Odor Control Technology Solutions Analysis & Recommendations

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Project name: North Transfer Station Odor Evaluation

Project no: D3665000

Client: Seattle Public Utilities

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1. Introduction

1.1 Background

The Seattle Public Utilities (SPU) North Transfer Station (NTS) has received odor complaints every summer since it opened in November 2016. Odor issues reported during 2021 were much worse than in prior years. SPU met with residents of the Wallingford neighborhood and hired Jacobs Engineering Group Inc. (Jacobs) as an odor consultant to evaluate the odor situation and suggest mitigation measures.

The NTS, also known as the North Recycling and Disposal Station, is a municipal waste collection and distribution facility located at 1350 North 34th Street, Seattle, Washington. The facility is located in the Wallingford neighborhood near Gas Works Park and the Burke-Gilman Trail, on the north side of Lake Union. Surrounding the facility are commercial neighbors to the west and south and dense residential areas directly to the north and east. Figure 1 shows the facility boundary and proximity to neighbors, with the green line representing the ambient air line around the facility, which follows the property's retaining wall. Herein this line is referred to as the fence line or the boundary line. With respect to odor goals, we refer to the fence line goal as the odor level at that boundary line.

Figure 1: Seattle Public Utilities North Transfer Station's Location and Proximity to Neighbors

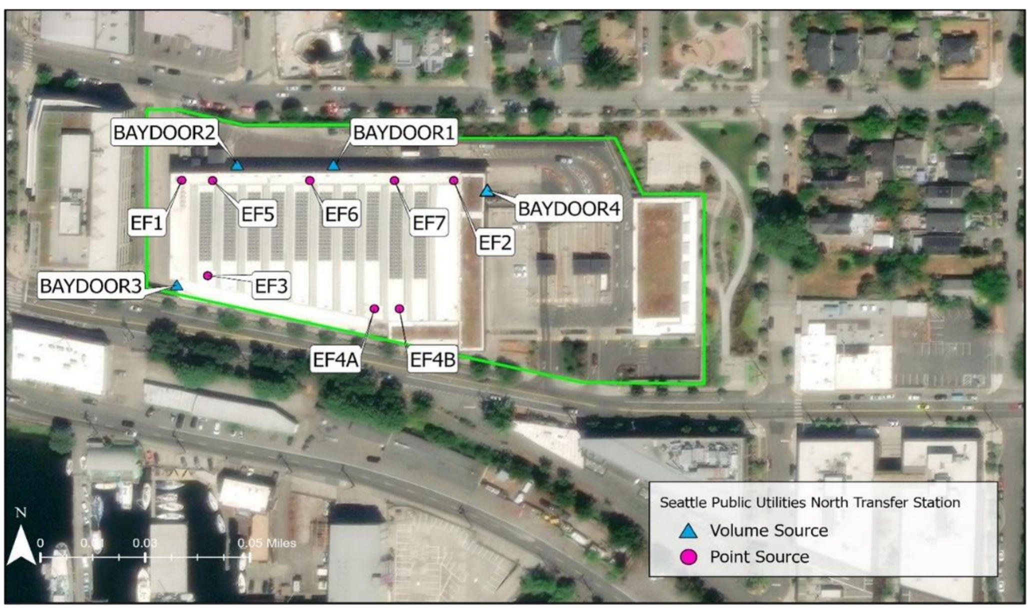

Figure 2: North Transfer Station's Rooftop stacks and Bay doors

As part of assessing the NTS's current conditions, Jacobs developed an air dispersion model to predict improvements to the odor strength and odor frequency by evaluation of several "what if" scenarios including installation of dispersion nozzles on roof stacks and five source odor reduction options. Figure 2 shows the location of the rooftop stacks and bay doors referenced. The modeling indicated installation of nozzles on roof stacks provided minimal odor reductions, and this option was screened out. The source odor reduction "what if" scenarios were used in the model and their results included the following:

- Scenario 1 – Continuous misting of neutralizer on the tipping floor using existing misting infrastructure. The model used a 20% odor reduction on emissions at all open bay doors (1, 2, and 4) (See Figure 2) and all roof stacks exhausting ventilated air pulled from the tipping floor (EF3, EF4A, EF4B, EF5, EF6, and EF7) (See Figure 2).
- Scenario 2 – Installing an airlock (air curtain) system on tipping floor bay doors. The model used an 80% reduction of odor emissions from bay doors 1, 2, and 4 (See Figure 2).
- Scenario 3 – Continuous misting of the odor neutralizer agent on the lower-level compactor area. The model used a 20% odor reduction on all roof stacks exhausting ventilated air from the lower level (EF1 and EF2 and portions of EF3, EF4A, and EF4B) (See Figure 2).
- Scenario 4 – Continuous misting of neutralizer on all roof exhaust stacks. The model used a 20% odor reduction on all roof stacks exhausting ventilated air from the tipping floor and lower level.
- Scenario 5 – Maximum control on all point and volume sources. Includes installing an airlock (air curtain) system on tipping floor bay doors (1, 2, and 4) (See Figure 2). The model used an 80% reduction on odor emissions from open bay doors. This scenario also includes, misting of neutralizer on the tipping floor, on the lower-level compactor area, and continuous misting of odor neutralizer on all roof exhaust stacks with existing misting infrastructure (EF1, EF2, EF5, EF6, and EF7) (See Figure 2). The model used a 20% odor reduction on all roof stacks.

Figure 3 shows the modeled impact of each odor reduction scenario on the odor concentrations along with the predicted exceedances. Overall, each odor reduction scenario reduced offsite odor impacts with Scenario 5 providing the most improvement. In this scenario, the maximum odor level is predicted to be 11.4 detection threshold (DT) units at the facility boundary, and the odor level exceeds the fence line goal of 5 DT (with 99% compliance, or 87 hours of allowable exceedance) for 108 hours over the course of 1 year (compliance with odor goal is 93.2%), which is greatly reduced from the baseline. Odor concentration or strength saw the largest benefit from reducing odors being emitted from the bay doors and roof top stacks. Reducing the odor frequency was predicted to attain the largest benefit from a combined approach represented by Scenario 5. The *Current Conditions Technical Memorandum*, submitted by Jacobs in 2024, presents a detailed discussion of the model and its results.

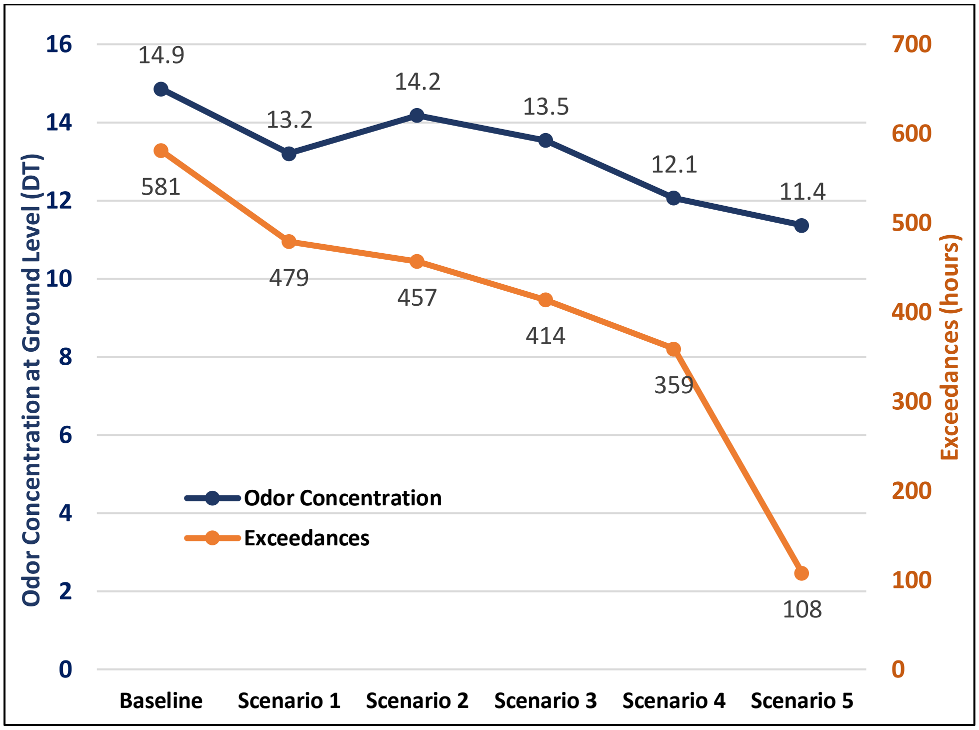

Figure 3: Odor Concentration Impacts for Each Scenario.

1.2 Objectives

The objective of this work was to identify and evaluate three odor control technology solutions that could improve the odor impacts offsite and to ultimately recommend solutions for implementation at SPU. The purpose of this technical memorandum (TM) is to document the evaluation of three alternatives. This TM describes each of the three odor reduction alternatives, breaks down their respective estimated conceptual costs (e.g., equipment, operation and maintenance [O&M]), and summarizes the advantages and disadvantages of each alternative. The TM also presents a recommendation for odor reduction implementation.

2. Technology Alternatives

The following three odor control technology solutions were evaluated:

- Alternative 1: Optimizing the existing misting system.

  The first alternative consists of improving the existing odor-neutralizing mist system by undergoing an optimization process. This is an important step for these types of systems to be most effective. Since the existing misting system includes the spray nozzle network treating the tipping floor and existing chemical dosing pump, an improvement in the operation of this system is expected to provide at least a 20% odor reduction on the tipping floor and where spray nozzles are installed at the roof exhaust stacks. The 20% odor reduction is a predicted engineering estimate based on expected performance of the respective alternative.

- Alternative 2: New vapor-mist system.

  The second alternative is the installation of a new vapor-mist system, which is an upgraded version of the water-mist system currently being used at NTS and is expected to provide better performance. For this alternative, the new system would require a new network of 4-inch high-density polyethylene (HDPE) piping for distribution of the vapor to the tipping floor to achieve at least a 20% reduction in odor. Distribution piping would be extended down to the lower level above the compactor area. Since this is a highly odorous location within the facility, a reduction of odors here will improve the odor levels at the roof exhaust stacks, where a portion of air from this level is conveyed. Additionally, the odors emitted through the open entrance to the lower level will be reduced.

- Alternative 3: Air curtains at bay doors.

  The third alternative is the installation of air curtains at the three bay doors on the tipping floor level. Each air curtain would be in operation whenever the bay door is opened and is expected to prevent the odors from being emitted outside these doors. This option does not apply to the entrance to the lower level, which does not have a bay door and is an open driveway. The air curtains are expected to attain an 80% reduction of odor emanating from these open bay doors. The 80% odor reduction is a predicted engineering estimate based on expected performance of air curtains.

Previous air dispersion modeling determined there will be a reduced odor impact to the surrounding area if odor emission is reduced at the bay doors and exhaust fan stacks, most notably EF4A, EF4B, and EF2. The selected alternatives include viable approaches to reduce odor emissions at these sources.

The following subsections provide descriptions of the evaluated technologies and the recommended approach for the facility.

2.1 Alternative 1: Optimizing the Existing Misting System

An existing misting system is used to control dust and odor. The tipping floor atomizing spray system has the capability to pump an odor-neutralizing chemical through a spray nozzle system. The layout of the spray nozzles located at the roof truss is shown on Figure 4. Water containing the odor-neutralizing chemical is pumped through a 0.5-inch pressure hose supported by aircraft cable along the roof truss. Spray nozzles are placed at 10-foot intervals and are rated for 3 gallons per hour.

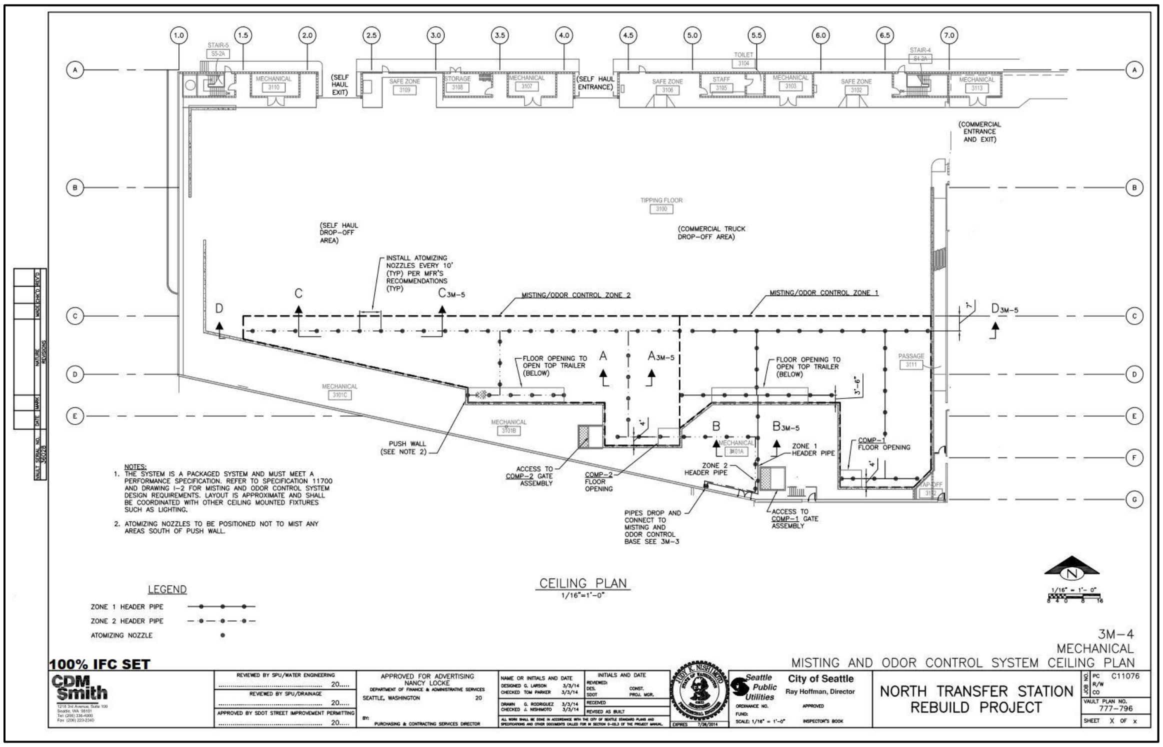

Figure 4: Spray Nozzle System Layout (From SPU Facility As-built Drawings)

Spray nozzles are also located at some roof stack exhausts for the facility ventilation, as shown on Figure 5.

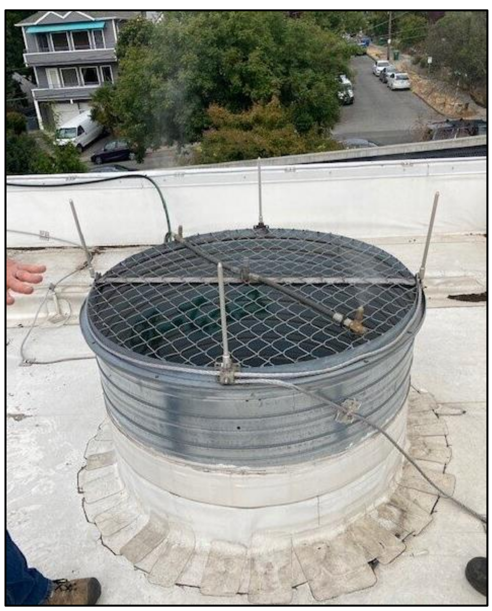

Figure 5: EF2 Stack Exhaust with Spray Nozzles

The odor-neutralizing chemical being used is Ecosorb® manufactured by OMI Industries (OMI) and is Product 606. The product is described as a broad-spectrum odor neutralizer and consists of a blend of plant oils, food grade surfactants, and purified water. The product is commonly used by diluting with water and pumping into the spray nozzle system, but it can also be used to spray directly on surfaces. The product is safe for staff and for the environment.

Misting systems using odor neutralizers have varying degrees of success and are recommended to be optimized for the specific application. The quantity of chemical being dosed into the water can be adjusted and, through an optimization process, the proper dosage rate can be established for the most effective use. Since odor on the tipping floor may not be always present, the amount of chemical can be adjusted to maximize its use during periods when odor levels are high and reduced during facility downtime (e.g., in the evenings). For the purpose of conceptual cost evaluations, it is assumed the current misting system is operational for 50% of the site's operational hours. The site's operational hours as per their website is from 8 a.m. to 5:30 p.m. Hence, it is assumed the misting system is operational for 4.75 hours per day.

For optimization of the NTS misting system, the process would include a site visit by the supplier to inspect the existing system and to identify any system components that need to be replaced or upgraded. The following optimization components were included in the evaluation of Alternative 1:

- Assess the power output and capacity of the current pump system and panel. If it is determined there is a need for an upgraded pumping system, the entire system may need to be replaced, or a new smaller misting system could be installed at strategic locations.
- Inspect the spray nozzles to verify they are not clogged, and the flow and pressure is adequate. If clogged, spray nozzles should be cleaned, and flow and pressure optimized.
- Rearrange the positioning of the spray nozzles and hose locations to better target necessary locations for odor reduction.
- Modify the dosing rate of the odor-neutralizing chemical, per the supplier's recommended rate. A range of dosing rates can be identified based on the odors at the facility and operation times.
- Use a different odor-neutralizing formulation, if available and recommended by the supplier.

2.1.1 Potential Conceptual Costs

Conceptual level costs associated with the above identified components of Alternative 1 are as follows:

- Capital Cost: $54,000 (approximate)
- Annual O&M Cost: $78,000 (approximate)
- 20-year Net Present Value with an escalation rate of 3%: $1,550,000

2.1.2 Capital Cost Assumptions

Assumptions that were used to develop the conceptual capital costs include the following:

- A site visit and assessment of existing conditions by the supplier.
- The potential upgrades to the existing misting system depend on the existing conditions assessment results conducted by the supplier and may range from $20,000 to $80,000.
- An average of $50,000 for the upgrades and $4,000 for supplier inspection.
- Potential upgrade costs depend on the following:
  - Ability of the existing control panel to support a larger pump/motor;
  - Quantity of new hoses/nozzles needed for replacement or to expand the treatment area;
  - Consider upgrades to the current system and an additional system treating strategic locations;

- Cost of using a new formulation.

- Capital costs do not include SPU "soft costs"

2.1.3 Advantages and Disadvantages

The advantages of Alternative 1 include the following:

- Use of existing equipment and piping network familiar to plant staff.
- Works well indoors due to mist containment (no wind) and for the reduction of dust.
- No additional footprint or new staff are required to operate the system.
- System operation can be customized to conserve chemicals during periods of low odor.

The disadvantages of Alternative 1 are as follows:

- Existing bird netting reduces access to install new nozzles or carry out any maintenance work on nozzles.
- System has been in use previously, but odors are still detected.
- Increased maintenance requirements due to nozzle location (high elevation above tipping floor), large quantity of spray nozzles and water usage demands.
- System lacks alarms to alert staff when the system goes down.
- System is winterized and does not operate when air temperatures are below 45 degrees Fahrenheit.

2.2 Alternative 2: New Vapor-Mist System

The existing system is designed to utilize the Ecosorb® chemical using water. However, the chemical can be used without the use of water for dilution. This "dry" system (i.e., without water) is referred to as a vapor-mist system and uses a fan to distribute the chemical through the piping network.

The OMI Ecosorb® vaporization system uses a high airflow to distribute Ecosorb® formula to eliminate odors. The vapor delivery system works by sending pressurized pure Ecosorb® Product 606 through a perforated pipe distribution system, creating a dry mist to reduce odor. Ecosorb® Product 606 is described as working by binding with odor-causing compounds in the air to neutralize odors. As per the Ecosorb® Engineering Manual, this product is U.S. Department of Agriculture-approved, and all ingredients are listed as non-toxic on the Canadian Domestic Substances List, European Inventory of Existing Chemical Substances, Australian Inventory of Chemical Substances, and the United States Toxic Substances Control Act lists.

Alternative 2 includes installation of a vapor-mist system to be used in conjunction with the current mist system. The current misting system utilizes 0.5-inch hoses, while the vapor system requires a pipe infrastructure, typically composed of 4-inch HDPE piping, located above the reach of equipment to avoid obstructing operations. A strategic approach for a new vapor-mist system would involve installing the distribution piping where the odor is most prevalent (i.e., above the tipping floor and near the compactor area). Implementation of Alternative 2 is designed to address odors on the tipping floor and compactor area and will reduce odors emitted from roof exhaust stacks for EF4A and EF4B. For the purpose of conceptual cost evaluations, it is assumed the new vapor system is operational for 50% of the site's operational hours. The site's operational hours as per their website is from 8 a.m. to 5:30 p.m. Hence, it is assumed the misting system is operational for 4.75 hours per day. Figure 6 shows an example of the OMI Ecosorb® Vaporization System, and Figure 7 shows a graphic of the perforated HDPE piping of the vapor system in operation.

Figure 6: Example of Vapor system

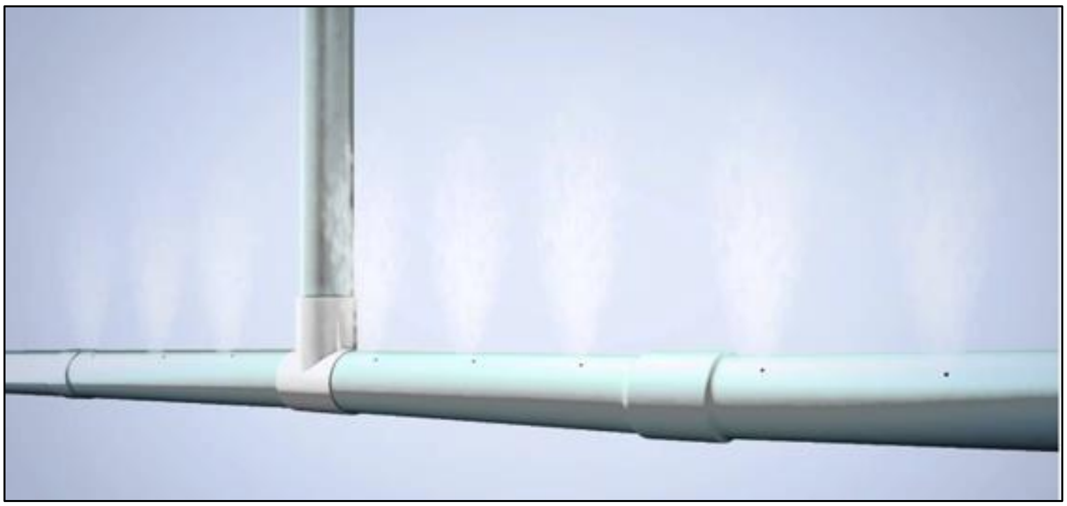

Figure 7: Graphic of Vapor System in Operation

2.2.1 Potential Conceptual Costs

Conceptual level costs associated with the above identified components of Alternative 2 are as follows:

- Capital Cost: $61,000 (approximate)
- Annual O&M Cost: $28,000 (approximate)
- 20-year Net Present Value with an escalation rate of 3%: $587,000

2.2.2 Capital Cost Assumptions

Assumptions that were used to develop the conceptual capital costs include the following:

- Includes a 5-horsepower vapor-mist system (fan motor).
- Installation includes up to 1,000 to 1,500 linear feet of distribution 4-inch HDPE piping.

- The 5-horsepower system has a coverage of 300 to 1,000 linear feet, which is adequate to cover the tipping floor and near the compactor area.
- The estimate is conservative and was initially based on locating piping around the perimeter of the facility. Since the intention is to place this inside the NTS near the compactor area, the required linear footage of piping will be less than the estimate.
- Capital costs do not include SPU "soft costs"

To gain a more accurate cost estimate, further discussions and a site visit are deemed essential to plan the piping layout. Notably, the initial installation cost may be subject to variables (e.g., location and system specifications).

2.2.3 Advantages and Disadvantages

The advantages of Alternative 2 include the following:

- Does not require water, resulting in no water consumption costs related to this alternative.
- May be more effective than the existing misting system that uses water.
- System operation can be customized to conserve chemicals during periods of low odor.
- Significantly less maintenance is required than the existing water-based misting system. Nozzles are not needed because the product is delivered through perforated HDPE pipes using air.
- The odor-neutralizing compound is biodegradable and non-toxic.

The disadvantages to Alternative 2 are as follows:

- New equipment and installation of a network of piping are required. Piping installation will need to account for the active working space of tipping floor equipment to avoid impacting daily operations.
- Requires chemicals resulting in an increase of ongoing operational costs.
- Additional power needed to operate the fan, which adds to ongoing operational costs.

2.3 Alternative 3: Air Curtain at Bay Doors

Industrial air curtains operate through a precisely controlled airflow mechanism designed to establish an effective air seal across openings. The process involves the intake of air into the unit, its acceleration within the fan housing, and subsequent distribution through a plenum along the length of the discharge nozzle. The discharged air forms a directed jet stream creating an air curtain. The air curtain results in approximately 80% of air being returned to the intake side, while 20% moves in the opposite direction. These air curtains are often equipped with automated sensors, activating when the bay door opens. The technology finds application in diverse scenarios, with a primary focus on temperature control, insect mitigation, and the prevention of odors and fumes infiltration. Notably, industrial air curtains work well at garage openings and bay doors, accommodating the passage of vehicles. For the bay doors at NTS, the supplier recommends two units be vertically installed covering the height of each bay door to ensure optimal performance. Figures 7 and 8 show an example of a vertically installed unit on a similar bay door and an installation schematic, respectively. For conceptual cost evaluations, it is assumed the new air curtains would be operational for 8 hours per day. This is a conservative estimate, assuming the facility would keep the bay doors open with the air curtains operational without impeding traffic flow. Bay doors shall remain closed when the station is closed and when customer traffic is not present.

Figure 8: A Unit Installed Vertically at a Bay Door

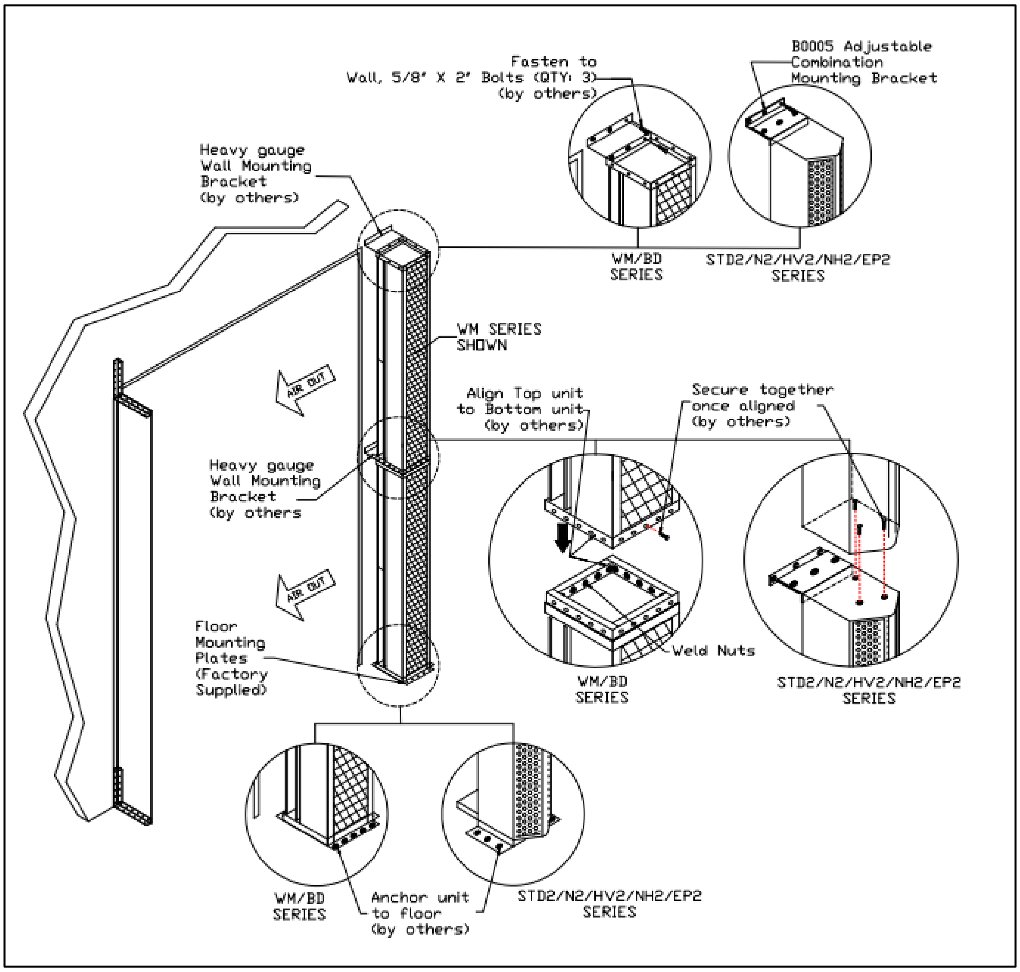

Figure 9: Air Curtain Installation Schematic.

For purposes of this evaluation, Alternative 3 includes an air curtain (composed of two units) at each of the three bay doors at the tipping floor level.

2.3.1 Potential Conceptual Costs

Conceptual level costs associated with the above identified components of Alternative 3 are as follows:

- Capital Cost: $167,000 (approximate)
- Annual O&M Cost: $20,000 (approximate)
- 20-year Net Present Value with an escalation rate of 3%: $556,000

2.3.2 Capital Cost Assumptions

Assumptions that were used to develop the conceptual capital costs include the following:

- The cost includes six blowers (two air curtain units set up vertically on either side of each the three bay doors).
- Installation is assumed to be 25% of the equipment cost (i.e., $34,000).
- Use of additional brackets mounted to the existing door frame, anchorage to the floor, and a bollard.
- Capital costs do not include SPU "soft costs"

2.3.3 Advantages and Disadvantages:

The advantages of Alternative 3 include the following:

- Proven technology for containment of odors, specifically for use at bay doors.
- Very low maintenance requirements.
- Allows for consistent, unimpeded traffic flow.

The disadvantages to Alternative 3 are as follows:

- New equipment required.
- Can result in elevated noise level while running.
- Occupies space around the truck bay entrance.
- Additional power to operate each unit adds to ongoing operational costs.

3. Operation and Maintenance Considerations

The O&M requirements for each alternative are comparatively different. O&M considerations for each technology include the following:

- Chemical consumption;
- Potable water demands;
- Electricity demands;
- Annual, monthly, and daily maintenance time and requirements.

Table 1 summarizes O&M estimates and describes typical maintenance activities associated with each alternative. Assumptions used for preparing these considerations are presented at the bottom of Table 1.

Table 1. Alternative-Specific Operation and Maintenance Considerations

O&M Consideration	Alternative 1: Optimize Existing Mist System	Alternative 2: New Vapor-Mist System	Alternative 3: Air Curtain
Annual Operations & Maintenance Estimated Hours	294.5	147.3	123.3
Annual Chemical Consumption (gallons)	219	219	N/A
Annual Potable Water Consumption (gallons)	3,285,000	N/A	N/A
Annual Electricity Consumption (Kilowatt-hr.)	43,481	29,817	65,043
Typical Maintenance Requirements	• Replenish chemical. • Water filter condition inspection. • Unclog spray nozzles. • Control panel inspection. • Pipe connection inspections. • Pump condition inspection. • Replacing parts as needed.	• Replenish chemical. • Control panel inspection. • Blower condition inspection. • Filter condition inspection. • Pipe connection inspections. • Pump condition inspection. • Replacing parts as needed.	• Blower condition inspection. • Filter condition inspection. • Replacing parts as needed.

O&M Consideration	Alternative 1: Optimize Existing Mist System	Alternative 2: New Vapor-Mist System	Alternative 3: Air Curtain
O&M Assumptions	• Cost for electricity is assumed as 8 cents/ Kilowatt-hr. • High pressure pump power requirement calculated based on 7.2 gallons per minute at 1,000 pounds per square inch and a standard chemical dosing pump.	• Cost for electricity is assumed as 8 cents/ Kilowatt-hr. • Blower power requirement is based on 1,000 cubic feet per minute blower operating at 18-inch w.c. pressure.	• Cost for electricity is assumed as 8 cents/ Kilowatt-hr. • 8 hours/day of operations for each of the six blowers. • The estimated Derated Annual Power consumption based on expected operation (Kilowatt-hr.) is 65,043 Kilowatt-hr. • The power requirement calculated is for all the number of units used (i.e., six).
Maintenance Assumptions	• 30 minutes of daily inspections while start-up/ shut down. • 2 hours of weekly inspections for maintenance. • 4 hours of quarterly inspections for maintenance. • Maintenance activities include, but are not limited to, checking pump condition, unclogging of nozzles/piping, control panel visual inspection, maintain water filter, filter replacement and pipe connections. • Labor rate for maintenance activities: 120$/hr.	• 15 minutes of daily inspections while start-up/ shut down. • 1 hour of weekly inspections for maintenance. • 2 hours of quarterly inspections for maintenance. • Maintenance activities include, but are not limited to checking effective operation, control panel visual inspection, filter check, filter replacement and checking pipe connections. • Labor rate for maintenance activities: 120$/hr.	• 15 minutes of daily inspections while start-up/ shut down. • 30 minutes of weekly inspections for maintenance. • 2 hours of quarterly inspections for maintenance. • Maintenance activities include, but are not limited to checking the blower, air filter condition and replacing the filter as needed. • Labor rate for maintenance activities: 120$/hr.

O&M Consideration	Alternative 1: Optimize Existing Mist System	Alternative 2: New Vapor-Mist System	Alternative 3: Air Curtain
Chemical Assumptions	• Costs per gallon used for the consumption calculations of Ecosorb® are the rates for QuickAir 900. Since, as per the vendor the costs for Ecosorb® and QuickAir 900 are equivalent. • Site operational hours as per website: 8 a.m. to 5:30 p.m. • Conservatively assumed mist is operational during 50% of all hours of operation (i.e., 4.75 hours/day). • Assumptions for chemical consumption calculation from supplier's emails. • Odor Level = High • 3 gals/day for 24 hours of operation: Estimated 0.6 gals per day for 4.75 hours of operation.	• Site operational hours as per website: 8 a.m. to 5:30 p.m. • Conservatively assumed vapor-mist system is operational during 50% of all hours of operation (i.e., 4.75 hours/day). • Consumption assumption: - 0.6 gallons/day for 4.75 hours of operation. • Assumptions for cost calculation: - 3 gallons/day – $96 daily operating cost. - 0.6 gallons/day will cost $19.2 daily.	• No chemicals used.
Water Assumptions	• Per the vendor's email the estimated water usage by this system is between 8,000 and 10,400 gallons per day. For the water consumption calculations, it is assumed an average of 9,000 gallons per day. • Costs used are from the general service commodity rates. • Range of $5.9 to $7.27: Average = $6.9 per 748 gallons, or $9.25 per 1,000 gallons.	• No water used	• No water used.

Note:
N/A = not applicable

4. Alternatives Evaluation

Economic and non-financial evaluation criteria for each of the alternatives are presented below for comparison purposes.

4.1 Economic Evaluation

Economic criteria include concept-level costs based on vendor quotes and certain key assumptions discussed above. Installation costs are provided by the supplier or estimated by Jacobs. Contractor markups and profit, permitting, sales tax, insurance and bonds are not included in the evaluation because they would be similar for each alternative. Table 2 summarizes the concept-level cost for the evaluated alternatives.

Table 2: Cost Estimate Summary of Alternatives

Item	Alternative 1: Optimize Existing Mist System	Alternative 2: New Vapor-Mist System	Alternative 3: Air Curtain
Capital Cost *	**$54,000**	**$61,000**	**$167,000**
Annual Costs *	**$78,000**	**$28,000**	**$20,000**
Electrical Power	$3,507	$2,385	$5,203
Maintenance	$35,340	$17,670	$14,790
Potable Water	$30,386	$0	$0
Chemicals	$7,780	$7,013	$0
20-year Net Present Value#	$1,550,000	$587,000	$556,000

* Values have been rounded up to the nearest thousand.
# Calculated with an assumed annual escalation rate of 3%.

4.2 Non-Financial Evaluation

A non-financial evaluation was conducted for the alternatives based on key evaluation criteria identified by SPU. The non-financial evaluation criteria are presented in Table 3. In consultation with SPU, each criterion was given a weighting factor, depending on the importance of the criterion for this specific application. The criteria in Table 3 are ordered from most important to least important based on feedback from SPU staff familiar with NTS.

Table 3: Non-Financial Criteria Categories

No.	Criterion	=	Description
1	Disruption of operations	=	The degree to which daily operations need to be modified
2	Footprint of the technology	=	The amount of physical space the technology encompasses
3	Need to increase staffing	=	Will there be a need for more employees?
4	Addl. environmental permits	=	Need for additional ongoing environmental permit(s) or changes to existing permit(s)
5	Increased/difficult O&M	=	Does the technology need maintenance or operated frequently?
6	Changes to traffic patterns	=	How will traffic patterns be impacted by the newly installed technology?

For each alternative, a rating between 1 and 5 has been assigned for each criterion. A rating of 5 indicates the most favorable score and 1 represents the least favorable score. Table 4 shows the criterion rating for each alternative.

Table 4: Criteria Ratings

	Disruption of Operation	Footprint of the Technology	Need to Increase Staffing	Additional Environmental Permits	Increased/Difficult Operations & Maintenance	Changes to Traffic Patterns
Alternative 1: Optimization of Existing System	5	5	5	5	3	5
Alternative 2: New Vapor-Mist System	5	4	5	5	4	5
Alternative 3: Air Curtain	5	4	5	5	4	5

The final score for each alternative is a weighted overall score out of 10 for all the criteria. Table 5 summarizes the criteria weighting and score of each evaluated alternative. The table also provides the final ranking of the alternatives based on the weighted scores.

Table 5: Weighted Score and Ranking of Alternatives.

		Weighted Score (normalized to scale 1-10)		
	Weighting	Alternative 1: Optimize Existing Mist System	Alternative 2: New Vapor-Mist System	Alternative 3: Air Curtain
Disruption of Operation	22	2.2	2.2	2.2
Footprint of the Technology	17	1.7	1.4	1.4
Need to Increase Staffing	16	1.6	1.6	1.6
Additional Environmental Permits	16	1.6	1.6	1.6
Increased/Difficult Operations & Maintenance	15	0.9	1.2	1.2
Changes to Traffic Patterns	14	1.4	1.4	1.4
Total Weighted Score (out of 10)		9.40	9.36	9.36
Ranking[1]:	**Ranking**	**1**	**2**	**2**

[1] Ranking is in ascending order with the most favorable score having the lowest ranking number.

Alternative 1: 'Optimizing existing mist system' has the highest weighted score mainly due to the smallest footprint since it's already installed on site. Alternative 2: 'New Vapor-Mist system' and Alternative 3: 'Air Curtain' are tied at rank number 2. This can be attributed to the fact that they're both new systems with minimal footprints and similar impacts on the various criteria.

5. Alternatives Evaluation Results

Figure 10 depicts the capital costs and annual O&M costs, as well as a breakdown of non-financial evaluation scores for each alternative. The bar charts represent the non-financial evaluation scores. The yellow line shows the capital costs, and the blue line shows the annual O&M costs. As described in Section 4, it can be noted the overall ratings of the three alternatives are very close. Figure 10 helps visualize the evaluation scores for the various criteria along with the capital and annual O&M costs for each alternative.

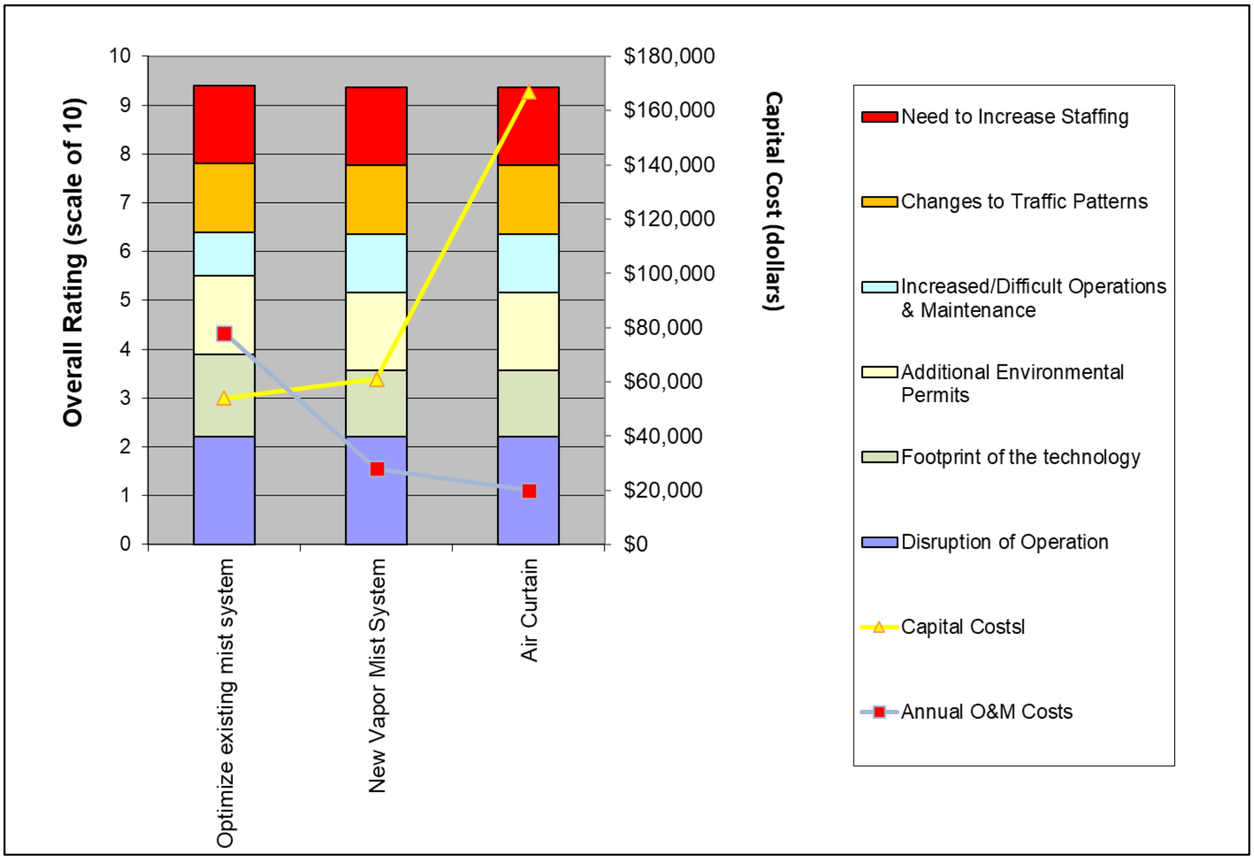

Figure 10: Capital Costs and Overall Rating

Cost benefit of each alternative was estimated by dividing the 20-year life cycle cost by the non-economic weighted score. Figure 11 shows the cost-to-benefit ratio of each alternative. The alternative with the lowest cost-to-benefit ratio (Alternative 3: Air Curtain) is the most desirable, since it represents the system that costs the least while providing the same non-economic benefit.

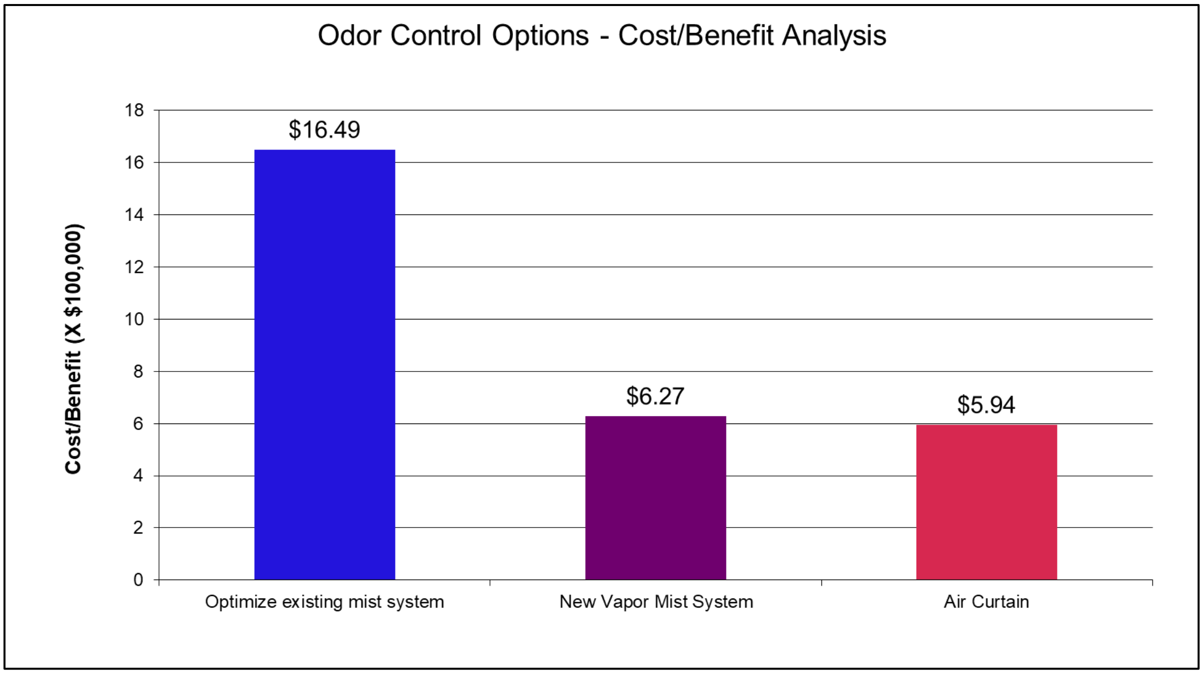

Figure 11: Cost/Benefit Analysis

6. Conclusions

The following conclusions have been made based on the modeling findings and evaluation of the odor control technology solutions:

- Per the air dispersion model, described in Section 1.1 and shown on Figure 3, Scenario 5 has the largest impact on odor reduction. With implementation of Scenario 5, under the worst-case meteorological conditions, the model predicts the maximum odor level to be 11.4 DT at the facility boundary, and the odor level exceeds the facility's goal of 5 DT (with 99% compliance, or 87 hours of allowable exceedance) for 108 hours over the course of 1 year (compliance with odor goal is 93.2%). This represents a substantial decrease from the baseline condition of 14.9 DT for 581 hours per year.
- As predicted based on the odor reduction technique, reducing odors on the tipping floor will have a beneficial impact on odor dispersion from the facility, especially from the following locations:
  - Rooftop stacks – Reducing odor from the ventilation systems serving the tipping floor will result in less odor emitted from the stacks located on the rooftop of the facility.
  - Bay doors – Reducing odors emitted through the bay doors will limit the odors escaping as vehicles move in and out of the facility.
- The existing mist systems typically need to be optimized for varying odor levels and operation times for most effective use. This means adjusting the durations and concentrations of chemicals being sprayed based on operational times and historical odor levels.
- The vapor-mist system is an improved system over the water-mist system. When used at the compactor level and tipping floor, it will lead to reduced odors emitted from the roof stacks and through the bay doors.
- Upon comparison, all alternatives have a very similar scoring for the non-financial criteria determined. Optimizing the existing system resulted in having the highest weighted score followed by the new vapor-mist system and air curtains being equally ranked.
- Optimizing the existing mist system has the highest operational cost and a high capital cost due to uncertainties of costs to update the system based on post-assessment recommendations. The costs for this alternative can be refined based on SPU's feedback on actual costs, actual chemical use, and actual water use. This alternative also requires site assessment by a vendor for recommended improvements.
- A new vapor-mist system has a higher capital cost, but lower O&M costs, than the existing water-mist system. This alternative can be refined with better scope definition for strategic locations to install piping.
- The air curtain for the three bay doors has the highest capital cost and lowest O&M cost but presented with the most desirable cost-to-benefit ratio.

7. Recommended Design

Considering economic evaluations, non-economic assessments, onsite observations, and odor modeling, we recommend implementing all three alternatives together, which is described as Scenario 5 (described in Section 1.1). As predicted by the model results and summarized on Figure 3, implementing all three alternatives will have the greatest impact on reducing odor concentration closer to the threshold agreed upon in the neighborhood agreements in addition to reducing the duration of odor exceedances.

The next steps recommended to move forward with implementing all three alternatives include the following:

- Perform a site visit to assess the existing misting system. This assessment will help obtain more accurate recommendations regarding required upgrades.
- Perform a cost and impact evaluation to determine the value of the recommended changes to the existing mist system.
- Determine strategic installation location(s) for the vapor-mist system to mitigate odors most efficiently. Recommended locations are above the tipping floor near the floor openings above the compactor area.
- Installation of vertical air curtains on the three most frequently used bay doors.