass; as well as additional non-game species such a creek chub. Further increase in the extent and abundance of filamentous green algae in lake littoral areas and streams. Continued shift in the species composition and decline in species richness of the phytoplankton, periphyton, zooplankton, and benthic invertebrate communities; decreases in the total abundance and biomass of benthic invertebrates and zooplankton may occur in some waters. Loss of several additional species common in oligotrophic waters, including *Daphnia galeata mendotae*, *Diaphanosoma leuchtenbergianium*, *Asplanchna priodonta*; all snails, most species of clams, and many species of mayflies, stoneflies, and other benthic invertebrates. Inhibition of nitrification.
5.0 to 4.5	Loss of most fish species, including most important sport fish species such as brook trout, and Atlantic salmon; few fish able to survive and reproduce below pH 4.5 (e.g., central mudminnow, yellow perch, and in some waters, largemouth bass). Measurable decline in the whole-system rates of decomposition of some forms of organic matter, potentially resulting in decreased rates of nutrient cycling. Substantial decrease in the number of species of zooplankton and benthic invertebrates and further decline in the species richness of the phyto-plankton and periphyton communities; measurable decrease in the total community biomass of zooplankton and benthic invertebrates in most waters. Loss of zooplankton species such as *Tropocyclops prasinus mexicanus*, *Leptodora kindtii*, and *Conochilis unicornis*; and benthic invertebrate species, including all clams and many insects and crustaceans. Reproductive failure of some acid-sensitive species of amphibians such as spotted salamanders, Jefferson salamanders, and the leopard frog.

LEGEND:

a — From Baker, et al. (1990)

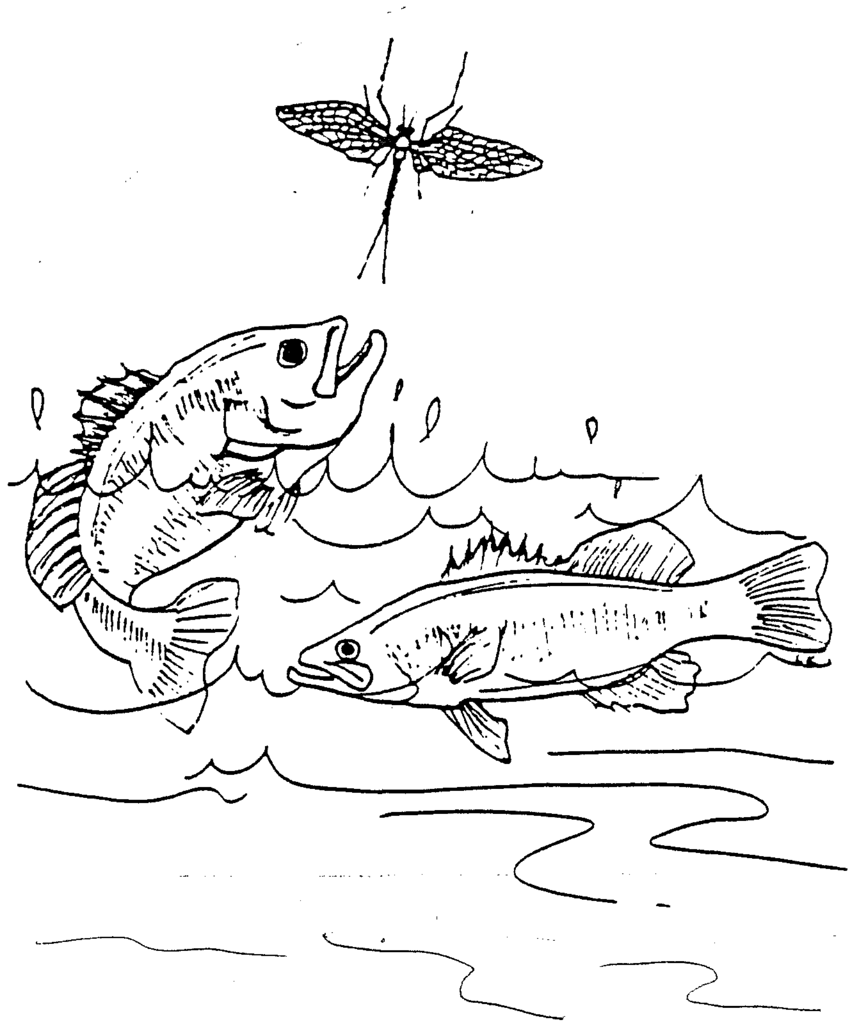
1.4.5 Information from Other States

The standards for pH vary greatly between the states and have been summarized by EPA (EPA 1988); the following section is based entirely on that summary.

All 50 states have adopted pH standards in which the numeric criteria are generally based upon an acceptable range of pH. In most states, the simple range is stratified by water classifications, different ranges being applied to different classes based on use or natural waterbody characteristics (e.g., freshwater versus marine). In some states, a maximum variation, such as 0.5 or 1.0 pH unit is accepted within the overall range. Many states, including Oregon, have a clause in which the naturally occurring value becomes the standard when outside the range of the numeric criteria.

A number of deviations from the typical standard are noteworthy. While no state has a pH standard which takes buffering capacity directly into account, three states (Delaware, Florida and Pennsylvania) do have separate standards for alkalinity stratified by natural alkalinity or by use. Alaska's pH standard disallows the addition of substances which will increase the buffering capacity of the water. Some states exempt certain waterbodies from pH standards. For example, Ohio exempts acid mine drainage streams which flow over sandstone, while in North Carolina, swamp waters are exempted. Finally, a few states include references to diurnal variability in their pH standards. Indiana allows daily changes correlated to photosynthesis, and Arkansas and Tennessee allow a 1.0 pH unit fluctuation over 24 hours.

The purpose of the pH standard is the protection of aquatic life, principally salmonid or resident fish, which have historically been judged to be the most sensitive beneficial uses.



2

TECHNICAL ANALYSIS OF POTENTIAL OPTIONS

2.1 ISSUES

2.1.1 Natural Range Versus Anthropogenic Effects

In developing a pH standard, it is necessary to be able to separate natural from anthropogenic effects. An underlying assumption in developing water quality standards is that the natural conditions represent the ideal and will provide for the greatest beneficial use. This assumption is primarily supported by the concept that native biological populations are adapted to natural conditions. It is often necessary to make this assumption because specific data do not exist.

Both natural and anthropogenic factors control pH. At any given location within an aquatic system, the observed pH reflects the chemical make-up of the water at that point. Any factor that affects that chemical make-up can or will affect the pH. The source of the water is a primary factor. The source is usually a drainage basin. Drainage basins typically have both surface water and groundwater components. In some aquatic systems, such as alpine lakes, the area of the drainage basin may be quite small, and so the impact of the drainage area is less and the waters' chemical make-up more closely represents its original source — precipitation. Water picks up dissolved substances from the land it passes over or through. Biological processes also affect the chemical make-up of the water. Any human activity that affects the source of the water or biological processes or contributes chemicals directly to the water may affect the pH.

Drainage basins vary widely in Oregon. Crater Lake has a drainage basin barely larger than its surface area, while the Columbia River drains considerable portions of five states and one Canadian province. Aside from the Columbia and Snake rivers, there are 19 major drainage basins in Oregon (Table 1-2). Water quality within these drainage basins is affected by the natural factors of: precipitation, vegetation, geology, and hydrology. Humans can affect water quality by direct discharges from storm sewers, municipalities, and industries. Nonpoint sources such as septic systems, urban runoff, agriculture, and forestry affect water quality via runoff and groundwater contamination. Urbanization, agriculture, and forestry affect the natural controlling factors of vegetation and hydrology.

Rivers: The dominant natural factor affecting water quality in most basins is precipitation. Geological material weathers and releases minerals through mineralization at a fairly consistent rate controlled by moisture and temperature. In basins with open drainage, precipitation constantly dilutes the total dissolved solids; whereas in closed systems where

Table 2-1: Summary of Ambient River Monitoring pH Data January 1, 1983 to December 31, 1992

BASIN NAME	pH (SU)[a]	pH STANDARD DEVELOPMENT	TOTAL ALKALINITY AS $CaCO_3$ (mg/L)	CONDUCTIVITY (μmhos/cm @ 25°C)	NUMBER OF DATA POINTS
North Coast	7.2	0.32	19	66	173
Mid Coast*	7.1	0.25	15	54	44
Umpqua	7.8	0.47	35	35	868
South Coast*	7.3	0.38	25	92	336
Rogue	8.1	0.34	63	260	1,539
Willamette	7.3	0.40	25	105	8,924
Sandy/Hood	7.5	0.36	20	51	154
Deschutes	8.1	0.46	55	119	453
John Day	8.1	0.97	115	285	879
Umatilla	8.3	0.61	49	115	203
Walla Walla**	–	–	–	–	–
Grande Ronde	8.1	0.58	70	144	5,209
Powder	8.1	0.33	164	346	163
Malheur River	8.2	0.32	364	883	344
Owyhee	7.9	0.32	143	357	126
Malheur Lake**	–	–	–	–	11
Goose & Summer Lakes**	–	–	–	–	6
Klamath	8.8	0.52	68	128	4,722

LEGEND:

a — Numbers are median values. * — Includes estuary data. ** — Insufficient data.

evaporation equals precipitation, total dissolved solids tend to increase over time. Precipitation also influences vegetation and soil formation which are important drainage basin characteristics impacting pH. Alkalinity and acidity are strongly correlated to total dissolved solids. These factors control the buffering capacity of the water, that is the resistance to changes in pH as the result of the addition of a given amount of acid or base. Poorly buffered waters are more likely to experience wide fluctuations in pH. Table 2-1 gives median pH, alkalinity, and conductivity values for Oregon river basins. Conductivity is proportional to total dissolved solids.

Biological processes affect pH in surface water systems primarily as a result of photosynthesis and respiration. As aquatic plants and algae photosynthesize, they produce oxygen and consume carbon dioxide. Plants and animals consume oxygen and produce carbon dioxide through respiration. This is important because the carbonate system which is composed of carbon dioxide, carbonic acid, and carbonate ions is the principle system regulating pH in water. The diurnal pattern of photosynthetic activity results in diurnal fluctuations in dissolved oxygen, dissolved carbon dioxide, and pH. Diurnal peaks in dissolved oxygen and pH typically occur in late afternoon. The lowest dissolved oxygen and pH occur in early morning just prior to the initiation of photosynthetic activity. The extent of biological activity impacts on pH is proportional to the amount of biological activity. In nutrient enriched streams higher levels of biological activity create greater fluctuations in pH. Nutrient enrichment often occurs as a result of human activities.

An examination of pH standard exceedances in Oregon (Table 2-2) shows that the Deschutes, Klamath, Grande Ronde, Umatilla, and John Day River Basins have the highest percent violations of the current basin pH standards. These violations are in almost all instances high end (i.e., alkaline) violations.

Table 2-2: Summary of Oregon pH Violations by Basin

Basin	Stations Processed	Data Values Checked	High-End Violations	Low-End Violations	Percent Violations
North Coast and Mid Coast	387	2,251	3	115	5
Lower Columbia	24	22	2	0	9
Umpqua	83	1,164	75	23	8
South Coast	245	688	0	16	2
Rogue	116	1,851	140	24	9
Willamette	701	9,725	282	24	3
Sandy/Hood	57	220	1	7	4
Deschutes	107	635	70	2	11
John Day	39	470	96	0	20
Umatilla	38	265	71	2	28
Walla Walla*	–	–	–	–	<1
Grande Ronde	100	5,137	1,681	1	33
Powder	14	125	4	0	3
Malheur River	23	162	2	0	2
Owyhee	18	514	2	0	0
Malheur Lake*	–	–	–	–	<1
Goose & Summer Lakes*	–	–	–	–	<1
Klamath	58	2,915	933	16	33

LEGEND:

* — Insufficient data for analysis.

Violations typically occur in the summer or when photosynthetic activity is at its peak. These basins are characterized by a relatively low level of human activity. Forestry and range land grazing are the primary human activities dominant in these water sheds. These activities would only have minimal impact on nutrient enrichment. They probably have affected water quality by altering hydrology, riparian areas, and shading. The impacts of these human activities on changes in pH is difficult to quantify. Pristine river basins in similar ecological zones that can be used for comparison do not exist. Likewise, historical data collected before these basins were affected also does not exist. It is therefore very difficult to determine what natural pH concentrations were in these basins. However, frequent pH standard exceedances in these basins which have: (1) minimal nutrient enrichment, and (2) consistent violations in the upper portions of these water sheds where human impacts are minimal would indicate that the current pH standard may be near or below natural pH ranges in these watersheds.

Low end pH (i.e., acid) violations in flowing waters are found almost exclusively in the coastal streams. These violations occur primarily during winter high rainfall events. As indicated in Table 2-1, coastal streams are very poorly buffered. Groundwater contributions to flow in coastal streams is minimal and flows tend to be very flashy in these streams with rapid response to rainfall events. The pH of rainfall would normally be near 5.7. No human activities have been recognized as occurring in these watersheds that would easily account for low pH in the streams. It is therefore likely that the current low end pH standard in the coastal basins of 6.5 is above naturally occurring pH conditions that occur in coastal streams during high rainfall events. These pH values seem to represent naturally occurring pH concentrations occurring during rainfall dominated runoff events.

Perhaps one of the best ways to determine natural pH ranges within a basin is to look at fall, winter, and spring values and compare them to summer values. In the winter, river flows are up, biological activity is reduced, and temperatures are lower. This has the effect of minimizing the impact from human sources. The pH values observed are more likely to reflect pH equilibrium values resulting from the natural dissolved common ion concentrations found in a basin. It might be expected that winter pH values would average less than summer values because of the reduced biological activity. While this generally holds true, in many basins, particularly those with higher alkalinities, winter pH medians are near or even greater than summer values. The four river basins in the state with the highest rate of pH standard violations under existing criteria are Klamath, Umatilla, Grande Ronde, and John Day (Table 2-2). The median summer/fall pH ranges for those for basins are respectively: 9.0/8.0, 8.4/7.7, 8.3/8.0, and 8.1/8.2. Three out of the four have median winter pH values of 8 or greater. Peak pH concentrations in summer would be expected to reach even higher diurnal ranges as a result of increased diurnal biological activity. These data indicate that natural pH ranges in these basin may be near or above the present standard of 8.5.

In addition to the difficulty of determining what the natural pH is in a given basin, a second difficulty arises in determining what level of diurnal variability is natural. Diurnal monitoring that has been conducted in the Grande Ronde River Basin over the last few years can shed some light on this question. The Minam River, which is in the Grande Ronde Basin is contained almost entirely within a wilderness area. It is probably the most pristine river in the state. Although the hydrology and geology of the Minam are considerably different than the upper Grande Ronde, it was looked at as a control. Diurnal pH variability in the Minam was measured at about 0.6 pH units. Monitoring in the Grande Ronde River above La Grande and therefore above most agricultural, and all industrial and municipal sources indicated diurnal variability commonly in the 1.2 to 1.6 pH unit range. Monitoring in reaches downstream from industrial, municipal, and agricultural sources indicated diurnal variability usually in the 1.4 to 2.5 pH unit range. This data indicates that natural variability exists that is at least 0.6 pH units and may be as high as 1.6 pH units in the Grande Ronde water shed.

Cascade Lakes: Nelson and Delwiche (1983) surveyed 63 lakes in the Oregon Cascades. Field pH values ranged from 5.47 to 9.51, while laboratory (air-equilibrated) pH ranged from 5.83 to 7.91. The wider range for field measurements reflects the non-equilibrium CO_2 conditions caused by photosynthesis and respiration in natural systems. Cultural (anthropogenic) nutrient enrichment can exacerbate pH fluctuations by increasing biological productivity. Anthropogenic effects are thought to be negligible for most Cascade lakes studied. Table 2-3 is a summary of chemical parameters in the Oregon Cascade lakes.

The Western Lake Survey (Landers, et al. 1987; WLS) used a stratified random sampling approach to obtain statistically valid data descriptions of lake chemistry. Forty-one lakes were sampled in the Oregon Cascades. Nelson (1991) has summarized pH and other chemistry data for Cascade lakes in Washington, Oregon, and California. Table 2-4 presents the distribution of alkalinity and pH in Oregon Cascade lakes from the WLS.

Oregon's Cascade lakes vary naturally in pH from about 5.5 to 9.5. Air-equilibrated pH values range from about 5.8 to 8.0. The wider range natural pH variation reflects CO_2 disequilibrium from biological photosynthesis and respiration. Wider pH variations are caused in nutrient-enriched systems that are poorly buffered (low alkalinity) and this effect is intensified by anthropogenic enrichment. Oregon's Cascade lakes are very poorly buffered but are generally not anthropogenically enriched with nutrients.

Other Oregon Lakes: Table 2-5 summarizes instantaneous observations of pH in Oregon lakes other than those in the Cascades (Johnson, et al. 1985). Reservoirs are excluded from this data base and lakes in the Coast Range and Eastern Oregon are discussed separately.

Of the 26 coastal lakes profiled by Johnson, et al. (1985), pH values were reported for 25. Only one lake had a pH value below 6.5, and that lake (Horsfall/Spirit in Coos County) is a very shallow dunal lake (maximum depth 3 ft.) in Oregon Dunes National Recreation Area. The lake has no surface inlet and its pH is most likely influenced by the surrounding dense growth of pines and other conifers with no anthropogenic influence. Two lakes, Eckman and Devil's, had pH values above 8.5. Eckman Lake, an impoundment and possibly seawater-influenced from tides on the Alsea River,

Table 2-3: Summary of Chemical Data for Oregon Cascade Lakes[a]

Parameter	Number of Lakes	Mean	Standard Deviation	Maximum	Minimum
Laboratory pH	63	6.96	0.59	7.91	5.83
Field pH	63	6.93	0.80	9.51	5.47
Conductivity (μmhos/cm @ 25°C)	63	17.03	13.95	57.68	2.58
Alkalinity (μeq/l)	63	137.60	135.80	526.70	1.05
Calcium (mg/L)	63	1.16	1.02	3.75	0.09
Magnesium (mg/L)	63	0.51	0.49	2.00	0.03
Sodium (mg/L)	63	1.13	0.94	3.90	0.12
Potassium (mg/L)	63	0.47	0.33	1.27	0.04
Sulfate (mg/L)	59	0.28	0.28	2.17	0.03
Chloride (mg/L)	60	0.83	0.62	4.10	0.30
-log, pCO_2 (field)	63	3.35	0.48	2.43	5.33
-log, pCO_2 (lab)	63	3.36	0.15	3.03	3.99
Fluoride (μg/l)	20	11.80	18.10	82.30	< 1.00
Aluminum (μg/l)	8	16.00	16.00	56.00	< 1.00
Total Organic Carbon (mg/L)	6	< 0.10	–	2.80	< 0.10
Silicate (mg/L)	62	7.03	7.27	26.56	0.05
Avg. Σ cations (μeq/l)	61	168.30	136.40	539.40	12.70
Avg. Σ anions (μeq/l)	59	172.90	142.60	578.80	18.00
Σ cations/Σ anions	59	0.99	0.15	1.30	0.39

LEGEND:

a — Source: Nelson and Delwiche (1983).

Table 2-4: Distribution of Alkalinity and pH in Cascade Lakes

Parameter	Data Set	Number of Lakes[c]	Parameter Range				
			<0	0–50	50–200	200–400	>400
Acid Neutralizing Capability (μeq/l)	Western Lake Summary[a]	Sample[d]	0	11	26	4	0
		Population[e]	0	113	275	43	0
	WRRI[b]	Sample[f]	0	14	20	14	3
Parameter	**Data Set**	**Number of Lakes[c]**	**Parameter Range**				
			<5.5	**5.5–6.5**	**6.5–7.5**	**7.5–8.5**	**>8.5**
Air-Equilibrated pH	Western Lake Summary	Sample	0	4	32	5	0
		Population	0	40	338	53	0
	WRRI	Sample	0	16	29	14	0

LEGEND:

a — Western Lake Summary (U.S. EPA year).
b — WRRI (Nelson and Delwiche 1983).
c — Entries represent sample or extrapolated population.
d — Lakes sampled = 41.
e — Population = 431.
f — Lakes sampled = 51 (Source: Nelson — 1991).

Table 2-5: Instantaneous pH Values in Oregon Non-Cascade Lakes[a]

COASTAL LAKES		EASTERN OREGON LAKES		EASTERN OREGON LAKES *(Cont.)*	
NAME	pH VALUE	NAME	pH VALUE	NAME	pH VALUE
Clear Lake (Lane County)	7.0	Abert Lake	10.1	Jubilee Lake	7.3
Devil's Lake	8.9	Cultus Lake	7.5	Langdon Lake	6.9
Garrison Lake	8.0	Davis Lake	8.2	Lava Lake	7.9
Mercer Lake	7.7	East Lake	8.0	Little Cultus Lake	8.1
Munsel Lake	7.0	Elk Lake	8.2	Little Lava Lake	7.8
Silticoos Lake	7.5	Goose Lake	9.3	Mann Lake	8.7
Sutton Lake	7.0	Malheur Lake	7.8	Minam Lake	
Tahnenitch Lake	7.1	Owyhee Lake	8.4	Mirror Lake	7.3
Tenmile Lake	7.0	Paulina Lake	8.4	North Twin Lake	8.2
Woahink Lake	7.2	Phillips Lake	8.2	Olive Lake	7.6
Cape Meares lake	7.4	Upper Klamath Lake	8.1	Penland Lake	8.0
Clear Lake (Douglas County	7.4	Wallowa Lake	8.1	South Twin Lake	8.3
Cleawox Lake	6.8	Agency Lake	9.6	Sparks Lake	6.5
Coffenbury Lake	7.6	Anthony Lake		Spring Lake	
Collard lake	7.0	Crump Lake	8.0	Strawberry Lake	6.5
Croft Lake	6.8	Delintment Lake	8.0	Summer Lake	9.7
Eckman Lake	9.3	Devil Lake (Klamath County)	7.9	Upper Cow Lake	7.8
Eel Lake	7.4	Devil's Lake (Deschutes County)		Walton Lake	8.3
Floras Lake	7.6	Dog Lake	7.6		
Horsfall/Spirit Lake	6.1	Fish Lake (Baker County)	7.0		
Lytle Lake	6.7	Fish Lake (Harney County)	7.2		
North Tenmile Lake	7.1	Glacier Lake	7.3		
Saunders Lake		Harney Lake	9.5		
Smith Lake	7.8	Harriette Lake			
Sunset Lake	8.2	Hart Lake	8.0		
Threemile Lake	7.6	Hosmer Lake	7.1		
Number	**25**			**Number**	**39**
Mean	**7.4**			**Mean**	**8.0**
Median	**7.3**			**Median**	**8.0**
Low	**6.1**			**Low**	**6.5**
High	**9.3**			**High**	**10.1**

LEGEND:

a — Source: Johnson, et al. (1985)

might be excluded. Devil's Lake is highly eutrophic from cultural influence, and thus does not represent natural conditions. Overall, it appears that Oregon coastal lakes could occasionally have natural pH values below 6.5, but above 6.0. Incidences of pH values greater than 8.5 do not appear to be natural.

Of the 44 eastern Oregon lakes, profiled by Johnson, et al. (1985), pH values were reported for 39. Reflective of the stream chemistry data, these lakes had much higher natural pH values than the coastal lakes, with mean and median pH values of 8.0. No lakes had pH values below 6.5, but six had values above 8.5, with a maximum value of 10.1. Of these six, five are closed basin lakes (no outlet) in the Great Basin, and are thus naturally alkaline. The sixth lake, Agency, is part of Upper Klamath Lake, and is hypereutrophic from primarily natural conditions. Overall, eastern Oregon lakes do not appear to have natural pH values below 6.5. Closed basin lakes, however, have natural pH values above 8.5 due to their evaporative concentration of alkaline components. With a median pH value of 8.0, it is likely that many other eastern Oregon lakes have diurnal and seasonal fluctuations of pH above 8.5.

- ***Buffering Capacity:***

Buffering capacity is the ability of water to resist a change in pH with the addition of a given amount of acid or base. Buffering capacity is determined by measuring alkalinity and acidity and is reported as equivalents of $CaCO_3$ in mg/L. A good data base exists for alkalinity in Oregon waters. Acidity data is generally not available. Table 2-1 summarizes alkalinity data for Oregon drainage basins. This data should be viewed with some caution because it combines data from different rivers and sites within a basin. Within a given basin there can be considerable variability in alkalinity values observed. As was discussed in Section 2.1.1, alkalinity is generally strongly correlated to total dissolved solids and conductivity.

Buffering capacity in Oregon water increases from west to east. The median alkalinity in the Mid Coast Basin was 15 as mg/L of $CaCO_3$ and the median alkalinity in the Malheur River Basin was 229 as mg/L of $CaCO_3$. Although the alkalinity of some streams that are found in arid areas such as the Umatilla may be relatively low (49 mg/L), the source of the water in these areas is usually a high mountain region of moderate precipitation (Blue Mountains). The geology of the drainage basin also has a pronounced effect on alkalinities. Areas with limestone formations such as the Wallowa River and Applegate Rivers have significantly higher alkalinities than nearby rivers draining basalt areas. Discharge of water from reservoirs also has a major impact on alkalinity. Typically, reservoir water is stored up during spring runoff and has a low alkalinity. Alkalinities are lowest during periods of high surface runoff (winter and spring) and highest during periods when groundwater discharge is dominant in stream flow (summer and fall).

Sufficient data do not exist to correlate diurnal pH fluctuations with alkalinity. The variance of pH as indicated by standard deviation (see Table 2-1) may be more of an indication of seasonal and interbasin variability than variability as a function of alkalinity. With the exception of the John Day River, the most highly buffered river basins in the state show a very low rate of pH standard exceedances. The lower Malheur river is one of the most nutrient enriched rivers in the state. Much of the enrichment can be attributed to agricultural activities. This river also has one of the highest alkalinities. The Malheur had one of the lowest percentage (2 percent) pH violations of any river in the state. The low number of pH violations may be at least partially attributed to the high buffering capacity of the stream.

There is no evidence that anthropogenic discharges, either point or nonpoint, have significantly affected buffering capacity in Oregon streams. Changes in flow and sources of water resulting from dams, diversions, irrigation withdrawal, and other water control projects is the most significant anthropogenic factor affecting buffering capacities in Oregon streams.

- ***Meteorological Effects:***

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) collects field data at two stations in the Oregon Coast Range and at one in the Oregon Cascades as part of a long-term atmospheric deposition network (NADP/NTN 1993). The Coast Range stations are Alsea Guard Ranger Station (44° 23′ 13″ N., 123° 37′ 23″ W.), and Hyslop Farm (44° 38′ 05″ N., 123° 11′ 24″ W.). The Cascade station is at Bull Run Reservoir (45° 26′ 52″ N., 122° 08′ 53″ W.).

Rainfall rates in the Coast Range are strongly seasonal, with peak rainfall typically occurring during the months of November, December, and January. Normal annual precipitation is between 65 and 90 inches at the coast, and may reach 200 inches at higher elevations (Taylor 1993a). The average-

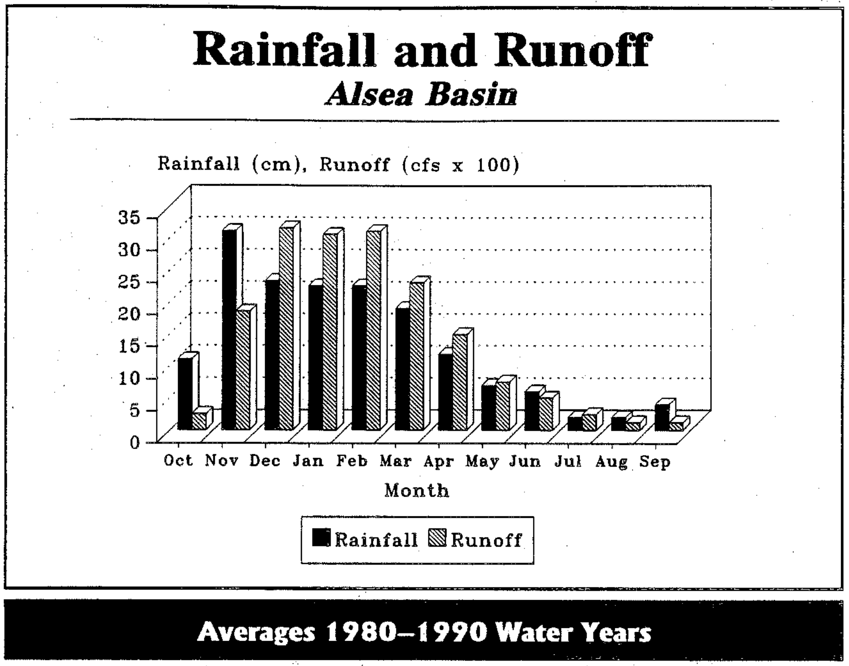


Figure 2-1: Monthly Average Rainfall and Runoff in The Alsea Basin from 1980 to 1990

annual precipitation at Alsea is 92 inches. Rainfall and runoff rates are very closely related in the Coast Range. Figure 2-1 shows histograms of the average monthly rainfall and runoff in the Alsea basin during the period 1980 to 1990. The runoff rate tends to lag rainfall somewhat during the fall months, but once the soil becomes saturated, from December through April, runoff is certainly dominated by water of a very low residence time.

The precipitation-weighted annual average pH values at the Alsea Ranger Station ranged from 5.32 to 5.54 between 1979 and 1991; those at nearby Hyslop Farm ranged from 5.37 to 5.57 between 1983 and 1991 (NADP/NTN 1993). The average alkalinities in Coast Range streams range from 15 (mid-coast) to 25 (south coast) mg/L as $CaCO_3$ (see Table 2-1). Considering the relationship shown in Figure 2-1, it follows that the pH values observed in runoff in the Coast Range are subject to a great influence from rainwater pH values, especially during the months of December through April.

Precipitation rates in the northern Oregon Cascades are also strongly seasonal, with peak rainfall and/or snowfall from November through March averaging over 75 percent of the annual total (Taylor 1993b). Typical annual precipitation is between 45 and 87 inches on the west side of the Cascade crest. Most of the area east of the crest is in the Cascade rain shadow and receives less than 12 inches per year (Taylor 1993b). The precipitation-weighted annual average pH values at Bull Run Reservoir ranged from 5.16 to 5.30 between 1982 and 1991 (NADP/NTN 1993).

2.1.2 Most Sensitive Beneficial Use

Given the limited amount of knowledge of the effects of pH upon the aquatic biota, two approaches may be taken in identifying the likely most sensitive beneficial use. First, known sensitivity can be used and extrapolated to similar groups. Some insect larvae, including those of the mayflies, stoneflies and caddisflies are sensitive to low pH in the range 5.5–6.0. Mollusks which secrete calcite shells are also sensitive to low pH in the range 5.5–6.0. A few single species of the minnow family (Cyprinidae) are extremely sensitive to low pH (range 6.0–6.5), yet others are tolerant. The eggs and fry of many salmonid species are sensitive to low pH, and adult salmonids are apparently at least as sensitive as most other fish to low pH. These species include rainbow, brook and brown trout, and chinook salmon. Salmonids are also generally more sensitive to low pH values than are the amphibians, even at the egg or larval stages.

On the other end of the pH scale, salmonid fishes also appear to be at least as sensitive to low hydrogen ion concentrations as other groups. Though no recent data have been generated, studies conducted earlier in the century show salmonids, including both trout and salmon species, to be sensitive to pH in the range 9.2 to 9.7, depending on the species and life stage. Non-salmonid fishes are, with some exceptions, more tolerant of high pH, with sensitivity appearing at or over pH 10 for most species tested (EIFAC 1969). Thus, a conservative approach to identifying the most sensitive beneficial uses by this cursory analysis would include salmonid fish rearing and spawning, resident fish and aquatic life, and possibly anadromous fish passage.

Second, a bottom-up approach can be taken by beginning with already threatened and endangered species. Tables 2-6 through 2-9 present the rare and/or threatened and endangered aquatic plants, invertebrates, fishes, and amphibians of Oregon, respectively. The tables show the status, distribution, and pH sensitivity, if known. We know very little about the specific pH sensitivity of any of these species except a few salmonids (i.e., rainbow trout and chinook salmon), and again must try to extrapolate within taxonomic groups. The net result is essentially equivalent to that stated above — a conservative approach based on sensitive and/or threatened and endangered species would include the resident fish and aquatic life beneficial use as well as those of salmonid rearing and spawning, and possibly anadromous fish passage.

The two approaches, although neither is rigorous, enable us to eliminate any strategy of stratifying the pH criteria by beneficial use. Conservatively applied, both approaches identify all salmonid fish as sensitive to high and low pH. This means that the resident fish and aquatic life beneficial use, which includes trout, should be applied as well as the anadromous fish passage and salmonid spawning and rearing uses. The key factor here is that the resident fish and aquatic life use is present in all waters of the state and at all times during the year. The result of this beneficial use analysis may be stated another way — we simply do not know enough about the effects of pH on the biota to reduce the level of protection at any specific time or place.

2.1.3 Variability

- ***Spatial Variability:***

There is tremendous variety in Oregon geography, from temperate coastal rain forests receiving over 200 inches of precipitation per year to arid high deserts receiving less than 10 inches. The geology includes sedimentary, metamorphic, and intrusive and extrusive igneous rocks. Under these conditions there is also considerable variability in pH ranges.

The coastal area streams typically have the lowest median pH value. Alkalinities are low primarily due to the high rainfall and partially to the geology. Nutrient levels are generally low and as a result biological activity and diurnal variability is also low. Almost all pH standard exceedances are low end violations occurring during the winter time high rainfall episodes. pH values typically range from near 7 in the winter to 7.5 in the summer.

Stream characteristics in the Willamette Valley vary widely. There are slow moving nutrient rich streams such as the Tualatin, Pudding, and Yamhill, and fast flowing nutrient low streams such as the McKenzie and North Santiam. Although nutrient levels and alkalinities vary more in the Willamette valley than they do on the coast, pH values are similar. There are very few violations either high or low, and pH values usually run from the low to the mid 7 range. There are several TMDL streams in the Willamette Valley that have elevated nutrient levels, and low dissolved oxygen that do not normally exceed pH standards.

Alkalinities and median pH values are a little higher in southwest Oregon streams. The South Umpqua and the Umpqua have extensive summer periphyton growth and there is considerable seasonal and diurnal pH variability in these streams. The South Umpqua has numerous summer pH violations. Alkalinities and pH values average higher in the Rogue but seasonal variability is less. There is no data on diurnal variability in the Rogue Basin. The median pH is 7.8 in the Umpqua Basin and 8.1 in the Rogue.

The Klamath Basin is somewhat unique. Upper Klamath Lake provides a tremendous reservoir of nutrient rich water. The lake is naturally eutrophic. Although the alkalinity in the Klamath river is relatively low, the Klamath has the highest median pH in the state at 8.8. There is considerable seasonable variability in the basin in response to seasonal phytoplankton activity.

Median pH values in all of the central and eastern Oregon streams are over 8. The Deschutes, John Day, Umatilla, and Grande Ronde all commonly exceed the 8.5 standard during the Summer. These four streams are all similar in having clear shallow water that encourages extensive periphyton growth. The Burnt, Malheur, and Owyhee rivers have relatively few violations. This may be because of the higher buffering capacities of these rivers. It could also be because they are typically more turbid in the monitored sections. The turbidity would limit the photosynthetic activity.

- ***Diurnal Variability:***

As was discussed in Section 2.1.1, pH varies diurnally in response to diurnal fluctuations in biological activity and dissolved gases. DEQ has conducted diurnal monitoring studies on the Tualatin, Pudding, Yamhill, Coquille, Bear, Rickreall, Klamath, and Grande Ronde rivers and creeks. These studies have indicated diurnal variability

Table 2-6: Threatened, Endangered, and Sensitive Aquatic Plants of Oregon[a]

Species	Habitat	Status	Distribution	Sensitivity
Agrostis microphylla var. *hendersonii* Henderson's bent-grass	Vernal ponds	C2	Jackson County	U
Artemisia campestris var. *borealis* Northern wormwood	Riparian	C1	Sherman County	U
Artemisia ludoviciana ssp. *estesii* Estes' artemisia	Riparian	C2	Crook, Deschutes, Jefferson Counties	U
Astragalus applegatei Applegate's milk-vetch	Alkaline wetland	C1	Klamath County	U
Bensoniella oregona Bensonia	Wetland	C2	Coos, Curry, Douglas, Josephine Counties	U
Calochortus longebarbatus var. *peckii* Peck's mariposa-lily	Wetland, riparian	C2	Crook, Wheeler, Harney Counties	U
Camassia howellii Howell's camas	Wetland	ONHP	Josephine County	U
Cardamine germata Purple tooth-wort	Bog	C2	Curry, Josephine, Jackson Counties	U
Cordylanthus maritimus ssp. *palustris* Salt-marsh bird's-beak	Salt marsh	C2	Coos, Lane, Tillamook Counties	U
Corydalis aquae-gelidae Cold-water corydalis	Riparian	C2	Clackamas, Marion, Multnomah Counties	U
Epilobium oreganum Oregon wil-low-herb	Bog	3C	Douglas, Josephine Counties	U
Erythronium elegans Coast Range fawn lily	Wetland	C2	Lincoln, Polk, Tillamook Counties	U
Gentiana setigera Waldo gentian	Bog	C2	Curry, Josephine Counties	U
Gratiola heterosepala Boggs Lake hedge-hyssop	Wetland	C2	Lake County	U
Hastingsia bracteosa Large-flow-ered rush-lily	Bog	C1	Josephine County	U
Howellia aquatilis Howellia	Wetland	PT	Clackamas, Marion, Multnomah Counties	U
Lepidium davisii Davis' pepper-grass	Clay playa	C2	Malheur County	U
Lilium occidentale Western lily	Bog	C1	Coos, Curry Counties	U
Limnanthes floccosa ssp. *bellingeriana* Bellinger's meadow-foam	Vernal pools	C2	Jackson, Klamath Counties	U
Limnanthes floccosa ssp. *grandiflora* Big-flowered wooly meadow-foam	Vernal pool edges	C2	Jackson County	U
Limnanthes floccosa ssp. *pumila* Dwarf meadow-foam	Vernal pool edges	C1	Jackson County	U

***Table 2-6: Threatened, Endangered, and Sensitive Aquatic Plants of Oregon*[a] (Continued)**

SPECIES	HABITAT	STATUS	DISTRIBUTION	SENSITIVITY
Lomatium bradshawii Bradshaw's lomatium	Wetland	LE	Benton, Lane, Linn, Marion Counties	U
Lomatium Cookii Cook's lomatium	Vernal pool edges	ONHP	Jackson, Josephine Counties	U
Montia howellii Howell's montia	Wetland, riparian	C2	Benton, Columbia, Lane, Linn, Multnomah Counties	U
Myosurus sessilis Sessile mouse-tail	Alkali wetland	C2	Gilliam, Jefferson Counties	U
Perideridia erythrorhyza Red-root yampah	Wetland	C2	Douglas, Klamath Counties	U
Plagiobothrys figuratus ssp. *corallicarpus* Coral seeded allocarya	Vernal pool	C2	Jackson, Josephine Counties	U
Plagiobothrys hirtus Hairy popcorn flower	Wetland	C1	Douglas County	U
Pleuropogon oregonus Oregon semaphoregrass	Wetland	C1	Lake, Union Counties	U
Rorippa columbiae Columbia cress	Riparian, wetland	C2	Crook, Harney, Klamath, Lake, Multnomah, Umatilla Counties	U
Sidalcea nelsoniana Nelson's sidalcea	Wetland	C1	Benton, Linn, Marion, Polk, Tillamook, Washington, Yamhill Counties	U
Sisyrinchium sarmentosum Pale blue-eyed grass	Wetland	C2	Clackamas County	U
Sullivantia oregana Oregon sullivantia	Waterfall	C2	Clackamas, Columbia, Hood River, Multnomah Counties	U
Thelypodium howellii ssp. *spectabilis* Howell's spectacular thelypody	Alkaline wetland	C1	Baker, Malheur, Union Counties	U
Lymbella fryei Moss	Wetland	C1	Coos, Lane Counties	U

LEGEND:

a — Source: Oregon Natural Heritage Program (1991).
C1 — Category 1 candidate.
C2 — Category 2 candidate.
3C — More widespread than previously believed, but recommended for C2 status by Oregon Natural Heritage Program.
LE — Federally listed as endangered.
ONHP — Proposed by Oregon Natural Heritage Program.
PT — Proposed for listing as threatened by USFWS.
U — Sensitivity not known.

Table 2-7: Sensitive Aquatic Invertebrates of Oregon[a]

Species	Status	Distribution	pH Sensitivity	
			<6.5	>9.0
Beer's False Water Penny Beetle	C2	Not known	?	?
Burnell's False Water Penny Beetle	C2	Not known	?	?
Denning's Agapetus Caddisfly	C2	Jackson County	?	?
Newcomb's Littorine Snail	C2	Not known	+	?
Cascades Apatanian Caddisfly	C2	Clackamas and Jefferson Counties	?	?
Vertree's Ceraclean Caddisfly	C2	Not known	?	?
Blue Mountains Cryptochian Caddisfly	C2	Grant County	?	?
Mt. Hood Primitive Brachycentrid Caddisfly	C2	Clackamas and Linn Counties	?	?
Green Springs Mt. Farulan Caddisfly	C2	Jackson County	?	?
Mt. Hood Farulan Caddisfly	C2	Multnomah County	?	?
Tombstone Prairie Farulan Caddisfly	C2	Linn County	?	?
Shortface Lanx (Giant Columbia River Limpet)	C2	Multnomah, Sherman and Wasco Counties	+	?
Columbia Pebblesnail (Great Columbia River Spire Snail)	C2	Multnomah and Wasco Counties	+	?
Schuh's Homoplectran Caddisfly	C2	Josephine and Klamath Counties	?	?
Abellan Hydropsyche Caddisfly	C2	Not known	?	?
Planarian Flatworm (*Kenkia rhynchida*)	C2	Harney County	?	?
Goeden's Lepidostoman Caddisfly	C2	Lincoln County	?	?
Fort Dick Limnephilus Caddisfly	C2	Lane County	?	?
Oregon Snail	C2	Klamath (?), Sherman and Wasco Counties	+	?
Wahkeetna Falls Flightless Stonefly	C2	Multnomah County	?	?
Columbia Gorge Neothremman Caddisfly	C2	Multnomah County	?	?
Alsea Ochrotrichian Micro Caddisfly	C2	Benton, Deschutes and Douglas Counties	?	?
Deschutes Ochrotrichian Micro Caddisfly	C2	Deschutes County	?	?
Vertree's Ochrotrichian Micro Caddisfly	C2	Not known	?	?
Tombstone Prairie Oligophlebodes Caddisfly	C2	Lane and Linn Counties	?	?
Clatsop Philocascan Caddisfly	C2	Clatsop County	?	?
Oregon Pearly Mussel	C2	Not known	+	?
Obrien Rhyacophilan Caddisfly	C2	Josephine County	?	?
Fender's Rhycophilan Caddisfly	C2	Not known	?	?
Haddock's Rhycophilan Caddisfly	C2	Benton County	?	?
One-spot Rhycophilan Caddisfly	C2	Hood River and Lane Counties	?	?
Malheur Cave Amphipod	C2	Josephine County	?	?
Siskyou Caddisfly	C2	Not known	?	?

LEGEND:

a — Source: Oregon Natural Heritage Program 1991.
C2 — Federal category 2 candidate.
+ — Possible acid sensitive; deposits calcite shell.
? — Sensitivity not known.

Table 2-8: Threatened, Endangered, and Sensitive Fishes of Oregon[a]

SPECIES	STATUS	DISTRIBUTION	pH SENSITIVITY[c]	
			<6.5	>9.0
Alvord Chub	Vuln.	Harney County	+	?
Borax Lake Chub	*E		+	?
Bull Trout	Crit.	Cold streams east of Cascades	+	+
California (Pit) Roach	Rare	Goose Lake drainage	?	o
Catlow Tui Chub	Vuln.	Lake and Harney Counties	+	?
Chinook Salmon Lower Columbia — Fall[b]	Crit.	Lower Columbia River streams	Yes	+
Chinook Salmon Snake — Fall[b]	*T	Wallowa County	Yes	+
Chinook Salmon Snake — Spring[b]	*T	Wallowa and Union Counties	Yes	+
Chinook Salmon South Coast — Fall[b]	Crit.	Coos and Curry Counties	Yes	+
Chum Salmon	Crit.	Oregon estuaries from Coos Bay north	+	+
Coastal Cutthroat Lower Columbia Anadromous[b]	Crit.	Lower Columbia River streams	+	+
Coho Salmon Lower Columbia[b]	Crit.	Lower Columbia River streams	+	+
Coho Salmon South Coast[b]	Crit.	Coos and Curry Counties	+	+
Foskett Spring Speckled Dace	*T		+	?
Goose Lake Lamprey	Crit.	Goose Lake drainage	?	o
Goose Lake Sucker	Crit.	Goose Lake drainage	+	o
Hutton Spring Tui Chub	*T		+	?
Lahontan Cutthroat Trout	*T	Malheur County	+	+
Lahontan Redside (Shiner)	Rare	Malheur County	+	?
Lost River Sucker	*E	Klamath County	+	?
Malheur Spotted Sculpin	Crit.	Harney County	?	?
Margined Sculpin	Vuln.	Morrow and Umatilla Counties	?	?
Millicoma Dace	?	Coos County	+	?
Oregon Chub Willamette[b]	Crit.	Lane, Benton and Linn Counties	+	?
Oregon Lakes Tui Chub	Vuln.	Lake County	+	?
Pit Sculpin	Rare	Goose Lake drainage	?	o
Redband/Inland Rainbow Trout	Vuln.	east of Cascades	Yes	+
Sheldon Tui Chub	Crit.	Lake County	+	?
Shortnose Sucker	*E		+	?
Tahoe Sucker	Crit.	Malheur County	+	?
Warner Sucker	*T		+	?
Westslope Cutthroat Trout	Vuln.	Grant County	+	+

LEGEND:

a — From Marshall, et al. 1992.
b — Specific fish stocks of concern.
c — Sensitive life stage; may be egg, fry, or adult.
*T — Threatened; federally listed.
*E — Endangered; federally listed.
+ — Possibly; other members of family sensitive.
o — Not extremely likely due to natural basin pH range.
? — Sensitivity not known.

Table 2-9: Sensitive Amphibians of Oregon[a]

Species	Status	Distribution	pH Sensitivity[b]	
			<6.5	>9.0
Black Salamander	Rare	Jackson and Josephine Counties	o	?
California Slender Salamander	Rare	Coastal Curry County	o	?
Cascade Frog	Crit.	Cascades above 2600 feet	o	?
Clouded Salamander	Crit.	West of Cascade crest	o	?
Cope's Giant Salamander	Crit.	Multnomah, Clackamas and Clatsop Counties	o	?
Del Norte Salamander	Vuln.	Curry, Coos and Josephine Counties	o	?
Foothill Yellow-legged Frog	?	southwestern Oregon	o	?
Larch Mountain Salamander	Vuln.	Multnomah and Hood River Counties	o	?
Northern Leopard Frog	Vuln.	Columbia and Snake River wetlands	o	?
Olympic Salamander	Vuln.	Western Oregon	o	?
Oregon Slender Salamander	Crit.	Cascades east of Willamette Valley	o	?
Red-legged Frog	Crit.	Western Oregon	o	?
Siskyou Mountains Salamander	Vuln.	Josephine and Jackson Counties	o	?
Spotted Frog	Crit.	Oregon east of Cascades	o	?
Tailed Frog	Vuln.	Coast Range, Cascades, Klamaths, and Blue-Wallowas	o	?

LEGEND:

a — From Marshall, et al. 1992.

o — Not likely between pH 6.5 and 6.0.

b — Sensitive life stage; may be egg, embryo, larva or adult.

? — Sensitivity not known.

is greatest in shallow, clear periphyton dominated streams. Rivers like the Tualatin, Pudding, and Klamath that are slow moving and turbid have limited diurnal variability. Diurnal variability in these streams was never more than a couple of tenths of a pH Unit. Diurnal variability of over 2 pH units was common on the Grande Ronde below La Grande. Although data is limited, it would appear from studies conducted so far that diurnal variability is more a function of physical and biological factors specific to a stream than it is related to buffering capacity.

- ***Seasonal Variability:***

Most Oregon streams demonstrate some seasonal pH variability. Factors that affect pH seasonally are precipitation, temperature, photosynthetic activity, turbidity, bottom scour, and flow regulation. Median pH values in most Oregon streams are higher in the summer than they are in the winter. Seasonal variability is greatest in streams like the Klamath that are most affected by photosynthetic activity. Median pH values in the Klamath differed by 1 pH unit between summer and winter. In some streams, there is little seasonal variability in median pH values. The John Day River Basin median summer pH values are slightly lower than fall, winter, and spring. Most streams statewide exhibited a 4 or 5 tenths pH unit difference between summer and winter. Seasonal differences do not appear to be greater in streams that exhibit pronounced diurnal variability than in those that do not. Diurnal variability is seasonal and in those streams where it occurs, it does so primarily in summer and fall.

2.1.4 Interactions With Other Standards

- ***Ammonia:***

Un-ionized ammonia (NH_3), not ammonium (NH_4^+), is toxic to aquatic organisms. Salmonids are especially sensitive. The balance between un-ionized ammonia and ammonium ion is controlled by a pH- and temperature-dependent equilibrium.

At a given temperature, the higher the pH, the more un-ionized ammonia will be present for a given amount of total ammonia. At a given pH, the higher the temperature, the more un-ionized ammonia will be present for a given amount of total ammonia. Table 2-10 shows examples of the percent un-

Table 2-10: Effects of pH and Temperature on Percent Ammonia Present in The Un-ionized Form[a]

At 15° Celsius		At pH 8.0	
pH	Percent NH_3	Temperature	Percent NH_3
6.5	0.08	5	1.1
7.0	0.26	10	1.8
7.5	0.83	15	2.6
8.0	2.6	20	3.7
8.5	7.7	25	5.1
9.0	21.0	30	7.0

LEGEND:

a — Source: APHA (1992).

ionized ammonia present at specific values of pH and temperature.

EPA has not set a single numeric limit for un-ionized ammonia or for total ammonia. Instead, the technical guidance from EPA gives formulas and tables for chronic (4 day average) and acute (1 hour average) toxicity for water with and without salmonids. Two examples of toxicity tables from the guidance (EPA 1986b) for a constant temperature of 15°C and a constant pH of 8.0 are shown in Tables 2-11 and 2-12, respectively. The tables cannot be extrapolated beyond pH 6.5 and 9.0. EPA also states that un-ionized ammonia is likely to be even more toxic above pH 9.0.

Increasing the water quality standard for pH from the present 8.5 to 9.0 would tend to reduce the acceptable levels of total ammonia allowed within the ammonia standard. Reducing the pH standard below pH 6.5 would result in less total ammonia being in the un-ionized form. However, any un-ionized ammonia that is present would be more toxic. Table 2-13 presents pH and un-ionized ammonia concentrations in Oregon basins.

- ***Metals:***

Hydrogen ion activity has a significant impact on the availability and toxicity of metals. The summary below is taken largely from Elder (1988) and Baker et al. (1990).

General Chemistry: Because the hydroxide precipitates of most metals are quite insoluble under natural water pH conditions, the metal is not able to exert a toxic effect. How-

Table 2-11: Ammonia Toxicity at Constant Temperature (15°C) and Varying pH[a]

pH	Chronic (4 day average)				Acute (1 hour average)			
	Salmonid		Nonsalmonid		Salmonid		Nonsalmonid	
6.5	2.2[b]	0.002[c]	2.2	0.002	30	0.026	30	0.026
7.0	2.2	0.06	2.2	0.006	24	0.066	24	0.066
7.5	2.2	0.019	2.2	0.019	14.9	0.128	14.9	0.128
8.0	1.33	0.035	1.33	0.035	6.9	0.184	6.9	0.184
8.5	0.44	0.035	0.44	0.035	2.3	0.184	2.3	0.184
9.0	0.16	0.035	0.16	0.035	0.86	0.184	0.86	0.184

LEGEND:

a — Source: EPA (1986b).

b — Numbers are in mg/L total ammonia (NH_3 + NH_4^+).

c — Numbers are in mg/L un-ionized ammonia.

Table 2-12: Ammonia Toxicity at Constant pH (8.0) and Varying Temperature[a]

TEMPERATURE (°C)	CHRONIC (4 DAY AVERAGE)				ACUTE (1 HOUR AVERAGE)			
	SALMONID		NONSALMONID		SALMONID		NONSALMONID	
0	1.53[b]	0.013[c]	1.53	0.013	8.0	0.065	8.0	0.065
5	1.44	0.018	1.44	0.018	7.5	0.092	7.5	0.092
10	1.37	0.025	1.37	0.025	7.1	0.130	7.1	0.130
15	1.33	0.035	1.33	0.035	6.9	0.184	6.9	0.184
20	0.93	0.035	1.31	0.035	6.8	0.26	6.8	0.26
25	0.66	0.035	0.93	0.035	4.8	0.26	6.8	0.26
30	0.47	0.035	0.67	0.035	3.5	0.26	4.9	0.26

LEGEND:

a — Source: EPA (1986b).
b — Numbers are in mg/L total ammonia (NH_3 + NH_4^+).
c — Numbers are in mg/L un-ionized ammonia.

Table 2-13: Hydrogen ion and Un-ionized Ammonia Concentrations in Oregon Basins[a]

BASIN	NUMBER OF DATA POINTS[b]	pH > 8.0 AND NH_3 > 0.035 mg/L		pH > 8.5 AND NH_3 > 0.035 mg/L		pH > 9.0 AND NH_3 > 0.035 mg/L	
		NUMBER	PERCENT	NUMBER	PERCENT	NUMBER	PERCENT
Columbia River Mainstem	13	0	0.0	0	0.0	0	0.0
North Coast	196	0	0.0	0	0.0	0	0.0
Mid Coast	80	0	0.0	0	0.0	0	0.0
Umpqua	780	9	1.2	9	1.2	8	1.0
Rogue	846	12	1.4	3	0.0	0	0.0
South Coast	303	0	0.0	0	0.0	0	0.0
Willamette	4,524	4	0.1	3	0.1	2	0.0
Sandy	83	0	0.0	0	0.0	0	0.0
Hood	68	0	0.0	0	0.0	0	0.0
Deschutes	404	0	0.0	0	0.0	0	0.0
John Day	348	1	0.3	1	0.3	0	0.0
Umatilla	252	3	1.2	3	1.2	2	0.8
Walla Walla[c]	–	–	–	–	–	–	–
Grande Ronde	509	3	0.6	3	0.6	2	0.4
Powder	231	2	0.9	2	0.9	0	0.0
Malheur River	445	3	0.7	1	0.2	0	0.0
Owyhee	165	1	0.6	0	0.0	0	0.0
Malheur Lake	9	0	0.0	0	0.0	0	0.0
Goose & Summer Lakes	6	1	16.7	1	16.7	1	16.7
Klamath	578	236	40.8	183	31.7	102	17.6

LEGEND:

a — Data from October 1, 1983 through September 30, 1993.
b — Total number of samples including analyses for temperature, pH, and total ammonia.
c — Insufficient data for analysis.

ever, the solubility of the hydroxide precipitate increases sharply as pH decreases. Each metal has its own range where this becomes a factor. Copper, for example, predominates as free ion below pH 6.0.

Another mechanism that reduces the availability of metals is adsorption of the metal to surfaces of iron and aluminum oxides. Under any given set of circumstances, the percentage adsorbed will decrease as pH decreases. The exact pH range where this takes place varies from metal to metal. However, within the range for any metal, a small change in pH results in a significant effect on the percent adsorption of the metal.

Sorption of metals on organic molecules such as humic acids is another means of reducing or increasing the availability of metals. Metal ions form linkages with the carboxyl and sulfhydryl groups. As the pH decreases there are more hydrogen ions to compete for these binding sites, resulting in a higher metal availability.

Hydrogen ion activity also impacts the sensitivity of organisms to a given amount of metal. There are two types of metals. Type I metals (e.g., cadmium, copper and zinc) are less toxic as the pH decreases. Type II metals (e.g., lead) are more toxic at lower pH values. The explanation for the reduction in toxicity at a lower pH is the competition between the metal ions and the hydrogen ions for the same cellular binding sites. There is no complementary explanation for increased toxicity with decreasing pH (Type II metals).

In summary, reductions in pH below "natural" levels will tend to increase metal availability and the toxicity of the amount of metal that is available. The exact pH where various impacts become important is very metal dependent.

Aluminum: As stated in Section 1.4.3, aluminum is the metal of greatest concern at low pH values. The toxicity and availability of aluminum are subject to the general chemistry discussed above, but are highly variable depending on site-specific conditions. The observed effects of aluminum at low pH actually range from severely detrimental to beneficial (Baker et al. 1990). Adverse effects of aluminum have been demonstrated at concentrations as low as 10-50 μg/l; for example, at pH 5.2 an aluminum concentration of 30 μg/l resulted in a significant reduction in brown trout growth in laboratory bioassays (Sadler and Lynam 1987, in Baker et al. 1990). At a pH of 5.1, an aluminum concentration of 75 μg/l caused greater than a 50 percent mortality of Atlantic salmon smolts in mesocosm experiments (Stogheim and Rosseland 1986, in Baker et al. 1990). Yet in other studies, addition of relatively small amounts of aluminum at low pH has resulted in improved survival of some species. Although pH controls speciation, it is not clear whether aluminum hydroxide complexes [$Al(OH)^{2+}$ and $Al(OH)_2^{+}$] or free aluminum ion (Al_{3+}) are the more toxic. The presence of calcium at concentrations as low as 100–150 μg/l tends to mitigate or reduce the toxicity of aluminum at low pH.

Other Metals: The concentrations of manganese and zinc tend to increase rapidly with decreasing pH, whereas the concentrations of copper, cadmium, lead, and chromium may or may not increase at low pH. Manganese, though at high concentrations in acid waters, does not appear to be highly toxic but may have sublethal effects. Zinc does appear to have toxic effects at low pH, and may be more toxic in combination with aluminum and/or copper. Generally, copper, cadmium, lead, and chromium are not viewed as major factors in the biological effects of acidification (Baker, et al. 1990).

- ***Temperature:***

The pH value does not directly affect temperature. Temperature and pH together may affect the toxicity of certain chemical species; these effects are addressed in the discussion of specific constituents in Section 2.1.4 (*Ammonia* and *Metals*). Though temperature and pH are independent stressors, they covary on a seasonal and diurnal basis, and tend to provide maximal stress to an individual or population at the same time. For example, in eutrophic situations, late summer afternoons provide maximum values of temperature, pH, and also dissolved oxygen. While any single parameter may not prove critical, the nature of stress is generally thought to be additive.

- ***Dissolved Oxygen:***

The pH value and dissolved oxygen concentrations tend to covary. Together they may affect the toxicity of certain chemical species, but studies to date are inconclusive.

2.2 IMPLEMENTATION

2.2.1 Sampling and Measurement Issues

- ***Instrumentation:***

All pH measurements should be made with a glass electrode pH meter. Meters need to be calibrated and maintained according to the manufacturer's recommendations. Meters are highly accurate when properly maintained and calibrated when measuring highly buffered solutions. Accuracy diminishes on low ionic strength solutions. Most of Oreg on's surface water is of low ionic strength. Special precautions need to be taken when measuring pH of solutions whose ionic strength differs radically from the calibration buffer. pH electrodes often will not indicate error on standard buffers but will give incorrect readings on low ionic solutions. Low ionic strength buffers can be prepared from dilute acid solutions. An alternative method recommended by some manufacturers for low ionic strength solutions is an adjustment of the ionic strength of the solution by adding a contaminant free KCL solution. Through the use of low ionic strength buffers and careful quality control, pH accuracies will typically be plus or minus 0.2 pH units or better. If pH electrodes are used for long periods of time (years) and only standard buffer solutions are relied upon for calibration and quality assurance, accuracies may fall to plus or minus 0.5 pH units or worse. Calibration and maintenance log books must be kept with all meters.

Hydrogen ion concentration is an unstable parameter and samples need to be analyzed immediately. The maximum legal (EPA) holding time is 2 hours. In most cases this means that pH measurement needs to be conducted in the field.

- ***Diurnal Variability:***

Since pH measurement can vary considerably over a diurnal period, any one particular grab sample may not be representative. Diurnal pH data can be collected using continuous monitoring equipment. This technique is expensive and time consuming. Ambient sampling using grab samples in most cases will give representative pH values. The conditions that produce pronounced diurnal variability are usually apparent to trained sampling personnel.

Any pH standard that would require diurnal monitoring data would be difficult to apply. Such a standard would leave most of the state unassessed. A more practicable approach would be a standard based on a level not to be exceeded. Grab samples could then be used to demonstrate exceedances. If it is suspected that daily maxima are being missed, diurnal monitoring could be employed or sampling scheduled during peak pH periods.

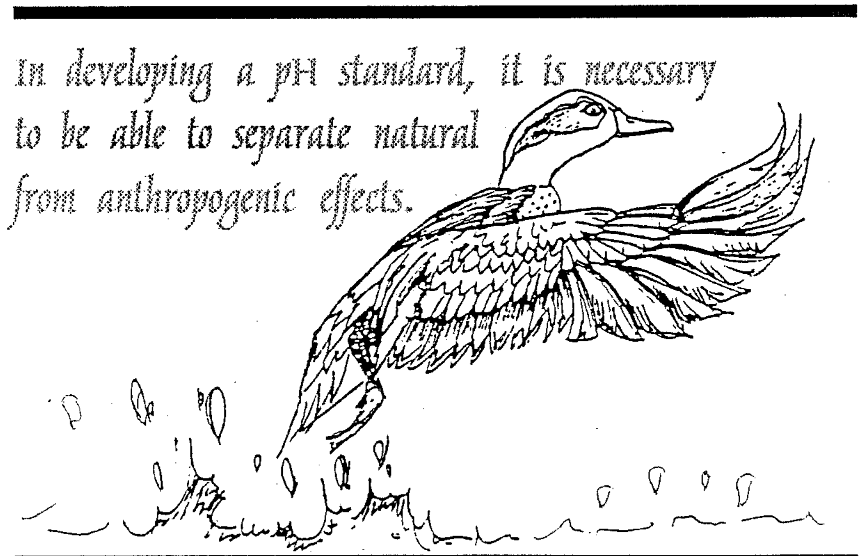
Continuous monitoring can bias data analyses because of the large number of values collected in a short period of time. Such data would be serially correlated and inappropriate for statistical analyses. Data used in determining percent compliance should be based on daily maximum or minimum values evenly distributed over the period of interest.

Prior to a stream being designated as water quality limited for pH, a complete study that determines diurnal variability should be conducted.

2.2.2 Compliance Issues

In order to measure compliance, a standard needs to specify how specific numerical limits are to be applied. A minimum amount of data must be collected to assure a satisfactory level of representativeness over a specific period of time. A significant number of exceedances must be specified to account for outliers.

Determining the source of pH violations is not straight forward. Unlike a chemical constituent that can be measured at an outfall, instream pH is the result of a complex series of chemical and biological interactions that may involve numerous variable natural and anthropogenic factors. In Oregon, pH violations have not been the result of acidic or basic discharges, but have been caused by perturbations of the biological systems or may be naturally occurring.



3

OPTIONS AND TECHNICAL RAMIFICATIONS

3.1 RETAIN THE EXISTING pH CRITERIA

As discussed in Section 1.3, the existing pH criteria are fully protective of aquatic life. However, as shown in Section 2.1.1, the existing criteria do not bracket the full range of natural variability in the state. Thus, the Department would need to continue to document nonanthropogenic exceedances and explain their occurrence in the biennial assessment (305(b)) report.

3.2 EXTEND THE ACCEPTABLE RANGE TO 6.0 pH UNITS IN THE COASTAL BASINS

Section 2.1.1 (*Meteorological Effects*) documents the relationship of rainfall, pH, and runoff in the Alsea Basin, which has the only climatological data in the Coast Range. The streams in the Coast Range are poorly buffered, resulting in some winter pH values below 6.5 in the absence of substantial anthropogenic effects. Extending the acceptable range of pH from 6.5 to 6.0 units from November 1 through April 30 could reduce the number of meteorologically related pH exceedances in the Coast Range.

3.3 EXTEND THE ACCEPTABLE RANGE TO 6.0 pH UNITS IN CASCADE MOUNTAIN LAKES

Section 2.1.1 (*Buffering Capacity*) demonstrates that some 10 percent of the Cascade Lakes have pH values which range under 6.5 units; the lakes sampled have been subject to little anthropogenic activity which would affect pH. They are very poorly buffered. Extending the acceptable range of pH from 6.5 to 6.0 would again have no measurable effect on beneficial uses and would reduce the number of pH exceedances attributable to natural range.

3.4 EXTEND THE ACCEPTABLE RANGE TO 9.0 pH UNITS IN SOME EASTERN OREGON BASINS

As summarized in Table 2-2, the John Day, Umatilla, Grande Ronde, and Klamath basins all experience high pH exceedances, but all exhibit high median pH in winter as well as summer (Section 2.1.1 — *Buffering Capacity*). Extending the acceptable range of pH to 9.0 units in these basins would reduce the number of pH exceedances, but would not affect those cases in which anthropogenic nutrient enrichment causes extremely high biological productivity. In these situations, pH is characteristically driven well over 9.0 units in late afternoon. A criterion of 9.0 pH units would be fully protective of beneficial uses.

3.5 ESTABLISH A POINT SOURCE LIMITATION OF 0.5 pH UNITS CHANGE

In addition to the general range of acceptable pH, it might be useful to limit the magnitude of pH change attributable to a single point source. This approach would limit the pH change from strong acids or bases, and would provide additional protection to poorly buffered bodies of water.

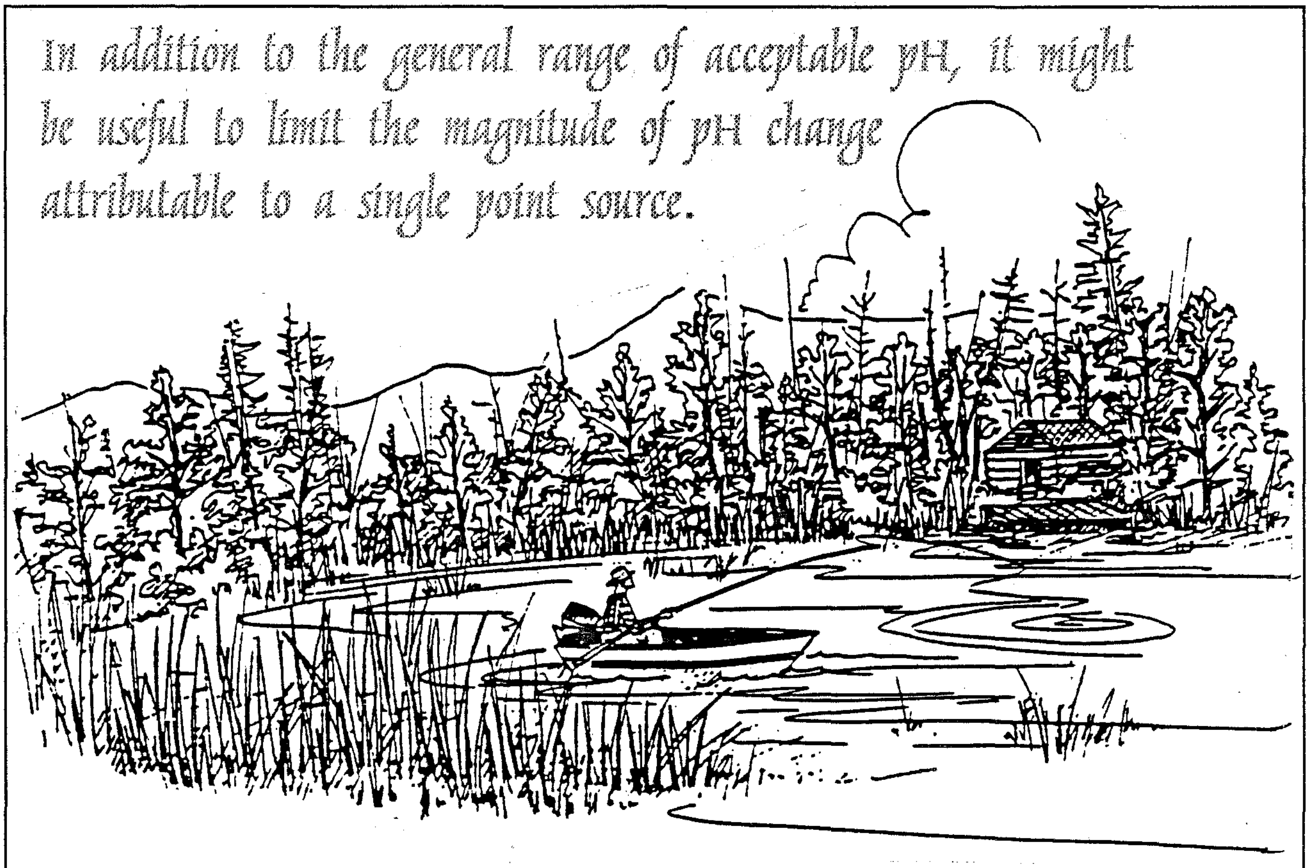
3.6 ESTABLISH AN ACTION LIMIT WHICH TRIGGERS A STUDY

Another scheme to improve protection of beneficial uses is the concept of an action limit. A pH exceedance of a given magnitude would serve as the trigger for a study designed to determine the cause of the exceedance. For example, a pH of over 8.7 where the criterion is 9.0 could automatically result in the initiation of a synoptic study, including diurnal sampling for pH, temperature, dissolved oxygen, and primary nutrients (phosphorus and nitrogen). The magnitude of the diurnal range of pH values would be a major indicator of anthropogenic enrichment.

3.7 TECHNICAL ADVISORY COMMITTEE PREFERENCES

The Technical Advisory Committee prefers to retain the present form of the pH standard with the following options:

- Extend the range in the Cascade Lakes from 6.5 to 6.0;
- Extend the range in some eastern Oregon basins from 8.5 to 9.0;
- Establish a point source limitation of 0.5 pH units; and
- Establish an action limit of 8.7 pH units for all basins with criteria of 9.0.



4

POLICY ANALYSIS

4.1 POLICY ADVISORY COMMITTEE PROCESS

The Policy Advisory Committee (PAC) was established to provide balanced input from diverse groups having a stake in the quality of the state's waters. Committee membership is shown in Table 4-1.

The Committee met approximately monthly during 1993, and twice monthly for much of 1994, after the Technical Subcommittees had outlined options and alternatives for discussion. Policy discussions were extensive, lasting from 9:00 a.m. until 4:00 p.m. Technical Subcommittee members were present at meetings to respond to questions and provide new iterations of alternatives being discussed by the PAC.

PAC members agreed that recommendations should be consensual if possible. Votes taken on most issues were nearly unanimous; those casting dissenting votes were invited to propose additional alternatives that would address their concerns, or write minority reports for inclusion in this paper. In the few cases when the group was evenly divided over an issue, no recommendation was made.

Table 4-1: Policy Advisory Committee

NAME	AFFILIATION
Craig Johnston, Chair	Northwestern School of Law
Ward Armstrong	Oregon Forest Industries Council
Bill Bakke	Oregon Trout
Nina Bell	Northwest Environmental Advocates
Bill Gaffi	Association of Clean Water Agencies
Bob Gilbert	James River Corporation
Jim Griggs	Confederated Tribes of the Warm Springs Reservation
Mike Houck	Urban Streams Council
Sha Spady	(Unaffiliated)
Terry Smith	League of Oregon Cities
Larry Trosi	Oregon Farm Bureau
Benno Warkenton	Oregon State University
Jim Whitty	Association of Oregon Industries

A list of interested parties, including nearly 300 names, was compiled. All parties received notices of meetings. Meetings were open to the public, and a public comment period was provided during the afternoon.

4.2 PUBLIC POLICY CONTEXT FOR THE STANDARD

The public policy context for the water quality standard for pH has not been prominent. There is very little public awareness of, or focus on, the pH standard itself. The Department included this standard in the triennial review because there were data indicating that the existing criteria for pH did not adequately bracket the naturally occurring range, especially in the Coast Range, Cascade Lakes and some eastern basins. Although pH itself may have toxic or deleterious effects on aquatic biota, other factors which covary with pH generally affect the biota first or more directly (e.g., dissolved oxygen). As described in the technical section, pH can also affect the toxicity of ammonia and metals. Moreover, most pH-related problems in the state are related to nonpoint source pollution, such as nutrient enrichment, as opposed to point sources seeking to discharge large amounts of acids or bases. Since salmonids are apparently the most sensitive of the aquatic biota to pH variations, environmental advocacies are very concerned with adequate margins of safety at the edges of the standard as well as with cumulative effects.

4.3 ISSUES

4.3.1 Level of Protection

The level of protection to the aquatic biota, particularly the salmonids, is the principal policy issue of concern. This is logical, since the initiative behind the change in the standard is to widen the criteria in some cases to allow for natural variability. Widening the acceptable range of pH may have the ramification of increased risk. As a corollary, the widening of criteria may narrow the margin for error (e.g., error of measurement), thus increasing risk, even though the beneficial use is considered fully protected.

To approach issues like these, the technical subcommittee couched its findings in terms of low, medium, or high certainty. Since there was a considerably larger body of recent data available on the ecological effects of low pH, the subcommittee had a higher degree of certainty here than for the effects of high pH. The subcommittee also had varying degrees of certainty on the reliability of the field data supporting the proposed changes. This combined uncertainty was the focus of the most of the Policy Advisory Committee's discussion on the level of protection of the pH standard.

4.3.2 Equity

The issue of equity to sources of point and nonpoint pollution generally comes into play when a standard affects both types of sources. In the past, pollution abatement has generally focused on permitted point sources. Equity becomes an issue with pH if an attempt is made to limit point sources specifically, as in the point source limitation. It is also a potential point of contention between nonpoint sources, when the assimilative capacity tends to be utilized by upstream sources and downstream sources have none.

4.4 ALTERNATIVES AND OPTIONS CONSIDERED

4.4.1 Extend The Acceptable Range to 6.0 pH Units in The Coastal Basins

The level of protection is the prime issue with this option. The technical subcommittee states with moderate degree of certainty that the exceedances are of nonanthropogenic origin, and with a high level of certainty that a pH of 6.0 will fully protect all beneficial uses. In response to the concern that historical pH values have been altered by decades of forest and agricultural practices, the technical subcommittee finds no good source of historical data, but based on present data and professional judgment, believes that present values do not deviate greatly from historical values.

The biggest problem with the level of protection is that there is no margin for safety at a pH value of 6.0. That is, the scientific literature shows that subtle impacts begin to occur at 6.0 or just below. Although pH can be reliably measured in the field to about plus or minus 0.1 units, this still leaves the concern for a margin of safety in the standard.

4.4.2 Extend The Acceptable Range to 6.0 pH Units in The Cascade Lakes

Again, the level of protection is the paramount policy issue. The technical subcommittee believes with a high degree of certainty that pH exceedances in the Cascade Lakes are of natural causation. However, in contrast to streams in the Coast Range, the Cascade Lakes have generally not been measurably impacted by man's activities. Since it is not likely that anthropogenic effects have caused natural pH values to shift, it is reasonable to believe that the biota indigenous to the Cascade Lakes are well adjusted to ambient water quality. Thus, the concerns for a margin of safety and level of risk are not as great for the Cascade Lakes as for streams in the Coast Range.

4.4.3 Extend The Acceptable Range to 9.0 pH Units in Some Eastern Basins

The level of protection or risk is also of great concern in the basins on the east side of the Cascades for which an increase in allowable pH is proposed. The technical subcommittee has a high level of certainty that pH exceedances in these basins are of natural origin, and a high degree of certainty that beneficial uses are fully protected at a pH of 9.0. The literature on the ecological effects of high pH, however, are largely dated, and are limited in numbers. This leaves a much more vague picture than at low pH of the value at which ecological impacts are felt. Also, the processes which affect pH in this range are biological, and pH can change very rapidly due to primary production or respiration over a few hours' time. Thus, the subcommittee must also state that there is no reliable margin for error or safety at pH 9.0.

Notwithstanding the conviction that natural pH values in these eastern basins naturally reach up to 9.0 units, any given stream may or may not be impacted by anthropogenic activities. Unimpacted reference streams are difficult to find, but streams like the headwaters of the Minam River demonstrate the natural tendency towards high pH. But the related policy question is whether the additional allowance in the criteria will tend to allow streams which would not normally (naturally) reach this pH level to be degraded to this range. Another related policy area of concern regards the effects of pH on ammonia toxicity. Ammonia toxicity increases with increasing pH. Since effluent limits for ammonia are calculated with a pH function, is it possible that pH will increase, thereby forcing tighter controls on ammonia effluent limits. But both concerns discount the intent of the antidegradation policy, which states that the remaining assimilative capacity in streams cannot be utilized without extensive public process. Thus, ambient pH values in eastern streams are not expected to increase just because the range of the criterion is increased.

4.4.4 Establish A Point Source Limitation of 0.5 pH Units Change

This option is offered as an opportunity to limit the effect any single permitted source can have on pH. Because the pH would stay within the criteria, the level of protection to the most sensitive beneficial use would remain the same. Equity is therefore the major policy issue with this option. As stated above, most pollution abatement has been through permitted sources. There is a strong perception on the part of permit holders that the burden should be shifted from their shoulders alone, and that this option for the pH standard will focus inappropriately on permitted sources.

4.4.5 Establish An Action Limit Which Triggers A Study

The action limit option attempts to minimize risk to beneficial uses. This is accomplished by using a percentage of values at a set level to trigger a study designed to identify whether a water quality problem actually exists. Given the ability to measure pH in the field, the technical subcommittee believes that the trigger should be set at 25 percent of the values occurring within 0.3 pH units or less of the criteria (i.e., 25 percent at pH 8.7 or over, or 25 percent at pH 6.3 or under). Given that there is no identified margin of safety for the most sensitive beneficial use at either end of the scale, this option could reduce risk by identifying the existence of problems before risk has been incurred.

4.5 POLICY ADVISORY COMMITTEE PREFERENCES

The Policy Advisory Committee preferences for the pH standard are shown in Table 4-2.

4.6 ISSUES NOT ADDRESSED

The issue of equity was not directly addressed by the proposed changes to the pH standard.

Table 4-2: Preferences and Level of Policy Advisory Committee Support

OPTION	LEVEL OF SUPPORT
Lower in Cascade Lakes	Unanimous
Raise in Eastern Basins	One dissent
Action Limit at 8.7	Unanimous

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RECOMMENDATIONS

The Department of Environmental Quality's recommendation for pH water quality standard was developed using the information provided in this issue paper, the Technical and Policy Advisory Committee's preferences, and the public comment obtained during the Public Workshops.

Technical Advisory Committee Preference: The Technical Advisory Committee preference was to lower the pH standard in the Cascade Lakes and raise it in several Eastern Oregon basins (Table 5-1).

Policy Advisory Committee Preferences: The Policy Advisory Committee preference was the same as the Technical Advisory Committee (Table 5-1) and to establish an action limit of 8.7 for the proposed Eastern Oregon change.

Summary of Public Comment from Public Workshops and Department Response: In May 1995, public workshops were held in La Grande, Bend, Portland, Medford, Eugene, and Newport. Presentations were given on each of the standards under review and a discussion period was held. A total of 46 members of the public participated, representing: local,

Table 5-1: Summary of Recommended Oregon pH Criteria

Basin Name	Estuarine	Freshwater	Other	Cascade Lakes
North Coast – Lower Columbia Basin	6.5–8.5	6.5–8.5	6.5–8.5[a]	NA
Mid Coast Basin	6.5–8.5	6.5–8.5	NA	NA
Umpqua Basin	6.5–8.5	6.5–8.5	NA	**6.0**–8.5[d]
South Coast Basin	6.5–8.5	6.5–8.5	NA	NA
Rogue Basin	6.5–8.5	6.5–8.5	NA	**6.0**–8.5[d]
Willamette Basin	NA	6.5–8.5	7.0–8.5[a]	**6.0**–8.5[d]
Sandy Basin	NA	6.5–8.5	7.0–8.5[a]	**6.0**–8.5[d]
Hood Basin	NA	6.5–8.5	7.0–8.5[a]	**6.0**–8.5[d]
Deschutes Basin	NA	6.5–8.5	7.0–8.5[a]	**6.0**–8.5[d]
John Day Basin	NA	6.5–**9.0**[d]	7.0–8.5[a]	NA
Umatilla Basin	NA	6.5–**9.0**[d]	7.0–8.5[a]	NA
Walla Walla Basin	NA	6.5–**9.0**[d]	NA	NA
Grande Ronde Basin	NA	6.5–**9.0**[d]	7.0–9.0[b]	NA
Powder Basin	NA	6.5–**9.0**[d]	7.0–9.0[b]	NA
Malheur River Basin	NA	7.0–9.0	NA	NA
Owyhee Basin	NA	7.0–9.0	NA	NA
Malheur Lake Basin	NA	7.0–9.0	NA	NA
Goose and Summer Lakes Basin	NA	7.0–9.0	7.5–9.5[c]	NA
Klamath Basin	NA	7.0–9.0	NA	**6.0–9.0**[d]

LEGEND:

a – Columbia River. c – Goose Lake. NA – Not applicable.
b – Snake River. d – Changes shown in **bold** type.

state, and federal agencies; industry; environmental groups; agriculture; forestry; consulting firms; and unaffiliated citizens. Written comments were also accepted in addition to participation in the workshops.

Workshop participants queried whether a trigger value should be recommended at the low end of the pH range similar to that recommended at pH 8.7. Two participants also expressed concern that the high-end trigger value should be 8.5 rather than 8.7 due to the comparative lack of research on beneficial use protection at that end of the pH spectrum.

Staff do not believe that a trigger value is needed above pH 6.0 in the Cascade Lakes. A substantial number of studies have been done to determine the impacts of acidic conditions on ecological integrity; the level of additional risk to beneficial uses incurred due to a change in the standard from 6.5 to 6.0 is well understood and judged to be acceptable.

Staff believe that a trigger value of 8.7 is appropriate for several reasons. First, beneficial use protection is considered adequate up to about pH 9.0. Existing evidence indicates that pHs up to 8.7 occur naturally and routinely in the five Eastern Oregon basins under consideration. If a trigger value were set at 8.5, there would be little advantage over the current standard since both would require Department action at pH 8.5.

Department of Environmental Quality Recommendation: The Department recommends that the pH criteria be changed as indicated in Table 5-1, and as recommended by both the Technical and Policy Advisory Committees. The Department further recommends that an action limit of 8.7 be instituted in both the five Eastern Oregon basins for which the upper allowable pH range may increase to 9.0 and the five Eastern basins for which the standard is already 9.0. Once 25 percent of the recorded pH values exceed 8.7, staff recommend that the Department determine the cause of the high pHs.

The Department recommends that the pH criteria be changed as indicated in Table 5-1, and as recommended by both the Technical and Policy Advisory Committees. The Department further recommends that an action limit of 8.7 be instituted in both the five Eastern Oregon basins for which the upper allowable pH range may increase to 9.0 and the five Eastern basins for which the standard is already 9.0. Once 25 percent of the recorded pH values exceed 8.7, staff recommend that the Department determine the cause of the high pHs.

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REFERENCES

American Public Health Association. 1992. *Standard Methods for the Examination of Water and Wastewater.* Seventeenth Edition. American Public Health Association, American Water Works Association and Water Pollution Control Federation, Baltimore.

Baker, J.P., D.P. Bernard, S.W. Christensen, M.J. Sale, J. Freda, K. Heltcher, D. Marmorek, L. Rowe, P. Scanlon, G. Suter, W. Warren-Hicks, and P. Welbourn. 1990. *Biological Effects of Changes in Surface Water Acid-Base Chemistry.* NAPAP report 13. In: National Acid Precipitation Assessment Program, Acidic Deposition: State of Science and Technology. Volume II.

Elder, John F. 1988. *Metal Biogeochemistry in Surface-Water Systems — A Review of Principles and Concepts.* U.S. Geological Survey Circular 1013.

European Inland Fisheries Advisory Commission. 1969. *Water Quality Criteria for European Freshwater Fish — Extreme pH Values and Inland Fisheries.* EIFAC Working Party on Water Quality Criteria for Freshwater Fish. Water Research 3:593–611.

Johnson, D. M., et al. 1985 *Atlas of Oregon Lakes.* Oregon State University Press, Corvallis.

Landers, D. H., et al. 1987. *Western Lake Survey*, Phase 1. Volume 1: *Population Descriptions and Physico-Chemical Relationships.* EPA/600/386/054a, U.S. EPA Office of Acid Deposition, Environmental Monitoring and Quality Assurance, Washington, DC.

Marshall, David B., Mark Chilcote, and Hal Weeks. 1992. *Sensitive Vertebrates of Oregon.* Oregon Department of Fish and Wildlife, Portland.

National Atmospheric Deposition Program. 1987. NADP/NTN Annual Data Summary. *Precipitation Chemistry of the United States.* Natural Resource Ecology Laboratory, Colorado State University, Fort Collins.

National Atmospheric Deposition Program (NRSP-3)/ National Trends Network. 1993. NADP/NTN Coordination Office, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins.

Nelson, Peter O. 1991. *Cascade Mountains.* pp. 531–563 In: Donald F. Charles (Ed.). *Acidic Deposition and Aquatic Ecosystems: Regional Case Studies.* Springer-Verlag, New York.

Nelson, Peter O., and W.K. Delwiche. 1983. *Sensitivity of Oregon's Cascade Lakes to Acid Precipitation.* Report No. WRRI-85, Water Resources Research Institute, Oregon State University, Corvallis.

Oregon Natural Heritage Program. 1991. *Rare, Threatened and Endangered*

Plants and Animals of Oregon. Oregon Natural Heritage Program, Portland.

Reid, George K. 1961. Ecology of Inland Waters and Estuaries. Van Nostrant Reinhold Company. New York.

Stumm, Werner, and James J. Morgan. 1970. *Aquatic Chemistry: An Introduction Emphasizing Chemical Equilibria in Natural Waters.* Wiley-InterScience, New York.

Taylor, George H., and Alexi Bartlett. 1993a. *The Climate of Oregon: Climate Zone 1 — The Oregon Coast.* Oregon Climate Service, Oregon State University, Report OCS-93-1a.

Taylor, George H., and Alexi Bartlett. 1993b. *The Climate of Oregon: Climate Zone 4 — Northern Cascades.* Oregon Climate Service, Oregon State University, Report OCS-93-1d.

U.S. Environmental Protection Agency. 1976. *Quality Criteria for Water 1976.* Office of Water Regulations and Standards, Washington, DC.

U.S. Environmental Protection Agency. 1986a. *Quality Criteria for Water 1986.* Office of Water Regulations and Standards, Washington, DC.

U.S. Environmental Protection Agency. 1986b. *Quality Criteria for Water 1986.* Ammonia. Office of Water Regulations and Standard, Washington DC.

U.S. Environmental Protection Agency. 1988. *Acidity-Alkalinity (pH).* Water Quality Standards Criteria Summaries: A Compilation of State/Federal Criteria. Office of Water Regulations and Standards, Washington, DC.

U.S. Geological Survey. 1990. *Water Resources Data, Oregon, Water Year 1989.* Volume 2. Western Oregon. U.S. Geological Survey Water-Data Report OR-89-2.

U.S. Geological Survey. 1991. *Water Resources Data, Oregon, Water Year 1990.* Volume 2. Western Oregon. U.S. Geological Survey Water-Data Report OR-90-2.

Wigington, P.J., T.D. Davies, M. Tranter, and K.N. Eshelman. 1992. *Comparison of Episodic Acidification in Canada, Europe and the United States.* Environmental Pollution 78:29–35.

Attachment 2

AWQMS Data for pH in Mud Springs Creek (a tributary to Trout Creek)