



# Nitrogen Optimization Plan and Report (2023)

City of Mount Vernon, WA

March 27, 2024



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Appendix A. WWTP Process Schematic



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# 1 Introduction

This section provides an overview of the City of Mount Vernon’s existing wastewater treatment plant (WWTP) and Optimization Plan and Annual Report requirements under the Puget Sound Nutrient General Permit (PSNGP). In general, the PSNGP requires nitrogen removal optimization and planning activities. The PSNGP defines an annual total inorganic nitrogen (TIN) discharge Action Level which, if exceeded, requires subsequent corrective actions that may lead to capital improvements to reduce TIN discharge loads below the Action Level. Mount Vernon’s Action Level is 396,000 lb TIN/yr. As of the writing of this Annual Report, portions of the PSNGP are subject to stays in the administrative appeal process agreed upon by Department of Ecology pending resolution of appeals to the state Pollution Control Hearings Board. Included in the PSNGP requirements currently subject to a stay are requirements involving influent nitrogen reduction measures and corrective actions for Action Level exceedance.

## 1.1 Existing Facilities Summary

The City of Mount Vernon (City) owns, operates, and maintains an activated sludge wastewater treatment plant (WWTP) that discharges to the Skagit River at river mile 10.7. The plant treats domestic and industrial wastewater from the City’s service area. The collection system includes two combined sewer overflow (CSO) outfalls. The WWTP is subject to discharge limits under National Pollutant Discharge Elimination System (NPDES) permit WA0024074 apart from coverage under the PSNGP. An aerial image of the WWTP site is shown in Figure 1-1.



**Figure 1-1. City of Mount Vernon wastewater treatment plant**  
(Site boundary approximate)

Liquid stream treatment begins with influent pumping, grit removal, fine screening, and primary clarification. Primary effluent flows to an aeration basin which has flexibility to be operated with different flow patterns, thus allowing zones to be taken out of service while maintaining forward flow. The aeration basin has design flexibility and appurtenances allowing for operation in a completely aerobic process or anoxic-aerobic Modified Ludzack Ettinger (MLE) process. Secondary effluent is disinfected using ultraviolet irradiation and discharged to the Skagit River. A liquid process schematic of the Mount Vernon WWTP is included in Appendix A.

Waste activated sludge (WAS) is thickened with a dissolved air flotation thickener (DAFT) and digested with primary sludge in a conventional mesophilic anaerobic digester to achieve Class B biosolids. Biosolids are dewatered by screw press and hauled to Boulder Park for land application.

Current annual average flow is approximately 4 million gallons per day (MGD). Dry weather average flow is less than 3 MGD. Peak hour flow firm capacity is 22 MGD; however, influent flows greater than 22 MGD have been recorded when using all available pumps to avoid or minimize combined sewer overflows (CSOs). Mount Vernon's collection system includes combined sewers, which contribute to high peak wet weather flow conditions and occasionally CSOs. In the mid-2000s the City constructed a CSO regulator in its collection system, which aided with CSO compliance. Thereafter, CSO control efforts have focused on treating flows at the WWTP with a large upgrade to the WWTP being completed in 2009, which increased peak flow capacity at the WWTP. Incremental improvements to the existing influent pump station in the years since have added reliability and capacity to convey these flows to the WWTP. As a result of these efforts, the City is in compliance with the criterion of one CSO per outfall per year on the 5-year rolling average.

As noted above, Mount Vernon's WWTP aeration basins are designed with features to be operated in either completely aerobic biochemical oxygen demand (BOD) removal mode or nitrogen removal mode with a MLE configuration. The capacity in nitrogen removal mode is approximately half of that for BOD removal mode as this mode was intended for seasonal use during dry weather conditions. Given these limitations it is not feasible to intentionally operate in nitrogen removal mode with long solids retention time (SRT) in the winter and even in the shoulder seasons the City runs a risk of CSO compliance issues related to hydraulic limitations. More specifically, the higher mixed liquor suspended solids (MLSS) concentration associated with longer SRT required for winter nitrogen removal (compared lower MLSS and SRT for BOD removal mode) would result in excessive solids loads on the secondary clarifiers.

Although the WWTP has operated in nitrogen removal mode in the past, WWTP influent BOD loads have exceeded the design BOD loads for nitrogen removal mode. Therefore, at current plant loadings, BOD removal mode is preferred to avoid unit process and plant capacity limitations in nitrogen removal mode described above, thereby maximizing plant capacity and the chances of avoiding CSOs. As such, the City has recently operated in BOD removal mode to provide adequate treatment capacity for conventional secondary treatment (BOD/total suspended solids [TSS] removal) required by the individual NPDES permit. However, the City's historical experience and WWTP features for potential TIN removal are valuable in the context of the PSNGP, which requires nitrogen removal optimization and planning.



## 1.2 Optimization Plan Requirements

Mount Vernon is classified as a “Moderate WWTP” in Table 8 of the PSNGP. Section S5.C of the Permit requires Moderate WWTPs to develop, implement, and maintain a Nitrogen Optimization Plan that will be submitted annually at the end of March through the Annual Report. Below are the verbatim requirements of the Nitrogen Optimization Plan as written in Section S5.C (Source: PSNGP):

### 1. Treatment Process Performance Assessment Requirements

Assess the nitrogen removal potential of the current treatment process and identify viable optimization strategies prior to implementation.

- a. *Treatment Assessment.* Develop a method to evaluate potential optimization approaches for the existing treatment process. Use the evaluation to:
  - i. Determine current (pre-optimization) process performance to determine the existing TIN removal performance for the WWTP.
  - ii. Create a list of potential optimization strategies capable of meeting the action level at the WWTP prior to starting optimization. Update the assessment and list of options as necessary with each Annual Report.
- b. *Identify and evaluate optimization strategies.* From the list developed in S5.C.1.a.ii, identify viable optimization strategies for each WWTP owned and operated by the Permittee. Prioritize and update this list as necessary to continuously maintain a working set of strategies for meeting the action level with the existing treatment processes. The Permittee may exclude any optimization strategy from the initial list created in S5.C.a.ii that was considered but found to exceed a reasonable implementation cost or timeframe. Documentation must include an explanation of the rationale and financial criteria used in the exclusion determination. If the Permittee finds no viable optimization strategies exist for their current treatment processes, they must immediately proceed to the identification of a corrective action under S5.D.
- c. *Initial Selection.* As soon as possible and no later than July 1, 2022, select at least one optimization strategy for implementation. Document the expected performance (i.e., % TIN removal or a calculated reduction in effluent load or concentration) for the initial optimization strategy prior to implementation.

### 2. Optimization Implementation

All Permittees in Table 8 must document implementation of the selected optimization strategy (from S5.C.1.c) during the first reporting period in the first Annual Report due March 31, 2023. Permittees must document implementation during every reporting period thereafter. The documentation must include:

- a. *Strategy Implementation.* Describe how the permittee implemented the selected strategy during each reporting period, following permit coverage. Including:
  - i. Initial implementation costs
  - ii. Length of time for full implementation, including start date.

- iii. Any adaptive management applied to refine implementation during the reporting period.
  - iv. Anticipated and unanticipated challenges.
  - v. Any impacts to the overall treatment performance as a result of process changes.
- b. *Discharge Evaluation.* By March 31 each year beginning in 2023, each Permittee in Table 8 must review effluent data collected during the previous calendar year to determine whether TIN loads are increasing.
- i. Using all accredited monitoring data, determine facility's annual average TIN concentration and load from the reporting period. If the annual TIN load exceeds the Action Level in Table 8 take the corrective action in S5.D.
  - ii. Determine the treatment plant's TIN removal rate observed during the reporting period.

Appendix C of the Permit further requires the Optimization Plan to include the following:

1. Description of the assessment method applied to evaluate the existing treatment process
2. Explanation of initial approach for optimization
3. Description of optimization plan implementation including start date, schedule for full implementation, implementation costs, and challenges including impacts to other measures of treatment plant performance



## 2 Influent Nitrogen Reduction Measures

Influent nitrogen reduction measures were considered by the City in PSNGP Year 1 (2022 calendar year; March 2023 reporting). The text below regarding influent nitrogen reduction measures was included in the Year 1 report and remains unchanged with respect to the City's ongoing consideration of such measures.

*The City considered septage handling practices, commercial, dense residential and industrial wastewater sources and potential influent nitrogen reduction measures associated with such sources.*

*The City does not accept septage and is characterized by older and low-density housing, even for new housing units, such that decentralized treatment for source reduction is not practical.*

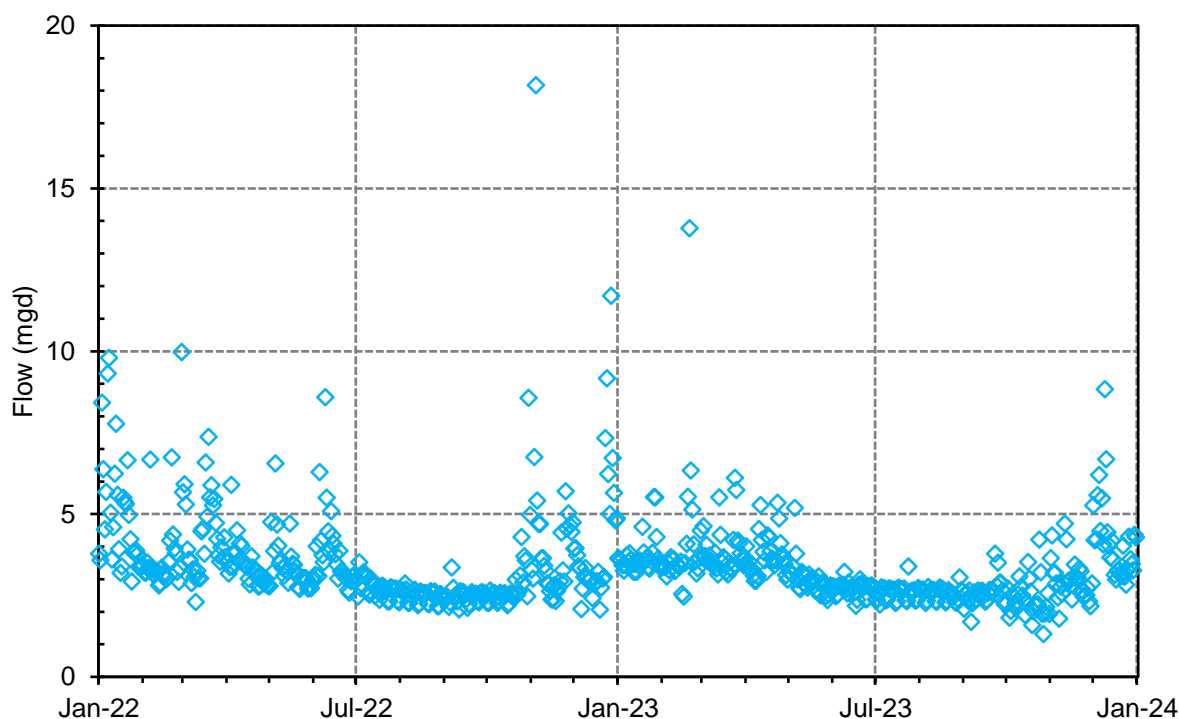
*One significant industrial discharger, Draper Valley Farms (Draper), discharges wastewater from poultry processing operations to the City's collection system. Draper is subject to discharge limits under State Waste Discharge Permit number ST0003861. Historically, industrial pretreatment has been with screening, chemical addition, and dissolved air flotation. Recent data for 2022 indicate average discharge flow of 0.3 MGD and BOD and TSS concentrations of approximately 230 and 50 mg/L. These concentrations and occasional ad-hoc nitrogen sampling coordinated with the City did not suggest elevated nitrogen discharge concentrations. Thus, the Draper effluent wastewater strength is similar order of magnitude to municipal wastewater strength and does not appear to be a disproportionately high source of influent nitrogen load.*

*A recently-completed upgrade at Draper circa July 2023 involved addition of a moving-bed bioreactor (MBBR) process. Planning and implementation of the MBBR upgrade began before the PSNGP was issued. The City's understanding is that the MBBR design is aerobic-only and does not include features for denitrification and thus significant TIN removal. The completion and commissioning of an aerobic-only MBBR may affect the City's influent wastewater characteristics and thus hypothetical nitrogen removal design and performance.*

### 3 Nitrogen Removal Assessment

A combination of historical data before and after PSNGP reporting requirements were used to assess nitrogen removal performance. A challenge in assessing performance prior to PSNGP reporting is that no influent  $\text{NH}_3\text{-N}$  or TKN data are available, thus making evaluation of historical influent loads and nitrogen removal performance impossible prior to PSNGP sampling that began in March 2022. Historical effluent  $\text{NH}_3\text{-N}$  data are available prior to March 2022 and were considered for potential insights regarding WWTP loads and treatment performance. As PSNGP coverage continues and more substantial and consistent data are obtained, the use of and reliance on such pre-PSNGP historical data can decrease.

WWTP influent flows are shown in Figure 3-1. Dry weather flows averaged approximately 2.5 MGD, while wet weather flows caused annual average flow to be higher at 3.6 and 3.2 MGD in 2022 and 2023, respectively. Wet weather events into early June were observed, which is in line with the City's experience in previous years.

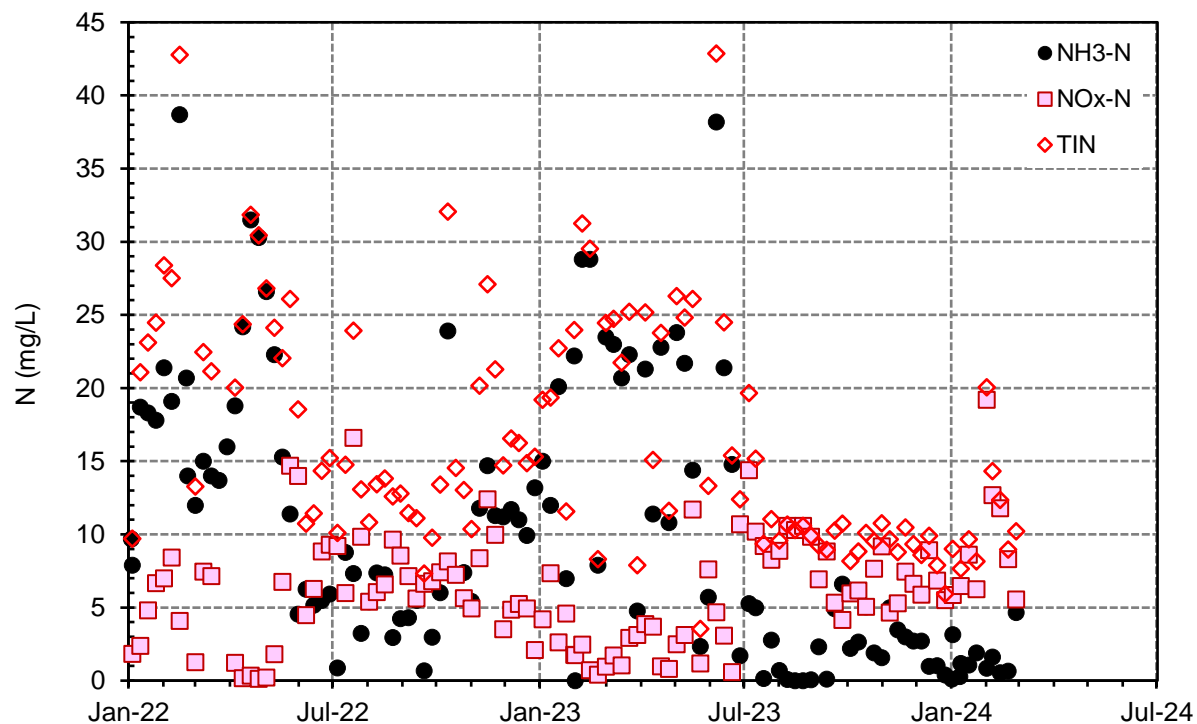


**Figure 3-1. Mount Vernon WWTP average daily influent flows**

(Note only influent flow is metered and reported for influent and effluent)

Though the City selected a full-scale Nuvoda MOB™ trial as the optimization effort for calendar year 2022, much of 2022's operation involved what could also be considered optimization which is a transition to nitrification-denitrification in summer. Furthermore, 2022 performance was obtained without the MOB media and process in place. Planning and construction occurred in 2022 and startup occurred in February 2023. Stable nitrification-denitrification with the MOB process in-place did not occur until July 2023. Thus, calendar years 2022 and 2023 included periods representative of performance with and without the MOB process.

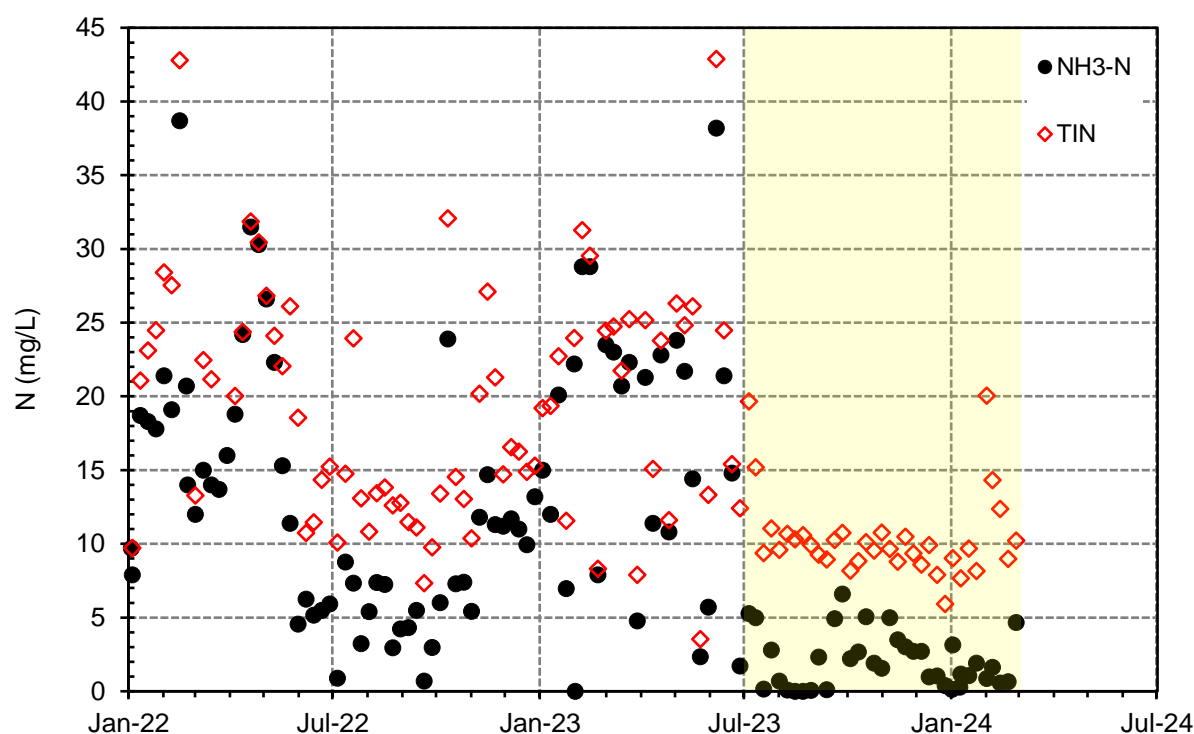
Effluent  $\text{NH}_3\text{-N}$ ,  $\text{NO}_x\text{-N}$ , and TIN concentrations are shown in Figure 3-2. These effluent TIN species show that various levels of nitrification and denitrification occurred in 2022 and 2023. Minimal nitrification and thus minimal nitrogen removal occurred in winter and spring 2022 prior to the MOB demonstration. In summer 2022, nitrification and thus nitrogen removal increased but later ceased into late fall, as expected with the onset of colder temperatures. MOB media was added in February 2023, but nitrification and nitrogen removal remained low until July 2023 when nitrification was established. Nitrification was ultimately established through a combination of operation at longer SRT, nitrifier bioaugmentation, and onset of warmer process temperatures. Thereafter, nitrogen removal was consistently maintained through summer 2024, where effluent TIN averaged 10 mg/L from July through December 2023. Data for the first quarter of 2024 indicated that nitrification has been maintained throughout the winter season, in contrast to other years where nitrification has consistently been lost.



**Figure 3-2. Mount Vernon WWTP effluent  $\text{NH}_3\text{-N}$ ,  $\text{NO}_x\text{-N}$ , and TIN concentrations**

Note: Jan 1 - Mar 30, 2022 effluent nitrogen species based on NPDES DMR data for  $\text{NH}_3\text{-N}$  and  $\text{NO}_x\text{-N}$  outside of PSNGP coverage and reporting.

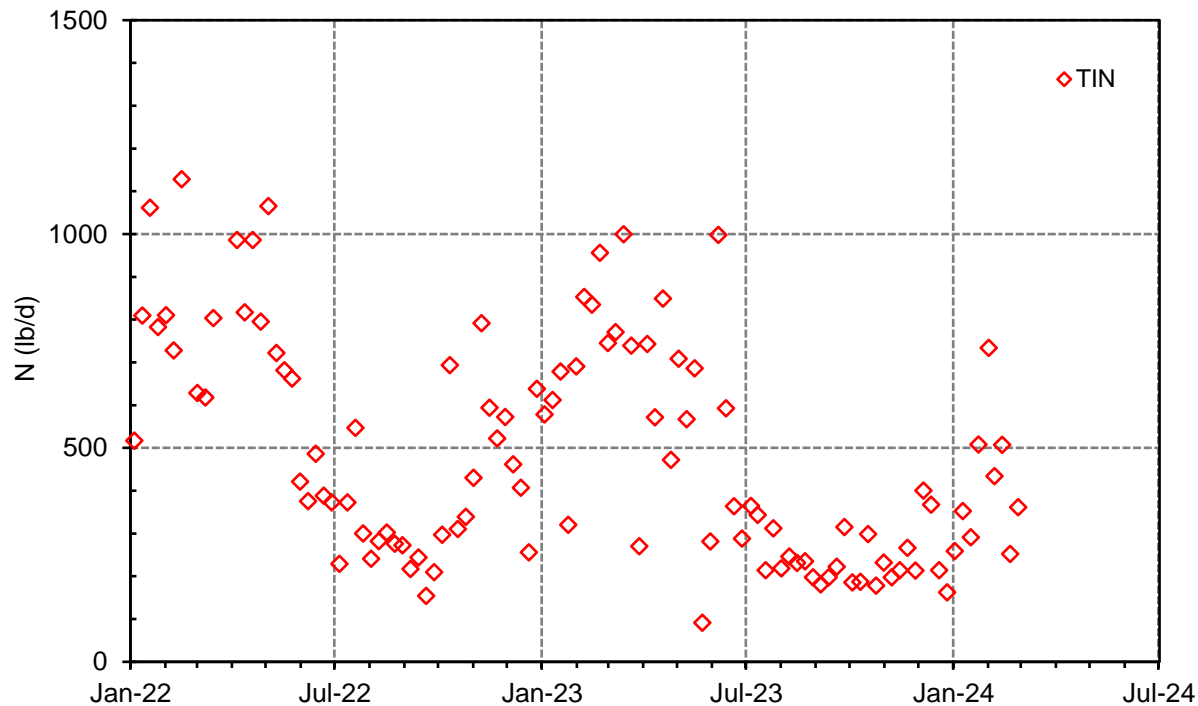
Figure 3-3 shows the same effluent TIN species data as Figure 3-2 but highlights the period of performance for the MOB demonstration after nitrification was established. Compared to comparable seasonal periods in prior years, the MOB process demonstrated lower, more consistent effluent TIN concentrations were achieved. Although nitrogen removal has been maintained year-round with the MOB demonstration, nitrogen removal efficiency decreased in winter. The decrease in denitrification efficiency in the winter is likely due to less favorable kinetics at colder temperatures and differences in influent wastewater characteristics for summer versus winter conditions. Long collection system retention times and warmer temperatures likely lead to higher soluble BOD concentrations in summer than in winter with colder temperatures and shorter collection system HRTs at wet weather flow conditions. As a result, caustic demand for process and effluent pH control has been noticeably higher for winter conditions than summer conditions. Caustic demand has averaged over 400 gpd in winter versus under 200 gpd in summer. In addition to lower denitrification efficiency, the added low-alkalinity wet weather flow component may also contribute to higher winter caustic demand. The City's winter caustic demand translates to an operations cost of approximately \$6,000 per week.



**Figure 3-3. Mount Vernon WWTP effluent  $\text{NH}_3\text{-N}$  and TIN concentrations highlighting performance after nitrification was established in MOB demonstration**

Note: Jan 1 - Mar 30, 2022 effluent nitrogen species based on NPDES DMR data for  $\text{NH}_3\text{-N}$  and  $\text{NO}_x\text{-N}$  outside of PSNGP coverage and reporting.

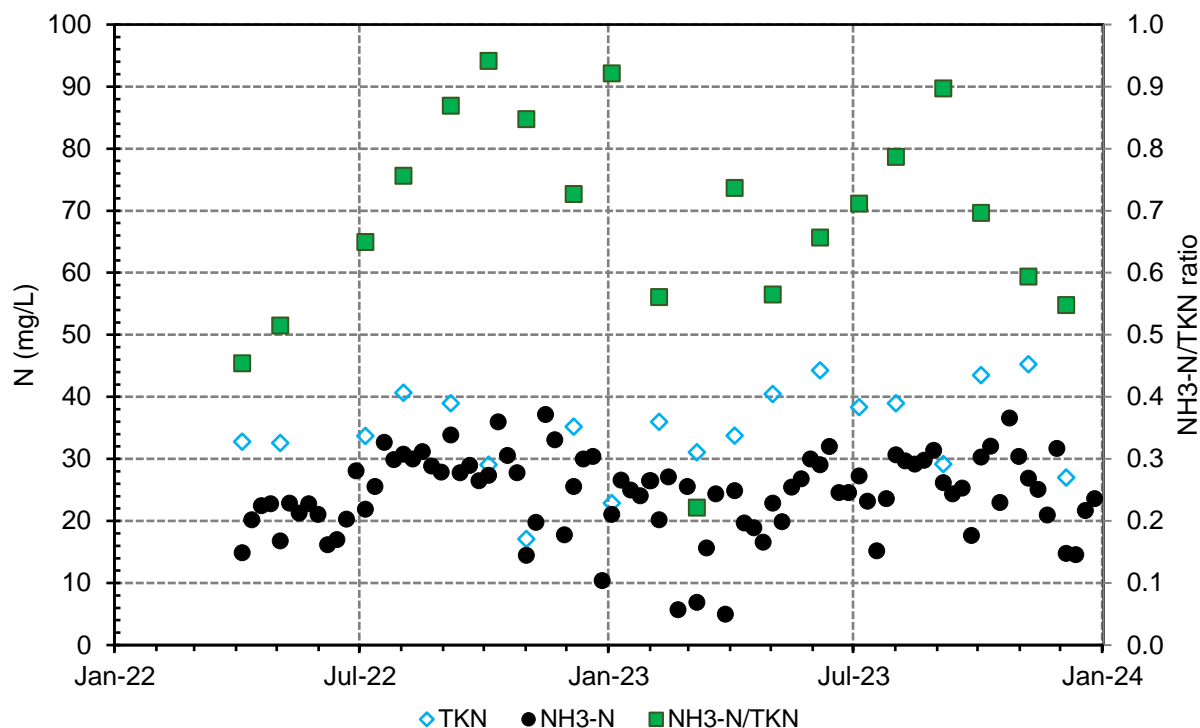
Effluent TIN loads are shown in Figure 3-4. Data reflect the discussion and data above. Operation prior to the MOB trial was characterized by shorter, less stable nitrogen removal period during summer only. Year-round nitrogen removal was achieved once the MOB process was established and characterized by more consistent and higher nitrogen removal in summer than winter.



**Figure 3-4. Mount Vernon WWTP daily effluent TIN loads highlighting performance after nitrification was established in MOB demonstration**

Note: Jan 1 - Mar 30, 2022 effluent TIN calculated based on NPDES DMR data for  $\text{NH}_3\text{-N}$  and  $\text{NO}_x\text{-N}$  outside of PSNGP coverage and reporting.

Influent  $\text{NH}_3\text{-N}$  and TKN concentrations and associated  $\text{NH}_3\text{-N/TKN}$  ratios for PSNGP-related sampling beginning in April 2022 and are shown in Figure 3-5. An erroneously high influent TKN measurement in June 2022 was removed from the dataset. Influent  $\text{NH}_3\text{-N/TKN}$  ratio averaged 0.67 for the entire dataset thus far. A distinct pattern in influent  $\text{NH}_{\text{NH}_3}\text{-N/TKN}$  ratio can be observed whereby the ratio appears to peak in late summer, exhibiting a potential seasonal pattern. A possible explanation is longer retention times and hydrolysis/ammonification of organic nitrogen to ammonium in the collection system when flows are low and collection system hydraulic retention time is longer. Ongoing monitoring and reporting under the PSNGP will develop a more robust and long-term dataset to evaluate the consistency of this potential pattern.



**Figure 3-5. Mount Vernon WWTP influent  $\text{NH}_3\text{-N}$ , TKN and  $\text{NH}_3\text{-N/TKN}$  ratio**  
(Erroneous influent TKN data removed in June 2022)

Summaries of monthly and annual influent and effluent nitrogen data are presented in Table 3-1 for 2022 and Table 3-2 for 2023. The estimated annual TIN discharge was approximately 203,000 lbs in 2022 and significantly under the Action Level of 396,000 lb/year. Thus, the City's base operation without MOB suggests elements of optimization are inherently part of standard operations and that there is low risk for Action Level exceedance, with or without MOB. Performance in June through December 2022 was characterized by partial nitrification-denitrification, which inherently achieves more TIN removal than strict BOD removal only. During this warmer time in particular, nitrification can be difficult to avoid as the plant "drifts" into partial nitrification despite operation at lower SRTs aiming for strict BOD removal only. When partial nitrification could not be avoided, the City used features of its plant such as the pre-anoxic zone and mixed liquor recycle capabilities to maximize denitrification and thus TIN removal. As such, much of 2022's operation outside of MOB trial efforts can be considered additional supplementary "ordinary" optimization.

Data for 2023 in Table 3-2 includes the MOB demonstration, although "mature" performance was not achieved until nitrification was established around July 2023. The estimated annual TIN discharge was approximately 155,000 lbs and less than that of 2022 despite the fact that the MOB system was not established until mid-year.

**Table 3-1. Mount Vernon WWTP nitrogen removal summary – 2022**

		INFLUENT							EFFLUENT				
		Flow <sup>c</sup>	NH <sub>3</sub> -N	NO <sub>x</sub> -N	TKN	NH <sub>3</sub> -N	NO <sub>x</sub> -N	TIN <sup>e</sup>	NH <sub>3</sub> -N	NO <sub>x</sub> -N	TIN	TIN	TIN
Month	Days	MGD	mg/L	mg/L	mg/L	lb/d	lb/d	lb/d	mg/L	mg/L	mg/L	lb/d	lb/mo
Frequency		Daily	1x/wk	1x/mo	1x/mo	calc'd	calc'd	calc'd	1x/wk	1x/wk	1x/wk	calc'd	calc'd
Jan-22 <sup>a</sup>	31	5.01	---	---	---	---	---	---	14.48	3.93	19.60	792	24,552
Feb-22 <sup>a</sup>	28	3.81	---	---	---	---	---	---	22.78	6.51	32.91	889	24,892
Mar-22 <sup>a</sup>	31	4.34	---	---	---	---	---	---	14.14	5.30	18.97	711	22,041
Apr-22 <sup>b</sup>	30	3.43	20.10	1.31	32.80	685	37	594	26.20	0.48	26.68	896	26,880
May-22	31	3.43	20.98	1.37	32.60	559	37	596	16.03	7.50	23.53	710	22,010
Jun-22	30	3.80	20.40	0.83	--- <sup>d</sup>	597	26	623	5.71	7.23	12.94	405	12,169
Jul-22	31	2.73	27.53	3.19	33.70	659	84	743	5.06	10.41	15.47	362	11,220
Aug-22	31	2.50	29.76	0.02	40.70	637	0	637	5.45	7.25	12.70	275	8,519
Sep-22	30	2.48	29.30	7.16	39.00	688	201	889	3.37	6.56	9.92	206	6,184
Oct-22	31	2.93	30.45	1.19	29.10	747	25	772	11.15	7.12	18.27	410	12,703
Nov-22	30	4.21	24.48	1.15	17.10	724	32	756	10.88	7.85	18.73	582	17,455
Dec-22	31	4.14	24.10	0.18	35.20	728	3	731	11.46	4.29	15.75	440	13,655
ANN. AVG.		3.57	25.23	1.82	32.53	669	49	705	12.22	6.20	18.79	556	16,857
ANN. TOT.		244,185 <sup>f</sup>						262,435 <sup>f</sup>	202,940 <sup>f</sup>				

Notes:

- Jan-Mar effluent TIN calculated based on NPDES DMR data for NH<sub>3</sub>-N and NO<sub>x</sub>-N outside of PSNGP coverage
- Coverage and reporting under PSNGP began in April 2022
- Influent flow metered and reported both as influent and effluent flow
- Erroneous influent TKN measurement in June removed from data set
- Influent TIN calculated as sum of monthly daily average NH<sub>3</sub>-N and NO<sub>x</sub>-N loads
- Estimate calculated based on average daily load times 365 days per year

Estimated TIN removal = (705 lb/d – 556 lb/d) / (705 lb/d) x 100 = 21%

Approximate effective influent TIN considering conversion of TKN = (669 lb NH<sub>3</sub>-N/d) / (0.67 lb NH<sub>3</sub>-N/TKN) + 49 lb NO<sub>x</sub>-N/d = 1048 lb N/d

Approximate effective TIN removal = (1048 lb N/d – 556 lb TIN/d) / (1048 lb N/d) x 100 = 47%



**Table 3-2. Mount Vernon WWTP nitrogen removal summary – 2023**

Month	Days	INFLUENT							EFFLUENT				
		Flow <sup>a</sup>	NH <sub>3</sub> -N	NO <sub>x</sub> -N	TKN	NH <sub>3</sub> -N	NO <sub>x</sub> -N	TIN <sup>b</sup>	NH <sub>3</sub> -N	NO <sub>x</sub> -N	TIN	TIN	TIN
	Frequency	MGD	mg/L	mg/L	mg/L	lb/d	lb/d	lb/d	mg/L	mg/L	mg/L	lb/d	lb/mo
		Daily	1x/wk	1x/mo	1x/mo	calc'd	calc'd	calc'd	1x/wk	1x/wk	1x/wk	calc'd	calc'd
Jan-23	31	3.71	24.66	0.83	22.9	723	24	747	15.25	4.11	19.37	576	17,848
Feb-23	28	4.06	21.02	0.56	36.0	670	17	687	22.25	1.27	23.40	687 <sup>c</sup>	19,248
Mar-23	31	3.88	13.00	0.53	31.1	404	16	420	17.69	2.21	19.90	695	21,530
Apr-23	30	3.75	20.03	0.70	33.8	682	19	701	16.58	2.34	18.92	659	19,767
May-23	31	3.00	25.02	0.93	40.5	593	25	618	13.59	5.23	18.82	467	14,470
Jun-23	30	2.71	27.58	0.57	44.3	647	13	660	19.03	4.77	23.80	560	16,810
Jul-23	31	2.58	22.33	0.05	38.4	500	1	501	3.30	10.52	13.82	308	9,564
Aug-23	31	2.56	30.16	8.89	39.0	690	199	889	0.17	10.05	10.22	225	6,987
Sep-23	30	2.58	23.40	1.76	29.2	522	39	561	3.49	6.31	9.80	229	6,859
Oct-23	31	2.40	30.48	1.31	43.5	729	20	749	2.68	6.81	9.49	216	6,691
Nov-23	30	2.97	26.18	0.28	45.3	554	4	558	3.55	6.02	9.57	223	6,669
Dec-23	31	4.21	18.68	1.28	27.0	675	66	741	1.29	6.80	8.08	286	8,860
ANN. AVG.		3.20	23.54	1.47	35.9	616	37	652	9.91	5.54	15.43	428	12,942
ANN. TOT.		224,686 <sup>d</sup>						238,161 <sup>d</sup>	155,303				

Notes:

- Influent flow metered and reported both as influent and effluent flow
- Influent TIN calculated as sum of monthly daily average NH<sub>3</sub>-N and NO<sub>x</sub>-N loads
- Erroneous effluent TIN Feb 1 based only on effluent NH<sub>3</sub>-N removed from data set
- Estimate calculated based on annual average daily load times 365 days per year

Estimated TIN removal = (652 lb/d – 428 lb/d) / (652 lb/d) x 100 = 34%

Approximate effective influent TIN considering conversion of TKN = (616 lb NH<sub>3</sub>-N/d) / (0.67 lb NH<sub>3</sub>-N/TKN) + 37 lb NO<sub>x</sub>-N/d = 956 lb TKN/d

Approximate effective TIN removal = (956 lb TKN/d – 428 lb TIN/d) / (956 lb N/d) x 100 = 55%

Estimated TIN removal efficiency was 21% in 2022 and 34% in 2023. For July through December 2023 with mature MOB system established, estimated TIN removal was 63%.

However, a more appropriate measure of nitrogen removal should consider influent TKN loads and the influent  $\text{NH}_3\text{-N}$ /TKN ratio because most of the organic nitrogen associated with the TKN measurement ultimately is ammonified to  $\text{NH}_3\text{-N}$  thus becoming an effective TIN load on the treatment facility. A small portion of the influent TKN may be refractory meaning non-biodegradable or very slowly biodegradable. The so-called refractory TKN is plant-specific but typically in the range of 1 to 2 mg/L. Thus, influent TKN plus any influent  $\text{NO}_x\text{-N}$  is a reasonable approximate of “effective” influent TIN load even if refractory TKN is unknown and/or neglected.

Using a more representative of “approximate effective TIN removal” considering influent  $\text{NH}_3\text{-N}$  loads, dataset average influent  $\text{NH}_3\text{-N}$ /TKN ratio of 0.67, influent  $\text{NO}_x\text{-N}$  loads, and effluent TIN loads, the approximate effective TIN removal can be estimated as follows:

- Calculate influent TKN load based on average daily  $\text{NH}_3\text{-N}$  load, which is measured more frequently than influent TKN, and dataset average  $\text{NH}_3\text{-N}$ /TKN ratio
- Add influent  $\text{NO}_x\text{-N}$  load to the above to determine “effective influent TIN”
- Calculate “effective TIN removal” based on “effective influent TIN” and measured effluent TIN

Using this approach, “effective TIN removal” was 47% in 2022 and 55% in 2023. For July through December 2023 with mature MOB system established, estimated “effective influent TIN” removal was 76%.

## 4 Optimization Alternatives

Results of the original PSNGP Year 1 optimization alternatives evaluation are summarized for reference in Section 4.1. Updates to optimization alternatives and associated evaluation and/or prioritization are discussed in Section 4.2.

### 4.1 Original Optimization Alternatives Summary

The PSNGP Year 1 Nitrogen Optimization Plan and Report covering the 2022 calendar year documented the development, evaluation, initial selection, and prioritization of optimization alternatives. The full details of the potential optimization strategies, their rationale and relevance to optimization, and evaluations and decision-making process around optimization selection can be found in that Year 1 report. A brief overview is presented below with discussion of changes, where relevant, based on ongoing optimization strategy assessment and adaptive management.

A variety of optimization concepts were considered for the WWTP. Few viable no-cost optimization concepts are available; most concepts require non-trivial capital and/or operations costs expenditures. Potential optimization strategies are listed in Table 4-1.

**Table 4-1. Potential optimization strategies for Mount Vernon WWTP**

Strategy	Strategy Title
1	Pressate Treatment
2	Summer Nitrogen Removal
3	RAS Reaeration
4	Automation Strategies for TIN Removal Modes
5	Nuvoda MOB™ Trial and Retrofit

The optimization strategy alternatives are briefly described in subsequent sections along with a qualitative assessment based on the following criteria and rankings as shown in Table 4-2:

- Ease of implementation
- Staff operational assessment (e.g., complexity, risk, labor, etc.)
- Long-term potential toward ultimate goal of year-round TIN removal
- Cost: capital and operations costs

**Table 4-2. Qualitative assessment criteria for optimization strategies**

Criterion	Qualitative ranking
Ease of implementation	Easy / Moderate / Difficult
Operational assessment	Easy / Moderate / Difficult
Long-term potential	Low / Medium / High
Cost	Low / Medium / High

Qualitative assessments for optimization alternatives 1 through 5 are summarized Table 4-3 through Table 4-7, respectively.

**Table 4-3. Alternative 1 “Pressate Treatment” qualitative assessment**

Criterion	Ranking/comments
<b>Ease of implementation</b>	<b>Moderate:</b> May be able to repurpose existing tankage.
<b>Operational assessment</b>	<b>Moderate to difficult:</b> Adds another process to manage and monitor. Not typically practiced for WWTPs the size of Mount Vernon.
<b>Long-term potential</b>	<b>Medium:</b> Provides benefits for WWTP TIN removal as interim or gap measure but is not a long-term approach for full year-round biological nitrogen removal.
<b>Cost</b>	<b>Medium to high:</b> Conveyance and process equipment required. Capital project.
<b>Conclusion</b>	A possible contingency option as corrective action if Action Level is exceeded, but not a preferred near-term optimization option due to cost and complexity.

**Table 4-4. Alternative 2 “Summer Nitrogen Removal” qualitative assessment**

Criterion	Ranking/comments
<b>Ease of implementation</b>	<b>Easy to moderate:</b> Existing configuration works. May require some automation features for summer wet weather mode.
<b>Operational assessment</b>	<b>Difficult:</b> Significant complexity. Seasonal nitrification transitions are challenging and can result in process upsets.
<b>Long-term potential</b>	<b>Low:</b> Not a long-term approach for full year-round biological nitrogen removal.
<b>Cost</b>	<b>Low:</b> No to low capital modifications required. Impacts operations cost (caustic) per WWTP experience.
<b>Conclusion</b>	A possible contingency option as corrective action if Action Level is exceeded, but not preferred. Not a viable year-round long-term nitrogen removal option. Base operation involves turning on denitrification capability if nitrification cannot be avoided in summer, so this is practiced to some extent already.

**Table 4-5. Alternative 3 “RAS Reaeration” qualitative assessment**

Criterion	Ranking/comments
<b>Ease of implementation</b>	<b>Easy:</b> Possible in existing configuration works.
<b>Operational assessment</b>	<b>Moderate:</b> Not inherently complex, but nitrification and TIN removal can be unstable.
<b>Long-term potential</b>	<b>Medium:</b> May extend nitrogen removal capacity at low SRTs (i.e., those traditionally for BOD removal only) but modest benefit is anticipated based on other full-scale WWTPs employing a similar strategy.
<b>Cost</b>	<b>Low:</b> No to low capital modifications required. Impacts operations cost (caustic) per WWTP experience.
<b>Conclusion</b>	A possible contingency option as corrective action if Action Level is exceeded, but not preferred. Not a viable year-round long-term nitrogen removal option without further upgrades and plant expansion.

**Table 4-6. Alternative 4 “automation strategies for TIN removal modes” qualitative assessment**

Criterion	Ranking/comments
<b>Ease of implementation</b>	<b>Easy:</b> I&C overlays on a base TIN removal mode.
<b>Operational assessment</b>	<b>Moderate:</b> Not complex, but will require programming, tuning, and instrument maintenance.
<b>Long-term potential</b>	<b>Medium:</b> Beneficial, but only once in a base TIN removal mode. Good optimization candidates if/when base nitrogen removal mode is established.
<b>Cost</b>	<b>Low:</b> Instruments only; no major capital cost. Expected to result in some energy and chemical savings vs. a basic TIN removal mode.
<b>Conclusion</b>	Not preferred as near-term approach. Requires a “base” nitrification-denitrification to build on; does not achieve nitrification-denitrification in-and-of itself. Retain these concepts for optimizing a long-term TIN removal process.

**Table 4-7. Alternative 5 “Nuvoda MOB” qualitative assessment**

Criterion	Ranking/comments
<b>Ease of implementation</b>	<b>Easy to moderate:</b> Existing configuration works with minor changes.
<b>Operational assessment</b>	<b>Easy to moderate:</b> MOB “overlays” on existing MLE process that operators are familiar with. Minimal process changes required.
<b>Long-term potential</b>	<b>High:</b> Viable year-round strategy in consistent operating mode. Potential for further optimization with I&C strategies for nitrogen removal.
<b>Cost</b>	<b>Medium:</b> Modest capital modifications required. Media, retention screens, and minor conveyance modifications.
<b>Conclusion</b>	The potential ability to achieve year-round TIN removal without plant expansion though the MOB process is attractive to the City. Early investigation of this technology and full-scale demonstration is of interest to the City as dual-purpose optimization and long-term TIN removal approach investigation.

The City chose to proactively pursue a full-scale MOB demonstration trial for its optimization strategy. Although other strategies such as summer nitrogen removal or RAS reaeration modes would have a lower cost for optimization, the associated incremental nitrogen removal benefit is limited, and they are poor candidates for achieving long-term nitrogen removal objectives. MOB was extremely attractive as a high-impact nitrogen removal technology with long-term year-round nitrogen removal potential. It is emphasized that the current effort is a temporary MOB demonstration trial only. Future capital expenditure would be required for a permanent MOB system purchase and installation.

During the Nuvoda MOB test program, significant improvements to TIN removal are still anticipated (and have been realized), and thus de-facto improved/optimized performance over baseline conditions is expected. With only one activated sludge aeration basin, the City cannot segregate “ordinary” optimization efforts from “technology testing” optimization efforts such as the MOB trial.

Should the MOB testing ultimately end with media removal rather than transition to a permanent or semi-permanent continued MOB operation with improved nitrogen removal, the City retains the ability to implement other “ordinary” optimization strategies identified herein which may provide interim TIN removal benefits although may not necessarily be long-term solutions for high levels of TIN removal in-and-of themselves. One such example optimization strategy is summer nitrogen

removal. The less compelling long-term potential for such “ordinary” optimization strategies is the main reason the City chose to act proactively with the MOB testing, which has greater long-term potential.

## 4.2 Optimization Alternatives Updates

The original PSNGP Year 1 optimization alternatives assessment approach and prioritization was not substantively changed. Information gleaned from implemented optimization activities and ongoing consideration of optimization alternatives did not warrant a detailed re-evaluation.



## 5 Optimization Implementation

This section describes optimization activities implemented this year and an overview of results, costs, and next steps.

### 5.1 Timing, Challenges and Adaptive Management

Optimization activities in 2022 involved contracting with Nuvoda for the full-scale demonstration and modifying WWTP facilities to accommodate the demonstration trial. Substantial completion of WAS piping modifications and media retention screen structure was completed in December 2022. See Figure 5-1 through Figure 5-3.



**Figure 5-1. Media screen structure and temporary piping at west end of aeration basin**





Figure 5-2. Media return piping into aeration basin channel below



Figure 5-3. Media retention screen inside structure



Key events, challenges, and adaptive management relevant to optimization activities documented in the 2023 Optimization Annual Reporting Period and the January-March 2024 period prior to Annual Report submittal are described in chronological order below:

January 2023 – Initial MOB test plan submittal to Ecology.

February 2023 – Revised MOB test plan submittal to Ecology. Test plan acceptance and trial startup with background non-nitrifying activated sludge condition.

March – June 2023: Significant media loss occurred upon startup. Media retention screen operation was modified to minimize media loss. Challenges faced with establishing nitrification with low SRT despite presence of media. Nitrification was ultimately established through operation at longer SRT, nitrifier bioaugmentation, and onset of warmer process temperatures.

July 2023 – December 2023: Stable nitrogen removal achieved. Supplemental alkalinity addition required.

December 2023: Unrelated to optimization activities, but of note to nitrogen removal performance and plantwide impacts, a boiler failure and temporary loss of temperature control resulted in anaerobic digester upset conditions (sour digester). Nitrogen removal performance in the activated sludge process did not appear to be affected by these conditions despite the high return organic loads from volatile acids. Digester recovery took approximately one month.

January – March 2024: Nitrogen removal sustained during winter conditions. Supplemental alkalinity (caustic) demand increased in winter. Root causes appear to be lower denitrification efficiency and possibly differences in influent water chemistry for dry weather vs wet weather flow conditions. Recently, a low dissolved oxygen operation has been initiated in effort to increase denitrification efficiency and reduce caustic demand.

## 5.2 Next Steps

The City plans to terminate the MOB trial in April 2024. Absent outside grant funding, the City's capital budget does not include monies for MOB permanent installation or ongoing full-scale operation including vendor equipment costs, capital upgrade costs, and increased chemical (caustic) costs. Aside from the potential MOB capital upgrade project, the observed caustic demand averaging over 400 gpd in winter full and associated chemical cost of approximately \$6,000 per week is not supported in the City's current operations budgeting and is beyond the scope of optimization. The City is considering returning to a summer nitrogen removal mode for ongoing optimization in absence of the Nuvoda MOB process.

## 5.3 Costs

Estimated costs associated with optimization are itemized in Table 5-1.

**Table 5-1. PSNGP expenditures summary**

<b>Cost Item / Description</b>	<b>Year</b>	<b>Approximate Cost</b>
Caustic addition during nitrification-denitrification	2022	\$10,700
MOB trial – Construction costs for temporary structures/modifications by others	2022	\$24,000
MOB trial – Construction costs for in-house labor by City	2022	\$4,500
Consultant fees – General Optimization and PSNGP	2022	\$68,000
	<b>2022 subtotal</b>	<b>\$107,200</b>
Caustic addition during nitrification-denitrification	2023	\$58,100
MOB trial – vendor costs	2023	\$128,550
Consultant fees – General Optimization and PSNGP	2023	\$54,470
	<b>2023 subtotal</b>	<b>\$241,120</b>

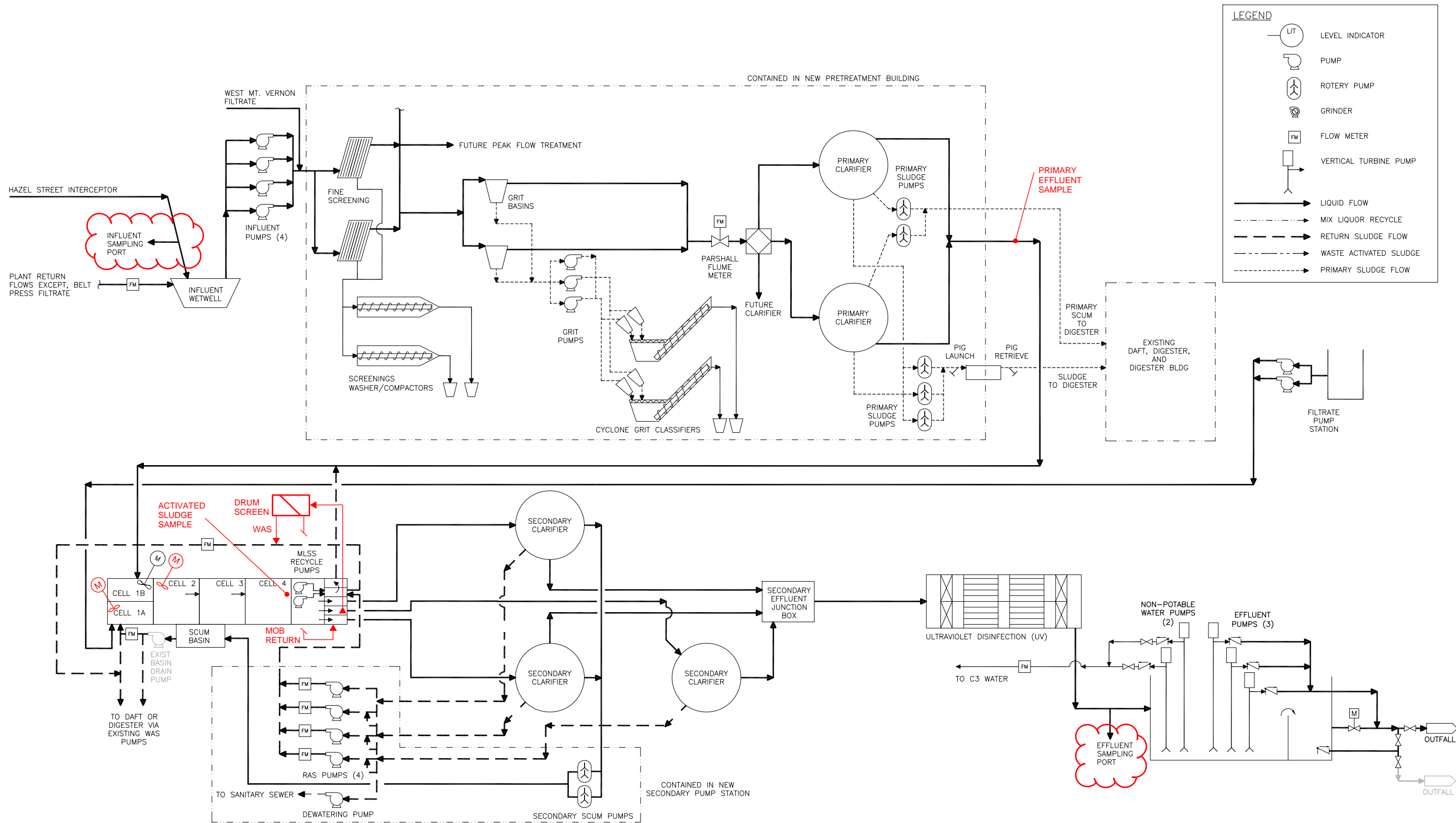
Notes:

- A. Costs are reported as actual costs incurred or as estimates based on level of effort and judgement around actual timing of costs incurred versus field activities, which may span reporting years. Costs are not escalated to present.

# Appendix A.

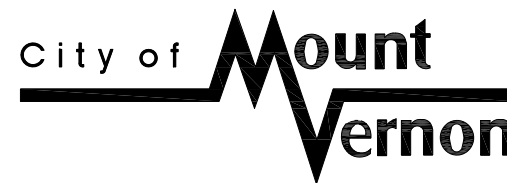
## WWTP Process Schematic

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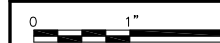


1	OCT 2009	AS RECORDED
ISSUE	DATE	DESCRIPTION

PROJECT MANAGER	ERIC C. BERGSTROM
DESIGNED	S. CHILUKURI
DRAWN	S. D. GUNDY
CHECKED	
PROJECT NUMBER	00000000018326



**WASTEWATER TREATMENT PLANT  
UPGRADE PHASE 1  
PLANT FLOW SCHEMATIC**



FILENAME	00G-09.dwg
SCALE	NONE

SHEET
<b>00G-09</b>