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Memorandum

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**Subject:** Task 2 – Marco Island RWPF Nutrient Removal Evaluation
**Project name:** Evaluation of Potential Reuse Nutrient Impacts and Nutrient Removal Strategies
**Attention:** Jeff Poteet, General Manager, Marco Island Utilities
**From:** Jacobs
**Date:** July 12, 2022

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# 1. Background

The City of Marco Island (the City) operates and maintains the Marco Island Reclaimed Water Production Facility (RWPF). The RWPF has a permitted 3-month average daily flow capacity of 4.9 million gallons per day (mgd) and currently produces approximately 2.3 mgd of treated effluent that meets requirements for unrestricted public access reuse, including high-level disinfection. Although it is not a permit limit, the RWPF achieves nitrogen removal to about 6 milligrams per liter (mg/L) total nitrogen (TN). The RWPF does not have a total phosphorus (TP) limit. The facility is colocated with the City's North Water Treatment Plant. The reclaimed water is used currently to irrigate golf courses, roadways, and commercial and residential properties, primarily on the west side of the City.

The City has more than 100 miles of canals and waterways and the Florida Department of Environmental Protection has listed Marco Island canals and waterways as being impaired for nitrogen based upon annual geometric mean total nitrogen concentrations exceeding 0.300 microgram per liter (µg/L.) Offshore areas from Marco Island also are listed as impaired for TN, TP, and fecal coliform bacteria.

To address increasing citizen concerns about declining water quality in the canals and waterway system, the City retained the services of Environmental Research and Design (ERD) in April 2020 to conduct a nutrient source evaluation and assessment and provide recommendations for water quality improvement. The final report for the study, entitled *Marco Island Nutrient Source Evaluation Project*, was submitted to the City in September 2021 (ERD Report).

The ERD Report presented a number of findings, conclusions, and recommendations, some of which identified on-island reuse irrigation as a contributing source of nitrogen and phosphorus to the waterway system and recommended reduction of on-island reuse irrigation as well as evaluation of alternate reuse disposal methods.

The City has a deep injection well for disposal of effluent water. However, the reuse of effluent water benefits the City by offsetting the use of potable water for irrigation purposes. It is in the interest of the City to maximize the potential offsets to potable water usage. As such, the City requested Jacobs to perform a limited review of the ERD Report to assess the findings and recommendations in that report related to reuse water, to develop effluent water quality criteria for the RWPF to allow maximal use of reuse water (Task 1), and to develop conceptual level RWPF improvements that could achieve these effluent water quality criteria, as well as project capital and operating cost impacts associated with these improvements (Task 2).

Jacobs' review of the ERD Report is provided in a separate technical memorandum. Jacobs did not find a compelling rationale for improvements to the RWPF based on the ERD Report. However, based on the community's interest in improving reuse water quality, the City requested Jacobs proceed with the effort to develop conceptual improvements to achieve two differing water quality endpoints for the effluent water from the RWPF:

- Achieving a consistent reduction of TP in treated effluent to less than or equal to 1 mg/L
- Achieving treatment at a level of Advanced Wastewater Treatment (AWT)

This technical memorandum summarizes the findings of the Task 2 evaluation.

The RWPF comprises the following major components:

- Four covered equalization tanks (prestressed concrete) with coarse bubble aeration for mixing
- An elevated headworks with three rotary drum screens
- Activated sludge treatment in two former package plants converted to a Modified Ludzack-Ettinger (MLE) process with five General Electric (Zenon) membrane bioreactor (MBR) skids
- Chlorine contact basin for disinfection using sodium hypochlorite
- Four open top aerobic holding tanks for waste sludge storage
- One rotary drum thickener, located in a building
- Two reuse storage tanks
- One reject pond, for off-specification effluent water
- Two biofilters for odor control

Waste solids are dewatered periodically by a mobile centrifuge that sets up onsite approximately every 2 weeks during peak season and approximately every 4 to 6 weeks during the off-peak time.

## 2. Purpose

The purpose of this technical memorandum is to summarize the findings from a high-level review of alternatives to enhance the ability of the RWPF to remove phosphorus and/or nitrogen at the current design treatment capacity (5.0 mgd) to achieve either:

- TP = 1 mg/L, or
- AWT of TN = 3 mg/L and TP = 1 mg/L

Order-of-magnitude capital and annual operations and maintenance (O&M) costs were estimated for planning purposes to quantify the impacts for the City if improvements were to be implemented.

## 3. Process Model

### 3.1 Process Model Calibration

A biological process model of the existing treatment plant was created using Jacobs proprietary Pro2D2™ process model, which is based on the International Water Association's ASM2 model. The model was roughly calibrated using typical operational information provided from January to April 2022 with a focus on effluent quality, basin mixed liquor suspended solids (MLSS), and mass of waste activated sludge (WAS) produced. A more-detailed calibration with additional wastewater characterization would be necessary before designing any improvements. However, the calibration, as done, is sufficient for the purposes of high-level alternatives evaluation. The model calibration results are summarized in Table 1.

**Table 1. Process Model Calibration Summary**

| Parameter | Operational Information | Model Result | Difference |
|---|---|---|---|
| Effluent CBOD5 (mg/L) | 3.5 | 2.1 | 1.4 mg/L |
| Effluent TN (mg/L) | 6.0 | 8.6 | 2.6 mg/L |
| Effluent TKN (mg/L) | 1.0 | 1.1 | 0.1 mg/L |
| Effluent $NH_3$-N (mg/L) | 0.0 | 0.0 | 0 mg/L |
| Effluent $NO_3$-N (mg/L) | 5.0 | 7.5 | 2.5 mg/L |
| Effluent TP (mg/L) | 3.4 | 3.3 | 0.1 mg/L |
| Effluent TSS (mg/L) | 0.6 | 0.5 | 0.1 mg/L |
| Aeration Basin MLSS (mg/L) | 7,500 (7,200–7,800) | 6,950 | 7% |
| Membrane Basin MLSS (mg/L) | 8,300 (7,800–8,800) | 8,300 | 0% |
| WAS (lb/d) | 4,500 | 4,100 | 10% |

CBOD5 = 5 day carbonaceous biochemical oxygen demand

lb/d = pound(s) per day

$NH_3$-N = ammoniacal nitrogen

$NO_3$-N = nitrate nitrogen

TKN = total kjeldahl nitrogen

TSS = total suspended solids

The mass of WAS produced and MLSS concentrations were within 10% of reported typical operation and considered in good agreement. Effluent quality predicted by the model also was in reasonable agreement with the actual effluent for this level of calibration. The effluent TN predicted by the model was about 2.6 mg/L greater than that observed. Effluent TKN, $NH_3$-N, and TP predicted by the model agreed with the actual data.

The annual geometric mean for effluent TN has been about 6 mg/L for the past 3 years. The difference in the model is likely the result of lower predicted denitrification. The model assumes a dissolved oxygen (DO) concentration of 2 mg/L in the aerobic portion of the process basins. If the air flow is adjusted to target lower DO in certain areas of the aeration basin, the modeled nitrate-N could be reduced such that the effluent TN concentration matches the observed 6 mg/L. However, this would require more study of DO concentrations in different areas of the aeration basin from operational data of the actual treatment plant. Also, there may be transient pockets of lower DO concentration in the existing basins that are not easily modeled. However, this level of refinement could be done in a more-detailed evaluation.

# 4. Flows and Loads Evaluation Basis

The process model that was created and roughly calibrated was used to evaluate treatment plant performance at design flow conditions of 5.0 mgd. The original design flow and load conditions described in the design drawings from 2010 were reviewed and compared with recent historical influent data from 2021 and from January to April 2022. Using engineering judgement, a flow and load basis for the evaluation was assumed, as summarized in Table 2.

**Table 2. Flow and Load Evaluation Basis Summary**

| Parameter | 2021 Avg | Jan–April 2022 | Original Design | Assumed Basis for Evaluation |
|---|---|---|---|---|
| CBOD5 (mg/L) | 248 | 267 | 200[c] | 250 |
| True CBOD5 (mg/L)[a] | 295 | 318 | n/a | 298 |
| TSS (mg/L)[b] | 153 | 141 | 250 | 200 |
| TKN (mg/L) | 51 | 63 | 40 | 60 |
| $NH_3$-N (mg/L) | 40 | 50 | n/a | 47 |
| TP (mg/L) | 5.6 | 6.5 | n/a | 6.5 |
| Flow (mgd) | 2.3 | 2.7 | 5.0 | 5.0 |

[a] Measured CBOD5 corrected for effect of nitrification inhibitor by dividing by 0.84

[b] VSS data not available. Assumed 70% of TSS.

[c] Described as BOD5 in design documents.

## 5. Potential Treatment Options

The current MLE process configuration includes an anoxic zone followed by an aerobic zone and targets partial removal of TN through one anoxic zone for denitrification with recycle of flow from the last aerobic zone (membrane tanks) to the anoxic zone. Generally, the MLE process can produce effluent TN in the 8 to 12 mg/L range. There are several treatment process configurations that can target additional TN removal, which generally involve a second anoxic zone (post-anoxic zone) after the aerobic zone. Supplemental carbon can be added to the post-anoxic zone to increase denitrification if the zone is carbon limited to improve TN removal.

TP removal can be accomplished biologically through enhanced biological phosphorus removal (EBPR) with the addition of an anaerobic zone or chemically by addition of a metal salt such as alum or ferric chloride to the process basins.

For the purposes of this evaluation, one typical alternative was identified for each treatment objective:

- Alternative 1 – Alum addition to the end of the existing process aeration basin to achieve TP of 1 mg/L
- Alternative 2 – Creation of a second anoxic zone with supplemental carbon addition to achieve TN of 3 mg/L and alum addition to the last aerobic zone before the membrane tanks to achieve TP of 1 mg/L

The expected effluent quality and other parameters of interest for each alternative are summarized in Table 3, including values for the current plant as-is at the design flow conditions for comparison.

**Table 3. Alternatives Effluent Quality and Other Parameters Summary**

| Parameter | Current Plant at Design Flow | Alternative 1 | Alternative 2 |
|---|---|---|---|
| CBOD5 (mg/L) | 2.3 | 2.3 | 1.6 |
| TSS (mg/L) | 0.5 | 0.5 | 0.5 |
| TN (mg/L) | 9.5 | 9.5 | 2.5 |
| TKN (mg/L) | 1.1 | 1.1 | 1.1 |
| $NH_3$-N (mg/L) | 0.0 | 0.0 | 0.1 |
| $NO_3$-N (mg/L) | 8.4 | 8.4 | 1.3 |
| TP (mg/L) | 3.2 | 0.7 | 0.1 |

| Parameter | Current Plant at Design Flow | Alternative 1 | Alternative 2 |
|---|---|---|---|
| Aeration Basin MLSS (mg/L) | 6,600 | 7,000 | 7,900 |
| Membrane Basin MLSS (mg/L) | 8,200 | 8,700 | 9,800 |
| WAS (lb/d) | 9,700 | 10,300 | 11,600 |

# 6. Implementation Requirements

## 6.1 Alternative 1

Alternative 1 would require the construction of an alum storage and feed system to add alum to the end of the existing aerobic zone in the MLE process. An estimated 165 gallons of 50% alum solution would be required to be added each day at a 5 mgd flow rate. The system would consist of one 7,500-gallon fiberglass reinforced plastic (FRP) storage tank and two duty metering pumps plus one standby pump in a concrete containment area enclosed within a building. Alum feed piping would be routed from the feed pumps to each process train. Effluent alkalinity was assumed to be nonlimiting. A simplified process flow diagram of this alternative is shown on Figure 1.

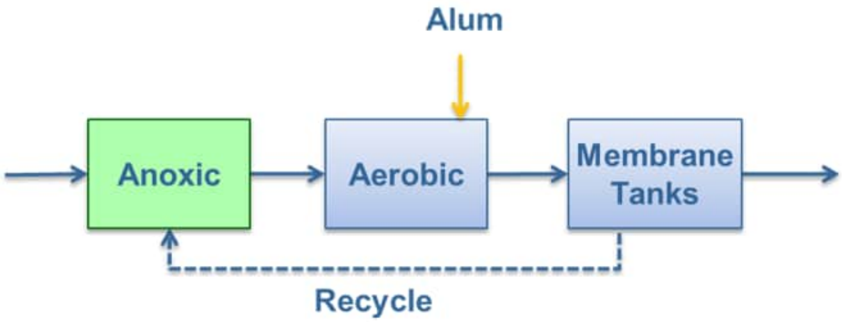

**Figure 1.** Process Flow Diagram – Alternative 1

## 6.2 Alternative 2

Alternative 2 would create a post-anoxic zone in each train by constructing baffle walls to separate the zone from the aerobic zone and conservatively assumes leaving a small re-aeration zone before the flow passes to the membrane tanks. However, it may be possible to just use the membrane tanks as the re-aeration zone; this option could be evaluated in design. Two submersible mixers would be added to each post-anoxic zone to keep them mixed. This alternative also assumes replacement of the diffuser system to accommodate the new process configuration.

This process would essentially be a four-stage (anoxic-aerobic-anoxic-aerobic) process similar to a four-stage Bardenpho process. However, the internal recycle flow would come from the MBR recycle rather than a separate nitrified recycle stream from the first aerobic zone to the first anoxic zone. In modeling this alternative, biological phosphorus removal was observed because the first anoxic zone runs out of nitrate, creating anaerobic conditions that are necessary for EBPR.

A supplemental carbon storage and feed system would be required to add carbon to the post-anoxic zone to drive denitrification down to achieve TN < 3 mg/L. Several products are available, such as methanol, acetic acid, and proprietary products such as Micro-C™ or Micro-Cg™. Micro-Cg™ was assumed for the purposes of this evaluation. Other carbon source alternatives should be evaluated in detail as well as further refinement of quantity requirements if this alternative were to be implemented. An estimated 285 gallons of Micro-Cg™ would be added each day at a 5 mgd flow rate. The system would consist of one 9,000-gallon FRP storage tank and two duty metering pumps plus one standby pump in a concrete containment area enclosed within a building. Supplemental carbon feed piping would be routed from the feed pumps to the post-anoxic zone of each process train.

In addition, it was assumed Alternative 2 would require the construction of an alum storage and feed system similar to Alternative 1 to use as a backup to the EBPR that was observed in modeling. A simplified process flow diagram of this alternative is shown in Figure 2.

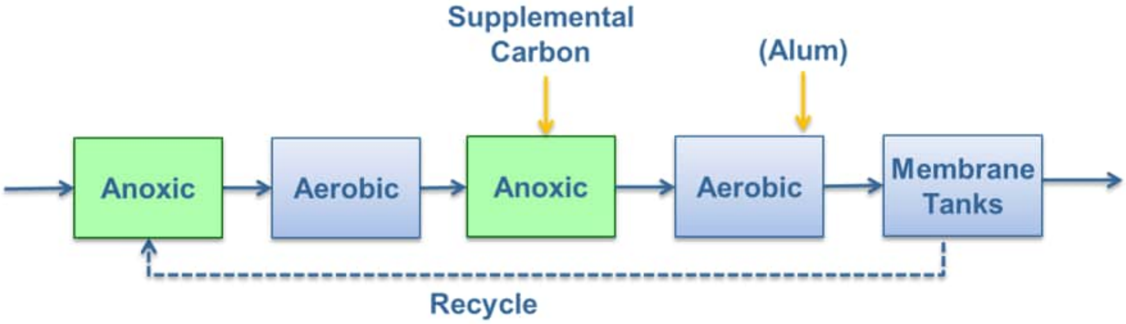

**Figure 2.** Process Flow Diagram – Alternative 2

## 7. Construction Cost Ranges

Class 5 order-of-magnitude level construction cost estimates were developed using Jacobs' proprietary Conceptual and Parametric Estimating System (CPES™). The estimates were prepared at a conceptual level (less than 5% design level) using cost factors, parametric techniques, and cost databases. The construction cost estimates for each alternative are summarized in Table 4 for planning purposes. Costs presented in the table include a 30% contingency but do not include non-construction costs such as permitting, engineering, and services during construction.

**Table 4. Estimated Construction Cost**

| Item | Alternative 1 | Alternative 2 |
|---|---|---|
| Alum Storage and Feed System | $548,000 | $548,000 |
| Supplemental Carbon Storage and Feed System | n/a | $578,000 |
| Process Basin Modifications | n/a | $1,217,000 |
| *Subtotal* | *$548,000* | *$2,343,000* |
| Additional Project Costs: | | |
| Demolition (0%/1%) | $0 | $24,000 |
| Overall Site Work (8%) | $44,000 | $188,000 |
| Plant Computer (6%) | $33,000 | $141,000 |
| Yard Electrical (12%) | $66,000 | $282,000 |
| Yard Piping (8%) | $44,000 | $188,000 |
| *Subtotal with Additional Project Costs* | *$735,000* | *$3,166,000* |
| Contractor Markups: | | |
| Overhead (15%) | $111,000 | $475,000 |
| *Subtotal with Contractor Markups* | *$846,000* | *$3,641,000* |

| Item | Alternative 1 | Alternative 2 |
|---|---|---|
| Profit (10%) | $85,000 | $365,000 |
| *Subtotal with Profit* | *$931,000* | *$4,006,000* |
| Mob/Bonds/Insurance (3%) | $28,000 | $121,000 |
| *Subtotal with Mob/Bonds/Insurance* | *$959,000* | *$4,127,000* |
| Contingency (30%) | $288,000 | $1,239,000 |
| **Total With Markups** | **$1,247,000** | **$5,366,000** |
| **Range** | **$873,000–$1,870,000** | **$3,756,000–$8,049,000** |

In providing options of costs for the alternatives, Jacobs has no control over cost or price of labor and materials, unknown or latent conditions of existing equipment or structures that may affect operation or maintenance costs, competitive bidding procedures and market conditions, and other economic and operational factors that may materially affect the ultimate project cost. Therefore, Jacobs makes no warranty that the actual project costs, financial aspects, or economic feasibility will not vary from Jacobs' options, analyses, projections, or estimates.

## 8. Estimated O&M Cost Impacts

The estimated annual O&M cost impacts at a 5 mgd flow rate are summarized in Table 5 and include chemical cost and power cost for additional mixers and chemical feed pumps. The estimates are based on the assumed unit price factors listed in the table notes. The estimated additional solids produced by each alternative are summarized in Table 5 as well. The cost for disposal of these solids could be estimated based on the City's unit cost per dry ton for processing and disposal of solids.

**Table 5. Estimated Annual O&M Cost Impacts**

| Item | Alternative 1 | Alternative 2 |
|---|---|---|
| Chemicals | | |
| Alum[a] | $34,000 | $0 |
| Supplemental carbon[b] | $0 | $213,000 |
| *Subtotal* | *$34,000* | *$213,000* |
| Electricity[c] | | |
| Mixers | $0 | $10,000 |
| Metering pumps | $800 | $800 |
| *Subtotal* | *$800* | *$10,800* |
| **Total Annual Cost** | **$35,000** | **$224,000** |
| | | |
| Solids | | |
| Additional WAS mass (dry ton/yr) | 110 | 292 |
| | | |

[a] Assumed alum cost of $0.56/gal

[b] Assumed Micro-Cg™ cost of $2.05/gal

[c] Assumed electricity cost of $0.12/kilowatt hour

dry ton/yr = dry ton(s) per year

# 9. Summary

A high-level review of alternatives to enhance the ability of the RWPF to remove phosphorus and nitrogen was completed for the current design treatment capacity (5 mgd) to achieve either:

- TP = 1 mg/L, or
- AWT of TN = 3 mg/L and TP = 1 mg/L

The estimated construction cost for improvements to achieve 1 mg/L TP is $900,000 to $1.9 million to add an alum storage and feed system. Annual O&M costs for chemicals and electricity are estimated to be $35,000 per year.

The estimated construction cost for improvements to achieve AWT level of treatment is $3.8 million to $8.0 million to create a second anoxic zone within the existing process tankage as well as to add supplemental carbon and alum storage and feed systems. Annual O&M costs for chemicals and electricity are estimated to be $224,000 per year.