DISCUSSION PAPER

Arrowsmith Water Service
Englishman River Water Intake Study
Phase 1 - Conceptual Planning

Discussion Paper 4-3 – Treatment Process Options

Prepared by: Keith Kohut and Matt Henney
Issued: January 28, 2010
Previous Issue: None

This discussion paper reviews and summarizes the potential water treatment processes suitable for the proposed Englishman River Water Treatment Plant, assesses future trends in treatment technology that may impact site planning, and presents treatment process scenarios suitable to treat Englishman River water for potable use.

1 Treatment Process Options

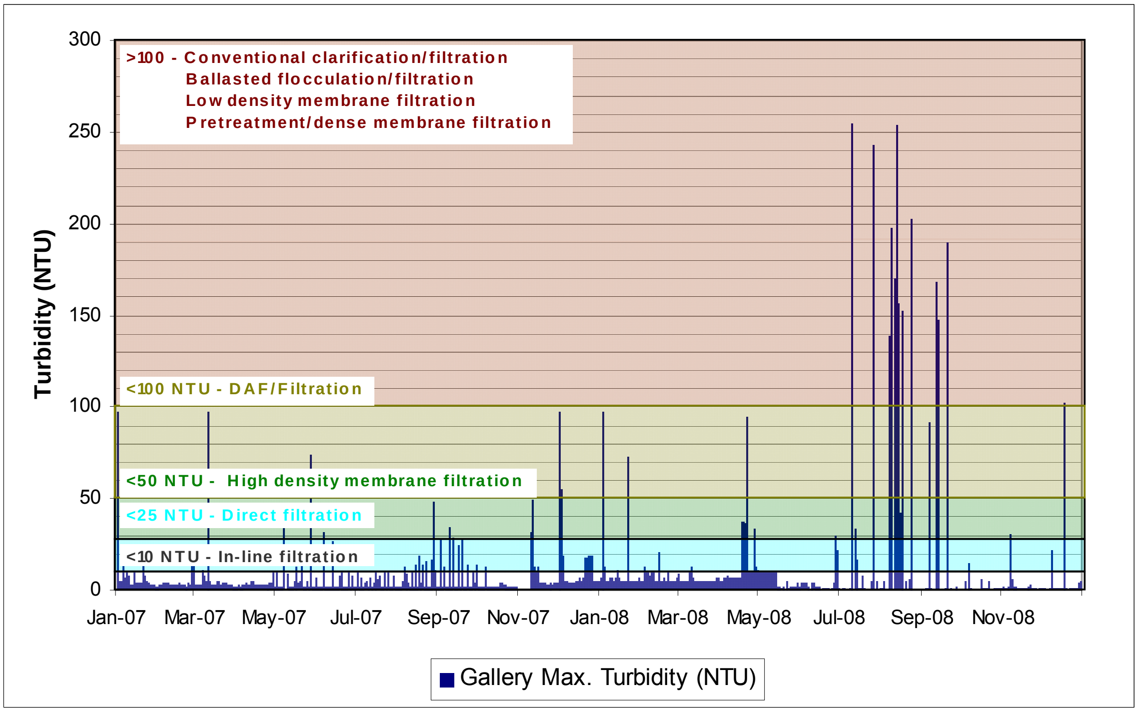
This section contains a review of treatment processes that are suitable for addressing the individual water quality issues for the Englishman River as identified in Discussion Paper (DP) 4-2. Specifically, treatment options for lowering turbidity, disinfection, water stabilization, and organic removal are identified and rejected if deemed unsuitable for the Englishman River. The feasible treatment processes are used to develop complete water treatment plant process scenarios in Section 3 of this paper.

1.1 Turbidity

Turbidity is the primary parameter of concern that must be addressed in order to make Englishman River water suitable for drinking. Treatment processes for turbidity focus on particulate removal, ending with a filtration step where suspended particles are adsorbed or physically strained from the treated water.

The variety of particulate removal processes used at water treatment plants are dependent on the maximum turbidity levels that need to be treated. Not surprisingly, the processes that are effective at higher turbidity levels generally have a higher capital cost and/or operating costs than the technologies that can only treat lower turbidity levels. Figure 1-1 provides a general guide for the maximum turbidity that different treatment technologies can typically effectively remove. These maximum turbidity limits are contrasted to raw water turbidity levels as measured at PRK1 from 2007 to 2008.

Figure 1-1
Turbidity/Maximum Technology Level Plot



Based on the magnitude of the turbidity spikes shown, the suitable technologies for particulate removal are limited if the treatment plant is run continuously throughout the year. Coupled with this, the robustness or tolerance of the process to changes in raw water conditions must be considered. The plot in Figure 1-1 shows how rapidly the turbidity changes. Most chemical-based treatment processes would be extremely difficult to control under these conditions. However, an option to consider is to cease plant operations when the most extreme turbidity events occur. During these events, the Arrowsmith water system would rely on stored water and on their groundwater supplies. This is similar to the approach currently used at the existing intake and water treatment plant though, if a filtration process is installed, the treatment plant would be shut down only during the most extreme turbidity events.

Temporarily shutting down the plant does offer some inconveniences and complicates the operation of the Arrowsmith water system. However, if this approach is used, the maximum raw water turbidity level that the proposed plant must treat can be lowered, allowing other treatment technologies with lower capital costs and less robust response to changing conditions to be considered. Based on the monitoring station turbidity data reviewed in DP 4-2, Table 1-1 lists the approximate percent of the time that the proposed water treatment plant would be offline for different particulate removal processes.

Table 1-1
Percentage of Turbidity Measurements Difficult to Treat per Technology

Process	Maximum Turbidity (NTU)	% Exceedences of Maximum Turbidity (Hours per Year)		
		MOE1 2008-2009	MOE2 2006-2007	PRK1 2008
In-Line Filtration	10	4.9% (430 hours)	3% (263 hours)	18.5% (1620 hours)
Direct Filtration	25	0.8% (70 hours)	2% (175 hours)	1.1% (96 hours)
High-Density Membranes	50	0.3% (26 hours)	2% (175 hours)	0.02% (2 hours)
DAF	100	0.1% (9 hours)	0% (0 hours)	>0.02% (2 hours)
Low-Density Membranes	>100	0%	0%	0%
Conventional Treatment	>100	0%	0%	0%
Actiflo®	>100	0%	0%	0%

The balance between capital savings and the amount of time that the proposed treatment plant would be in operation should be discussed with the stakeholders of the Arrowsmith water system to confirm the maximum turbidity level against which the treatment processes will be designed. The subsections below describe the treatment technologies for turbidity removal in greater detail.

1.1.1 Conventional Treatment

Conventional treatment involves coagulation, flocculation, and sedimentation followed by media filtration. This process is used to remove finer suspended and colloidal particles that are not screened out as water enters the plant intake, and is founded on the principle that particles tend to settle in water at an increasing rate corresponding to particle size and density. Coagulation is the addition of a chemical coagulant to the water to encourage suspended solids to floc together to form larger particles and, sometimes, greater densities. There are a variety of coagulants of different properties, and bench-scale tests are required to estimate the optimum coagulant dose to apply to the specific water conditions of each site. Next, the flocculation process involves gently mixing the water at low energy to encourage further aggregation and larger floc. The water then undergoes sedimentation, where the floc settles out of the water. The rate at which the floc settles out is enhanced by increasing particle size. The addition of inclined tubes or plate settler modules to the sedimentation process increases the efficiency of the settling process. Floc collected at the bottom of the sedimentation basin is removed, while the clarified water is removed from at or near the surface.

Filtration is usually used as a final particulate removal treatment step. Media filtration involves passing water though a granular media bed. Particles are removed from the water stream through contact with the media and other retained particles. The media bed is usually composed of varying grain-sized materials such as crushed sand (quartzite) and anthracite that are stacked to form varying pore spaces for water to travel through. A polymer is often used to enhance the filtration process.

1.1.2 Dissolved Air Flotation

Dissolved air flotation (DAF) is an alternative to sedimentation. DAF is often used to remove low-density particles such as algae and suspended solids of smaller particle sizes. DAF replaces the sedimentation process in conventional treatment. Instead of encouraging the settling of floc, DAF introduces a cloud of very fine bubbles that attach to the floc to lower its effective density and rapidly floats the floc to the surface of the water. From there, the floc is skimmed from the surface. The DAF step is followed by a filtration step, similar to the conventional treatment process, described above.

1.1.3 Direct Filtration

In certain applications, the amount of particulates to remove from the water is low enough that the primary steps of removing larger particles from the water through settling or flotation is unnecessary. In these situations, the sedimentation or flotation steps can be omitted in favour of relying solely on filtration. In this case, water would be subjected to coagulation and flocculation to generate larger sized floc, and removed immediately via media filtration. This sequence of treatment steps is referred to as direct filtration.

For some waters, flocculation can also be omitted. Coagulation followed immediately by filtration is referred to as in-line filtration. With this process, the chemical coagulant is used primarily to de-stabilize the particles in the raw water to promote their attachment and retention by the filter media. Both direct and in-line filtration require smaller footprints and have lower capital costs than conventional treatment. However, direct and in-line filtration are only effective for lower raw water turbidity conditions. Excessive particulates in the water can blind the media, eventually leading to particulates breaking through the media into the next stages of treatment. Both processes will also be difficult to control under rapidly changing conditions.

Based on the PRK1 turbidity data summarized in **Table 1-1**, in-line filtration would be unsuitable for treating Englishman River water nearly 20% of the year. Due to the significant amount of time an Englishman River in-line filtration treatment plant would need to be shut down, it is not recommended that in-line filtration be pursued as a viable option for the proposed water treatment plant.

1.1.4 Membrane Filtration

Membranes are thin sheets or tubes of natural or synthetic material that are selectively permeable to substances in solution. Membrane treatment involves water passing through the pores of a membrane, with suspended and/or dissolved solids being physically strained out of the water stream.

Membranes for drinking water typically come in a collection of fine filaments mounted into cartridges or racks. For more turbid waters, the racks are less densely packed with membranes to provide more space for solids. Lower membrane density comes with a greater capital cost, as more membranes are needed for a specific production rate, thus high-density membranes are preferred when their use is possible.

A number of membrane technologies exist that are designed for a variety of applications. For most water treatment applications, the different types of membranes can be generally classified by pore size. From order of largest pore sized to smallest, the different membrane treatments are: microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. Microfiltration, with pore sizes ranging from 10 to 0.1 μm in diameter, is employed to remove bacteria and colloidal particles. Ultrafiltration, with pore sizes ranging from 0.1 to 0.01 μm, is used to remove bacteria, some viruses, and some organic compounds. Nano filters, with pore sizes ranging from 0.01 to 0.001 μm, remove all viruses and many larger compounds and so are often considered for such applications as water softening. Reverse osmosis, with pore sizes as small as 0.001 μm in diameter, is used to desalinate brackish water. Water quality and the target objective for membrane use must be evaluated to select an appropriate membrane. Membranes with pores too large will allow undesirable particles to pass through the membrane. Conversely, membranes with pores too small usually require pre-treatment to remove larger particles upstream and also require increasing energy input.

Microfiltration or ultrafiltration are appropriate for the Arrowsmith water quality objectives. As these technologies have limited ability to remove dissolved organic compounds, it is typically necessary to provide flocculant dosing prior to membrane filtration in the process stream. However, the inappropriate use of coagulants can shorten the life of membranes. Pilot studies are typically required to verify to what extent particle removal can be improved when a coagulant is used and to monitor the impact on membrane condition and performance.

1.1.5 Actiflo®

Actiflo® is the proprietary name for a ballasted flocculation and high-rate settling process. Ballasted flocculation refers to a process in which heavy carrier particles, called micro-sand, are injected into the process following coagulation. With the aid of an added polymer, the floc particles bind to the micro-sand and settle out at a faster rate.

The Actiflo® system will produce a more dilute, but constant waste stream than the waste of a traditional coagulation/flocculation/sedimentation process. This waste stream will contain settled solids and low levels of coagulant, polymer, and micro-sand. Almost all the microsand is recycled by pulling sand from settled sludge via hydrocyclones.

Two of Actiflo®'s main advantages are that it has proven to be highly effective at maintaining consistent treatment during very significant and sudden turbidity events and that its high loading capacity allows it to treat greater flows of water within a limited available footprint. An example of one of these units is at the Red Deer Water Treatment Plant, which treats surface water from the Red Deer River in Alberta. The original plant used conventional treatment and was previously able to produce high quality water, but was not able to adequately respond to rapid changes in the raw water quality. After retrofitting the plant with Actiflo® units, a doubling of clarification capacity was achieved within the original footprint and response to fluctuating water quality was improved. The Red Deer River experienced a 1-in-100 year flood event in June 2005, during which raw water turbidity exceeded 3000 NTU. During this event, the Actiflo® units produced clarified water turbidity below 3.0 NTU and average filtered water turbidity at 0.1 NTU.

The Actiflo® process is typically followed by a filtration step, similar to that described under conventional treatment.

1.2 Disinfection

Another key treatment component for Englishman River water is the disinfection objectives for the control and protection from microbiological parameters such as *Escherichia coli*, *Giardia lamblia* and *Cryptosporidium parvum*. While disinfection credits will be granted for filtration, a primary disinfectant is still required to ensure that all the microbiological removal objectives have been met. It is also prudent to include redundancy to act as a “double barrier” against microbiological parameters, should an operating error occur during filtration.

Secondary disinfection should also be included to ensure that a disinfectant residual is present in the distribution system to protect the quality of the treated water as it travels from treatment plant to the consumers. Chlorine, in the form of free chlorine or combined chlorine (chloramines), will be required for secondary disinfection. The following subsections review primary and secondary disinfection options available.

1.2.1 Free Chlorine

Free chlorine is very effective at destroying viruses and bacteria and, in many systems, is used to achieve the virus inactivation component of the disinfection objectives. In contrast, chlorine is less effective for inactivating *Giardia* and is not effective at inactivating *Cryptosporidium*. Therefore, if only free chlorine is used for disinfection, the proposed water treatment will require a particulate removal process that achieves the entire inactivation/removal objective for *Cryptosporidium*. Conventional treatment or membrane filtration can achieve this objective, but it should be noted that a disinfectant 'double-barrier' against *Cryptosporidium* will be absent.

As with all surface water treatment systems, the formation of harmful disinfection byproducts (DBPs) must be considered. Typically DBPs occur from the reaction of an oxidant with organic material. Trihalomethanes (THMs) and haloacetic acids (HAAs) are the DBPs most often associated with chlorination that are currently addressed in the Guidelines for Canadian Drinking Water Quality, while guidelines for other DBPs are currently in development. Data for the existing Englishman River Water Treatment Plant, which uses free chlorine for disinfection, indicates that THM and HAA formation has been negligible. DBP formation will therefore likely not be an issue, but monitoring for DBPs should continue following construction of the proposed water treatment plant.

Chlorine can either be delivered or generated on site. For a treatment plant of the size required for Arrowsmith, the options available are as follows:

- Bulk delivery of 12% sodium hypochlorite solution
- 0.8% sodium hypochlorite solution generated on site
- Bulk delivery of liquefied chlorine gas in 68 kg cylinders or tonners

Each form of chlorine has its own advantages, disadvantages and economical impacts that will be evaluated at a later stage in the design.

1.2.2 Chloramines

Chloramines, also referred to as combined chlorine, are generated by adding ammonia to chlorinated water. Chloramines are not as strong an oxidant as free chlorine, but produce a more stable and longer lasting residual. This is useful for water systems where it is difficult to ensure that a free chlorine residual will reach the furthermost points of the distribution system.

One challenge with chloramines is that the ammonia and free chlorine must be mixed at a specific ratio. Mixing the two chemicals at a different ratio can produce undesirable forms of chloramines that cause taste and odour issues. An additional consideration is that chloramines are often an environmental concern in BC, particularly when used near fish bearing water bodies. As chloramine residuals are more stable than free chlorine, a chloramine residual is more likely to reach sensitive water bodies should a water main break occur. For this reason, the Department of Fisheries and Oceans and the BC Ministry of the Environment are unlikely to grant approval for a new water treatment plant using chloramines near the Englishman River. The various groups of environmental stakeholders interested in the Englishman River would also likely strongly object. Therefore, it is recommended that chloramines not be used for the proposed Englishman River Water Treatment Plant.

1.2.3 UV and Free Chlorine

Ultraviolet (UV) irradiation has become an accepted technology used to inactivate protozoa such as *Cryptosporidium* and *Giardia*. Water is passed through a reactor containing lamps holding mercury gas. When the gas is excited by energizing the lamps, UV light is emitted into the water. UV targets the DNA of the protozoa that destroys their ability to reproduce, effectively inactivating them and rendering them harmless.

UV is less effective at destroying or inactivating some viruses, such as adenoviruses and the tobacco mosaic virus. Much higher doses are needed to treat these viruses, which greatly increases the cost. Thus, UV is rarely applied for virus inactivation at this scale. Another important characteristic of UV is that it leaves no residual after water leaves the UV reactors. Therefore, UV disinfection will need to be accompanied by chlorine disinfection to achieve virus inactivation and to produce a chlorine residual for the distribution system.

UV reactors can be separated into two types: medium pressure (MP) lamp and low pressure-high output (LPHO) lamp reactors. The LPHO lamps contain a smaller volume of mercury gas at a lower pressure; pressures are in the order of 1 kPa for LPHO lamps and between 40 and 40,000 MPa for MP lamps. LPHO lamps radiate along a narrow spectrum of wavelengths, centered on the wavelength that best targets mutation in DNA. In contrast, MP lamps emit energy along a broad range of wavelengths. In terms of operation, LPHO reactors are more energy efficient, but require many more lamps to produce the same UV dose as MP reactors. This translates to each LPHO reactor containing more lamps and having a larger reactor footprint than their MP counterpart.

1.3 pH Stabilization

Corrosion control, in the form of stabilizing the treated water's pH, can be achieved by adding more alkalinity to act as a 'buffer' against pH-changing agents. Laboratory experiments have revealed that, for water with a neutral pH, raising the alkalinity to as little as 30 to 40 mg/L as $CaCo_3$ is typically sufficient for effective lead corrosion control (Health Canada, 2009). Typical treatment processes for pH stabilization are examined in the following subsections. The effectiveness of the chemicals examined can be approximated using pH balance models such as the Rothberg, Tamburini, and Winsor model (Rothberg and Scuras, 1994), and verified during bench-scale and pilot-scale testing.

1.3.1 Limestone Contactor

This process involves passing water through a chamber containing limestone ($CaCO_3$) stones. A portion of the limestone dissolves in the water, boosting the alkalinity of the water. Limestone contactors are a convenient treatment process due to their simplicity and low maintenance requirements. However, limestone contactors are not as practical for large treatment plants because of the size of contact chamber required. Based on 2015 water demands listed in Discussion Paper DP 3-2, a contact chamber approximately 1500 m^3 in size is needed. This would translate to significant capital costs and increase in the overall footprint of the proposed treatment plant. Therefore, it is not recommended that a limestone contactor be used for the proposed Arrowsmith Water Treatment Plant.

1.3.2 Alkalinity Adjustment

Sodium carbonate (Na_2CO_3), also known as soda ash, is the most commonly used chemical added to boost the alkalinity of treated water. Hydrated lime can also be used, but is more difficult to handle. Both soda ash and lime are purchased in solid form and must be dissolved into solution or made into a slurry prior to being injected into the treated water.

It is recommended that soda ash be used to raise alkalinity when treating water from the Englishman River. Alkalinity can improve the effectiveness of coagulant chemicals, reducing daily coagulant chemical consumption and, therefore, should be added prior or during coagulation.

1.4 Organics Removal

A treatment process specifically targeting organic material for removal may not be necessary for the proposed water treatment plant. The filtration and disinfection steps may be sufficient to meet the design total organic carbon removal objectives or alternative criteria. The organics removal treatment options discussed below should only be considered if pilot testing indicates that filtration and disinfection are insufficient.

1.4.1 Oxidation

Oxidation typically precedes filtration, to partially break-down byproduct precursor material that may form unwanted DBPs during reaction with the disinfectant. Typical oxidants used in this application are potassium permanganate ($KMnO_4$), ozone (O_3) and, in some cases, high doses of chlorine (hyperchlorination). Potassium permanganate is purchased in solid form and must be dissolved into solution on site before being injected. Ozone must be generated on site, using compressed air or oxygen as its chemical supply.

Potassium permanganate is the weakest of the common oxidants. However, it is commonly used where some oxidation is needed on a seasonal basis. It is relatively easy to handle. However, permanganate dose optimization must be suitably monitored as overdosing can lead to a discolouration (pink tint) of the water. Excess permanganate typically settles in the distribution pipe, prolonging water discolouration in the distribution system well after permanganate overdosing has ceased. Manganese dioxide precipitation can also be problematic unless the process is properly controlled.

Hyperchlorination requires an additional dechlorination step downstream to lower the treated water chlorine residual to a range more suitable for drinking water. Due to the concern over formation of unwanted DBPs, hyperchlorination is no longer commonly used.

Ozone, while extremely effective, is considered a relatively complicated and expensive technology. While feasible if used for multiple purposes such as to remove unappealing tastes and odours, the quality of the Englishman River water is high enough that ozone would be an excessively expensive and complicated treatment technology to use in comparison to the alternatives.

Compared to the other alternatives available for organic removal, oxidation is not recommended to treat the Englishman River water. As the oxidation would likely occur prior to filtration, there is some concern that oxidizing untreated surface water itself could lead to the formation of undesirable DBPs. The existing water quality data suggests that THM and HAA formation is low under chlorine dosages currently being used. However, hyperchlorination may lead to higher THM and HAA formation, as well as to the formation of unregulated DBPs such as haloketones, nitorsamines, or trihalonitromethanes. Potential ozone DBPs include bromate, adehydes and carboxylic acids. DBPs caused by permanganate have not been identified.

1.4.2 Activated Carbon

For this treatment process, activated carbon media comes into contact with water to be treated, so that organics in the water adsorb to the porous surface of the media. With continual use, eventually a substantial portion of the activated carbon’s surface will be covered with organics and become “exhausted”. The exhausted media must then either be removed or recharged via chemical addition.

Activated carbon comes in two general forms: granulated activated carbon (GAC) and powdered activated carbon (PAC). Granulated carbon has a large grain size, and can be placed as the top layer of a conventional media filter or placed in its own, mono-media filter situated prior to or downstream of the filters. Alternatively, PAC is made of small particles and is usually injected into the raw water supply upstream of the main process. PAC is sufficiently light that it will remain suspended in turbulent water, coming in contact with various organics that are present, until removed during settling (or flotation) and filtration.

The type of activated carbon recommended for use is primarily dependent on the occurrence of high organics in the Englishman River. If concentrated organics are persistent in the river all year round, then GAC is a more cost-effective form of activated carbon. If high organic concentrations occur only periodically or seasonally, then PAC becomes a more economic option, as activated carbon is then only used when organics are a parameter that needs to be addressed.

For the proposed water treatment plant, it is recommended that activated carbon be used if additional organic removal is required. Bench and pilot-scale testing, will determine the extent of organic removal required.

1.4.3 Ion Exchange

Ion exchange resins behave similarly to activated carbon, in that a media is introduced to the water to which organics sorb to the surface. The media and adsorbed organics are then separated from the treated water during filtration. In this case, the media are polymer resins mounted to a synthetic base. Ion exchange for organic removal is advantageous when the raw water contains other ions that should be removed during treatment. However, this is not the case for Englishman River water. Ion exchange resins designed for organic removal are currently a proprietary product and are significantly more expensive than activated carbon. It is therefore recommended that ion exchange resins not be used at the proposed water treatment plant.

2 Trends in Water Treatment Technology

As time progresses, water treatment technologies, analytical methods, and regulations become more sophisticated. Based on the historical trends, general developments in treatment technology and operation philosophy can be predicted.

2.1 Improved Process Performance

Research and testing have resulted in continual advancements in water treatment process technology. Historically, while the fundamental techniques by which treatment processes treat water remain the same, the efficiency of these processes improves. For example, some processes have been developed that require fewer chemicals and less power to operate. Particulate removal processes with higher design loading rates have been developed, which lead to smaller footprint requirements. Therefore, one can conservatively assume that future expansions to the proposed water treatment plant will require less space per unit of treated water than the processes used in the original design.

2.2 Sustainability

The environmental impact of water treatment plant construction and operation will continue to receive greater attention on two fronts: residuals management and resource consumption.

2.2.1 Residual Management

Waste will be inevitably generated during plant operation. Particulate removal processes generate a sludge containing particles rejected from the raw water; chemical spills must be captured and disposed of; and daily operator duties will generate waste. The importance of residual management has progressed such that residuals generally undergo treatment or neutralization before disposal, where once it was acceptable to discharge untreated waste downstream of the plant intake.

A relatively new development in residual management is the “zero-liquid discharge” approach, whereas no waste from the plant is returned to the raw water source. Waste from the treatment processes is dewatered and, where possible, the removed water is recycled to the head of the plant and treated. Where this is not possible, on-site disposal, such as artificial wetlands, may be used. The dewatered waste solids are disposed of at landfills. Sanitary wastewater is sent to a nearby wastewater treatment facility or dealt with through on-site management. It is recommended that a sustainable residuals management system be developed for the proposed water treatment plant.

2.2.2 Resource Consumption

Public interest continues to grow in regards to resource consumption by public utility infrastructure, including water treatment plants. Predominantly, the industry is moving towards more energy efficient features. In addition to substantially reducing negative environmental impacts, these features can also reduce operating costs.

Various sustainable design principles and methods of implementation and measurement have been developed, such as the Leadership in Energy and Environmental Design (LEED®) rating system. LEED® is a voluntary building rating system created by the United States Green Building Council for the purpose of improving the energy and environmental performance of new and existing commercial, institutional, and high-rise residential buildings. Growing interest in Canada led to the establishment of the Canadian Green Building Council in 2003. Whether or not LEED® certification is the intention, it is recommended that specific LEED® sustainable design principles and strategies be applied to the proposed water treatment plant.

3 Proposed Treatment Scenarios

In the following subsections different combinations of treatment processes are identified to treat Englishman River water. These treatment combinations will be used to develop conceptual level treatment plant designs to aid in evaluating various potential plant sites along the Englishman River banks.

3.1 Scenario 1: Direct Filtration

Scenario 1 involves the following processes:

- Alkalinity addition via chemical addition
- Coagulation/flocculation
- Media filtration
- UV irradiation
- Chlorination

A process flow diagram for Scenario 1 is provided as **Figure 3-1**. UV is required to ensure that the removal/inactivation objectives for *Cryptosporidium* and *Giardia* are met. The points at which alkalinity and pH adjustment occur are not critical and can be done earlier or later during the treatment process stream. Similarly, chlorination can occur at any point after media filtration. However, the treatment processes are listed above in their most efficient order. Alkalinity adjustment is recommended first, as the increased alkalinity will improve coagulation and flocculation. Chlorination is recommended to follow UV irradiation as UV can degrade the chlorine residual.

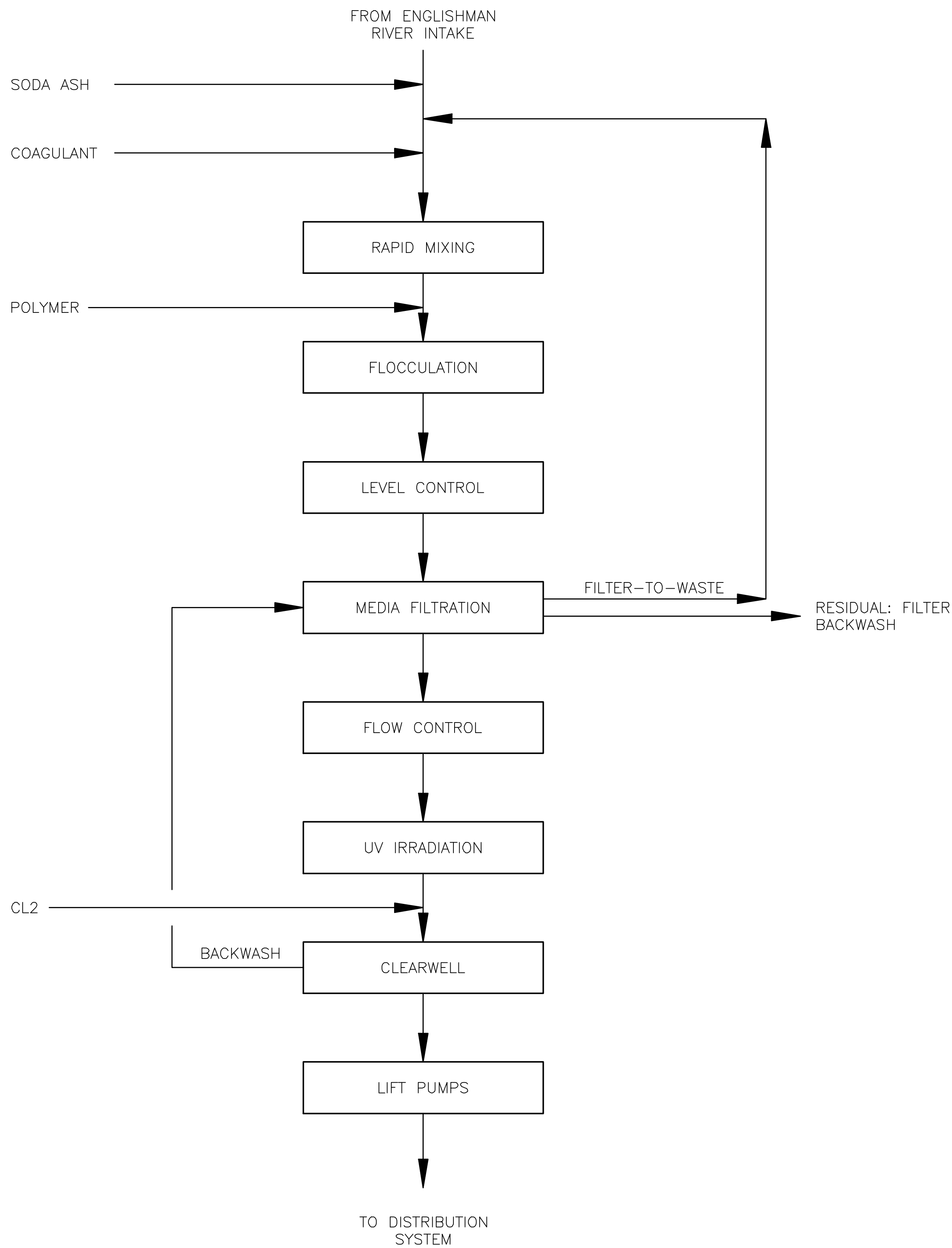
Scenario 1 is suitable for Englishman River water when turbidity is below 30 NTU.

3.2 Scenario 2: Conventional Treatment

Scenario 2 involves the following processes:

- Alkalinity addition via chemical addition
- Coagulation/flocculation/sedimentation
- Media filtration
- UV irradiation
- Chlorination

A process flow diagram is presented as **Figure 3-2**. Combined with chlorination, conventional treatment is sufficient to achieve the Arrowsmith microbiological control objectives and, therefore, UV irradiation is not required. However, UV treatment is recommended to ensure that a "double disinfection barrier" against the protozoa is maintained. This will act as added security should breakthrough occur in one of the filters. UV reactors will have significant power requirements, likely



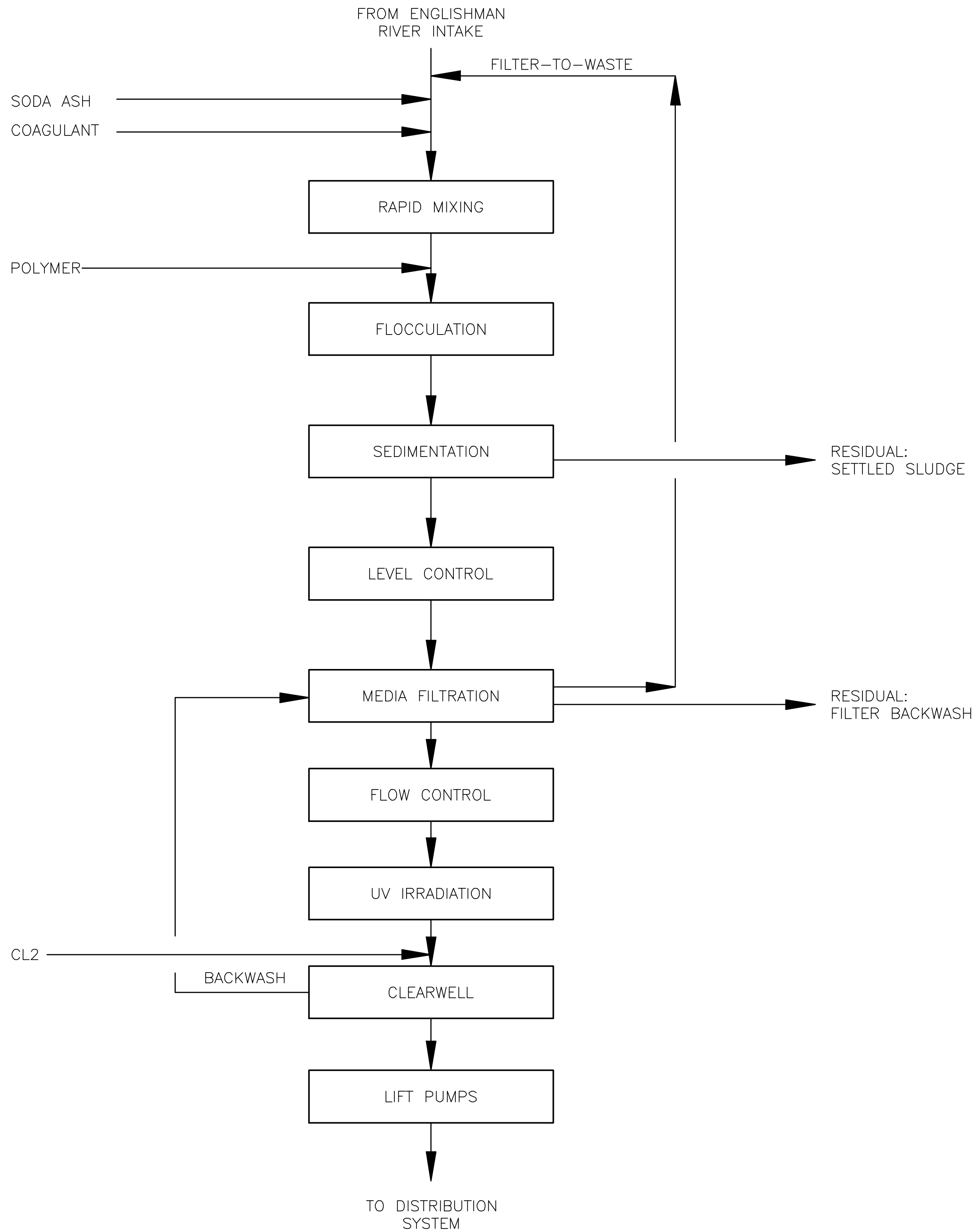
PROJECT No. 20092356
DATE: JAN 2010
APPROVED: K. KOHUT
SCALE: NONE
DWG. No. FIG 3-1

Associated Engineering

ARROWSMITH WATER SERVICES

ENGLISHMAN RIVER WATER INTAKE STUDY

FIG 3-1. SCENARIO 1 - DIRECT FILTRATION



PROJECT No. 20092356
DATE: JAN 2010
APPROVED: K. KOHUT
SCALE: NONE
DWG. No. FIG 3–2

Associated Engineering

ARROWSMITH WATER SERVICES

ENGLISHMAN RIVER WATER INTAKE STUDY

FIG 3-2. SCENARIO 2 - CONVENTIONAL TREATMENT

in the order of 15 MWh/year for LP and 200 MWH/year for MP reactors, but have a relatively small footprint and will, therefore, have only a small impact on plant sizing requirements.

Scenario 2 is suitable for Englishman River water for all turbidity levels observed.

3.3 Scenario 3: Dissolved Air Flotation

Scenario 3 involves the following processes:

- Alkalinity addition via chemical dosing
- Coagulation/flocculation/DAF
- Media filtration
- UV irradiation
- Chlorination
- pH adjustment via chemical dosing

A process flow diagram is presented as **Figure 3-3**. As with Scenario 2, UV irradiation is not required, but, at this stage, is recommended as a 'double barrier' to Cryptosporidium and *Giardia*. Proprietary versions of DAF are available, such as AquaDAF™, which boast higher loading capacities and smaller footprints in exchange for higher capital cost. For siting considerations, it will be assumed that a non-proprietary DAF system will be included.

Scenario 3 is suitable for Englishman River water when turbidity is below 100 NTU.

3.4 Scenario 4: Membrane Filtration

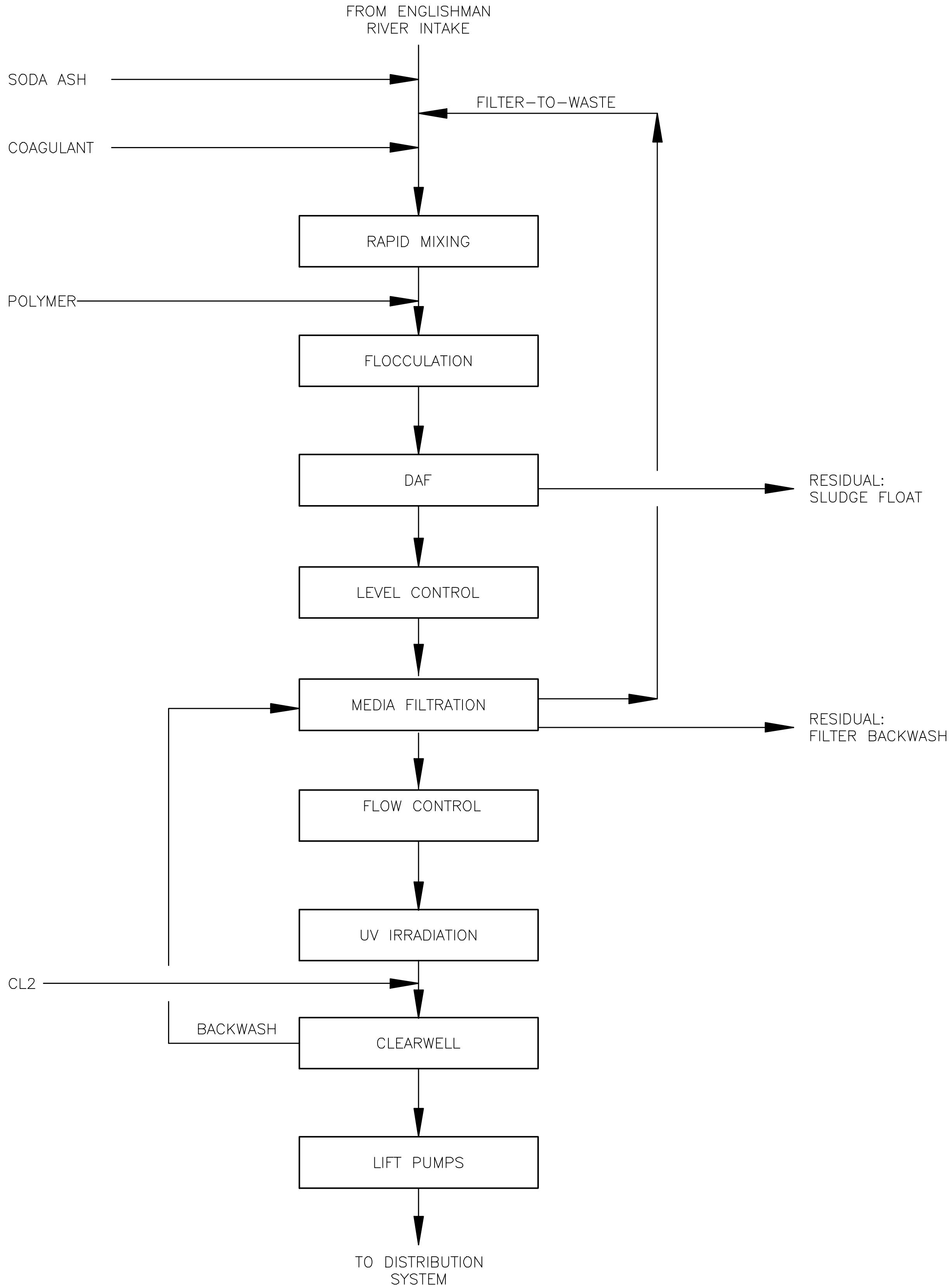
Scenario 4 involves the following processes:

- Alkalinity addition via chemical dosing
- Coagulation/flocculation
- Membrane filtration
- Chlorination
- pH adjustment via chemical dosing

A process flow diagram is presented as **Figure 3-4**. Although incorporated into the design, the use of chemicals for coagulation/flocculation may only be required during turbidity events. However alkalinity addition is still recommended for corrosion control. UV irradiation was not included in the treatment process stream, as the risk and impact of breakthrough is several orders of magnitude less for membranes than media filters. If high density membranes are used, Scenario 4 is suitable for Englishman River water for all turbidity levels observed.

3.5 Scenario 5: Actiflo®

Scenario 5 involves the following processes:



PROJECT No.	20092356
DATE:	JAN 2010
APPROVED:	K. KOHUT
SCALE:	NONE
DWG. No.	FIG 3–3

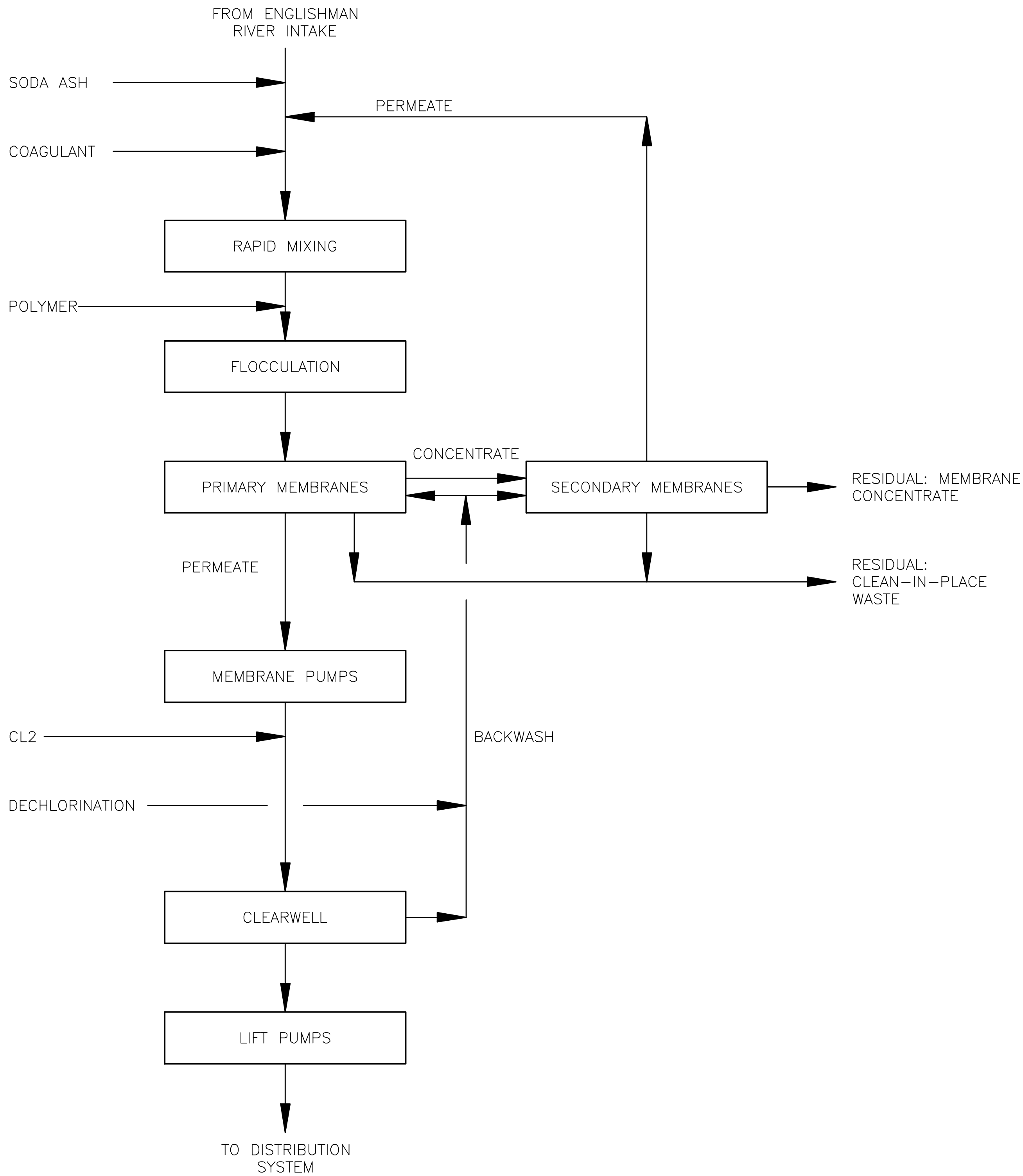
Associated Engineering

ARROWSMITH WATER SERVICES

ENGLISHMAN RIVER WATER INTAKE STUDY

FIG 3-3. SCENARIO 3 - DISSOLVED AIR FLOTATION

Time: 16:23 Date: 2010/1/21 Lt/Drawing Scale: 1=1.000 AutoCAD File: P:\20092356\01_CONCEPT_PLANNING\ENGINEERING\03.00_CONCEPTUAL_FEASIBILITY_DESIGN\DISCUSSION_PAPER_4-3\DRAWINGS\FIG_3-2.DWG (SL)



Time: 15:25 Date: 2010/1/22 Plot Scale: 1=1 (Paper Space) AutoCAD File: P:\20092356\01_CONCEPT_PLANNING\ENGINEERING\03.00_CONCEPTUAL_FEASIBILITY_DESIGN\DISCUSSION_PAPER_4-3\DRAWINGS\FIG_3-4.DWG (SL)

PROJECT No. 20092356
DATE: JAN 2010
APPROVED: K. KOHUT
SCALE: NONE
DWG. No. FIG 3-4

Associated Engineering

ARROWSMITH WATER SERVICES

ENGLISHMAN RIVER WATER INTAKE STUDY

FIG 3-4. SCENARIO 4 -MEMBRANE FILTRATION

- Alkalinity addition via chemical dosing
- Actiflo® (enhanced coagulation, flocculation, sedimentation)
- Media filtration
- UV irradiation
- Chlorination
- pH adjustment via chemical dosing

A process flow diagram is presented as **Figure 3-5**. As with Scenarios 2 and 3, UV irradiation is not required, but, at this stage, is recommended as a 'double barrier' to *Cryptosporidium* and *Giardia* should breakthrough occur in one of the filters.

Scenario 5 is suitable for Englishman River water for all turbidity levels observed.

4 Other Sizing Considerations

The following subsections identify other components to a water treatment plant that will contribute to the size of the treatment plant site. Note that not all of the elements need to be incorporated, but will add convenience to plant operations.

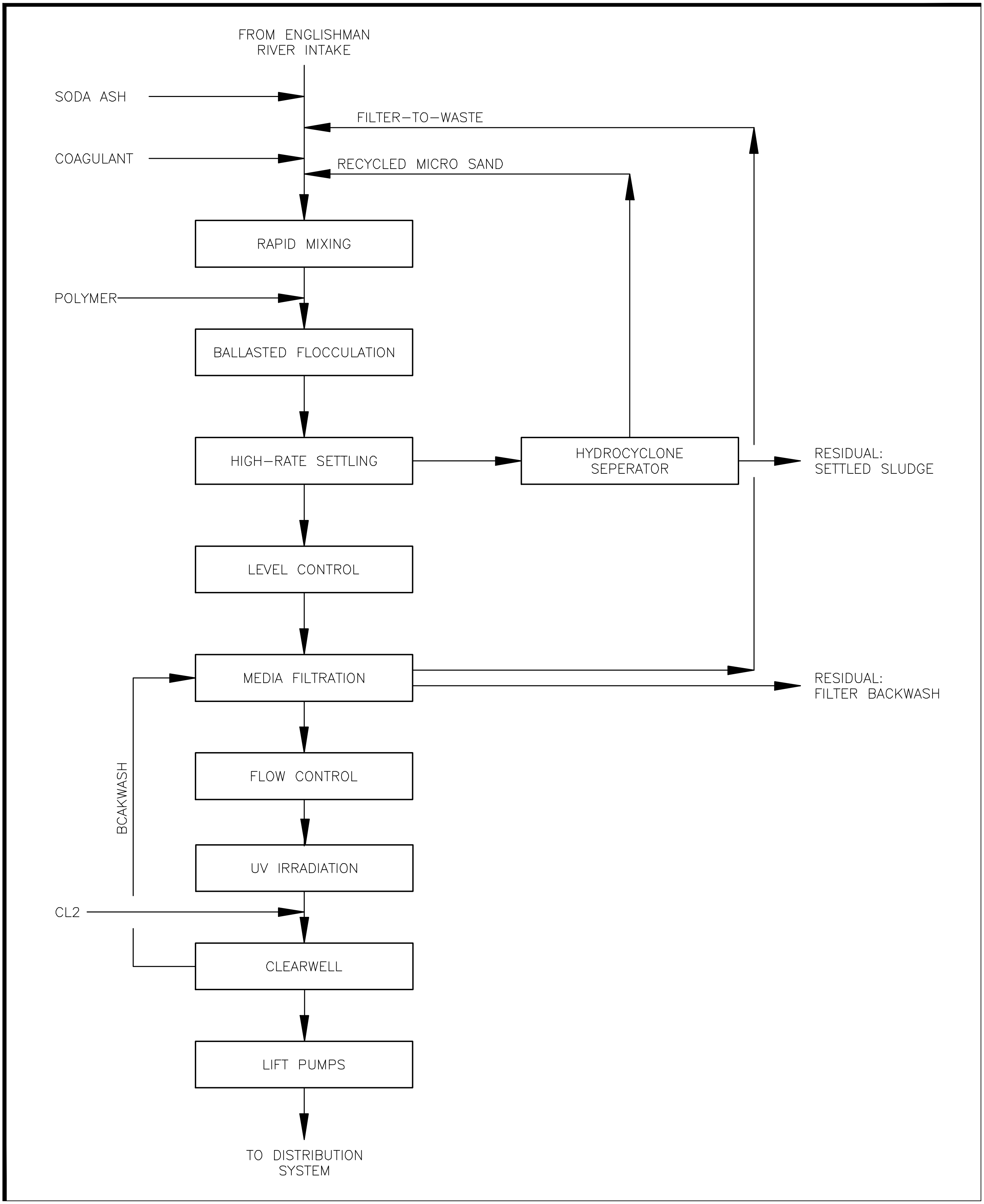
4.1 Other Facilities

In addition to the space required for the actual treatment processes, a number of other rooms should be included. The critical rooms required are as follows:

- Chemical storage rooms
- Membrane storage area
- Mechanical equipment storage room and workshop
- Electrical equipment storage room and workshop
- Electrical room
- Building mechanical room
- Loading dock for bulk supplies
- Plant control room
- Laboratory

Worksafe BC regulations require that hazardous chemicals, such as chlorine, must be stored in an isolated chemical room, accessible only from the outside. A dry scrubber in an adjacent room will be included in the design, for the purpose of capturing any chlorine gas that may form during a significant leak to prevent the gas from venting to the atmosphere.

For operator convenience, and to outfit the plant for public viewing or tours, inclusion of the following rooms should be considered:



Time: 15:26 Date: 2010/1/22 Plot Scale: 1=1 (Paper Space) AutoCAD File: P:\20092356\01_CONCEPT_PLANNING\ENGINEERING\03.00_CONCEPTUAL_FEASIBILITY_DESIGN\DISCUSSION_PAPER_4-3\DRAWINGS\FIG_3-5.DWG (SL)

PROJECT No.	20092356
DATE:	JAN 2010
APPROVED:	K. KOHUT
SCALE:	NONE
DWG. No.	FIG 3-5

Associated Engineering

ARROWSMITH WATER SERVICES

ENGLISHMAN RIVER WATER INTAKE STUDY

FIG 3-5. SCENARIO 5 - ACTIFLO

- Offices
- Meeting room
- Reception lobby
- Locker rooms and washrooms with showers
- Lunch room
- Filing room
- Janitor storage room

4.2 Residual Management

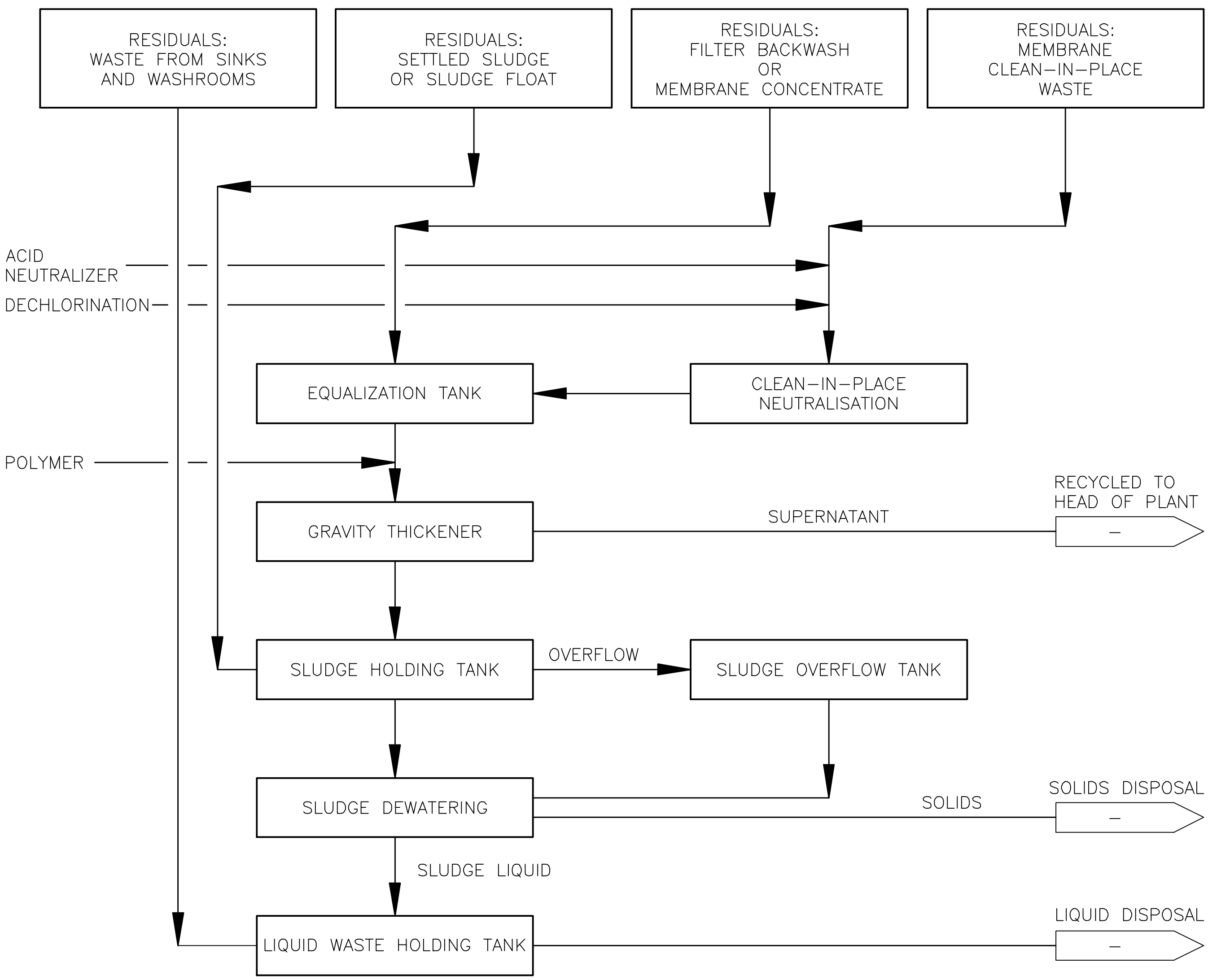
Of the raw water entering the proposed treatment plant, approximately 90 to 97% will leave the plant as drinking water. The remaining water is sent to waste. For conventional treatment systems, water thick with sediment will be removed from the treatment stream as sludge. For media filtration, water is pulled from the treatment stream to backwash and ripen newly cleaned filters. Water will also be sent to waste after being use to clean the membranes or carry particles rejected by the membranes out of the filter system.

In the interests of sustainability, both in minimizing waste production and maximizing the amount of drinking water produced from a given amount of raw water, a “zero-liquid” discharge approach is recommended. Waste produced from the drinking water treatment processes will undergo additional treatment to extract water from the waste stream to send back to the head of the plant. In effect, water originally sent to waste can be recycled to be treated as drinking water.

A typical dewatering process stream is show in **Figure 4-1**. Depending on the solids content of the waste, the waste will be increasingly thickened and the supernatant removed, before undergoing a final dewatering stage. The more dilute the waste the more thickening required. For raw water with a turbidity typically below 1 NTU, the approximate solids content for different waste streams, in order of most dilute to thickest, are estimated as follows:

- Media filtration: filter-to-waste (0.04% solids)
- Membrane filtration: reject waste (0.4% solids)
- Media filtration: backwash waste (0.5% solids)
- Actiflo® sludge (0.5% solids)
- Sedimentation/DAF sludge (4% solids)

The waste is first sent to holding or equalization tanks. As much of the waste is generated in sporadic, high volume events, the holding tanks allow waste treatment to done continuously and at a lower capacity. This in turn leads to smaller sized dewatering facilities being required. It is undesirable to hold the more dilute waste streams, namely, the waste with less than 1% solids content, with the thicker sludge in the same holding tank, as this will dilute the sludge and increase residual treatment costs.



Time: 16:23 Date: 2010/1/21 Lt/Drawing Scale: 1=1.000 AutoCAD File: P:\20092356\01_CONCEPT_PLANNING\ENGINEERING\03.00_CONCEPTUAL_FEASIBILITY_DESIGN\DISCUSSION_PAPER_4-3\DRAWINGS\FIG_3-2.DWG (SL)

PROJECT No. 20092356
DATE: JAN 2010
APPROVED: K. KOHUT
SCALE: NONE
DWG. No. FIG 4—1

Associated Engineering

ARROWSMITH WATER SERVICES

ENGLISHMAN RIVER WATER INTAKE STUDY

FIG 4-1. RESIDUAL MANAGEMENT

The dilute sludge is dosed with polymer to promote further aggregation of the solid particles and thickened in a gravity thickener. Supernatant from the thickeners can be sent to the head of the plant for drinking water treatment. The thickened waste joins sludge in a second holding tank, then is subjected to a dewatering process. A variety of dewatering technologies are commonly used, including the following:

- Centrifuge
- Drum dehydrator
- Filter press
- Belt press

Specific dewatering technologies will be evaluated in a later stage of design. The dewatered solids can then be shipped to a landfill for disposal or on-site composting field. Water removed during this final stage of dewatering may still have high solids content, meaning that simply sending the decanted water back to the head of the treatment plant may drastically change the raw water chemistry. If the impact is significant, the centrate should be discharged to the sanitary sewer for treatment.

5 Summary

Based on the available water quality, the following combinations of treatment processes should be considered for the proposed Englishman River water treatment plant:

- *Scenario 1:* Direct filtration: alkalinity addition, coagulation/flocculation, media filtration, UV irradiation, chlorination, pH adjustment
- *Scenario 2:* Conventional treatment using sedimentation: alkalinity addition, coagulation/ flocculation/sedimentation, media filtration, UV irradiation, chlorination, pH adjustment
- *Scenario 3:* DAF: alkalinity addition, coagulation/flocculation/ DAF, media filtration, UV irradiation, chlorination, pH adjustment
- *Scenario 4:* Membrane filtration: alkalinity addition, coagulation/flocculation, membrane filtration, chlorination, pH adjustment
- *Scenario 5:* Actiflo®: alkalinity addition, Actiflo®, media filtration, UV irradiation, chlorination, pH adjustment.

Bench-scale and pilot testing will determine whether additional treatment, in the form of activated carbon, is needed for the removal of organics. Some of the scenarios have a lower capital cost, but have a maximum raw water turbidity limit above which they cannot effectively treat. Some historical turbidity events have exceeded these limits. Thus, the operation philosophy of the proposed water treatment plant must be considered when evaluating the treatment options. If the plant were designed to shut down during the more extreme turbidity events, a less expensive treatment option could be used.

Residual management and sustainability will likely be a prominent feature of the proposed treatment plant. It is recommended that a “zero-liquid” discharge approach be taken and that LEED® sustainable design principles be incorporated into plant design.

6 List of References

1. Health Canada, 2009. Guidance on Controlling Corrosion in Drinking Water Distribution Systems, June 2009.

2. Rotherberg, M.R., and Scuras, S.E., 1994. The Rothberg, Tamburini & Winsor Model for Water Process and Corrosion Chemistry, Version 4.0”, Distributed through the AWWA Software Library.