APPENDIX C-3

LOW-LIFT PUMPING STATION

Utilities Kingston

POINT PLEASANT
WATER TREATMENT PLANT EXPANSION

TECHNICAL MEMORANDUM NO. 3
LOW LIFT PUMPING STATION UPGRADE

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1.0 INTRODUCTION

Utilities Kingston retained J.L. Richards & Associates Limited, in association with CH2MHILL Canada Limited, to complete a Class Environmental Assessment (Class EA) to expand the treatment capacity at the Point Pleasant Water Treatment Plant (WTP), previously referred to as the Kingston West WTP, in order to implement the June 2007 Master Plan for Water Supply for the City of Kingston Urban Area. This Master Plan identified works that will be required to meet existing and future demand increases within the urban area of Kingston resulting from growth. The Master Plan Class EA determined that the expansion of the Point Pleasant WTP is of high priority. Therefore the purpose of this Class EA study is to identify the preferred strategy for meeting future water treatment needs at the Point Pleasant WTP.

The Point Pleasant WTP, located at 80 Sunny Acres Road, supplies water to the Kingston West water distribution system, and currently has a rated capacity of 45.5 megalitres per day (ML/d). This Class EA study will examine alternative strategies to increase the functional capacity of the WTP to 80 ML/d by the year 2012 in order to accommodate demand. With ever more stringent treated water quality requirements, and an expanding Kingston population, there may be a need to improve both the capacity and treated water quality of the existing facility.

A number of important issues are being reviewed and addressed through five Technical Memoranda prepared as part of the Class EA process, as summarized below:

Technical Memorandum No. 1:	Source Water Quality and Drinking Water Treatment Objectives
Technical Memorandum No. 2	Existing Facility Condition Assessment and Treatment Limitations
Technical Memorandum No. 3	Low Lift Pumping Station Upgrade
Technical Memorandum No. 4	Treatment Process Expansion
Technical Memorandum No. 5	Treated Water Pumping and Storage Upgrade

This Technical Memorandum (TM No. 3) describes both the existing Low Lift Pumping Station as well as the upgrades necessary to meet future pumping requirements.

The current WTP rated capacity is to increase from 54 488 m^3/d to 80 000 m^3/d. Raw water pumping capacity will be evaluated on the basis of a 90 000 m^3/d capacity to ensure that all backwash and in-house water use will be accounted for. This value will be confirmed during the preliminary design phase once the amount of backwash and in-house water required is finalized.

For the purposes of this Tech Memo, the raw water system includes the following:

- Raw Water Intake and Pipe
- Screening
- Low Lift Pumps
- Raw Water Conveyance to the Flocculation Tanks

Existing raw water systems were reviewed and evaluated in Tech Memo No. 2. The following recommendations were made:

- The zebra mussel system needs to be upgraded (diffuser reinstated at intake and chlorine piping not routed through the sluice gate).
- The additional headloss due to higher flows through the intake pipe will have to be considered in the low lift pumping upgrades.
- Capacities of existing screens and condition of underwater components need to be assessed.
- The Permit to Take Water will have to be increased.
- Submerged portions of the traveling screen should be inspected, unless the screen is to be replaced.
- Low lift pumping firm capacity needs to increase to approximately 90 000 m^3/d (from current 54 509 m^3/d).
- Pumping combinations need to be evaluated with options potentially including new and existing pumps.
- Variable speed drive(s) or pump staging in combination with a raw water rate control valve would improve control of flow to the treatment process.
- Hydraulics and Net Positive Suction Head characteristics of new pumping will need to consider additional headloss through intake pipe, gates, and screens.

- Raw water transmission piping to the WTP and flow metering will likely need to be twinned or replaced.
- Ensure floor drains do not discharge back to Lake Ontario.

2.0 RAW WATER INTAKE AND INTAKE PIPE

An existing 1200 mm diameter reinforced concrete intake pipe extends approximately 520 m into Lake Ontario and terminates at a wooden crib inlet equipped with a coarse bar rack. The intake was retrofitted to include chlorine piping for zebra mussel control. The chlorine line is routed through an isolation sluice gate in the low lift pump station and would have to be relocated to close the gate.

Based on the anticipated plant expansion to 90 000 m^3/d (for a net functional WTP output of 80 000 m^3/d), the entry velocity into the intake would increase to 0.08 m/s and the velocity in the intake pipe would increase to 0.9 m/s. These are considered to be within acceptable design ranges. At a flow of 90 000 m^3/d, the headloss through the intake would increase by approximately 1 m, and the water level in the low lift pump wet well would decrease accordingly. Hydraulic modeling was undertaken to approximate the head losses to be expected from the intake structure to the low lift well. The anticipated water level in the low lift well is a function of the lake level, the piping configuration, and the water flow rate. At 90 000 m^3/d, and a normal lake level of 75 m, the water level in the low lift pumping well would be approximately 73.7 m, which is above the minimum well water level of 72.75 m. Similarly, at a low lake level of 74.1 m, the level in the wet well would be approximately 72.8 m, which is marginally above the existing minimum 72.75 m. Therefore, the existing intake appears to be in acceptable condition and provides adequate conveyance capacity for the proposed 90 000 m^3/d flow. The additional headloss can be accommodated with the pump upgrades to ensure that the water levels throughout the treatment system remain at the required level.

Upgrade options include:

- **Maintenance of the existing intake pipe.** In this option, modifications would be required to the zebra mussel chlorine feed piping. Although the zebra mussel control line must be relocated to close the raw water intake gate, this gate is not used often. Rerouting would require exposing the pipe outdoors and completing a hot tap to connect the chorine supply line. This option is recommended to permit the gate to be regularly exercised and closed in the event that emergency work is required in the downstream wells.

- **Twinning of the intake pipe.** This option provides redundancy for the intake pipe. Hydraulically, it appears that the existing pipe has adequate capacity and a new intake line is not warranted. In the long term, this option may be necessary and could feed a new wet well to provide raw water intake redundancy and additional capacity.

3.0 SCREENING

The intake pipe discharges through a slide gate to the screen chamber which includes a vertical manual trash screen (12 mm to 16 mm openings), and a mechanical traveling screen. The vertical trash screen panels are removed by a hoist for cleaning. The automatic screen includes nominally 1 050 mm wide panels made up of woven stainless steel mesh at approximately 12 mm centers. Although a 40 year life, or greater, is not unusual for this style of screen, an underwater inspection should be completed if it is to be retained.

If an underwater inspection reveals that the existing traveling screen is in reasonable condition, and it does not pose a significant hydraulic restriction, then replacement is not warranted. This screen is not heavily used as it accumulates limited debris. The manual trash screen does not require replacement and represents limited head loss.

Relocation of the low lift wet well and screening chamber is not warranted considering the space is not required for other processes, and relocation would present a significant cost in excess of $1 million or more.

In the long term, a second raw water intake could feed a second screen channel and low lift pumping station.

4.0 LOW LIFT PUMPING STATION

After passing through the screening channel, water discharges to the low lift pump wet well. The low lift pumping station and intake is illustrated schematically in Figure 1.

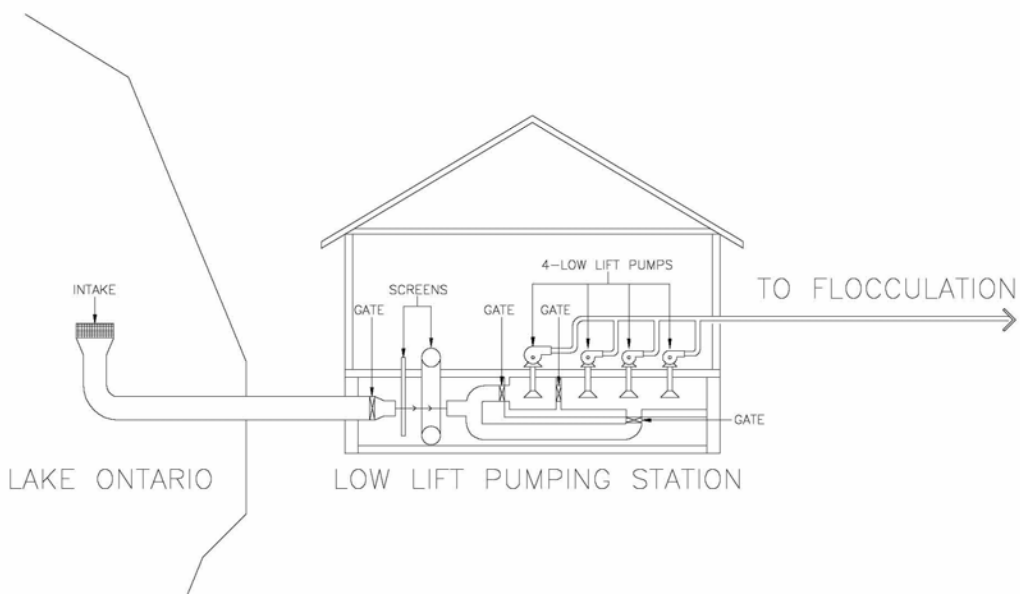

Figure 1 – Schematic of Existing Low Lift Pumping Station

The vertical turbine low lift pumps are situated above a 405 m^3 wet well. The pump well is divided into two chambers as follows:

1. Chamber 1: Nominally 3.7 x 5.6 m, supplying LLP#1
2. Chamber 2: Nominally 7.0 x 8.1 m, supplying LLP#2, 3, and 4
3. Both wells are nominally 5.8 m deep from the bottom of the well (elevation 70.4 m) to the top of concrete in the pump room above.
4. Each chamber is connected to the incoming screen well and to each other by 600 x 600 mm openings equipped with sluice gates. At 90 000 m^3/d, the average velocity through one opening would be 2.9 m/s, and through two openings concurrently, 1.6 m/s. Each chamber can be isolated from each other, as shown in Figure 1.

The existing low lift pumps are single-stage fixed speed pumps, as summarized in Table 1.

Table 1 - Summary of Low Lift Pumps

Pump ID	Manufacturer	Rated Capacity (L/s / m3/d)	TDH	NPSH (m)	Drive (type/HP)	Notes
LLP#1 (1977, diesel drive 2004))	Fairbanks Morse	315 L/s 27 255 m^3/d	13.9 m	7.3 m	Diesel & electric	Draws from its own wet well (see Figure 1)
LLP#2 (1989)	Fairbanks Morse	315 L/s 27 255 m^3/d	13.9 m	7.3 m	Electric	Draws from combined wet well (see Figure 1)
LLP#3 (1977)	Fairbanks Morse	158 L/s 13 627 m^3/d	13.9 m	Not Recorded	Electric	Draws from combined wet well (see Figure 1)
LLP#4 (1977)	Fairbanks Morse	158 L/s 13 627 m^3/d	13.9 m	Not Recorded	Electric	Draws from combined wet well (see Figure 1)

The existing pumps appear to have been well maintained. It is not unusual for pumps similar to the existing to achieve a service life in excess of 40 years, therefore, the possibility of retaining them in the upgraded pumping station should be considered.

Performance of the existing pumps was evaluated during testing conducted on-site. Because of operational constraints, only one operation point could be tested for each pump. However, this point was compared with its published pump curve – this confirmed that the existing pumps operate approximately as suggested by their pump curves. Thus, provided that the flow rates and configuration is appropriate, the existing pumps could remain in service as part of the proposed upgrades.

An important consideration in determining the suitability of the existing pumps is the Net Positive Suction Head (NPSH) required (NPSHR) and available (NPSHA) for the pumps. The NPSH is a measure of the pressure that conveys the liquid into the eye of the pump impeller. NPSH accounts for atmospheric pressure, static head, vapour pressure, and friction losses prior to the pump impeller. With insufficient NPSH, cavitation can occur, resulting in a reduction of pump efficiency and potential damage to the impeller. Because pumps operating at the published NPSHR value are already experiencing 3% degradation in head due to cavitation (by definition), ANSI/HI 9.6.1 recommends applying a safety factor of between 1.1 and 1.3 (or a margin of 600 mm) to determine a NPSH value at which cavitation will not occur. In other words, the published NPSHR is multiplied by the safety factor to determine the allowable NPSH. The available NPSH in the final installation must be greater than this allowable NPSH. Based on the current minimum water level in the low lift suction well, all four pumps can operate at their rated capacity and be within their respective NPSH requirements at a factor of up to 1.22, or with the 600 mm margin. With a factor of greater than 1.22, there will be insufficient NPSH available for Low Lift Pump No. 1. The other three low lift pumps will have sufficient NPSH available at the rated low well level for margin factors from 1.22 to 1.3. Note that the water level in the wet well will only approach the rated low level of 72.75 m when the water level in Lake Ontario is at its lowest level and the flow through the intake is at its rated maximum (as discussed above, with the new rated capacity of 90 000 m^3/d, the low level is expected to be 72.8 m). As low lake levels and maximum demand are not likely to occur frequently, and the NPSH available for Pump No. 1 is adequate up to a safety factor of 1.22, there is limited risk of cavitation. It is also noted that at no time is the NPSHA less than the published NPSHR. The other three low lift pumps will have NPSHA that exceeds the NPSHR with a safety factor of 1.3 at the rated flow and minimum low lift pumping well level. Therefore, existing pumps have suitable NPSH characteristics for the future operation. During the Preliminary Design, the wet well configuration and flow patterns should be evaluated to reduce the risk of turbulence or unbalanced flows at the pump suction.

During the design phase, the flow and suction characteristics for the low lift wet well will need to be compared to Hydraulic Institute (HI) standards to ensure that adequate submergence and flow streamlines are attained for proper and efficient pump operation.

Design considerations include:

- Actual performance of existing pumps should be evaluated in the field to assess efficiency and operating point. As a minimum, premium efficiency motors should be considered for existing pumps to be maintained.
- Net Positive Suction Head characteristics for the proposed pump arrangement should be considered carefully, particularly with a lower wet well level caused by increased flow and head loss through the raw water inlet and screen.
- Flow patterns in the wet well must be evaluated relative to good practice (Hydraulic Institute) to avoid turbulence or patterns that may contribute to cavitation.
- A firm capacity should be established. A firm capacity equivalent to average day demand versus maximum day demand could be considered if cost savings are significant or if standby may be provided by the Central Water Treatment Plant.

- Standby pumping capacity, in the event of loss of electrical power to the WTP, should be established. Ten States Standards recommends that standby pumping equivalent to the average day demand be provided as a minimum. Considerations include the frequency and duration of power outages, the quantity and type of storage in the distribution system, and potential fire fighting demands. The distribution system model should be used to estimate the minimum required standby low lift pumping, which, aside from the water stored onsite, should match the minimum required high lift pumping capacity.
- Gas or diesel driven pumps should be compared to a central standby power generating station. Either way, peak shaving of electrical demand could be implemented by using diesel or gas driven engines during peak demand periods.
- Control of the raw water flow rate to the treatment process must be evaluated. The original design included a 600 mm diameter motorized modulating valve to control the flow rate to the treatment process. This valve is no longer operational, and flow control can only be achieved by turning low lift pumps off and on. The ability to modulate the pumping output from one or more pumps with variable speed drives would improve the control of flow to the treatment process and should be compared with reinstatement of the raw water flow regulating valve and staging of pumps.
- Conveyance capacity and redundancy between the low lift pumping station and the treatment process must be evaluated. Raw water pumped by the low lift pumps flows through a 750 mm diameter concrete pressure pipe to the rapid mixing tanks. The piping reduces from 750 mm diameter to 600 mm diameter for the flow meter and motorized butterfly valve. The raw water transmission piping is stainless steel indoors and appears to be reinforced concrete pipe below grade. The piping appears to be in good condition.
- Accuracy of the existing flow meter should be evaluated.
- Any upgrades should take into account potential modifications to the plant beyond the 20 year life period considered for the current upgrades.

The following sections consider options to upgrade the Low Lift Pumping Station.

Low Lift Pumping Capacity Requirements

The current nameplate capacity of the low lift pumps is 81 764 m^3/d, with a firm nameplate capacity of 54 509 m^3/d. Nameplate capacity in the event of a power failure is currently 27 255 m^3/d.

The intended pumping station capacity is 90 000 m^3/d, which corresponds to the 20 year projected maximum day capacity plus in-house and backwash water requirements (to be confirmed during the preliminary design). With reference to historic treated daily water demands, the maximum day/average day factor is 1.39, and the minimum day/average day ratio is 0.82. Additionally, Operations Staff have indicated that typically one small pump (13 627 m^3/d) cannot maintain levels in the treatment process, and yet one large pump (27 255 m^3/d) is larger than required.

Based on the foregoing, the following capacities are recommended:

- **Total Low Lift Pumping Capacity:** Equivalent to plant rating plus backwash requirements (90 000 m^3/d; to be confirmed during preliminary design).
- **Firm Pumping Capacity**: Nominally 90 000 m^3/d. This approach allows maximum day demands to be independently met by the Water Treatment Plant if the largest pump is out of service (to be confirmed during preliminary design).
- **Smallest Pump:** Capacity greater than the 20 year minimum day demand projection. For the current operation, flow rate control in the form of a rate control valve or variable speed drives would be provided.
- **Emergency Pumping Capacity:** Based on the Maximum Day flow of 90 000 m^3/d and a Maximum Day/Average Day factor of 1.40, a nominal Emergency Pumping Capacity of 65 000 m^3/d (average day demand) is recommended, based on existing plant flow information. Standby power may be provided by an emergency back-up generator system, or directly by fuel-fired engine driven pumps, as described at the end of this section.

The following tables provide four different pump options to meet the flow requirements. While the exact orientation is to be confirmed during the preliminary design stage, these options illustrate the range of options available.

Table 2 - Pump Configuration Option No. 1

Pump	Nominal Capacity (m^3/d)	Total Dynamic Head (TDH) (m)	New/Existing
LLP No. 1	27 255	13.9	Existing
LLP No. 2	27 255	13.9	Existing
LLP No. 3	13 627	13.9	Existing
LLP No. 4	13 627	13.9	Existing
LLP No. 5	27 255	13.9	New
Total Capacity (m^3/d)	109 019		
Firm Capacity (m^3/d)	81 764		
Standby Capacity (m^3/d)	68 137		

The advantages of this scenario involve maintaining the existing pumps and adding one new pump. This would keep costs lower, as only one new pump is required. In addition, there are only two different types of pumps (three at 27 255 m^3/d and two at 13 627 m^3/d), which would simplify maintenance and operation of the pumps. Disadvantages with this option include the fact that there would be four older pumps as part of the installation. This option would also require flow control to meet minimum current production without pump cycling. In addition, this configuration would not meet the maximum day demand with firm capacity.

Table 3 - Pump Configuration Option No. 2

Pump	Nominal Capacity (m^3/d)	Total Dynamic Head (TDH (m)	New/Existing
LLP No. 1	27 255	13.9	Existing
LLP No. 2	27 255	13.9	Existing
LLP No. 3	27 255	13.9	New
LLP No. 4	27 255	13.9	New
Total Capacity (m^3/d)	109 020		
Firm Capacity (m^3/d)	81 765		
Standby Capacity (m^3/d)	54 510 or 81 765 (depending upon chosen configuration)		

The advantages of this scenario include the fact that two of the four pumps would be new, saving some costs, while updating some of the pumping equipment. In addition, all pumps are identical, simplifying operation and maintenance. Aside from having two older pumps, the main disadvantage is that the firm capacity is less than the Maximum Day demand.

Table 4 - Pump Configuration Option No. 3

Pump	Nominal Capacity (m^3/d)	Total Dynamic Head (TDH (m)	New/Existing
LLP No. 1	27 255	13.9	Existing
LLP No. 2	27 255	13.9	Existing
LLP No. 3	35 500	13.9	New
LLP No. 4	35 500	13.9	New
Total Capacity (m^3/d)	125 510		
Firm Capacity (m^3/d)	90 010		
Standby Capacity (m^3/d)	62 755 or 71 000 (depending upon chosen configuration)		

The advantages of this scenario include the fact that two of the four pumps would be new, saving some costs, while updating some of the pumping equipment. This pumping configuration meets the Maximum Day flow with firm capacity. Disadvantages include the cost of two new (larger) pumps, and the fact that the two existing pumps are aging. In addition, based on current minimum to average flows, the older existing pumps may be preferentially run most of the time because the new pumps are larger.

Table 5 - Pump Configuration Option No. 4

Pump	Nominal Capacity (m^3/d)	Total Dynamic Head (TDH) (m)	New/Existing
LLP No. 1	27 255	13.9	Existing
LLP No. 2	27 255	13.9	Existing
LLP No. 3	21 000	13.9	New
LLP No. 4	21 000	13.9	New
LLP No. 5	21 000	13.9	New
Total Capacity (m^3/d)	117 510		
Firm Capacity (m^3/d)	90 255		
Standby Capacity (m^3/d)	63 000 or 69 255 (depending upon chosen configuration)		

This option requires the addition of three new pumps (for a total of five), which could present some difficulty in "squeezing" an additional pump into the low lift pumping station (there are only four currently installed). Since there would be only two types of pumps, maintenance would be simplified, but there would be one additional pump to maintain above the current configuration.

To determine the standby pumping capacity for each of the above options, the nominal pump capacities were added to arrive at the combination that came closest to the recommended 65 000 m^3/d flow rate. Since the low lift pumping capacity should roughly match the high lift pumping capacity (with on-site storage acting as a buffer), the actual emergency pumping rates will likely be dictated by the high lift emergency pumping capacity. Refer to Technical Memorandum No. 5 for information regarding the high lift pumping station and onsite storage. There are essentially two options to provide power for standby pumping for the equivalent of an average day demand (65 000 m^3/d); gas or diesel-driven pumps, or standby electric generator(s). The advantages and disadvantages, including a comparison of capital cost vs. operational costs, redundancy, and operational flexibility will be confirmed during the design stages. However, budgetary pricing of new pumps has been obtained for a preliminary comparison of the order-of-magnitude costs for the various options, as shown in Table 6.

Table 6 - Budgetary Cost Estimates for New Pumps for Various Options

Option	New Pump Capacity (m^3/d)	Quantity	Unit Cost	Total Cost
1	27 255	1	$110 000	$110 000
2	27 255	2	$110 000	$220 000
3	35 500	2	$110 000	$220 000
4	21 000	3	$110 000	$330 000

Notes:
- Costs are for the pumps only, not for additional valves, starters, MCCs, piping etc., since these details will be determined during the design stages.
- Costs are budgetary figures subject to change and are provided for illustrative purposes only.
- Note that unit costs for all three pump sizes is the same. The same pump model would be supplied, with each rated capacity supplied with a different impeller trim to optimize efficiency at the duty point.

5.0 RAW WATER CONVEYANCE TO THE FLOCCULATION TANKS

Raw Water Conveyance to the Treatment Building

At a flow rate of 90 000 m^3/d, the velocity in the 750 mm diameter raw water transmission main would be slightly below 2.3 m/s, which is relatively high. The existing flow element is out of range as it is sized to measure from 0 to 50 000 m^3/day. The upgrade options include:

- **Retain Existing Installation:** Maintaining the existing raw water main does provide sufficient capacity for the expanded plant, but with little margin at full capacity, and provides no redundancy.
- **Twin the Raw Water Main:** Twinning of the main resolves hydraulic limitations as well as provides additional redundancy and reliability in the operation. Low lift pumps could be configured to half the capacity pump to one main and the other half pump to the second main. Mains would be interconnected to permit flow balancing and flexibility in pump operation/selection. The new main would not necessarily need to have the same diameter as the existing one. Exact sizing and routing would be determined during the

design phase based on Utilities Kingston's preferences and anticipated future pumping requirements.

- **Replace the Existing Raw Water Main:** The existing main must be maintained until the proposed main is constructed and commissioned. Unless the space occupied by the existing main is useful for another application, there is no apparent reason to remove and decommission this line. In addition, the cost of a new main would be increased due to the larger size requirement.

Raw Water Flow Control

Control of raw water flow rates facilitates a stable treatment process by eliminating surges and changes in flow rates. Typically raw water flow control is based on maintaining influent channel levels. Options for flow control include:

- **Provide a modulating valve in the raw water line.** This may be the most economical and least complex approach. This option avoids complex and more costly drives, and a single control loop may be used for any combination of low lift pumps. Modulating a valve at the discharge of the pumps also reduces energy demand by pushing the pump operating point to the "left" on the pump curve. As the operating point moves left, the power requirement is reduced, although the hydraulic efficiency is also reduced. If the low lift discharge line to the treatment areas were to be twinned, two rate control valves would be required with their own dedicated flow meters.
- **In the second option, variable speed drives are provided for all or some of the pumps.** As a minimum, VFDs would be provided for at least two pumps to provide some level of redundancy. If variable frequency drives are used, they are associated with their own inherent losses and may require additional equipment to cool the MCC room. Initial and repair costs for the VFDs will also be higher than soft start starters, for example.

Because of the extra capital and maintenance costs associated with VFDs, and the relatively simple operation of rate control valves, the first option may prove to be more cost-effective. The first option, however, represents a lower efficiency because flow control is achieved by increasing losses in the discharge piping to reduce the flow to the treatment areas. Once the discharge piping configuration is determined in the preliminary design phase, the final decision regarding rate-control can be made.

6.0 CONCLUSION

This technical memorandum summarizes the various options for the low lift pumping station upgrade at the Point Pleasant WTP. The final decisions with regard to the many options listed above will be deferred to the preliminary design stages, when the impact of all upgrades, as well as the constraints of site layout, are fully understood. However, at this time, the following configuration is viewed as preferred, although as the design, particularly for the treatment areas, is further developed, this configuration will be optimized.

- No upgrades to the intake structure or intake pipe.
- Upgrade the intake slide gate as discussed in Section 2.0.
- Based on preliminary costs shown in Table 6, Option 1, which includes one new pump, appears to represent the lowest capital cost.
- Install a second low lift discharge pipe to the new water treatment area. The size and layout of this new line will be determined during the design stage, as it depends on provisions of future expansion, site layout, and proportion of flow to existing and new treatment areas.
- Implement modulating valves on the raw water piping to provide rate-control of the low lift pump discharge and the treatment process.