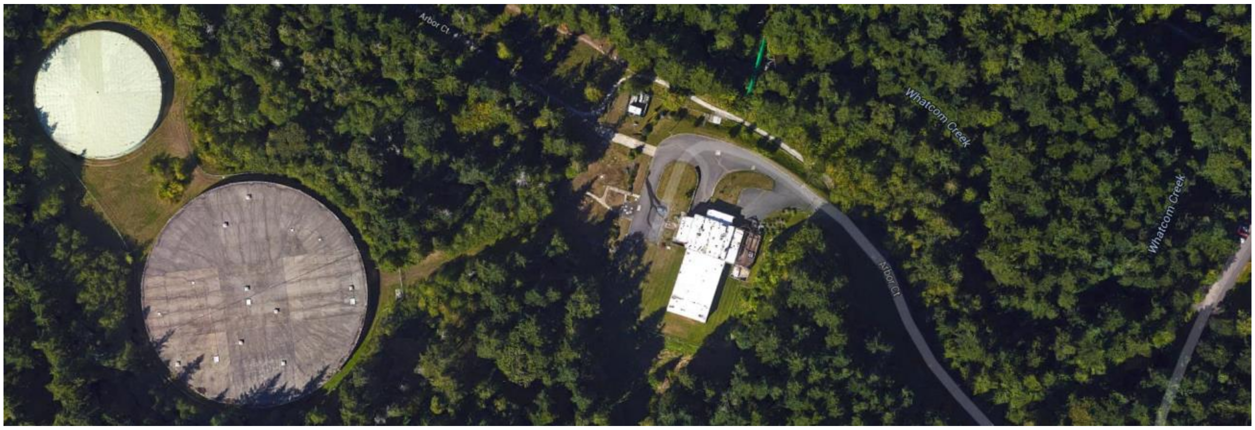

Water Treatment Plant Pretreatment

Project Overview: EW-0180

This project examines the raw water supply system and assesses the condition of and considers improvements to critical raw water supply infrastructure assets including the gate house, tunnel, screen house, industrial and water treatment plant pipelines, and chlorination facilities.

In 2011, a filter-clogging evaluation was completed. The report noted that *even completely protected and secured water sources require some level of pretreatment.* A pretreatment system was recommended as a basic element of the water treatment plant. Specifically, a dissolved air flotation (DAF) pretreatment system was recommended as the best and most sustainable solution to manage treatment of raw water from Lake Whatcom.

The project included three phases - Phase 1 was site analysis and condition assessment of current infrastructure (completed in October 2014), Phase 2 was the design and specifications for selected project elements (begun spring 2015), and Phase 3, construction, began in 2016 and completed in late 2018.

The DAF pretreatment system will complement the existing long-term strategy for watershed protection. While the use of DAF pretreatment is on the leading edge of treatment technology and is used throughout Europe and the United States, Bellingham's DAF project will be one of first applications in Washington State.

The construction project was completed in November 2018, and on budget. The trail, which had been closed for construction, reopened.

For the final phase, staff developed an application to pursue a $12 million Drinking Water State Revolving Fund (DWSRF) loan.

Status

Accomplishments: Construction complete in October 2018.

Monthly Message: Includes images, recent accomplishments, work that is pending.

- project update for November 2018 (PDF)
- project update for October 2018 (PDF)
- project update for September 2018 (PDF)

- project update for August 2018 (PDF)
- project update for July 2018 (PDF)
- project update for June 2018 (PDF)
- project update for May 2018 (PDF)
- project update for APRIL 2018 (PDF)
- project update for MARCH 2018 (PDF)
- project update for FEBRUARY 2018 (PDF)
- project update for JANUARY 2018 (PDF)
- project update for DECEMBER 2017 (PDF)
- project update for NOVEMBER 2017 (PDF)
- project update for OCTOBER 2017 (PDF)
- project update for SEPTEMBER 2017 (PDF)
- project update for AUGUST 2017 (PDF)
- project update for JULY 2017 (PDF)
- project update for JUNE 2017 (PDF)
- project update for MAY 2017 (PDF)
- project update for April 2017 (PDF)
- project update for March 2017 (PDF)
- project update for February 2017 (PDF)
- project update for January 2017 (PDF)
- project update for December 2016 (PDF)
- project update for November 2016 (PDF)

Supporting Documents

- October 2013 Water System Plan Update submitted to Department of Health (PDF)
- June 2012 Final Report 8 MB (PDF)
- City Council Presentation 4-16-12 (PDF)
- Final Draft Report 8 MB (PDF)
- Executive Summary from Final Draft Report 1MB (PDF)
- Appendix B - Benefit and Cost of Phosphorus-Reducing Activities in the Lake Whatcom Watershed 1 MB (PDF)

Project Details

- Status - Construction
- Contract Awarded - August 2016
- Contract Amount - $11,375,658.56
- Contractor - Stellar J Corporation
- Completion Date: October 2018
- Final Contract Amount: $12.6 M

Affected Neighborhoods

- City-wide

Participating Departments

- Public Works

contacts

Freeman Anthony, P.E.
project engineer
Phone: (360) 778-7700
Public Works Contacts

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

November 2018

Editor: Amy Cloud (accloud@cob.org)
City Engineer: Chad Schulhauser, PE (cmschulhauser@cob.org)
Project Engineer: Freeman Anthony, PE (fanthony@cob.org)

What's the latest?
The trail is open, roads at the facility has been paved *(pictured below)*, and we are working towards planting the various vegetation around the site. And, the amazing "story of water" fence (funded by the "1% for the Arts" program, *pictured at left*) has been dedicated. We are very close to the finish line. (Really!)

And what else?
The new Dissolved Air Dissolved Air Floatation (DAF) building is now functional and serving its purpose of removing solids from the lake water before it reaches the water treatment plant. We are testing the new low-strength hypochlorite (safer for operators) and that work is nearly complete. Once this is completed, the new systems will be officially ready for City use. The contractor is also working on installing the access driveway, replacing various chemical pipes, cleaning up the site, and working on a short list of items that need attention before we can close out the construction.

What IS left to do?
Not much! The landscaper is working towards planting, some chemical piping is being installed, and the contractor has a bit of touch-up work still to complete.

Also good to know: Work hours are 7 a.m. to 5:30 p.m. Monday through Thursday, and until 3:30 p.m. on Fridays, with occasional Saturday work. Flaggers may still be on-site at Whatcom Falls Park.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

October 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony, PE (fanthony@cob.org)
City Engineer: Chad Schulhauser, PE (cmschulhauser@cob.org)

What's the latest?

An apology. We thought, and therefore announced, that trail would re-open on Monday, Oct. 8. As observant trail fans know, it did not. However, we have been given a new "fixed and firm" date of Friday, Oct. 26. I am sorry we were not able to re-open on the date we originally announced, I know that was frustrating for all who have been waiting so patiently.

And what else?

The new Dissolved Air Dissolved Air Floatation (DAF) building is up and running! Water is flowing through the new system and cleaning and clarifying the water with great efficiency. The majority of the solids are being removed and floated to the surface as part of this process. *(pictured at left)*

We are completing testing of all equipment and systems in the DAF building and are now gearing up to test the hypochlorite-generation equipment. This is the equipment *(pictured below)* that will allow us to develop low-strength (i.e. less than household bleach) chlorine, which is much safer for our plant operators.

So what's left to do?

We are finishing up electrical work on the hypochlorite-generation equipment, as we prepare to test the pumps, tanks and control system. We continue to work on landscaping around the site, finishing the stormwater infrastructure, and preparing to pave.

Also good to know: Work hours are 7 a.m. to 5:30 p.m. Monday through Thursday, and until 3:30 p.m. on Fridays, with occasional Saturday work. Flaggers may still be on-site at Whatcom Falls Park.

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DAF Monthly Message

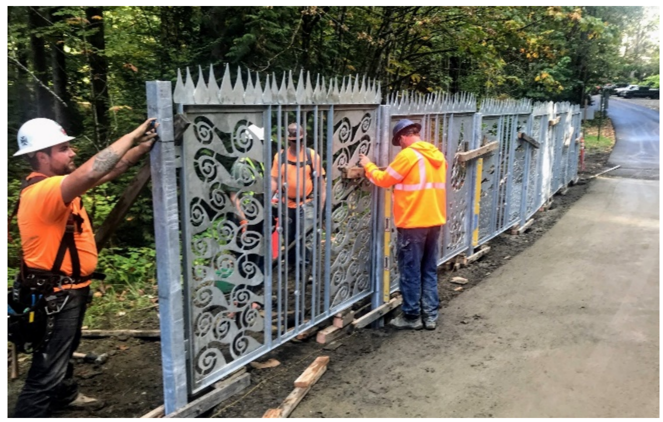
WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

September 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony, PE (fanthony@cob.org)
City Engineer: Chad Schulhauser, PE (cmschulhauser@cob.org)

What's the latest?

Got some good news to share! For those of you anxious to know when the trail will re-open, we have a planned-for date: Monday, Oct. 8. (As always, though, you'll want to "stay tuned" for possible update.) And as for the new Dissolved Air Floatation (DAF) water pretreatment building? Well that's nearly ready as well.



And, thanks to the "1% for the Arts" program, we'll have a one-of-a-kind gate adjacent to the trail. That installation is happening soon. Here's a sneak peek of the gate that tells the tale of water progress.

And what else?

We are in full on test mode for the new Dissolved Air Floatation (DAF) water pretreatment building: we're currently testing everything from the heating-ventilation-air conditioning (HVAC) equipment to the pumps, gates and other drinking water treatment equipment. We have water flowing through the concrete DAF basins and will begin treating the water with the DAF system in the coming weeks. Meanwhile, outside the facility, our two stormwater bioretention ponds are nearing completion.

So what's left to do?

We are testing all DAF equipment to ensuring it's all working properly before plant operators go to work in the new facility. We're finishing up electrical work for the hypochlorite generation in preparation for testing that as well. And we continue to do physical site work such as installing plants, trees, fencing and asphalt.

We are installing new security cameras and updating the fire alarm system. (And, as you see on the left, finishing up roof work including handrails all around.)

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

August 2018

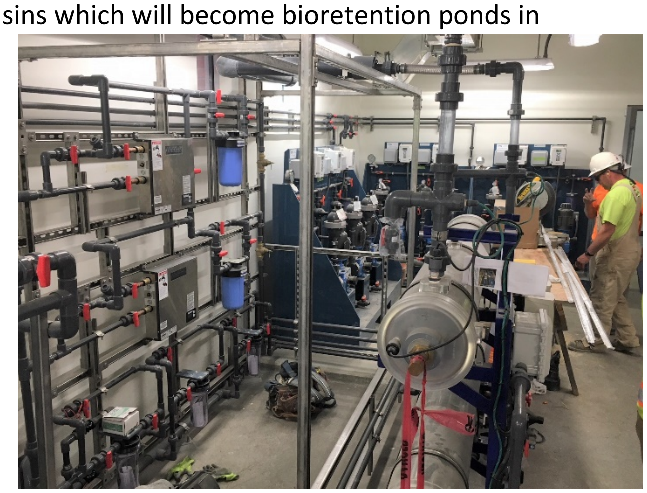
Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony, PE (fanthony@cob.org) *on leave*
City Engineer: Chad Schulhauser, PE (cmschulhauser@cob.org)

What's the latest?

Well, I've said it before and will probably say it again: work on the new Dissolved Air Floatation (DAF) water pretreatment building is nearing completion. (Really, it is!)

For instance, inside the facility we now have power, so we can turn on and test everything to make sure it all works. We are working to finish installing the heating-ventilation-air conditioning (HVAC) and electrical items to wrap up the facility. We are focused on getting everything ready to test the pre-treatment equipment; that will start shortly. Once we know everything is working and functional, operators will be able to settle in to their new work space.

On the outside, we've been digging two big stormwater basins which will become bioretention ponds in the near future. We are also nearly finished with the siding, roofing and grading work.



So, what's left to do?

As I indicated last month, our primary focus is to check out all the DAF equipment to make sure it's working properly. We also need to wrap up installation of the hypochlorite generation (pictured) so we can get that equipment ready to test. In addition to the testing, we are working hard to prepare the site for installation of new fencing, plants and trees, and asphalt.

We should be close on the on the cameras, intrusion alarms and the fire alarm installation.

Also good to know: Work hours are 7 a.m. to 5:30 p.m. Monday through Thursday, and until 3:30 p.m. on Fridays, with occasional Saturday work. Flaggers may still be on-site at Whatcom Falls Park.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

July 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony, PE (fanthony@cob.org) *on paternity leave*
City Engineer: Chad Schulhauser, PE (cmschulhauser@cob.org)

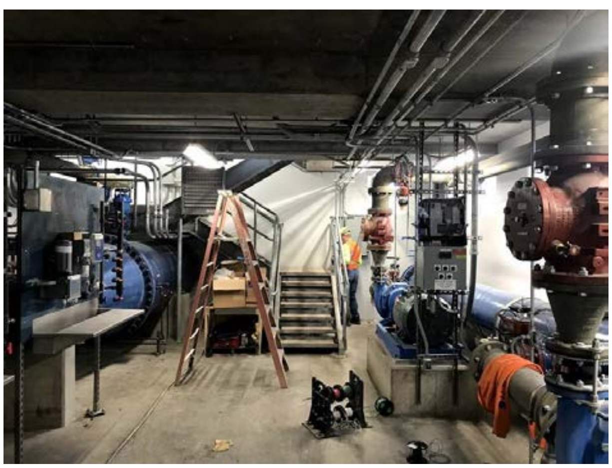
What's the latest?

It might feel like the old math conundrum of "approaching infinity" – you keep getting closer, but you're never there. Well, we're getting closer and should be "there" (i.e. done with construction) this Fall.

We've almost finished all work outside the two new structures – the Dissolved Air Floatation (DAF) and hypochlorite storage buildings. We're also working on two stormwater ponds and the piping that goes with them, as well finishing up the roofs. We're continuing to paint inside and out. Soon we'll be installing metal siding below the brick façade.

Nearly all the stormwater piping and catch basins have been installed, as well as the potable water supply for the new building which was connected by the City.

Park users and nearby neighbors will appreciate one major "To Do" associated with this construction project that we can now mark "Done" – the repair and re-paving of Silver Beach Road (*pictured above*), which was completed on Friday the 13th no less.



On the inside, we have installed a lot of heating-ventilation-air conditioning (HVAC) equipment including a large air handling unit on the roof of the new Water Pretreatment building. Soon the Plant Operators will be able to move into their new control room.

What's next?

Most of our effort now is to finish up the installation of equipment inside the building, so we can begin to test the new pre-treatment process. The DAF equipment is mostly installed, and the remaining work is mostly electrical to ensure the equipment has power and controls. The new hypochlorite generation equipment is being installed as well. We hope to start testing the equipment in August. And on the way: cameras, intrusion alarms and the fire alarm installation.

Also good to know: Work hours are 7 a.m. to 5:30 p.m. Monday through Thursday, and until 3:30 p.m. on Fridays, with occasional Saturday work. Flaggers may still be on-site at Whatcom Falls Park.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

May 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony, PE (fanthony@cob.org) *now on paternity leave*
City Engineer: Chad Schulhauser, PE (cmschulhauser@cob.org)

What's the latest?

As I've been promising the past few months, we're in the home stretch of construction now. Which means that all the walls are up for the new Water Pretreatment Plant (WPP) – also known as the Dissolved Air Flotation (DAF) facility - and exterior brick veneer is mostly done, and we're working away on the piping, inside and out (which is at various levels of completion…)

We have tested all the pipelines for both raw water and treated water; they are approved for use. As well, the 36" water treatment plant drain has been connected to the existing 48" drain and we've connected the plant's sanitary sewer line to the City's. And we have now connected all storm drains to a new catch basin that's just north of the new building.

And what else?

We are building a cantilevered walkway to connect the DAF plant and the hypochlorite building (still need to pour some concrete and finish grading the asphalt pavement there.)

Doors to the DAF are being installed, while windows for the hypochlorite generation room and new office spaces are all in. The building's roof is done – and has been approved. All the aluminum handrails are in, as well as some of the exterior railings. And the electrical circuitry from the original water treatment plant to the DAF facility have been checked and accepted. Conduit work is nearly done. We're pulling in cabling for communications and have nearly completed design of the System Control and Data Acquisition software.

What's next?

We will finish up the heating-ventilation-air conditioning (HVAC) ducting and set-up, and are moving on the new facility's camera systems and intrusion alarms. (And fire alarms, of course.) We'll soon be grading and shaping the access road leading to the water treatment and pretreatment facilities. And the pond to the east of the DAF will be completed.

Among the yet-to-be done work: front entrance to the DAF, complete with hand railings; metal siding insulation; roofing the hypochlorite storage and generation area and the new office space; safety railings atop the DAF; install the rest of the windows; finish installation of lighting and equipment, and then test it all.

We're going solar (correction!) We ARE installing solar panels; however, it's not technically part of the DAF project and they are not at the new building. The sun-seekers will be placed atop the reservoir for the Water Treatment Plant in late summer, once DAF construction is done. The solar panel project is grant-funded, utilizes local companies, and will help off-set DAF energy usage.

Also good to know: Flaggers may still be on-site at Whatcom Falls Park. Work hours are 7 a.m. to 5:30 p.m. Monday through Thursday, and until 3:30 p.m. on Fridays, with occasional Saturday work.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

May 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

"In the books": Since last month, we've wrapped up a lot of work at the new Dissolved Air Floatation (DAF) Water Pretreatment Plant. The outside work is nearly done and we're doing a lot inside the new structures. We've backfilled the 48-inch raw water and treated water piping to and from the DAF and begun placing the 36-inch plant drain. The floor drain lines and mud valve drain lines are all connected to a single line leaving the DAF, headed to the sewer. The roof drains are all connected.

But wait, there's more: The flashing to weatherize the windows has been installed in these areas. The parapet for the hypochlorite-generation building has been built and is ready for roofing. We've got conduits in place and the lighting is going in. The wall studs and drywall are finished, as is some painting. Handrail around the basins are in place. Permanent metal stairs have been installed so workers can more easily move from one area to another. The roof of the DAF is nearly complete.

Then what? Next month we'll wrap up the brickwork on the building's exterior (we've already finished the southern and east sides of the DAF.) Systems should be installed with connection to power and controls. The heating-ventilation-air condition (HVAC) ductwork should be nearly complete. And the remainder of the drain lines should be nearly done as well.

We're going solar! It's not technically part of the DAF project, but by a happy confluence of opportunity, we will be installing solar panels at the Water Treatment Plant in late summer. The solar panel project is grant-funded, utilizes local companies, and will off-set DAF energy usage. Stay tuned for more information (or email me with your questions.)

Also good to know: Flaggers may still be on-site at Whatcom Falls Park. Work hours are 7 a.m. to 5:30 p.m. Monday through Thursday, and until 3:30 p.m. on Fridays, with occasional Saturday work.

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How much longer?

Not long now! We've been at work on the new water pretreatment facility since November 2016, and we're in the final months. We expect to have completed the new facility by the end of the summer.

PS: remember last issue's "Word of the Day"? That'll come in handy to help you fully appreciate the ***flocculator*** stands (pictured below) being placed ☺

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

April 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

What's happening at the site now?

Good stuff! The 48-inch pipes *(pictured at left)* going into and out of the Dissolved Air Floatation (DAF) facility are now installed, fully welded, and have passed all inspections. The lines have been coated for corrosion protection and the pipes have been backfilled.

We are filling basins to test the slide gates, which control water entering and leaving the DAF basins. The DAF building's roof is in progress and the roof for the hypochlorite building is also underway. We're placing the drains for that roof now. Meantime, the tanks for making and storing the hypochlorite are now in place.

The floor of the hypochlorite generation room has been leveled and we're putting in forms for housekeeping pads for equipment. We've got metal studs in DAF building's electrical and mechanical rooms. And all the walls in the conference and operators room are now installed. We're beginning to do the insulation and sheetrock.

And what else?

How about a Word of the Day? "Flocculation." Vertical flocculators – the paddles that will push along the floating material – and their motors are in place. Also in place: motors for gate-openers in basins, cable trays to hold wiring for the power and controls for all motors in DAF gallery, electrical room panels, and lighting and control panels for the DAF pipe gallery.

We've begun brick-laying on the south side of the DAF building, as the insulation and flashing are in place. Roof and perimeter drains are connected through the building and out through the exterior walls. Eventually that roof water will drain into ponds (that are yet to be excavated.)

What's next?

Next month, after we've leak-tested the 48-inch piping, we'll begin backfilling them. We'll continue the brick work and roofing. We'll also install windows and get started on the metal siding. We'll be closer to completing work in the Water Treatment Plant, including the new plant operator room and the hypochlorite generation room instrumentation. And then… we'll be begin painting and labelling systems and piping.

Also good to know:

Now that it's Spring, daylight lasts longer – and we realize trail users are eager to get back out there. Soon, just not yet. Flaggers may still be on-site at Whatcom Falls Park as needed. The current work hours are 7 a.m. to 5:30 p.m. Monday through Thursday, and until 3:30 p.m. on Fridays, with occasional Saturday work.

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How much longer?
You have been so patient – just a few months more! We've been at work on the new water pretreatment facility for 18 months, and now we're heading into the final lap of construction. We expect to have completed the new facility by the end of this coming summer – or sooner. I'll keep you updated on the timeline.

For more project information, click here.

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

March 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

What's happening at the site now?

Dear patient trail-lovers, good news is on the horizon! The largest, as well as many intricate, portions of this complex construction project are complete. While there is a lot of work yet to come, here's what has been done: building walls are up, the big tanks have been placed so we can produce our own hypochlorite; and we've set on the roof beams. And more specifically…

The 66-inch line was installed with all 48-inch connection T-joints and valves. All piping has been coated and is in use. The valves and joints are buried in sand to allow drainage and to allow future work (or connections.) Final coverage of the pipe area will be done after all connections are done.

Injection of the exterior and interior walls of the new Dissolved Air Floatation (DAF) water pretreatment facility has begun. All exterior cracks have been sealed and approved by the project structural engineer. We've begun placing and compacting drain rock at the building's perimeter. The air barrier which applied to the concrete exterior walls has begun and will later be covered with insulation and brick. The roof of the DAF has been vapor sealed and is ready for the adhesive and insulation which will then be final coated with the roofing material. The interior walls of the DAF have been smoothed for painting and interior door frames are being installed.



And what else?

Electrical work inside the DAF building has been moving along with the installation of cable trays and conduits. We've mounted permanent lighting in various areas of the DAF. Large junction boxes are on site for installation. The light pole base at the new gate location has been poured.

Roof beams for the hypochlorite storage building and embeds which will hold the hollow core slabs are in place.

Then what?
In April, we'll begin the metal stud framing walls and insulation. The sheetrock areas will be completed and trim installed. We'll also be installing windows and many of the doors, and start placing bricks. More electrical work will take place and connections of the large diameter piping to and from the DAF connecting to the 66-inch main line into the existing water treatment plant. The hypochlorite storage room roof as well as the roof over the DAF building will be completed. Railing around the roofs will begin. Some metal siding work should begin.

Also good to know:
It's officially Spring now and daylight lasts longer, so we realize trail users are eager to get back at it. Soon, but not yet… Flaggers may still be posted on-site at Whatcom Falls Park as needed. The new work hours are 7 a.m. to 5:30 p.m. Monday through Friday, with occasional Saturday work.

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Thank you for your patience. We've been at work on the new water pretreatment facility since November 2016 – but as I noted up top, we're coming up on the home stretch of construction. We expect to have completed the new building by the end of this coming summer. If that timeline changes, you'll see that information here.

For more project information, click here.

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

for February 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

What's happening at the site now?

It looks like an actual real building now! But there is still a lot of work underway, inside, and yet to be done.

The new Dissolved Air Floatation (DAF) building's leakage test has been completed successfully and wall cracks are now sealed. As soon as perimeter drain pipes are in, we can begin the backfill process. Walls inside the DAF have been chipped and smoothed for painting, which is soon to come.

We are working to complete 66-inch piping planning and have begun placing electrical conduit and other electrical installations. We are crack-sealing DAF walls and testing them.

And what else?

The saturator tanks (pictured) have been installed. The piping for the air saturation process is well underway. The 24-inch recycle line pumps are being mounted and piping for them is mostly in place. We're sealing the 48-inch raw water line to exterior of DAF building.

We're doing perimeter drain and roof drain work. And we've finished the dock foundation and have formed and poured the extension to the existing building foundation.

Then what?

We'll be working inside the original Water Treatment Plant, moving out old equipment and tearing down unneeded walls. That will displace WTP operators, temporarily.

Also good to know:

In winter especially, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park as needed. The crew's work schedule is now 7 a.m. to 3:30 p.m. Monday through Friday.

If you've missed any of these monthly updates, they're archived on the City's website. From the home page, "search" Capital Projects, then DAF. You'll find the updates going back to November 2016.

And why are we doing this?

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And… for how much longer?
Thank you for your patience. We've been at work on the new water pretreatment facility since November 2016 - which probably feels like forever to those who used the trail that's been closed during construction. The good news is we're coming up on the home stretch of construction. We expect to have completed the new building by the end of this coming summer. If that timeline changes, I'll include that information here.

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# # #

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

for January 2018

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

What's happening at the site now?

The roof of the new Water Pretreatment (Dissolved Air Flotation aka DAF) building is made up of hollow core panels, which are now set in place. This work provides some timely relief from the rain in the DAF building – but also makes the DAF building much darker inside.

Valve placement that allows the large basins in the DAF to drain were completed and the gates which allow water transfer between basins installation was completed. Piping (for effluent) in the DAF basins was installed and completed.

The interior walls of the DAF building are getting chipped and smoothed for painting. The large diameter raw water line was completed inside the DAF pipe gallery. The 24-inch recycle line and its supports were also completed outside the build.

And what else?

Pads for the new hypochlorite storage tanks and brine tank were completed in the Hypochlorite Building. The walls have been formed and poured up to the level of the brick corbel (corbel is what supports brick façade.) And we've poured and formed the dock foundation and existing building foundation extension.

The new analyzer equipment has been installed and made functional, while new soda ash lines were completed and tested.

What comes next?

We need to demolish some equipment and walls in the existing Water Treatment Plant to make room for new equipment and operator control room. (Which means Plant Operators are working in a temporary office set-up.)

Next month 66-inch piping planning will be completed. Electrical conduit placement and other electrical installation will begin. We'll also begin crack-sealing the new building walls, to keep water from entering or leaving the building, and then test them. We've also got the perimeter drain and roof drain work to begin. And completion of 24-inch recycle line outside the DAF and sealing of 48-inch raw waterline to exterior of DAF building.

Also good to know:

In winter especially, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach

Road and Lakeway Drive, entering Whatcom Falls Park as needed. The crew's work schedule is 7:30 a.m. to 4 p.m. Monday through Friday through the winter.

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This is to make sure the City's drinking water, which is drawn from Lake Whatcom, is as clean and safe as it can be. We're building a Dissolved Air Flotation (DAF) pre-treatment plant to remove as many particulates as possible from the water, in order to maximize the City's Water Treatment Plant efficiency. And because the goal for this new facility is to ensure that it will *maximize the efficiency* of our current water treatment plant in the *safest way* possible, we are leaving behind chlorine gas and moving to hypochlorite which we create on-site because it is safer.

And… for how much longer?
Thanks for your patience! We've been working on the new water pretreatment facility for over a year, which likely feels like forever to those who used the trail that's been closed during construction. The good news is we're more than half way through construction. We expect to have completed the new building by the end of this coming summer. If that timeline changes, I'll include that information here.

For more project information, click here.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

for December 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

What's happening at the site now?

It's exciting to report that the new Water Pretreatment (dissolved air flotation) building concrete walls and floors have been completed. Demolition inside the existing Plant is underway now, in preparation for improvements and changes to the control of the new DAF equipment and manufacture of the hypochlorite.

And construction of the hypochlorite building is coming along nicely. (That's where large tanks of brine and equipment to make and store the hypochlorite solution will be.) The base slab, which will support four 7,500-gallon tanks, was poured and the walls have been poured up to the same floor level as the current WTP.

We are now using sodium hypochlorite exclusively as our disinfection at the Water Treatment Plant. It's a great change because it is safer in handling and storage than the chlorine gas we previously used. Now the gas is completely disconnected and no longer on-site at the WTP.

The new technical monitoring equipment is being installed now.

And what else?

Connection to the 48-inch industrial pipeline went well (that's the pipe used by Georgia-Pacific back when the tissue mill was running.) It will be a back-up to the existing 66-inch line to the Water Treatment Plant. This connection gives access to a temporary tie-in to the 48-inch line while work is done on the 66-inch line.

What comes next?

Next month the roofing components for the DAF will be delivered and installed. Any water leaks in the DAF walls will be permanently sealed. The 66-inch tie-in work and some pipe work will begin and backfill of the sides of the building should get started. We'll continue pouring the hypochlorite building walls until they reach final elevation (full height.) We'll be done with the inside demolition work soon, and will transition to new installation.

Also good to know:

As always, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park as needed. The crew's work schedule is 7 a.m. to 4:30 p.m. Monday through Friday through the winter.

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Remind me why we're doing this?

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Thanks for your patience! We've been working on the new water pretreatment facility for over a year, which likely feels like forever to those who used the trail that's been closed during construction. The good news is we're more than half way through construction. We expect to have completed the new building by the end of this coming summer. If that timeline changes, I'll include that information here.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

November 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

How much longer?

Thanks for your patience so far. We've been at work at on the new water pretreatment facility for one year now, which probably feel interminable to folks who were users of the trail that's been closed during construction. The good news is we're more than half way through construction. We expect to have completed the new building by the end of this coming summer. If that timeline changes, I'll include that information here.

What's happening at the site now?

Work on the hypochlorite building is well begun. This building will house large tanks of brine and hypochlorite equipment to make the hypo solution and other tanks to store the solution.

We are now using sodium hypochlorite exclusively as our disinfection at the Water Treatment Plant. It's a great change because it is safer in handling and storage than the chlorine gas we previously used. Now the gas is completely disconnected and no longer on-site at the WTP.

The new technical monitoring equipment is being installed now.

And what else?

The walls of the **DAF water pretreatment facility** have risen to their peak in most areas of the building – hitting an elevation of 312-feet.

Another milestone is tying in the 48-inch industrial line (used by the Georgia-Pacific tissue mill when it was in operation) as a backup to the existing 66-inch line to the Water Treatment Plant.

We've done the leak-testing on basins in the DAF structure to ensure that the multiple phases of the dissolved air floatation process react independently of one another – no leaks, which is good news. So now we're grinding and patching the concrete walls to make them smooth.

We've begun installing conduits from the existing water treatment plant to the DAF pretreatment facility for electrical, communication, security and fire systems, as well as to carry the sodium hypochlorite. Electrical work has been done for the technical monitoring devices power to enable communication with the WTP control system.

Meanwhile the **hypochlorite building** is progressing. We've got the under-slab piping and vapor barrier in place, the thickened edge slab steel has been placed and concrete has been poured. The reinforcing steel within the concrete slab (flooring) has also been fitted with connections that will support four 7500-gallon tanks.

What comes next?

Next up, we'll be pouring walls for the hypochlorite building and the remainder of the walls on the DAF building. Completing the planning for the 48-inch industrial line tie in and the 66-inch raw water tie-in.

The actual tie-ins (connections) are to be done towards the end of this month and the beginning of next month (December.)

Also good to know:
As always, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park as needed. The crew's work schedule is 7 a.m. to 5:30 p.m. Monday through Thursday work week. However, there could be occasional Friday work.

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And WHY are we doing this?
This is to make sure the City's drinking water, which is drawn from Lake Whatcom, is as clean and safe as it can be. We're building a Dissolved Air Flotation (DAF) pre-treatment plant to remove as many as particulates as possible from the water, in order to maximize the City's Water Treatment Plant efficiency. And because the goal for this new facility is ensure that it will *maximize the efficiency* of our current water treatment plant in the *safest way* possible, we are leaving behind chlorine gas and moving to hypochlorite which we create on-site because it is safer.

For more project information, click here.

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

October 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

What's happening at the site now?

Work on the foundation of the hypochlorite building is well underway, with the footings on cement-like backfill material. The hypochlorite facility will house large tanks of brine and hypochlorite equipment to make the hypo solution and other tanks to store the solution.

Currently the Water Treatment Plant (WTP) is using Sodium Hypochlorite as a disinfectant. The trial was successful, so chlorine gas is no longer on standby. The chlorine gas has been disconnected and those components have been completely removed.

And what else?

We are placing pipes in the pipe and pump gallery of the new Water Pretreatment or "Dissolved Air Floatation" (DAF) building. We're getting ready to do leak-testing on the various basins in the DAF structure to ensure that the multiple phases of the DAF process react independently of one another.

Walls are being formed for the upper level on the DAF structure which support the roof. These walls have many windows and a brick-and-metal façade so that the new building will closely resemble the existing Water Treatment Plant.

Another milestone – tying in of the existing 48-inch industrial line (formerly used by the Georgia-Pacific tissue mill) for a backup to the existing 66-inch line to the Water Treatment Plant will happen at the end of this month or early in November.

As a reminder…

We're switching from chlorine gas to hypochlorite created on-site. That's because the goal for this new facility is ensure that it will *maximize the efficiency* of our current water treatment plant in the *safest way* possible. That's why we are eliminating the need to transport or store chlorine gas which we currently use to clean water, by switching to hypochlorite which is safer.

What comes next?

Next month we'll be pouring the walls of the DAF building and the hypochlorite building. Work inside the existing Water Treatment Plant will begin with installation of new technical monitoring equipment (and removal of some old equipment.) And we'll tear down some walls to make room for an upgraded

Operator Control area. The 66-inch line supplying the WTP with water will be modified to allow water to be routed to the DAF. And, to ensure all work continues to go smoothly, our contractor is bringing on additional staff.

Also good to know:

As always, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park as needed. The crew is now working 7 a.m. to 5:30 p.m. Monday through Thursday work week. However, there could be occasional Friday work.

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And we are we doing this - why?

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DAF Monthly Message
WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM
September 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

Second verse, same as the first

Now that the first floor has hardened, we're up on the second story doing the same thing - pouring concrete floors and putting in the support beams and reinforcement for the second and third floor walls and stairs. The flooring and walls will have space for pipes, vents and conduits to save drilling holes later as we make electrical and other connections between the existing Water Treatment Plant and the new pretreatment facility.

What else is happening now?

The new, temporary hypochlorite tanks are in place and filled, ready to begin use this month as a replacement for chlorine gas. We are testing the temporary hypochlorite system; once it performs flawlessly for two weeks, we will permanently transition to hypochlorite – and leave behind chlorine gas forever.

We're starting to receive large sections of pipe, which will go into the pump and pipe gallery (in the front on the bottom floor of the new building.) These are the pipes that will deliver raw water into the pretreatment plant from the existing 66-inch line, which brings water from Lake Whatcom.

And we're now removing the fencing and the concrete slab that provided outdoor storage for the chlorine gas cylinders, to make room for the hypochlorite building.

Why the switch from chlorine gas to hypochlorite create on-site?

Our goal for this new facility is ensure that it will *maximize the efficiency* of our current water treatment plant in the *safest way* possible. That's why we are eliminating the need to transport or store chlorine gas which we currently use to clean water, by switching to hypochlorite which is safer and will be produced right at the plant. So, related to that, we have set up temporary tanks to be able to phase-in the hypochlorite as it replaces chlorine gas as a disinfectant. We got the connections in place now and are working with the electrical subcontractor to set up the electronic controls.

And then what?

Next month, once the new building's floors are completed, we'll be waterproofing and insulating the exterior walls, then drainage at the perimeter of the pretreatment building will be completed.

Also good to know:

As always, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park as needed. The crew is still on a scheduled 6 a.m. to 4:30 p.m.

Monday through Thursday work week. However, there could be occasional Friday work.

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# # #

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

August 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

What's happening at the site now

The single biggest and most visual change is that all the concrete walls have been poured. So we now have all perimeter walls for the new pre-treatment facility at the Water Treatment Plant. And all the interior walls – for the first floor, including the basins – have been poured. It's now possible to see where the windows and doors will be.

As a reminder, the goal of this new facility is ensure that not only will it *maximize the efficiency* of our current water treatment plant – it will do so in the *safest way* possible. That's why we are eliminating the need to transport or store chlorine gas which we currently use to clean water, by switching to hypochlorite which is safer and will be produced right at the plant. So, related to that, we have set up temporary tanks to be able to phase-in the hypochlorite as it replaces chlorine gas as a disinfectant. We got the connections in place now and are working with the electrical subcontractor to set up the electronic controls.

The biggest change you never saw:

Massive planning and preparation helped ensure that an overnight transition from the old transformer to the new one and the new automatic transfer switch went flawlessly. City crews and our electrical contractor literally worked through the night so that there would be no interruption of water service for City customers. Mission successful.

And then what?

Coming up, we'll be pouring concrete for the second floor walls and begin making electrical connections between the existing Water Treatment Plant and the new pretreatment facility. We'll be testing the temporary hypochlorite.

Also good to know:

As always, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park as needed. The crew is still on a scheduled 6 a.m. to 4:30 p.m. Monday through Thursday work week. However, there could be occasional Friday work.

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# # #

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

July 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

When are workers actually on-site?

The work week is scheduled 6 a.m. to 4:30 p.m. Monday through Thursday, although the status of construction sometimes requires work on Fridays.

What's happening at the site now?

The goal of our new facility is ensure that not only will it *maximize the efficiency* of our current water treatment plant – it will do so in the *safest way* possible. That's why we are eliminating the need to transport or store chlorine gas which we currently use to clean water, by switching to hypochlorite which is safer and will be produced right at the plant. (If you didn't know, chlorine gas is so toxic it was used as a chemical weapon during World War I. But it also happens to be a very effective disinfectant.)

So, related to that, we have set up temporary tanks – on a concrete pad in front of the Water Treatment Plant – to be able to phase-in the hypochlorite as it replaces chlorine gas as a disinfectant.

Last month we showed you the steel structural supports going in for the new Water Treatment Plant walls. Those walls have now been poured – and they're 18' tall! Some of the walls – which will be basins to hold water – are 18" thick, while others (for the second and third floors) are a foot thick. We put up 60' of wall, east to west, so far.

And then what?

Next month the temporary hypochlorite will be connected and tested. The new transformer and main distribution panel will be connected to PSE. We'll continue pouring wall and begin to connect underground drain piping to aid in future facility maintenance. Also coming up: we'll backfill against the new building's west wall after insulation goes in.

Also good to know:

As always, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park as needed.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

June 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

Are workers still on a four-day schedule?

Not anymore. Since construction activity has hit its stride, the contractor is likely to resume a five-day work schedule, adding back Fridays, in order to keep progress maximized. They're still likely to start work at 7 a.m. and work past 5 p.m.

What's happening at the site now?

This month the visuals started going vertical.

Plant drains and floor drains were placed this month - under and throughout the waterproofing which is under the reinforcement steel in the foundation (base slab.)

And the wall reinforcement steel has been connected to the base slab reinforcement. Concrete was poured 2-feet thick for the base slab. Once that was poured and the forms removed, then the crew was able to begin layout for wall panels. The reinforcement steel for the walls (pictured here) is in place on the poured and cured slabs.

Meanwhile the electrical crew has been busy placing the conduits that we'll need for upgrading to the new transformer, which is set up to handle more electricity as needed. A new Automatic Transfer Switch (ATS) was placed on its pad in the basement of the current water treatment plant. The ATS can recognize if power (from Puget Sound Energy) is out; it will automatically start the large generator at the plant and switch over to it for power.

And then what?

Over the next few months, wall steel will be placed for the DAF and wall forms will be poured/filled with concrete. Forms will be moved to get all walls poured and then the upper concrete floors and the basins will be poured in a sequence. AN electrical switchover to the new Transformer and the new ATS will take place.

Also good to know:

As always, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

May 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

The work week has shortened to four days, is that slowing construction progress?

Not at all. We're really chugging along *and* utilizing a lot of local professionals. This month we began on the foundation for the new water treatment plant – excavating for the trench drains, laying down fabric and then ballast rock (from Cowden Gravel) a foot deep on top of that fabric.

We also began layout for installation of the new plant's drains and floor drains (utilizing Pacific Surveying and Engineering), which will be reinforced with steel and concrete for structural integrity (and all inspected by GeoTest.) Drains were installed and inspected by City staff.

What else?

Planning by the electrical subcontractor is ongoing. And some work has been done inside the current generator room (which houses the back-up generator for the water treatment plant and the pending DAF plant.) And we've put in new conduits for connections to the electrical transfer switch.

And then what?

Next we'll laying down steel reinforcement on top of the slab, above the waterproofing. Once the steel is inspected and approved, a water-stop material will be placed where the concrete will be joined – to ensure against water infiltration into the new building and so that the tanks inside do not leak out. Once this work is done, we'll be ready to pour concrete – two-feet thick – into the DAF base slab forms.

Also good to know:

Our contractor's crews are working a four-day week, 7 a.m. to 5:30 p.m., Monday through Thursday (not including holidays) – with occasional Fridays on the job, in order to accommodate some sub-contractors. As always, weather conditions could influence activity at the construction site. Flaggers are posted at the corner of Arbor Court and Silver Beach Road, and near the intersection of Silver Beach Road and Lakeway Drive, entering Whatcom Falls Park.

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DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

April 2017

Editor: Amy Cloud (accloud@cob.org)
Project Engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

We had spring breaks this month, did that slow up work on the water treatment plant?

Nope. In fact, we got the temporary gate for the project was installed along with fencing to completely secure the work site. So there are extra protections in place now, including additional lighting and cameras for 24-hour surveillance. We know this may surprise some folks who're riding their bikes or jogging into the site – but it is a safety and liability issue.

What else?

We have been shoring up the new building's footprint in order to complete excavation for the new building. That means there has been more trucking activity, with rocks coming in and excavation material headed out. It's been interesting to see that most of the excavated matter has been glacial flow material - cemented soils and rocks with clay.

The excavated area is prepared with a special separation fabric - immediately after excavation - then covered with ballast material (i.e. heavy stuff, to ensure stability) for the permanent drainage layer under the slab.

And electrical work is underway. We're installing conduits before we take delivery of the new transformer and automatic transfer switch. The electrical conduits - and piping under the new building – have to be in place before we can put in the reinforcing steel or pour the concrete. (So you know, electrical inspections happen throughout this ongoing process, to ensure it's all compliant.)

And then what?

Next we'll be waterproofing and putting in the steel reinforcement on the bottom "slab" (foundation) for the new building. And before back-filling, drains will be connected to ensure temporary and permanent drainage. Pretty soon the automatic transfer switch and the new transformer will arrive, which means we can prepare to transfer power from the current transformer and transfer switch to the new, future permanent ones.

Also good to know:

Our contractor's crews are working a four-day week, 7 a.m. to 5:30 p.m., Monday through Thursday (not including holidays) – with occasional Fridays on the job, in order to accommodate some sub-contractors. As always, weather conditions could influence activity at the construction site. Workers park at the east end of Arbor court and in the first ten spaces along Silver Beach Road, entering Whatcom Falls Park.

By the way, if you've missed any of these monthly updates, they're archived on the City's website. From the home page, "search" Capital Projects and then DAF. You'll find the Monthly Messages going back to December 2016.

And… why are we doing this?

This is to make sure the City's drinking water - drawn from Lake Whatcom - is as clean and safe as it can be. We're building a Dissolved Air Flotation (DAF) pre-treatment plant to remove as many as particulates as possible from the water, in order to maximize the City's Water Treatment Plant efficiency. For more project information, click here.

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

March 2017

editor: Amy Cloud (accloud@cob.org)
project engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

More crazy weather in March… Any effect on work on the water treatment plant?

we're living in interesting times, that's for sure! But we were able to carry on working. This last month we completed the common utility trench - for natural gas, 1350 and 480 volt power lines, fiber optic and a chemical feed line - to all connecting vaults. We also set new utility poles outside the new building's footprint, as well as a new gas meter. So, now that work is done for the utilities' reroute, excavation can begin for the DAF's shoring.

What else?

We've also installed contractor parking signs and security measures closer to Silver Beach Road to help with setting the new gate and lighting. Meanwhile, City staff and others are conducting inspections to ensure that all permits, rules and regulations are being met. And water quality is checked and reported for water collected and treated on-site.

And then what?

Coming up: we'll be shoring soils and the Arbor Court roadway near the entrance to the water treatment plant. Once this safety work is done, we can begin further excavation of the DAF footprint - at about 12 feet below roadway grade - to begin the foundation. This work will trigger flagging of Silver Beach Road traffic and (of course ;-) more trucks and construction workers coming and going.

And here's something cool. That dirt that's being excavated? It's not going to waste! We're trucking it over to the pending Pump Track site, by the upper parking lot.

Also good to know:

Since earlier this month our contractor's crews are working a four-day week (7 a.m. to 5:30 p.m.) Monday through Thursday (not including holidays.) As always, weather conditions could influence activity at the construction site. Workers will be parking at the east end of Arbor court and in the first ten spaces along Silver Beach Road, entering Whatcom Falls Park.

By the way, if you've missed any of these monthly updates, they're archived on the City's website . From the home page, "search" Capital Projects and then DAF. You'll find the Monthly Messages going back to December 2016.

And… why are we doing this?

This is to make sure the City's drinking water - drawn from Lake Whatcom - is as clean and safe as it can be. We're building a DAF pre-treatment plant to remove as many as particulates as possible from the water, in order to maximize the City's Water Treatment Plant efficiency. For more project information, click here.

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

February 2017

editor: Amy Cloud (acloud@cob.org)
project engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

Did the recent wintry weather that shut down schools affect work on the water treatment plant?

Fortunately we were able to carry on working; in fact, we got a *lot* done. This last month we've been working to locate existing utilities and documenting the condition of the pipes, wires and conduits in place currently. And that means big pits! We brought in a Vactor truck and dug as deep as 8-feet down to find exact locations of installations and utilities.

Is it true the original Wood Stave Industrial line was uncovered? What is that?

During excavation, old water pipes made of wood were found that likely date back to the early 1900's. An unexpected find, one that offers a glimpse of the history of Bellingham's water system.

And then what?

The utilities for the existing water treatment plant - and the future DAF expansion - will all be rerouted. Power on existing poles will be transferred to underground conduits recently installed in a common utility trench.

To that end, demolition work is beginning on some existing facilities in order to make way for concrete work on the new plant. Sometime mid-March the existing utility poles will be - what contractors call - "wrecked out" when all current cables are moved underground and made fully functional.

So next month that utility transfer will occur to ensure continual operation of water treatment plant during construction (on a temporary basis) and after that permanent connections will be made. Then comes excavation for DAF building below-road-grade and excavation of the slope behind it for safety during foundation construction. Materials continue to be delivered to the site and more crew will arrive to begin forming of DAF foundation. And then - inspections by engineering staff and special inspectors throughout the construction process.

Also good to know…

Beginning in March, or contractor's crews will be working a four-day week (7 a.m. to 5:30 p.m.) Monday through Thursday (not including holidays.) As always, weather conditions could influence activity at the construction site.

Why are we doing this again?

This is to make sure the City's drinking water - drawn from Lake Whatcom - is as clean and safe as it can be. We're building a DAF pre-treatment plant to remove as many as particulates as possible from the water, in order to maximize the City's Water Treatment Plant efficiency. For more project information, click here.

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

January 2017

editor: Amy Cloud (acloud@cob.org)
project engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

Was any work done during the freezing cold stretch?

Yes, quite a lot actually. The trees atop where the new Dissolved Air Flotation (DAF) water treatment plant will be have come down, we've ground up the stumps, and our contractor (Stellar J) is working on excavation of the hillside.

What else is going on?

As we move into 2017 - two months into a two-year construction project - tree debris and slash from the excavation are being hauled away this week. That work to be complete before the last week of January. We're also re-routing some utilities into their "future" locations in the new water treatment plant. This will move the utilities out of the way of construction, with some moving from above-ground poles to underground conduits.

By the way, none of this utility work will affect the Park or nearby residents, it's all contained within the construction zone.

Then what?
Pretty soon the demolition work will begin on some existing facilities in order to make way for concrete work on the new DAF plant. And we are trenching for the new gas and power connections that will be installed over the next few weeks along with temporary connections for contractor operations.

As always, weather conditions could influence activity at the site, but you can expect to see workers on the job approximately 7:30 a.m. to 4:30 p.m. weekdays (not including holidays.)

And… why are we doing this?
This is to make sure the City's drinking water - drawn from Lake Whatcom - is as clean and safe as it can be. We're building a DAF pre-treatment plant to remove as many as particulates as possible from the water, in order to maximize the City's Water Treatment Plant efficiency. For more project information, click here.

DAF Monthly Message

WATER TREATMENT PLANT, NEW PRE-TREATMENT SYSTEM

December 2016

editor: Amy Cloud (acloud@cob.org)
project engineer: Freeman Anthony (360/778-7924, fanthony@cob.org)

What do I need to know?

The trees atop where the new Dissolved Air Flotation (DAF) water treatment plant site are coming down now. That is Job 1 in this 18-24 month construction process. That means some big (as in logging truck big) rigs coming and going.

What else is going on?

This month our contractor (Stellar J) will finish connections to the sediment tank to keep any pollutants from construction activities out of nearby woodlands and creeks. They will have a survey sub-contractor on-site to mark the limits for tree removal and corners for the new DAF building. Once that's done, a different sub will begin clearing the brush and trees to make room for the new buildings.

We expect that the fencing will be completed as soon as the tree removal is done, which will limit access to the work zones for safety purposes. There will likely be more vehicle traffic in and out with extra personnel on-site along, with construction equipment visible. You may hear chainsaws and chipping as brush, limbs and trees are cleared.

And soon we'll have our signs up to alert you to potential hazards, and to share more about the project and our partners. More details to come!

And! We'll have a Safety Drill on Tuesday, Dec. 20 - so you could hear alarm horns and see on-site safety activities taking place.

Then what?

Next month excavation begins where the trees once were. That will bring entail additional construction equipment and workers on-site. Weather conditions may always influence activity at the site, but you can typically expect to see workers on the job approximately 7:30 a.m. to 4:30 p.m. weekdays (not including holidays.)

And... why are we doing this?

This is to make sure the City's drinking water - drawn from Lake Whatcom - is as clean and safe as it can be. We're building a DAF pre-treatment plant to remove as many as particulates as possible from the water, in order to maximize the City's Water Treatment Plant efficiency. For more project information, click here.

And soon we'll have our signs up to alert you to potential hazards, and to share more about the project and our partners. More details to come!


Look closely… can you see the worker in the tree?

"DAF Monthly Message"

NEW WATER TREATMENT PLANT

November 2016

editor: Amy Cloud (acloud@cob.org)
project engineer: Fritz Anthony (360/778-7924, fanthony@cob.org)

What's this all about?

It's about making sure the City's drinking water - drawn from Lake Whatcom - is as clean and safe as it can be. We're building a Dissolved Air Flotation (DAF) pre-treatment plant to remove as many as particulates as possible from the water, in order to maximize the City's Water Treatment Plant efficiency. For more project information, click here.

Construction will begin at the end of November and take 18-24 months. During that time there will be trail closures and parking limitations at the intersection of Arbor Court and Silver Beach Ave. Tree removal at the construction site may change some view corridors.

What's happening now?

The City's contractor was begun moving equipment and a mobile office onto the site, and requested underground utility locates in order to safely plan for on-site excavations (it's the “call before you dig” law.) Local utilities and the City performed the "locates" and placed semi-permanent markings for the contractor.

Starts with marking - or placing "locate marks" - where the utilities are, before disturbing the round.

Then what?

By December, you'll see fencing go up around the project perimeter, and the trail will close. The contractor will be placing stormwater pollution and prevention measures to eliminate runoff from the site to the streams near the Water Treatment Plant. More equipment and workers will arrive to install these measures and begin doing exploratory excavations on current piping, which they'll tie into during construction.

Workers will be on the job approximately 7:30 a.m. to 4:30 p.m. weekdays (not including holidays.)

The contractor's construction trailer has rolled in, as the team gears up to begin work.

City of Bellingham Washington

2013 Water System Plan Update





CH2MHILL

October 2013

City of Bellingham

2013 Water System Plan Update

October 2013

This document has been prepared under the direction of a registered professional engineer.

CH2MHILL®

P.O. Box 91500

BELLEVUE, WA 98004

Executive Summary

ES-1 Introduction

This update of the City's 2009 Water System Plan was undertaken primarily to incorporate the planned implementation of Dissolved Air Flotation (DAF) at the Whatcom Falls Water Treatment Plant. This update includes analysis related to this key treatment issue that arose since completion of the 2009 Water System Plan, as well as analysis related to recent modifications to the distribution system related to distribution system water quality. Much of the content of the 2009 Water System Plan remains valid – other than where it is revised herein – and continues to document the City's overall plan for its water system. This document is hereby referred to herein as the Water System Plan Update (WSP Update) and is intended to complement and supplement the 2009 Water System Plan to form the City's overall water system planning approach for the 6-year and 20-year planning horizons – beginning in 2013.

ES-2 Water Use

The WSP Update includes water use data from 2008, 2009, 2010, 2011, and partial data from 2012. The 2009 Water System Plan included historical water use data only through 2007. The additional years of historical water use data, combined with the data presented in the 2009 Water System Plan as well as water use data from the 1990s enables identification of changing trends in water use. The most notable trend in historical water use downward with respect to maximum day demand (MDD) and flat to slightly declining for average day demand (ADD) – despite the fact that population and water service connections have increased. Historical water use is presented in Figure E-1.

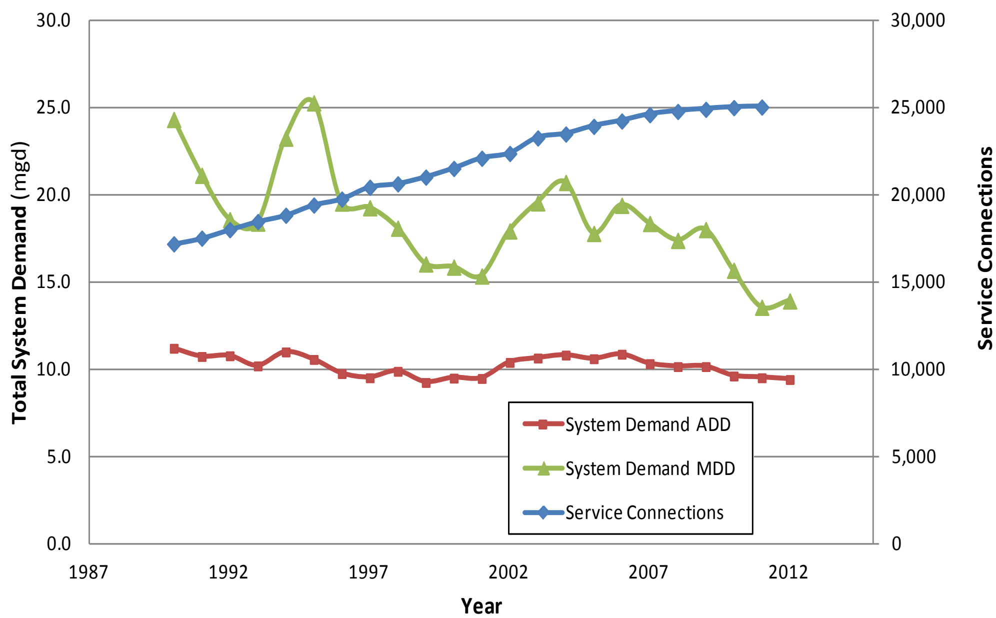


FIGURE E-1
Historical Water Use and Service Connections

Future water use was estimated by escalating the 2012 ADD equivalent to an annual population growth rate of 1.3 percent. This 1.3 percent annual growth rate is just over half as much as the 2.5 percent annual growth rate that was used in the 2009 Water System Plan for estimating future water use, and reflects an updated measure and understanding of local growth trends. Estimated future water use is presented in Table E-1. It is important to estimate future water use as accurately as possible to assess the need for infrastructure improvements. Updated historical and estimated future water use is substantially less than the same from the 2009 Water System Plan. These updates resulted in the deferral distribution system pumping and storage improvements.

TABLE E-1
Estimated Future ADD, MDD, ERUs, and WTP Production

	Total System Demand			
Year	**ADD (mgd)**	**MDD (mgd)**	**Equivalent Residential Units (ERUs)**	**WTP Production (mgd)**
2012	9.4	14.0	47,236	14.6
2018	10.2	16.7	51,042	17.3
2022	10.8	17.5	53,749	18.2
2032	12.2	20.0	61,159	20.8

ES-3 Distribution System Analysis

The major elements that comprise the City's distribution system are storage reservoirs, pump stations, and distribution system pipelines. The City's water storage and pump station facilities were evaluated based on updated actual water use and updated estimates of future water use, which resulted in deferral of improvement needs presented in the 2009 Water System Plan.

The bulk of the City's distribution system storage is contained within its lowest pressure zone – the 276 North Pressure Zone. Water flows into this zone by gravity from the Whatcom Falls Water Treatment Plant. Relatively small storage reservoirs serve higher-elevation pressure zones. Pump stations lift water to these higher-elevation pressure zones. Because most all of the City's pump stations have capacities greater than peak hour demand within the pressure zones they supply, storage from the lower 276 North Pressure Zone can be counted on to serve these upper-elevation pressure zones.

The updated pump station and storage evaluation completed as part of this WSP Update resulted in the improvements presented in Table E-2. However, none of these improvements are planned within the 6-year planning horizon.

TABLE E-2
Summary of Planned Pumping and Storage Improvements

Improvement	ID Number
Pumping	
Kearney Road Pump Station	PS-1
Balsam Lane Pump Station Capacity Expansion	PS-2
40th Street Pump Station	PS-3
980 Pump Station	PS-4
King Mountain Pump Station	PS-5
Storage	
Samish Hill Reservoir	ST-1
King Mountain Reservoir	ST-2

ES-4 Treatment Analysis

In late July and August of 2009 the filters at the City's WTP began clogging much earlier in filter runs than typical. Filter runs became substantially shorter than normal, requiring more frequent filter backwashing. The result of shorter filter runs and increased filter backwashing was greatly reduced WTP capacity – to the point the City implemented mandatory water restrictions, for the first time, to reduce customer demand. It should be noted that voluntary water restrictions are implemented each summer as a means of encouraging conservation during this time of typically-high customer water demand. The water restrictions were successful in reducing customer demand to match WTP capacity. Toward the end of August and into September, filter runs gradually began to return to normal and customer demand dropped, as it customarily does at that time of the year.

Filter clogging was attributed to algae in Lake Whatcom. Monitoring revealed higher than typical counts of most algae species. Although the reasons for the intense algae bloom of the summer of 2009 is the subject of varied speculation, historical and on-going algae monitoring shows that summertime algae blooms in Lake Whatcom have been increasing over the past decade. It is speculated that despite efforts to reverse this trend, summertime algae blooms in Lake Whatcom will continue to increase in intensity and duration over the near-term future. Increased Lake Whatcom algae could again result in summertime algae blooms that prevent the WTP from treating sufficient supply to meet customer demand in the future.

In response to the 2009 algae event, the City completed a study that is presented in a report entitled "Filter-Clogging Algae Mitigation Evaluation," dated June 2012 – hereinafter referred to as the Algae Mitigation Report. The Algae Mitigation Report evaluated treatment, intake, and lake management improvements and included a recommendation for the City to implement Dissolved Air Flotation (DAF) to mitigate adverse algae conditions. As presented in the Algae Mitigation Report, DAF was determined to be the technically superior treatment approach with respect to mitigating the algae problem, as well as being one of the lower cost treatment alternatives. DAF was also determined to be technically superior and far less costly than any of the intake alternatives. Lake Management was determined to be inadequate as a stand-alone mitigation approach because of the many years that will pass before improved water quality with respect to algae will be observed.

In general, the schedule for DAF implementation includes preliminary and detailed design beginning in 2014 – including the DOH-required submittals for the Project Report and the Construction Documents. Construction and commissioning would begin in late 2015 and extend into 2017.

ES-5 Improvement Program

The Improvement Program presented in Table E-3 replaces what was developed for the 2009 Water System Plan. The largest capital improvement over the 6-year planning horizon is the implementation of DAF at the Whatcom Falls Water Treatment Plant.

ES-6 Financial Program

The City recently completed a rate study for its water and sewer utilities, entitled "2012 Water and Sewer Rate Update." The study presented a 6-year financial plan from 2013 through 2018. Key findings and recommendations resulting from the study include rate increases of 9.0% in 2013, 8.0% per year from 2014 through 2016, 6.0% for 2017 and 2018. The rate study included accounting for capital investment that matches the quantity presented in the Improvement Program in Table E-3. The rate increases planned for implementation by the City are anticipated to be more than adequate to cover utility expenses, including planned capital improvements

TABLE E-3
Improvement Program

Project	ID Number	Total Project Cost	2013	2014	2015	2016	2017	2018	2019 – 2032
Kearney Road Pump Station	PS-1	--	--	--	--	--	--	--	X[1]
Balsam Lane Pump Station Capacity Expansion	PS-2	--	--	--	--	--	--	--	X
40th Street Pump Station	PS-3	--	--	--	--	--	--	--	X
Future 980 Pump Station	PS-4	--	--	--	--	--	--	--	X
King Mountain Pump Station	PS-5	--	--	--	--	--	--	--	X
Samish Hill Reservoir	ST-1	--	--	--	--	--	--	--	X
King Mountain Reservoir	ST-2	--	--	--	--	--	--	--	X
Dissolved Air Flotation	T-1	$11,000,000	--	$500,000	$1,000,000	$6,000,000	$3,500,000	--	--
Marietta Re-Chlorination Station	T-2	--	--	--	--	--	--	--	X
Disinfection Improvements	T-3	$1,000,000	--	$100,000	$200,000	$700,000	--	--	--
Screening Relocation Improvements	T-4	$2,000,000	--	$250,000	$250,000	$1,500,000	--	--	--
Water System Plan Update	PN-1	$100,000	--	--	--	--	--	$100,000	--
Metering Program	M-6	$9,500,000	$1,000,000	$2,500,000	$2,500,000	$2,500,000	$1,000,000	--	--
Annual Water Main Replacement Program	PL-1	$12,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	--
Property Acquisitions in Lake Whatcom Watershed	WS-1	$25,950,000	$950,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	--
Water Quality Projects in Lake Whatcom Watershed	WS-2	$5,770,000	$570,000	$600,000	$700,000	$1,000,000	$1,400,000	$1,500,000	X
GP Hydro Project	HP-1	$400,000[2]	$400,000	--	--	--	--	--	X
Nooksack River Dam and Pipeline Improvements	S-1	$10,200,000	--	--	$200,000	--	--	$10,000,000	--
Total	--	**$77,920,000**	**$4,920,000**	**$10,950,000**	**$11,850,000**	**$18,700,000**	**$12,900,000**	**$18,600,000**	--

1 Each of the projects designated with an "X" in the timeframe beyond the 6-year planning horizon were not incorporated into the financial program for the water utility. Therefore, estimated costs were not developed for these improvements.
2 The total project for the GP Hydro Project is preliminarily estimated to be approximately $3,000,000. The amount beyond the initial evaluation is not shown in the table because it is assumed the project will not be completed until beyond the 6-year planning horizon.

Contents

List of Tables

List of Figures *(Figures 3-1, 3-2, 3-3, 3-6 and 5-1 can be found at the end of this WSP Update.)*

Appendices

C Filter Clogging Algae Mitigation Evaluation (Executive Summary, only)
D SEPA Compliance
E Review Consistency
F Dept. of Commerce – Notice of Intent to Adopt Amendment
G Public Meeting
H City Council Adoption

1. Introduction

The City of Bellingham (City) hereby updates its Water System Plan, which was completed in September 2009. The Washington State Department of Health (DOH) water system identification number for the City's municipal system is 05600.

This update does not replace the 2009 Water System Plan in its entirety, but instead provides updated analysis related to a key treatment issue that arose since completion of the 2009 Water System Plan, as well as recent modifications to the distribution system related to distribution system water quality. Much of the content of the 2009 Water System Plan remains valid – other than where it is revised herein – and continues to document the City's overall plan for its water system. This document is hereby referred to herein as the Water System Plan Update (WSP Update) and is intended to complement and supplement the 2009 Water System Plan to form the City's overall water system planning approach for the 6-year and 20-year planning horizons – beginning in 2013.

In support of the treatment and distribution elements cited above, the City's historical and estimated future water use have been supplemented with updated information. The resulting improvements from the treatment and distribution analysis comprise a revised Improvement Program, which is presented herein – replacing the one in the 2009 Water System Plan. In support of the new Improvement Program, a summary of the City's financial strategy is summarized herein.

In summary, this WSP Update is comprised of updates to the following elements of the 2009 Water System Plan:

- **Water Use:** This WSP Update incorporates recent water use information and provides a revised estimate of future water use projections for the overall system and hereby replaces those elements from the 2009 Water System Plan. Other water use elements from the 2009 Water System Plan remain valid.
- **System Analysis:** This WSP Update includes hydraulic analysis of the distribution system (pipelines, pump stations, storage reservoirs) that reflects recent piping modifications within the distribution system. Facility description from the 2009 Water System Plan has not been repeated herein and remains valid. In addition to the analysis of the 2009 Water System Plan, analysis related to water age within the distribution system was completed because of recent related water quality impacts associated with loss of chlorine residual.
- **Treatment Analysis:** This WSP Update includes discussion of the planned dissolved air flotation (DAF) system to address annual summertime Lake Whatcom algae blooms that reduce capacity at the Whatcom Falls Water Treatment Plant (Plant). The City began planning for this improvement after the summer of 2009, during which Plant capacity was reduced to the point customer demand could not be met – resulting in the need for mandatory water restrictions. The DAF improvement was not included in the 2009 Water System Plan because the 2009 Water System Plan had been completed prior to the summertime algae bloom. This planned improvement is the primary stimulus for this WSP Update. This WSP Update also includes evaluation of the need for additional filtration capacity based on updated water use estimates.
- **Improvement Program:** The Improvement Program developed for this WSP Update reflects the updated analyses presented herein. This Improvement Program hereby replaces the 2009 Improvement Program in its entirety.

- **Financial Program:** Simultaneous to the completion of this WSP Update, the City completed a rate study for its water and wastewater utilities. The results of the rate study, entitled "2012 Water and Sewer Rate Update," which includes increased water rates to cover escalating costs and near-term capital improvements, are briefly summarized herein.

Documentation of requisite compliance with the State Environmental Policy Act (SEPA) is presented in Appendix D. The requisite statement of Local Government Consistency from Whatcom County is included as Appendix E.

2. Water Use

Updated historical and projected City water use is presented in this section. This section includes water use data from 2008, 2009, 2010, 2011, and partial data from 2012. The 2009 Water System Plan included historical water use data only through 2007. The additional years of historical water use data, combined with the data presented in the 2009 Water System Plan as well as water use data from the 1990s enables identification of changing trends in water use. The additional years of historical water use data also support estimating future water use because these same trends can be incorporated into those estimates.

2.1 Historical Water Use

Historical water use is presented in Table 2-1 and Figures 2-1 and 2-2. From this table and these figures, several trends are identifiable, including:

- Steadily increasing service connections since 1990 with a reduced rate of increase in service connections over the past few years.
- Average Day Demand (ADD) for the City's system has declined overall since 1990 as well as in the past few years.
- Similar to ADD but at a greater rate, Maximum Day Demand (MDD) for the City's system has declined overall since 1990 as well as in the past few years.
- Per-connection ADD and MDD water use has declined steadily and substantially since 1990.
- The MDD/ADD demand ratio has declined over the years, which reflects the more-rapid decline in MDD than ADD.
- Water treatment plant (WTP) production at the Whatcom Falls WTP has declined over the years in parallel with the decline in MDD. The City generally operates the WTP to match system demand on a daily basis.
- Water use data from 2008 through 2012 – data that was not available for the 2009 Water System Plan – reflects decline in each of the water use metrics presented in Table 2-1. This recent decline has a substantial impact on estimates of future water use.

Overall, it is clear that despite growth in population, which is reflected in the growth in number of service connections, total water use has been declining. There is both a decline in overall system ADD and MDD, but a much greater decline in MDD. The reason for this decline is the marked reduction in the quantity of water used per connection, which generally reflects the ever-increasing awareness of individual customers to conserve and use water wisely. These trends are reflected in many other communities throughout western Washington – particularly as it relates to reductions in MDD, which results primarily from reduced summertime outdoor watering.

The extent to which the further reduction in per-connection water use continues into the future is uncertain. However, the City's ongoing program to convert two thirds of its customers, which are currently unmetered, to metered customers will likely lead to further per-connection water use reductions and could potentially result in negligible growth in overall system ADD and MDD for several years to come.

TABLE 2-1
Historical Water Use

Year	Service Connections	Total System Demand ADD (mgd)	Total System Demand MDD (mgd)	Per-Connection Demand ADD (gpcpd)	Per-Connection Demand MDD (gpcpd)	Demand Ratio MDD/ADD	WTP Production (mgd)
1990	17,173	11.2	24.3	652	1,415	2.17	25.3
1991	17,498	10.7	21.1	613	1,206	1.97	21.9
1992	17,985	10.8	18.6	598	1,032	1.72	19.3
1993	18,447	10.2	18.4	552	995	1.80	19.1
1994	18,810	11.0	23.2	584	1,235	2.12	24.2
1995	19,394	10.6	25.3	544	1,302	2.39	26.3
1996	19,736	9.7	19.5	494	989	2.00	20.3
1997	20,416	9.5	19.2	465	942	2.03	20.0
1998	20,611	9.9	18.1	479	877	1.83	18.8
1999	20,996	9.2	16.0	440	763	1.74	16.7
2000	21,493	9.5	15.8	441	737	1.67	16.5
2001	22,076	9.5	15.3	429	694	1.62	15.9
2002	22,352	10.4	17.9	464	801	1.73	18.6
2003	23,240	10.6	19.5	457	840	1.84	20.3
2004	23,464	10.8	20.7	460	882	1.92	21.5
2005	23,905	10.6	17.8	443	743	1.68	18.5
2006	24,210	10.9	19.4	448	800	1.79	20.2
2007	24,573	10.3	18.3	420	746	1.78	19.1
2008	24,759	10.1	17.4	410	702	1.71	18.1
2009	24,880	10.1	18.0	408	723	1.77	18.7
2010	24,978	9.6	15.7	384	627	1.63	16.3
2011	25,011	9.5	13.5	380	541	1.43	14.1
2012	--	9.4	13.9	--	--	1.48	14.5

1. Abbreviations: mgd = million gallons per day; gpcpd = gallons per connection per day

2. WTP Production = Total System MDD plus 4% to account for uses at the Whatcom Falls WTP, including filter backwashing, filter-to-waste, and other minor uses prior to delivery to customers.

3. The 2012 MDD was a recorded value on August 3, 2012.

4. The number of service connections for 2012 was assumed to be unchanged from the end of 2011 (25,011) - reflecting slowing growth and poor economic conditions. The actual number at the end of 2012 was not available at the time this data was assembled.

5. The estimated 2012 ADD was estimated to be 99.3% of the 2011 ADD based on a comparison of the first 7 months of available water use data from 2012 and the same data from 2011.

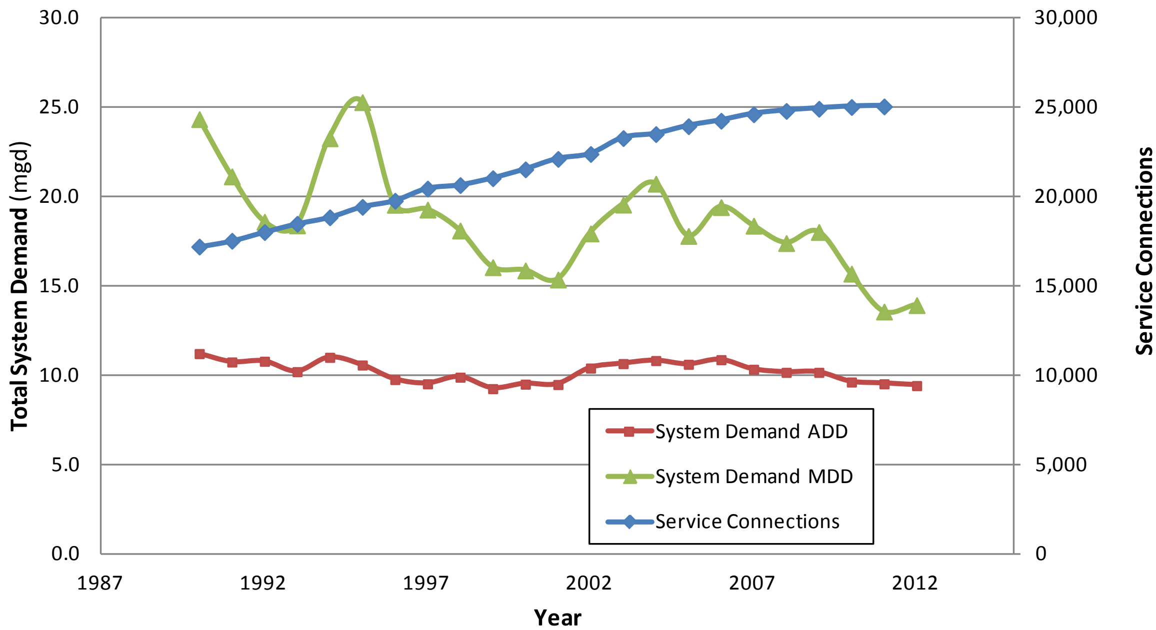


FIGURE 2-1
Historical Water Use and Service Connections

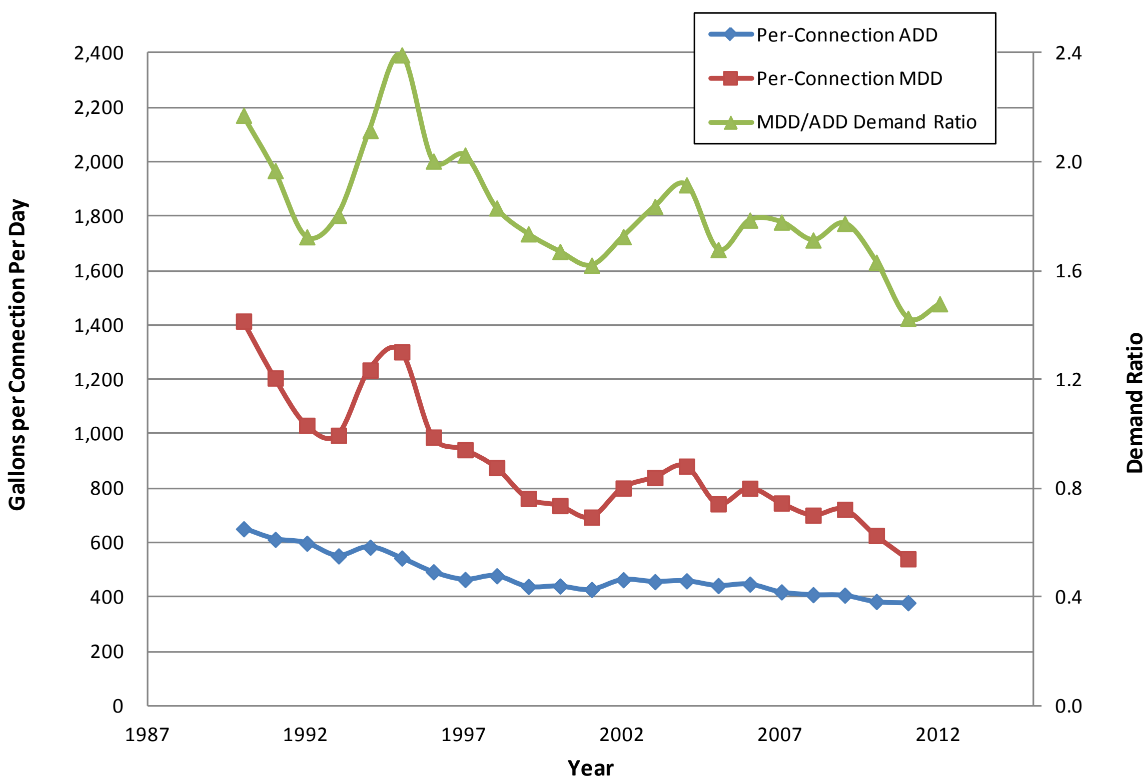


FIGURE 2-2
Historical Per-Connection Water Use and Demand Ratio

2.2 Estimated Future Water Use

Projected water use is presented in Table 2-2 – extending from the current year, 2012, through the 20-year planning horizon. Because the 2012 calendar year was not complete at the time this WSP Update was prepared, an entire year of actual ADD for 2012 was not available; however, it was estimated to be slightly less than the ADD for 2011 – by 0.7 percent. This estimate was developed after a review of master meter data at the water treatment plant for the first 8 months of 2012 showed that water use for this 8-month period was 99.3% of water use for the same period in 2011.

TABLE 2-2
Estimated Future ADD, MDD, ERUs, and WTP Production

	Total System Demand			
Year	ADD (mgd)	MDD (mgd)	Equivalent Residential Units (ERUs)	WTP Production (mgd)
2012	9.4	14.0	47,236	14.6
2018	10.2	16.7	51,042	17.3
2022	10.8	17.5	53,749	18.2
2032	12.2	20.0	61,159	20.8

1. The estimated 2012 ADD was estimated to be equal to the 2011 ADD multiplied by 1.2% based on a comparison of date from the first 7 months of 2011 and 2012.

2. The 2012 MDD was a recorded value on August 16, 2012, as presented in Table 2-1.

3. The 2018 and 2032 MDDs were estimated using the average of the MDD/ADD demand ratios for 2007 through 2012 (using estimated 2012 ADD) multiplied by the corresponding 2018 and 2032 ADDs.

4. Future ERUs were estimated using the 199 gpd/ERU value from the 2009 Water System Plan.

5. WTP Production = Total System MDD plus 4% to account for WTP uses.

6. 2018 and 2032 estimates of ADD and ERUs are based on an annual population growth rate of 1.5%.

Actual MDD data for 2012 was available at the time this WSP Update was prepared, as presented in Table 2-1. However, future MDD was not estimated based on this 2012 MDD value. MDD is more affected by seasonal weather conditions and therefore subject to greater year-to-year variability than ADD. Future MDD was estimated by applying an average of the MDD/ADD demand ratio from the last few years (2007 through 2012) to the estimated future ADD values for 2018 and 2032. This approach reduces the impact of the very low MDD values from 2010, 2011, and 2012 which resulted from unseasonably cool summers. At the same time, however, this approach provides an accounting of the longer-term and recent decline of the City's MDD. It appears that the trend toward reduced MDD can be attributed, in part, to unseasonably cool summers during the 2010 to 2012 period as well as longer-term changes in customer water use.

Future water use (6-year, 10-year, and 20-year projections) was estimated by escalating the 2012 ADD equivalent to an annual population growth rate of 1.3 percent. This population growth rate estimate represents the annualized increase associated with the latest growth rate estimates adopted by the City for utility planning as well as the City's overall Comprehensive Plan. This 1.3 percent annual growth rate is just over half as much as the 2.5 percent annual growth rate that was used in the 2009 Water System Plan for estimating future water use, and reflects an updated measure and understanding of local growth trends. The estimated future water use presented in Table 2-2 is approximately 60 percent of what was estimated in the 2009 Water System Plan. This much-lower estimate of future water use results, in part from a lower ADD baseline starting point, but more-significantly from the lower annual growth rate.

It is important to estimate future water use as accurately as possible to assess the adequacy of water rights as well as the need for infrastructure improvements. Although not specifically addressed in this WSP Update, the City has adequate municipal water rights to meet its current and projected ADD and MDD. With respect to infrastructure need, however, an accurate estimate of future MDD is of primary importance because MDD is used as the key criterion to establish the capacity of supply and treatment improvements.

3. Distribution System Analysis

Analysis of the City's distribution system capacity, incorporating distribution system improvements since 2009 and updated water use, is presented in this section. The major elements that comprise the City's distribution system are storage reservoirs, pump stations, and distribution system pipelines. The City's water storage and pump station facilities were evaluated based on the updated actual water use and updated estimates of future water use, which resulted in changes from the improvement needs presented in the 2009 Water System Plan.

The analysis presented herein is for capacity purposes, only, and does not address condition-related facility issues. The City is initiating an Asset Management Program that will continue through 2013 to identify condition-related facility improvement needs for its drinking water and wastewater facilities. Upon its completion, the results of that program will be incorporated into the City's Water Plan.

The City's distribution system pipelines were not evaluated with respect to capacity as part of this WSP Update because the City's actual water use has declined what was documented in the 2009 Water System Plan, updated estimates of future water use are much lower than in the 2009 Water System Plan, and because there have been no changes to fire flow requirements. As a result, the distribution system pipeline analysis presented in the 2009 Water System Plan remains valid, even though somewhat conservative. No system improvements or modifications are warranted or planned because of distribution system pipeline capacity deficiencies.

In addition to the storage and pumping evaluation presented herein, a distribution system water age evaluation was undertaken because of recent concerns relating to maintaining a chlorine residual within the distribution system at the Marietta Reservoir and Kearney Road Reservoir. The purpose of the water age evaluation was to develop a relative comparison of reservoir residence time for existing and potential alternative configurations. The objective of reducing water age is to facilitate maintaining a detectable chlorine residual within the distribution system, which is required.

The analysis presented herein is based on updated water use, as presented in Section 2, which includes substantial reductions in average and peak water use in recent years and more modest projections of growth in water use than what were presented in the 2009 Water System Plan. The analyses were based on current water use as well as projected water use for the 6-, 10-, and 20-year planning horizons. Distribution of water use throughout the water system remains the same as developed for the 2009 Water System Plan.

The City's latest service area map, pressure zone map, and hydraulic profile are presented at the end of this WSP Update as Figures 3-1, 3-2, and 3-3, respectively. These figures reflect recent changes in the City's service area via annexation and distribution system modifications in the vicinity of the Kearney Road Reservoir and James Street Pump Station.

3.1 Pressure Zone Demands

The system-wide existing and projected water use is summarized in Section 2 and was used for analyzing the overall system. However, water use for individual pressure zones is also necessary to analyze pumping, storage, and pipeline facilities. A summary of the current pressure zone average day demands (ADDs), as developed from existing customer billing records and meter locations, is presented in Table 3-1. Also presented in Table 3-1 is estimated future ADD on a per-zone basis based on a distribution of growth anticipated by the City. The combined estimated growth in water use for the City is the same as that presented in Table 2-2.

TABLE 3-1
Summary of ADD per Pressure Zone (gallons per minute)

Pressure Zone	2012	2018	2022	2032
276 North[1]	2,917	3,152	3,172	3,427
350 Cordata[2]	804	869	1,107	1,410
457 South[3]	1,335	1,443	1,442	1,550
460 King Mountain	9	10	41	73
519 Dakin & Consolidation[4]	826	893	905	934
780 Birch Street	10	11	16	28
541 College Way	52	56	56	56
696 Padden Yew	282	305	336	389
730 Alabama Hill	221	239	276	330
830 Reveille[5]	17	19	63	108
873 Governor Road[5]	53	57	106	179
Total	6,527	7,053	7,507	8,486
Total (mgd)	9.4	10.2	10.8	12.2

[1] Includes demands for Montgomery Road Water Association, Water District #2, and LWW&SD.

[2] Includes demands for Deer Creek Association.

[3] Includes demands for California Street Water Association.

[4] Includes demands for the 660 Huntington Pressure Zone, LWW&SD, Water District #7, and Glen Cove Cooperative.

[5] The 830 Reveille Pressure Zone and the 873 Governor Road Pressure will be combined to 870 Samish Hill Pressure Zone within the 20-year planning horizon.

3.2 Pump Stations

Description of the City's pump stations is presented in the 2009 Water System Plan. The only changes to the City's pump stations since 2009, include: (1) the addition of the Samish Crest Pump Station, which provides domestic service for 20 new houses adjacent to the existing Parkhurst Reservoir; and (2) the re-connection of the James Street Pump Station suction from the 276 North

Pressure Zone to the 519 Dakin & Consolidation Pressure Zone. The Samish Crest Pump Station does not provide fire flow to the 20 houses; but instead, fire flow protection is provided from a private fire system supplied from a fire department connection just down-slope from these 20 homes – within the 873 Governor Road Pressure Zone.

Capacity analyses of the City's major pump stations were based on the updated water use information summarized in Section 2 are presented in the subsections below, after a discussion of evaluation methodology. Pumping deficiencies identified are summarized in Section 3.6.1 and planned improvements for mitigating these deficiencies are presented in Section 3.7.1.

3.2.1 Capacity Evaluation Methodology

The pump station capacity evaluation accounts, where applicable, for pumped zones that are supplied from the zone into which the pump station being evaluated supplies. In other words, a pump station at a lower elevation within the overall water system must not only have the capacity to supply water to the pressure zone it directly discharges to, but also to all of the pumped zones above, that draw water from pressure zone being directly supplied. Pump stations are required, at a minimum, to meet the maximum day demand (MDD) of the pressure zone they supply, in addition to the demands of pressure zones above – as discussed above. The difference in demand from the pressure zone between the peak hour demand (PHD) and MDD is supplied from the storage that establishes the hydraulic grade line of the pressure zone and provides directly, stored supply. Pressure zones that are directly served by storage are referred to as "open" zones while pressure zones that do not have storage within the zone are referred to as "closed" zones.

Pump stations that supply open zones are evaluated with respect to their "firm" capacity, as opposed to their total capacity. Total capacity refers to the capacity of a pump station with all pumps operating. Firm capacity refers to the capacity of a pump station with the largest pump out of service. This capacity evaluation approach is described in the Washington State Department of Health Design Manual.

Pump stations supplying closed zones must have the capacity to supply peak hour demand (PHD) – not just maximum day demand (MDD). As stated above, the difference between PHD and MDD is typically provided by distribution system storage, which is not available in closed zones. In addition to PHD, pump stations supplying closed zones must meet fire flow demand requirements within each pressure zone. Pump stations serving closed zones are required to be equipped with a backup power supply, which is the case for the City's pump stations serving these zones.

Where two pump stations supply a particular zone, they were evaluated with respect to their combined capacity as though they are a single, combined pump station. This is a valid evaluation approach in recognition that each pump station does not need to completely redundant to each other – each having the capacity to meet the demand needs of the pressure zones they supply. In fact, because they are physically remote from each other, two separate facilities already have a slight inherent increase in redundancy and reliability than a single, larger-capacity facility. Since the two facilities are evaluated with respect to their capacity as a single, combined pumping facility, their combined firm capacity (capacity with the largest pump out of service) is defined by removing only the largest of the pumps from the two facilities (one pump total) from service.

A summary of key evaluation elements of the pump stations evaluated are presented in Table 3-2. For those locations where two pump stations directly supply a pressure zone, both pump stations are listed together in the first column of Table 3-2. This applies to the Dakin & Consolidation Pump Station and the Woburn Pump Station, which both pump to the 519 Dakin & Consolidation Pressure Zone. This also applies to the Consolidation Pump Station and the 38th Street Pump Station, which both pump to the 696 Padden Yew Pressure Zone.

TABLE 3-2
Major City Pump Stations[1]

Pump Station(s)	Zone Supplied from Pump Station	Higher-Elevation Pressure Zones Served from Supplied Zone	Pumps to a Reservoir?	Demand Capacity Criterion
Otis Street[2]	457 South	541 College Way 696 Padden Yew; 873 Governor Road; 830 Reveille; 980 Samish Crest	Yes	MDD
Dakin & Consolidation PS; Woburn PS[2]	519 Dakin & Consolidation	696 Padden Yew; 730 Alabama Hill; 780 Birch Street; 660 Huntington; 830 Reveille; 873 Governor Road; 980 Samish Crest	Yes	MDD
James Street	530 King Mountain	None	No	PHD
College Way	541 College Way	None	No	PHD+FF
Short Street	350 Cordata	None	No	PHD+FF
Consolidation PS; 38th Street PS	696 Padden Yew	873 Governor Road; 830 Reveille	Yes	MDD
Birch Street	780 Birch Street	None	No	PHD+FF
Balsam Lane	730 Alabama Hill	None	No	PHD+FF
Governor Road	873 Governor Road	980	Yes	MDD
Huntington	660 Huntington	None	No	PHD
Reveille	830 Reveille	None	No	PHD+FF

[1] The Huntington, Samish Heights, Raymond, and Bonanza pump stations are very small pump stations that do not provide fire flow and serve areas that are not anticipated to grow substantially. All but the Huntington pump station are anticipated to be decommissioned and replaced within the 20-year planning horizon.

[2] The 696 Padden Yew Pressure Zone and the three higher-elevation pressure zones supplied from the 696 Padden Yew Pressure Zone can be supplied either via the Consolidation Pump Station or the 38th Street Pump Station. As a result, for the purpose of this analysis (and as an element of conservatism) the demand associated with these pressure zones was accounted in the evaluation of both the Otis Street Pump Station and the combined evaluation of the Dakin & Consolidation Pump Station / Woburn Pump Station.

3.2.2 Otis Street

As shown in Table 3-3, the Otis Street pump station has adequate capacity through the 6-year, 10-year, and 20-year planning period to meet the demands of the 457 South Pressure Zone. No capacity improvements to the Otis Street pump station are needed.

TABLE 3-3
Otis Street Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (MDD) Required[1]	2,837	3,066	3,252	3,667
Existing Total Capacity	7,000	7,000	7,000	7,000
Existing Firm Capacity	5,500	5,500	5,500	5,500
Excess (Deficient) Capacity	2,663	2,434	2,248	1,833

[1] Includes MDDs for 457 South, 541 College Way' 696 Padden Yew, 873 Governor Road, and 830 Reveille

3.2.3 Dakin & Consolidation; Woburn Street

The Dakin & Consolidation Pump Station (formerly referred to as the Dakin & Yew Pump Station) is the primary pump station serving the 519 Dakin & Consolidation Pressure Zone (formerly the 519 Dakin & Yew Pressure Zone). The Woburn Street Pump Station serves as a redundant backup pump station. The two smaller, normal-operating pumps at the Woburn Street Pump Station are periodically operated manually to maintain operating condition and aid circulation of the distribution system. The two larger, high-flow pumps are controlled by a low pressure sensor on the discharge of the pumps that could initiate service in the event of a fire flow condition. As a result, the Woburn Street Pump Station typically only operates during such low pressure conditions.

As shown in Table 3-4, the combined capacity of these two pump stations far exceeds the required demands of the 519 Dakin & Consolidation Pressure Zone and each of the pressure zones above that are served directly or indirectly from the 519 Dakin & Consolidation Pressure Zone for each of the planning horizons listed. The 696 Padden Yew, 830 Reveille, and 873 Governor Road Pressure Zones

TABLE 3-4
Dakin & Consolidation Pump Station; Woburn Street Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (MDD) Required[1]	2,312	2,499	2,733	3,012
Existing Total Capacity	12,900	12,900	12,900	12,900
Existing Firm Capacity	10,900	10,900	10,900	10,900
Excess (Deficient) Capacity	8,588	8,401	8,167	7,888

[1] Includes MDDs for 519 Dakin & Consolidation, 696 Padden Yew, 730 Alabama Hill, 780 Birch Street, 830 Reveille, and 873 Governor Road.

were included in the capacity evaluation presented in Table 3-4, as an element of conservatism, even though the 696 Padden Yew Pressure Zone (and the small zones above it) is also served from the 457 South Pressure Zone via the 38th Street Pump Station. No capacity improvements are planned at either the Dakin & Consolidation Pump Station or the Woburn Street Pump Station.

3.2.4 James Street

The James Street Pump Station supplies the 530 King Mountain Pressure Zone from the 519 Dakin & Consolidation Pressure Zone. Supply via the 519 Dakin & Consolidation Pressure Zone instead of the 276 North Pressure Zone is a modification the City completed in 2011, as described previously. The 530 King Mountain Zone is a closed zone; it is not served directly by storage. The James Street Pump Station must meet the peak hour demand (PHD) of the 530 King Mountain Pressure Zone. In addition, because it supplies a closed zone it would typically be required to have fire flow capacity to meet fire demands. However, the James Street Pump Station does not have fire flow capacity. To alleviate this deficiency, in 2011 the City extended the 519 Dakin Yew Pressure Zone to much of the 530 King Mountain Pressure Zone area to provide fire flow. Consequently, the James Street Pump Station is not required to provide fire flow capacity.

As shown in Table 3-5, the James Street Pump Station has adequate capacity to meet the domestic PHD needs of the 530 King Mountain Pressure Zone through the 10-year planning horizon. However, by the 20-year planning horizon, capacity expansion will be necessary.

TABLE 3-5
James Street Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (PHD) Required[1]	22	24	101	180
Existing Total Capacity	240	240	240	240
Existing Firm Capacity	120	120	120	120
Excess (Deficient) Capacity	98	96	19	(60)

[1] Closed zone (not served directly by storage). Fire flow is not required because it is served by a parallel distribution piping system extended from the 519 Dakin & Consolidation Pressure Zone.

3.2.5 Short Street

The Short Street pump station supplies water to the 350 Cordata Pressure Zone from the 276 North Pressure Zone, and is the only means of boosting water to this zone. The 350 Cordata Pressure Zone is a closed zone; it is not served directly by storage. The Short Street Pump Station must meet the peak hour demand (PHD) of the 350 Cordata Pressure Zone. In addition, because it supplies a closed zone, it must also provide fire flow capacity to meet fire demands.

As shown in Table 3-6, the Short Street Pump Station has adequate capacity to meet the domestic PHD needs as well as the fire flow needs of the 350 Cordata Pressure Zone through the 10-year planning horizon. However, by the 20-year planning horizon, some minor capacity expansion is anticipated to be necessary based on growth projections used. This estimated future need will be

TABLE 3-6
Short Street Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (PHD) Required	1,978	2,138	2,724	3,470
Demand (Fire Flow) Required	3,500	3,500	3,500	3,500
Combined Demand Required	5,478	5,638	6,224	6,970
Existing Total Capacity	9,250	9,250	9,250	9,250
Existing Firm Capacity	6,750	6,750	6,750	6,750
Excess (Deficient) PHD Capacity	1,272	1,112	526	(220)

re-evaluated in the future based on actual water use information at that time as well as updated growth projections at that time.

It should also be noted that the City recently installed the Kellogg PRV that enables water from the 519 Dakin & Consolidation Pressure Zone to flow into the eastern-most end of the 350 Cordata Pressure Zone. This PRV provides an emergency back-up supply (not full-capacity) in the event there's a problem with the Short Street Pump Station. This PRV will also allow water into the 350 Cordata Pressure Zone during very high demand within the zone, including a fire flow condition.

3.2.6 College Way

The College Way Pump Station supplies water to the 541 College Way Pressure Zone from the 457 South Pressure Zone, and is the only means of boosting water to this zone. The 541 College Way Pressure Zone is a closed zone; it is not served directly by storage. The College Way Pump Station must meet the peak hour demand (PHD) of the 541 College Way Pressure Zone. In addition, because it supplies a closed zone, it must also provide fire flow capacity to meet fire demands. As shown in Table 3-7, the 541 College Way pump station has sufficient capacity through the 6- , 10-, and 20-year planning periods. No improvements are planned over the 20-year planning horizon.

TABLE 3-7
College Way Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (PHD) Required	128	138	138	138
Demand (Fire Flow) Required	2,000	2,000	2,000	2,000
Combined Demand Required	2,128	2,138	2,138	2,138
Existing Total Capacity	3,400	3,400	3,400	3,400
Existing Firm Capacity	2,400	2,400	2,400	2,400
Excess (Deficient) PHD Capacity	272	262	262	262

3.2.7 Consolidation; 38th Street

The Consolidation and 38th Street pump stations supply water to the 696 Padden Yew Pressure Zone from the 519 Dakin & Consolidation Pressure Zone and the 457 South Pressure Zone, respectively. The 696 Padden Yew Pressure Zone includes storage that directly serves the 696 Padden Yew Pressure Zone; therefore, fire flow capacity is not required from these two pump stations because it is provided from storage. As shown in Table 3-8, the combined capacity of Consolidation Pump Station and the 38th Street Pump Station are adequate to meet the estimated future demands of the 696 Padden Yew Pressure Zone as well as the higher-elevation zones that are supplied from the 696 Padden Yew Pressure Zone.

TABLE 3-8
Consolidation Pump Station; 38th Street Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (MDD) Required[1]	562	607	798	1,033
Existing Total Capacity	1,900	1,900	1,900	1,900
Existing Firm Capacity	1,400	1,400	1,400	1,400
Excess (Deficient) Capacity	838	793	602	367

[1] Includes MDDs for 696 Padden Yew, 830 Reveille, 873 Governor Road, and 980 Pressure zones.

3.2.8 Birch Street

The Birch Street Pump Station supplies water to the 780 Birch Street Pressure Zone from the 519 Dakin & Consolidation Pressure Zone, and is the only means of boosting water to this zone. The 780 Birch Street Pressure Zone is a closed zone; it is not served directly by storage. The Birch Street Pump Station must meet the PHD of the 780 Birch Street Pressure Zone. In addition, because it supplies a closed zone, it must also provide fire flow capacity as well to meet fire demands.

As shown in Table 3-9, the 780 Birch Street pump station has sufficient capacity through the 6-, 10-, and 20-year planning periods. No improvements are planned over the 20-year planning horizon. It should also be noted that service from the Birch Street Pump Station and the 780 Birch Street Pressure Zone will be extended in the future to five existing residences currently served by two small booster pumps (Raymond Pump Station and Bonanza Pump Station; refer to Figure 3-3).

TABLE 3-9
Birch Street Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (PHD) Required	25	27	39	69
Demand (Fire Flow) Required	750	750	750	750
Combined Demand Required	775	768	776	796
Existing Total Capacity	2,340	2,340	2,340	2,340
Existing Firm Capacity	1,240	1,240	1,240	1,240
Excess (Deficient) PHD Capacity	465	472	464	444

3.2.9 Balsam Lane

The Balsam Lane pump station supplies water to the 730 Alabama Hill Pressure Zone. It is the only means of boosting water to this zone. The 730 Alabama Hill Pressure Zone is a closed zone; it is not served directly by storage. The Balsam Lane Pump Station must meet the PHD of the 730 Alabama Hill Pressure Zone. In addition, because it supplies a closed zone, it must also provide fire flow capacity as well to meet fire demands.

As shown in Table 3-10, the Balsam Lane pump station has adequate capacity to meet PHD requirements of the 730 Alabama Hill Pressure Zone. However, it does not currently have adequate capacity to meet the combined PHD and fire flow requirement. This deficiency will increase as growth continues in the 730 Alabama Hill Pressure Zone.

TABLE 3-10
Balsam Lane Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (PHD) Required	544	588	678	813
Demand (Fire Flow) Required	1,500	1,500	1,500	1,500
Combined Demand Required	2,044	2,088	2,178	2,313
Existing Total Capacity	2,200	2,200	2,200	2,200
Existing Firm Capacity	1,600	1,600	1,600	1,600
Excess (Deficient) PHD Capacity	(444)	(488)	(578)	(713)

3.2.10 Governor Road

The Governor Road pump station supplies water to the 873 Governor Road Pressure Zone, which is supplied directly by storage from the Parkhurst Reservoir. The recently completed Samish Crest Pump Station is also served from the 873 Governor Road Pressure Zone, and it supplies the new 980 Pressure Zone. The Samish Crest Pump Station is considered to be a "temporary" pump station to serve approximately 20 additional houses that are at too high an elevation to be supplied from the 873 Governor Road Pressure Zone.

As shown in Table 3-11, the Governor Road Pump Station has adequate capacity to meet the MDD capacity need of the Governor Road Pressure Zone through the 10-year planning horizon. Beyond that, additional capacity will be necessary. However, long-term utility planning for this area by the City includes eventual replacement of the Governor Road Pump Station, the Parkhurst Reservoir, and the new Samish Crest Pump station with newer, larger-capacity facilities that will meet the needs of the broader area and enable combination of the 830 Reveille Pressure Zone and 873 Governor Road Pressure Zone.

When future development proceeds at the higher elevations just to the north of the 873 Governor Road Pressure Zone, it will serve as a catalyst to combine the 873 Governor Road Pressure Zone and the 830 Reveille Pressure Zone into a single, new 870 Samish Hill Pressure Zone. This new 870

TABLE 3-11
Governor Road Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (MDD) Required[1]	87	94	152	472
Existing Total Capacity	1,460	1,460	1,460	1,460
Existing Firm Capacity	360	360	360	360
Excess (Deficient) Capacity	273	266	208	(112)[2]

[1] Includes MDDs for 873 Governor Road and 980 Pressure zones.

[2] The Governor Road Pump Station is expected to be abandoned and replaced by the new 40th Street Pump Station and 870 Samish Hill Reservoir before there is a capacity deficiency at the Governor Road Pump Station.

Samish Hill Pressure Zone will be served by a new reservoir, the 870 Samish Hill Reservoir, and will be supplied from a new pump station (40th Street Pump Station) to be located at the site of the existing 40th Street Reservoir. Development at even higher elevations, including the homes served from the existing, temporary Samish Crest Pump Station, will be combined into a new, expanded 980 Pressure Zone. This new 980 Pressure Zone will be a closed zone and will be supplied from a new pump station (Future 980 Pump Station) located at the site of the new 870 Samish Hill Reservoir.

No specific development proposals or plans for the area exist at this time. However, development in this area is expected to prompt the need for the 870 Samish Hill Reservoir, the 40th Street Pump Station, and the Future 980 Pump Station sometime between the 6- and 20-year planning horizons.

3.2.11 Reveille

The Reveille Pump Station supplies water to the 830 Reveille Pressure Zone from the 696 Padden Yew Pressure Zone and is the only means of boosting water to this zone. The 830 Reveille Zone is a closed zone; it is not served directly by storage. The Reveille Pump Station must meet the PHD of the 830 Reveille Pressure Zone. In addition, because it supplies a closed zone, it must also provide fire flow capacity as well to meet fire demands.

As shown in Table 3-12, the Reveille Pump Station has adequate capacity meet PHD requirements through the 6-year planning horizon. However, sometime after that (depending on actual growth and development within the 830 Reveille Zone), additional pumping capacity will be necessary. Unless the 870 Samish Hill Reservoir and associated facilities are in place (refer to discussion above for the Governor Road Pump Station), the City will expand the capacity of the pump station by replacing the smaller (100-gpm) of the two existing pumps with a larger pump to meet projected PHD. The City does not intend to modify the pump station to provide fire flow because fire flow capacity is forthcoming once the 870 Samish Hill Reservoir is completed and placed into service.

TABLE 3-12

Reveille Pump Station Capacity Evaluation (gpm)

Demand/Capacity	2012	2018	2022	2032
Demand (PHD) Required	43	46	109	267
Demand (Fire Flow) Required	750	750	750	750
Combined Demand Required	793	796	859	1,017
Existing Total Capacity	300	300	300	300
Existing Firm Capacity	100	100	100	100
Excess (Deficient) PHD Capacity	(693)	(696)	(759)	(917)

3.3 Storage

Description of the City's distribution system reservoirs is presented in the 2009 Water System Plan. There have been no storage volume additions or subtractions since the 2009 Water System Plan. As is required, the City's overall water system was evaluated with respect to required storage volume, and individual pressure zones served directly (or indirectly as in closed zones) from storage were also evaluated with respect to required storage volume. Many of the City's pressure zones are not served directly from storage, which is acceptable if the pump station supplying these zones is designed and operated appropriately to meet PHD plus fire flow. Some of these zones are planned to be served directly from new storage in the future, but the timing for these improvements is dependent on the pace of growth within these closed zones. Per-zone storage evaluations were not undertaken for closed zones because in most cases they will continue to remain as closed zones. In cases where closed zones could be modified to be served directly from storage, the precise volume of storage needed will be assessed when development is imminent.

The updated storage evaluation, based on the updated demands presented in Table 3-1 herein, is presented in Tables 3-13 through 3-18. It should be noted that surplus storage available in the City's 276 North Pressure Zone is accounted in higher-elevation pressure zones, as described in the subsections below, which is appropriate given the generous capacity of the pump stations lifting water to these upper pressure zones. This apportionment of the City's storage resources is critical to avoid over-counting the need for additional storage at higher elevations.

The methodology for determining the required storage volume for each pressure zone is presented in the 2009 Water System Plan. Note that fire suppression volume is based on the fire flow requirements for each pressure zone, as presented in the 2009 Water System Plan, multiplied by two hours.

Storage deficiencies identified in the subsections below are summarized in Section 3.6.2. Planned improvements for mitigating these deficiencies are presented in Section 3.7.2.

3.3.1 System-Wide

A summary of the storage evaluation for the overall system is presented in Table 3-13. As shown in Table 3-13, there is adequate total storage within the existing overall system through the 10-year planning horizon. After that, additional storage is projected to be required. These projected storage needs will be met with storage implemented in response to development pressure. This additional future storage will be added to the existing system where it is needed, within pressure zones that need additional storage, not within pressure zones that already have excess storage. The general location and capacity of future storage is identified in the per-zone storage evaluation sections below.

TABLE 3-13
System-Wide Storage Evaluation (million gallons)

Storage Component	2012	2018	2022	2032
Operational	1.65	1.65	1.65	1.65
Equalization	1.28	1.39	1.48	1.67
Standby	18.80	20.31	21.63	24.44
Fire Suppression	0.42	0.42	0.42	0.42
Total Required	21.73	23.35	24.75	27.76
Available[1]	23.19	25.69	25.69	25.69
Surplus (Deficit)	1.46	2.34	1.08	(2.07)

[1] Available storage includes the 1.18 MG of dead storage at Marietta Reservoir. It also includes the subtraction of 5 million gallons of volume dedicated to chlorine contact storage at Whatcom Falls II in 2012 and 2.5 million gallons of chlorine contact storage in future years. The future reduction in chlorine contact storage results from reduced requirements associated with the implementation of the planned Dissolved Air Flotation project (refer to Section 4.1 for further discussion).

3.3.2 276 North

A summary of the storage evaluation for the 276 North Pressure Zone is presented in Table 3-14. As shown in Table 3-14, there is surplus storage in the 276 North Pressure Zone through the 20-year planning horizon. However, it must be noted that most of this surplus storage is available for use by higher-elevation pressure zones that are served directly from the 276 North Pressure Zone. This is true as long as the pump stations supplying these higher-elevation pressure zones have adequate capacity to provide the required PHD for these zones, which is the case for both zones. The two higher-elevation pressure zones that depend on this surplus storage are the 519 Dakin & Consolidation Pressure Zone and the 457 South Pressure Zone. The surplus storage in the 276 North Pressure Zone is adequate to meet the storage needs of these two other zones through the 10-year planning horizon. However, surplus storage from the 276 North Pressure Zone is also available to the higher-elevation pressure zones that are served from these two pressure zones. The availability of surplus storage from the 276 North Pressure Zone has been accounted for in the storage evaluations presented herein of each of the pressure zones that have storage reservoirs. These pressure zones include: 457 South, 519 Dakin & Consolidation, 696 Padden Yew, and 873 Governor Road.

TABLE 3-14

276 North Pressure Zone Storage Evaluation (million gallons)[1]

Storage Component	2012	2018	2022	2032
Operational[2]	0.00	0.00	0.00	0.00
Equalization	0.73	0.79	0.85	0.97
Standby	10.74	11.61	12.44	14.14
Fire Suppression	0.42	0.42	0.42	0.42
Total Required	11.48	12.40	13.18	15.11
Available[2]	19.01	21.51	21.51	21.51
Surplus (Deficit)	7.54	9.11	8.33	6.40

[1] Includes the demands of the 350 Cordata Pressure Zone, which is a closed zone served directly from the 276 North Pressure Zone.

[2] Operational storage is zero because the storage reservoirs in the 276 North Pressure Zone is supplied by gravity and no operational volume is necessary. However, as described in Table 3-13, a portion of Whatcom Falls II Reservoir is dedicated to meeting disinfection contact requirements (CT requirements) – 5 million gallons in 2012 and 2.5 million gallons in future years, after DAF has been implemented.

3.3.3 457 South

A summary of the storage evaluation for the 457 South Pressure Zone is presented in Table 3-15. As shown in Table 3-15, there is insufficient storage in the 457 South Pressure Zone. However, as stated above, there is surplus storage in the 276 North Pressure Zone, which supplies the 457 South Pressure Zone via the Otis Street Pump Station. The Otis Street Pump Station has adequate pumping capacity to meet the PHD requirements of the 457 Pressure Zone, which enables accounting surplus storage from the supplying 276 North Pressure Zone to the 457 South Pressure Zone.

TABLE 3-15

457 South Pressure Zone Storage Evaluation (million gallons)[1]

Storage Component	2012	2018	2022	2032
Operational	0.75	0.75	0.75	0.75
Equalization	0.27	0.30	0.29	0.32
Standby	4.00	4.32	4.32	4.63
Fire Suppression	0.30	0.30	0.30	0.30
Total Required	5.02	5.36	5.45	5.69
Available	1.70	1.70	1.70	1.70
Surplus (Deficit)	(3.32)	(3.66)	(3.75)	(3.99)
Transfer from 276 North	3.32	3.66	3.75	3.99
Resulting Surplus (Deficit)	0	0	0	0
Remaining in 276 North	4.22	5.45	4.58	2.41

[1]Includes the demands of the 541 College Way Pressure Zone, which is a closed zone served directly from the 457 South Pressure Zone.

3.3.4 519 Dakin & Consolidation

A summary of the storage evaluation for the 519 Dakin & Consolidation Pressure Zone (formerly the 519 Dakin & Yew Pressure Zone) is presented in Table 3-16. As shown in Table 3-16, there is insufficient storage in the 519 Dakin & Consolidation Pressure Zone. However, as stated above, there is surplus storage in the 276 North Pressure Zone, which directly supplies the 519 Dakin & Consolidation Pressure Zone via the Dakin & Consolidation Pump Station and the Woburn Street Pump Station. These two pump stations have adequate pumping capacity to meet the PHD requirements of the Dakin & Consolidation Pressure Zone, which enables accounting surplus storage from the supplying 276 North Pressure Zone to the 519 Dakin & Consolidation Pressure Zone.

TABLE 3-16
519 Dakin & Consolidation Pressure Zone Storage Evaluation (million gallons)[1]

Storage Component	2012	2018	2022	2032
Operational	0.39	0.39	0.39	0.39
Equalization	0.21	0.22	0.23	0.25
Standby	3.07	3.32	3.50	3.93
Fire Suppression	0.42	0.42	0.42	0.42
Total Required	3.67	3.94	4.13	4.58
Existing Storage	1.50	1.50	1.50	1.50
Surplus (Deficit)	(2.17)	(2.44)	(2.63)	(3.08)
Transfer from 276 North	2.17	2.44	2.63	3.08
Resulting Surplus (Deficit)	0	0	0	0
Remaining in 276 North[2]	2.05	3.01	1.93	(0.67)[3]

[1] Includes demand for the 730 Alabama Hill, 780 Birch Street, 660 Huntington, and 530 King Mountain pressure zones, which are all closed zones served directly from the 519 Dakin & Consolidation Pressure Zone.

[2] These values include the subtraction of surplus 276 North storage capacity to entirely mitigate the deficit in the 457 South Pressure Zone over the 20-year planning horizon.

[3] This deficit is shown as being in the 276 North Pressure Zone given the high pumping capacity from the 276 North Pressure Zone to the 519 Dakin & Consolidation Pressure Zone. However, this future deficiency could also be addressed with new storage in the 519 Dakin & Consolidation Pressure Zone.

Note that the remaining storage in the 276 Pressure Zone, as presented in Table 3-16 includes meeting the full storage deficit for the 457 South Pressure Zone of the 20-year planning horizon. Therefore, the storage needs of the 519 Dakin & Consolidation Pressure Zone can only be met through the 10 year planning horizon. After that, additional storage is projected to be necessary.

3.3.5 696 Padden Yew

A summary of the storage evaluation for the 696 Padden Yew Pressure Zone is presented in Table 3-17. As shown in Table 3-17, there is insufficient storage in the 696 Padden Yew Pressure Zone. However, as stated above, there is surplus excess storage in the 276 North Pressure Zone, which directly supplies the 519 Dakin & Consolidation Pressure Zone and the 457 South Pressure Zone. The 696 Padden Yew Pressure Zone is supplied from the combined capacity of the

TABLE 3-17
696 Padden Yew Pressure Zone Storage Evaluation (million gallons)[1]

Storage Component	2012	2018	2022	2032
Operational	0.07	0.07	0.07	0.07
Equalization	0.06	0.06	0.08	0.08
Standby	0.86	0.93	1.15	1.12
Fire Suppression	0.18	0.18	0.18	0.18
Total Required	1.00	1.07	1.30	1.27
Existing Storage	0.80	0.80	0.80	0.80
Surplus (Deficit)	(0.20)	(0.27)	(0.42)	(0.47)
Transfer from 276 North	0.20	0.27	0.42	None
Resulting Surplus (Deficit)	0	0	0	(0.47)
Remaining in 276 North[2]	1.85	2.74	1.51	(0.67)[3]

[1] Includes demand for the 830 Reveille Pressure Zone, which is a closed zone served directly from the 696 Padden Yew Pressure Zone.

[2] These values include the subtraction of surplus 276 North storage capacity to entirely mitigate the deficit in the 457 South Pressure Zone over the 20-year planning horizon, as well as meeting the storage deficit of the 519 Dakin & Consolidation Pressure Zone through the 10-year planning horizon.

[3] As stated in Footnote 3 of Table 3-16, this deficit is shown as being in the 276 North Pressure Zone. However, this deficiency could also be addressed in part or in whole with new storage in the 519 Dakin & Consolidation Pressure Zone, the 457 South Pressure Zone, or the 696 Padden Yew Pressure Zone, or the future 870 Samish Hill Pressure Zone.

Consolidation Pump Station and the 38th Street Pump Station, which are supplied from the 519 Dakin & Consolidation Pressure Zone and 457 South Pressure Zone, respectively.

Consequently, even though the surplus storage in the 276 North Pressure Zone has already been accounted in evaluating the storage needs of the 519 Dakin & Consolidation Pressure Zone and the 457 South Pressure Zone, there remains additional surplus capacity, as presented in Table 3-16, after the storage deficits of these two pressure zones are met through the 10-year planning horizon but not for the 20-year horizon. There is adequate surplus storage capacity from the 276 North Zone through the 6-year planning horizon to meet the storage deficiencies of the 519 Dakin & Consolidation Pressure Zone, the 457 South Pressure Zone, as well as the higher-elevation 696 Padden Yew Pressure Zone. It is possible to account the remaining surplus capacity from the 276 North Pressure Zone in the 696 Padden Yew Pressure Zone because the combined capacity of the Consolidation Pump Station and the 38th Street Pump Station meet the PHD requirements of the 696 Padden Yew Pressure Zone.

In summary, no additional storage is needed for the 696 Padden Yew Pressure Zone through the 10-year planning horizon.

3.3.6 873 Governor Road

A summary of the storage evaluation for the 873 Governor Road Pressure Zone is presented in Table 3-18. As shown in Table 3-18, there is a slight storage deficiency in the 873 Governor Road Pressure Zone. However, as stated above for the 276 North Pressure Zone, and re-iterated for the 519 Dakin & Consolidation Pressure Zone, the 457 South Pressure Zone, and the 696 Padden Yew

TABLE 3-18
873 Governor Road Pressure Zone Storage Evaluation (million gallons)

Storage Component	2012	2018	2022	2032
Operational	0.06	0.07	0.07	0.07
Equalization	0.01	0.01	0.02	0.06
Standby	0.12	0.13	0.25	0.83
Fire Suppression	0.09	0.09	0.09	0.09
Total Required	0.19	0.22	0.34	0.96
Existing Storage	0.18	0.18	0.18	0.18
Surplus (Deficit)	(0.01)	(0.04)	(0.16)	(0.78)
Transfer from 276 North	0.01	0.04	0.16	None
Resulting Surplus (Deficit)	0	0	0	(0.78)
Remaining in 276 North	1.84	2.7	1.35	(0.67)

Pressure, there is surplus storage 276 North Pressure Zone that be accounted in the 873 Governor Road Pressure Zone through the 10-year planning horizon. Refer to the discussion above for the 696 Padden Yew Pressure Zone regarding how surplus storage can be accounted in the 696 Padden Yew Pressure Zone. The 873 Governor Road Pressure Zone is supplied from the 696 Padden Yew Pressure Zone via the Governor Road Pump Station. The Governor Road Pump Station has sufficient capacity to meet PHD to transfer the surplus storage from the 276 North Pressure Zone to the 873 Governor Road Pressure Zone.

In summary, similar to the 696 Padden Yew Pressure Zone, no additional storage is needed for the 873 Governor Road Pressure Zone through the 10-year planning horizon. However, similar to the 696 Padden Yew Pressure Zone, additional storage for the 20-year horizon, is projected to be necessary.

3.4 Water Age Analysis

The City has observed a loss of chlorine residual at the Kearney Road Reservoir and the Marietta Reservoir – both serving the City's 276 North Pressure Zone. Neither of these reservoirs have pump stations that directly draw water from them to higher pressure zones. Therefore, these reservoirs experience limited turnover unless water level in the entire 276 North Pressure Zone, including at Whatcom Falls Reservoir I and Whatcom Falls Reservoir II is purposely drawn down by reducing production at the Whatcom Falls Water Treatment Plant to a level below customer water usage for several days. Limited turnover in the reservoirs results in elevated water age, a resulting loss of chlorine residual, and a corresponding potential for bacteriological contamination.

Over the past two years, on a weekly basis, the City draws down reservoir levels in the 276 North Pressure Zone on a weekly basis to promote turnover of the reservoirs. This operational approach has resulted in maintaining chlorine residual throughout the system. The City plans to continue this operational approach indefinitely, as long as it remains successful. However, the City has also evaluated alternative improvement approaches to enhance water age conditions at both Marietta Reservoir and Kearney Road Reservoir. Some of these improvement approaches are either underway or planned for implementation, while others will only be implemented if determined in the future to be necessary.

In addition to drawing down the reservoirs in the 276 North Pressure Zone, including the Marietta Reservoir, to enhance maintenance of a chlorine residual, the City has modified the single-inlet/outlet reservoir connection so that the inlet is on one side of the reservoir and the outlet on the other. Check valves restrict inlet water flows into the reservoir to the inlet line and outlet water flows to the separate outlet line. In tandem with this improvement, the City plans to change its primary supply location to Water District No. 2 from the Marine Dr/Bennett Dr meter location to near the outlet of the Marietta Reservoir. Supplying Water District No. 2 from the Marietta Reservoir will increase the volume of water flowing through the Marietta Reservoir and reduce water age at this location.

At the Kearney Road Reservoir, where chlorine residual has fallen at times to undetectable levels on the outlet of the reservoir, the City has analyzed the impact of installing a small pump station that would lift water from the outlet of the Kearney Road Reservoir to the 519 Dakin & Consolidation Pressure Zone. This pump station would force water to flow through the Kearney Road Reservoir and substantially reduce water age. Because the 519 Dakin & Consolidation Pressure Zone is already served from two other large-capacity pump stations, this new pump station could be a relatively simple station with two equal-sized, single-speed pumps operated as the primary means of lifting water to the 519 Dakin & Consolidation Pressure Zone. On-site back-up power would not be necessary because of the surplus of existing pumping capacity. Alternatively, should the City decide to implement this improvement, the discharge of the pump station could be to the 350 Cordata Pressure Zone instead of the 519 Dakin & Consolidation Pressure Zone. A pump station supplying the 350 Cordata Pressure Zone would be somewhat more complicated with either a re-circulation loop for single-speed pumps or variable speed drives. The better discharge alternative would need to be evaluated closer to the time of implementation in consideration of development pressure and patterns in the local area. If discharge is to the 519 Dakin & Consolidation Pressure Zone, control of the existing Dakin & Consolidation Pump Station and Woburn Street Pump Station would be revised to provide peak demand and fire flow capacity, periodic operation, and redundant back-up operation.

Water age was modeled to evaluate the beneficial impacts of the improvements described above at the Marietta Reservoir and Kearney Road Reservoir sites using the City's existing distribution system hydraulic model. The results of the modeling are presented in Figure 3-4 for the Marietta Reservoir and Figure 3-5 for the Kearney Road Reservoir.

What is clear from Figure 3-4 is that water age at the Marietta Reservoir will continue to be elevated. This reservoir is located at the end of the distribution system with minimal use nearby to promote cycling or turnover. Whether or not the improvements described above are enough to enable maintenance of a detectable chlorine residual is uncertain. If after implementation of the improvements, it is still not possible to maintain a detectable chlorine residual, a re-chlorination station will be necessary at the Marietta Reservoir. If a re-chlorination station is determined to be necessary, it will be implemented, but for the purposes of this planning effort, it is assumed that it will not be necessary and therefore is not included in the Improvement Program within the 6-year planning horizon. If needed, the new re-chlorination station could be comprised of a small pre-engineered building housing a chlorine metering pump, a chlorine residual analyzer, SCADA monitoring, and space for two 55-gallon drums of sodium hypochlorite.

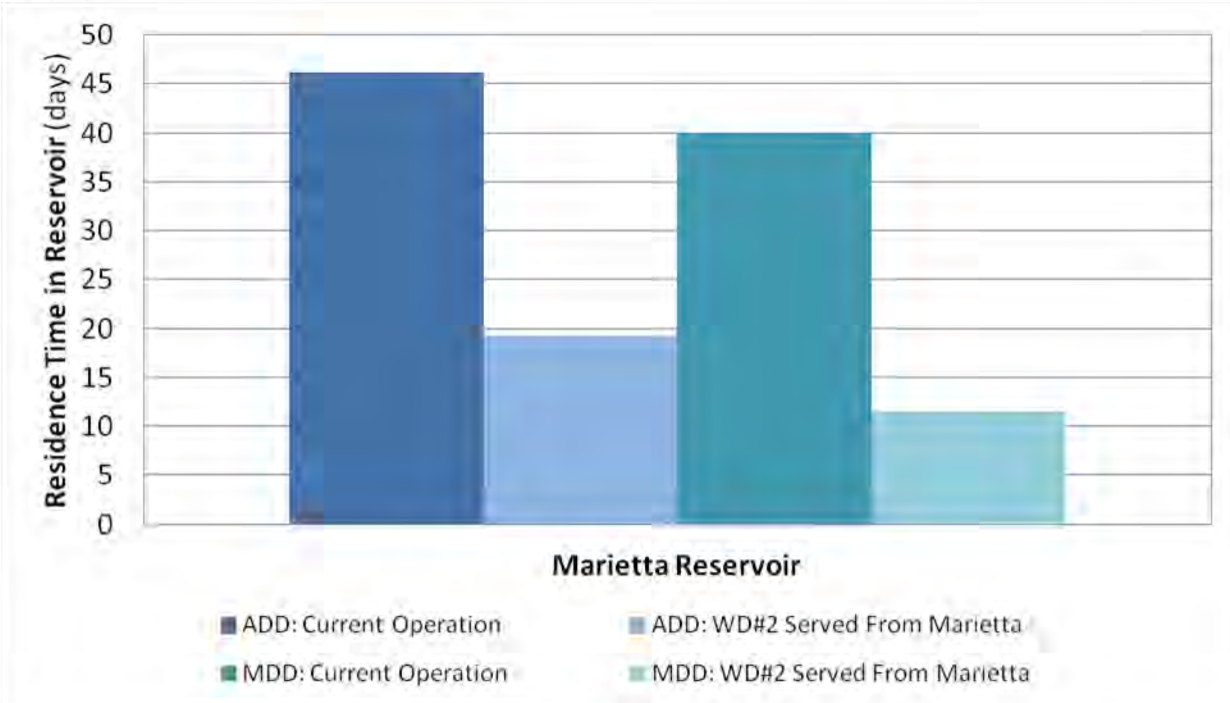


FIGURE 3-4
Marietta Reservoir Water Age Evaluation

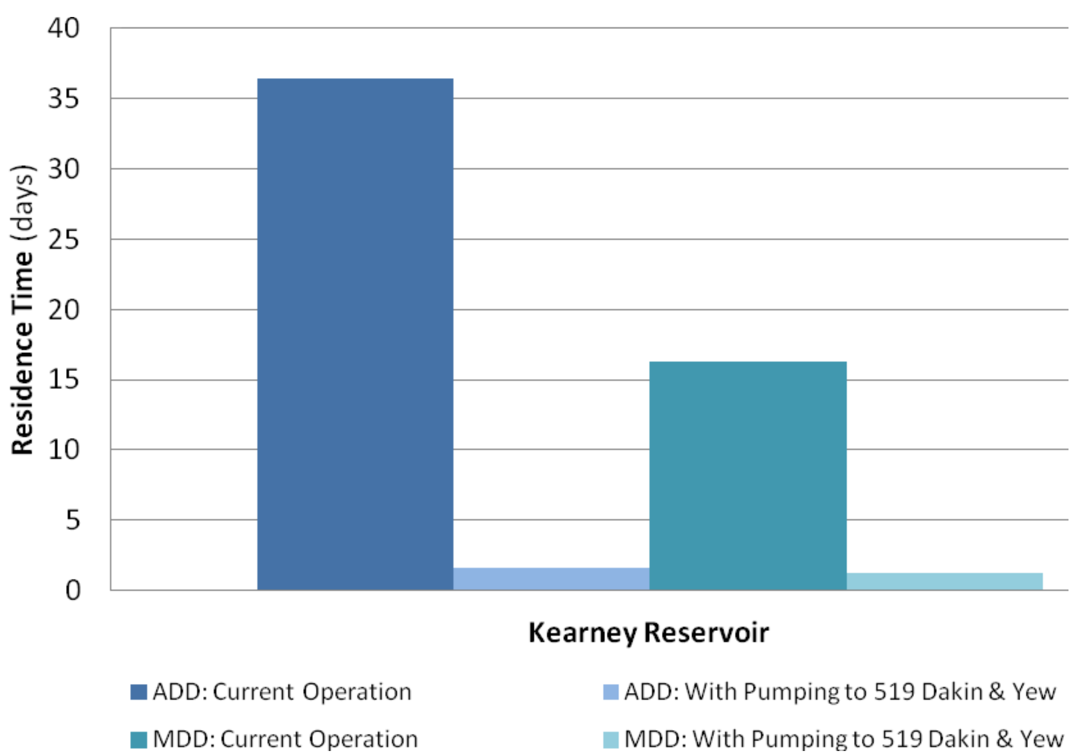


FIGURE 3-5
Kearney Road Reservoir Water Age Evaluation

As presented in Figure 3-5, for the Kearney Road Reservoir, the potential new pump station to the 519 Dakin & Consolidation Pressure Zone drastically reduces water age and could enable maintenance of a chlorine residual at this location. Supplying the 519 Dakin & Consolidation Pressure Zone from the Kearney Road Reservoir instead of the existing pump stations increases water age within the 519 Dakin & Consolidation Pressure Zone by up to two days under ADD conditions. However, this additional water age would not be expected to create any water quality challenges.

3.5 Anticipated Development / Planned Improvements

The City regularly receives development interest and proposals throughout the City. Where such development is relatively small and involves filling in small undeveloped portions of already-developed areas, the need for additional water system infrastructure is minimal and typically limited to pipeline extensions. In these cases, development does not prompt the need for additional pumping and storage facilities. However, where development proposals are more extensive and reach to areas lacking water service, additional pumping and storage facilities are typically needed in addition to pipeline extensions.

The addition of these pumping and storage facilities must be thoughtfully planned and coordinated with other, existing storage and pumping facilities to avoid excessive facility redundancy and the associated service inefficiency and higher operating costs. Via comprehensive, pro-active utility planning, the City incorporates pumping and storage infrastructure needs for these more extensive development proposals, where applicable, into mitigating other known or anticipated system deficiencies and improving overall system efficiency. In other words, in some cases it is possible to address pumping or storage deficiencies within the existing system with pumping and storage facilities that serve new development.

Two particular areas within the City where development interest has existed for several years, are the King Mountain area on the north side of the City and the Samish Hill area east of Interstate 5 and north of Lake Padden, just to the east of the 696 Padden Yew Zone. Water service to these two development areas is presented in the two sections below.

3.5.1 King Mountain Area

The King Mountain area is situated primarily to the north of the 350 Cordata Pressure Zone and west of the existing 530 King Mountain Pressure Zone. Lower-elevation portions of the King Mountain area could be served in the near-term future from the 350 Cordata Pressure Zone, or with recent extension of the 519 Dakin & Consolidation Pressure Zone, service directly from that zone is possible.

Development at higher elevations on King Mountain would require a new continuously-operating pump station serving a closed pressure zone. This pump station, referred to hereinafter as the King Mountain Pump Station, would be situated at the Kearney Road Reservoir Site and would lift water from the outlet of the Kearney Road Reservoir at a hydraulic gradient of 276 feet elevation to a hydraulic gradient of 630 feet elevation. Alternatively, suction to this pump station could be from the 519 Dakin & Consolidation Pressure Zone at or near the Kearney Road Reservoir, or more likely adjacent to the existing James Street Pump Station. In either case, a new transmission pipeline connected to the pump station discharge would be necessary to connect the new pump station to the distribution area. Evaluation of these two alternatives will be undertaken at the time planning for development in this area is initiated.

Additional storage at King Mountain is not currently necessary. However, if at some point in the longer-term future, storage is needed to mitigate a system-wide need, a new storage reservoir could be implemented to serve the existing 350 Cordata Pressure Zone, which is a closed zone – not served directly from a storage reservoir. The City has identified this potential future reservoir as the King Mountain Reservoir. Tentatively, the overflow elevation of this reservoir would be 370 feet, and it would serve to raise the hydraulic gradient of the existing 350 Cordata Pressure Zone to 370 feet. It would be supplied from the existing Short Street Pump Station with minor facility modifications. Additional distribution system pipeline improvements may be necessary to improve flow from the Short Street Pump Station to the new reservoir, which would need to be evaluated during the planning phase for this potential future project.

Raising the gradient to 370 feet elevation would expand the reach of the future 370 Cordata Pressure Zone to the west side of King Mountain. The volume of the potential future King Mountain Reservoir will be determined closer to the time it is implemented. Additionally, alternative locations (even locations beyond the King Mountain area) will be evaluated if/when additional storage is determined to be necessary for the overall water system.

3.5.2 Samish Hill Area

The more-southerly area of development interest exists between the existing 830 Reveille Pressure Zone and the 873 Governor Road Pressure Zone. The addition of a future storage reservoir, a future pump station, and associated connecting transmission pipeline to serve this higher-elevation area will enable combination of the 830 Reveille Pressure Zone and the 873 Governor Road Pressure Zone into a new 870 Samish Hill Pressure Zone. Doing so will result in fire flow capacity to the existing 830 Reveille Pressure Zone and enable replacement of the Reveille Pump Station, Parkhurst Reservoir, and Governor Road Pump Station. The new, replacement facilities will include a single, new pump station at the 40th Street Reservoir site (future 40th Street Pump Station), a single new storage reservoir (future Samish Hill Reservoir) that would have an overflow elevation of 870 feet, and a connecting transmission pipeline between the two. The volume of this reservoir will be determined closer to the time of its implementation. These additional facilities are necessary to extend service to most of the Samish Hill area. However, if development of the Samish Hill area does not occur, these additional facilities will not be necessary, including the Samish Hill Reservoir.

In addition, the existing 980 Pressure Zone that was recently extended from the 873 Governor Road Pressure Zone via the Samish Heights Pump Station, which does not have fire flow capacity, would be replaced by a new pump station lifting water to a larger 980 Pressure Zone area. This new pump station is referred to as the “980 Pump Station,” and it would have fire flow capacity and supply all of the surrounding higher-elevation areas that are too high to be served from the future Samish Hill Reservoir.

3.6 Summary of Pumping and Storage Deficiencies

Pumping and storage deficiencies identified via the evaluations presented in the sections above are summarized in Table 3-19. Note that there are no storage deficiencies projected within the 6-year planning horizon and only two pumping deficiencies projected within the 10-year planning horizon. More discussion of these deficiencies is presented in the subsections below. The future Kearney Road Pump Station is not addressed in this section because it is not a deficiency related to an existing pump station, but instead an improvement to alleviate the excessive water age issue at Kearney Road Reservoir.

TABLE 3-19
Summary of Pumping and Storage Deficiencies (gpm for pumping and million gallons for storage)

Deficiencies	2012	2018	2022	2032
Pumping				
Short Street	--	--	--	220
James Street	--	--	--	60
Balsam Lane	444	488	578	713
Governor Road	--	--	--	112
Reveille	693	696	759	917
Storage				
System Wide	--	--	--	2.07
276 North Pressure Zone[1]	--	--	--	0.67
696 Padden Yew Pressure Zone	--	--	--	0.47
873 Governor Road Pressure Zone	--	--	--	0.78

[1] Refer to Tables 3-14 through 3-18 for review of how the transfer of surplus storage in the 276 North Pressure Zone results in an estimated future deficiency in the 276 North Pressure Zone. Estimated future deficiency in the 276 North Pressure Zone is anticipated to be corrected by additional storage in higher-elevation pressure zones – not additional storage in the 276 North Pressure Zone.

3.6.1 Pumping

The only deficiencies at existing pump stations within the 10-year planning horizon are at Balsam Lane and at Reveille. In these two cases, the deficiencies exist now, and in both cases PHD needs are met, but the combined fire flow / PHD requirement is not met. Deficiencies were identified at the 20-year planning horizon for these two pump stations, as well as for three other pump stations – Short Street, James Street, and Governor Road. Discussion of how the City plans to address each of these deficiencies is presented in Section 3.7.1.

3.6.2 Storage

No storage deficiencies are identified within the 10-year planning horizon. At the 20-year planning horizon the projected total storage deficiency will be approximately two million gallons. Storage deficiencies are shown in Table 3-19 at the 20-year planning horizon for the overall distribution system, the 276 North Pressure Zone (because of transfers to higher pressure zones), the 696 Padden Yew Pressure Zone, and the 873 Governor Road Pressure Zone. Surplus storage from the

276 North Pressure Zone was used, to the extent available, to mitigate deficiencies for all of the higher-elevation pressure zones.

The projected future storage needs at the 20-year planning horizon, as presented in Table 3-19, are planned to be met via storage improvements that will be needed to accommodate development, as described in Section 3.5, in the Samish Hill area and/or on King Mountain. The timing and pace of development in these areas is uncertain at this time. In the event growth does not occur in these areas soon enough to enable the associated storage facilities to mitigate any storage deficiencies within the City's overall system that might exist at the time, storage volume expansion could be pursued by replacing one or more existing, smaller reservoirs within the upper-elevation pressure zones with larger ones. This would also be an opportunity to replace a future aging and deteriorating storage reservoir with a larger, new reservoir.

3.7 Planned Pumping and Storage Improvements

The planned distribution system improvements presented in this section are based on the evaluations presented in Sections 3.2, 3.3, and 3.4 and the resulting deficiencies summarized in Section 3.6. Where applicable and practical, the deficiencies summarized in Section 3.6 will be addressed in coordination with anticipated development presented in Section 3.5. The planned improvements presented herein include only one pumping improvement to be implemented within the 6-year planning horizon. The remainder of the improvements will be implemented at an unspecified time after the 6-year planning horizon.

Discussion of these improvements is presented in Sections 3.7.1 and 3.7.2 and a summary of the improvements is presented in Section 3.7.3.

3.7.1 Pumping Improvements

The pump station deficiencies identified in Table 3-19 are planned to be addressed as described below:

- **Short Street Pump Station:** This projected 20-year deficiency will be addressed with the addition of the King Mountain Reservoir, which will add storage to the existing closed 350 Cordata Pressure Zone. The new King Mountain Reservoir will have an overflow elevation of 370 feet elevation to extend the reach of the existing 350 Cordata Pressure Zone. The existing Short Street Pump Station will not need to simultaneously provide fire flow and PHD and therefore will no longer have a capacity deficiency.
- **James Street Pump Station:** This projected 20-year deficiency will be addressed in the long-term future by the replacement of the existing pumps with pumps of higher capacity. In the event that development high on the west side of King Mountain results in a new King Mountain Pump Station (refer to Section 3.5.1 and below in this section) and a new closed pressure zone, the existing 530 King Mountain Pressure Zone would be incorporated into the new 630 King Mountain Pressure Zone and the existing James Street Pump station would be removed from service.
- **Balsam Lane Pump Station:** This deficiency is planned to be addressed by replacement of the existing pumps with pumps of higher capacity. An additional pump will not be necessary, but

improvements to electrical switchgear and connecting piping will be necessary. This improvement is planned to be implemented beyond the 6-year planning horizon when the existing pumps have reached their useful service life.

- **Governor Road Pump Station:** This projected 20-year deficiency will be addressed with the new storage and pumping facilities associated with the anticipated new development in the Samish Hill area. With the implementation of this new development, the Governor Road Pump Station will be replaced by a new, higher-capacity pump station at the 40th Street Reservoir site – the 40th Street Pump Station.
- **Reveille Pump Station:** Similar to the projected 20-year deficiency at the Governor Road Pump Station, the current deficiency at the Reveille Pump Station will be addressed with the new storage and pumping facilities associated with the anticipated new development in the Samish Hill area. With the implementation of this new development, the Reveille Pump Station will be replaced by a new, higher-capacity pump station at the 40th Street Reservoir site – the 40th Street Pump Station.

In addition to the pumping improvements described above that address deficiencies with existing pump stations. The City has identified a potential improvement, the **Kearney Road Pump Station,** that it will consider implementing in the future if deemed necessary to reduce excess water age at the Kearney Road Reservoir, as described in Section 3.4. This potential pump station is included for implementation within the 20-year planning horizon, but is not budgeted within the 6-year planning horizon.

Three additional pump stations will be necessary to support long-term future growth in the two development areas described in Section 3.5. The timing for each of these future pump stations depends on the timing and pace growth and development, but each are anticipated beyond the 6-year planning horizon. These three pump stations are described below:

- **40th Street Pump Station:** This pump station will be necessary to lift water to the future Samish Hill Reservoir, which is described in Section 3.5.2 above and in Section 3.7.2 below. It will be situated at the existing 40th Street Reservoir Site and lift water from the 696 Padden Yew Pressure Zone. It would have a capacity of approximately 1,500 gpm and be equipped with three equal-sized (500 gpm) pumps. A transmission pipeline from this pump station to the new Samish Hill Reservoir would also be included as part of this project.
- **980 Pump Station:** As described in Section 3.5.2, this pump station would supply development at the highest elevations in the Samish Hill area – elevations too high to be served from the future 870 Samish Hill Pressure Zone. It would be situated at the future Samish Hill Reservoir site and be supplied from that reservoir. New distribution system piping would convey water from this pump station to new service connections.
- **King Mountain Pump Station:** As described in Section 3.5.1, this pump station would supply development at the highest elevations on King Mountain and would be situated at the Kearney Reservoir Site. It could be developed as an expansion of the planned Kearney Road Pump Station, housed within the same building, or it could be developed as a stand-alone pump station elsewhere on or near the same site, or adjacent to the existing James Street Pump Station. The King Mountain Pump Station will be a more complex pump station than the Kearney Road Pump Station, and it is not anticipated to be needed until beyond the 6-year

planning horizon. This new pump would include a new transmission pipeline extending from the pump station discharge to the new King Mountain distribution system.

3.7.2 Storage Improvements

The storage deficiencies identified in Table 3-19 for the 20-year planning horizon are planned to be addressed as part of the anticipated development on King Mountain and in the Samish Hill area. No storage deficiencies were identified within the 6-year and 10-year planning horizon. Therefore, no specific reservoir improvements are identified for this timeframe. The two reservoirs associated with the King Mountain development area and the Samish Hill development area, include: the **King Mountain Reservoir** and **Samish Hill Reservoir**, respectively. These two reservoirs are anticipated to meet the projected 20-year deficiencies presented in Tables 3-19 for the water system as a whole, as well as for the identified per-zone deficiencies. The **King Mountain Reservoir** will be supplied from the existing Short Street Pump Station, with some minor improvements, and the project will require some distribution system capacity improvements to enable effective filling from the Short Street Pump Station. The timing of these two reservoirs is based primarily on the timing of development, but is generally anticipated beyond the 6-year planning horizon.

3.7.3 Summary of Pumping and Storage Improvements

A summary of planned pumping and storage improvements is presented in Table 3-20. Improvements (additions) that impact the City's distribution system hydraulic profile are reflected in Figure 3-6 at the of this WSP Update. The decommissioning of pumping and storage facilities described above are also reflected in the hydraulic profile.

TABLE 3-20
Summary of Planned Pumping and Storage Improvements

Improvement	ID Number
Pumping	
Kearney Road Pump Station	PS-1
Balsam Lane Pump Station Capacity Expansion	PS-2
40th Street Pump Station	PS-3
980 Pump Station	PS-4
King Mountain Pump Station	PS-5
Storage	
Samish Hill Reservoir	ST-1
King Mountain Reservoir	ST-2

4. Treatment Analysis

In late July and August of 2009 the filters at the City's WTP began clogging much earlier in filter runs than typical. Filter runs became substantially shorter than normal, requiring more frequent filter backwashing. The result of shorter filter runs and increased filter backwashing was greatly reduced WTP capacity – to the point the City implemented mandatory water restrictions, for the first time, to reduce customer demand. It should be noted that voluntary water restrictions are implemented each summer as a means of encouraging conservation during this time of typically-high customer water demand. The water restrictions were successful in reducing customer demand to match WTP capacity. Toward the end of August and into September, filter runs gradually began to return to normal and customer demand dropped, as it customarily does at that time of the year.

Filter clogging was attributed to algae in Lake Whatcom. Monitoring revealed higher than typical counts of most algae species. Although the reasons for the intense algae bloom of the summer of 2009 is the subject of varied speculation, historical and on-going algae monitoring shows that summertime algae blooms in Lake Whatcom have been increasing over the past decade. It is speculated that despite efforts to reverse this trend, summertime algae blooms in Lake Whatcom will continue to increase in intensity and duration over the near-term future. Increased Lake Whatcom algae could again result in summertime algae blooms that prevent the WTP from treating sufficient supply to meet customer demand in the future.

In response to the 2009 algae event, the City completed a study that is presented in a report entitled "Filter-Clogging Algae Mitigation Evaluation," dated June 2012 – hereinafter referred to as the Algae Mitigation Report. The Algae Mitigation Report included a recommendation for the City to implement Dissolved Air Flotation (DAF) to mitigate adverse algae conditions.

The purpose of this section is two-fold:

- **Dissolved Air Flotation:** Formally incorporate DAF into the City's water system planning strategy and reference the alternative evaluation and pilot testing work supporting the planned implementation of DAF.
- **Filtration Capacity:** Address the need for additional filtration capacity at the WTP in light of recent water use trends as well as the City's plan to implement DAF.

These two topics are addressed in the following subsections.

4.1 Dissolved Air Flotation

As presented in the Algae Mitigation Report, several alternatives to mitigate the adverse impacts of Lake Whatcom algae on WTP capacity were evaluated. The alternatives evaluated were grouped into three main categories, treatment, intake, and lake management, and are presented in Table 4-1. In addition to the alternatives in Table 4-1, the "No Action" alternative was included in a Triple Bottom Line Plus evaluation phase to establish a lowest-cost baseline for comparison.

Each of the treatment alternatives evaluated are commonly used in the municipal water treatment industry and are commonly-considered alternatives for algae removal. Each would be implemented somewhere at the existing WTP site. Each of the intake alternatives includes withdrawing water

TABLE 4-1
Summary of Alternatives Evaluated

Treatment	Intake	Lake Management
Dissolved Air Flotation	Secondary Intake via In-Water Pipeline	Lake Management
Ballasted Sedimentation	Secondary Intake via Over-Land Pipeline	
Plate and Tube Settling	New Dual-Intake System	
Upflow Clarification		
Conventional Sedimentation		
Micro-Screening		
Ozonation		
Additional Filters		

from Lake Whatcom at a location different from the existing intake location that has a substantially lower concentration of algae. Each of the intake alternatives includes the capability to withdraw water at more than one depth. The Lake Management alternative is essentially the ongoing Lake Whatcom Management Program, which comprises the City's, Whatcom County's, and Lake Whatcom Water and Sewer District's ongoing and long-term efforts to improve Lake Whatcom water quality. Lake management will continue to be implemented regardless of the results of the evaluation. It was included as part of the mitigation evaluation to assess whether it could be successful as a stand-alone approach instead of a complementary approach to a treatment or intake approach.

As presented in the Algae Mitigation Report, DAF was determined to be the technically superior treatment approach with respect to mitigating the algae problem, as well as being one of the lower cost treatment alternatives. DAF was also determined to be technically superior and far less costly than any of the intake alternatives. Lake Management was determined to be inadequate as a stand-alone mitigation approach because of the many years that will pass before improved water quality with respect to algae will be observed.

In recognition that DAF was the best approach for mitigating the adverse impacts of Lake Whatcom algae, DAF was pilot tested during the late summer of 2011. Pilot testing showed DAF to be effective at mitigating the algae impacts – restoring filtration capacity to levels when algae concentrations in Lake Whatcom are negligible. The results of the pilot testing are included under separate cover, entitled: "Whatcom Falls Water Treatment Plant Dissolved Air Flotation Pilot Testing," dated March 2012. This same pilot testing report is also appended to the Algae Mitigation Report.

The City intends to pursue the design and construction of a new DAF facility in a phased approach. The phased approach will be based on an initial two-train DAF facility with easy expansion for a future third train, which would likely not be needed for many years into the future. Each of the trains would have a nominal capacity of 10 mgd. The timing for the third train would depend on the intensity of algae blooms in the future in combination with growth in water use. The phased implementation of DAF minimizes the initial capital cost of a DAF facility and eliminates the potential for constructing more DAF capacity than is necessary.

This phased DAF-implementation approach complements the City's on-going commitment to lake management, water quality improvement in Lake Whatcom, and TMDL compliance via the Lake

Whatcom Management Program. Over the long-term future, as phosphorous-reducing lake management measures demonstrate success at improving water quality and reducing algae blooms, the need for further expansion of the initial phase of DAF implementation could potentially be avoided entirely.

In general, the schedule for DAF implementation includes preliminary and detailed design beginning in 2014 – including the DOH-required submittals for the Project Report and the Construction Documents. Construction and commissioning would begin in late 2015 and extend into 2017.

In addition to the planned DAF improvement, the City will undertake two related projects that will be precipitated by DAF implementation. First, the existing gas chlorine system at the Plant does not include a chlorine neutralization system. Upgrading this condition or switching to an alternative disinfection system, such as bulk sodium hypochlorite or on-site generated hypochlorite will need to be addressed simultaneous to DAF implementation. The project will include evaluation of alternative disinfection systems and design and construction of an upgrade of the existing system or a new system. Obtaining a building permit for the new DAF facility is anticipated to prompt the upgrade of the existing chlorine system. This project is referred to in the Improvement Program as "T-3: Disinfection Improvements."

Second, the existing Screen House facility upstream of the Plant is an aging structure whose current primary function is screening to keep fish and large debris out of the Plant. Its traveling screens are 70 years old and are in relatively good condition, but the City intends to pro-actively move this screening function to the Plant – just upstream of the DAF process. Other component elements of the Screen House facility are showing signs of deterioration. Once the screening function has been relocated to the future DAF facility at the Plant, the City plans to bypass the Screen house facility. The bypass improvements will include new buried pipelines and valves that will connect to the existing pipelines leading to the Plant and to the industrial (untreated) supply system. This project is referred to in the Improvement Program as "T-4: Screening Relocation Improvements."

An additional benefit of the DAF facility is added chlorine disinfection contact credit. Currently, the City is required to provide "1-log" of chlorine disinfection for giardia inactivation, which is the requirement for filtration facilities without pre-filtration clarification processes. This disinfection contact is provided in the Whatcom Falls II Reservoir. The City reserves the bottom 5 million gallons of the reservoir to ensure sufficient chlorine contact volume. With the addition of DAF, the City will be eligible to receive from DOH an addition 0.5-log credit for giardia inactivation, which will reduce the volume it needs to reserve in Whatcom Falls II Reservoir to 2.5 million gallons. This reduction in storage volume allocated to chlorine contact helps to defer the need for additional distribution system storage. This reduction is acknowledged in the footnote of Table 3-13 and is accounted throughout the storage evaluation presented in Section 3.3.

4.2 Filtration Capacity

A description of the City's Whatcom Falls Water Treatment Plant is presented in Section 3.3.2 of the 2009 Water System Plan. When the WTP is not being adversely impacted by algae, it has a capacity of 24 mgd with one of its six filters out of service for backwashing.

The 2009 Water System Plan identified the need for additional filtration capacity based on the projected intersection of estimated water use and the 24-mgd capacity of the WTP. That project intersection was 2014. As stated above in Section 2.2 of this WSP Update, the updated estimated future water use is much less than what was estimated in the 2009 Water System Plan. The 20-year estimate of WTP production is 20.8 mgd, which is less than the 24-mgd capacity of the WTP with one filter out of service for backwashing. Therefore, discounting the impact of algae on the WTP capacity, there is no need to add new filters at the WTP.

However, summertime algae blooms do adversely impact filtration capacity at the WTP. The magnitude of reduced capacity depends on the severity and intensity of the algae bloom, which is different each summer. Only in the summer of 2009 has algae reduced WTP capacity to a point below total customer demand. Therefore, the only data point reflecting the extent to which WTP capacity was reduced by algae is from the summer of 2009.

During the summer of 2009, mandatory water restrictions, were implemented when the WTP could not meet customer demand, which was approximately 17 mgd at the time the mandatory water restrictions were implemented. One day after mandatory water restrictions were implemented, customer demand dropped to approximately 10 mgd. Operations staff adjusted the filter loading rate to as high as 4.82 gallons per minute per square foot (gpm/sf) to maximize plant capacity to meet the reduced demand. It was not possible to increase the filter loading rate beyond this point because of the excessive filter backwash frequency. Filter run times had reduced to 3.5 hours during this time from a typical summer run time of 15 hours. The result was a WTP capacity of approximately 10 mgd under the algae conditions observed in early August of 2009.

It should be noted that the impact of algae on the capacity of the WTP is extremely variable – depending heavily on actual algae biomass as well as algae species configuration. The WTP capacity of 10 mgd in 2009 represents an apparent historical "maximum-impact" administered by Lake Whatcom algae. The impact of Lake Whatcom algae on WTP capacity has been less severe in 2010, 2011, and 2012 than in 2009, even though there was substantial reduction in WTP capacity during these past three years. The WTP production capacity was adequate during these years because peak summertime customer demand was relatively low in comparison to previous years.

The addition of DAF is necessary to mitigate the adverse impacts of summertime algae blooms will be completely mitigated and enable the filtration capacity at the WTP to be 24-mgd based on a maximum filter loading rate of 6 gallons per minute per square foot (gpm/sf). Consequently, given the City's plan for implementing DAF over the next few years, there is no need for additional filtration capacity at the WTP within the 6-year and 20-year planning horizons.

5. Improvement Program

The Improvement Program presented herein replaces what was developed for the 2009 Water System Plan. The Improvement Program from the 2009 Water System Plan is presented in Appendix A with comments regarding the status of each of the listed projects. Note that most of the projects presented in Appendix A were not undertaken because anticipated development did not occur and because actual water use and estimated future water use are lower than cited in the 2009 Water System Plan.

Each improvement project is designated with an improvement project number related to the type of improvement to facilitate, as applicable, referencing between the narrative discussion presented in Sections 3 and 4, Table 3-20, Table 5-1, and Figure 5-1 (at the end of this WSP Update). The treatment, storage, pumping, and pipeline projects are each presented in Sections 3 and 4 of this WSP Update. The metering project is presented in Section 4 of the 2009 Water System Plan. The planning, watershed, hydropower, and supply projects are described in the following paragraph. The letter designations relating to improvement type for each of the improvement numbers are listed below:

- Treatment (T)
- Storage (ST)
- Pumping (PS)
- Pipeline (PL)
- Metering (M)
- Planning (PN)
- Watershed (WS)
- Hydropower (HP)
- Supply (S)

Planning (PN). The planning project, PL-1, is the next water system plan update the City intends to execute. It is understood that actual timing for this project may vary, but in no case will it extend beyond the timeframe required by WADOH.

Watershed (WS). Property Acquisitions in Lake Washington (WS-1) is part of the City's on-going program to reduce phosphorous loading to Lake Whatcom. Water Quality Projects in Lake Whatcom Watershed (WS-2) are those improvement projects also intended to reduce runoff and phosphorous loading to Lake Whatcom.

Hydropower (HP). The GP Hydropower Project (HP-1) is intended to generate hydropower from the pipeline that formerly conveyed water to the Georgia Pacific Mill.

Supply (S). The Nooksack River Dam and Pipeline Improvements (S-1) will be implemented to make improvements to the fish screens at the Nooksack River diversion dam and to make improvements that are anticipated to be necessary on the existing Nooksack River transmission pipeline between the Nooksack River diversion and Lake Whatcom. The scope of improvements to the diversion dam and pipeline will be determined during the planned initial evaluation.

The schedule for implementation of the Improvement Program is presented in Table 5-1. Estimated project costs presented in Table 5-1 are planning-level Class V estimates as defined by the Association for the Advancement of Cost Engineering International (AACEI).

The estimated costs were prepared for guidance in utility budgeting and securing adequate funding based on information available at the time of the estimate. The final cost of the project will depend upon the actual labor and material costs, competitive market conditions, implementation schedule, and other variable factors. As a result, final project costs will vary from the estimates presented herein.

TABLE 5-1
Improvement Program

Project	ID Number	Total Project Cost	2013	2014	2015	2016	2017	2018	2019 – 2032
Kearney Road Pump Station	PS-1	--	--	--	--	--	--	--	X[1]
Balsam Lane Pump Station Capacity Expansion	PS-2	--	--	--	--	--	--	--	X
40th Street Pump Station	PS-3	--	--	--	--	--	--	--	X
Future 980 Pump Station	PS-4	--	--	--	--	--	--	--	X
King Mountain Pump Station	PS-5	--	--	--	--	--	--	--	X
Samish Hill Reservoir	ST-1	--	--	--	--	--	--	--	X
King Mountain Reservoir	ST-2	--	--	--	--	--	--	--	X
Dissolved Air Flotation	T-1	$11,000,000	--	$500,000	$1,000,000	$6,000,000	$3,500,000	--	--
Marietta Re-Chlorination Station	T-2	--	--	--	--	--	--	--	X
Disinfection Improvements	T-3	$1,000,000	--	$100,000	$200,000	$700,000	--	--	--
Screening Relocation Improvements	T-4	$2,000,000	--	$250,000	$250,000	$1,500,000	--	--	--
Water System Plan Update	PN-1	$100,000	--	--	--	--	--	$100,000	--
Metering Program	M-6	$9,500,000	$1,000,000	$2,500,000	$2,500,000	$2,500,000	$1,000,000	--	--
Annual Water Main Replacement Program	PL-1	$12,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	--
Property Acquisitions in Lake Whatcom Watershed	WS-1	$25,950,000	$950,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	--
Water Quality Projects in Lake Whatcom Watershed	WS-2	$5,770,000	$570,000	$600,000	$700,000	$1,000,000	$1,400,000	$1,500,000	X
GP Hydro Project	HP-1	$400,000[2]	$400,000	--	--	--	--	--	X
Nooksack River Dam and Pipeline Improvements	S-1	$10,200,000	--	--	$200,000	--	--	$10,000,000	--
Total	**--**	**$77,920,000**	**$4,920,000**	**$10,950,000**	**$11,850,000**	**$18,700,000**	**$12,900,000**	**$18,600,000**	**--**

[1] Each of the projects designated with an "X" in the timeframe beyond the 6-year planning horizon were not incorporated into the financial program for the water utility. Therefore, estimated costs were not developed for these improvements.
[2] The total project for the GP Hydro Project is preliminarily estimated to be approximately $3,000,000. The amount beyond the initial evaluation is not shown in the table because it is assumed the project will not be completed until beyond the 6-year planning horizon.

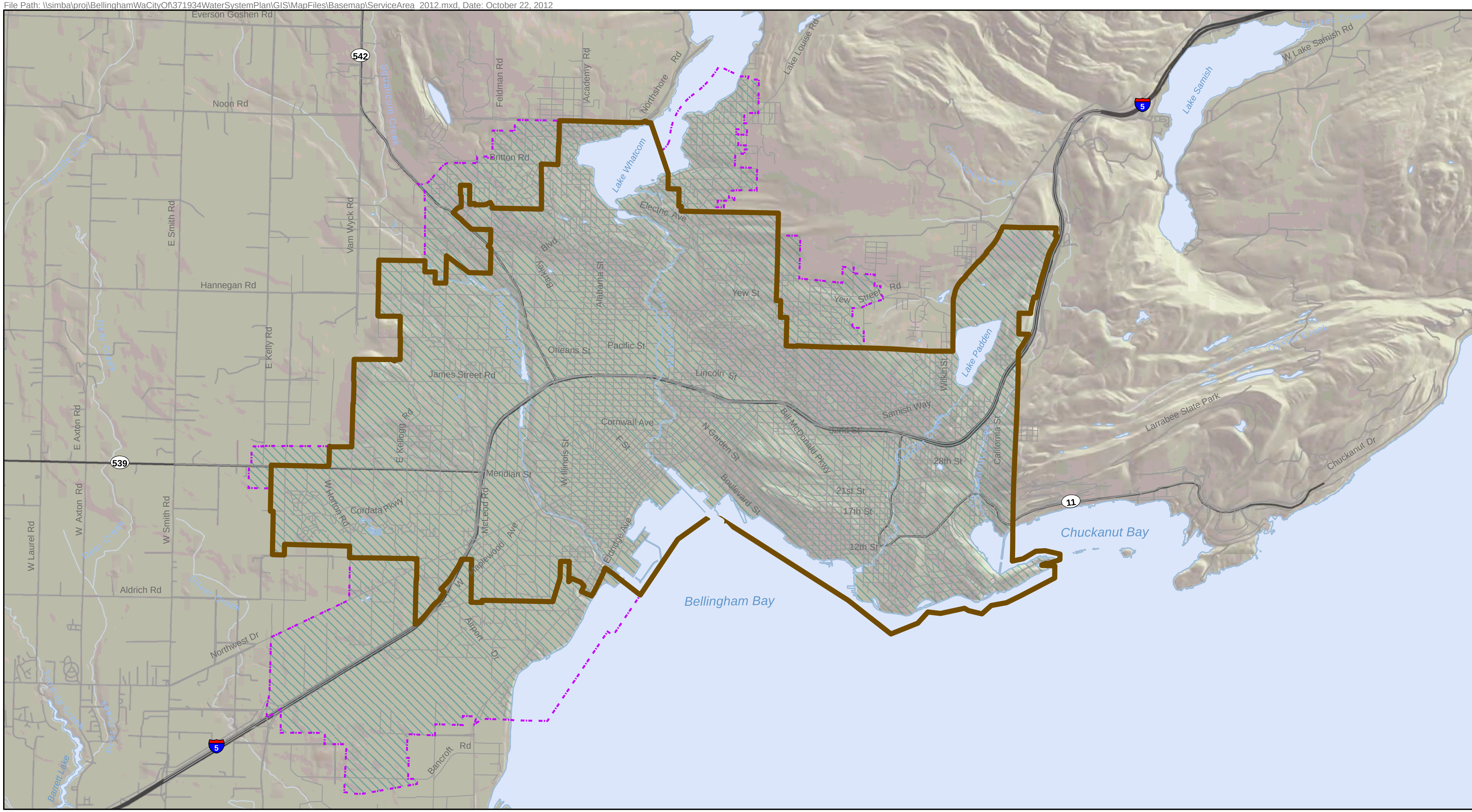
6. Financial Program

The City recently completed a rate study for its water and sewer utilities, entitled "2012 Water and Sewer Rate Update." A copy of the executive summary of the rate study is included as Appendix B. The study presented a 6-year financial plan from 2013 through 2018. Key findings and recommendations resulting from the study include rate increases of 9.0% in 2013, 8.0% per year from 2014 through 2016, 6.0% for 2017 and 2018. Key factors prompting the need for these increases include:

- **O&M:** Operating costs are expected to increase by 2% – 5% per year, with a higher near-term impact due to costs associated with the metering program. When the metering program has been completed (by 2017), these incremental costs are expected to go away.
- **Debt:** The proposed 2013 – 2018 water utility capital funding strategy contemplates a total of $35.5 million in revenue bond proceeds (net of issuance costs and reserve requirements) to fund the projected capital costs. An $11.6-million bond issue in 2015 is expected to increase the water utility's annual debt burden by about $983,000 per year beginning in 2016; a 2018 bond issue of $23.9 million would increase annual debt service by an additional $2.1 million (for a total of $3.1 million per year by the end of the study period). In addition, with the planned transfer of $5 million of existing bond proceeds from the sewer utility to the water utility, the water utility is assumed to fund a proportionate share of debt service on the 2011 Revenue Bond. In the near-term, this amounts to about $270,000 per year.
- **Capital:** Consistent with prior recommendations, the forecast incorporates a policy to fund system reinvestment through water rates. The prior water rate study completed in 2007 established an annual funding level based on annual depreciation expense, net of debt principal. However, given the projected increases in debt service discussed above, this analysis reflects a revised benchmark (50% of annual depreciation expense) to stabilize the annual funding level. By the end of the study period, the annual transfers for system reinvestment are projected to increase to about $1.4 million. This is in addition to cash funding provided through system development charges.
- **Reserve Funding:** Consistent with the prior study, this analysis reflects a policy assumption that the water utility maintains an operating (or "working capital") reserve with a balance sufficient to cover 60 days of projected operating expenses. Because the City has currently been maintaining an operating reserve balance of 5% (about 18 days) of budgeted expenses, this analysis phases in the higher reserve target over several years. In addition, this analysis introduces a separate "rate stabilization reserve" intended to provide additional security against revenue risk associated with volumetric revenues, preserving the City's ability to meet its debt obligations even in low sales years. The target balance for this reserve is 50% of annual debt service for debt issued on or after January 1, 2011. Debt issued prior to 2011 is not included in this calculation because the covenants for that debt do not allow use of a rate stabilization reserve to meet bond coverage requirements.
- **Expansion of Reduced-Rate Program:** This study included the evaluation of the incremental impact of expanding the City's reduced-rate program based on the low-income threshold established by Whatcom County ($35,000 per year). Based on staff recommendations, the adopted rates assume that this program is expanded.

The rate study included accounting for capital investment that matches the quantity presented in the Improvement Program in Table 5-1. Because the rate study was completed just prior to completion of this WSP Update, it also includes some planned improvements from the 2009 WSP Update that are no longer anticipated within the 6-year planning horizon. As a result, the rate increases planned for implementation by the City are anticipated to be more than adequate to cover utility expenses, including planned capital improvements.

Figures



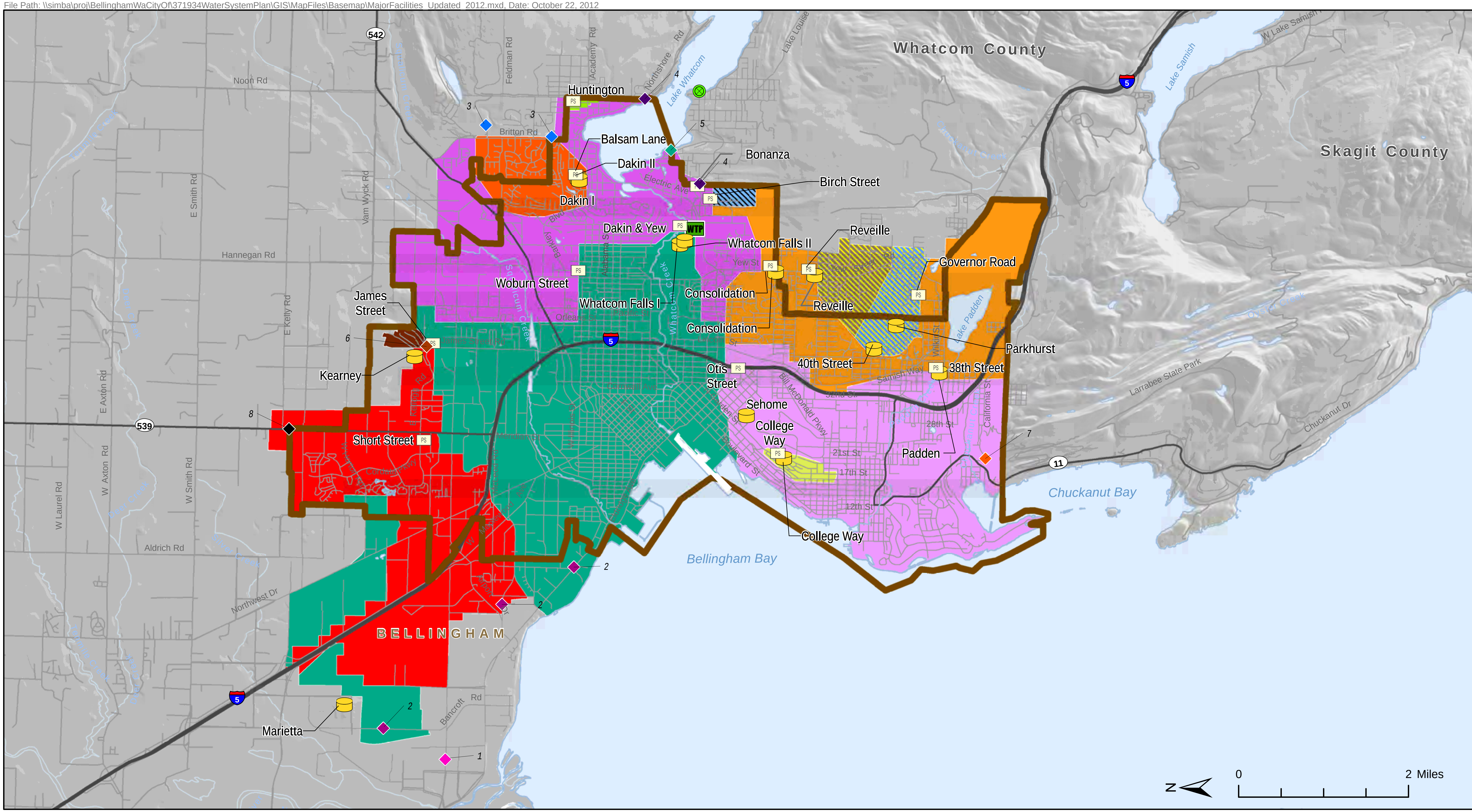
Source: City of Bellingham (2009) and Whatcom County (2006).

City Limits
Urban Growth Area
Retail Service Area

0 2 Miles

Figure 3-1
Service Area
City of Bellingham
2012 Water System Plan Update

CH2MHILL



Pressure Zone

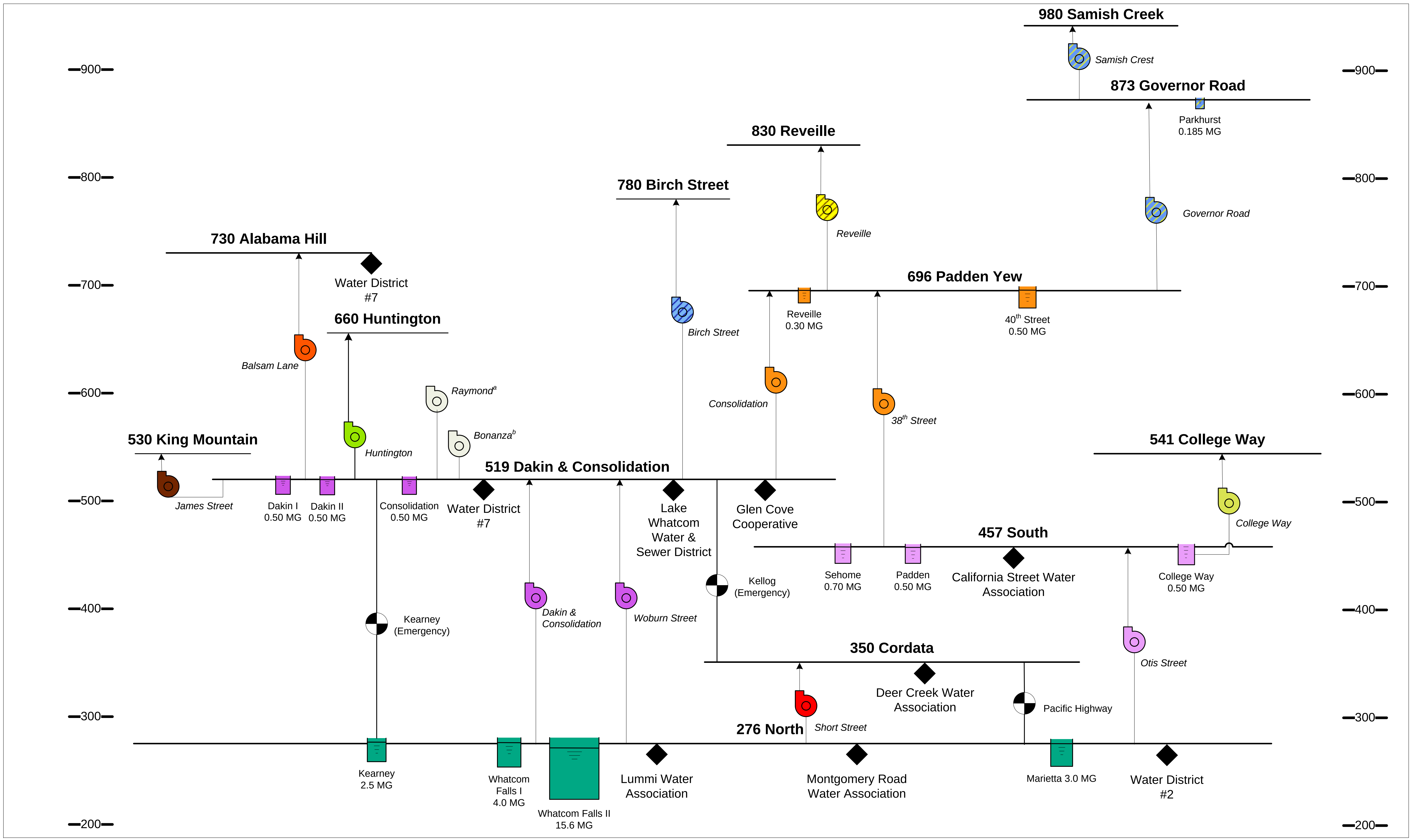
- 730 Alabama Hill
- 780 Birch Street
- 580 College Way
- 350 Cordata
- 519 Dakin Yew
- 873 Governor Road
- 660 Huntington
- 460 King Mountain
- 276 North
- 696 Padden Yew
- 830 Reveille
- 457 South

Intertie Type

- 1= Lummi Water Association
- 2= Water District #2
- 3= Water District #7
- 4= Lake Whatcom Water and Sewer District
- 5= Glen Cove Cooperative
- 6= Montegomery Road Water Association
- 7= California Street Water Association
- 8= Deer Creek Water Association

- Intake
- Pump Station
- Reservoir
- Water Treatment Plant
- City Limits

Figure 3-2
Major Facilities and Pressure Zones
City of Bellingham
2012 Water System Plan Update

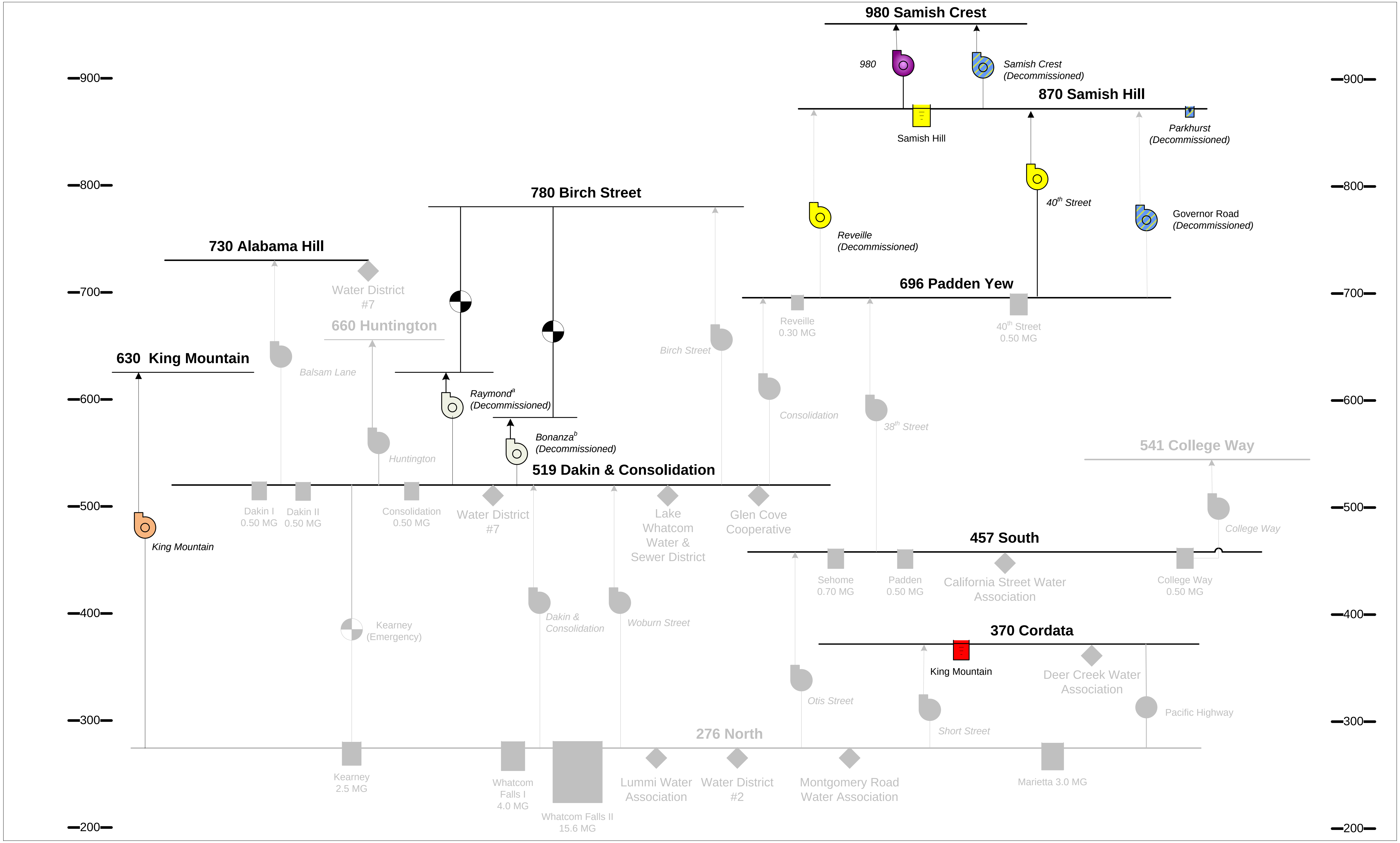


[a] Raymond pump station serves 1 home.

[b] Bonanza pump station serves 4 homes.

Figure 3-3
Existing Hydraulic Profile
City of Bellingham
2012 Water System Plan Update

CH2MHILL



Pressure Zone | Reservoir | *Pump Station* | Intertie | PRV

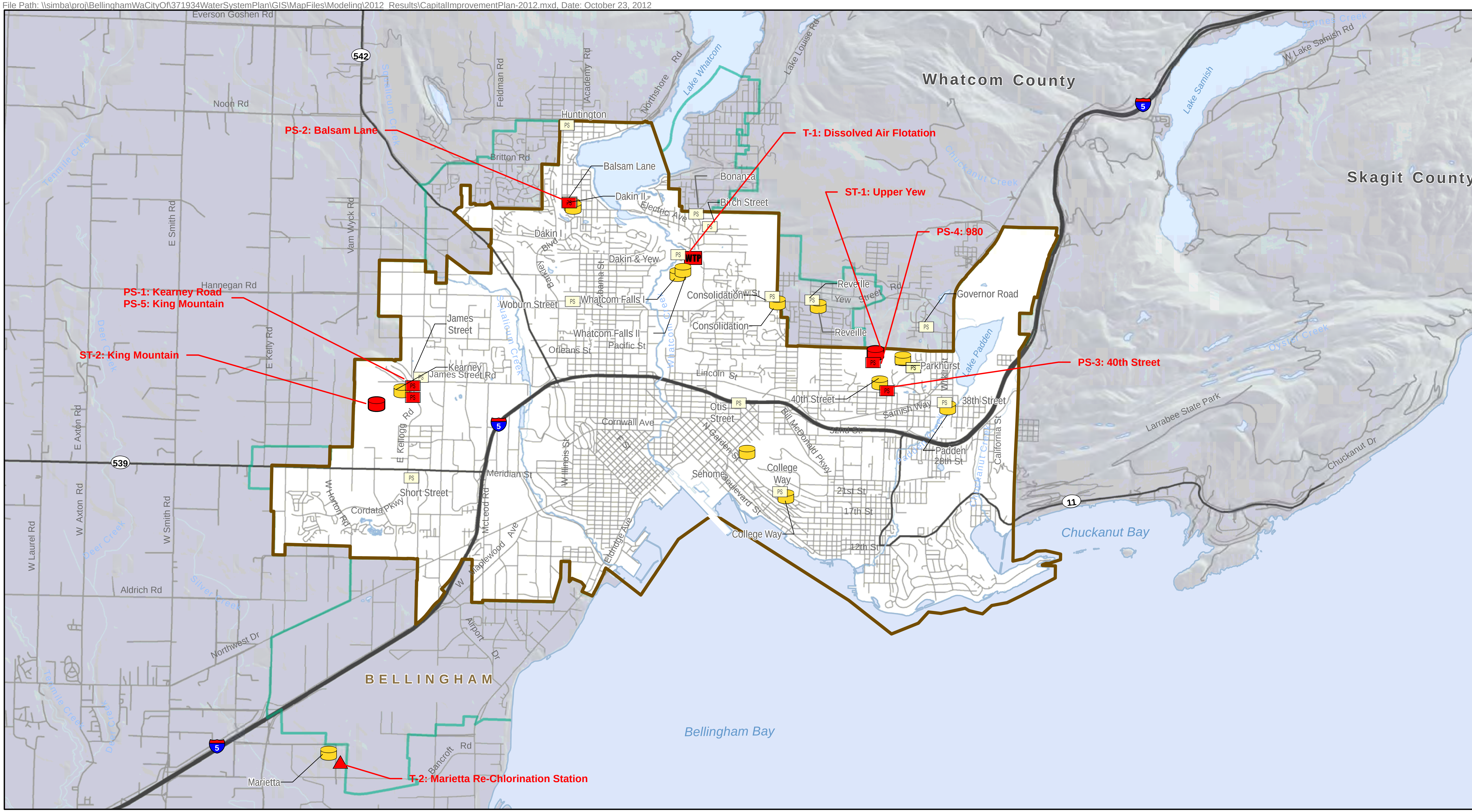
[a] Raymond pump station serves 1 home.

[b] Bonanza pump station serves 4 homes.

Figure 3-6
Future Hydraulic Profile
City of Bellingham
2012 Water System Plan Update

CH2MHILL

File Path: \\simba\proj\BellinghamWaCityOf\371934WaterSystemPlan\GIS\MapFiles\Modeling\2012_Results\CapitalImprovementPlan-2012.mxd, Date: October 23, 2012



Legend:
- Pump Station
- Reservoir
- Water Treatment Plant Improvement
- Pump Station Improvement
- Storage Improvement
- Re-chlorination Station Improvement
- Existing Retail Service Area
- City Limits

N

0 2 Miles

Figure 5-1
2012 Improvement Program
City of Bellingham
2012 Water System Plan Update

APPENDIX A
Status of 2009 Water System Plan Improvement Program

Appendix A - Status of Improvement Program from 2009 Water System Plan

Project	ID Number	Project Cost	2009	2010	2011	2012	2013	2014	2015 - 2028	Status/Comments
870 Upper Yew Reservoir, 1.35 MG	ST-1	$5,919,000							$5,919,000	Not completed/lower-than-anticipated development pressure
460 King Mountain Reservoir, 1.9 MG	ST-2	$6,340,000				$450,000	$5,890,000			Not completed/lower-than-anticipated development pressure
Padden Reservoir: 457 South, 2.5 MG	ST-3	$8,997,000							$8,997,000	Not completed/lower-than-anticipated development pressure
730 Alabama Hill Reservoir, 1.5 MG	ST-4	$4,858,000							$4,858,000	Not completed/lower-than-anticipated development pressure
519 Dakin & Yew Reservoir, 2.2 MG	ST-5	$5,937,000							$5,937,000	Not completed/lower-than-anticipated development pressure
New 40th Street Pump Station	PS-1	$2,664,000							$2,664,000	Not completed/lower-than-anticipated development pressure
New Kearney Road Pump Station	PS-2	$4,250,000		$300,000	$3,950,000					Not completed/lower-than-anticipated development pressure
Consolidation Pump Station Upgrade	PS-3	$1,295,000							$1,295,000	Not completed/lower-than-anticipated development pressure
Reveille Pump Station Upgrade	PS-4	$1,503,000							$1,503,000	Not completed
950 Rezone Area Constant Pressure PS	PS-5	$1,705,000							$1,705,000	Not completed/lower-than-anticipated development pressure
New James Street Pump Station	PS-6	$3,210,000	$230,000	$2,980,000						Not completed/revised improvement executed
870 Upper Yew Reservoir West Connection	PL-1	$1,702,000							$1,702,000	Not completed/lower-than-anticipated development pressure
870 Upper Yew Reservoir East Connection	PL-2	$1,689,000							$1,689,000	Not completed/lower-than-anticipated development pressure
King Mountain Reservoir West Connection	PL-3	$2,853,000							$2,853,000	Not completed/lower-than-anticipated development pressure
Transmission Main to 950 Rezone Area	PL-4	$459,000							$459,000	Not completed/lower-than-anticipated development pressure
Yew Street Transmission Main Extension	PL-5	$2,060,000							$2,060,000	Not completed/lower-than-anticipated development pressure
Annual Main Replacement	PL-6	$9,500,000	$1,500,000	$600,000	$2,600,000	$1,600,000	$1,600,000	$1,600,000		Completed/ongoing
Sunset Drive Phase 2 Water Mains	PL-7	$300,000	$300,000							Completed
Mt Baker Highway Replacement II	PL-8	$900,000			$100,000	$400,000	$400,000			Completed
Filtration Rate Increase[2]	TR-1	X								Not completed/reduced water use
Filter Addition[2]	TR-2	X							X	Not completed/reduced water use
WTP: Air Scour System	TR-3	$950,000	$950,000							Completed
Hydraulic Model, 3-yr Updates	PN-1	$100,000		$100,000						Completed
Metering Program	M-1	$9,000,000			$2,000,000	$2,000,000	$2,000,000	$3,000,000		Underway
Nooksack Diversion Passage	DV-1	$10,000,000						$10,000,000		Not completed/inadequate funding participation by other entities
		TOTALS	**$2,980,000**	**$3,980,000**	**$8,650,000**	**$4,450,000**	**$9,890,000**	**$14,600,000**	**$41,641,000**	

APPENDIX B
2012 Water and Sewer Rate Study
(Executive Summary only)

City of Bellingham, WA

Final Draft Report for
2012 WATER & SEWER RATE UPDATE

August 2012

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FCS GROUP
Solutions-Oriented Consulting

August 27, 2012

Mr. Bob Bandarra, Superintendent of Operations
City of Bellingham
210 Lottie Street
Bellingham, WA 98225

Subject: 2012 Water & Sewer Rate Update

Dear Mr. Bandarra:

FCS GROUP is pleased to submit this final draft report documenting the findings and recommendations of the 2012 Water & Sewer Rate Update conducted for the City of Bellingham. Enclosed is a description of the background and methodology followed for each major task in the study, a discussion of findings and policy implications, and a description of the final recommendations.

It has been a pleasure to work with City staff on this effort. We look forward to working with you in the future, and we encourage the City to direct any comments or questions regarding this study to us at (425) 867-1802.

Sincerely,

Ed Cebron
Principal

Gordon Wilson
Project Manager

Chris Gonzalez
Project Consultant

EXECUTIVE SUMMARY

The City engaged FCS GROUP in February 2012 to perform a comprehensive rate study for its water and sewer utilities. The rate study includes the following components:

- A review of water and sewer utility revenue requirements incorporating:
  - A revised metering schedule reflecting the conversion of the City's unmetered water customers to metered water service by January 22, 2017, as required by the Water Use Efficiency Rule established by the Washington State Department of Health
  - Recent trends in water demands suggesting that per capita water usage has been declining, and will continue to decline
  - Recent economic conditions that have impacted both the behavior of existing customers and the addition of new customers to the water and wastewater systems
  - A change in customer service policy to allow credit cards to be used for monthly utility payments without a separate transaction fee
- Development of recommended water and sewer rates based on projected revenue needs and an updated cost-of-service analysis for each utility
  - For water, shifting separately metered condos from the non-single family to the single-family customer class

In addition to development of projected rates, this report addresses the following elements:

- A review of the City's cost of providing fire protection service, in response to the Washington State Supreme Court's decision in *Lane v. Seattle*
- An update of rates for untreated water service
- An update of sewer rates for the City's special industrial users (SIUs)
- A potential expansion of the existing low-income discount program
- The rate impact of monthly billing

We are preparing separate issue papers that discuss:

- An update of water and sewer SDCs to reflect current estimates of the City's investment in infrastructure and system growth
- A review of the City's methodology for recovering costs from Lake Whatcom Water & Sewer District (LWWSD)
- Development of a wholesale water rate to facilitate possible water sales to other communities

This study developed a multi-year financial plan integrating these various elements, projecting operating and capital costs for the six-year planning period from 2013 to 2018.

Key findings and recommendations resulting from the study include:

Water

- Overall water rate revenue should be increased by 9.0% in 2013, 8.0% per year from 2014 – 2016, and by 6.0% per year from 2017 – 2018. Key factors that drive these adjustments are:
  - ***O&M:*** Operating costs are expected to increase by 2% – 5% per year, with a higher near-term impact due to costs associated with the metering program. When the metering program has been completed (by 2017), these incremental costs are expected to go away.
  - ***Debt:*** The proposed 2013 – 2018 water utility capital funding strategy contemplates a total of $35.5 million in revenue bond proceeds (net of issuance costs and reserve requirements) to fund the projected capital costs. An $11.6-million bond issue in 2015 is expected to increase the water utility's annual debt burden by about $983,000 per year beginning in 2016; a 2018 bond issue of $23.9 million would increase annual debt service by an additional $2.1 million (for a total of $3.1 million per year by the end of the study period). In addition, with the planned transfer of $5 million of existing bond proceeds from the sewer utility to the water utility, the water utility is assumed to fund a proportionate share of debt service on the 2011 Revenue Bond. In the near-term, this amounts to about $270,000 per year.
  - ***Capital:*** Consistent with prior recommendations, the forecast incorporates a policy to fund system reinvestment through water rates. The prior water rate study completed in 2007 established an annual funding level based on annual depreciation expense, net of debt principal. However, given the projected increases in debt service discussed above, this analysis reflects a revised benchmark (50% of annual depreciation expense) to stabilize the annual funding level. By the end of the study period, the annual transfers for system reinvestment are projected to increase to about $1.4 million. This is in addition to cash funding provided through SDCs.
  - ***Reserve Funding:*** Consistent with the prior study, this analysis reflects a policy assumption that the water utility maintains an operating (or "working capital") reserve with a balance sufficient to cover 60 days of projected operating expenses. Because the City has currently been maintaining an operating reserve balance of 5% (about 18 days) of budgeted expenses, this analysis phases in the higher reserve target over several years. In addition, this analysis introduces a separate "rate stabilization reserve" intended to provide additional security against revenue risk associated with volumetric revenues, preserving the City's ability to meet its debt obligations even in low sales years. The target balance for this reserve is 50% of annual debt service for debt issued on or after January 1, 2011. Debt issued prior to 2011 is not included in this calculation because the covenants for that debt do not allow use of a rate stabilization reserve to meet bond coverage requirements.
  - ***Expansion of Reduced*****-**Rate Program: This study included the evaluation of the incremental impact of expanding the City's reduced-rate program based on the low-income threshold established by Whatcom County ($35,000 per year). Based on staff recommendations, the adopted rates assume that this program is expanded.
- The water rate schedule shown in **Table EX-1** is recommended for adoption as inside-City rates. Per City policy, outside-City customers would pay rates that are 1.5 times the rates shown in **Table EX-1**.

Table EX-1: Summary of Proposed 2013 – 2018 Inside-City Water Rates

Single-Family Residential & Water Districts	2012	2013	2014	2015	2016	2017	2018
Unmetered Single-Family							
Monthly Flat Rate:							
Single-Family Residence	$29.96	$32.66	$35.27	$38.09	$41.14	*All Customers Are Metered*	
Duplex	$59.92	$65.31	$70.54	$76.18	$82.28		
Transitional Single-Family							
Monthly Fixed Rate							
5/8" Meter	$11.61	$16.33	$17.90	$19.35	*Combined With Metered Single-Family Residential Rates*		
3/4" Meter	$15.97	$22.46	$24.62	$26.62			
Volume Rate per ccf	$1.53	$1.27	$1.42	$1.64			
Metered Single-Family & Water Districts							
Monthly Fixed Rate:							
5/8" Meter	$11.61	$13.10	$14.21	$15.42	$19.35	$20.33	$21.46
3/4" Meter	$15.97	$18.02	$19.55	$21.21	$26.62	$27.97	$29.52
1" Meter	$24.69	$27.85	$30.23	$32.78	$41.15	$43.24	$45.64
1-1/2" Meter	$46.51	$52.47	$56.94	$61.76	$77.52	$81.44	$85.98
2" Meter	$72.68	$82.00	$88.98	$96.51	$121.13	$127.27	$134.36
3" Meter	$142.49	$160.76	$174.44	$189.21	$237.48	$249.52	$263.41
4" Meter	$221.02	$249.35	$270.57	$293.48	$368.37	$387.03	$408.58
6" Meter	$439.16	$495.45	$537.62	$583.14	$731.93	$769.02	$811.83
Volume Rate per ccf:							
Metered Single-Family Residential	$1.53	$1.58	$1.63	$1.67	$1.72	$1.82	$1.94
Water Districts	$1.53	$2.18	$2.94	$3.82	$4.10	$4.38	$4.67

Non-Single-Family & Irrigation	2012	2013	2014	2015	2016	2017	2018
Multi-Family, Non-Residential, & Irrigation							
Monthly Fixed Rate:							
5/8" Meter	$19.51	$21.00	$21.75	$22.39	$25.56	$28.32	$30.86
3/4" Meter	$27.82	$29.95	$31.01	$31.93	$36.44	$40.39	$44.01
1" Meter	$44.45	$47.85	$49.55	$51.01	$58.22	$64.53	$70.32
1-1/2" Meter	$86.01	$92.59	$95.88	$98.70	$112.66	$124.86	$136.06
2" Meter	$135.89	$146.28	$151.49	$155.94	$178.00	$197.27	$214.97
3" Meter	$268.90	$289.46	$299.76	$308.58	$352.23	$390.36	$425.38
4" Meter	$418.54	$450.54	$466.57	$480.30	$548.24	$607.59	$662.10
6" Meter	$834.21	$898.00	$929.95	$957.32	$1,092.71	$1,211.02	$1,319.66
8" Meter	$1,333.00	$1,434.93	$1,485.99	$1,529.71	$1,746.06	$1,935.11	$2,108.70
10" Meter	$2,081.10	$2,240.24	$2,319.94	$2,388.21	$2,725.98	$3,021.12	$3,292.14
12" Meter	$2,829.39	$3,045.74	$3,154.11	$3,246.93	$3,706.15	$4,107.41	$4,475.88
Volume Rate per ccf:							
Multi-Family & Non-Residential	$1.53	$1.63	$1.77	$1.93	$1.94	$1.94	$1.97
Irrigation	$2.30	$2.30	$2.30	$2.30	$2.30	$2.30	$2.35
Untreated Water							
Monthly Fixed Rate:							
5/8" Meter		$16.80	$17.40	$17.91	$20.45	$22.66	$24.69
3/4" Meter		$23.96	$24.81	$25.54	$29.15	$32.31	$35.21
1" Meter		$38.28	$39.64	$40.81	$46.58	$51.62	$56.26
1-1/2" Meter		$74.07	$76.70	$78.96	$90.13	$99.89	$108.85
2" Meter		$117.02	$121.19	$124.75	$142.40	$157.82	$171.98
3" Meter		$231.57	$239.81	$246.86	$281.78	$312.29	$340.30
4" Meter		$360.43	$373.26	$384.24	$438.59	$486.07	$529.68
6" Meter		$718.40	$743.96	$765.86	$874.17	$968.82	$1,055.73
8" Meter		$1,147.94	$1,188.79	$1,223.77	$1,396.85	$1,548.09	$1,686.96
10" Meter		$1,792.19	$1,855.95	$1,910.57	$2,180.78	$2,416.90	$2,633.71
12" Meter	$13,359.00	$2,436.59	$2,523.29	$2,597.54	$2,964.92	$3,285.93	$3,580.70
Volume Rate per ccf:		$1.30	$1.42	$1.54	$1.55	$1.55	$1.58
0 - 296,000 ccf per Month	$0.070						
> 296,000 ccf per Month	$0.756						

Outside-City rates are 1.5 times the rates shown above.

The rate forecast shown in **Table EX-1** reflects:

- Across-the-board increases to the unmetered rate structure, based on the aggregate rate revenue increases of 9.0% in 2013, and 8.0% per year from 2014 – 2016. Based on the planned metering schedule, no customers will be in this class beyond 2016.
- Separation of water districts from other single-family customers. A review of recent water consumption patterns suggests that the water districts served by the City use water in a materially different way than the City's other metered single-family customers. These districts equate to roughly 300 homes based on the master meters that are tracked in the City's billing system, but appear to be using as much water as 2,100 homes. Consequently, the proposed rate structure improves equity by establishing a separate rate structure for these districts. Note that this study also included the development of a potential resale rate structure for future wholesale customers, which could also serve as a basis for recovering costs from these customers.
- Introduction of a customer class for newly metered customers, designed to recover approximately 65% of costs from fixed charges and 35% from volume rates. Excluding water districts from other single-family residences as discussed above, the existing metered single-family rate structure currently generates about 56% of its revenue from fixed charges – under the proposed strategy, it would gradually increase its reliance on the fixed charge until it reaches the 65% target after three years. After three years the two customer classes would be merged. This three-year transition period in which there would be two single-family metered classes moderates the increases to both groups – those who are moving from unmetered to metered, and the existing metered customers whose rates will be shifting to a greater reliance on fixed charges.
- Linking of the untreated water rate structure to the non-residential rate structure. Because roughly 20% of the revenue requirement is attributable to water treatment, the untreated water rate structure is set at 80% of the non-residential rate structure. The City's current untreated water customer will pay significantly less under this structure, which is an equitable outcome given that the existing structure is primarily a fixed rate and was based on the historical demand patterns of a different (and significantly larger) industrial customer. In addition to improving equity, this change also makes it easier to attract future customers for untreated water.

Sewer

- Overall sewer rate revenue should be increased by 6.5% in 2013 (the increase in the previously adopted 2013 rate structure), 8.0% in 2014, 7.0% per year from 2015 – 2016, 6.0% in 2017, and 4% in 2018. The key factors driving the proposed adjustments are:
  - ***O&M:*** Operating costs are generally expected to increase by 2% – 5% per year.
  - ***Debt:*** The proposed 2013 – 2018 sewer utility capital funding strategy contemplates a total of $32.2 million in debt proceeds (net of issuance costs and reserve requirements) to fund projected capital costs. Public Works Trust Fund (PWTF) loans are assumed to account for $13 million of this debt, adding about $740,000 to the sewer utility's annual debt service burden beginning in 2014. The remaining $19.2 million is assumed to come from additional bond issuance from 2015 – 2018, which is expected to add about $1.6 million to the sewer utility's annual debt service. As previously noted, the sewer utility's annual debt service is reduced to account for a transfer of $5 million of bond proceeds (and related debt service obligations) to the water utility.
  - ***Capital:*** Consistent with prior recommendations, the forecast incorporates a policy to fund system reinvestment through sewer rates. The sewer rate study done as part of the

City's 2009 Comprehensive Sewer Plan established an annual funding level based on annual depreciation expense, net of debt principal. For consistency with the water utility, this analysis reflects a revised benchmark, 50% of annual depreciation expense. By the end of the study period, annual transfers for system reinvestment are projected to increase to about $2.1 million.

- ***Reserve Funding:*** Consistent with the prior study, this analysis reflects a policy assumption that the sewer utility maintains an operating (or "working capital") reserve with a balance sufficient to cover 60 days of projected operating expenses. In addition, this analysis introduces a separate "rate stabilization reserve" that intends to provide additional security against revenue risk associated with volumetric revenues, preserving the City's ability to meet its debt obligations even in low sales years. The target balance for this reserve is 50% of annual debt service. The sewer utility's sole outstanding revenue bond allows the use of a rate stabilization reserve.

♦ The sewer rate schedule shown in **Table EX-2** is recommended for adoption as inside-City rates. Consistent with City policy, outside-City customers would pay rates that are 1.5 times the rates shown in **Table EX-2**.

Table EX-2: Summary of Proposed 2013–2018 Inside-City Sewer Rates

Sewer Rate Structure	2012	2013	2014	2015	2016	2017	2018
Single-Family Residential							
Monthly Flat Rate:							
Single-Family Residence	$33.23	***$33.97***	***$35.07***	$37.24	$39.47	$41.66	$43.16
Unmetered Duplex	$66.46	***$67.94***	***$70.15***	$74.48	$78.95	$83.32	$86.31
Multiple Dwelling Units							
Monthly Fixed Rate	$33.23	***$33.97***	***$35.07***	$37.24	$39.47	$41.66	$43.16
Volume Rate per ccf (> 8 ccf per Month)	$3.49	***$4.09***	***$4.66***	$4.99	$5.43	$5.80	$6.07
Domestic-Strength Non-Residential							
Monthly Fixed Rate	$33.97	***$33.97***	***$35.07***	$37.24	$39.47	$41.66	$43.16
Volume Rate per ccf (> 8 ccf per Month)	$3.82	***$4.09***	***$4.66***	$4.99	$5.43	$5.80	$6.07
Medium-Strength Non-Residential							
Monthly Fixed Rate	$19.60	***$33.97***	***$35.07***	$37.24	$39.47	$41.66	$43.16
Volume Rate per ccf (> 8 ccf per Month)	$2.45	***$4.09***	***$4.66***	$4.99	$5.43	$5.80	$6.07
High-Strength Non-Residential							
Monthly Fixed Rate	$19.60	***$33.97***	***$44.35***	$56.84	$59.84	$62.97	$65.23
Volume Rate per ccf (> 8 ccf per Month)	$2.45	***$4.09***	***$6.09***	$7.83	$8.44	$8.98	$9.40

The rate forecast shown in **Table EX-2** reflects:

- Creation of three strength classes for non-single-family customers.
  - Domestic-Strength Non-Residential: Includes metered duplexes, residential properties with multiple dwelling units, and the City's current commercial customers. Based on system planning criteria in the City's Comprehensive Sewer Plan, this class (and the single-family residential class) is assumed to generate wastewater with an average concentration of 235 mg/L of biochemical oxygen demand (BOD) and 270 mg/L of suspended solids (SS).
  - Medium-Strength Non-Residential: Includes customers that generate wastewater averaging between 250 mg/L and 500 mg/L of BOD and/or between 300 mg/L and 500 mg/L of SS. Based on average strength ratings of the customers included in this

class, this class is assumed to generate wastewater with an average strength of 355 mg/L of BOD and 155 mg/L of SS for the purpose of allocating costs.

– High-Strength Non-Residential: Includes customers that generate wastewater averaging over 500 mg/L of BOD and/or SS. Based on average strength ratings of the customers included in this class, this class is assumed to generate wastewater with an average strength of 1,131 mg/L of BOD and 235 mg/L of SS for cost allocations.

With respect to the strength standards, a customer's higher strength rating defines their class. For example, a customer generating wastewater with an average strength of 320 mg/L of BOD and 150 mg/L of SS would be grouped in the "medium-strength" class. It is worth noting that in this analysis, the "medium-strength" and "high-strength" classes only include special industrial users (SIUs) due to a lack of data identifying the business types (and related wastewater strengths) of specific commercial customers. As a future enhancement to this structure, the City should consider reviewing its commercial customer base and moving certain types of businesses to higher strength classes based on their average strength ratings. With this change, it would be prudent for the City to develop a list of best-management practices (BMPs) that customers can follow to be considered for reclassification into a lower strength class.

- Elimination of the industrial strength surcharges included in the existing SIU rate structure ($0.19 per pound of BOD; $0.16 per pound of SS). City staff indicated that the City has not actually been able to impose these surcharges due to an inability to directly measure BOD and SS discharges with the equipment currently in place. The proposed rate structure uses average BOD and SS discharges as the basis for developing differential fixed and volume-based rates.

- For 2013, the fixed charge for domestic-strength non-residential customers is kept at its current level. The fixed charges for single-family and multiple-dwelling-unit customers are increased to match the domestic-strength fixed charge, based on the assumption that these three classes generate wastewater of comparable strength. The SIU rates are increased to match the domestic-strength residential rates. For 2014 – 2015, the high-strength non-residential rates are phased to reflect the differential BOD and SS discharges. The other rates are adjusted accordingly to generate the targeted amount of revenue. A review of the costs allocated to the medium-strength class suggested that based on estimated BOD and SS loadings, its rates should be approximately the same as the domestic-strength rates. Consequently, the rate forecast shown in **Table EX-2** reflects the assumption that medium-strength rates are equal to domestic-strength rates through 2018. It is worth noting that the medium-strength class' wastewater characteristics may change if the City expands the class (the medium-strength class now includes only one customer), possibly warranting a separate rate structure in the future.

- Consider a more detailed review of the City's state excise tax reporting practices. A cursory review of City tax worksheets found that the City might have an opportunity to reduce its tax expenses, given various deductions and exemptions allowed under State law. This review may also provide the supporting documentation that the City would need in order to request a refund from the Department of Revenue for historical tax payments. The findings presented in this report assume the implementation of the identified refinements moving forward, but do not incorporate an assumed refund of past payments.

APPENDIX C
Filter Clogging Algae Mitigation Evaluation
(Executive Summary only)

Final Report

Filter-Clogging Algae Mitigation Evaluation

Prepared for CITY OF BELLINGHAM • WASHINGTON •

Prepared by CH2MHILL®

21 Bellwether Way, Unit 111
Bellingham, WA 98225

June 2012

Executive Summary

This report presents the study undertaken by the City of Bellingham (City) to evaluate alternatives to mitigate the adverse impacts of seasonal algae in Lake Whatcom to the City's Whatcom Falls Water Treatment Plant (WTP). This study was undertaken in the second half of 2011 and completed in early 2012.

ES.1 Background and Purpose

In late July and August of 2009 the filters at the City's WTP began clogging much earlier in filter runs than typical, requiring more frequent filter backwashing. The result was greatly reduced WTP capacity – to the point the City implemented mandatory water restrictions, for the first time, to reduce customer demand to match the reduced WTP capacity.

Filter clogging was attributed to algae in Lake Whatcom – the City's source water. Although the reasons for the intense algae bloom of the summer of 2009 is the subject of varied speculation, historical and on-going algae monitoring shows that summertime algae blooms in Lake Whatcom have been increasing over the past decade.

In 1998, Lake Whatcom water quality failed to meet the Washington State dissolved oxygen standard and was placed on Washington's list of polluted waters (Section 303d of the Clean Water Act). As a result of the listing, Ecology initiated a Total Maximum Daily Load (TMDL) study to restore lake water quality. The TMDL study showed that human actions were causing increased phosphorous loading and therefore reduced dissolved oxygen. Meeting the TMDL requirements for phosphorous and dissolved oxygen is expected to take many years to complete, and compliance with the TMDL requirements is the cornerstone of the long-term response to improving lake quality.

Despite on-going coordinated efforts, via the Lake Whatcom Management Program, by the City, Whatcom County, and Lake Whatcom Water and Sewer District to reverse this trend, summertime algae blooms are expected to continue increasing in intensity over the near-term future. Recognizing that it is unacceptable to be in a position wherein it risks falling short of meeting summertime customer water demand, the City initiated this study to evaluate alternative solutions and select a path forward for subsequent implementation.

ES.2 Alternatives Evaluated

The alternatives evaluated for mitigating clogging of the filters at the City's WTP were grouped into three main categories: treatment, intake, and lake management. These alternatives are presented in Table ES-1. In addition to these pro-active alternatives, the "No Action" alternative was included in the Triple Bottom Line Plus evaluation phase as a means of establishing a lowest-cost baseline for comparison.

Each of the treatment alternatives considered for this study are commonly used in the municipal water treatment industry and are commonly-considered alternatives for algae removal. Each would be implemented somewhere at the existing WTP site. They are not, however, equal with respect to removal performance, advantages, disadvantages, and cost.

TABLE ES-1
Summary of Alternatives Evaluated

Treatment	Intake	Lake Management
Dissolved Air Flotation	Secondary Intake via In-Water Pipeline	Lake Management
Ballasted Sedimentation	Secondary Intake via Over-Land Pipeline	
Plate and Tube Settling	New Dual-Intake System	
Upflow Clarification		
Conventional Sedimentation		
Micro-Screening		
Ozonation		
Additional Filters		

Notes:
Other potential solutions were acknowledged and considered but not evaluated in detail because their feasibility was believed to be questionable based on prior experience and/or a lack of prior application or success. These other potential solutions include: hypolimnetic oxygenation, floating shade balls, lake aeration.

Three intake alternatives were identified for consideration and evaluation. Each of the intake alternatives includes withdrawing water from Lake Whatcom at a location different from the existing intake location that has a substantially lower concentration of algae. Each of the intake alternatives includes the capability to withdraw water at more than one depth.

The Lake Management alternative is essentially the Lake Whatcom Management Program. The Lake Whatcom Management Program is the management forum for improving lake quality and via which compliance with the TMDL requirements for dissolved oxygen and phosphorous is being pursued. Lake management will be implemented regardless of the results of this evaluation. Meeting the TMDL requirements is the cornerstone of the long-term strategy to improve water quality, including reducing algae concentrations.

ES.3 Evaluation of Alternatives

Evaluation of the alternatives to mitigate the adverse impacts of filter-clogging algae at the City's water treatment WTP was implemented in three distinct phases. These three phases include:

- Screening of Alternatives: This first phase, "screening of alternatives," was implemented to eliminate from further consideration and evaluation alternatives that were deemed "not selectable" based on one or more screening criteria. This approach enabled more subsequent focus and effort in developing and evaluating those alternatives that were deemed to have greater promise for selection and implementation. Three treatment alternatives, one intake alternative, and the lake management alternative were eliminated from further consideration during screening because they did not meet all of the screening criteria.

- Evaluation of Alternatives: This second phase of the evaluation process reflects a more-detailed evaluation of the remaining alternatives. This evaluation phase resulted in identification of the best alternative within categories as well as a best overall alternative based primarily on technical criteria. During this evaluation phase Dissolved Air Flotation (DAF) was determined to be the best treatment alternative and "Secondary Intake via In-Water Pipeline" (Intake Alternative 1) was determined to be the best intake alternative. DAF was determined to be the best overall alternative based on technical performance criteria.

- **Triple Bottom Line Plus Evaluation:** This third phase of the evaluation process reflects evaluation based on a "Triple Bottom Line Plus" (TBL+) approach for the best alternatives per category (as determined in the second phase of evaluation). Additionally, the "No Action" alternative was evaluated as a baseline comparison. This approach enabled scrutiny with respect to financial, social, environmental, and technical objectives. The alternatives evaluated using the TBL+ approach included: DAF, Intake Alternative 1, Additional Filters, and No Action.

The results of the TBL+ evaluation are presented in Figure ES-1 at the end of the Executive Summary. The evaluation criteria are presented in Section 7 of the main body of the report. The TBL+ evaluation results, as well as the results of the more-technically-based second phase of the evaluation process, showed DAF to be the superior alternative for mitigating the filter-clogging algae condition at the City's WTP.

In recognition of the fact that DAF technology is ideally suited to address the filter-clogging algae issue at the Lake Whatcom Water Treatment Plant, DAF was pilot testing during the summer of 2011 to confirm its performance. The pilot testing showed that DAF was very effective at removing algae from the Lake Whatcom supply. Not only was it effective at removing algae, but it was also shown to be effective at removing total organic carbon (TOC), reducing (by up to 25 percent) the formation potential for total trihalomethanes (TTHMs) – a key disinfection byproduct, and most-importantly it was shown to greatly extend filter runs. Extended filter runs results in increased total filter production during algae bloom conditions, which was the primary limitation during the 2009 Lake Whatcom algae bloom.

ES.4 DAF Implementation

In recognition of DAF's ranking as the best alternative for filter-clogging algae mitigation at the City's WTP, a discussion of DAF implementation was developed. Key elements of the implementation discussion relate to project schedule and options for reducing initial capital cost – should the City decide to pursue implementation of a DAF system. An example project schedule that reflects compliance with key Washington State Department of Health requirements and milestones is presented in Figure ES-2 at the end of this Executive Summary. The example schedule conveys the overall timeframe for DAF implementation.

A summary of the initial capital cost (construction and non-construction) for three DAF facility capacities, ranging from 30 mgd to 16 mgd is presented in Table ES-2. A three-train DAF system offers maximum redundancy and capacity to meet significant growth in long-term future customer water demand. The 2-train DAF options are geared toward matching initial capacity with recent trends in peak customer water demand and minimizing initial capital cost. Regardless of the initial capacity and the number of parallel treatment trains, a new DAF facility would be designed to be easily expanded if customer water demand changes.

TABLE ES-2
Summary of Initial Capital Cost for DAF Implementation Options

3-Train 30-mgd system	2-Train 20-mgd system	2-Train 16-mgd system
$ 14,500,000	$ 11,000,000	$ 10,400,000

ES.5 Recommendation

Annual seasonal Lake Whatcom algae blooms present an on-going seasonal risk to the City with respect to meeting the supply needs of its customers. As a result, the City should pursue the design and construction of a new DAF facility in a phased approach based on an initial two-train DAF facility with easy expansion for a potential future third train. The overall timeframe for this first phase of implementation, as well as key milestones, would be similar to that presented in Figure ES-2. A key ancillary benefit of DAF implementation based on the pilot testing completed in the late summer of 2011 is that DAF can be expected to lead to a reduction of the City's TTHMs by 25 percent.

The phased approach will eliminate the potential for constructing more DAF capacity than is necessary to ensure a continuous, reliable, high-quality drinking water supply – even during intense algae blooms in Lake Whatcom. The phased DAF-implementation approach complements the City's on-going commitment to lake management, water quality improvement, and TMDL compliance via the Lake Whatcom Management Program. Over the long-term future, as phosphorous-reducing lake management measures demonstrate success at improving water quality and reducing algae blooms, the need for further expansion of the initial phase of DAF implementation could potentially be avoided entirely.

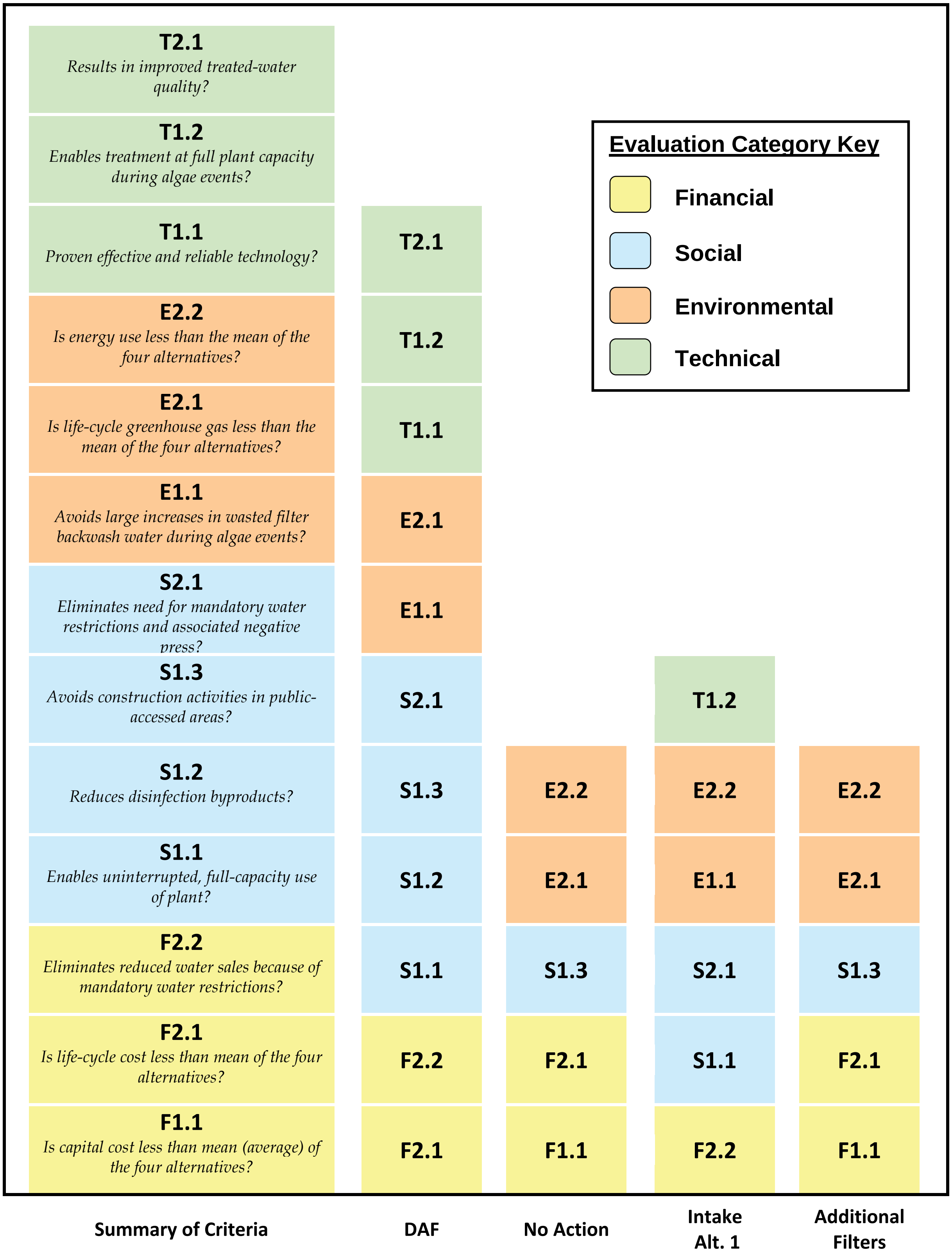

FIGURE ES-1
TBL+ Evaluation Results

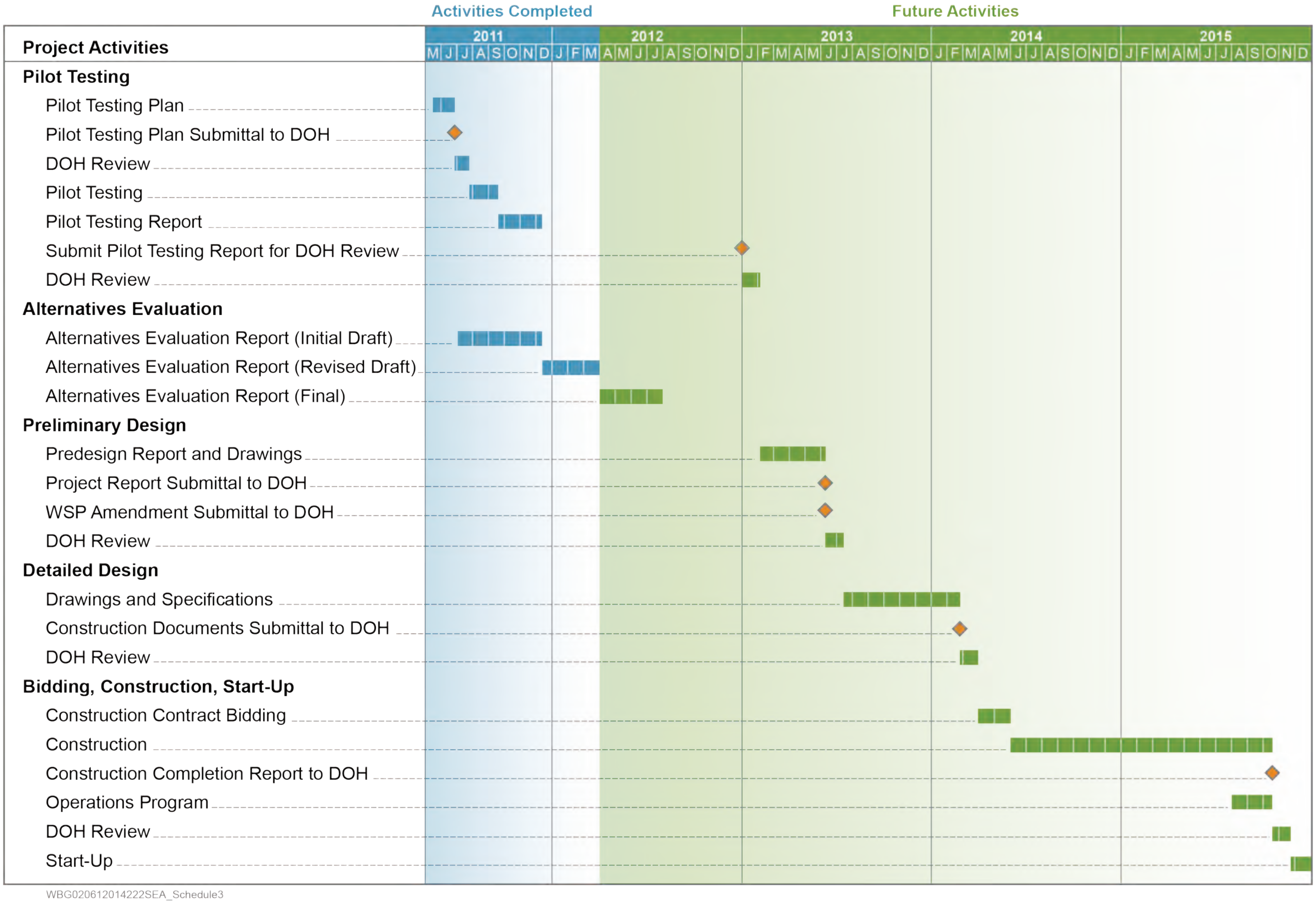

FIGURE ES-2
Example DAF Project Schedule

APPENDIX D
SEPA Compliance

PLANNING AND COMMUNITY DEVELOPMENT DEPARTMENT
210 Lottie Street, Bellingham, WA 98225
Telephone: (360) 778-8300 Fax: (360) 778-8302 TTY: (360) 778-8382

SEP2013-00029

Determination of Non-Significance (DNS)

Date of Issuance of Threshold Determination: August 7, 2013

Description of Proposal: Update to the City's 2009 Water System Plan. This update is a non-project action and does NOT replace the 2009 Water System Plan. The purpose of the 2013 Water System Plan Update (WSP Update) is to supplement the existing 2009 Plan with water system planning for the 6 and 20-year planning period AND to include the planned implementation of Dissolved Air Flotation (DAF) at the Whatcom Falls Water Treatment Plant. Elements of the 2013 WSP Update may be incorporated into the City's 2016 Comprehensive Plan Update.

Project Location: The WSP Update applies to the Bellingham Service Area (city limits) and those areas outside the city limits where water is provided by the city to other entities for distribution including; Whatcom County Water District #'s 2 and 7, Lummi Water and Sewer District, Deer Creek Association, Glen Cove Water Co-Op, Lake Whatcom Water and Sewer District, California Street and Montgomery Road Water Associations.

Proponent: City of Bellingham Public Works Department, Martin Kjelstad, contact, 360-778-7941 or email: mkjelstad@cob.org

Lead Agency: City of Bellingham, Planning and Community Development Department (PCDD).

Environmental Information Considered: SEPA Checklist including Part D Supplemental Sheet for non-project actions dated 7/17/2013 and *Preliminary* 2013 Water System Plan Update dated 1/13/2013 by CH2MHill.

The lead agency for this proposal has determined that the project does not have a probable adverse impact on the environment. An environmental impact statement is not required under RCW 43.21.C.030 (2) c. This decision was made after review of a completed environmental checklist on file with the lead agency. This information is available to the public on request.

This DNS is issued under WAC 197-11-340(2); the lead agency will not act on this proposal for 14-days from the date of this DNS. Comments must be submitted by Wednesday August 21, 2013.

Responsible Official: Jeff Thomas, Director
Planning and Community Development Department
210 Lottie Street, Bellingham, WA 98225

Signature________________________________

Staff Contact: Steven Sundin, Planner
Planning and Community Development Department
210 Lottie Street, Bellingham, WA 98225
(360) 778-8359 or email: ssundin@cob.org

Appeal rights: Pursuant to BMC 16.20.210(D), there is no administrative appeal of this environmental determination. The City of Bellingham seeks to comply with the American Disabilities Act. If you have special needs, please call (360) 778-8300 (voice) or (360) 676-6883 (TDD).

CITY OF BELLINGHAM WASHINGTON

RECEIVED

JUL 17 2013

City of Bellingham
Planning & Community Development

Planning

Permit Center
210 Lottie Street
Bellingham, WA 98225
phone: 360-778-8300
fax: 360-778-8301
www.cob.org

Land Use Application

Check all permits you are applying for in the boxes provided. Submit this application form, the applicable materials listed in the corresponding permit application packet(s) and application fee payment.

☐ Accessory Dwelling Unit ☐ Binding Site Plan ☐ Clearing Permit ☐ Conditional Use Permit ☐ Critical Area Permit ☐ Critical Area Exemption ☐ Design Review ☐ Grading Permit ☐ Home Occupation ☐ Institutional ☐ Interpretation ☐ Landmark – Historic Certificate of Alteration ☐ Legal Lot Determination ☐ Nonconforming Use Certificate	☐ Parking Adjustment Application ☐ Planned Development ☐ Rezone ☒ SEPA ☐ Shoreline Permit ☐ Shoreline Exemption ☐ Subdivision-Short Plat/Lot Line Adjustment ☐ Subdivision-Preliminary Plat ☐ Subdivision-Final Plat ☐ Variance ☐ Wireless Communication ☐ Zoning Compliance Letter ☐ Other:	**Office Use Only** Date Rcvd: 7/17/2013 Case #: SEP2013-29 Process Type: II Neighborhood: N/A Area Number: N/A Zone: " Pre-Ap. Meeting: " Concurrency: "

NON-PROJECT!

Project Address: 210 Lottie Street

Tax Assessor Parcel Number(s): N/A

Project Description: 2013 Water Plan Update

Applicant/Agent ☒ Primary Contact for Application

Name: City of Bellingham **Phone:** 360-778-7900

Address: 210 Lottie St. **Fax:** 360-778-7901

City, State, Zip: Bellingham, WA 98225 **E-mail:**

Owner(s) ☐ Applicant ☒ Primary Contact for Application

Name: Martin Kjelstad, Project Engineer **Phone:** 360-778-7941

Address: 210 Lottie St **Fax:** 360-778-7901

City, State, Zip: Bellingham WA 98225 **E-mail:** mkjelstad@cob.org

Property Owner(s)

I am the owner of the property described above or am authorized by the owner to sign and submit this application. I grant permission for the City staff and agents to enter onto the subject property at any reasonable time to consider the merits of the application and post public notice. I certify under penalty of perjury of the laws of the State of Washington that the information on this application and all information submitted herewith is true, complete and correct.

I also acknowledge that by signing this application I am the responsible party to receive all correspondence from the City regarding this project including, but not limited to expiration notifications. If I, at any point during the review or inspection process, am no longer the Applicant for this project it is my responsibility to update this information with the City in writing in a timely manner.

Signature by Owner/Applicant/Agent [signature], Date 7/17/2013

City and State where this application is signed: Bellingham (City), WA (State)

Exhibit C

State Environmental Policy Act Environmental Checklist

The State Environmental Policy Act (SEPA), chapter 43.21C RCW, requires all governmental agencies to consider the environmental impacts of a proposal before making decisions. An environmental impact statement (EIS) must be prepared for all proposals with probable significant adverse impacts on the quality of the environment. The purpose of this checklist is to provide information to help you and the agency identify impacts from your proposal (and to reduce or avoid impacts from the proposal, if it can be done) and to help the agency decide whether an EIS is required.

Checklist

The following sections contain the completed checklist. Checklist questions are in normal font and responses are in italic font.

Background

1. Name of proposed project, if applicable: *City of Bellingham 2013 Water System Plan Update*
2. Name of applicant: *Martin Kjelstad, Utilities Project Engineer, City of Bellingham*
3. Address and phone number of applicant and contact person:

   210 Lottie Street
   Bellingham, WA 98225
   Phone: (360) 778-8000

4. Date checklist prepared: *7/16/2013*
5. Agency requesting checklist: *City of Bellingham*
6. Proposed timing or schedule (including phasing, if applicable):

   The Plan Update will take effect after adoption by the City Council, and approval by WADOH, which is expected in mid 2013.

7. Do you have any plans for future additions, expansion, or further activity related to or connected with this proposal? If yes, explain.

   The plan update documents the City's strategy for continuing to provide safe and reliable potable water service to existing customers and increased service capacity. The proposal anticipates that growth based on the adopted population projections will result in increased demand for municipal water service. This demand will in turn create a need for extension of water distribution lines, *storage, and treatment facilities. The plan Update will be an element of the City Comprehensive Plan, and serves as a guide for the maintenance and expansion of the utility within the service area, in accordance with local, county, and state requirements.*

This plan Update is a guidance document for planning and design of future water system facilities and to help the City use its water resources in the most efficient manner possible. The City's water system provides water for about 27,380 household and businesses. The plan addresses all aspects of the City's water system in compliance with state requirements. The plan documents the existing water resources available to the City and evaluates supply enhancement options, provides a water conservation strategy, as well as operations and maintenance recommendations. The plan update provides a capital improvement program tied to the City's CIP that assures financial capability for phased implementation of the planning recommendations.

Projects listed in the capital improvement program are subject to review under WAC 197-11-704 and 197-11-800 and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 . While some projects might be categorically exempt, others will require preparation of a separate detailed checklist and SEPA threshold determination.

8. List any environmental information you know about that has been prepared, or will be prepared, directly related to this proposal.

   Under the authority of Chapter 197-11-635 WAC, the SEPA documents prepared for Bellingham' Comprehensive Plan are incorporated by reference herein. Additional documents directly related to the proposed Water System Plan include:

   a. Whatcom County Coordinated Water System Plan Update, 2009

9. Do you know whether applications are pending for governmental approvals of other proposals directly affecting the property covered by your proposal? If yes, explain.

   No other applications are known.

10. List any government approvals or permits that will be needed for your proposal, if known.

    The Water System Plan Update needs the approval of the City Council and WADOH. Individual elements of the capital improvement plan and extension of water lines greater than 8-inch-diameter will be subject to project SEPA review, and Whatcom County, or Bellingham Critical Area Review.

    Some projects that involve work in surface waters likely would require Hydraulic Project Approval from the Washington State department of Fish and Wildlife. Separate SEPA checklists must be prepared for projects that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22.

11. Give a brief, complete description of your proposal, including the proposed uses and the size of the project and site. There are several questions later in this checklist that ask you

to describe certain aspects of your proposal. You do not need to repeat those answers on this page.

The City proposes to update to its Water System Plan. The Plan Update is prepared to comply with the requirements of the WADOH as set forth in WAC 246-290-100. Adoption of this document is a non-project action designed to improve and update the existing Plan that was adopted by ordinance effective in 2009. The plan will apply throughout the incorporated limits of the City, areas of unincorporated Whatcom County specified as the out-of-city service area and where applicable, to users of contractual water service or supply.

This checklist covers the potential significant environmental impacts resulting from the adoption of the plan described above. Following adoption of this plan, other detailed regulations which implement the plan may be developed. Future SEPA reviews may be required for project actions undertaken to implement the adopted Plan (that is, construction of capital facilities).

The City retains the authority to impose site-specific mitigation measures to address probable significant adverse environmental impacts within the City limits or on water system projects where the City assumes lead agency. Under the authority of Chapter 197-11-635 WAC, the SEPA documents prepared for Bellingham's Comprehensive Plan are incorporated by reference herein; these documents include the Bellingham Comprehensive Plan.

12. Location of the proposal. Give sufficient information for a person to understand the precise location of your proposed project, including a street address, if any, and section, township, and range, if known. If a proposal would occur over a range of area, provide the range or boundaries of the site(s). Provide a legal description, site plan, vicinity map, and topographic map, if reasonably available. While you should submit any plans required by the agency, you are not required to duplicate maps or detailed plans submitted with any permit applications related to this checklist.

    SEPA review for this plan will apply to the entirety of the Bellingham Service Area. The service area is outlined in Figure 1-1 of the Water System Plan. The Water System Comprehensive Plan (the plan) applies to the water service utility of the City of Bellingham. In addition to serving commercial, residential and industrial connections within the city limits, the system provides water to the Whatcom County WD 2, Whatcom County WD 7, Lummi Water and Sewer District, Deer Creek Association, Glen Cove Water Co-Op, Lake Whatcom Water &Sewer District, California Street Water Association, and the Montgomery Road Water Association. The plan included under this SEPA review will apply to all areas within Bellingham's retail water service area and wholesale water service area.

Environmental Elements

1. Earth

    a. General description of the site: *Flat, rolling, hilly, steep slopes, and mountainous.*

    Bellingham rings the shore of Bellingham Bay to the west. It lies east of Mount Baker and Lake Whatcom. The water system planning area can be characterized as rolling with a series *of east to west trending valleys formed by streams and rivers traveling through the area of the City.*

b. What is the steepest slope on the site (approximate percent slope)?

Steep slopes greater than 30 percent represent a relatively small percentage of the City's total acreage. A majority of Bellingham's existing development has taken place in areas with slopes of less than 15 percent. Areas of steep slopes are concentrated on the City's perimeter, adjacent to the saltwater bodies that surround the area as well as along the creeks and rivers that flow through the City.

c. What general types of soils are found on the site (for example, clay, sand, gravel, peat, muck)? If you know the classification of agricultural soils, specify them and note any prime farmland.

The soils within Bellingham reflect the region's glacial geologic history. Sedimentary rocks of the Chuckanut Formation with a metamorphic rock called phyllite and glacially derived sand and gravel are exposed at the far south end of Lake Whatcom. The Chuckanut Formation, often referred to as Chuckanut Sandstone, extends from the Cascade Range to Lummi Island and is a group of rocks that includes layers of sandstone, conglomerate, shale, and coal.

d. Are there surface indications or history of unstable soils in the immediate vicinity? If so, describe.

Areas with a history of unstable soils exist in a number of locations throughout the City, including the vertical bluffs along the creeks and rivers that flow through the City. These areas are relatively stable under ordinary conditions. However, seismic events of moderate to high magnitude could cause slope failures, or exacerbate erosion and landslide hazards in areas where the bluff is fractured, or where talus slopes are low.

e. Describe the purpose, type, and approximate quantities of any filling or grading proposed. Indicate source of fill.

As a non-project action, the proposal does not involve site alterations of any kind. Future project actions that are not categorically exempt pursuant to Chapter 197-11-800 WA and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 , and which require issuance of a City license or permit will be subject to review under the City and Whatcom County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

f. Could erosion occur as a result of clearing, construction, or use? If so, generally describe.

Because the proposal is a non-project action, it will not result in clearing or construction-related erosion. Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master

Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City of Bellingham or Whatcom County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

g. About what percent of the site will be covered with impervious surfaces after project construction (for example, asphalt or buildings)?

The proposal is a non-project action that does not involve construction of impervious surfaces.

h. Proposed measures to reduce or control erosion, or other impacts to the earth, if any:

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City of Bellingham or Whatcom County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

2. Air

a. What types of emissions to the air would result from the proposal (that is, dust, automobile, odors, and industrial wood smoke) during construction and when the project is completed? If any, generally describe and give approximate quantities if known.

Because the proposal is a non-project action, it does not involve construction, and will not result in emissions to the air. It is acknowledged, however, that regardless of the proposed action reviewed herein, continued development activity will increase the amount of air pollution in the Bellingham Area (for example, through the location of new sources or through increases in automobile traffic).

Are there any off-site sources of emissions or odor that may affect your proposal? If so, generally describe.

No. As a non-project action, the proposal will neither result in any emissions or odors, nor will it be affected by such emissions.

b. Proposed measures to reduce or control emissions or other impacts to air, if any:

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

3. Water

   a. Surface:

      i. Is there any surface water body on or in the immediate vicinity of the site (including year-round and seasonal streams, saltwater, lakes, ponds, wetlands)? If yes, describe type and provide names. If appropriate, state what stream or river it flows into.

         Numerous named and unnamed streams flow through the water system's planning area into Bellingham Bay. Named streams include Whatcom Creek, Squalicum Creek, Chuckanut Creek, and Padden Creek.

      ii. Will the project require any work over, in, or adjacent to (within 200 feet) the described waters? If yes, please describe and attach available plans.

         No. Because the action is a non-project proposal, it will not involve any work over, in, or adjacent to the waters described above. The City and County will continue to require either a shoreline substantial development permit or a shoreline permit exemption for any project-related work occurring within 200 feet of the jurisdictional waters described above. Operation of the municipal diversions and transmission pipeline will continue to require operation in, over and adjacent to various water bodies including the Middle Fork of the Nooksack River, Whatcom Creek, Anderson Creek, and Lake Whatcom.

      iii. Estimate the amount of fill and dredge material that would be placed in or removed from surface water or wetlands and indicate the area of the site that would be affected. Indicate the source of fill material.

         Because the proposal is a non-project action, it does not involve fill and dredge material. Future project applications that involve the removal or placement of dredge or fill materials would be subject to review and mitigation under the City's Shoreline Management Master Program.

         Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

      iv. Will the proposal require surface water withdrawals or diversions? Give general description, purpose, and approximate quantities if known.

         Bellingham water source is a diversion from the Middle Fork of the Nooksack River under the Safe Drinking Water Act.

      v. Does the proposal lie within a 100-year floodplain? If so, note location on the site plan.

Portions of the water system plan's planning area lie within 100-year floodplains.

vi. Does the proposal involve any discharges of waste materials to surface waters? If so, describe the type of waste and anticipated volume of discharge.

None. Because the proposal is a non-project action, it does not involve any discharges of waste materials.

b. Ground

i. Will ground water be withdrawn, or will water be discharged to ground water? Give general description, purpose, and approximate quantities if known.

No

ii. Describe waste material that will be discharged into the ground from septic tanks or other sources, if any (for example: Domestic sewage; industrial, containing the following chemicals...; agricultural; etc.). Describe the general size of the system, the number of such systems, the number of houses to be served (if applicable), or the number of animals or humans the system(s) are expected to serve.

No

c. Water runoff (including stormwater)

Because the proposal is a non-project action, it will not result in additional sources of runoff. Development that is fostered by the availability of public water service could increase the City's cumulative total of impervious surfaces, leading to increases of stormwater flow. The potential increase of runoff in the City and County has not been assessed.

i. Describe the source of runoff (including storm water) and method of collection and disposal, if any (include quantities, if known). Where will this water flow? Will this water flow into other waters? If so, describe.

As a non-project action, the proposal does not include any measures designed specifically to reduce or control surface, ground, and runoff water impacts. Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

ii. Could waste materials enter ground or surface waters? If so, generally describe.

As a non-project action the proposal does not involve the discharge of waste materials. Discharge of treated wastewater to Bellingham Bay will increase in proportion to population growth. Future project-level actions which require issuance of any state or *local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.*

d. Proposed measures to reduce or control surface, ground, and runoff water impacts, if any:

As a non-project action, the proposal does not include any measures designed specifically to reduce or control surface, ground, and runoff water impacts. However, future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

4. Plants

a. Check or circle types of vegetation found on the site:

X deciduous tree: alder, maple, aspen, other

X evergreen tree: fir, cedar, pine, other

X shrubs

X grass

X pasture

X crop or grain

X wet soil plants: cattail, buttercup, bullrush, skunk cabbage, other

X water plants: water lily, eelgrass, milfoil, other

X other types of vegetation

Bellingham and the out-of-city service areas support a diversity of native and nonnative plants, including all of the species listed above. Native shrubs, herbs, grasses, and wetland plants also exist within the Planning Area. The shorelines support a variety of estuarine and marine aquatic vegetation.

b. What kind and amount of vegetation will be removed or altered?

Because the proposal is a non-project, programmatic action, it would not involve the removal or alteration of vegetation. Continued development activity will result in increased native vegetation removal.

c. List threatened or endangered species known to be on or near the site.

Documented habitats for endangered, threatened, and priority species are known to exist within Bellingham and the out-of-city service area. These areas have been designated on Whatcom County Critical Area maps.

d. Proposed landscaping, use of native plants, or other measures to preserve or enhance vegetation on the site, if any:

Because the proposal is a non-project, programmatic action, it does not directly involve landscaping or vegetation enhancement. Vegetation removal in Critical Areas is reviewed and conditioned under City and County ordinances.

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

5. Animals

a. List any birds and animals which have been observed on or near the site or are known to be on or near the site:

birds: hawk, heron, eagle, songbirds, other

mammals: deer, bear, elk, beaver, other

fish: bass, salmon, trout, herring, shellfish, other

The water service area and the source watershed contains a variety of habitat types that provide shelter, feeding and breeding sites for a number of migrating and indigenous bird species. Rare and endangered species sighted in Whatcom County include the northern bald eagle and the peregrine falcon. Important bird species known to exist within the area include: great blue herons; common loon; brandt geese; harlequin ducks; pigeon guillemots; coots; ruddy ducks; hooded mergansers; red winged black birds; belted king fishers; and mallard ducks.

Large and medium sized mammals such as deer, coyotes, skunks, and otters are found within the City limits. Bear, cougar, fox, beaver, and elk occur in the out-of-town service area and related watersheds. For further information, refer to the Comprehensive Plan.

Puget Sound bull trout, chinook salmon and Hood Canal summer chum have been listed as threatened under Endangered Species Act. Additional fish in the vicinity of the service area *include coho and pink salmon, steelhead and cutthroat trout and variety of saltwater species. Shorelines and creeks provide habitat for various life stages of these fish.*

b. List any threatened or endangered species known to be on or near the site.

As noted above, rare and endangered species sighted in the service area and watersheds include bull trout, chinook and Hood Canal summer chum salmon, northern spotted owl, marbled murrelet, and the northern bald eagle. The Southern Resident orca whale, listed as an endangered species, range includes water in the vicinity of Bellingham.

c. Is the site part of a migration route? If so, explain.

The water service area and municipal watershed lie within the Pacific Flyway. Consequently, numerous waterfowl use the wetlands, ponds, and surrounding marine waters as a migratory rest stop, or as a permanent wintering area.

d. Proposed measures to preserve or enhance wildlife, if any:

Because the proposal is a non-project, programmatic action, it does not directly involve impacts to wildlife.

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

6. Energy and natural resources

a. What kinds of energy (electric, natural gas, oil, wood stove, solar) will be used to meet the completed project's energy needs? Describe whether it will be used for heating, manufacturing, etc.

The principal energy sources associated with the planning area are electricity, propane, natural gas, and petroleum. Electrical power, propane, natural gas, and petroleum have historically all been provided for heating, lighting, operation of electrical appliances and manufacturing. Population growth is likely to occur regardless of this non-project proposal. As this growth and associated development occurs, the demand for sources of energy will increase. As a non-project action, the proposal would not create any additional needs for energy. Future water treatment requirements may require technologies such as ultraviolet light disinfection, which would increase the water system electric energy usage.

b. Would your project affect the potential use of solar energy by adjacent properties? If so, generally describe.

As a non-project action, the proposal would not affect solar energy by adjacent properties.

c. What kinds of energy conservation features are included in the plans of this proposal? List other proposed measures to reduce or control energy impacts, if any:

Because the proposal is a non-project action, no specific energy conservation measures are proposed.

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

7. Environmental Health

a. Are there any environmental health hazards, including exposure to toxic chemicals, risk of fire and explosion, spill, or hazardous waste that could occur as a result of this proposal? If so, describe.

Because the proposal is a non-project action, no environmental health hazards are posed.

i. Describe special emergency services that might be required.

Because the proposal is a non-project action, no emergency services will be required.

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

ii. Proposed measures to reduce or control environmental health hazards, if any:

Because the proposal is a non-project action, no specific measures are proposed to reduce or control environmental health hazards.

b. Noise

i. What types of noise exist in the area which may affect your project (for example, traffic, equipment, operation, other)?

Because the proposal is a non-project action, it will not be affected by, noise.

ii. What types and levels of noise would be created by or associated with the project on a short-term or a long-term basis (for example: traffic, construction, operation, other)? Indicate what hours noise would come from the site.

Because the proposal is a non-project action, it will not generate noise on either a short or a long-term basis.

iii. Proposed measures to reduce or control noise impacts, if any:

None are proposed.

8. Land and shoreline use

a. What is the current use of the site and adjacent properties?

The proposal is to adopt a water system plan that includes strategies for providing future water service to land within the City of Bellingham and areas of unincorporated Whatcom County. The Water System Comprehensive Plan is a functional element of the City Comprehensive Plan that provides a more detailed report on existing conditions within the City. The plan implements the goals and policies of the City of Bellingham Comprehensive Plan and is consistent with land use regulations adopted in accordance with the Comprehensive Plan.

b. Has the site been used for agriculture? If so, describe.

Citywide, Bellingham does not have any land exclusively zoned for agricultural uses. There are areas in the UGA zoned for commercial forest and rural use that allow for a wide range of agricultural uses.

c. Describe any structures on the site.

Bellingham possesses a diverse range of residential, commercial, manufacturing, and public/institutional structures, including many Victorian era homes and downtown commercial and public buildings.

d. Will any structures be demolished? If so, what?

No. Because the proposal is a non-project action, it will not involve the demolition of any structures.

e. What is the current zoning classification of the site?

Zoning varies within City Limits as described in Title 20 of the BMC and within the UGA and other service areas according to WCC Title 20.

f. What is the current comprehensive plan designation of the site?

Bellingham Comprehensive Plan, was adopted in June, 1980 and last updated in 2005 designates the city's retail service area as Urban. The Whatcom County Comprehensive Plan was adopted in 1996 and last revised in 2008 established the Urban Growth Area that the City serves with potable water.

g. If applicable, what is the current shoreline master program designation of the site?

None of the proposed policy changes directly relate to shorelines.

h. Has any part of the site been classified as an "environmentally sensitive" area? If so, specify.

Yes. The City keeps a map of environmentally sensitive areas on file. An assessment of the Critical Areas in the out-of-city service area in Whatcom County is on file with Whatcom County.

i. Approximately how many people would reside or work in the completed project?

Because the proposal is a non-project action this question is inapplicable. The 2000 census estimated the population within Bellingham was 67,171.

j. Approximately how many people would the completed project displace?

Because the proposal is a non-project action no displacement impacts are anticipated.

k. Proposed measures to avoid or reduce displacement impacts, if any:

Because the proposal is a non-project action, no displacement impact mitigation is proposed.

l. Proposed measures to ensure the proposal is compatible with existing and projected land uses and plans, if any:

The proposal is a non-project action; however, it is a component of and consistent with the Bellingham Comprehensive Plan.

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

9. Housing

a. Approximately how many units would be provided, if any? Indicate whether high, middle, or low-income housing.

No housing will be provided as part of this project.

b. Approximately how many units, if any, would be eliminated? Indicate whether high, middle, or low-income housing.

No housing will be eliminated as part of this project.

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of

Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

c. Proposed measures to reduce or control housing impacts, if any:

None needed.

10. Aesthetics

a. What is the tallest height of any proposed structure(s), not including antennas; what is the principal exterior building material(s) proposed?

As a non-project programmatic action, the proposal does not involve the construction of any structures.

b. What views in the immediate vicinity would be altered or obstructed?

As a non-project programmatic action, the proposal does not involve the alteration or obstruction of views.

c. Proposed measures to reduce or control aesthetic impacts, if any:

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

11. Light and glare

a. What type of light or glare will the proposal produce? What time of day would it mainly occur?

Because the proposal is a non-project programmatic action, it would not produce any light or glare. Levels of artificial lighting and glare will increase with population and business growth in the Planning Area.

b. Could light or glare from the finished project be a safety hazard or interfere with views?

Because the proposal is a non-project action, it would not create light or glare safety hazards or view obstructions. Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project *actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.*

c. What existing off-site sources of light or glare may affect your proposal?

None. As a non-project action, the proposal would not be affected by light or glare.

d. Proposed measures to reduce or control light and glare impacts, if any:

No measures are proposed. Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

12. Recreation

a. What designated and informal recreational opportunities are in the immediate vicinity?

The City has many parks, a waterfront trail, and a boat launch. Additional recreation opportunities abound in the mountains to the east of Bellingham.

b. Would the proposed project displace any existing recreational uses? If so, describe.

No, because the proposal is a non-project action it would not affect existing recreational uses.

c. Proposed measures to reduce or control impacts on recreation, including recreation opportunities to be provided by the project or applicant, if any:

None required.

13. Historic and Cultural Preservation

a. Are there any places or objects listed on, or proposed for, national, state, or local preservation registers known to be on or next to the site? If so, generally describe.

Because the proposal is a non-project action, it would not directly affect historical sites. The City has a long history and many historic buildings.

b. Generally describe any landmarks or evidence of historic, archaeological, scientific, or cultural importance known to be on or next to the site.

Several Native American tribes populated the area well before the City was founded. There were also several small communities that developed and receded during the boom and bust cycles of the 1800s. This history indicates that archaeologically and historically important sites likely exist within the planning area.

c. Proposed measures to reduce or control impacts, if any:

Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

14. Transportation

a. Identify public streets and highways serving the site, and describe proposed access to the existing street system. Show on site plans, if any.

Because the proposal is a non-project action, it is not directly served by public streets.

b. Is site currently served by public transit? If not, what is the approximate distance to the nearest transit stop?

Because the proposal is a non-project action, it does not directly affect public transit operations.

The Whatcom Transit Authority provides service to the Planning Area.

c. How many parking spaces would the completed project have? How many would the project eliminate?

Because the proposal is a non-project action, it does not directly involve the creation or elimination of parking spaces.

d. Will the proposal require any new roads or streets, or improvements to existing roads or streets, not including driveways? If so, generally describe (indicate whether public or private).

Because the proposal is a non-project action, it does not directly involve the creation of new streets or improvement to existing roads.

e. Will the project use (or occur in the immediate vicinity of) water, rail, or air transportation? If so, generally describe.

The proposed action would not seek to employ water, rail, or air transportation facilities.

f. How many vehicular trips per day would be generated by the completed project? If known, indicate when peak volumes would occur.

Because the proposal is a non-project action, it would not directly generate any vehicle trips.

g. Proposed measures to reduce or control transportation impacts, if any:

None are proposed.

15. Public Services

a. Would the project result in an increased need for public services (for example: fire protection, police protection, health care, schools, other)? If so, generally describe.

Because the proposal is a non-project action, it will not generate a requirement for increased public services. The plan provides analysis of existing conditions with regard to water service available for potable use and fire protection. This analysis allows for development of improvement recommendations consistent with the goals and policies of the City Comprehensive Plan. The Plan defines the City's intended measures to reduce or control impacts of growth with regard to water service and related public services.

b. Proposed measures to reduce or control direct impacts on public services, if any.

Implementation of the Capital Improvement Element of the Bellingham Comprehensive Plan will reduce or control future impacts to public services. Future project-level actions which require issuance of any state or local permit or license; and that are not categorically exempt under Chapter 197-11-800 WAC and City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will be subject to review under the City and County SEPA Ordinances (Chapter 16.20 BMC, Chapter 16.08 WCC). After reviewing applications for such project actions, the City or County may determine that mitigation measures are necessary to avoid probable significant adverse environmental impacts.

16. Utilities

a. The following utilities are currently available at the site: electricity, natural gas, water, refuse service, telephone, sanitary sewer, septic system.

All of the above utilities are found in the planning area. For more detailed information, please refer to the Comprehensive Plan.

b. Describe the utilities that are proposed for the project, the utility providing the service, and the general construction activities on the site or in the immediate vicinity which might be needed.

As growth and development occurs, demands for public services will increase. The Capital Facilities & Utilities Element of the Comprehensive Plan is intended to ensure that new growth and development is provided with adequate public services and facilities concurrent with the approval of new development.

Signature

The above answers are true and complete to the best of my knowledge. I understand that the lead agency is relying on them to make its decision.

Signature: [signature] 7/17/13

Date Submitted:

Supplemental Sheet for Non-Project Actions

Because these questions are very general, it may be helpful to read them in conjunction with the list of the elements of the environment.

When answering these questions, be aware of the extent the proposal, or the types of activities likely to result from the proposal, would affect the item at a greater intensity or at a faster rate than if the proposal were not implemented. Respond briefly and in general terms.

1. How would the proposal be likely to increase discharge to water; emissions to air; production, storage, or release of toxic or hazardous substances; or production of noise?

   The proposed adoption of the Water System Comprehensive Plan will not alter any existing requirements for environmental review under Chapters 16.20 BMC (that is, the SEPA Implementing Ordinance). Environmental review for plan related proposals in the UGA would be conducted under existing Whatcom County Ordinance. These provisions will continue to be employed in the review and mitigation of individual project applications. Possible indirect affects of the proposed action relating to water, air, environmental health, and noise are summarized below:

   Withdrawal and/or Discharges to Water: *The City of Bellingham Water System Comprehensive Plan outlines a program to utilize the existing water rights. Growth in the City and UGA will cause an increase in the amount of wastewater discharged to Bellingham Bay.*

   Emissions to air, release of toxic or hazardous substances, and noise: *The potential adverse environmental impacts of urban growth relating to increased emissions are not significant as discussed in the Bellingham Comprehensive Plan.*

   Proposed measures to avoid or reduce such increases are:

   Withdrawals of Surface and Ground Water: *The Conservation Chapter of the Water System Plan outlines the City's programs to promote the efficient use of water resources. As feasible opportunities are identified the City will also pursue wastewater reuse to reduce demands on the water system.*

   Emissions to air, release of toxic or hazardous substance, and noise: *No measures are proposed beyond project specific environmental review and enforcement of implementing ordinances in compliance with the City Comprehensive Plan.*

2. How would the proposal be likely to affect plants, animals, fish, or marine life?

   The Plan will not directly affect plants, animals, fish, or marine life. Growth and development within the service area may negatively impact plant and animal populations. Surface water *withdrawals could impact these resources through lower instream flows that affect the migration, spawning, and rearing habitat of fish.*

Proposed measures to protect or conserve plants, animals, fish, or marine life are:

Adoption of this water system plan would not require inclusion of any specific measures to conserve plants, animals, fish, or marine life. City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will require mitigation for the protection and conservation of plants, animals, fish and marine life.

3. How would the proposal be likely to deplete energy or natural resources?

The proposal would not directly deplete energy or natural resources. Growth and development in the service area will consume energy and natural resources.

Proposed measures to protect or conserve energy and natural resources are:

The proposal does not require inclusion of any specific measures to conserve energy. The City's watershed management programs and water conservation programs conserve and protect a broad range of natural resources. City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will require the protection or avoidance to reduceimpacts

4. How would the proposal be likely to use or affect environmentally sensitive areas or areas designated (or eligible or under study) for governmental protection; such as parks, wilderness, wild and scenic rivers, threatened or endangered species habitat, historic or cultural sites, wetlands, floodplains, or prime farmlands?

The proposal would not affect environmentally sensitive areas or areas designated for governmental protection.

Proposed measures to protect such resources or to avoid or reduce impacts are:

City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will require the protection or avoidance to reduce impacts.

5. How would the proposal be likely to affect land and shoreline use, including whether it would allow or encourage land or shoreline uses incompatible with existing plans?

Availability of water within the designated service area is consistent with the adopted land use plans of both the City of Bellingham and Whatcom County. The Water System Plan is also consistent with shoreline designations in the City of Bellingham Shoreline Master Program. Potential impacts of changes in land and shoreline use were assessed in the City of Bellingham's and Whatcom County's Comprehensive Plans.

No specific measures have been proposed.

Proposed measures to avoid or reduce shoreline and land use impacts are:

No specific measures have been proposed. The plan contains policies that assure compatibility with adopted land use designations including those within the Shoreline Management Program *jurisdiction within the City of Bellingham and in the unincorporated areas of Whatcom County. City of Bellingham Critical Area, BMC 16.55 and City of Bellingham Shoreline Master Program, BMC 22 will require the protection or avoidance to reduce impact and provide mitigation.*

6. How would the proposal be likely to increase demands on transportation or public services and utilities?

   The proposal provides mechanism to assure adequate public water service and supply to the adopted water service area.

   Proposed measures to reduce or respond to such demand(s) are:

   Not applicable.

7. Identify, if possible, whether the proposal may conflict with local, state, or federal laws or requirements for the protection of the environment.

   No aspect of the proposal is in conflict with local, state, or federal laws, or requirements for the protection of the environment. The proposal complies with the Washington State enforcement of the Federal Safe Drinking Water Act and the WADOH requirements under 246-290-100 WAC regarding water system plans.

Starr, Fiona E.

From:	Starr, Fiona E.
Sent:	Wednesday, August 07, 2013 11:08 AM
To:	'sepaunit@ecy.wa.gov'; 'separegister@ecy.wa.gov'; 'susan.murron@ecy.wa.gov'; 'pds@co.whatcom.wa.us'; 'joriburnett@cityofferndale.org'
Cc:	Sundin, Steven C.
Subject:	SEP2013-00029 DNS
Attachments:	SEP2013-00029 DNS.pdf; SEP2013-00029Exhibit C Env.Checklist.pdf

SEP2013-00029

Determination of Non-Significance (DNS)

Date of Issuance of Threshold Determination: August 7, 2013

Description of Proposal: Update to the City's 2009 Water System Plan. This update is a non-project action and does NOT replace the 2009 Water System Plan. The purpose of the 2013 Water System Plan Update (WSP Update) is to supplement the existing 2009 Plan with water system planning for the 6 and 20-year planning period AND to include the planned implementation of Dissolved Air Flotation (DAF) at the Whatcom Falls Water Treatment Plant. Elements of the 2013 WSP Update may be incorporated into the City's 2016 Comprehensive Plan Update.

Project Location: The WSP Update applies to the Bellingham Service Area (city limits) and those areas outside the city limits where water is provided by the city to other entities for distribution including; Whatcom County Water District #'s 2 and 7, Lummi Water and Sewer District, Deer Creek Association, Glen Cove Water Co-Op, Lake Whatcom Water and Sewer District, California Street and Montgomery Road Water Associations.

Proponent: City of Bellingham Public Works Department, Martin Kjelstad, contact, 360-778-7941 or email: mkjelstad@cob.org

Lead Agency: City of Bellingham, Planning and Community Development Department (PCDD).

This DNS is issued under WAC 197-11-340(2); the lead agency will not act on this proposal for 14-days from the date of this DNS. Comments must be submitted by Wednesday August 21, 2013.

Staff Contact: Steven Sundin, Planner
Planning and Community Development Department
210 Lottie Street, Bellingham, WA 98225
(360) 778-8359 or email: ssundin@cob.org

Fiona Starr, Office Assistant
Planning & Community Development, City of Bellingham
210 Lottie Street, Bellingham WA 98225
360-778-8300 (main) 360-778-8357 (direct)
fstarr@cob.org

Planning
Permit Center
210 Lottie Street
Bellingham, WA 98225
phone: 360-778-8300
fax: 360-778-8301
www.cob.org

DECLARATION OF MAILING

Project/Permit No.: SEP2013-00029

I, Fiona Starr, declare the following:

I am an employee of the City of Bellingham Planning and Community Development Department, over the age of 18, a resident of the State of Washington and have no interest in the proposal described in the attached notice. I certify that I mailed a true and correct copy of the attached notice to recipients on the attached list, postage prepaid.

Dated this 7th day of August, 2013 at Bellingham, Washington.

[signature]
Signature

WDFW REGION 4
ATTN SEPA COORDINATOR
16018 MILL CREEK BLVD
MILL CREEK WA 98012-1296

NOOKSACK TRIBAL COUNCIL
C/O FISHERIES MANAGER
PO BOX 157
DEMING WA 98244

LUMMI NATION
TRIBAL HISTORIC OFFICE
2616 KWINA ROAD
BELLINGHAM WA 98226

WHATCOM COUNTY HEALTH DEPT.
INTEROFFICE MAIL

WCWD # 2
1615 BAYON RD
BELLINGHAM WA 98225

LUMMI TRIBAL SEWER & WATER
DISTRICT
2156 LUMMI VIEW DR
BELLINGHAM WA 98226

DEER CREEK WATER ASSOCIATION
PO BOX 30230
BELLINGHAM WA 98228

LAKE WHATCOM WATER & SEWER
DISTRICT
1220 LAKEWAY DR
BELLINGHAM WA 98226

GLEN COVE WATER CORPORATION
1623 EUCLID AVE
BELLINGHAM WA 98229

DNS MAILING LIST
Last updated 03/21/2012

1(A)	DEPT OF ECOLOGY ENVIRON REVIEW SECTION P O BOX 47703 OLYMPIA, WA 98504-7703	DNS and Checklist, **REQUIRED NOTIFICATION, ALL PUBLISHED SEPAS** E_MAIL: sepaunit@ecy.wa.gov
1(B)	SUSAN MURRON DEPT OF ECOLOGY 1440 10TH ST STE 102 BELLINGHAM WA 98225-7028	DNS and Checklist, **REQUIRED NOTIFICATION, ALL PUBLISHED SEPAS** E_MAIL: susan.murron@ecy.wa.gov
1(C)	CHAD YUNGE DEPT OF ECOLOGY 1440 10TH ST STE 102 BELLINGHAM WA 98225-7028	FOR SHORELINE PERMITS ONLY - DNS & Checklist, REQUIRED NOTIFICIATION, ALL PUBLISHED SEPAS E-MAIL: cyun461@ecy.wa.gov
2	US ARMY CORP OF ENG Attn: Randel Perry 1440 10th St #102 BELLINGHAM, WA 98225	DNS and Checklist, Anything involving wetlands E_MAIL: randel.j.perry@usace.army.mil
3	WDFW, REGION 4 ATTN: SEPA COORDINATOR 16018 MILL CREEK BLVD MILL CREEK, WA 98012-1296	DNS and Checklist, Anything involving fish or wildlife
4	JEFF KAMPS WDFW, REGION 4 PO BOX 1100 LA CONNER, WA 98257-1100	DNS and Checklist, FRESH WATER including Lake Whatcom and fish and wildlife within City of Bellingham.
	BRIAN WILLIAMS WDFW, REGION 4 Same address	DNS and Checklist, MARINE WATERS including estuaries
5	DNR NW REGIONAL OFFICE 919 TOWNSHIP STREET SEDRO-WOOLLEY, 98284-9384.	DNS and Checklist, Anything involving logging or major clearing
6	NOOKSACK TRIBAL COUNCIL C/O FISHERIES MANAGER P O BOX 157 DEMING, WA 98244	DNS Only, Anything involving fish-bearing water bodies
7	LUMMI NATION TRIBAL HISTORIC OFFICE 2616 KWINA ROAD BELLINGHAM, WA 98226	DNS and Checklist, Anything involving fish-bearing water bodies
8	WHATCOM CO. HEALTH DEPT Inter-Office Mail	DNS and Checklist, Anything involving septic systems or potable water
9	RON COWAN BHAM SCHOOL DISTRICT 1306 DUPONT BELLINGHAM, WA 98225	DNS and Checklist, Anything involving schools or significant enrollment increases
10	NEIGHBORHOOD REP	DNS Only, Courtesy Notice, All

	(SEE LIST OF MAYOR'S REPS)	published SEPAS
11	NSEA info@n-sea.org	DNS Only, Courtesy Notice, Anything involving water. Email notification.
12	BELLINGHAM HERALD Community News Department 1155 North State St Bellingham, WA 98225	DNS Only, Large or Controversial Projects Only
13	OFFICE OF ARCHAEOLOGY & HISTORIC PRESERVATION P O BOX 48343 OLYMPIA, WA 98504-8343	DNS and Checklist, Anything involving historic buildings or archaeology
14	MIKE STONER PORT OF BELLINGHAM P.O. BOX 1677 BELLINGHAM, WA 98227-1677	DNS and Checklist, Anything involving the Port of Bellingham
15	DEPT. OF TRANSPORTATION ROLAND STORME (no physical address listed)	DNS and Checklist, Anything involving State Highways e-mail: roland.storme@wsdot.wa.gov
16	NW CLEAN AIR AGENCY 1600 S 2[ND] ST MT VERNON, WA 98273	DNS and Checklist, Anything involving dust, discharges to air, or asbestos
17	J.E. "SAM" RYAN, CBO WHATCOM CO. PLANNING DEPT. 5280 NORTHWEST DR, STE B BELLINGHAM, WA 98226	DNS and Checklist, Anything involving Whatcom County or Lake Whatcom email: pds@co.whatcom.wa.us
18	EPA 1200 6TH AVE SEATTLE, WA 98101	DNS and Checklist, NEPA Only
19	RENEE LaCROIX ENVIRONMENTAL RESOURCES DIV PUBLIC WORKS DEPARTMENT	DNS for any project involving development adjacent to streams, wetlands or Bellingham Bay.
21	JORI BURNETT, DIRECTOR COMMUNITY DEVELOPMENT	DNS and Checklist, Anything involving the Northern UGA email: JoriBurnett@cityofferndale.org
20	Entire Planning Group	E_MAIL: grp_pcd@cob.org

Whatcom County Water District #7

· WCWD7@qwestoffice.net

WCWD #2

· 1615 Bayon Road

Bellingham, WA 98225

~~Lummi Water and Sewer District~~

Lummi Tribal Sewer and Water District

, 2156 Lummi View Drive

Bellingham, WA 98226

Deer Creek Water Association

PO BOX 30230

Bellingham, WA 98228

Lake Whatcom Water and Sewer District

1220 Lakeway Drive

Bellingham WA 98226

Glen Cove Water ~~Cooper~~ Corporation

1623 Euclid Ave

Bellingham 98229

APPENDIX E
Review Consistency

Washington State Department of Health
Division of Environmental Health
Office of Drinking Water

Local Government Consistency Review Checklist

Water System Name: City of Bellingham PWS ID: 05600

Planning/Engineering Document Title: 2013 Water System Plan Update Plan Date: update 1/2013

Local Government with Jurisdiction: City of Bellingham

WAC 246-290-108 Consistency with local plans and regulations:
Consistency with local plans and regulations applies to planning and engineering documents under WAC 246-290-106, 246-290-107, and 246-290-110(4)(b (ii).

1) Municipal water suppliers must include a consistency review and supporting documentation in its planning or engineering document describing how it has addressed consistency with **local plans and regulations**. This review must include specific elements of local plans and regulations, as they reasonably relate to water service as determined by Department of Health (DOH). Complete the table below and see instructions on back.

Local Government Consistency Statement	Page(s) in Planning Document	Yes – No – Not Applicable
a) The water system service area is consistent with the adopted land use and zoning within the applicable service area.	Original WSP	
b) The six-year growth projection used to forecast water demand is consistent with the adopted city/county's population growth projections. If a different growth projection is used, provide an explanation of the alternative growth projection and methodology.	Original Water System Plan	
c) Applies to cities and towns that provide water service: All water service area policies of the city or town are consistent with the utility service extension ordinances of the city or town.	Original WSP	
d) Service area policies for new service connections are consistent with the adopted local plans and adopted development regulations of all jurisdictions with authority over the service area [City(ies), County(ies)].	Original WSP	
e) Other relevant elements related to water supply are addressed in the water system plan, if applicable; Coordinated Water System plans, Regional Wastewater plans, Reclaimed Water plans, Groundwater Area Management plans, and Capital Facilities Element of Comprehensive plans.	Original Water System Plan	

I certify that the above statements are true to the best of my knowledge and that these specific elements are consistent with adopted local plans and development regulations.

[signature] Date: 7/17/13

Signature

Martin Kjelstad, Project Engineer, City of Bellingham Public Works

Printed Name, Title, & Jurisdiction

Consistency Review Guidance

For Use by Local Governments and Municipal Water Suppliers

This checklist may be used to meet the requirements of WAC 246-290-108. When using an alternative format, it must describe all of the elements; 1a), b), c), d), and e), when they apply.

For **water system plans (WSP)**, a consistency review is required for the retail service area and any additional areas where a municipal water supplier wants to expand its water right's place of use.

For **small water system management programs**, a consistency review is only required for areas where a municipal water supplier wants to expand its water right's place of use. If no water right place of use expansion is requested, a consistency review is not required.

For **engineering documents**, a consistency review is required for areas where a municipal water supplier wants to expand its water right's place of use (water system plan amendment is required). For non-community water systems, a consistency review is required when requesting a place of use expansion. All engineering documents must be submitted with a service area map per WAC 246-290-110(4)(b)(ii).

A) Documenting Consistency: Municipal water suppliers must document all of the elements in a consistency review per WAC 246-290-108.

1 a) Provide a copy of the adopted **land use/zoning** map corresponding to the service area. The uses provided in the WSP should be consistent with the adopted land use/zoning map. Include any other portions of comprehensive plans or development regulations that are related to water supply planning.

1 b) Include a copy of the **six-year growth projections** that corresponds to the service area. If the local population growth rate projections are not used, provide a detailed explanation on why the chosen projections more accurately describe the expected growth rate. Explain how it is consistent with the adopted land use.

1c) Include water service area policies and show that they are consistent with the **utility service extension ordinances** within the city or town boundaries. This applies to cities and towns only.

1 d) Include all **service area policies** for how new water service will be provided to new customers.

1 e) **Other relevant elements** related to water supply planning as determined by the department (DOH). See Local Government Consistency – Other Relevant Elements, Policy B.07, September 2009.

B) Documenting an Inconsistency: Please document the inconsistency, include the citation from the comprehensive plan or development regulation, and provide direction on how this inconsistency can be resolved.

C) Documenting Lack of Consistency Review by Local Government: Where the local government with jurisdiction did not provide a consistency review, document efforts made and the amount of time provided to the local government for their review. Please include: name of contact, date, and efforts made (letters, phone calls, and e-mails). In order to self-certify, please contact the DOH Planner.

APPENDIX F
Dept of Commerce –
Notice of Intent to Adopt Amendment

6/19/13

Department of Commerce

Innovation is in our nature.

Notice of Intent to Adopt Amendment

60 Days Prior to Adoption

Indicate one (or both, if applicable):

☒ **Comprehensive Plan Amendment**
☐ **Development Regulation Amendment**

Pursuant to RCW 36.70A.106, the following jurisdiction provides notice of intent to adopt a proposed comprehensive plan amendment and/or development regulation amendment under the Growth Management Act.

Jurisdiction:	City of Bellingham, Public Works
Mailing Address:	210 Lottie Street Bellingham, WA 98225
Date:	6/19/2013

Contact Name:	Martin Kjelstad
Title/Position:	Project Engineer
Phone Number:	360-778-7941
E-mail Address:	mkjelstad@cob.org

Brief Description of the Proposed/Draft Amendment: *If this draft amendment is provided to supplement an existing 60-day notice already submitted, then please provide the date the original notice was submitted and the Commerce Material ID number (located in your Commerce acknowledgement letter.)*	*Update to the Water System Plan Dated 2009. Added Projects and Information to match the existing Capital Improvement Program.*
Is this action part of the periodic review and update? *GMA requires review every 8 years under RCW 36.70A.130(4)-(6).*	Yes: _X_ No: ___
Public Hearing Date:	Council Coucil:
Proposed Adoption Date:	Fall 2013

REQUIRED: Attach or include a copy the proposed amendment text.

STATE OF WASHINGTON

DEPARTMENT OF COMMERCE

1011 Plum Street SE • PO Box 42525 • Olympia, Washington 98504-2525 • (360) 725-4000
www.commerce.wa.gov

June 20, 2013

Martin Kjelstad
Project Engineer
City of Bellingham
210 Lottie Street
Bellingham, Washington 98225

Dear Kjelstad:

Thank you for sending the Washington State Department of Commerce (Commerce) the following materials as required under RCW 36.70A.106. Please keep this letter as documentation that you have met this procedural requirement.

City of Bellingham - Proposed update to the Water System Plan Dated 2009. Added projects and information to match the existing Capital Improvement Program. These materials were received on June 20, 2013 and processed with the Material ID # 19268.

We have forwarded a copy of this notice to other state agencies.

If this submitted material is an adopted amendment, then please keep this letter as documentation that you have met the procedural requirement under RCW 36.70A.106.

If you have submitted this material as a draft amendment, then final adoption may occur no earlier than sixty days following the date of receipt by Commerce. Please remember to submit the final adopted amendment to Commerce within ten days of adoption.

If you have any questions, please contact Growth Management Services at reviewteam@commerce.wa.gov, or call Dave Andersen (509) 434-4491 or Paul Johnson (360) 725-3048.

Sincerely,

Review Team
Growth Management Services

APPENDIX G
Public Meeting

Public invited to learn about Water System Plan Update

Posted: September 10, 2013 8:36:27 AM PDT

The public is invited to learn about the Water System Plan Update at 10 a.m. on Monday, September 30 at the Bellingham Public Library Lecture Room, 210 Central Ave.

This update to the 2009 Water System Plan (Plan) incorporates the planned implementation of a pre-treatment method known as Dissolved Air Flotation (DAF) at the Whatcom Falls Water Treatment Plant. The update includes an analysis of the related key treatment issues that have developed since the completion of the 2009 Plan as well as analysis related to recent modifications to the distribution system related to distribution system water quality.

Most of the content of the 2009 Plan remains valid and continues to document the City's overall plan for the water system. The update document is intended to supplement and update the 2009 Plan for form the City's overall water system planning approach for the six-year and 20-year planning horizons.

To view the complete Plan update visit the city website:
http://www.cob.org/documents/pw/utilities/water-comp-plan-update-agency-review-03-2013.pdf

###

Media Contact:
Eric Johnston, Assistant Director, Operations
Public Works Department
(360-778-7710
ecjohnston@cob.org

Water System Plan Update September 30 2013

Description

This update to the 2009 Water System Plan (Plan) incorporates the planned implementation of a pre-treatment method known as Dissolved Air Flotation (DAF) at the Whatcom Falls Water Treatment Plant. The update includes an analysis of the related key treatment issues that have developed since the completion of the 2009 Plan as well as analysis related to recent modifications to the distribution system related to distribution system water quality.

Most of the content of the 2009 Plan remains valid and continues to document the City's overall plan for the water system. The update document is intended to supplement and update the 2009 Plan for form the City's overall water system planning approach for the six-year and 20-year planning horizons.

To view the complete Plan update visit the city website: http://www.cob.org/documents/pw/utilities/water-comp-plan-update-agency-review-03-2013.pdf

Time

Start: 10:00 AM
End: 11:00 AM

Location

Bellingham Public Library Lecture Room, 210 Central Ave.
Bellingham

Contact

Martin Kjelstad, Engineer
mkjelstad@cob.org
360-778-7941

CITY OF BELLINGHAM WASHINGTON

Please sign in...thank you!

Pubic Meeting			Water System Plan Update-Monday, Sept 30, 2013		
NAME	**STREET ADDRESS**	**ZIPCODE**	**PHONE**	**EMAIL**	**MAILING LIST?**
Ray Nickel	1019 39th Ave SE Suite 100 Puyallup WA 98374		253-604-6604	vnickel@parametrix.com	
Larry Magura	Black & Veatch 5885 Meadows Rd #700 Lake Oswego, OR 97035	97035	503-443-4411	maguralm@bv.com.	

Providing this information is voluntary per the Open Public Meetings Act (RCW 42.30).

APPENDIX H
City Council Adoption

City Council Agenda Bill

20143
Bill Number

Subject: 2013 Water System Plan Update Approval

Summary Statement: In 2012 at the direction of the City Council, the City began work on an update to the Comprehensive Water System Plan. As required by state law, the Water System Plan is required to be updated on a regular basis. The Water System Plan, once approved by the City and appropriate state agencies, is incorporated into the overall City Comprehensive Plan. The draft plan has been reviewed by the public, County and state agencies; all comments have been addressed and a SEPA determination has been issued. The Water System Plan is ready for final, formal approval by the City Council. With this approval, the Water System Plan will be used in managing the system and incorporated as a technical element of the Comprehensive Plan.

Previous Council Action: March 2013 Council approval of draft for submittal and review; December 2012 adoption of service charge revisions; April 2012 Council direction to proceed with Water System Plan update.

Fiscal Impact: Projects and policies contained in the water system set the agenda for future actions by the water utility. The plan includes a financial analysis and rate study to support the recommendations of the plan.

Funding Source: Water Fund

Attachments: Resolution
Executive Summary - Draft 2013 Water System Plan
NOTE: Full Water System Plan Update available on the City's website under Quick Links
http://www.cob.org/services/utilities/water.aspx

Public Hearing Notice
Written Comment to City Council

Meeting Activity	Meeting Date	Staff Recommendation	Presented By	Time
Public Hearing Council Vote Requested	14-Oct-2013	Pass Resolution	Ted Carlson, PW Director Eric Johnston, Asst. PW Director, Operations	15 min

Council Committee:

Public Works / Public Safety
Stan Snapp, Chair
Terry Bornemann; Gene Knutson

Committee Actions:

Agenda Bill Contact:
Eric Johnston 360-778-7710
ecjohnston@cob.org

Reviewed By	Initials	Date
Ted Carlson, PW Director	TOC	9/24/13
Legal	MTS	9/25/13
Mayor	KL	9.24.13

Council Action:

RESOLUTION NO. 2013-21

RESOLUTION APPROVING THE CITY OF BELLINGHAM 2013 WATER SYSTEM PLAN

WHEREAS, the City of Bellingham is required to maintain and update a water system plan in accordance with WAC 246-290; and

WHEREAS, the water system plan sets forth the policies, practices and capital projects necessary to maintain and operate the water system and protect the public health and welfare of the citizens of Bellingham; and

WHEREAS, as directed by the City Council, staff with the assistance of the consulting firm CH2M Hill has prepared a Water System Plan conforming to the state requirements; and,

WHEREAS, as directed by the City Council, staff with the assistance of the consulting firm CH2M Hill has prepared a Water System Plan Update conforming to State requirements; and,

WHEREAS, the plan has been reviewed by the Washington State Department of Health and Department of Ecology; and,

WHEREAS, the plan is been reviewed for conformance with the State Environmental Policy Act (SEPA) as required and a determination of non-significance has been issued; and,

WHEREAS, the plan has been available for review by customers inside the City's service area, all adjacent water purveyors and the general public as required; and

WHEREAS, the policies and projects contained in the 2013 City of Bellingham Water System Plan Update are consistent with the goals and objectives of the City and generally conform to the overall comprehensive plan.

NOW THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF BELLINGHAM THAT:

The City of Bellingham 2013 Water System Plan Update, from which the executive summary is attached and a full version is available through the City of Bellingham website, is hereby approved for use.

City of Bellingham
City Attorney
210 Lottie Street
Bellingham, Washington 98225
360-778-8270

PASSED by the Council this 28th day of October, 2013.

Council President

APPROVED by me this 31st day of October, 2013.

Mayor

ATTEST:
Finance Director

APPROVED AS TO FORM:

Office of the City Attorney

City of Bellingham
City Attorney
210 Lottie Street
Bellingham, Washington 98225
360-778-8270

Final Report

Filter-Clogging Algae Mitigation Evaluation

Prepared for

City of Bellingham Washington

Prepared by

CH2MHILL

June 2012

Final Report

Filter-Clogging Algae Mitigation Evaluation

Prepared for

CITY OF BELLINGHAM WASHINGTON

Prepared by

CH2MHILL

21 Bellwether Way, Unit 111
Bellingham, WA 98225

June 2012

Executive Summary

This report presents the study undertaken by the City of Bellingham (City) to evaluate alternatives to mitigate the adverse impacts of seasonal algae in Lake Whatcom to the City's Whatcom Falls Water Treatment Plant (WTP). This study was undertaken in the second half of 2011 and completed in early 2012.

ES.1 Background and Purpose

In late July and August of 2009 the filters at the City's WTP began clogging much earlier in filter runs than typical, requiring more frequent filter backwashing. The result was greatly reduced WTP capacity – to the point the City implemented mandatory water restrictions, for the first time, to reduce customer demand to match the reduced WTP capacity.

Filter clogging was attributed to algae in Lake Whatcom – the City's source water. Although the reasons for the intense algae bloom of the summer of 2009 is the subject of varied speculation, historical and on-going algae monitoring shows that summertime algae blooms in Lake Whatcom have been increasing over the past decade.

In 1998, Lake Whatcom water quality failed to meet the Washington State dissolved oxygen standard and was placed on Washington's list of polluted waters (Section 303d of the Clean Water Act). As a result of the listing, Ecology initiated a Total Maximum Daily Load (TMDL) study to restore lake water quality. The TMDL study showed that human actions were causing increased phosphorous loading and therefore reduced dissolved oxygen. Meeting the TMDL requirements for phosphorous and dissolved oxygen is expected to take many years to complete, and compliance with the TMDL requirements is the cornerstone of the long-term response to improving lake quality.

Despite on-going coordinated efforts, via the Lake Whatcom Management Program, by the City, Whatcom County, and Lake Whatcom Water and Sewer District to reverse this trend, summertime algae blooms are expected to continue increasing in intensity over the near-term future. Recognizing that it is unacceptable to be in a position wherein it risks falling short of meeting summertime customer water demand, the City initiated this study to evaluate alternative solutions and select a path forward for subsequent implementation.

ES.2 Alternatives Evaluated

The alternatives evaluated for mitigating clogging of the filters at the City's WTP were grouped into three main categories: treatment, intake, and lake management. These alternatives are presented in Table ES-1. In addition to these pro-active alternatives, the "No Action" alternative was included in the Triple Bottom Line Plus evaluation phase as a means of establishing a lowest-cost baseline for comparison.

Each of the treatment alternatives considered for this study are commonly used in the municipal water treatment industry and are commonly-considered alternatives for algae removal. Each would be implemented somewhere at the existing WTP site. They are not, however, equal with respect to removal performance, advantages, disadvantages, and cost.

TABLE ES-1
Summary of Alternatives Evaluated

Treatment	Intake	Lake Management
Dissolved Air Flotation	Secondary Intake via In-Water Pipeline	Lake Management
Ballasted Sedimentation	Secondary Intake via Over-Land Pipeline	
Plate and Tube Settling	New Dual-Intake System	
Upflow Clarification		
Conventional Sedimentation		
Micro-Screening		
Ozonation		
Additional Filters		

Notes:
Other potential solutions were acknowledged and considered but not evaluated in detail because their feasibility was believed to be questionable based on prior experience and/or a lack of prior application or success. These other potential solutions include: hypolimnetic oxygenation, floating shade balls, lake aeration.

Three intake alternatives were identified for consideration and evaluation. Each of the intake alternatives includes withdrawing water from Lake Whatcom at a location different from the existing intake location that has a substantially lower concentration of algae. Each of the intake alternatives includes the capability to withdraw water at more than one depth.

The Lake Management alternative is essentially the Lake Whatcom Management Program. The Lake Whatcom Management Program is the management forum for improving lake quality and via which compliance with the TMDL requirements for dissolved oxygen and phosphorous is being pursued. Lake management will be implemented regardless of the results of this evaluation. Meeting the TMDL requirements is the cornerstone of the long-term strategy to improve water quality, including reducing algae concentrations.

ES.3 Evaluation of Alternatives

Evaluation of the alternatives to mitigate the adverse impacts of filter-clogging algae at the City's water treatment WTP was implemented in three distinct phases. These three phases include:

- **Screening of Alternatives:** This first phase, "screening of alternatives," was implemented to eliminate from further consideration and evaluation alternatives that were deemed "not selectable" based on one or more screening criteria. This approach enabled more subsequent focus and effort in developing and evaluating those alternatives that were deemed to have greater promise for selection and implementation. Three treatment alternatives, one intake alternative, and the lake management alternative were eliminated from further consideration during screening because they did not meet all of the screening criteria.

- **Evaluation of Alternatives:** This second phase of the evaluation process reflects a more-detailed evaluation of the remaining alternatives. This evaluation phase resulted in identification of the best alternative within categories as well as a best overall alternative based primarily on technical criteria. During this evaluation phase Dissolved Air Flotation (DAF) was determined to be the best treatment alternative and "Secondary Intake via In-Water Pipeline" (Intake Alternative 1) was determined to be the best intake alternative. DAF was determined to be the best overall alternative based on technical performance criteria.

- **Triple Bottom Line Plus Evaluation:** This third phase of the evaluation process reflects evaluation based on a "Triple Bottom Line Plus" (TBL+) approach for the best alternatives per category (as determined in the second phase of evaluation). Additionally, the "No Action" alternative was evaluated as a baseline comparison. This approach enabled scrutiny with respect to financial, social, environmental, and technical objectives. The alternatives evaluated using the TBL+ approach included: DAF, Intake Alternative 1, Additional Filters, and No Action.

The results of the TBL+ evaluation are presented in Figure ES-1 at the end of the Executive Summary. The evaluation criteria are presented in Section 7 of the main body of the report. The TBL+ evaluation results, as well as the results of the more-technically-based second phase of the evaluation process, showed DAF to be the superior alternative for mitigating the filter-clogging algae condition at the City's WTP.

In recognition of the fact that DAF technology is ideally suited to address the filter-clogging algae issue at the Lake Whatcom Water Treatment Plant, DAF was pilot testing during the summer of 2011 to confirm its performance. The pilot testing showed that DAF was very effective at removing algae from the Lake Whatcom supply. Not only was it effective at removing algae, but it was also shown to be effective at removing total organic carbon (TOC), reducing (by up to 25 percent) the formation potential for total trihalomethanes (TTHMs) – a key disinfection byproduct, and most-importantly it was shown to greatly extend filter runs. Extended filter runs results in increased total filter production during algae bloom conditions, which was the primary limitation during the 2009 Lake Whatcom algae bloom.

ES.4 DAF Implementation

In recognition of DAF's ranking as the best alternative for filter-clogging algae mitigation at the City's WTP, a discussion of DAF implementation was developed. Key elements of the implementation discussion relate to project schedule and options for reducing initial capital cost – should the City decide to pursue implementation of a DAF system. An example project schedule that reflects compliance with key Washington State Department of Health requirements and milestones is presented in Figure ES-2 at the end of this Executive Summary. The example schedule conveys the overall timeframe for DAF implementation.

A summary of the initial capital cost (construction and non-construction) for three DAF facility capacities, ranging from 30 mgd to 16 mgd is presented in Table ES-2. A three-train DAF system offers maximum redundancy and capacity to meet significant growth in long-term future customer water demand. The 2-train DAF options are geared toward matching initial capacity with recent trends in peak customer water demand and minimizing initial capital cost. Regardless of the initial capacity and the number of parallel treatment trains, a new DAF facility would be designed to be easily expanded if customer water demand changes.

TABLE ES-2
Summary of Initial Capital Cost for DAF Implementation Options

3-Train 30-mgd system	2-Train 20-mgd system	2-Train 16-mgd system
$ 14,500,000	$ 11,000,000	$ 10,400,000

ES.5 Recommendation

Annual seasonal Lake Whatcom algae blooms present an on-going seasonal risk to the City with respect to meeting the supply needs of its customers. As a result, the City should pursue the design and construction of a new DAF facility in a phased approach based on an initial two-train DAF facility with easy expansion for a potential future third train. The overall timeframe for this first phase of implementation, as well as key milestones, would be similar to that presented in Figure ES-2. A key ancillary benefit of DAF implementation based on the pilot testing completed in the late summer of 2011 is that DAF can be expected to lead to a reduction of the City's TTHMs by 25 percent.

The phased approach will eliminate the potential for constructing more DAF capacity than is necessary to ensure a continuous, reliable, high-quality drinking water supply – even during intense algae blooms in Lake Whatcom. The phased DAF-implementation approach complements the City's on-going commitment to lake management, water quality improvement, and TMDL compliance via the Lake Whatcom Management Program. Over the long-term future, as phosphorous-reducing lake management measures demonstrate success at improving water quality and reducing algae blooms, the need for further expansion of the initial phase of DAF implementation could potentially be avoided entirely.

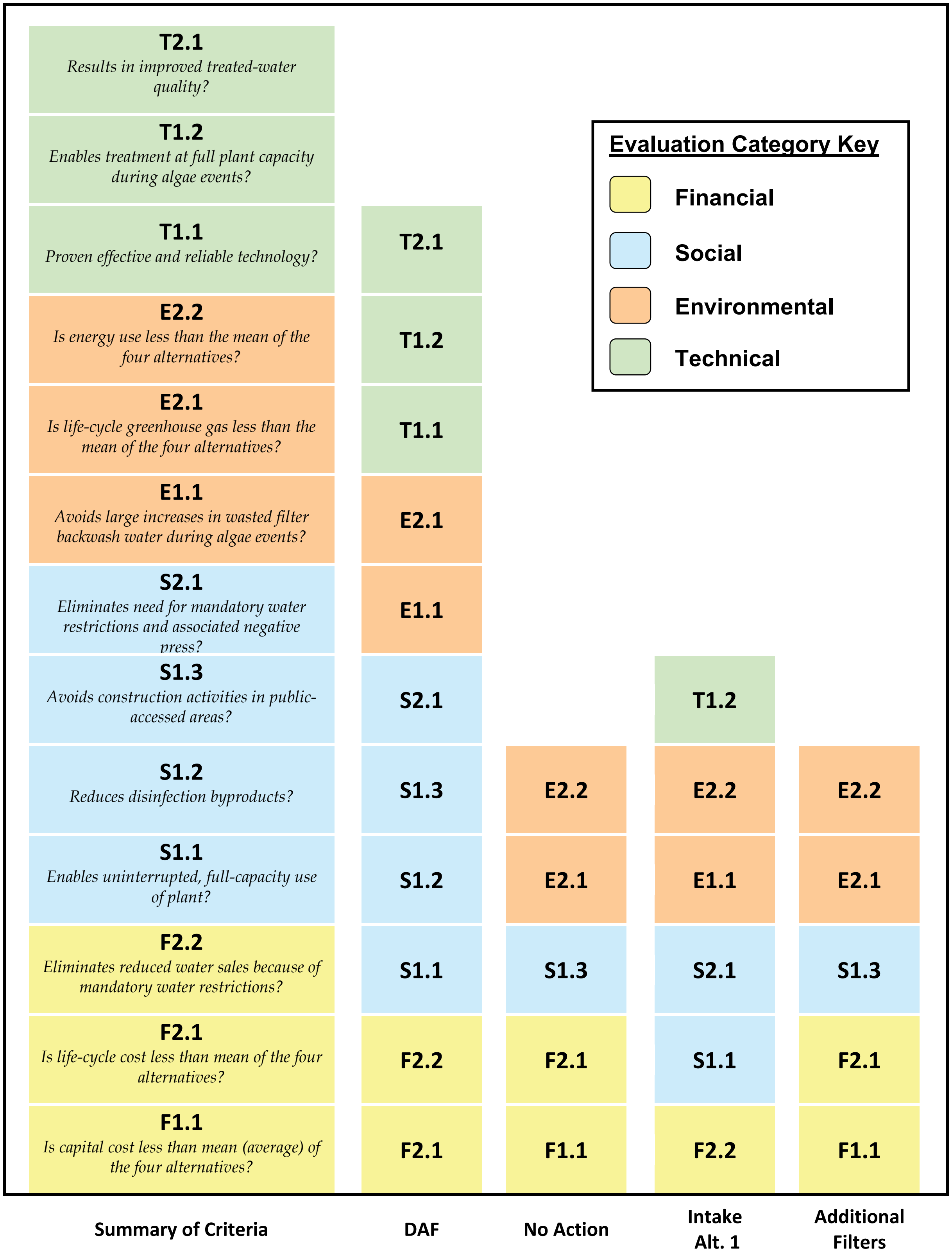

FIGURE ES-1
TBL+ Evaluation Results

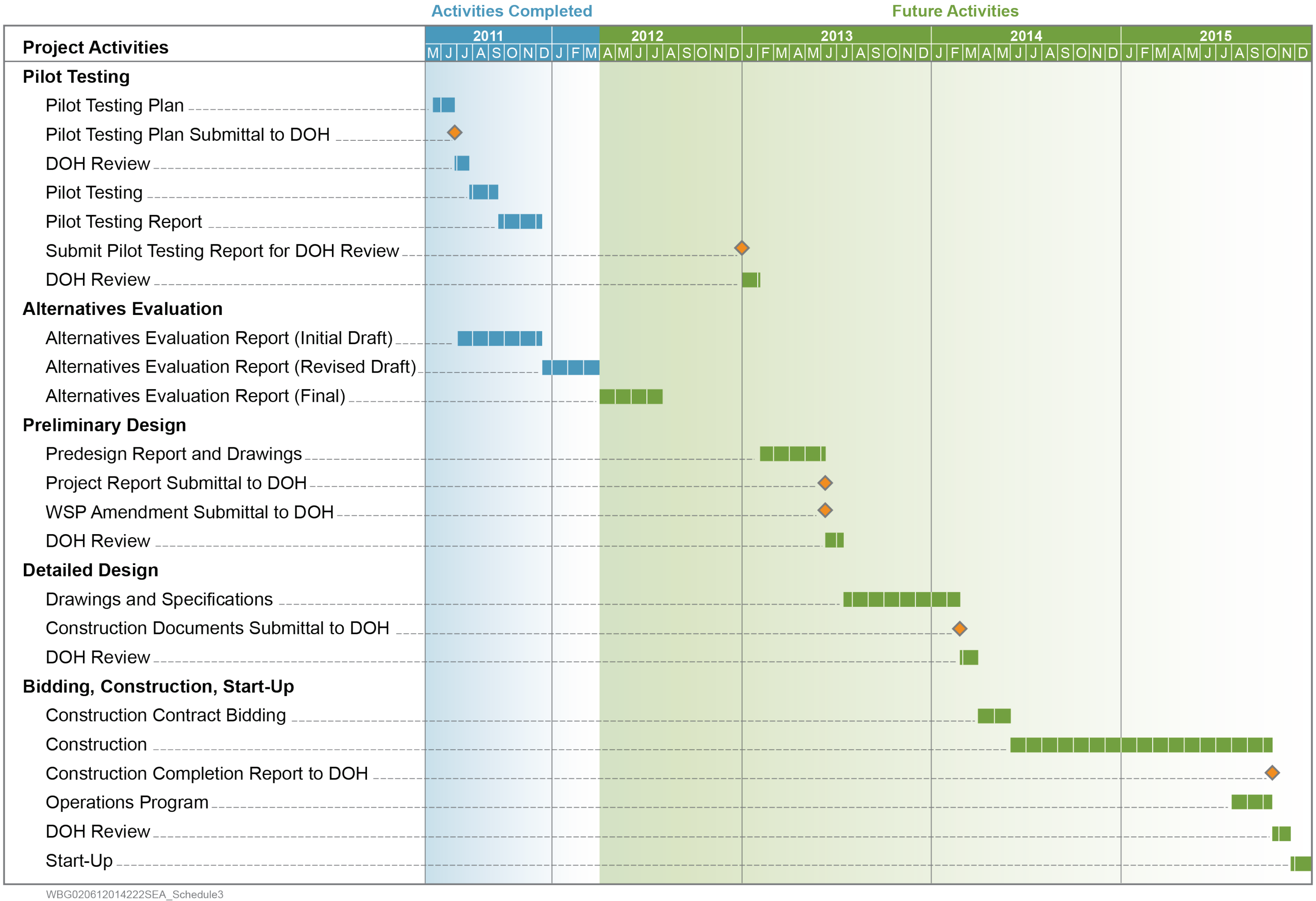

FIGURE ES-2
Example DAF Project Schedule

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Appendices

1. Introduction

This report presents the study undertaken by the City of Bellingham (City) to evaluate alternatives to mitigate the adverse impacts of seasonal algae in Lake Whatcom to the City's Whatcom Falls Water Treatment Plant (WTP). This study was undertaken in the second half of 2011 and completed in early 2012.

1.1. Background

In late July and August of 2009 the filters at the City's WTP began clogging much earlier in filter runs than typical. Filter runs became substantially shorter than normal, requiring more frequent filter backwashing. The result of shorter filter runs and increased filter backwashing was greatly reduced WTP capacity – to the point the City implemented mandatory water restrictions, for the first time, to reduce customer demand. It should be noted that voluntary water restrictions are implemented each summer as a means of encouraging conservation during this time of typically-high customer water demand. The water restrictions were successful in reducing customer demand to match WTP capacity. Toward the end of August and into September, filter runs gradually began to return to normal and customer demand dropped, as it customarily does at that time of the year.

Filter clogging was attributed to algae in Lake Whatcom. Monitoring revealed higher than typical counts of most algae species. Although the reasons for the intense algae bloom of the summer of 2009 is the subject of varied speculation, historical and on-going algae monitoring shows that summertime algae blooms in Lake Whatcom have been increasing over the past decade. It is speculated that despite efforts to reverse this trend, summertime algae blooms in Lake Whatcom will continue to increase in intensity and duration over the near-term future. Increased Lake Whatcom algae could again result in summertime algae blooms that prevent the WTP from treating sufficient supply to meet customer demand.

1.2. Purpose

The City recognizes that it is unacceptable to be in a position wherein it annually risks falling short of meeting existing and future summertime customer water demand. As a result, it initiated the study to evaluate alternative solutions and select a path forward for subsequent implementation. Specifically, the purpose of this study is to:

- Document existing Lake Whatcom water quality conditions in the context of historical conditions and potential future conditions
- Identify, describe, and evaluate treatment, intake, and lake management alternatives to mitigate clogging by algae of the filters at the City's WTP
- Select an alternative for potential implementation that most efficiently and cost-effectively benefits the City and its customers

2. Existing Conditions

The City has carefully monitored its Lake Whatcom supply for decades. Historical and ongoing monitoring reflects a gradual decline in water quality conditions, including the increased algae growth that has adversely impacted the City's Whatcom Falls Water Treatment WTP. While efforts are underway to reverse this decline via on-going watershed management activities, the time it will take to achieve measurable improvement is uncertain. Therefore, evaluation of alternatives to mitigate the adverse effects of algae must be undertaken with an understanding of current and past observed water quality conditions as well as the recognition that current conditions and declining water quality trends may continue for several or even many years. A summary of the events, conditions, and activities that have led to the need for this study are presented in the following sections.

2.1. 2009 Summer Algae Impacts

Lake Whatcom remains a highly reliable, high quality supply. However, steadily declining water quality and increasing algae in Lake Whatcom over the years has concerned the City. The summertime algae bloom of 2009 provided the specific impetus for the City to initiate this study to find the best way to mitigate the adverse impacts of increased algae.

As stated above, in late July and August of 2009 the filters at the City's WTP began clogging early in filter runs, resulting in substantially reduced WTP capacity. Monitoring revealed elevated algae counts in Lake Whatcom and that a slime produced by blue-green algae was responsible for the filter clogging. Most of the algae were tiny rod-shaped and spherical Cyanobacteria that have been collectively referred to as *Aphanocapsa* and *Aphanothece* – or more commonly "blue-green" algae. These do not appear to produce algal toxins. They are, however, extremely slimy because the individual cells are embedded in a thick, sticky mucilage.

Historical algae monitoring has shown that algae production in Lake Whatcom has been steadily increasing for the past decade. However, it is speculated that factors contributing to elevated algae in Lake Whatcom during the summer of 2009 included: (1) a very large January rain storm event in the Lake Whatcom watershed, (2) extended, record-setting hot summer weather, and (3) discontinued diversion of Nooksack River water because of blockage of the Nooksack River intake resulting from the January 2009 rain storm event. While similar elevated algae counts and lowered filtration capacity was observed in the summers of 2010 and 2011, it was not as severe as in 2009. There was not a problem meeting customer demand in the summers of 2010 and 2011. It should be noted that weather, storm, and Nooksack River diversion conditions were all different in 2010 and 2011 than in 2009.

A key indicator of WTP capacity is the measure of Unit Filter Run Volume (UFRV). UFRV is the measure of how much water is passed through a filter before that filter becomes clogged to the point that it has to be cleaned by backwashing. UFRVs at the WTP typically range from 7,000 to 10,000 gal/sf during late winter and spring to 2,000 to 3,000 gal/sf and sometimes lower during mid-to late summer. During early August of 2009, UFRVs dropped to below 900 gal/sf on several days in a row. At that point, filter run times were down to an average of 3.5 hours and a new filter was being be placed into backwash mode every 30 minutes. These short filter runs and increased backwashing frequency lowered WTP capacity below customer water demand and at that time the voluntary water restriction program was marketed more heavily than normal to encourage reduction in customer water demand. After voluntary water restrictions were deemed insufficient, mandatory water restrictions were implemented. Within two days, mandatory water restrictions sufficiently reduced demand to below WTP capacity.

The WTP UFRVs over the past few years is presented in Figure 2-1 below.

FIGURE 2-1
Trend of Plant Unit Filter Run Volumes

2.2. Lake Whatcom Water Quality

Current and recent Lake Whatcom water quality is documented annually by Western Washington University (WWU) in collaboration with the City. Annual reports of this documentation dating back to the 1990s can be found at www.wwu.edu/iws. Each annual report comprises the historical data of the previous year's report. So, the latest report comprises the entire historical water quality record that is available.

The City and WWU have collaborated on Lake Whatcom water quality monitoring since the early 1960s. In 1981, the City and WWU began regular data collection on: temperature, pH, dissolved oxygen, conductivity, turbidity, nutrients (nitrogen and phosphorus), and other representative parameters. The primary objective this monitoring effort is to provide a record of Lake Whatcom's water quality over time and identify water quality trends. Water quality data have been collected at several sites in Lake Whatcom. The latest available water quality data for Lake Whatcom at the City's WTP intake is presented in Table 2-1. Table 2-1 is a duplication of Table 3 of the "Lake Whatcom Monitoring Project 2009/2010 Final Report."

TABLE 2-1
Summary of Lake Whatcom Water Quality at City Intake (Water Quality Data Year Oct. 2009 – Sept. 2010)
(This table is excerpted from Table 3 of "Lake Whatcom Monitoring Project 2009/2010 Final Report")

Parameter	Minimum	Median	Mean[1]	Maximum	No. of Samples
Alkalinity (mg/L $CaCO_3$)	18.0	19.0	19.2	20.8	30
Conductivity (μS/cm)	56.8	58.1	58.2	60.3	110
Dissolved oxygen (mg/L)	9.2	10.9	10.7	12.3	110
pH	7.2	7.8	7.7	8.3	110
Temperature (^oC)	6.8	12.7	13.2	21.7	110
Turbidity (NTU)	<2	<2	<2	<2	30
Nitrogen – ammonium (μg-N/L)	<10	<10	<10	13.3	30
Nitrogen – nitrate/nitrite (μg-N/L)	100.9	254.3	231.4	355.8	30
Nitrogen – total (μg-N/L)	239.4	388.8	369.9	480.9	30
Phosphorus – soluble (μg-P/L	<5	<5	<5	11.0	30
Phosphorus – total (μg-P/L)	<5	<5	<5	13.5	30
Chlorophyll (μg/L)	2.0	3.4	3.5	5.9	30
Secchi depth (m)	4.3	5.4	5.5	7.0	10
Coliforms – fecal (cfu/100 mL)[2]	<1	1	1	1	10

[1] Uncensored arithmetic means except coliforms (geometric mean);
[2] Censored values replaced with closest integer (i.e., <1 $\Rightarrow$ 1).

In addition to the data presented in Table 2-1, data for total organic carbon (TOC), metals, and algae are also presented in the annual Lake Whatcom water quality reports. Current TOC in Lake Whatcom at the existing WTP intake ranged as follows (per data collected by WWU):

- February 9, 2010: 1.4 mg/L at the surface and 4.6 mg/L at a depth of 10 meters
- August 5, 2010: 2.6 mg/L at the surface and 8.0 mg/L at a depth of 10 meters

It should be noted that raw water TOC measured at the WTP has been shown to be very consistent over the years, as presented in Table 2-2.

The TOC data presented in Table 2-2 averages 2.1 mg/L with only three annual maximums exceeding 3.0 mg/L.

The only metals that were measured at the WTP intake site above detection limits were iron and zinc – at very low levels. No year-to-year trend has been indentified in Lake Whatcom for metals.

TABLE 2-2
WTP Historical Raw Water TOC (mg/L)

Year	Annual Average	Annual Maximum
2000	1.8	2.4
2001	2.2	3.9
2002	2.1	3.1
2003	2.3	4.1
2004	2.1	2.3
2005	2.2	2.7
2006	2.2	2.5
2007	2.1	2.6
2008	2.1	2.4
2009	2.2	2.4
2010	2.1	2.7
2011	2.1	2.3

Algae counts for various algae types are presented in the annual Lake Whatcom water quality reports. These counts show the relative breakdown of algae types for a given sample. Recent algae counts show blue-green algae to be the dominant type in terms of counts. These blue-green algae are known to be primary filter-clogging algae. Algal counts are difficult to measure accurately and consistently from sample to sample and are time consuming. Therefore they are not done on a daily basis to observe changes in the source water. Chlorophyll is an indirect measure of algal biomass and is an effective parameter for assessing changes in biological productivity of a lake on a daily basis. Chlorophyll does not exhibit a consistent relationship with algal counts.

While some of the parameters presented above have remained relatively steady over the years, long-term Lake Whatcom monitoring reveals a few trends that are reflective of conditions that favor or are reflective of increased algae growth. These trends include:

- **Dissolved Oxygen (DO):** DO has been trending lower in the lower parts of Lake Whatcom – in the hypolimnion. Basins 1 and 2 already exhibit severely anoxic conditions. In 2010, Basin 3 was shown to have some lower DO values at depth. The decline in DO is increased algae in the upper parts of the Lake – the epilimnion. These algae then die and fall into the hypolimnion and are consumed by bacteria that also consume DO.

- **pH:** Variation in pH values between daytime highs and night time lows have increased. pH increases with photosynthesis. Increased algae increases photosynthesis.

- **Nitrogen:** Dissolved nitrogen has trended lower in the epilimnion. Lower concentrations of dissolved nitrogen reflect increased algae growth.

- **Chlorophyll:** Chlorophyll has trended substantially upward (approximately doubling since 1994), reflecting increased algal biomass.

- **Phosphorous:** Overall Phosphorous concentration has trended upward in Lake Whatcom. However, total phosphorous is difficult to accurately track at any given time because it transitions between soluble and insoluble forms via consumption by algae as well as other processes. Phosphorous is the limiting nutrient for algae production in Lake Whatcom, and as it relates to algae growth is the most concerning of all the water quality parameters collected.

- **TOC:** Despite some variation reported by WWU at the existing WTP intake at 10 meters depth in Basin 2, TOC measured in the raw water at the WTP has remained relatively consistent since 2000.

- **Algae:** Algae has trended upward. As stated above, Chlorophyll is an indirect measure of algal biomass, which reflects the total mass of all combined algae types – of which there are many. Essentially all of the individual algae types monitored show increases over time to current. Blue-green algae of the type that are believed primarily responsible for filter clogging at the WTP have shown substantial increases since initial monitoring in the early 1990s. Similar to Chlorophyll, blue-green algae have roughly doubled in concentration since 1994.

Most of the conditions, activities, and factors in the Lake Whatcom watershed that have contributed to a downward trend in water quality parameters remain in place. Efforts to reverse this trend are well underway, but are expected to take years to have measurable beneficial impact.

2.3. Disinfection By-Products

The City's WTP consistently meets all state and federal regulations currently in place for potable drinking water – even during periods of reduced production due to algal blooms. However, one area of specific interest over the past 15 years within the municipal drinking water industry is disinfection by-products (DBPs), which result from the chlorination of drinking water. DBPs occur when water that contains organic material (measured as TOC) reacts with chlorine, which is added for disinfection.

The primary DBPs regulated by the state and federal government are Total Trihalomethanes (TTHMs) and Haloacetic Acids (HAA5s). Figure 2-2 shows the trend of these DBPs in the City's water system. As shown, the City is well below the standards of 0.080 mg/L for TTHMs and of 0.060 mg/L for HAA5. Therefore, meeting the current regulations is not of concern. Even changes in monitoring and reporting requirements in 2012 related to compliance at each specific sampling site, as opposed to averaging over all sampling sites, are not anticipated to present a concern with respect to compliance.

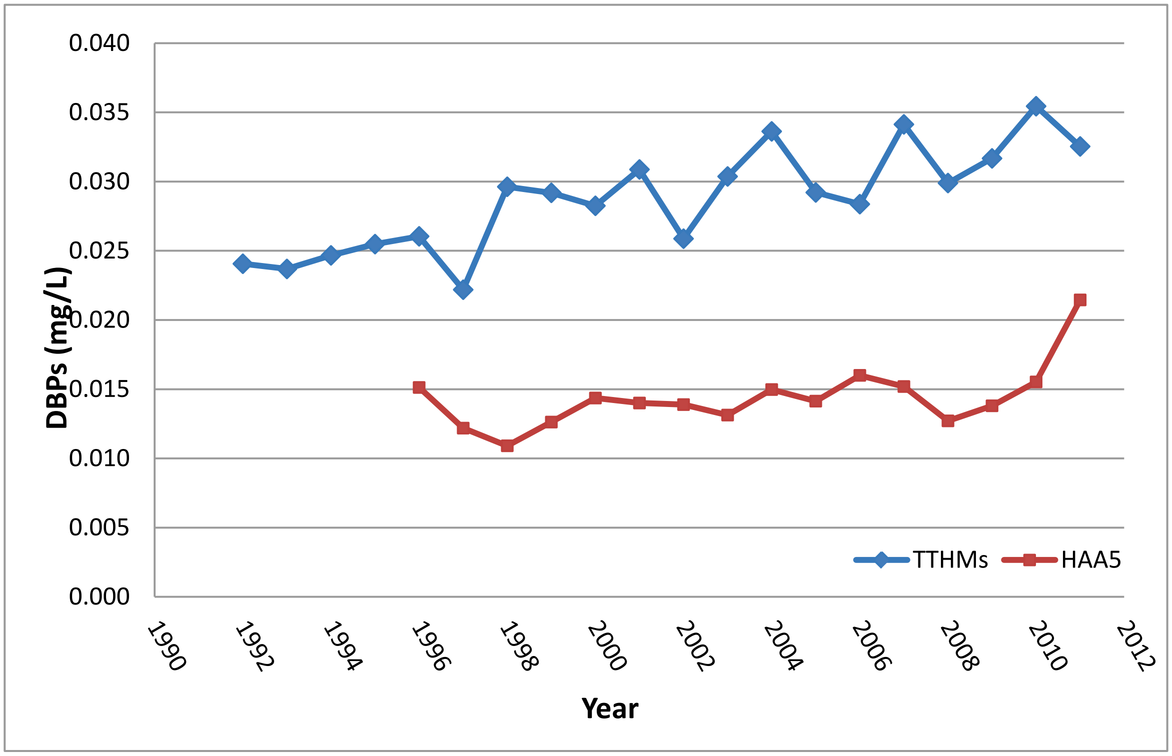

FIGURE 2-2
Historical DBPs in the City's Water System

However, it is important to note that the long-term trend of TTHM formation is increasing. The trend of HAA5 has been flat since monitoring began in 2001. In the future, the regulations may tighten and reduce the permitted levels of TTHMs and HAA5s. While the City's DBP levels may remain below regulatory requirements for some time to come, increases in DBPs reflect a level of source and finished water quality degradation.

2.4. Historical Lake Whatcom Management and TMDL Study

Lake Whatcom management surfaced as a major focus in the 1980s. Since then, several key management efforts, studies, and programs have been undertaken to address concerns about lake water quality. These include:

- In 1981, the City, Whatcom County, and Water District No. 10 (now Lake Whatcom Water and Sewer District) discussed jointly sharing local match contribution for a state grant to conduct a Lake Whatcom Restoration Study. Those early discussions led to the first Lake Whatcom Watershed Management Plan (LWWMP), which was released in draft form in late 1986 and revised in 1987. The LWWMP identified management actions to address key watershed issues. However, the LWWMP concluded that even though phosphorus was the limiting nutrient in Lake Whatcom, the lake would experience no significant change in water quality – even under the most intensive land use scenario evaluated.

- In 1986, the City completed a study of Lake Whatcom's continued use as a water source. The study concluded that water quality at the time was very good and would continue to meet water quality standards into the future.

- In the late 1980s, at Whatcom County's request, Washington Department of Natural Resources negotiated a land exchange that brought 7,500 acres in the Lake Whatcom watershed into public ownership.

- In 1992, the City, Whatcom County, and Lake Whatcom Water and Sewer District adopted the "Lake Whatcom Management Policies" by joint resolution (Whatcom County No. 92-73; City of Bellingham No. 92-68; Lake Whatcom Water and Sewer District No. 560). The policies included several goals and focus areas that were later consolidated into program areas, such as land preservation, stormwater, recreation, etc.

- The current Lake Whatcom Management Program was established in 1998 by Interlocal Agreement between the City, Whatcom County, and Water District No. 10. The goal of the program was to jointly manage and implement programs affecting the Lake Whatcom watershed and that continues to be the primary program goal today.

- In 2000, the Inter-jurisdictional Coordinating Team (ICT) was created to help coordinate the activities and programs from the Lake Whatcom Management Program. The ICT continues to meet regularly, and is comprised of staff from the City, Whatcom County, and Lake Whatcom Water and Sewer District (LWWSD). The ICT continually evaluates program effectiveness and reviews the progress of tasks identified for the five-year Lake Whatcom Management Program.

Despite coordinated historical lake management efforts, Lake Whatcom water quality continues to deteriorate. Phosphorous entering the lake from residential development, forest practices, other human-caused sources, and natural sources has been identified as the key factor leading to this deterioration. Increased phosphorus entering the lake has resulted in widespread seasonal algal blooms and dissolved oxygen deficits.

In 1998, Lake Whatcom water quality failed to meet the Washington State dissolved oxygen standard and was placed on Washington's list of polluted waters (Section 303d of the Clean Water Act). Section 303d states that in lakes, human actions may not decrease the one-day minimum oxygen concentration more than 0.2 mg/L below estimated natural conditions. As a result of the listing of Lake Whatcom per Section 303d, Ecology initiated a Total Maximum Daily Load (TMDL) study to determine what needed to be done to restore lake water quality. The TMDL study was completed by Ecology in November 2008. The TMDL study showed that human actions were causing an exceedance of this dissolved oxygen standard.

Although there are no specific numerical standards or criteria for phosphorous, phosphorous was listed for Lake Whatcom per Section 303d. The TMDL addressed total phosphorus as the primary cause of reduced dissolved oxygen. Previous study had shown that phosphorous is the limiting nutrient for algae growth in Lake Whatcom. Increased algae growth is the cause of reduced dissolved oxygen.

In response to these listings, a Total Maximum Daily Load (TMDL) study was initiated by Washington State Department of Ecology (Ecology) to determine the amount of phosphorous reduction needed to return Lake Whatcom to acceptable water quality standards. The TMDL study was completed in 2008.

The TMDL study computed that approximately 86 percent of developed acreage in the watershed would need to be returned to "natural" conditions to achieve the phosphorous reduction goal. The amount of phosphorous reduction computed to meet the TMDL goal is approximately 1,100 kilograms (2,400 pounds)/year.

Compliance with the TMDL is being pursued by the City, Whatcom County, and LWWSD through the Lake Whatcom Management Program (LWMP). The LWMP's 2010-2014 Work Plan was submitted to Ecology in 2010 to satisfy the requirements of the Summary Implementation Strategy, which is also the first step in the development of a Detailed Implementation Plan (DIP). The DIP details how TMDL compliance will be achieved. Specifically, it will identify phosphorus reduction activities, the implementation schedule for those activities, the cost of implementation (annual and total), and the period of time to achieve TMDL compliance.

In 2012 Ecology is planning to include TMDL compliance as part of the new NPDES stormwater program requirements. Completion of the DIP and ongoing assessment of implementation actions and monitoring will be NPDES permit requirements. The Lake Whatcom stakeholders acknowledge that meeting the TMDL requirements for phosphorous and dissolved oxygen is expected to take many years to complete. Meeting the TMDL requirements is therefore the cornerstone of the long-term response to improving lake quality, including reducing algae concentrations. Consequently, relying solely on lake management to achieve reduced algae growth and associated algae impacts at the City's WTP would not be an effective short-term mitigation strategy.

2.5. Historical Water Demand

Any alternative approach to mitigating the adverse algae impacts must be implemented in consideration of the City's current and projected water usage. Assessing projected water usage is facilitated by reviewing historical water demand.

Like many municipalities in western Washington State, the City's water system demand has held steady or declined in the last 10 to 20 years. The primary reason observed throughout western Washington State for this decline is the reduction in per-capita water usage. That reduction is related to a variety of water conservation efforts, including in-home water – reduction devices and reduced outdoor watering. The greatest single contributor has been shown to be reduced summertime outdoor watering. It is this reduced summertime outdoor watering that has the biggest reduction impact in peak day water use (maximum day demand [MDD]). In addition, reduced economic activity for businesses and industries that have traditionally used large amounts of water has also contributed to this decline. A key stimulus in the reduction of per-capita water demand is the overall heightened awareness of the need to conserve water. That awareness has been brought about, in part, through years of education as well as several drought periods during the 1990s and early 2000s.

What has been observed to be an even greater stimulus in reducing per-capita and overall water use is increases in the pricing of water, particularly as it relates to the consumption portion of pricing structures. Increasing-block rate structures that result in higher usage charges, as greater volumes of water are consumed, have greatly curbed summertime water use. Most of the City's residential customers do not have service meters. Therefore, the impact of such rate structures is not applicable to the City of Bellingham. However, service meters are planned to be installed on these un-metered customers by 2017. Rate-impact stimulus on per-capita water use reduction could become evident at that time.

The City's historical municipal water demand and associated service connections are presented in Figure 2-3. The data in Figure 2-3 reflects demand for treated water from the Whatcom Falls Water Treatment WTP and does not include past non-potable water demand from the old Georgia-Pacific paper mill or from the Puget Sound Energy co-generation facility. Figure 2-3 presents the steady, somewhat declining, average day demand (ADD) in contrast to the steady increase in service connections. More noticeable is the greater decline in maximum day demand (MDD) since 1990.

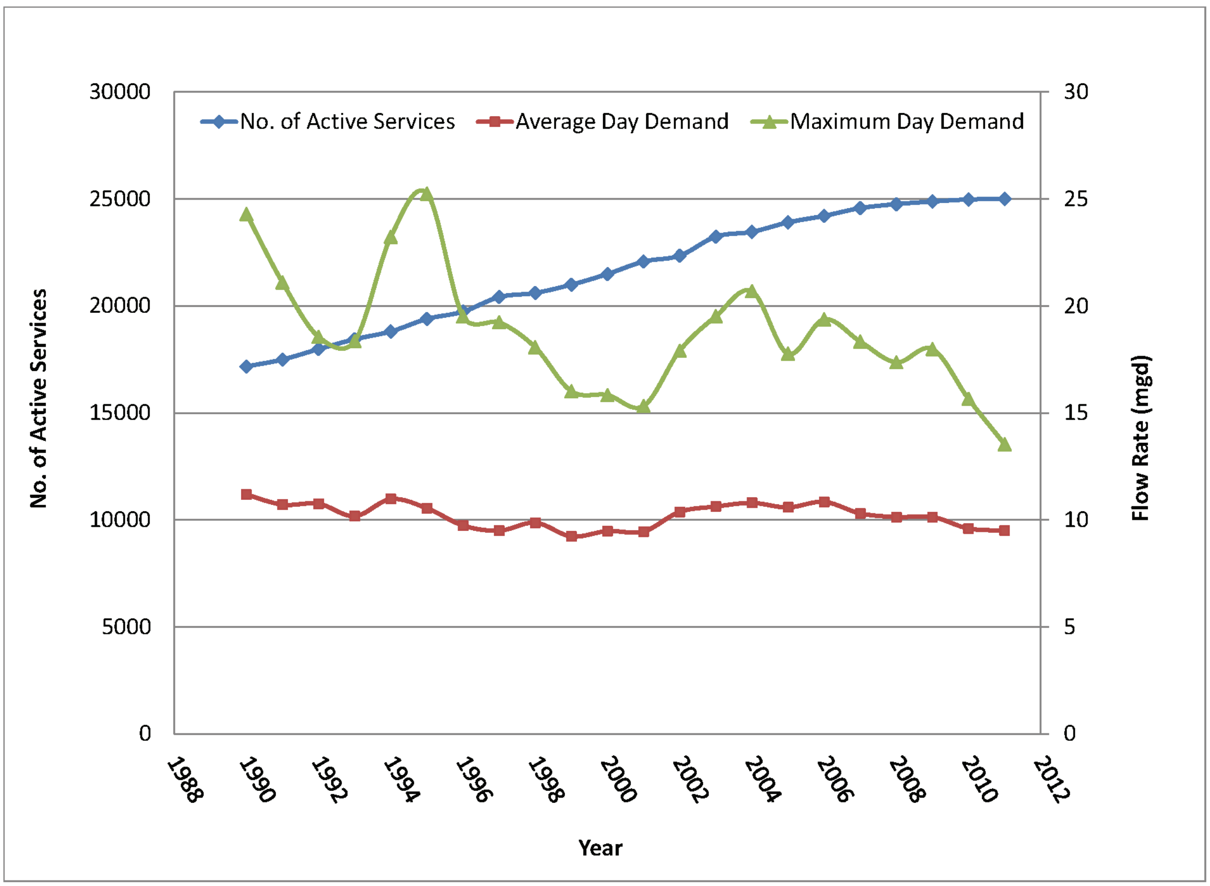

FIGURE 2-3
Historical City of Bellingham Municipal Water Demand

Supply, treatment, and pumping systems are typically designed to meet the anticipated MDD. In the case of supply and treatment, water that is used as a byproduct of treatment, must also be included. For example, approximately 4 percent of the water entering the City's WTP goes to backwashing filters and subsequent ripening prior bringing the filters on line for production. The hydraulic capacity of the alternatives considered herein for mitigating the adverse algae conditions must be sized to meet the current and projected MDD of the City's municipal water system. In addition, sizing must also address other anticipated water uses, such as selling treated water to other municipalities in Whatcom County on a wholesale basis or possibly non-potable (non-treated) water to potential future industries within the City.

2.6. Algal Impacts on Northwest Water Utilities

In the past five years, much like the City of Bellingham, several Northwest water utilities have experienced significant impacts resulting from algal blooms in their source water. A summary of these utilities, including the City of Bellingham, and the algal impacts is presented in Table 2-3. Further discussion of these algae issues, with the exception of the City of Bellingham's, is presented in subsections below.

TABLE 2-3
Summary of Algal Impacts on Selected Northwest Water Utilities

Treatment Plant	Capacity (mgd)	Existing Treatment	Algal Impacts	Mitigation Considered
Bellingham, WA – Lake Whatcom WTP	25	In-Line Filtration	Reduced production from filter clogging algae	Evaluating several alternatives
Everett, WA – Lake Chaplain WTP	120	Direct Filtration	Reduced production from filter clogging zooplankton	Evaluating DAF and lake management
Seattle, WA – Cedar WTP	180	Ozone – Ultraviolet Disinfection	Reduced production, clogging of screens, valves, meters, and monitoring equipment	Evaluating several alternatives
Joint Water Commission WTP (Hillsboro, OR)	75	Conventional Filtration	Taste and odor events, screen clogging, and detection of algal toxins in source water	Selected ozone and biological filtration
Salem, WA – Geren Island WTP	100	Slow Sand Filtration	Reduced production from filter clogging algae	Evaluating alternatives including DAF
Medford, OR – Duff WTP (Medford Water Commission)	45	Conventional Filtration with Ozone	Detection of algal toxins in up-stream sources	Monitoring and ozone disinfection

2.6.1. Everett – Lake Chaplain WTP

The City of Everett treats water from Chaplain Reservoir by direct filtration with alum as a primary coagulant. Chlorine and soda ash are added after filtration for disinfection and corrosion control. Since 2004, the City has experienced five episodes of shortened filter run times as a result of holopedium, a zooplankton that feeds on freshwater algae.

The episodes reduced average filter run times from approximately 30 hours to a range of 6 to 20 hours. Of the five episodes since 2004, two were strongly correlated to holopedium, two were weakly correlated to holopedium, and one may be correlated to daphnia.

Contributing factors were identified in some cases. For example, in 2004 and 2007 high winter turbidity was experienced in the reservoir which is believed to have added additional nutrients. In 2005, unusually warm winter temperatures may have contributed to the increase in holopedium concentration. The City is currently evaluating mitigation measures, including:

- Raw water screening
- Dissolved air flotation
- Relocating the intake to deeper water
- Adding surface wash to filters
- Introducing "zooplanktivorous" fish
- Lighting areas of the lake to attract holopedium
- Adding calcium to the reservoir

2.6.2. Seattle – Cedar WTP

The City of Seattle's treats its unfiltered Cedar supply using ozone, UV disinfection, chlorination, fluoride, and lime. Water for the Cedar WTP is typically withdrawn from the Lake Youngs reservoir. A temporary, backup alternative is bypassing of Lake Youngs, whereby water is withdrawn directly from the Cedar River. This backup approach can only be implemented when Cedar River turbidity is low.

In 2008, 2010, and 2011 large blooms of cyclotella that formed dense filaments were experienced in Lake Youngs. The 2008 bloom was the first incident of identified cyclotella in the City's Lake Young's reservoir. The blooms resulted in clogging of treatment equipment (analyzer screens, ozone cooling system, chemical feed pump strainers, fish screens, flow meters) as well as downstream distribution system clogging of PRV pilots, meter screens, distribution analyzers, and even customer washing machines.

Contributing factors were identified as nutrient inputs to the lake from storm events via the Cedar River and upstream fluoride addition on incoming water to the lake, which contributes phosphorous as a byproduct to the fluoride.

The City is currently evaluating mitigation measures that include:

- Temporarily bypassing Lake Youngs during blooms
- Physical changes to prevent equipment and instrument clogging
- Nutrient reduction strategies (relocating fluoride addition, reduced input to Lake Youngs during storms, hypolimnetic withdrawal)

- Installing continuous monitoring stations
- Improved management of invasive species

2.6.3. Joint Water Commission (Hillsboro, OR)

The Joint Water Commission (JWC) is a water supply commission jointly owned and operated by the Oregon cities of Hillsboro, Beaverton, and Forest Grove, as well as the Tualatin Valley Water District. JWC's water treatment plant treats water from the Tualatin River using a conventional water treatment process (flocculation, clarification, and filtration), with alum as a primary coagulant and pre-chlorination in the sedimentation basins to control algae.

In 2008 and 2010, JWC experienced significant taste and odor events at the water treatment plant related to upstream algae. The taste and odor events were treated with the addition of powdered activated carbon. While helpful, this approach did not completely eliminate the problem. During the 2008 taste and odor event, the algal toxin, microsysten-LR, was detected in the Tualatin River, which raised additional concerns about algal toxin impacts.

JWC is currently pilot testing ozone and biological filtration for taste and odor control, as well as algal toxin destruction.

2.6.4. Salem, OR – Geren Island WTP

The City of Salem, OR treats water from the Santiam River using slow sand filtration. The City has four 5-acre slow sand filter cells and two unlined cells that are used as a pretreatment roughing filter. Cleaning each cell is a labor-intensive and time-consuming process that typically takes twelve days to scrape the top layer of filtered material (schmutzdecke), add sand, and ripen the filter.

In 2009 and 2011, the City experience algal blooms that reduced filter runs to as short as three days, which is very poor for slow sand filtration facilities. The City of Salem developed an accelerated cleaning procedure to put the sand filters back on line within seven days of scraping. Still, there were supply shortfalls during the algae bloom. In 2009, the City first experienced even more extensive filter clogging and since that time it has put a monitoring program in place for algae and has begun evaluating mitigation measures. These measures include limiting light to the active slow sand cells as well as pretreatment using dissolved air flotation.

2.6.5. Medford, OR – Duff WTP (Medford Water Commission)

The Medford Water Commission (MWC) treats water from the Rogue River using ozone and conventional filtration. In 2009, 2010, and 2011 health advisories were listed on Lost Creek Lake, which is located approximately 30 miles upstream from Medford, OR on the Rogue River. The health advisories were issued because of high levels of cyanobacteria levels in the lake. Testing for algal toxins in the lake confirmed the presence of microcystis-LR and anatoxin-a. There are currently no state or federal guidelines or maximum contaminant levels for these compounds, and MWC is proceeding pro-actively and cautiously – in close coordination with Oregon State regulators.

In 2002, MWC installed ozone at its water treatment plant for taste and odor control and operates its ozone system at low dosages to meet these needs. However, ozone can also be used to effectively destroy algal toxins at similar low dosages. MWC is pro-actively monitoring for algal toxins at its plant and upstream in Lost Creek Lake and continuing close coordination with Oregon State regulators.

3. Description of Alternatives

The alternatives considered for mitigating clogging of the filters at the City's WTP are grouped into three main categories, treatment, intake, and lake management. Descriptions of these alternatives, in their respective categories, are presented in the following subsections.

3.1. Treatment Alternatives

The City has long reaped the benefits of having such a high quality water supply as Lake Whatcom. When the existing WTP was constructed in 1968, the Lake Whatcom supply only required the addition of a single coagulant chemical to enable effective filtration – followed by disinfection. This type of water treatment plant is referred to as "in-line filtration" because it does not include either a flocculation process or a clarification process prior to the filters. In-line filtration is a low-cost filtration approach that is only suitable to low-turbidity water supplies like Lake Whatcom. Effective operations of in-line filtration, such as is the case at the City's WTP, results in lower overall treatment costs as opposed to other treatment systems that include flocculation and clarification. Because high-quality water supplies like Lake Whatcom are not typical, the City is one of only a few communities that are supplied from in-line treatment plants.

While Lake Whatcom continues to be a high-quality, low-turbidity supply, the increasing presence and concentration of seasonal algae could potentially drive the City to implement treatment prior to filtration. Treatment prior to filtration is typically referred to as "pretreatment." Pretreatment is common throughout the municipal treatment industry and oftentimes is comprised of a clarification process.

Several treatment alternatives were proposed for evaluation. Each treatment alternative would be sited somewhere at the existing WTP site. Each treatment alternative, except the "Additional filters" alternative, are "pretreatment" alternatives in that they would be incorporated upstream of the existing filters to remove algae and particulate material prior to filtration.

For the purpose of this study, the pre-treatment alternatives are assumed to have a capacity of 30 mgd which roughly matches the capacity of the Whatcom Falls Water Treatment Plant with all six filters operating. It should also be noted that each of the pre-treatment alternatives could be designed to be expandable in the future. Should the City decide to move forward with design and implementation of one of the treatment alternatives, sizing criteria would be based on the latest projections of customer demand at that time.

Each of the treatment alternatives considered for this study are commonly used in the municipal water treatment industry and are commonly-considered alternatives for algae removal. They are not, however, equal with respect to their removal performance, advantages, disadvantages, and cost. The treatment alternatives considered for this study include:

- Dissolved Air Flotation (DAF)
- Ballasted Sedimentation (Actiflo®)
- Plate and Tube Settling

- Upflow Clarification (Superpulsator®)
- Conventional Sedimentation
- Micro-Screening
- Ozonation
- Additional Filters

3.1.1. Dissolved Air Flotation (DAF)

DAF was first used as a pretreatment for conventional granular media in South Africa and Scandinavia in the 1960s and became more widely used worldwide in the 1980s and 1990s. DAF has become relatively common in the U.S. because it provides a cost-effective alternative to conventional sedimentation, including where removal of algae is necessary. There are over 30 municipal installations in North America with capacities greater than 5 mgd in operation, the largest of which is a 200 mgd plant in New Jersey.

In the DAF process, the solids are separated out by floating the floc to the water surface, as opposed to settling the floc to the bottom of the basin. After the flocculation process, DAF introduces air bubbles at the bottom of a contactor to float the floc. The air bubbles are produced by reducing pressurized recycle water stream saturated with air to ambient pressure.

The "float" is scraped or floated from the top of the reactor, and the clarified water is removed via underflow channels at the bottom of the reactor. A schematic of a typical DAF unit is provided in Figure 3-1.

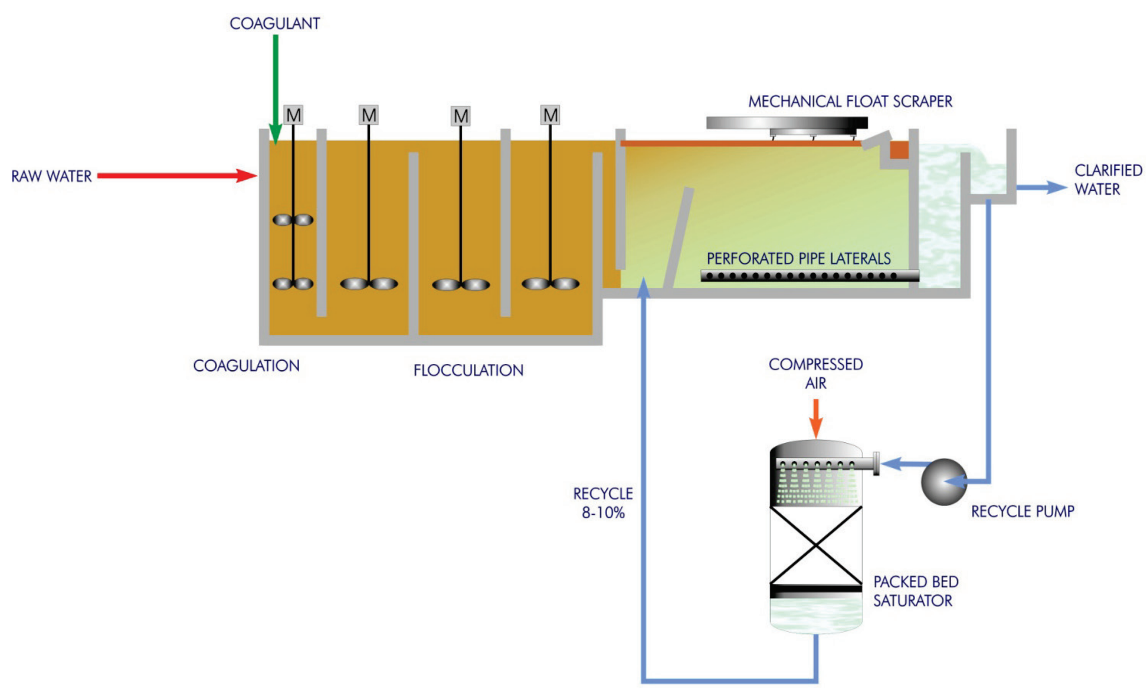

FIGURE 3-1
DAF Schematic

Advancements in DAF technology have enabled increasing loading rates from a high of 8 gpm/sf for "standard" systems to "high-rate" DAF systems that can be run up to 16 gpm/sf or higher. Three manufacturers provide high-rate DAF systems in North America for municipal water treatment above 5 mgd. These manufacturers and their associated DAF models are:

- Infilco Degremont: AquaDAF®
- ITT Leopold: ClariDAF®
- Roberts Filter/Enpure: EnfloDAF®

The first high rate DAF systems were introduced in North America about 10 years ago, and now most of the DAF systems being installed are "high-rate" systems. Each manufacturer has developed modifications to the traditional DAF system to allow for higher surface loading rates. These include:

- AquaDAF®: false floor with orifice plates and float basin with width larger than length
- EnfloDAF®: deeper float basin and patented dispersion nozzles
- ClariDAF®: modification to orifices in collection laterals

A summary of the advantages and disadvantages of DAF for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-1.

TABLE 3-1
Advantages and Disadvantages of DAF

Advantages	Disadvantages
DAF is very effective at removing algae because of algae's low density and propensity to float.	DAF is less compatible with the addition of powdered activated carbon (PAC) than other clarification processes because PAC tends to settle and DAF is a flotation process. This disadvantage relates to DAF's potential future utility to mitigate taste and odor, algal toxins, and other contaminants that could potentially impact the City's supply.
Flocculation for DAF typically requires only 5 to 10 minutes of detention time, which is less than for conventional settling and plate settlers.	DAF requires more energy than conventional sedimentation and plate settling
The DAF process is less likely to lyse (rupture) algal cells than Actiflo, ozonation, and micro-screening; thus, reducing the potential to release algal toxins and produce taste and odor.	DAF includes more mechanical equipment than conventional sedimentation and plate settling.
DAF can produce more concentrated sludge using mechanical removal than other clarification processes.	
DAF typically operates at surface loading rates ranging from 8 to 16 gpm/sf. This high loading rate enables a smaller footprint than other clarification processes, except Actiflo.	
This process does not impart much additional headloss to the existing system. Therefore, pumping of the process flow stream is not required.	

3.1.2. Ballasted Sedimentation (Actiflo®)

Actiflo® is a proprietary process of high-rate clarification that uses microsand-enhanced flocculation and plate settling to produce a clarified effluent. Actiflo consists of a rapid mix chamber where a coagulant is added, followed by an injection chamber where microsand and a polymer are added (high-energy mixing environment), and then a maturation chamber (lower-energy mixing to build floc and attach to sand). Typical detention time for these three steps is about 6 minutes. Following these chambers, water enters the settling tank where the microsand-floc settles quickly. The process water is further clarified by flowing upward through settling tubes and into effluent channels. Total Actiflo retention time is between 10 and 15 minutes. The microsand sludge at the bottom of the settling tank is pumped to a hydrocyclone, where it is separated from the sludge by centrifugal force. The sand is then returned to the head of the process for reintroduction in the injection chamber. The separated sludge is removed at concentrations of 0.1 to 0.2.

A schematic of the Actiflo process is presented in Figure 3-2.

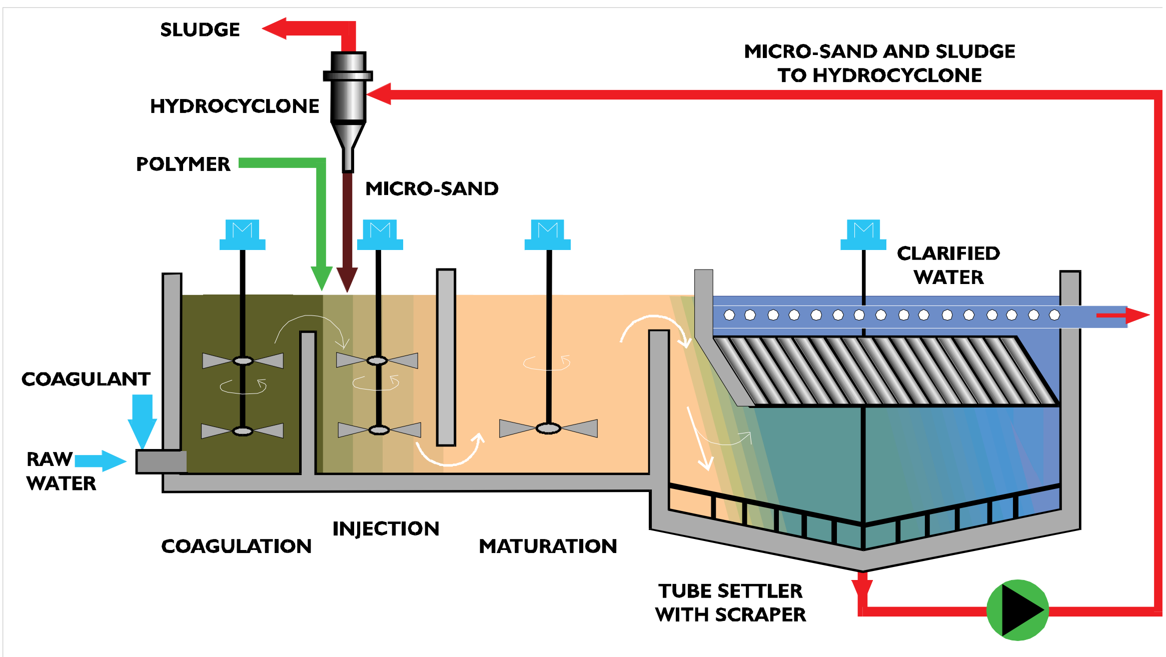

FIGURE 3-2
Actiflo® Process Schematic

A summary of the advantages and disadvantages of ballasted sedimentation for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-2.

TABLE 3-2
Advantages and Disadvantages of Actiflo

Advantages	Disadvantages
Actiflo operates at very high loading rates (15 to 25 gpm/sf) – higher than other clarification processes, which reduces facility footprint and associated cost.	Actiflo requires continual replenishment of sand because of sand losses from the sludge separation process. Lose sand would end up in the sanitary sewer system. Although the amount of sand would be minor to negligible, it could contribute to collection system pump wear.

TABLE 3-2
Advantages and Disadvantages of Actiflo

Advantages	Disadvantages
Although not currently an issue with the Lake Whatcom supply, Actiflo easily adjusts to changes in raw water quality, including large swings in raw water turbidity.	Like DAF, Actiflo requires more energy than other clarification processes.
Actiflo is compatible with the addition of powdered activated carbon (PAC), like other clarification processes that involve gravity settling. This advantage relates to the potential future need to mitigate taste and odor, algal toxins, and other contaminants that could potentially impact the City's supply.	Similar to DAF, Actiflo includes more mechanical equipment than other clarification processes.
Actiflo has been shown to be as effective as, or better than, other clarification processes except DAF at removing algae (DAF has been shown to be the most effective at removing algae). The key to this performance is the microsand.	Although Actiflo has been shown to be moderately effective at removing algae, it's high energy mixing combined with micro-sand addition have greater potential for lysing algal cells and releasing toxins or taste and odor compounds.
This process does not impart much additional headloss to the existing system. Therefore, pumping of the process flow stream is not required.	Actiflo can require high polymer dosages to be effective and these high polymer dosages can have a negative effect on downstream filtration processes.

3.1.3. Plate Settling

Inclined parallel plates or tubes are an enhancement of the traditional conventional sedimentation process that enables a substantial reduction in facility footprint from what conventional sedimentation requires. Loading rates for inclined plate settling can typically range from 2 to 4 gpm/sf based on facility footprint as opposed to 0.5 gpm/sf for conventional sedimentation. Both plates and tubes are used in the municipal water treatment industry. Plates tend to be more efficient, while tubes tend to be less expensive. For the purpose of this study, and because of the greater removal efficiency, this alternative is assumed to be comprised of inclined plates.

Inclined plate settling is accomplished in an open basin where water flow is conveyed in either of the following ways though the plates: (1) from top to bottom downward between the plates (co-current), (2) from bottom to top upward between the plates (counter-current), or horizontally from one side of the plates to the other (cross-current). Most new plate settling processes use a combination of cross- and counter-current flow by introducing the process water near the bottom of one side of the plates and withdrawing it at the top of the other side of the plates. A schematic diagram of a counter-current inclined plate settling process is presented in Figure 3-3.

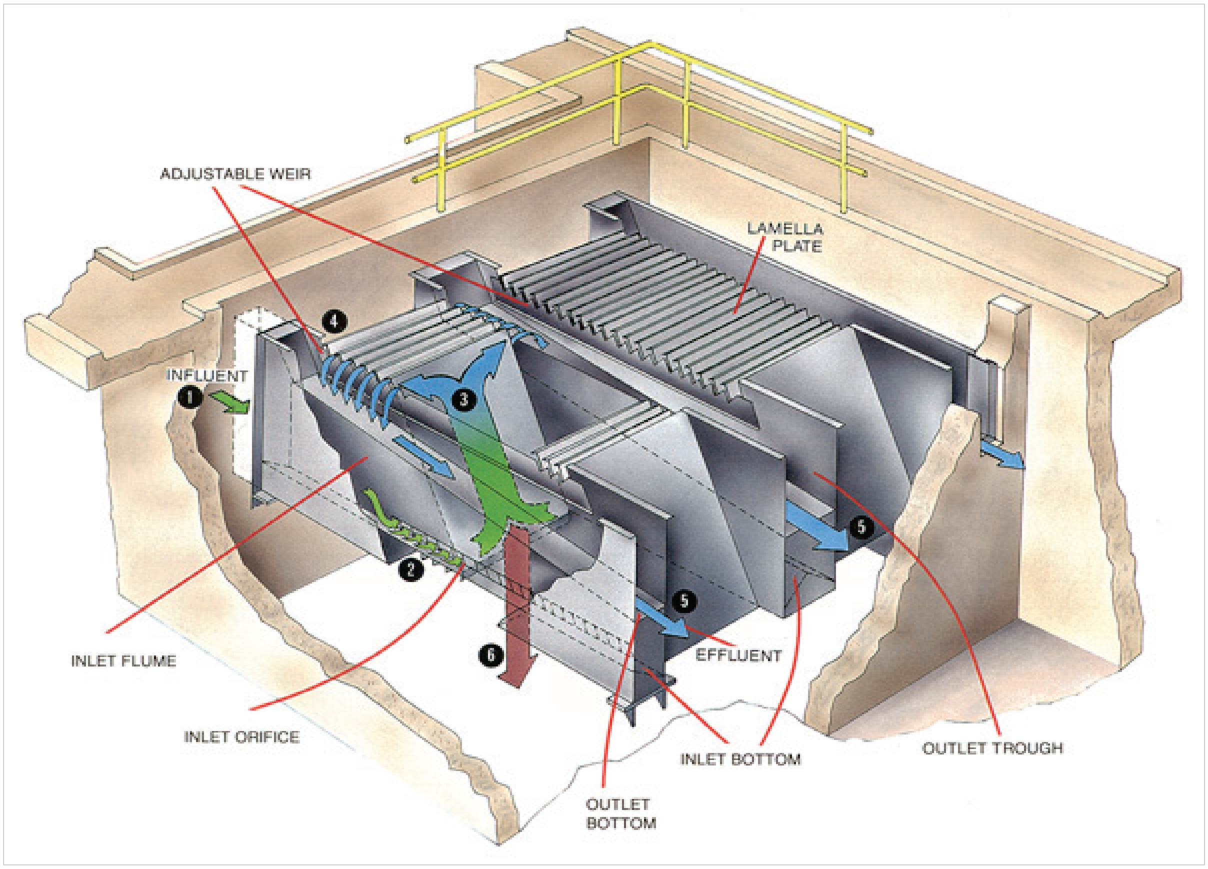

FIGURE 3-3
Counter-Current Plate Sedimentation

The material costs for the plates or tubes can vary depending on the materials required for the installation. Solids loading on surfaces and removal of solids can be a problem in some configurations. Similar to conventional sedimentation, 30 minutes or more of detention time in the flocculation process is necessary. Plate and tube settlers have been in use for many years in water treatment and are a widely accepted technology for settling of flocculated solids.

A summary of the advantages and disadvantages of plate settling for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-3.

TABLE 3-3
Advantages and Disadvantages of Plate Settling

Advantages	Disadvantages
Less mechanical equipment and complexity than DAF, Actiflo, and SuperPulsator.	Moderate to poor effectiveness at removing algae when compared to DAF. Increased coagulant and polymer chemical are required to optimize algal flocc formation and settling because of low density of algae. Increased chemical usage will result in increased waste sludge for disposal.
Similar to conventional sedimentation, flocculation for plate settling requires 30 minutes or more of detention time.	Larger facility footprint than DAF, Actiflo, and SuperPulsator because it's loading rate is substantially less than these two other clarification processes and requires more flocculation time.

TABLE 3-3
Advantages and Disadvantages of Plate Settling

Advantages	Disadvantages
Like conventional sedimentation and DAF, plate settling is less likely to lyse (rupture) algal cells than Actiflo, ozonation, and micro-screening; thus, reducing the potential to release algal toxins and produce taste and odor.	
This process does not impart much additional headloss to the existing system. Therefore, pumping of the process flow stream is not required.	
Plate settling is compatible with the addition of powdered activated carbon (PAC), like other clarification processes that involve gravity settling. This advantage relates to the potential future need to mitigate taste and odor, algal toxins, and other contaminants that could potentially impact the City's supply.	

3.1.4. Upflow Clarification

Upflow clarification combines flocculation and sedimentation into a single unit process. It is preceded by rapid mixing where a coagulant chemical is added. Eliminating the separate flocculation process reduces facility footprint. Upflow clarification maintains a large, set volume of flocculated solids within the unit, which further enhances flocculation by forcing inter-particle collision and agglomeration. The flocculated solids form what is referred to as a "solids blanket." Cohesion of the blanket is achieved through the use of coagulant and polymer addition – additional to the rapid mixing process.

Upflow clarifiers typically operate at a relatively high loading rate (2 to 4 gpm/sf) with respect to conventional sedimentation, similar to plate settling. The facility footprint of upflow clarification is less than that for plate settling because of the elimination of the flocculation process.

Degremont Technologies, a subsidiary of Suez Environment, manufacturers a popular version of the upflow clarification process for municipal water treatment, referred to as a "Superpulsator®" clarifier. The Superpulsator® clarifier uses a vacuum pump and vacuum chamber to produce a "pulsing" effect within the solids blanket, which serves as the flocculation zone. Pulsing expands the blanket to increase the rate of inter-particle collisions. Inclined plates are included and are situated within the solids blanket. The inclined plates aid horizontal distribution of upward flow and enhance separation of the upward-flowing clarified water from the solids blanket that is held stationary. Clarified water flows upward from the sludge blanket and collects in effluent troughs.

A schematic diagram of an upflow clarifier is provided in Figure 3-4.

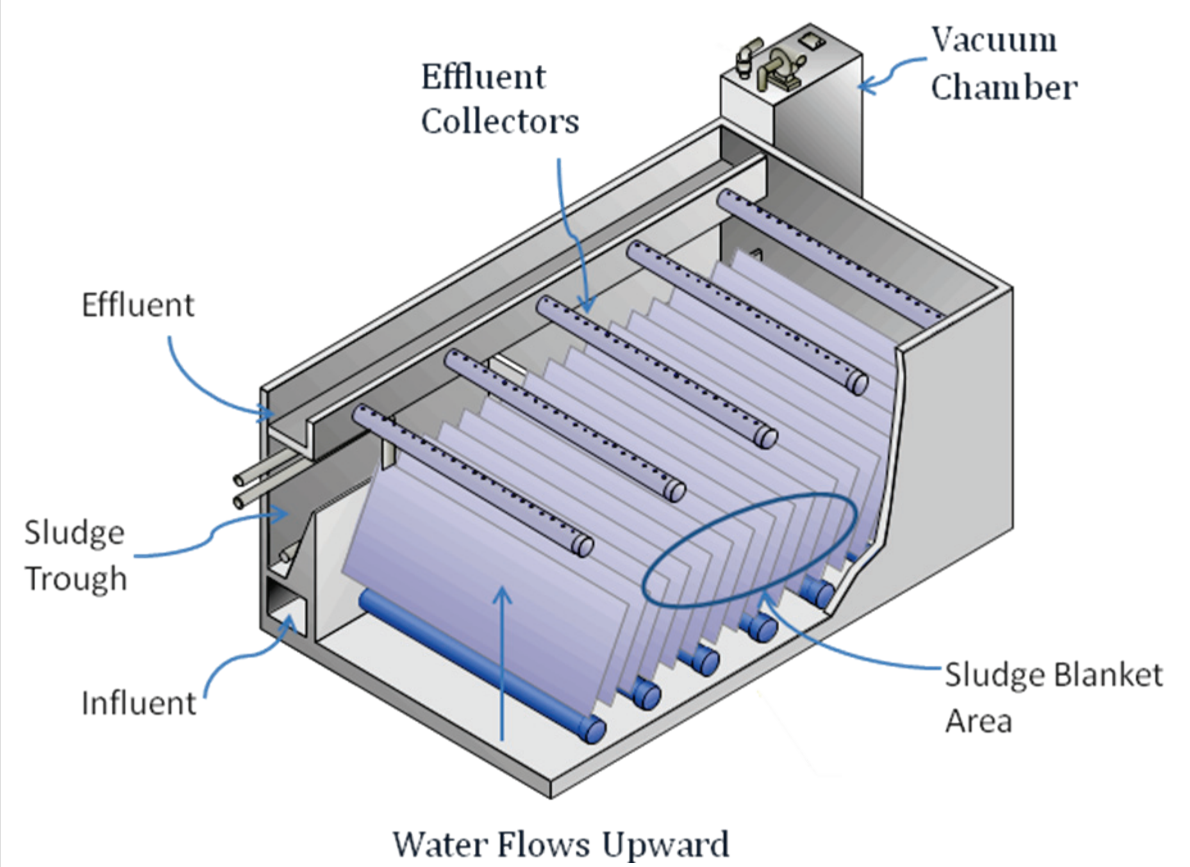

FIGURE 3-4
Upflow Clarifier Schematic

The solids blanket is maintained at a set height within the unit by use of a central, submerged solids overflow weir. As solids accumulate in the blanket, they continually overflow the submerged weir into a hopper that is evacuated at a set interval, thus removing solids from the process. Typical solids concentrations range from 0.5 to 2 percent in the concentrated sludge, depending on the solids residence time.

A summary of the advantages and disadvantages of upflow clarification for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-4.

TABLE 3-4
Advantages and Disadvantages of Upflow Clarification

Advantages	Disadvantages
Slightly less mechanically equipment and complexity than DAF and Actiflo. No submerged moving parts.	Moderate effectiveness at removing algae when compared to DAF. Increased coagulant and polymer chemical are required to optimize algal flocc formation and settling because of low density of algae. Increased chemical usage will result in increased waste sludge for disposal.
No separate flocculation step. Flocculation occurs within the upflow clarification basin.	Larger facility footprint than DAF and Actiflo because it’s loading rate is substantially less than these two other clarification processes.

TABLE 3-4
Advantages and Disadvantages of Upflow Clarification

Advantages	Disadvantages
Similar to conventional sedimentation, plate settling, and DAF, upflow clarification is less likely to lyse (rupture) algal cells than Actiflo, ozonation, and micro-screening; thus, reducing the potential to release algal toxins and produce taste and odor.	Although rapid changes in raw water quality are not typical in Lake Whatcom, upflow clarification does not respond well to such changing conditions. Operational challenges result with rapid changes in raw water quality.
This process does not impart much additional headloss to the existing system. Therefore, pumping of the process flow stream is not required.	Upflow clarification may require a period of one to two days of operation to establish the solids blanket for consistent effluent quality.
Upflow clarification is advantageous with the addition of powdered activated carbon (PAC) because of the lengthy detention time of the solids within the unit, which maximizes the time that PAC is in contact with the flowstream. This advantage relates to the potential future need to mitigate taste and odor, algal toxins, and other contaminants that could potentially impact the City's supply.	Polymer addition is typically necessary to maintain cohesion of the solids blanket.

3.1.5. Conventional Sedimentation

Conventional sedimentation has a long history of effective performance throughout the municipal water treatment industry in this country as well as world-wide. Because of its low loading rate (typically 0.5 gpm/sf) it occupies a large facility footprint as compared to other clarification processes. Detention times in conventional sedimentation basins is typically 3 to 4 hours to ensure effective settling, depending on how challenging the raw water material is to settle. High rate clarification processes such as DAF, Actiflo, plate and tube settling, and upflow clarification are all process that have been developed as higher-efficiency alternatives to conventional sedimentation.

Conventional sedimentation is preceded by two processes: (1) rapid mixing to effect particle coagulation using a coagulant chemical and polymer and (2) flocculation to develop flocc that settles effectively. Rapid mixing is a high-energy process with a detention time typically two minutes or less to connect particles and the coagulant chemicals. Flocculation is typically effected in two or three low-energy mixing stages of progressively-reduced mixing energy to produce large flocc that will settle effectively. Flocculation times of 30 minutes or more are typically required for effective flocc development.

A summary of the advantages and disadvantages of conventional sedimentation for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-5.

TABLE 3-5
Advantages and Disadvantages of Conventional Sedimentation

Advantages	Disadvantages
Less mechanically equipment and complexity than high-rate clarification processes.	Moderate to poor effectiveness at removing algae when compared to DAF. Increased coagulant and polymer chemical are required to optimize algal flocc formation and settling because of low density of algae. Increased chemical usage will result in increased waste sludge for disposal.
Conventional sedimentation is compatible with the addition of powdered activated carbon (PAC), like other clarification processes that involve gravity settling. This advantage relates to the potential future need to mitigate taste and odor, algal toxins, and other contaminants that could potentially impact the City's supply.	Because of its low loading rate (0.5 gpm/sf), conventional sedimentation has a larger facility footprint than any other clarification process. Large footprint results in siting challenges as well as high capital cost.
Like plate settling and DAF, conventional sedimentation is less likely to lyse (rupture) algal cells than Actiflo, ozonation, and micro-screening; thus, reducing the potential to release algal toxins and produce taste and odor.	Flocculation for conventional sedimentation requires 30 minutes or more of detention time.
Although not an issue with the Lake Whatcom supply, conventional sedimentation can accommodate large quantities of settled sludge from high-turbidity waters or waters requiring large quantities of coagulant and polymer chemicals to promote effective settling.	Because of the large facility footprint, automated sludge collection is typically extensive and expensive.
This process does not impart much additional headloss to the existing system. Therefore, pumping of the process flow stream is not required.	

3.1.6. Micro-Screening

Micro-screening refers to the use of a stainless steel screen for straining or filtering particulate material. Several micro-screening manufacturers exists. These products are most commonly used in the municipal drinking water industry as a preliminary process to membrane filtration or reverse osmosis. The process works by trapping particulate material on the screen and building up a filter cake on the screen. The filter cake screens much smaller material than the openings in the screen. Build up of the filter cake results in corresponding buildup of headloss across the screen. Headloss buildup to 7psi (16 feet) is typical before cleaning of the screen is initiated. Screen cleaning is an automated process that involves suction pressure on the upstream side of the screen to dislodge and remove the filter cake. In some systems brushes are also used. A schematic diagram of a micro-screen filter manufactured by Amiad Filtration Systems is presented in Figure 3-5.

Micro-screening is typically considered for the purpose of algae removal because of the small facility size, its associated low initial capital cost, and because it will retain algae if the screen mesh size is small enough. However, micro-screening requires more available head than other technologies. There is insufficient head available between the City's existing WTP and the screen house to operate micro-screens without pumping. Additionally, micro-screens typically clog and become very difficult and problematic to clean when they are sized with openings small enough to filter algae. Although incidental removal of algae with micro screens is possible, as long as algae concentrations are low, there is no track record in this country of micro-screening being implemented primarily for the removal of algae at a municipal water treatment facility.

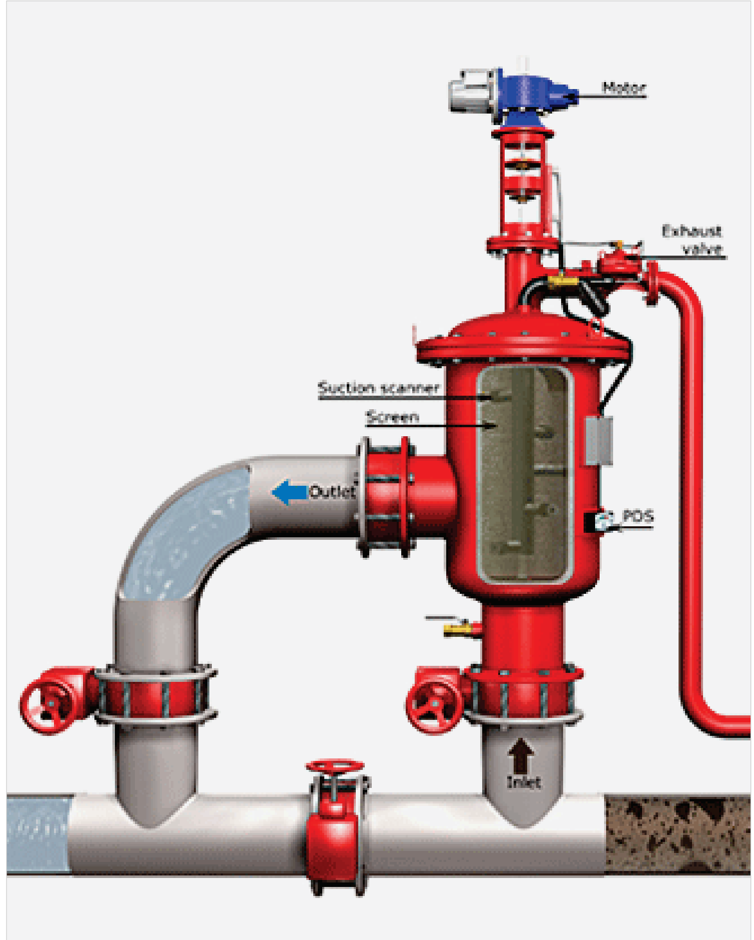

FIGURE 3-5
Micro-Screen Filter (Amiad Filtration Systems)

A summary of the advantages and disadvantages of micro-screening for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-6.

TABLE 3-6
Advantages and Disadvantages of Micro-Screening

Advantages	Disadvantages
Micro-screening has a small facility footprint and associated low initial capital cost.	If micro-screens are used for algae removal, they will clog and be difficult clean.
Coagulant or polymer addition is not necessary.	Head available for micro-screening must typically be 7 psi or greater. This head is not available at the City's WTP.
	There is no track record of successful use of micro-screening primarily for removing algae from the flow stream at a municipal water treatment facility in this country.

3.1.7. Ozonation

Ozone is one of the most powerful disinfectants and oxidants available for use in the municipal water treatment industry. It is generated on site by passing dry air or oxygen between two electrodes, which converts some of the oxygen to ozone. Ozone is typically imparted to the process flowstream through micro bubbles in a concrete contact basin or in a pipeline that provides contact between the water and the ozone bubbles. Ozonation has used been successfully in this country for many years and in Europe since the early 1900s. In addition to being used to meet disinfection requirements, ozonation is a common and successful means of neutralizing taste and odor compounds, many of which are byproducts of algae respiration.

Because of its association with algae via effective taste and odor neutralization of algae-based compounds, and history of providing enhancement to filtration in many water treatment plants, it warrants consideration for neutralizing the filter-clogging impacts of algae. However, ozonation does not have a track record of success reducing the filter-clogging effects of algae. Ozonation kills algae, lysing algal cell structure, but does not remove it from the flowstream. An ozonation system that would lyse algal cell structure would need to be designed to also neutralize the release of potential toxins and taste and odor compounds.

A summary of the advantages and disadvantages of ozonation for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-7.

TABLE 3-7
Advantages and Disadvantages of Ozonation

Advantages	Disadvantages
Pumping of the process flow stream is not required.	It is unclear whether or not ozonation would reduce the filter-clogging effects of algae. This impact would need to be pilot tested. There is no track record of using ozonation alone ahead of filtration to reduce algae filter clogging.
System can be designed to neutralize algal toxins and taste and odor compounds.	High ozonation doses could produce disinfection byproducts such as bromates, aldehydes, and ketones.
No liquid waste stream associated with this process.	Ozone converts some of the total organic carbon (TOC) to assailable organic carbon (AOC), which would need to be removed prior to the distribution system to prevent biological re-growth.

3.1.8. Additional Filters

This alternative involves the addition of two filters to the existing six filters at the City's WTP. The two filters would be situated in line, adjacent to the two filters furthest from the WTP control room to form parallel rows of four filters each. Two additional filters would expand filter area and therefore increase the capacity of the WTP, which could be used to mitigate the capacity-reducing effects of the filter-clogging algae. Two additional filters, in the absence of filter-clogging algae, at a rate of 5 gpm/sf, would result in an additional

8 mgd of WTP capacity. The resulting WTP capacity would be approximately 32 mgd with one filter out of service. During these normal-operating times, filter run times (the time a filter produces water prior to being taken out of service for backwashing) are generally long – typically 30 hours or more.

When filter run length is reduced, there is a minimal impact on WTP capacity as long as the filter run length is not reduced to less than 5 hours or so. When filter run lengths are reduced by filter-clogging algae to 5 hours and less, WTP capacity is greatly reduced. This WTP capacity reduction occurs because of the following three key reasons:

- Increased percentage of WTP capacity must be dedicated to filter backwashing
- The filter-to-waste process that precedes re-starting the filter after backwashing
- The associated non-filtration time before and in-between these processes

During the summertime 2009 algae bloom, filter run times dropped to as low as 3.5 hours. As discussed previously, this filter run time reduction resulted in a corresponding reduction in WTP capacity. As a consequence, the City implemented voluntary and mandatory water use restrictions to enable the reduced-capacity of the WTP to meet the restricted customer demand. If the City had two additional filters during the 2009 algae bloom, it may have been able to meet customer demand if no further reduction in filter run times had occurred. Further reduction in filter run times to less than two hours would likely have made any addition in filtration capacity – whether two new filters, four new filters, or more – ineffective at meeting customer demand. More discussion of this is presented in Section 5.1.

A summary of the advantages and disadvantages of additional filters for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-8.

TABLE 3-8
Advantages and Disadvantages of Additional Filters

Advantages	Disadvantages
Minimal additional operation and system complexity.	The primary disadvantage of additional filters to relates to the uncertainty of the intensity of future algae blooms and the associated intensity of impact they would have on filter clogging. More intense algae blooms could render the addition of filters relatively to completely ineffective at increasing WTP capacity.
Space for two additional filters is readily available on site and the site disruption and complexity to add two addition filters is minimal.	Additional filters will not have any ancillary treatment benefits that other pre-filtration clarification processes will have such as the reduction in taste and odor compounds, reduction in disinfection byproduct pre-cursors, reduction in emerging contaminants.
Pumping of the process flow stream is not required.	Because of greatly-increased filter backwashing during filter-clogging algae blooms, a high percentage of WTP water will be used for filter backwashing, and therefore wasted.
Although additional treatment WTP capacity is not needed at this time, additional filters would provide additional treatment WTP capacity that could be put to beneficial use in the longer-term future. This additional capacity would be reduced, potentially greatly reduced, or even negated during algae events – depending on the intensity of the algae event.	Increased filter backwashing will increase flows to the City's wastewater treatment plant, which will increase pumping and other treatment costs there.

3.2. Intake Alternatives

Three intake alternatives were identified for consideration and evaluation. Each of the intake alternatives includes withdrawing water from Lake Whatcom at a location different from the existing intake location that has a substantially lower concentration of algae. Each of the intake alternatives includes the capability to withdraw water at more than one depth in the lake. Two of the alternatives involve maintaining continued use of the existing intake as a measure of redundancy, operational flexibility, and preserving peak hydraulic capacity. The third alternative involves replacement and abandonment of the existing intake. The intake alternatives are listed as follows:

- Secondary Intake via In-Water Pipeline (Intake Alternative 1)
- Secondary Intake via Over-Land Pipeline (Intake Alternative 2)
- New Dual-Intake System (Intake Alternative 3)

A summary of the intake alternatives is presented in the Sections 3.2.4 through 3.2.6 below.

Each of these alternatives involve extending the new, secondary, or replacement intake from the existing Gate House on the shoreline of Lake Whatcom to the same model-predicted location and depth where algae concentration is substantially lower than the location of the existing intake. The CE-QUAL-W2 model developed and used for the Lake Whatcom TMDL study was used to identify the "algae-favorable" location upon which these alternatives are based. A discussion of this modeling effort and the results is presented in Section 3.2.1.

The primary difference between the first two intake alternatives identified above is the routing of the intake pipeline. Intake Alternative 1 (Secondary Intake via In-Water Pipeline) involves installing the pipeline within the lake (laid on the bottom and weighted down and/or anchored on a pile-bent structure). Intake Alternative 2 (Secondary Intake via Over-Land Pipeline) would be installed in Lake Whatcom Boulevard and equipped with a pump station at the location where the intake pipeline extends from on-shore into the lake. Intake Alternative 3 (New Dual-Intake System) is similar to Intake Alternative 1 (same in-lake pipeline alignment); however, it includes abandoning the existing intake and replacing it with a new intake in Basin 2 at the same 30-foot depth as the existing intake. A map showing the intake pipeline alignments of these three alternatives is presented in Figure 3-6.

3.2.1. Modeling the Location of a New Intake

For the purposes of this study, the location of the new intake was identified using the Corps of Engineer's CE-QUAL-W2 model that was previously developed and calibrated for Lake Whatcom as part of the Lake Whatcom TMDL Study. The model was calibrated in 2003 from 2002 and 2003 data and was acknowledged to be a reasonably representative model simulation of algae conditions for the purposes of this study. It is understood that re-modeling with updated information may be warranted, depending on the results of this study and whether the City elects to pursue implementation of a new intake.

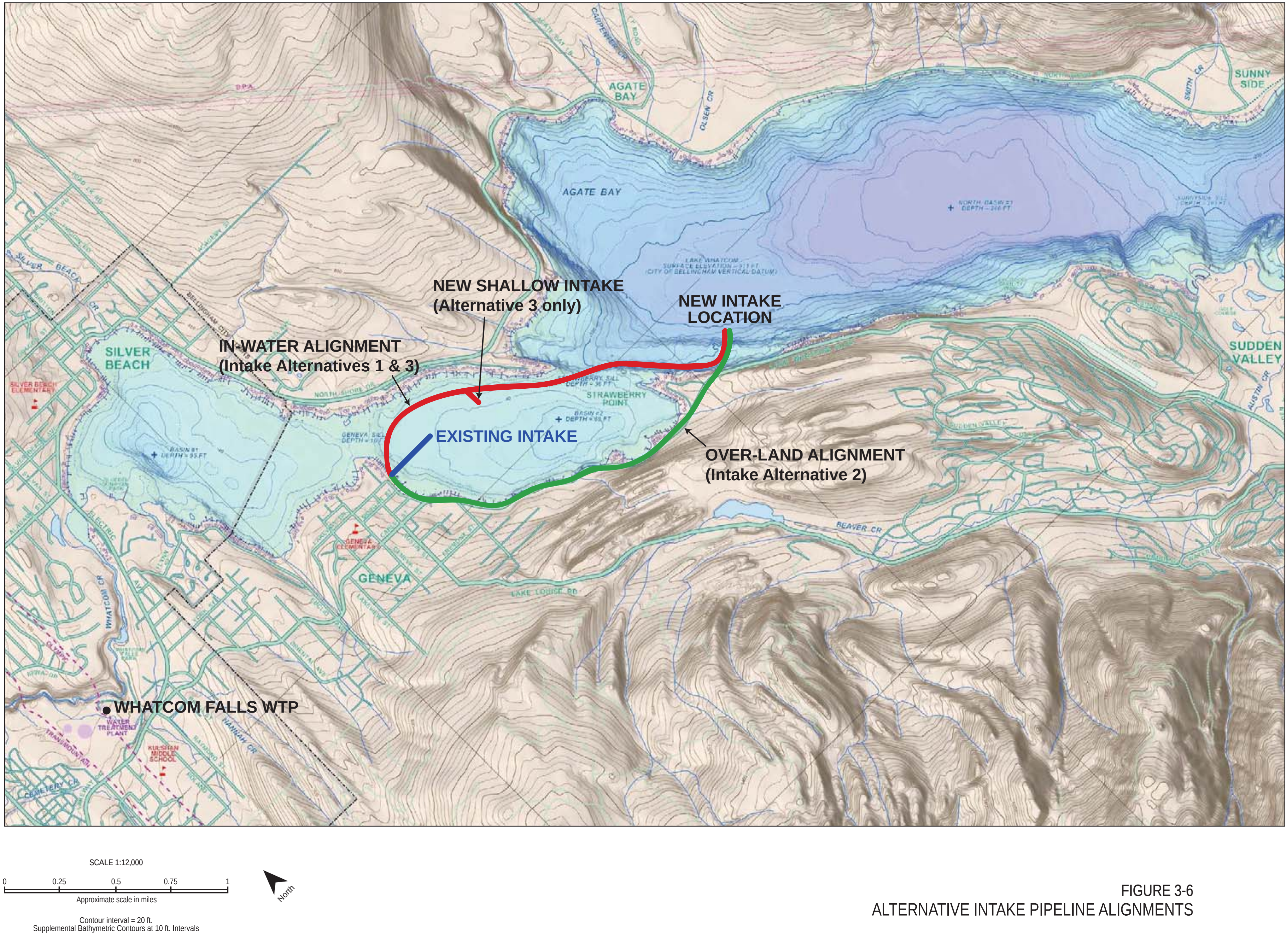

FIGURE 3-6
ALTERNATIVE INTAKE PIPELINE ALIGNMENTS

The CE-QUAL-W2 modeling is summarized in the report presented in Appendix A. The modeling addressed base case (2003), current (2011), and future build-out conditions. Current and future build-out conditions were projected from the base case condition. In addition to the existing intake location in Basin 2, three other locations in Basin 2 were simulated, and four locations in Basin 3 were simulated. Shallow, medium, and deep locations in the water column were simulated.

The following is a summary of key results of the modeling:

- Algae concentrations were estimated to be lowest at depths below 30 meters in Basin 3. Varying the location within Basin 3 at depths below 30 meters had negligible impact on estimated algae concentrations.

- Lower algae concentrations could be attained within Basin 2 by moving the intake to the deepest part of Basin two at approximately 20 meters. The model predicts blue-green algae concentrations at approximately 38 percent less than at the existing intake location. This was the only location within Basin 2 where significantly lowered algae concentrations were predicted. However, it should be noted that the model predicted substantially-reduced dissolved oxygen concentration at this location in the hypolimnion of Basin 2, which is in alignment with years of actual data collected in the hypolimnion of Basins 1 and 2. Even if there were interest in withdrawing water from this location in Basin 2 because of the moderately-lower algae concentration modeled, doing so would not be advisable because of the low dissolved oxygen (anoxic) conditions, as described in Section 3.2.2.

- Algae concentrations at shallow depths less than 10 meters in Basin 3 were predicted to be 20 to 30 percent less than the algae concentrations at shallow depths in Basin 2.

- Model-predicted algae concentrations only varied by up to 5 percent between existing land use and full build-out land use scenarios.

The modeling enabled establishment of a location within Basin 3 for a new intake that could work as a replacement to the existing intake or as a supplemental intake to the existing intake. An optimized intake location with respect to algae is one at depth within the hypolimnion of Basin 3. The model predicts minimal change in algae concentration at depth within the hypolimnion from the south end to the north of Basin 3. Therefore, there is no reason to extend a new intake pipeline from the existing gate house any further than necessary into Basin 3. For the purpose of this study it was assumed that the new intake location would be at a depth of approximately 120 feet near the northern end of Basin 3, as shown in Figure 3-6.

3.2.2. Avoiding Low Dissolved Oxygen

As stated above in Section 3.2.1, the deepest part of Basin 2, which extends to a depth of approximately 60 feet, is an area of lower algae concentration that might be of interest for locating a new, supplemental intake. While a reduction in blue-green algae concentration of 38 percent is likely not enough to warrant situating a new intake at this location, it does raise an issue related to the impact at the WTP of withdrawing water from Lake Whatcom with low or zero dissolved oxygen. Water near the bottom of lakes sometimes becomes anoxic as organic debris and algae die, sink, decompose, and consume oxygen. Waters with low or zero dissolved oxygen are challenging to treat, whether those levels are permanently low or become low, seasonally, because of summertime temperature stratification, as is the case in Lake Whatcom. The reasons why these waters are challenging to treat and should be avoided are as follows:

- Seasonal low dissolved oxygen conditions produce dramatic and unpredictable changes in raw water quality during the fall "turn over" period when stratified water becomes de-stratified. During this time, chemical dosages would need to be changed to keep up with the changing raw water quality and the precise nature of those chemical changes would not be easy to predict. It may be necessary to take the WTP out of production to trouble-shoot and test new chemical dosage combinations. There would be similar but less dramatic changes during late spring and summer as dissolved oxygen concentration is gradually reduced to zero or close to zero.

- Anoxic waters are themselves difficult to treat simply because of the low dissolved oxygen. These waters tend to change certain already-oxidized metals in the lake sediments, such as iron and manganese, into dissolved constituents that are conveyed to the treatment process where they are subsequently oxidized and can be conveyed into the distribution system where they create aesthetic, taste, and odor problems.

- Sulfur, which is a component of living tissue and most organic material, is released when it decays and forms hydrogen sulfide in anoxic conditions. Hydrogen sulfide smells like rotten eggs and thus makes water objectionable. Hydrogen sulfide has been measured since 1999 in the hypolimnion of Basins 1 and 2 – reflective of the severely anoxic conditions at these locations.

- Nitrogen is leached from organic material in both well-oxygenated and anoxic conditions. In anoxic conditions, Nitrogen is transformed into ammonia. Ammonia has a high chlorine demand and thus can interfere with chlorine disinfection. Additional chlorine becomes necessary to overcome this increased demand. Additionally, when ammonia combines with chlorine it forms various types of "chloramines" – some of which produce odors.

3.2.3. Hydraulic Capacity Considerations

In identifying each of these alternatives, it is important that hydraulic capacity of the existing intake system be considered. Historical withdrawals through the intake were substantially greater when the Georgia-Pacific Mill was in operation than they are today. Current municipal peak summertime demand is approximately 20 mgd. The other on-going, intermittent water use via the existing intake is the occasional use at Puget Sound Energy's small power plant on the City's waterfront that is used as a peaking supply. When in use, which is intermittent, this power plant consumes about 0.8 mgd of untreated water from the City's Lake Whatcom supply.

Although withdrawals to meet current demand through the existing intake are much less than historical withdrawals, the City intends to maintain hydraulic capacity of the intake system for future growth within its service area, potential expansion of municipal water supply service to areas currently served by other supplies, for potential future power generation projects, and for potential future industrial uses.

The capacity of the existing intake system is limited by the hydraulic capacity of the tunnel between the gate house and the screen house, which is approximately 108 mgd. The City's instantaneous water right from Lake Whatcom is 82 mgd. While minimizing the hydraulic capacity of a new intake system would reduce its cost, doing so could be disadvantageous as it relates to the future and potential future uses described above. The intake alternatives were developed with these two key flow parameters mind. The hydraulic capacities for each of the alternatives are presented as part of the descriptions of the intake alternatives in Sections 3.2.5 through 3.2.7.

3.2.4. Fish Guard Requirement

Per Revised Code of Washington (RCW) 77.57.010 fish guard devices are required on all intakes and diversions from lakes and rivers. Fish guard devices are oftentimes screens but can be other devices and structures, such as velocity barriers, if those other devices are demonstrated to be applicable and effective. Washington Department of Fish and Wildlife (WDFW) is the agency with jurisdiction over fish guards in Washington State.

A similar federal requirement (Section 7 of Endangered Species Act [ESA]) for fish guard devices involving the National Marine Fisheries Service (NMFS) and/or the United States Fish and Wildlife Service (USFWS) applies if there are threatened, endangered or anadromous fish species. The fish guard device design criteria for fish screens are the same for the federal and state criteria. However, because there are no threatened, endangered, or anadromous fish species in Lake Whatcom, the ESA Section 7 requirement does not apply.

As a result, although the City's existing Lake Whatcom intake does not have a fish screen, it is assumed for the purposes of this study that a fish screen will be required for a new Lake Whatcom intake – should the City select to pursue implementation of a new intake. Evaluation of fish guard devices, including a fish screen or other devices that may be less costly to clean and maintain, would be undertaken as part a preliminary design process.

As part of development of design criteria for a fish guard device, the City may elect to evaluate whether a fish guard device is necessary and whether such a device could be avoided. If a new intake were to be designed to be deep and away from the shoreline it could potentially be demonstrated that a fish guard devices is not necessary because no fish commonly reside at this location. RCW 77.55.231 allows for the potential to implement less-rigorous fish guard devices. It would be necessary to negotiate with WDFW and present a solid case based on a biological evaluation. While it is not common, there are instances where fish screens have been avoided on lakes and rivers.

3.2.5. Secondary Intake via In-Water Pipeline (Intake Alternative 1)

This alternative includes implementing a new, secondary intake that would function as a supplemental or alternate intake to the existing intake. It would be operated when algae conditions warrant. The new intake pipeline would extend from the existing Gate House along the bottom of Lake Whatcom to a location in Basin 3, as shown in Figure 3-6.

The new intake would be equipped with new fish-screened intake openings at one or two depths within the hypolimnion of Basin 3. In combination with the existing intake, which is at a depth of 30 feet, the combined intake system would have multi-level intake capability.

For the purpose of this evaluation, the hydraulic capacity of the new, supplementary intake would be 40 mgd. This hydraulic capacity was established in recognition of the following factors:

- The existing intake would be available to meet demands that exceed 40 mgd. However, the existing system would not have the same algae-favorable water quality as the new, supplemental intake.

- The 40 mgd capacity exceeds current projections of future peak day water demands for the City's municipal water system. It should be noted that water from the new, supplementary intake, with is low algae concentration, could be blended with water from the existing intake to meet demands that exceed 40 mgd during periods of high algae at the City's existing intake.

- Establishing the capacity of the new, supplemental intake system at 40 mgd results in a less costly new supplemental intake than if implementing it at the full Lake Whatcom water right of 82 mgd. This implementation strategy incorporates continued reliance on the existing intake for potential future high flows.

- The new intake system would retain its existing 108 mgd hydraulic capacity via the existing intake and would have a hydraulic capacity of 40 mgd through the new, supplemental intake.

Any future demands ensure adequate capacity to meet current and projected municipal, which comfortably exceeds current and projected municipal demand. The existing intake would remain in service and retain its current gravity capacity of 108 mgd.

A summary of the advantages and disadvantages of Intake Alternative 1 (Secondary Intake via In-Water Pipeline) for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-9.

TABLE 3-9
Advantages and Disadvantages of Intake Alternative 1 (Secondary Intake via In-Lake Pipeline)

Advantages	Disadvantages
Minimal on-land disruption of Lake Whatcom Boulevard, which is a primary access route to residents and businesses.	Extensive examination, study, and evaluation of subsurface geotechnical conditions and bathymetry needed to develop effective design of intake pipeline installation.
New supplemental and combined (existing and new supplemental) intake system conveys lake withdrawal entirely by gravity.	Similar to each of the intake alternatives, extensive environmental permitting will be required, as well as extended time to complete the permitting process.

TABLE 3-9
Advantages and Disadvantages of Intake Alternative 1 (Secondary Intake via In-Lake Pipeline)

Advantages	Disadvantages
New supplemental portion of intake system has a reduced diameter in comparison with Intake Alternative 3, which reduces the cost of this improvement.	
With respect to maximizing use of existing infrastructure, this alternative makes continued use of the City's existing intake, which remains functional after nearly 70 years of service.	
New supplemental portion of intake system would provide complete intake redundancy "upstream" of the existing Gate House, which would improve intake reliability.	

3.2.6. Secondary Intake via Over-Land Pipeline (Intake Alternative 2)

Like Intake Alternative 1, this alternative includes implementing a new, secondary intake that would function as a supplemental, secondary, or alternate intake to the existing intake. It would be operated when algae conditions warrant. The new intake pipeline would extend from the existing Gate House overland in Lake Whatcom Boulevard along the south side of the lake to a location in Basin 3, as shown in Figure 3-6.

Like Intake Alternative 1, the new intake would be equipped with new fish-screened intake openings at one or two depths within the hypolimnion of Basin 3. In combination with the existing intake, which is at a depth of 30 feet, the combined intake system would have multi-level intake capability.

Although this alternative minimizes the length of new in-lake pipeline installation and its associated installation challenges and uncertainties, a new over-land intake pipeline system would require a pump station to convey water through the over-land pipeline in Lake Whatcom Boulevard, above lake level, back into the existing tunnel at the Gate House. For the purpose of this evaluation, and for the reasons described above for Intake Alternative 1, the hydraulic capacity of the new, supplementary intake would be 40 mgd.

A summary of the advantages and disadvantages of Intake Alternative 2 (Secondary Intake via Over-Land Pipeline) for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-10.

TABLE 3-10
Advantages and Disadvantages of Intake Alternative 2 (Secondary Intake via Over-Land Pipeline)

Advantages	Disadvantages
A lesser amount (than the other intake alternatives) of evaluation of uncertain subsurface geotechnical and bathymetric conditions within Lake Whatcom.	Extensive disruption to the public and to traffic along Lake Whatcom Boulevard during construction.
New supplemental portion of intake system would provide complete intake redundancy “upstream” of the existing Gate House, which would improve intake reliability.	Pumping of the flow through the new supplemental intake will be necessary.
	Property rights acquisition (purchase or easement) will be necessary for the intake pump station and will likely also be necessary for several segments of the intake pipeline.

3.2.7. New Dual-Intake System (Intake Alternative 3)

This alternative is essentially the same as Intake Alternative 1(Secondary Intake via In-Water Pipeline) except that the existing intake is removed from service and replaced with a new intake at a 30-foot depth in Basin 2 (at a different location than the existing intake). The intake pipeline alignment would be in the lake and would extend to the same location in Basin 3 as Intake Alternatives 1 and 2, as shown in Figure 3-6. The rationale behind this alternative is implementing a new intake and abandoning the existing intake, which will eventually need repair and replacement.

The new intake would be equipped with two fish-screened intake locations. One of the screened intake locations would be relatively shallow (in the epilimnion) along the alignment of the new intake pipeline location in Basin 2. The other would be at greater depth in the hypolimnion at the same depth and location as the other two alternatives in Basin 3. The hydraulic capacity of this intake alternative would be 108 mgd for the nearest and shallow intake opening in Basin 2 (matching the gravity conveyance capacity of the City’s existing intake) and 40 mgd for the intake openings in Basin 3 (the same as Intake Alternatives 1 and 2).

A summary of the advantages and disadvantages of Intake Alternative 3 (New Dual-Intake System) for mitigating the adverse impacts of filter-clogging algae is presented in Table 3-11.

TABLE 3-11
Advantages and Disadvantages of Intake Alternative 3 (New Dual-Intake System)

Advantages	Disadvantages
Minimal on-land disruption of Lake Whatcom Boulevard, which is a primary access route to residents and businesses.	Extensive examination, study, and evaluation of subsurface geotechnical conditions and bathymetry needed to develop effective design of intake pipeline installation.
The new intake system conveys lake withdrawal entirely by gravity.	Similar to each of the intake alternatives, extensive environmental permitting will be required, as well as extended time to complete the permitting process.

TABLE 3-11
Advantages and Disadvantages of Intake Alternative 3 (New Dual-Intake System)

Advantages	Disadvantages
New intake system is entirely new and does not rely on the existing intake that is constructed of wood, is 70 years old, and presumably has a limited remaining useful life.	This new intake system will have two fish-screened intake openings as opposed to only one for Intake Alternatives 1 and 2. More fish screens results in more annual operations and maintenance costs.
	With respect to maximizing use of existing infrastructure, this alternative does NOT make continued use of the City's existing intake, which remains functional after nearly 70 years of service.

3.3. Lake Management Alternative

This alternative was identified and included for consideration in recognition of the fact that the City and Whatcom County have already implemented the Lake Whatcom Management Program (LWMP) for the purpose of improving Lake Whatcom water quality, as is described in Section 2.4. While the City's and County's efforts with respect to the LWMP predate the Lake Whatcom TMDL Study described in Section 2.4, it is the management forum via which compliance with the TMDL requirements for dissolved oxygen and phosphorous is being pursued. Although this lake management alternative, based upon compliance with the TMDL requirements, is considered as part of this evaluation as a stand-alone strategy for mitigating the algae issues at the City's WTP, it will be implemented regardless of the results of this evaluation. As stated in Section 2.4, meeting the TMDL requirements is the cornerstone of the long-term strategy to improve water quality in Lake Whatcom, including reducing algae concentrations.

The City and Whatcom County are both entirely committed to continuing vigorous pursuit of implementation of activities and opportunities to improve Lake Whatcom water quality, which includes reduction in seasonal algae production. Compliance with TMDL standards is a requirement and key primary objective of the LWMP. The City and County are continuing their efforts through the LWMP regardless of the results of this evaluation and regardless of whether the City ultimately pursues implementation of other alternatives to mitigate the adverse impacts of filter-clogging algae at the City's WTP. Consequently, lake management will be, at a minimum, an important complementary element of the overall long-term strategy to address filter-clogging algae and maintain Lake Whatcom as a high quality drinking water supply.

Therefore, for the purposes of this evaluation, the Lake Whatcom Management Program is essentially the lake management alternative considered herein for mitigating the filter-clogging algae conditions that have been observed in recent years. As stated in Section 2.4, via the LWMP, the City of Bellingham, Whatcom County, and Lake Whatcom Water and Sewer District will be completing a Detailed Implementation Plan (DIP) to comply with the TMDL requirements. The DIP will identify phosphorous-reduction measures, annual program budgets for implementing those measures, estimated target time-frames for implementation of measures, and an overall estimate of the duration needed to meet the TMDL standards for dissolved oxygen and phosphorous.

Although these elements of the LWMP remain to be developed, it is understood by the stakeholders involved with the TMDL that the duration to meet the TMDL standards will be many years if not decades. Presumably, when the TMDL standards for dissolved oxygen and phosphorous are met, algae conditions in Lake Whatcom will not present the same challenges to filtration at the City's WTP that they did in the summer of 2009. The uncertainty with respect to the duration needed to meet the TMDL standards represents the primary disadvantage of this lake management alternative for implementation to mitigate the filter-clogging algae at the City's WTP.

One of the key elements of the City's preliminary development of its long-term lake management strategy, as well as development of the DIP, is an initial comparison of several selected phosphorus-reducing and phosphorus-removal strategies with respect to their cost and their impact on reducing phosphorous entering Lake Whatcom. This comparison is presented in tech memo format in Appendix B. The results of this initial work present a relative comparison of phosphorous–reduction measures on a cost per unit of phosphorous removed. This work not only forms one of the initial steps toward development of the DIP and the long-term lake management strategy to be implemented by the LWMP, but is intended to inform policy decisions by the City of Bellingham now and in the short-term future. Additionally, aggressive long-term pursuit of the TMDL requirements could enable a more-cost-effective initial implementation of a stand-alone algae mitigation strategy for the City's WTP, as is discussed Section 8.It should be noted that a lake management approach that has been implemented at other lake locations was also considered as part of an overall lake management approach for this application. This other lake management approach is referred to as "hypolimnetic oxygenation" which is the process of oxygenating the hypolimnion of the lake to keep it from becoming anoxic during summertime temperature stratification. Hypolimnetic oxygenation is typically accomplished by generating oxygen on shore and piping it into the lake, along the lake bottom, through pipelines with diffusers to disseminate the oxygen. The cost and complexity of this approach increases substantially with lake size.

Because anoxic conditions are known to leach phosphorous from the lake bottom sediments and settled organic material (including decaying algae), phosphorous from this source can be a substantial contributor to the overall phosphorous concentration in the lake. During the fall "lake turnover," when the lake becomes de-stratified, the phosphorous is liberated to the epilimnion where it becomes an available nutrient source for algae in spring and summer. Effective hypolimnetic oxygenation keeps this phosphorous contribution at bay, and therefore helps reduce algae growth.

Hypolimnetic oxygenation was not developed further beyond this initial consideration because the amount of the total Lake Whatcom phosphorous budget for phosphorous leached from lake bottom sediments was identified as being negligible as part of the lake modeling effort described in Section 3.2.1. The relative contribution of phosphorous from this source is presented in Figure 3 on page 6 of Appendix A.

Other lake management approaches such as covering the lake with black polypropylene balls to shade the lake from sunlight (to reduce algae growth) and aerating the lake with surface mixers or fountains were identified, but not considered. In the case of each of these approaches, both would be prohibitively expensive, ineffective, and would likely result in a multitude of other problems.

4. Screening of Alternatives

Evaluation of the alternatives to mitigate the adverse impacts of filter-clogging algae at the City's water treatment WTP was implemented in three distinct phases. These three phases include:

- **Screening of Alternatives:** This first phase, "screening of alternatives," was implemented to eliminate from further consideration and evaluation alternatives that were deemed "not selectable" based on one or more screening criteria. The results of this screening are presented in this section of the report. This approach enabled more subsequent focus and effort in developing and evaluating those alternatives that were deemed to have greater promise for selection and implementation.

- **Evaluation of Alternatives:** This second phase of the evaluation process is presented in Section 6 of this report and reflects a more-detailed evaluation of the remaining alternatives. This evaluation phase results in identification of the best alternative within each of the three main alternative categories (as applicable for alternatives evaluated beyond the screening phase) as well as a best overall alternative based on detailed evaluation criteria and ranking based mostly, but not entirely, on technical performance.

- **Triple Bottom Line Plus Evaluation:** This third phase of the evaluation process is presented in Section 7 of this report and reflects evaluation based on a "Triple Bottom Line Plus" approach. In this evaluation phase, the best alternative for each of the three main alternative categories (as applicable for alternatives evaluated beyond the screening phase) are evaluated along with a "No Action" alternative and any other selected alternatives that may appear attractive despite not ranking highest with its main alternative category. This Triple Bottom Line Plus evaluation approach enabled focusing this City-accepted method on the alternatives warranting the greatest scrutiny with respect to financial, social, environmental, and technical objectives.

The process for screening of alternatives is presented in the following three subsections that address the screening criteria that were developed, the screening matrix itself, and a discussion of the screening results.

4.1. Screening Criteria

Criteria used for screening the alternatives were developed in recognition that there are a few "deal breakers" related to mitigating the summertime algae condition at the WTP. Alternatives that do not respond positively to these "deal breakers" were deemed to not warrant additional evaluation. The criteria developed for screening that represent these "deal breaker" issues include the following:

- **History of successful performance for algae removal?** Alternatives that do not have some history or documented track record of having been successfully and reliably implemented for the purpose of removing algae were deemed to not warrant further consideration and evaluation. Alternatives that do not have such a history may possibly have some level of success at removing algae and alleviating the City's filter-clogging algae condition. However, the intention of this criterion is to avoid capital expenditure on alternatives that have an uncertain level of performance, potentially leading to substantial sunk cost.

- **Can flow stream be conveyed by gravity?** A new pump station to convey the entire flow stream will be expensive to construct and operate, add substantial complexity to the City's supply and treatment system, and reduce supply reliability. As a result, because there are other viable treatment and intake alternatives that do not require the addition of a pump station, any treatment or intake alternatives that do require a pump station were deemed to not warrant further consideration and evaluation.

- **Can alternative reasonably be accommodated on WTP site?** This screening criterion applies to the treatment alternatives, only. Some of the treatment alternatives can be accommodated on the City's existing WTP site within area that is already cleared of forest or with relatively minimal additional clearing, excavation, and utility relocation. Inter-department transfer of property from the adjacent City of Bellingham Whatcom Falls Park would be necessary for some alternatives. Because there are viable treatment alternatives with a relatively small facility footprint that can be accommodated on site, treatment alternatives that require large amounts of forest clearing, excavation, or private property acquisition were deemed to not warrant additional consideration and evaluation.

- **Addresses problem upon implementation?** Any alternative selected for implementation must effectively address the problem, functionally and reliably removing algae from the City's supply flow stream prior to the existing filters at the WTP. Alternatives that are known take many years and/or are known to have an uncertain period of time to implement and achieve success were deemed to no warrant additional consideration and evaluation.

The screening criteria were developed so that an alternative for which a "yes" answer is appropriate, warrant further evaluation. Conversely, those alternatives for which a "no" answer is appropriate for any one of the screening criteria, were dropped from further evaluation.

4.2. Screening Matrix

Screening of the alternatives was completed as a group in a workshop setting by the project team comprised of City of Bellingham and CH2M HILL staff. Assigning "yes," "no," or "n/a" was discussed among the group for each alternative and each screening criteria until a consensus was reached. The resulting screening matrix is presented in Exhibit 4-1.

EXHIBIT 4-1
Screening Matrix

Alternative	Screening Criteria [1]: History of successful performance for algae removal?	Can flowstream be conveyed by gravity?	Can alternative reasonably be accommodated on WTP site?	Addresses problem upon implementation?
Treatment Alternatives				
Clarification				
Dissolved Air Flotation (DAF)	yes	yes	yes	yes
Ballasted Sedimentation (Actiflo)	yes	yes	yes	yes
Plate and Tube Settling	yes	yes	yes	yes
Upflow Clarification (Superpulsator)	yes	yes	yes	yes
Conventional Sedimentation	yes	yes	no	yes
Micro-Screening	no	no	yes	yes
Ozonation	no	yes	yes	yes
Additional Filters	yes	yes	yes	yes
Intake Alternatives				
Secondary Intake via In-Water Pipeline	n/a	yes	n/a	yes
Secondary Intake via Overland Pipeline	n/a	no	n/a	yes
Replace Existing Intake	n/a	yes	n/a	yes
Lake Management Alternative	yes	n/a	n/a	no

Notes:
[1] Alternatives given a "no" to any of the screening criteria were dropped from further evaluation.

4.3. Results of Screening

As stated above, the purpose of the screening process was to eliminate alternatives from further consideration and evaluation that were deemed "not selectable." In achieving that purpose, the screening process resulted in eliminating the following alternatives from further consideration and evaluation:

- **Conventional Sedimentation:** This alternative was deemed to be unreasonably large to be accommodated at the WTP site without extensive environmental impacts. Given its large size, it was deemed unnecessary to further evaluate this alternative given that there are other viable and more-effective treatment alternatives with a much smaller facility footprint.

- **Micro-Screening:** This alternative was deemed to not warrant further consideration for two reasons: (1) there is no track record of its successful and effective use as a stand-alone process for algae removal in a municipal water treatment plant, and (2) micro-screening cannot be implemented without pumping in this application.

- **Ozonation:** This alternative was deemed to not warrant further consideration because there is no track record of its successful implementation for the expressed purpose of reducing or eliminating algae-filter-clogging problems.

- **Secondary Intake via Overland Pipeline:** This alternative was deemed to not warrant further consideration because it requires a pump station for the intake flow that would be conveyed from the new secondary intake.

- **Lake Management Alternative:** The City and County are committed to on-going and future efforts to improving water quality in Lake Whatcom. These efforts are being pursued as part of the Lake Whatcom Management Program with a key goal of meeting the TMDL requirements for phosphorous and oxygen. However, this alternative was deemed to not warrant further consideration for the immediate and near-term purpose of mitigating the adverse impacts of filter-clogging algae. The reason for discontinuing consideration of this alternative is that its implementation and the observation of beneficial results will take many years, if not decades. The actual duration cannot be accurately predicted. An alternative without a definite, predictable timeframe was deemed unacceptable for further consideration.

The alternatives that were not screened (eliminated) from further evaluation were further developed and evaluated in greater detail, as presented in Sections 5 and 6, respectively. These alternatives include:

Treatment Alternatives

- Dissolved Air Flotation (DAF)
- Ballasted Sedimentation (Actiflo)
- Plate Settling
- Upflow Clarification (Superpulsator)
- Additional Filters

Intake Alternatives

- Secondary Intake via In-Water Pipeline (Intake Alternative 1)
- Replacement of Existing Intake (Intake Alternative 3)

5. Development of Alternatives

Screening of the initial list of alternatives reduced the number of alternatives remaining to be evaluated to five treatment alternatives and two intake alternatives. Further development of these alternatives is presented below in Sections 5.1 and 5.2. A key part of the development of these alternatives and their estimated costs is presented in Section 5.3.

5.1. Treatment Alternatives

The five treatment alternatives remaining after the screening process include the following:

- Dissolved Air Flotation (DAF)
- Ballasted Sedimentation (Actiflo)
- Plate Settling
- Upflow Clarification (Superpulsator)
- Additional Filters

These treatment alternatives can be divided into two groups – pretreatment or high rate clarification (each of these pretreatment processes are high-rate clarification) and filtration. The high rate clarification processes have varying treatment effectiveness with respect to algae and have varying hydraulic loading rates, as discussed in Section 3. These hydraulic loading rates have a greater impact on facility area requirements than all other design criteria. In fact, the area requirements for some of these high rate clarification processes would make it challenging to situate them at the WTP site.

Figure 5-1 shows the approximate layout area requirements of each of the high rate clarification process alternatives. Included in Figure 5-1 for reference is conventional clarification, which was dropped from further consideration as part of the alternatives screening process. It is clear from Figure 5-1 why it would be exceedingly challenging and invasive to accommodate conventional clarification at the WTP site. Conversely, the area requirements presented in Figure 5-1 clearly indicate that DAF and Ballasted Sedimentation (Actiflo) have the most siting flexibility. As stated above, the reason for these reduced areas is because of their high loading rates compared to the other high rate clarification processes.

While the general siting location presented in Figure 5-1, is possible, substantial excavation would be necessary because of an existing hill. Other siting options could be substantially less costly to implement. Because of their smaller area requirements, DAF and Actiflo offer much greater siting flexibility and could be accommodated on other parts of the site where less excavation is necessary and where connections to existing yard piping is less costly. Two siting options that can accommodate DAF and Actiflo but cannot accommodate the other high rate clarification processes are presented in Figure 5-2.

The Additional Filters alternative does not provide many of the same ancillary treatment benefits provided by the pretreatment alternatives, such as TOC reduction, reduction in disinfection byproduct formation potential, and the extension of filter runs. However, adding two filters to the existing WTP would be less costly than a pretreatment system with a capacity of 30 mgd and it would substantially increase WTP capacity when algae concentrations are negligible, low, or moderate. The key concern regarding the Additional Filters alternative, as discussed in Section 3.1.8, is the potential limited benefit on WTP capacity if greater concentrations of algae in Lake Whatcom were to reduce filter run lengths to two hours or less. Whether or not Lake Whatcom algae concentrations will continue to increase to a point where such filter run length reductions occur is not known.

Given the possibility that algae blooms of greater intensity than what occurred in the summer of 2009 could occur in the future, net production capacity (excluding filter-backwashing and filter-to-waste volumes) of the WTP was plotted for varying filter run times. The capacity of the existing six filters at varying filter loading rates (up to the 6 gpm/sf allowed by Washington State Department of Health) was plotted to show how existing WTP capacity varies with changing filter run time. On the same graph, the capacity of an expanded WTP (two additional filters for a total of eight filters) was also plotted at the same filter loading rates.

These plots, presented in Figure 5-3, demonstrate how net WTP capacity varies with filter run time. When filter run times are long, which is the case when raw water algae concentration is low, two additional filters add substantially to the capacity of the WTP – up to 8 mgd. As filter run times are reduced to less than 3 hours, the increase associated with two additional filters is to approximately 5 mgd and the overall capacity of the WTP is greatly reduced. As filter run times drops to between 1 and 2 hours, the benefit to WTP capacity of two additional filters is minimal and insufficient to assist in meeting customer water demand.

The uncertainty of the extent to which future algae events in Lake Whatcom reduce filter run time at the WTP is the key disadvantage of the Additional Filters alternative and why it could prove to be ineffective when the additional capacity is needed the most.

5.2. Intake Alternatives

The two intake alternatives deemed to warrant further consideration and evaluation, Intake Alternative 1 (Secondary Intake via In-Water Pipeline) and Intake Alternative 3 (New Dual-Intake System), both involve installation within Lake Whatcom. These alternatives avoid the extensive cost and disruption associated with installation in Lake Whatcom Boulevard as well as a new pump station and its associated cost and complexity. As presented in Figure 3-6, the alignment of the intake pipelines for both Intake Alternatives 1 and 3 are the same.

However, the intake pipeline diameter for each would be different. The diameter of the entire new supplemental intake pipeline for Intake Alternative 1 would be 60 inches to enable conveyance of 40 mgd by gravity from Basin 3. The diameter of the new intake pipeline for Intake Alternative 3 would be 78 inches to the new screened intake in Basin 2 to enable up to 108 mgd of gravity conveyance capacity (to match the existing intake pipeline) and 60 inches between the Basin 2 intake and the new intake in Basin 3 to enable 40-mgd gravity conveyance capacity.

Intake Alternative 3 includes a new shallow intake in Basin 2 with fish screens to replace the existing intake that would be abandoned. This new shallow intake is not necessary for Intake Alternative 1 because Intake Alternative makes continued use of the existing intake.

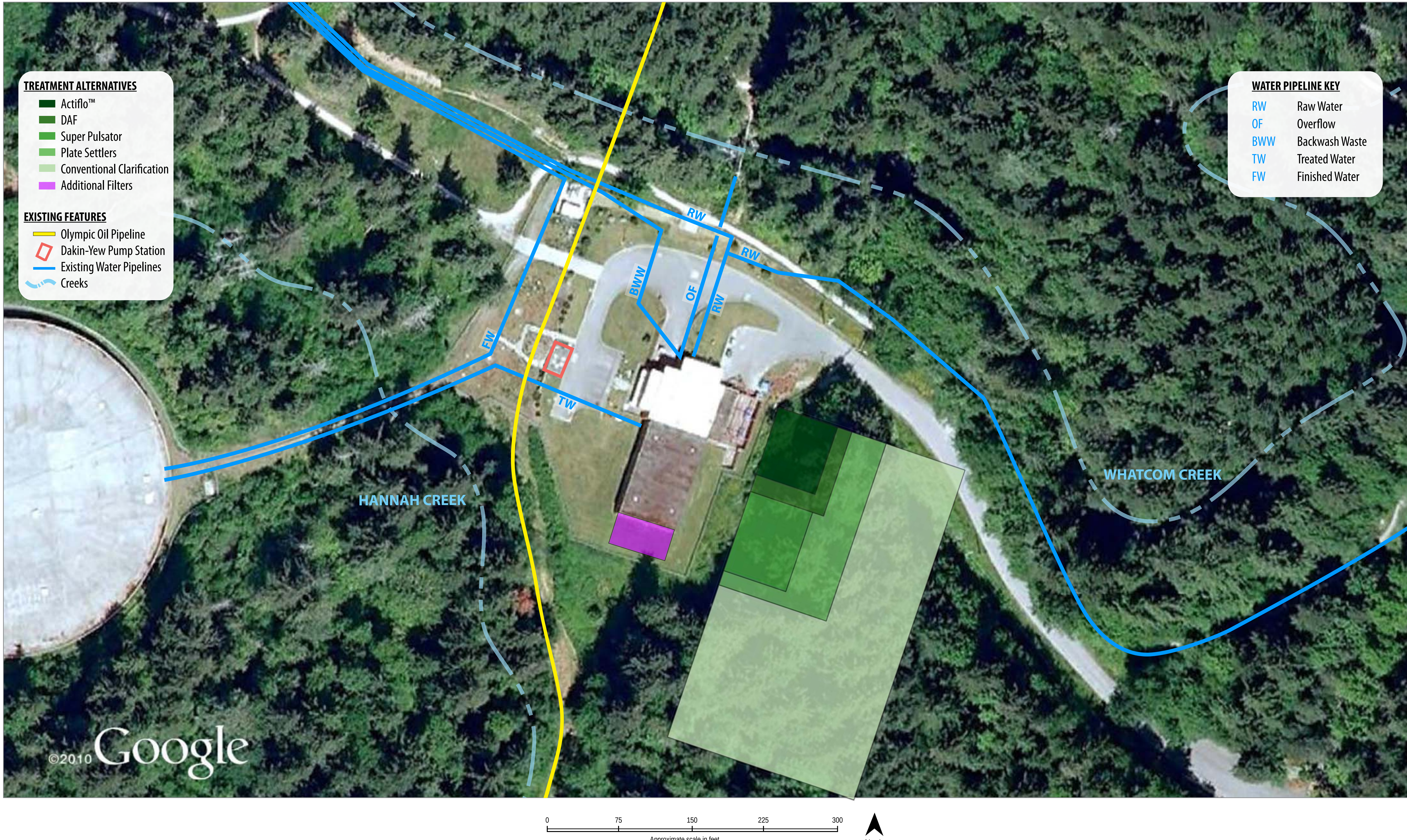

FIGURE 5-1
AREA REQUIREMENTS FOR
TREATMENT ALTERNATIVES

CH2MHILL.

WBG082411034416SEA | 421550.WF.02 Fig5-1_AreaRequiremntsPretreatmntAlternatives 20jan12 kk . lw . lh

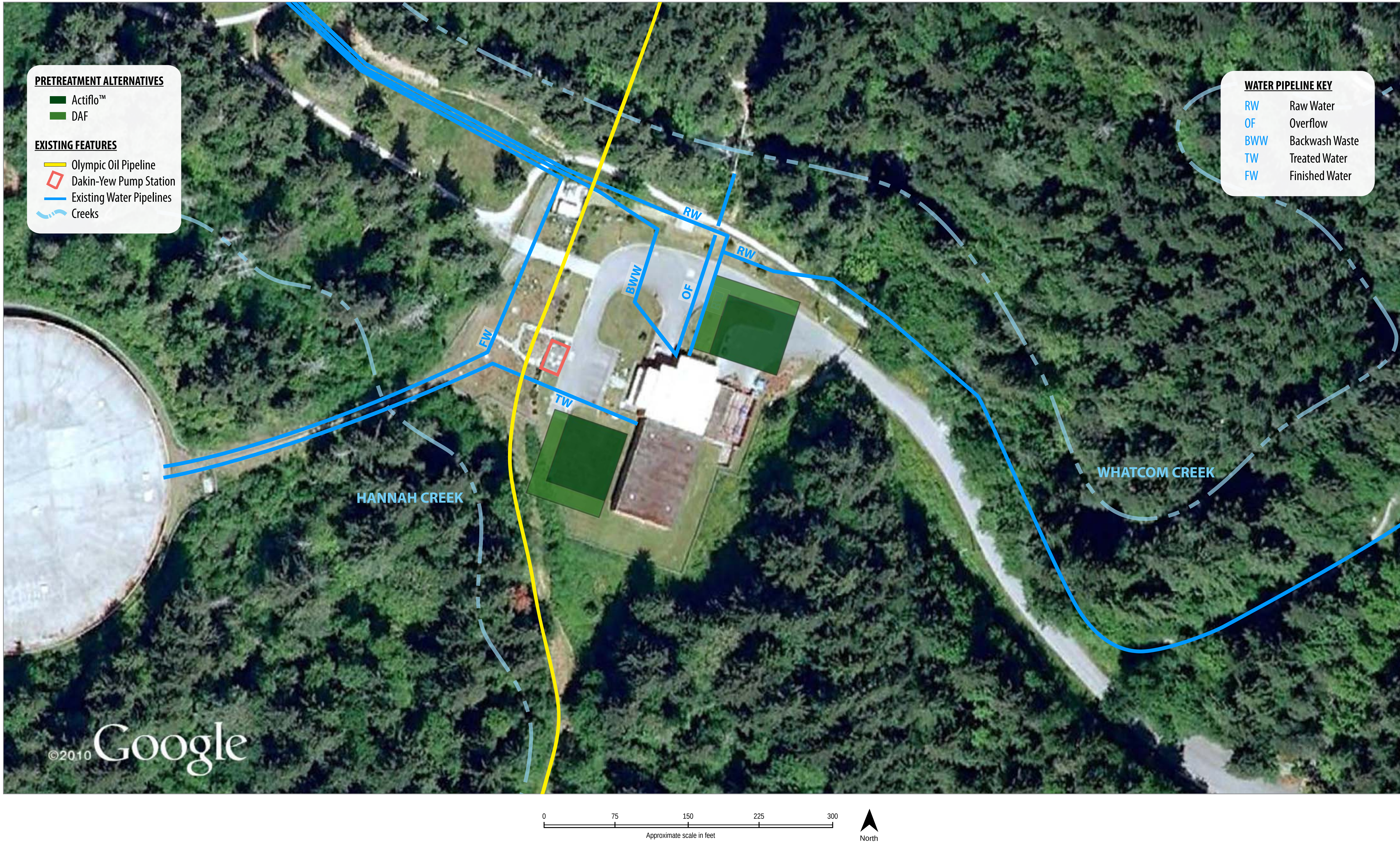

FIGURE 5-2
ALTERNATIVE SITE LAYOUTS FOR DAF AND ACTIFLO

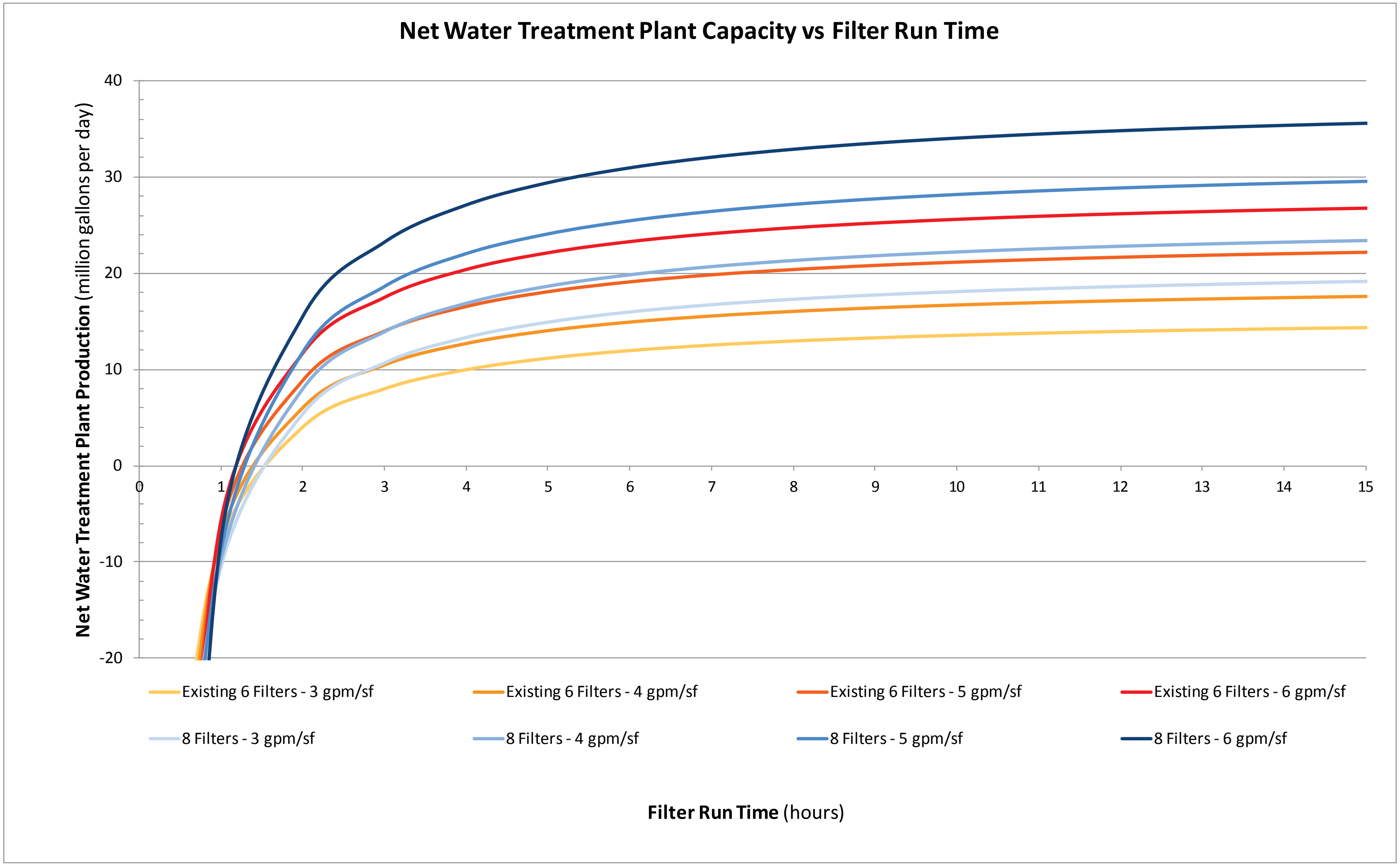

FIGURE 5-3
Net Water Treatment Plant Capacity vs. Filter Run Time

Both intake alternatives would include a new fish-screened intake in Basin 3 that extends to a depth of approximately 120 feet to ensure it is well within the hypolimnion and below the typical range of depths where Lake Whatcom algae reside. Schematic detail of the configuration of the extension of the intake pipeline in Basin 3, the associated fish screens, and the on-shore housing of electric control equipment is presented in Figure 5-4. It should also be noted that Intake Alternative 3 has three times the number of fish screens as Intake Alternative 1 and two on-shore electrical equipment housings instead of one. The reason for these additional fish screens and extra on-shore electrical equipment housing is that Intake Alternative 3 includes the new, shallow-depth intake in Basin 2, at twice the capacity as the new intake in Basin 3, to replace the existing intake system.

These additional fish screens add substantially to system complexity as well as capital and operations and maintenance costs. The detail presented in Figure 5-4 would be similar for the new intake in Basin 2 associated with Intake Alternative 3, except that the new electrical equipment housing would be on the north shore of Lake Whatcom.

5.3. Estimated Costs

Estimated initial capital, annual operations and maintenance, and 20-year life-cycle costs were developed for each of the alternatives. The estimates were developed to the “concept level” or “Class 5” level of accuracy as defined by the Association for the Advancement of Cost Engineering International (AACEI). This level of cost estimating is considered accurate to +30 to -20 percent.

The estimated costs were prepared for guidance in evaluation of alternatives and selection of a preferred alternative for implementation based on information available at the time of the estimate. The final cost of the project will depend upon the actual labor and material costs, competitive market conditions, implementation schedule, and other variable factors. As a result, the final project costs will vary from the estimates presented herein. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions.

5.3.1. Initial Capital

Initial capital costs were developed for each of the alternatives. A summary of these costs is presented in Table 5-1.

Markups applied in developing the construction portion of the initial capital cost estimate are listed below.

- General Conditions: 5%
- Contractor Overhead: 10%
- Profit: 6%
- Mobilization/Bond/Insurance: 10%
- Contingency: 30%
- Escalation Rate to Midpoint of Construction: 12.8%
- Whatcom County, WA Sales Tax: 8.7%

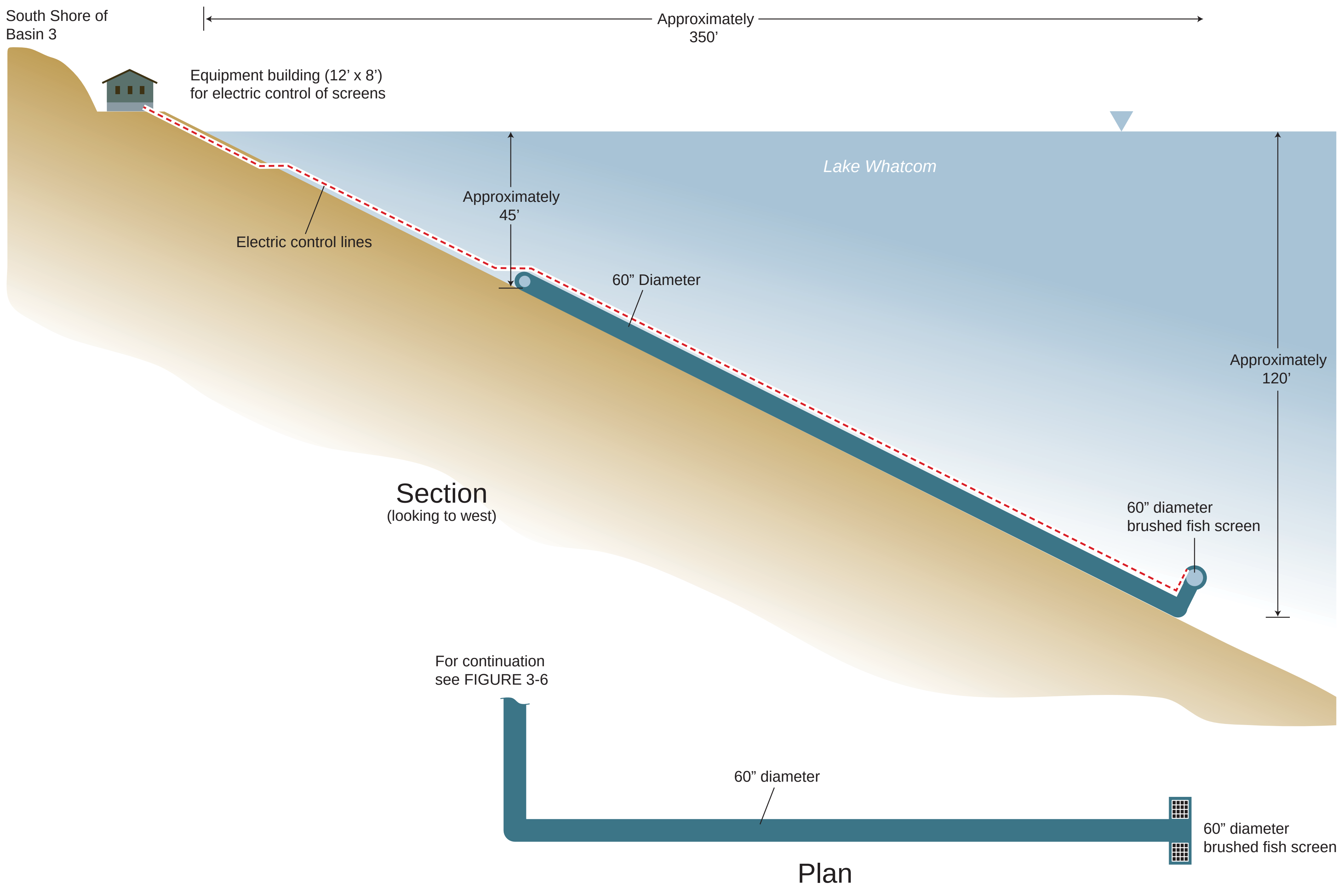

FIGURE 5-4
BASIN 3 INTAKE DETAIL FOR
INTAKE ALTERNATIVES 1 AND 3

TABLE 5-1
Summary of Estimated Initial Project Costs

Process Improvement	Plate Settling	DAF	SuperPulsator	Actiflo	Additional Filters	Intake Alternative 1	Intake Alternative 3
Construction Costs:							
Construction Cost Subtotal	$ 9,342,000	$ 5,756,000	$ 6,653,000	$ 5,143,000	$ 2,338,000	$ 13,463,000	$ 14,679,000
Subtotal with Contractor OH (10%)	$ 10,276,000	$ 6,332,000	$ 7,318,000	$ 5,657,000	$ 2,572,000	$ 14,809,000	$ 16,146,000
Subtotal with Contractor Profit (6%)	$ 10,893,000	$ 6,711,000	$ 7,757,000	$ 5,997,000	$ 2,726,000	$ 15,698,000	$ 17,115,000
Subtotal with Contractor Mob, Bonds Ins (10%)	$ 11,982,000	$ 7,383,000	$ 8,533,000	$ 6,596,000	$ 2,999,000	$ 17,268,000	$ 18,827,000
Subtotal with Contingency (30%)	$ 15,577,000	$ 9,597,000	$ 11,093,000	$ 8,575,000	$ 3,898,000	$ 22,448,000	$ 24,475,000
Escalation to Yr 2014 (12.8%)	$ 17,570,000	$ 10,826,000	$ 12,513,000	$ 9,673,000	$ 4,397,000	$ 25,321,000	$ 27,607,000
Construction w/ Sales Tax (8.7%)	**$ 19,099,000**	**$ 11,768,000**	**$ 13,602,000**	**$ 10,515,000**	**$ 4,780,000**	**$ 27,524,000**	**$ 30,009,000**
Non-Construction Costs:							
Pilot Testing	NA	$130,000	$ 200,000	$ 200,000	NA	NA	NA
Property for Screen Control House	NA	NA	NA	NA	NA	$ 500,000	$ 500,000
Geotechnical/Bathymetry[1]	$ 70,000	$ 70,000	$ 70,000	$ 70,000	$ 70,000	$ 400,000	$ 400,000
Modeling/WQ Monitoring	NA	NA	NA	NA	NA	$100,000	$100,000
Permitting	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 400,000	$ 400,000
Engineering and Construction Management [2]	$ 3,438,000	$ 2,118,000	$ 2,448,000	$ 1,893,000	$ 860,000	$ 2,752,000	$ 3,001,000
Startup[3]	$ 382,000	$ 235,400	$ 272,000	$ 210,300	$ 95,600	$ 275,200	$ 300,100
Total	**$ 23,189,000**	**$ 14,521,000**	**$ 16,792,000**	**$ 13,087,000**	**$ 6,006,000**	**$ 31,952,000**	**$ 34,710,000**

Notes:

[1] Treatment and intake alternatives both require geotechnical evaluation; however, only the intake alternatives require detailed bathymetric survey of Lake Whatcom.

[2] Eighteen percent of construction was used for treatment alternatives. Ten percent was used for intake alternatives because design is anticipated to be less complicated and more costly.

[3] Startup percentage for treatment alternatives estimated at two percent of construction cost with sales tax; one percent for intake alternatives.

Note that “Escalation Rate to Midpoint of Construction” is assumed to reflect a midpoint of construction timeframe of approximately July 2014. It is understood that the actual timeframe for implementation of either a treatment alternative or an intake alternative are uncertain. It is also understood that it is expected to take approximately one additional year to complete environmental permitting for an intake alternative as opposed to a treatment alternative; however, no distinction in the escalation rate was made with respect to this difference.

No estimate of land acquisition (none anticipated), legal, and project administration/management by the City are included in the estimated initial capital costs.

The estimated non-construction costs were prepared as follows:

- **Pilot Testing:** Pilot testing was deemed necessary to implement DAF, Actiflo, and Superpulsator clarification, but not plate settling. DAF pilot testing has already been completed. No pilot testing is necessary for additional filtration, and pilot testing is not applicable to the intake alternatives.

- **Property for Screen Control House:** The estimated cost for property rights acquisition for the Screen Control House is an allowance that is subject to substantial potential variation – depending on whether the property is purchased, an easement is required, and whether the property is directly adjacent to Lake Whatcom or not.

- **Geotechnical/Bathymetry:** Substantial geotechnical evaluation will be necessary for the intake alternatives to assess conditions of the lake bottom along the intake pipeline alignment. It will be necessary to drill boreholes at multiple locations along the alignment from a floating barge in the lake. Geotechnical evaluation of the WTP site will be more limited and focused. Bathymetric survey applies only to the intake alternatives.

- **Modeling/WQ Monitoring:** Modeling was completed as part of this project to identify a suitable location and depth for a new intake. However, given the cost of a new intake, additional modeling and focused lake water quality monitoring were deemed warranted to provide further confirmation of the initial modeling.

- **Permitting:** Permitting requirements for a new supplemental intake will be more extensive for a new supplemental intake than for additional treatment. Permits/approvals/lease agreements and associated work products for a new intake system are anticipated to include: US Army Corps of Engineers Section 10 and 404, Biological Assessment, Hydraulic Project Approval, Ecology 401, DNR Lease, Shoreline Development, Critical Area Review, Environmental Impact Statement, and Building. Similarly, new treatment improvements are anticipated to require the following permits/approvals: Shoreline development (depending on siting of the treatment unit), SEPA, and Building.

- **Engineering and Construction Management:** The estimated cost for engineering and construction management was 18 percent for the treatment improvements and 15 percent for the intake improvements. These percentages were based on the construction cost subtotal. The reason for the difference is the reduced complexity of the design for the intake alternatives.

- **Startup:** An allowance for start-up, testing, and trouble-shooting of the new treatment system and equipment, as well as the new intake system, including the new fish screen, was included at a rate of 2 percent of the construction cost subtotal.

5.3.2. Annual Operations and Maintenance

Annual operations and maintenance costs were developed for each of the alternatives and are presented in Table 5-2. It should be noted that no additional estimated labor costs were included for either the treatment improvements or the intake improvements. In both cases, the amount of additional labor by City staff is expected to be minimal, and it is expected that additional routine operations and maintenance requirements can be covered by existing City staff.

For the intake alternatives, the two greatest contributors to the annual operations and maintenance costs are related to the fish screens. Annual fish screen inspections are anticipated to be necessary to confirm the condition and functionality of the fish screens. These inspections can be accomplished by divers or potentially by a remote-controlled, underwater camera. No repair work is associated with these inspection dives.

In addition to the annual fish screen inspections, “10-yr Fish Screen Maintenance” was included as a cost allowance to account for the fact that the fish screens will need to be removed and rehabilitated/repaired or removed and replaced. The fish screens are motorized mechanical devices that will eventually experience some level of failure. Extraction and subsequent re-installation of the fish screens will be costly and require barge and crane equipment. These once-in-10-year costs were divided evenly by 10 to develop an annual estimate of the cost.

Annual operations and maintenance cost for the treatment alternatives was divided into two line items – one based on continuous year-round operation and the other based on 3-month operation. The approach here is based on the acknowledgement that the City may elect to only operate the new treatment systems for the summertime months when they are anticipated to be necessary to address increased algae in Lake Whatcom. That stated, because the new pretreatment systems are expected to substantially improve treatment performance of the existing WTP, it is understood the City may elect operate the new treatment systems on a year-round basis.

5.3.3. Net Present Value

Estimates of net present value over a 20-year period were computed for each of the alternatives to enable comparison of the combined initial capital and annual operations and maintenance costs. Annual operations and maintenance costs presented in Table 5-3 were used in the net present value estimates. An annual interest rate and inflation rate of 5 percent and 3 percent, respectively, were used in the computation. Estimates of net present value were developed for the treatment alternatives based on continuous year-round operation and on 3-month operation.

TABLE 5-2
Summary of Estimated Annual O&M Costs

Process Improvement	Plate Settling	DAF	SuperPulsator	Actiflo	Additional Filters	Intake Alternative 1	Intake Alternative 3
Chemical	$ 25,400	NA	$ 42,400	$ 45,600	NA	NA	NA
Electrical	$ 17,800	$ 30,300	$ 42,800	$ 30,100	$ 5,500	$ 890	$ 3,550
Residuals	$ 1,800	NA	$ 2,100	$ 3,900	NA	NA	NA
Equipment Repair, Replacement, Misc (30%)[1]	$ 13,500	$ 9,100	$ 26,200	$ 23,800	$ 1,600	NA	NA
Fish Screen Building Maintenance	NA	NA	NA	NA	NA	$ 4,230	$ 4,230
Annual Fish Screen Inspection	NA	NA	NA	NA	NA	$ 9,210	$ 27,640
10 yr Fish Screen Maintenance [2]	NA	NA	NA	NA	NA	$ 200,600	$ 477,000
Total (year-round operation)	**$ 59,000**	**$ 39,000**	**$ 113,000**	**$ 103,000**	**$ 7,000**	**$ 34,400**	**$ 83,100**
Total (3-month operation) [3]	**$ 14,750**	**$ 9,750**	**$ 28,250**	**$ 25,750**	**$ 1,750**	*NA*	*NA*

Notes

[1] Equipment repair, replacement, and associated miscellaneous costs for treatment alternatives based on 30% of chemical, electrical, and residuals handling costs.

[2] Every 10 years each fish screen will need to be extracted for repair and rehabilitation and replaced. These once-per-10yr costs were divided by 10 to annualize them.

[3] Three-month O&M costs based on the assumption that new treatment facilities would only be needed during late summer algae-bloom period.

TABLE 5-3
Summary of Estimated Net Present Value Costs

Process Improvement	Plate Settling	DAF	SuperPulsator	Actiflo	Additional Filters	Intake Alternative 1	Intake Alternative 3
Initial Capital	$ 23,189,000	$ 14,521,000	$ 16,792,000	$ 13,087,000	$ 6,006,000	$ 31,952,000	$ 34,710,000
O&M (year-round operation)	$ 59,000	$ 39,000	$ 113,000	$ 103,000	$ 7,000	$ 34,400	$ 83,100
O&M (3-month operation)	$ 14,750	$ 9,750	$ 28,250	$ 25,750	$ 1,750	NA	NA
NPV Cost (year-round operation)	**$ 24,159,000**	**$ 15,163,000**	**$ 18,650,000**	**$ 14,781,000**	**$ 6,121,000**	**$ 32,490,000**	**$ 36,011,000**
NPV Cost (3-month operation)	**$ 23,432,000**	**$ 14,682,000**	**$ 17,257,000**	**$ 13,512,000**	**$ 6,036,000**	**NA**	**NA**

6. Evaluation of Alternatives

The alternatives that passed the screening phase of evaluation presented in Section 4 were further evaluated, as presented in this section. This further evaluation was completed in two steps. First, the treatment alternatives and the intake alternatives were evaluated separately based on non-cost criteria. Note that the lake management alternative did not pass the alternatives screening phase. Then, once the best treatment alternative and intake alternative were identified based on non-cost evaluation criteria, those two alternatives were evaluated with respect to each other – also based on non-cost criteria. The cost information presented in Section 5.3 was then incorporated into this phase of the evaluation process. The evaluation criteria for this phase of the evaluation process, completed evaluation matrices, and the results of this phase of the evaluation process are presented in the subsections below.

Results of this phase of evaluation were used to select alternatives warranting further scrutiny and evaluation based on the Triple Bottom Line Plus approach. The Triple Bottom Line Plus phase of evaluation is presented in Section 7.

6.1. Evaluation Criteria

A brief summary of the evaluation criteria for the treatment alternatives is presented as follows:

- **Algae removal effectiveness:** This evaluation criterion relates to the effectiveness that treatment processes have demonstrated within the municipal drinking water industry at removing algae.

- **Minimizes algal toxin release:** Although algal toxins are not believed to be an issue with algae that have historically been present in Lake Whatcom, it could potentially become an issue in the future as the algae community in Lake Whatcom changes and as regulatory requirements tighten.

- **Maximizes flexibility to treat emerging contaminants:** Emerging contaminants are constituents that are not currently regulated, but that could be regulated in the future. These contaminants could include micro-biological constituents, pharmaceutical products, fire-retardant products, etc. These constituents are not currently believed to be in Lake Whatcom at substantial or even measurable levels. And, while they are not expected to increase in concentration in the future, it is not out of the realm of possibility that they could increase. Treatment processes that can accommodate adsorption via the addition of powdered activated carbon are generally believed to be more effective at removing these emerging contaminants.

- **T&O effectiveness:** While algae-induced taste and odor has not been a challenging issue for the City's existing WTP, minor to moderate taste and odor observed during the summer time algae season has been observed. Treatment effectiveness related to minimizing taste and odor impacts could become very important in the future if and when the character and composition of the algae in Lake Whatcom change.

- **Minimizes system complexity/ease of operation:** Treatment systems that are complex, having many mechanical parts and complicated controls, are more prone to equipment failure and are generally not favored. Conversely, treatment systems that are easy to operate with changing raw water quality and equipment failure are generally favored. These systems tend to result in more consistent and reliable performance.

- **Maximizes "sustainability":** Each of the treatment systems considered for this project use energy, produce residual solids that must be handled and disposed, and are comprised to varying degrees of materials. This criterion was included to provide a cursory assessment of the relative sustainability of each treatment alternative.

- **Minimizes "footprint"/siting flexibility:** This criterion enables differentiation between treatment processes that have a larger facility layout. Primary options for siting a new pretreatment facility is the east side of the existing WTP, the north side (influent side), and the west side of the WTP. Treatment processes with a larger facility footprint cannot be as easily on any of these sides of the existing facility, may require purchase of substantial additional property, and possibly environmental mitigation of adjacent forested and wet areas.

- **Minimizes disinfection byproducts:** Clarification processes are generally effective to some degree at removing TOC. TOC combines with chlorine disinfectant to produce disinfectant byproducts. Removing TOC typically results in reduced production of disinfection byproducts. Clarification, when combined with filtration, results in greater combined TOC removal than filtration alone.

A brief summary of the evaluation criteria for the intake alternatives is presented as follows:

- **Minimizes construction disruption:** This criterion relates primarily to construction of the intake pipeline between the existing Gate House and the new intake location. With limited roadway access and egress to the south side of Lake Whatcom, disruption of traffic flow for several weeks would present substantial challenge to the local community.

- **Minimizes permitting challenges:** A new intake will require several environmental permits. Environmental permits will be challenging to obtain regardless of the intake alternative selected.

- **Preserves existing hydraulic capacity:** Although the amount of typical flow through the existing intake system is substantially less than hydraulic capacity, preserving intake capacity for growth and other potential future uses is important and warrants consideration. Alternatives that supplement the continued use of the existing intake preserve existing hydraulic capacity.

- **System complexity / ease of operation:** A new intake with a screen to prevent fish from entering the system will be more complex than the City's existing intake, which does not have a fish screen. Therefore, the alternative with fewer fish screens will be less complex and be easier to operate.

The evaluation criteria for comparing the best of the treatment and the best of the intake alternatives are listed below and are mostly the same or similar to the evaluation criteria summarized above. These criteria were modified, where necessary and applicable, to be relevant to both treatment and intake alternatives. More discussion of the evaluation of each of these "best" alternatives with respect to these evaluation criteria is presented in Section 6.2.3.

- Minimizes construction disruption to the community
- Minimizes permitting challenges
- Long-term certainty of continued effectiveness
- Maximizes sustainability
- Minimizes WTP disruption
- Minimizes system complexity / ease of operation

6.2. Evaluation Matrices

Evaluating the alternatives was completed as a group in a workshop setting by the project team comprised of City of Bellingham and CH2M HILL staff. Evaluation matrices presented as Exhibits 6-1, 6-2, and 6-3 were completed by the group based on the evaluation criteria described in Section 6.1. Exhibit 6-1 was completed for the treatment alternatives based on the selected criteria relevant to these types of alternatives. Similarly, Exhibit 6-2 was completed based on evaluation criteria relevant to the intake alternatives. The alternatives presented in Exhibits 6-1 and 6-2 with the highest score – the alternatives deemed the best within their category – were evaluated and ranked, as presented in Exhibit 6-3.

To complete the evaluation matrices, the group assigned a relative weight or importance (from 1 to 5) to each of the evaluation criteria. Then, each alternative was ranked (also from 1 to 5) with respect to each evaluation criteria. Total scores for each alternative were computed by multiplying the weight for each evaluation criterion by the assigned ranking. Each of those multiplication products were summed to produce a total score for each alternative.

6.3. Results of Evaluation

Evaluation results are presented separately in the subsections below for the treatment alternatives, intake alternatives, and the best alternatives from each of those two categories.

EXHIBIT 6-1
Evaluation Matrix for Treatment Alternatives

Alternative	Evaluation Criteria: Algae removal effectiveness	Minimizes algal toxin release	Maximizes flexibility to treat emerging contaminants	T&O effectiveness	Minimizes system complexity / ease of operation	Maximizes "Sustainability"	Maximizes siting flexibility	Minimizes disinfection byproducts	Total Score
Criteria Weighting (1)	**5**	**4**	**3**	**4**	**4**	**4**	**3**	**3**	
Dissolved Air Flotation (DAF)	5	5	3	5	3	3	4	4	**122**
Ballasted Sedimentation (Actiflo)	4	2	4	4	2	2	5	4	**99**
Plate Settling	3	3	4	4	4	4	1	3	**99**
Upflow Clarification (Superpulsator)	3	3	4	4	2	3	3	4	**96**
Additional Filters	3	3	1	1	4	4	4	1	**81**

Notes

[1] Criteria weighting reflects relative importance (5 = most important; 1 = least important).

[2] Relative scoring of each alternative with respect to each criterion:
5 = excellent; 4 = very good; 3 = satisfactory; 2 = questionable; 1 = unacceptable

EXHIBIT 6-2
Evaluation Matrix for Intake Alternatives

Alternative	Evaluation Criteria: Minimizes Construction Disruption	Minimizes Permitting Challenges	Preserves Existing Hydraulic Capacity	System Complexity / Ease of Operation	Total Score
Criteria Weighting (1)	**3**	**2**	**5**	**4**	
Secondary Intake via In-Water Pipeline	3	3	3	4	**46**
Replace Existing Intake	3	3	1	3	**32**

Notes

[1] Criteria weighting reflects relative importance (5 = most important; 1 = least important).

[2] Relative scoring of each alternative with respect to each criterion:

5 = excellent; 4 = very good; 3 = satisfactory; 2 = questionable; 1 = unacceptable

EXHIBIT 6-3
Evaluation of Best Intake and Best Treatment Alternatives

Alternative	Minimizes construction disruption to the community	Minimizes permitting challenges	Long-term certainty of continued effectiveness	Maximizes sustainability	Minimizes WTP disruption	Minimizes system complexity / ease of operation	Total Score
	Evaluation Criteria						
Criteria Weighting (1)	**3**	**2**	**5**	**2**	**2**	**4**	
Intake Alternative 1	2	2	2	4	4	2	**44**
Dissolved Air Flotation (DAF)	3	4	5	3	2	3	**64**

Notes
[1] Criteria weighting reflects estimated relative importance of each criterion (5 = most important; 1 = least important).
[2] Relative scoring of each alternative with respect to each criterion:
5 = excellent; 4 = very good; 3 = satisfactory; 2 = questionable; 1 = unacceptable

6.3.1. Treatment Alternatives

As presented in Exhibit 6-1, DAF is the treatment alternative that received the highest ranking with respect to the other alternatives within the treatment category, and was thereby deemed to be the "best" of the treatment alternatives to mitigate the algae condition at the City's WTP. As shown by the ranking, DAF was deemed to be superior to the other alternatives by a wide margin.

Ranking of the treatment alternatives produced the following key results:

- DAF was far superior to the other alternatives. The main reason for this was the superior algae removal effectiveness of DAF, which was deemed to be the most important evaluation criteria. Secondarily, DAF was ranked markedly higher than the other pretreatment alternatives with respect to minimizing algal toxin release as well as treating for taste and odor impacts. While these two factors have not yet substantially evidenced themselves in the Lake Whatcom supply, it is uncommon for water supplies with algae issues to not have also have algal toxin or taste and odor issues to some degree.

- The pretreatment alternatives other than DAF (Ballasted Sedimentation, Plate Settling, and Upflow Clarification) each had similar scores that were substantially lower than the ranking for DAF and substantially greater than the ranking for the Additional Filters alternative. The primary reason for this is their reduced performance with respect to DAF, as stated above. However, it should also be noted that these pretreatment alternatives each offer substantial benefit with respect to algae removal and the other evaluation criteria when combined with the effective filtration process the City currently employs.

- The Additional Filters alternative received an overall ranking that was substantially below all of the other treatment alternatives. Its ranking was lower primarily because it does not offer most of the same primary and ancillary benefits offered by the pretreatment improvements. Simply adding more filters does not result in the ancillary benefits achieved by pretreatment process that substantially improve water quality prior to the filtration process, which results in improved filter run times as well as capacity. The greatest concern with implementing this alternative is that if future algae blooms in Lake Whatcom result in filter run times that are markedly lower than what was observed during the algae bloom of 2009, this alternative may offer no additional benefit.

Evaluating the treatment alternatives based on non-criteria resulted in a clearly-preferred technological approach. Comparing those results with the estimated costs presented in Section 5.3 enables further confirmation of the treatment approach deemed best-suited for this application.

The results of the evaluation ranking presented in Exhibit 6-1 and the estimated Net Present Values presented in Table 5-3 are presented graphically in Figure 6-1. What is clear from Figure 6-1 is that the lowest-ranking alternative, Additional Filters, had the lowest estimated cost and the highest-ranking alternative, DAF, had an estimated cost similar to Actiflo, which was the second lowest cost and the lowest of the high-rate clarification processes. Given that the lowest-ranking alternative is the least-well-suited for this application from a treatment technology standpoint, it would be challenging to make a case for its selection. Therefore, the highest-ranking alternative from a treatment technology standpoint appears even more attractive given that its cost is nearly the same as lowest of the other treatment alternatives.

6.3.2. Intake Alternatives

As presented in Exhibit 6-2, Intake Alternative 1 was ranked higher than Intake Alternative 3. The primary reasons for this result are: (1) Intake Alternative 1 makes use of the existing intake pipeline, which has capacity that exceeds the hydraulic capacity of the existing tunnel, and (2) Intake Alternative 1 has fewer new fish screens than Intake Alternative 3 and is therefore less complex and challenging to operate.

Adding the estimated costs presented in Section 5.3 provides further confirmation of Intake Alternative 1 as the intake approach deemed best-suited for this application. The results of the evaluation ranking presented in Exhibit 6-2 and the estimated Net Present Values presented in Table 5-3 are presented graphically in Figure 6-2. What is clear from Figure 6-2 is that Intake Alternative 1 is the best approach based on non-cost evaluation criteria and is also the lower-cost intake alternative.

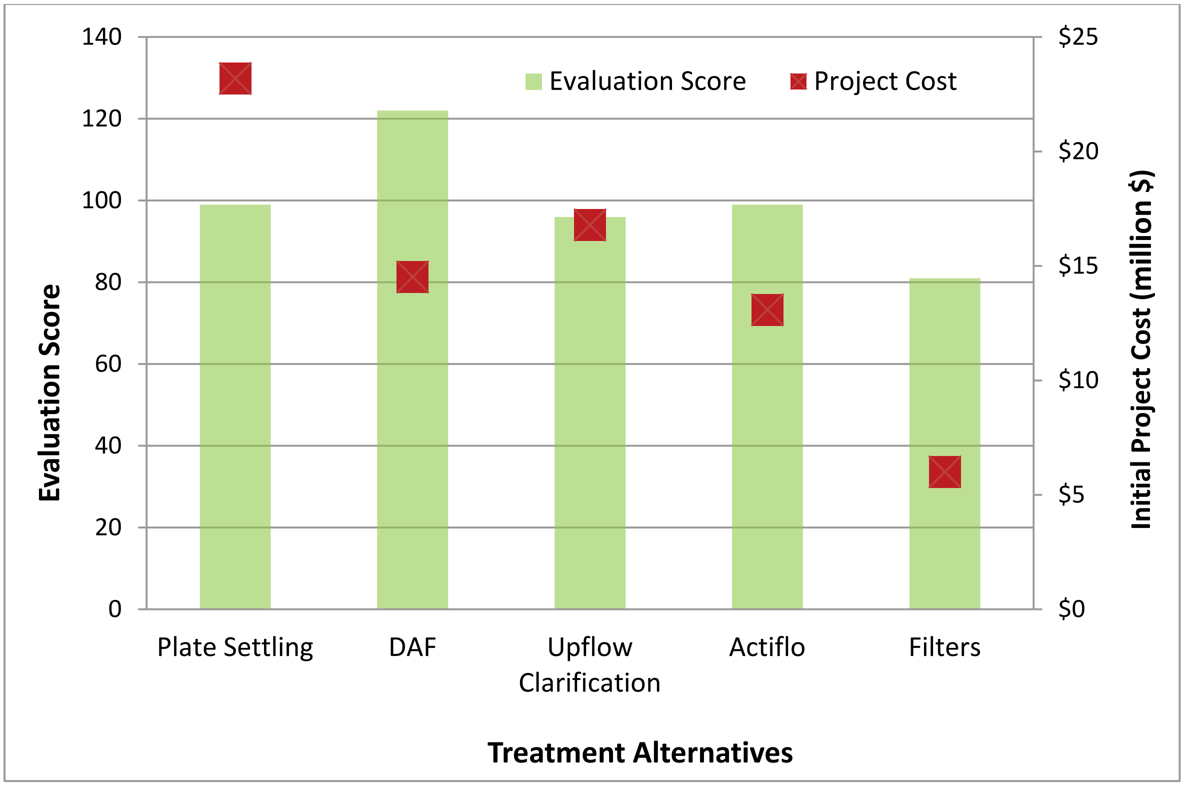

FIGURE 6-1
Treatment Alternative Evaluation Results and Estimated NPV Costs

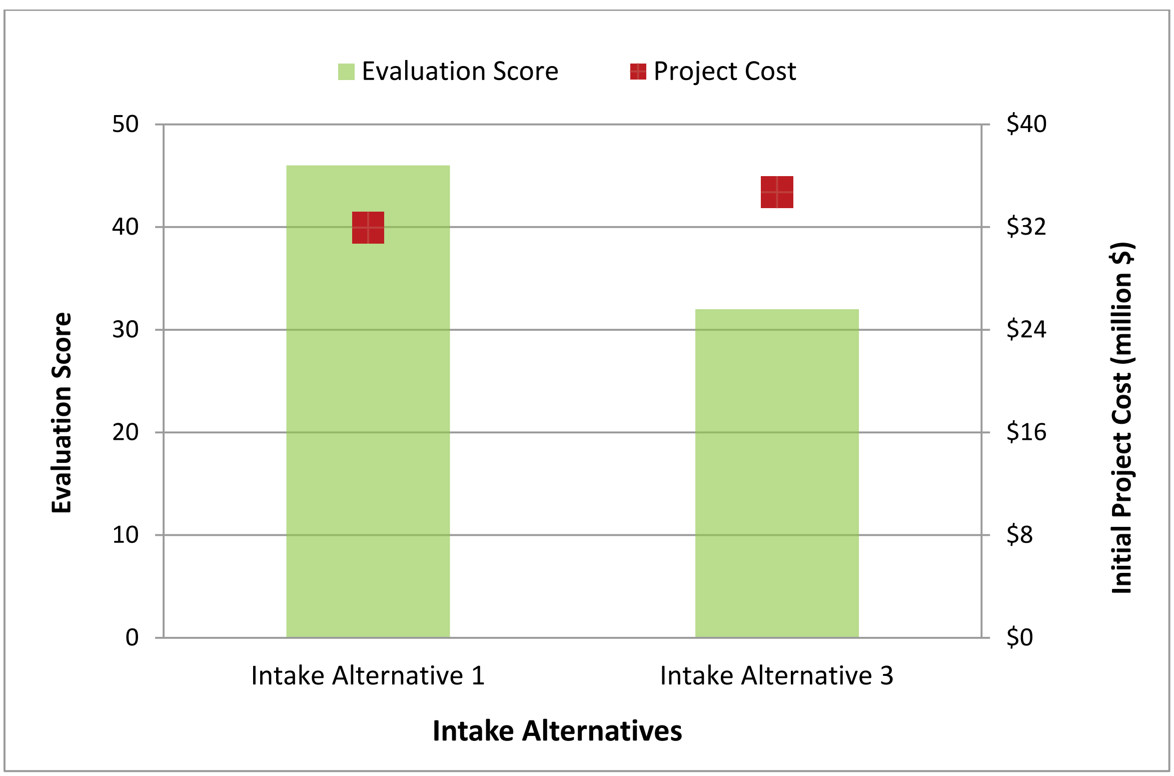

FIGURE 6-2
Intake Alternative Evaluation Results and Estimated NPV Costs

6.3.3. Comparison of Best Intake and Treatment Alternatives

As presented in Exhibit 6-3, DAF was ranked higher than Intake Alternative 1 with respect to the non-cost evaluation criteria developed specifically for this direct comparison. Specifically, the difference between these two alternatives with respect to each evaluation criteria is as follows:

- **Minimizes construction disruption to the community:** While there will be construction vehicle to and from the WTP site for a new DAF treatment unit, there is anticipated to be less disruption to the community because of construction at the WTP site than in and on the shoreline of Lake Whatcom. The WTP is mostly out of site from the residential and commercial public.

- **Minimizes permitting challenges:** Because of the extensive in-water work in Lake Whatcom, the Intake Alternative 1 will require more permitting and the associated time and expense associated with permitting than the DAF treatment alternative.

- **Long-term certainty of continued effectiveness:** The DAF treatment process has an extensive history of effectively and reliably removing algae and is known to be the best available treatment technology available for algae removal. DAF is acknowledged to be effective at removing algae of varying speciation and concentration; therefore, its certainty of continued effectiveness is high. Intake Alternative 1 is based on locating a new, supplemental intake deep within the hypolimnion of Basin 3 – below the level where most algae, in particular blue-greens, are known to reside. Additionally, historical and ongoing monitoring of dissolved oxygen levels in Basin 3, at depth, show that they are mostly relatively high when compared to the anoxic conditions in the hypolimnion Basins 1 and 2. What is uncertain is how long those dissolved oxygen levels will remain high enough to avoid problem associated with anoxia. Therefore, the uncertainty as it relates to Intake Alternative 1 does not relate primarily to the future presence of algae at depth, but instead to the potential for anoxic conditions that could result in the type of treatment challenges described in Section 3.2.2.

- **Maximizes sustainability:** DAF and Intake Alternative 1 were ranked similarly with respect to sustainability, but it was believed that Intake Alternative 1 could be viewed slightly more sustainable because it is associated with less electrical power consumption, chemical consumption, and production of solids that require disposal.

- **Minimizes water treatment WTP disruption:** While construction of a new DAF treatment process would be undertaken without extended disruption to the existing WTP, it would present extensive coordination challenges to operations staff and result in periodic WTP shut downs. Intake Alternative 1 could be implemented with minimal impact to WTP operations, with only one or two brief shut downs when the connection to the existing Gate House is made.

- **Minimizes system complexity / ease of operation:** The two alternatives were relatively similar with respect to this criterion; however, Intake Alternative 1 was deemed to be less attractive with respect to this criterion. The primary reason for this is the mechanical fish screen deep in Lake Whatcom will require annual inspection and periodic retrieval and repair to maintain. These activities, while periodic will require extensive coordination to address equipment that is not readily accessible.

The results of the evaluation ranking presented in Exhibit 6-3 and the estimated Net Present Values presented in Table 5-3 are presented graphically in Figure 6-3. While DAF was ranked substantially higher with respect to non-cost criteria, as presented in Exhibit 6-3, its estimated 20-year Net Present Value (based on year-round operation) was much less than the same for Intake Alternative 1. DAF is ranked higher than Intake Alternative 1 based on non-cost evaluation criteria and is much less costly to implement.

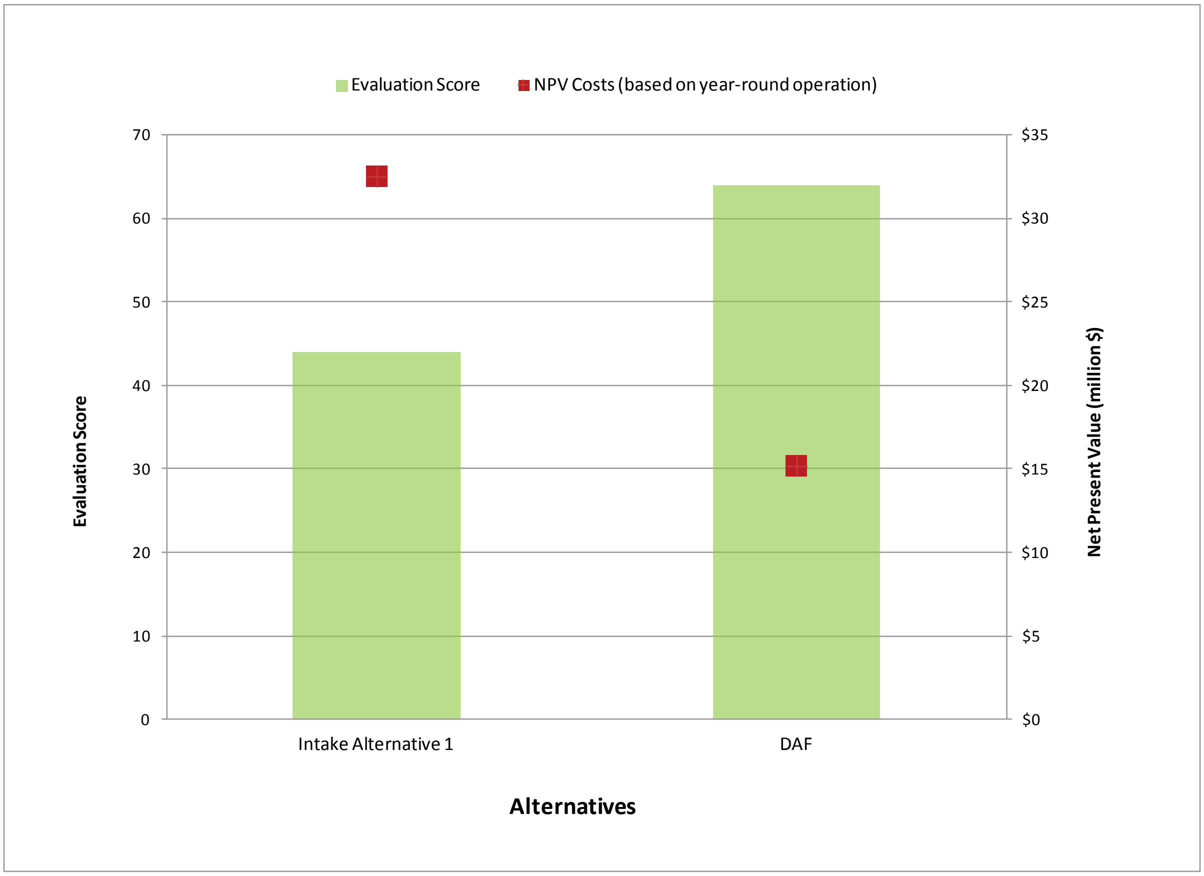

FIGURE 6-3
Best Treatment and Intake Alternatives Evaluation Results and Estimated NPV Costs

6.3.4. Summary of DAF Pilot Testing

DAF was ranked as the best approach for mitigating the adverse impacts of filter-clogging algae at the City's WTP. This result is consistent with DAF's recognized standing in the municipal water treatment industry as the best, most effective, and most reliable available technology for removing algae prior to filtration. In recognition of this standing, as well as the need to pro-actively develop an effective mitigation approach to the filter-clogging algae, pilot testing of DAF was undertaken during the summer of 2011 when algae concentrations in Lake Whatcom were expected to be at their highest for the season. While the DAF pilot testing was implemented prior to completion of the formal process to evaluate alternatives to mitigate the filter-clogging at the City's WTP, the results of the DAF pilot testing process were not incorporated into the evaluation process. A copy of the DAF pilot testing report is presented in Appendix C.

The pilot testing showed that DAF was very effective at removing algae from the Lake Whatcom supply. Not only was it effective at removing algae, but it was also shown to be effective at removing total organic carbon (TOC), reducing the formation potential for total trihalomethanes (TTHMs) – a key disinfection byproduct, and most-importantly it was shown to greatly extend filter runs. Extended filter runs results in increased total filter production during algae bloom conditions, which was the primary limitation during the 2009 Lake Whatcom algae bloom.

The DAF process tested during the 2011 testing was shown to be effective at a wide range of DAF hydraulic loading from 10 up to 20 gpm/sf. Hydraulic loading rate is a key design criterion with respect to facility cost. The higher the loading rate, the lower the plan layout of the facility, and the lower the facility cost. The demonstrated success of the 20 gpm/sf DAF loading rates during pilot testing enables consideration of a phased implementation approach. A phased implementation approach could result in an initial capital cost substantially less than that presented in Table 5-1. This phased implementation approach is presented in Section 8.

7. Triple Bottom Line Plus

The Triple Bottom Line Plus (TBL +) evaluation approach has a demonstrated track record of enabling consideration of alternatives based on criteria that fall into four key categories – financial, social, environmental, and technical. The City is familiar with the TBL + evaluation approach and has experience using it to evaluate alternative infrastructure improvements. The TBL + approach was used for this project, as presented in this section, for evaluating alternatives that:

- Passed the alternatives screening process presented in Section 4, thus eliminating alternatives deemed to not be feasible, effective, or otherwise warrant further consideration

- Were determined to be the best within their alternative category (i.e. treatment, intake, and lake management), as presented in Section 5

- Were relatively low cost and potentially attractive even if they were not determined to be the best within a particular alternativecategory

In addition, the alternatives selected for evaluation using the TBL + approach were also compared against doing nothing to address this filter-clogging algae issue – the "No Action."

7.1. Applicability of TBL+ to Evaluation Approach

The TBL + evaluation approach is effective at addressing different types or categories of alternatives because they tend to vary with respect to each of the four key evaluation categories (financial, social, environmental, and technical). Conversely, while TBL + can be used to evaluate similar alternatives, such as the treatment alternatives considered for this project, it is more effective to evaluate such alternatives based on key technical and financial criteria – as was done for this project. For this project, this TBL + evaluation approach was reserved, as stated above, for evaluating the best technical alternatives, a selected low-cost promising alternative, and the "No Action" alternative.

This TBL + evaluation phase builds on the alternatives screening phase presented in Section 4 by focusing only on alternatives that were deemed feasible and warranting of further evaluation and scrutiny – alternatives that don't have any "fatal flaw" characteristics associated with them. As stated, this phase of the evaluation process was not employed to distinguish between similar types of alternatives that are best evaluated based on specific technical evaluation criteria.

The alternatives evaluated using the TBL+ approach presented herein and the rationale for their inclusion in this phase of the evaluation process is presented below:

- **Dissolved Air Flotation:** DAF was determined to be the best of the treatment alternatives, as presented in Section 6.

- **No Action:** This alternative enables direct comparison of the best alternative, regardless of its alternative category, with deferring action.

- **Intake Alternative 1:** This alternative was determined to be the best of the intake alternatives, as presented in Section 6.
- **Additional Filters:** This alternative is the lowest-cost treatment alternative and could be effective if algae events do not reduce filter run times to less than two hours.

7.2. TBL+ Evaluation Method and Criteria

Each of the four evaluation categories (e.g. financial, social, environmental, and technical) were weighted equally in terms of importance and each of the categories were divided into two specific objectives. One, two, or three key evaluation criteria were identified for each objective to enable assessment of whether the objectives were met or not. The evaluation criteria were developed to allow for either a "yes" or "no" response. "Yes" responses indicate that the criterion has been met. A summary of the evaluation objectives and criteria within each evaluation category are presented in Table 7-1. Each objective and criterion are designated with an identification number to aid correlation between Table 7-1 and Figure 7-1, presented in the following section.

TABLE 7-1
TBL + Evaluation Objectives and Criteria

Evaluation Category	Objective	Criteria
Financial	**F1:** Minimize capital cost	**F1.1:** Is capital cost less than mean (average) of the four alternatives?
	F2: Minimize life-cycle cost	**F2.1:** Is life-cycle cost less than mean of the four alternatives?
		F2.2: Eliminates reduced water sales because of mandatory water restrictions?
Social	**S1:** Protect public health and safety	**S1.1:** Enables uninterrupted, full-capacity use of plant?
		S1.2: Reduces disinfection byproducts?
		S1.3: Avoids construction activities in public-accessed areas?
	S2: Preserve community reputation, status, and economic vitality	**S2.1:** Eliminates need for mandatory water restrictions and associated negative press?
Environmental	**E1:** Minimize local impact	**E1.1:** Avoids large increases in wasted filter backwash water during algae events?
	E2: Minimize global impact	**E2.1:** Is life-cycle greenhouse gas less than the mean of the four alternatives?
		E2.2: Is energy use less than the mean of the four alternatives?
Technical	**T1:** Maximize treatment reliability	**T1.1:** Proven effective and reliable technology?
		T1.2: Enables treatment at full plant capacity during algae events?

TABLE 7-1
TBL + Evaluation Objectives and Criteria

Evaluation Category	Objective	Criteria
Financial	**F1:** Minimize capital cost	**F1.1:** Is capital cost less than mean (average) of the four alternatives?
	T2: Maximize treatment performance	**T2.1:** Results in improved treated-water quality?

7.3. City of Bellingham Values

The TBL+ evaluation objectives and criteria presented above are in alignment with the City's goals and objectives, which are summarized in the "Legacies and Strategic Commitments" document presented in Appendix D. They are also in alignment with the City's Public Works Department's mission statement, which is comprised of:

"Enhance Bellingham's quality of life through the construction and operation of a safe, effective physical environment; to protect public health & safety and the natural environment; and to provide our neighborhoods, our businesses and our visitors with the efficient, quality services necessary to meet the demands of our growing, diverse community."

The mission statement addresses each of the three categories of the TBL evaluation approach. Combining the technical evaluation criteria forms the basis of a complete, comprehensive evaluation framework. The City has a long and established commitment to social equity and environmental protection in addition to balancing financial impacts with technical performance. This TBL+ phase of the evaluation process reflects even-handed consideration of these four evaluation categories.

7.4. Results of TBL+ Evaluation

The results of the TBL+ evaluation process is presented graphically in the bar chart presented in Figure 7-1. The bar chart presents the relative ranking of each of the four alternatives. Based on the evaluation criteria developed, DAF was ranked highest of the four alternatives. This result is in alignment with the evaluation presented in Section 6, which ranks DAF as the best alternative.

7.5. Discussion of Results of TBL+ Evaluation

A discussion of the rationale for the evaluation results for each of the evaluation criteria and each of the alternatives is presented in the following subsections. The subsection headers below identified as each of the evaluation criteria.

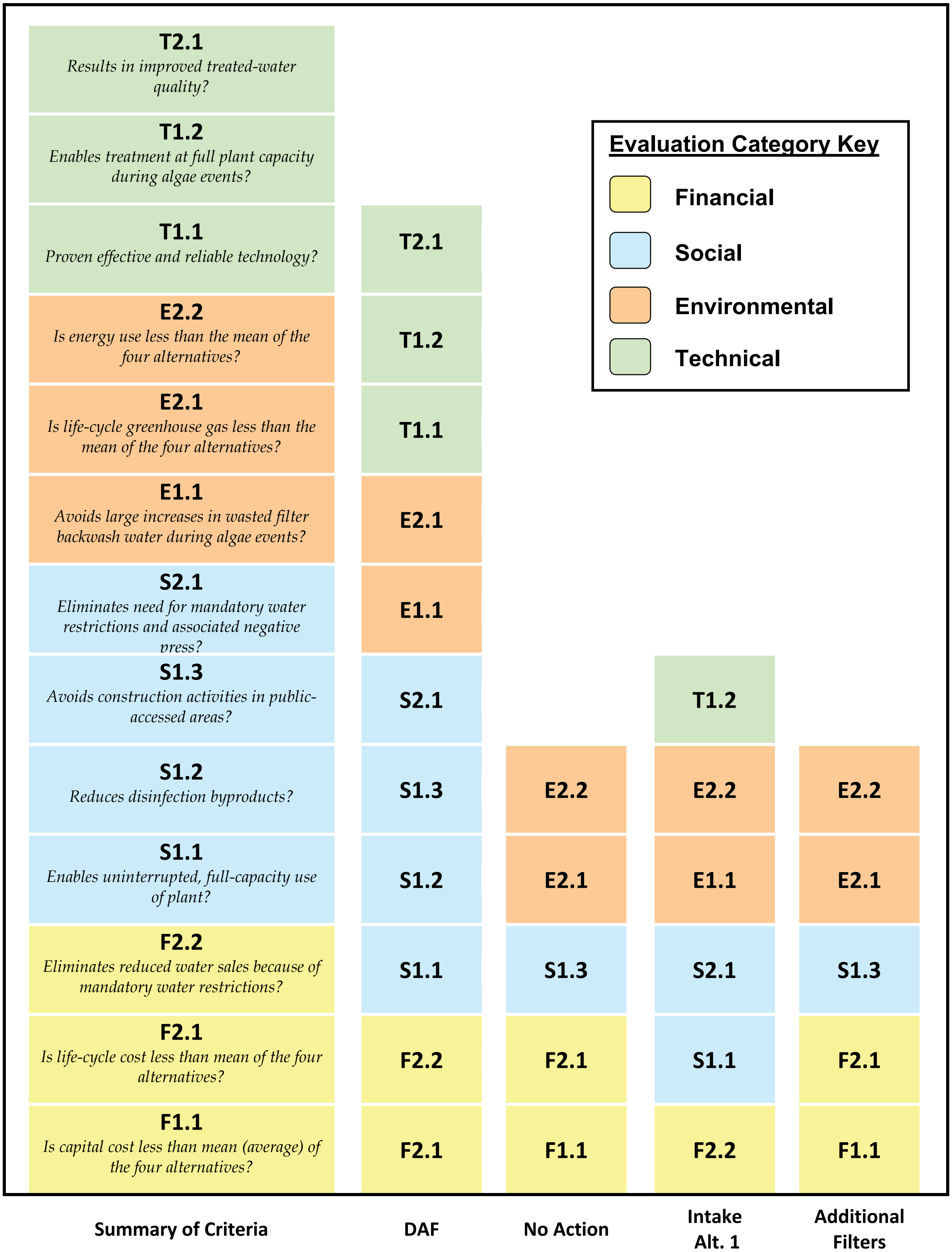

FIGURE 7-1
TBL+ Evaluation Results

7.5.1. Is capital cost less than the mean (average) of the four alternatives? (F1.1)

The estimated capital cost for the alternatives is listed below – along with the mean of the estimated capital cost for each alternative. These costs are the same as those presented in Section 5. Clearly, the capital cost for the No Action alternative is $0. The alternatives are listed in order of least cost to greatest cost – reflecting that the No Action and Additional Filters alternatives met this evaluation criterion.

- No Action: $0
- Additional Filters: $6,006,000
- **Mean: $13,119,750**
- DAF: $14,521,000
- Intake Alternative 1: $31,952,000

7.5.2. Is life-cycle cost less than mean of the four alternatives? (F2.1)

The results for this criterion were the same as for F1.1 presented above. The estimated life-cycle cost for the alternatives is listed below – along with the mean of the estimated capital cost for each alternative. These costs are the same as those presented in Section 5 for the DAF, Additional Filters, and Intake Alternative 1 alternatives.

The life-cycle cost for the No Action alternative is based on a 20-year period of lost revenue due to the impact of mandatory water restrictions. An annual interest rate and inflation rate of 5 percent and 3 percent, respectively, were used in the computation. The following assumptions were made in developing this estimated life-cycle cost:

- The entire City is metered. This assumption is justified because the entire City will be metered by 2017, as required by statute. This assumption enables use of the City's volume rate to compute the lost revenue.
- The City's 2012 Inside-City volume rate of $1.53 per 1 CCF (100 cubic feet) was used to compute the annual lost revenue.
- It was assumed that mandatory water restrictions would occur every other year and when they occur they dampen total City demand by 10 mgd for 15 days, 5 mgd for 20 additional days, and 3 mgd for 25 additional days. These are speculative assumption is based on 15 days of mandatory water restrictions (which severely reduces customer demand by 10 mgd) and a residual follow-on impact on customer demand once the mandatory water restrictions are removed. The total reduction in customer demand would be 350 million gallons or approximately 470,000 CCF. This equates to a total of $720,000 of lost revenue over the course of the year when the mandatory restrictions occur.

It should be noted that no similar estimate of lost revenue from water sales was developed for the Additional Filters alternative in recognition of the difficulty in assessing the intensity of any future algae blooms and whether or not they would result in the need for mandatory water restrictions. Therefore, the estimated life-cycle cost of the Additional Filters alternative should be considered to be "at least" the value presented in Table 5-3 – given that it could be greater if future potential lost revenue were accounted.

The alternatives are listed in order of least cost to greatest cost – reflecting that the No Action and Additional Filters alternatives met this evaluation criterion.

- No Action: $6,000,000
- Additional Filters: $6,036,000
- DAF: $14,682,000
- **Mean: $14,802,000**
- Intake Alternative 1: $32,490,000

7.5.3. Eliminates reduced water sales because of mandatory water restrictions? (F2.2)

DAF removes algae from the raw water prior to filtration. Therefore, the filters operate efficiently and there is no need for mandatory water restrictions. Intake Alternative 1 avoids live algae by withdrawing water from deep in Basin 3. Therefore, there would be no mandatory water restrictions related to this alternative. Conversely, the No Action alternative is anticipated to result in mandatory water restrictions and associated lost revenue from water sales. Although it was quantified, as discussed above, it should be expected that the Additional Filters alternative would, to a lesser degree than the No Action alternative, result in mandatory water restrictions and associated lost revenue from water sales.

7.5.4. Enables uninterrupted, full-capacity use of plant? (S1.1)

DAF and Intake Alternative 1 both enable full-capacity use of the City's WTP because they either remove or avoid filter-clogging algae prior to the filtration process. Conversely, the No Action and Additional Filters alternatives do not include changing the algae concentration of the water treated by the filters. As such, these two alternatives are defined by their reduced-filter-capacity characteristics.

7.5.5. Reduces disinfection byproducts? (S1.2)

Disinfection byproducts such as total trihalomethanes and haloacetic acids have been linked to cancer development and are regulated at the federal and state level because of their health impacts. The concentration of these byproducts in the City's distribution system is well below the regulatory limit. However, reducing disinfection byproducts – regardless of the absolute concentration – is generally considered to be beneficial from a public health standpoint.

As presented in Section 3, DAF reduces disinfection byproducts (primarily total trihalomethanes) because it removes the organic precursors that combine with chlorine to form the disinfection byproducts. The No Action and Additional Filter alternatives do nothing to change the treatment process at the WTP; therefore, there is no reduction in disinfection byproducts. Intake Alternative 1 withdraws water from a different part of the lake than current; however, the total organic carbon (TOC) concentration at lower lake depths has been shown to typically be greater than at shallow depths. Therefore, disinfection byproducts would, at best, not be reduced with Intake Alternative 1, and could, in fact, increase.

7.5.6. Avoids construction activities in public-accessed areas? (S1.3)

DAF and the Additional Filters alternatives both involve construction at the City's WTP site, which is in a portion of Whatcom Falls Park that is restricted from public access. The No Action alternative does not involve construction activities. Only Intake Alternative 1 would include construction within areas that are access by the public. Public health and safety is more easily achieved when interaction between the public and construction activities can be avoided.

7.5.7. Eliminates need for mandatory water restrictions and associated negative press? (S2.1)

Negative press related to water restrictions could adversely impact the City's reputation and reduce its ability to attract new business and preserve economic vitality. For the reasons described above for evaluation criteria F2.2 and S1.1, DAF and Intake Alternative 1 avoid mandatory water restrictions and associated negative press while the No Action and Additional Filters alternatives do not.

7.5.8. Avoids large increases in wasted filter backwash water during algae events? (E1.1)

DAF and Intake Alternative 1 mitigate the filter-clogging algae that enter the City's WTP via the existing intake by removing the algae and by avoiding live algae, respectively. Therefore, there are no large increases in wasted filter backwash water during algae events. Conversely, both the No Action alternative and Additional Filters alternatives rely on the increased frequency of filter backwashing during algae events to keep the filters in service, which results in large increases in filter backwash water wasted to the sanitary sewer system.

7.5.9. Is life-cycle greenhouse gas less than the mean of the four alternatives? (E2.1)

A 20-year life-cycle greenhouse gas total was computed, in terms of CO_2 production, for each of the alternatives based on their initial construction combined with 20 years of annual CO_2 production. The greenhouse gas estimates are for the incremental additional quantity associated with each alternative beyond what is already produced annually as part of normal WTP operations. The largest component of annual production was electric power consumption, which is what the annual CO_2 production was based upon. The initial construction total was based on all key elements of construction, including transport of materials and labor as well as disposal of waste excavation.

- No Action: 240 tons of CO_2 (0 construction; 12 annual)
- Additional Filters: 480 tons of CO_2 (240 construction; 12 annual)
- DAF: 1,420 tons of CO_2 (380 construction; 50 annual)
- **Mean: 2,120 tons of CO_2**
- Intake Alternative 1: 6,350 tons of CO_2 (6,250 construction, 5 annual)

It is interesting to note that the life-cycle estimates for each of the four alternatives varied substantially with respect to their total, but also with respect to the component elements comprising the total (initial construction and annual operations). The No Action alternative produces the least amount of greenhouse gas because it involves no new construction and because the associated additional filter backwash pumping is for only a portion of the year. The Additional Filters alternative is essentially the same as the No Action alternative, except for the construction of the two new filters. DAF operations, because of seasonal higher electric power consumption, produces more greenhouse gas than the No Action and Additional Filters alternatives, but still less than the mean of the four alternatives. Intake Alternative 1 produces by far the most greenhouse gas because of the large amount associated with the steel pipeline and steel piles. Steel production and fabrication is a very high producer of greenhouse gas compared to other activities such as concrete construction and excavation.

7.5.10. Is energy use less than the mean of the four alternatives? (E2.2)

Annual energy (electrical) use for each of the alternatives, except the No Action alternative, is presented in Table 5-2. At first, it may appear that the No Action alternative uses no energy because it does not involve additional mechanical equipment that requires electrical power. However, for the purpose of this evaluation criterion the increased energy associated with increased filter backwashing during an algae event was estimated.

This electrical power was based on estimating the extra filter backwashing that would be necessary as opposed to if there were little or no algae to contribute to filter clogging. The electrical power estimate was based on use of filter backwash pumps (two 75-hp motors), the air-scour blower (one 75-hp motor), and an estimate of roughly 10 times the amount of filter backwashing at the peak of an algae bloom as when no algae bloom exists, which is consistent with observed conditions from the summer 2009 algae bloom. The estimated increased power usage on the peak day was estimated to be 1,300 kilowatt hours. For the purpose of this evaluation it was assumed that there would be roughly 20 days of peak-algae-bloom impact every year.

It is understood that an actual algae bloom would likely extend for a longer period of time, but not at the same intensity; therefore, the assumption presented here represents a reasonable “ballpark” estimate the additional seasonal electrical power impact from additional filter backwashing. Also for the purpose of this evaluation criterion, this additional electrical power usage was included with the Additional Filters alternative because with respect to electrical power consumption, these two alternatives are nearly the same, with the exception that the Additional Filters alternative produces more net treated water under most conditions because it includes eight filters instead of the existing six. The power use associated each of four alternatives is presented as follows:

- Intake Alternative 1: 10,000 kilowatt hours
- No Action: 26,000 kilowatt hours
- Additional Filters: 26,000 kilowatt hours
- **Mean: 36,000 kilowatt hours**
- DAF: 84,000 kilowatt hours (3-month operation)

Intake Alternative 1 has relatively little electrical power consumption, and it is related entirely to the continually-operated rotating cleaning brushes on the fish screen. The No Action and Additional Filters alternatives have a moderate amount of additional electrical power consumption related to the additional filter backwashing that occurs seasonally. DAF is more mechanically complex because of its flocculation mixers and diffused-air system and requires more electrical power than the other three alternatives over the anticipated 3 months of operation.

7.5.11. Proven effective and reliable technology? (T1.1)

DAF has demonstrated its effectiveness and reliability at removing algae under a variety of conditions for many years. DAF is ideally suited to remove algae and is ideally suited to remove algae from the consistent, low-turbidity Lake Whatcom supply. Conversely, the No Action and Additional Filters alternatives do not have a history of demonstrated success at removing algae. Withdrawing water from a part of the lake where live algae doesn't currently exist would be beneficial from the standpoint of reducing filter clogging. However, other water quality problems should be expected, as presented in Section 3.2.2, that makes pursuing intake relocation unattractive.

7.5.12. Enables treatment at full plant capacity during algae events? (T1.2)

A treatment system that cannot operate efficiently at its maximum capacity at a time when that maximum capacity is needed, is ineffective at meeting the peak customer demands for which it was designed. For the reasons described above for evaluation criteria F2.2 and S1.1, DAF and Intake Alternative 1 avoid filter-clogging algae impacts and enable operation of the City's WTP at its full capacity – even during algae events. Conversely, the No Action and Additional Filter alternatives do not.

7.5.13. Results in improved treated-water quality? (T2.1)

The No Action and Additional Filters alternatives do not include any modification of the existing treatment process and therefore have no impact on treated-water quality. Intake

Alternative 1, as described in Section 3.2.2 and Section 7.5.5, will likely result in reduced treated-water quality. Conversely, DAF will result in improved treated-water quality because it will reduce disinfection byproducts (primarily total trihalomethanes) and TOC. DAF pilot testing completed during the late summer of 2011on the Lake Whatcom supply showed that DAF could reduce total trihalomethanes production by 25 percent. DAF will also reduce algal toxins that may enter the system and will help reduce taste and odor resulting from algae and algae respiration byproducts. DAF also will enable improved treatment of contaminants that may be regulated in the near- or long-term future, such as microbiological, pharmaceutical, and fire-retardant contaminants. It is understood that these contaminants are likely not present at measurable levels in Lake Whatcom presently, and that ongoing efforts to improve Lake Whatcom quality should keep Lake Whatcom clear of these contaminants.

8. DAF Implementation

In recognition of the results of Sections 6 and 7 – DAF's ranking as the best alternative for filter-clogging algae mitigation – a discussion of DAF implementation is presented in this section. The implementation discussion presented herein covers regulatory agency requirements, an example project schedule, and options for reducing project cost. In doing so, it describes the approximate overall process and timeframe for DAF implementation. The purpose for presenting this DAF implementation discussion is to aid the decision-making process with respect to pursuit of a filter-clogging algae mitigation approach. The implementation discussion here is not intended to establish at this time the details of an implementation approach, sequence, and schedule.

8.1. Regulatory Agency Requirements

The purpose of this section is to summarize the approval requirements of the regulatory agency with jurisdiction over municipal water treatment, which is Washington Department of Health (DOH). Other permits and approvals will also be necessary, including but not limited to, State Environmental Policy Act (SEPA) approval, a building permit, a clearing and grading permit, and possibly critical areas and shorelines permits. However, compliance with DOH approval at key milestones will define the order of implementation activities. The key DOH approval activities and a brief associated discussion are summarized as follows:

- **Pilot Testing Plan (Protocol):** Pilot testing is required for all treatment system improvements, with very limited exceptions. Pilot Testing Plans are required per Section 12. 3.3 of DOH's Water System Design Manual and WAC 246-290-676(3)(b). The Pilot Testing Plan for the DAF pilot testing that was completed during the late summer of 2011 was already reviewed and approved by DOH in June of 2011.

- **Pilot Testing Report:** A Pilot Testing Report summarizing the activities and results of a pilot test is required per Section 12.3.4 of the Water System Design Manual and WAC 246-290-676(3)(e). Upon completion in September 2011DAF pilot testing, a Pilot Testing Report was completed; however, it has not been submitted to DOH for approval because the City has not decided to pursue DAF implementation. The Pilot Testing Report is available to be submitted to DOH should the City decides to pursue implementation of a new DAF treatment process.

- **Water System Plan Amendment:** An amendment to the City's Water System Plan is required per WAC 246-290-110 because the DAF project is not included in the City's existing Water System Plan. The reason this project is not included in the current Water System Plan is that the Water System Plan was completed prior to the filter-clogging algae bloom of 2009. The Water System Plan Amendment could be completed using information already developed and included in this report.

- **Project Report:** A Project Report is required for review and approval by DOH per WAC 246-290-110. It would detail key elements of a preliminary design, including: design criteria, alternatives analysis, estimated costs, proposed methods for startup, testing, operations, and other relevant project planning information. Much of the information presented in this report could be used to supplement the required elements of a Project Report.

- **Construction Documents:** Construction documents that detail the design of a new treatment process or facility are required to be reviewed and approved by DOH per WAC 246-290-120. These are the documents that would be used to bid the construction contract a new DAF treatment process. Construction documents would be completed as part of the design phase of the project, which would follow completion of the Project Report and its review and approval by DOH.

- **Construction Completion Report:** A Construction Completion Report (DOH Form 331-121) must be completed and submitted to DOH for approval per WAC 246-290-120(5) prior to sending DAF-treated water to customers. The Construction Completion Report certifies the project was construction in conformance with the previously-DOH-approved Construction Documents.

- **Operations Program:** An amendment to the City's existing Operations Program for the WTP must be developed per WAC 246-290-645(5). It is required to be submitted for DOH review and approval as an addendum to the Water System Plan. Addenda to the Water System Plan are required in conformance with WAC 246-290-100. The Operations Program would be developed, reviewed, and approved by DOH during construction, prior to start-up and testing of the new DAF treatment process.

8.2. Example Project Schedule

DAF implementation requires obtaining the DOH approvals presented above. Those approvals are typically sought and obtained sequentially using work products developed at various key stages of project completion. A possible project schedule that includes key activities and milestones that define the critical path and overall duration is presented in Figure 8-1.

For the purpose of this presentation, the project schedule presented in Figure 8-1 assumes the City begins implementation at the beginning of 2013 – given that the decision to pursue implementation could occur sometime over the course of 2012. The primary purpose of the example project schedule, in addition to identifying key, critical-path activities, is to quantify the approximate duration to placing a new DAF system into service. The project schedule presented in Figure 8-1 would have the same activities and same activity durations regardless of when it might be initiated.

The activity durations presented in Figure 8-1 are approximate and based on implementation at a steady but not overly-aggressive pace and mostly in sequential order of key, critical-path activities (minimal parallel completion of such future activities). Activity durations could potentially be shortened and parallel completion of some activities could be pursued if implementation became necessary on a shorter timescale.

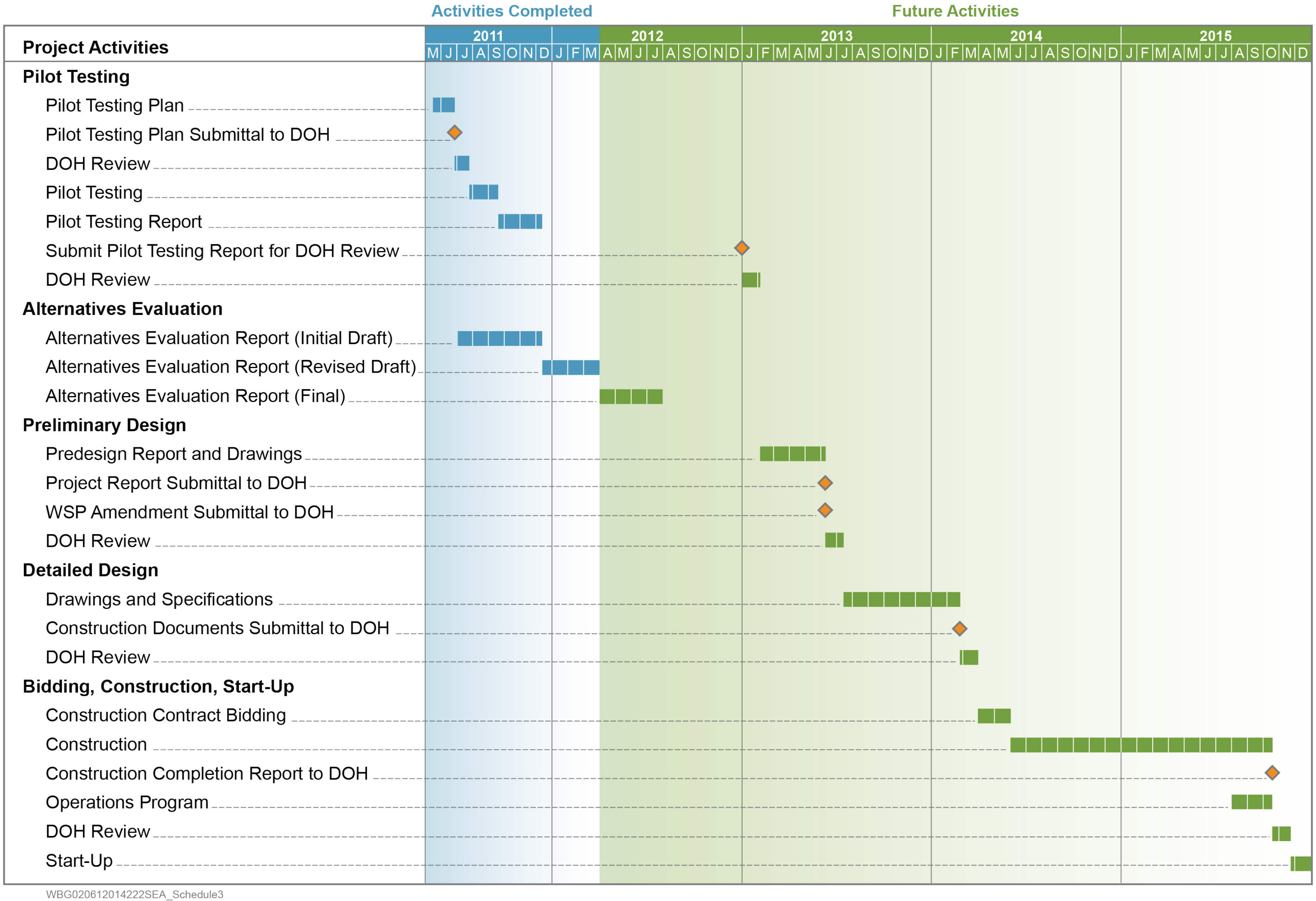

FIGURE 8-1
Example DAF Project Schedule

8.3. Cost-Reduction Options

The project costs presented in Section 5 for DAF and the other pretreatment alternatives were based on a capacity of 30 mgd, as explained in Section 3.1. Establishing a set capacity facilitated an equitable comparison of pretreatment alternatives based on cost. However, as presented in Section 2.5, it appears that 30 mgd of DAF capacity may not be necessary now or in the near-term future to meet summertime peak water demand. Also, a new DAF facility is not necessary for regulatory compliance with treatment and water quality standards. Its purpose is to enable the existing filters to perform more effectively to meet peak customer water demand.

As a result, given that falling short with respect to regulatory compliance is not a primary concern, it appears possible and prudent to examine options and rationale for reducing project cost by reducing the initial capacity and associated cost of the facility. The cost-reduction options relate to reducing the number of treatment trains, optimizing the initial DAF facility capacity in alignment with current and near-term future customer water demand, and evaluating the impact of DAF hydraulic loading rates on facility cost.

When a treatment process is necessary to ensure regulatory compliance, flexibility, reliability, and redundancy are of paramount importance. In this case, however, the DAF treatment system would not be needed for regulatory compliance, but instead to aid meeting customer water demand. Consequently, balancing initial capital cost savings with reduced flexibility, reliability, and redundancy warrants consideration.

8.3.1. Two vs. Three DAF Treatment Trains

Pretreatment processes are not subject to the same rigorous regulatory standard applied to filters, which requires facility capacity be based on one unit being out of service. This requirement applies to filters in recognition that they are regularly out of service for backwashing. Current design of clarification processes like DAF enable continuous operation – even as solids are being removed from the flowstream. Therefore, it is possible and somewhat common, depending on the goals and objectives of the specific installation, to have only two parallel clarification treatment trains. Doing so provides a reasonable level of system redundancy in the event that one train is not operational.

In such cases, one of the two clarification treatment trains may be operated at a higher hydraulic loading rate than the design criterion loading rate – resulting in an expected reduction in treatment performance. Reduced clarification performance over a short period of time may be acceptable given that the intent of pretreatment is to improve the quality of the water entering the filtration stage.

The initial capital cost estimate for DAF presented in Table 5-1 is based on three parallel DAF treatment trains with a capacity of 10 mgd each based on a hydraulic loading rate of 16 gpm/sf. This three-train cost-estimate-development approach was based on a more-robust approach with respect to reliability, operational flexibility, and redundancy. Also note that hydraulic loading rate is a key planning, cost-development, and design criterion for pretreatment processes. The results of the DAF pilot testing support the use of 16 gpm/sf as a relatively high loading rate, which enables keeping the capital cost of the DAF facility as low as practical and the facility footprint as small as possible. More discussion of the DAF pilot testing and the use of hydraulic loading rate is presented Section 6.3.4, Appendix C, and below in Section 8.3.3.

All treatment processes and systems, including pretreatment, are designed with some level of redundancy to ensure reliability and operational flexibility. This is accomplished with parallel treatment trains and process that have a combined capacity equal to that necessary to meet the anticipated maximum day customer demand. Three parallel trains for pretreatment is a common approach, as stated above, because it offers a high degree of operational flexibility, reliability, and redundancy.

For example, with three parallel 10-mgd trains and one out of service, there would still be 20 mgd of capacity to help meet maximum day water demand. Based on recent historical data, 20 mgd appears to be greater than the maximum day water demand for the City of Bellingham. Conversely, two parallel 15-mgd trains would have the same overall capacity as three parallel 10-mgd trains, but would only leave 15 mgd of available capacity if one of the two 15-mgd trains were out of service. A single 15-mgd DAF treatment train may not be adequate to enable meeting customer water needs during maximum day water demand.

As a result, it is clear that three parallel 10-mgd trains provide somewhat greater reliability, operational flexibility, and redundancy than two parallel 15-mgd trains. However, three treatment trains are not required to meet treatment goals or standards, and are not absolutely necessary. Additionally, if the needed capacity of the overall system to meet anticipated customer water demand is substantially less than 30 mgd, the initial need for three parallel treatment trains may be less important. Because of the additional equipment and mechanized systems associated with an additional treatment train, three trains cost more than two trains for facilities with the same combined capacity.

8.3.2. Optimizing Initial Installed Capacity

While three 10-mgd DAF treatment trains provide greater reliability, operational flexibility, and redundancy than two 15-mgd DAF treatment trains, this advantage may not be put to beneficial use if 30 mgd of treatment capacity is not necessary. As presented in Section 2.5, the City's recent historical water demand, in particular the maximum day water demand, has declined in recent years. Given this fact, it would be more cost effective and technically sound to install a new DAF facility with an initial capacity that better reflects anticipated water demand. The new DAF facility would also need to have maximum flexibility to be expanded in the future when additional DAF treatment capacity becomes necessary.

As described above, and as presented in Section 2.5, it is not necessary to initially install 30 mgd of DAF treatment capacity to meet maximum day customer water demand. Installing an initial capacity of 20 mgd would provide adequate DAF treatment capacity to meet current and expected near-term future maximum day water demand. A DAF facility with an initial 20-mgd capacity would be comprised of two parallel 10-mgd treatment trains based on a hydraulic loading rate of 16 gpm/sf. A parallel, third 10-mgd DAF treatment train could be added in the future, as necessary, to meet peak summertime demand. The timing for the need for this third train is uncertain, but if demand trends continue, it may not be necessary for well beyond 20 to 30 years from now.

It would be necessary to operate both of the parallel 10-mgd treatment trains to meet the City's current and near-term future anticipated maximum day water demand. Reliance on both trains to meet demand without having one out of service incorporates less redundancy and flexibility than a three-train system, but is a common and acceptable treatment approach. In the event that one treatment train is out of service, the other can be operated at a higher hydraulic loading rate than the 16 gpm/sf design criteria and a portion of the raw water flow can be bypassed around the DAF process directly to the filters, matching the existing in-line filtration mode. This approach, even though less than optimal, would greatly reduce algae concentration in the raw water flow stream and extend filter run times enough to help them meet peak summertime customer water demand.

8.3.3. DAF Hydraulic Loading Rate

As presented in Appendix C, DAF pilot performance was consistently excellent at hydraulic loading rates up to 16 gpm/sf. While 16 gpm/sf is a relatively high rate for DAF system operation, and as a design criterion, it is in keeping with industry trends toward maximizing hydraulic loading rate in an effort to optimize cost efficiency. All other project elements and aspects equal, facility cost decreases with increased loading rate criteria, which applies to any clarification process.

Also as presented in Appendix C, the DAF pilot system also performed well at 20 gpm/sf. This hydraulic loading rate is at the upper limit of where high performance would be expected. Because this hydraulic loading rate is at the upper end of the loading rates tested on the Lake Whatcom supply, and because there are no known DAF systems designed with capacities based on a loading rate so high, 16 gpm/sf was the loading rate used for estimated the capital costs presented in Section 5. This 16 gpm/sf loading rate would be a reasonable hydraulic loading rate upon which to base a cost effective DAF system design for the City's needs, should the City pursue implementation.

It should be noted that two parallel 10-mgd treatment trains based on a hydraulic loading rate of 16 gpm/sf have a capacity of 25 mgd based on a hydraulic loading rate of 20 gpm/sf. While the DAF pilot testing on Lake Whatcom water from the late summer period of 2011 showed impressive results at 20 gpm/sf, it would not be prudent to rely on consistent performance at this rate in the absence of additional pilot data to provide confirmation. However, because capacity beyond 20 mgd is not necessary at this time, there would be ample opportunity over the years to test a new DAF system at this higher rate under actual conditions to assess when there might actually be a need for a third DAF treatment train.

In keeping with how loading rate impacts DAF facility capacity and initial capital cost, an optional approach to initially implementing a two-train 20-mgd DAF facility would be to base the design on 20 gpm/sf instead of the more-conservative 16 gpm/sf. While this impact would not have much of a cost-reduction impact as reducing the number of treatment trains from three to two, it would save capital cost and it warrants consideration. Two more-aggressively designed, 10-mgd DAF treatment trains based on 20 gpm/sf – resulting in a 20-mgd DAF facility capacity – would have a capacity of 16 mgd if operated at 16 gpm/sf.

A new DAF facility based on this loading rate criteria could potentially be able to meet peak summertime customer demand during algae bloom conditions for many years to come –

especially considering that some raw water flow could be bypassed around the DAF process to meet the total supply need. Continued monitoring of summertime demand conditions through 2012 and into the coming years would aid selection of a hydraulic loading rate criterion along with balancing the potential for reduced algae-removal performance on overall WTP capacity.

8.3.4. Summary of Initial Capital Costs

Initial capital costs were developed and presented in Table 5-2 for a 30-mgd, three-train DAF facility based on 16 gpm/sf. Initial capital costs for the two cost-reducing options described above in Section 8.3.3 were developed to compare against the DAF cost presented in Table 5-2. These three estimated initial capital costs are presented in Table 8-1.

TABLE 8-1
Summary of Initial Capital Cost for DAF Implementation Options

	DAF Implementation Options		
Cost Elements	**3-Train** **30 mgd @ 16 gpm/sf**	**2-Train** **20 mgd @ 16 gpm/sf** (25 mgd @ 20 gpm/sf)	**2-Train** **16 mgd @ 16 gpm/sf** (20 mgd @ 20 gpm/sf)
Construction Costs:			
Construction Cost Subtotal	$ 5,756,000	$ 4,310,000	$ 4,070,000
Subtot. with Contr. OH (10%)	$ 6,332,000	$ 4,741,000	$ 4,477,000
Subtot. with Contr. Profit (6%)	$ 6,711,000	$ 5,025,000	$ 4,746,000
Subtot. w/ Mob, Bonds, Ins (10%)	$ 7,383,000	$ 5,528,000	$ 5,221,000
Subtotal with Contingency (30%)	$ 9,597,000	$ 7,186,000	$ 6,787,000
Escalation to Yr 2014 (12.8%)	$ 10,826,000	$ 8,106,000	$ 7,656,000
Constr. w/ Sales Tax (8.7%)	**$ 11,768,000**	**$ 8,811,000**	**$ 8,322,000**
Non-Construction Costs:			
Pilot Testing	$130,000	$130,000	$130,000
Geotechnical	$ 70,000	$ 70,000	$ 70,000
Permitting	$ 200,000	$ 200,000	$ 200,000
Eng. & Constr. Man. (18%)	$ 2,118,000	$ 1,586,000	$ 1,498,000
Startup (2%)	$ 235,400	$ 176,000	$ 166,000
Total	**$ 14,521,000**	**$ 10,973,000**	**$ 10,386,000**

What is clear is that the greatest savings in initial capital cost is achieved by reducing the number of treatment trains from three to two. Additional cost-reduction is achieved by basing the capacity of the facility on a higher, less-conservative hydraulic loading rate.

9. Summary of Key Conclusions and Recommendations

This report summarizes the identification, description, and evaluation of treatment, intake, and lake management alternatives to mitigate the adverse impacts of the seasonal filter-clogging algae at the City's WTP. This work resulted in an alternative that was deemed best-suited to mitigate the filter-clogging algae. Key conclusions and recommendations are presented in the following subsections.

9.1. Conclusions

- DAF is the best available treatment technology for mitigating the filter-clogging algae at the City's WTP. DAF is also the best, most-reliable overall technical approach for mitigating the filter-clogging algae at the City's WTP.

- DAF is acknowledged in the municipal water treatment industry as the best, most effective, and most reliable available technology for removing algae.

- DAF pilot testing showed that DAF can effectively treat Lake Whatcom algae at a relatively high rate.

- DAF will help improve the City's water quality by reducing the disinfection byproduct known as total trihalomethanes (TTHMs), total organic carbon (TOC), and other algae byproducts such as algal toxins and taste and odor compounds. A reduction in TTHMS of 25 percent can be anticipated. While these individual water quality parameters do not currently present regulatory compliance problems for the City, more intense algae blooms should be expected to present greater associated challenges.

- An intake solution to the filter-clogging algae condition at the City's WTP is more than double the cost of DAF and comes with uncertainty with respect to the quality of water it would withdraw.

- Additional filters could be effective at increasing plant capacity during an algae bloom as long as the intensity of the bloom does not reduce filter run times at the WTP to approximately 2 hours or less. The intensity of future algae blooms is unknown.

- The City is fully committed to reducing phosphorous entering Lake Whatcom to preserve and improve lake water quality and to meet the TMDL for Lake Whatcom. However, because of the long time duration to achieve the TMDL goals, lake management is not a viable, stand-alone alternative for mitigating the adverse algae clogging conditions at the City's WTP in the near-term future. Lake management will, over the long-term future, be part of a combined solution to minimize algae impacts at the WTP.

- As presented in this report, DAF was determined to be the best alternative using a technical evaluation approach as well as a TBL+ evaluation approach – even when considering the “Do Nothing” alternative.

9.2. Recommendations

Algae blooms occur annually in Lake Whatcom during the late summer and early fall timeframe. To date, the blooms have only resulted in mandatory water restrictions once. However, these blooms are expected to get progressively more intense over time, despite the fact that conditions in 2010 and 2011 were more favorable to reduced algae bloom intensity. Such future blooms present a risk to the City with respect to meeting the supply needs of its customers.

As a result, the City should pursue the design and construction of a new DAF facility in a phased approach, as discussed in Section 8, DAF Implementation. The phased approach should be based on an initial two-train DAF facility with easy expansion for a future third train, which would likely not be needed for many years into the future. The phased implementation of DAF will minimize the initial capital cost of a DAF facility. The phased approach will also eliminate the potential for constructing more DAF capacity than is necessary to ensure a continuous, reliable, high-quality drinking water supply – even during challenging times when there are intense algae blooms in Lake Whatcom. Based on the pilot testing completed in the late summer of 2011, DAF can be expected to lead to the reduction of the City’s TTHMs by 25 percent.

This phased DAF-implementation approach complements the City’s on-going commitment to lake management, water quality improvement, and TMDL compliance via the Lake Whatcom Management Program. Over the long-term future, as phosphorous-reducing lake management measures demonstrate success at improving water quality and reducing algae blooms, the need for further expansion of the initial phase of DAF implementation could be avoided entirely.

Appendix A
Lake Whatcom CE-QUAL-W2 Modeling Of Possible Water Intake Locations for the City of Bellingham

Lake Whatcom CE-QUAL-W2 Modeling Of Possible Water Intake Locations for the City of Bellingham

Prepared for:

City of Bellingham

Prepared by:

Chris Berger and Scott Wells

November 2011

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Executive Summary

The City of Bellingham's existing water supply system has experienced problems with water containing high algae concentrations flowing into the intake located in Lake Whatcom. An existing CE-QUAL-W2 water quality model of Lake Whatcom (Berger and Wells, 2005; Berger and Wells, 2007) was used to help identify potential new locations for the intake within the lake where concentrations of algae and particulate organic matter might be reduced. The CE-QUAL-W2 model was originally developed as part of a Total Maximum Daily Load Study performed by the Washington State Department of Ecology (Pickett and Hood, 2008). The model simulates a wide range of water quality and hydrodynamic parameters including blue-green algae, total algae, dissolved oxygen, nutrients, organic matter, temperature, water level and water velocity.

A total of 31 scenarios were simulated with the intake located at different locations within Lake Whatcom and at varying depths. Also simulated were 3 different land use conditions including a base case (2002/2003), existing (2011), and full build out of the watershed. The Lake Whatcom HSPF watershed model (The Cadmus Group, Inc. and CDM, 2007a and 2007b) was used to develop tributary inflows for the land use conditions. Because of the long residence time of Lake Whatcom (5-10 years), the scenarios were simulated over an extended period of time (11 years for the existing and base case land uses, 6 years for the full build out land use) so that model predictions were dependent on the land use conditions rather than the initial conditions of the model.

Model predictions indicated that order of magnitude reductions of algae concentrations in the intake only occurred when the intake was moved to deep locations (>30 meters) within basin #3. Algae grew closer to the water surface where more light for photosynthesis was available, so deeper intake locations had much lower algae concentrations. When the intake was placed at locations within the much shallower basin #2, the reduction of algae concentrations were smaller. At the deepest point in basin #2 (approximately 20 meters deep), blue-green algae concentrations in the intake for the July-October period were 39% less than at the existing location. At this location water with low dissolved oxygen concentrations water was withdrawn by the intake. With the intake placed at a relatively shallow depth (10 meters) at various locations in basin #3, the model predicted only a 20%-30% reduction in algae concentrations relative to the existing location.

Figure 1 shows maximum algae, maximum particulate organic matter, and minimum dissolved oxygen concentrations with the intake located near the bottom at various locations moving southeast from basin #2 into basin #3. At the north end of basin #3 (model segment 29), peak blue-green algae were reduced 80% and peak total algae concentrations were 90% less relative to concentrations at the existing intake locations in basin #2. Particulate organic matter (POM) concentrations were only slightly less than those in basin #2. POM consists mostly of dead algae cells and settles out of the water column toward the bottom.

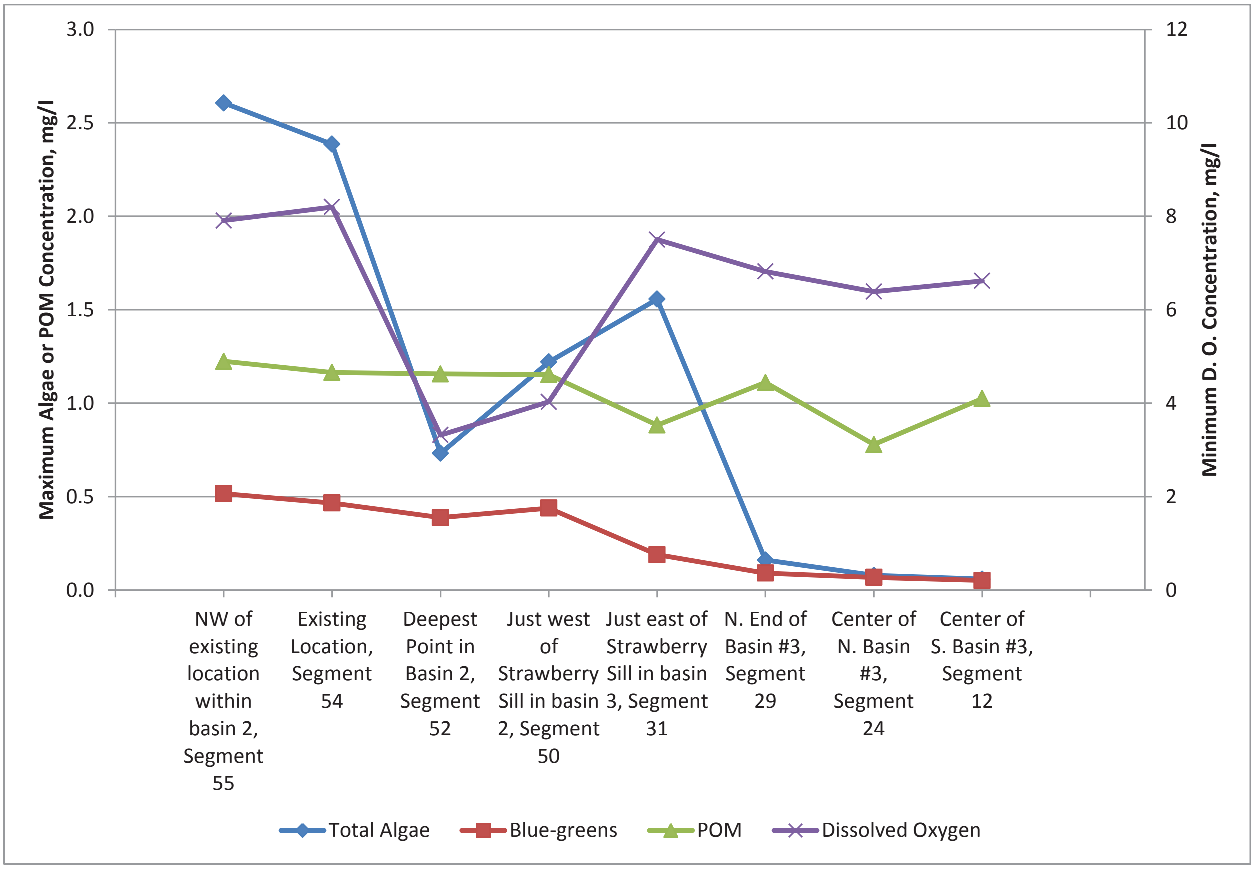

Figure 1. Maximum total algae, blue-green algae and particulate organic matter (POM) concentrations with intake located near bottom and at different locations within lake, moving along the lake axis from north end of basin 2 to the south. Minimum dissolved oxygen concentrations were also shown. The watershed loading for these scenarios was for existing conditions.

Introduction

The purpose of this modeling effort is to identify one or more locations in Lake Whatcom (Figure 2) that are predicted to be favorable for a new water supply intake for the City of Bellingham with respect to algae and particulate organic matter (POM). Because of increased algae growth in Lake Whatcom, the water supply intake can be susceptible to inflows of algae and POM. The intake can convey algae and POM into the treatment plant as a result of their deposition in the water column. This can have a deleterious effect on the water treatment plant process.

The model study was made to compare intake amounts of algae and POM based on estimated current water quality conditions and projected future water quality conditions. Intake locations that were deemed favorable with respect to algae and POM were those that were modeled to have less algae and POM than the City's existing intake location. As such, favorable intake locations were favorable only with respect to other locations within Lake Whatcom, which is the primary objective of this work – identifying "favorable" locations within Lake Whatcom for a new intake. The results of this modeling are based on a calibrated hydrodynamic and water quality model of Lake Whatcom (Berger and Wells, 2005; Berger and Wells, 2007). This modeling effort then is based on field data from 2002 and 2003 and is considered an estimate of "favorable" locations based on this prior work.

Background

Lake Whatcom is a large natural lake which was first listed on the 1998 Washington State 303(d) list of water bodies that do not meet the criterion for dissolved oxygen. Located next Bellingham, it is approximately 10 miles long, has a surface area of approximately 5000 acres, and a maximum depth of over 100 meters. Residence time is approximately 5-10 years. Lake Whatcom is within a relatively small watershed, and the lake's surface area is large in comparison to the size of its watershed. Eutrophication processes in the lake have been facilitated by the availability of nutrients, leading to concerns about land development within the watershed.

A water quality and hydrodynamic model of Lake Whatcom, Washington was developed as part of a Total Maximum Daily Load Study (Berger and Wells, 2005) using the model CE-QUAL-W2 Version 3.2. In further work on the TMDL, the model was upgraded to Version 3.5 and recalibrated based on updated information (Berger and Wells, 2007; Pickett and Hood, 2008).

The Corps of Engineer's model CE-QUAL-W2 is two-dimensional (longitudinal and vertical, x-z) consisting of directly coupled hydrodynamic and water quality transport models. This model has been under development for many years and is a public-domain code maintained by the Corps of Engineers, Waterways Experiments Station (WES), located in Vicksburg, Mississippi. Version 3.5 has undergone rigorous testing and has been successfully applied to many river basin systems (Cole and Wells, 2005). Further information about CE-QUAL-W2 Version 3 is shown at http://www.ce.pdx.edu/w2. The current release version of the model is Version 3.7.

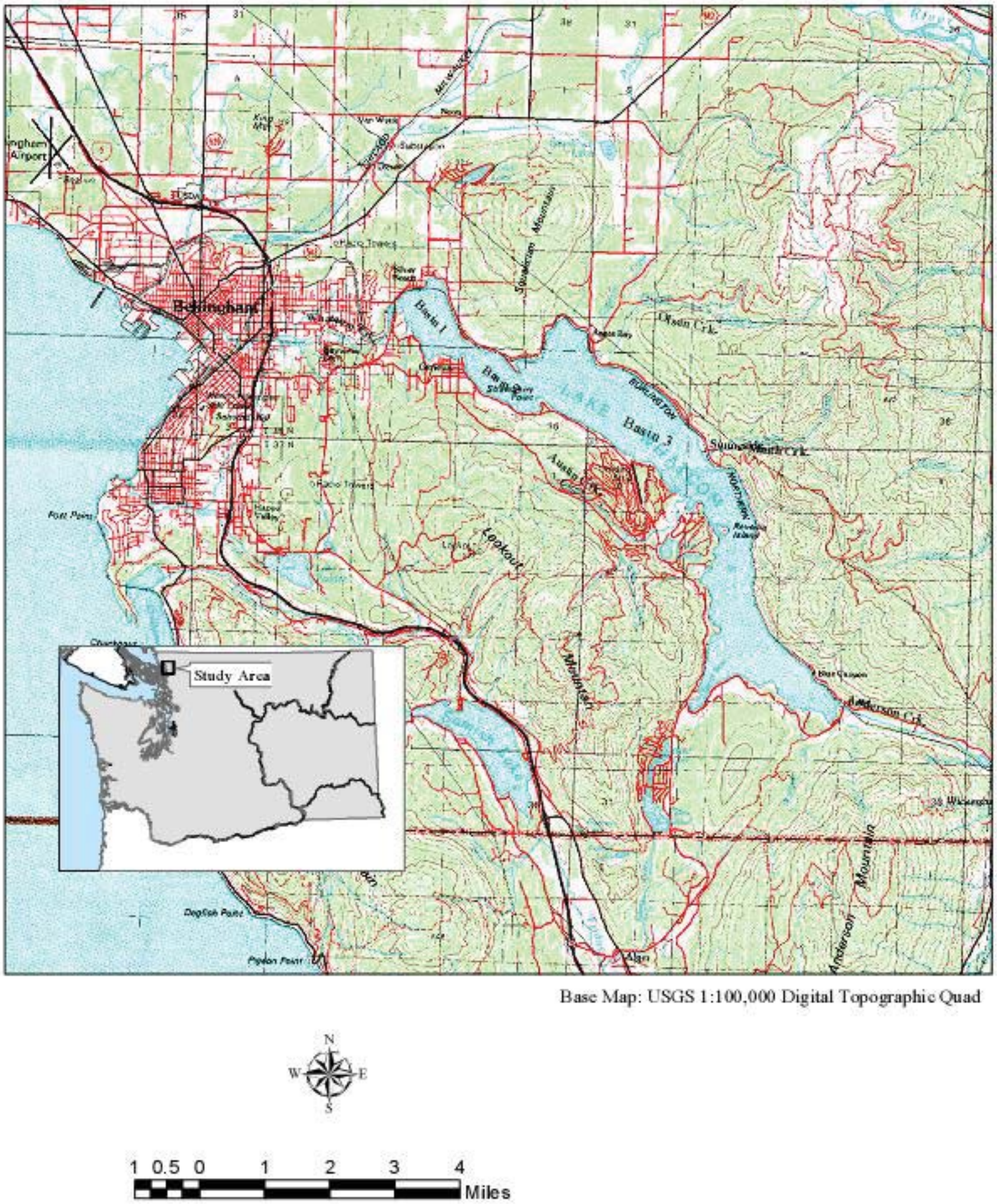

Figure 2. Lake Whatcom and vicinity (Pitz, 2005).

Primary physical processes simulated were surface heat transfer, short-wave and long-wave radiation and penetration, convective mixing, wind and flow induced mixing, inflow density stratification as impacted by temperature and dissolved and suspended solids. Major chemical constituents and biological processes simulated include: atmospheric exchange on DO, photosynthesis, respiration, organic matter decomposition, nitrification, and chemical oxidation of reduced substances; uptake, excretion, and regeneration of phosphorus and nitrogen and nitrification-denitrification under aerobic and anaerobic conditions; carbon cycling and alkalinity-pH-CO2 interactions; trophic relationships for 3 phytoplankton species; and the accumulation and decomposition of detritus and organic sediment. For this application phosphorus and nitrogen organic matter compartments were added specially to represent the phosphorus (P) and nitrogen (N) mass contained in dissolved and particulate organic matter and the sediments. Thus the stoichiometry of the organic matter is variable and the user is able to set dynamic values of N and P in all tributaries associated with organic matter and to track these quantities within the domain of the CE-QUAL-W2. There were also sufficient data to model 3 phytoplankton species: diatoms, greens, and blue-greens.

The pie chart in Figure 3 shows the relative magnitude of phosphorus sources in Lake Whatcom. Inflows from tributaries and groundwater inflows account for approximately three-quarters of the phosphorus loading. Organic sediment contributions to phosphorus were simulated using two methods. The first method uses a constant, or zero order, release and demand and was labeled “anoxic sediment release” in Figure 3. The 0 order process uses a specified sediment oxygen demand and anoxic release rates for phosphorus, ammonium and inorganic carbon that were temperature dependent. Nutrient releases do not occur when dissolved oxygen concentrations were above a minimum value (0.1 mg/l for the Lake Whatcom model). Anoxic sediment release accounts for only a small fraction of the total phosphorus load to the lake because the actual volume of water containing less than 0.1 mg/l dissolved oxygen was very small relative to the total volume of the lake.

The second method uses a sediment compartment to accumulate organic sediments and allow their decay. The organic sediments consist primarily of particulate organic matter (detritus) settled to the bottom, and their decay accounts for approximately one quarter of the phosphorus load (labeled “oxic sediment release” in pie chart). Nutrient releases and oxygen demand were thus dependent upon sediment accumulation – a 1st ¬order process. However, there was no release of phosphorus or other diagenesis products when overlying water was anoxic because this sediment compartment only simulates the oxic (oxygenated) decay of organic matter.

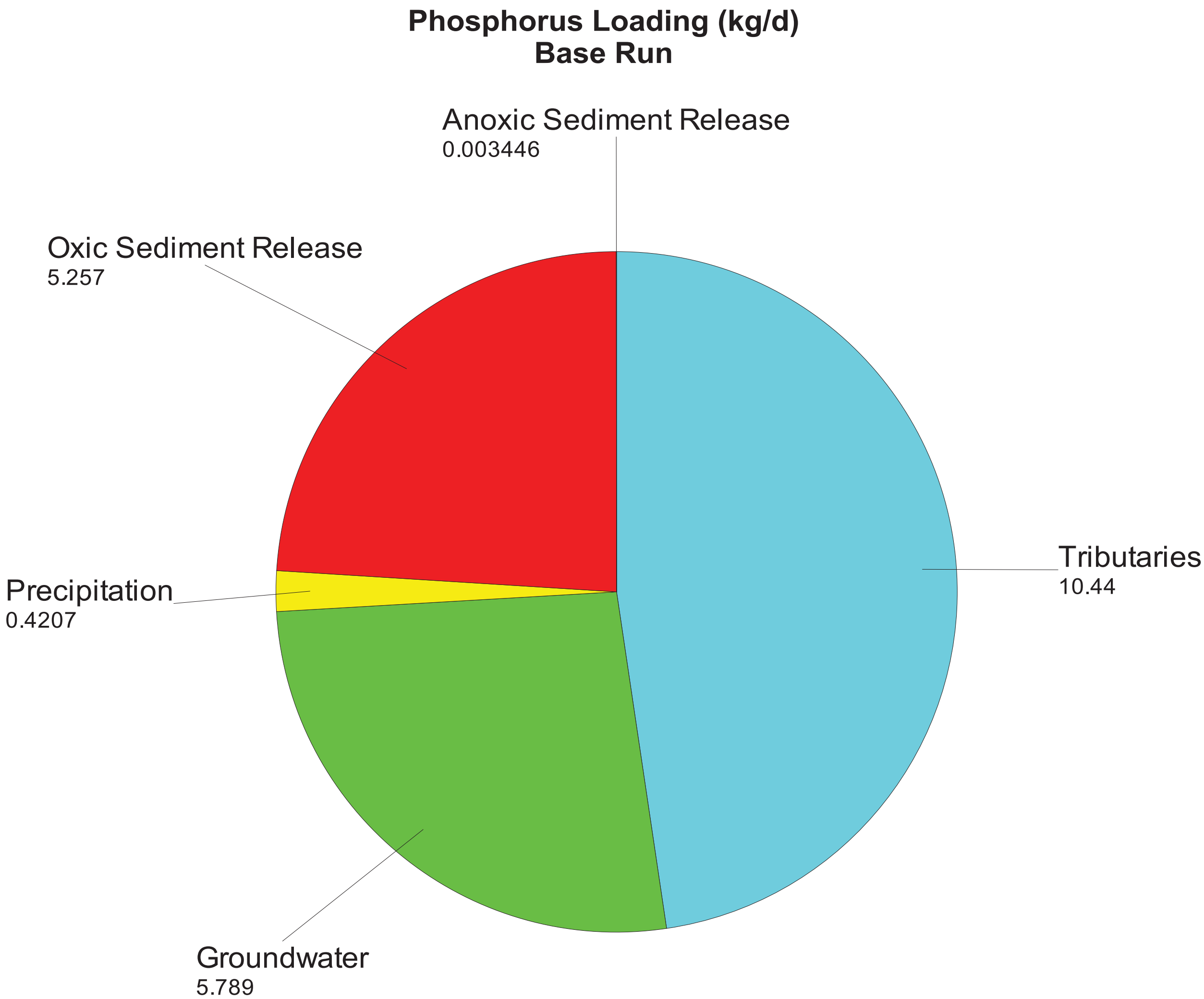

Figure 3. Pie chart showing sources of phosphorus loads to Lake Whatcom.

The Lake Whatcom bathymetry and basins are shown in Figure 4. Basin 3, much larger and deeper than the other two basins, contains 96% of the lake's volume. A plan view of the CE-QUAL-W2 grid layout is shown in Figure 5. The model was divided into five branches and two water bodies. Branches 1 through 3 simulated basin 3 and branches 4 and 5 represented basins 1 and 2. The length of the model segments ranged from 16 meters to 821 meters. Model layers have a thickness of 1 or 3 meters. Three meter layer thicknesses were used only in the deeper sections of Basin 3. Model vertical layers and longitudinal segments are shown in Figure 6.

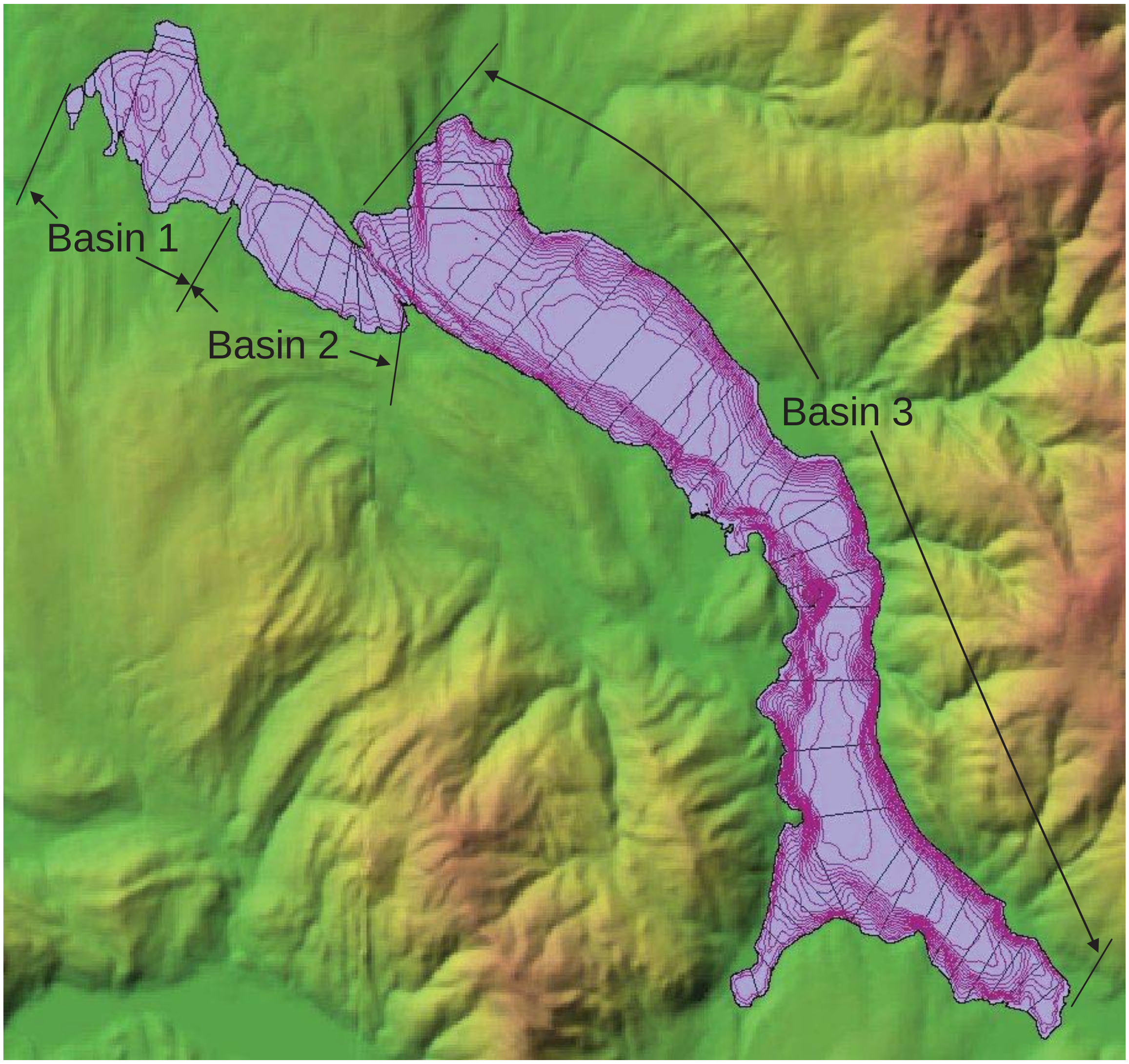

Figure 4. Lake bathymetry and topography around Lake Whatcom. The lake's basins were also shown.

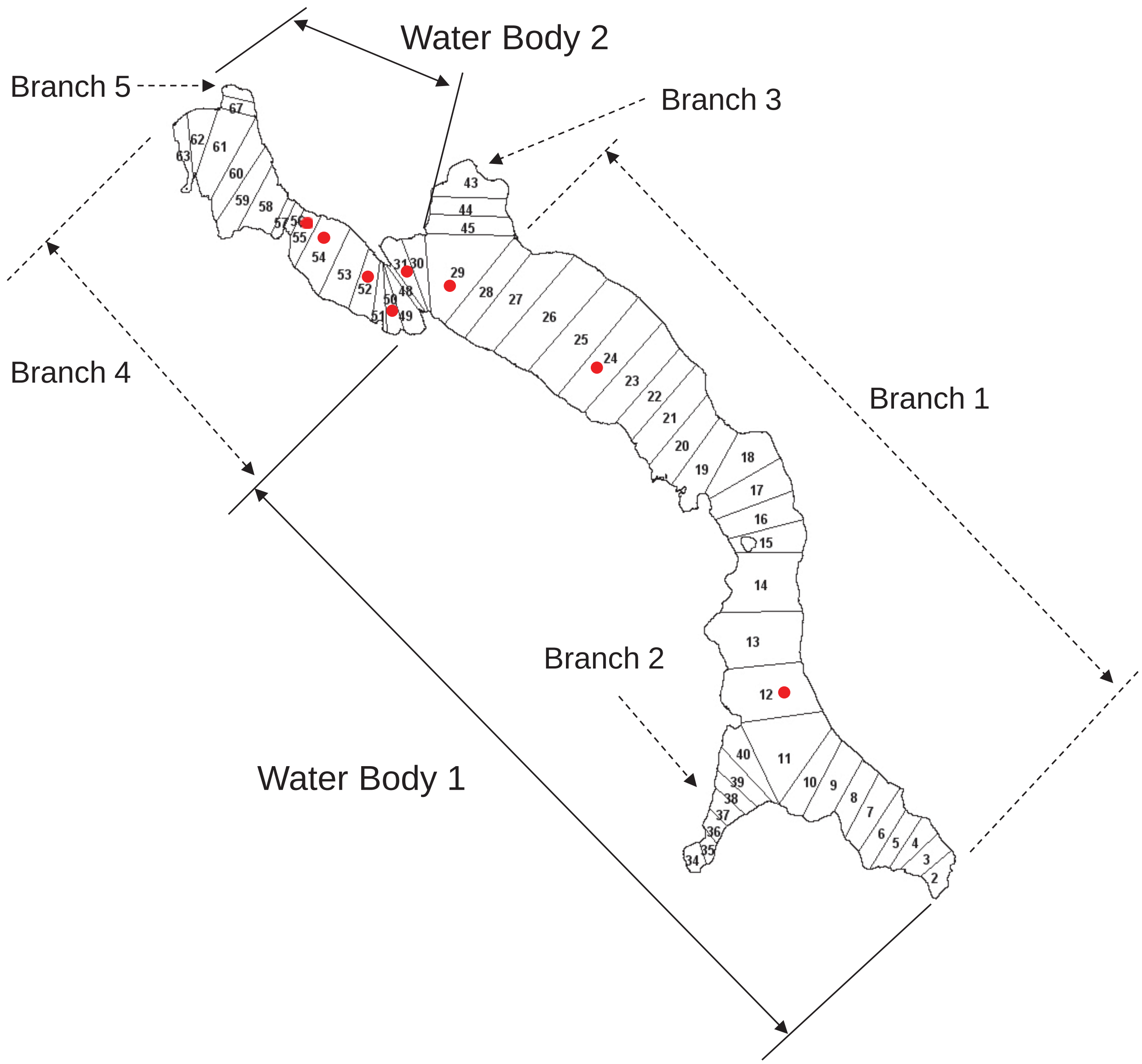

Figure 5. Plan view of the Lake Whatcom model grid showing model segments, branches, and water bodies. Segments where potential intake locations were investigated were marked with the "●" symbol.

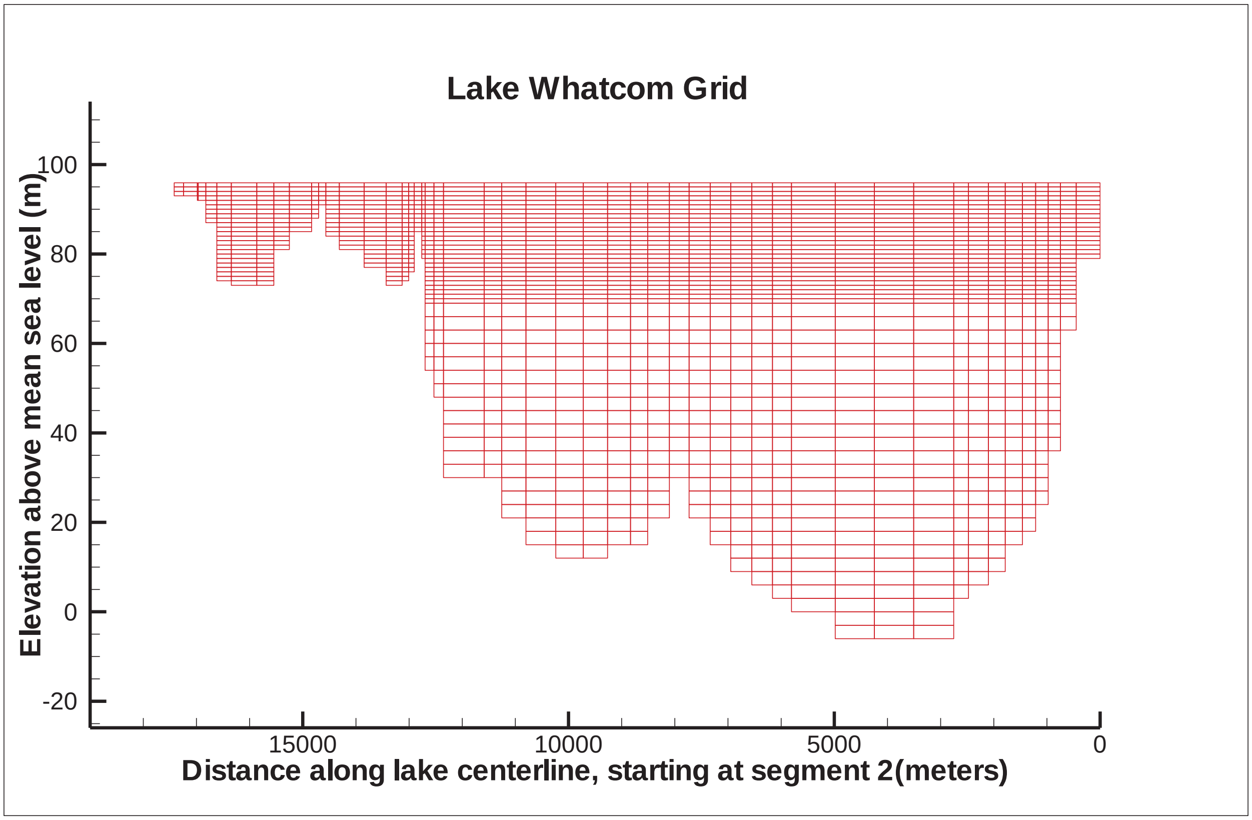

Figure 6. Longitudinal segments and vertical layer elevations of Lake Whatcom model. Only layers below the full pool elevation are shown.

Scenarios

The location of the City of Bellingham's water intake was moved to various locations and depths within Lake Whatcom. Model segments where the intake was placed are identified in Figure 5. In addition, scenarios were simulated with different land use and tributary nutrient loadings. These included a base case (2002/2003), existing land use (2011), and full build-out land use simulations with tributary loads generated by the Lake Whatcom HSPF watershed model (The Cadmus Group, Inc. and CDM, 2007a and 2007b). Base case inputs were the same as those used for the calibration years 2002 and 2003 of the CE-QUAL-W2 model developed for the Lake Whatcom TMDL Study. The water surface elevations for the simulations were generally between 95 m to 96 m MSL. Scenarios were simulated for up to 11 years so that the model results would not be overly influenced by the initial conditions. In doing so, for each of the three different land use conditions (base case, existing, and future build-out), the model predicts future algae and other water quality parameters. This was accomplished by using a looping tool which permitted multiple runs with the same boundary conditions where the initial condition of a run was equal to the final conditions of the previous simulation. This ensured that model predictions were more dependent upon tributary inflows rather than the initial conditions. The base case and existing land use scenarios were simulated then for a total of 11 years (or 10 loops, with the first loop being 2 years and all others being 1 year). However, the full build-out scenario was only simulated through 5 loops (6 years) because of nitrogen limitation (insufficient nitrogen available for increases in algae growth) in the input files for this scenario. Nitrogen limitation is rare in freshwater systems and it is believed that the nitrogen limitation for the build-out condition results from a deficiency in the input data. A total of 31 scenarios were simulated, and these were listed in Table 1.

To search for favorable intake locations in Lake Whatcom, the existing condition scenario was simulated at multiple points and depths within the lake. If a location seemed promising or where simulating the base case or full build out might be informative, these scenarios were also simulated. As shown in the next section, algae and POM concentrations of the full build out scenario were generally within 10% of that of the existing conditions scenario, so it was unlikely that promising intake locations were overlooked by only simulating the existing conditions scenario.

Table 1. Scenario simulations.

Scenario #	Intake Segment #	Intake Elev. (m)	Approx. Depth (m)	Watershed Loading Scenario*	Comments
1	54	85	10	Base	Existing Location of Intake
2	54	85	10	Existing	Existing Location of Intake
3	54	85	10	FBO	Existing Location of Intake
4	52	85	10	Existing	SE of existing location within basin 2
5	55	85	10	Existing	NW of existing location within basin 2
6	50	78	17	Existing	Just west of Strawberry Sill in basin 2
7	31	60	35	Existing	Just east of Strawberry Sill in basin 3, close to bottom
8	31	60	35	FBO	Just east of Strawberry Sill in basin 3, close to bottom
9	31	60	35	Base	Just east of Strawberry Sill in basin 3, close to bottom
10	31	85	10	Existing	Just east of Strawberry Sill in basin 3, 10 m depth
11	24	85	10	Existing	Center of N. Basin #3, 10 m depth
12	24	50	45	Existing	Center of N. Basin #3, 45 m depth
13	24	50	45	FBO	Center of N. Basin #3, 45 m depth
14	24	18	77	Existing	Center of N. Basin #3, 77 m depth
15	24	18	77	FBO	Center of N. Basin #3, 77 m depth
16	24	18	77	Base	Center of N. Basin #3, 77 m depth
17	12	85	10	Existing	Center of S. Basin #3, 10 m depth
18	12	50	45	Existing	Center of S. Basin #3, 45 m depth
19	12	50	45	FBO	Center of S. Basin #3, 45 m depth
20	12	0	95	Existing	Center of S. Basin #3, 95 m depth
21	12	0	95	FBO	Center of S. Basin #3, 95 m depth
22	29	35	60	Existing	North end of Basin #3, 60 m depth
23	29	35	60	FBO	North end of Basin #3, 60 m depth
24	29	35	60	Base	North end of Basin #3, 60 m depth
25	29	85	10	Existing	North end of Basin #3, 10 m depth
26	29	75	20	Existing	North end of Basin #3, 20 m depth
27	29	65	30	Existing	North end of Basin #3, 30 m depth
28	29	55	40	Existing	North end of Basin #3, 40 m depth

Scenario #	Intake Segment #	Intake Elev. (m)	Approx. Depth (m)	Watershed Loading Scenario*	Comments
29	29	45	50	Existing	North end of Basin #3, 50 m depth
30	52	75	20	Existing	Deepest location in Basin #2
31	52	75	20	FBO	Deepest location in Basin #2

*Base=Base Conditions, FBO=Full Build Out Land Use, Existing Land Uses

Results

Intake concentrations of algae and particulate organic matter (POM) concentrations were compared for the different scenarios. Average annual concentrations for the intake were listed in Table 2. Average concentrations for the July-October period were shown in Table 3. Table 4 shows the results in Table 3 but ranked based on total algae and POM from least to the greatest, and Table 5 shows the results of Table 3 sorted according to model segment location. Table 6 lists the maximum intake concentrations. Generally, the deeper the intake, the lower the algae concentrations withdrawn by the intake. Figure 7 shows predicted total algae concentrations with the intake located at various depths in segment 29 (north end of basin #3). Watershed loadings for these scenarios corresponded to existing land use. Concentrations decrease by an order of magnitude between an intake depth of 10 m to near the bottom at a depth of 60 m. Algae require light to grow and concentrations were greater near the surface where more light was available. On the other hand particulate organic matter concentrations in the intake remained approximately the same with increasing depth (Figure 8). Particulate organic matter in Lake Whatcom consisted primarily of dead algae during the summer months, which would settle out of the photic zone to the bottom.

When the intake was placed at different locations within basin #2 (scenarios #1 through #6) algae concentrations remained roughly the same at most locations. However at the deepest point in basin #2 (scenarios 30 and 31), the average July-October total algae concentration decreased 47% relative to the existing location for the full build out scenario. Concentrations of blue green algae, which are thought to be the primary cause of the clogging in the intake, decreased 39%. Particulate organic matter increased by 27% relative to the existing location and conditions. Maximum blue-green concentration decreased by 10% and maximum total algae concentration decreased by 67%. Minimum dissolved oxygen concentration, which was 8.11 mg/l at the existing location for the full build out scenario (scenario 3), dropped to 3.05 mg/l with the intake at the deepest point of basin. With the intake at the existing location, the model predicted zero dissolved oxygen concentrations in the hypolimnion of basin #2 during the summer. This prediction was consistent with measured dissolved oxygen data (Matthews et al., 2011). When the intake was moved to the deepest point in basin #2, a vertical current was created where water drawn into the intake was replaced by oxygenated water flowing from above. This vertical current prevented the minimum dissolved oxygen concentrations from dropping to zero for scenarios 30 and 31. Order of magnitude decreases in concentrations in the intake only occurred when the intake was moved across the sill separating basin #2 and #3 (Strawberry Sill) and into deeper water.

With the intake at a depth of 10 m total algae concentrations during the July-October dropped approximately 20% when moving the intake along the axis of the lake from basin #2 into basin #3 (Figure 9). Particulate organic matter concentrations decreased 35% and blue green algae concentrations dropped 28%. Peak concentrations showed a similar pattern (Figure 10), with total algae concentration in the intake being reduced 24% with the intake (at a 10 m depth) being moved from the existing location in basin #2 to the south of basin #3.

Much larger decreases of algae in the intake occurred when it was placed near the bottom in the deep areas of basin #3. Figure 11 shows total algae, blue-green algae, and POM concentrations in the intake as it was shifted from the relatively shallow basin #2 southeast along the lake axis through basin #3. In segment 31, just east of the sill separating basin #2 and #3, total algae and blue-green algae concentrations for the July-October period had decreased 95% relative to basin #2 concentrations.. Peak concentrations of total algae, blue-green algae, and POM with the intake near bottom were plotted in Figure 12. At the bottom of segment 29, near the north end basin #3, maximum total algae concentrations were 90% less than concentrations in basin #2 and peak blue-green concentrations were 80% less.

The use of base case, existing land use, full build-out land use watershed loadings did not result in large differences in intake algae and other water quality concentrations. For instance, at the existing location of the outlet (scenarios 1-3) the peak blue-green concentration for base case was 0.454 mg/l for the base case, 0.466 mg/l for existing land use, and 0.473 mg/l for full build-out land use. At the bottom of segment 29 near the north end of basin #3, peak blue-green concentrations were 0.087 mg/l for the base case, 0.091 for existing land use, and 0.092 mg/l for full build out land use (scenarios 22-24).

Predictions of Algae Growth in Basin 3

Data collected by Western Washington University as part of annual Lake Whatcom water quality monitoring reveals a doubling of chlorophyll a in the shallow depths of Basin 3 between 2002 and 2010. The model was run in an attempt to demonstrate duplication of these results. To accomplish this, a base case simulation was run with the intake placed at a shallow depth of approximately 3 meters in segment 29. Model segment 29 was located in the north end of basin 3 (Figure 5). The model was run through 8 loops (9 years) so that water quality differences between year 9 and year 1 could be evaluated. This 8 year period can then be used to simulate the difference between years 2010 and 2002. This approach assumes no change to land use and watershed conditions in the base case model input files. Table 7 and Table 8 show that algae concentrations approximately doubled over the 8 year period which is similar to actual chlorophyll observations documented in the annual Lake Whatcom reports. Because chlorophyll a is an indirect measure of algae concentration, their trends are typically similar.

Table 2. Average concentrations of algae, particulate organic matter (POM) and dissolved oxygen in intake for the entire year.

Scenario #	Intake Segment #	Approx. Depth (m)	Water-shed Loading Scenario*	Diatoms (mg/l)	Chloro-phyta (mg/l)	Blue-greens (mg/l)	Total Algae (mg/l)	POM (mg/l)	D. O. (mg/l)
1	54	10	Base	0.323	0.007	0.134	0.463	0.404	10.50
2	54	10	Existing	0.335	0.008	0.139	0.482	0.420	10.52
3	54	10	FBO	0.356	0.011	0.140	0.507	0.442	10.57
4	52	10	Existing	0.295	0.007	0.130	0.433	0.405	10.32
5	55	10	Existing	0.381	0.008	0.149	0.538	0.421	10.76
6	50	17	Existing	0.171	0.006	0.104	0.281	0.446	9.30
7	31	35	Existing	0.037	0.004	0.039	0.080	0.355	9.57
8	31	35	FBO	0.042	0.006	0.040	0.087	0.376	9.58
9	31	35	Base	0.035	0.004	0.038	0.076	0.344	9.61
10	31	10	Existing	0.298	0.007	0.131	0.436	0.346	10.53
11	24	10	Existing	0.255	0.007	0.108	0.370	0.323	10.52
12	24	45	Existing	0.008	0.004	0.028	0.040	0.357	9.21
13	24	45	FBO	0.010	0.005	0.028	0.043	0.375	9.21
14	24	77	Existing	0.003	0.004	0.023	0.029	0.338	8.56
15	24	77	FBO	0.003	0.005	0.023	0.032	0.354	8.54
16	24	77	Base	0.002	0.003	0.022	0.028	0.329	8.62
17	12	10	Existing	0.259	0.007	0.107	0.374	0.341	10.46
18	12	45	Existing	0.006	0.004	0.024	0.033	0.370	9.15
19	12	45	FBO	0.008	0.005	0.023	0.036	0.387	9.16
20	12	95	Existing	0.002	0.003	0.019	0.024	0.350	8.56
21	12	95	FBO	0.002	0.005	0.019	0.026	0.365	8.56
22	29	60	Existing	0.005	0.004	0.026	0.035	0.368	8.95
23	29	60	FBO	0.007	0.006	0.026	0.038	0.386	8.95
24	29	60	Base	0.005	0.004	0.025	0.033	0.357	9.01
25	29	10	Existing	0.286	0.007	0.125	0.418	0.333	10.51
26	29	20	Existing	0.128	0.005	0.064	0.197	0.359	10.06
27	29	30	Existing	0.049	0.004	0.044	0.097	0.358	9.66
28	29	40	Existing	0.019	0.004	0.033	0.056	0.359	9.38
29	29	50	Existing	0.007	0.004	0.028	0.040	0.361	9.12
30	52	20	Existing	0.148	0.005	0.099	0.252	0.451	9.03
31	52	20	FBO	0.157	0.007	0.103	0.268	0.474	9.01

*Base=Base Conditions, FBO=Full Build Out Land Use, Existing Land Uses

Table 3. Average concentrations of algae, particulate organic matter (POM) and dissolved oxygen in intake for the July-October period.

Scenario #	Intake Segment #	Approx. Depth (m)	Water-shed Loading Scenario*	Diatoms (mg/l)	Chloro-phyta (mg/l)	Blue-greens (mg/l)	Total Algae (mg/l)	POM (mg/l)	D. O. (mg/l)
1	54	10	Base	0.249	0.007	0.230	0.486	0.441	9.47
2	54	10	Existing	0.258	0.008	0.238	0.504	0.461	9.50
3	54	10	FBO	0.271	0.011	0.242	0.525	0.487	9.51
4	52	10	Existing	0.240	0.007	0.220	0.467	0.444	9.29
5	55	10	Existing	0.263	0.009	0.255	0.527	0.450	9.80
6	50	17	Existing	0.141	0.005	0.150	0.296	0.545	7.27
7	31	35	Existing	0.008	0.002	0.013	0.023	0.435	8.88
8	31	35	FBO	0.009	0.003	0.013	0.025	0.480	8.80
9	31	35	Base	0.008	0.002	0.013	0.023	0.435	8.88
10	31	10	Existing	0.217	0.007	0.229	0.453	0.354	10.07
11	24	10	Existing	0.218	0.007	0.183	0.408	0.302	10.44
12	24	45	Existing	0.003	0.003	0.013	0.019	0.460	8.72
13	24	45	FBO	0.004	0.004	0.013	0.021	0.487	8.70
14	24	77	Existing	0.001	0.003	0.012	0.016	0.455	7.86
15	24	77	FBO	0.001	0.005	0.012	0.018	0.485	7.80
16	24	77	Base	0.001	0.003	0.012	0.015	0.437	7.94
17	12	10	Existing	0.238	0.008	0.195	0.442	0.299	10.37
18	12	45	Existing	0.003	0.003	0.013	0.019	0.447	8.86
19	12	45	FBO	0.004	0.004	0.012	0.020	0.473	8.85
20	12	95	Existing	0.000	0.003	0.012	0.015	0.428	8.21
21	12	95	FBO	0.000	0.004	0.012	0.016	0.456	8.18
22	29	60	Existing	0.002	0.003	0.012	0.018	0.489	8.37
23	29	60	FBO	0.002	0.005	0.012	0.019	0.519	8.33
24	29	60	Base	0.002	0.003	0.012	0.017	0.469	8.44
25	29	10	Existing	0.216	0.007	0.217	0.440	0.337	10.18
26	29	20	Existing	0.053	0.002	0.052	0.107	0.413	9.37
27	29	30	Existing	0.011	0.002	0.016	0.029	0.448	8.91
28	29	40	Existing	0.005	0.003	0.013	0.021	0.469	8.75
29	29	50	Existing	0.003	0.003	0.013	0.018	0.484	8.52
30	52	20	Existing	0.116	0.004	0.137	0.257	0.561	6.80
31	52	20	FBO	0.117	0.006	0.145	0.268	0.589	6.61

*Base=Base Conditions, FBO=Full Build Out Land Use, Existing Land Uses

Table 4. Reordered Table 3 (average concentrations of algae, particulate organic matter (POM) and dissolved oxygen in intake for the July-October period) ranked based on total algae and POM from least to greatest.

Scenario #	Intake Segment #	Approx. Depth (m)	Watershed Loading Scenario*	Diatoms (mg/l)	Chloro-phyta (mg/l)	Blue-greens (mg/l)	Total Algae (mg/l)	POM (mg/l)	D. O. (mg/l)	Total algae and POM, mg/l
20	12	95	Existing	0.000	0.003	0.012	0.015	0.428	8.21	0.443
16	24	77	Base	0.001	0.003	0.012	0.015	0.437	7.94	0.452
7	31	35	Existing	0.008	0.002	0.013	0.023	0.435	8.88	0.458
9	31	35	Base	0.008	0.002	0.013	0.023	0.435	8.88	0.458
18	12	45	Existing	0.003	0.003	0.013	0.019	0.447	8.86	0.466
14	24	77	Existing	0.001	0.003	0.012	0.016	0.455	7.86	0.471
21	12	95	FBO	0.000	0.004	0.012	0.016	0.456	8.18	0.472
27	29	30	Existing	0.011	0.002	0.016	0.029	0.448	8.91	0.477
12	24	45	Existing	0.003	0.003	0.013	0.019	0.460	8.72	0.479
24	29	60	Base	0.002	0.003	0.012	0.017	0.469	8.44	0.486
28	29	40	Existing	0.005	0.003	0.013	0.021	0.469	8.75	0.490
19	12	45	FBO	0.004	0.004	0.012	0.020	0.473	8.85	0.493
29	29	50	Existing	0.003	0.003	0.013	0.018	0.484	8.52	0.502
15	24	77	FBO	0.001	0.005	0.012	0.018	0.485	7.80	0.503
8	31	35	FBO	0.009	0.003	0.013	0.025	0.480	8.80	0.505
22	29	60	Existing	0.002	0.003	0.012	0.018	0.489	8.37	0.507
13	24	45	FBO	0.004	0.004	0.013	0.021	0.487	8.70	0.508
26	29	20	Existing	0.053	0.002	0.052	0.107	0.413	9.37	0.520
23	29	60	FBO	0.002	0.005	0.012	0.019	0.519	8.33	0.538
11	24	10	Existing	0.218	0.007	0.183	0.408	0.302	10.44	0.710
17	12	10	Existing	0.238	0.008	0.195	0.442	0.299	10.37	0.741
25	29	10	Existing	0.216	0.007	0.217	0.440	0.337	10.18	0.777
10	31	10	Existing	0.217	0.007	0.229	0.453	0.354	10.07	0.807
30	52	20	Existing	0.116	0.004	0.137	0.257	0.561	6.80	0.818
6	50	17	Existing	0.141	0.005	0.150	0.296	0.545	7.27	0.841
31	52	20	FBO	0.117	0.006	0.145	0.268	0.589	6.61	0.857
4	52	10	Existing	0.240	0.007	0.220	0.467	0.444	9.29	0.911
1	54	10	Base	0.249	0.007	0.230	0.486	0.441	9.47	0.927
2	54	10	Existing	0.258	0.008	0.238	0.504	0.461	9.50	0.965
5	55	10	Existing	0.263	0.009	0.255	0.527	0.450	9.80	0.977
3	54	10	FBO	0.271	0.011	0.242	0.525	0.487	9.51	1.012

*Base=Base Conditions, FBO=Full Build Out Land Use, Existing Land Uses

Table 5. Reordered Table 3 (average concentrations of algae, particulate organic matter (POM) and dissolved oxygen in intake for the July-October period) based on model segment number.

Scenario #	Intake Segment #	Approx. Depth (m)	Watershed Loading Scenario*	Diatoms (mg/l)	Chloro-phyta (mg/l)	Blue-greens (mg/l)	Total Algae (mg/l)	POM (mg/l)	D. O. (mg/l)	Total algae and POM, mg/l
17	12	10	Existing	0.238	0.008	0.195	0.442	0.299	10.37	0.741
18	12	45	Existing	0.003	0.003	0.013	0.019	0.447	8.86	0.466
19	12	45	FBO	0.004	0.004	0.012	0.020	0.473	8.85	0.493
20	12	95	Existing	0.000	0.003	0.012	0.015	0.428	8.21	0.443
21	12	95	FBO	0.000	0.004	0.012	0.016	0.456	8.18	0.472
11	24	10	Existing	0.218	0.007	0.183	0.408	0.302	10.44	0.710
12	24	45	Existing	0.003	0.003	0.013	0.019	0.460	8.72	0.479
13	24	45	FBO	0.004	0.004	0.013	0.021	0.487	8.70	0.508
16	24	77	Base	0.001	0.003	0.012	0.015	0.437	7.94	0.452
14	24	77	Existing	0.001	0.003	0.012	0.016	0.455	7.86	0.471
15	24	77	FBO	0.001	0.005	0.012	0.018	0.485	7.80	0.503
25	29	10	Existing	0.216	0.007	0.217	0.440	0.337	10.18	0.777
26	29	20	Existing	0.053	0.002	0.052	0.107	0.413	9.37	0.520
27	29	30	Existing	0.011	0.002	0.016	0.029	0.448	8.91	0.477
28	29	40	Existing	0.005	0.003	0.013	0.021	0.469	8.75	0.490
29	29	50	Existing	0.003	0.003	0.013	0.018	0.484	8.52	0.502
24	29	60	Base	0.002	0.003	0.012	0.017	0.469	8.44	0.486
22	29	60	Existing	0.002	0.003	0.012	0.018	0.489	8.37	0.507
23	29	60	FBO	0.002	0.005	0.012	0.019	0.519	8.33	0.538
10	31	10	Existing	0.217	0.007	0.229	0.453	0.354	10.07	0.807
7	31	35	Existing	0.008	0.002	0.013	0.023	0.435	8.88	0.458
9	31	35	Base	0.008	0.002	0.013	0.023	0.435	8.88	0.458
8	31	35	FBO	0.009	0.003	0.013	0.025	0.480	8.80	0.505
6	50	17	Existing	0.141	0.005	0.150	0.296	0.545	7.27	0.841
4	52	10	Existing	0.240	0.007	0.220	0.467	0.444	9.29	0.911
30	52	20	Existing	0.116	0.004	0.137	0.257	0.561	6.80	0.818
31	52	20	FBO	0.117	0.006	0.145	0.268	0.589	6.61	0.857
1	54	10	Base	0.249	0.007	0.230	0.486	0.441	9.47	0.927
2	54	10	Existing	0.258	0.008	0.238	0.504	0.461	9.50	0.965

*Base=Base Conditions, FBO=Full Build Out Land Use, Existing Land Uses

Table 6. Maximum concentrations of algae and particulate organic matter (POM) and the minimum concentration of dissolved oxygen in the intake.

Scenario #	Intake Segment #	Approx. Depth (m)	Watershed Loading Scenario*	Dia-tom Max. (mg/l)	Chloro-phyta Max. (mg/l)	Blue-green Max. (mg/l)	Total Algae Max. (mg/l)	POM Max. (mg/l)	D. O. Min. (mg/l)
1	54	10	Base	2.180	0.017	0.454	2.279	1.120	8.22
2	54	10	Existing	2.280	0.019	0.466	2.386	1.165	8.20
3	54	10	FBO	2.440	0.024	0.473	2.546	1.234	8.11
4	52	10	Existing	1.980	0.017	0.419	2.079	1.103	8.35
5	55	10	Existing	2.500	0.019	0.517	2.607	1.224	7.91
6	50	17	Existing	1.140	0.012	0.439	1.221	1.153	4.03
7	31	35	Existing	1.470	0.016	0.190	1.557	0.883	7.50
8	31	35	FBO	1.550	0.021	0.196	1.640	0.941	7.43
9	31	35	Base	1.400	0.014	0.183	1.483	0.847	7.61
10	31	10	Existing	2.190	0.020	0.455	2.298	1.052	9.22
11	24	10	Existing	1.780	0.020	0.372	1.883	0.999	9.17
12	24	45	Existing	0.099	0.006	0.104	0.138	0.816	7.40
13	24	45	FBO	0.107	0.009	0.106	0.150	0.839	7.34
14	24	77	Existing	0.021	0.005	0.068	0.079	0.779	6.39
15	24	77	FBO	0.028	0.007	0.067	0.081	0.794	6.27
16	24	77	Base	0.020	0.005	0.065	0.074	0.771	6.52
17	12	10	Existing	1.870	0.021	0.403	1.972	0.959	8.67
18	12	45	Existing	0.123	0.007	0.056	0.164	0.979	7.50
19	12	45	FBO	0.144	0.009	0.056	0.187	1.002	7.44
20	12	95	Existing	0.005	0.005	0.052	0.059	1.025	6.62
21	12	95	FBO	0.007	0.007	0.051	0.061	1.049	6.55
22	29	60	Existing	0.103	0.009	0.091	0.161	1.111	6.82
23	29	60	FBO	0.125	0.014	0.092	0.184	1.137	6.72
24	29	60	Base	0.089	0.007	0.087	0.143	1.097	6.93
25	29	10	Existing	2.070	0.020	0.430	2.178	0.977	9.30
26	29	20	Existing	1.870	0.020	0.340	1.974	0.948	8.39
27	29	30	Existing	1.730	0.018	0.191	1.828	0.897	7.87
28	29	40	Existing	0.454	0.009	0.138	0.516	0.843	7.57
29	29	50	Existing	0.115	0.008	0.127	0.176	0.942	7.16
30	52	20	Existing	0.668	0.011	0.388	0.732	1.157	3.32
31	52	20	FBO	0.719	0.017	0.418	0.787	1.216	3.05

*Base=Base Conditions, FBO=Full Build Out Land Use, Existing Land Uses

Table 7 . July-October averages of base case model predictions with intake located at North End of Basin 3 at a depth of 3 meters (model segment 29).

Description	Diatoms (mg/l)	Chloro-phyta (mg/l)	Blue-greens (mg/l)	Total Algae (mg/l)	POM (mg/l)	D. O. (mg/l)
Year 1 (2002)	0.06	0.01	0.12	0.19	0.13	9.34
Year 9 (2010)	0.13	0.01	0.25	0.38	0.23	9.57

Table 8. Maximums of base case model predictions with intake located at North End of Basin 3 at a depth of 3 meters (model segment 29).

Description	Diatoms (mg/l)	Chloro-phyta (mg/l)	Blue-greens (mg/l)	Total Algae (mg/l)	POM (mg/l)	D. O. (mg/l)
Year 1 (2002)	1.00	0.03	0.20	1.05	0.70	8.84
Year 9 (2010)	2.03	0.02	0.41	2.13	0.81	9.03

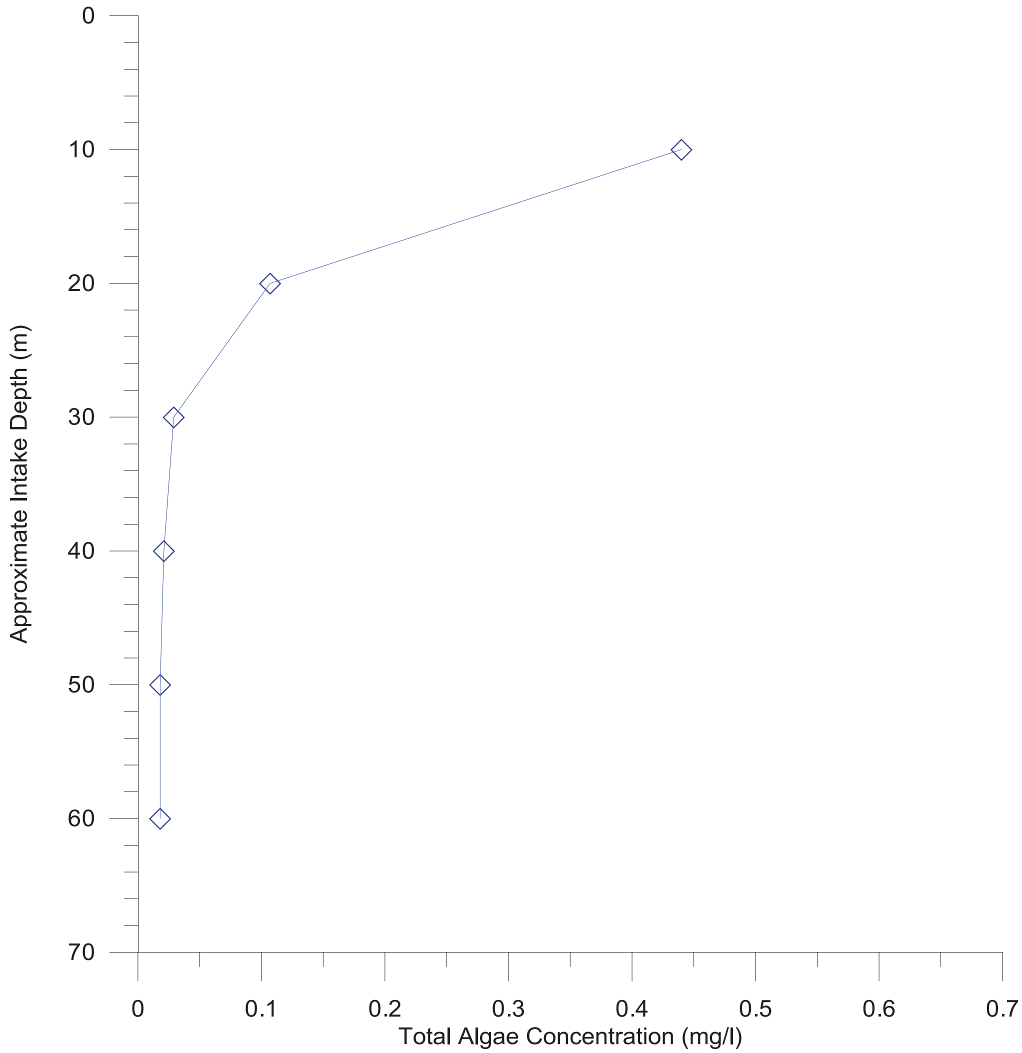

Figure 7. Total algae concentrations in intake at different depths at segment 29 (North end of basin #3). The concentrations were July-October averages (Table 3). Plotted scenarios include scenario 22 and scenarios 25 through 29 (Existing land uses).

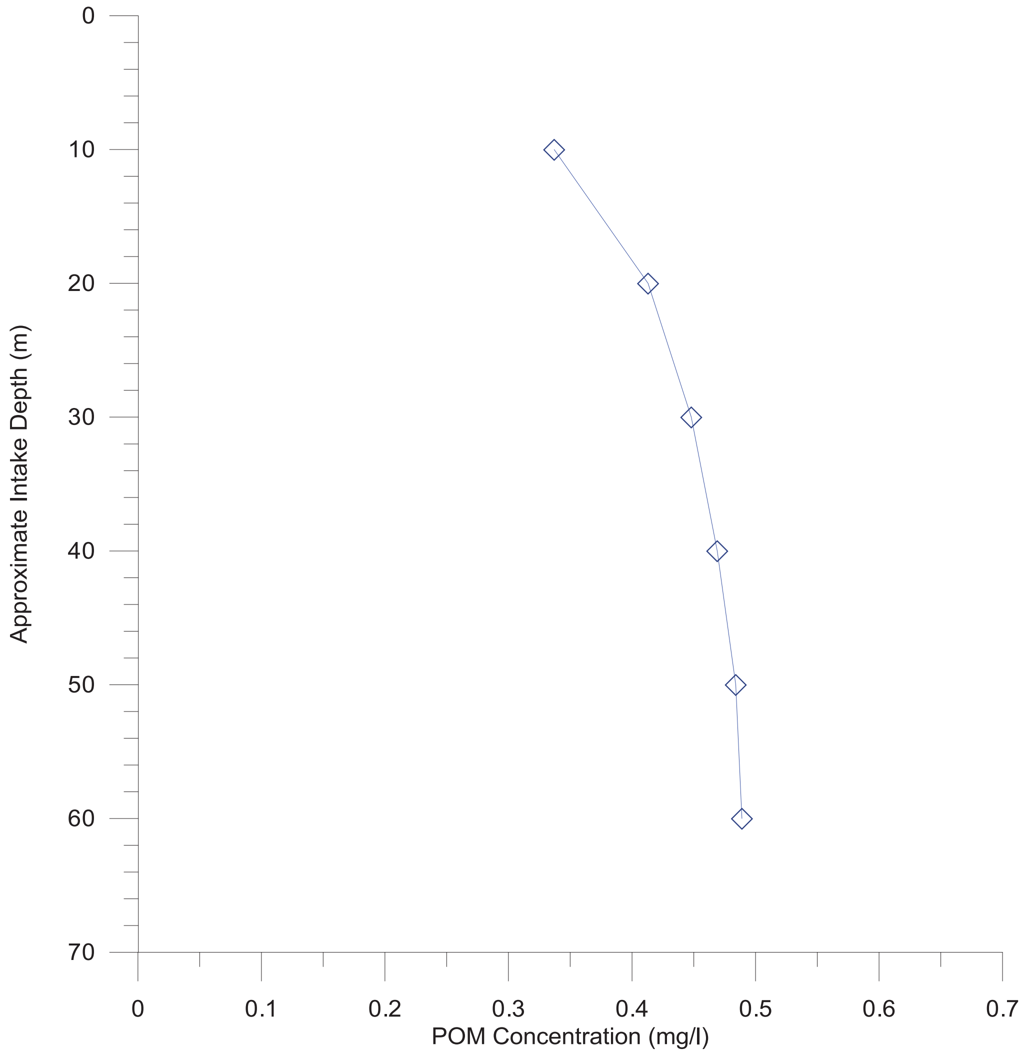

Figure 8. Particulate organic matter concentrations in intake at different depths at segment 29 (North end of basin #3). The concentrations were July-October averages (Table 3). Plotted scenarios include scenario 22 and scenarios 25 through 29 (Existing land uses).

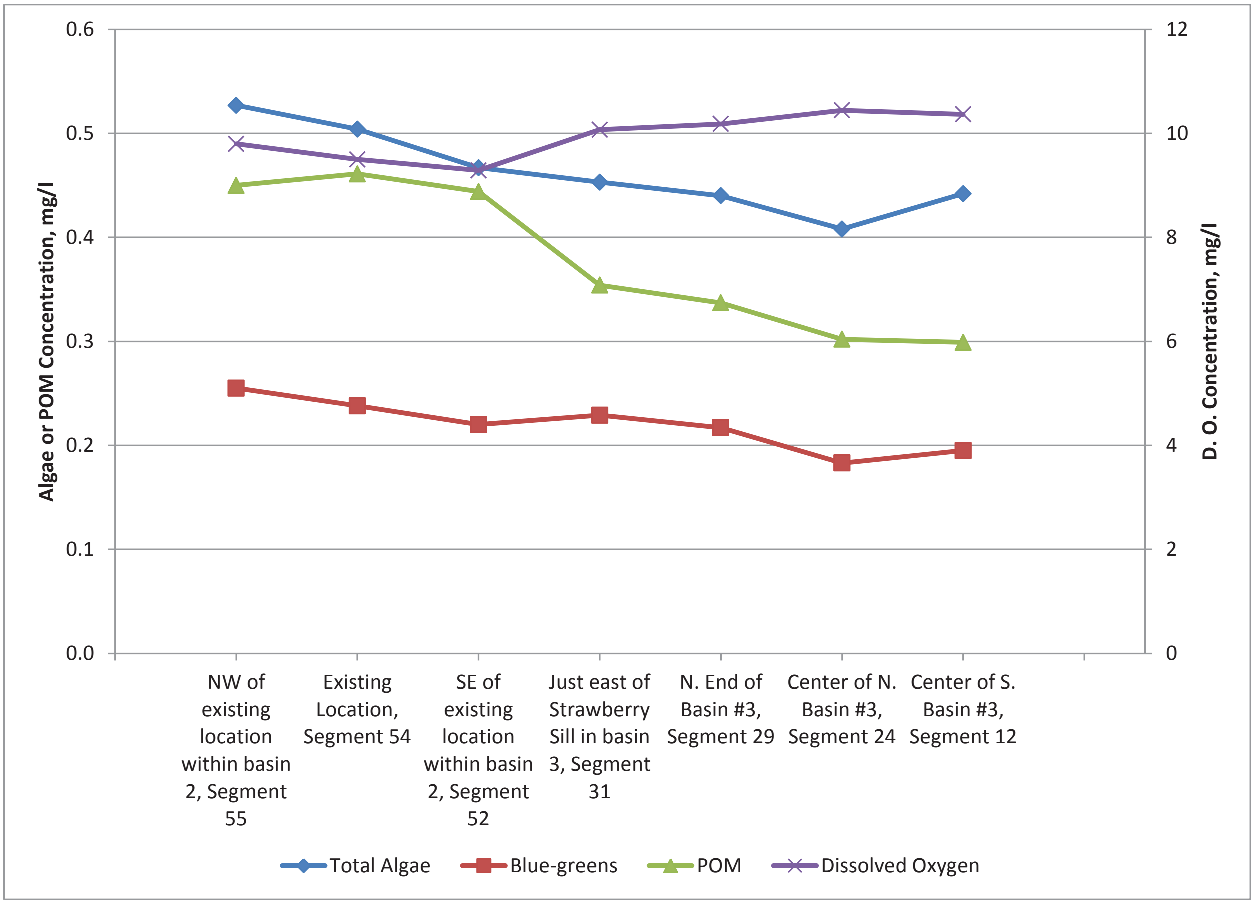

Figure 9. Total algae, blue-green algae, particulate organic matter (POM) and dissolved oxygen concentrations for July-October period with intake at an approximate depth of 10 m and at different locations within lake, moving along lake axis from north end of basin 2 to the south of basin 3. The watershed loading for these scenarios was for existing conditions.

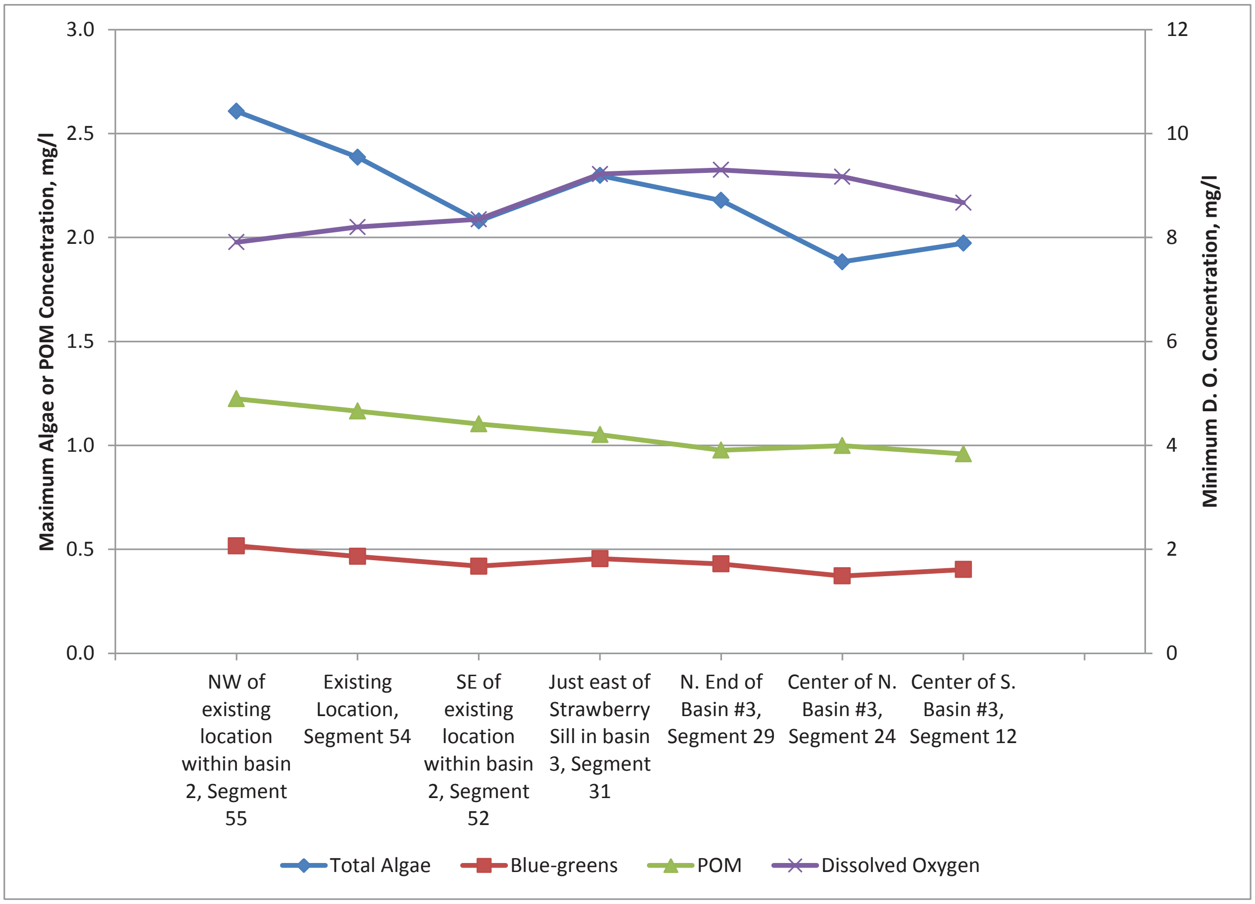

Figure 10. Maximum total algae, blue-green algae and particulate organic matter (POM) concentrations with intake at an approximate depth of 10 m and at different locations within lake, moving along lake axis from north end of basin 2 to the south. Minimum dissolved oxygen concentrations were also shown. Minimum dissolved oxygen concentrations were also shown. The watershed loading for these scenarios was for existing conditions.

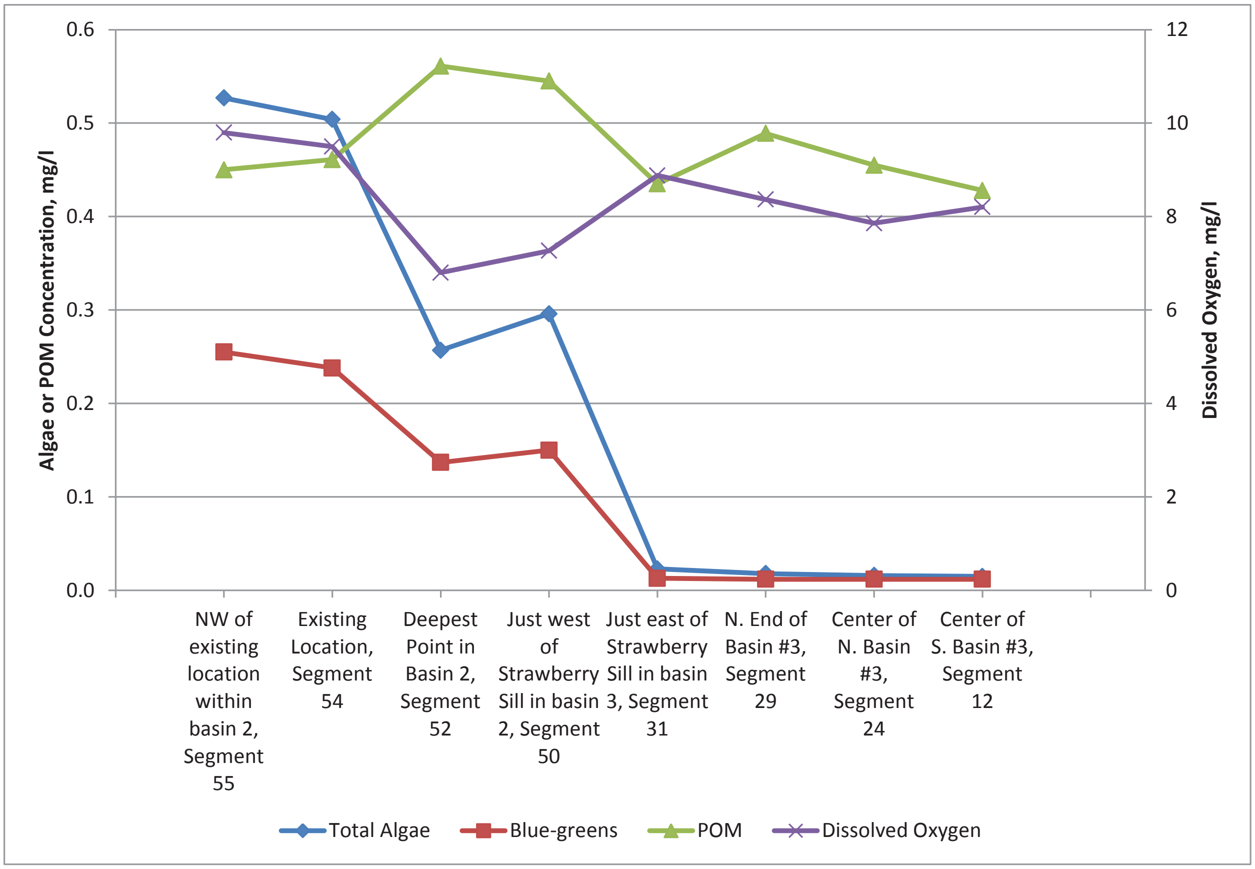

Figure 11. Total algae, blue-green algae, particulate organic matter (POM), and dissolved oxygen concentrations for July-October period with intake near bottom and at different locations within lake, moving along lake axis from north end of basin 2 to the south. The watershed loading for these scenarios was for existing conditions.

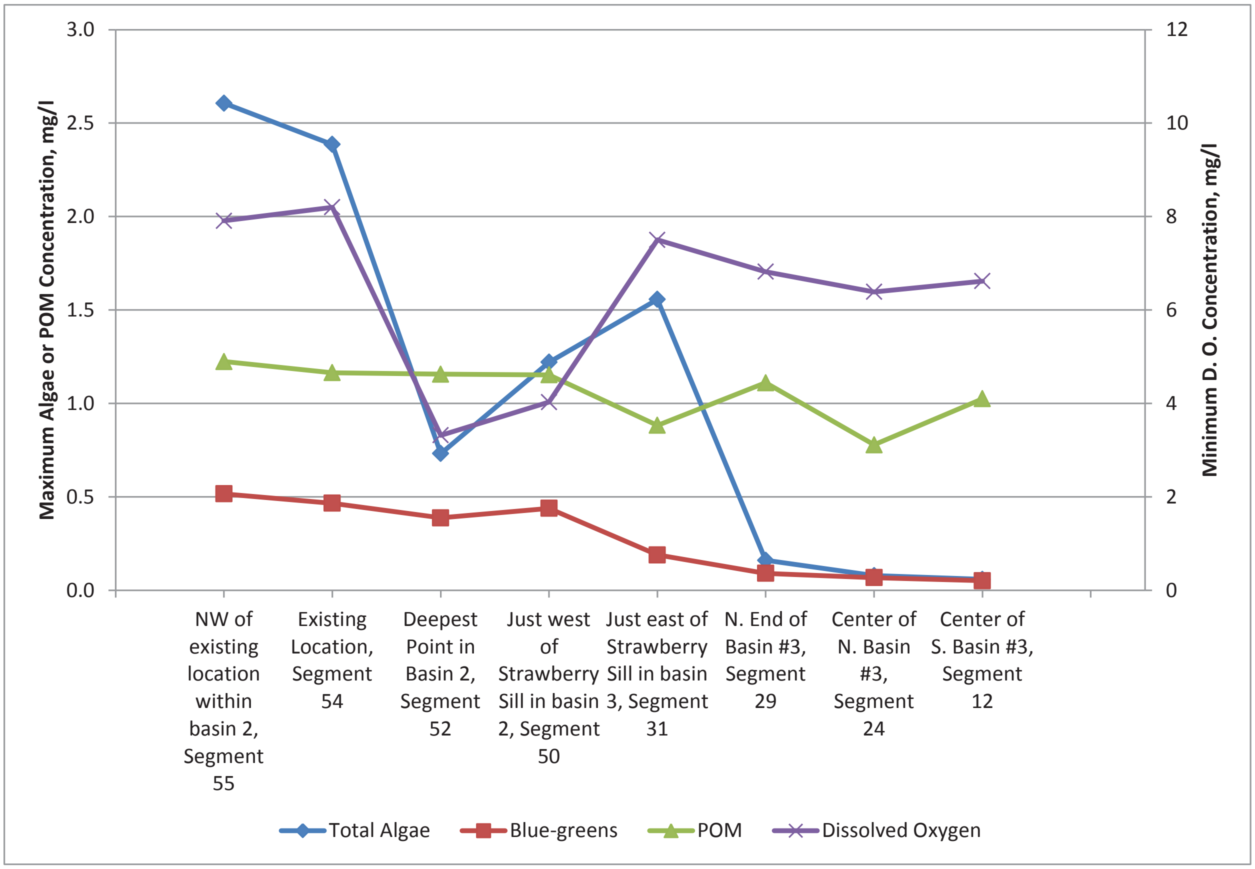

Figure 12. Maximum total algae, blue-green algae and particulate organic matter (POM) concentrations with intake located near bottom and at different locations within lake, moving along the lake axis from north end of basin 2 to the south. Minimum dissolved oxygen concentrations were also shown. The watershed loading for these scenarios was for existing conditions.

Summary and Conclusions

Using the CE-QUAL-W2 Lake Whatcom water quality model the City of Bellingham's water intake was moved to various locations within the lake with the goal of withdrawing water minimizing algae and particulate organic matter concentrations. Multiple scenarios were simulated with different intake locations and depths using watershed loadings corresponding to 2002-2003 land use (base case), existing land use, and full build-out land use. Tributary inflows were created by the Lake Whatcom HSPF model. Model simulations were performed for a period of 11 years in order for the model results not to be influenced by initial conditions. From the model predictions the following conclusions can be made:

- Algae concentrations dropped significantly when the intake was moved into the deep waters of basin 3. The intake had to be at least 30 m deep before an order of magnitude decrease in algae concentrations occurred.
- Within basin #2, the largest drop in algae concentration occurred when the intake was placed at the basin's deepest point. The July-October average blue-green algae concentrations were 39% less than at the existing location for the full build out scenario, but particulate organic matter concentrations increased 27%. Average total algae concentrations for the July-October period

decreased by 47%. Maximum blue-green concentration decreased by 10% and maximum total algae concentration decreased by 67%. Minimum dissolved oxygen concentration in the intake dropped to 3.05 mg/l, indicating possible anaerobic conditions near the bottom of the basin. Large decreases of intake algae concentrations did not occur at other intake locations within basin #2.

- When the intake was placed at a relatively shallow depth of 10 m in basin #3, algae concentrations were only reduced 20%-30% relative to concentrations for basin #2. To have a large reduction in algae concentrations, the intake had to be placed in much deeper waters.

- Although algae concentrations were greatly reduced when the intake was placed deep in basin #3, particulate organic matter (POM) concentrations were similar to POM concentrations near the surface.

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Appendix B
Benefit and Cost of Phosphorus-Reducing Activities in the Lake Whatcom Watershed

Benefit and Cost of Phosphorus-Reducing Activities in the Lake Whatcom Watershed

PREPARED FOR: Clare Fogelsong, City of Bellingham
Martin Kjelstad, PE, City of Bellingham

REVIEWED BY: Phil Martinez, PE, CH2M HILL

PREPARED BY: Amy Carlson, PE, CH2MHILL

DATE: December 15, 2011

Background and Purpose

Management of the Lake Whatcom drinking water reservoir is challenged by excessive nutrient loading that causes increased algal blooms that in turn results in reduced treatment capacity, increased treatment costs, and increased disinfection by-products at the City's Whatcom Falls Water Treatment Plant. In addition to the basic response needed to protect water supply delivery, a response is also required to the listing of Lake Whatcom as an impaired water body under the tenants of the Clean Water Act, the Total Maximum Daily Load (TMDL) listing for Total Phosphorus.

Lake Whatcom Management Program (LWMP) members, the City of Bellingham, Whatcom County, and Lake Whatcom Water and Sewer District, have researched, selected, and implemented several actions over the past 20 years to improve lake water quality. These actions have been described in work plans produced every five years that guide a multi-faceted response to many pollution issues. Although previous work plans have included many actions to reduce phosphorus loading, the current five year work plan (2010-2014 Work Plan) significantly increases the emphasis on phosphorus reduction actions. The reason for this emphasis is that phosphorous reduction was also the basis for the Summary Implementation Strategy (SIS), the first step in the TMDL response process. Even though the SIS is not yet completed, LWMP staff are beginning development of the next component of the TMDL response, the Detailed Implementation Plan (DIP) which requires identification of specific actions, costs of those actions, committed funding sources, and an implementation timeline for reducing the pollutant load (phosphorus) and thereby removing the lake from TMDL impaired status (delist).

The purpose of this study is to provide an initial comparison of several selected phosphorus-reducing and phosphorus-removal strategies that may inform policy decisions and the development of the DIP. To this end, the project team estimated phosphorus reduction and associated costs on a per-unit basis of specific in-watershed activities selected by City staff from the Lake Whatcom Management Program 2010-2014 Work Plan. The results of this work form an initial step in guiding further evaluation of activities and development of the DIP to comply with TMDL requirements.

Assumptions, Limitations, and Context

This work can inform the prioritization of watershed activities based on phosphorus reduction benefit. It can also guide and prioritize further evaluation of specific activities to assess their feasibility and effectiveness throughout the watershed for inclusion in the forthcoming DIP. It is understood that other factors beyond the computed phosphorous-reduction and associated unit costs presented herein also contribute to prioritization. These other factors may including: other studies, regulatory requirements, public expectations, political will, and others.

The following are assumptions and limitations upon which the estimates presented herein were based, including:

- The information upon which the estimates were based is from existing sources, where available and applicable, as well as information provided by the City. No new site-specific data was collected as part of this study. Additionally, anecdotal evidence of the phosphorous-reduction effectiveness is not incorporated into this work.

- The information provided in this summary memorandum is for planning-level purposes only to aid the City of Bellingham and Whatcom County in decision-making and/or prioritization and should not be used for design or construction.
- For this study, it was assumed each individual activity was independent of the others. Therefore, the phosphorus reduction estimates are for that activity only and don't include phosphorus reduction benefits of other activities.
- 'Benefit' only includes phosphorus reduction benefit, not a broader public benefit. Activities that may not be as cost-effective at reducing phosphorous may warrant consideration based on other factors. These other factors may include aesthetics, temperature reduction, public expectation, or other (non-phosphorus) water quality improvements.
- Costs are those that would primarily impact public entities (the City, County, and/or Water/Sewer District), not the cost to the private sector (such as cost to developers).
- Costs do not include the cost of land acquisition that might be required for implementation of activities such as bio-filtration swales or rain gardens.
- Costs do not include lost tax revenue to the County and City associated with changing the zoning ("down-zoning") of properties in the watershed to preclude development was not included in this work. In addition, the lost value to the property owner of down-zoning was not included in this work.
- Costs to property owners related to ordinance changes that govern development or changes related to forest practices were not included. In addition, costs associated with attempting to negotiate and implement such changes have not been included.
- Costs do not include annual operating and maintenance costs.
- The activities considered in this work were identified by members of the Lake Whatcom Management Program and do not represent all phosphorous-reducing activities that could be undertaken. Addressing the impact of Asian Clams was not included in this work because this issue came to light after this work was substantially complete.
- The extent to which each of the phosphorous reduction activities can be implemented in the watershed was not covered in this work. This, additional work task will be a key element of developing an effective DIP.

Watershed Activities

A working group consisting of staff from the City of Bellingham and Whatcom County prepared an initial draft of in-watershed activities based upon the Lake Whatcom Reservoir Management Program 2010-2014. CH2MHILL, the City, and the County collaboratively refined the list of activities, as presented in the summary list below:

1. Reducing development potential / developable land
2. Restoration of natural functions on acquisition properties
3. Bio-filtration: vegetated swales
4. Bioretention: rain gardens
5. Bio-filtration: street trees
6. Lawn replacement & landscaping: retrofit to provide bioretention
7. Infiltration: dry wells
8. Infiltration: trenches
9. Infiltration: pervious pavement
10. Infiltration: basin
11. Rainwater reuse
12. Onsite dispersion
13. Media filters
14. Sizing culverts to eliminate erosion

15. Street sweeping
16. Controlling erosion through streambank stabilization or restoring stream buffer vegetation
17. Regulations: Phosphorus fertilizer ban
18. Education: Watershed signs
19. Education: Mass mailings
20. Education: Online information
21. Education: Newspaper ads
22. Education: Video presentations
23. Education: Community events (public meetings)
24. Education: Onsite training/workshops
25. Education: Resident contact
26. Education: Project consultation
27. Incentives
28. Transition from Ecology Water Quality Assurances of Forest Practices to pre-development conditions
29. Design standards for new and retrofitted roads
30. Reconfigure roadside ditches
31. Reconfigure streets
32. Vehicle trips - reduce and redirect
33. Recreational facility design and use (Improving existing facilities)
34. Watershed-wide enforcement
35. Animal waste: wildlife (goose)
36. Septic system transition to sewer connection

Summary of Results

Exhibit 1 presents a graphical summary of the cost-benefit in terms of dollars per pound of phosphorus removed for each of the activities.

Exhibit 2 presents a tabular summary of the cost-benefit in terms of dollars per pound of phosphorus removed for each of the activities.

Exhibit 3 contains the detailed information which is the basis for phosphorus reduction estimates and costs contained in this memorandum. Exhibit 3 includes all of the 36 activities except for the education, incentives, and enforcement activities, which were separated out to allow for an off-line comparison. This was done to allow the City and County to compare education activities amongst themselves separate from the other activities.

Exhibit 4 contains a summary of information available in the literature about effectiveness of different education methods and also incentives and enforcement. This summary provides the City of Bellingham and Whatcom County with a planning tool to assist in prioritizing which type of education methods to implement.

Exhibits 1-4 are attached to this memorandum.

Benefit in Terms of Phosphorus Reduction

For this cost-benefit study, benefit is defined solely as phosphorus reduction. While each activity may have other benefits such as aiding in regulatory compliance or to addressing a public safety issue, the benefit described in this study is only phosphorus reduction. These activities may not lead to a measurable phosphorus reduction but may be a good idea for those other reasons. In the case of some of the activities, quantifying a phosphorus reduction was not possible. This was because information was not found in the literature.

Cost of Activities

These costs are estimates of capital costs. In some cases, where they were readily available, annual maintenance costs are also provided within Exhibit 3. Note that costs shown in Exhibit 3 only reflect public cost (that is, cost to the public agency) and not other costs such as cost to developers.

Attachments:

Exhibit 1 –Summary of Cost-Benefit

Exhibit 2 - Tabular Summary of Cost-Benefit

Exhibit 3 – Details of Cost-Benefit Analysis for Watershed Activities (except for education/incentives/enforcement)

Exhibit 4 - Education/Incentives/Enforcement Activities

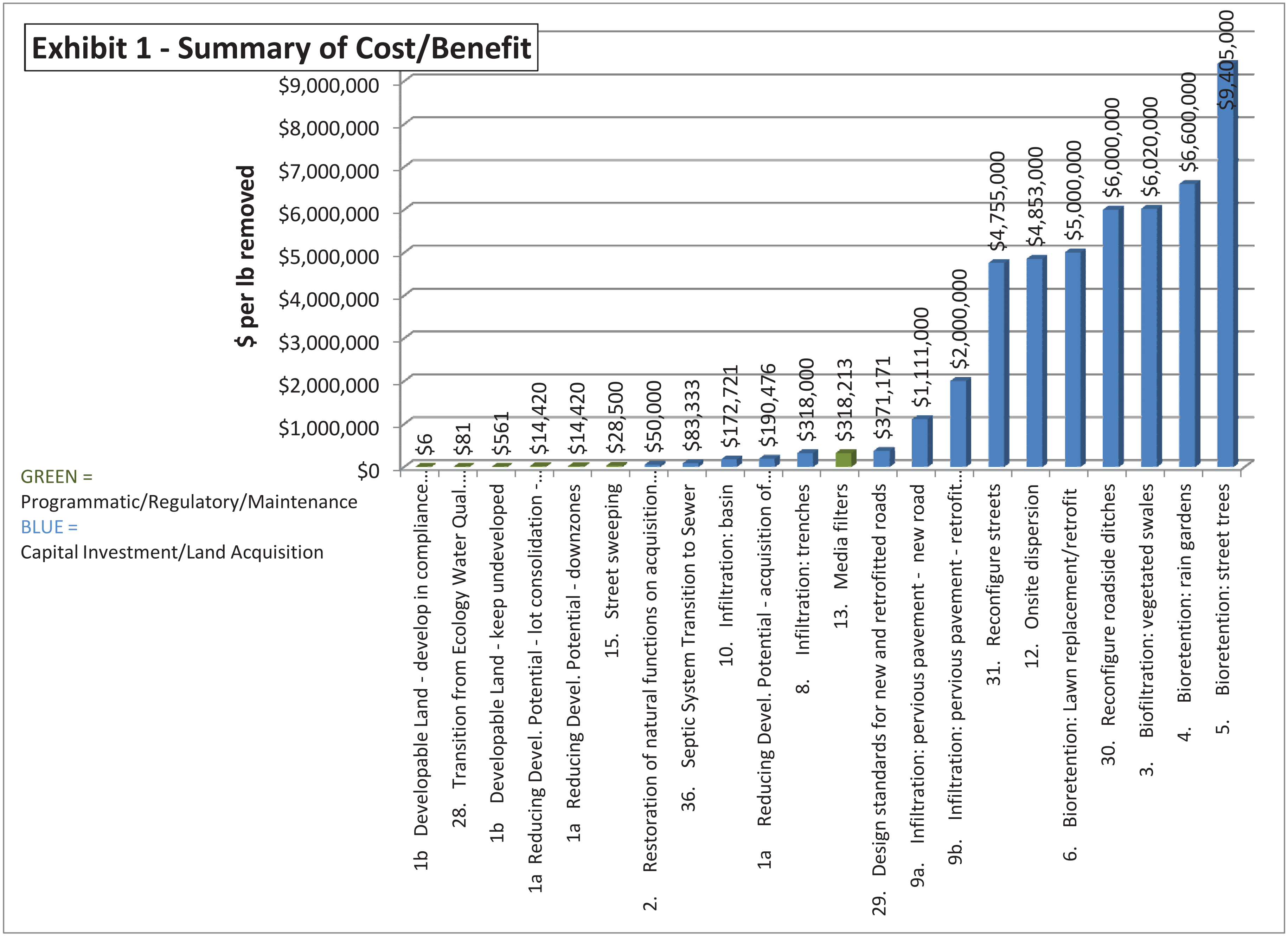
Exhibit 1 - Summary of Cost/Benefit
$ per lb removed
$9,000,000
$8,000,000
$7,000,000
$6,000,000
$5,000,000
$4,000,000
$3,000,000
$2,000,000
$1,000,000
$0
$6
$81
$561
$14,420
$14,420
$28,500
$50,000
$83,333
$172,721
$190,476
$318,000
$318,213
$371,171
$1,111,000
$2,000,000
$4,755,000
$4,853,000
$5,000,000
$6,000,000
$6,020,000
$6,600,000
$9,405,000
1b Developable Land - develop in compliance…
28. Transition from Ecology Water Qual…
1b Developable Land - keep undeveloped
1a Reducing Devel. Potential - lot consolidation - …
1a Reducing Devel. Potential - downzones
15. Street sweeping
2. Restoration of natural functions on acquisition…
36. Septic System Transition to Sewer
10. Infiltration: basin
1a Reducing Devel. Potential - acquisition of…
8. Infiltration: trenches
13. Media filters
29. Design standards for new and retrofitted roads
9a. Infiltration: pervious pavement - new road
9b. Infiltration: pervious pavement - retrofit…
31. Reconfigure streets
12. Onsite dispersion
6. Bioretention: Lawn replacement/retrofit
30. Reconfigure roadside ditches
3. Biofiltration: vegetated swales
4. Bioretention: rain gardens
5. Bioretention: street trees
GREEN =
Programmatic/Regulatory/Maintenance
BLUE =
Capital Investment/Land Acquisition

Exhibit 2: Tabular Summary of Cost-Benefit Evaluation

Activity	Benefit		Cost		Cost/Benefit ($ / lb)
	Phosphorus Reduction	Units	Initial Capital	Units	
1. Reducing development potential / developable land					
Reducing Devel. Potential - acquisition of open space	1.05	lb/acre/year	$200,000	per acre	$190,476
Reducing Devel. Potential - lot consolidation - residential	minimal	lb/acre/year	$20,000	total	$14,420
Reducing Devel. Potential - downzones	minimal	lb/acre/year	$20,000	total	$14,420
Developable Land - develop in compliance with City ordinance [1]	2498	lb/yr for the watershed	$15,000	total	$6
Developable Land - keep undeveloped [1]	2775	lb/yr for the watershed	$1,402,000	total	$561
2. Restoration of natural functions on acquisition properties	1.0	lb/acre/year	$50,000	per acre	$50,000
3. Biofiltration: vegetated swales	20	%	$8	per sf of treated area	$6,020,000
4. Bioretention: rain gardens	50	%	$22	per sf of treated area	$6,600,000
5. Bioretention: street trees	40	%	$25	per sf of treated area	$9,405,000
6. Bioretention: Lawn replacement / retrofit	75	%	$25	per sf of treated area	$5,000,000
7. Infiltration: dry wells [2]	-	-	-	-	-
8. Infiltration: trenches	70	%	$1.48	per sf of treated area	$318,000
9a. Infiltration: pervious pavement - new road	60	%	$4.43	per sf of treated area	$1,111,000
9b. Infiltration: pervious pavement - retrofit existing	60	%	$8	per sf of treated area	$2,000,000
10. Infiltration: basin	100	%	$50,000	per acre of treated area	$172,721
11. Rainwater reuse [3]	minimal	lb/year	-	-	-
12. Onsite dispersion	40	%	$12.90	per sf of treated area	$4,853,000
13. Media filters [4]	52	%	$1.10	per sf of treated area	$318,213
14. Sizing ditches/culverts to eliminate erosion [3]	minimal	lb/year	-	-	-
15. Street sweeping [5]	60	%	$0.11	per sf swept	$28,500
16. Controlling erosion through streambank stabilization or restoring stream buffer vegetation [8]	moderate	lb/year	-	-	-
17. Regulations: Phosphorus fertilizer ban [6]	0.5	lb/acre/year	-	-	-
18. Education: Watershed signs [7]	-	-	-	-	-
19. Education: Mass mailings [7]	-	-	-	-	-
20. Education: Online information [7]	-	-	-	-	-
21. Education: Newspaper ads [7]	-	-	-	-	-
22. Education: Video presentations [7]	-	-	-	-	-
23. Education: Community events (public meetings) [7]	-	-	-	-	-
24. Education: Onsite training/workshops [7]	-	-	-	-	-
25. Education: Resident contact [7]	-	-	-	-	-
26. Education: Project consultation [7]	-	-	-	-	-
27. Incentives [7]	-	-	-	-	-
28. Transition from Ecology Water Qual. Assurances of Forest Practices to pre-development conditions	0.1	lb/acre/year	$200,000	total	$80.65
29. Design standards for new and retrofitted roads	60	%	$1.48	per sf of treated area	$371,171
30. Reconfigure roadside ditches	20	%	$8.00	per sf of treated area	$6,000,000
31. Reconfigure streets	30	%	$10.00	per sf of treated area	$4,755,000
32. Vehicle trips - reduce and redirect [3]	minimal	lb/year	-	-	-
33. Recreational facility design and use (improving existing facilities) [3]	minimal	lb/year	-	-	-
34. Watershed-wide enforcement [7]	-	-	-	-	-
35. Animal waste: wildlife (goose) [9]	0.3	lb/goose/year	-	-	-
36. Septic System Transition to Sewer	0.6	lb/septic system/yr	$50,000	per septic system	$83,333

Notes:

[1] As compared to developing conventionally

[2] At the direction of the City did not assess cost-benefit of this activity because activity is not feasible throughout most of the watershed (due to soil and groundwater conditions)

[3] Did not characterize cost or cost-benefit after determination of minimal direct phosphorus reduction benefit

[4] Evaluated several types of media filters; Phosphorus Reductions and Costs shown in this table are on conservative end of range

[5] $/lane mile swept to be determined

[6] no cost-benefit characterized because cost to implement ordinance already expended; assuming no cost for enforcement; enforcement/education/incentives covered on Table 2

[7] Activities 18 through 37 (education/incentives/enforcement) summarized on Table 2 of this deliverable and not summarized here

[8] stream buffer provides indirect phosphorus reduction benefit (by reducing velocities and promoting infiltration); stream channel stabilization could have significant phosphorus reduction benefit

[9] At the direction of the City did not assess cost-benefit of this activity because implementation of this activity is not acceptable

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
1a	**Reducing development potential**					
1a(i)	Acquisition of existing open space	lb/acre/year	1.05	$200,000 per acre for land acquisition**	In the first year, $200,000/acre cost with a 1.05 lb/acre benefit = $190,476/lb	Acquisition does not include any land cover changes or site management. Phosphorus removal estimate is equal to the difference between developed land loading (blended pervious and impervious) and undeveloped land loading, per the Lake Whatcom TMDL study (Ecology 2008a). Developed pervious (82% of developed area): 1.24 lb/acre/year; Developed impervious (18% of developed area); The land use acreages indicated that 18 percent of the developed area is impervious. Therefore, the blended loading calculates to 1.20 lb/acre/year: 0.99 lb/acre/year (CDM 2008; Ecology 2008) Deciduous Forest: 0.14 lb/acre/year; Evergreen Forest: 0.16 lb/acre/year; Mixed Forest: 0.14 lb/acre/year; An overall total phosphorus loading of 0.15 lb/acre/year was assigned. 1.20 (Developed land loading) – 0.15 (Undeveloped land loading) = 1.05 lb/acre/year (developed land loading and undeveloped land loading from CDM 2008; Ecology 2008) Cost equals the sum of the current price of open space parcels and cost to process acquisition **Note that this study does not consider costs to the private sector (i.e. developers) only to the public sector (i.e. administrative costs to administer development). This is especially important to note for these items 1a and 1b.
1a(ii)	Lot consolidation - residential	lb/acre/year	*Minimal benefit*	$20,000 total, watershed wide**	'minimal benefit' estimated as 0.01 lb/acre/year; Assuming can implement on only 5% of developable land (5% of 2,774 acres or 138.7 acres); $20k / (138.7 * 0.01) = $14,420/lb for the first year	Phosphorus removal estimate would equal the difference between multi-family and single family residential phosphorus loading, which is not likely a significant difference. Furthermore, lot consolidation would occur as opportunities present themselves, not uniformly across the watershed. The actual phosphorus loading reduction is therefore expected to be relatively small. Cost to process lot consolidation – 2 FTEs for 1 month, assuming $100,000 per FTE for 1 year plus additional administration work
1a(iii)	Downzones	lb/acre/year	*Minimal benefit*	$20,000 total, watershed wide**	'minimal benefit' estimated as 0.01 lb/acre/year; Assuming can implement on only 5% of developable land (5% of 2,774 acres or 138.7 acres); $20k / (138.7 * 0.01) = $14,420/lb for the first year	Phosphorus loading reduction would result from reduced lot density (i.e., residential to public/recreational, commercial to public/recreational, commercial to residential). There are too few industrial zoned parcels in the watershed to include in this evaluation. Minton (2011) does not report a significant difference in phosphorus loading between single-family residential, multi-family residential, and commercial/industrial land. As with lot consolidation, downzoning would occur as opportunities present themselves, not uniformly across the watershed. The actual phosphorus loading reduction is therefore expected to be relatively small. Cost to process downzone – 2 FTEs for 1 month, assuming $100,000 per FTE for 1 year plus additional administration work

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
1b	**Developable land**					Assumes 2,774 acres of developable land in the watershed. This represents the difference between developed land under the "full buildout" and the "base scenarios" in the Lake Whatcom TMDL Study (Ecology 2008a). Phosphorus loading rate assumptions used: • 0.20 lb/acre/year from undeveloped land (see item 1a, reference: CDM 2008; Ecology 2008) • 0.3 lb/acre/year (City-estimated) from land developed in compliance with City's LID standards • 1.20 lb/acre/year from conventionally developed land (reference: CDM 2008; Ecology 2008) Assumes that the "baseline" condition is conventional development of all 2,774 acres of developable land in the watershed. (1.20 lb/acre/year developed land loading)(2,774 acres of developable land) = 3,330 lb/year (0.3 lb/acre/year developed land loading)(2,774 acres of developable land) = 832 lb/year 3,330 – 832 = 2,498 lb/year (Cost equal to the permitting and processing cost for developing a 1) SFR residential and 2) commercial in compliance with City LID standards, administrative costs only estimated at 1 FTE for 2 months, assuming $100k per FTE per year.) (1.20 lb/acre/year developed land loading)(2,774 acres of developable land) = 3,330 lb/year (0.2 lb/acre/year undeveloped land loading)(2,774 acres of developable land) = 555 lb/year 3,330 – 555 = 2,775 lb/year (Cost equal to the building department revenue that would have been generated from a 1) SFR residential and 2) commercial) PLUS the administrative costs as determined above)
1b(i)	Benefit of developing all conventionally	lb/year (watershed-wide)	0 *(as baseline for other options under item 1b)*	$0 *(as baseline for other options under item 1b)*	--	
1b(ii)	Benefit of developing all land in compliance with City ordinance *as compared to* developing all of conventionally	lb/year (watershed-wide)	2,498	$15,000 **	for the first year: $15,000 / 2,498lbs/yr = $6/lb	
1b(iii)	Benefit of keeping developable land undeveloped *as compared to* developing all of it conventionally	lb/year (watershed-wide)	2,775	$15,000 + $500/acre (estimated same as above PLUS $500/acre) **	for the first year: ($15,000 +$500/acre * 2,774 acres) / 2,498lbs/yr = $561/lb	
2	**Restoration of natural functions on acquisition properties**	lb/acre/year	1.0	$50,000 / acre **	In the first year, $50,000/acre cost with a 1.0 lb/acre benefit = $50,000/lb	Assumes restoration is to forested conditions. This would take several years to achieve. The phosphorus loading under restored conditions would be expected to be lower than that for land developed in compliance with City LID standards (see item #1a). The phosphorus loading benefit would be the difference between developed and restored land loading rates: 1.20 – 0.20 lb/acre/year = 1.0 lb/acre/year TP removed by restoring land to forested conditions. See also notes for item #1. Continued access and limited use of restored lands would probably occur to a higher degree than in the case of natural land preservation. Cost equal to the total cost for planning, design, construction and planting, and maintenance until the site is self-sufficient, estimated at $50,000 per acre. **Note that this study does not consider costs to the private sector (i.e. developers) only to the public sector (i.e. administrative costs to administer development). This is especially important to note for these items 1a and 1b.

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
3	**Biofiltration: vegetated swales[1]**	%	20	Construction: $8/sf of area treated	Assuming 20% removal of phosphorus at $8 per square foot of treated area = $6,020,000/lb (*Example calculation, which applies to all other cost-benefit calculations in this study: 8,974 lb/year total Phosphorus loading watershed-wide, with 31,000 acres in the watershed equates to an average of 0.29 lb/year per acre; 20% removal yields a 0.06 lb of phosphorus removed per acre per year. At $8/sf of treated area, and 43,560 sf in an acre, the cost to treat one acre is $348,480. $348,480 to remove 0.06 lb of phosphorus equates to $6,020,000 per lb of Phosphorus removed. Note that the results of this calculation are independent of the scale on which it is based. i.e. yields the same answer regardless of 1 acre, 10 acres, or 100 acres, or watershed-wide implementation*)	Assumes no infiltration. CWP (2008) reports 10-20% flow reduction plus an additional 20-40% reduction of TP in the surface flow. Geosyntec (2008) reports 36% reduction. The "Dayton" swale in Seattle in the NPDES BMP database reported no TP removal (inflow concentration of 0.18 mg/l, outflow concentration of 0.19 mg/l). Other literature reports only limited TP removal for biofiltration swales.
		%	77-100			"Geneva Swales" testing results (provided by Whatcom County via email, 10/3/2011).
		lb/swale/year	0.02 – 6.71 Avg: 0.86			2010 City data – range of phosphorus removal of all 11 facilities listed as swales: 0.02 – 6.71 lbs (Bellingham 2011). 2009 City data – range of phosphorus removal: 0.07 – 2.65 lbs Cost - Silver Beach Creek Outreach Program cited a cost for the Lahti Drive bio-infiltration swale (design, survey, and permitting): $24,356.04; OR Total cost (including design, survey, permitting, construction, and annual maintenance) of at least 5 of the 10 swales included in the Detailed Phosphorus analysis.
4	**Bioretention: rain gardens[1]**	%	50	Construction: $18.90 - $32.80/sf of treated area	Assuming 50% removal of phosphorus at $22 per square foot of treated area = $6,600,000/lb	CWP (2008) reports 80% flow reduction (40% if there are underdrains) plus an additional 25-50% reduction of TP in overflow. Tetra Tech (2008) reports overall 70 % reduction. Given limited infiltration capability of the soils in the watershed, assume a 50% TP reduction credit.
		mg/L TP	+0.04			NPDES Urban BMP Performance Tool - University of Connecticut 2005; higher outflow concentration; no volume data available.
		lb/rain garden/year	0.04-5.90			2009/2010 City data: Bloedel Raingarden 1 – 5.51 acres treated, 100% treatment efficiency; BloedelRaingarden 2 – 0.34 acres treated, 10% treatment efficiency Net phosphorus removal requires that rain gardens are sized correctly. The City has indicated that monitoring found one of its rain gardens exports phosphorus. Total cost (including design, survey, permitting, construction, and annual maintenance) of the Bloedel rain gardens.
		lb/year (watershed-wide)	423			An estimated 30% of the developed basin can accommodate rain gardens; 50% TP removal efficiency assumed; 2,352 acres of developed land in the watershed (Ecology 2008a); loading rate from developed land assumed to be 1.20 lb/acre/year (see item #1). Cost: Estimate number of rain gardens needed to treat the full 30% of the developed basin that can accommodate it. Multiply the number of rain gardens by the cost estimated from the above Bloedel rain gardens (the result will likely be a cost range).

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
5	**Bioretention: street trees[1]**	%	15	No quote provided by Filterra Systems (as surrogate, use $18.90 - $32.80/sf of treated area)	Assuming 40% removal of phosphorus at $25 per square foot of treated area = $9,405,000/lb	Center for Watershed Protection (CWP 2008) reports a 15% flow reduction; but gives no further credit for reduction of TP in the remaining surface flow. Washington Department of Ecology (Ecology) TAPE Program (Ecology 2011) made a preliminary determination that Filterra has poor phosphorus reduction and does not meet phosphorus treatment criteria of 50% removal.
		lb/tree/year	0.0014			Assumes 0.36 mg/L TP in runoff (Minton 2011); 845 gal/tree stormwater runoff reduction (McPherson et al. 1999); Filterra's whitepaper reports 56.5% TP removal efficiency in a Bellingham study. Cost: Quotes for Filterra system
		%	74			Charles River Watershed Association (CRWA) 2009 reports 74% TP removal from street trees.
6	**Lawn replacement & landscaping: retrofit to provide bioretention[1]**	%	75	As a surrogate, use item 4 above: Construction: $18.90 - $32.80/sf of treated area	Assuming 75% removal of phosphorus at $25 per square foot of treated area = $5,000,000/lb	Lawns often sit atop poorly draining subsoils, resulting in limited infiltration of rainfall and extensive runoff. The subsoils can be amended with compost, greatly increasing infiltration capacity. The amended soils can then be replanted either with native plants or reseeded in grass. CWP (2008) reports a 75% flow reduction attributable to amended soils. No treatment for TP is credited for surface runoff. Therefore assign a 75% TP reduction credit for the replaced lawn area. Assumes fertilizer restriction is enforced.
7	**Infiltration: dry wells[1]**	n/a	n/a	--	--	Phophorus removal is likely similar to rain gardens or infiltration trenches. New dry wells are not likely an option in the Lake Whatcom watershed, because Ecology requires them to be located in cobble areas, which are not naturally present in the watershed. Therefore, this item was not evaluated further.
8	**Infiltration: trenches[1]**	%	(-)100 - 65	$1.48 per sf of treated impervious surface.	Assuming 70% removal of phosphorus at $1.48 per square foot of treated area = $318,000/lb	NPRPD 2007 – Infiltration

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
9a	**9a - Infiltration: pervious pavement (new road)** [1]	%	60	$4.43 per sf of treated impervious surface.	Assuming 60% removal of phosphorus at $4.43 per square foot of treated area = $1,111,000/lb	CWP (2008) reports 45% flow reduction (no underdrains) plus an additional 25% reduction of TP in the underflow. Tetra Tech (2008) reports overall 67% reduction. Assign a 60% TP reduction credit (for the pervious pavement area, only). This estimate addresses the TP removal from the retrofitted road surface only. There would be a lower % removal of TP on a watershed-wide basis. Cost for new road (from SPU); Retrofitting existing road would be more expensive, as it would include the breakup and removal of the existing road surface and road bed. The difference between the $8/sf for the retrofit and the $4.43/sf for the new is to remove the existing road and roadbed to make way for the new pervious pavement.
9b	**9b - Infiltration: pervious pavement (retrofit existing road)** [1]	%	60	$8 per sf of treated impervious surface.	Assuming 60% removal of phosphorus at $8 per square foot of treated area = $2,000,000/lb	
10	**Infiltration: basin**[1]	%	100	$6/sf of infiltration basin ($100,000 for an infiltration basin treating approx. 2 acres)	Assuming 100% removal of phosphorus at $50,000 per acre of treated area = $172,721/lb	Assumes 100% infiltration to groundwater, with no discharge to surface runoff. This item was formerly listed as "Sand filter" – see also item #13, Media Filters Cost: based upon recent experience on M Street project for City of Auburn (infiltration pond as stormwater management)
11	**Rainwater reuse**	lb/L water	*Minimal benefit*	--	--	Roof runoff presumably contributes a minimal fraction of the total phosphorus load, as rooftop runoff does not contain significant phosphorus concentrations. However, it likely contributes to phosphorus loading reductions when combined with other residential BMPs such as bioretention (i.e., lawn replacement) and if used widely throughout the watershed. Also note that phosphorus concentrations in rooftop runoff can vary seasonally, with a presumed high loading from leaf litter in the fall season. However, since no documentation is available, did not include this within the context of this study. CWP (2008) reports 40% flow reduction. A Bellingham study of the Rain Barrel Program concluded that 24% of captured roof runoff was infiltrated and the remainder dispersed into landscaped areas.
12	**Onsite dispersion**	%	40	$12.90/SF	Assuming 40% removal of phosphorus at $12.90 per square foot of treated area = $4,853,000/lb	Evaluated as a stand-alone activity. CWP (2008) reports 50-75% flow reduction but gives no further credit for reduction of TP in the remaining surface flow. Given limited infiltration capability of the soils in the watershed, assign a 40% TP reduction credit.

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
13	**Media filters**	%	50-90	Aquip: Construction cost= $0.81 to 1.8/sf of treated impervious surface Annual Maintenance cost = $0.29 to $0.80 per sf of treated surface. BaySaver: Construction Cost = 0.34 to 0.91 per sf of treated impervious, Maintenance cost = $0.06 to $0.17 per sf of treated impervious surface area.	8974 lb/year P loading watershed-wide, assuming 70% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 6,281 lbs and costs $1,620,000,000 at $1.20/sf, for a cost/benefit for the first year only of approximately $257,957/lb	The TAPE website (Ecology 2011) identifies the following six proprietary devices certified by Ecology as effective for stormwater phosphorus treatment, reducing total phosphorus by at least 50%. The percentage removals shown for Pilot and Conditional Uses are preliminary. Aquip Enhance Stormwater Filtration System: 60-90% TP reduction (Conditional Use) Americast Filterra System: less than 50% TP removal (Conditional Use) FloGard Perk Filter: 62% TP removal (General Use) Request quote from BaySaver Technologies BayFilter: 55% TP removal (Conditional Use) Aquashield AquaFilter: No TP removal % identified (Pilot Use) WSDOT Media Filter Drain: 86% TP removal (General Use) Cost: from Manufacturers
	Sand Filters	%	50	Construction cost= $1.00 sf of treated impervious surface	8974 lb/year P loading watershed-wide, assuming 50% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 4,487 lbs and costs $1,350,000,000 at $1.00/sf, for a cost/benefit for the first year only of approximately $300,949/lb	Sand filters: CWP (2008) credits a 59% reduction of TP. Geosyntec (2008) reports 30%. WA Dept. of Ecology bestows a 50% phosphorus removal credit for this BMP (i.e., a minimum 50% P removal). Assign a 50% TP reduction credit. Assumes all treated water is discharged to surface runoff.
		lb/filter/year	4.77 – 34.84 Avg: 14.91			2009/2010 City data – "Sandfilter" and "Sandfilter/Infiltration" (Bellingham 2011). Does not include the Electric Ave Sandfilter.
	StormFilter® with PhosphoSorb ™	lb/acre/year	0.80	Construction Cost: $0.52 to 1.31 per sf of treated impervious. Maintenance Cost: $0.06 to $0.25 per year per sf of treated impervious surface area.	8974 lb/year P loading watershed-wide, assuming 52% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 4,666 lbs and costs $1,350,000,000 at $1.10/sf, for a cost/benefit for the first year only of approximately $318,312/lb	Contech StormFilter® with PhosphoSorb ™ (www.contech-cpi.com) reports: Influent: 0.02 – 0.49 mg/L; Effluent: 0.025-0.083 mg/L (these values reflect manufacturer's field testing at Cable Street, Whatcom County). Phosphorus removal rate of 67% is reported for influent TP concentrations greater than 0.1 mg/l (CONTECH 2010). Loading rate of 1.20 lb/acre treated/year assumed (see item #1). Cost: Request quotes from manufacturers
		%	21-83 Avg: 52			PhosphoSorb Media – testing at Cable Street StormFilter (total phosphorus).

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
	StormFilter® with ZPG media	%	-24-79 Avg: 28	Construction Cost: $0.52 to 1.31 per sf of treated impervious. Maintenance Cost: $0.06 to $0.25 per year per sf of treated impervious surface area.	8974 lb/year P loading watershed-wide, assuming 28% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 2,812lbs and costs $1,350,000,000 at $1.10/sf, for a cost/benefit for the first year only of approximately $591,151/lb	ZPG Media – testing at Cable Street StormFilter (total phosphorus). Cost: Request quotes from manufacturers
		lb/filter/year	0.02 – 3.16 Avg: 1.04			2009/2010 City data: "Filter" (11 total) (Bellingham 2011).
		lb/filter/year	0.02 – 1.47 Avg: 0.49			2009/2010 City data: "Stormfilter" (subset of "Filter" – 4 total) (Bellingham 2011). Electric Ave (two values reported), Poplar (WQF 132), Poplar (WQF 133)
		lb/filter/year	0.00 – 4.69 Avg: 1.11			2009/2010 City data: "Enhanced Filter" (4 total) (Bellingham 2011). E. Beachview, Silvern Lane, Alabama Vault, Lakeside Vault.
	StormCeptor with Imbrium	lb/acre/year	0.21	Construction Cost: $1.50 per sf of treated impervious. Maintenance Cost: $0.25 per year sf of treated impervious surface area.	For the first year, 0.21 lb/acre removed with $1.50/sf ($65,340/acre) is $311,142/lb	Enhanced settling technology: Imbrium – Stormcepter: 20% removal efficiency and 1.07 lb/acre treated/year pre-treatment loading assumed. The Imbrium testing reports: "The Stormceptor can remove approximately 20-30% of the Total Phosphorus from influent stormwater (Madison, Wisconsin study; Como Park, Minnesota study)." Cost: Request quotes from manufacturers
14	**Sizing ditches and culverts to eliminate erosion**	lb/culvert/year	*Minimal*	--	--	Standard circular culverts replaced with flat bottom culverts to eliminate exit scour (erosion at the culvert outlet). Very little literature exists quantifying the TP reduction attributable to stream channel stabilization. Long-term studies performed at Lake Tahoe indicate that shoreline disturbance contributes 4% of the lake's phosphorus load while stream channel erosion of stream channels draining to the lake contribute 2% of the lake's phosphorus load (California Regional Water Quality Control Board 2010). Thus non-urban erosion at Lake Tahoe contributes only a minor portion of the phosphorus load. It should be pointed out that Lake Tahoe has a considerably different soils and geology regime than Lake Whatcom, making a direct comparison tentative. Therefore, it is estimated that a minimal to moderate phosphorus loading benefit from this activity could be expected only if this is applied consistently over the entire watershed.
15	**Street sweeping**	%	60 (street) 10 (basin)	$6,000 per lane mile (per year)	$6000 per lane mile = $0.11 per sf;	Shoemaker (2000) states that 40-75% of street-related TP can be collected by mechanical and vacuum-assisted sweepers, respectively. However, on a watershed basis, USGS (2002) reports a TP reduction of 5-14% while Northern Virginia Planning District Commission reports a 9-11% reduction. The City of Seattle conducted extensive street sweeper testing (Seattle Public Utilities and Herrera Consultants 2009) but did not report phosphorus data. The City of Bellingham conducted a single analysis of phosphorus content of sweepings but the data was insufficient to allow calculation of removal rate. Assign the following TP reduction credit: 60% for the street area; 10% on a basin-wide basis. Cost: *City provided $6,000 per lane mile per year*

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
16	**Controlling erosion through 1) streambank improvements and 2) restoring stream buffer vegetation**		*Moderate benefit*	--	--	The benefit to phosphorus load reductions from stream buffer protection is attributed to erosion control; however, stream buffer vegetation also contributes phosphorus by export of organic material. Note: Phosphorus loading associated with streambank erosion depends on the TSS/TP correlation (soil composition) and local hydrology regime. Restoring and preserving the stream buffer's vegetation would involve enforcement of the City's designated stream buffer widths. As with item #14 (culvert sizing to control erosion), the maximum phosphorus loading benefit from this activity could be expected only if this is applied consistently over the entire watershed. Available for farming land, but limited data available for urban areas. See notes for item #14. Excerpt from literature: "Although buffer zone vegetation reduces erosion, it is not considered effective for the removal of phosphorus over the long term because phosphorus retained by plants in the spring and summer is released with plant senescence in the fall. Therefore, lakeside residents have been asked to circumvent this natural recycling by collecting beach debris and cutting, harvesting, and removing excess buffer zone vegetation two to three times per year as suggested by Dillaha et al. _1986_. Measurements indicate that typical shoreline debris material has a water content of about 75% and contains about 0.25% phosphorus by dry weight. Therefore, a total phosphorus loading reduction of about 70 kg/year could be attained if each lakeside property owner removed 225 kg of vegetative litter and beach debris _wet weight_ from their property per year." (Canale, RP; Redder, T; Swiecki; W, Whelan, G. Phosphorus Budget and Remediation Plan for Big Platte Lake, Michigan. *Journal of Water Resources Planning and Management.* 2010, 136 (5), 576-586). Cost: Cost would be equal to the total cost of planning, design, construction and planting, and maintenance until the site is self-sufficient, based on research results (reference in the region).
17	**Regulations: Phosphorus fertilizer ban**	lb/acre/year	0.5	$0	--	A number of articles review general lawn phosphorus contribution but none of them identify numeric contributions. Vadas (2008) documents very high phosphorus losses if heavy rainfall occurs within a few days of fertilization. Lehman (2009) documents a 28% reduction in TP concentrations in a river following a ban on fertilizers. Gross (1990) and Erickson et al. (2005) measured measured phosphorus losses due to leaching caused by infiltrating rainfall from grassed areas. Both reported minimal phosphorus losses due to surface runoff because the sandy soils used in these studies had very high rates of infiltration and produced very little surface runoff. Easton (2004) also reported that the majority of phosphorus loss observed from lawn plots was due to leaching. However, his study also reported substantial surface runoff from the lawn plots and an associated phosphorus loss of 0.5-1.0 kg/ha/yr (0.5-0.9 lbs/acre/year). Unfertilized lawns can also contribute soil-bound phosphorus to surface runoff. Given the uncertainty of the contribution of soil-associated phosphorus in the Lake Whatcom Watershed and the very limited data on lawn-generated phosphorus loadings, a unit-load reduction due to the fertilizer ban cannot be reliably estimated at this time. A conservative estimate of 0.5 lbs TP/acre/yr of lawn area may be justified. Cost: assumes no cost for annual enforcement.

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
18	**Education: Watershed signs**	-	-	-	-	See Exhibit 4: Education, Incentives and Enforcement Matrix.
19	**Education: Mass mailings**	-	-	-	-	
20	**Education: Online information**	-	-	-	-	
21	**Education: Newspaper ads**	-	-	-	-	
22	**Education: Video presentations**	-	-	-	-	
23	**Education: Community events (public meetings)**	-	-	-	-	
24	**Education: Onsite training/workshops**	-	-	-	-	
25	**Education: Resident contact**	-	-	-	-	
26	**Education: Project consultation**	-	-	-	-	
27	**Incentives**	-	-	-	-	
28	**Transition from Department of Ecology Water Quality Assurances of Forest Practices to 'Pristine', pre-development conditions**	lb/acre/year	0.10	$200,000 (Administrative only, no capital)	For the first year, 2,480 lbs reduction for $200,000 is $80.65/lb	Phosphorus reduction is equal to the difference between loading from pristine forested land and forested land that meets forest practice conditions. Forest loading is 0.15 lbs/acre/year (see item #1). 'Pristine' forest loading assumed to be 0.05 lbs/acre/year, so the benefit is 0.15-0.05 = 0.10 lbs/acre/yr. At base (2003) conditions, 88% of 31,183.9 acre watershed is in wetland or forest cover, so the total (watershed-wide) net benefit is 2,480 lbs. (note: TP removal stated as lb/acre/year applies only to acres under forest/wetland land uses). Assume 2 FTEs for 1 year, with 1 FTE per year at $100,000
29	**Design standards for new and retrofitted roads**	%	60	$1.48 per sf of treated impervious surface.	8974 lb/year P loading watershed-wide, assuming 60% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 5,384 lbs and costs $1,350,000,000 at $1.48/sf, for a cost/benefit for the first year only of approximately $371,171/lb	Narrower roads constructed under new design standards would produce less runoff than conventional road widths, but it is not clear that reduced runoff would result in reduced TP loads. Use of pervious pavement for new and retrofitted roads could reduce TP by that shown in item #9: 60% TP reduction credit (pervious pavement area, only). Pervious-paved parking lanes might achieve a similar reduction if travel lane runoff was directed across the parking lanes.
30	**Reconfigure roadside ditches**	%	20	$8 /sf of swale	8974 lb/year P loading watershed-wide, assuming 20% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 1,795 lbs and costs $10,802,880,000 at $8/sf, for a cost/benefit for the first year only of approximately $6,000,000/lb	Most roadside ditches could likely be reconstructed into biofiltration swales. This could reduce TP by that shown in item #3 (Biofiltration Swales): 20% TP reduction credit. Cost: see item #3 (Biofiltration Swales). Cost assumed similar

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
31	**Reconfigure streets**	%	20-40	$10/sf of street	8974 lb/year P loading watershed-wide, assuming 30% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 2,692 lbs and costs $12,801,000,000 at $9.48/sf, for a cost/benefit for the first year only of approximately $4,755,000/lb	This approach would result in narrow paved streets, on the order of 22-26 feet in width. The remainder of the street ROW would be largely devoted to bioretention for street slopes less than 3%. For streets with slopes ranging from 3-10%, biofiltration swales with check dams and other measures would be installed to enhance infiltration. The City of Seattle has more than 10 years of experience with this approach through its nationally-known SEA Streets Project and subsequent street edge projects (Seattle Public Utilities 2011). The enhanced biofiltration swales on the moderately-sloped streets could be expected to readily achieve the phosphorus reduction identified under Reduction Measure #3: Biofiltration Swales – 20%. The bioretention areas installed along the gently sloped streets would likely experience relatively higher runoffs than the typical bioretention facilities discussed under Reduction Measure #4: Bioretention. Therefore the assigned TP reduction credit is reduced from 50% to 40% for street bioretention. Prior to installing bioretention areas in a public ROW, it is important that the infiltration rates and water table conditions of the local subsoils be documented. Otherwise seasonally high water table levels could result in undesirable ponding or local seepage onto adjacent properties. Cost: equal to the sum of the costs of items #3 and #29
32	**Vehicle trips - reduce and redirect**	n/a	Minimal direct benefit	--	--	Vehicle trip reduction via increased transit and bike. Vehicles by themselves are not expected to contribute a substantial amount of phosphorus loading to runoff. Therefore, this item will be characterized in the main text rather than quantified.
33	**Recreational facility design and use (Improving existing facilities)**	lb/acre/year	Minimal direct benefit	--	--	Assumes there would be a net phosphorus decrease from reduction of shoreline erosion and elimination of fertilizer. However, no numeric estimate is made of phosphorus reduction or avoidance for this reduction measure. Of the four recreational facilities with Lake Whatcom shoreline, Bloedel-Donovan Park has the most developed land area and supports the most intensive shoreline recreation. The remaining three parks have limited road and trail access to the lake shore but no shoreline development, are mostly forested, and could be expected to contribute minimal TP loading. See Item #33 – Figure 1.
34	**Watershed-wide enforcement**	-	-	-	-	See Exhibit 4: Education, Incentives and Enforcement Matrix.
35	**Animal waste: wildlife (goose)**	lb/goose/year	0.25	--	--	Unit estimates of TP production (lb TP/goose/year): Sherer et al. (1995): 1.2 Manny (1975): 0.35 Kear (1963): 1.4 The middle value of 1.2 lb TP/goose/year is assigned. For resident goose, the majority of the food eaten by a goose is likely to come directly from the watershed. Therefore the net new phosphorus produced by a goose is assumed to be 20%. Thus the TP contribution of is assumed to be 0.2 x 1.2 = 0.25 lb TP/goose/year. No estimate of the Lake Whatcom goose population has been found. Cost: an order-of-magnitude estimate may be available by researching other jurisdictions with goose control programs (or restoration sites and treatment wetland facilities with such a program). Cost estimate would be a general, annual programmatic cost.

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
36	**Septic system transition to sewer connection**	lb/septic system/year	0.6	$50,000 per septic system ($50,000 x 92 septic systems = $4,600,000)	0.6 lb/septic system x 92 septic systems = 55 lb total at $4,600,000 is $83,333/lb (for the first year)	Table 12 of the Soil Conservation Service report for Whatcom County indicated that virtually all of the shoreline soils had severe limitations for septic systems. The subset of soils used for this analysis was limited to those soils that were identified as having a shallow (three feet or less) depth to seasonal bedrock, hardpan or water table, or as being subject to seasonal flooding. These are the conditions that would promote phosphorus migration. According to a visual inspection of the known septic systems mapped in the Lake Whatcom 2008 Stormwater Comprehensive Plan (CH2M HILL 2008), there are approximately 92 septic systems within 150 feet of the lake shoreline located in soils susceptible to phosphorus leaching. These were assumed to be capable of leaching TP to Lake Whatcom. Data from EPA (2002) indicate that for the typical septic systems 0.8 lb TP/person/year reaches the leach field. Assuming three persons per house, leach field phosphorus was calculated to be 3 x 0.8 = 2.4 lbs/house/year. Using a midpoint value of leaching phosphorus from Dudley and May (2007) of 25%, it is assumed that one-quarter of leach field phosphorus reaches the lake. 0.25 x 2.4 yields an estimate of 0.6 lb/year of phosphorus loading to the lake for each of the 92 identified houses. The total estimated phosphorus loading benefit from converting these homes to sewered is therefore equal to 92 septic systems x 0.6 lb/septic system/year. This loading estimate is somewhat speculative but it provides an order of magnitude of the potential lake phosphorus loading attributable to septic systems. [a] Cost (lb/septic/year): research with other jurisdictions the total administrative and capital cost to transition one SFR from septic to sewer. Cost estimate not to include annual sewer operations. [b] Cost: equal to the cost estimate in ([a]) multiplied by 92 septic systems.
		lb/year (watershed-wide)	55.2			

Notes:

[1]definitions of the terms biofiltration, bioretention, and infiltration, in the context of this study:

Infiltration: water percolates into the ground and does not re-enter the surface water flows; mechanism of phosphorus reduction is stormwater volume reduction (activities in this study: dry wells, infiltration trenches, pervious pavement, and infiltration basin (activities 7, 8, 9, and 10, respectively)

Biofiltration: Mechanism of phosphorus reduction is plant uptake of pollutants, assumes no infiltration (activities in this study: vegetated swales (activity 3))

Bioretention: Mechanisms of phosphorus reduction are both plant uptake of pollutants and some infiltration (activities in this study: rain gardens (activity 4), street trees (activity 5), and lawn replacement (activity 6))

Exhibit 4. Education, Incentives and Enforcement Matrix

		Reference																Relative Estimated Effectiveness (by Category)				
	Activity	a	a	a	b	c	d	e	f	g	h	h	i	j	k	l	Average % [1]	Pet Waste	Fertilizer	Car Washing	SW Mgmt on Private Property	Septic System Maintenance
Category	Performance Measure	% effectiveness	% would change behavior	% followed advice of	% in favor	% in favor	% noticed	% noticed	% noticed	% influenced by	% supportive of	% motivated by	% interested	% interested	% made changes to yard care habits	% very or somewhat						
EDUCATION	Watershed interpretive signs					2	4					1					2	Very Low	Very Low	Very Low	Very Low	Very Low
	Mass mailings	55		50	10	31			4	55	49	12	23	46			34	Moderate	Moderate	Moderate	Moderate	Moderate
	Online information (website)	45			13		3						8				17	Low	Low	Low	Low	Low
	Newspaper ads	56				15	33		38	46	66	36	12				38	Moderate	Moderate	Moderate	Moderate	Moderate
	Video presentations (or TV ads)	56.9	19			19	71	66	28	43		27	15		52.4		40	Moderate	Moderate	Moderate	Moderate	Moderate
	Community events (public meetings)					2	0				75	4		26			21	Low	Low	Low	Low	Low
	Resident contact (home visit)										49			18			34	Moderate	Moderate	Moderate	Moderate	Moderate
	Onsite training/workshops	39								49					23.5	35	37	n/a	Moderate	n/a	Moderate	Moderate
	Technical assistance	45									67						56	n/a	High	n/a	High	High
INCENTIVES	Convenient disposal		17														17	Low	n/a	n/a	n/a	n/a
	Store coupons										82			54			68	n/a	High	n/a	High	n/a
	Yard waste pickup													48			48	n/a	Moderate	n/a	Moderate	n/a
	Rain barrel													44			44	n/a	Moderate	n/a	Moderate	n/a
	Food waste pickup													37			37	n/a	Moderate	n/a	Moderate	n/a
	Compost bin													28			28	n/a	Low	n/a	Low	n/a
ENFORCEMENT	Watershed-wide		7								58						33	Moderate	Moderate (*Note: No literature found on effectiveness of enforcement actions on fertilizer use. 'Moderate' effectiveness based on surrogate described below.*)	Moderate	Moderate	Moderate
																		Notes for this Category: ***0.3 lb TP/dog/year;*** *A dog averages 1/3 pound of waste per day with a phosphorus content of 1% (Carrasco 2003). A dog therefore produces up to 1.2 pounds of phosphorus per year. Conservatively assume that all waste remains on the ground and that up to 25% of the phosphorus reaches the lake via surface runoff. Thus, 1.2 lb/dog/year x 25% = 0.3 lb/dog/year TP reduction benefit with pet waste elimination. An estimate of the number of dogs in the watershed could yield an estimate for the whole watershed.*	Notes for this Category: ***0.5 lb/acre/year*** *- See Table 1 'phosphorus fertilizer ban' - estimate of loading from fertilizer use. A moderate estimated effectiveness is assumed based on available literature reviewed to-date.*	Notes for this Category: *No information found in the literature on P-loading from car washes. Phosphorus may be phased out of detergents and car wash soaps. Effective enforcement is not likely to be feasible; incentives such as car wash coupons have been found somewhat popular, and are likely to be more effective than education alone because cost is a main reason cited by survey participants (Silver Beach Creek - reference j) as the reason for washing vehicles at home instead of a commercial car wash.*	Notes for this Category: ***0.62 lb/acre/year;*** *Assumes a loading rate from conventionally-developed SFRs of 1.24 lb/acre/year, and 50% TP removal from retrofits (see Table 1, Bioretention). Thus, the TP reduction benefit is equal to 0.62 lb/acre/year. Could assume that 30% of the developed area would potentially be retro-fitted to compliance with City LID standards.*	Notes for this Category: *To calculate the TP reduction benefit, need a loading rate from failing septics - not found in the literature to-date. The loading rate from properly maintained septics within 150 feet of the lake shoreline is estimated to be* ***0.6 lb/septic system/year*** *(see Table 1, Septic System Transition to Sewer).*

[1] These results are intended to be used for discussion only due to the widely varying nature and purpose of the supporting studies/references.

Reference	
a	Center for Watershed Protection. 1999. A Survey of Residential Nutrient Behavior in the Chesapeake Bay. Ellicott City, Maryland. July 1999.
b	Cascadia Consulting Group, Inc. 2009. Evaluation of Seattle Public Utilities' Public Involvement and Education Programs. Prepared for Seattle Public Utilities. Seattle, Washington. February 2009.
c	Fairbank, Maslin, Maullin & Associates. 2001. San Mateo Countywide Stormwater Pollution Prevention Program: 2001 Residential Survey. June 2001.
d	Pelegrin Research. 2004. Storm Water Public Education Program: Resident Population Telephone Survey – 2004 Evaluation and Next Steps. Prepared for [California] State Water Resources Control Board and Rogers and Associates. Los Angeles, California. October 2004.
e	Maine Department of Environmental Protection. 2005. Assessment of Maine's Stormwater Phase II & NPS Outreach Campaign: 2003/2004. February 2005.
f	Evans/McDonough Company, Inc. 2003. Evaluation of Watershed Watch Campaign Effectiveness: 2003 Public Opinion Survey and Focus Groups. Prepared for Santa Clara Valley Urban Runoff Pollution Prevention Program. Oakland, California. November 2003.
g	Rockwood Research, University of Minnesota Extension Service. 1999. Evaluation of Spring 1999 Stormwater Media Outreach: Think Clean Water Campaign. Twin Cities, Minnesota.
h	Riley Research Associates. 2002. Do Clean Rivers Begin at Home? Exploring the Obstacles and Motivations of Homeowner Behavior: A Survey of Public Habits in Oregon's Tualatin River Watershed. Prepared for Oregon Clean Water Services and Tualatin Basin Public Awareness Committee.
i	Gilmore Research Group. 2005. Surface Water Study [telephone survey of Bellevue, Redmond, and Shoreline residents].
j	Silver Beach Creek Outreach Program. Final Report. Accessed at: http://www.cob.org/documents/pw/lw/psp-final-report.pdf
k	Cascadia Consulting Group, Inc. and Applied Research Northwest. 2008. Yard Care and Water Quality Study: A Telephone Survey of Lake Whatcom and Samish Watershed Residents. Prepared for Whatcom County Public Works. June 2008.
l	Applied Research Northwest and Cascadia Consulting Group, Inc. 2008. Final Report: City of Bellingham Water Conservation Survey. Prepared for the City of Bellingham, Washington. January 2008.

Appendix C
Whatcom Falls Water Treatment Plant Dissolved Air Flotation Pilot Testing Report

Final Report

Whatcom Falls
Water Treatment Plant
Dissolved Air Flotation Pilot Testing

City Project Number: EW-180

Prepared for

City of Bellingham, WA

March 2012

CH2MHILL®

21 Bellwether Way, Unit 111
Bellingham, WA 98225

Final Report

Whatcom Falls
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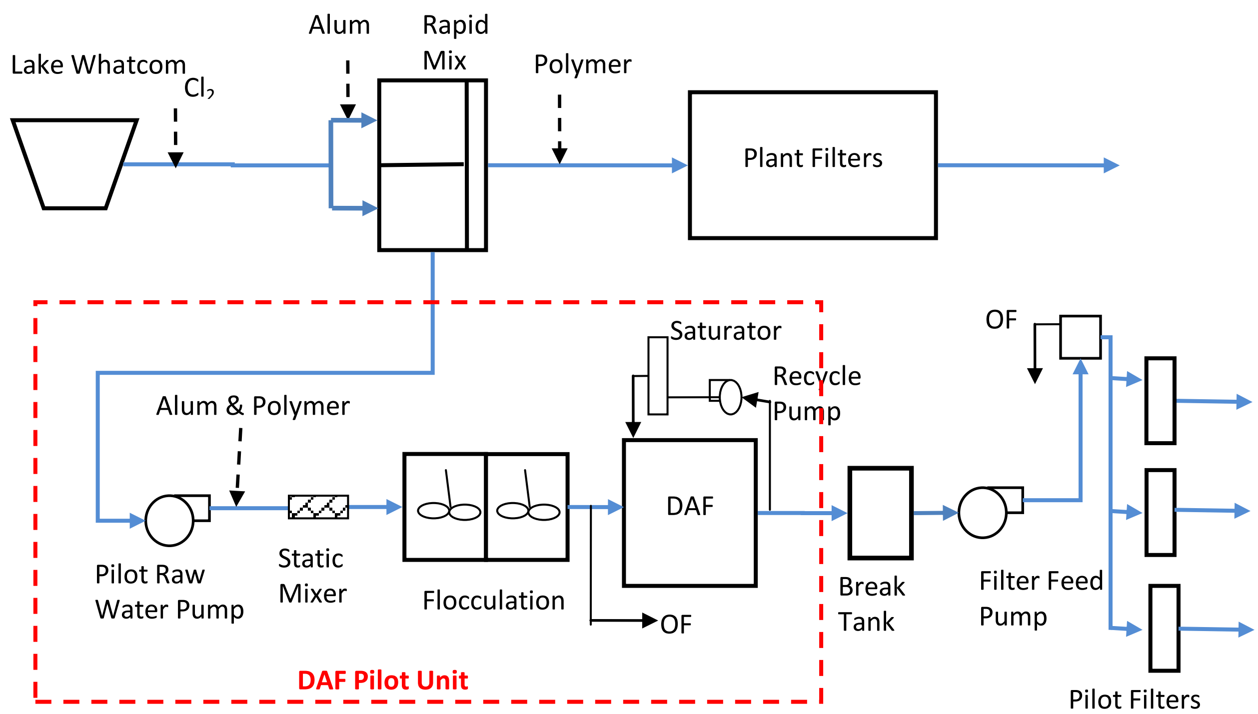
Executive Summary

The City of Bellingham (City) operates the Whatcom Falls Water Treatment Plant (WTP). This in-line filtration plant has a peak capacity of 29 million gallon per day (MGD) when all six filters are on line and a firm capacity of 24 MGD when one filter is off line for backwashing or maintenance. The source water is Lake Whatcom, a large natural lake that in recent years has seen increases in algal counts that have affected the performance of the WTP during late summer. A 6-week pilot testing of dissolved air flotation (DAF) was conducted at the WTP in the late summer of 2011. The goal of the testing program was to evaluate the performance of DAF with respect to how it improves overall WTP performance and capacity during summertime algae conditions.

Figure ES-1 shows a schematic of the DAF pilot system (including pumping, mixing, and flocculation) within the dashed-red border, how it was connected to the City's WTP, and its position upstream of the City's pilot filters. The City's WTP pilot filters were used as a key performance measure of the beneficial impact of the DAF process.

FIGURE ES-1
Schematic of DAF Pilot Unit



DAF loading rates were varied from 10 gallon per minute per square foot (gpm/sf) to 20 gpm/sf over the course of the testing to evaluate the performance of DAF at ever-increasing loading rates with the understanding that successful performance at higher loading rates can lead to reduced DAF construction cost. Table ES-1 summarizes the DAF runs completed during pilot testing.

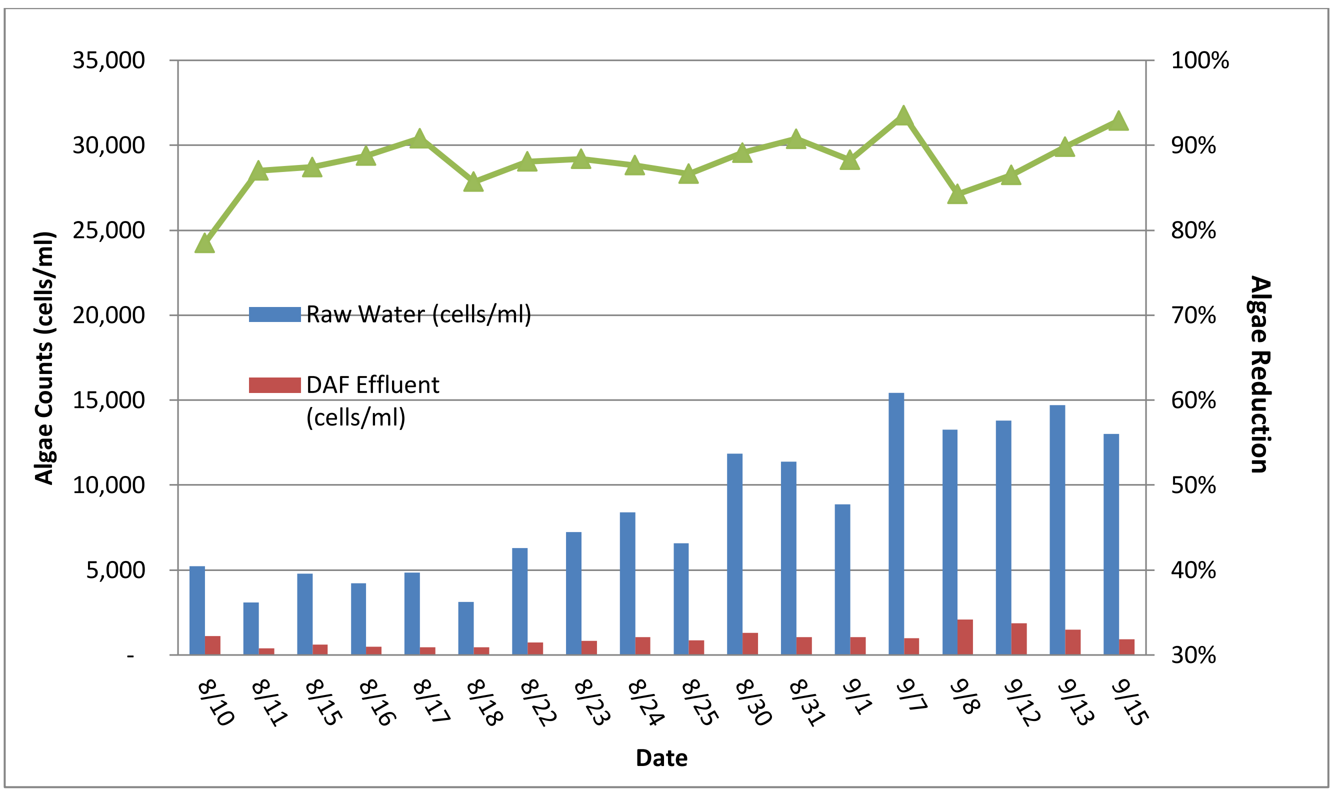
The DAF pilot test met all of the key goals and objectives established in the testing plan, which was developed prior to the pilot test, and which was approved by Washington State Department of Health (DOH). The pilot test demonstrated that for the Lake Whatcom supply, DAF effectively removed algae, increased filter production, reduced total organic carbon (TOC) and color, and reduced the formation potential for total trihalomethanes (TTHMs). While DAF's demonstrated beneficial impact to the treatment process was widespread among the parameters listed above, the two most critical and defining parameters are algae count reduction and improved filter performance.

TABLE ES-1
DAF Pilot Test Runs and Conditions

Week	Objective	Floc Time (min)	Alum Dose (mg/L)	Polymer Dose (mg/L)	DAF Loading (gpm/sf)	Pilot Filters Loading (gpm/sf)
1	10 gpm/sf DAF loading rate. No polymer	5	10	-	10	5, 6 & 7
2	10 gpm/sf DAF loading rate. No polymer	5	10	-	10	5, 6 & 7
3	10 gpm/sf DAF loading rate. With polymer	5	10	0.1-0.35	10	5, 6 & 7
4	14 gpm/sf DAF loading rate. With polymer	5	11	0.3	14	5, 6 & 7
5	16 gpm/sf DAF loading rate. With polymer	4.4	11	0.3	16	5, 6 & 7
6	20 gpm/sf DAF loading rate. With polymer	8	10	0.4	20	5, 6 & 7
7	Repeat Optimal Testing Run (16 gpm/sf DAF loading rate)	4.4	10	0.2-0.3	16	5, 6 & 7

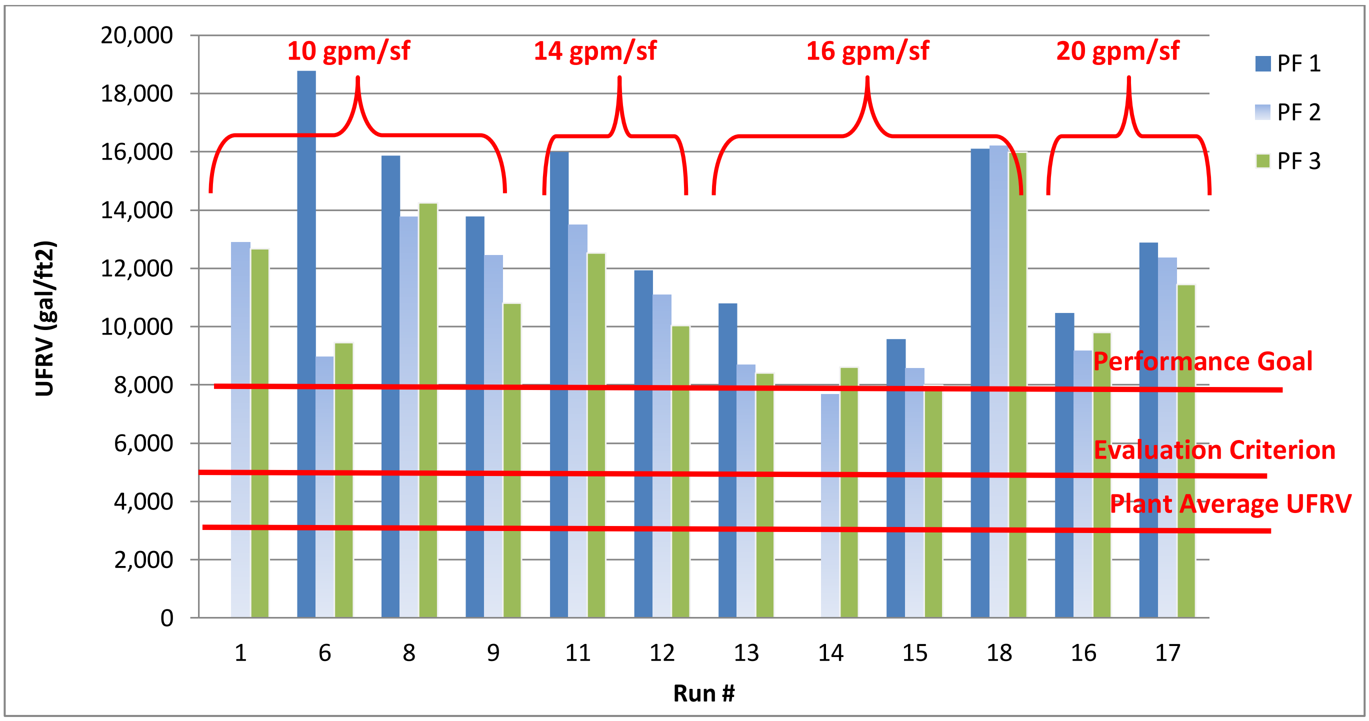
First, the algae-count reduction achieved by the DAF process is presented in Figure ES-2 (same figure as Figure 4-2). These algae reduction results were encouraging given that, while the algae population in Lake Whatcom is effective at clogging the City's WTP filters, its total algae counts are relatively low when compared to other algae-laden waters. Reducing the amount of algae in the raw water is important because it enables improved treatment performance of filtration, disinfection, and other processes downstream.

FIGURE ES-2
Algae Counts and Reduction



Second, even more important than the algae reduction results are the pilot filtration performance results. It is important to keep in mind that the specific reason for evaluating DAF pretreatment is the dramatically reduced performance of the City's WTP filters during summertime algae blooms. The most common measure of filter performance used under these circumstances is unit filter run volume (UFRV), which is a measure of the volume of water passed through a square foot of filter area before the filter needs to be backwashed. Lake Whatcom blue-green algae, even at relatively low counts, severely reduces UFRV at the City's WTP filters to roughly 3,000 gallons per minute per square foot (gpm/ft^2) – down from roughly 7,000 to 9,000 gpm/ft^2 at other "peak-UFRV times" of the year. As presented in Figure ES-3, the pilot test results showed that DAF increased UFRV in the pilot filters to above 8,000 gpm/ft^2 (the performance goal for pilot test), which is more than double what the City's full-scale WTP filters were able to do during the same DAF pilot test period. This UFRV result is the single-most defining parameter demonstrating the success of the DAF process at removing algae from the Lake Whatcom supply and improving performance of the City's WTP.

FIGURE ES-3
Pilot Filter UFRV in Each Pilot Test Run



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SECTION 1

Introduction

1.1 Purpose and Scope

The City of Bellingham (City) operates the Whatcom Falls Water Treatment Plant (WTP). This in-line filtration plant has a peak capacity of 29 million gallon per day (MGD) when all six filters are on line and a firm capacity of 24 MGD when one filter is off line for backwashing or maintenance. The source water is Lake Whatcom, a large natural lake that in recent years has seen increases in algal counts that have affected the performance of the WTP during late summer. A 6-week pilot testing of dissolved air flotation (DAF) followed by filtration was conducted at the WTP in summer of 2011. The goal of the testing program was to evaluate the performance of the DAF, specifically in terms of algae reduction and improvement in filtration productivity.

The original testing protocol for the pilot testing is described in the memorandum “Whatcom Falls Water Treatment Plant: Pilot Testing Plan for Dissolved Air Flotation” (CH2M HILL, June 2011; Attachment A). The testing program was designed to:

1. Establish ability of DAF to effectively remove algae prior to filtration
2. Establish coagulant and polymer dosage rates required with DAF
3. Determine impacts of DAF pretreatment on filtration performance
4. Monitor other water quality parameters in filtered water

1.2 Organization of Document

This report summarizes the flocculation/DAF and filtration pilot testing conducted for the Whatcom Falls WTP. The remainder of this report is divided into the following sections:

- **Section 2, Testing Methodology**, includes methodology, descriptions, and layouts of the pilot unit processes, equipment used, and sampling analysis/frequency.
- **Section 3, Testing Runs and Conditions**, describes all the testing runs completed during the testing period.
- **Section 4, Testing Results**, evaluates the key items of interest based on pilot test results as compared to goals or regulatory limits.
- **Section 5, Conclusions**, summarizes the pilot testing results and describes how they relate to the proposed processes and design criteria.

SECTION 2

Background

2.1 Raw Water Supply

The raw water source of the Whatcom Falls WTP is Lake Whatcom. Raw water is taken from the lake and pre-treated through travelling screens at the Screen House. A small dose of chlorine (0.6 mg/L) is added to raw water at the Screen House from which water is conveyed via a 66-inch pipe to the WTP. The plant consists of two rapid mix basins and six dual-media filters. Normally only one rapid mix basin is on line. The plant uses Alum as a coagulant along with polymer, both of which can be added at multiple locations prior to and at the rapid mix basins.

Historical raw water characteristics of the Whatcom Falls WTP are presented in Table 2-1. The data show that this water has low turbidity, hardness, alkalinity, color, and metals. Total organic carbon (TOC) concentrations are low and consist primarily of dissolved organics (DOC).

TABLE 2-1
Whatcom Falls WTP Historical Raw Water Quality (2007-2010)

Parameter	Units	Minimum	Average	Maximum
Temperature	Celsius	6	12	18
Turbidity	NTU	0.41	0.74	2
Alkalinity	mg/L as CaCO3	19.5	20.7	22.5
Hardness	mg/L as CaCO3	17.3	21.2	23
pH	S.U.	7.2	7.3	7.4
Conductivity	umohs/cm	57	60.6	75
Apparent Color	PtCo	13	14	15
TOC	mg/L	1.8	2.2	2.6
DOC	mg/L	1.8	2.1	2.3
UV254	1/cm	0.046	0.056	0.103
Iron	mg/L	<0.01	-	0.08
Manganese	mg/L	<0.001	-	0.012
Aluminum	mg/L	<0.010	0.06	0.098
Chloride	mg/L	<2	2.2	3
Sodium	mg/L	2	4.4	5
Sulfate	mg/L	3.6	7.4	10
Chlorophyll	µg/L	2	3.5	5.9
Algae [a]	#/ml	-	-	100,000

[a] Estimated algae counts based on historical algae counts

Raw water used at the pilot test was drawn from the rapid mix basin no. 1 via the basin drain line. This rapid mix basin was filled initially with raw water without any chemical addition. The inlet valve to the rapid mix basin was then adjusted to obtain a fill rate close to the drain rate so that the basin water surface was maintained relatively constant. The basin water surface level was also monitored and interlocked with the plant control system throughout the pilot testing to avoid the rapid mix basin overflow. Typically, the level in rapid mix basin no. 1 was a few inches higher than the level in rapid mix basin no. 2 and the downstream filter influent flume to prevent backflow of plant treated water into the pilot plant raw water.

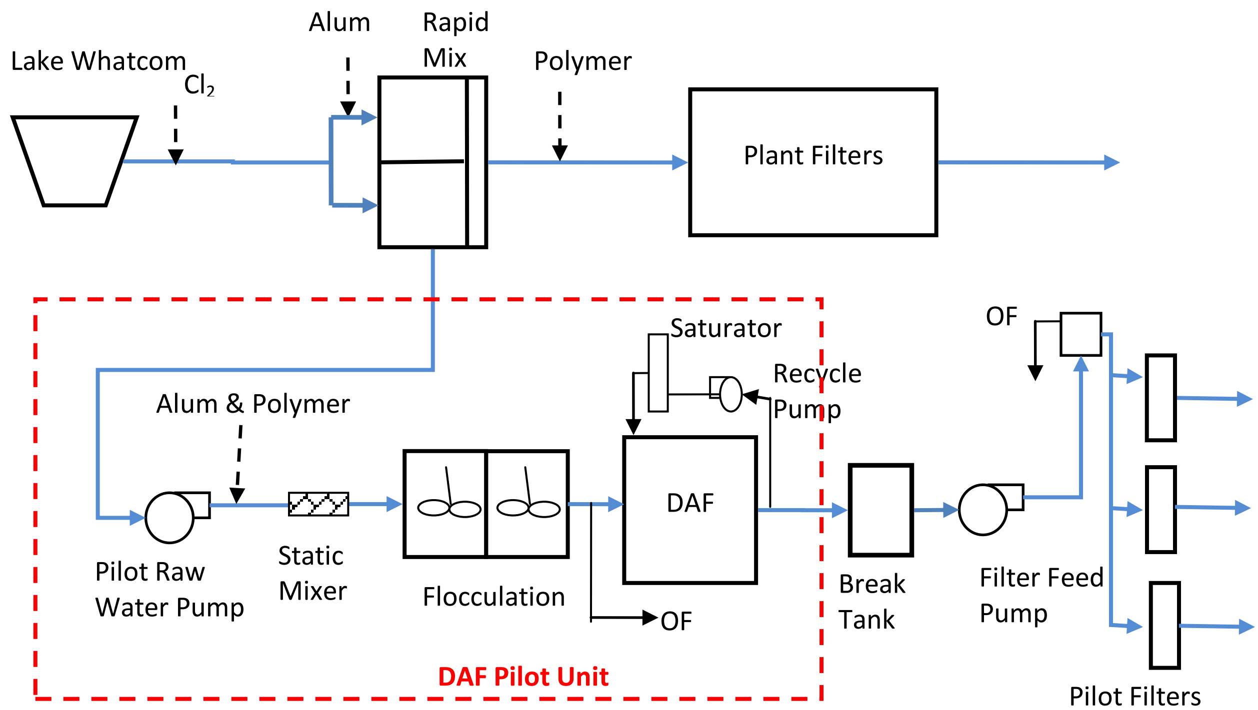
2.2 Pilot Unit Processes

The pilot testing setup includes the following key components:

- Roberts Flocculation/DAF pilot trailer with influent pumping and chemical feed systems
- The City's existing pilot filters and filter influent pumping

The schematic of the process units (Figure 2-1) shows the key elements of the WTP and the DAF pilot system. Figure 2-1 also shows where the DAF pilot system connected to the WTP.

FIGURE 2-1
Schematic of DAF Pilot Unit



2.2.1 Flocculation/ Dissolved Air Flotation Pilot Trailer

The flocculation and DAF pilot units were provided in a trailer by Roberts Water Technologies and Enpure (Roberts). The trailer also houses an influent pump, flow control valves, chemical feed system, on-line water quality analyzers, and system control panel. Figure 2-2 shows the inside and outside of the trailer.

FIGURE 2-2 (a)
Inside of Pilot Trailer

FIGURE 2-2 (b)
Outside of Pilot Trailer

2.2.1.1 Raw Water Pumping

A constant speed pump, a flow meter, and flow control valve assembly were used to deliver the desired raw water flow from the plant rapid mix basin to the pilot flocculation tanks. Three metering pumps and chemical day tanks could deliver three different chemicals to the raw water line, followed by an in-line static mixer. Raw water and DAF effluent pH, turbidity, and UV254 were continuously monitored at 1-minute intervals using the on-line analyzers.

2.2.1.2 Flocculation Unit

Two 2-stage flocculation basins are provided at the top of the trailer. Each stage has a dimension of 24 inches long by 36 inches wide by 42 inches deep. Each stage is equipped with a vertical mixer. The speed of each individual mixer can be controlled to up to 342 rpm via the pilot system control panel. During the testing, one or both flocculation basins have been put in service depending on the flocculation time requirement. Attachment B includes the process and instrumentation diagram (P&ID) of the flocculation system.

2.2.1.3 Dissolved Air Flotation Unit

Flocculated water gravity flows to the DAF unit through a baffled entrance. A flow meter and flow control valve assembly controls the desired flow rate to DAF. Excess flow overflows via a drainpipe to the City sewer system. The DAF unit consists of an air saturator and compressor, recycle pumping, and a DAF tank with sludge removal and effluent collection capability. The DAF tank has a flotation surface area of approximately 4 square feet. The recycle pump uses between 6 and 12 percent of the DAF effluent and pumps it to a pressurized vessel called saturator, where the water is supersaturated with air. The saturator receives compressed air. It is pressurized at 60 to 80 psi to saturate air into the water solution. This air-saturated water is then recycled back to the head of the tank. During the pilot testing, the recycle rate was optimized and held between 10 and 12 percent by switching tank nozzles in the contact zone when raw water flow changes were made.

The air in the water comes partially out of solution and floats upwards, carrying flocculated particles with it. The particles rise all along the length of the tank and accumulated at the top, where they are removed by periodic hydraulic de-sludge. The underflow from the DAF tank is the treated effluent that is then sent to filtration.

The system is set up to run automatically. All operating parameters were available for display and control via the control panel inside the trailer. Figure 2-3 shows additional pictures of the DAF components. Attachment B includes the P&ID of DAF by Roberts.

FIGURE 2-3 (a)
DAF Effluent End

FIGURE 2-3 (b)
Floc Float on Top of DAF

2.2.2 Pilot Filters

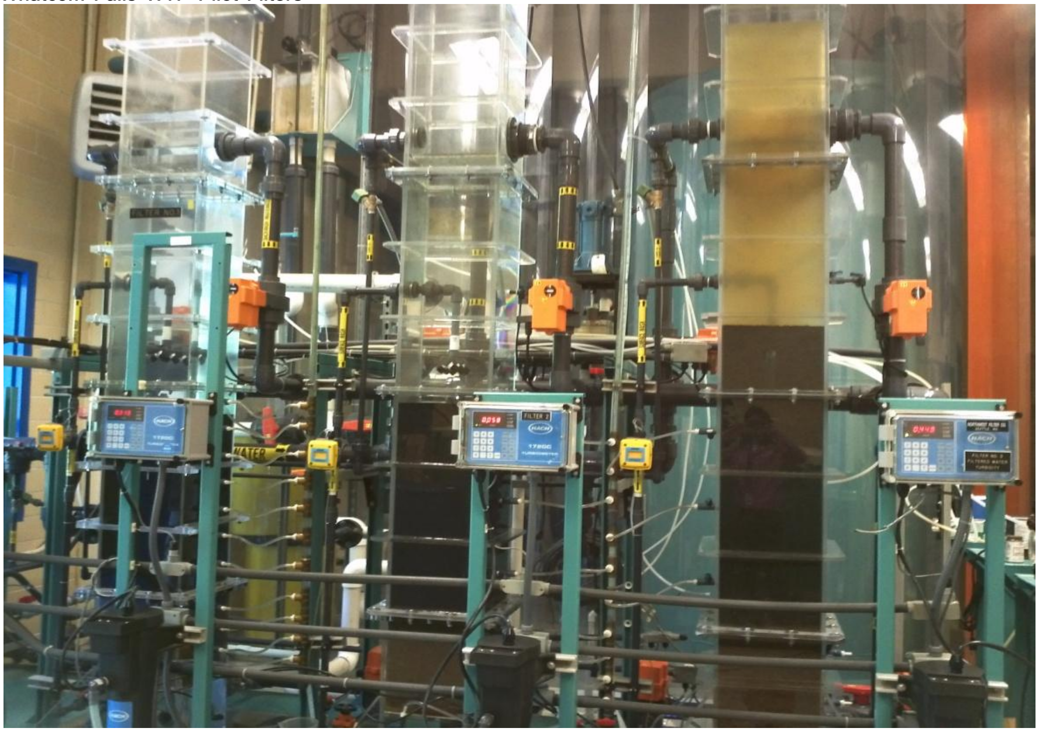
The WTP has three pilot filters, which were used in the pilot testing. Each pilot filter has dimensions of 12 square inches (1 square foot) by 12 feet high. All three are loaded with filter media matching the existing filters: 31 inches anthracite over 11 inches sand. The pilot filters are operated as constant head, effluent flow control filters.

The filter pilot plant is operated by a programmable logical controller (PLC), which can operate the filters in one of three modes: 1) run, backwash, and stop, 2) run, stop, and wait, 3) run, backwash, and continue with next cycle. During the pilot test, the filter system was set up to run in mode 1), that is, when either turbidity or headloss breakthrough is reached the filter will stop running, automatically backwash and standby until it is commanded to start running again. The filter breakthrough criteria include reaching 8.2 feet of headloss, reaching 0.07 NTU of turbidity for 120 minutes, or reaching particles of 100 count/mL. The third breakthrough criterion, 100 particles/mL, was not included in the filter automatic backwash and stop command. Therefore, filters would run until one of the other pre-set parameters was met, or an operator manually stopped them.

On-line analyzers on each filter provide continuous monitoring of turbidity, particle counts and head loss. The data was retrieved at 5-minute intervals for the pilot test. During the pilot testing, each filter was operated at 5, 6, and 7 gallon per minute per square foot (gpm/sf).

The clarified water from DAF was pumped to an elevated overflow box that, in turn, fed by gravity to the pilot filters. The WTP owns the filter influent pump. To avoid the situation that the filter influent pump runs dry when the DAF system is off-line or during a de-sludge event, a break tank was installed at the filter influent pump suction to provide buffering. Figure 2-4 shows the pilot filters.

FIGURE 2-4
Whatcom Falls WTP Pilot Filters



2.3 Sampling and Analysis

2.3.1 Sampling Methodology

Sampling of each process consisted of both grab and continuous sampling methods, depending upon the unit process and sample analysis to be performed. Table 2-2 lists the types of samples that were taken, frequency of samples, and the unit processes sampled.

Continuous samples were taken from the process using equipment recommended flow rates and nonreactive tubing and materials to obtain the most representative samples.

TABLE 2-2
Whatcom Falls WTP Pilot Test Sampling Schedule

Parameter	DAF Feed	DAF Effluent	Pilot Filter 1 Effluent	Pilot Filter 2 Effluent	Pilot Filter 3 Effluent
Turbidity	c	c	c	c	c
Particle Counts			c	c	c
Apparent Color	2	2	2	2	2
Alkalinity	1	1	1		
pH	2	2	2	2	2
Total Iron	1 per week	1 per week	1 per week	1 per week	1 per week
Dissolved Iron	1 per week	1 per week	1 per week	1 per week	1 per week
Total Manganese	1 per week	1 per week	1 per week	1 per week	1 per week
Dissolved Manganese	1 per week	1 per week	1 per week	1 per week	1 per week
Total Aluminum	2	2	2	2	2

TABLE 2-2
Whatcom Falls WTP Pilot Test Sampling Schedule

Parameter	DAF Feed	DAF Effluent	Pilot Filter 1 Effluent	Pilot Filter 2 Effluent	Pilot Filter 3 Effluent
Dissolved Aluminum	2	2	2	2	2
UV254	2	2	2	2	2
Temperature	2	2	2	2	2
Phycocyanin/Chlorophyll a using handheld instrument	2	2	2		
Algae/Chlorophyll a by offsite lab	1	1			
TOC/DOC by offsite lab	1	1			

Notes: The numbers refer to the number of times a day that samples are collected except noted otherwise. “C” refers to continuous sampling by the on-line analyzers.

2.3.2 Sampling Location

Grab samples were taken twice (typically 9 AM and 2 PM) daily from each unit process for lab analysis. The sampling points were selected to obtain the representative samples. The raw water and clarified water (DAF effluent) samples were taken from the drain line of the raw water turbidity meter and clarified water turbidity meter inside of flocculation/DAF trailer. The filter effluent samples were taken from the corresponding filter effluent turbidity meters located in the pilot filter room.

2.3.3 Sampling Analysis

2.3.3.1 Onsite Analysis

Particle and turbidity of various flow streams were continuously monitored. Raw water and DAF effluent turbidity samples were analyzed using Hach 1720E online turbidimeters installed in Roberts’ flocculation/DAF pilot trailer. Turbidity and particle counts of three pilot filters’ effluent were continuously analyzed using Hach 1720C online turbidimeters and Chemtrac PC2400 particle counters provided by the City.

Throughout the pilot testing, the dedicated staff of the City conducted all the onsite sampling and lab analysis. Temperature and pH were measured using pH meter with automatic temperature compensation. Onsite Phycocyanin/Chlorophyll a were measured using a handheld fluorometer AquaFluor manufactured by Turner Designs. All other parameters were analyzed onsite with manual titration or using the Hach DR-5000 UV-spec at the appropriate wavelength following the Hach methods. The analysis methods are listed in Table 2-3.

TABLE 2-3
Onsite Analyses and Methods

Parameter	Analysis Methods	Description
Apparent Color	Hach Method 8025	Platinum-Cobalt Standard Method (15 to 500 CU)
Alkalinity	SM 2320B	Potentiometric Titration
Total or Dissolved Iron	Hach Method 8008	FerroVer Method (0.02 – 3.00 mg/L)
Total or Dissolved Manganese	Hach Method 8149	1-(2-Pyridylazo)-2-Naphthol PAN Method (0.006 to 0.700 mg/L)
Total or Dissolved Aluminum	Hach Method 8012	Aluminon Method (0.008 – 0.800 mg/L)
UV254	Hach Method 10054	Ultraviolet Absorption at 254 nm wavelength

2.3.3.2 Offsite Analysis

The remaining parameters, including TOC, DOC, algal counts, and chlorophyll a concentrations, were analyzed at offsite labs. TOC/DOC samples were collected and sent to Edge Analytical Laboratories for analysis. They were measured using SM 5310B method with the method detection limit of 0.12 mg/L for DOC and 0.065 for TOC. Algae and chlorophyll samples were collected and sent to the laboratory at the Institute for Watershed Studies, which is a research and academic support facility that is affiliated with Huxley College of the Environment, Western Washington University (WWU), for analysis by Dr. Robin Matthews, PhD.

During the pilot testing one pilot filter sample was collected for simulated distribution total trihalomethanes (TTHMs) and haloacetic acids (HAA5) analysis. This analysis was conducted in CH2M HILL's Applied Sciences Laboratory.

SECTION 3

Testing Runs and Conditions

3.1 Pilot Test Performance Goals

Before beginning pilot testing, quantitative minimum evaluation criteria and goals for the quality of the treatment processes were determined. Table 3-1 presents these parameters and values. The evaluation criteria denote the level of achievement expected as a result of the pilot testing, whereas the goal reflects the desired limits beyond what is necessary. Meeting or exceeding the evaluation criteria is a measure of the success of the pilot study, while meeting or exceeding the goals is an extra benefit.

TABLE 3-1
Performance Goals for Whatcom Falls WTP Pilot Study

Sample Point	Parameter	Evaluation Criteria	Goal
Clarified water	Total algae removal	--	>95% removal
Clarified water	Turbidity (steady-state)	<1.0 NTU	0.5 NTU
Filter Effluent	Turbidity (steady-state)	<0.07 NTU	<0.05 NTU
Filter Effluent	Turbidity spike (ripening)	0.2 NTU	<0.1 NTU
Filter Effluent	Particle counts (steady-state)	< 100 p/ml >2 μm	< 20 p/ml > 2 μm
Filter Effluent	Particle removal (steady-state)	2-log	2.5 log
Filter Effluent	Ripening time	30 minutes	< 15 min. to <0.1 NTU
Filter Production	Unit filter run volume	>5,000 gal/ft2	>8,000 gal/ft2

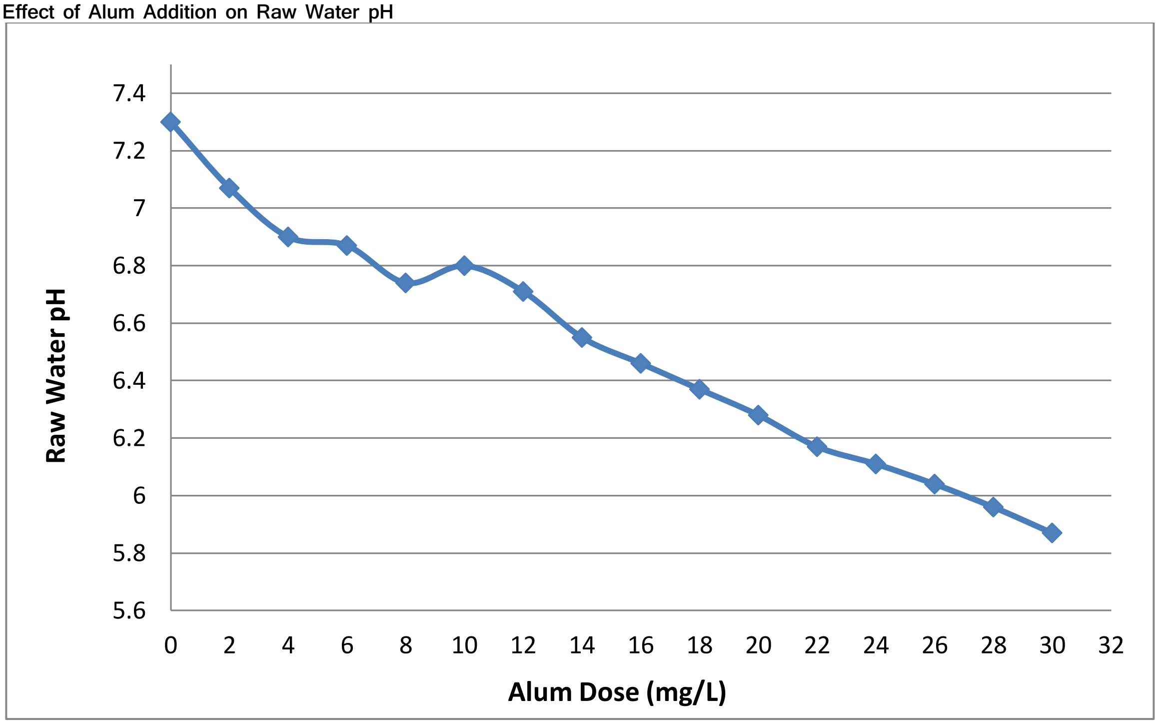
3.2 Bench-Scale Tests

A series of bench-scale tests were performed to help determine the optimal chemical doses used in the pilot testing. The determined chemical doses were adjusted minimally throughout the pilot testing while the DAF loading rates changed.

3.2.1 Titration – Effects of Alum Addition on Water pH

The first bench-scale test was performed to determine the effects of various doses of alum addition on raw water pH. Since alum is acid solution and the historical data show that raw water alkalinity is approximately 20 mg/L as $CaCO_3$, caution is needed so that raw water pH will not drop too much by alum addition. Titration was done by adding an incremental volume of pre-prepared alum solution into 1,000 mL of raw water and measuring pH at each step. Figure 3-1 shows the trend between alum dose and raw water pH obtained from the titration test. At the alum dose range of 6 to 16 mg/L, raw water pH was maintained above 6.4.

FIGURE 3-1
Effect of Alum Addition on Raw Water pH



3.2.2 Jar Test – Alum/Polymer Doses

The bench-scale tests were conducted using the jar testing equipment provided by Roberts, which consists of the air compressor, a saturator, and a series of jars to simulate the flocculation tanks and DAF (Figure 3-2). Chemical injection and mixing could be supplied as needed and the air-saturated water at varied rates could be injected to simulate different recycle rates.

FIGURE 3-2
Flocculation/DAF Bench-Scale Test Equipment by Roberts

Various doses of alum and polymer that are currently used at the plant were tested. Turbidity and UV254 of the clarified water from each run were measured. Two sets of tests were completed. The first one tested alum addition only. The second one tested alum addition with polymer (Sumaclear P20, Summit Chemical Company). Table 3-2 shows the run conditions, observed floc appearance, and the water quality data during the first set of tests. When 6 to 16 mg/L of alum was added, raw water turbidity was reduced from 0.77 NTU to approximately 0.2 NTU. Raw water UV254 (as an indicator of TOC) was reduced by approximately 50 percent. It appears that alum doses between

8 to 10 mg/L during the jar test obtained the optimal clarified water quality in terms of the combination of both parameters. This is consistent with what the WTP is currently dosing at the rapid mixing upstream of the plant filters.

TABLE 3-2
Bench-scale Flocculation and DAF Testing Results – Alum Only

Jar Test Number	Alum Dose (mg/L)	Floc Appearance	Turbidity (NTU)	UV254 (1/cm)
1	6	Small, scattered	0.249	0.026
2	8	Pin	0.200	0.028
3	10	Pin	0.219	0.019
4	12	Pin	0.250	0.018
5	14	Pin	0.223	0.019
6	16	Getting larger	0.214	0.018

Notes:
Raw water turbidity: 0.77 NTU, UV254: 0.048 1/cm
Rapid mix: 1 minute retention time at 250 rpm
1st stage flocculation: 5 minutes at 80 rpm, 2nd stage flocculation: 5 minutes at 40 rpm
DAF float time: 5 minutes, recycle rate: 10 to 12 percent

Table 3-3 represents the testing conditions and results of the second jar testing where both alum and polymer were dosed. It appeared that increasing polymer dose from 0.1 to 0.3 mg/L consistently reduced the UV254. There was little benefit to add over 0.3 mg/L polymer in terms of turbidity reduction. However, lower doses of polymer ranging from 0.1 to 0.2 mg/L may help reduce turbidity by forming smaller and easily floatable floc. Based on the bench-scale test results, the following chemical addition was selected as a starting point during the pilot testing

- Alum dose = 10 mg/L
- Polymer = 0.1 to 0.2 mg/L (when used)

TABLE 3-3
Bench-scale Flocculation and DAF Testing Results – Alum and Polymer

Jar Test Number	Alum Dose (mg/L)	Polymer Dose (mg/L)	Floc Appearance	Turbidity (NTU)	UV254 (1/cm)
1	8	0.1	Smaller pin	0.187	0.020
2	8	0.2	Pin	0.185	0.019
3	8	0.3	Medium pin	0.246	0.017
4	10	0.1	Pin	0.216	0.018
5	10	0.2	Pin	0.202	0.016
6	10	0.3	Medium pin	0.232	0.016

Notes:

Raw water turbidity: 0.77 NTU, UV254: 0.048 1/cm

Rapid mix: 30-second retention time at 250 rpm; adding polymer at end of rapid mix after coagulation

1st stage flocculation: 5 minutes at 60 rpm, 2nd stage flocculation: 5 minutes at 40 rpm

DAF float time: 5 minutes, recycle rate: 10 percent

3.3 Pilot Testing Runs

The original schedule of the pilot testing was four to five weeks. One set of conditions would be tested each week, with the last week reserved for repeating the optimal run determined based on the previous tests. The pilot testing actually lasted for seven weeks, due to some equipment and operations and maintenance (O&M) issues with the pilot system. Table 3-4 summarizes all the runs conducted during the testing. Some of them did not reach the pre-set termination criteria, that is, terminal headloss, turbidity, or particle counts. They are included in the table and evaluation because they still provide valuable information to determine the pilot unit performance and the filter headloss accumulation. All the raw data from testing are available in the electronic format by request (Attachment C).

The following paragraphs provide brief descriptions of the test goals, as well as what actually occurred in each week.

Week 1: Troubleshooting was conducted on a couple of issues after system startup, including raw water supply modification, DAF recycle pump power trip issue, filter feed pump air binding. A first run with 10 gpm/sf of DAF loading and 10 mg/L alum only was completed.

Week 2: Pilot Runs 2 through 5 were conducted. Pilot filter 1(PF 1) was offline during Runs 2 and 3 due to a backwash problem. Runs 2, 3, and 4 were terminated before filter terminal headloss was achieved due to operational issues or maintenance on the pilot system (DAF and/or filters). Run 5 was a full run at 10 gpm/sf of DAF loading without polymer addition.

Week 3: Pilot Runs 6 to 9 were conducted with 10 gpm/sf of DAF loading and alum plus polymer addition. Occasional DAF recycle pump and pilot filter valves issues occurred. Run 6 and Run 8 were fully completed runs.

Week 4: Pilot Runs 10 to 12 were conducted. DAF loading was increased to 14 gpm/sf while the chemical dosages were kept the same. The raw water flow to the flocculation was maintained at approximately 63 gpm as well. Run 10 was terminated before terminal headloss, turbidity, or particle breakthrough was achieved due a continuing power issue with the DAF recycle pump. Runs 11 and 12 were complete runs.

Week 5: Pilot Runs 13 to 15 were conducted. Raw water flow was increased to approximately 72 gpm and DAF feed was increased to 64 gpm (equivalent to 16 gpm/sf loading). Run 14 terminated earlier for PF 1 due to a plant-wide power failure.

Week 6: Pilot Runs 16 through 18 were completed. Runs 16 and 17 tested system performance at 20 gpm/sf of DAF loading rate and the same chemical doses. The clarified water flow rate was accomplished by modifying the overflow piping between flocculation basins and DAF so that no overflow occurred when raw water flow was increased to approximately 80 gpm. Run 18 was a duplicate run of the optimal test condition – 16 gpm/sf of DAF loading.

Week 7: This was a week outside of the original testing plan. The WTP staff conducted additional experimental runs to determine the effectiveness of flocculation without DAF during an algae bloom condition. These were tested in Runs 19 and 20 where raw water was still fed to the flocculation and DAF with typical chemical addition, but the DAF recycle pump and air compressor were turned off. The purpose of Runs 21 and 22 was to provide a baseline comparison between the pilot filters and plant filters. Plant flocculated water was fed to the pilot filters and plant filters. Both sets of filters were operated at the same loading rates (5 and 6 gpm/sf). The effluent headloss, turbidity, particles, and filter run times were compared.

TABLE 3-4
Pilot Test Runs and Conditions

Week	Run	Duration	Raw Water Flow (gpm)	Floc Time (min)	Alum Dose (mg/L)[a]	Polymer Dose (mg/L)[a]	DAF Influent Flow (gpm)	DAF Loading (gpm/sf)	DAF Recycle Rate[a]	Pilot Filter 1 Loading (gpm/sf)	Pilot Filter 2 Loading (gpm/sf)	Pilot Filter 3 Loading (gpm/sf)	Note
1	1	15:30 8/10 - 14:45 8/12	63	5	10	-	40	10	12%	5	6	7	DAF @ 10 gpm/sf, alum
2	2	17:00 8/12 - 12:00 8/13	63	5	10	-	40	10	12%	-	5	6	Repeat 10 gpm/sf run, alum
	3	14:45 8/14 - 8:00 8/15	63	5	10	-	40	10	12%	-	5	6	Repeat 10 gpm/sf run, alum
	4	15:05 8/15 - 12:25 8/16	63	5	10	-	40	10	12%	5	6	7	Repeat 10 gpm/sf run, alum
	5	14:50 8/16 - 11:40 8/19	63	5	10	-	40	10	12%	5	6	7	Repeat 10 gpm/sf run, alum
3	6	14:10 8/19 - 10:05 8/22	63	5	10	0.1-0.2	40	10	12%	5	6	7	DAF @ 10 gpm/sf, alum & polymer
	7	16:10 8/22 - 6:35 8/23	63	5	10	0.1-0.2	40	10	12%	5	6	7	Repeat 10 gpm/sf, alum & polymer
	8	12:05 8/23 - 21:10 8/25	63	5	10	0.35	40	10	12%	5	6	7	Repeat 10 gpm/sf, alum & polymer
	9	8:10 8/26 - 6:05 8/28	63	5	11	0.3	40	10	12%	5	6	7	Repeat 10 gpm/sf, alum & polymer
4	10	15:10 8/29 - 4:40 8/30	63	5	11	0.3	56	14	12%	5	6	7	DAF @ 14 gpm/sf, both chemicals
	11	13:45 8/30 - 16:25 9/1	63	5	11	0.3	56	14	12%	5	6	7	Repeat 14 gpm/sf run
	12	9:00 9/2 - 9:00 9/4	63	5	11	0.3	56	14	12%	5	6	7	Repeat 14 gpm/sf run
5	13	9:45 9/4 - 8:10 9/6	72	4.4	11	0.3	64	16	11-12%	5	6	7	DAF @ 16 gpm/sf
	14	14:50 9/6 - 13:10 9/7	72	4.4	11	0.3	64	16	11-12%	5	6	7	Repeat 16 gpm/sf run
	15	14:05 9/7 - 8:10 9/9	72	4.4	11	0.3	64	16	11-12%	5	6	7	Repeat 16 gpm/sf run
6	16	16:50 9/9 - 3:45 9/11	78	8	10	0.4	78	20	12%	5	6	7	DAF @ 20 gpm/sf
	17	8:50 9/12 - 3:45 9/14	78	8	10	0.4	78	20	12%	5	6	7	Repeat 20 gpm/sf run
	18	8:00 9/15 - 15:50 9/17	72	4.4	10	0.3	64	16		5	6	7	Optimal run @ 16 gpm/sf
7	19	17:10 9/17 - 5:40 9/18	72	4.4	10	0.3	64	16		5	6	7	No DAF recycle
	20	11:40 9/19 - 22:50 9/19	63	5	10	0.2	40	10		5	6	7	No DAF recycle
	21[b]	9:50 9/20 - 2:25 9/21	-	-	-	-	-	-		5	6	7	Post-pilot Filter Comparison
	22[b]	11:00 9/21 - 3:20 9/22	-	-	-	-	-	-		5	6	7	Post-pilot Filter Comparison

Notes:

[a] The listed parameters were average values or range measured. The actual values in the pilot testing varied around the values shown due to the accuracy of the instrument and equipment in the real operation.

[b] Pilot filters and plant filters were tested at the same loading rates with plant flocculated raw water. DAF was not in operation.

SECTION 4

Testing Results

4.1 Flocculation Performance

Two 2-stage flocculation basins were installed upstream of the DAF. After chemical injection, raw water passes through an in-line mixer and then enters one or two of the flocculation basins. Two important operating parameters, flocculation time and mixing intensity, were evaluated during the pilot testing. Table 4-1 summarizes these parameters at varied influent flow rates.

TABLE 4-1

Flocculation Operating Conditions during Pilot Testing

Floc Influent Flow (gpm)	Number of Duty Floc Train	Floc Time (min)	Stage 1 G (1/s)	Stage 2 G (1/s)	Stage 1 GT	Stage 2 GT
63	1	5	135	68	20,000	10,000
72	1	4.4	135	68	18,000	8,900
78	2	8	135	68	33,000	16,000

During the test runs with DAF loading rates of 10 through 16 gpm/sf, only one flocculation train was in service. The total detention time (flocculation time) with one flocculation train was between 4.4 and 5.0 minutes. When two flocculation basins were used at DAF loading rate of 20 gpm/sf (influent flow increased to 78 gpm), the flocculation time was increased to about 8 minutes. This was done to ensure adequate flocculation time was available at this peak loading. With a single floc train in service, the detention time would have been 4 minutes or less.

Typical detention times for conventional coagulation/gravity settling processes are 30 to 45 minutes and three stages. For DAF, most WTPs have 10 minutes of flocculation time with two stages at maximum flow. During this pilot, it was demonstrated that short flocculation times during moderate water temperatures (15 to 20 degrees Celsius) did not affect the DAF and filter performance based on the discussion below. Visual observations of the floc formed with 5 minutes flocculation time and the mixer speeds above show a pin-floc that is good for flotation.

Mixing intensity within the basins is typically represented by velocity gradient (G) or the product of G and detention time (GT). The typical G values for two-stage tapered floc basins range from 70 to 120 1/s (stage 1) and 40 to 60 1/s (stage 2) for DAF processes. The GT values presented in Table 4-1 resulted in G values in these ranges.

4.2 Dissolved Air Flotation Performance

Roberts had a dedicated operator for their pilot trailer throughout the testing. The operator was responsible for controlling raw water to the flocculation tanks, setting up the appropriate chemical addition, controlling appropriate flow to the DAF, optimizing the flocculation and DAF operation and accurate operation of the equipment and instrument within the trailer. The major O&M activities involved include:

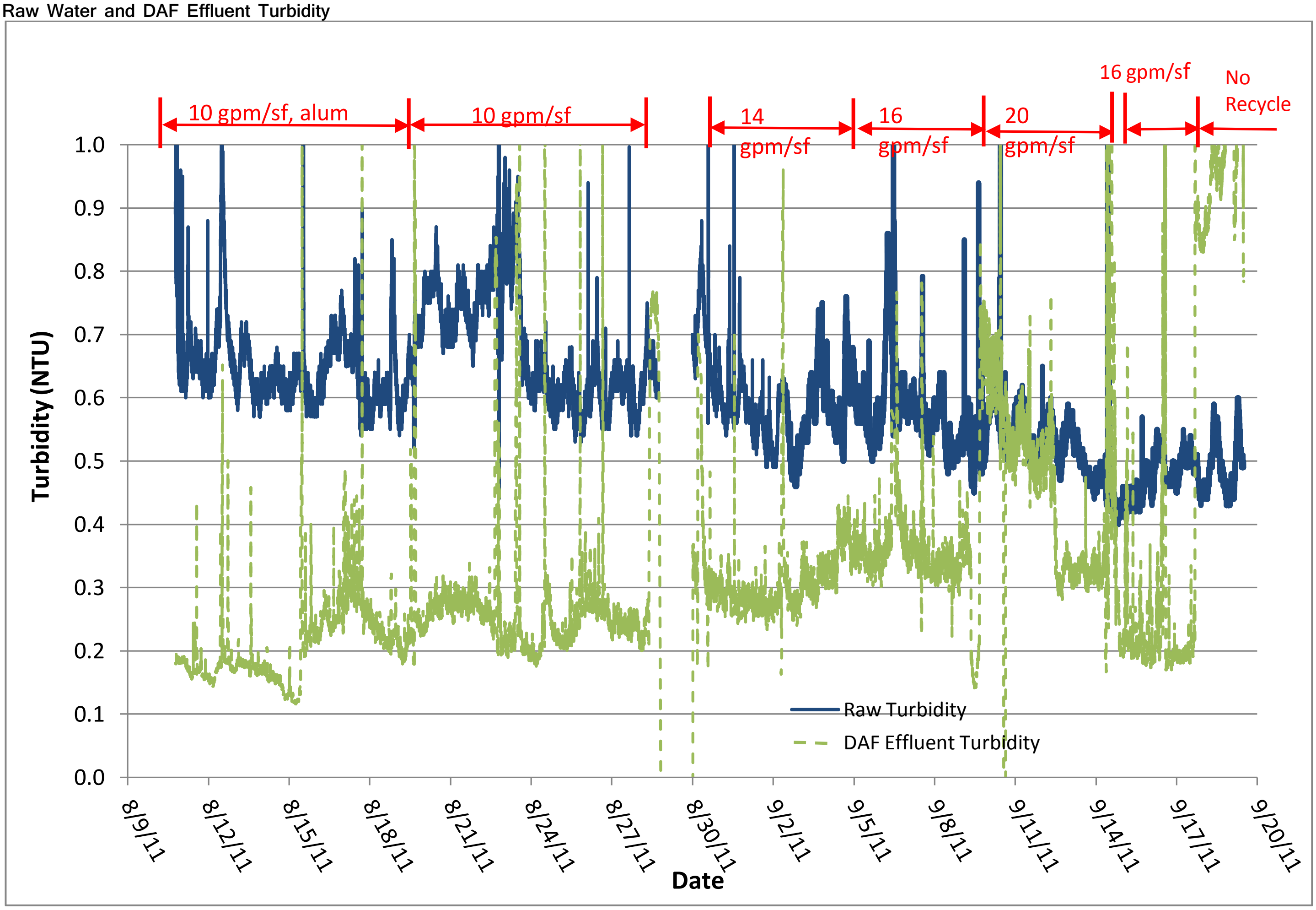
- Set up and calibrate chemical metering pumps each time before raw water flow rate changed.
- Change out the injection nozzles at the bottom of the DAF tank to obtain the desired DAF recycle rate when DAF loading rates changed.
- Modify the overflow piping between flocculation and DAF before 20 gpm/sf DAF loading was tested.

Overall, the flocculation and DAF had a fairly consistent and satisfactory performance throughout the testing.

4.2.1 Turbidity

Figure 4-1 shows the turbidity of raw water and DAF effluent during the entire pilot testing. The observed DAF effluent turbidity spikes occurred when the DAF system was shut down for maintenance.

FIGURE 4-1
Raw Water and DAF Effluent Turbidity



The trends indicate that raw water turbidity during the first 10 days ranged between 0.6 and 0.7 NTU, then increased to between 0.7 and 1.0 NTU from August 19 to 23, 2011. After that date, it reverted to the 0.6 to 0.7 NTU range. During the later stage of the testing, raw water turbidity gradually dropped to below 0.6 NTU and as low as 0.4 NTU at the end of the testing.

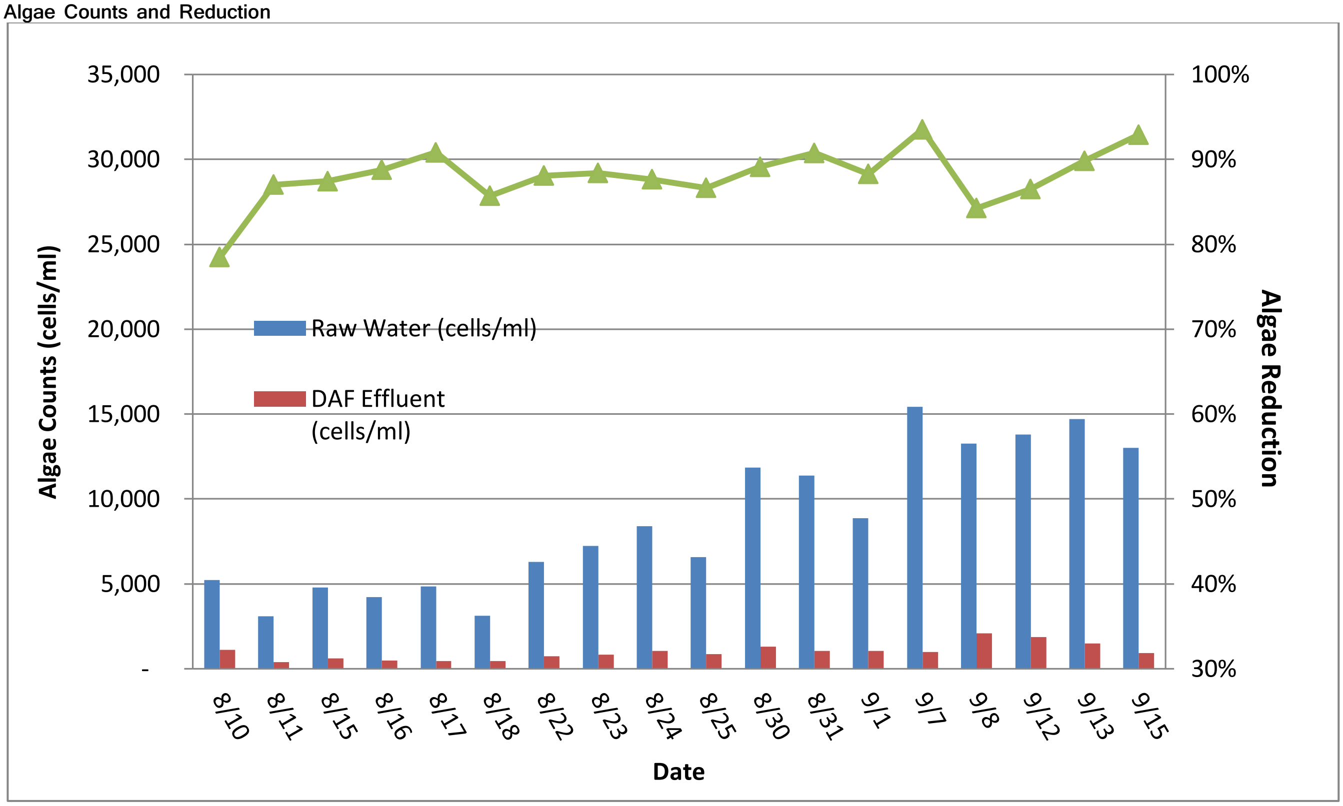
When DAF was loaded at 10 gpm/sf, the DAF effluent turbidity was initially below 0.2 NTU for about a week then increased to between 0.2 and 0.3 NTU range. It appeared that the DAF effluent turbidity levels were independent of raw water turbidity and polymer addition. However, the DAF effluent turbidity did slightly increase when DAF loading rate increased. For example, when DAF loading rate was 14 gpm/sf, the average DAF effluent turbidity was about 0.3 NTU. When DAF loading rate increased to 16 gpm/sf, the DAF effluent turbidity increased to between 0.3 and 0.4 NTU. In addition, when DAF loading further increased to 20 gpm/sf, the DAF effluent turbidity was almost at the same level as raw water during the first 20 gpm/sf run and then reduced to 0.3 and 0.35 NTU range in the second 20 gpm/sf run. During the optimal run at 16 gpm/sf DAF loading, the DAF effluent turbidity was back to the level obtained at the beginning of the testing, which is approximately 0.2 NTU. When DAF recycle pump was turned off, the DAF effluent turbidity jumped higher than raw water turbidity, which is over 1 NTU most of the time. This high effluent turbidity was likely caused by the floc that suspended in the effluent when the DAF did not work properly.

Except during the first 20 gpm/sf run where the DAF effluent turbidity was close to raw water turbidity, DAF consistently produced effluent with turbidity below 0.5 NTU, which was the DAF turbidity performance goal.

4.2.2 Algae

Daily algae counts in raw water and DAF effluent during the pilot testing are from the grab samples collected by WTP staff and counted by WWU. Note the algae counting approach for the pilot test samples was different from that used for the routine raw water algae monitoring. The algae counting during the pilot testing included all algae in whole water samples. It involved settled raw water counts with full taxonomic identification and estimation of cell density in cyanobacteria colonies. While the routine algae monitoring, which provided the basis for raw water historical algae counts, utilizes 20 µm plankton net tows to collect only large cells. In addition, the counting was to the level of cells or colonies identified to division. Therefore, the historical algae data are not comparable to the algae data obtained during the pilot testing. Figure 4-2 shows the daily algae counts during the pilot testing. It shows that raw water algae counts increased as the testing proceeded. The highest value (30,665 cells/mL) occurred at the end of the test. Compared to raw water algae counts, DAF effluent appeared to have a relatively stable algae count. The algae reduction by DAF ranged from 78 to 95 percent, with an average of 88 percent, which is below the algae reduction goal of 95 percent. However, the removal of algae by the DAF pilot system is still significant, and the reduction in algae to the filtration process has a significant impact on filtration performance, as detailed later in this report.

FIGURE 4-2
Algae Counts and Reduction



During the testing, the handheld fluorometer was used to obtain the daily readings of chlorophyll a and Phycocyanin of raw water and DAF effluent. The instrument gave relative values that are supposed to be proportional to the measured fluorescence compared to an adjustable secondary standard. The intent of using the handheld fluorometer is to provide an easier way to quantify the algae relatively by tracking the relative chlorophyll a or phycocyanin values in the water. Figure 4-3 shows the comparison between chlorophyll a counted by WWU and relative chlorophyll a measured in the plant lab using the handheld fluorometer. Note that chlorophyll a counted by WWU has a unit of µg/L, while the relative chlorophyll a does not have a unit. Despite of some issues with the handheld instrument repeatability, two sets of measurements have shown a very consistent trend. Table 4-2 shows the removal efficiencies of algae, chlorophyll a, and phycocyanin obtained using different methods. They also showed general agreement among each method.

FIGURE 4-3
Raw Water Chlorophyll a Measurement Comparison

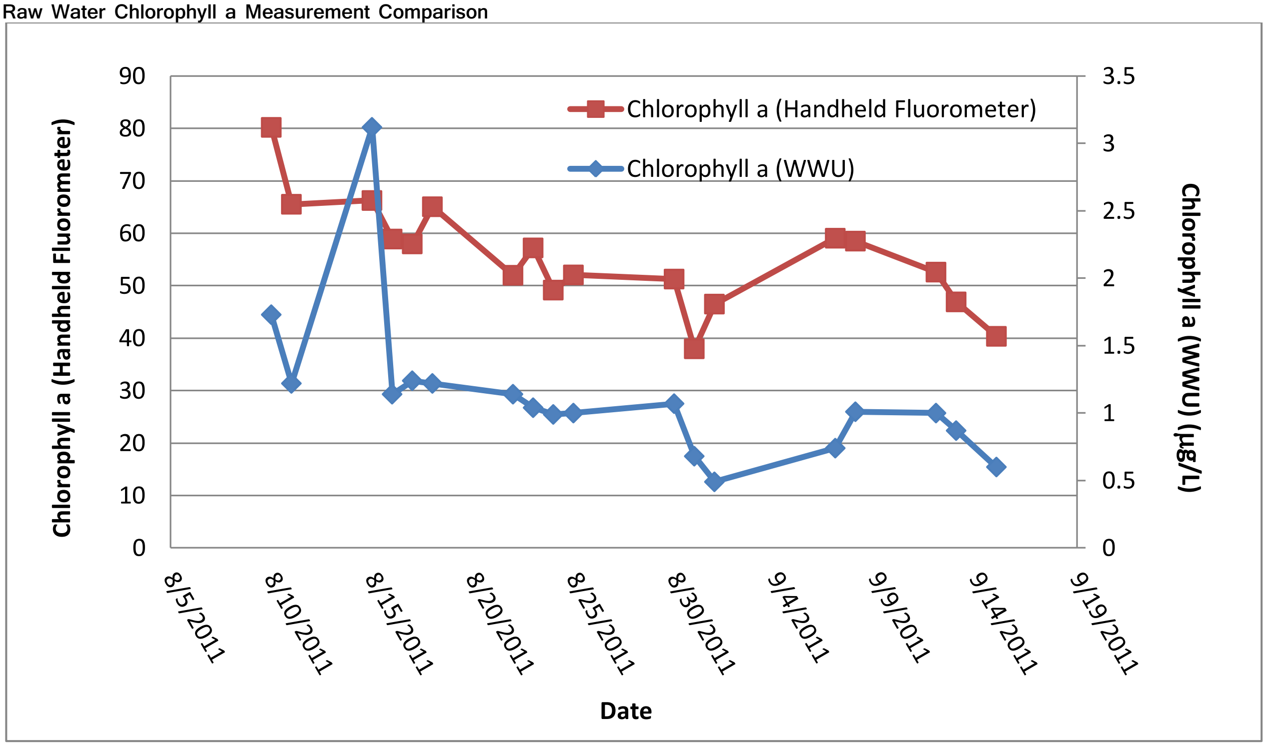


TABLE 4-2

Removal Efficiency Comparison of Algae Counts by Different Methods

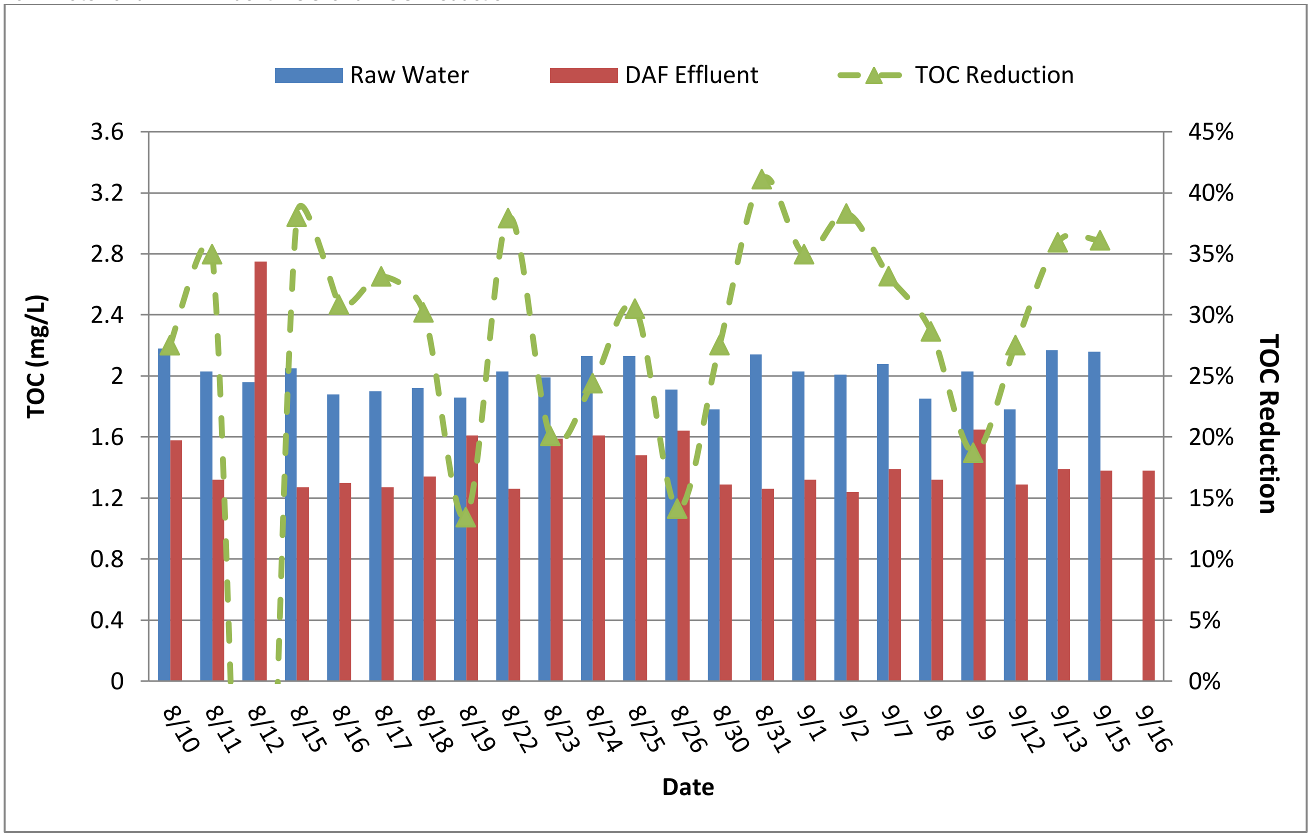
	Algae Removal (WWU)	Chlorophyll Removal (WWU)	Chlorophyll Removal (handheld fluorometer)	Phycocyanin Removal (handheld fluorometer)
Average	88%	86%	72%	48%
Max.	95%	97%	84%	98%
Min.	78%	40%	15%	14%

4.2.3 TOC/DOC

TOC is a primary measurement of organic content in water supplies and a measurement of disinfection by-product precursors, which are organic compounds that can combine with chlorine disinfectant to form disinfection by-products. The City currently meets the regulatory standards for disinfection by-products and is not expected have difficulty meeting these standards anytime soon. As a result, TOC/DOC removal was not a primary objective for this pilot testing and the pilot testing was not optimized for TOC/DOC removal. However, during the pilot test influent and effluent TOC/DOC concentrations were measured. The reason for monitoring TOC/DOC during the pilot testing is that the addition of a clarification process such as DAF to the existing in-line filtration system could potentially subject the City to TOC removal requirements under the Stage 1 Disinfection by-product rule (DBPR).

Grab samples were also collected daily for TOC/DOC measurement. Raw water TOC and DOC data from the first 13 days indicated that over 90 percent of TOC was DOC. Therefore, only TOC was measured afterwards. Figure 4-4 shows the raw water and DAF effluent TOC data and TOC reduction by DAF. The reduction ranged from 14 to 40 percent. No correlation between TOC reduction and DAF loading rates was observed.

FIGURE 4-4
Raw Water and DAF Effluent TOC and TOC Reduction



Enhanced coagulation is a requirement under the Stage 1 DBPR (U.S. Environmental Protection Agency [USEPA], 1998). For the rule, USEPA developed a matrix (Table 4-3) to determine the amount of TOC reduction required in a clarification process. The matrix is based on the amount of raw water TOC present and on the alkalinity of the source water.

TABLE 4-3
Required Removal of TOC by Enhanced Coagulation

	Source Water Alkalinity (mg/L as CaCO3)		
Source Water TOC (mg/L)	**0-60**	**>60-120**	**>120**
> 2.0 - 4.0	35%	25%	15%
> 4.0 - 8.0	45%	35%	25%
> 8.0	50%	40%	30%

Source: USEPA, 1998

The average raw water alkalinity of the Whatcom Falls WTP was 20.7 mg/L as $CaCO_3$ and the average raw water TOC was higher than 2.0 mg/L. According to Table 4-3, the required removal of TOC by enhanced coagulation would be 35 percent. One of the alternative compliance criteria set forth by USEPA in the Stage 1 D/DBPR is that if the finished water (post-filtration) TOC is less than 2.0 mg/L, the plant would be exempt from meeting the 35 percent removal requirement for TOC removal in enhanced coagulation. Based on the historical plant filter effluent TOC data, the post-filtration water from Whatcom Falls WTP would easily be below 2.0 mg/L; therefore, the WTP would qualify for the exemption. The additional removal of TOC in the clarification process may reduce the formation of disinfection by-products (DBPs). To confirm this potential reduction, one Simulated Distribution System (SDS) test was conducted during the pilot testing. Results of the SDS testing are presented in Section 4.3.

4.2.4 Other Water Characteristics

Other water characteristics that could help evaluate DAF performance include pH, apparent color, metal (iron, manganese, and aluminum) and UV254. Table 4-4 summarizes the data analyzed by the WTP lab during the pilot testing.

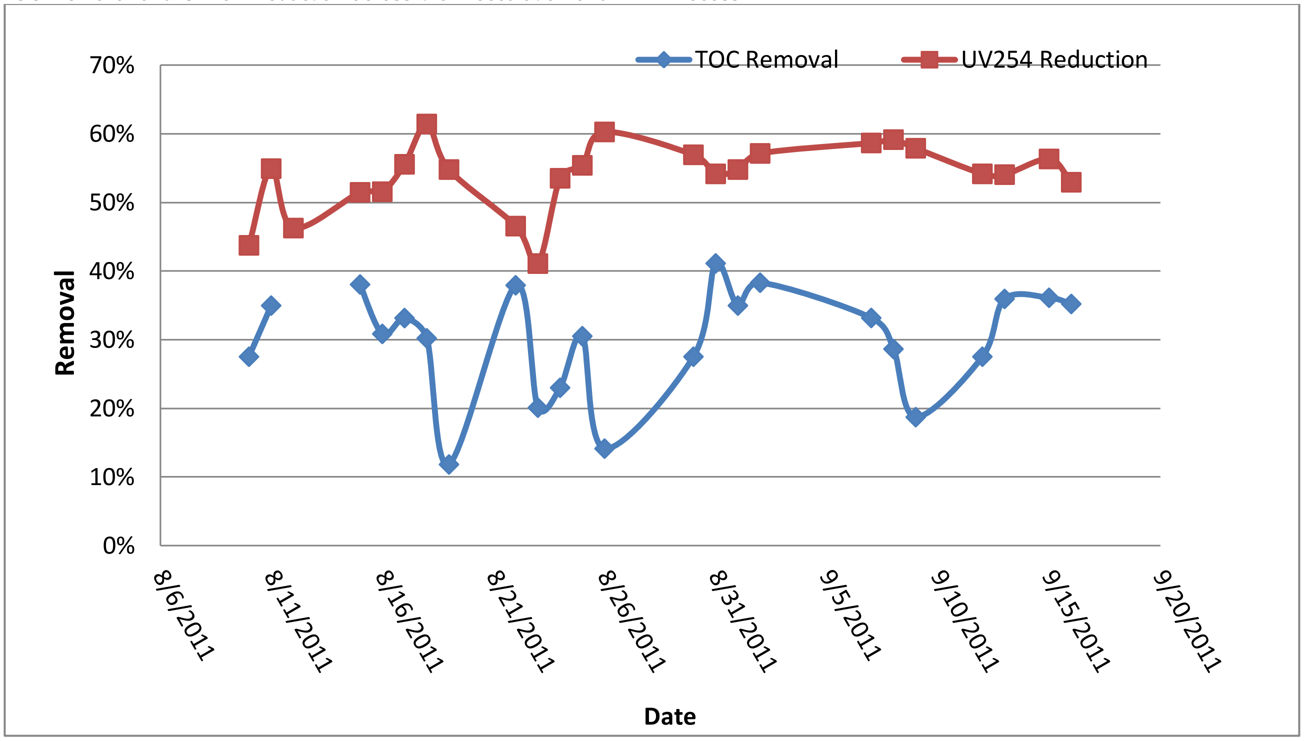
TABLE 4-4
Other Characteristics of Raw Water and DAF Effluent

	Raw Water				DAF Effluent			
	Average	Minimum	Maximum	Number of Data Points	Average	Minimum	Maximum	Number of Data Points
pH (S.U.)	7.40	7.07	7.61	46	6.85	6.54	7.55	46
Apparent Color (C.U.)	11	1	19	45	7	0	20	44
Alkalinity (mg/L as $CaCO_3$)	19.6	0.0	23.1	26	14.0	13.4	20.9	24
Total Iron (mg/L)	0.014	0.000	0.040	5	0.008	0.000	0.020	5
Dissolved Iron (mg/L)	0.006	0.000	0.020	5	0.004	0.000	0.010	5
Total Manganese (mg/L)	0.004	0.000	0.010	5	0.003	0.000	0.009	5
Dissolved Manganese (mg/L)	0.002	0.000	0.006	5	0.002	0.000	0.005	5
Total Aluminum (mg/L)	0.030	0.001	0.192	44	0.111	0.077	0.653	44
Dissolved Aluminum (mg/L)	0.009	0.000	0.037	43	0.020	0.001	0.042	43
UV254 (1/cm)	0.035	0.028	0.039	46	0.016	0.011	0.027	46

Based on the table, alum addition during the testing lowered pH down to 6.5. This was consistent with titration study performed before the pilot testing. Apparent color of DAF effluent varied in a much wider range compared to raw water. This was likely caused by alum floc that occasionally captured in the DAF effluent sample. Alkalinity was reduced from approximately 20 mg/L as $CaCO_3$ to 14 mg/L as $CaCO_3$ from the addition of alum as coagulant. Dissolved and total iron and manganese were virtually non-detects on the raw and DAF effluent samples. Total and dissolved aluminum were measured to ensure that complete coagulation was occurring and that overdosing was not happening. Significant concentrations of dissolved aluminum would be an indicator of this. The low level of aluminum (<0.2 mg/L total aluminum and < 0.04 mg/L dissolved aluminum) detected in raw water was likely from leakage coming from the common effluent channel for both plant rapid mix basins. Water in the effluent channel was flocculated water from the duty rapid mix basin. Some of the flocculated water may have leaked back to the rapid mix basin no. 1, which was used as pilot test raw water wet well. DAF effluent had slightly higher total and dissolved aluminum levels than raw water, due to the addition of alum. The resulting aluminum level in the DAF effluent was still too low to cause any concern.

UV254 was measured as an on-line surrogate to assess the efficiency of coagulation in reducing TOC. UV254 is typically used in the water industry as a surrogate for TOC because in many waters a direct relationship can be developed for TOC to UV254. Raw water UV254 during pilot testing was relatively stable (in the range of 0.028 to 0.039 1/cm). There was between 41 and 61 percent of UV254 reduction across the flocculation and DAF process. Figure 4-5 shows TOC removal and UV254 reduction across the flocculation and DAF process. No discernable relationship was observed between TOC and UV254 removal, likely due to the low organics levels in raw water.

FIGURE 4-5
TOC Removal and UV254 Reduction across the Flocculation and DAF Process

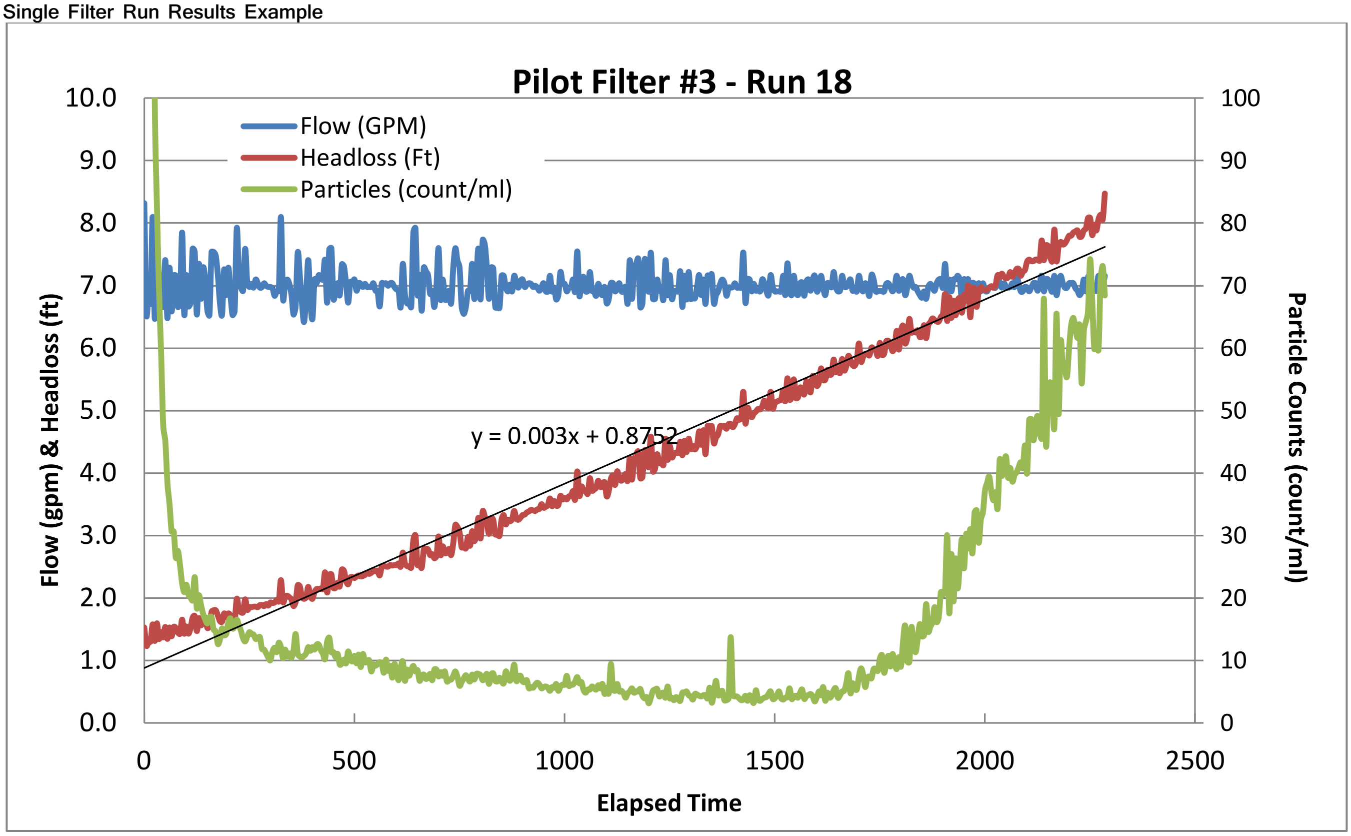


UV254 is also important to establish specific ultraviolet absorbance (SUVA), which can be an indicator of coagulant performance for organics removal. Typically, SUVA values less than 2 L/mg-m indicates that coagulation is optimized for organics removal and very little additional organics can be removed by continued optimization of coagulation. The SUVA is calculated by dividing the ultraviolet absorbance of the sample (in 1/cm) by the DOC of the sample (in mg/L) and then multiplying by 100 cm/m. The DAF effluent SUVA during testing ranged from 1.0 to 1.9 L/mg-m, with an average of 1.3 L/mg-m. Therefore, there would be little gained for organics removal by adding additional coagulant.

4.3 Filter Performance

The WTP staff was responsible for pilot filter operation. Filter effluent turbidity and particle counts, as well as the headloss across the filter medium were monitored and recorded. Figure 4-6 provides an example of how each filter performance was trended and evaluated. Filter run time, ripening time, and effluent quality were evaluated based on the recorded data.

FIGURE 4-6
Single Filter Run Results Example

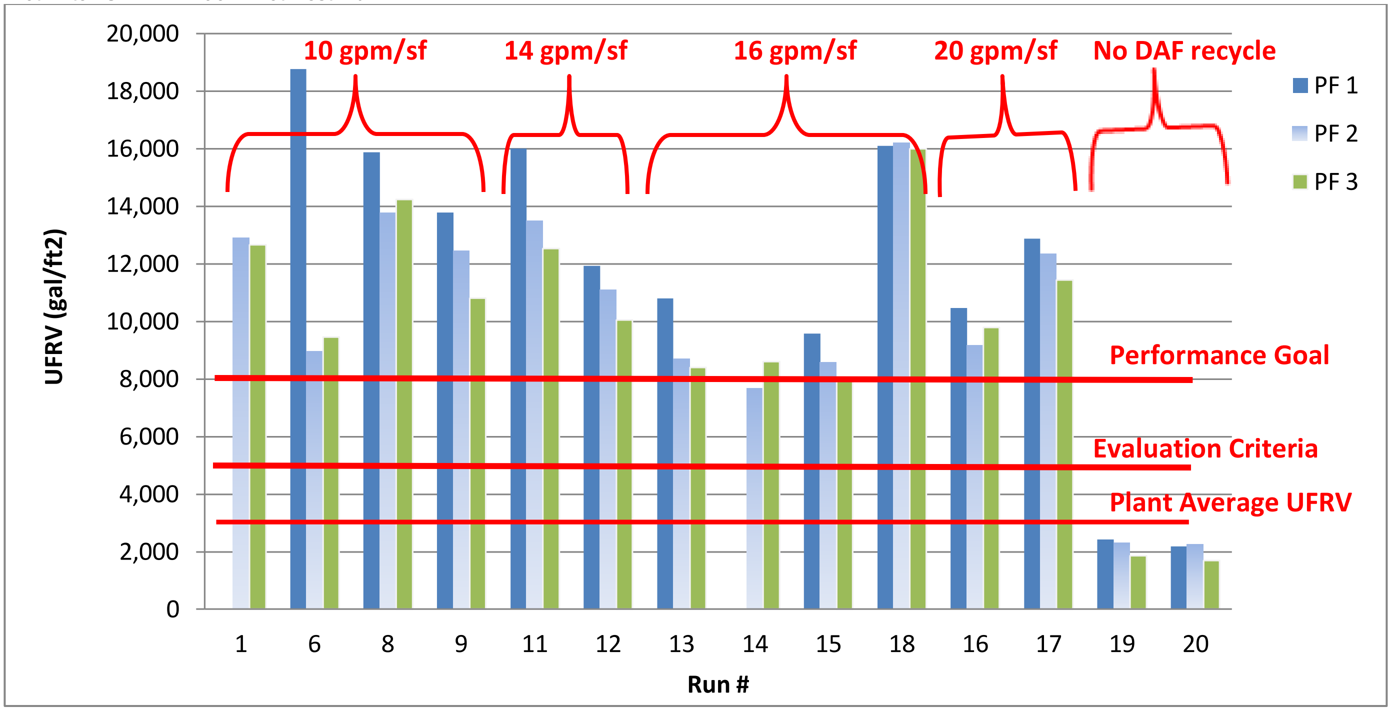


4.3.1 Unit Filter Run Volume

Unit filter run volume (UFRV) is the measure of the production capability of a filter. It is the amount of water treated between backwash events in gallons per square foot (gal/ft^2). This parameter is utilized to compare productivity/performance of filters running at different loading rates. A criterion value of 5,000 gal/ft^2 (considered a minimum to assess DAF success) was used for this testing, with a performance goal of 8,000 gal/ft^2 identified for this pilot test. The performance goal of 8,000 gal/ft^2 was established because it reflects an average of the highest UFRV values the City observes during a typical year – representing relatively favorable treatment conditions.

Figure 4-7 shows the UFRV of the three pilot filters in pilot runs that were completed to breakthrough. On almost every run, the pilot filter UFRV was based on particle breakthrough greater than 100 particles/mL. They are grouped based on the DAF loading rates, which are shown at the top of the bar chart. The loading rates of three pilot filters were 5, 6, and 7 gpm/sf for PF 1, PF 2, and PF 3, respectively. There was an exception in Run 1 where PF 2 was loading at 5 gpm/sf and pilot filter 3 at 6 gpm/sf. Excluding the last two runs where the DAF recycle was turned off, all runs achieved UFRVs above 5,000 gpm/sf, which is the pilot evaluation criterion. All runs except pilot filter 2 in Run 14 achieved the UFRV above 8,000 gpm/sf, which is the pilot performance goal. The filter 2 UFRV in Run 14 was approximately 7,680 gpm/sf – essentially at the 8,000 gpm/sf goal). For comparison purposes, the average of the actual City WTP UFRV during the DAF pilot test period is shown as 3,000 gpm/ft^2 (UFRV ranged from 2,600 to 3,600 gal/ft^2). The plant filters are normally operated at about 3.5 gpm/sf loading. The pilot filters with the DAF pretreatment process had UFRVs 5,000 to 13,000 gal/ft^2 greater than the plant filters during the pilot test period. Note that the pilot filters were operated at a higher loading rate than the plant filters.

FIGURE 4-7
Pilot Filter UFRV in Each Pilot Test Run



No obvious correlation between the DAF loading rate or DAF effluent turbidity and the filter UFRV has been identified. For example, Runs 14 and 15 had relatively low UFRVs based on Figure 4-7. However, the DAF effluent turbidity during these two runs (from 14:50 September 6 to 8:10 September 9) from Figure 4-1 did not show obvious difference from turbidity in other runs. It appeared that other factors, such as particle count and size distribution in DAF effluent, might have impact that is more significant on filter run time.

When DAF recycle was turned off in Runs 19 and 20, the UFRV dropped dramatically to about 2,000 gal/ft^2. All filters were terminated for backwash due to the effluent turbidity breakthrough (0.07 NTU). Clearly, operating the DAF flocculation system and not operating the DAF recycle system to simulate complete DAF operation was not observed to be effective at improving filter performance.

4.3.2 Filter Effluent Turbidity

The filter effluent turbidities during steady-state operation for all pilot filters were low, below the turbidity breakthrough criterion. All the pilot filters had particle or headloss breakthrough earlier than turbidity breakthrough (0.07 NTU criterion). When a filter run was deemed completed (due to particle or headloss breakthrough), the filter effluent turbidity was 0.03 to 0.04 NTU.

In Runs 19 and 20, when DAF recycle was turned off, turbidity became the controlling factor to terminate the filter runs before the backwash. Again, this demonstrated the importance of the complete DAF process to ensure long filter life.

4.3.3 Filter Ripening Time

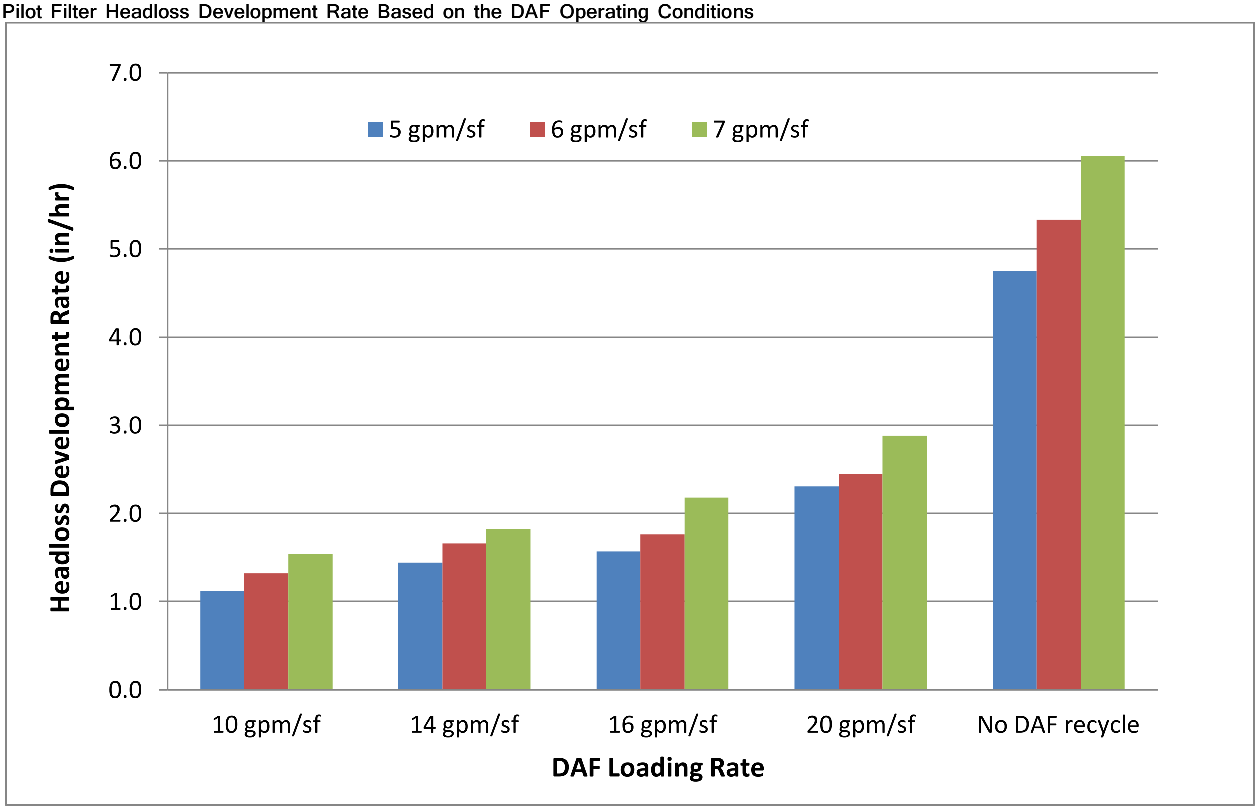
The filter ripening time is the amount of time before the filter is ready to produce water that meets a specified turbidity goal. The water produced by the filter before it is “ripened” is the amount of filter effluent that would go to waste. The ripening turbidity goal for this pilot testing was 0.1 NTU in less than 15 minutes.

The pilot filter effluent turbidity during testing was recorded in 5-minute intervals; therefore, the filter ripening time was determined to the nearest 5-minute interval. It was found that it took between 0 and 15 minutes for the filter effluent to drop below 0.1 NTU. Most of the runs were able to obtain less than 0.1 NTU during the first 5 minutes. Comparatively, the full-scale plant filters had ripening times of 5 minutes or less From this limited data, and the DAF-reduction of particles in the filter influent, ripening times could increase slightly in the future but are not expected to exceed 10 minutes. The difference between the current ripening time of 5 minutes versus a 10 minute ripening time, at a filter loading rate of 3.5 gpm/sf, results in a small reduction in the volume of water each individual filter produces of approximately 0.6 %.

4.3.4 Filter Headloss

During testing, filter headloss was monitored and the headloss development rate was determined on each filter on every run to provide a sense of how fast the headloss was built up at varied DAF and filter loading rates. Figure 4-8 shows the average rate for each filter during runs with the same DAF loading rates. It indicates that the rate of filter headloss development increased with increases in filter loading rate or DAF loading rates. The last set of columns on the figure show that when DAF recycle was turned off, the coagulated water fouled the pilot filters with a rate much faster.

FIGURE 4-8
Pilot Filter Headloss Development Rate Based on the DAF Operating Conditions



4.3.5 Particles Removal

Particles in the size larger than 2 μm were measured continuously. They are used as a surrogate for determining the likelihood of microbial breakthrough. Although particle counts and particle reduction are not regulated, many utilities have begun using particle counters to augment their turbidimeters to monitor filter effluent. Figures 4-9 and 4-10 show the average filter effluent particles counts and the log reduction of particles through the entire pilot process (including flocculation, DAF, and filters) in steady state for each run. These figures demonstrate that during the entire pilot testing, the particle counts in filter effluent averaged below 20 count/mL. In addition, the pilot system achieved greater than 2-log particle reduction during steady-state operation.

Particle counts also have value in observing the operation of filters as they approach and run through breakthrough. As mentioned previously, in most of the filter runs 100 counts/mL particle threshold value was exceeded before the headloss or turbidity threshold values were reached. Determining the filter run time and productivity based on this particle threshold provided a greater level of protection of the integrity of the process and finished water quality.

In every run, the particle breakthrough always occurred first for the filter with the highest loading (7 gpm/sf), then for the filter with the medium loading (6 gpm/sf). The filter with 5 gpm/sf loading had the latest particle breakthrough. This can be demonstrated by one example shown in Figure 4-11. The full-scale plant historically terminates filter runs based on headloss of 8.2 feet. At this termination point, the particle counts are typically well below 100 particles/ml.

The pilot filter particle breakthrough occurring well before terminal headloss demonstrates there may be potential for additional gains in filter productivity beyond which was demonstrated in this pilot test, with additional pre-treatment optimization to enhance particle retention on the filters. The other conclusion is that the pumping of the DAF effluent to the filters may have altered the size distribution of particles in the filter influent, thereby having an effect on the particle retention in the filters.

FIGURE 4-9
Pilot Filter Effluent Particle Counts in Each Run

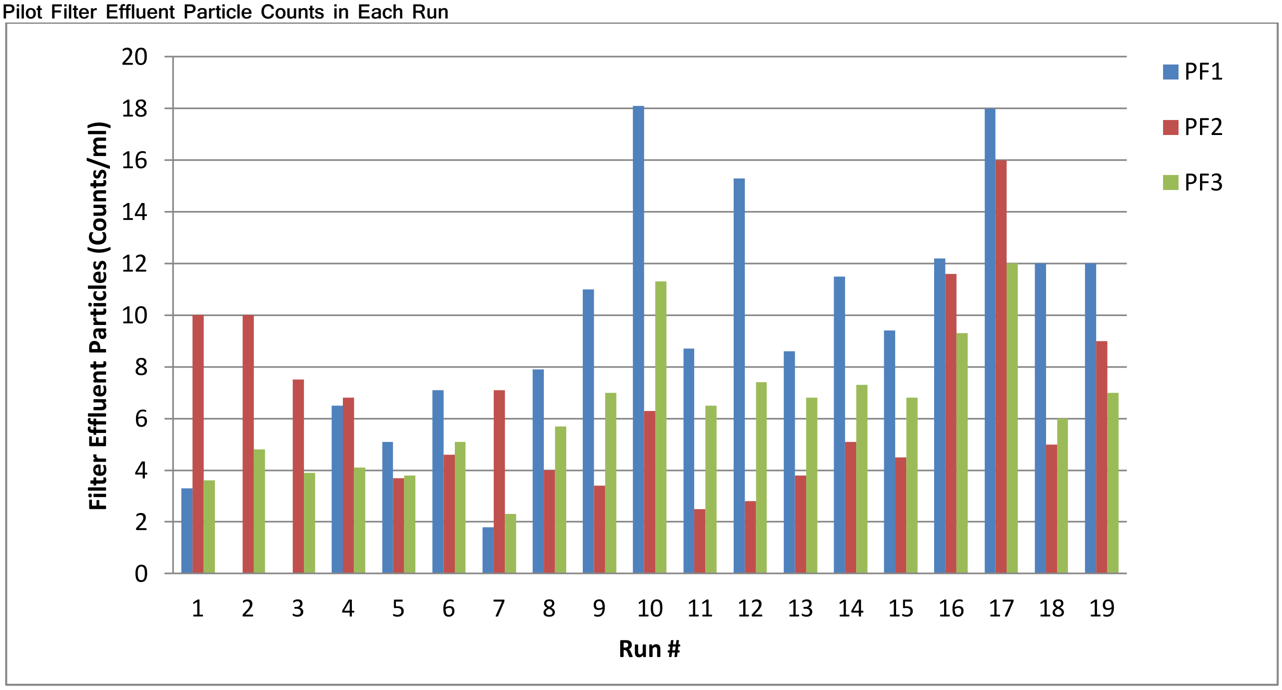


FIGURE 4-10
Particles Log Removal across the Entire Pilot Processes

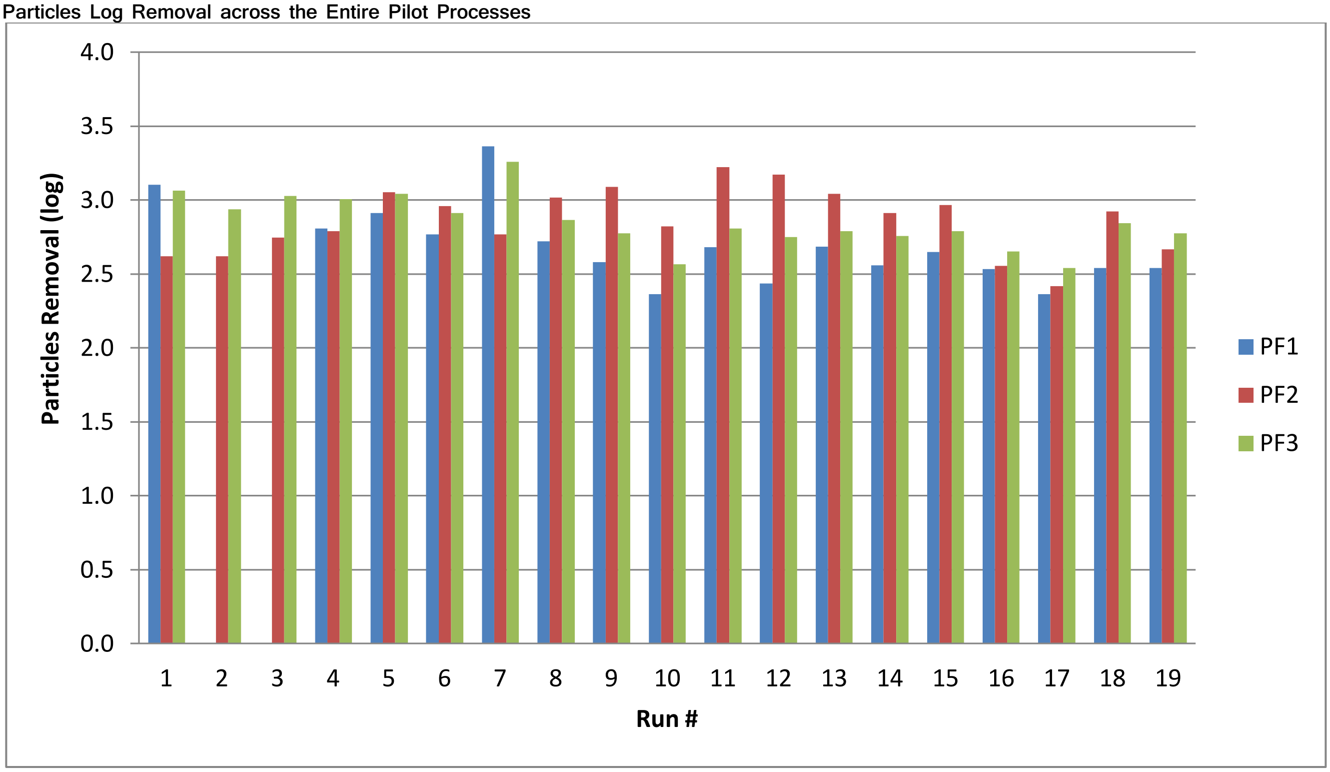
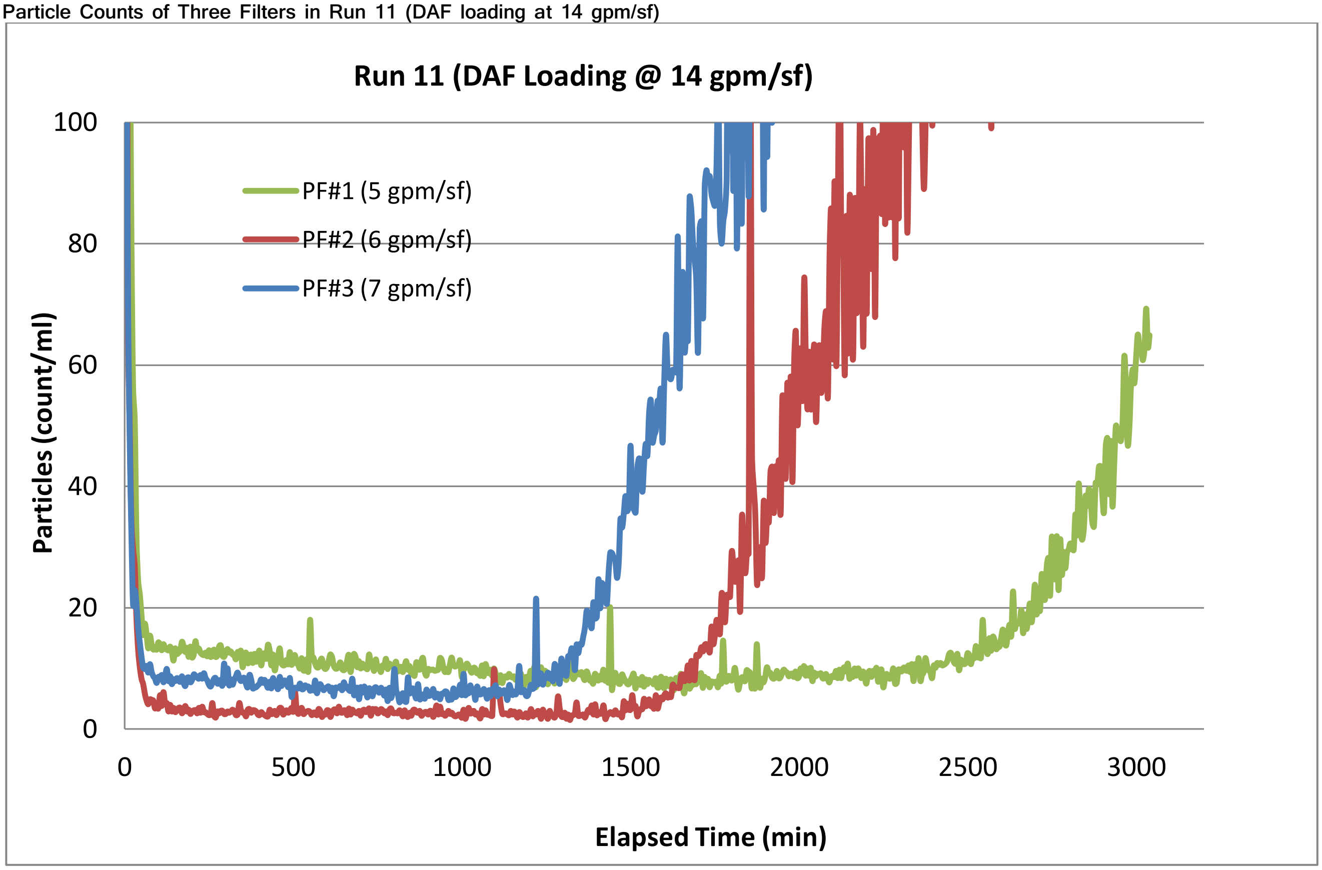


FIGURE 4-11
Particle Counts of Three Filters in Run 11 (DAF loading at 14 gpm/sf)



4.4 Simulated Distribution System Disinfection By-Products

TOC is a precursor compound. When it is combined with free chlorine used for disinfection, it can result in the formation of DBPs known as TTHMs and HAA5s. These compounds are regulated by the Washington Department of Health under the Stage 1 and Stage 2 disinfection by-product rule at concentrations of 80 parts per billion (ppb) and 60 ppb, respectively. The City has never exceeded these concentrations under the regulation's compliance method.

When TOC removal is enhanced, DBPs are typically reduced by two methods:

1. Less organic material in the treated water reduces the initial chlorine demand/decay, thereby making it possible in some cases to reduce the initial chlorine dose for disinfection and for distribution system residual.
2. Less organic material in the water results in less reactions to form DBPs

To determine the effects of the DAF system in removal of organics and the resulting DBPs, a sample of the filter effluent was taken on September 13, concurring with Run 17 of the pilot test, and the City's quarterly sampling for DBPs. The pilot filter effluent was shipped to CH2M HILL's Applied Sciences Laboratory to conduct SDS analysis. In this testing, a sample is dosed with free chlorine, and is held for prescribed times that correspond to water ages in the distribution system. At each time, the water is quenched of chlorine to stop the formation of DBPs and sent to the laboratory for determination of the DBP concentration.

For the SDS testing for the City, an initial dose of 1.5 mg/L of chlorine was chosen at 19 degrees Celsius and a pH of 7.4, with 1 day, 3 day, and 7 day holding times. The 1.5 mg/L dose of chlorine was chosen to ensure a minimum of 0.2 mg/L chlorine residual would remain after 7 days. While 7 days is excessive for the City's distribution system, it gives us a "worst-case" scenario to review.

Figures 4-12 and 4-13 show the results from the City's sampling and the laboratory SDS sampling. Some conclusions can be drawn from the data collected.

- Filter effluent TOC from the pilot filters was 1.09 mg/L against a TOC concentration on average of 1.3 mg/L from the plant filters. Therefore, the pilot filter effluent has less organic material to react.
- The SDS testing chlorine dose of 1.5 mg/L was significantly higher than the plant dose on the day of testing of 1.0 mg/L. Therefore, the testing is conservative in that more chlorine (approx 0.5 mg/L) may have been added than was required for a 3- to 4-day detention time.
- With the two variables above in consideration, a decrease was observed in TTHM formation of 25 percent at 1-day detention time between the current distribution system and the SDS sample. The 3-day SDS TTHM formations were at or below the 1-day detention time system samples.
- For HAA5s, the SDS samples were higher by 15 to 35 percent than the distribution samples. This can primarily be attributed to the biodegradation of HAA5s in the City's distribution system. This is evident in the small reduction in HAA5s from the Marietta (4-day) sample as compared to the 1- and 3-day system samples. In the SDS testing, this biological reduction could not be simulated.

FIGURE 4-12
Comparison of TTHM Results from the City's Sampling and the Laboratory SDS Sampling

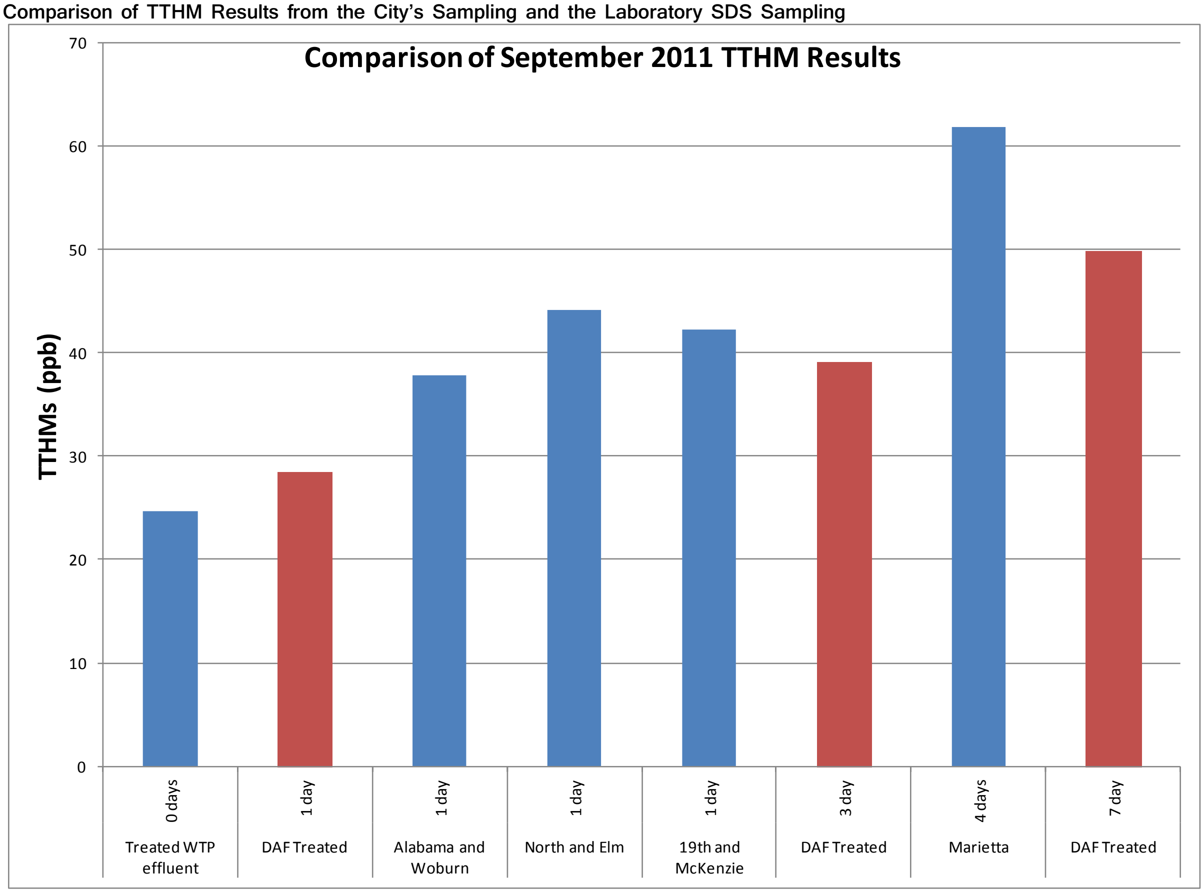
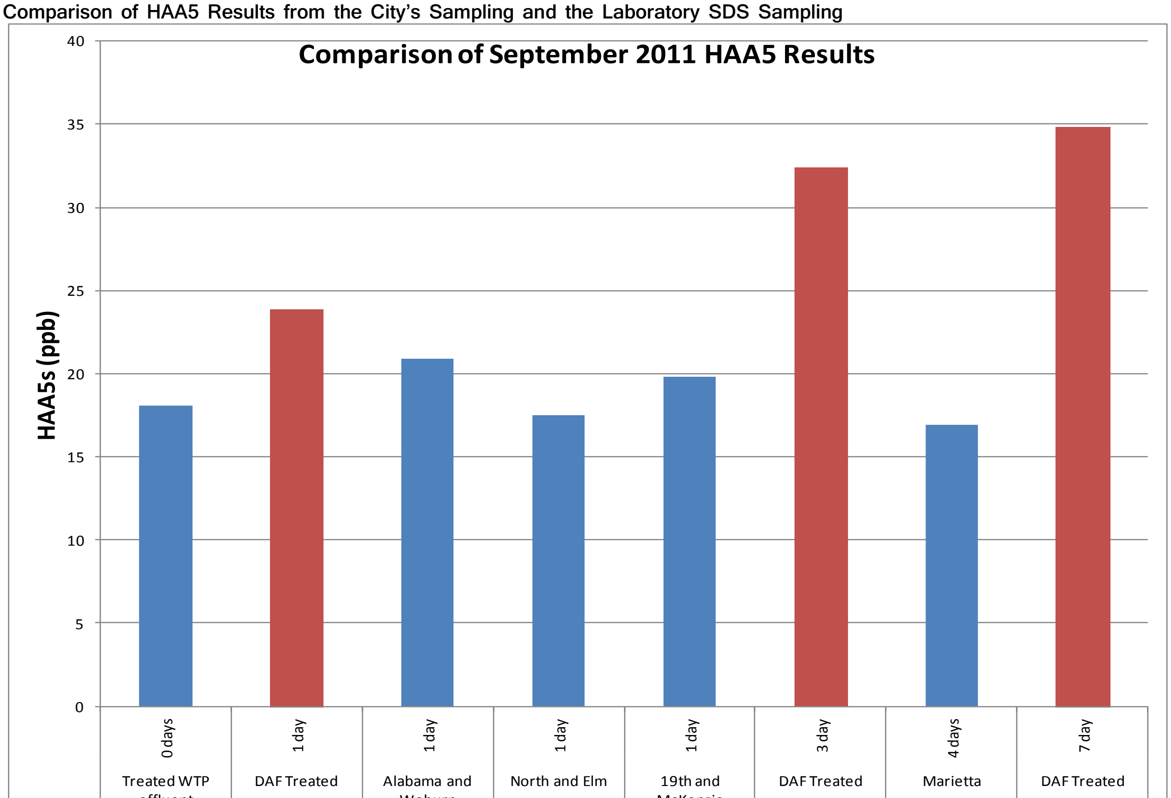


FIGURE 4-13
Comparison of HAA5 Results from the City's Sampling and the Laboratory SDS Sampling



4.5 Post-Pilot Filter Comparison

Two additional filter runs were conducted after the DAF and filter pilot testing. The purpose was to compare the performance of full-scale plant filters and pilot filters at the same loading rates. Three pilot filters were loaded at 5, 6, and 7 gpm/sf using the plant coagulated raw water – the same water feeding to the plant filters during normal operation. Two of plant filters were started at the same time and loaded at 5 and 6 gpm/sf. Particles, turbidity, and headloss were monitored.

The results of these two post-pilot tests were consistent. They showed the following:

- All pilot filter runs terminated on particle counts (over 100 count/mL), while both plant filter runs terminated on headloss (exceeded 8.2 feet of headloss). Based on these termination criteria pilot filters had 16 to 19 percent higher UFRV compared to plant filters, as shown in Figure 4-14. In another words, on average the pilot filters had 300 to 700 gal/ft^2 higher UFRV than the plant filters. The difference was within the reasonable range considering the scaling factor from the pilot filters to the plant filters. The other variable was that flocculated raw water gravity flows to the plant filters while it was pumped to the pilot filter. The shearing force imposed by the centrifugal filter feed pump may change the characteristics of the particles in the filter feed.
- The headloss buildup rates of the plant filters were higher than the rates of the pilot filters. As shown in Figure 4-15, in one of post-pilot runs, plant filter at 6 gpm/sf reached the headloss cutoff criterion (8.2 feet) after about 450 minutes of operation. It was followed by the plant filter operated at 5 gpm/sf, which had run time of approximately 660 minutes. Three pilot filters had slower headloss development.
- During the steady-state operation, the plant filter effluent particle counts were consistently lower than pilot filter effluent particle counts. Based on Figure 4-16, the plant filter effluent particle counts were always maintained below 12 count/mL, while the pilot filter effluent turbidity varied between 10 and 20 count/mL.
- Filter effluent turbidity levels were similar for pilot filters and full-scale plant filters. They ranged between 0.03 and 0.04 NTU throughout the testing.

FIGURE 4–14
Average UFRV of Plant Filters and Pilot Filters during Post-Pilot Filter Comparison Test

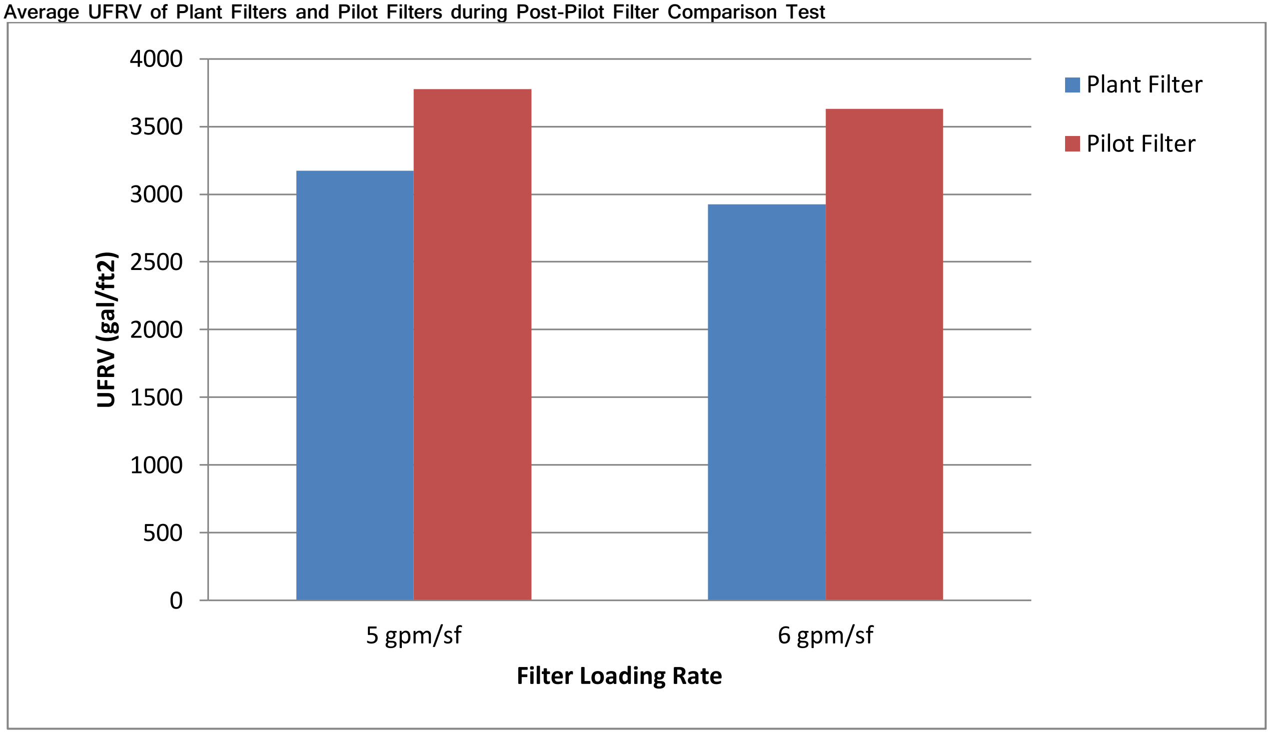


FIGURE 4-15
Filter Effluent Headloss during Post-Pilot Filter Comparison Test

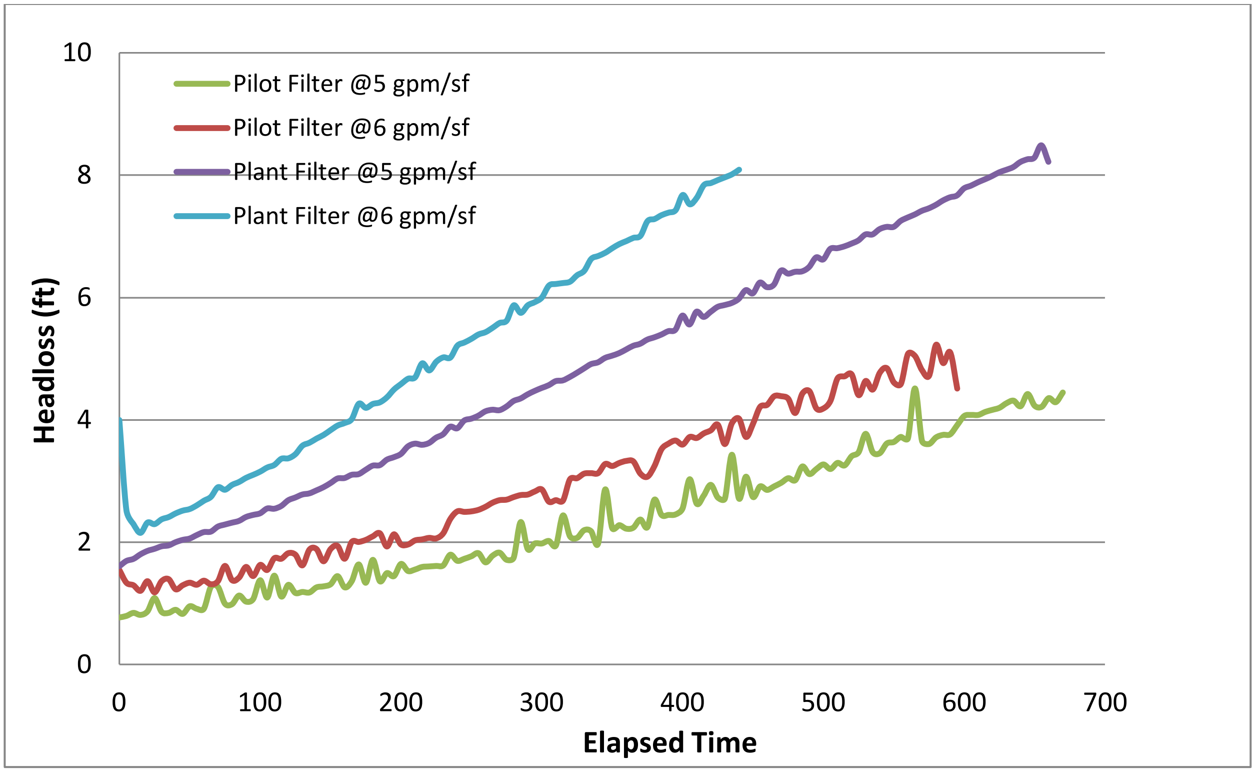
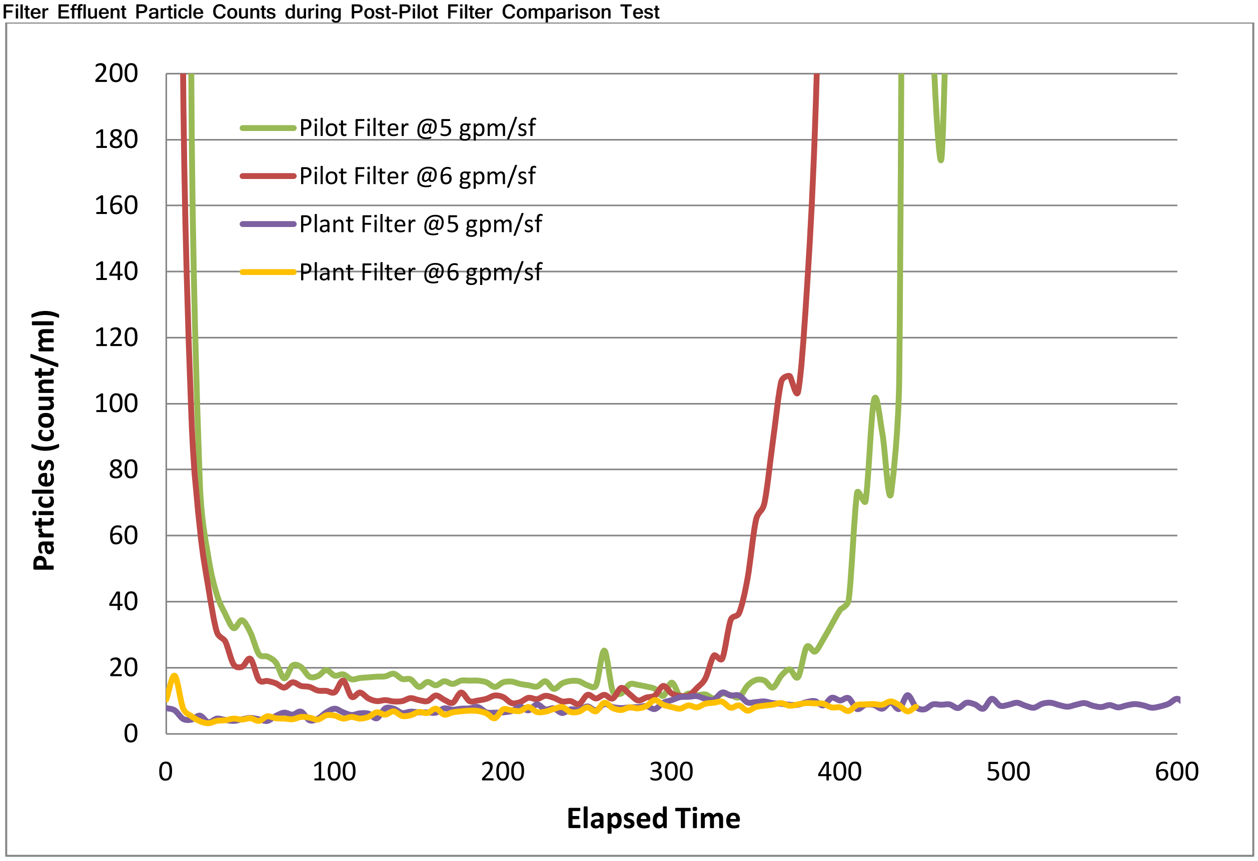


FIGURE 4-16
Filter Effluent Particle Counts during Post-Pilot Filter Comparison Test



SECTION 5

Conclusions

The pilot testing demonstrated that for the Lake Whatcom supply, DAF effectively removed algae, increased filter production, reduced TOC and color, and reduced the formation potential for TTHMs. In addition, specific results and conclusions are summarized below:

- The primary purpose of the pilot testing was to evaluate the performance of DAF on algae removal and filter production capacity. The testing was conducted during August and September to capture the most likely algal bloom period. The test demonstrated that DAF had exceptional performance at a wide range of loading rates. Besides algae removal, DAF also improved other water quality parameters, such as TOC, DOC, color and turbidity.
- Flocculation at 5 minutes detention time was adequate for DAF performance.
- There was no clear correlation between DAF loading rate and the DAF performance, or between DAF loading rate and pilot filter performance. Tests with DAF loading rate up to 20 gpm/sf were able to achieve UFRV close to or higher than 8,000 gal/ft^2.
- Pilot filters with DAF clarified water had superior performance during the testing than did the full-scale plant filters without DAF pretreatment – as measured by UFRV. The pilot filters had significantly higher UFRV (over 8,000 gal/ft^2) than did the plant filters, which had average UFRV values of approximately 3,000 gal/ft^2.
- The simulated distribution system test indicated that filtration with DAF pretreatment reduces the TTHM formation potential by over 25 percent.
- Table 5-1 summarizes the pilot test performance goals previously presented in the report. Results from the testing were added to the last column in the table to compare against the criteria and goals.
  - The 95% algae removal goal was established during planning phase based on observed performance of DAF in other high-algae water treatment applications. Meeting or not meeting this goal does not define success for the DAF process. Total algae removal through the DAF process ranged from 78 to 95 percent. This was slightly lower than the performance goal (>95 percent). However, the pilot testing was conducted with raw water algae at relatively low levels (< 12,000 cells/mL), which drove the percent removal lower than would have been anticipated for higher levels. Nevertheless, DAF-clarified water algae levels were consistently very low, which led to the superior UFRV performance summarized above. Improved UFRVs more directly indicate the success of the testing than algae reduction.
  - Clarified water turbidity varied between 0.2 NTU and 0.4 NTU in most runs (well below the performance goal), except in the first 20 gpm/sf run, where the clarified water turbidity was close to raw water. For this particular run accumulated floc was discovered to have clogged the turbidimeter and connecting tubing.
  - Pilot filter effluent turbidity during steady state was between 0.03 and 0.04 NTU, below the 0.05 NTU performance goal.
  - Although pilot filter effluent had higher particle count compared to the full-scale plant filters, pilot filter effluent particle counts during steady state were still lower than the performance goal of 20 count/mL. The particle reduction was between 2.4 and 3.4 logs, mostly at or above the 2.5 log reduction goal.
  - Pilot filter ripening time (the time needed to achieve a filter effluent turbidity of 0.1 NTU) was always less than the 15-minute performance goal. In most of the runs, the ripening time was less than 5 minutes.
  - Pilot filter UFRV was between 7,680 and 18,800 gal/ft^2. This well exceeded the evaluation criterion and approached or exceeded the performance goal of 8,000 gal/ft^2. This represents significant improvement of filter production in summer time.

TABLE 5-1
Performance Goals Compared to Actual Results for Whatcom Falls WTP Pilot Study

Sample Point	Parameter	Evaluation Criteria	Goal	Results
Clarified water	Total Algae Removal	--	>95% removal	78% - 95% [a]
Clarified water	Turbidity (steady-state)	<1.0 NTU	0.5 NTU	< 0.4 NTU [b]
Filter Effluent	Turbidity (steady-state)	<0.07 NTU	<0.05 NTU	0.03- 0.04 NTU
Filter Effluent	Turbidity spike (ripening)	0.2 NTU	<0.1 NTU	< 0.2 NTU
Filter Effluent	Particle counts (steady-state)	< 100 p/ml >2 μm	< 20 p/ml > 2 μm	< 20 p/ml
Filter Effluent	Particle removal (steady-state)	2-log	2.5 log	2.4 – 3.4 log
Filter Effluent	Ripening time	30 minutes	< 15 min. to <0.1 NTU	< 15 min
Filter Production	Unit Filter Run Volume	>5,000 gal/ft^2	>8,000 gal/ft^2	7,680 – 18,800 gal/ft^2

[a] The 95% algae removal goal was established during planning phase based on observed performance of DAF in other high-algae water treatment applications. Meeting or not meeting this goal does not define success for the DAF process. The pilot testing at Whatcom Falls WTP was conducted with raw water algae at relatively low levels (< 12,000 cells/mL), which drove the percent removal lower than would have been anticipated for higher levels. Nevertheless, DAF-clarified water algae levels were consistently very low, which led to the superior UFRV performance summarized in this table. Improved UFRVs more directly indicate the success of the testing than algae reduction.

[b] Except during Run 16 (the 20 gpm/sf DAF loading run referenced above) where turbidity was measured at 0.5 to 0.6 NTU. This was likely incorrect data due to the contamination of the turbidimeter.

Attachment A
Whatcom Falls Water Treatment Plant: Pilot Testing Plan for Dissolved Air Flotation

Whatcom Falls Water Treatment Plant:
Pilot Testing Plan for Dissolved Air Flotation

Draft for DOH Review

Prepared for

City of Bellingham, WA

June 2011

CH2MHILL

LEE HUNTER ODELL
STATE OF WASHINGTON
29695
REGISTERED
PROFESSIONAL ENGINEER
EXPIRES 11-01-12

This Pilot Testing Plan was prepared under the direct guidance of a Professional Engineer certified in Washington State.

Contents

Introduction

The City of Bellingham operates the Whatcom Falls Water Treatment Plant (WTP), a 24 million gallon per day (MGD) in-line filtration plant (with one filter out of service). The source water is Lake Whatcom, a large natural lake that in recent years has seen increases in algal counts that have affected the performance of the WTP during late summer. Most recently, in 2009, algal counts reduced the filter production to unacceptably low levels, resulting in mandatory water restrictions. Table 1 lists historic raw water quality for Lake Whatcom.

TABLE 1
Whatcom Falls Water Treatment Plant Raw Water Quality

Parameter	Units	Min	Average	Max
Temperature	Celsius	6	12	18
Turbidity	NTU	0.41	0.74	2
Alkalinity	mg/L as CaCO3	19.5	20.7	22.5
Hardness	mg/L as CaCO3	17.3	21.2	23
pH	S.U.	7.2	7.3	7.4
Conductivity	umohs/cm	57	60.6	75
Apparent Color	PtCo	13	14	15
TOC	mg/L	1.8	2.2	2.6
DOC	mg/L	1.8	2.1	2.3
UV254	1/cm	0.046	0.056	0.103
Iron	mg/L	<0.01	-	0.08
Manganese	mg/L	<0.001	-	0.012
Aluminum	mg/L	<0.010	0.06	0.098
Chloride	mg/L	<2	2.2	3
Sodium	mg/L	2	4.4	5
Sulfate	mg/L	3.6	7.4	10
Chlorophyll	ug/L	2	3.5	5.9
Algae	#/ml	0	-	100,000

The City is now in the process of evaluating several alternatives, including new treatment prior to filtration at the WTP to mitigate these impacts to the WTP. One of the potential treatment alternatives is dissolved air flotation (DAF). Because of the demonstrated successful performance of DAF throughout the municipal water treatment industry, the City is planning to pilot test DAF during the anticipated period of increased algae during the late summer of 2011. This pilot testing is planned for implementation in parallel with the overall evaluation by the City of treatment alternatives as well as non-treatment alternatives for algae mitigation. The City will incorporate the results of the DAF pilot testing into the overall evaluation of alternatives to mitigate the impacts of algae in Lake Whatcom to the filters at the existing WTP.

This proposed testing plan was developed to guide DAF pilot testing as well as to solicit Washington State Department of Health (DOH) review, comment, and approval, which is required per WAC 246-290.

Background on DAF Technology

DAF was first used as a pretreatment for conventional granular media in South Africa and Scandinavia in the 1960s and became more widely used worldwide in the 1980s and 1990s. DAF is becoming more common in the U.S. because it provides a cost-effective alternative to conventional sedimentation when the contaminant material to be removed is more-easily floated than settled, as is the case with algae.

In DAF, the solids are separated out by floating the floc to the water surface, as opposed to settling to the bottom of the basin. The process introduces air bubbles at the bottom of the contactor to float the floc. The air bubbles are produced by reducing to ambient pressure a pressurized recycle water stream saturated with air. The "float" is scraped mechanically or removed hydraulically from the top of the reactor, and the clarified water is removed from a location well beneath the surface. A schematic of a typical DAF unit is provided in Exhibit 1. Note that the unit that will be tested at Whatcom Falls Water Treatment Plant does not include lateral draw-off piping for the clarified water.

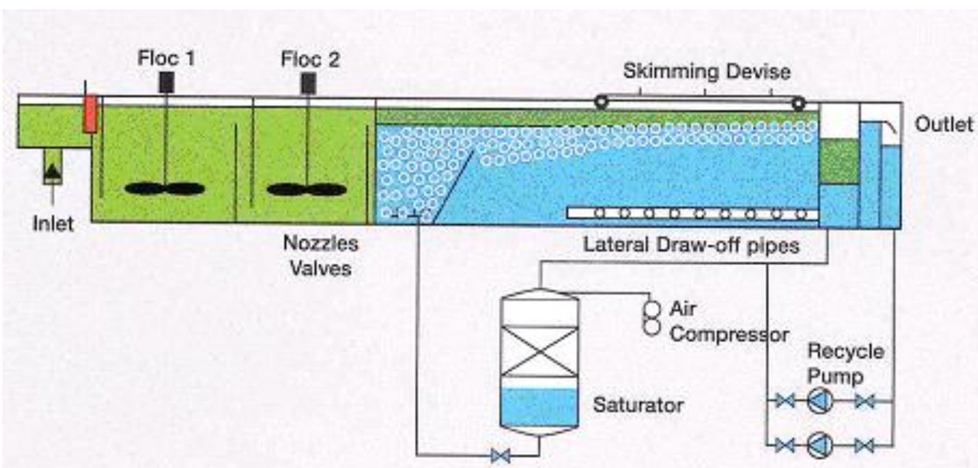


EXHIBIT 1
DAF Schematic

DAF is less costly than conventional flocculation-sedimentation for two reasons: the flocculation section is less than half the size of a conventional process. Detention times required for both flocculation and clarification are less than in conventional treatment. This results in a much smaller reactor than is possible for a conventional process. DAF also produces a more concentrated sludge than conventional treatment, although the sludge may contain entrapped air and need to be de-aerated. DAF requires much more energy input than conventional treatment and considerably more mechanical equipment to run the system.

High-rate DAF (above 8 gpm/sf surface loading rate) has been used in drinking water treatment in the last 10 to 15 years to increase the surface loading rate and decrease the footprint of the system. These High-Rate DAF systems have been designed up to 16 gpm/sf loading rate and run up to 20 gpm/sf in some situations. The largest High-Rate DAF facility in North America is located in Oradell NJ at 200 MGD.

Pilot testing DAF is necessary to help define the key unit process design parameters, predict effluent water quality (under various conditions), and simulate the effects of DAF pretreatment on filtration. The key parameters that need to be obtained in pilot testing include:

- Coagulant (dose and type)
- Coagulant polymer (dose and type; if it is needed)
- Flocculation time
- DAF surface overflow rate
- DAF sludge production and concentration

Pilot Testing Timing and Duration

The DAF pilot testing is planned for mid-August through mid-September of 2011 to coincide with the historical peak in blue-green algae growth. Blue-green algae have been identified as the dominant algae species that most-impacted filter performance at the WTP. The precise timing for the pilot testing may be shifted by a week or two based on the actual observed and measured growth in algae biomass over the summer.

The duration of the DAF pilot testing is anticipated to be approximately four weeks to achieve the pilot testing goals cited later in this testing plan, including demonstrating effective DAF performance under actual high-algae Lake Whatcom conditions during peak water demand periods. Since the primary objective of the use of DAF is for algae removal, testing during other seasons would not provide data necessary for the design basis of the pretreatment system.

Anticipated Full-Scale DAF Operations

While DAF is primarily a best available technology for algae removal, it can offer other benefits to water quality and WTP performance such as reduced total organic carbon (TOC) and longer filter run times even during periods when algae is not a significant impact to the existing treatment process (in-line filtration).

During the testing, we will gather data to determine what effects the DAF pretreatment will have on other water quality and performance parameters. Pending the review of this data and the City's long-term goals, a decision will be made as to whether full-scale DAF pretreatment would be for periodic, seasonal use only or as a full-time, year-round pretreatment step.

Pilot Test Goals

Pilot testing goals are important to establish at the beginning of testing to ensure the initial test plan, and adjustments during testing, are maintained with the end in mind. For the pilot testing on Lake Whatcom, there are four main goals:

1) Establish ability of DAF to effectively remove algae prior to filtration
2) Establish coagulant and polymer dosage rates required with DAF
3) Determine impacts of DAF pretreatment on filtration performance
4) Monitor other water quality parameters in filtered water

The evaluation criteria listed in Table 2 are the minimum values that need to be achieved in order for a pilot test run to be considered successful.

TABLE 2
Performance Goals for Whatcom Falls WTP DAF Pilot Study

Sample Point	Parameter	Evaluation Criteria	Goal
Clarified water	Total Algae Removal	--	>95% removal
Clarified water	Turbidity (steady-state)	<1.0 NTU	0.5 NTU
Filter Effluent	Turbidity (steady-state)	<0.07 NTU	<0.05 NTU
Filter Effluent	Turbidity spike (ripening)	0.2 NTU	<0.1 NTU
Filter Effluent	Particle counts (steady-state)	< 100 p/ml >2um	< 20 p/ml > 2 μm
Filter Effluent	Particle removal (steady state)	2-log	2.5 log
Filter Effluent	Ripening time	30 minutes	< 15 min. to <0.1 NTU
Filter Production	Unit Filter Run Volume	>5,000 gal/ft2	>8,000 gal/ft2

Piloting Setup

The pilot testing setup will include the following key components:

1) Pumping from WTP raw water pipeline
2) Roberts/Enpure Floc/DAF pilot with chemical feed systems
3) City's existing pilot filters

A schematic of the pilot testing setup is shown in Exhibit 2. Between the DAF effluent and pilot filters, there may be a need to pump to get the water to the flow split box on the pilot filters. This is being evaluated now. If a pump is needed, it will be a non-shearing type pump that will maintain the characteristics of any floc carried out of the DAF system to maintain filterability and replicate what we would expect in a gravity arrangement at the full-scale system.

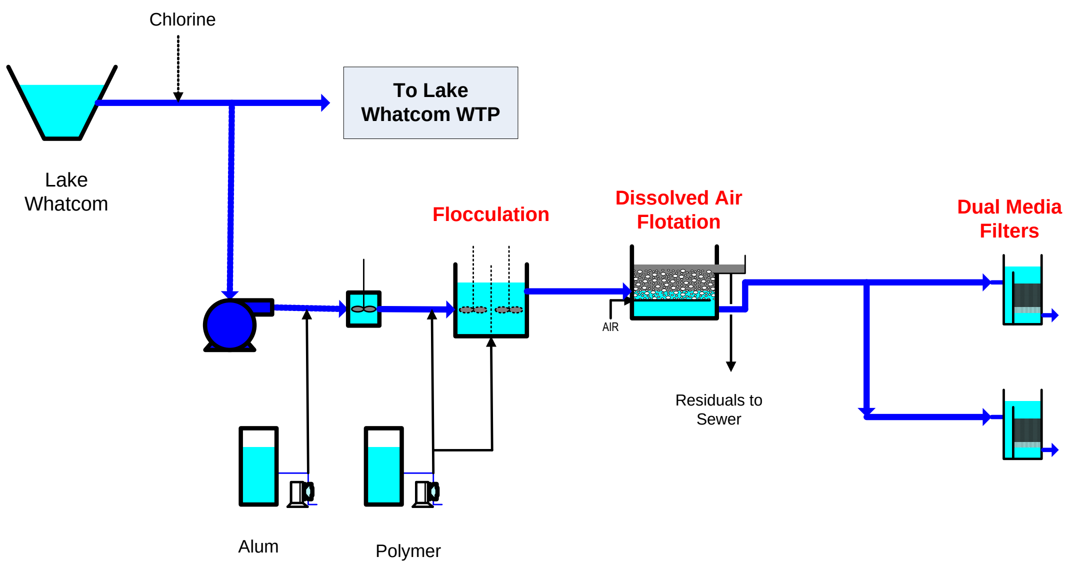


EXHIBIT 2
Pilot Testing System Schematic

Testing Methodology

The pilot testing will focus on the following areas:

- Flocculation Time
- DAF performance
- Filter performance
- Determination of filter run volume

Table 3 presents a summary of the pilot test runs that are expected to be conducted.

TABLE 3
Pilot Testing Plan for Lake Whatcom WTP

Week	Objective	DAF Loading Rate	Filter Loading Rate
1	Coagulant/Polymer Dosage	10 gpm/sf	5, 6, and 7 gpm/sf
2	Flocculation Times	10 gpm/sf	5, 6, and 7 gpm/sf
3	DAF at various loading rates	12, 16, 20 gpm/sf	5, 6, and 7 gpm/sf
4	Conduct optimal testing runs	Optimal	5, 6, and 7 gpm/sf

Coagulant and Polymer Dosage and Flocculation Time

Alum dosages will be tested at the bench scale during the startup week at doses between 5 and 20 mg/L to determine the best starting dose for pilot testing. A jar testing unit will be provided on-site by Roberts/Enpure for this purpose. Additionally, polymer may be tested to determine if it is necessary to enable the DAF system to meet the cited pilot testing performance goals. The best starting dosages for Alum and polymer will be used in the first week to establish pilot scale performance and make adjustments as necessary.

During the second week of testing, the impact of flocculation time on the DAF performance will be assessed. Flocculation time will start at 10 minutes, and then be reduced to 7.5 minutes and then 5 minutes.

DAF Performance

During weeks 1 and 2 we will run DAF at 10 gpm/sf to demonstrate baseline performance of the unit at a historically-typical loading rate. During weeks 3 and 4, the DAF loading rate will be increased from 12 to 20 gpm/sf. The optimal coagulant/polymer dose will be used, along with the best performing flocculation time. The DAF recycle rate will be tested starting at 8 percent and will be increased to 10 and 12 percent at times to observe impacts on DAF effluent turbidity and particles. In week 4, the best performing DAF loading rate will be tested for a minimum of two consecutive runs to confirm performance.

Filter Performance

The existing pilot filters at the WTP will be utilized for this pilot study. The pilot plant consists of three individual filter columns with dimensions of 12” square (1 square foot) by 12’ high (see photo).

The filter pilot plant is operated by a PLC which can operate the filters in one of three modes: 1) run, backwash, and stop, 2) run, backwash, and filter, 3) run continuously past breakthrough. On-line monitors on each filter can provide turbidity, and head loss data at 5-minute intervals. Particle counts can also be taken as necessary.

Two filter columns will be loaded with filter media matching the existing filters: 31 inches anthracite over 11 inches sand. The filters will be operated at different loading rates, between 5 and 7 gpm/sf.

Unit Filter Run Volume

The amount of water treated by each filter will be estimated by projecting the head loss development to 8 feet (current WTP terminal head loss parameter) or based on the actual turbidity breakthrough (0.07 NTU). The amount of water treated per unit area of filter between backwash events in gallons per square foot (gal/ft^2) is termed the unit filter run volume (UFRV). This filtration parameter will be used to evaluate filter performance within the context of DAF performance at various loading rates and to compare filters at different loading rate. For the purposes of this pilot testing, the UFRV should be greater than 5,000 gal/ft^2 to be classified as a successful filter run. Exhibit 3 shows that the relationship between the UFRV and the percent of produced water lost to backwash, based on typical municipal water treatment filtration performance, is not linear. As the UFRV increases to values greater than 8,000 gal/sf, the produced water lost to backwashing is minimized. Therefore, UFRV is an effective parameter for evaluating overall filtration performance.

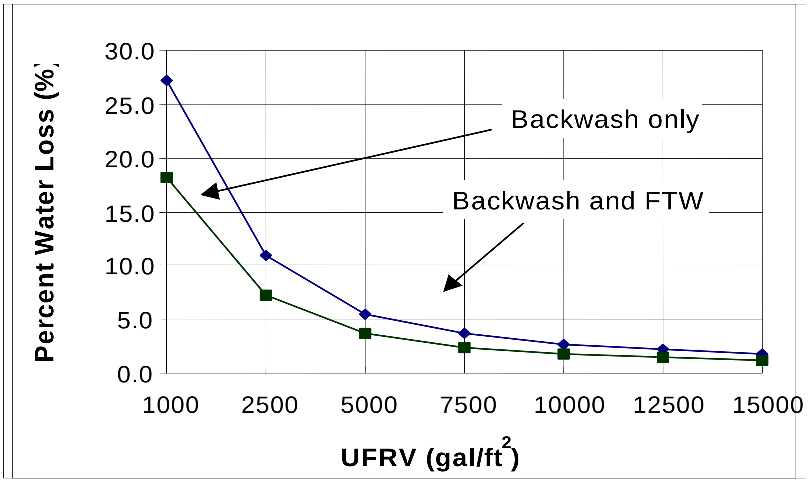


EXHIBIT 3
Percent of Water Lost to Backwash vs. UFRV

Data Collection and Analysis

Data to Be Collected

Table 4 provides a summary and frequency of the data that will be collected during the pilot testing. Table 5 provides a summary of the types of analyses to be performed for each sample. The City's existing HACH DR5000 in the WTP laboratory will be utilized for the on-site wet chemistry testing.

TABLE 4
Sampling Program for Pilot Testing 1

Parameter	Raw	DAF Effluent	Filtered Effluent
Turbidity	c	c	c
Color	2	2	2
pH	c	c	3
Alkalinity	1	1	1
Temperature	c	3	3
Particle Count	c (from plant)	c	c
Iron and Manganese (total and dissolved)[3]	1	1	1
Aluminum (total and dissolved)	2	2	2
Algal Counts	1 or 2	1 or 2	1 or 2
TOC	1 (each run)	1 (each run)	1 (each filter)
DOC	1 (each run)	1 (each run)	1 (each filter)
UV_{254}	c	c	3

[1] Numbers refer to the daily frequency samples are collected. "c" refers to continuous sampling.

[2] A run consists of a 24 to 36-hour run time. Approximately 4 runs will be completed each week.

[3] Iron and Manganese will be collected once or twice per week since very low concentration is anticipated.

TABLE 5
Analysis Type For Parameters

Parameter	Continuous	Laboratory (Off-Site)	On-Site Lab (Hach or EPA Method #)
Turbidity	X		
Color			X (8025)
pH	X		X (8156)
Alkalinity			X (SM2320B
Temperature	X		
Particle Count	X		
Iron and Manganese		X	X (8008,8034)
Aluminum		X	X (8012)
TOC/DOC		X	
UV_{254}	X		X (10054)

Data Review

Pilot plant data will be summarized and reviewed on a weekly basis to ensure that the testing is on the right track, to prepare for the next week's planned pilot testing, to assess the need for modifications of the testing plan, and to assess whether the duration of the testing needs to be extended.

Pilot Plant Operation and Schedule

The DAF pilot plant will be set up starting on Monday August 1st. Testing is expected to start by Monday August 15th through Friday September 9th. The startup schedule for testing will be modified if weekly algal counts performed by the City show that the algal bloom is beginning earlier than expected.

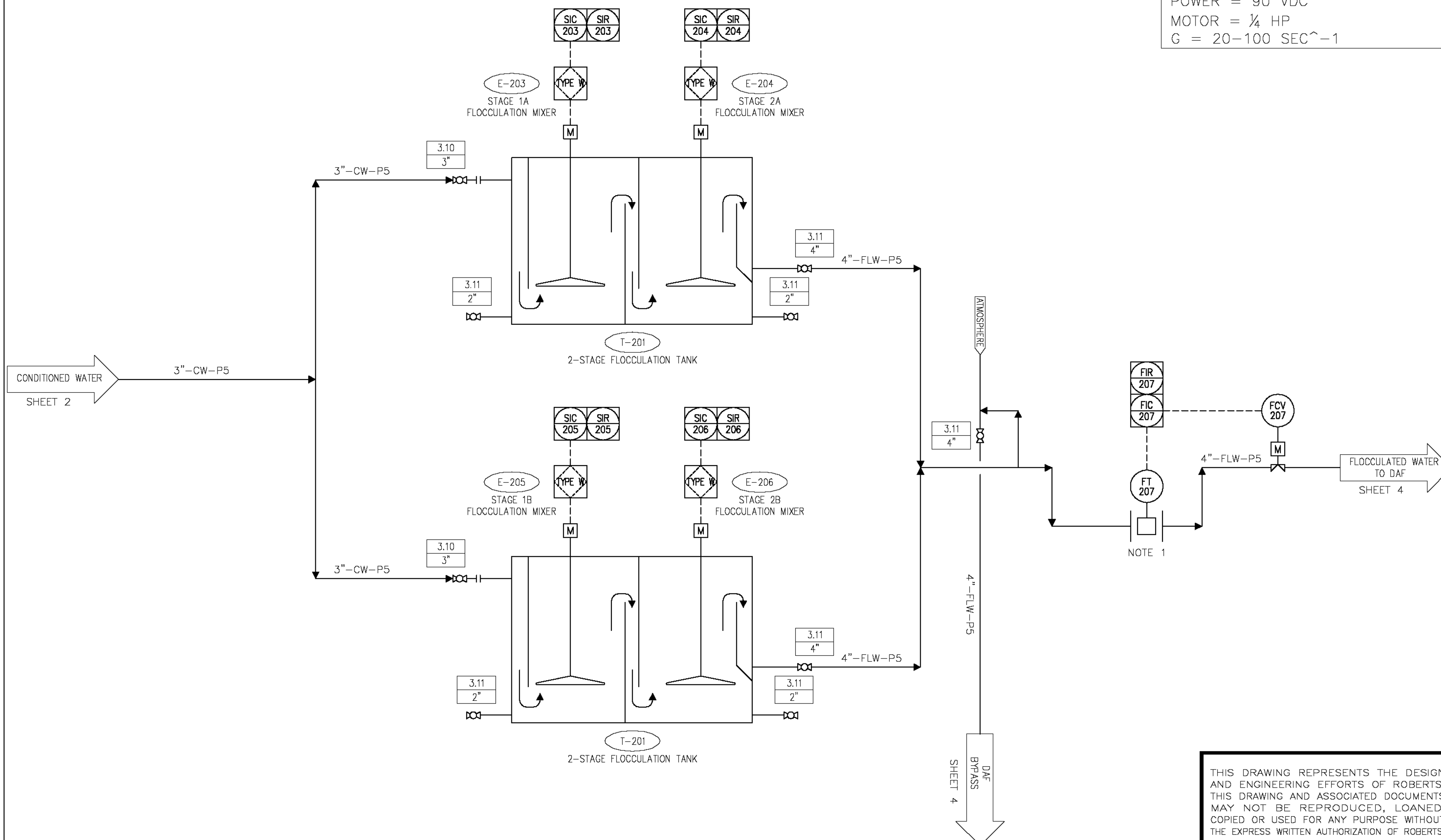
The pilot plant will operate 5 days a week, 24 hours per day for a period of 4 weeks. The pilot facilities will be staffed a period of approximately 8 hours per day. The automatic data logging equipment on each pilot trailer will allow for unstaffed operation at night.

Attachment B
Process Instrumentation Diagrams of Pilot Flocculation and DAF System by Roberts

NOTES:

1. ALLOW FIVE (5) STRAIGHT PIPE DIAMETERS UPSTREAM AND TWO (2) STRAIGHT PIPE DIAMETERS DOWNSTREAM OF MAGMETER. ALSO, ENSURE FULL PIPE FLOW.

T-201/T-202
2-STAGE FLOCCULATION TANKS
VOLUME = 393 GAL/TANK HRT/STAGE = 2.5 MINS (@40 GPM) MAT'L = HDPE
E-203/E-204/E-205/E-206
FLOCCULATION MIXERS
SPEED RANGE = 0-300 RPM POWER = 90 VDC MOTOR = ¼ HP G = 20-100 SEC^-1



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NO.	REVISION	BY	DATE	CHECKED	DATE	DRAWN
			6/6/11	GMG	5/12/11	MRB

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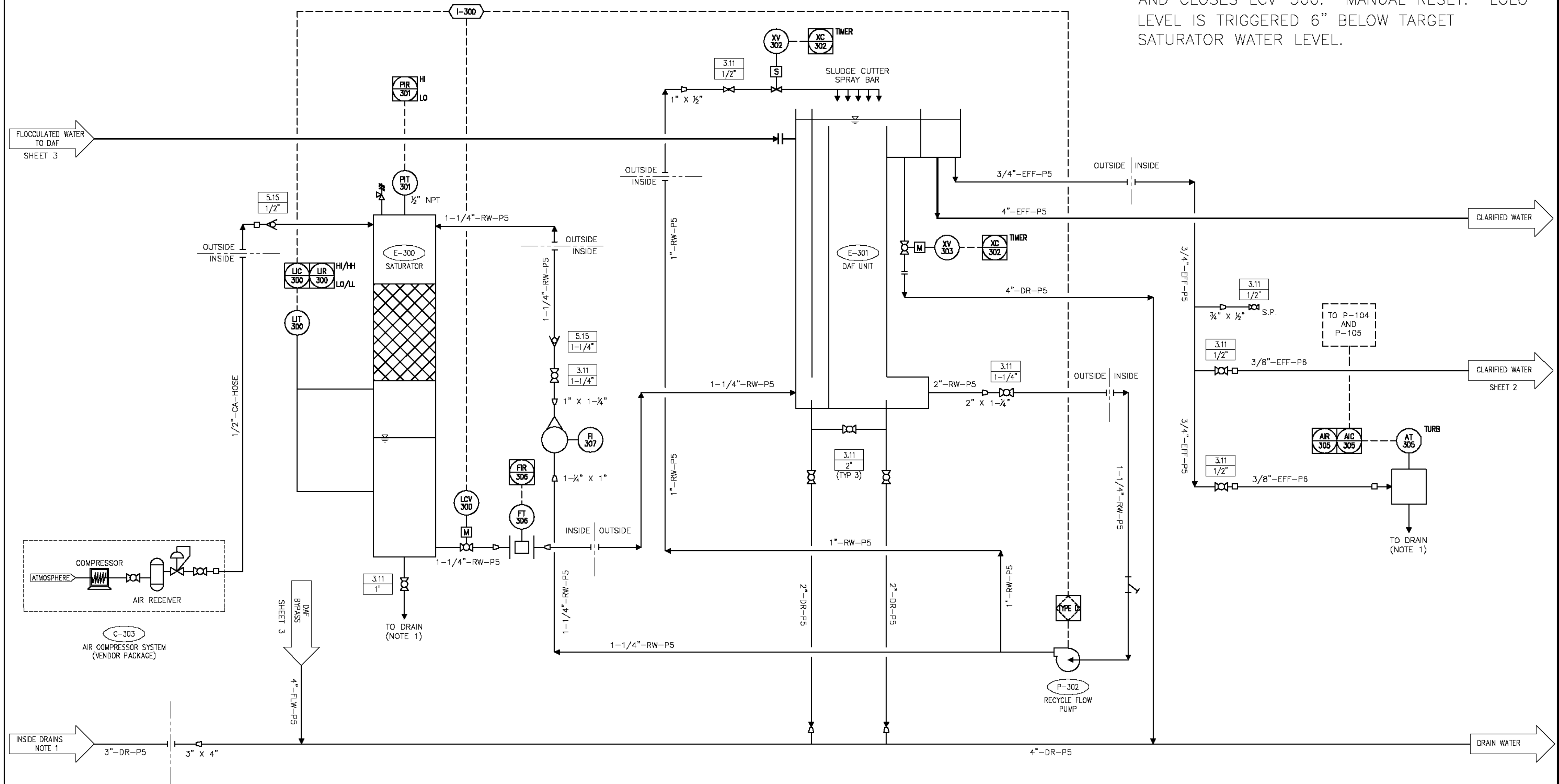
PROCESS PIPING AND INSTRUMENTATION DIAGRAM SHEET #3
DAF PILOT PLANT

SCALE NTS
CONTRACT 51153-T
SECTION A
DWG NO. 10583-E3

NOTES:

1. ALL DRAINS TO 3" COLLECTION MANIFOLD INSIDE CONTAINER OR 4" MANIFOLD OUTSIDE CONTAINER.
2. ALLOW FIVE (5) STRAIGHT PIPE DIAMETERS UPSTREAM AND TWO (2) STRAIGHT PIPE DIAMETERS DOWNSTREAM OF MAGMETER. ALSO, ENSURE FULL PIPE FLOW.

I-300: – HIHI LEVEL IN SATURATOR STOPS P-302 AND CLOSES LCV-300. MANUAL RESET. HIHI LEVEL IS TRIGGERED 6" ABOVE TARGET SATURATOR WATER LEVEL.
– LOLO LEVEL IN SATURATOR STOPS P-302 AND CLOSES LCV-300. MANUAL RESET. LOLO LEVEL IS TRIGGERED 6" BELOW TARGET SATURATOR WATER LEVEL.



E-300	E-301	P-302	C-303
SATURATOR	DAF UNIT	RECYCLE PUMP	AIR COMPRESSOR SYSTEM
OPERATING PRESS. = 65 PSIG	SURFACE AREA = 4 SF	Q = 22 GPM	AIR FLOW = 2.6 SCFM @ 90 PSI
PACKING MAT'L = JEAGER TRIPAK	DE-SLUDGE = HYDRAULIC	TDH = 260'	MAX. PRESS. = 150 PSI
TANK MAT'L = 304 SS	MAT'L = 304 SS	TYPE = CENTRIFUGAL	POWER = 120 VAC
	NOZZLES = 3	POWER = 230/460/3/60	MOTOR = 0.8 HP
		MOTOR = 1.5 HP	

NO.	DRAWN	DATE	REVISION	CHECKED	DATE	BY
	MRB	5/12/11		GMG	5/27/11	

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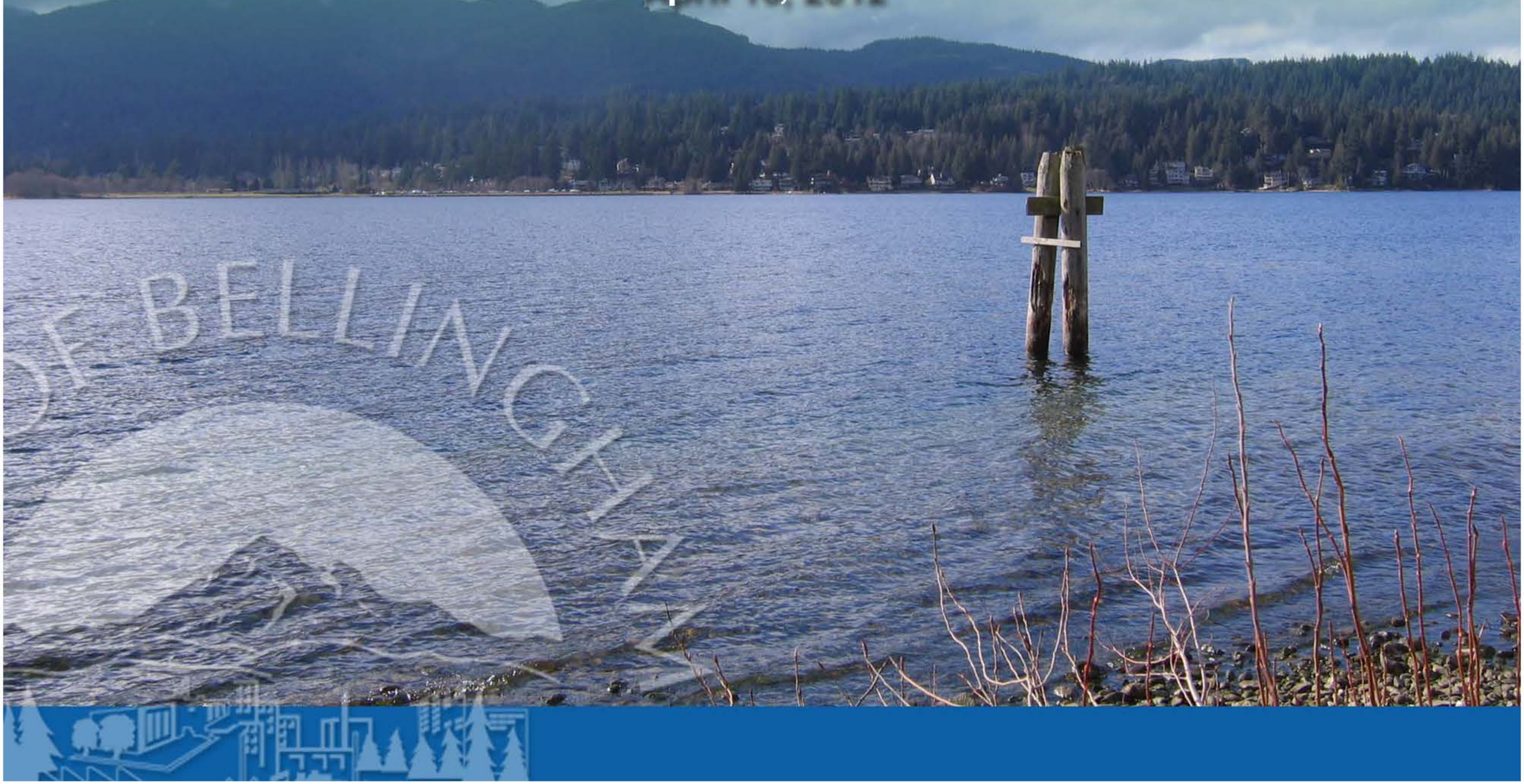
PROCESS PIPING AND INSTRUMENTATION DIAGRAM SHEET #4
DAF PILOT PLANT

SCALE NTS
CONTRACT 51153-T
SECTION A
DWG NO. 10583-E4

Filter-Clogging Algae Mitigation Evaluation

Whatcom Falls Water Treatment Plant

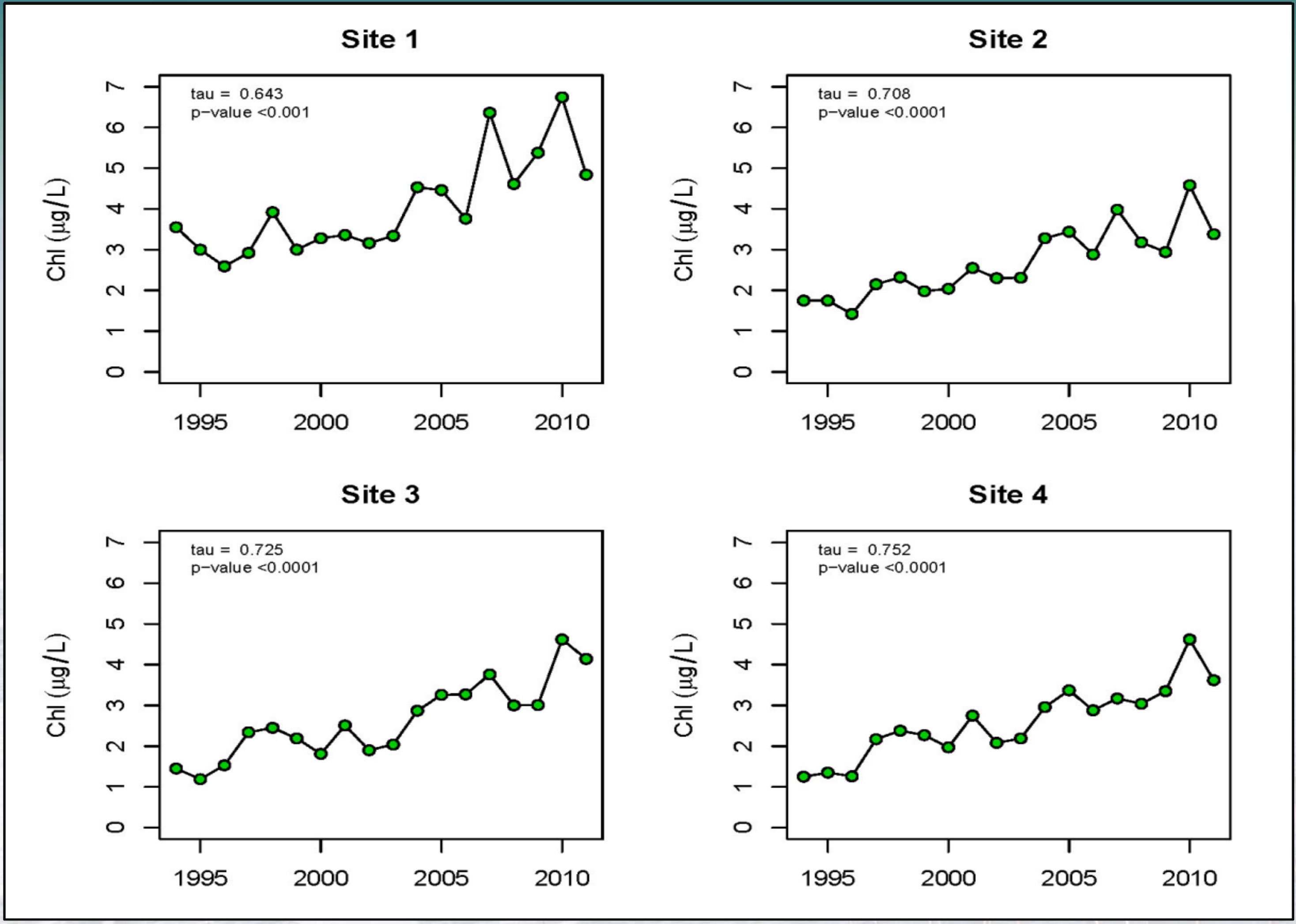
April 16, 2012



Overview of Presentation

- Background
- Objectives of Study
- Alternatives Evaluated
- Evaluation Approach
- Dissolved Air Flotation (DAF) Pilot Testing
- DAF Implementation
- DAF vs No Action
- Conclusions and Recommendations

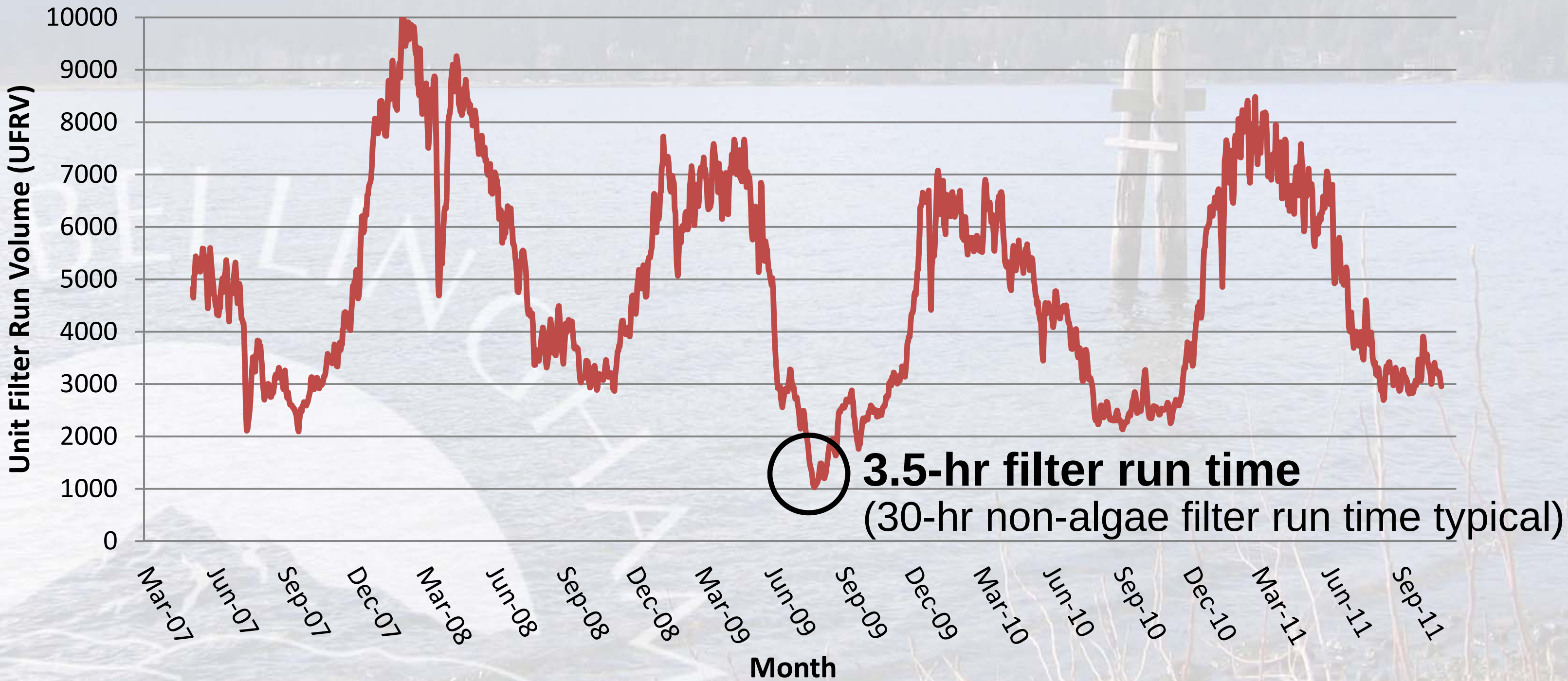
Background: Algae Levels Are Increasing



Lake Whatcom Monitoring Project 2010/2011 Report
Dr. Robin A. Matthews, February 24, 2012

Background: 2009 Summer Algae Impacts

- Elevated blue-green algae
- Reduced filter capacity at Lake Whatcom WTP
- Mandatory water restrictions



Objectives of Study

- Document water quality conditions and trends
- Identify a broad range of alternatives (treatment, intake, lake management)
- Pilot test the best treatment alternative
- Evaluate alternatives
- Recommend alternative for implementation

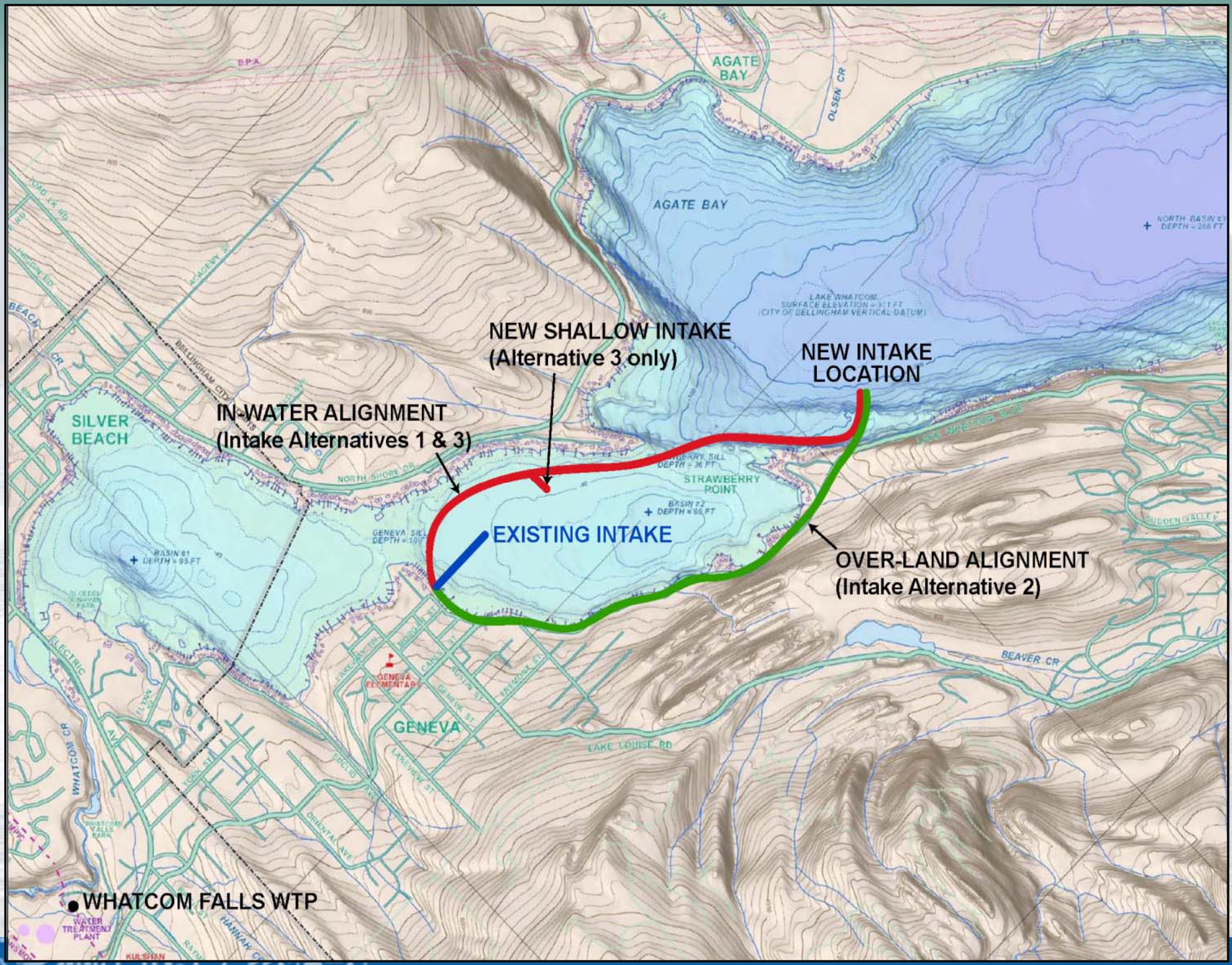
Alternatives Evaluated

Lake Management	Treatment	Intake	No Action
Lake Management*	Dissolved Air Flotation	Intake Alternative 1: ***Secondary Intake via In-Water Pipeline***	No Action
	Ballasted Sedimentation	Intake Alternative 2: ***Secondary Intake via Over-Land Pipeline***	
	Plate and Tube Settling	Intake Alternative 3: ***New Dual-Intake System***	
	Upflow Clarification		
	Conventional Sedimentation		
	Micro-Screening		
	Ozonation		
	Additional Filters		

*Lake Management will continue to be implemented via the Lake Whatcom Management Program. It was evaluated as part of this study to assess its short term impacts in comparison to treatment and intake alternatives.

Treatment Alternatives

Intake Alternatives



Evaluation Approach

- Preliminary screening
- Detailed technical evaluation
- Triple Bottom Line Plus (TBL+) evaluation

PRELIMINARY SCREENING
Fatal Flaw Criteria

↓

DETAILED TECHNICAL EVALUATION
Technical Criteria

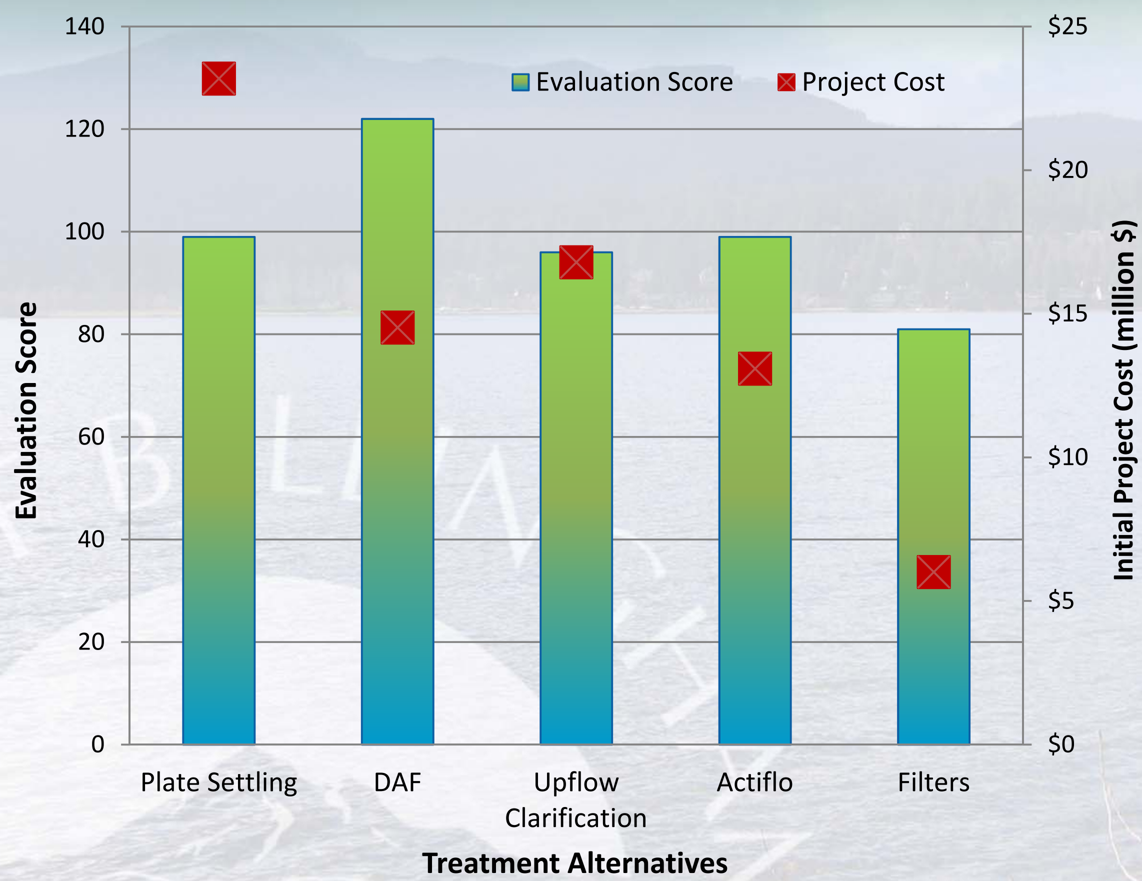
↓

TRIPLE BOTTOM LINE PLUS EVALUATION
Social, Environmental, Financial, & Technical Criteria

Preliminary Screening

Lake Management	Treatment	Intake	No Action
Lake Management **Lake Management will continue to be implemented but has limited short term impact on algal mitigation.**	Dissolved Air Flotation	Intake Alternative 1: ***Secondary Intake via In-Water Pipeline***	No Action
	Ballasted Sedimentation	~~Intake Alternative 2:~~ ~~***Secondary Intake via Over-Land Pipeline***~~	
	Plate and Tube Settling	Intake Alternative 3: ***New Dual-Intake System***	
	Upflow Clarification		
	~~Conventional Sedimentation~~		
	~~Micro-Screening~~		
	~~Ozonation~~		
	Additional Filters		

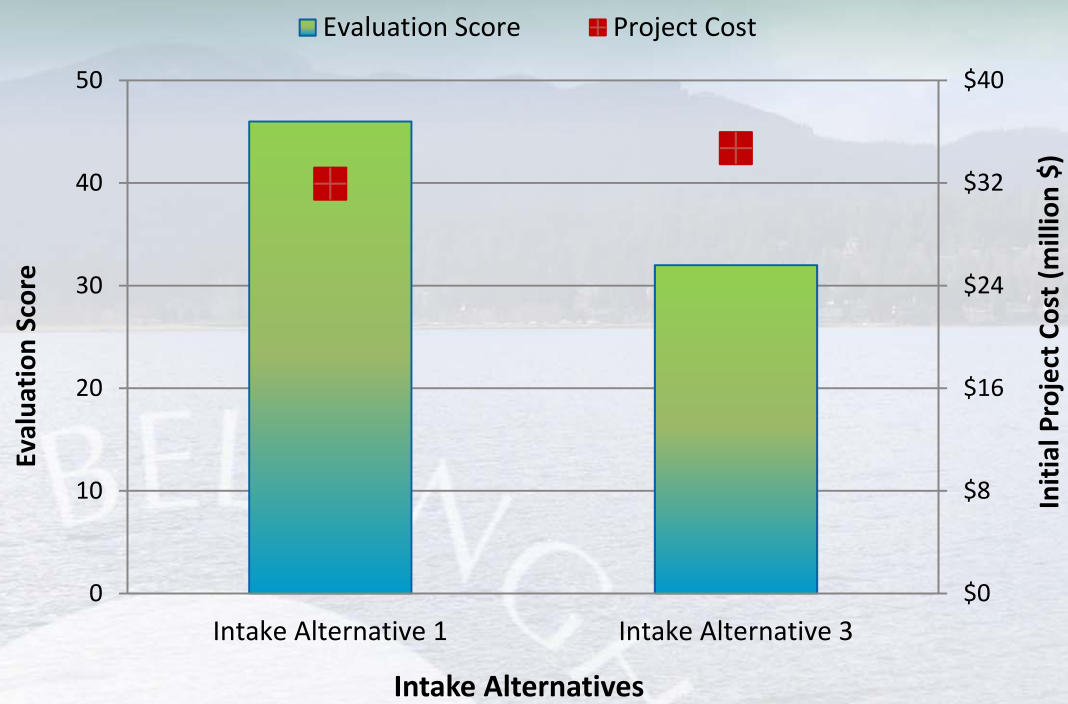
Detailed Technical Evaluation (Treatment Alternatives)



Evaluation Criteria

- Algae removal effectiveness
- Minimizes algal toxin release
- Maximizes flexibility to treat emerging contaminants
- T&O effectiveness
- Minimizes system complexity/ease of operation
- Maximizes "sustainability"
- Minimizes "footprint"/siting flexibility
- Minimizes disinfection byproducts

Detailed Technical Evaluation (Intake Alternatives)



Evaluation Criteria

- Minimizes construction disruption
- Minimizes permitting challenges
- Preserves existing hydraulic capacity
- System complexity/ ease of operation

Alternatives Carried into TBL+ Evaluation and their 20-year Life-cycle Costs

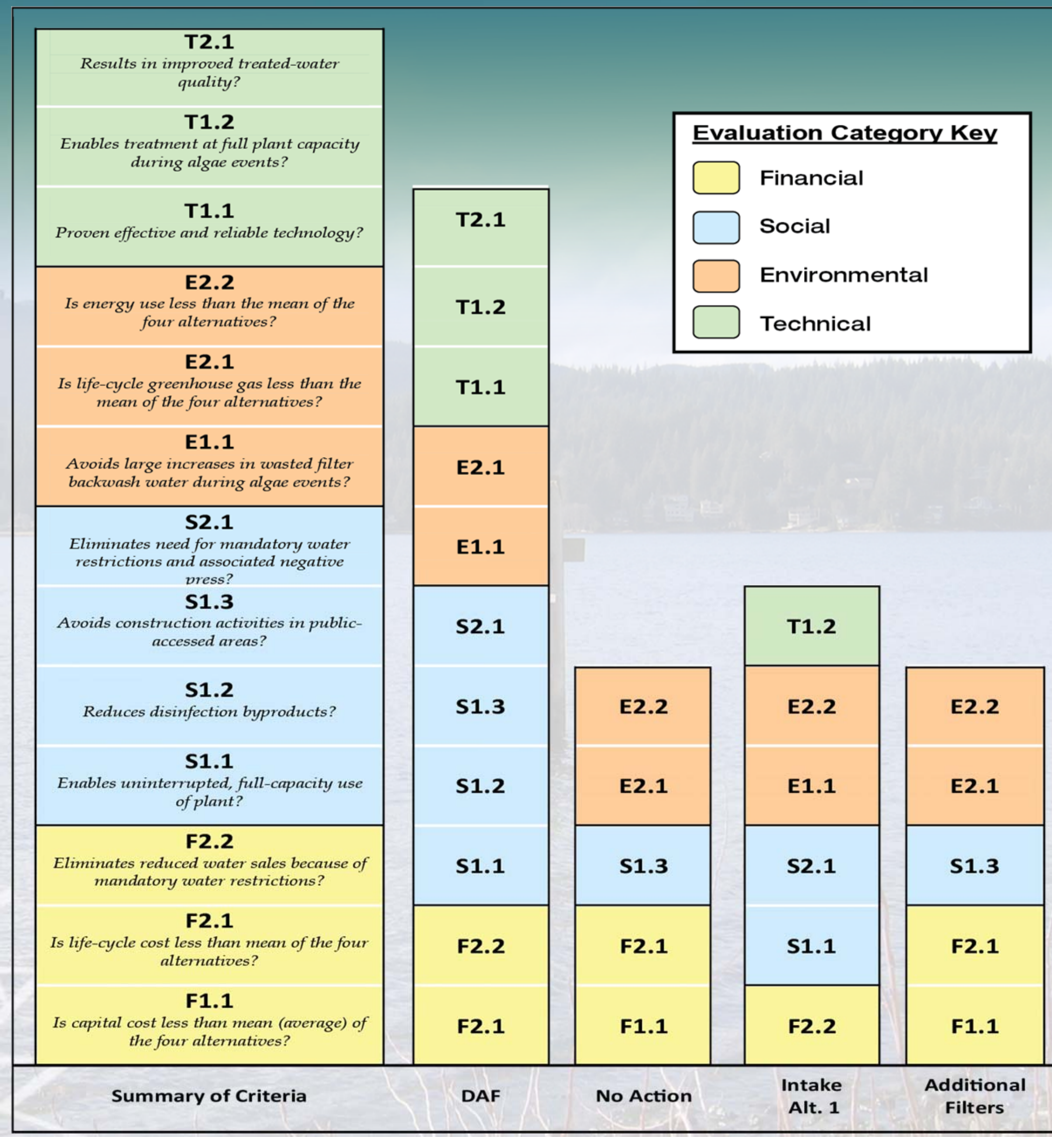
• Intake Alternative 1:	$32,490,000
• DAF:	$14,682,000
• Additional Filters:	$ 6,036,000
• No Action:	$ 6,000,000*

* Estimate based on lost water sales revenue over 20 years

TBL+ Evaluation

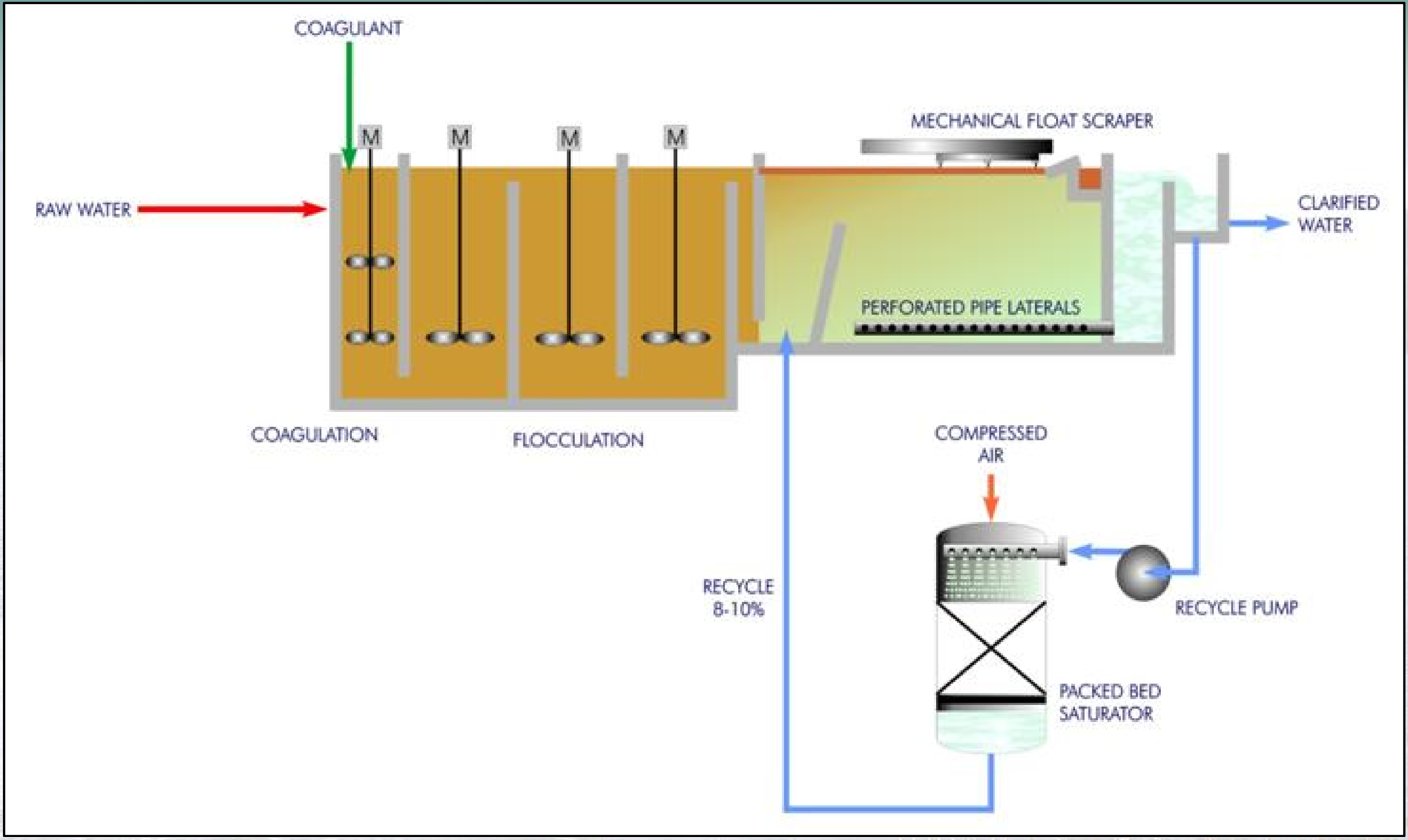
Evaluation Objectives

- Financial
  - Minimize capital cost
  - Minimize life-cycle cost
- Social
  - Protect public health and safety
  - Preserve community reputation, status, and economic vitality
- Environmental
  - Minimize local impact
  - Minimize global impact
- Technical
  - Maximize treatment reliability
  - Maximize treatment performance



DAF Pilot Testing (Aug/Sept 2011)

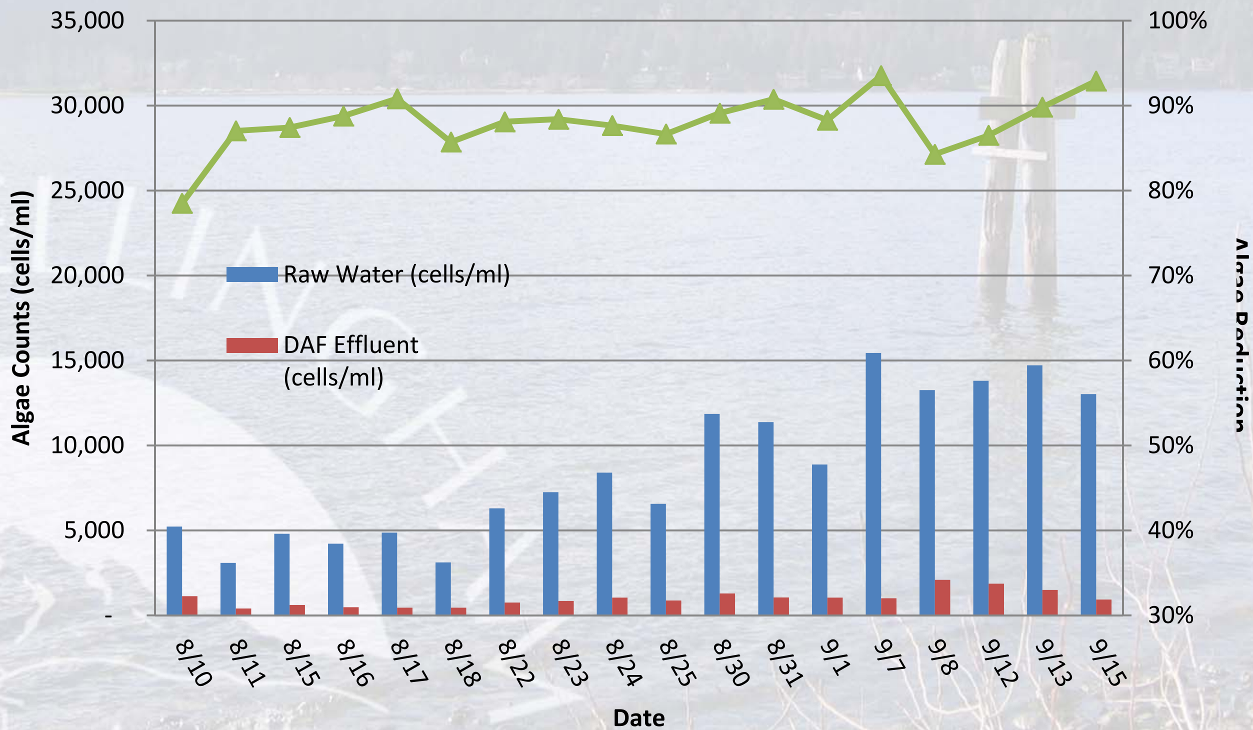
Schematic of DAF Process



DAF Pilot Waste Float

DAF Pilot Test Results

- DAF improved filter capacity to non-algae levels
- DAF successful at high flow rates
- DAF will reduce TTHMs by up to 25%
- Algae reduction (80 to 95%)

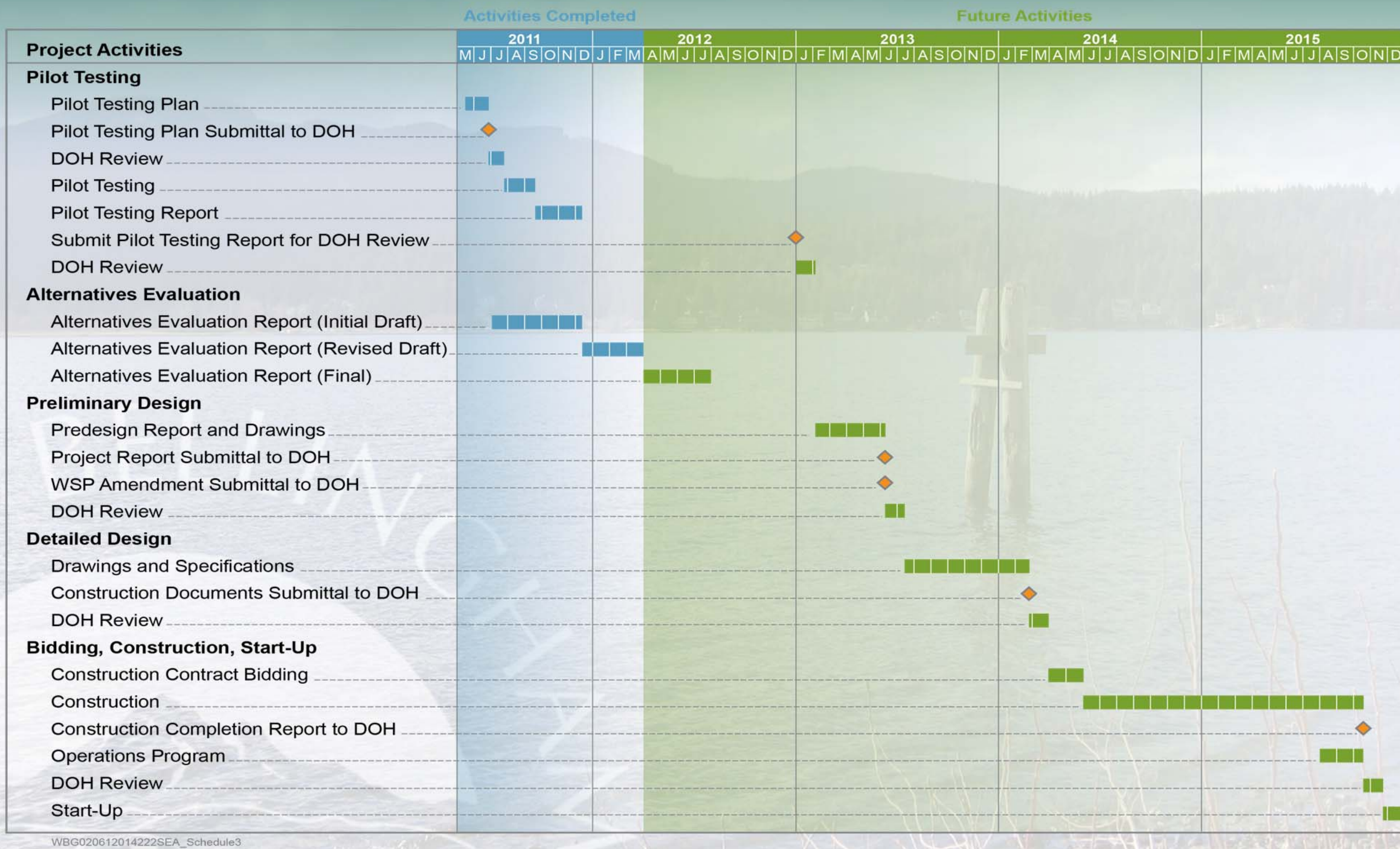


DAF Implementation Options (potential initial capital costs)

- 3-Train (30-mgd system) $14,500,000
- 2-Train (20-mgd system) $11,000,000
- 2-Train (16-mgd system) $10,400,000

DAF Implementation (example schedule):

3 yrs from decision to pursue, until DAF in service



Implications of No Action

- Uncertainty of meeting customer supply needs and providing fire protection
- Compromises supply reliability needed to keep and attract new businesses
- Lost revenue during mandatory restrictions
- Compromises supply reliability to enable expansion of service as regional wholesaler
- Lost opportunity to reduce TTHMs

Conclusions and Recommendations

- DAF is best mitigation approach
  - Best treatment technology
  - Less costly than intake alternative
  - DAF will reduce TTHMs by up to 25%
- Implement DAF in a phased approach
  - Initial installation of two parallel DAF treatment trains
  - Design expandability for third train
  - Third train could potentially be many years away, if ever
  - DAF phasing complements on-going lake management

Questions?

Presented by:
Ted Carlson, Director, Public Works Department
Bob Bandarra, Public Works Superintendent of Operations
Phil Martinez, P. E., Project Manager, CH2MHill