CITY OF BELLINGHAM SOURCE WATER AND TREATMENT TRENDS

A SUMMARY OF FINDINGS FROM LAKE WHATCOM MONITORING AND FROM DRINKING WATER TREATMENT

2004

DRAFT REPORT 02/23/05

CITY OF BELLINGHAM

SOURCE WATER AND TREATMENT TRENDS

INSIDE THIS REPORT

This report is a dynamic document that outlines observations in Lake Whatcom. These observations may have long-term implications for the lake and ultimately for the City's water supply. This report will be updated as new data becomes available, and will evolve to reflect the implications of new data and data analysis.

CURRENT DRAFT REPORT DATE: 02/23/05

INTRODUCTION: OUR SOURCE WATER LAKE WHATCOM

Recorded uses of Lake Whatcom as a source of high quality drinking water go back to 1885 when the Bellingham Bay Improvement Company operated the water works for the town of Whatcom. At this time the intake was located near the Larsen Mill on the shores of what is now Bloedel Donovan Park in basin 1 of the lake.

In 1939 a new intake pipe was built in the Geneva area in basin 2 of Lake Whatcom. A screenings and chlorination plant was added to the treatment process at this time. Today the City of Bellingham utilizes the same intake pipeline that was put in in 1939 and treats this water with an in-line filtration plant that was built in 1968. Prior to filtration, the City uses alum flocculation to trap particles in its source water. Following filtration, chlorine is applied to the water for microbial safety, and soda ash is applied to reduce the corrosion of our water transmission pipes and our customer's plumbing. This water serves all of the City residents as well as over 15,000 residents living near our urban boundaries.

The lake continues to provide drinking water that meets all drinking water standards. Our treated drinking water contributes to the quality of life we enjoy in Bellingham. Yet, in the past few years the lake has been showing signs of change which deserve attention. We find ourselves at a point of change, where decisions made now will determine which direction lake water quality will go. Shall the lake continue on its upward cycle of increasing organic matter, or will we make decisions now to halt this progression? The trend lines taken out into the future do not bode well for the future purity of the lake as our water source.

Lake Whatcom is beginning to exhibit water quality that would be expected of a lake that is abutted by land uses including transportation and urban development. It is only within the last ten years that changes in water quality have became apparent in the lake itself. Changes observed in water treatment have only been observed within the last two years at the treatment plant. It is thought that the reduction observed in water quality has been exacerbated by the decrease in the amount of Middle Fork Nooksack water that is diverted into the lake by the City of Bellingham.

Because of changes in source water quality the City has now found itself unable to meet its internal standards for drinking water quality, particularly in the summer months, and keep up with water demand. This trend has only recently been observed. The amount of algae coming into the Water Filtration Plant in late spring and summer has increased. This increase in turn impacts our ability to meet quality standards (expressed in particle counts) and attain sufficient water production. This phenomenon will be detailed in this report as well as the costs associated with increasing the level of treatment to Lake Whatcom.

Lake Whatcom has been used as a drinking water supply for 120 years. Land use practices from this time has shifted from primarily mining, logging and lumber mills, to logging and residential development. Currently the lake is home to 4,239 residents. Of this total 1,509 residences are in the City limits. Approximately 65% of the lake watershed is currently used for timber production.

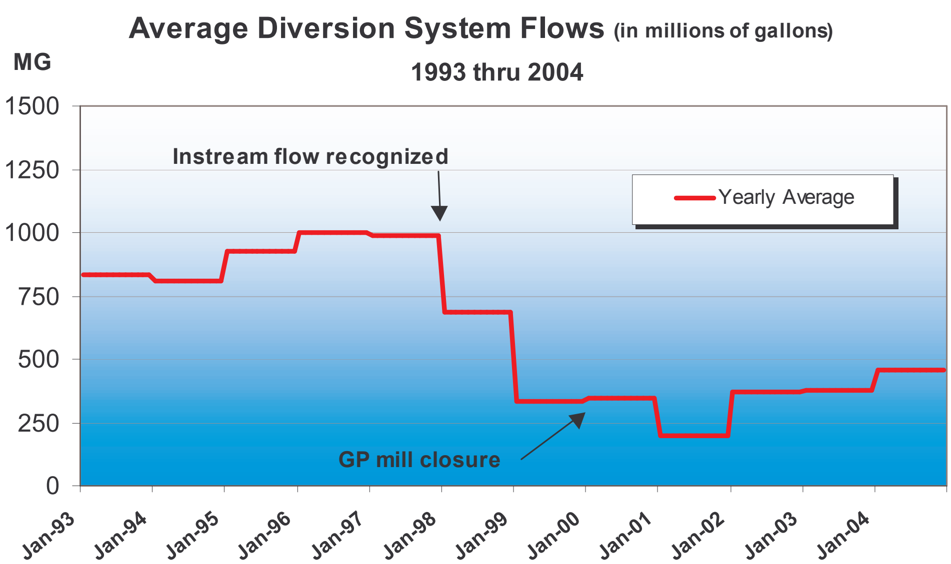
1.0 LAKE WATER BALANCE AND THE DIVERSION SYSTEM

The City of Bellingham began utilizing the Middle Fork of the Nooksack River to supplement the water supply in Lake Whatcom in 1964. The use of the diversion system has helped assure that the City maintains adequate supplies in critical water use periods. It was always assumed that the use of the diversion also imparted water quality benefit to Lake Whatcom. It is just now that the City is diverting less water into the lake, that the realization is confirmed that this is in fact likely the case.

The City use of the Middle Fork has been reduced due to voluntary recognition of the prescribed minimum levels of water needed for fish in this river system. Since 1998 the City diverts water from the Middle Fork only when "excess" water is available in the river, above what is determined to be sufficient to support fish rearing, migration, and spawning. The chart below shows the average totals of water that has been diverted from the Middle Fork since 1993.

This marked decrease in the amount of water used to supplement Lake Whatcom corresponded to a large reduction of water used by the City's largest water user, Georgia Pacific Corporation. In late 2000 the Georgia Pacific Corporation reduced the amount of water it utilized from Lake Whatcom by over 75%. The combination of these two phenomenon have worked to increase the residence time of water in Lake Whatcom.

One of the unintended but beneficial results from the City's use of the diversion prior to 1998 and of the large amounts of water withdrawal by Georgia Pacific, was that it helped dampen the effects of increases in nutrients and algae in Lake Whatcom. It has been suggested that the City return to pre-1998 diversionary practices to attain water quality benefit in Lake Whatcom. This is not a plausible scenario for two reasons. One, minimum instream flow levels in the Middle Fork of the Nooksack need to be recognized. These established minimum stream flow requirements in the Middle Fork are not predictable



The Georgia Pacific Plant (GP) has had marked reductions in the amount of water it uses from Lake Whatcom. For example, the average monthly water consumption used by GP in 1997 was 1,140 million gallons. By 2003 this amount had been reduced to 216 million gallons a month.

and are expected to change. Therefore, the City's ability to make use of the diversion is difficult to forecast. In July 2004, the City was successful in automating this diversion system. This automation helps get the Middle Fork Nooksack water to the lake at the time when it is most plentiful in the river: generally late at night. Even with the constraints detailed above, the City continues to operate the diversion to optimize water storage to ensure adequate supplies, and for maximum water quality benefit.

There is a second reason why increasing the use of the diversion is not viewed widely as a solution for lake water quality benefit. While the diversion helps mask the water quality phenomenon in Lake Whatcom, it does nothing to solve this problem. The concept is analogous to the application of perfume to hide an offensive odor. The odor is not diminished, it is simply masked by the scent of the perfume

2.0 ALGAE LEVELS IN LAKE WHATCOM

The report *Relationship between Drinking Water Treatment Chemical Usage and Lake* Whatcom Water Quality *and Algal Data* (October 2004) is included in the Appendix of this report. This report was drafted by Dr. Robin Matthews, Director of the Institute for Watershed Studies. Dr. Matthews and her staff have been the primary entity involved in research on Lake Whatcom since mid-1980. Part of this research involves the collection and identification of algae in Lake Whatcom.

Algae found in Lake Whatcom vary with the seasons. Much as the conditions in a garden favor the bloom time of certain plants, conditions in a lake will favor the bloom of certain algae species. For example, in late summer when most of the essential plant nutrients have been used up in the water column, the algae species Cyanophyta (blue-green algae) will predominate because it possesses the unique ability to utilize nitrogen from the atmosphere. Chemical dosages applied at the treatment plant appear to be most susceptible to the amount of blue-green algae in the source water.

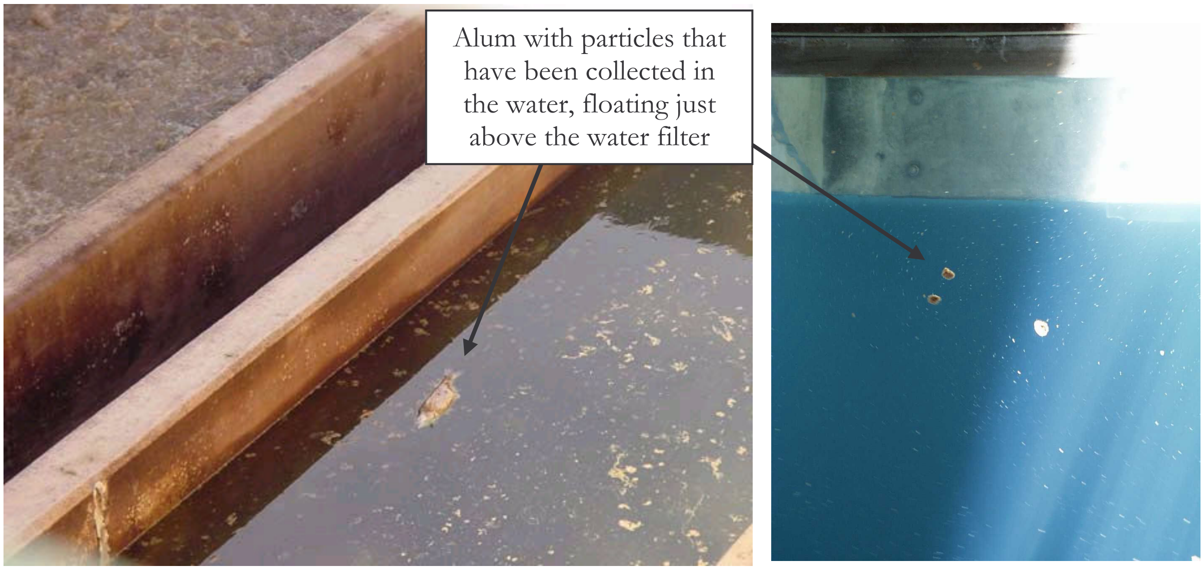
As the report *Relationship between Drinking Water Treatment Chemical Usage and Lake Whatcom Water Quality and Algal Data* concludes, there have been increases in algae found in Lake Whatcom. These increases occur specifically in the species of algae that are found in the lake in summer months. It is also interesting to note that the specific algae peaks observed in the lake correspond with the increases in alum doses observed at the treatment plant (Section 3.0).

Increases in lake algae are perhaps most dramatic in the amounts of golden algae (Chrysophyta) and green algae (Chlorophyta) observed in the lake since 1992. Increases observed in algae in the lake have necessitated the first ever use of an expanded range (y-axis) for charting these algae in the Lake Whatcom Annual Report over the past two years. What this means specifically is that the counts of this type of algae are orders of magnitude higher in recent years than they have been in the past 10 years.

Interestingly, in the past it appears the treatment plant was not as sensitive to golden or green algae, as chemical doses have not increased in proportion to the increases in this type of algae. As the attached report indicates, this trend may be changing. During 2003-2004 the green algae showed its first correlation to alum dose. The 2003-2004 season saw green algae at the highest levels observed to date on the lake. This may be an indication that the green algae observed in Lake Whatcom have risen to sufficient concentrations to impact treatment plant operations. This helps explain the peak in alum dosages observed in June 2004. June 2004 saw an abnormal rise in alum dose. It would also fall to reason that the increases observed in algae are the most likely contributor to increases in disinfection by-products found in treated water as discussed in Section 4.0 of this report.

Photo courtesy of the Institute for Watershed Studies

3.0 ALUM DOSAGE RATES AND PARTICLE COUNTS



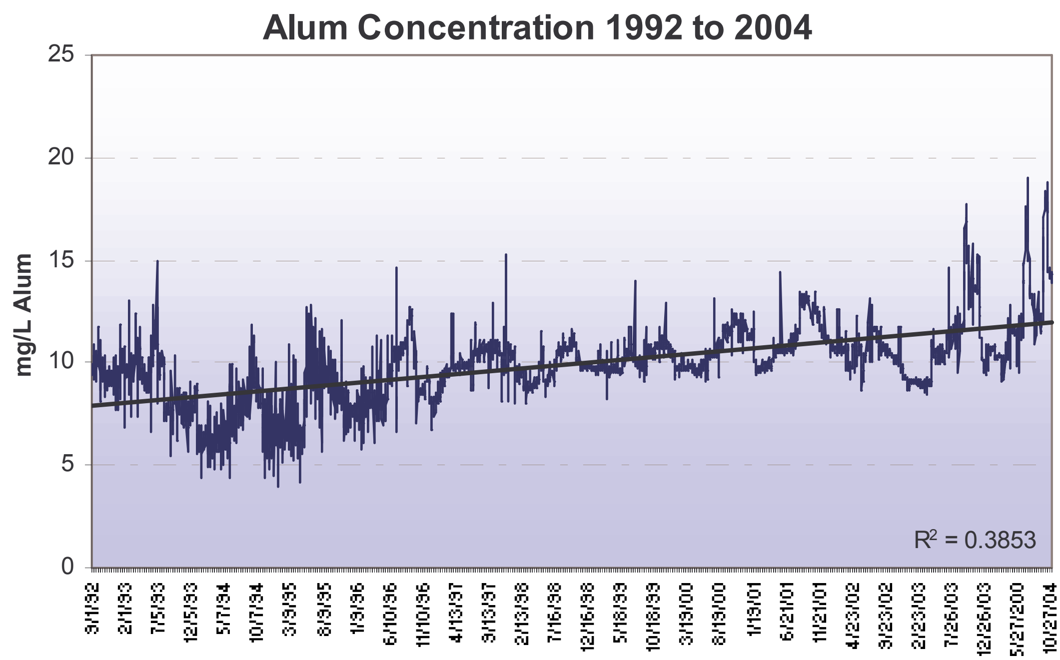
ALUMINUM SULFATE HELPS CLARIFY THE WATER PRIOR TO FILTRATION

Aluminum sulfate (alum) has been used to treat our source water since the water filtration plant was initially put into operation in 1968. Alum effectively causes particles to clump together, making them easier to filter out of the water. Large-scale commercial use of aluminum salts dates back to the beginning of the twentieth century.

Aluminum salts used in the coagulation and sedimentation processes are an integral part of the multi-barrier approach to drinking water treatment. This approach protects the public from life-threatening diseases, such as typhoid, cholera, and cryptosporidiosis. In addition, aluminum salts make drinking water more palatable by clarifying the water and removing many impurities that affect its color. Alum is the coagulant preferred by many water utility managers and operators because of industry experience with alum as well as its effectiveness, availability, purity, and cost.

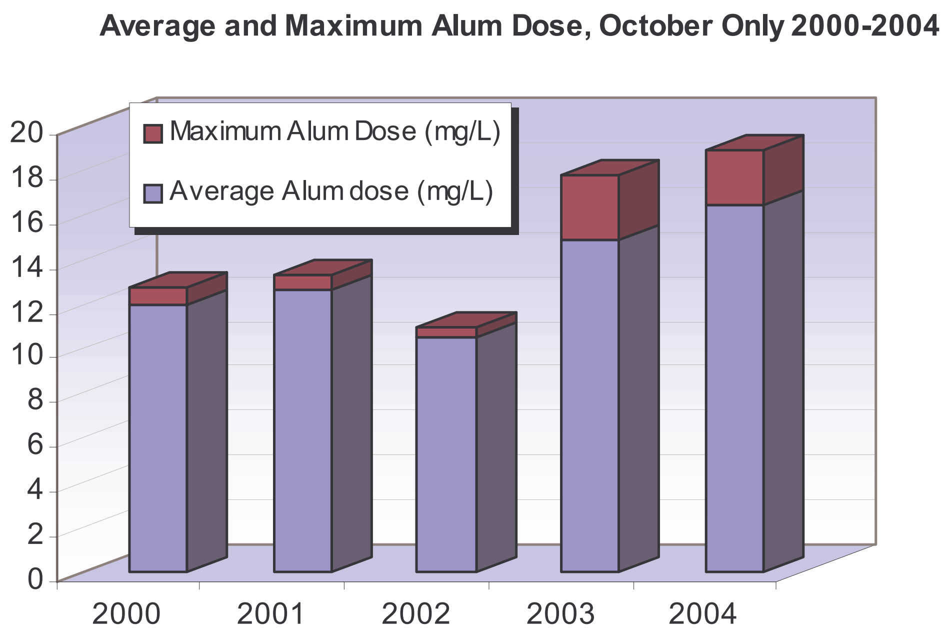
Alum dosage rates depend on the quality of the source water. *Generally speaking, the more particles in the source water the more alum that will be needed to clarify the water.* The City has always applied higher alum dosages in the late summer. Recently, treatment plant operators have observed the alum levels needed to clarify the water during treatment have increased. The City Water Treatment Plant has tracked alum dosage rates since 1992. The results are depicted in the chart on page 7.

The chart on the following page shows the amount of alum that has been applied to the source water to treat it. The dates depict a twelve-year period ending November 04, 2004. Observing the chart in detail it becomes apparent that there are seasonal trends to alum dosages. Late summer has traditionally been the time when algal production in Lake Whatcom is highest and therefore more alum is necessary to clarify the water for drinking. There has been an increase through time in the amount of alum needed to clarify the water. Alum dosages have been the highest in the last two years reaching a peak of 19 parts per million (mg/L). This level is the highest alum dosage ever recorded for the utility. June 2004 saw the highest alum doses ever used to clarify the water during that time period. It is thought that these trends



are related to two primary factors: 1) less water diverted into the lake since 1998, masking the increases in nutrients (Section 1.0) and, 2) greater algae counts in the source water (Section 2.0).

The chart below shows the increasing amounts of alum being applied to treat water in late summer. The more alum that is utilized to treat the water, the more frequently filters need to be taken off-line to clean. The City is now at the point where during high alum-use periods, that it is unable to maintain internal water quality standards set for its treated water, and still keep up with water demand. Particle counts in this treated water exceeds the 20 particles per ml standard the City has set, as demand necessitates longer filter runs to keep up with the water needed to serve customers. During these times the water still meets all Safe Drinking Water Act Standards.



FACTORS INFLUENCING ALUM DOSE

Since 1992 the Water Utility has had three different operational goals for what constituted treated water at the Water Filtration Plant.

(1) 1992 to 1998: Goal was to keep treated water turbidity to a level of 0.10 NTU. Particle counts not utilized to determine sufficiency of treatment.

(2) 1999: Particle counters had been installed in 1995 and the Utility had enough confidence in their performance to use them to guide operations. Goal was changed keep particle counts at or below 10 particles > 2 microns in treated water. The Industry had changed in its appreciation of particle counting as being a better indication of the safety of water and of the sufficiency of treatment.
2002: In late 2002 particle counts were added to the computer system that controls the Plant. At this point the filters were being backwashed at a headloss that was meant to correspond to 10 particles in the >2 micron range. This allowed tighter control of treatment sufficiency as it is now based on actual particle count values.

(3) November 2003: Goal was changed from 10 particles in the > 2 micron range to 20 particles in the > 2 micron range per milliliter. This change was made to match EPA's Partnership for Safe Water goals and to save money on treatment costs. **Trend of decreasing alum dosages should have resulted but did not occur due to an increase in source water particulates**.

PARTICLE COUNTING TO ASSESS TREATMENT

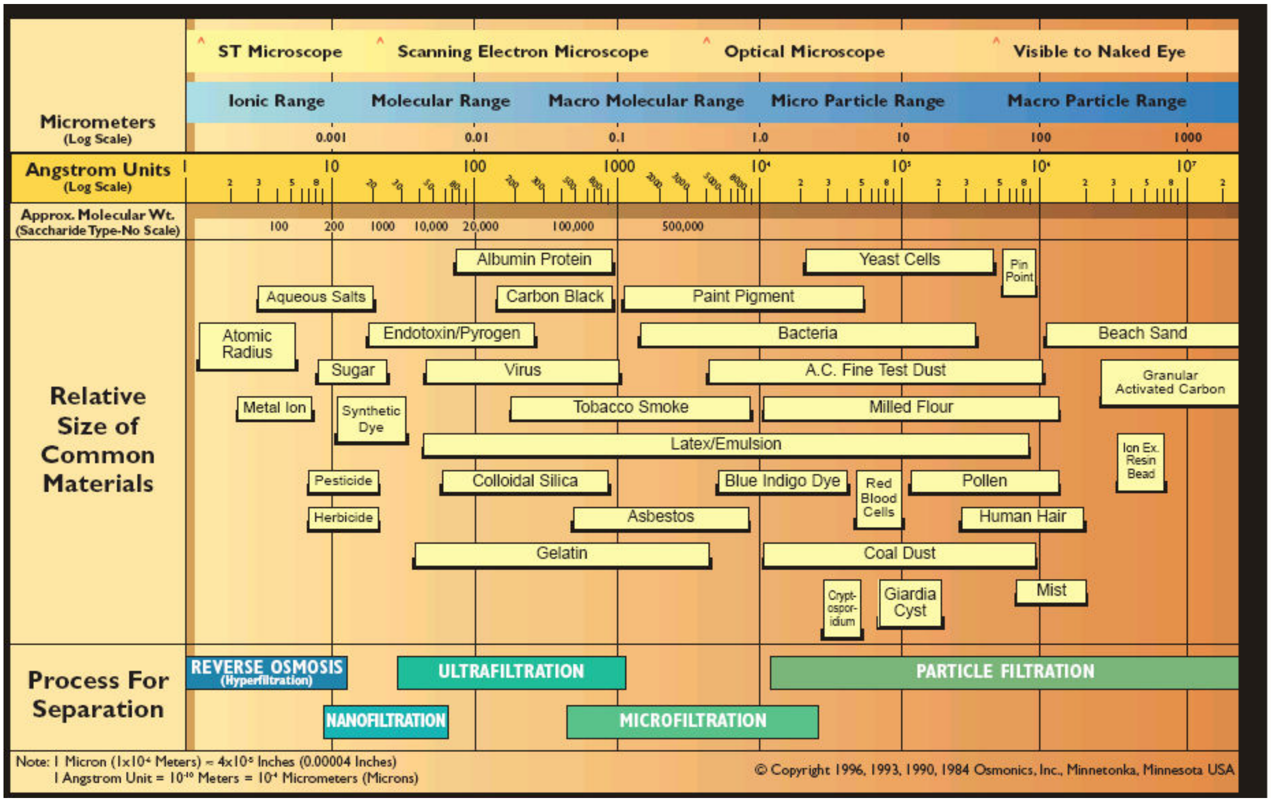
Particle counters are a tool to help water utilities determine their filtration effectiveness and ultimately the safety of their treated water. Water utilities look at particles and their different size ranges as water enters a treatment plant and after it is filtered. This way a utility can focus on those treatment methods that remove particles in the sizes that are associated with disease-causing organisms.

Currently, the City's goal is to treat water with only 20 particles per milliliter (ml) remaining in the greater than 2 micron size range. Water utilities all over the country are tasked with the goal of removing particles in the protozoan cyst size range (3 microns for cryptosporidium cysts). Protozoan cysts are resistant to chlorine disinfection and have been shown to be a major source of illness to those with weakened immune systems. Organisms like viruses and bacteria are even smaller than cysts, but the dual barrier of alum application/filtration and chlorine disinfection is designed to remove these organisms. Furthermore, chlorine disinfection works more effectively on bacteria and viruses than it does on protozoan cysts.

A filtration spectrum is included on the top of the following page. As the filtration spectrum illustrates, particle filters like the ones the City of Bellingham uses are able to remove over half of the contaminants depicted above and to the right of the green box labeled "Particle Filtration". Our target is to measure only 20 particles per milliliter in the size best depicted by the "cryptosporidium" designation. None of the contaminants depicted to the left of the cryptosporidium cell are typically capable of being removed through particle filtration. This is why chlorination occurs following filtration. The City uses particle counting in the >2 micron range to assess our removal of those organisms most resistant to chlorine disinfection (cysts).

2 micron size range

smaller larger



The Filtration Spectrum shown above is used to illustrate the size ranges of many common substances. Many of the substances shown are not commonly found in water supplies.

The chart above helps illustrate why particle size ranges and counting particles in these size ranges helps the City optimize treatment to remove disease causing organisms. The City had a target of 10 particles in the 2 micron size range and above, per 1 ml of water up until 2003. In late 2003 this goal was raised to 20 particles to match the level required for the EPA's Partnership for Safe Water goals. This level also works to reduce chemical and backwash water needs and thus reduces the costs of water treatment.

Much as a coffee filter is capable of keeping coffee grounds from the finished product, filters are a critical process in water treatment. In filtration, one is able to remove particles larger than the pore size of a filter. In other words, if a particle is larger than the pore size of the filter, it will not be able to pass through the filter. There are many different types of filters, some of which are shown above. As water flow increases, or when particle loading is high, the use of a backwashing becomes more necessary. The current particle filters (macrofiltration) that the City employs can be expected to remove particles in the 10 micron size ranges but is not as effective in removing those particles to the left of the schematic above, including bacteria, viruses and algae toxins.

As the spectrum above illustrates, a simple way to classify particle filters is by the size of the particles they remove. When the discussion of improving water treatment options for the City of Bellingham arise, technologies employing ultrafiltration or nanofiltration are a likely choice. The costs of these technologies are detailed in Section 6.0. It is important to understand that filtering smaller particles usually requires more driving force (pressure). It is also important to note that filters remove a certain percentage of particles at a given particle size, and the percentage removed is usually related to the price of the filter.

4.0 DISINFECTION BY-PRODUCT LEVELS IN TREATED WATER

The fact that disease could be spread through drinking water was not commonly known until the latter part of the 1800s. In the early 20th century water works began disinfecting drinking water supplies with chlorine. This practice was followed by the virtual elimination of waterborne diseases such as cholera, typhoid, dysentery, and hepatitis A. It is now commonly known that disinfection of water kills or renders harmless microbiological organisms that cause disease and immediate illness.

The most common method of disinfection is still through the use of chlorine application to drinking water supplies. Not only is chlorine effective against waterborne agents such as bacteria and viruses in the source water, it also provides residual protection to inhibit microbial growth after the treated water enters the distribution system. This means it continues working to keep the water safe as it travels from the treatment plant to the consumer's tap.

Chlorine provides a degree of public health reliability in drinking water safety which regulatory officials cannot easily replace. However, even though chlorine has been a literal lifesaver with regard to drinking water, it also has the potential to form by-products that are known to produce harmful health effects. When chlorine comes into contact with natural organic matter in raw water supplies (algae, humic matter) certain chlorinated organic compounds result from the interaction between the two. Some of these compounds have been linked with potential long-term health effects. Long-term consumption of chlorinated surface water is now know to increase a persons risk of some digestive system cancers.

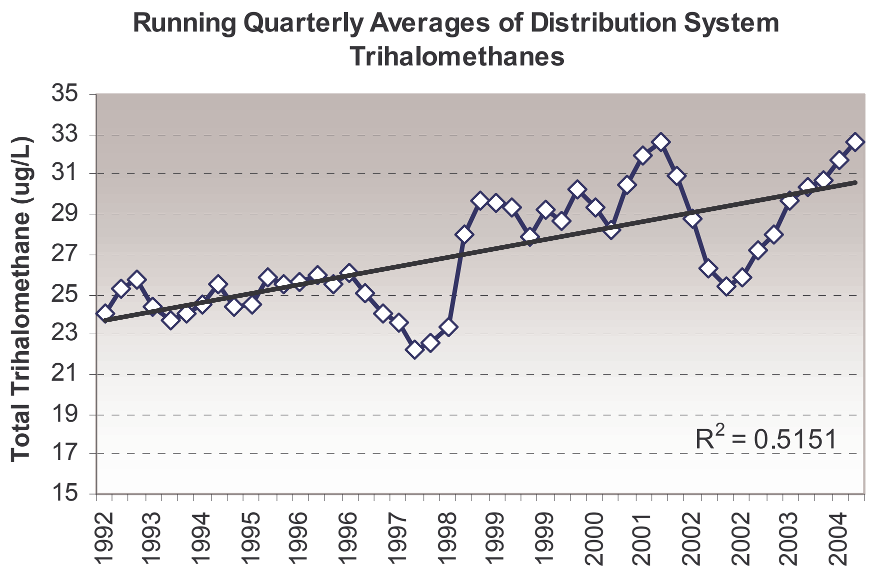
Permissible levels of some of these chlorinated organic byproducts are regulated at specific levels through the Safe Drinking Water Act. These contaminants are called disinfection by-products. The most common by-products are a group of compounds called trihalomethanes (THMs). The maximum contaminant level for THMs is currently set at 80 parts per billion (ug/L). **The risk of becoming sick from drinking inadequately disinfected water is much greater, estimated to be thousands, if not more, times higher than the chemical risks from disinfection by-products**.

The formation of disinfection by-products is a greater concern for water systems that use surface water, such as rivers and lakes, as their source. Surface water systems serving a population greater than 10,000 must regularly test their treated water at points in their distribution system to determine if THMs are present. If the THMs exceed the limits set by the U.S. Environmental Protection Agency (EPA), the water system must take action to correct the problem.

Since the mid-1970s, when the threat posed by disinfection by-products became known, water utilities have been reviewing their operations to minimize THM formation without compromising public health protection. This has involved adjustment to the type and amount of chlorine used as well as where it is applied. In addition, the treatment process has been expanded to remove the naturally occurring organic matter that reacts with chlorine to produce THMs.

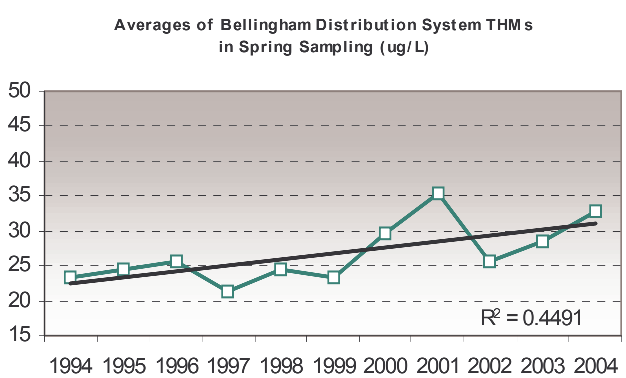
Other means of disinfection besides chlorine are available. However, these methods may also produce harmful by-products. In addition, alternative disinfectants cannot provide the residual protection (that is, continuing to disinfect in the city-wide distribution system) of chlorine-based disinfectants, so they are used in combination with chlorine.

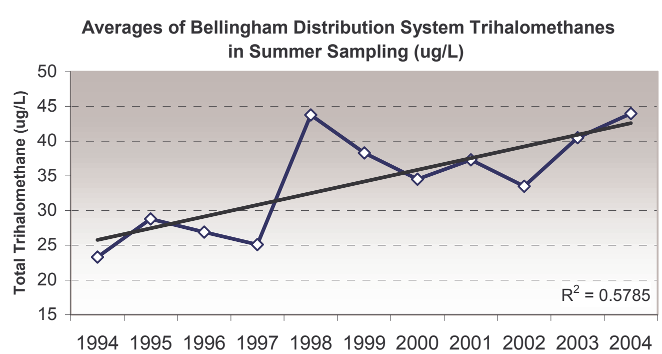
Trihalomethanes are monitored at four locations in the City's distribution system. Monitoring occurs at quarterly intervals: March, June, September and December. The following charts show the results of the City of Bellingham monitoring for trihalomethanes since 1992.



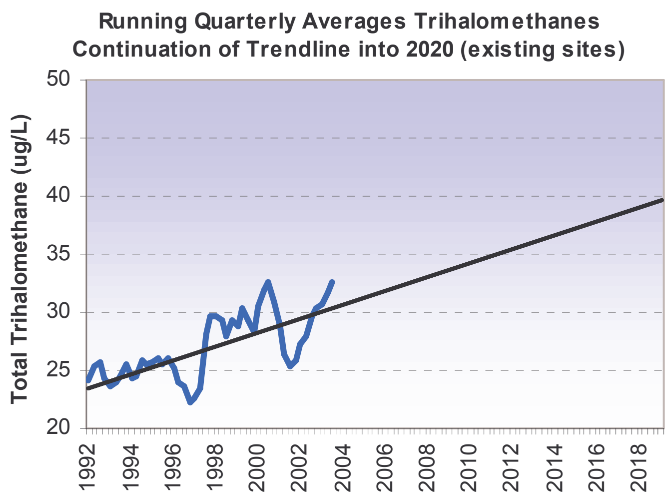
Trihalomethanes are currently reported to the Washington State Department of Health in annual running averages, where 80 ug/L is the maximum contaminant level. As this chart illustrates, the average trihalomethane level in the City distribution system has been increasing, but remains well below the 80 ug/L standard. This increase appears to occur after 1998. This date is also when similar changes were observed in algae counts in Lake Whatcom and in alum dosages applied to treat source water.

The creation of disinfection by-products is dependent on three things: 1) organic matter in the source water, 2) chlorine dose, and 3) contact time of the treated water with chlorine. There have been no changes in the amount of chlorine applied to the water during treatment for the last 20 years. The contact time for chlorinated water was intentionally increased in 1994 in response to regulations aimed at deactivating protozoan cysts. The four years proceeding this increase in contact time did not result in an increase in disinfection by-products. It falls to reason then that the increases observed in organic matter in the source water are the most likely reason for the increases in THMs observed since 1998. Further confirmation can be observed in the charts of 2nd and 3rd quarter trihalomethane levels.

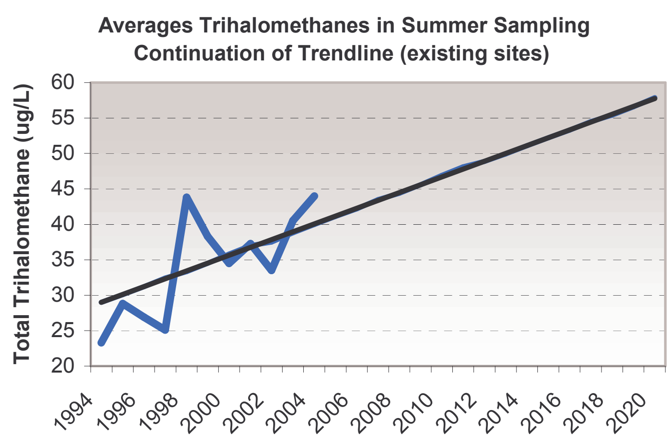




This upward trend that is observed for trihalomethanes can be applied to future years to help predict the levels that would be expected if all else stayed the same. The graphs depicted below show the expected increases in total THM levels if current trends continue. The first graph depicts THM levels as a whole reported as a running average, the second graph shows the expected THM level from the September sampling. Late summer and early fall are the times of highest organic matter in Lake Whatcom and also the time where the highest THMs are observed in treated water.



The predictions for THMs displayed to the left assume that all conditions relating to THM sampling will stay the same. Due to changes in the Safe Drinking Water Act under the Stage II Disinfection By-product Rule, this will not be the case. Water utilities will change the way they sample for THMs to reflect more of a worse-case scenario condition. The rationale behind the change is that people that drink water in the areas of the distribution system with higher THMs don't have the luxury of moving around the system to lower their THM intake levels. The Stage 2 Rule will change the way trihalomethanes are monitored and reported by 2006.



Currently all four sites in the distribution system that are sampled for THMs are pooled together and averaged each quarter for reporting purposes. Changes to the Stage II Rule will have water utilities tasked with finding those areas in their distribution systems that represent worse case scenario THM conditions. Utilities will then be required to start utilizing site-specific averaging from these high THM sites. The Environmental Protection Agency estimates that this change to the Disinfection By-product Rule will reduce the incidence of bladder cancer alone by 182 cases a year.

The City has recently begun the task of identifying its highest THM sites in the distribution system. Preliminary results are included below. As the table below indicates, the City should expect the total trihalomethane levels to increase due to the changes imposed by the Stage II Disinfection By-product Rule. These increases will likely be 40% of current levels at the identified high-risk sites.

Date of Sample	Site	THM (ug/L)
06/08/04	Average of regular City monitoring program Quarterly samples	**32.7**
06/15/04	Curtis Road	36.6
06/15/04	Britton Loop	42.3
06/15/04	Cornwall Dock	44.6
06/15/04	Larabee State Park	50.1
06/15/04	Pacific Highway	59.0
06/15/04	Average of long residence time sites	**46.5**
	Maximum Contaminant Level	**80.0**
09/07/04	Average of regular City monitoring program Quarterly samples	**44.0**
09/07/04	Country Lane (Lummi tap)	40.7
09/07/04	Britton Loop	47.4
09/07/04	Cornwall Dock	54.1
09/07/04	Larabee State Park	53.5
09/07/04	Pacific Highway	65.4
09/07/04	Mitchell Way	58.9
	Average of long residence time sites	**52.2**

As the monitoring data above shows, the City's actual reported THM levels will undoubtedly increase due to changes in the Stage II Disinfection By-Product Rule. One thing that is apparent is that the site the City has been reporting as its worse case scenario site (Marietta Reservoir), has actually not been a true representation of worse case scenario conditions in its distribution system.

5.0 OTHER WATER QUALITY INDICATORS OBSERVED IN THE LAKE SINCE 1998

The Lake Whatcom Monitoring Program's Annual Report has recorded observations about water quality changes observed in recent monitoring of Lake Whatcom. It is stated in the 2002/2003 report that the most likely cause for changes to Lake Whatcom is increasing biologic productivity due to increases in internal and external phosphorus loading.[1] Water quality changes in Lake Whatcom show a subtle shift from very clean source water to water which is still clean but on the path to slow decline.

Changes seen in Lake Whatcom through almost two decades of monitoring have been the most evident in basin 2. Observations of changing conditions began in 1999. It was observed that these changes coincided with the drastic reductions in the amount of water diverted from the Middle Fork of the Nooksack River and with reductions in water withdrawal from basin 2 to Georgia Pacific.[2] While it is not possible to attribute changing water quality to any specific action, the combination of factors that lead to the increased retention time in the lake would certainly be a likely cause of the increased productivity now observed.

Specific changes observed in basin 2 include increases in oxygen deficit rates in the summer months, increases in ammonia and hydrogen sulfide levels in low oxygen periods and increases in algae levels in summer and fall. As a matter of fact, algae levels have increased throughout Lake Whatcom in recent years. It is an important distinction to note that when conditions of low-oxygen occur at the bottom sediments in a lake, there is typically a generation of nutrients. Nutrients like phosphorus are released from sediments under low-oxygen conditions and this internal cycling of phosphorus encourages algal growth. It is one of the few instances in nature where a positive feedback loop is formed. Low-oxygen conditions help release phosphorus bound in nutrient rich sediments, the phosphorus supports the growth of algae which in turn dies and falls to the sediments and in its decay contributes to low-oxygen conditions.

Internal phosphorus loading in lakes can be a major source of phosphorus to a lake even when external sources of phosphorus have been curtailed by best management practices. Estimates of the phosphorus loading from sediments in Long Lake Washington were estimated to be 25-55% of the phosphorus derived from external sources.[3] Shagawa Lake, Minnesota experiences internally recycled summer phosphorus pulses during June, July, and August that are thought to constitute approximately 65% of the total phosphorus loading.[3] While Lake Whatcom would not be expected to have such a large contribution of recycled inorganic phosphorus from the sediments as these lakes do, it is important to be aware of the potential impacts internal loading can have on a lake system.

It is interesting to note that both water utilities that use Lake Whatcom as source water have observed an overall increase in the pH of the source water. This pH increase is a sign of algal productivity. The process of photosynthesis causes an increase in pH by the removal of carbonate and subsequently carbonic acid from the source water.

1. Matthews, Robin A, Mike Hilles, Joan Vandersypen, Robert J. Mitchell, and Geoffrey B. Matthews, April 2004. Lake Whatcom Monitoring Project 2002/2003.

2. Matthews, Robin A, Mike Hilles, Joan Vandersypen, Robert J. Mitchell, and Geoffrey B. Matthews, April 2003. Lake Whatcom Monitoring Project 2001/2002.

3. As sited in Peterson, Spenser A. February 1981. Sediment Removal as a Lake Restoration Technique. U.S. Environmental Protection Agency, EPA-600/3-81-013.

6.0 COSTS ASSOCIATED WITH INCREASING THE HYDRAULIC CAPCITY AND THE LEVEL OF TREATMENT OF SOURCE WATER

Confronted with changes in source water quality, a utility can choose to apply additional treatment to the source water to improve finished water quality. A filtration plant like the one the City operates is still the most common type of water treatment facility in operation in the U.S. today. Even so, there have been many advancements made in water treatment technologies since the City of Bellingham's Water Filtration Plant was put into service in 1968. This Section looks at the likely treatment upgrades and the costs associated with these upgrades.

The City currently operates an in-line filtration plant with a process capacity of 24 million gallons a day (mgd) and a hydraulic capacity of 36 mgd. Each of the City's six 2-bay gravity filters are 560 ft^2 (each bay is 20' x 14'). The current average daily water consumption for the City fluctuates between 8 mgd – 12 mgd depending on the water demand seen with seasonal variations.

The City would take one of two likely paths in upgrading its water treatment plant to improve finished water quality. The two options for improvement are ones that are currently recognized by the water treatment industry to be effective, based on many factors including finished water quality, cost, and compliance with upcoming Safe Drinking Water Act regulations. Any upgrade would also take into account increasing the hydraulic process capacity of the plant at the same time to maximize the benefit of the capital investment. Increasing the process capacity of the water treatment plant to 36 mgd is the most likely projection.

1) Option 1: This upgrade would consist of building additional gravity filters and would include ultraviolet disinfection (UV) as the primary disinfectant.
2) Option 2: This upgrade would consist of building additional gravity filters, would add membrane filtration, and would include ultraviolet disinfection (UV) as the primary disinfectant.

Option 1

Option 1 includes a 12 mgd expansion to increase the plant process capacity to 36 mgd. This option would entail building additional gravity filters and would include ultraviolet disinfection (UV) for that full 36 mgd. The current research and the regulatory climate are showing strong support for using UV disinfection for water treatment. The ease of operating UV systems, their small footprint, and cost, make UV a competitive option for removing pathogens and minimizing disinfection by-products. New U.S. Environmental Protection Agency rules give a very favorable rating for UV disinfection, since it is now known to be a broad spectrum disinfectant (bacteria, viruses and protozoa) and, makes UV treatment technology an attractive option for utilities.

An ultraviolet disinfection system consists of lamps that are enclosed in individual quartz sleeves for protection against dirt and breakage, and reactor chambers that hold the lamps in either a horizontal or vertical configuration. Ultraviolet works by causing rapid DNA damage to disease causing organisms. One disadvantage is that UV light does not leave a disinfectant residual, requiring the utility to apply a longer-lasting disinfectant such as chlorine, to preserve the safety of the treated water on its way through the distribution network. The advantage of this approach though is that less chlorine would be applied to the treated water then would be necessary when utilizing chlorine alone. This should ultimately result in less disinfection by-product formation.

The gravity filter expansion and UV treatment for 36 mgd option will incur the following costs (estimates):

Increasing plant size to accommodate an additional 12 mgd	0.5 million dollars
Gravity Filtration Capability for an additional 12 mg	3.0 million dollars
UV disinfection capability for 36 mgd	3.5 million dollars
Engineering /legal/controls and related expenses (30%)	2.0 million dollars
TOTAL:	**9.0 million dollars**

This is an estimate based on expansion costs at other utilities and is in 2003 dollars. When actual plant expansion is evaluated, the City may choose to explore other treatment options based on new technologies and integration with existing infrastructure and equipment.

The financing for the plant upgrade would be through a debt management plan that allows the City to finance the costs of planning, design, land acquisition, building expansion, equipment, and general construction. The utility revenue bond may or may not be for the entire project costs as some financing could come from the City's water capital reserve fund that receives its revenues from system development charges on all new construction.

The average customer within the service area of the City's water utility may see an increase in their annual water bill by approximately $2.72/month to fund these improvements. These estimates do not include any additional funds necessary to offset an increase in the operations and maintenance (O&M) costs associated with operating a larger plant after expansion.

Option 2

To increase the "level of treatment" membrane filtration would be the likely technology selected over any other conventional types of filtration. Water treatment professional now view membrane filtration paired with UV disinfection as one of the best treatment technologies for municipal water treatment. Option 1 above does not include membrane filtration, while this option does. Membrane filtration would increase the level of treatment applied to the source water and ultimately improve finished water quality.

Membrane filtration includes pressure filtration through porous membranes with a very low molecular weight cutoff rate. The pore size cutoff on the types of filters used is basically what determines the type of membrane filtration from ultrafiltration and nanofiltration to reverse osmosis. The figure on page 9 of this report helps illustrate this concept. The use of membrane technology would likely result in reductions in such contaminants as trihalomethanes, as the organic matter needed for their formation would be removed with much greater efficiency than is possible with granular media. The costs associated with installation and start-up of membrane filtration technology in Bellingham follows (estimates):

Increasing plant size to accommodate an additional 12 mgd	0.5 million dollars
Gravity Filtration Capability for an additional 12 mg	3.0 million dollars
UV disinfection capability for 36 mgd	3.5 million dollars
Engineering /legal/controls and related expenses (30%)	2.0 million dollars
Membrane filtration installation for 36 mgd (estimate)	**27.0 million dollars**
TOTAL:	**36.0 million dollars**

This is an estimate based on expansion costs at other utilities and is in 2003 dollars. When actual plant expansion is evaluated, the City may choose to explore other treatment options based on new technologies and integration with existing infrastructure and equipment.

As mentioned in Option 1, financing for this type of improvement would be through a debt management plan. Most of the utility revenue bonds are issued on a 20-year cycle and it is expected that this option would be similar to that debt policy. Depending on what options the City uses to fund the project, it is expected that the average water customer within the City water utility service area would see their annual water bill increase by approximately $8.16/month to fund improvements of this magnitude. These estimates do not include any additional funds necessary to offset an increase in the operations and maintenance (O&M) costs associated with operating a larger plant after expansion.

7.0 CONCLUSIONS

Currently the City of Bellingham has good drinking water quality. It goes without saying that the retention of good quality source water is a goal for all those who drink this water. This report details changes that have been observed recently in Lake Whatcom and in treated water that warrant attention. These changes have longer-term implications as to the continued good quality of our water source.

The evidence that the water quality in Lake Whatcom has been declining within the last ten years is well documented. This decline has been shown in elevated rates of oxygen depletion, which has been followed by elevated levels of nutrients and algae observed in the lake. More recently, higher chemical dosage rates have become necessary at the treatment plant to clean the water to City standards. Treated water is also showing higher disinfection by-product levels, which are thought to be caused by increases in the organic matter in Lake Whatcom.

While it is clear that the lake is showing signs of change, what is less clear is the appropriate response to the changes observed. There are no easy answers, no cheap and easy alternatives for water quality improvement. Alternatives for water quality improvement have been offered, but none present an easy or particularly attractive alternative for the City. Some of these alternatives are detailed below.

As Section 1.0 details, the most obvious changes in water quality have been observed since the City reduced the volume of water it diverts into Lake Whatcom. This change coincided with a large reduction in the volume of water used by the City's largest industrial customer. These two phenomenon have worked to increase the residence time of water in Lake Whatcom, effectively reducing the amount of clean water that had been available to flush the lake. While major advances have been made in 2004 to automate the diversion dam to make Middle Fork Nooksack River water more available to the City, the ability to depend on this system is less clear. The established minimum stream flow requirements in the Middle Fork are less predictable and are expected to change. Therefore, the City's ability to make use of the diversion is difficult to forecast. Similarly, the flushing effect that was realized in the lake from the City's largest industrial customer is no longer occurring at its former levels.

Finding another source water has been suggested, but this scenario is probably the most unlikely of the alternatives offered. Assuming that water rights would even be made available to the City of Bellingham for current and future needs, there would also be the very real logistics of obtaining the pumps, pipelines, and rights-of way to get this source to the treatment plant. This is assuming the treatment plant would even be located appropriately.

The alternative of moving the water intake pipe into the largest and deepest basin of the lake has been suggested. Basin 3 would presumably offer a cleaner water source, not as prone to the effects of low oxygen conditions that are observed in basins 1 and 2 of the lake. It would be wise to first consider the very real physical constraints of this scenario. These include the hydraulic considerations of moving the intake pipe a mile east, over and past a 36 foot deep sill, and the subsequent loss of the current gravity flow conditions in the intake that this move would create. Furthermore, the presumption that water quality at the Strawberry Sill area is superior is not confirmed by preliminary analysis. Though basin 2 of Lake Whatcom develops anoxic conditions in the summer, this basin does possess the unique distinction of having no actual tributaries to speak of. Tributaries are a direct conduit to the lake of pollutants picked up from near shore land activity, most obviously during rain events.

The report *Strawberry Sill Water Quality Analysis* (Appendix 2) summarized the results of six years of water quality monitoring at Strawberry Sill.[4] The report showed some unexpected findings which included a slightly higher total organic carbon concentration at the sill compared to the intake in basin 2. Nutrients found at the sill had a higher variability and were at times higher than those levels found at the intake. All in all, water quality patterns were similar at the sill to those found at the intake in basin 2.

It is thought that the water quality at Strawberry Sill may be under the direct hydrologic influence of Agate Bay and its tributaries. Carpenter and Olsen Creeks are major perennial tributaries to Lake Whatcom and both discharge directly to Agate Bay northeast of the Strawberry Sill. It would fall to reason that either the loading contributed by these tributaries, and/or hydraulic short-circuiting from the shallow sill area may be the reasons for water quality variations seen in this area in relation to the intake.

Increasing the level of treatment applied to Lake Whatcom is an alternative detailed in Section 6.0. The more expensive alternative presented in Section 6.0 would need to be pursued to realize water quality benefit. Other treatment options are available, and for all, increasing the ability to remove particulates is correlated with increases to the price of the treatment option.

Lake Whatcom is not a simple ecological system, and the solutions for water quality improvement are similarly complex. Part of the challenge of projecting declining trends in water quality towards the future is the inevitable realization that the price of responsibility is also high. Management options to reduce the impacts of land use to the lake have real costs too. There has been a long period of time when overall lake water quality appeared to be impervious to our impacts on its shores. This period appears to be over. From the available data, we look to be at a unique point where management options pursued now will determine which side of the hill we fall. One side will result in a continuation of the current trends observed for increases in organic loading to the lake and all the resulting water quality implications. The other side would hopefully lead to a leveling off of negative water quality indicators, and perhaps a reduction in their levels.

4. Matthews, Robin A, March 2004. Strawberry Sill Water Quality Analysis. Institute for Watershed Studies, Western Washington University.

Appendix 1

Appendix 2