Science & Technical Support Section's
SciFYI
King County
Department of Natural Resources and Parks
Water and Land Resources Division
A science section digest of current environmental issues in King County
September 2015

Cooling down streams: addressing warm summer water temperatures in Green River Tributaries

By Andrew Miller and Chris Knutson

There are many ecological benefits to planting trees in riparian areas adjacent to streams and rivers. One of the most important is lowering summer water temperatures which are too high for many aquatic animals. Cool water temperatures are critical for development of salmon and trout, and high temperatures can result in stress and even death. Healthy streamside vegetation provides shade to the channel, blocking solar radiation and reducing the heat reaching the stream.

In spite of this obvious benefit, all streamside planting projects face the question: how much will the trees planted actually affect stream water temperatures? Trying to answer that question is complicated. Vegetation planted adjacent to streams can take decades to fully mature, so direct measurement of its effect on stream temperatures is not practical. However, water quality models can estimate the impact of new vegetation once it reaches maturity. After a series of riparian plantings were completed on Newaukum Creek (**Figure 1**), King County scientists applied water quality models to calculate the increase in effective shade and the associated decreases in solar heat loads and maximum water temperature during critical summer conditions.

Model results showed how vegetation increases effective shade and reduces solar heat loads and maximum temperatures (**Figure 2**). Modeled effective shade increased by as much as 58 percent in Newaukum Creek, while the

FIGURE 1. Aerial photo showing Newaukum Creek flowing through the Enumclaw Plateau, which lies in the middle section of the Newaukum Creek watershed. While Newaukum Creek supports deciduous vegetation in riparian areas in some portions of the watershed, the Enumclaw Plateau is dominated by agricultural land use leaving the stream banks of Newaukum Creek lacking trees and shrubs. In order to reduce temperatures, King County planted areas along Newaukum Creek in 2012 (shown in green on the map).

(Continued on page 2)

solar heat loads were reduced in planted areas by as much as 61 percent. Modeled water temperature was reduced by as much as 0.9 °C with an average reduction of 0.3 °C in the reach that was planted.

While such temperature reductions may appear modest, this is likely due to the small area planted; only 1.1 percent of the riparian areas of the modeled reach in Newaukum Creek were planted with trees in 2012. It's also important to consider that many riparian areas of Newaukum Creek are largely devoid of trees in the predominantly agricultural Enumclaw plateau (**Figure 1**). Therefore, much of the benefit from adding trees could be lost downstream as water flows through terrain with that receives full sun.

To demonstrate the additional benefit from continued tree planting, a planting scenario was modeled where all riparian areas with little to no vegetation were replaced with mature trees similar to what was planted in 2012 (infill planting scenario in **Figure 2**). This action resulted in an average temperature reduction of 2.5 °C in the reach affected by planting, and an additional 6.0 km of Newaukum Creek was estimated to meet the Washington State summer temperature standard of 16.0 °C. While other factors also affect temperature, such as stream flow discharge, climate, and groundwater influence, the critical importance of shade in controlling temperature in small streams lends credence to this model's utility as a tool for quantifying the thermal benefits of riparian planting.

In addition to the shade modeling effort described above, King County took hemispherical photographs (a digital photograph through a wide angle lens that allows the sky in all directions to be simultaneously visible) of trees overhanging Newaukum Creek along the replanted reaches when trees were planted in 2012 (see **Figure 3**). This process

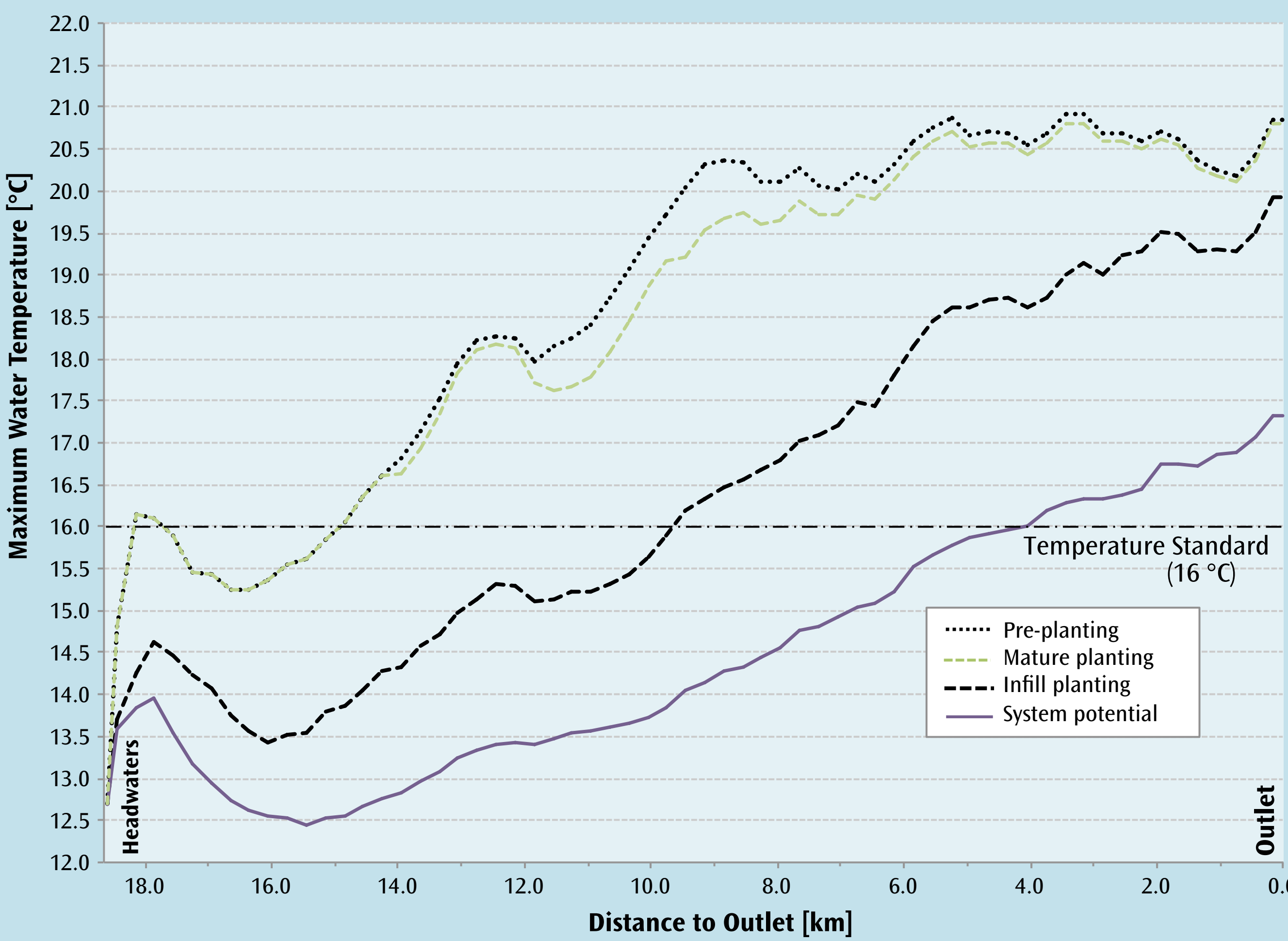


FIGURE 2.

Plot of estimated temperatures along the modeled reach of Newaukum Creek. Each line represents a different planting scenario: the black dotted line (pre-planting) represents conditions prior to the planting on Newaukum Creek in 2012; the green dashed line (mature planting) represents vegetation planted in 2012 reaching maturity; the black dashed line (infill planting) represents a scenario where all unvegetated areas adjacent to Newaukum are planted with small trees that reach maturity; and the solid purple line (system potential) represents a scenario where all areas adjacent to Newaukum Creek being covered in mature coniferous trees.

was repeated in 2014 to measure the increase in effective shade from the growth of the newly planted vegetation.

Most of the data showed moderate increases in effective shade and canopy coverage (5-15%) at the photo locations. These results indicate that even in a short time frame (2 years), as the vegetation matures, it provides a significant shade benefit to the stream.

It is clear that trees provide benefits to adjacent streams. King County will continue to track the growth of planted vegetation through time by repeating the hemispherical photography at regular intervals. It is our goal to create a series of images of the selected reaches that can be used to assess the most effective plant species, planting methods, and plant densities for temperature benefits. The information gathered can also be used to continue the modeling work described above. This is likely to be increasingly important in the future as King County works to adapt to the projected impacts of land-use and climate change.

For the full report, go to http://your.kingcounty.gov/dnrp/library/2015/kcr2677.pdf

FIGURE 3.
Example of a hemispherical photograph taken from the middle of the stream channel in Newaukum Creek in 2012 and 2014. A computer program is used to calculate the amount of solar radiation reaching the stream through the vegetation overhead.

SCIENCE SECTION SUCCESSFULLY COMPLETES MAJOR FEDERAL RESEARCH GRANTS

The Science Section provides data and analysis to assist in environmental management, and while most of our work focuses on King County, we often do grant-funded research work that benefits not just King County residents, but the entire region. In 2010 and 2011, the Science Section successfully competed for over $5 million of grant funding sponsored by the federal Environmental Protection Agency (EPA) under the National Estuary Program. Over the past five years, the Science Section worked with multiple regional partners to complete the following six projects:

- Modeling the stormwater infrastructure needed to improve water quality and flow in the Green-Duwamish watershed, and for all of Puget Sound.
- Identifying sources of PCBs found in Lake Washington fish and developing strategies for reducing contaminant levels so that fish there are safe to eat.
- Evaluating how human activities affect nitrogen inputs and low dissolved oxygen in Quartermaster Harbor on Vashon Island, so that water quality can be improved.
- Developing better tools for using stream insects to report stream health, and increasing regional collaboration and consistent use of these tools.
- Applying an experimental design to nine rural watersheds to assess the effectiveness of King County's land use regulations.
- Assessing small stream habitat conditions in the Lake Washington/Cedar/Sammamish Watershed to inform salmon recovery efforts.

Each of these multi-year projects was successful in generating valuable information that will benefit the entire Puget Sound region. The results are already being used to advance local and state programs, plans and policies that promote salmon recovery, toxic reduction, stream health, and water quality. More details about these and other projects can be found at www.kingcounty.gov/depts/dnrp/wlr/sections-programs/science-section/doing-science.aspx.

Lake Sammamish Water Quality Response to Land Use Change

Rachael Gravon and Deb Bouchard

As the sixth largest lake in Washington and the second largest in King County, Lake Sammamish is designated a water of state wide significance and is an important and valuable natural resource. It is one of the major recreational lakes in King County and in 2014 was selected as one of eight national urban wildlife refuge programs by the United States Fish and Wildlife Service. There are both State and County parks along the shore, and the lake is utilized by fishermen, boaters, water skiers, and picnickers. The lake is also host to numerous homes and residences, and supports an array of wildlife.

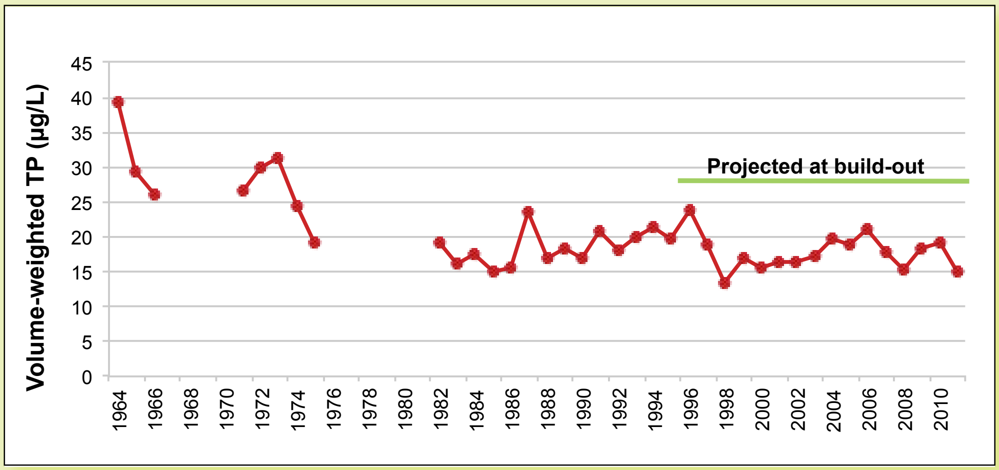


FIGURE 4.
Mean annual whole lake volume-weighted total phosphorus in Lake Sammamish, compared with projected at full build-out. Gaps in monitoring data occur between from 1967-1970, and 1976-1981.

The Lake Sammamish Water Quality Response to Land Use Change Study evaluated data collected from the 1960s through 2011 to describe how Lake Sammamish has responded to watershed development, in particular nutrient inputs associated with that development. The study focuses on total phosphorus, chlorophyll-a, and water clarity, parameters often used in lake management to estimate a lake's productivity, or potential for producing excessive algal growth. The study is part of the ongoing King County Major Lakes Monitoring Program that assesses water quality in Lake Washington, Lake Sammamish, and Lake Union. Both the King County Major Lake and Stream Monitoring Programs are designed to protect the significant investment in freshwater quality improvement and protection made by the people of King County.

Water quality monitoring of Lake Sammamish began in the early 1960s when the Municipality of Metropolitan Seattle (METRO; now merged with King County Department of Natural Resources and Parks) conducted a study of Lake Sammamish water quality to determine if sewage discharged from the City of Issaquah's wastewater treatment plant and a large dairy facility were having an adverse effect on the lake. As a result of this study, wastewater diversion was proposed for Lake Sammamish in order to reduce the total phosphorus inputs into the lake. The diversion decreased the external total phosphorus load to the lake by about 35 percent, and led to a decrease in phosphorus from 32 µg/L to below 20 µg/L (**Figure 4**). Additionally, chlorophyll-a (a pigment found in algae) declined and water clarity increased, providing evidence that diversion was effective in improving water quality.

Research in the 1970s and 1980s documented the threat of increasing phosphorus in runoff from impervious surfaces as watershed development increased. Between 1970 and 1990 the percent of developed area in the Lake Sammamish watershed more than doubled – from 15 percent to 36 percent. This increase was primarily due to an increase of single family residences in the Issaquah Creek Basin and the East Side Sub-basin (**Figure 5**). Consistent with the research, annual mean phosphorus levels in the lake were consistently over 20 µg/L by the mid-1990s, likely related to the increased urbanization surrounding the lake. A modeling effort in 1995 predicted that phosphorus levels would continue to increase further to 28 µg/L at build-out if measure were not taken.

Concerns about lake water quality influenced the establishment of the inter-jurisdictional Lake Sammamish Initiative, and a citizen's task force, Partners for a Clean Lake Sammamish. Together, these groups worked to complete the 1996 Lake Sammamish Water Quality Management Plan. The plan called for long-term watershed protections involving forest retention and stormwater controls placed on new development to retain phosphorus, as well as short-term actions to reduce phosphorus loading to the lake. In addition, two other multi-jurisdictional basin planning efforts were completed in 1994 (East Lake Sammamish and Issaquah Creek) to protect water quality. In 1998, King County implemented its Surface Water Design Manual, and in 2001, the State Stormwater Management Manual for Western Washington.

The assessment of lake conditions in this study showed that mean annual total phosphorus has not changed significantly between 1980 and 2011, even though there has been substantial population growth in the basin and a significant increase in the amount of impervious area. The apparent increase observed in the mid-1990s leveled off over time and did not match modeled projections. Additionally, mean summer chlorophyll-a has remained stable (about 3.5 µg/L), and summer water transparency has averaged over 5.0 meters since 1998.

Wastewater diversion and watershed protections instituted in the mid-1990s likely have contributed to the stable annual lake total phosphorus concentrations. While these results tell us that Lake Sammamish water quality management strategies, such as forest retention, are effective, continued implementation along with continued monitoring is necessary to ensure that water quality is maintained.

The full Lake Sammamish Water Quality Response to Land Use Change report can be found at: http://your.kingcounty.gov/dnrp/library/2014/kcr2654/kcr2654-rpt.pdf.

To view or download Lake Sammamish water quality data, please visit the King County Major Lakes Monitoring Page at: http://green2.kingcounty.gov/lakes/.

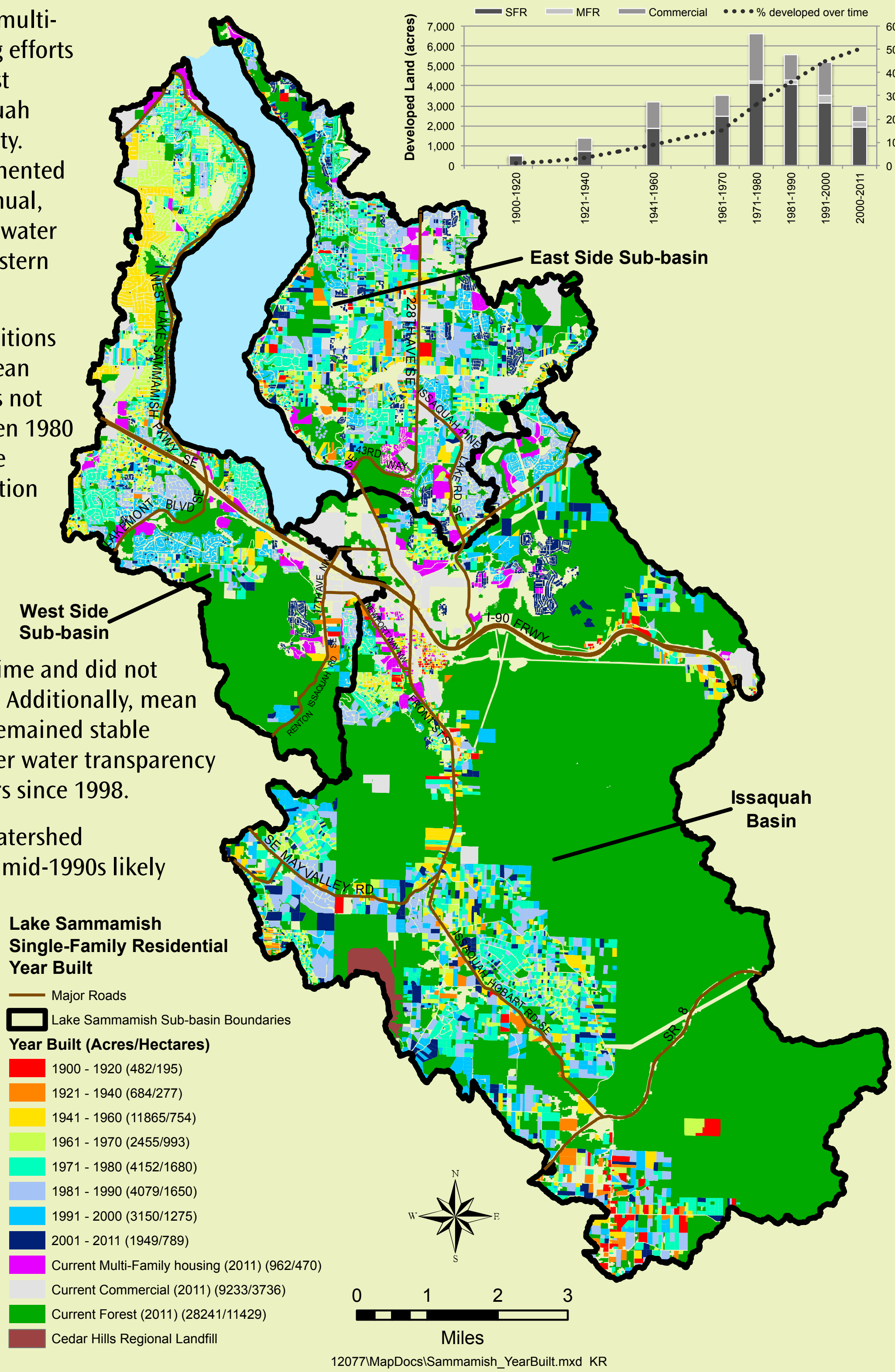


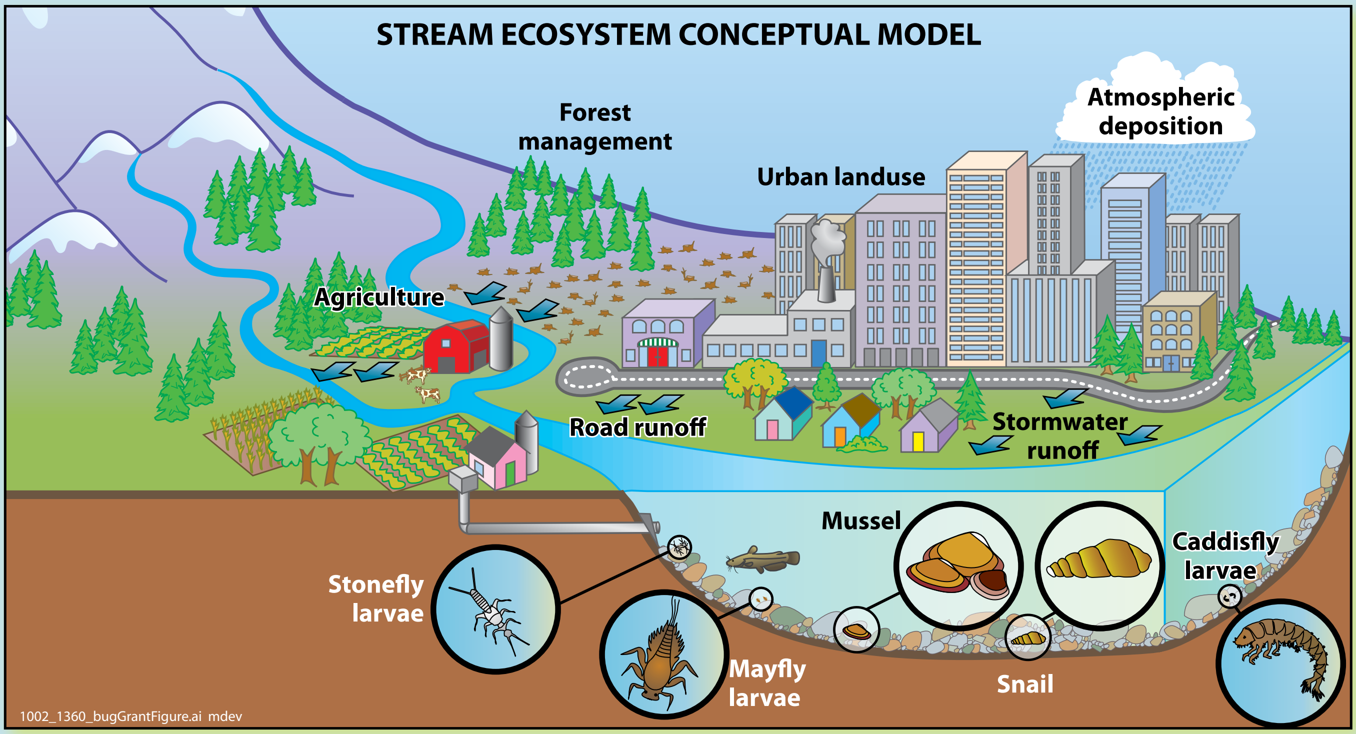
FIGURE 5.
Single-family residential land use built by decade and current multi-family, commercial, and forest land use (2011).

It's all about stream bugs

By Chris Gregersen, King County ecologist

In 2014, King County employees, seasonal workers, and interns visited over 175 stream locations throughout the county to collect bugs…but why? Stream bugs, known to scientists as benthic macroinvertebrates, are the bottom dwelling organisms that you can see that don't have a backbone.

Insect larvae, worms, snails, clams, and crayfish are all excellent indicators of stream health and water quality. As indicator species, stream bugs reflect the overall water quality and stream conditions. Not only do the types and amounts of bugs reflect the water and stream habitat quality at the particular stream location, but because they are constantly exposed to any water flowing past them, they are indicators for the entire watershed upstream of where they live.



A conceptual model of how watershed activities influence stream bugs

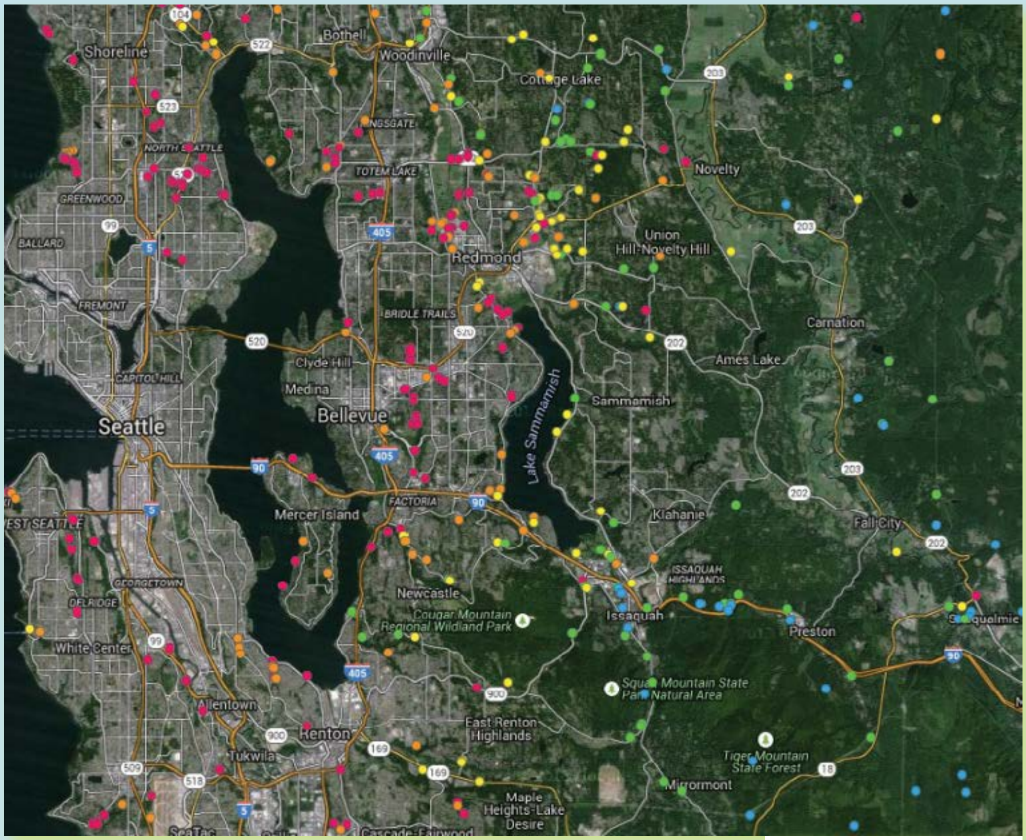
Last year alone, over 350 different species of macroinvertebrates were encountered during our sampling throughout King County. This vast array of species exhibits a wide range of pollution tolerance, habitat usage, and adaptability to changing conditions. To characterize the health of the bug community, the Benthic Index of Biotic Integrity (B-IBI) was developed to calculate a score for stream health based on the numbers and species of stream bugs found in a sample. The B-IBI score ranges from 0 to 100, with corresponding categories ranging from "Very Poor" to "Excellent" stream health.

A King County employee samples a stream's benthic macroinvertebrates.

Getting from bugs to a B-IBI score is an intricate process. Bugs are first sampled using specialized nets placed in the stream bottom. Using this, a sampler can stir the sediment where the bugs are living, and allow the current to sweep any bugs into the net. The contents of the net are then transferred to a sample bottle, preserved, and later sent to a laboratory. The lab will then analyze the sample contents and both identify and count any species found. This information is then uploaded into the King County-managed Puget Sound Stream Benthos database (www.pugetsoundstreambenthos.org). This database was developed in 2008 and allows regional groups to share, manage, and analyze macroinvertebrate data as well as make it accessible to the public. Built-in calculation features allow instant calculation of B-IBI scores directly from the lab reported data, which can then be mapped and shared. This has resulted in substantial regional collaboration and made possible various assessments of habitat and stream conditions in King County and throughout the region.

In addition to the database and annual monitoring, King County has lead regional efforts to enhance the use of the B-IBI tool. With funding from an EPA grant from 2010-14, King County worked with regional partners and experts to enhance the B-IBI analysis tools and scoring system, standardize protocols, and encourage collaboration across all jurisdictions sampling in the Puget Sound region. This work has helped King County not only update the B-IBI with the latest scientific information, but also engage with over 100 individuals from almost 50 organizations and jurisdictions ranging from the city level up to federal agencies.

This work contributes to the efforts to restore Puget Sound, as the B-IBI is one of the Puget Sound Partnership's vital signs. King County is also working on a Washington State Department of Ecology funded project aimed at developing strategies and cost estimates for restoring 30-plus basins from "fair" to "good" B-IBI, and protecting those that score "excellent."



Data from the Puget Sound Stream Benthos database showing a sample of B-IBI scores from the central Puget Sound region.

Condition of Biotic Integrity	B-IBI$_{0-100}$ Score
Excellent	80-100
Good	60-80
Fair	40-60
Poor	20-40
Very poor	0-20

Beyond regional monitoring, B-IBI is also an important tool for King County scientists to measure the effectiveness of specific stream restoration projects as well as monitor specific land uses and their impacts to stream health. Stream restoration projects utilize B-IBI by sampling in several locations in and around stream restoration projects over time.

By identifying control areas that represent the project area prior to restoration, scores can be compared between the restored areas and non-restored areas, as well as reaches downstream that might benefit from restoration. B-IBI is also used to monitor specific land use actions such as biosolid application and land development. By taking samples over time in basins where specific actions are occurring, scientists can use B-IBI to track any resulting changes in the aquatic environment.

B-IBI is an important tool for scientists in the Puget Sound region. Stream health is critical for bugs, fish, and people alike, and using B-IBI helps us identify those streams where the biological condition is impaired. Even though they are very small, stream bugs are helping scientists understand and restore stream health throughout King County and Puget Sound.

How to calculate the benefits of planting trees to help meet carbon reduction goals

By Jen Vanderhoof

In 2013, the King County Department of Natural Resources and Parks (DNRP) made a commitment to go "Beyond Carbon Neutral" by setting an ambitious target to meet and even exceed zero net greenhouse gas emissions for all of its operations. To determine the progress at reaching this goal, greenhouse gas emissions (measured in terms of metric tons of carbon dioxide equivalent, or MT CO2e) generated by the department's various operations are added together and compared to the amount of carbon taken from the atmosphere ("sequestered") by various off-setting activities, such planting trees. Although the department has many projects that involve tree planting, a big question remained: how do you calculate the amount of carbon sequestered by newly planted trees in order to help assess whether or not you are meeting the goal?

The amount of carbon sequestered depends upon the age of the tree. It is not practical to physically measure the amount of carbon sequestered from fully mature, individual trees – the timescale is too long. Likewise, newly planted trees are very small and far below their eventual sequestration capacity. Therefore, calculating sequestration relies on coming up with a model or formula that involves a series of steps and assumptions.

A first step in determining a carbon sequestration calculation formula is to choose a time frame over which carbon sequestration would be calculated. After considering several options, we selected the relatively simple approach of calculating the carbon sequestered over the lifetime of trees planted during a given calendar year. Then we needed to decide how long a tree "lifetime" lasts. A review of the literature suggested that a leveling-off for the rate of sequestration occurs at about 100 years, so we selected 100 years as the lifetime for trees planted each year.

The next decision was which data source to use for carbon-sequestration estimates for individual trees. Several lookup tables are available that provide default estimates of carbon sequestration that represent average forest conditions by region, ownership class, forest type, and productivity

class. These tables are very general and created from data collected in geographic areas that may or may not be similar to where we plant trees. We ultimately selected a set of individual-tree based look-up tables, created by US Department of Energy (USDOE). Although the authors warn that these tables are intended to be used for trees in urban settings, these tables appeared to be most appropriate for our situation, where we often only have the total number of trees and not the size of area planted. Because these tables only went to year 60, data in the tables were extrapolated to year 100. We chose USDOE's sequestration rates for Fast-growing Hardwood and Moderate-growing Conifer for 2013 and 2014 calculations based on the predominant species planted in those years. Based on the approximate proportions planted of those two tree types, the average amount of carbon sequestered over the lifetime of each tree planted in 2013 and 2014, provided it lives to 100 years, is estimated to be 13.88 MT CO_2e.

The final step in estimating carbon sequestered from tree planting activities was to determine tree survival rate. After reviewing forestry data and comparing results to other studies, we settled on relatively conservative survival rate of 20 percent.

The final formula for calculating the total carbon sequestered from a year's tree planting activities is:

MT CO_2e x S x T

where:

MT CO_2e is the lifetime equivalent of metric tons of CO_2 for each tree, derived from modified USDOE tables;
S is the tree survival rate (we assumed 0.2, or 20 percent);
and
T = number of trees planted in a given year (by surveying King County projects, we estimated that King County projects included planting 67,213 trees in 2013, and 83,255 in 2014).

After applying this formula (and rounding to the nearest 1,000), we estimate that carbon sequestration from the department's tree planting activities in 2013 and 2014 amounts to approximately 187,000 and 231,000 MTCO_2e, respectively, over their lifetime.

As more research is done in this field, we may refine our calculation methods. Further, trees planted this year won't reach these sequestration levels for another 100 years. But as we plant more trees each year, and King County's proposed Strategic Climate Action Plan increasingly relies on promoting tree planting as a tool to address climate change, it is clear that the department's tree-planting activities help meet our carbon reduction goals.

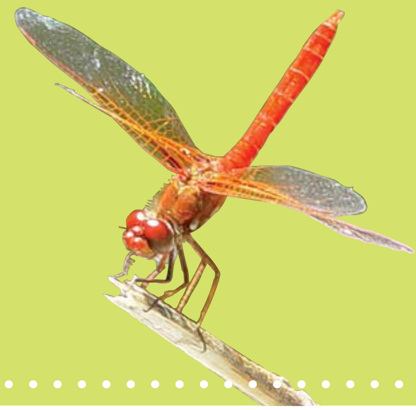
More information on King County Climate change efforts is found here:
www.kingcounty.gov/environment/climate.aspx

2015 Annual Science Seminar

King County's Science and Technical Support Section sponsor annual half day Science Seminars. Visiting lecturers and King County employees present recent findings from their environmental monitoring programs.

The 2015 Annual Science Seminar is scheduled for:

Thursday, November 5th,
8th Floor Conference Room at King Street Center.
201 South Jackson Street, Seattle, WA. 98104



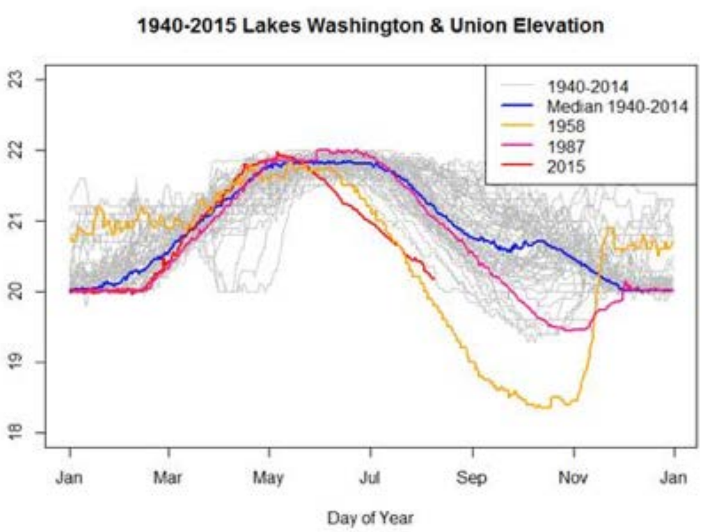
The Science Seminars provide an opportunity for sharing relevant and recent information and are open to all interested environmental science professionals and the public.

Please look for upcoming announcements on the 2015 Seminar topics.

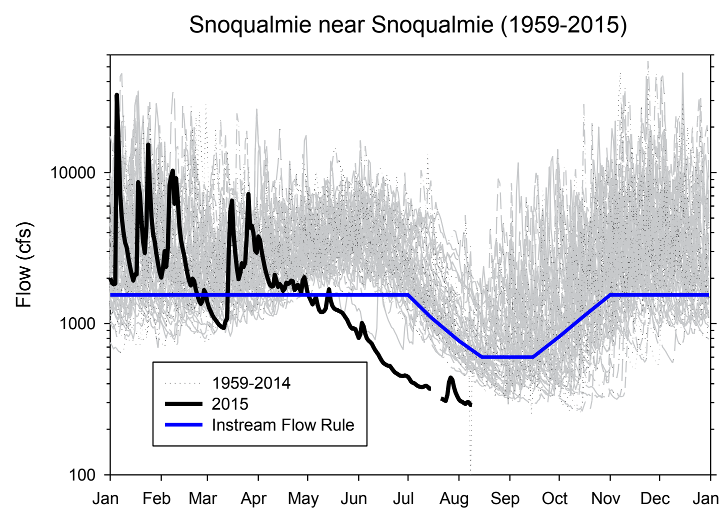
For more information on Science Seminars please visit: http://green2.kingcounty.gov/scienceseminars/.

Science and Technical Support Section Drought Monitoring

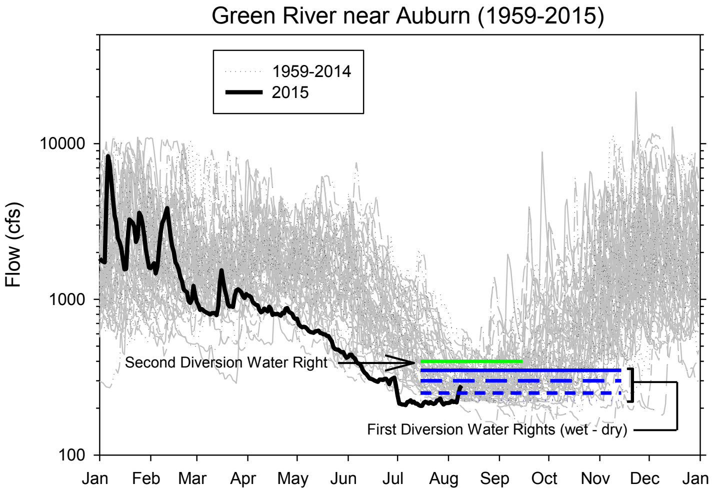
Stream flows and temperatures during this unusually warm and dry year are being monitored daily by the Science and Technical Support Section. The following report is extracted from their summary for the week of 8/3 - 8/9. If you are interested in receiving their full reports, please contact Jim Simmonds at jim.simmonds@kingcounty.gov.



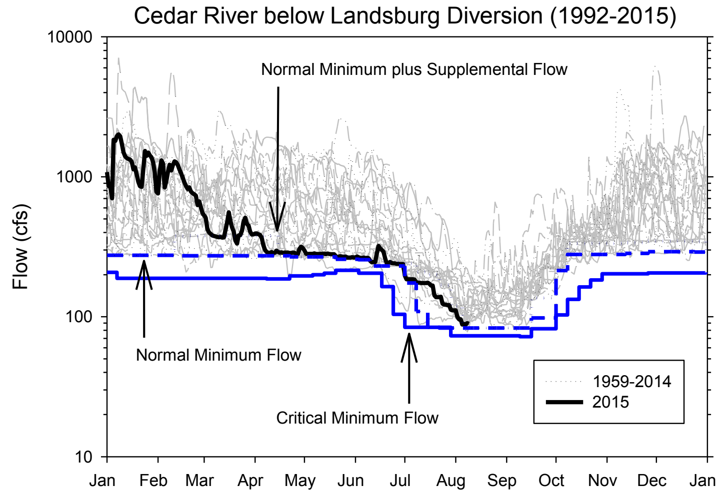
Lake Washington water levels are the second lowest ever recorded for the week based on U.S. Army Corps of Engineer records that go back to 1940, above the 1958 minimum. The Corps of Engineers anticipate Lake Washington's level will drop below 20 feet this summer, the first time since October 1987.



Flow in the Snoqualmie River is lower than the minimum instream flow established by Washington Administrative Code, which allows the state to curtail withdrawals by holders of junior water rights.



Flows in the Green River are higher than instream flows required during drought years for Tacoma Public Utilities to withdraw water from the Green River using its primary water right claim under agreements with the Muckleshoot Tribe, but are below the minimum instream flow established by Washington Administrative Code for Tacoma Public Utilities to withdraw water from the Green River with its second diversion water right.



Flows in the Cedar River are higher than the normal minimum flow required by the Habitat Conservation Plan to be maintained by Seattle Public Utilities during normal years.

Stream gauges show that 11 of 16 rivers and 6 of 23 creeks with over 15 years of flow data and real-time data delivery had the lowest flows ever recorded for the week ending August 9. Lower-than-normal flows and elevated water temperature can harm salmon and other fish at several points of their life cycles. In particular, adult salmon could have difficulties reaching upstream spawning grounds if flows remain below normal. Low flows also decrease available wetted habitat for spawning and rearing, limit food availability, and increase predation.

Data collected by the Muckleshoot Tribe show that 994 adult Chinook salmon and about 33,000 sockeye salmon had migrated past the Ballard Locks into the Lake Washington watershed as of August 9. This is about 31% of the 10-year average Chinook return by August 9 and about 27% of the 10-year average sockeye return by that date. Over the past 10 years, an average of 98% of the sockeye run had passed the Ballard Locks by August 9.

The Washington Department of Fish and Wildlife is encouraging people to submit reports of suspected blockages or distressed fish or wildlife on their website.

On August 11, Seattle, Everett, Tacoma, and the Cascade Water Alliance moved to the second stage – voluntary reduction – of their water shortage response plans and are now asking customers to help by voluntarily reducing water use by 10 percent.

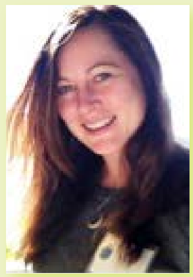
More information is available at: www.seattle.gov/util/MyServices/Water/AbouttheWaterSystem/WaterSupply/index.htm and here http://www.savingwater.org/.

Contributors to King County's SciFYI

Debra Bouchard

Debra Bouchard has been a senior limnologist/water quality planner with the King County Science and Technical Support Section since 1999. She manages the County's Swimming Beach Monitoring Program and co-manages the Lakes and Streams Routine Monitoring programs.

Rachael Gravon



Rachael Gravon joined the Science and Technical Support Section in 2013 as a water quality planner and limnologist. Rachael received her Master's degree in Freshwater Ecology from Western Washington University, where she studied relationships between lake water quality and freshwater algae populations and participated in numerous lake and stream monitoring programs. She provides technical support on various projects involving lake, stream, and watershed management.

Chris Gregersen

Chris Gregersen is an ecologist in the King County Science section focusing on stream ecology and fisheries. His work includes investigating riverine habitat use by juvenile salmonids and their response to restoration, aquatic health monitoring, and salmonid population assessment. Chris is a proud WSU graduate, and comes to us with a diverse background in fisheries work from both Idaho Fish and Game and Washington Department of Fish and Wildlife.

Chris Knutson

Chris Knutson is a Water Quality Planner in the King County Science and Technical Support Section. Chris works on a variety of freshwater related projects including: small lakes volunteer monitoring program, aquatic plant and invasive species issues, microbial source tracking, harmful algal blooms, and various other aquatic monitoring projects. Chris also manages the Science Summer Youth Intern program. He has a BA in Environmental Planning and Policy from Western Washington University and is the current President of the Washington State Lake Protection Association (WALPA).

Andrew Miller

Andrew joined the King County Science and Technical Support Section in the fall of 2013 as a water quality planner. He supports ongoing monitoring programs that track general river and stream health via measurement and assessment of stream flow and in-stream concentrations of bacteria, nutrients, conventionals, and other parameters. Andrew received his Master's degree in Forest Hydrology from West Virginia University, where he studied the hydrologic impacts of mountaintop removal coal mining.

Jen Vanderhoof

Jen is a Senior Ecologist in the Science and Technical Support Section. Her work often focuses on issues related to wildlife, biodiversity, and climate change. Jen frequently contributes to interdisciplinary projects involving the Parks Division, Roads Services Division, the Director's Office, and the Floodplain Management Section. Jen's hobbies include photography, and she brings this talent to bear at work whenever possible.

Dave White

Dave Is the Science and Technical Support Section Manager within King County's Water and Land Resources Division. Dave has held several positions over the past 17 years within Department of Natural Resources and Parks, including the Wastewater, Parks, and Solid Waste Divisions. Dave previously worked as an environmental consultant, as a university researcher, and as a Fisheries Officer in the Peace Corps in West Africa. He has an undergraduate degree in Environmental Science, and master's degrees in Natural Resource Management and Public Policy.

Published by:

King County
Department of Natural Resources and Parks
Water and Land Resources Division
Science and Technical Support Section

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Web Design/Production: Fred Bentler

Available on the Web at:
http://www.kingcounty.gov/environment/wlr/science-section/sci-fyi-newsletter.aspx

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