NORTH AMERICAS LARGEST MBR WWTP…..BREAKING IT DOWN TO MAKE IT COST EFFECTIVE AND A SMALL PLANT MENTALITY

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Introduction

At this writing the City of Canton Water Reclamation Facility (WRF) is the largest membrane bioreactor activated sludge (MBR) process in North America and its design was set into motion in 2010. It was ready for bid in late 2013, construction began in March 2014 and initiation of the first MBR train is expected to occur in the first half of 2016. The project cost per gallon of treated wastewater is under $2.25 and significantly lower than most MBR plants. The average daily design flow (ADF) is 39 million gallon per day (MGD) and the peak day flow is 88 MGD. The average daily flow is three to four times greater than any MBR operating at the time design began.

MBR plants have been placed in operation with increased capacity since, however the Canton WRF, to our knowledge is still the largest plant of those operating or under construction as of 2015. The Canton WRF activated sludge process design includes biological nutrient removal for total nitrogen and phosphorus to levels of 8.0 mg/l and 0.7 mg/l respectively. The initial project team meeting was a somber experience when confronted with the physical magnitude of the MBR process and surrounding system components. Intense efforts to optimize the plant design during the 30% phase resulted in maximum use of existing facilities and a large plant having characteristics of a small plant. This approach led the project to a very low cost per gallon of treated wastewater based on the average design flow.

The paper and/or presentation will explain the design, optimization methodology, and cost efficiencies. Flows, unit process and MBR process components and trains, associated support systems, levels of redundancy, chemicals systems and control aspects will be mentioned. Construction sequencing to convert a conventional plant to MBR with little and almost no temporary facilities was accomplished. Construction, and operation and maintenance (O&M) cost control considerations and/or methodology will be explained. Implementation methods considered and used, as well as maximum use of existing facility were instrumental with cost control.

MBR plants continue to grow in size. The industry has been adapting to the increased size of MBR plants as they have been constructed. The construction of the Canton MBR plant is significant and demonstrates that membranes can be utilized in large plant applications and implemented economically. Larger plants will continue to be constructed and presently each is a stepping stone to the next.

Plant Background

Planning for the current secondary treatment upgrade at the Canton WRF began in 1994. Annual average daily flows had reached 85 percent of the plant design capacity since 1990. Additionally, adverse impacts during peak flow events and a possible increase in average daily flow by addition of a significant discharger (3 to 4 MGD) prompted the planning.

The conventional secondary treatment plant was originally constructed in the 1970's to replace a smaller and outdated facility. The ADF of the original plant was 33 MGD. Process units were designed and the site developed for an incremental expansion of all treatment areas. An upgrade in the 1980's converted the conventional activated sludge facility to a nitrifying secondary treatment plant with no increase in the ADF.

The existing facility had an ADF of 33 MGD and a peak day flow of 66 MGD. The peak instantaneous flow was approximately 88 MGD and established based on the maximum pumping capacity of the influent pump station with the largest pump out of service. Existing concentrations for the influent pollutant characteristics were considerably lower than when the plant was initially designed in the 1970's.

The study of 1995 confirmed the service area and tributary flows anticipated over the next 20 to 40 years. The treatment plant was evaluated for the limiting process units based on hydraulic performance, biological performance and recognized standards in the industry. The limiting process, secondary treatment had a 33 MGD average daily capacity and a 47 MGD peak flow capacity. Peak flow capacities were identified lower than previously due to changes in the process type and recognized standards used in the industry. Other unit process peak hydraulic capacities were between 66 MGD and 90 MGD. The study concluded an immediate need to upgrade the plant hydraulically. The 1995 study established the new ADF at 39 MGD based on the existing and projected future flows from the service area. The peak day hydraulic capacity of the plant was established at 88 MGD. This peak day flow was selected based on the influent pump station peak capacity with one pump out of service. The peak instantaneous flow was established at the peak pumping capacity of the influent pump station, which is 110 MGD.

Treatment levels contained in the WRF National Pollutant Discharge Elimination System (NPDES) permit were equal to best available demonstrated control technology (BADCT) treatment levels: Total Suspend Solids (TSS) of 12 mg/l, carbonaceous biochemical oxygen demand (CBOD) of 10 mg/l and ammonia of 2 to 3 mg/l depending on the time of year. Phosphorus and total nitrogen did not have established limits. Treatment performance evaluations during this study identified that actual unit process performance was well above expected levels and that the secondary process was under loaded with respect to the flows being received at the WRF. Unlike the needed peak flow upgrade, secondary treatment had sufficient capacity for biological treatment based on the actual average daily flow of the 1990's. Therefore, the 1995 study recommended a phased improvement approach.

Recommended Phase I Improvements included upgrade of the preliminary treatment process by optimizing all unit processes and adding two additional primary settling tanks. This addition would be sufficient for the treatment of peak flows and equalization of flows up to 110 MGD. Two new secondary clarifiers were added to increase hydraulic capacity from 47 MGD to 70 MGD. Other Phase I Improvements concluded feasible and necessary to optimize the WRF included the replacement of the influent bar screens, optimization of the secondary process aeration system, converting from chlorine gas to sodium hypochlorite, upgrade to the instrumentation and control system while maximizing the use of the existing equipment and the addition of septage receiving.

Recommended Phase II Improvements included expanding the secondary treatment process by adding one aeration tank, two additional secondary settling tanks and four additional tertiary filters to the existing twelve filters. These improvements were not recommended until certain conditions occurred, which consisted of the following:

- When the average daily influent flow reaches approximately 35 MGD,
- Primary effluent BOD concentrations approach 90 mg/l,
- Effluent nutrient limits become more stringent,
- And/or the WRF peak influent flows regularly exceed the preliminary treatment process and available primary settling tanks being used for equalization.

The cost opinion, developed in 1995, for improvements in all phases (I & II) was approximately $24,000,000. The Phase I Improvements were implemented and operational by the year 2000 for a cost then of approximately $10,000,000.

More Recent Plant Operations

Treatment and equalization of influent flows in the preliminary treatment process was working well. Five settling tanks were needed for primary treatment and three tanks were used for equalization; however, increase occurrences of flows over 70 MGD were being conveyed to secondary treatment. Although infrequent, flows through secondary and post treatment had reached the peak hydraulic capacity of the influent pumps (110 MGD).

NPDES Permit Renewal and Looking to the Future

In about 2008, the City began to proactively address the WRF NPDES permit renewal which was soon to occur. Ohio EPA had indicated that a compliance schedule to meet a new phosphorus limit will be part of the permit renewal and that by about 2025 the NPDES permit will likely have a total nitrogen limit. Furthermore, the previous improvements of 2000 maximized the use of existing equipment and facilities. At the time of the next improvement much of the equipment will be reaching or surpassing a life span of 40 years. Items that had been optimized in 2000 would be reaching an age of 15 to 20 years and ready for rehabilitation. The City therefore proceeded with a study for the WRF with regard to meeting phosphorus and total nitrogen limits with consideration given to the other components of the facility. The study goals were:

1. Modify the treatment process to reduce phosphorus either biologically or by chemical addition.
2. Modify the treatment process to reduce total nitrogen.

3. Increase the plant average day capacity of secondary treatment from approximately 35 MGD to 39 MGD.
4. Increase the secondary treatment and all downstream unit process peak daily design flows from 70 MGD to 88 MGD.
5. Provide a peak instantaneous flow through capacity equal to 110 MGD since this was the peak instantaneous flow which had been processed and/or passed through the WRF since the improvements of 2000.

The study was completed in March of 2010. It evaluated proceeding with phosphorus removal improvements separate and apart from total nitrogen reduction improvements. Both chemical and biological phosphorus removal processes were considered. Total nitrogen removal processes were considered to meet new limits; however, implementation was ten years after the phosphorus removal project.

A comparison evaluation considered implementing phosphorus and total nitrogen improvements as one project. Advance treatment processes considered in the evaluation for total nitrogen removal were upgrading the nitrification process by expanding the aeration process units and secondary settling to achieve biological nitrogen removal. Selectors and recycle systems would be utilized to enhance the kinetic action whereby phosphorus and total nitrogen removal would occur through a conventional biological nutrient removal (BNR) process. Alternative processes to the conventional BNR process with selectors that were evaluated consisted of integrated fixed film activated sludge (IFAS) and MBR.

The conditions now facing the City of Canton, more stringent permit limits and increased plant through flow, constitute the conditions outlined in the 1995 study identifying when to implement Phase II type improvements. Therefore, in addition to treating to the new effluent limits which would include phosphorus and total nitrogen, the average day capacity of the secondary treatment process would need to be increased from approximately 35 MGD to 39 MGD and the peak flow of all processes after primary settling would need to be increased from approximately 70 MGD to 88 MGD. Additionally, the WRF had begun to experience and treat peak instantaneous flows up to 110 MGD. Accordingly, plant flow conditions, influent pollutant loadings and effluent permit limits established from this study of 2010 are as follow:

Design Flow Parameters

Average Daily Design Flow	39 MGD
Minimum Day Flow	16 MGD
Maximum Month Flow	42 MGD
Peak Day Flow	88 MGD
Peak Instantaneous Flow	110 MGD

Pollutant Characteristics	*Influent*	*Effluent*
CBOD	150 mg/l	10.0 mg/l
TSS	170 mg/l	12.0 mg/l
Phosphorus	5 mg/l	< 1.0 mg/l
Ammonia	26 mg/l	3.0 mg/l
Total Nitrogen		<8.0 mg/l
Dissolved Oxygen		6.0 mg/l

Summary of 2010 Study Alternatives

Following is a summary of upgrades and/or expansions necessary to accomplish the long term goals of the City, which included phosphorus removal to less than 1 mg/l, total nitrogen removal to less than 8 mg/l and increased flow capacity of all unit process after primary settling to a peak daily flow rate of 88 MGD. The plant hydraulic thru flow capacity would be 110 MGD; however, the peak day capacity of process unit would be 88 MGD.

Alternatives evaluated are:

Alternative 1: Upgrade to accomplish phosphorus removal by chemical addition. Hydraulic capacity through secondary, tertiary treatment and post treatment is 70 MGD.

Alternative 2: Upgrade to accomplish phosphorus reduction biologically. Hydraulic capacity through secondary, tertiary treatment and post treatment is 79 MGD.

Alternative 3: Upgrade to accomplish phosphorus removal by chemical addition and total nitrogen reduction biologically. This is Alternative 1 with an increase in hydraulic capacity to 88 MGD.

Alternative 4: Upgrade to accomplish phosphorus and total nitrogen reduction biologically. This is Alternative 2 with an increase in hydraulic capacity to 88 MGD.

Alternative 5: Upgrade to accomplish phosphorus removal by chemical addition and total nitrogen reduction biologically with IFAS and the hydraulic capacity is 88 MGD.

Alternative 6: Upgrade to accomplish phosphorus and total nitrogen reduction biologically with MBR and the hydraulic capacity is 88 MGD.

The following table provides a summary overview of the improvements necessary to accomplish the upgrade associated with each alternative listed previously.

Table 1
Study Alternatives by Process Area

Process Area	1	2	3	4	5	6
Coarse Screens	NC	NC	NC	NC	NC	NC
Influent pumps	NC	NC	NC	NC	NC	NC
Grit Removal	2 New	2 New	2 New	2 New	2 New	2 New
Pre-aeration Tank	2 New	2 New	2 New	2 New	2 New	2 New
New Fine Screens	N/A	N/A	N/A	N/A	4-6 mm	2-3 mm
Primary Settling	R. Exist	R Exist	Delete	Delete	R Exist	Delete
Primary Scum Removal	NC	NC	Delete	Delete	NC	Delete
Activated Sludge Process	NC	2 New	2 New	4 New	1 New	M. Exist.
Secondary Settling	1 New	R Exist	3 New	2 New	2 New	Delete
Secondary Scum Removal	NC	NC	NC	NC	NC	Delete
Tertiary Filtration	NC	NC	4 New	4 New	4 new	Delete
Post Aeration	M. Exist	M Exist	M Exist	M Exist	M Exist	M. Exist
Disinfection	NC	NC	NC	NC	NC	?
Chem P Storage (gallons)	16,000	8,000	16,000	8,000	8,000	8,000

Notes with regard to the proceeding table.

- NC – No change recommended for the existing process unit.
- # New – Number of process units required to accomplish upgrade intent.
- N/A – Unit process does is not necessary for secondary treatment alternative.
- Delete – Process unit no longer needed and can be eliminated, function changed or demolished.
- R. Exist – Upgrade the existing process unit by replacing all equipment. Structure unchanged.
- M. Exist – Upgrade the existing process by making equipment and structural modifications to accomplish the selected process unit.
- ? – The need for the process unit is questioned.

- # mm - Fine Screen improvement and the size of screen needed.
- 8,000 – Desired on-site chemical storage capacity.
- Blue color indicates existing unit processes common to all alternatives
- Green color indicates upgraded unit processes common to all alternatives.
- Yellow color indicates process units not necessary for the alternative activated sludge process
- Red color indicates process units that are unique to the alternative activated sludge process.

2010 Study Summary of Costs

Once the necessary improvements for each alternative were identified, the associated construction costs and O&M costs were determined based on the conceptual improvement. Costs for implementing the improvement such as engineering, geotechnical, permits and others, were determined and added to the capital cost associated with the construction to develop a project cost for each alternative. This estimate of total project cost and the associated calculated O&M costs the next 20 years were then totaled to establish a 20 year life cycle cost. All costs presented are based on a 2010 base year; the year the study was completed. Cost are summarized in Tables 2 and 3.

Cost for each of the six alternative improvement approaches are subdivided into two phases and are based on the noted alternative intent.

Alternative 1 and 2:

The primary intent of Alternative 1 and 2 is to implement improvements to reduce P during Phase I and to upgrade the hydraulic capacity to the same levels as indicated in each Phase 1 and 2 as describe in Alternative 3 through 6. The Phase 2 improvements of Alternative 1 and 2 also include the addition of total nitrogen removal improvements since they are not included in Phase 1 of Alternative 1 and 2.

The primary difference between Alternative 1 versus 3 and Alternative 2 versus 4 is when the total nitrogen reduction improvement is added. The final total implemented improvements are the same for Phase 1 plus Phase 2, for Alternative 1 and 3, and Alternative 2 and 4.

Alternatives 3 through 6:

Phase I improvements are to reduce phosphorus and total nitrogen, increase the ADF for secondary treatment from 35 MGD to 39 MGD, and increase peak flows so all unit processes can pass a peak flow of 70 MGD. The Phase 2 improvement is to complete the remaining project goals by increasing all unit process peak flow capacity from the 70 MGD to 88 MGD. Also understood is that the peak instantaneous hydraulic flow through capacity of all unit processes will be 110 MGD.

Table 2
Total Construction and Project Cost
(Million Dollars)

Area of Cost	**1**	**2**	**3**	**4**	**5**	**6**
Phase I Improvements	42.9	40.6	72.2	67.6	60.0	62.8
Phase 2 Improvements	51.6	63.2	18.8	28.4	28.4	0.0
Total Construction Cost	**94.5**	**103.8**	**91.0**	**96.0**	**88.4**	**62.8**
Cost to Implement	**13.4**	**14.3**	**13.0**	**13.8**	**12.6**	**9.3**
Total Capital Project Cost	**107.9**	**118.1**	**104.0**	**109.8**	**101.0**	**72.1**

Table 2 presents the total project costs for the combined phase 1 and 2 improvements for each alternative.

Table 3
Alternatives Construction Cost by Process Area
(Million Dollars)

Area of Work	1	2	3	4	5	6
Coarse Screens	0	0	0	0	0	0
Influent pumps	0	0	0	0	0	0
Grit & Pre-aeration	2.5	2.5	2.5	2.5	2.5	2.5
New Fine Screens	0	0	0	0	3.4	3.4
Primary Settling	3.8	3.8	0	0	3.0	0.8
Activated Sludge Process	35.7	50.0	36.0	46.0	32.0	44.0
Existing Secondary Settling	3.9	3.9	3.9	3.9	3.9	0.4

New Secondary Process Facilities	22.3	18.0	22.3	18.0	18.00	0
Tertiary Filtration	15.4	15.4	15.4	15.4	15.4	1.5
Post Treatment	.6	.6	.6	.6	.6	.6
Chemical Systems	1.3	.6	1.3	.6	.6	.6
Solids Handling Facilities	4.0	4.0	4.0	4.0	4.0	4.0
Miscellaneous	5.0	5.0	5.0	5.0	5.0	5.0
Total Construction Cost	**94.5**	**103.8**	**91.0**	**96.0**	**88.4**	**62.8**

Table 3 presents the total construction costs for the combined phase 1 and 2 improvements for each alternative and by unit process area.

Table 4 presents the 20 year O&M costs of each alternative and is based on how the improvements where phased for implementation.

O&M Cost Factors:

- Power cost was determined by summarizing all equipment, horsepower, run time and energy used based on a historical trend of plant flows.
- The primary difference between O&M cost for Alternatives 1 and 3 and 2 and 4 is the incurred cost or lack thereof depending on when the improvements were implemented.
- Sludge and chemical cost were estimated based on calculated sludge production and chemical additions for the associated secondary treatment process for each Alternative.
- Capital maintenance is the general repair and maintenance of equipment and any equipment recoating that might be needed.

It should be noted that Alternatives 5 and 6 have significant cost associated with media replacement and membrane replacement respectively.

Table 4
Alternatives Operation and Maintenance Costs.
(Million Dollars)

Area of Cost	1	2	3	4	5	6
Power	44.8	57.0	68.5	79.8	77.6	67.7
Chemical	3.6	0.8	3.6	0.8	0.8	0.8
Sludge Disposal	44.5	47.5	41.6	42.6	47.5	40.0
Capital Maintenance	1.1	1.0	0.8	0.8	1.0	0.8
Media Replacement	0	0	0	0	5.0	0
Membrane Replacement	0	0	0	0	0	8.0
20 Year O&M Cost	**94.0**	**106.3**	**114.5**	**124.0**	**131.9**	**117.3**
Present Worth for O&M	**34.2**	**38.7**	**41.8**	**45.3**	**48.7**	**43.3**

Table 5 presents the present worth 20 year life cycle cost for each alternative, total improvement to accomplish all of the project goals and is in base year 2010.

Table 5
Alternatives Life Cycle Cost
(Million Dollars)

Area of Cost	1	2	3	4	5	6
Total Capital Project Cost	107.9	118.1	104.0	109.8	101.0	72.1
Present Worth for O&M	34.2	38.7	41.8	45.3	48.7	43.3
Total Project Present Worth Cost	**142.1**	**156.8**	**145.8**	**155.1**	**149.7**	**115.4**

Cost Effective and Feasible Solutions

A review of the cost summaries indicates that Alternate 6; MBR is the most feasible and cost effective long term improvement with respect to life cycle costs. This improvement if implemented immediately will address all of the 2010 study goals and it has the lowest life cycle cost. The capital cost is in line with the first phase of improvements for the other alternates and is well below the capital cost of all other alternatives when improvements are implemented to satisfy all 5 goals of the 2010 Study. The O&M cost for the Alternative 6 are of the same relative magnitude as for Alternatives 3, 4 and 5. This would be expected since they all are providing the same level of treatment and they all utilize the activated sludge process or a modification thereof.

As explained in the background section of this paper, the City of Canton pursued only the immediate necessary improvements since 1994 and those that were cost effective. The significance of the improvements implemented in 2000 is that they did not include the phase 2 improvements. Two of the Alternatives, 5 and 6, were not recognized technologies being used at the time of the 1995 Study. Cost savings have therefore been maximized over the past 20 years based on the improvement evaluated, phased, and selected for implementation.

Selected Plant Improvements - Focus On Optimization of Operation and Construction Cost

The 2010 study proposed various treatment technologies to accomplish the study goals. Alternatives 1, 2, 3, 4 and 5 require the significant addition of concrete structures and replacement of most of the existing process equipment throughout the plant. The equipment and all associated structures would require continued maintenance and up keep in the future. Unlike these five alternatives, Alternative 6 - MBR does not require new concrete structures and/or replacement of existing process equipment. Alternative 6 is the selected improvement based on cost, a simplified plant, fewer new structures, elimination of existing processes and the quality of the effluent which will be realized. Following is an overview summary of the proposed improvement by plant process area, operation and/or aspects of optimization.

Influent Screening and Pumping

Reuse existing influent coarse screen and influent pumping system having a peak hydraulic capacity of 110 MGD will remain. The capacity is limited by the pump system.

Preliminary Treatment

A new preliminary treatment facility will be constructed in the existing pre-aeration tanks to avoid new excavations and new tank construction. The new advanced preliminary treatment facility consists of longitudinal grit/grease removal and fine screens. The fine screen structure and system was designed as two stage. Bids were taken for either single stage (2mm) or two stage (6mm followed by 2mm) fine screens. The City selected to proceed with two stage screening based on the bid prices, expected reduced stress on the 2mm screen and increased reliability/longevity that two stage screening should provide as opposed to single stage screening.

A new preliminary treatment solids building will be constructed for removed grit, grease, and screenings. Solids are washed and compacted to reduce odors, return organics for treatment, reduce handling and improve the consistency of the solid being disposed at the landfill.

The design maximized the use of the existing pre-aeration blower system for reuse with the grit and grease removal system. Operational costs are being optimized by replacing existing positive displacement blowers with new more efficient turbo blowers. The system is being automated to help simplify the operator's efforts when basins are being added or blowers rotated.

The existing primary settling process was removed from the new plant configuration since inorganics were being removed in the advance preliminary treatment process. The elimination of the primary settling tanks also allows sources of carbon and organics to enter the activated sludge process whereby normal treatment operation is anticipated to occur without the addition of a carbon supplement to aid the total nitrogen biological reaction.

MBR Supplier Pre-Selection for Secondary Treatment

The existing tanks available for use in the activated sludge process consist of the eight primary settling tanks, six activated sludge tanks, and eight secondary settling tanks. Any need for additional tanks will require new tank construction. MBR was the selected secondary treatment process. Only two membrane suppliers had large plant experience and the largest operating plant was 25 to 40 percent of the proposed plant for Canton WRF.

These two membrane suppliers were notified by letter in mid-August, 2010 and invited to submit proposals based on a "best value pre-selection process". The pre-selection process utilized allowed each supplier to submit their best process application for the site specific conditions. Prior to submitting the proposal, both suppliers were invited to visit the project site, make presentations of their membrane system to the Owner and guide the Owner on visits at two (2) plants using their membrane system. The two suppliers selected to propose were GE Water & Process Technology (GE) and Enviroquip of Ovivo, (Ovivo). Proposal were due on Friday September 17, 2010. Ovivo submitted their proposal on Monday September 13, 2010. On Wednesday September 15, 2010, GE submitted a letter declining to submit a proposal. The pre-selection process provided one of the best methods to competitively secure membrane system pricing, and to make a selection of the membrane system supplier to be used in the final design. Ovivo was the selected membrane system supplier and they became part of the design team at the 30 percent design level. Utilizing the pre-select process extended to multiple membrane suppliers and engaging the selected supplier in the final design document preparation resulted in the City obtaining a sound and cost effective project for implementation.

The selected membrane system was capable of being installed in the existing six activated sludge tanks without new tank construction or using the existing primary and secondary settling tanks. These sixteen settling tanks then became available for other uses. The use of the MBR technology for the plant upgrade permitted complete upgrade of the secondary treatment process within the existing basins and without new construction of tank and/or pumping structures.

Influent Flow Control and Equalization

A flow control chamber after preliminary treatment is use to control peak flow to the MBR process and to redirect peak flow to and from equalization. Peak hydraulic flow to the membranes is controlled and limited to not more than 88.0 MGD by converting the existing primary settling tanks and secondary settling tanks to Stage 1 and Stage 2 equalization respectively. The total equalization volume is in excess of 10 million gallons.

Secondary Treatment Aspects

Phosphorus removal is being accomplished first by biological nutrient removal to approximately 1 mg/l. An iron salt chemical feed system is provided to supplement phosphorus removal below levels achieved by bio P.

Total nitrogen is being removed through a selector process whereby internal recycle systems and activated sludge basin volumes are divided into zones for biological nutrient removal.

A carbon source chemical feed system is being provided in the event some supplemental carbon is needed. Various types of carbon supplements were evaluated and the synthetic and/or refined glycerin is being proposed. This type of carbon supplement simplifies and significantly reduces the chemical storage and feed system capital cost maintenance costs and safety issues. The supplement anticipated to be used is slightly more expensive to purchase but the chemical cost are offset by reduced capital cost, operational costs and anticipated improved process performance as has been documented when used at other facilities.

Five existing blowers having a combined 3,600 horsepower are being rehabilitated to provide the needed air to the membrane basin for an approximate total cost of $1,000,000 as opposed to complete blower replacement for about $5,000,000. Three new turbo type blowers are being added for the process air. The existing air piping and associated systems are being used when possible to minimize the purchase and installation of new materials.

Flexibility in the process air system is provided by the use of a swing air zone which can be used to convert a portion of the anoxic volume to aeration.

A simple array of process control instruments provides the necessary real time monitoring of the secondary treatment process. These instruments for monitoring MLSS, DO, pH and temperature communicate with the secondary process control system for automated equipment operation. Data is provided to the historian in the plant control system for monitoring and trending of the process.

A new process control system is being provided for control of secondary treatment process which includes upgrading of the existing blowers control system. This new control system is an inner loop fiber optic system that controls all secondary treatment process components. The existing plant control system is being maintained and updated as necessary to accept communication from the new system and to replace existing and outdated aspects, bring the overall plant control outer loop to today's technology and performance standards.

Tertiary Filters

The existing tertiary filter facility which is significantly undersized (67 MGD) for the new peak day flow (88 MGD) will no longer be needed since MBR activated sludge is being used in the secondary treatment process. The existing filters will be demolished as well as other non-essential facilities which will no longer be needed. Although there is a cost to demolish and remove old facilities, it is less expensive than properly maintaining the areas to a level safe for the staff.

Post Treatment

Post treatment improvements will include the addition of a post aeration system to supplement the existing turbulent weir discharge. The existing disinfection system will be removed. Normal operation of the plant will not include disinfection. The removal of the disinfection process was predicated on results of a study performed in Ohio which identified that the disinfection process when installed after the MBR process, provides no additional treatment to the effluent from a MBR activated sludge plant. An emergency disinfection feed pump system will be installed for emergency back up and the existing contact tank will remain. Chemical storage facilities will not be installed, rather chemicals, for emergency disinfection will be maintained in temporary storage tanks supplied by the chemical supplier.

Sludge Facilities

The existing sludge facility consisted of combined sludge thickening by gravity. Thickened sludge was pumped to dewatering equipment, the dewatered sludge was conveyed to incinerators, and the ash was sent to the landfill. New regulations would require significant investment to upgrade and/or replace the incinerator process. The process is being modified to include aerated liquid sludge storage and a much more simplified sludge pumping system which discharges to the existing dewatering system. The existing dewatering equipment that was updated approximately 10 years ago will remain. Dewatered raw sludge will be hauled to one of three local landfills for disposal. This approach to sludge treatment and disposal has costs that are significantly less than upgrading, operating and maintaining other handling and/or stabilization processes.

Small Plant Mentalities

Project Implementations

Having the membrane supplier identified through the pre-select process, provided the City the ability to pre-purchase the membrane system as opposed to assigning it to the General Construction Contractor (GC). Assigning the pre-selected supplier and their submitted proposal with final design amendments to the GC is a typical approach and most often used based on the writer's experience. However, the membrane system cost on this project was approximately $29,000,000. The membrane system and other final construction costs were estimated to total between $75,000,000 and $80,000,000. A total cost which may have precluded many local area GCs from bidding. Therefore, the membrane system was pre-purchased by the City, whereby the GC contract amount would be reduced to less than $50,000,000. This lower contract value permitted a more competitive bid field and climate since larger local GCs could bid and bond the improvement as opposed to the larger contract value.

Parallel Preliminary Treatment Train Size Optimization

The preliminary treatment process utilizing longitudinal grit/grease and two stage fine screening was subdivided into flow trains as associated with influent flow rates. The grit/grease system consists of two trains each having a capacity of approximately 60 MGD. The two stage fine screening system has three trains, each having a capacity of approximately 40 MGD. The capacity of each grit/grease and screening train is such that only one train of each needs to operate during normal daily flows and below maximum monthly flows. This approach permits the plant staff the ability to address normal maintenance when units are in standby mode and it will prolong the service life of the equipment while easing the demand for operator attention while in operation. The operator can therefore focus their effort on operations rather than balancing maintenance and operations.

Equalization and Plant Flow Control and/or Optimization

Equalization of influent flows after preliminary treatment provides the operator flexibility in the operation of the secondary treatment process. Equalization like the preliminary treatment process is divided into two stages. This division in equalization capacity permits the operator the ability to maintain a condition in each stage and in the associated equalization tanks whereas maintenance and operator attention can be limited to as few tanks as possible. The use of multiple tanks for equalization and 2 Stages also allows the operator flexibility to control when peak flow equalization occurs, use of equalization for diurnal flow control and it minimizes the amount of support equipment associated with each Stage.

MBR Process Configuration, Incremental Capacity and Manageability

The selected MBR activated sludge process will be installed in the existing six activated sludge tanks. Other secondary treatment process facilities which exist at the Canton WRF include influent rate of flow control valves to each of the six activated sludge tanks, the existing five blowers, a single return activated sludge (RAS) sludge well and pumps, a combined waste sludge pump system and combined influent/effluent flow channels.

Various configurations of the MBR activated sludge process were evaluated after the supplier pre-selection and early in the detailed design phase. Considered was a combined influent system, combined effluent system, combined RAS, combined air systems, combined internal recycle systems and combined WAS system as associated with the six activated sludge tanks. This approach was similar to the existing plant configuration. The associated equipment for the new process is large and heavy requiring hoists, cranes and lifts to move. Each equipment component is expensive to replace, often non-standard and replacement parts are costly. The individual cost of each equipment item is well above the authorized purchase capability of the Canton WRF staff. It would likely be necessary to maintain a large inventory of spare equipment and/or parts or nearly every purchase would require approval by City Council.

The associated piping or conveyance channels are large requiring large spaces and massive structures. Re-splitting of these combined flows when redirected to the activated sludge basins or other tributary tanks requires massive control structures, weirs and/or channels creating undesirable hydraulic conditions or control structures. It would require significant new construction, large elevated pipes and operational difficulties to control flows. The support equipment for the pumps, structures and control system are also massive or of significant members.

An alternative approach consisted of a combined influent flow which would be split to each of the six basins utilizing the existing influent control valves. Each basin would then be configured as a separated treatment train complete with all components. Accordingly, separate internal recycle, RAS, waste activated sludge (WAS) and effluent systems would be part of and within each train whereby each train operates as a separate independent treatment plant. This approach reduces the size and weight of equipment making it more manageable by the operator. Replacement equipment and part costs now are within the financial limitations of the Canton WRF staff ability to purchase without Council action. The cost associated with parts inventory is less and the inventory is more readily available by the manufacturers since the components are more standard and common stock items. Pipes and conveyance systems are of smaller diameter and can for the most part be piped rather than constructing massive concrete channels, wells and structures. The plant control is also broken down into smaller parallel components whereby an upset has less impact on the overall operation. Monitoring of multiple smaller process components provides a better view for the operator to follow trends, outliers and address problems on an incremental basis.

The aeration system for the overall process is separated into two; a process air system and a scour air system. Although both provide air for treatment, each have their own influences on the process.

The separation of these system and separate air control valves to each basin permits convenient monitoring and control to adjust air flow as necessary to the individual process areas. Overview monitoring of the air systems and trending among each of the smaller demand areas permits the operator a more detailed control overview of the process whereby undesirable conditions can be identified easily, earlier and likely the impact will be smaller with respect to the overall plant flow

Ancillary support systems to the treatment process such as chemical feed system for phosphorus removal, carbon addition and membrane maintenance and the waste sludge system is configured whereby each of the six trains have their own dedicated equipment and they can be operated independently of the other.

Current Project Status

"The Canton WRF Phosphorus and Total Nitrogen Upgrade" project was bid in the last quarter of 2013. The final design included some additional improvements not included in the 2010 Study which increased the cost accordingly. The final membrane system pre-purchase agreement was secured prior to bidding for approximately $29,000,000. This together with the successful construction bid of approximately $46,000,000 and other associated project cost such as engineering, etc.; established an after bid project cost of approximately $82,000,000 or approximately $2.10 per gallon (ADF) of wastewater treated. It should be noted that this project cost includes sludge facility improvements and general site improvements such of new pavement throughout the site. Refer to Table 3 for more information on each improvement area.

Construction commenced in March 2014 and the first milestone improvements have been or are nearing completion which includes preliminary treatment. Milestone 1 consists of improvements that are necessary before the MBR process can be made operational. Milestone 2 consist of systematically converting each activated sludge train over to MBR. Milestone 2 has a construction duration of approximately 20 months. After completion, Milestone 3 will commence which addresses existing facilities that were needed until all the MBR trains were made operational. Milestone 3 will abandon, modify or demolish these remaining facilities. Milestone 3 is expected to have a construction period of 4 to 6 months.