# Assessment of Potential Impacts to Federally Listed Salmonids from Community Water Fluoridation in Sonoma County

February 2015

Prepared for:

Sonoma County Department of Health Services

Prepared by:

Cardno

Shaping the Future

**Cardno**
2300 Clayton Road, Suite 200, Concord, California 94520 USA

# Table of Contents



# Attachments

# Tables



# Figures



# Acronyms

| | |
|---|---|
| ATSDR | Agency for Toxic Substance and Disease Registry |
| AWWA | American Water Works Association |
| BO | Biological Opinion |
| Cal/EPA | California Environmental Protection Agency |
| cfs | cubic feet per second |
| CC | Coastal California |
| CCC | Central California Coast |
| CDC | Center for Disease Control and Prevention |
| CDFW | California Department of Fish and Wildlife, formerly the California Department of Fish and Game (CDFG) |
| CESA | California Endangered Species Act |
| CEQA | California Environmental Quality Act |
| CPSTF | Community Preventive Services Task Force |

| | |
|---|---|
| DPS | Distinct Population Segments |
| ESU | Evolutionary Significant Unit |
| FESA | Federal Endangered Species Act |
| FSA | fluorosilicic acid |
| HHS | U.S. Department of Health and Human Services |
| LC | lethal concentration |
| $LC_{50}$ | median lethal dose |
| LOAEC | lowest observed adverse effect concentration |
| mg/L | milligrams per liter |
| MMWD | Marin Municipal Water District |
| MOS | margin of safety |
| NAF | sodium fluoride |
| NCRWQCB | North Coast Regional Water Quality Control Board |
| NMFS | National Marine Fisheries Service, now known as NOAA Fisheries |
| NMWD | North Marin Water District |
| NOAA | National Oceanic and Atmospheric Administration |
| NOAEC | no observable adverse effect concentration |
| NPDES | National Pollution Discharge Elimination Sysem |
| NSF | National Sanitation Foundation |
| pH | hydrogen potential |
| ppm | parts per million |
| PCE | Primary Constituent Elements |
| SCDHS | Sonoma County Department of Health Sevrices |
| SCWA | Sonoma County Water Agency |
| SFS | sodium fluorosilicate |
| USACE | U.S. Army Corp of Engineers |
| USEPA | U.S. Environmental Protection Agency |
| USFWS | U.S. Fish and Wildlife Service |
| USPHS | U.S. Public Health Service |
| WWTP | Wastewater Treatment Plant |

# 1 Executive Summary

The Sonoma County Department of Health Services (SCDHS) is in the process of evaluating the feasibility of adding fluoride to the community drinking water supply in Sonoma County as a public intervention to improve oral health through the prevention of tooth decay. The Sonoma County Water Agency (SCWA) is responsible for the treatment and distribution of community drinking water within the SCWA service area which includes parts of Sonoma County and Marin County. A key component to SCDHS's evaluation is to weigh the oral health benefits of community water fluoridation with potential adverse effects such as the possible adverse effect to fish and wildlife that may be exposed to fluoridated community water in the environment. This report is focused on the assessment of potential impacts associated with community water fluoridation on federally listed salmonids in streams within the SCWA service area. The assessment generally follows U.S. Environmental Protection Agency (USEPA) ecological risk assessment guidelines.

The oral health benefit of community water fluoridation in the prevention of tooth decay is well documented. For over fifty years, public health agencies in the U.S., including the U.S. Public Health Service (USPHS), the Center for Disease Control and Prevention (CDC), and the U.S. Department of Health and Human Services (HHS) have recommended fluoridation of community drinking water supplies. Initially, in 1962, the USPHS recommended that community drinking water contain a fluoride concentration within the range of 0.7 to 0.9 mg per liter (mg/L; or parts per million [ppm]). In 2011, HHS updated the earlier USPHS recommendation to a proposed fluoridation goal of 0.7 mg/L. The USEPA has established a Maximum Contaminant Level (MCL) for fluoride of 4 mg/L, and defined the MCL as, "The level of contaminant in drinking water below which there is no known or expected risk to health." Currently, approximately 74% of the U.S. population is served by fluoridated community water. For the purpose of this assessment it was assumed that fluoridated community water would contain fluoride at a concentration of 0.7 mg/L.

There are three species of salmonids that are listed as threatened or endangered under the Federal Endangered Species Act (FESA) that are known to occur in streams within the SCWA service area. These are the Central California Coast (CCC) coho salmon (endangered), Coastal California (CC) Chinook salmon (threatened), and the Central California Coast (CCC) steelhead (threatened). Coho salmon are also listed as endangered under the California Endangered Species Act (CESA).

Chinook salmon are limited to the mainstem and larger tributaries of the Russian River watershed that contain adequate flow to support upstream migration and spawning during the fall to early winter time frame. They are known to occur in Dry Creek and sporadically may be found in other streams when conditions are suitable. Chinook salmon are essentially absent from the Russian River from mid-July through mid-August, but a few juvenile Chinook salmon may be present from mid-June to mid-August between the Dry Creek confluence to the estuary. Coho salmon primarily inhabit streams in the lower Russian River basin, including Willow Creek, Sheephouse Creek, Freezeout Creek, Austin Creek and its tributaries, Dutch Bill Creek, Green Valley Creek, and possibly Mark West Creek. Coho salmon also inhabit Dry Creek as well as some of its tributaries, including Mill Creek and Palmer Creek. They may be present at various life stages in these creeks throughout the year. Coho salmon are not present in or native to the Petaluma River, Novato Creek, or Sonoma Creek. Steelhead are the most widely distributed of the three listed salmonids and are known to occur in nearly all permanent streams in the basin including Petaluma River, Novato Creek, and Sonoma Creek. They are present throughout the year and are known to rear during the summer in some of the very low flow portions of small creeks.

For the purpose of this assessment, it was assumed that fluoridated community water would be distributed throughout the SCWA service areas in Sonoma and Marin Counties. The SCWA service area in Sonoma County includes the Russian River watershed that is a direct tributary to the Pacific Ocean and the Petaluma River and Sonoma Creek watersheds, both of which drain to the northern section of San Pablo Bay. The SCWA service area extends southward to Marin County via water deliveries to the North Marin Water District (NMWD) and the Marin Municipal Water District (MMWD). The Marin County service area watersheds drain to San Pablo Bay (Novato Creek, San Rafael Creek, Corte Madera Creek, Gallinas Creek, Miller Creek) and to Richardson Bay (Arroyo Corte Madera del Presidio, Coyote Creek). The MMWD has been fluoridating its water supply for several decades and is therefore not considered in this report.

Fluoridated community water could enter these streams by direct discharge from wastewater treatment plants (WWTPs) or through return flows which may include surface water runoff associated with numerous activities such as irrigation of crops, urban landscaping, residential lawn irrigation, car washing, etc or through applications such as recycled water used in agricultural irrigation that recharges groundwater that later discharges back to streams. Following several meetings with SCWA staff it was determined that return flows entering small creeks where steelhead rear during dry summer low-flow periods would experience the highest potential fluoride exposures because fluoridated community water could potentially make up a large proportion of the water in the creeks relative to the natural flows. In contrast, WWTPs within the SCWA service area only discharge treated water to the streams during late fall to late spring when stream flows are typically higher. During the dry late-spring through early-fall months, all WWTP treated water is stored or recycled; several of the WWTPs within the SCWA service area typically recycle all treated water through the entire year. In addition, WWTPs that do discharge to streams have minimum dilution requirements that must be achieved as stipulated in their National Pollution Discharge Elimination System (NPDES) permits and as required by the North Coast Regional Water Quality Control Board (NCRWQCB) Basin Plan. For those WWTPs that discharge treated water to streams within the SCWA service area, permitted dilution rates range from 1% to 5% meaning that discharged treated water can contribute only 1% to 5% of the total stream flow. For the purpose of this assessment, it was assumed that fluoride mass is conserved during treatment and WWTP effluent concentrations would be equal to the assumed community water fluoridation level of 0.7 mg/L. This is a conservative assumption as some fluoride is likely removed from the system during wastewater treatment. It was also assumed that domestic uses of fluoride, such as fluoridated toothpaste, would have negligible effect on wastewater fluoride concentrations relative to the assumed community water fluoridation level of 0.7 mg/L.

Three streams within the SCWA service area were the focus of this assessment, as follows:

- Green Valley Creek. Within the SCWA service area, the only stream in which endangered coho salmon could spawn and rear downstream of a WWTP, and therefore could potentially be impacted by WWTP discharges, is Green Valley Creek. From October 1 to May 14 the Forestville Water District's WWTP discharges treated water to Jones Creek which flows into Green Valley Creek. This WWTP has a 1% of streamflow dilution requirement.
- Paulin Creek. Steelhead are known to rear during the dry summer low-flow months in Paulin Creek. It is a tributary to Santa Rosa Creek and flows almost entirely through urbanized areas of Santa Rosa. As such, during low flow periods, creek water where steelhead are rearing may be comprised largely of return flow water. Because of the known summer-time low flow conditions of Paulin Creek, it was identified as the worse-case scenario.
- Santa Rosa Creek. Santa Rosa Creek was selected as a representative scenario for assessing potential impacts associated with return flows in urban areas because it provides steelhead rearing habitat and was the only small stream (other than Green Valley Creek) that had any water quality or stream flow measurement data.

These three streams were considered to be representative of the full range of stream flows, salmonid species, and discharge types. The two most important water quality parameters for the assessment were determined to be water hardness[1] and existing fluoride concentrations in the streams. Water hardness is known to modulate (reduce) fluoride toxicity in fish. Background concentrations of fluoride in the streams were considered important because fluoride present in either WWTP discharges or return flows would be additive to background concentrations already present in the streams. To support this assessment, SCWA collected a total of four water samples from Paulin Creek and Santa Rosa Creek in July 2014. All four samples were analyzed for fluoride and water hardness. Background fluoride concentrations ranged from not detected to 0.12 mg/L. These levels of fluoride are typical of background levels in streams. Water hardness in the creeks ranged from 137 to 304 mg/L calcium carbonate ($CaCO_3$). Water hardness in SCWA source water[2] collected in 2013 from Wohler collectors 1, 2, and 6 and Mirabel collectors 3, 4, and 5 ranged from 98 to 109 mg/L $CaCO_3$. Note that Wohler collector 6 is currently the primary source of SCWA water and little water is obtained from the other collectors. The ranges of water hardness in source water and creek water would be considered "hard" to "very hard". For the purpose of assessing potential impacts to salmonids it was assumed that WWTP treated water and return flow water would contain 0.7 mg/L fluoride, the concentration that is likely to be recommended for community water fluoridation. It was further assumed that natural background fluoride concentrations would conservatively be 0.23 mg/L which is based on the maximum fluoride concentration measured by the SCWA in Russian River-derived source water and samples collected from Santa Rosa and Paulin Creeks.

Review of the aquatic toxicity literature pertaining to adverse effects of fluoride on salmonids identified five studies that were determined to be relevant and usable for this assessment. All five studies were conducted using either rainbow trout or brown trout. No reliable and useable studies on Chinook salmon, coho salmon, or steelhead were found. From the trout studies, the lowest observable adverse effect concentration (LOAEC) and the highest no observable adverse effect concentration (NOAEC) that was lower than the LOAEC were identified. The NOAEC is 4.4 mg/L and the LOAEC is 5 mg/L. The NOAEC of 4.4 mg/L was selected for assessing potential impacts to salmonids because the NOAEC represents a concentration at which adverse effects on individual salmonids or salmonid populations would not be expected.

Potential impacts to salmonids in the creeks were assessed by integrating information on fluoride exposure and fluoride toxicity. Results shown in the table below are expressed as the margin of safety, or MOS, whereby values greater than 1 indicate the degree of protectiveness. MOS values were calculated by dividing the NOAEC of 4.4 mg/L by the estimated fluoride concentration in stream water after taking into account dilution and the background fluoride concentration in streams which was assumed to be 0.23 mg/L. As indicated in the table, WWTP discharges to Green Valley Creek have a relatively high margin of safety primarily because of the stringent dilution requirement of 100:1 stream flow to WWTP discharge which is equivalent to a dilution of 1% of streamflow. Forestville Water District records show dilution rates[3] closer to 0.2% to 0.5% of stream flow. The worse-case scenario, Paulin Creek, which was assumed to have zero dilution of return flow water containing 0.7 mg/L fluoride (e.g., 0% dilution has a 6.3-fold margin of safety. Santa Rosa Creek, which was assumed to have higher dry-summer natural flows than Paulin Creek, assuming 50% dilution of return flow water, has a 9.5-fold margin of safety.

These margin of safety estimates are considered conservative, and greater protection is likely afforded given the relative water hardness of streams in Sonoma County. As noted earlier, water hardness is known to modulate fluoride toxicity in fish by the formation of calcium and magnesium complexes which renders the fluoride less bioavailable. More specifically, it has been shown that water hardness and

[1] The U.S. Geological Survey (USGS) defines water hardness as the amount of dissolved calcium and magnesium in the water (USGS 2014). Water hardness is most often reported as $CaCO_3$.

[2] The primary sources of SCWA community drinking water are the Wohler collectors 1, 2, and 6, the Mirabel collectors 3, 4, and 5.

[3] Dilution rates may be expressed as either dilution ratios or percent dilution. The North Coast Regional Water Control Board's Basin Plan calls for minimum dilution ratios for WWTPs of 100:1 unless an exemption has been granted. A dilution ratio of 100:1 is equal to a percent dilution of 1.0%.

fluoride toxicity in fish are inversely related. That is, as water hardness increases, toxicity decreases. While the true fluoride NOAEC associated with water of the hardness measured in Paulin Creek and Santa Rosa Creek is unknown, the available data on the relationship between water hardness and toxicity indicate that it would be substantially higher than 4.4 mg/L meaning that the margin of safety for all four cases shown in the table would be correspondingly higher.

| Fluoride Source | Receiving Water | Percent Dilution[1] | Fluoride Concentration (mg/L) | Margin of Safety |
|---|---|---|---|---|
| Forestville WWTP | Green Valley Creek | 0.2% | 0.23 | 19 |
| Forestville WWTP | Green Valley Creek | 1.0% | 0.23 | 19 |
| Return Flow from Urbanized Areas | Santa Rosa Creek | 50% | 0.47 | 9.5 |
| Return Flow from Urbanized Areas | Paulin Creek | 0% | 0.70 | 6.3 |

1. Percent dilution of WWTP discharge or return flow as a percentage of flow in the receiving water (e.g., a dilution ratio of 100:1 is equivalent to a percent dilution of 1.0%).

The primary focus of this assessment was on the direct effects of fluoride exposure to salmonids. Fluoride released to local streams as a result of community water fluoridation could also affect salmonid food sources, such as aquatic and benthic invertebrates and small fish. Camargo (2003) published a review of the scientific literature and found that adverse effects to invertebrates and other species of fish generally occur within the same fluoride concentration range as reported herein for salmonids and that water hardness also modulates toxicity in these food item species (Camargo 2003). Therefore, potential impact to salmonids as a result of fluoride-related effects on food sources is highly unlikely.

In summary, the results of this assessment indicate that fluoridation of the community water supply in Sonoma County at a fluoride concentration of 0.7 mg/L is unlikely to harm federally listed salmonids that occur in streams within the SCWA service area.

There are a number of uncertainties associated with any ecological risk assessment. The key uncertainties associated with this assessment include:

- Toxicity values (LOAECs and NOAECs) based largely on rainbow trout and brown trout. The degree of uncertainty is considered low given that rainbow trout and steelhead are the same species and extremely similar to coho and Chinook salmon which are both closely related and in the same genus (*Oncorhynchus*). Brown trout are in a different but closely aligned genus (*Salmo*) within the same family (Salmonidae).

- Extrapolation of toxicity results for fish raised in the laboratory to those residing in the wild. The degree of uncertainty is considered moderate, but it is not possible to judge the direction (e.g., overly conservative versus not sufficiently conservative). However, because toxicity values were selected at the very low spectrum of the available and usable toxicity values, it is unlikely that toxicity was under-estimated. Moreover, the highest NOAEC and lowest NOAEC that were selected for this assessment were based on toxicity studies conducted in water with hardness ranging from about 22 to 73 mg/L $CaCO_3$. Recent sampling by the SCWA suggests that hardness is much higher in these streams, thus mitigating toxicity, which was not directly accounted for in this assessment.

- Exposure concentrations for WWTPs based on NPDES or Basin Plan requirements for dilution. The degree of uncertainty is low given that dilution requirements are subject to regulatory enforcement.

- Exposure concentrations for streams receiving return flows. These scenarios have the highest degree of uncertainty because there is uncertainty in both the proportionate mix of natural stream flows and the return flows contributing to streams, particularly during the dry summer low-flow period. This uncertainty has largely been mitigated by assessing the worst-case Paulin Creek scenario which assumed 100% return flow contribution in an urbanized area with no contribution of natural stream water.

The following recommendations may be considered should the County decide to fluoridate community drinking water within the SCWA service area.

- Collect seasonal water samples for both fluoride and hardness analysis given that the findings of this assessment are based on the assumptions that fluoride concentrations in streams are no greater than 0.7 mg/L and water hardness is in the range of 22 to 73 mg/L $CaCO_3$, the range of water hardness used in the toxicity studies upon which the NOAEC and LOAEC were taken. If fluoride concentrations in streams exceed the protective concentration or if water hardness is found be much lower than 22 mg/L $CaCO_3$ then appropriate action should be taken to ensure that the community water fluoridation program remains protective of salmonids in receiving waters.

- Periodically collect samples for fluoride analysis from WWTPs to confirm that treated water discharged to receiving waters does not contain fluoride concentration exceeding a level that could cause harm to salmonids. If fluoride concentrations in discharged treated water exceed potentially harmful levels then appropriate action should be taken to ensure that the community water fluoridation program remains protective of salmonids in receiving waters.

# 2 Introduction

The Sonoma County Department of Health Services (SCDHS) is in the process of evaluating the feasibility of adding fluoride to the community drinking water supply in Sonoma County as a public intervention to improve oral health through the prevention of tooth decay. The Sonoma County Water Agency (SCWA) is responsible for the treatment and distribution of community drinking water within the SCWA service area which includes parts of Sonoma County and Marin County. A key component to SCDHS's evaluation is to weigh the oral health benefits of community water fluoridation with potential adverse effects such as the possible adverse effects to fish and wildlife that may be exposed to fluoridated community water in the environment. This report is focused on the assessment of potential impacts associated with community water fluoridation on federally listed salmonids in streams within the SCWA service area.

## 2.1 Dental Health Statement

The oral health benefit of community water fluoridation in the prevention of tooth decay is well documented (CPSTF 2002). For over fifty years, public health agencies in the U.S., including the U.S. Public Health Service (USPHS), the Center for Disease Control and Prevention (CDC), and the U.S. Department of Health and Human Services (HHS) have recommended fluoridation of community drinking water supplies. Initially, in 1962, the USPHS recommended that community drinking water contain a fluoride concentration within the range of 0.7 to 0.9 mg per liter (mg/L; or parts per million [ppm]) (CPSTF 2002). On January 7, 2011, HHS updated the earlier USPHS recommendation to a proposed fluoridation goal of 0.7 mg/L. The current recommendation is based on a scientific assessment conducted by HHS and the U.S. Environmental Protection Agency (USEPA) to balance the oral health benefits of fluoride with the potential adverse effects from excessive fluoride exposure (HHS 2011). According to the CDC (2013a), children aged 8 years and younger may have a greater chance of developing dental fluorosis at drinking water fluoride concentrations greater than 2 mg/L. Dental fluorosis is characterized by scattered white flecks, spots, or chalky lines on the surface of the teeth, generally not observable except by a dental health professional (CDC 2013a). The USEPA has established a Maximum Contaminant Level (MCL) for fluoride of 4 mg/L (EPA 2009). The USEPA (2009) defined the MCL as, "The level of contaminant in drinking water below which there is no known or expected risk to health." Currently, approximately 74% of the U.S. population is served by fluoridated community water (CDC 2013b).

## 2.2 Ecological Concerns Related to Federally Listed Species

The potential addition of fluoride into surface waters from community water fluoridation within the SCWA service area could affect water quality and is one of the key habitat elements that could be affected by fluoridation. The SCWA service area in Sonoma County includes the Russian River watershed that is a direct tributary to the Pacific Ocean. The Sonoma County portion of the SCWA service area also extends south into the Petaluma River watershed and southeast to the City of Sonoma where Sonoma Creek drains to San Pablo Bay. In Marin County the service area includes water deliveries to the North Marin Water District (NMWD) and the Marin Municipal Water District (MMWD). The Marin County portion of the SCWA service area includes watersheds that drain to San Pablo Bay (Gallinas Creek, Miller Creek, Novato Creek, San Rafael Creek, Corte Madera Creek) and to Richardson Bay (Arroyo Corte Maderal del Presidio, Coyote Creek). These watersheds provide habitat for several special status fish species; three that are protected under the Federal Endangered Species Act (FESA) and one that is also protected as endangered under the California Endangered Species Act (CESA). "Taking" of listed species is prohibited by both the FESA and CESA. "Take" is a broad term and includes harm or harass, and therefore applies to any action that may affect a listed species. The discharge of fluoridated community drinking water into receiving waters within the these watersheds that support listed species could be considered a take under FESA or CESA if that discharge results in levels of fluoride that would be harmful to a listed species.

A series of listings began during the late 1990s in response to declining west coast salmon and steelhead populations. Salmon are defined by Evolutionarily Significant Units (ESUs) and steelhead populations by Distinct Population Segments (DPSs). These terms are very similar and are used to describe different subpopulations ("species" under the FESA) of salmon and steelhead. These populations are distinct and are strongly influenced by differences in watershed geology and hydrology as well as genetics.

The Central California Coast (CCC) coho salmon (*Oncorhynchus kisutch*) ESU was listed as a threatened species on October 31, 1996 (61 FR 56138), and because of continuing declines in abundance was subsequently reclassified as an endangered species on June 28, 2005 (70 FR 37160). In addition, coho salmon inhabiting streams south of Punta Gorda (which includes the Russian River) have been listed by the California Department of Fish and Wildlife (CDFW) as endangered under the CESA. Critical habitat was designated on May 5, 1999 (64 FR 24049).

The Coastal California (CC) Chinook salmon (*O. tshawytscha*) ESU, which includes coastal rivers south of the Klamath System to the Russian River, was listed as a threatened species on September 16, 1999 (64 FR 50394). Following a 5-year status review, its status was unchanged on June 28, 2005 (70 FR 37160) and again when the status was updated on April 14, 2014 (71 FR 20802). Critical habitat was designated on September 2, 2005 (70 FR 53488).

The Central California Coast (CCC) steelhead (*O. mykiss*) ESU was designated as threatened on August 18, 1997 (62 FR 43937). The CCC steelhead includes populations ranging from those in the Russian River south to Aptos Creek in Santa Cruz County, plus populations in streams entering San Francisco Bay (*e.g*., Sonoma Creek, Napa River, Alameda Creek). The status was reaffirmed on January 5, 2006 (71 FR 834). Designation of critical habitat for CCC steelhead was published on September 24, 2005 (70 FR 52488 and 52630).

When critical habitat was designated for steelhead and Chinook salmon, the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS), now known as NOAA Fisheries, included a list of Primary Constituent Elements (PCEs) specific to each species. These PCEs include sites essential to support one or more of the life stages of the species to which it applies (i.e., sites for spawning, rearing, migration, and foraging). These sites in turn contain physical or biological features essential to the conservation of the species (for example, spawning gravels, water quality and quantity, side channels, forage species). Specific types of sites and the features associated with them include, but are not limited to the following:

1. Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.

2. Freshwater spawning sites with water quantity and quality conditions and substrate (e.g., gravel stream bed) supporting spawning, incubation, and larval development.

3. Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

4. Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

NMFS developed a similar list of species habitat requirements and essential features for CCC coho salmon (64 FR 24049):

1. Juvenile summer and winter rearing areas,
2. Juvenile migration corridors,
3. Areas for growth and development to adulthood,
4. Adult migration corridors, and
5. Spawning areas.

Within these areas, essential features of coho salmon critical habitat include adequate: (1) substrate, (2) water quality, (3) water quantity, (4) water temperature, (5) water velocity, (6) cover/shelter, (7) food, (8) riparian vegetation, (9) space, and (10) safe passage conditions.

Under Section 7(a)(2) of the FESA, federal agencies must consult with either NOAA Fisheries or the USFWS to “insure that any action authorized, funded, or carried out by such an agency is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat.…”. In the present case, the endangered and threatened species are anadromous[4] salmonids, which are managed by NOAA Fisheries. Should the County proceed with community water fluoridation, it will need to be determined whether any aspects of the project would require consultation with NOAA Fisheries. Similarly, certain aspects of the project may be subject to the California Environmental Quality Act (CEQA) and various permitting requirements.

## 2.3 Assessment Approach

The approach used to assess potential impacts to federally listed salmonids from community water fluoridation was developed iteratively through meetings with the SCDHS and the SCWA. The assessment approach that was developed is consistent with the USEPA’s guidance on ecological risk assessment (USEPA 1997 1998), but tailored to specifically address the community water distribution, wastewater treatment, and environmental factors unique to Sonoma County and the SCWA service area[5]. The assessment approach comprises four key components: (1) Salmonid Life Histories and Distribution in Sonoma County Streams, (2) Exposure Assessment, (3) Toxicity Assessment, and (4) Risk Characterization.

Information concerning salmonid life histories and distribution within Sonoma County was obtained from readily available literature and agency reports as well as through organizations focused on watershed protection and salmonid habitat restoration in Northern California.

Preliminary scoping for the Exposure Assessment included the following:

- Identification of streams within the SCWA service area where salmonids ware known to be present, referred to herein as Candidate Streams;
- Preliminary determination of when different salmonids and life stages are present in Candidate Streams;
- Identification and characterization of wastewater treatment plant (WWTP) discharges to Candidate Streams;

[4] Anadromous fish are those that are born in freshwater, spend most of their lives in the sea, and then return to freshwater to spawn.

[5] For the purpose of this assessment, the SCWA service area is defined as the entire area that encompasses the SCWA community drinking water distribution system which serves portions of Sonoma County and Marin County.

- Evaluation of water flow regime of Candidate Streams; and,
- Consideration of the degree of urbanization contributing to return flows within the relevant portions of Candidate Streams.

These key considerations were identified early on in the assessment process as it became apparent that WWTP discharges to streams in Sonoma County occur only during high flow seasons (late fall through early spring) and the fact that WWTPs are required under their NPDES permits and the North Coast Regional Water Quality Control Board (NCRWQCB, 2001) North Coast Region “Basin Plan” to meet stringent effluent to stream dilution requirements. In contrast, return flows (e.g., water from various applications such as irrigation of lawns, car washing, agricultural irrigation with potable or recycled water, all of which may contribute to either direct surface runoff to streams or contribute to groundwater that later discharges to streams) occurring during the low flow dry season (late spring to early fall) are not regulated and have the greatest potential for salmonid exposure to fluoride from community water because a much higher proportion of the stream water will be comprised of community water. Because steelhead utilize a large number of Sonoma County streams during the summer for rearing, it was determined that the return flow scenario warranted focused attention.

The Toxicity Assessment component is entirely based on data obtained from aquatic toxicity studies of fluoride, most of which are published in the peer-reviewed literature.

The Risk Characterization component is the component where exposure and toxicity information are integrated to determine whether salmonids would be at risk from community water fluoridation through return flows or WWTP discharges.

In summary, two scenarios were selected for assessment purposes:

- WWTP discharges during high stream flow seasons; and,
- Return flows during low stream flow seasons.

The details of how these two scenarios were assessed including the selection of three streams for focused assessment are provided in the following sections.

# 3 Community Water Fluoridation

In the U.S., three different compounds have been used to fluoridate community drinking water supplies: sodium fluoride (NaF), sodium fluorosilicate (SFS; $Na_2SiF_6$), and fluorosilicic acid (FSA; $H_2SiF_6$), the latter being the most commonly used additive (ADA 2005; CDC 2013b). To ensure the safety of these fluoride additives for use in drinking water supplies, they must meet standards established by the American Water Works Association (AWWA) and the NSF International (formerly the National Sanitation Foundation). As indicated in Section 2.1, the currently proposed recommendation for community water fluoridation is 0.7mg/L (HHS 2011). Conceptually, the fluoridation of community drinking water means to adjust the naturally occurring fluoride concentration upwards to the concentration recommended for tooth decay prevention (ADA 2005).

The following sections discuss the chemical properties of fluoride, the community water fluoridation process, and how and where fluoridated community water enters aquatic environments (e.g., streams) within the SCWA service area.

## 3.1 Chemical Properties of Fluoride

Fluoride is the ionic form of the element fluorine which is classified as a halogen along with three other common elements: chlorine, bromine, and iodine (ATSDR 2003). Like the other halogens, elemental fluorine is a diatomic molecule ($F_2$). Similar to elemental chlorine ($Cl_2$), fluorine exists at room temperature as a gas. Fluorine is not found in the natural environment as it is highly reactive and easily hydrolyzes (reacts with water) to form hydrogen fluoride and oxygen. Hydrogen fluoride, also known as hydrofluoric acid or HF, readily dissolves in water to form hydrogen ions ($H^+$) and fluoride ions ($F^-$). Because of its highly corrosive properties, HF is not used for community water fluoridation. In the natural environment, fluoride exists as the free ion, $F^-$, or as a salt. Examples of fluoride salts include those used for treating community drinking water supplies such as NaF, SFS, and FSA. These salts tend to be very water soluble and are ideally suited for use in drinking water fluoridation. Other fluoride salts such as calcium fluoride ($CaF_2$) and magnesium fluoride ($MgF_2$) have very low water solubility and would not be useful for drinking water fluoridation (HSDB 2014). However, the interaction of fluoride with calcium, magnesium, and other elements in water is an important property of the fluoride ion as water hardness is reported to modulate fluoride toxicity to aquatic organisms. The relationship between water hardness and toxicity in fish is discussed in greater detail in Section 6.

## 3.2 Community Water Fluoridation Process

The following discussion on the community water fluoridation process that may be adopted by Sonoma County is based on the draft *Fluoridation Preliminary Design Report* prepared by MWH (2013) on behalf of the SCDHS. As noted in Section 3.1 above, possible fluoridation additives that could be used to fluoridate community water include NaF, SFS, and FSA. Evaluation of these three additives found that FSA would be the most cost effective and would require less handling and therefore lower risk of worker exposures (MWH 2013). FSA would be fed to the water system as a 23 percent FSA solution using metered pumps. Caustic soda is currently used to adjust the pH of community drinking water, and the use of FSA for fluoridation would likely result in an increased use of caustic soda for additional pH adjustment. Following an evaluation of the existing SCWA treatment and water distribution infrastructure, MWH (2013) recommended chemical feed systems at two locations to fluoridate the community drinking water supply with a second phase adding fluoridation at three well sites.

The Wohler facility, located near Forestville, was selected for FSA feed to the Santa Rosa Aqueduct, which originates near Wohler collectors 1, 2 and 6. The River Road facility, also located near Forestville, was selected for FSA feed to the Cotati Intertie pipeline, which originates near Mirabel collectors 3, 4, and 5 and wells 1 through 7.

The SCWA also operates three groundwater wells located in the Santa Rosa Plain: the Todd Road Well, the Sebastopol Road Well, and the Occidental Road Well. All are located along the Cotati Intertie pipeline southwest of Santa Rosa (MWH 2013). These wells are periodically used as a secondary source of water supply. Because of the distance between each of these wells, it would not be possible to fluoridate water from these wells at a central location, and each would likely require its own fluoridation system (MWH 2013).

## 3.3 Releases of Fluoridated Water to Aquatic Environments

There are two primary hydrologic pathways by which fluoridated community water could enter the stream environment, point source discharges from wastewater treatment plants and non-point source return flows. Both of these pathways are described below. In addition, there are secondary pathways, including release of stored reservoir waters that are fluoridated, commercial/industrial operational releases, and potential future injection of water (that would be fluoridated by SCWA) into aquifers for groundwater banking.

Regarding release of fluoridated waters in reservoir storage to receiving streams, there is one known situation whereby the NMWD may occasionally back-feed water supplied by SCWA (which would be fluoridated) into Stafford Lake for storage. This back-feed operation sometimes occurs in dry years (Pers. Comm., Chris DeGabriele). The water from SCWA is mixed with natural runoff held in the reservoir. There is a small instream flow release from Stafford Lake into Novato Creek, which could introduce fluoride to this steelhead bearing stream when these circumstances occur. This pathway is not considered further because the operations that would release fluoridated water occur only intermittently, because the fluoridated water that would be stored in the reservoir would be mixed with natural runoff (thus the concentration of fluoride in the water would be a mix of community fluoridated water with fluoride present in natural runoff according to the proportional amounts present from each source), and because this is the only known, unique instance of this type of water management that does not apply to other water supply and treatment situations.

Fluoride may be generated by commercial/industrial operations such as electronics manufacturing, printed circuit board manufacturing, electroplating, and glass etching (ATSDR 2003). Fluoride from commercial and industrial sources may be released directly as a point source discharge to streams, subject to discharge limits under an NPDES permit, or by discharge to a WWTP where treated water may then be released to streams. Fluoride may also be naturally present in surface water runoff or in groundwater that contributes to the baseflow of streams. Since fluoride released from commercial/industrial operations and fluoride that is naturally present in runoff are pathways wholly independent of fluoridated community water, these sources of fluoride are not analyzed in this report. SCWA does not currently inject water into the aquifer for groundwater banking, but the practice is being considered and if it were to do so, it would potentially introduce fluoridated water that would mix with groundwater. The mixed natural groundwater and injected fluoridated water could then discharge to surface flow in streams. As groundwater injection is not a current operation of SCWA, this pathway is not further analyzed in this report.

### 3.3.1 <u>Waste Water Treatment Plant Discharges</u>

There are nine wastewater treatment facilities within the SCWA service area that would receive fluoridated water (Figure 3-1), eight of which discharge to streams. Several of the wastewater treatment facilities can discharge to more than one stream. There are other wastewater treatment plants throughout Sonoma County, but these are not shown because they do not receive water originating from the SCWA service area, and therefore would not be discharging fluoridated wastewater under the proposed County program. The City of Healdsburg wastewater treatment plant is within the SCWA service area but they have been fluoridating water under their own program that has been in existence for about 75 years. Therefore, the City of Healdsburg would not receive SCWA fluoridated water and was excluded from further consideration in this assessment.

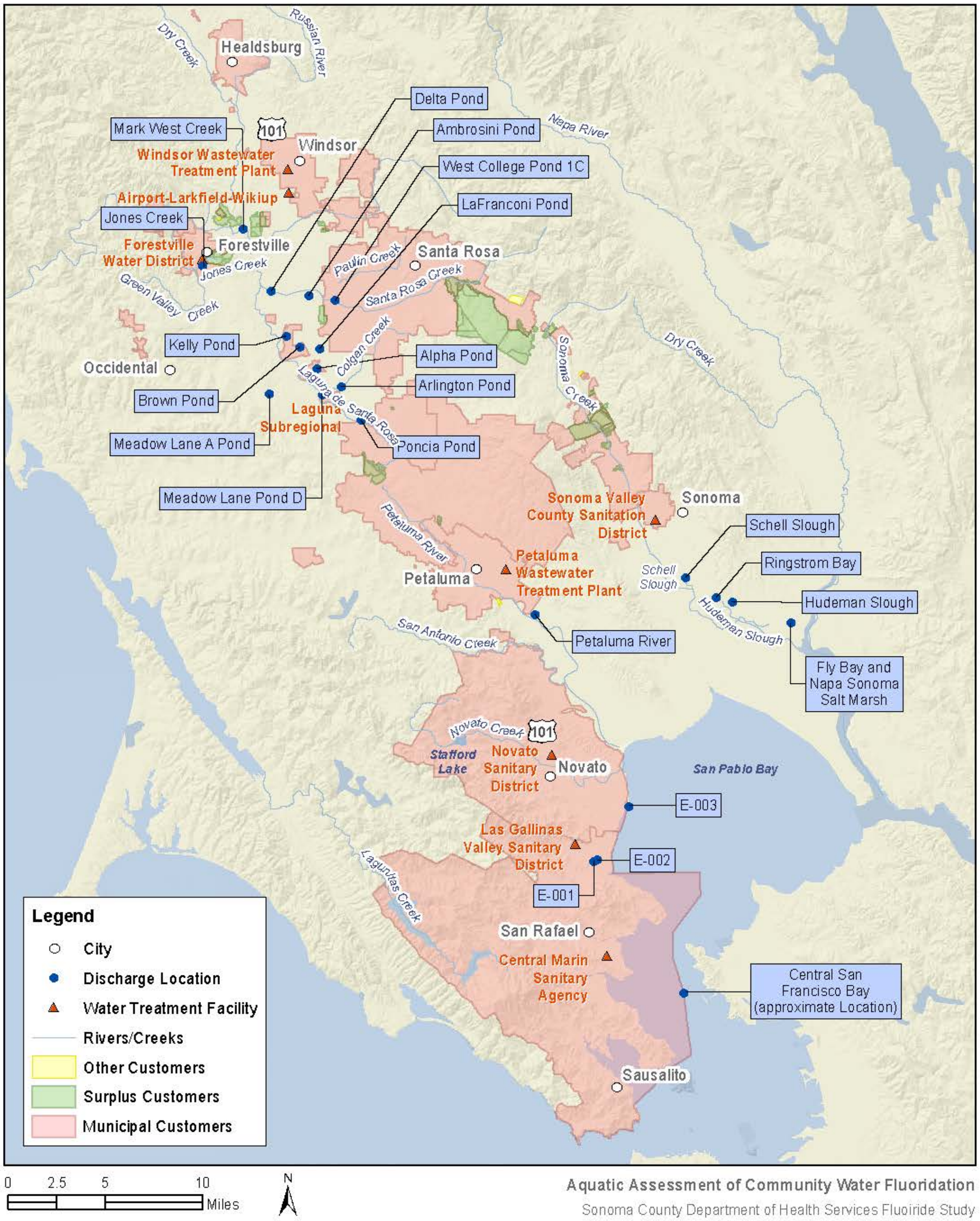
The nine wastewater treatment facilities that collect water that is at least in part sourced from the SCWA service area water are listed in Table 3-1. One treatment facility, Airport-Larkfield-Wikiup WWTP, does not discharge to any waterbody; all of the treated water is recycled for irrigation and land application uses. The MMWD and the NMWD discharge from treatment facilities either directly into San Pablo Bay or to San Francisco Bay, or within the tidal channels close to the Bay (e.g., Miller Creek). The MMWD has been fluoridating its water supply (in part provided by the SCWA) since 1973 (http://www.marinwater.org/208/Fluoridation). Therefore we have excluded the MMWD from further consideration in this assessment. The Sonoma WWTP discharges into the tidal channels along San Pablo Bay, primarily to Schell and/or Hudeman Slough which are tributary to Sonoma Creek, or to several other discharge points along the baylands. The Ellis Creek Water Recycling Facility (Petaluma WWTP) discharges into the tidally-influenced portion of the Petaluma River, at a point that is approximately 10 miles upstream of San Pablo Bay.

Treatment plants that discharge to non-tidal freshwater streams include the Laguna Subregional WWTP, the Windsor WWTP, and the Forestville WWTP. Although the Laguna Subregional WWTP is permitted to discharge to multiple locations including Laguna de Santa Rosa, Roseland Creek, Colgan Creek, and at three different locations on Santa Rosa Creek, it currently only discharges to Santa Rosa Creek. The Windsor WWTP discharges to Mark West Creek. The Forestville WWTP discharges to Jones Creek, which is a tributary to Green Valley Creek, which flows into the Russian River.

### 3.3.2 Return Flows

Return flow is defined as “that part of irrigation water that is not consumed by evapotranspiration and that returns to its source or another body of water” (Langbein and Iseri 1960). Return flows can occur through either the groundwater or surface runoff hydrologic pathways. Return flow to groundwater is the quantity of water applied at or near the land surface which infiltrates back (returns) to the groundwater system. Groundwater can then slowly discharge back to streams, which typically comprises the “baseflow” in channels during the dry summer season in Sonoma County. Return flows also include surface runoff returning to streams during the dry season that is generated by application of water for various purposes.

Water used for irrigation purposes or applied for other commercial and private uses may contribute to surface runoff in urbanized areas, either directly entering the storm drainage system that is routed to receiving waters, or by infiltration to the groundwater system where it can replenish the water table and return as surface flow to streams. Common water uses in urbanized areas that lead to return flow are irrigation of crops, golf courses, parks, lawns, ornamental plantings in public and commercial areas, and domestic wastewater disposal through septic systems. Other water applications such as car washing will run off impermeable surfaces and enter the storm drain systems directly contributing to streamflow. Recycled water from treatment plants applied to irrigation uses may be a source of return flows. Many variables, including the type of water application (sprinkler, drip, or surface irrigation), vegetation type, volume and rate of irrigation water applied, soil type, all influence the extent to which water will replenish groundwater and/or generate surface runoff. For purposes of this study we use the term “return flow” to collectively refer to these types of water applications in urban areas that return to streams through either surface or groundwater pathways.




Cardno ENTRIX

**FIGURE 3-1**
**Sonoma County Water Agency Service Area and Wastewater Treatment Plants in the Service Area**

**Table 3-1. Wastewater Treatment Plants Within SCWA Service Area That Would Receive Fluoridated Water**

| Water Treatment Facility | Receiving Water | Approximate Annual Discharge (million gallons) | Predominantly SCWA Treated Water | Period of Permitted Discharge to Receiving Waters | Discharge Dilution Rate |
|---|---|---|---|---|---|
| Airport-Larkfield-Wikiup | Irrigation and land application only | 400 | Yes | n.a. | n.a. |
| Forestville | Jones Creek | 17 | Yes | Oct 1 – May 14 | 1% [2] |
| Laguna Subregional | Laguna de Santa Rosa<br>Roseland Creek, Colgan Creek, Santa Rosa Creek | 6,600 | Yes | Oct 1 – May 14 | 5% [3] |
| Petaluma (Ellis Creek Water Recycling Facility) | Petaluma River | 2,000 | Yes | Oct 21 – April 30 | none |
| Sonoma Valley | Schell or Hudeman Slough<br>Ringstrom Bay, Fly Bay, Napa Sonoma Salt Marsh | 950 | Yes | Nov 1 – Apr 30 | none |
| Windsor | Mark West Creek | 319 | No | Oct 1 – May 14 | 1% |
| [1] Marin Municipal Water District:<br>Las Gallinas & Central Marin Sanitation Districts | Miller Creek<br>San Pablo Bay and Central San Francisco Bay | | No | | n.a. |

| | | | | | |
|---|---|---|---|---|---|
| Novato Sanitation District:<br>Novato WWTP | San Pablo Bay | 1,034 | Yes | Sept - May | n.a. |

Data source for table is NPDES permits for the treatment facilities and consultation with SCWA
n.a. = not applicable, does not discharge to a stream channel
Discharge dilution rate is specified as a percent of the receiving water flow
[1] Water is currently fluoridated by MMWD
[2] The discharge to Jones Creek cannot exceed 1% of the flow in Green Valley Creek as measured at Iron Horse Bridge
[3] The Laguna WWTP can release at a dilution rate of up to 5% of the Russian River flow as measured at Hacienda Bridge

The proportion of runoff contributed by return flows has not been well documented. A search for studies addressing quantification of return flows applicable to the Mediterranean climate of California yielded limited information. DeWalle (2000) performed a stepwise regression analysis for 39 urbanized basins in the U.S. using USGS gaging records to analyze the effect of population density on streamflow. That study found that low flows can be augmented by urbanization due to return flows associated with population growth. The hydrologic impacts of urbanization varied markedly among regions of the United States for equivalent population densities, with greater sensitivity to population density increases in the Western and North Central regions of the U.S.

Although there is a lack of quantitative data describing the hydrologic pathways by which return flows contribute to surface streamflow, we make simplifying assumptions to address the potential for fluoridated water to re-enter the hydrologic cycle after use in the community, and to thereby contribute to surface flows in streams that support aquatic species. The assumptions and analytical approach are discussed in Section 5.0 Exposure Assessment.

It is noted that, theoretically, fluoride released to soils through landscape irrigation, agricultural irrigation, or other mechanisms using either fluoridated community water or treated wastewater as a source may become bound to available cations in the soil and consequently fluoride could “concentrate” in soils. Fluoride bound to soils in this manner could then be released by rainwater percolation if that rainwater is at a sufficiently lower pH than the fluoridated community water or the treated wastewater. Santa Rosa (2013) reports that the SCWA adjusts community drinking water prior to distribution to a pH ranging from about 7.3 to 8.6 with an average final pH of about 8.2. Russian River water has been reported to exhibit a pH ranging from about 7.4 to 8.5 and Santa Rosa Creek water has been reported to exhibit a pH ranging from about 7.1 to 8.2. Thus, even if such a theoretical release of fluoride from soils were to occur, such release would then be modulated by the natural pH levels in the streams which are not dissimilar to those of the pH-adjusted community drinking water or the treated wastewater. Moreover, if such releases were to occur it would be in response to a rain event which would also have the effect of increasing streamflows further diluting any additional fluoride entering the system.

# 4 Distribution of Federally Listed Salmonids

Chinook salmon, coho salmon, and steelhead use different areas and habitats within the Russian River watershed, and all these species use the lower Russian River as a migration corridor between the ocean and upstream spawning and rearing habitat. Juveniles, during their downstream migration to the ocean also pass through this same reach. The life history of each species is somewhat different and accounts for differences in the relative potential of exposure to fluoride potentially released to streams as a result of community water fluoridation. Steelhead also use the Petaluma River, Novato Creek, and Sonoma Creek. Chinook salmon have been documented in Sonoma Creek, but these are from the Central Valley fall-run Chinook salmon ESU and are not listed and will not be addressed in this assessment.

### Chinook salmon

Chinook salmon are limited to the mainstem and larger tributaries of the Russian River watershed that contain adequate flow to support upstream migration and spawning during the fall to early winter time frame (Chase et al. 2007; Coey 2002). Upstream migration occurs from the last week in August (if the mouth of the river is open) and can continue through December, but the peak of the Chinook salmon run is normally October and November (Chase et al. 2005). Spawning begins in November (Cook 2008), and probably continues into January, but detection of spawning is usually prevented by high flows by this time.

Spawning habitat is located primarily upstream of Healdsburg, to Ukiah and in the West Fork Russian River in the main stem Russian River and in Dry Creek (Cook 2008). Spawning has been documented in Santa Rosa Creek (S. Brady, City of Santa Rosa, Pers. Comm with S. Chase in 2005 as cited in Chase et al. 2007) and is suspected to occur in Mill Creek (tributary to Dry Creek), Austin Creek, and Green Valley Creek based on the capture of juvenile fish during out migrant trapping studies as referenced in Chase et al. (2007). However, juvenile Chinook have been documented rearing in non-natal tributary streams (streams that were not used for spawning) in California's Central Valley (Maslin et al. 1990) and in tributaries to portions of Puget Sound (Beamer et al. 2013). These studies showed that Chinook salmon fry moved out of the main rivers where they were spawned and into tributaries for rearing. Chinook salmon were observed spawning in Santa Rosa Creek in 2002 and juvenile fish also were captured in 2004.

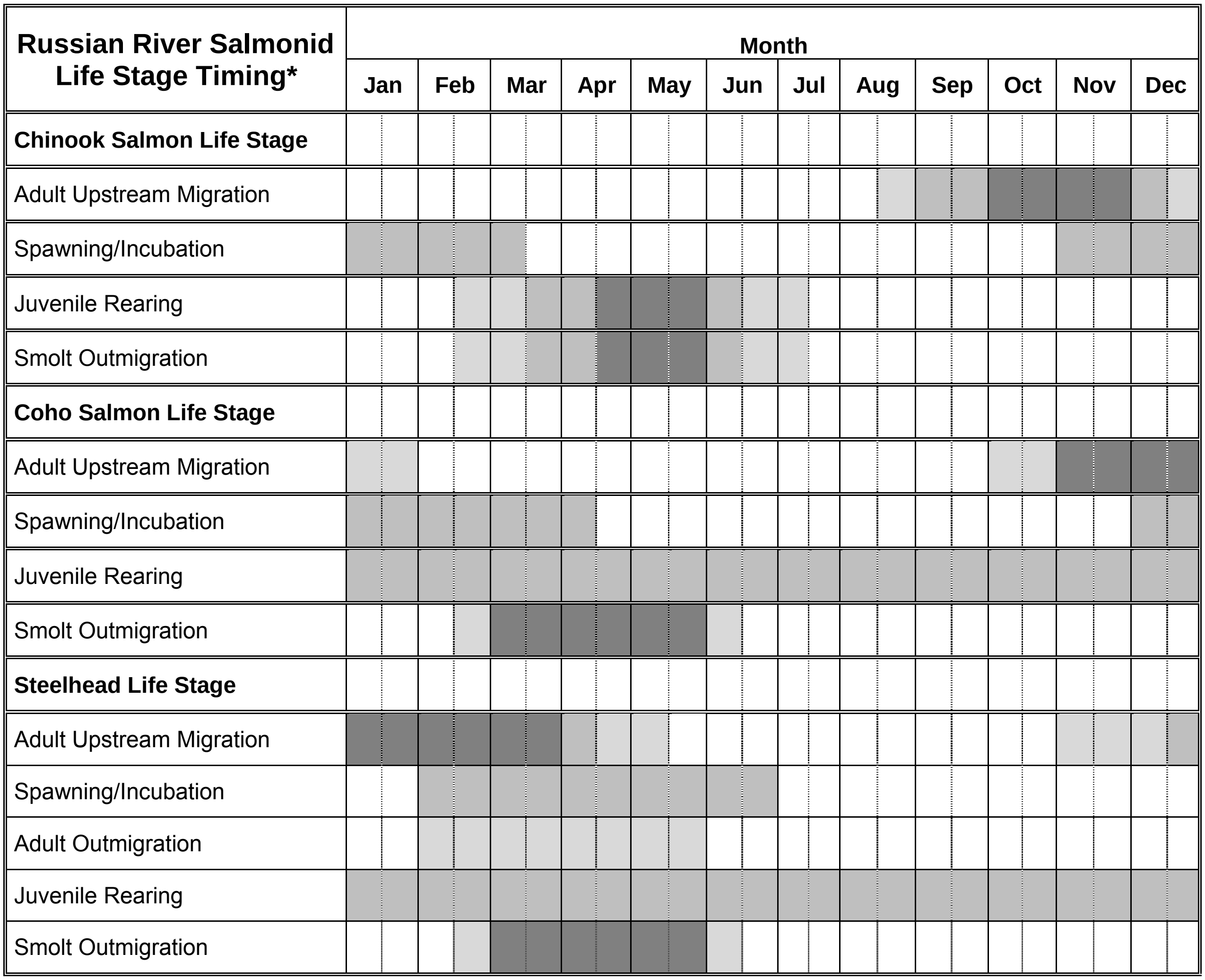
Juvenile Chinook salmon are recognized as having two life history strategies; ocean type, where the fish spend very short periods in freshwater and emigrate at 2 to 4 months of age, and stream type, where they spend a full year in freshwater before emigrating to the ocean. In the Russian River, juvenile Chinook display the ocean type strategy almost exclusively. The main period of emigration occurs from approximately late-February through June in the main stem Russian River (Table 4-1).

Chinook salmon spend from two to five years maturing in the ocean prior to returning to spawn. Most of the returning adults in the Russian River are composed of three year old fish (SCWA 2007).

### Coho salmon

Coho salmon are likely the most habitat selective salmonid in the Russian River watershed. Coho prefer cold water (≤16.3°C), well-shaded, low gradient stream channels that typically include dense riparian canopy often associated with coniferous forest watersheds. Coho salmon primarily inhabit streams in the lower basin, including Willow, Sheephouse, Freezeout, Austin Creeks and tributaries, Dutch Bill and Green Valley Creeks, and possibly Mark West Creek. Coho salmon also inhabit Dry Creek as well as some of its tributaries, including Mill and Palmer Creeks (Coey 2002).

**Table 4-1. Life Stage Timing for Russian River Salmonids**




Legend

| | |
|---|---|
| Not likely to be present | |
| Present in low numbers | |
| Present in moderate numbers | |
| Peak abundance of species | |

*Timing for upstream adult migration and downstream smolt migration is based on detections at Wohler Dam (Chase et al. 2005)

At least historically, populations of coho were also documented in the Maacama and Forsythe Creeks (Coey 2002). Coho salmon are not present in or native to the Petaluma River, Novato Creek, or Sonoma Creek.

Coho have a fairly rigid life history and almost all fish return to spawn as three year olds. They spend approximately eighteen months in freshwater (as fertilized eggs and juveniles) and eighteen months in the ocean, although jacks can return earlier. Coho migrate upstream during November and December and spawn primarily during December and January (Shapovalov and Taft 1954). Since coho spawn in relatively small tributaries, they are dependent on rain to provide sufficient streamflow to allow for passage and spawning. Juveniles hatch out from March through May and spend an entire year rearing in the streams before migrating downstream from February into June (Table 4-1). This rigid life history means that within most coastal streams including the Russian River watershed, there are three separate cohorts or groups that are essentially reproductively isolated from each other because they spawn in successive years (Table 4-2).

**Table 4-2. Coho Salmon Cohorts**

| | Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| Cohort 1 | Spawns/Young | Yearling/Outmigration | Ocean Rearing to Adult |
| Cohort 2 | Yearling/Outmigration | Ocean Rearing to Adult | Spawns/Young |
| Cohort 3 | Ocean Rearing to Adult | Spawns/Young | Yearling/Outmigration |

Note the lack of overlap for spawning adults (all spawn as 3-year old fish and are reproductively isolated from other cohorts.

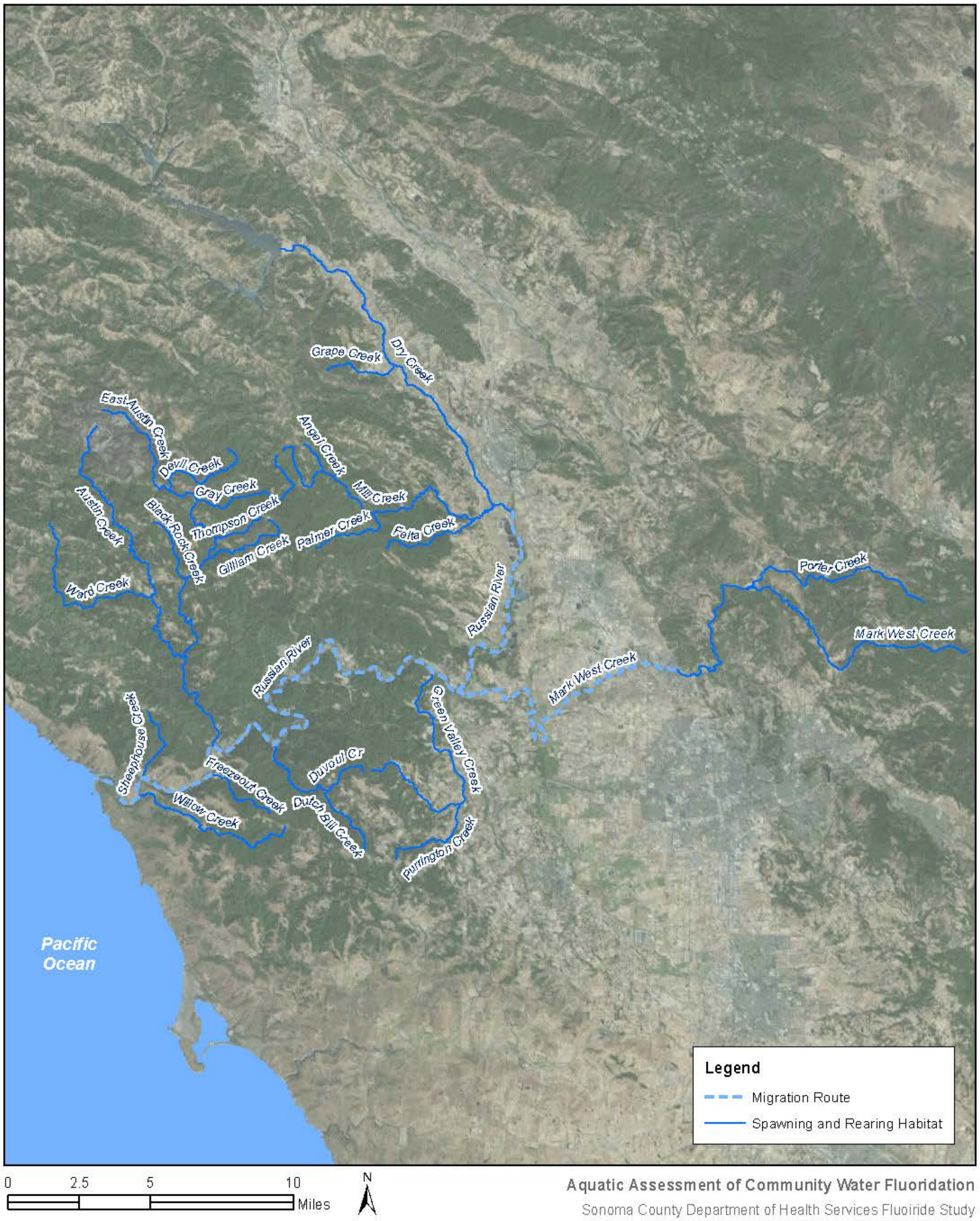
Coho salmon have been documented in 24 creeks in the Russian River watershed (http://cohopartnership.org/watersheds.html). Some of these sites were the result of re-introductions, but most contained wild coho salmon (Figure 4-1).

**Steelhead**

Steelhead inhabit nearly all permanent streams in the basin. Where there is little overlap between coho and Chinook spawning and rearing habitat, steelhead distribution for spawning and rearing overlaps with both coho and Chinook salmon. Steelhead have been documented in Mark West, Santa Rosa, Piner, Paulin, Brush, Mayacama, and Millington Creeks (Chase 2010; Cook 2003; Coey 2002). Steelhead have also been documented in Sheephouse, Austin, Ward, Green Valley, and Mill Creeks and also occupy many of the cooler tributaries throughout the watershed. Limited steelhead rearing occurs in the mainstem Russian River with peak abundances recorded in the Canyon Reach located between Cloverdale and Hopland and near Ukiah (Cook 2003). Spawning habitat in the Russian River overlaps with Chinook salmon (mainly upstream of Cloverdale). Limited rearing has been observed in the mainstem Russian River above the Wohler Dam. Steelhead have also been documented rearing in the lower river near the confluence with Austin Creek and in the estuary (SCWA, unpublished data). Although steelhead are widely distributed in the basin, the overall population is likely depressed compared to historical levels. Steelhead are also known to occur in Novato Creek, Sonoma Creek, and the Petaluma River (Becker et al. 2007).

The opposite of coho salmon, steelhead have a highly flexible life history strategy and are more of a habitat generalist. Steelhead juveniles can spend less than a year to more than two years rearing in the freshwater, and can either remain in freshwater and mature or migrate to the ocean to do so (Shapovalov and Taft 1954; Moyle 2002).

Also adult steelhead do not necessarily die after spawning and can return to the ocean, feed and grow some more, and return to spawn several times (Shapovalov and Taft 1954; Moyle 2002). Anadromous adult steelhead enter the Russian River from at least November through May, although based on hatchery returns peak migration occurs in January through March (Chase et al. 2005).




Aquatic Assessment of Community Water Fluoridation

Sonoma County Department of Health Services Fluoride Study

**FIGURE 4-1**
**Known Streams Supporting Spawning and Rearing of Coho Salmon in the Russian River Watershed**

The steelhead life history in the Russian River show adult steelhead migrating upstream beginning in the fall with a peak from January through March (Table 4-1). Steelhead migrate upstream when winter flows are high and this allows them to gain access to many of the smaller tributary streams not accessible to Chinook or coho salmon. Steelhead spawn from February through April. Adults that survive spawning (called kelts) will migrate back to the ocean during this time. Young fish rear for up to two or more years using habitats in pools, riffles, and runs. Some juveniles will move downstream and rear in the estuary.

# 5 Exposure Assessment

Exposure Assessment is the process of estimating the magnitude and duration of exposure to chemical stressors (USEPA 1997). As briefly discussed in Section 2.3, the exposure assessment approach was to first identify where listed coho salmon, Chinook salmon, and steelhead could encounter fluoride associated with community water fluoridation during their life-cycle. Initially, only those locations within the SCWA service area (see Figure 3-1) were considered since these would be the locations where fluoridated water would be delivered that could potentially enter stream channels either through direct treated water discharge, or though return flows. Secondly, in consultation with SCWA fishery biologists, the distribution of the three listed salmonid species with the SCWA service area was determined. Thereafter, the exposure assessment was narrowed to identify three scenarios ranging from representative to “worse-case”. The worse-case scenario would be the situation where the listed species are likely to be present when:

- Fluoride is at the maximum plausible concentration, undiluted by high flows from natural runoff,
- Fluoride is at the maximum plausible concentration, undiluted by mixing of SCWA sourced water with other non-fluoridated water supplies that may be available within the service area,
- One (or more) of the listed species is likely to inhabit a section of stream which has a discharge of fluoride for a considerable portion of its life cycle (i.e., months).

Additionally, excluded from the worse-case scenario is the situation when:

- Fluoride has limited bioavailability to fish due to the presence of saline water mixing, whereby interaction of fluoride ion with calcium and magnesium in seawater renders it much less soluble and therefore less bioavailable.

Based on the understanding that WWTPs are required to achieve a 100:1 receiving water to effluent dilution ratio (in the absence of NPDES permit exemptions) and because the WWTPs within the SCWA service generally do not discharge to streams during low stream flow seasons, it was determined that return flows would likely be of greater concern than WWTP discharges. Thus, the intent was to select at least one scenario associated with discharge from a wastewater treatment facility and two scenarios based on fluoride exposure associated with return flows.

## 5.1 Wastewater Treatment Facility Scenario

For the wastewater treatment facility scenario, we immediately eliminated the Las Gallinas and Central Marin wastewater treatment plants because the MMWD has been fluoridating their water for over 40 years under their own program. We also eliminated the Novato Sanitary District treatment facility, the Petaluma treatment facility, and the Sonoma Valley treatment facility because they all discharge either directly into the Bay, or into the tidal sloughs and tidally influenced channels of the Bay where salt water interactions would reduce the concentration of bioavailable fluoride. The Airport-Larkfield-Wikiup treatment facility was eliminated because it does not discharge to a stream. Consequently, only the Forestville, Laguna subregional, and Windsor treatment facilities were considered because they discharge to freshwater streams (see Table 3-1) that also support listed species.

In the case of the Laguna facility, there is currently one discharge point into Santa Rosa Creek that is downstream of known summer rearing habitat for steelhead. During the summer period there is no discharge permitted to surface streams, consistent with all of the other wastewater facilities in Sonoma

County. The NPDES permit for the Laguna facility allows wastewater discharges to surface streams outside of the summer season that are diluted to 5% of stream flow, based on the flows gaged on the Russian River at the Hacienda Bridge. However, the Laguna facility sends most of its wastewater to the Geysers for groundwater injection rather than discharge to local streams. During the fall-winter-spring seasons, steelhead could be migrating upstream from the Russian River into Santa Rosa Creek, and would potentially be exposed to fluoridated water releases from the Laguna facility if released during those periods. However, upstream migration does not occur until there is a substantial increase in flow in Santa Rosa Creek, the vast majority of which is generated by natural rainfall-runoff in the upper watershed along the Mayacamas mountain range. Consequently, flow volume in Santa Rosa Creek would be high, diluting fluoride concentrations potentially released from the Laguna facility when steelhead are likely to be present. The Windsor wastewater treatment facility discharges to Mark West Creek. However, water is supplied to Windsor by sources in addition to SCWA water which would mix and dilute the fluoride concentration delivered by SCWA. The Forestville wastewater treatment facility discharges to Jones Creek, which is a tributary just upstream from Green Valley Creek which supports all three listed species. Forestville receives the majority of its water from SCWA. Therefore, Forestville was selected to represent a worse-case scenario for exposure to fluoridated water associated with WWTP discharges.

### 5.1.1 Forestville Wastewater Treatment Facility Exposure Assessment

The Forestville wastewater treatment facility discharges into Jones Creek, which is approximately 0.5-mile upstream from its confluence with Green Valley Creek. Discharge is restricted to the period October 1 to May 14, and the NPDES permit requires that the discharge rate not exceed one-percent of the Green Valley Creek flow (as measured at Iron Horse Bridge). Figure 5-1 shows the location of the treatment plant, Jones Creek, Green Valley Creek, and the Russian River. There are no streamflow gaging records in the Green Valley Creek watershed (Gold Ridge RCD 2013). However, the Forestville wastewater facility tracks streamflow when they are discharging effluent so as to meet or exceed the required 1% of streamflow dilution rate. Records provided by the treatment plant for the month of February 2014 show that the effluent discharge on February 11$^{th}$ was 0.384 MGD (0.59 cfs [cubic feet per second]) and streamflow was 163 MGD (252 cfs), which is a dilution ratio of 420:1[6] (0.24% of streamflow) which is well below the maximum 1% of streamflow requirement.

No data were available on influent or effluent fluoride concentrations from the Forestville WWTP. However, data collected by the SCWA in May and June 2013 show that fluoride concentrations in treated effluent from five other Sonoma County WWTPs ranged from 0.12 to 0.80 mg/L with an average fluoride concentration of 0.24 mg/L (n=11). All fluoride concentrations were equal to or less than 0.21 mg/L except for one outlier concentration of 0.80 mg/L measured in Occidental WWTP effluent (SCWA 2014a). Excluding the one outlier effluent result, the remaining results are consistent and within the range of fluoride concentrations measured annually by the SCWA in Russian River-derived source water between 2002 and 2012 (0.1 to 0.23 mg/L) (SCWA 2014b), and samples collected by the SCWA from Santa Rosa and Paulin Creeks in 2014 (0.1 to 0.12 mg/L) (see Appendix 1). A consistent pattern in the SCWA (2014a) WWTP influent/effluent results was not observed, and therefore, it was not possible to assess the effectiveness of fluoride removal during waste water treatment. Therefore, for the purpose of this assessment, it was assumed that fluoride mass was conserved during treatment and WWTP effluent concentrations would be equal to the community water fluoridation level of 0.7 mg/L. This is a conservative assumption as some fluoride is likely removed from the system during wastewater treatment.

Assuming that the fluoride concentration in the tertiary treated effluent released by the treatment plant is the same 0.7 mg/L as the source water supplied by SCWA, and the assumed background concentration of natural runoff in the receiving water of Green Valley Creek is 0.23 mg/L, then the resulting

[6] Calculated as 252 cfs/0.59 cfs = 420:1 = 0.24% of streamflow

concentration of fluoride in Green Valley Creek would be 0.231 mg/L on this date[7]. In other words, the 0.24% of streamflow dilution rate is so high that the assumed natural concentration of fluoride in Green Valley Creek is nearly unchanged by the contribution of fluoridated water from the wastewater treatment plant. Alternatively, if it is assumed that the treatment plant discharged at the maximum threshold 1% of streamflow compliance requirement, then the maximum fluoride concentration could reach 0.234 mg/L[8], which is just 0.003 mg/L higher than with a 0.24% of streamflow dilution rate. It should be recognized that the concentration of fluoride determined here also assumes that all of the water treated and discharged by the Forestville treatment plant is from fluoridated water delivered by SCWA under the proposed program. There may be some water that enters the treatment plant that is not sourced by SCWA, and therefore would not be fluoridated, which would have the effect of further diluting the fluoride concentrations discharged to receiving waters.

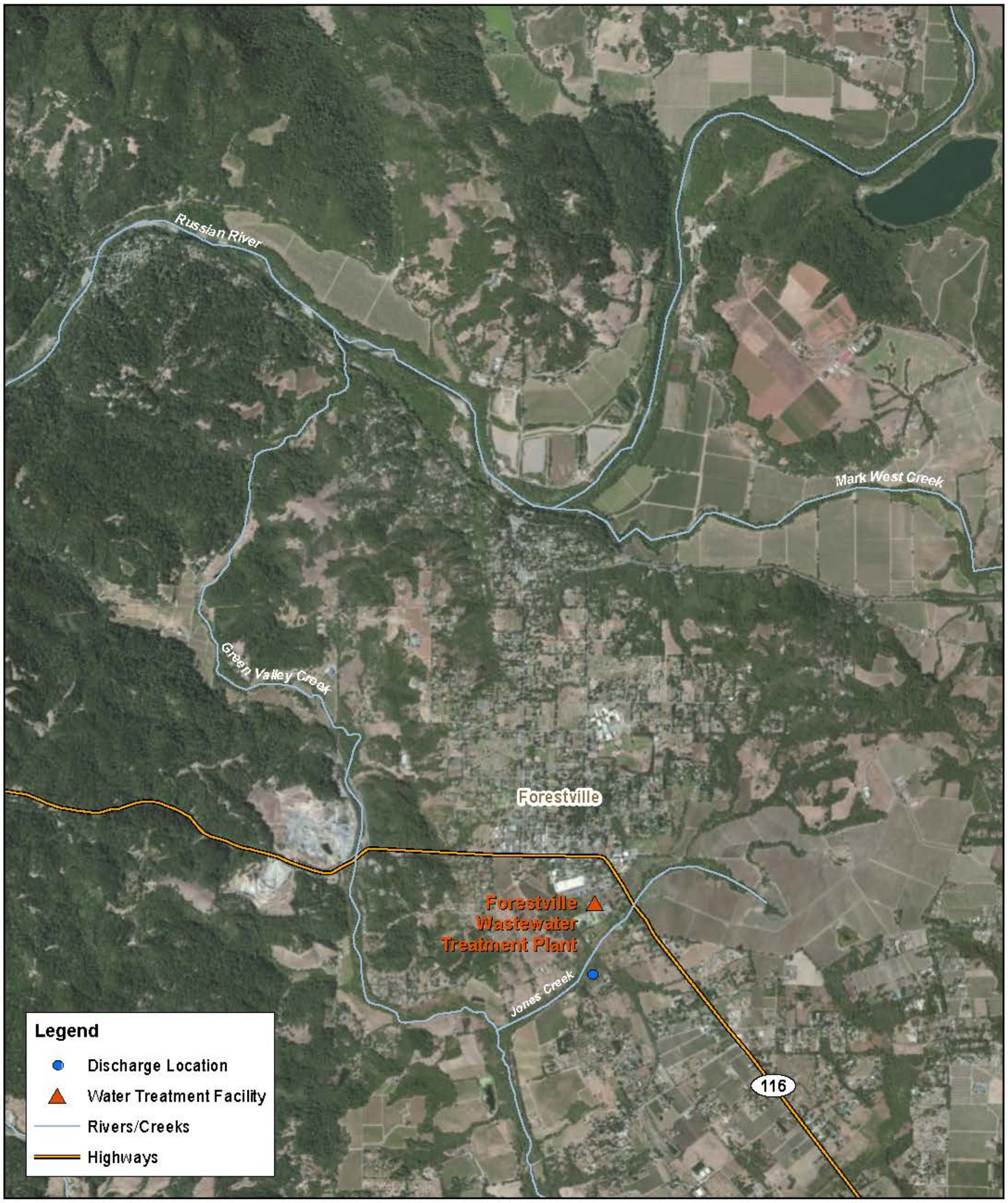
It is noted that for the sampling of records provided by the treatment plant, in February 2014 there were only 6 days of discharge to Jones Creek, in March 8 days, and in April 10 days of discharge. The lowest rate of dilution was 127:1 (0.79% of the Green Valley Creek flow), while on most days the dilution ratio was 171:1 (0.56% of the streamflow) or greater. Based on these records treatment plant discharges are usually diluted to a greater extent than the 100:1 requirement, and are not continuous throughout a given month, but rather occur intermittently.

### 5.1.2 Paulin Creek Exposure Assessment

Unlike the Forestville wastewater treatment plant scenario, return flows represent an unregulated and diffuse, non-point source of fluoride contribution to streams within the SCWA service area. As discussed in section 3.3.2, there is very little information on an appropriate methodology (or any data in Sonoma County) from which to derive a quantification of the proportionate contribution of return flows to streams. In general, Paulin Creek represents a situation where the contribution of return flows is likely to be highest relative to other urban streams within the SCWA service area. This is because the Paulin Creek watershed arises almost entirely within an urbanized drainage area. Figure 5-2 shows the Paulin Creek watershed. There is very little non-urbanized land-use so that contributions from return flows are more likely to be greater than compared with watersheds that have non-urbanized drainage areas contributing to streamflow. Fluoride would be at its maximum concentration in the dry summer period, when there is no precipitation-generated surface runoff to dilute fluoride from return flows in small streams like Paulin Creek. Summer flow must come from either groundwater drainage to the stream which supports the baseflow during the summer, or from return flows via surface runoff through the storm drain system, (as described previously in section 3.3.2) due to application of fluoride treated water for irrigation of vegetation, car washing, etc. The groundwater contribution to summer baseflows could be a mixture of natural, non-fluoridated water, and could in part be associated with fluoridated water which has infiltrated from summer irrigation of lawns, golf courses, etc. back to the groundwater table.

[7] The fluoride concentration calculation in Green Valley Creek is: [ (0.23 mg/L x 420) + (0.7 mg/L x 1)]/421 = 97.3/421 = 0.231 mg/L

[8] The fluoride concentration calculation in Green Valley Creek is: [(0.23 mg/L x 100) + (0.7 mg/L x 1)]/101 = 23.7/101 = 0.234 mg/L




0 1,250 2,500 5,000 Feet
N

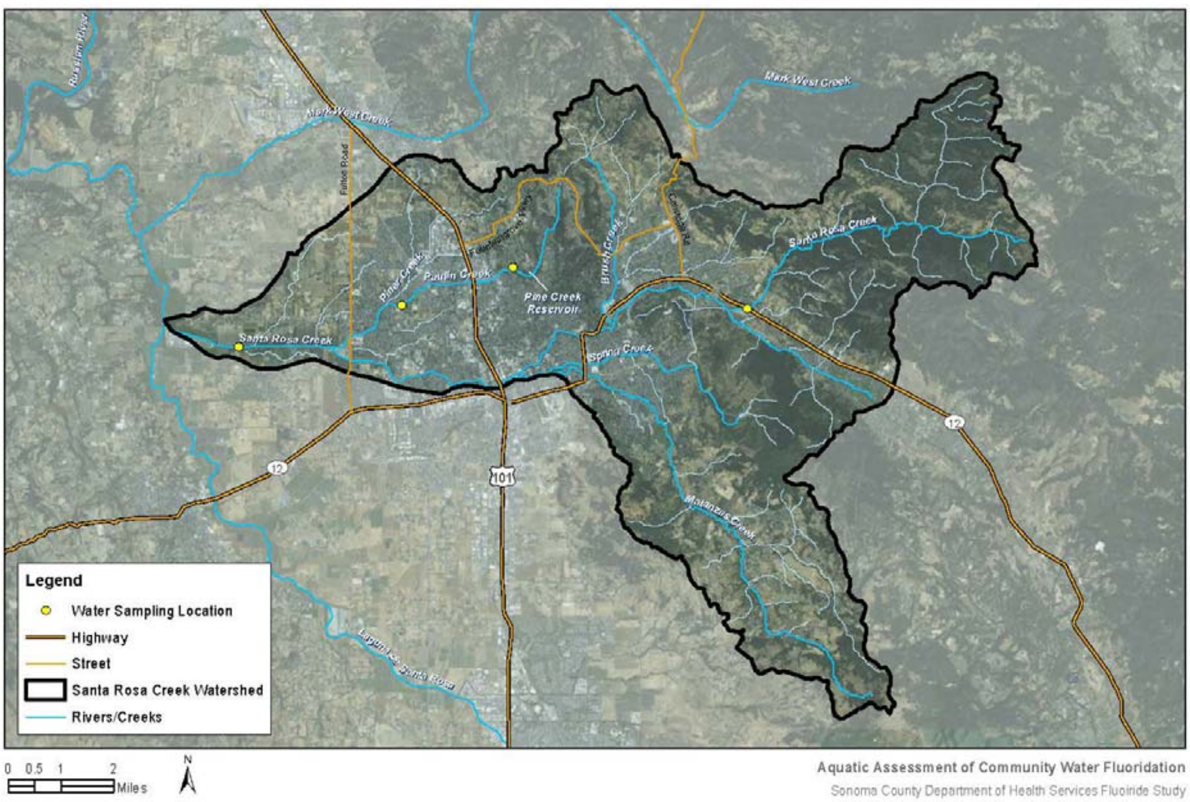
Aquatic Assessment of Community Water Fluoridation
Sonoma County Department of Health Services Fluoride Study

Cardno ENTRIX

FIGURE 5-1
Forestville Wastewater Treatment Plant
and Green Valley Creek

Since quantification of fluoridated water contribution via return flows is unknown, we make a simplifying worse-case assumption for Paulin Creek that the urbanized watershed is contributing only fluoridated water via return flows, with no natural non-fluoridated water contribution for dilution. In this worse-case scenario, fluoride concentration draining to Paulin Creek would be 0.7 mg/L, the same as the fluoridated source water concentration. Although flows are quite low in the summer, (probably only tenths of a cfs based on visual observations made for this study in late June 2014), Paulin Creek is known to support steelhead rearing through the summer period (see section 4.0), and therefore this scenario would represent an exposure pathway to steelhead.

Although we postulate here that 100 percent of the discharge into Paulin Creek during summer is derived from fluoridated water return flows, in all likelihood some portion of the summer baseflow would be from groundwater discharge to the stream that originated from natural rainfall recharge of the groundwater table during the winter months. This would represent non-fluoridated water contributing to Paulin Creek baseflow, which when mixed with fluoridated return flows would dilute the concentration of fluoride in the stream.




Aquatic Assessment of Community Water Fluoridation
Sonoma County Department of Health Services Fluoride Study

Cardno ENTRIX

FIGURE 5-2
Santa Rosa Creek and
Paulin Creek Watersheds

Water samples were collected by SCWA (July 25, 2014) at two locations on Paulin Creek (see Figure 5-2) to test for fluoride and water hardness. Water hardness reduces the concentration of free fluoride ion by binding to calcium, magnesium, and other elements, and consequently reduces the bioavailability and toxicity of fluoride. Water hardness effects on toxicity are further discussed in Section 6. The water samples were analyzed by Alpha Analytical Laboratories, Inc. and the lab results are shown in Table 5-1 (full lab report is provided in Attachment 1).

**Table 5-1. Paulin Creek Fluoride and Hardness Sampling Results**

| | Fluoride (mg/L) | Hardness (mg/L) |
|---|---|---|
| Site 1. Near Chanate Road at hospital, (downstream from Piner Reservoir) | 0.12 | 137 |
| Site 2. Near confluence with Piner Ck (about Marlow Road) | ND | 304 |

ND = not detected at detection limit of 0.1 mg/L.

### 5.1.3 Santa Rosa Creek Exposure Assessment

Similar to the Paulin Creek exposure assessment, another example of potential exposure to fluoride in the aquatic environment is in association with return flows on Santa Rosa Creek. Santa Rosa Creek provides year-round flow that supports steelhead rearing during the summer. Unlike Paulin Creek, the Santa Rosa Creek watershed is not fully urbanized, particularly the headwaters arising in Hood Mountain Regional Park in the Mayacamas Mountains (see Figure 5-2). In addition there is tributary inflow from Matanzas Creek, and other smaller tributaries such as upper reaches of Brush Creek, that also arise in non-urban areas. Consequently, some portion of the summer base flow in Santa Rosa Creek is very likely associated with natural groundwater discharge. As Santa Rosa Creek flows westerly through the urbanized sections of the city, flow increases, and some of the contribution from the urbanized area is likely to be from return flows that would comprise fluoridated water under the proposed treatment program. As previously discussed, prediction of the proportionate contribution of fluoridated return flows to base flows during the summer period is not known, and therefore some reasonable assumptions are made here for purposes of this analysis. In general, it was assumed that because some of the Santa Rosa Creek watershed is outside of urbanized areas the summer baseflows would not be 100-percent fluoridated return flows.

The SCWA made a streamflow measurement on Santa Rosa Creek (on July 25, 2014) at the Highway 12 crossing near Oakmont, which is nearly entirely outside of the urbanized city area. Flow was 0.13 cfs. On the same day, discharge recorded by the USGS gage approximately 11 miles downstream at Willowside Road was 0.8 cfs. There are no other gaging records to account for how much of the 0.8 cfs at Willowside Road (beyond the 0.13 cfs measured at Highway 12) is due to other tributary inputs, such as Matanzas Creek, much of which is outside of the urbanized area. Therefore, a simplifying assumption was made that one-half of the total flow at Willowside Road is due to natural discharge of groundwater and one-half would be due to return flows carrying only fluoridated water. Assuming that the naturally occurring fluoride level is 0.23 mg/L (we note that this is greater than the samples measured in Table 5-2) and given the assumption of one-half the flow is from return flows, then Santa Rosa Creek near Willowside Road would have a fluoride concentration that is 0.47 mg/L[9], which is about two-thirds the source treatment concentration of 0.7 mg/L.

Water samples were taken (July 25, 2014) by SCWA at two locations on Santa Rosa Creek, one at the Highway 12 bridge crossing and one at the Willowside Road gaging station (see Figure 5-2) to test for fluoride and hardness. Results are provided in Table 5-2 (full lab report is provided in Attachment 1). Hardness results are further discussed in Section 6 as they relate to toxicity.

---

[9] The fluoride concentration calculation is: [ (0.23 mg/L x 1) + (0.7 mg/L x 1)]/2 = 0.93/2 = 0.465 mg/L

**Table 5-2. Santa Rosa Creek Fluoride and Hardness Sampling Results**

| | Fluoride (mg/L) | Hardness (mg/L) |
|---|---|---|
| Site 1. Highway 12 near Oakmont | 0.10 | 244 |
| Site 2. Willowside Road | ND | 266 |

ND = not detected at a detection limit of 0.1 mg/L.

# 6 Toxicity Assessment

Toxicity Assessment, also referred to as Effects Analysis, is the process of evaluating the available toxicity studies to characterize the relationships between chemical exposure and toxic response under laboratory and field conditions (USEPA 1998). Toxicity data compiled from relevant studies are used to derive toxicity benchmarks to assess adverse effects to project species. The focus of this project-specific toxicity assessment is to identify the range of fluoride concentrations that are protective of salmonids and conversely to identify the range of fluoride concentrations that correspond to adverse effects in salmonids. The threshold below which adverse effects are not expected and above which adverse effects may occur will be used in the Risk Characterization (Section 7) to describe the potential impacts to salmonids as a result of community water fluoridation within the SCWA service area.

## 6.1 Literature Review

Although fluoride can occur in numerous moieties or formulations, for purposes of this assessment, the focus was on published toxicity studies in which the authors used the typical forms of fluoride used to treat municipal water systems such as sodium fluoride (NaF), fluorosilicic acid (FSA; $H_2SiF_6$), or sodium fluorosilicate (SFS; $Na_2SiF_6$). Although FSA is most commonly used for community water fluoridation, most of the relevant fluoride toxicity studies utilized NaF as it represents a generally accepted method for fluoride toxicity testing. Because all three forms of fluoride result in rapid and complete hydrolysis and dissociation producing free fluoride ion (Urbansky and Schock 2000; Pollick 2004), and the aquatic toxicity studies reviewed report fluoride concentrations in terms of fluoride ion, the specific form of ionic fluoride used (e.g., NaF, FSA, or FSA) is not likely a factor directly influencing toxicity. However, both FSA and SFS will tend to reduce the pH of the water upon application, requiring potable water suppliers to adjust the pH after fluoride application (Urbansky and Schock 2000). Because pH may be a modulating factor in fluoride toxicity to fish, pH was among several factors considered in the evaluation of the fluoride toxicity studies.

All reasonably retrievable and available scientific literature addressing the potential toxicity of fluoride to salmonids was reviewed, including both acute and chronic effects, and effects observed on various stages of the salmonid life cycle. The review included retrieval, collation, synthesis and evaluation of regulatory toxicity information, reported use information and research studies and other reports of direct toxicity and indirect impacts to fluoride exposures during their complete lifecycle. Because the available literature on the specific federally listed salmonids that are the subject of this assessment was very limited, the literature review considered any species within the family Salmonidae (e.g., salmon, trout, and whitefish).

Using the above guidelines, a comprehensive review of available fluoride toxicity data was conducted according to the following sequences:

- Collect, collate, synthesize, and evaluate literature and reports that provide laboratory and field data about the toxicity of fluoride to aquatic biota with an emphasis on salmonids.

- Review the scientific literature to identify the body of research on acute and chronic effects of fluoride on the salmonids of concern, including direct toxicity effects as well as indirect impacts covering their full lifecycle. Where available, utilize reports and data documenting toxicity to salmonid species typical of those in streams in the SCWA service area, including the Central California Coast steelhead, California Coast Chinook salmon, and the Central California Coast coho salmon.

- Review investigations addressing physiochemical influences on fluoride toxicity, including alteration of concentration effects and water quality conditions such as temperature, pH, and especially the water hardness.

- Provide a short summary and defensible critique of relevant studies that can be used to evaluate the potential safe levels and/or potential adverse impacts to salmonids of fluoride introduction at 0.7 mg/L in the potable water supply.

- Provide the results of the reviews in a simple matrix for use by the County in their evaluation of fluoridation options.

## 6.2 Overview of Aquatic Toxicity Benchmarks

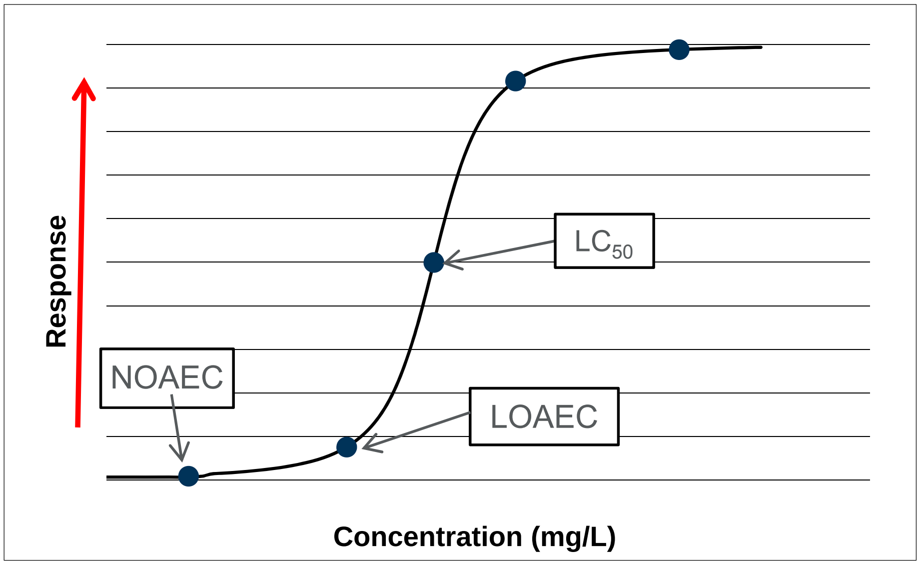
Controlled laboratory tests are most commonly used to evaluate the potential toxicity of chemicals to birds, mammals, and aquatic organisms. In fish and other aquatic organisms, they are focused on determination of the Lowest Observable Adverse Effect Concentration (LOAEC) resulting in an adverse effect to one of several physiological or behavioral endpoints. In contrast to the LOAEC, at lower exposures, another measured exposure concentration is the No Observable Adverse Effect Concentration (NOAEC) which is the highest concentration that does not result in adverse effects to any of the endpoints of interest. The terms LOAEC and NOAEC are analogous to the terms LOAEL and NOAEL as used in mammalian toxicity, where LOAEL means lowest-observable-adverse-effect-level and NOAEL means no-observable-adverse-effect-level, most often in units of mg per kg per day (mg/kg-day) administered dose. The most common adverse effects tested and considered in ecological risk assessments are mortality, reproductive, developmental, and behavioral, referred to as measurement endpoints. Under USEPA (1997) ecological risk assessment framework, measurement endpoints are then aligned with ecosystem relevant endpoints such as community-level or population-level impacts, referred to as assessment endpoints. For federally listed species, protection of individuals is also a statutory goal under the FESA.

LOAECs and NOAECS are typically determined in tests that expose test specimen to a series of tiered chemical concentrations which are used to determine the point at which a percentage (usually 50%) of the animals exhibit an adverse effect to one of the endpoints listed above. For impacts on survival, the most common metric is the $LC_{50}$, defined as the concentration that is lethal to 50% of the population tested. Similarly, other types of adverse effects (e.g., non-lethal effects such as reproductive effects or behavioral effects) can be described by the $EC_{50}$, defined as the concentration that results in adverse effects to 50% of the population tested. The $LC_{50}$ and $EC_{50}$ test results have been used for decades as the basis to estimate the NOAEC and LOAEC. The threshold below which adverse effects are not likely and above which adverse effect may occur lies within the range of concentrations between the NOAEC and the LOAEC as illustrated in Figure 6-1. In ecological risk assessments, results are often presented based on bounding the NOAEC and the LOAEC since the true threshold between effect and no-effect is unknown, but must fall between the highest NOAEC and the lowest LOAEC (USEPA 1997). The highest degree of certainty may be use of only the NOAEC as a no-effect benchmark, in particularly for federally listed species since there is an emphasis under the FESA to project not only populations but individual listed species.

## 6.3 Toxicology of Fluoride

Human exposure to low levels of fluoride has clearly been shown to be beneficial in tooth decay prevention (CDC 2013a). Likewise, fluoride exposure has been shown to be toxic to aquatic organisms at concentrations exceeding those necessary for tooth decay prevention (Pollick 2004). In humans, fluoride can accumulate in hard tissues of the body and is known to be important in mineralization of bone and teeth. At high levels it has been known to cause dental and skeletal fluorosis for which the USEPA has established a drinking water standard of 4 mg/L (USEPA 2009; CDC 2013a).

**Figure 6-1. Generalized Sigmoidal Concentration-Response Curve**




The toxic effects of fluoride compounds have been studied in aquatic invertebrates such as the water flea (*Daphnia magna*) (Dave 1984; LeBlanc 1980), brine shrimp (*Artemia salina*) (Pankhurst et al. 1980), Indian prawn (*Penaeus indicus*) (McC!urg 1984; Hemens and Warwick 1972), and caddisfly (*Hydropsyche* spp.) (Camargo and Tarazona 1990). In general, fluoride toxicity tests conducted in soft water appear more sensitive than those tested in hard or sea water. In fish, fluoride toxicity is influenced by the physiochemical characteristics of the water. Studies have demonstrated that the tolerance of fish to fluoride exposure is increased by low temperatures and high levels of calcium hardness (Angelovic et al. 1961; Herbert and Shurben 1964). Pimentel and Bulkley (1983) found that the 96-hour $LC_{50}$ values for fluoride exposure to rainbow trout (*Oncorhynchus mykiss*) increased from 51 to 193 mg/L as water hardness levels rose from 17 to 385 mg/L $CaCO_3$. Pimental and Bulkley (1983) plotted these $LC_{50}$ values against the water hardness levels and found a positive relationship of decreasing fluoride toxicity with increasing water hardness. The authors concluded that the salmonid species survived concentrations of fluoride in hard water that were lethal in soft water due to the protective effect of $CaCO_3$. USEPA (1984) tabulated $LC_{50}$s associated with varying hardness levels from several studies on rainbow trout (Pimental and Bulkley 1983; Herbert and Shurben 1964; Neuhold and Sigler 1960) (Table 6-1). The calculated regression from these values provides further evidence of the inverse relationship between fluoride toxicity and hardness (Figure 6-2). According to Smith et al. (1985), the protective effect of water hardness on fluoride toxicity to sticklebacks (*Gasterosteus aculeatus*) and fathead minnows (*Pimephales promelas*) was due to the precipitation of fluoride as calcium and magnesium salts.

## 6.4 Selection of Fluoride Toxicity Studies Relevant to the Assessment of Salmonids in Sonoma County

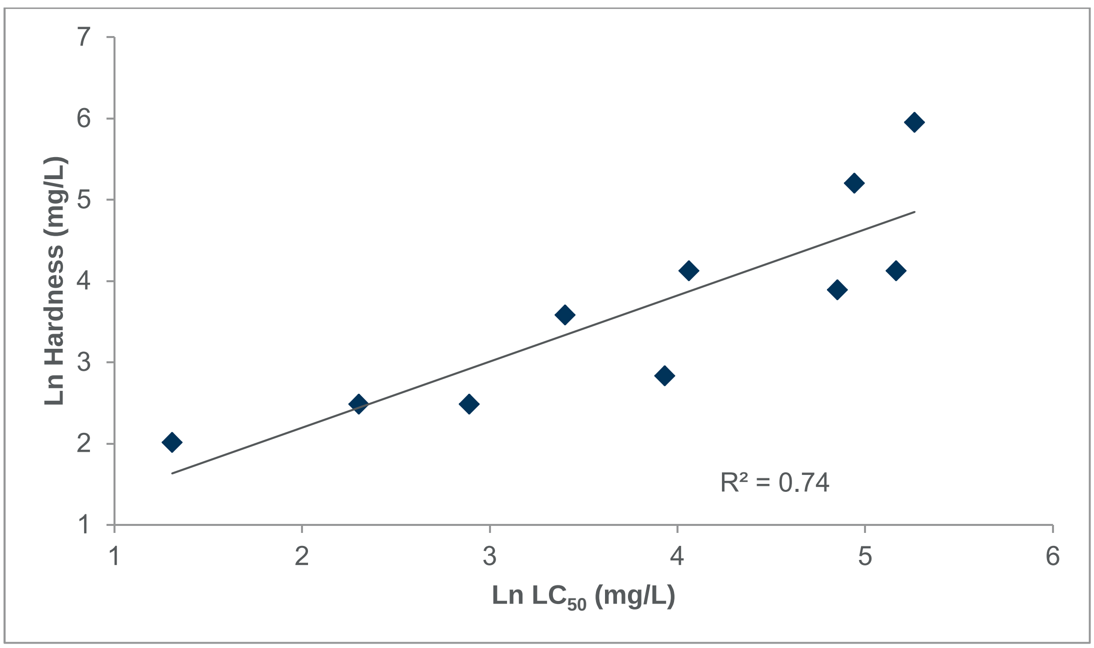
Because the objective of this assessment is specifically to identify the potential adverse impacts on salmonids utilizing streams within the SCWA service area after introduction of fluoride to the potable water system, the review and evaluation focused on determination of safe levels of fluoride in water. Studies that were scientifically defensible, and reported test exposures to adult and early life stages of salmonids, were given the highest weighting.

**Table 6-1. Fluoride Toxicity Values for Rainbow Trout Exposed to Varying Levels of Water Hardness**

| Hardness (mg/L) | $LC_{50}$ (mg/L) |
|---|---|
| 7.5 | 3.7 |
| 12 | 10 |
| 12 | 18 |
| 17 | 51 |
| 36 | 30 |
| 49 | 128 |
| 62 | 58 |
| 62 | 175 |
| 182 | 140 |
| 385 | 193 |

Source: USEPA (1984).

**Figure 6-2. Relationship of Water Hardness to $LC_{50}$ in Rainbow Trout**




Adapted from data presented in EPA (1984).

Each of the available aquatic exposure publications and reports reviewed were evaluated for project relevance and scientific credibility using the following general criteria:

- Does the study evaluate the acute or chronic toxicity of fluoride?
- Are the test species appropriate for comparison to the listed salmonids of interest?
- Does the study include clearly defined controls?

- Does the study include fluoride concentrations that reflect the range of concentrations anticipated in community fluoridated water or potentially in streams within the SCWA service area and do the test concentrations bracket the concentrations of interest?
- Does the study include water hardness data?
- Does the study include appropriate statistics typical of the test regime (e.g., statistical differences between test groups and control groups, statistically significant exposure-response relationship)?
- Is the age of the study a concern?
- Are there contrary or conflicting studies?
- Does the study provide clear, concise summary of the results?
- Does the study make defensible extrapolations of the results or are the authors “extending” their opinions?
- Have the results of the study been reproduced by others?
- Do we agree with the conclusions of the authors? If not, why?

Using these general criteria initially, we identified and collected toxicology studies from numerous sources to include in the review, primarily those published in the peer-reviewed literature. All studies were included in a matrix of information that provided a basis for comparison of the general criteria and subjected to review. All studies considered to be potentially relevant to the project are summarized in Attachment 2.

## 6.5 Summary of Relevant Fluoride Toxicity Studies

The complete list of publications reviewed is presented in the Reference section (Section 7). Studies determined to be relevant to this assessment are summarized in Attachment 2. After careful consideration, it was determined that use of an $LC_{50}$ as a protective benchmark for this project would not be appropriate since by definition the $LC_{50}$ infers mortality to 50% of the population and this would not be acceptable under the FESA. For the same reason it was determined that a NOAEC was the most appropriate benchmark concentration for this project because it represents a “no-effects” concentration. The relevant NOAECs and LOAECs identified in the literature review and taken from Attachment 1 are summarized in Table 6-2. From this table the highest NOAEC (4.4 mg/L) that is lower than the lowest LOAEC (5 mg/L) was identified as the protective no-effects benchmark for this project. This no-effects benchmark is considered conservative given the Camargo (1996) study upon which this NOAEC is taken was conducted using relatively soft water relative to hardness of water within the SCWA service area. The SCWA has reported that the hardness of community drinking water within the SCWA service area ranges from 139 to 146 mg/L $CaCO_3$ (City of Santa Rosa 2014). The SCWA has also reported that source water[10] collected in 2013 from Wohler collectors 1, 2, and 6 and Mirabel collectors 3, 4, and 5 ranged from 98 to 109 mg/L $CaCO_3$ (SCWA 2014b). As discussed in Section 5.2, SCWA recently collected water samples for fluoride and hardness analysis from two of the creeks identified for evaluation in this assessment, Santa Rosa Creek and Paulin Creek. Creek water hardness concentrations ranged from 137 to 304 mg/L $CaCO_3$.

Following the USGS (2014) hardness classification, Santa Rosa Creek and Paulin Creek water would be classified as ranging from hard to very hard. Using a simplistic extrapolation of the measured water hardness data to the USEPA toxicity/hardness data presented in Table 6-1, it is clear that even the lowest hardness values in the sampled creeks would translate to a relative $LC_{50}$ for fluoride toxicity in the Sonoma County creeks approaching 150 mg/L fluoride.

Figure 6-3 compares the range of $LC_{50}$s reported for salmonids against the no-effect threshold of 4.4 mg/L fluoride (Figure 4). This plot clearly shows the propensity of $LC_{50}$ values greater than 50 mg/L

[10] The primary sources of SCWA community drinking water are the Wohler collectors 1, 2, and 6, the Mirabel collectors 3, 4, and 5, and seven vertical wells all of which are located along the Russian River near Forestville.

whereas the no-effects threshold of 4.4 mg/L is at the extreme low end of the concentration range. Several LOAECs as well as one $LC_{50}$ are lower than 4.4 mg/L.

The studies upon which these very low values were based were found to be either not relevant to this project or were found to be not usable for assessment purposes. These are discussed in the next section.

**Figure 6-3. Comparison of Fluoride $LC_{50}$ to No-Effects Threshold in Salmonids**

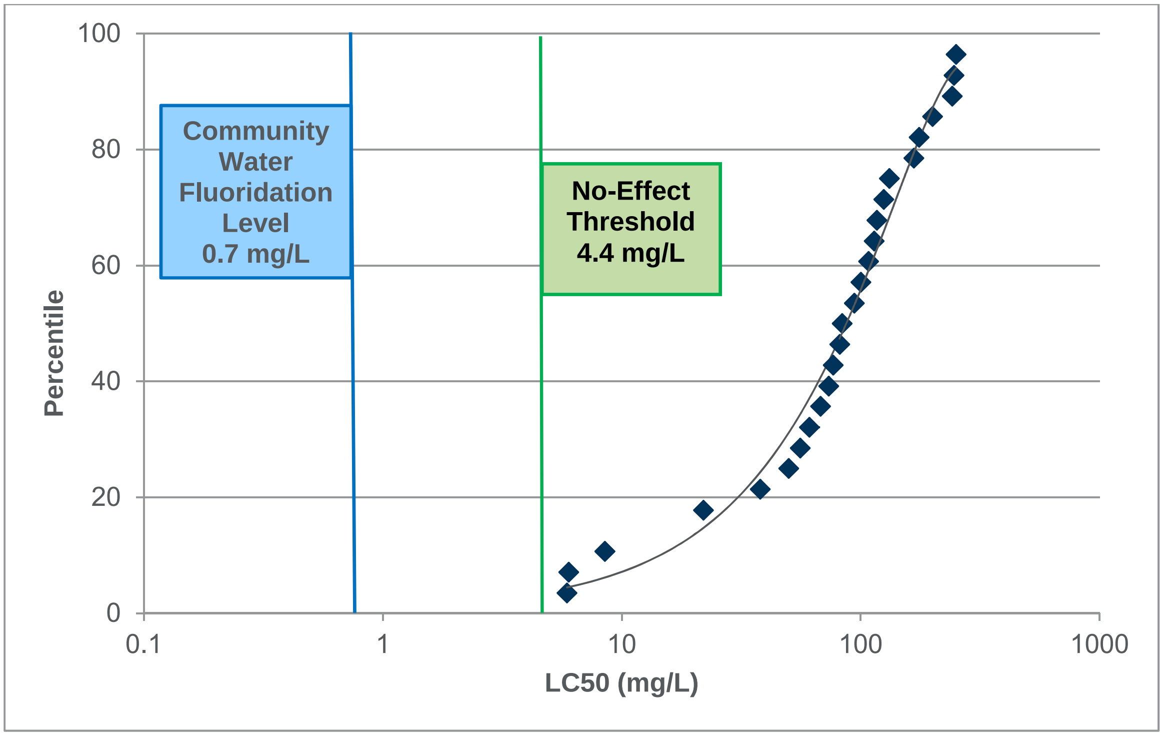



**Table 6-2. Summary of Relevant NOAECs and LOAECs**

| Study | Species | Life Stage | Hardness* (mg/L $CaCO_3$) | NOAEC (mg/L) | LOAEC (mg/L) |
|---|---|---|---|---|---|
| Camargo 1996 | RT | F&F | 21.8 | 3.1 | NR |
| Camargo 1996 | BT | F&F | 21.8 | **4.4** | NR |
| Wright 1977 | BT | F&F | 73 | NR | 5 |
| Camargo & Tarazona 1991 | RT | F&F | 22.4 | 22 | 34 |
| Camargo & Tarazona 1991 | BT | F&F | 21.2 | NR | 34 |
| Herbert & Shurben 1964 | RT | Y&A | 45 | 50 | NR |
| Herbert & Shurben 1964 | RT | Y&A | 320 | 100 | NR |
| Vallen 1968 | RT | Y&A | 320 | 100 | NR |

RT = rainbow trout; BT = brown trout; F&F = fry and fingerlings; Y&A = yearlings and adults; NR = not reported.

*The SCWA reports community water hardness ranging from 139 to 146 mg/L $CaCO_3$, and recent SCWA sampling and analysis reports water hardness in Santa Rosa and Paulin Creeks ranging from 137 to 304 mg/L $CaCO_3$ (City of Santa Rosa 2014; Attachment 2).

## 6.6 Discussion

Experimental conditions reported in many of the fluoride toxicity studies do not report or take into account all the potential confounding variables that may affect toxic response. Thus, making reasonable comparisons and evaluation of the validity of data is often problematic on a quantitative basis. Much of the published data on the interactions of fluoride and environmental conditions, especially water hardness, are complicated by confounding combinations of hardness and fluoride. Thus, effects reported for many studies using calculated fluoride and hardness levels were actually occurring at low hardness levels (BCMOE 2011). Hardness of the exposure waters was, therefore, a primary consideration in the evaluation of the toxicity studies reviewed for this assessment.

Although several studies suggest adverse effect levels to salmonids lower than 5 mg/L, these studies generally contain questionable approaches or study designs, failure to report important parameters (e.g., fluoride measurements, hardness) or are not relevant to the exposure scenarios or toxic endpoints of concern for this assessment.

Examination of the lowest reported effects concentrations for fluoride to salmonids (and some other fishes) are often extrapolations of $LC_{50}$ tests that do not have appropriate or adequate spacing of test concentrations to determine a reasonable NOAEC or LOAEC. That is, in some cases, the lowest effects were assumed to occur at concentration extrapolated below the lowest treatment concentration.

Most aquatic laboratory toxicity tests using salmonids at various life stages report toxicity thresholds above 10 mg/L and some as high as 100 mg/L or more. In order to address studies that reported unusually low or high values, some as low as 0.2 to 0.5 mg/L, these “outlier” studies were critically evaluated for relevance, usability, and validity. The six studies that fell into this category are discussed below.

**Ellis et al. 1948**. This study was published as a U.S. Fish and Wildlife Service (USFWS) report, as cited in Neuhold and Sigler (1960), but is not currently publically available. Neuhold and Sigler (1960) report that this was a study conducted in rainbow trout eggs exposed to fluoride. According to Neuhold and Sigler (1960), the authors’ reported delayed hatching of several hours at 1.5 mg/L fluoride. The study is not published in the peer-reviewed literature and is not publically available, so the methods cannot be evaluated. It is not clear what the biological significance of delayed hatching would be or its relevance to this assessment given that the more critical exposure scenario for this assessment is steelhead rearing, particularly during low water flow regimes, as discussed in Section 5. It is not known whether water hardness was reported in this study. This study was not considered usable for this assessment because of the questionable relevance of delayed hatching and because study methods and conditions are unknown.

**Angelovic et al. 1961**. This was a study conducted on rainbow trout exposed to fluoride in “soft water” generated by filtration through a “commercial water softener” to remove excess calcium and magnesium. The authors reported $LC_{50}$s of 2.3 and 2.6 mg/L for “soft water”. Water hardness data were not reported, but the reporting of “soft water” by the authors suggests that the study water hardness is very low and likely not representative of the hard to very hard water of Sonoma County streams. This study was not considered usable for this assessment because of the very soft water exposure regime used.

**Neuhold and Sigler 1960**. This was a study of rainbow trout exposed to fluoride in soft water with calcium concentrations less than 3 mg/L (equivalent to 7.5 mg/L $CaCO_3$). These authors reported $LC_{50}$s ranging from 2.7 to 4.7 mg/L. This finding is consistent with the numerous other publications that report $LC_{50}$ values as low as this when the exposure water is soft water. As discussed above for the Angelovic et al. (1961) study, this study, using a reported low calcium concentration in the study exposure water is not likely representative of conditions of interest to the SCWA service area since it has been documented that the Sonoma County streams, for the most part, consist of hard to very hard water. As previously discussed, recent sampling of two Sonoma County creeks by the SCWA reported hardness levels ranging from 137 to 304 mg/L $CaCO_3$ (Attachment 2) At these levels of water hardness, fluoride toxicity has been shown in numerous publications to be exceedingly less than at the concentrations reported in this study utilizing very soft water. This study was not considered usable for this assessment because of the very soft water exposure regime used.

**Damkaer and Dey 1989**. One of the most cited studies reporting exceedingly low concentrations associated with toxicity in salmonids was a behavioral study conducted by staff at the National Oceanic and Atmospheric Administration (NOAA) to evaluate the effect of fluoride in the water on salmonid migration in the Columbia River separating Oregon and Washington. This was a two-phase study where the first phase comprised field observations on the Columbia River and the second phase comprised a laboratory study at the Big Beef Creek Fish Research Station located on Hood Canal in the Puget Sound near Seattle, Washington. This study has been cited throughout the literature and has driven a possible behavioral "toxicity" value very low, causing some of the concern by regulators and the public with respect to community water fluoridation. Critical review of this study, as discussed below, strongly suggests that such concern is not warranted.

In the first phase of the study, Damkaer and Dey (1989) *qualitatively observed* migration of adult salmonids past the John Day dam on the Columbia River as they pass through a fish ladder. Their study included evaluation of the delay in selection of the appropriate ladder (north side or south side of the River) after fish approached the entry pool for the ladders. The authors reported a delay in behavioral response time that they attribute to fluoride concentrations in the River from an aluminum plant on the north side of the River just upstream of the dam. The reports of elevated fluoride concentrations in the River preceded this study and the authors assumed, without verification or concurrent monitoring of fluoride, that the impact of fluoride on fish sense of migration was the source of the observed behavioral effects. It is clear that numerous other factors could have been attributed to any delay in choice of ladder. In fact, a critical review of the study and its apparent confounding factors was provided by Shepard in 2006 that clearly and critically describes the problems with the study and refutes the conclusions by Damkaer and Dey (1989).

The authors suggest that their observation of the delay prior to entering the ladder to traverse the dam and continue upstream "*appeared to contribute to increased mortality and may have affected the spawning success of migrating adult salmonids*." This conjecture by the authors was never verified and remains as unsupported speculation. They made the speculation based on other historic data on the River but had no relation to the concentrations of any contaminants, including fluoride, in the River. In fact, according to a critical review by Shepard (2006), their statement is only hypothetical:

> *"The lack of response by migrating salmonids to flow alterations below the dam focused attention on the* ***possibility*** *that* ***something*** *in the water* ***might*** *be causing fish to avoid the north fish way and delay their passage.* ***If behavior-altering pollutants were present*** *at even very low concentrations, migrating adult salmonids* ***might*** *sense and respond to them."*

Clearly, conjecture cannot be scientifically defensible and for these reasons and others this phase of the study was considered to be neither sound nor relevant. In the second phase of their study, Damkaer and Dey (1989) reported behavioral effects related to avoidance of fluoride in a side-by-side two chamber flume designed to validate the earlier field studies. One flume chamber received fluoride treatment to bring the fluoride concentration up to either 0.5 or 0.2 mg/L. The other flume received no fluoride. Chinook, coho, and chum salmon were held one at a time in a holding pool just downstream of the two flumes and provided a choice of swimming up the flume treated with fluoride or up the flume not treated with fluoride. In 1983, fish were allowed 60 minutes to decide which flume, if any, to swim through. In 1984, fish were only allowed 20 minutes to make this decision. Data from 1983 and 1984 were pooled for statistical analyses. The authors reported no differences in flume choice for Chinook or coho salmon exposed to 0.2 mg/L fluoride; chum salmon were not included in the 0.2 mg/L exposure scenario. No difference in flume choice was reported for chum salmon exposed to 0.5 mg/L fluoride. However, the authors reported that for Chinook salmon, more fish (42 fish) chose the flume without fluoride treatment than the flume with fluoride treatment (16 fish; $p<0.001$). For coho salmon, more fish (41 fish) chose the flume without fluoride treatment than the flume with fluoride treatment (21 fish; $p<0.05$). Interestingly, 54 Chinook salmon failed to make any choice and 35 coho salmon failed to make any choice. Deamker and Dey (1989) concluded that 0.5 mg/L fluoride may adversely affect migration of adult salmon and that 0.2 mg/L fluoride may be near or below the threshold for sensitivity in Chinook and coho salmon. There are several factors related to study design and reporting that render this study unusable for establishing a definitive NOAEC or LOAEC for the purpose of this assessment:

1) Data from 1983 and 1984 were pooled for statistical analysis. Therefore, it is not possible to discern whether the time allowed (60 minutes in 1983 and 20 minutes in 1984) to choose a flume influenced flume selection.
2) Control tests were conducted with no fluoride treatment to either plume, but the results of the control tests were not reported. In is unclear whether a placebo treatment of water without fluoride was used, or if the control tests were simply done on natural water flowing through the two flumes. It appears that controls tests were carried out only at the beginning of the study and not at the end of the study when water temperatures and fish ripeness would have changed substantially.
3) It was reported that fluoride concentrations in 1983 were “approximately” 0.5 mg/L fluoride in the treatment flume. There is no indication anywhere in the paper that fluoride concentrations were actually measured in the flume study. It appears they were likely estimated based on estimates of fluoride treatment flow rate and water flow rate through the flume. Damkaer and Dey (1989) also did not report the source or grade of fluoride used in the laboratory tests nor did they report fluoride analysis of the treatment material prior to application to the flume water. These shortfalls raise serious questions about the accuracy of the 0.2 mg/L and 0.5 mg/L fluoride exposure concentrations in the treated flume.
4) While the authors state that the two flumes were of equivalent size and water flow, no water flow measurements were taken, at least not reported. Flow velocity has been shown to be a sensitive factor in salmonid migration and is a cue for salmonid navigation (Weaver 1963).
5) Replicate study groups were not employed and the findings have not been duplicated by others, thus increasing the possibility that the “significant” findings were due to chance even though the authors reported statistically significant differences.

In summary, the Damkaer and Dey (1989) study may provide useful information for developing further hypotheses regarding the potential effects of fluoride on salmonid behavior, thus suggesting the need for future more robust studies, but does not provide definitive results that would be considered usable for establishing NOAECs and LOAECs for use in this assessment.

**Camargo and Tarazona 1991.** These authors conducted short-term static bioassays with brown trout and rainbow trout fingerlings exposed to five different concentrations of fluoride in soft water (22 mg/L $CaCO_3$) for 8 days. Test fish in fluoride exposures showed hypoexcitability, darkened backs, and a decrease in respiration before their death, but the $LC_{50}$ values were quite high (even for relatively soft water) where $LC_{50}$ values ranged from 92.4, 85.1, 73.4 and 64.1 mg/L fluoride for rainbow trout and 135.6, 118.5, 105.1 and 97.5 mg/L fluoride for brown trout. This study was not considered usable or relevant to this assessment because of the soft water exposure regime and the inconsistent findings relative to what other report for the relationship between toxicity and water hardness.

**Camargo 2003**. As a summary of the previous work on fluoride toxicity to aquatic organisms, Camargo (2003) reviewed and documented numerous prior studies that provided data about the relative acute and chronic toxicity to plants, invertebrates and fishes. Among the several physiochemical and body size impacts on fluoride toxicity, the clear result is that hardness is a primary factor in the toxicity to aquatic species studied. This publication supports the contention throughout this section that the toxicity of fluoride to fish (salmonids included) is critically and proportionately associated with water hardness.

## 6.7 Toxicity Assessment Summary

The review of available toxicity studies on the effects of fluoride exposure to salmonids considered usable for this assessment identified five studies reporting a total of six NOAECs and three LOAECs (Table 6-2). From these studies, the lowest LOAEC reported was 5 mg/L fluoride and the highest NOAEC less than the lowest LOAEC was 4.4 mg/L fluoride. As shown in the Figure 6-3, the vast majority of $LC_{50}$s fall well above these levels. The available and usable fluoride toxicity studies were conducted under a wide range of water hardness conditions. Water hardness modulates fluoride toxicity to fish such that fluoride toxicity is inversely correlated with water hardness. While the NOEAC and LOAEC identified in this assessment were derived from studies of relatively low water hardness relative to Sonoma County streams where water hardness is expected to be hard to very hard there is unsufficient fluoride toxicity data at the higher water hardness concentrations that would be more representative of Sonoma County streams specifically in the context of bounding NOAECs and LOAECs. Therefore, while the selected NOAEC and LOAEC are not perfectly representative of Sonoma County stream conditions, they are conservatively representative as they are based on studies conducted using relatively softer water. The NOAEC of 4.4 mg/L fluoride was selected as the toxicity benchmark for this assessment because it represents a no-effect level rather an effects level. For federally listed species, a no-effect level is more relevant as it assures that no effects would be anticipated to either individual salmonids or populations of salmonids.

# 7 Risk Characterization

Risk Charcterization is the process of integrating toxicity information and exposure information to estimate ecological risk or conversely the margin of safety or protectiveness (USEPA 1998). As discussed in Section 6, because the ecological receptors of interest are salmonids that are protected under the FESA and CESA, it is important that the risk characterization address potential impacts to both individual salmonids as well as salmonid populations. For this assessment, the margin of safety (MOS) was calcluated under each of the three scenarios to represent the degree of protectiveness.

The MOS is calculated as follows:

$$MOS = \frac{NOAEC}{EC}$$

Where,

MOS = margin of safety (unitless)

NOAEC = No Observable Adverse Effect Concentration (4.4 mg/L fluoride)

EC = Exposure Concentration (mg/L fluoride)

The risk characterization results are presented in Table 7-1. For the Forestville WWTP, dilutions of 1% or 0.2% of streamflow result in MOSs of 19 in both cases because the fluoride contribution from the WWTP is negligible as compared to the assumed natural background concentration of fluoride (0.23 mg/L). This finding illustrates that WWTP dilution requirements specified either in NPDES permits or by the Basin Plan are protective of these discharges. Even under the worst case scenario of Paulin Creek receiving 100% return flow containing 0.7 mg/L fluoride and no dilution from natural water, there is 6.3-fold margin of safety. The Santa Rosa Creek scenario of 50% dilution relative to receiving waters is likely the best estimate return flow scenario for summertime conditions in a creek when steelhead are present for rearing. As shown on Table 7-1, this scenario shows a MOS of 9.5. The worst-case scenario for Paulin Creek resulting in an MOS of 6.3 shows that fluoridation of community drinking water in the SCWA service area will not result in harm to listed salmonids.

**Table 7-1. Risk Characterization Results**

| Fluoride Source | Receiving Water | Percent Dilution[1] | Fluoride Concentration (mg/L) | Margin of Safety[2] |
|---|---|---|---|---|
| Forestville WWTP | Green Valley Creek | 0.20% | 0.23 | 19 |
| Forestville WWTP | Green Valley Creek | 1.0% | 0.23 | 19 |
| Return Flow from Urbanized Areas | Santa Rosa Creek | 50% | 0.47 | 9.5 |
| Return Flow from Urbanized Areas | Paulin Creek | 0% | 0.70 | 6.3 |

1. Percent dilution of WWTP discharge or return flow as a percentage of flow in the receiving water (e.g., a dilution ratio of 100:1 is equivalent to a percent dilution of 1.0% of streamflow).
2. MOS estimates are likely under-stated because of the very hard SCWA source water and Sonoma County creek water relative to the low hardness of water used in the toxicity studies defining the LOAEC and the NOAEC.

The primary focus of this assessment was on the direct effects of fluoride exposure to salmonids. Fluoride released to local streams as a result of community water fluoridation could also affect salmonid food sources, such as aquatic and benthic invertebrates and small fish. Camargo (2003) published a review of the scientific literature and found that adverse effects to invertebrates and other species of fish generally occur within the same fluoride concentration range as reported herein for salmonids and that water hardness also modulates toxicity in these food item species (Camargo 2003). Therefore, potential impact to salmonids as a result of fluoride-related effects on food sources is highly unlikely.

## 7.1 Uncertainty Discussion

Uncertainty is inherent to all ecological risk assessments. For this assessment of potential impacts to listed salmonids from exposure to community fluoridated water released to streams within the SCWA service area either via WWTPs or via return flows, conservative estimates of fluoride toxicity (e.g., use of the NOAEC) as well as exposure estimates that consider an unlikely high contribution of fluoridated water to the natural creek water demonstrate the protectiveness of the findings.

The key uncertainties associated with this assessment include.

- Toxicity values (LOAECs and NOAECs) based largely on rainbow trout and not specifically on the listed salmonids evaluated in this assessment. The degree of uncertainty is considered low given that rainbow trout are the same species as steelhead and in the same family of fish (Salmonidae) as Chinook and coho salmon.
- Extrapolation of toxicity results for fish raised in the laboratory to those residing the wild. The degree of uncertainty is considered moderate, but it is not possible to judge the direction (e.g., overly conservative versus not sufficiently conservative). However, because toxicity values were selected at the very low spectrum of toxicity values, it is unlikely that toxicity was under-estimated. Moreover, the highest NOAEC and lowest NOAEC that were selected for this assessment were based on toxicity studies conducted in water with hardness ranging from about 22 to 73 mg/L $CaCO_3$. Recent sampling by the SCWA suggests that hardness is much higher in these streams, thus mitigating toxicity, which was not directly accounted for in this assessment.
- Exposure concentrations for WWTPs based on NPDES or Basin Plan requirements for dilution. The degree of uncertainty is low given that dilution requirements have regulatory enforcement.
- Exposure concentrations for streams receiving return flows. These scenarios have the highest degree of uncertainty because there is uncertainty in both the proportionate mix of natural stream flows and return flows contributing to streams, particularly during the dry summer low-flow period. This uncertainty has largely been mitigated by assessing the worst-case Paulin Creek scenario which assumed 100% return flow contribution with no contribution of natural stream water.

## 7.2 Recommendations

The following recommendations may be considered should the County decide to fluoridate community drinking water within the SCWA service area.

- Collect seasonal water samples for both fluoride and hardness analysis given that the findings of this assessment are based the assumption of fluoride concentrations in streams no greater than 0.7 mg/L and hardness in the range of 22 to 73 mg/L $CaCO_3$, the range of hardness used in the toxicity studies upon which the NOAEC and LOAEC were taken. If fluoride concentrations in streams exceed 0.7 mg/L or if hardness is found be much lower than 22 mg/L $CaCO_3$ then appropriate action should be taken ensure that the community water fluoridation program remains protective of salmonids in receiving waters.

- Periodically collect samples for fluoride analysis from WWTPs to confirm that treated water discharged to receiving waters does not contain fluoride concentration exceeding a level that could cause harm to salmonids. If fluoride levels in discharged treated water exceed a level that may potentially be harmful to salmonids, then appropriate action should be taken ensure that the community water fluoridation program remains protective of salmonids in receiving waters.

# 8 References


American Dental Association (ADA). 2005. Fluoridation Facts. ADA Statement Commemorating the 60th Anniversary of Community Water Fluoridation. Chicago, Illinois. 69 pp.

Angelovic, J.W., W.F. Sigler, J.M. Neuhold. 1961. Temperature and fluorosis in rainbow trout. *J. Water Pollut. Control Fed.* 33:371-381.

Beamer, E.M., W.T. Zackey, D. Marks, D. Teel, D. Kuligowski, R. Henderson. 2013. Juvenile Chinook salmon rearing in small non-natal streams draining into the Whidbey Basin. Skagit River System Cooperative, LaConner, WA.

Becker, G.S., I.J. Reining, D. A. Asbury, A.Gunther. 2007. San Francisco Estuary Watersheds Evaluation. Identifying Promising Locations for Steelhead Restoration in Tributaries of the San Francisco Esutary. Report prepared by the California State Coastal Conservancy, by the Center for Ecosystem Management and Research. August 2007.

British Columbia Ministry of Environment (BCMOE). 2011. Ambient Water Quality Criteria for Fluoride. 5.0 Aquatic Life. September. http://www.env.gov.bc.ca/wat/wq/BCguidelines/fluoride/fluoridetoo-04.html

Camargo, J.A. 1996. Comparing levels of pollutants in regulated rivers with safe concentrations of pollutants for fishes: a case study. *Chemosphere* 33:81-90.

Camargo, J.A. 2003. Fluoride toxicity to aquatic organisms: a review. *Chemosphere* 50:251-264.

Camargo, J.A., J.V. Tarazona. 1991. Short-term toxicity to fluoride ion (F-) in soft water to rainbow trout and brown trout. *Chemosphere* 22:605-611.

Center for Disease Control and Prevention (CDC). 2013a. Facts for Dental Fluorosis. http://www.cdc.gov/fluoridation/safety/dental_fluorosis.htm

Center for Disease Control and Prevention (CDC). 2013b. Fluoridation Basics. http://www.cdc.gov/fluoridation/basics/index.htm

Chase, S. 2010. Sonoma County Water Agency's Stream Maintenance Program: Initial Fish and Water Temperature Investigations: 2005-2007, Sonoma County Water Agency Report, 25 January, 2010.

Chase, S.D., D.J. Manning, D.G. Cook, S.K. White. 2007. Historic Accounts, Recent Abundance and Current Distribution of Threatened Chinook Salmon in the Russian River, California. *Calif. Fish Game.* 93(3); 130-148.

Chase, S.D., R. Benkert, D. Manning. 2005. Sonoma County Water Agency's Mirabel Rubber Dam/Wohler Pool Fish Sampling Program: Year 5 Results 2004. Sonoma County Water Agency Report, 31, December 2005.

City of Santa Rosa. 2014. 2013 Water Quality Report. Board of Public Utilities, City of Santa Rosa.

Community Preventive Services Task Force (CPSTF). 2002. Recommendations on Selected Interventions to Prevent Dental Caries, Oral and Pharyngeal Cancers, and Sports-Related Craniofacial Injuries. *Am. J. Prev. Med.* 23:16-20.

Coey, R. 2002. Draft Russian River Basin Fisheries Restoration Plan, California Department of Fish and Game, July 2002 Review Draft.
http://ca-sgep.ucsd.edu/focus-areas/healthy-coastal-marine-ecosystems/russian-river-coho/
http://cohopartnership.org/watersheds.html

Cook, D. 2008. Chinook Salmon Spawning Study, Russian River, Fall 2002-2007. Sonoma County Water Agency Report, 2008.

Cook, D., 2003. Upper Russian River Steelhead Distribution Study. Sonoma County Water Agency Report, March 2003.

Damkaer, D.M., D.B. Dey. 1989. Evidence for fluoride effects on salmon passage at John Day Dam, Columbia River, 1982-1986. *N. Amer. J. Fish. Manage.* 9:154-162.

Dave, G. 1984. Effects of fluoride on growth, reproduction and survival in *Daphnia magna*. *Comp. Biochem. Physiol.* 78C:425-431.

DeWalle, D.R., B. Sistock, T. Johnson. 2000. Streamflow variations with population growth on urbanizing catchments in the United States. Proceedings of Watershed Management and Operations Management, 2000 1-6. Fort Collins, Colorado, June 20-24.

Ellis, M.M., B.A. Westfall, M.D. Ellis. 1948. Determination of water quality. U.S. F&W Research Report 9, 122 pp.

Gold Ridge Resource Conservation District. 2013. The Green Valley Creek Watershed Management Plan, Draft Phase II, March.

Hazardous Substance Data Base (HSDB). 2014. Toxicology Data Network, National Library of Medicine. http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

Hemens, J., R.J. Warwick. 1972. The effects of fluoride on estuarine organisms. *Water Res.* 6:1301-1308.

Herbert, D.W.M., D.S. Shurben. 1964. The toxicity of fluoride to rainbow trout. *Water Waste Treat.* 10:141-142.

Hibbs, B., W. Hu, R. Ridgway. 2011. Origin of stream flows at the wildlands-urban interface, Santa Monica Mountains, California, U.S.A. *Environmental & Engineering Geoscience*, Vol. XVII, No. 4, November. .

Langbein, W.B. and Kathleen T. Iseri. 1960. Science in your watershed. General introduction and hydrologic definitions. Manual of hydrology: Part 1. General surface-water techniques. Geological Survey Water Supply Paper 1541-A.

LeBlanc, G.A. 1980. Acute toxicity of priority pollutants to water flea (*Daphnia magna*). *Bull. Environ. Contam. Toxicol.* 24:684-691.

Maslin, P.E., W.R. McKinney, T.L. Moore. 1996. Intermittent streams as rearing habitat for Sacramento River Chinook salmon. Anadromous Fish Restoration Program, U. S. Fish and Wildlife Service, Stockton.

McClurg, T.P. 1984. Effects of fluoride, cadmium and mercury on the estuarine prawn *Penaeus indicus Water SA* 10(1):40-45.

Moyle, P.B. 2002. Inland Fishes of California. Revised and Expanded. University of California Press, Berkeley. 502 pp.

MWH. 2013. Fluoridation Preliminary Engineering Design Report. Draft. Prepared for the Sonoma County Department of Health Services. June.

Neuhold, J.M., W.F. Sigler. 1960. Effects of sodium fluoride on carp and rainbow trout. *Transactions of the American Fisheries Society* 89(4):358-370.

North Coast Regional Water Quality Control Board (NCRWQCB). 2011. Water Quality Control Plan for the North Coast Region. Santa Rosa, CA. May.

Parkhurst, N.W., C.R. Boyden, J.B. Wilson. 1980. The effect of a fluoride effluent on marine organisms. *Environ. Pollut.* 23(4):299-312.

Pillai, K.S., U.H. Mane. 1984. The effect of fluoride on fertilized eggs of a freshwater fish, *Catla catla* (Hamilton). *Toxicol. Let.* 22:139-144.

Pimentel, R., R.V. Bulkley. 1983. Influence of water hardness on fluoride toxicity to rainbow trout. *Environ. Toxicol. Chem.* 2:381-386.

Shapovalov, L., A.C. Taft. 1954. The life histories of steelhead rainbow trout (Salmo gairdneri gardneri) and silver salmon (Oncorhynchus kisutch). *CDFG Fish Bull*. 98 1-275.

Smith, L.R., T.M. Holdsen, N.C. Ibay, R.M. Block, A.B. De Leon. 1985. Studies on the acute toxicity of fluoride ion to stickleback, fathead minnow, and rainbow trout. *Chemosphere* 14(9):1383-1389.

Sonoma County Water Agency (SCWA). 2014a. Source water and waste water treatment plant influent and effluent fluoride concentration data provided to Cardno ENTRIX by Sonoma County Water Agency on June 6.

Sonoma County Water Agency (SCWA). 2014b. Sonoma County Water Agency – Caissons 1 thru 6 – 2013 Water Quality Report. March 26.

United States Department of Health and Human Services (HHS). 2011. HHS and EPA Announce New Scientific Assessments and Actions on Fluoride. http://wayback.archiveit.org/3926/20140108162323/http:/www.hhs.gov/news/press/2011pres/01/20110107a.html

United States Environmental Protection Agency (USEPA). 1984. Surface Water Quality Standard Documentation for Fluoride.

United States Environmental Protection Agency (USEPA). 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (Interim Final). Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response. EPA 540/R-97/006. June.

United States Environmental Protection Agency (USEPA). 1998. Guidelines for Ecological Risk Assessment. Risk Assessment Forum. Washington, DC. EPA/630/R-95/002F. April.

United States Environmental Protection Agency (USEPA). 2009. National Primary Drinking Water Regulations . Washington, DC. EPA/816-F-09-004. May.

United States Geological Survey. (USGS). 2014. Water Hardness. http://water.usgs.gov/edu/hardness.html

Vallen, S. 1968. The toxicity of fluoride to fish. *Vatten* 24:51-58.

Woodwiss, F.S., G. Fretwell. 1974. The toxicity of sewage effluents, industrial discharge and some chemical substances to brown trout (Salmo trutta) in the Trent River Authority Area. *Wat. Pollut. Control* (G.B.) 73: 396.

Weaver, C.R. 1963. Influence of water velocity upon orientation and performance of adult migrating salmonids*. Fish. Bull.* 63(1):97-121.

Wright, D.A. 1977. Toxicity of fluoride to brown trout fry (*Salmo trutta*). *Environ. Pollut.* 12:57-62L

# Attachment 1

## Sonoma County Water Agency Water Hardness and Fluoride Analytical Results for Santa Rosa and Paulin Creeks

Alpha Analytical Laboratories Inc.
e-mail: clientservices@alpha-labs.com
Corporate: 208 Mason St., Ukiah, CA 95482 • Phone: (707) 468-0401 • Fax: (707) 468-5267
Bay Area: 6398 Dougherty Rd., Suite 35, Dublin, CA 94568 • Phone: (925) 828-6226 • Fax: (925) 828-6309
Central Valley: 9090 Union Park Way, Suite 113, Elk Grove, CA 95624 • Phone: (916) 686-5190 • Fax: (916) 686-5192

ELAP Certificates 1551, 2728, and 2922

08 August 2014

Sonoma County Water Transmission
Attn: Todd Schram
404 Aviation Blvd.
Santa Rosa, CA 95403
RE: Fluoridation
Work Order: 14G2052

Enclosed are the results of analyses for samples received by the laboratory on 07/28/14 15:50. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jeanette Poplin

Jeanette L. Poplin For Sheri L. Speaks
Project Manager

Alpha Analytical Laboratories Inc.
e-mail: clientservices@alpha-labs.com
Corporate: 208 Mason St., Ukiah, CA 95482 • Phone: (707) 468-0401 • Fax: (707) 468-5267
Bay Area: 6398 Dougherty Rd., Suite 35, Dublin, CA 94568 • Phone: (925) 828-6226 • Fax: (925) 828-6309
Central Valley: 9090 Union Park Way, Suite 113, Elk Grove, CA 95624 • Phone: (916) 686-5190 • Fax: (916) 686-5192

# CHEMICAL EXAMINATION REPORT



Sonoma County Water Transmission
404 Aviation Blvd.
Santa Rosa, CA 95403
Attn: Todd Schram

Report Date: 08/08/14 12:58
Project No: 0617-A9
Project ID: Fluoridation

| Order Number | Receipt Date/Time | Client Code | Client PO/Reference |
|---|---|---|---|
| 14G2052 | 07/28/2014 15:50 | SCWT | |

## ANALYTICAL REPORT FOR SAMPLES

| Sample ID | Laboratory ID | Matrix | Date Sampled | Date Received |
|---|---|---|---|---|
| Santa Rosa Crk #1 F,H | 14G2052-01 | Water | 07/25/14 11:24 | 07/28/14 15:50 |
| Santa Rosa Crk #2 F,H | 14G2052-02 | Water | 07/25/14 13:50 | 07/28/14 15:50 |
| Paulin Crk #1 F,H | 14G2052-03 | Water | 07/25/14 12:10 | 07/28/14 15:50 |
| Paulin Crk #2 F,H | 14G2052-04 | Water | 07/25/14 13:20 | 07/28/14 15:50 |

Alpha Analytical Laboratories Inc.
e-mail: clientservices@alpha-labs.com
Corporate: 208 Mason St., Ukiah, CA 95482 • Phone: (707) 468-0401 • Fax: (707) 468-5267
Bay Area: 6398 Dougherty Rd., Suite 35, Dublin, CA 94568 • Phone: (925) 828-6226 • Fax: (925) 828-6309
Central Valley: 9090 Union Park Way, Suite 113, Elk Grove, CA 95624 • Phone: (916) 686-5190 • Fax: (916) 686-5192

# CHEMICAL EXAMINATION REPORT



Sonoma County Water Transmission
404 Aviation Blvd.
Santa Rosa, CA 95403
Attn: Todd Schram

Report Date: 08/08/14 12:58
Project No: 0617-A9
Project ID: Fluoridation

| Order Number | Receipt Date/Time | Client Code | Client PO/Reference |
|---|---|---|---|
| 14G2052 | 07/28/2014 15:50 | SCWT | |

## Alpha Analytical Laboratories, Inc.

| | METHOD | BATCH | PREPARED | ANALYZED | DILUTION | RESULT | PQL | NOTE |
|---|---|---|---|---|---|---|---|---|
| **Santa Rosa Crk #1 F,H (14G2052-01)** | | **Sample Type: Water** | | | **Sampled: 07/25/14 11:24** | | | |
| **Metals by EPA 200 Series Methods** | | | | | | | | |
| **Calcium** | EPA 200.7 | AG43038 | 07/30/14 11:38 | 08/06/14 14:16 | 1 | **43 mg/L** | **1.0** | |
| **Magnesium** | " | " | " | " | " | **34 "** | **1.0** | |
| **Conventional Chemistry Parameters by APHA/EPA Methods** | | | | | | | | |
| **Hardness, Total** | SM2340B | AG43038 | " | 08/06/14 14:16 | 1 | **244 mg/L** | **5** | |
| **Anions by EPA Method 300.0** | | | | | | | | |
| **Fluoride** | EPA 300.0 | AG42931 | 07/29/14 14:05 | 07/29/14 14:05 | 1 | **0.10 mg/L** | **0.10** | |
| **Santa Rosa Crk #2 F,H (14G2052-02)** | | **Sample Type: Water** | | | **Sampled: 07/25/14 13:50** | | | |
| **Metals by EPA 200 Series Methods** | | | | | | | | |
| **Calcium** | EPA 200.7 | AG43038 | 07/30/14 11:38 | 08/06/14 14:21 | 1 | **44 mg/L** | **1.0** | |
| **Magnesium** | " | " | " | " | " | **38 "** | **1.0** | |
| **Conventional Chemistry Parameters by APHA/EPA Methods** | | | | | | | | |
| **Hardness, Total** | SM2340B | AG43038 | " | 08/06/14 14:21 | 1 | **266 mg/L** | **5** | |
| **Anions by EPA Method 300.0** | | | | | | | | |
| Fluoride | EPA 300.0 | AG42931 | 07/29/14 14:19 | 07/29/14 14:19 | 1 | ND mg/L | 0.10 | |
| **Paulin Crk #1 F,H (14G2052-03)** | | **Sample Type: Water** | | | **Sampled: 07/25/14 12:10** | | | |
| **Metals by EPA 200 Series Methods** | | | | | | | | |
| **Calcium** | EPA 200.7 | AG43038 | 07/30/14 11:38 | 08/06/14 14:26 | 1 | **27 mg/L** | **1.0** | |
| **Magnesium** | " | " | " | " | " | **17 "** | **1.0** | |

Alpha Analytical Laboratories Inc.  e-mail: clientservices@alpha-labs.com
Corporate: 208 Mason St., Ukiah, CA 95482 • Phone: (707) 468-0401 • Fax: (707) 468-5267
Bay Area: 6398 Dougherty Rd., Suite 35, Dublin, CA 94568 • Phone: (925) 828-6226 • Fax: (925) 828-6309
Central Valley: 9090 Union Park Way, Suite 113, Elk Grove, CA 95624 • Phone: (916) 686-5190 • Fax: (916) 686-5192

# CHEMICAL EXAMINATION REPORT



Sonoma County Water Transmission
404 Aviation Blvd.
Santa Rosa, CA 95403
Attn: Todd Schram

Report Date: 08/08/14 12:58
Project No: 0617-A9
Project ID: Fluoridation

| Order Number | Receipt Date/Time | Client Code | Client PO/Reference |
|---|---|---|---|
| 14G2052 | 07/28/2014 15:50 | SCWT | |

## Alpha Analytical Laboratories, Inc.

| | METHOD | BATCH | PREPARED | ANALYZED | DILUTION | RESULT | PQL | NOTE |
|---|---|---|---|---|---|---|---|---|
| **Paulin Crk #1 F,H (14G2052-03)** | | | **Sample Type: Water** | | | **Sampled: 07/25/14 12:10** | | |
| **Conventional Chemistry Parameters by APHA/EPA Methods** | | | | | | | | |
| **Hardness, Total** | SM2340B | AG43038 | " | 08/06/14 14:26 | 1 | **137 mg/L** | **5** | |
| **Anions by EPA Method 300.0** | | | | | | | | |
| **Fluoride** | EPA 300.0 | AG42931 | 07/29/14 14:34 | 07/29/14 14:34 | 1 | **0.12 mg/L** | **0.10** | |
| **Paulin Crk #2 F,H (14G2052-04)** | | | **Sample Type: Water** | | | **Sampled: 07/25/14 13:20** | | |
| **Metals by EPA 200 Series Methods** | | | | | | | | |
| **Calcium** | EPA 200.7 | AG43038 | 07/30/14 11:38 | 08/06/14 14:31 | 1 | **42 mg/L** | **1.0** | |
| **Magnesium** | " | " | " | " | " | **48 "** | **1.0** | |
| **Conventional Chemistry Parameters by APHA/EPA Methods** | | | | | | | | |
| **Hardness, Total** | SM2340B | AG43038 | " | 08/06/14 14:31 | 1 | **304 mg/L** | **5** | |
| **Anions by EPA Method 300.0** | | | | | | | | |
| Fluoride | EPA 300.0 | AG42931 | 07/29/14 14:48 | 07/29/14 14:48 | 1 | ND mg/L | 0.10 | |

Alpha Analytical Laboratories Inc. e-mail: clientservices@alpha-labs.com
Corporate: 208 Mason St., Ukiah, CA 95482 • Phone: (707) 468-0401 • Fax: (707) 468-5267
Bay Area: 6398 Dougherty Rd., Suite 35, Dublin, CA 94568 • Phone: (925) 828-6226 • Fax: (925) 828-6309
Central Valley: 9090 Union Park Way, Suite 113, Elk Grove, CA 95624 • Phone: (916) 686-5190 • Fax: (916) 686-5192



# CHEMICAL EXAMINATION REPORT

Sonoma County Water Transmission
404 Aviation Blvd.
Santa Rosa, CA 95403
Attn: Todd Schram

Report Date: 08/08/14 12:58
Project No: 0617-A9
Project ID: Fluoridation

| Order Number | Receipt Date/Time | Client Code | Client PO/Reference |
|---|---|---|---|
| 14G2052 | 07/28/2014 15:50 | SCWT | |

## Metals by EPA 200 Series Methods - Quality Control

| Analyte(s) | Result | PQL | Units | Spike Level | Source Result | %REC | %REC Limits | RPD | RPD Limit | Flag |
|---|---|---|---|---|---|---|---|---|---|---|
| **Batch AG43038 - Metals Digest** | | | | | | | | | | |
| **Blank (AG43038-BLK1)** | | | | Prepared: 07/30/14 Analyzed: 07/31/14 | | | | | | |
| Calcium | ND | 1.0 | mg/L | | | | | | | |
| Magnesium | ND | 1.0 | " | | | | | | | |
| **LCS (AG43038-BS1)** | | | | Prepared: 07/30/14 Analyzed: 07/31/14 | | | | | | |
| Calcium | 8.46 | 1.0 | mg/L | 8.00 | | 106 | 85-115 | | | |
| Magnesium | 7.28 | 1.0 | " | 8.00 | | 91.0 | 85-115 | | | |
| **Duplicate (AG43038-DUP1)** | **Source: 14G2026-02** | | | Prepared: 07/30/14 Analyzed: 07/31/14 | | | | | | |
| Calcium | 19.1 | 1.0 | mg/L | | 18.8 | | | 1.68 | 20 | |
| Magnesium | 11.5 | 1.0 | " | | 11.7 | | | 1.66 | 20 | |
| **Matrix Spike (AG43038-MS1)** | **Source: 14G2026-02** | | | Prepared: 07/30/14 Analyzed: 07/31/14 | | | | | | |
| Calcium | 26.1 | 1.0 | mg/L | 8.00 | 18.8 | 91.6 | 70-130 | | | |
| Magnesium | 18.3 | 1.0 | " | 8.00 | 11.7 | 82.5 | 70-130 | | | |
| **Matrix Spike (AG43038-MS2)** | **Source: 14G1736-01** | | | Prepared: 07/30/14 Analyzed: 07/31/14 | | | | | | |
| Calcium | 26.3 | 1.0 | mg/L | 8.00 | 18.1 | 102 | 70-130 | | | |
| Magnesium | 19.5 | 1.0 | " | 8.00 | 11.7 | 98.3 | 70-130 | | | |
| **Matrix Spike Dup (AG43038-MSD1)** | **Source: 14G2026-02** | | | Prepared: 07/30/14 Analyzed: 07/31/14 | | | | | | |
| Calcium | 25.4 | 1.0 | mg/L | 8.00 | 18.8 | 81.8 | 70-130 | 3.03 | 20 | |
| Magnesium | 17.9 | 1.0 | " | 8.00 | 11.7 | 76.5 | 70-130 | 2.62 | 20 | |

Alpha Analytical Laboratories Inc. e-mail: clientservices@alpha-labs.com

Corporate: 208 Mason St., Ukiah, CA 95482 • Phone: (707) 468-0401 • Fax: (707) 468-5267
Bay Area: 6398 Dougherty Rd., Suite 35, Dublin, CA 94568 • Phone: (925) 828-6226 • Fax: (925) 828-6309
Central Valley: 9090 Union Park Way, Suite 113, Elk Grove, CA 95624 • Phone: (916) 686-5190 • Fax: (916) 686-5192

# CHEMICAL EXAMINATION REPORT



Sonoma County Water Transmission
404 Aviation Blvd.
Santa Rosa, CA 95403
Attn: Todd Schram

Report Date: 08/08/14 12:58
Project No: 0617-A9
Project ID: Fluoridation

| Order Number | Receipt Date/Time | Client Code | Client PO/Reference |
|---|---|---|---|
| 14G2052 | 07/28/2014 15:50 | SCWT | |

## Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

| Analyte(s) | Result | PQL | Units | Spike Level | Source Result | %REC | %REC Limits | RPD | RPD Limit | Flag |
|---|---|---|---|---|---|---|---|---|---|---|
| **Batch AG43038 - Metals Digest** | | | | | | | | | | |
| **Blank (AG43038-BLK1)** | | | | Prepared: 07/30/14 Analyzed: 07/31/14 | | | | | | |
| Hardness, Total | ND | 5 | mg/L | | | | | | | |
| **Duplicate (AG43038-DUP1)** | **Source: 14G2026-02** | | | Prepared: 07/30/14 Analyzed: 07/31/14 | | | | | | |
| Hardness, Total | 95.3 | 5 | mg/L | | 95.4 | | | 0.00105 | 200 | |

Alpha Analytical Laboratories Inc.
e-mail: clientservices@alpha-labs.com
Corporate: 208 Mason St., Ukiah, CA 95482 • Phone: (707) 468-0401 • Fax: (707) 468-5267
Bay Area: 6398 Dougherty Rd., Suite 35, Dublin, CA 94568 • Phone: (925) 828-6226 • Fax: (925) 828-6309
Central Valley: 9090 Union Park Way, Suite 113, Elk Grove, CA 95624 • Phone: (916) 686-5190 • Fax: (916) 686-5192

## CHEMICAL EXAMINATION REPORT



Sonoma County Water Transmission
404 Aviation Blvd.
Santa Rosa, CA 95403
Attn: Todd Schram

Report Date: 08/08/14 12:58
Project No: 0617-A9
Project ID: Fluoridation

| Order Number | Receipt Date/Time | Client Code | Client PO/Reference |
|---|---|---|---|
| 14G2052 | 07/28/2014 15:50 | SCWT | |

### Anions by EPA Method 300.0 - Quality Control

| Analyte(s) | Result | PQL | Units | Spike Level | Source Result | %REC | %REC Limits | RPD | RPD Limit | Flag |
|---|---|---|---|---|---|---|---|---|---|---|
| **Batch AG42931 - General Preparation** | | | | | | | | | | |
| **Blank (AG42931-BLK1)** | | | | Prepared & Analyzed: 07/29/14 | | | | | | |
| Fluoride | ND | 0.10 | mg/L | | | | | | | |
| **LCS (AG42931-BS1)** | | | | Prepared & Analyzed: 07/29/14 | | | | | | |
| Fluoride | 5.81 | 0.10 | mg/L | 5.56 | | 105 | 90-110 | | | |
| **Duplicate (AG42931-DUP1)** | **Source: 14G2061-01** | | | Prepared & Analyzed: 07/29/14 | | | | | | |
| Fluoride | ND | 0.10 | mg/L | | ND | | | | 20 | |
| **Matrix Spike (AG42931-MS1)** | **Source: 14G2061-01** | | | Prepared & Analyzed: 07/29/14 | | | | | | |
| Fluoride | 5.74 | 0.10 | mg/L | 5.56 | ND | 102 | 80-120 | | | |
| **Matrix Spike (AG42931-MS2)** | **Source: 14G2075-01** | | | Prepared & Analyzed: 07/29/14 | | | | | | |
| Fluoride | 5.81 | 0.10 | mg/L | 5.56 | ND | 105 | 80-120 | | | |
| **Matrix Spike Dup (AG42931-MSD1)** | **Source: 14G2061-01** | | | Prepared & Analyzed: 07/29/14 | | | | | | |
| Fluoride | 5.74 | 0.10 | mg/L | 5.56 | ND | 102 | 80-120 | 0.0968 | 20 | |

Alpha Analytical Laboratories Inc.
e-mail: clientservices@alpha-labs.com
Corporate: 208 Mason St., Ukiah, CA 95482 • Phone: (707) 468-0401 • Fax: (707) 468-5267
Bay Area: 6398 Dougherty Rd., Suite 35, Dublin, CA 94568 • Phone: (925) 828-6226 • Fax: (925) 828-6309
Central Valley: 9090 Union Park Way, Suite 113, Elk Grove, CA 95624 • Phone: (916) 686-5190 • Fax: (916) 686-5192

**CHEMICAL EXAMINATION REPORT**



Sonoma County Water Transmission
404 Aviation Blvd.
Santa Rosa, CA 95403
Attn: Todd Schram

Report Date: 08/08/14 12:58
Project No: 0617-A9
Project ID: Fluoridation

| Order Number | Receipt Date/Time | Client Code | Client PO/Reference |
|---|---|---|---|
| 14G2052 | 07/28/2014 15:50 | SCWT | |

**Notes and Definitions**

| | |
|---|---|
| DET | Analyte DETECTED |
| ND | Analyte NOT DETECTED at or above the reporting limit |
| NR | Not Reported |
| dry | Sample results reported on a dry weight basis |
| RPD | Relative Percent Difference |
| PQL | Practical Quantitation Limit |

Alpha Analytical Laboratories Inc.
e-mail: clientservices@alpha-labs.com

Laboratory & Corporate: 208 Mason Street, Ukiah, CA 95482
707-468-0401 • Fax: 707-468-5267

Service Center & Micro Lab: 6398 Dougherty Road, Suite 35, Dublin, CA 94568
925-828-6226 • Fax: 925-828-6309

# Chain of Custody Record

Reports and Invoices will be delivered by e-mail in .pdf format.

Lab No. 1462052 Page____ of____

| Report to: | Invoice to (if different): | Project Info for Report: |
|---|---|---|
| Company: Sonoma County Water Agency | Company: | Project Name: FLUORIDATION |
| Attn: Todd Schram | Attn: | |
| Address: 404 Aviation Blvd Santa Rosa CA 95403 | Address: | Project No: 0617-A9 |
| Phone/Fax: 707-524-1173 | Phone/Fax: | PO/Reference: |
| E-mail Address: tschram@scwa.ca.gov | E-mail Address: | |

Samplers Signature: Todd Schram
Print: Todd Schram

Signature below authorizes work under terms stated on reverse side.

TAT: 10 days ◯ Rush: 5 days ◯ 48 hours ◯ Other: ___ days ◯

Lab Approval Required For Rush TATs

Sample Notes (lab use only): Temperature: 4.2 deg. C; Shipment Method: ; Custody Seals: ◯ Y / N ◯

| Sample Identification | Date | Time | 40ml VOA | Poly | Amber | Sleeve | Other | HCL | HNO3 | H2SO4 | Other | None | Water | Soil | Other | Total Number of Containers | FLUORIDE | TOTAL HARDNESS | Sample Notes or CDPH Source Numbers: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Santa Rosa Crk #1 F | 7/25/14 | 11:24 | | ✓ | | | | | | | | ✓ | ✓ | | | | X | | |
| Santa Rosa Crk #1 H | 7/25/14 | 11:24 | | ✓ | | | | | ✓ | | | | ✓ | | | | | ✓ | Log under Water Transmission |
| Santa Rosa Crk #2 F | 7/25/14 | 13:50 | | ✓ | | | | | | | | ✓ | ✓ | | | | ✓ | | per Ellen (SP) |
| Santa Rosa Crk #2 H | 7/25/14 | 13:50 | | ✓ | | | | | ✓ | | | | ✓ | | | | | ✓ | 7-29-14 |
| Paulin Crk #1 F | 7/25/14 | 12:10 | | ✓ | | | | | | | | ✓ | ✓ | | | | ✓ | | |
| Paulin Crk #1 H | 7/25/14 | 12:10 | | ✓ | | | | | ✓ | | | | ✓ | | | | | ✓ | |
| Paulin Crk #2 F | 7/25/14 | 13:20 | | ✓ | | | | | | | | ✓ | ✓ | | | | ✓ | | |
| Paulin Crk #2 H | 7/25/14 | 13:20 | | ✓ | | | | | ✓ | | | | ✓ | | | | | ✓ | |

| Relinquished by: | Received by: | Date: | Time: |
|---|---|---|---|
| Todd Schram | Bob Schultz | 7/25/14 | 15:08 |
| Bob Schultz | [illegible] | 7/28/14 | 0910 |
| | | 7/28/14 | 1500 |

CDPH Write On EDT Report? ◯ Yes ◯ No
State System Number:________
If "Y" please enter the Source Number(s) in the column above.

CA Geotracker EDF Report? ◯ Yes ◯ No
Global ID: Sampling Company Log Code:
EDF to (Email Address):

Travel and Site Time: Mileage: Misc. Supplies:

# Attachment 2

## Summary of Fluoride Toxicity Studies Conducted on Salmonids

**Attachment 2**
**Summary of Fluoride Toxicity Studies Conducted on Salmonids**

| Test Organism | Life Stage | NOAEC (mg/L) | LOAEC (mg/L) | LC50 (mg/L) | Endpoint | Exposure (hours) | Control Group? | Treatments (mg/L) | Hardness (mg/L CaCO3) | Usable for Assessment? | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RT | Egg | | 1.5 | | Delayed hatchi | Unknown | Unknown | Unknown | Unknown | No | Ellis et al. 1948[b] |
| RT | Egg | | | 222 - 273 | Mortality | 424 | Yes | 100, 200, 300, 400, 500 | <8 | No | Neuhold and Sigler 1960 |
| RT | Egg | | | 242 - 261 | Mortality | 214 | Yes | 100, 200, 300, 400, 500 | <8 | No | Neuhold and Sigler 1960 |
| RT | Egg | | | 237 - 281 | Mortality | 167 | Yes | 100, 200, 300, 400, 500 | <8 | No | Neuhold and Sigler 1960 |
| RT | Egg/Fry | | | 61 - 85.3 | Mortality | 825 | Yes | Not Reported | <8 | No | Neuhold and Sigler 1960 |
| RT | F&F | | | 2.3 | Mortality | 240 | Yes | 2, 4, 7, 13, 25 | Soft | No | Angelovic et al. 1961 |
| RT | F&F | | | 2.6 | Mortality | 240 | Yes | 2, 4, 7, 13, 25 | Soft | No | Angelovic et al. 1961 |
| RT | F&F | | | 2.7 - 4.7 | Mortality | 480 | Yes | 2, 4, 7, 13, 25 | <8 | No | Neuhold and Sigler 1960 |
| RT | F&F | 3.1 | | | Mortality | Non-specific | Yes | 33.9, 53.8, 90.3, 146, 228 | 21.8 | Yes | Camargo 1996 |
| BT | F&F | 4.42 | | | Mortality | Non-specific | Yes | 33.9, 53.8, 90.3, 146, 228 | 21.8 | Yes | Camargo 1996 |
| BT | F&F | | 5 | | Mortality | 240 | Yes | 5, 10, 15, 20, 30, 60 | 73 | Yes | Wright 1977 |
| RT | F&F | | | 5.9 | Mortality | 240 | Yes | 2, 4, 7, 13, 25 | Soft | No | Angelovic et al. 1961 |
| RT | F&F | | | 6 | Mortality | 120 | Yes | 2, 4, 7, 13, 25 | <3 | No | Neuhold and Sigler 1962 |
| RT | F&F | | | 22 | Mortality | 120 | Yes | 2, 4, 7, 13, 25 | <3 | No | Neuhold and Sigler 1962 |
| RT | F&F | 22.3 | 34.2 | | Mortality | 192 | Yes | 22.3, 34.2, 57.3, 91.4, 144 | 22.4 | Yes | Camargo and Tarazona 1991 |
| BT | F&F | | 33.9 | | Mortality | 192 | Yes | 33.9, 53.8, 90.3, 146, 228 | 21.2 | Yes | Camargo and Tarazona 1991 |
| RT | F&F | | | 38 | Mortality | 96 | Yes | 10, 18, 32, 56, 100, 180, 320, 560 | 17 | Yes | Pimentel and Bulkley 1983 |
| RT | F&F | | | 50 | Mortality | 192 | Yes | 22.3, 34.2, 57.3, 91.4, 144 | 22.4 | Yes | Camargo and Tarazona 1991 |
| RT | F&F | | | 55.9 | Mortality | 168 | Yes | 22.3, 34.2, 57.3, 91.4, 144 | 22.4 | Yes | Camargo and Tarazona 1991 |
| RT | F&F | | | 68 | Mortality | 144 | Yes | 22.3, 34.2, 57.3, 91.4, 144 | 22.4 | Yes | Camargo and Tarazona 1991 |
| RT | F&F | | | 73.6 | Mortality | 120 | Yes | 22.3, 34.2, 57.3, 91.4, 144 | 22.4 | Yes | Camargo and Tarazona 1991 |
| BT | F&F | | | 76.8 | Mortality | 192 | Yes | 33.9, 53.8, 90.3, 146, 228 | 21.2 | Yes | Camargo and Tarazona 1991 |
| BT | F&F | | | 81.8 | Mortality | 168 | Yes | 33.9, 53.8, 90.3, 146, 228 | 21.2 | Yes | Camargo and Tarazona 1991 |
| RT | F&F | | | 83.7 | Mortality | 96 | Yes | Not Reported | 22.4 | Yes | Camargo 1991 |
| BT | F&F | | | 94.1 | Mortality | 144 | Yes | 33.9, 53.8, 90.3, 146, 228 | 21.2 | Yes | Camargo and Tarazona 1991 |
| RT | F&F | 100 | | | Mortality | 21 | Not Reported | Not Reported | 320 | Yes | Vallen 1968 |
| RT | F&F | | | 100.2 | Mortality | 72 | Yes | Not Reported | 22.4 | Yes | Camargo 1991 |
| RT | F&F | | | 108 | Mortality | 96 | Yes | 10, 18, 32, 56, 100, 180, 320, 560 | 49 | Yes | Pimentel and Bulkley 1983 |
| BT | F&F | | | 114 | Mortality | 120 | Yes | 33.9, 53.8, 90.3, 146, 228 | 21.2 | Yes | Camargo and Tarazona 1991 |
| RT | F&F | | | 117 | Mortality | 96 | Yes | 10, 18, 32, 56, 100, 180, 320, 560 | 182 | Yes | Pimentel and Bulkley 1983 |
| BT | F&F | | | 131.9 | Mortality | 96 | Yes | Not Reported | 21.2 | Yes | Camargo 1991 |
| RT | F&F | | | 167 | Mortality | 96 | Yes | 10, 18, 32, 56, 100, 180, 320, 560 | 385 | Yes | Pimentel and Bulkley 1983 |
| BT | F&F | | | 175.7 | Mortality | 72 | Yes | Not Reported | 21.2 | Yes | Camargo 1991 |
| RT | F&F | | | 200 | Mortality | 96 | Yes | 75, 150, 200, 300, 400 | 23 - 62 | Yes | Smith et al 1985 |
| CkS | Y&A | 0.2 | 0.5 | | Behavioral | 1[a] | Yes | 0.2, 0.5 | Not Reported | No | Damkaer and Dey 1989 |
| CoS | Y&A | 0.2 | 0.5 | | Behavioral | 1[a] | Yes | 0.2, 0.5 | Not Reported | No | Damkaer and Dey 1989 |
| CmS | Y&A | 0.5 | | | Behavioral | 1[a] | Yes | 0.5 | Not Reported | No | Damkaer and Dey 1989 |
| RT | Y&A | | | 8.5 | Mortality | 504 | Unknown | Unknown | Unknown | No | Herbert and Shurben 1964[c] |
| RT | Y&A | | | 8.5 | Mortality | 48 | Unknown | Unknown | Hard | No | Herbert and Shurben 1964[c] |
| RT | Y&A | 50 | | | Mortality | 504 | Unknown | Unknown | 45 | Yes | Herbert and Shurben 1964[c] |
| RT | Y&A | 100 | | | Mortality | 504 | Unknown | Unknown | 320 | Yes | Herbert and Shurben 1964[c] |
| BT | Y&A | | | 125 | Mortality | 48 | Unknown | Unknown | Unknown | No | Woodwiss and Fretewell 1974 |

RT = rainbow trout, BT = brown trout, CkS - Chinook salmon, CoS = coho salmon, CmS = chum salmon.
F&F = fry and fingerling.
Y&A = yearling and adult.
NOAEC = no observable adverse effect concentration, LOAEC = lowest observable adverse effect concentration, LC50 = lethal concentration to 50% of the population tested.
a. For tests conducted in 1983 fish were allowed 60 minutes to make a choice. The time was reduced to 20 minutes for tests conducted in 1984.
b. Study not publically available, cited in Neuhold and Sigler (1960). Whether certain paramaters were repored in the oringal report is unknown.
c. Study not publically available, cited in varous papers including Pimentel and Bulkley (1983), Wright (1977), Camargo and Tarzona (1991), and Smith (1985). Whether certain parameters were repored in the oringal report is unknown.