Rivanna Water and Sewer Authority
Moores Creek Wastewater Treatment Plant

Odor Control Evaluation Report

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1.1 Introduction

The Rivanna Water and Sewer Authority (RWSA) retained Hazen and Sawyer to conduct an odor control evaluation and prepare an odor control report for the Moores Creek Wastewater Treatment Plant (WWTP). The purpose of the Moores Creek WWTP Odor Control Evaluation project is to assess the odors generated by the Moores Creek WWTP and identify the operating strategies and/or capital construction projects necessary to minimize migration of detectable odors beyond the plant property line.

The Moores Creek WWTP Odor Control Evaluation Project includes the following:

- Odor sampling for speciation and sensory analyses of the foul air
- Dispersion modeling to determine the percent removal required to eliminate detection of odors beyond the Moores Creek WWTP property boundary line
- Evaluation of alternatives for achieving the odor reduction objectives. A range of appropriate odor control technologies is considered, including:
    - Packed tower wet scrubber
    - Carbon adsorption units
    - Biofiltration
    - Regenerative thermal oxidizers (RTOs) and Recuperative thermal oxidizers
- Recommendations and costs for implementation of odor control, including both operating strategies and construction of odor control facilities. Given the high cost of providing total odor control at the WWTP boundary, recommendations for phased implementation are provided.

1.2 Background

1.2.1 General Plant Background

The Moores Creek Wastewater Treatment Plant was constructed in two phases. The first phase, built on the north side of Moores Creek and completed in the late 1950s, consisted of a grit basin, grit decanting bed, pre-aeration basins, primary, intermediate, and final clarifiers, primary and secondary trickling filters, sludge drying beds, and primary and secondary digesters.

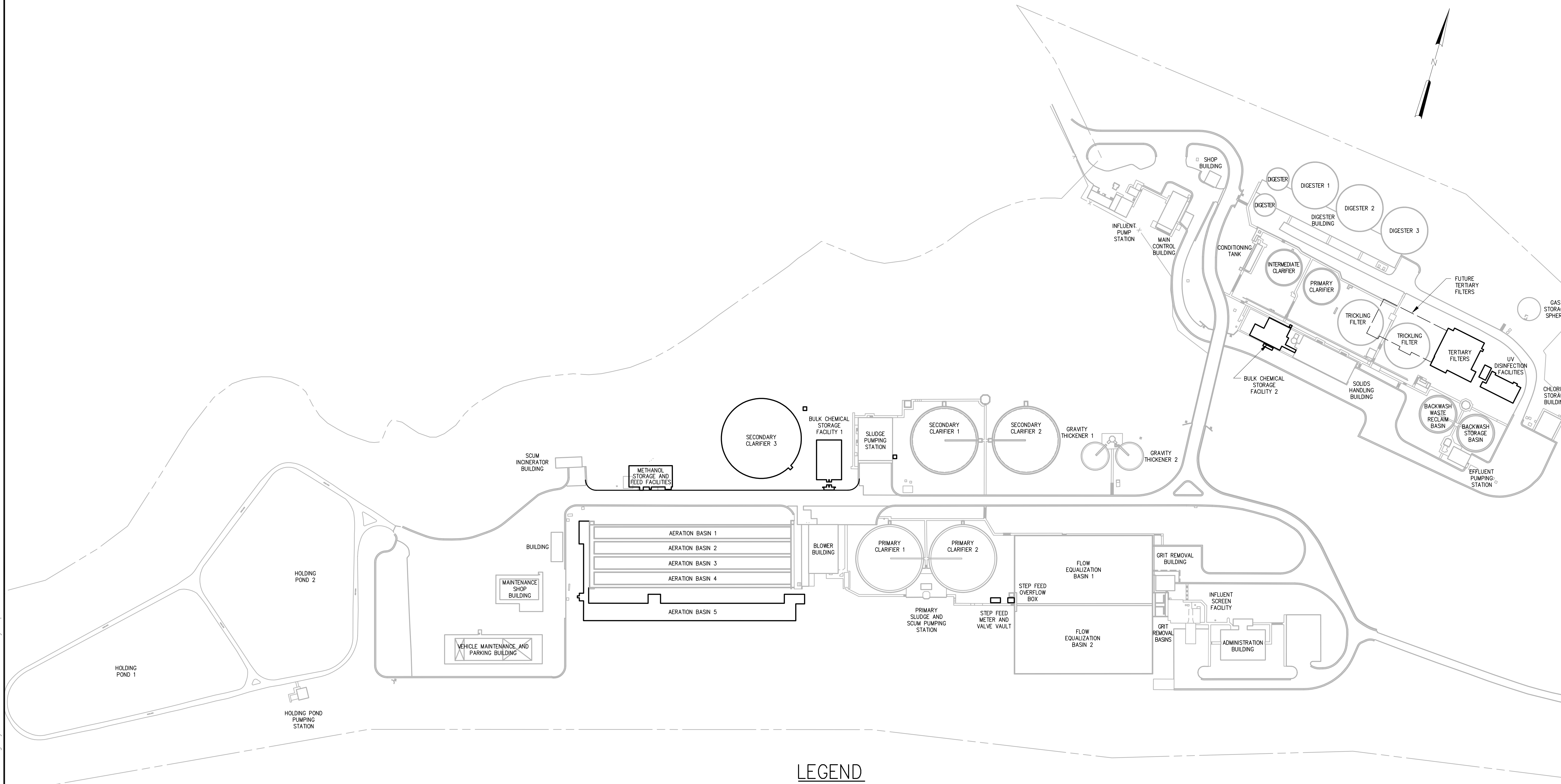
The second phase of the Moores Creek WWTP was completed in 1983, and included a major expansion and upgrade. While some of the original treatment units remained in service, many were decommissioned. The newer facilities are designed for a flow of 15 mgd and are located on the south side of Moores Creek. The 1983-vintage facilities were upgraded in 2005 to include a new fine screen facility for screening the plant influent. Therefore, the current treatment train currently consists of: preliminary screening and grit removal, daily flow equalization, primary clarification, biological treatment, secondary clarification, chlorination/dechlorination and tertiary settling in the flocculation and settling basins, and final basins. In 1988, with the desire to create an initial anoxic zone, retrofits to the aeration basins were constructed. However, given the plant's limited ability to control the dissolved oxygen in the aeration basins, true anoxic conditions are not typically achieved in the initial stage of the aeration basins. The solids treatment train consists of gravity thickening for waste activated sludge (WAS), anaerobic digestion for combined WAS and primary sludge and sludge dewatering via a plate and frame filter press, with the addition of lime and ferric chloride. Dewatered cake was previously mixed with wood chips and composted on-site; however, in response to odor complaints from the citizenry, RWSA ceased composting operations and closed the facility in February 2007. Dewatered cake is now composted at a contract composting facility near Richmond, Virginia.

Hazen and Sawyer is currently designing upgrades to the Moores Creek WWTP to comply with the nutrient removal criteria issued by the Virginia DEQ for dischargers to the Chesapeake Bay. For the nutrient removal improvements project, the design capacity of the Moores Creek WWTP will remain at 15 mgd; however, the plant will be retrofitted to hydraulically pass an expanded peak flow capacity of 37.5 mgd. The odor control evaluation included in this report considers, and is based upon, the facilities that will be constructed as part of the nutrient removal improvements. A site plan, showing both existing and new facilities to be constructed as part of the nutrient removal improvements project is shown in Figure 1-1. New facilities include an additional aeration basin, a new secondary clarifier, chemical storage and feed facilities, tertiary filters, ultraviolet disinfection, and the addition of a centrifuge to the dewatering facility.

The Moores Creek plant does not currently include any odor control facilities. All basins and channels, with the exception of the anaerobic digesters, are open to the atmosphere. RWSA's sole means of mitigating odors is via implementing best available operating procedures.

1.2.2 Odor Background

As is typical for many wastewater treatment plants, RWSA periodically receives odor complaints from nearby citizens. RWSA documents the complaint, ambient conditions, and RWSA's follow-up action, which typically includes a site visit by RWSA personnel, in their comprehensive Odor Complaint Log. As part of this project, Hazen and Sawyer reviewed the Odor Complaint Log, and the review revealed several trends. The complaint log provided by RWSA, which contained records from September 2004 to October 2007, stated that the foul air smelled like "sewage or rotten eggs". During air inversions and



LEGEND

——— NEW NUTRIENT REMOVAL FACILITIES

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MOORES CREEK WWTP
ODOR CONTROL EVALUATION

PROPOSED SITE PLAN FOR NUTRIENT REMOVAL UPGRADE

HAZEN AND SAWYER
Environmental Engineers & Scientists

brisk winds, foul odors were detected beyond the plant's boundary. Various odor complaints also resulted during the vacuuming/pumping of the primary clarifier grease pit and the secondary clarifier scum pits. Overall, a significant number of the complaints were reported during the period of August 2006 through October 2006. While the on-site compost facility was in operation, a number of the complaints were thought to be due to odors generated at the compost facility. In response to this, RWSA retained Hazen and Sawyer to prepare an odor study for the compost facility. The study included odor speciation and sensory analysis sampling similar to that included in this project. The compost facility study, which was completed in June 2006, found the following:

"It is apparent from the Compost 2 Project that there is no "quick-fix", low-cost solution to providing for composting at the Moores Creek WWTP while ensuring elimination of odor detection off-site. To ensure elimination of observation of odors off-site, enclosure and active odor control of the facilities are required. Once the requirement for enclosure and odor control at composting facilities is established, the economic advantage of composting decreases significantly. This same issue has resulted in closure of numerous composting facilities including those in Henrico County, VA; Hickory, NC, and the Washington Suburban Sanitary Commission's (WSSC) composting sites at the Western Branch WWTP and Site 2."

As the most-cost effective means of eliminating migration of composting-related odors off site, RWSA closed the on-site composting facility and now hauls the dewatered cake to a contract composting facility in Richmond, Virginia.

Based on review of the Odor Complaint Log after closure of the on-site Composting Facility, the number of odor complaints between June 2007 and October 2007 was significantly reduced compared to the same period in 2006 (22 in 2007 vs. 40 in 2006). There were no complaints about the smell of "composting" any more. However, complaints based on odors described as "foul sewage" or "feces" persisted. One odor complaint was reported when the primary clarifier was taken out of service for inspection related to the ongoing nutrient removal improvements project.

Although closure of the on-site Composting Facility reduced the odor complaints, RWSA is continuing to respond to citizens' requests to reduce detectable off-site odors; as a result, this study was commissioned. To better characterize and evaluate the odors and potential for off-site detection, plant-wide odor sampling was conducted. The sampling program and results are described in the following section.

Section 2.0
Odor Evaluation and Results

2.1 General

This study included a limited odor sampling program, which was undertaken to obtain characteristics of the odor generation potential of various unit processes, for use in an air dispersion model. The sampling data was used in an air dispersion model to predict the transport of foul air from the plant. The goal of the limited sampling and air dispersion modeling is to allow for the development of a ranking (prioritization) of odor generation potential. The odor sampling plan is described below.

2.2 Identification of Potential Odor Sources

After a preliminary review of the plant site, a site tour to assess odor generation potential, and discussions with RWSA staff, the following sampling locations were selected for field and sensory sampling:

- Moores Creek Influent Pumping Station, in front of the coarse bar rack during a septage truck discharge
- Flow Equalization Basin, at the turbulent influent section
- West primary clarifier, adjacent to the bridge (quiescent sample)
- West primary clarifier effluent trough (turbulent sample)
- Gravity thickener, just inside the weir
- Aerated grit removal basins (downstream of the fine screens/upstream of the Flow Equalization Basins)
- Sludge conditioning tank, directly above the diffuser discharge
- In-plant clarifier drop box

Table A1 in Appendix A provides information about the dimensions, surface area, and air flow at each sampling location.

In addition to the sampling locations identified above, the holding ponds, and the aeration basins, when upgraded for nutrient removal, may also be a potential source of odors. In fact, since the upgraded aeration basins will include true initial anaerobic and anoxic zones, followed by aerobic zones, the potential for odor generation at the aeration basins will be increased. Since the current operation of the aeration basins does not adequately represent the future anoxic/aerobic conditions, odor sampling of the current aeration basins would not yield representative results. Therefore, library data, obtained from other projects with aeration basins and influent wastewater characteristics similar to that at the Moores Creek WWTP, were used in the evaluation. Due to access considerations and safety concerns, sampling of the holding ponds was not feasible. However, given that the holding ponds are used to store raw influent, the odor generation potential of the holding ponds is considered to be similar to that of the flow equalization basins.

Solids handling facilities also generally have the potential for significant odor generation. On the date of sampling, the solids handling facility was not in operation and therefore not sampled; however, provision of odor control for the solids handling facility is evaluated as a part of this master plan report.

2.3 Odor Sampling

Samples from the eight locations noted above were taken on June 25, 2007. On the day of sampling, there was no precipitation, the ambient air temperature ranged from 68 to 87 degrees F, the wastewater temperature ranged from 71 to 73 degrees F and the plant processed 9.1 mgd, including a recycle stream of 0.865 mgd. Two types of samples were collected:

1. Samples were collected in the field to obtain hydrogen sulfide and mercaptan data.

2. Sensory samples were taken to determine the dilution to threshold ratio (D/T) and dose response slope. The D/T determines the number of dilutions required to obtain a detection threshold of 1. The dose response slope compares the intensity of the sample to the D/T. The flatter the dose response slope the more persistent the odor. Likewise, a steep dose response slope indicates an odor that is not persistent in the atmosphere.

The sensory samples were collected with an equilibrium flux chamber. Because the chamber was set directly on the wastewater surface, the samples were not diluted by ambient air. The flux chamber was connected by Tedlar tubing to a vacuum box. Ten liter Tedlar bags were placed inside the vacuum box and used for sample collection. The bags were conditioned prior to actually collecting the samples by introducing foul air into the bag and then refilling with actual sample. Samples were then shipped via overnight air to the St. Croix Sensory Inc. laboratory, in Lake Elmo, Minnesota. Sensory analyses followed ASTM E679 and ASTM E544 methodology and were analyzed within 24 hours of collection.

2.4 Sensory Analysis

Upon receipt of the samples by St. Croix laboratories, all samples were evaluated within 24 hours of collection, which is a requirement established by ASTM protocols. Sensory analyses included the following:

- Threshold Determination: A 10 to 12 member panel evaluated the samples using an olfactometer. All panel members had been previously screened to determine their sensory sensitivity. The majority of the panel members had what was considered average sensitivity. The panel also included members with less than and greater than average sensitivity.

  Each member "sniffs" three sniffing tubes each comprised of five ports. Only one of the ports contains the odor and the remaining ports are odor free. The method used is considered the "forced choice" method whereas each member is forced to choose which port has the odorous sample. Based on this, a threshold can be determined based on statistics.

  This determines the dilution to threshold ratio (D/T) which is the number of dilutions it would take to reach an odor threshold of 1. As an example, if a sample has a D/T of 1,000, it would take 1,000 dilutions to reach the threshold. In this case, a D/T of 1 is where 50% of the panel members witness the odor. Since it is a log-log function, the absolute D/T is 0.1 which is the point where no panel members witness the odor.

  The D/T does not consider any specific odorants such as hydrogen sulfide, but provides a composite analysis of each specific odor.

- Odor Intensity: Each panel member then determines the intensity of the odor by comparing the odor with an odorant with known intensity characteristics (n-butanol). Although the intensity is not used directly, it provides data to determine the dose-response of the odor. The dose response slope is a plot of the intensity verses the D/T and is negative.

The dose-response of an odor serves to judge the pervasiveness of the odor. The flatter the dose-response slope the more pervasive the odor. Typically, either reduced sulfur compounds or organic sulfur compounds will have a flatter dose-response slope. Likewise, the steeper the slope, the less pervasive the odor. Ammonia will typically have a fairly steep dose-response slope. For reference, consider that hydrogen sulfide typically has a slope of -0.5. A more pervasive odor will linger for a greater period of time in the atmosphere. A more conservative odor treatment approach should be considered for more pervasive odors.

This sensory data is utilized in the air dispersion model, which for the purpose of this project was used solely to develop a ranking or prioritization of the potential odor generation sources.

Table 2-1 presents the basic sensory and library data used in the evaluation:

Table 2-1

Sensory Odor Data [(1)]

Area	Sub-Area	D/T	Dose-Response Slope
Influent Pumping Station	Screening, Grit and Effluent Channel	9,200	-0.46
Grit Basin	-	13,000	-0.56
Flow Equalization Basin	-	2,100	-0.40
Primary Clarifier	Quiescent Area	2,200	-0.38
	Weir Area	1,600	-0.38
Aeration Basins	Anoxic and Pre-Anoxic Zones	655	-0.40
	Aerobic Zones	252	-0.40
	Post Anoxic	128	-0.40
	Re-aeration Zones	26	-0.40
In-Plant Clarifier	Quiescent Area	1,200	-0.34
	Weir Area	6,000	-0.34
Gravity Thickeners	Quiescent Area	550	-0.36
Conditioning Tank	-	2,100	-0.43

Note: [(1)] All data other than for the aeration basins was acquired via field sampling and laboratory analysis. Library data was used for the evaluation of the aeration basins.

2.5 Dispersion Modeling

The purpose of performing dispersion modeling is to determine theoretical transport distances of individual as well as a combination of odor sources. This transport modeling is then used to prioritize provision of odor control for the various sources. In interpreting the results of transport modeling, it is important to consider the following:

- *The concept of thresholds (modeling endpoints)*: In order to successfully solve an odor problem, the odor concentration must be reduced below the threshold level at a specified location (receptor). Even if the intensity of the odor is reduced, the odor will remain to be witnessed and the problem will not be deemed to have been solved.

  As indicated previously, a D/T of 1 is the level where 50% of a typical population can witness the odor. As the D/T increases, a greater percentage of the population will be able to witness the odor. When performing dispersion modeling, an evaluation-specific D/T endpoint must be established. Refer to the modeling assumption discussion below regarding selection of the D/T criteria for this project.

- *Impact of meteorological conditions*: Odor transport will be impacted by the following meteorological conditions:
  - o Wind direction: Although obvious, assuming some wind speed, wind direction will dictate the direction of the odorous air. However, even in “calm air” conditions, the direction of a predominant air mass will also be important. The continental air mass is usually predominant. However, during the summer periods, the tropical air mass will influence the direction and during the winter months, the polar air mass will influence the direction.
  - o Wind speed: The speed of the wind creates the horizontal mixing component. Odors travel the farthest when low horizontal mixing occurs, i.e. low wind speeds. “Calm air” conditions are defined when the wind speed is less than 1 meter/second. Assuming that the air is truly calm, the direction of the odor will be dependent on the direction of the predominant air mass.
  - o Air stability: Whereas wind speed controls the horizontal mixing component, air stability controls the vertical mixing component. Six classes of air stability are defined (A-F) where stability class A occurs when the air is least stable (high vertical mixing) and stability class F occurs when the air is the most stable. Odors will transport the farthest during periods of high stability (low vertical mixing/Class F).

    Assuming no impacts from coastal air regimes and considering a typical day, the wind speed will typically decrease and the air stability will tend to increase during the nighttime hours. This is due to cooling of the earth reducing the net radiation. As the land warms, greater net radiation occurs, low pressures are produced, and the wind speed increases and the air stability decreases.

For this project, Hazen and Sawyer recommends the use of the EPA Screen Model, Version 5. This model predicts radial transport distances based on selected meteorological conditions. The model is considered conservative, but based on its use for similar projects, has proven to be very reliable.

Within the model it is necessary to make several assumptions. The following assumptions were utilized in performing the dispersion modeling:

- Odor *Emission Rates (model input)*: The emission rate used is in terms of D/T x meter^3/second. This rate is used for average conditions. However for peak (puff) conditions, the average emission rate is modified as follows:
  - o $OER_p = OER_a \times (60/t)k$
  - o Where OER_p = Peak odor emission rate
    - ▪ OER_a = Average odor emission rate
    - ▪ t = duration time (3 minutes)
    - ▪ k = 0.5 for stability classes A and B

  - 0.33 for stability class C
  - 0.2 for stability class D
  - 0.167 for stability classes E and F

- *Meteorological Conditions*: Since all of the sources are area type sources, it is known that the longest transport distance will occur during period of low wind speeds and high air stability. Therefore, for this application, a wind speed of 1 meter/second (the lowest that can be used in the model) and an F air stability class are assumed.

- *Modeling Endpoints*: In the past, the U.S. used a sensory evaluation procedure that required a presentation rate of 3.3 liters/minute to the panel member. The European and New Zealand standard, however, used a presentation rate of 20 liters/minute. The increased presentation rate increased the perceived threshold levels for the same sample. The U.S. has now adopted the increased presentation rate of 20 liters/minute. On the average, the D/T increased by a factor of 3.4. Thus, the following endpoints therefore were assumed:

  - Average conditions: 3.4 D/T (previously 1 D/T)
  - Peak conditions: 17 D/T (previously 5 D/T)

- *Flagpole Height*: For this application a flagpole height (receptor height) of 10 feet is assumed.

- Other:

  - Setting: Urban
  - Temperature: 80 degrees F

2.6 Modeling Results

As noted previously, the primary result of the dispersion modeling for this project is an assessment of potential for a particular source to generate odors that are detectable off-site. The potential for generation of odors that are detectable off site for the eight locations sampled can be categorized in terms of significance, which can be defined as follows:

Very significant impact: Odors from these sources will definitely migrate off the facility property.

Significant impact: Odors from these sources will also migrate off the facility property, but at a lesser distance.

Minor significant impact: These sources will only migrate off property during extreme meteorological conditions including “calm air” conditions.

No impact: These odors should not migrate off property boundaries.

The modeling found that for all modeled locations, with the exception of portions of the aeration basins and the gravity thickener, under both average and peak conditions, the odor generation potential could be classified as either significant or very significant. For the aeration basins, the initial zones, in which the wastewater is transported from anoxic or anaerobic conditions to aerobic conditions for the first time, has the highest odor generation potential (significant impact), whereas in the post-anoxic and re-aeration zones, odor generation is unlikely, and the modeling showed these areas had no impact. The finding that the gravity thickeners could be classified as no impact is consistent with staff reports that odor generation from the gravity thickeners is directly related to operating practices. Specifically, when the thickened WAS can be wasted to the digesters at an appropriate rate, odor generation at the gravity thickeners can be controlled. However, when operational or maintenance activities downstream in the solids handling train prevent appropriate wasting of thickened WAS, the gravity thickeners have a greater potential to generate odors.

2.7 Prioritization of Odor Control Needs

Based on the speciation and sensory sampling, the dispersion modeling, proximity to receptors (i.e. WWTP boundary), and considering those facilities not sampled as well, which includes the solids handling facility and the holding ponds, the ranking for potential for generation of odors detectable off-site, from highest to lowest is as follows:

1. Influent Pumping Station/Septage Receiving
2. Equalization Basins and Holding Ponds
3. Solids Handling Facility, Conditioning Tank and In-plant Clarifiers
4. Primary Clarifiers
5. Screenings and Grit Removal Facilities
6. Gravity Thickeners
7. Aeration Basins

A significant contributing factor in the influent pumping station being ranked as having the highest odor generation potential is contributions from septage receiving operations. Septage, due to the long holding times in septic tanks and tank trucks, is septic upon arrival at the plant, and accordingly generates the most offensive odors at the influent pumping station. Given the potential for the septage to generate odors and the proximity of the influent pumping station to the plant boundary, separation of septage receiving operations from the influent pumping station, by constructing a new separate septage receiving station, is recommended.

The recommendation for separate septage receiving, as well as application of “best management” type operating procedures and constructed odor control for each of these unit processes is evaluated and presented in the next two sections.

Section 3.0
Treatment Technology Evaluation

3.1 General

Having identified the need for odor control at multiple unit processes, the next step is to evaluate means by which to control odors generated at the plant. The first line of defense in controlling odors and being a "good neighbor" is to implement those operational practices that can prevent the generation or migration of odors utilizing the facilities currently available. The tour of the plant, conversations with RWSA staff and review of the plant O&M manual and operating data indicates that RWSA staff currently implement such best management practices to the extent possible given the available facilities. Examples of currently employed best management practices include: operating the gravity thickener at an optimal wasting rate to prevent odor generation, limiting use of the equalization basins to one basin under normal operating conditions (so as to limit the detention time to the greatest extent possible), adding deodorant to grit and screenings dumpsters and increasing the frequency of dumpster changeout, and scheduling basin outages where possible for periods of favorable meteorologic conditions. Implementation of best management practices can only control odors so far, and thus to further reduce odors at the Moores Creek WWTP, implementation of active odor control technologies at the Moores Creek WWTP must be considered. Technologies evaluated include those traditionally used for control of odors at wastewater treatment plants, which are: packed tower wet scrubbing, carbon adsorption, and biofiltration. Regenerative and recuperative thermal oxidation are also considered due to their energy efficient nature. Descriptions of each odor control technology are included below. A comparison of the different technologies is included in Table 3-1, which follows the descriptions of the technologies.

3.2 Odor Control Technologies

3.2.1 Carbon Adsorption

Activated carbon adsorbers are used commonly for odor control. Activated carbon, also called activated charcoal or activated coal, is a general term which covers carbon material mostly derived from charcoal. A typical carbon adsorption system consists of a containment device (drum or vessel), ductwork to effect proper circulation of the foul air through the activated carbon bed, a grease filter mist eliminator to clean the air from water and grease particles and a means for moving the gas stream through the bed (such as a fan or a blower). Packed activated carbon beds can be configured into small transportable drums or canisters, or into large fixed contacting vessels depending on the application. Once the adsorption capacity of the carbon has been exceeded, the carbon must be regenerated. The carbon can be regenerated onsite with water. During the regeneration cycle, the carbon is flushed with water to remove the bound sulfides from the carbon. The flushing water is then discharged to the WWTP for treatment. The life of a carbon bed is limited and the carbon can only be regenerated a limited number of times. With each regeneration, the removal efficiency is decreased, and after the prescribed number of regenerations, the carbon must be replaced. Spent carbon is considered a hazardous waste, and as such is expensive to dispose of, and be disposed of in accordance with all applicable local, state and federal regulations. The life of carbon, prior to requiring generation can be short, measured in terms of weeks, or at times, days. This can result in an extremely maintenance intensive, and therefore expensive, operation

The rate of adsorption for different constituents or compounds will depend on the nature of the constituents or compounds being adsorbed. It has also been found that the removal of odors depends on the concentration of the hydrocarbons in the odorous gas. Typically, hydrocarbons are adsorbed preferentially before polar compounds such as hydrogen sulfide.

Carbon adsorbers are typically sized for air flows of 25,000 – 30,000 scfm. Given the volume of air to be treated at Moores Creek, and the potential for maintenance intensive operations, coupled with the need to dispose of hazardous waste, use of carbon adsorbers at the Moores Creek WWTP is not recommended.

3.2.2 Biofiltration

Generally, biofiltration is the removal and oxidation of volatile organic compounds (VOCs) from contaminated air by beds of organic media, such as compost or soil. Billions of indigenous microorganisms inherent within the biofilter media convert the organic compounds to carbon dioxide and water. These naturally occurring microorganisms consume the odorous compounds in a safe, moist, oxygen-rich environment. Within the general biofiltration treatment technology, there are variations in the process, which include application of moisture, or use of inorganic media. These alternative biofiltration technologies are commonly referred to as biotrickling filters and biotowers, respectively.

Biofilters

Biofilters used for odor scrubbing are beds of bulk media such as soil, peat, or compost, through which foul air is drawn. Biofilters generally remove up to approximately 90% of the biodegradable components of foul air. In biofilters, factors such as the oxygen concentration, moisture content, temperature, pH, foul air residence time, and porosity of the media must be controlled very carefully to maintain effective removal of odors in the air. Failure to maintain any one of these factors at optimal conditions may seriously impact the performance of a biofilter. For example, good moisture distribution throughout the media is essential because breakthrough of foul air can occur in the dryer areas of the media. Also, changes in porosity of the media due to moisture content changes and settling of the media can significantly affect pressure requirements for the foul air blower. Once a biofilter fails, regaining adequate performance may be difficult. Biofilters have traditionally performed well in warm climates such as Florida and California; the effectiveness of a biofilter may be limited in cooler temperature regions. Additionally, biofilters require a larger surface area for installation than a scrubber system and significant concentrations of ammonia can cause toxicity within the filter.

Biotrickling Filters

Biotrickling filters are similar to biofilters; the main difference between the two is the need for constant moisture application over the media in a biotrickling filter. A smaller footprint is required for a biotrickling filter than for a biofilter. However, with biotrickling filters, addition of supplemental nutrients, including nitrogen and phosphorous, can be required.

Biotowers

From the exterior, a biotower looks similar to a packed tower wet chemical scrubber, but differs in that it does not require chemical addition. Biotowers are similar to biofilters in operating principle, but utilize inorganic media, rather than organic media. Systems are typically pre-engineered, vendor-supplied system made of FRP or HDPE shells. The shell contains media that is completely inert. The inert media receives either constant recycle spray or intermittent once-through spray humidification, depending on the vendor's approach. The spray is also the source of trace nutrients for the biological system, as opposed to biofilters, where nutrients (such as trace organics, nitrogen, phosphorous, and potassium) are typically contained in the media itself. The spray rate (or sump makeup water rate) in a biotower is sometimes used to control the resulting pH of the biological system and thus selectively target different types of microorganisms that consume different types of odor-causing compounds. If the loading to the biotower is not too concentrated, the spray water that carries the required nutrients can be the plant effluent. If the odors are too concentrated or if the plant effluent water does not contain sufficient nitrogen, phosphorous, potassium and trace organics, then supplemental nutrients may be required.

Given the low removal odor removal efficiency, coupled with the large footprint required, and the lesser degree of system reliability (when compared to wet chemical scrubbing), use of biofiltration technologies for the Moores Creek WWTP is not recommended.

3.2.3 Packed Tower Wet Scrubbing

Packed tower scrubbers are very common for odor control at wastewater treatment plants. Packed tower wet scrubbers are typically designed to remove 99.9% of the odorous compounds in foul air. Foul air is blown into the scrubber at the bottom of the scrubber tank and passes through a bed of packing material. The packing material is typically inert plastic, shaped to provide the maximum surface area per unit volume. While in the packing material, the air comes in contact with scrubbing liquid that is distributed by spray nozzles located above the packing material. After the air passes through the packing material and countercurrent flow of scrubbing liquid, it passes through a mist eliminator and exits the scrubber. The scrubbing liquid collects in a sump at the bottom of the scrubber and is recirculated using a recirculation pump.

Given the need to minimize the potential for odor migration off-site, two stage scrubbers are recommended for use at Moores Creek. Multi-stage scrubbers require scrubbing liquid that typically consists of water, sodium hydroxide/caustic (NaOH), and sodium hypochlorite (NaOCl). Caustic reacts with hydrogen sulfide in the foul air to form sodium sulfide and water. If the pH drops below 10, this reaction can be reversed, and hydrogen sulfide will be regenerated. In order to keep the sulfide ion from reforming hydrogen sulfide, sodium hypochlorite is added. Sodium hypochlorite reacts with the sulfide ion to convert it to sulfite, which remains dissolved in water.

Wet chemical scrubber units require scrubber towers, (two for each two stage system), fans to convey the foul air to the scrubber, recirculation pumps to return the scrubbing liquid to the top the scrubbers, chemical storage facilities, and chemical feed facilities. The chemical storage facility must be constructed with retaining walls and sump pumps to contain and control chemical spills, as well as heat tracing for the chemical storage tanks. A building is required for the chemical feed pumps. Scaffolding is typically provided for access to the top of the scrubbers. Typically, the scrubbers, or packed towers, themselves operate reliably and thus redundant scrubbers are not provided. However, redundant chemical feed pumps and recirculation pumps are typically provided.

Wet chemical scrubbing is the most prevalent odor control technology used at wastewater treatment plants. It is a proven and reliable technology for treating large volumes of foul air and is therefore the recommended technology for use in providing odor control to the foul air generated at the various unit processes at the Moores Creek WWTP.

3.2.4 Regenerative and Recuperative Thermal Oxidizers

Recuperative and regenerative thermal oxidizers utilize atmospheric oxygen and heat to oxidize odorous gases to carbon dioxide, sulfur oxide, and other non-odorous gases. The oxidizer unit provides the thermal energy required for this conversion process. The thermal energy is supplied by an external fuel source, typically natural gas. A natural gas burner is located in the oxidation chamber. VOCs are oxidized when present in the gas stream, releasing heat, hereby reducing the quantity of natural gas required to sustain the oxidation process.

A recuperative thermal oxidizer recovers a portion of the thermal energy remaining in the exhaust gas and uses it to preheat the incoming gas stream, reducing the amount of fuel required for oxidation. Regenerative thermal oxidizers (RTOs) recover a much larger portion of the energy found in the exhaust stream than recuperative thermal oxidizers. RTOs use a ceramic media as a heat exchanger. The inlet gases pass through heated ceramic media, which preheats the incoming gases. Then, the gases enter the oxidation chamber where pollutants are oxidized. These systems are typically 90-95% thermally efficient and have a destruction efficiency of 97-99%, depending on the system design.

Since regenerative and recuperative thermal oxidation processes have comparable destruction efficiencies, the process selection is mainly based on economics. The capital costs of recuperative thermal oxidizers are only slightly lower (typically 5-10%) than the capital costs of regenerative thermal oxidizers. However, due to their relatively low thermal efficiency, recuperative thermal oxidizers are only cost effective when inexpensive fuel is available (such as digester gas) or when the pollutant gas stream contains significant quantities of oxidizable compounds, since the oxidation of these compounds reduces the amount of external fuel required for the oxidation process. For dilute gas streams (as found in odor control applications), the lower fuel costs associated with regenerative thermal oxidizers normally make RTOs the less expensive alternative.

Generally, thermal oxidation is considered neither practical nor cost effective to treat air collected from liquid processes when compared to scrubbers which have proven effectiveness and are considered reliable treatment devices. In addition, there may be potential problems with obtaining and maintaining an air permit. Therefore, thermal oxidation is not recommended for use at the Moores Creek WWTP.

3.3 Comparison of Odor Control Technologies

Table 3-1 presents a comparison of the conventional odor control technologies evaluated for the Moores Creek WWTP. All odor control technologies considered include collecting the foul air and treating it. Collection of the foul air requires that open basins be covered. As a means of eliminating odor migration in a cost-effective manner, it might seem advantageous to cover select basins without providing for transport and treatment of the foul air. Such an approach is not optimal and has several disadvantages, which include:

- High potential for odor migration, which could minimize or negate the intended effect of installing active odor control elsewhere on-site.
- Increased corrosion rate for covers and mechanical equipment.
- Creation of hazardous working conditions for employees within the tanks.

This approach is not recommended for implementation at the Moores Creek WWTP. Rather, as detailed in the sections above, based on the volume of air to be treated at Moores Creek WWTP and the need for reliability in the treatment process, wet chemical scrubbing is recommended for treatment of all foul air at the plant. The location and sizing of the wet chemical scrubbers for the various unit processes, for the three treatment options, are described in Section 4.

Table 3-1

Comparison of Odor Control Technologies

Technology	Advantages	Disadvantages	Notes
Packed Tower Wet Scrubber	• Simple and stable operation and maintenance • System efficiency not dependent on nozzle performance • Effective removal performance at high H_2S concentrations • Able to treat large volumes of air economically • Relatively small footprint	• Requires periodic cleanings • Limited effectiveness on organic-based odor-causing compounds, such as reduced-sulfur organic species • Require storage and handling of potentially hazardous chemicals • Remove few or no VOCs regulated under Title V of the Clean Air Act • Are relatively tall (30 ft), which can create aesthetic issues	• Proven and reliable technology • Current standard at many plants • Extremely effective with high H_2S concentrations • Removing few VOCs is usually not an issue, unless the scrubber system is being provided for VOC removal
Carbon Adsorption	• No chemical storage or recirculation pumps are required • Simple operation and maintenance • Cost effective removal at H_2S concentrations below 5 ppm • Can remove a wider range of odorous compounds than wet scrubbers • Removes VOCs	• As influent H_2S concentrations increase, the life expectancy of a carbon bed decreases, resulting in high carbon replacement demands • Carbon bed replacement is expensive in terms of fresh carbon and the labor necessary to change out beds • Spent carbon becomes a waste solid that must be disposed of properly • Foul air streams containing particulate matter may plug the system	
Biofiltration	• Provide effective treatment for a wide variety of odor-causing compounds • Once constructed, they are easy to maintain and do not require chemical addition • Can also remove VOCs regulated under Title V of the Clean Air Act	• As H_2S concentrations and odorous-air volume increases, effective treatment can become very land-intensive • A typical compost-style biofilter bed lasts for roughly 3 to 5 years, after which time it must be rebuilt; • Short-circuiting of the media at higher airflow rates may result in inadequate odor	
Biotowers	• Requires substantially lower detention times (8 to 15 seconds for H_2S) • The media can be stacked higher • The inert media have a very long bed life. • Reduces potential footprint and requirements for media displacement	• Tend to struggle with effective treatment of the reduced sulfur organic species like dimethyl sulfide	
Recuperative/Regenerative Thermal Oxidation	• Low fuel consumption	• Considered neither practical nor cost effective to treat air collected from liquid processes when compared to scrubbers • Potential problems with obtaining and maintaining an air permit	

Section 4.0
Recommendations

4.1 General

As evidenced by the fact that odor complaints have continued following closure of the Compost Facility, and given the limited odor control provided by continued implementation of best management practices, active odor control is necessary to minimize detection of odors beyond the plant boundary. Based on discussions with RWSA staff, we understand that the surrounding community has a preference for zero detection of odors offsite. Given the variability in influent wastewater characteristics, the influence of climatic and operational parameters and the critical mission of the plant in meeting NPDES permit requirements, **it is cost prohibitive to design a system that would guarantee that odors will never migrate off site**. For the purposes of this report, the best achievable odor control is considered to be 99.7% removal where odors would only be detectable offsite at a frequency of approximately 1 day per year. The costs to implement this approach are considerable, but have been developed and are presented herein.

Recognizing the adjacent citizens' request for reduction in odors coupled with the Authority's commitment to ratepayers to be fiscally responsible, and considering the estimated costs of constructing the nutrient removal upgrades to the Moores Creek WWTP, recommendations for lower cost alternatives have been developed and are also included in this report. The lower-cost alternatives include:

1. Scaling back on constructed odor control to provide 99% odor removal. This would translate into approximately 3 days per year during which odors may be detectable offsite. Active odor control facilities would significantly reduce the intensity of offsite odor detection even during times when offsite detection may occur.

2. Scaling back further on constructed odor control to provide 95% odor removal. Under this scenario, odors may be detectable offsite up to approximately 18 days per year. Again, because of the active odor control facilities that would be installed, any detected odor would be far less objectionable in nature than under current conditions. It should be noted that the vast majority of U.S. plants, including those located in urban areas, provide odor control at or below the 95% level.

To allow for comparison of the three options, layouts as well as capital, O&M and life cycle costs have been developed for each option. Capital costs include all sitework, mechanical equipment, ductwork, structural, architectural, electrical and I&C work required for installation of fully-functional scrubber facilities. O&M costs include operation of the fans and recirculation pumps and chemical costs. These are the major O&M costs associated with wet chemical scrubber facilities, and are based on the following:

- $0.25 per pound of dry sodium hydroxide delivered as a 12.5% solution
- $1.50 for the sodium hypochlorite
- Electrical costs of $0.056 per kwh

The life cycle costs are based on a 20 year life cycle and a 5% interest rate. A contingency of 30%, which is commensurate with cost estimating associated with a conceptual level evaluation, such as included herein, is applied to the capital costs. For ease of comparison, the capital, O&M and life cycle costs of the three options are included in Table 4-3.

4.2 99.7% Odor Removal (Option 1)

Option 1 represents the most comprehensive odor control scenario. Under this scenario, in addition to best management practices, all potential odor sources would be enclosed or covered and the air exhausted to an odor control unit. Elements included in Option 1, by unit process, are listed below. The volume of foul air generated at each area is included in Table 4-1.

- <u>Influent Pumping Station</u> – Cease septage dumping at the influent pump station, and instead construct a separate septage receiving station on the north side of the plant that would allow for direct discharge to either the anaerobic digesters or the primary clarifiers. Cover the influent channels, aerated grit chambers, and wetwell associated with the influent pumping station and scrub the foul air.

- <u>Flow Equalization Basins</u> – Cover the equalization basins and scrub the foul air. Due to high cost of covering basins as large as the equalization basins, (2 each at 280' x140', for a total of 1.8 acres), decommissioning the equalization basins and replacing them with one or two above grade prestressed concrete tanks was evaluated. It was determined that the cost of constructing the prestressed concrete tank is less costly than the cost to cover the equalization basins by approximately $3.5M (i.e. $2.7M for concrete tank versus $6.2M for covers). However, providing the equivalent volume in a prestressed concrete tank within the constructability and hydraulic constraints will require the construction of a equalization basin pumping station. Therefore, Option 1 includes decommissioning of the equalization basins, replacement with one 4.5 million gallon prestressed concrete storage tank, constructing an equalization basin pumping station, and scrubbing the foul air in the headspace of the tank.

- Holding Ponds – Similar the equalization basins, providing a cover over the holding ponds to allow for foul air capture prior to scrubbing, would be very costly due to the area of the holding ponds, which is approximately 4.3 acres. Given the size of the holding ponds, the cost of conversion to pre-stressed concrete tanks is less than covering the holding ponds in their existing configuration. Therefore, for the holding ponds, Option 1 includes decommissioning of the holding ponds, construction of two pre-stressed concrete tanks, and scrubbing the foul air.

- Influent Screen Facilities – Construct a building to enclose the screens, compaction equipment and roll-off container, cover all channels, and scrub the foul air.

- Grit Removal Facilities – Cover the aerated grit basins and associated channels, enclose the grit cyclones, classifiers, and dumpster in a building. Scrub the foul air from the channels, basins and building.

- Primary Clarifiers – Cover the entire surface of the two primary clarifiers, including the outboard launders and scrub the foul air. Note that due to the diameter of the clarifier and launder, use of a dome type cover, which increases the air volume to be scrubbed, is required. Also, capture and scrub the foul air from the primary clarifier scum/grease pit.

- Gravity Thickeners - Cover the entire surface of the two gravity thickeners, including the outboard launders and scrub the foul air. Note that due to the diameter of the gravity thickener and launder, use of a dome type cover, which increases the air volume to be scrubbed, is required.

- Aeration Basins - Cover all stages of the five aeration basins and scrub the foul air.

- In-plant Clarifiers - Cover the entire surface of the two in-plant clarifiers and scrub the foul air. Note that due to the diameter of the clarifiers, use of a dome type cover, which increases the air volume to be scrubbed, is required.

- Conditioning Tank – Cover the tank, and scrub foul air. Note that the 16’ width of the tank allows for use of a flat cover, which minimizes the volume of air to be scrubbed.

- Solids Handling Building - Scrub foul air from the press/centrifuge room and truck loading area in the Solids Handling Building.

- Digesters – Collect and scrub foul air that may be released from the pressure relief valves (PRVs) located on the digester covers. Normally, air is not released from the PRVs; the collection and scrubbing would allow for capture of air release in the event the PRV leaks or during routine valve maintenance.

Table 4-1

Foul Air Flow Generation Rates by Unit Process

Location	Air Flow Rate to Odor Control (cfm)
Influent Pump Station	2,300
Septage Receiving	1,000
Sludge Dewatering Building	33,200
Conditioning Tank	440
In-Plant Primary Clarifiers**	2,800
Launder only	100
Influent Screen Channels	200
Influent Screen Building	2,100
Grit Basins	250
Grit Cyclones/Classifiers	11,200
EQ Basins	44,700
Gravity Thickeners**	1,700
Launder only	100
Primary Clarifiers**	14,800
Launder only	700
Scum/grease pit	100
Aeration Basins	21,900
Anaerobic, Anoxic and first two aerobic stages only	19,200
Holding Pond	75,200
Digester PRVs	Intermittent/Minimal

Note:
** Assumes dome covers, as required by basin dimensions

As noted in Chapter 3, wet chemical scrubbing is the recommended odor control technology for treatment of the foul air generated on-site. To ensure satisfactory odor removal, two stage scrubbers, with ten feet of packing depth are recommended for all scrubber facilities. Since wet chemical scrubbers require scrubber towers with recirculation pumps, fans, chemical storage tanks for sodium hypochlorite and sodium hydroxide, containment, and a building for chemical metering pumps, the most cost effective means of providing scrubbing at a plant is often to centralize scrubbing operations. Given the natural divide in the Moores Creek WWTP created by the creek, the need for at least two scrubber facilities, one on the north side, for solids handling related facilities and one for the south side, for the liquid treatment facilities is evident. In addition, due to air volume generated from the holding ponds and the distance between the holding ponds and the other areas to be scrubbed on the south side, provision of two scrubber facilities on the south side is warranted. Therefore, three scrubber facilities are required for option 1. The facilities served by each scrubber are listed below:

Scrubber 1 serves:

- Septage Receiving Station
- Moores Creek Influent Pump Station
- Conditioning Tank
- In-plant clarifiers
- Solids Handling Building
- Digester PRVs

Scrubber 2 serves:

- Influent Screen Channels
- Influent Screen Building
- Grit Basins
- Grit Cyclones/Classifiers
- EQ Basins
- Gravity Thickeners
- Primary Clarifiers and scum/grease pit
- Aeration Basins

Scrubber 3 serves:

- Holding Ponds

The number of scrubbers, the air flow to be treated at each odor control facility and the recommended scrubber diameter are included in Table 4-2.

Table 4-2

Characteristics of Scrubbers Recommended for Option 1 (99.7% Odor Removal)

Scrubber No.	Total Air Flow (cfm)	Number of Two Stage Scrubbers	Scrubber Diameter (ft)
1	39,900	1	12
2	96,800	3	12
3	75,200	2	12

As shown in Table 4-2, the scrubber towers themselves are large, and the facilities at each location must be located to allow for bulk delivery of sodium hypochlorite and sodium hydroxide. The recommended site layout for Option 1 is shown in Figure 4-1.

Capital, O&M and life cycle costs for Option 1 have been developed and are presented in Table 4-3 below. Table 4-3 also includes the capital, O&M and life cycle costs for Options 2 and 3. To facilitate comparison of the options, Table 4-4 provides a summary of what is included in each option and under which phase the improvements would be implemented in the phased approach that is discussed in Section 4.5.

Table 4-3

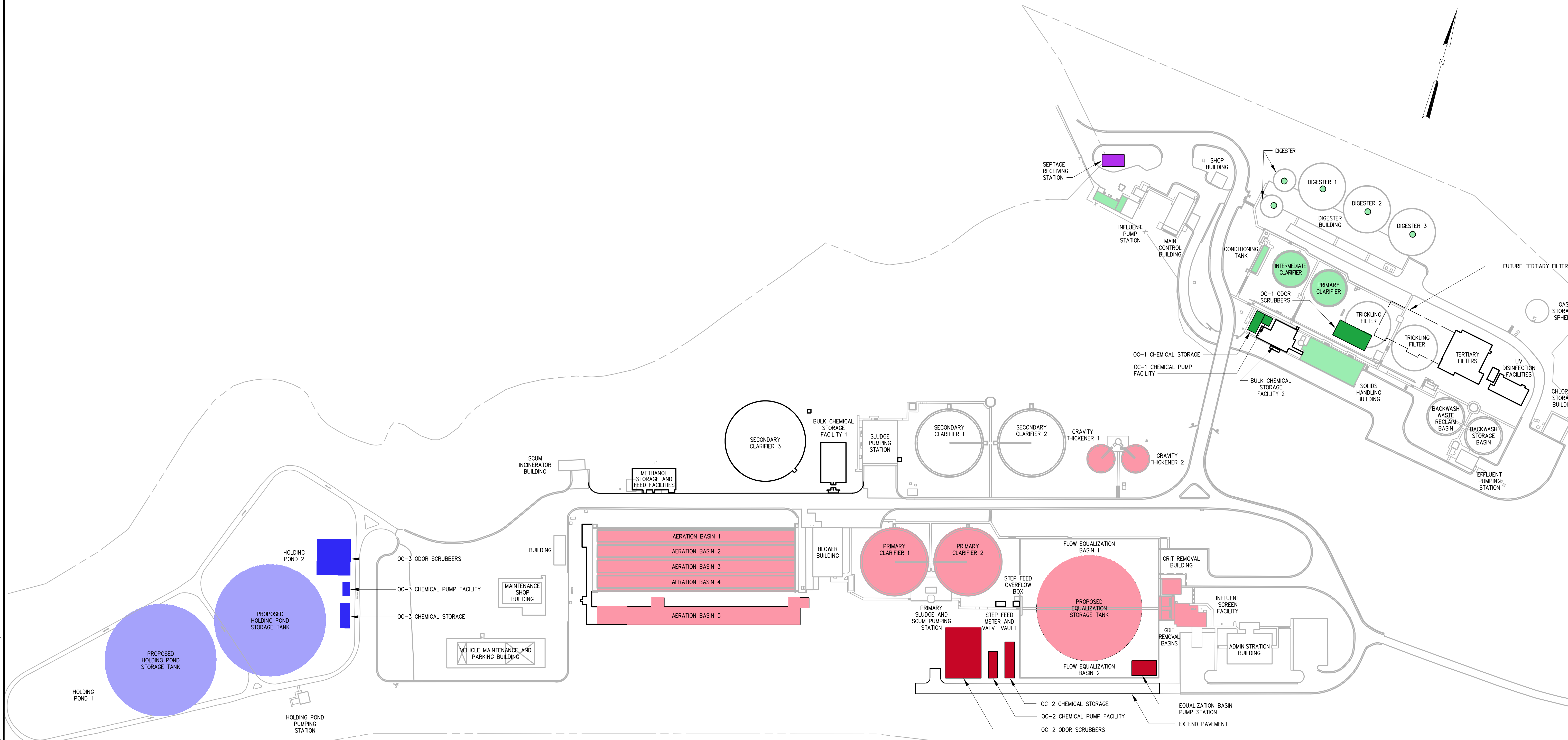
Summary of Capital, O&M and Life Cycle Costs for Three Odor Control Options

	99.7% removal (Option 1)	99% removal (Option 2)	95% removal (Option 3)
Capital costs			
Septage Receiving Station	$1,705,000	$1,705,000	$1,705,000
Northside Scrubber 1	$1,208,000	$1,208,000	$1,208,000
Southside Scrubber 2	$12,249,000	$11,949,000	$5,696,000
Holding Ponds Scrubber 3	$9,658,000	--	--
Total Capital Costs	$24,820,000	$14,862,000	$8,609,000
Total Capital Costs with 30% Contingency	**$32,266,000**	**$19,321,000**	**$11,192,000**
Annual O&M costs	**$913,000**	**$576,000**	**$257,000**
Total 20-year life cycle costs	**$43,649,000**	**$26,503,000**	**$14,393,000**

Table 4-4
Summary of Capital Improvements Included by Option

Improvement	99.7% Removal Option 1	99% Removal Option 2	95% Removal Option 3	Phased Approach
Separate Septage Receiving Station	X	X	X	1
Influent Pumping Station:				
Cover channels, wetwell, and grit chambers; scrub foul air	X	X	X	1
Flow Equalization Basin:				
Construct pre-stressed concrete tanks and pumping station; scrub foul air	X	X		5
Construct automated washdown system			X	1
Holding Ponds:				
Construct pre-stressed concrete tanks; scrub foul air	X			5
Construct new plant drain pump station, automated washdown system, and bypass Primary Effluent		X	X	1
Influent Screen Facilities				
Construct enclosure, cover channels; scrub foul air	X	X		2
Frequent dumpster changeout, mist with odor-masking agent			X	1
Grit Removal Facilities				
Construct enclosure, cover channels and basins; scrub foul air	X	X		2
Frequent dumpster changeout, mist with odor-masking agent			X	1
Primary Clarifiers				
Cover entire surface of clarifier and launder, as well as grease/scum pit; scrub foul air	X	X		4
Cover launder, as well as grease/scum pit; scrub foul air			X	2
Gravity Thickeners				
Cover entire surface of thickener and launder; scrub foul air	X	X		4
Cover launder and scrub foul air			X	2
Aeration Basins:				
Cover all five stages and scrub foul air	X			4
Cover initial stages and scrub foul air		X	X	3
In-plant Clarifiers				
Cover entire surface of clarifier; scrub foul air	X	X	X	1
Conditioning Tank				
Cover and scrub foul air	X	X	X	1
Solids Handling Building				
Scrub foul air from press/centrifuge room and truck loading area	X	X	X	1
Digesters				
Collect and scrub foul air from Pressure Relief Valves	X			5

Notes: X = included in the Option
1,2,3,4,5 = For phased approach, the number indicates the phase in which the improvement will be implemented.



LEGEND

NEW NUTRIENT REMOVAL FACILITIES

ODOR CONTROL SYSTEM 1 FACILITIES

ODOR CONTROL SYSTEM 2 FACILITIES

ODOR CONTROL SYSTEM 3 FACILITIES

SEPTAGE RECEIVING STATION

200 100 0 200'

1"=200'-0"

MOORES CREEK WWTP
ODOR CONTROL EVALUATION

OPTION 1
99.7% REMOVAL

HAZEN AND SAWYER
Environmental Engineers & Scientists

4.3 99% Odor Removal (Option 2)

Option 2 is identical to Option 1 with the exception of treatment of foul air generated at the digester PRVs, holding ponds and aeration basins. Under Option 2, air released from the digester PRVs would be vented to the atmosphere. For the other two unit processes, the following elements, which include best management practices as opposed to constructed odor control for the holding ponds, are recommended:

- Holding Ponds – Modify existing best management practices (BMP) to minimize the potential for odors. Note that construction of improvements is required in order to implement the recommended BMP. Best management practices would include:

    - Normally keeping the ponds empty (i.e. free of influent wastewater), clean and free of solids deposition, and restricting use to storm flow equalization or storage during scheduled or unscheduled plant maintenance activities. Use of the Holding Ponds for equalization of diurnal peaks would cease.

    - Construct a new plant drain pump station that would remove process drains from the holding ponds and allow for the holding ponds to normally be empty, except during storms or maintenance activities.

    - Diverting flow to the holding ponds downstream of the influent screen facilities and grit removal basins and primary clarifiers. This would be a change to the current diversion location, which can be either up or downstream of the influent screens. The change in location of diversion would serve to minimize rags and plastics conveyed to the holdings ponds, which will reduce the potential for odor generation. More significantly, the change in location would also reduce the solids conveyed to the holding ponds, which would minimize the potential for deposition of biological solids in the holding ponds, and facilitate cleanup of the ponds. This would require construction of new bypass facilities downstream of the primary clarifiers.

    - Cleaning the basins completely following each use. As noted previously, the holding ponds are large, occupying approximately 4.3 acres. The holding ponds have a steep side slope and are used to store untreated wastewater. As such, clean up by operations or maintenance personnel would be time consuming and dangerous. Therefore, to effect the recommended clean-up, while minimizing human risk, upgrades to the existing infrastructure, including construction of an automated wash down system for each of the holding ponds is recommended. The automated system will required a high volume and pressure in the plant's non-potable water system and thus will require upgrades to the pumping and piping associated with the existing non-potable water system.

- Aeration Basins - Rather than covering all stages of all five aeration basins and scrubbing the foul air as was included in Option 1, under Option 2 the aeration basin area to be covered and scrubbed would be limited to the initial stages of the aeration basin. The stages to be covered and scrubbed would include the initial anaerobic and anoxic stages, as well as the first two aerobic stages. It is in these stages that, due to the initial anaerobic/anoxic conditions, followed by introduction of air (oxygen), there is the highest odor generation potential.

The volume of foul air generated by partially covering the aeration basins, as well for all other areas is included in Table 4-1, above.

As noted in Section 3, and for Option 1 above, wet chemical scrubbing is the recommended odor control technology for the majority of the foul air generated on-site. To ensure satisfactory odor removal, two stage scrubbers, with ten feet of packing depth are recommended for all scrubber facilities. Since wet chemical scrubbers require scrubber towers with recirculation pumps, fans, chemical storage tanks for sodium hypochlorite and sodium hydroxide, containment, and a building for chemical metering pumps, the most cost effective means of providing scrubbing at a plant is often to centralize scrubbing operations. Given the natural divide in the Moores Creek WWTP created by the creek, the need for at least two scrubber facilities, one on the north side, for solids handling related facilities and one for the south side, for the liquid treatment facilities is evident. A total of two scrubber facilities are required for option 2. The facilities served by each scrubber are listed below:

Scrubber 1 serves:

- Septage Receiving Station
- Moores Creek Influent Pump Station
- Conditioning Tank
- In-plant clarifiers
- Solids Handling Building

Scrubber 2 serves:

- Influent Screen Channels
- Influent Screen Building
- Grit Basins
- Grit Cyclones/Classifiers
- EQ Basins
- Gravity Thickeners
- Primary Clarifiers and scum/grease pit
- Aeration Basins – anaerobic, anoxic and first two aerobic stages

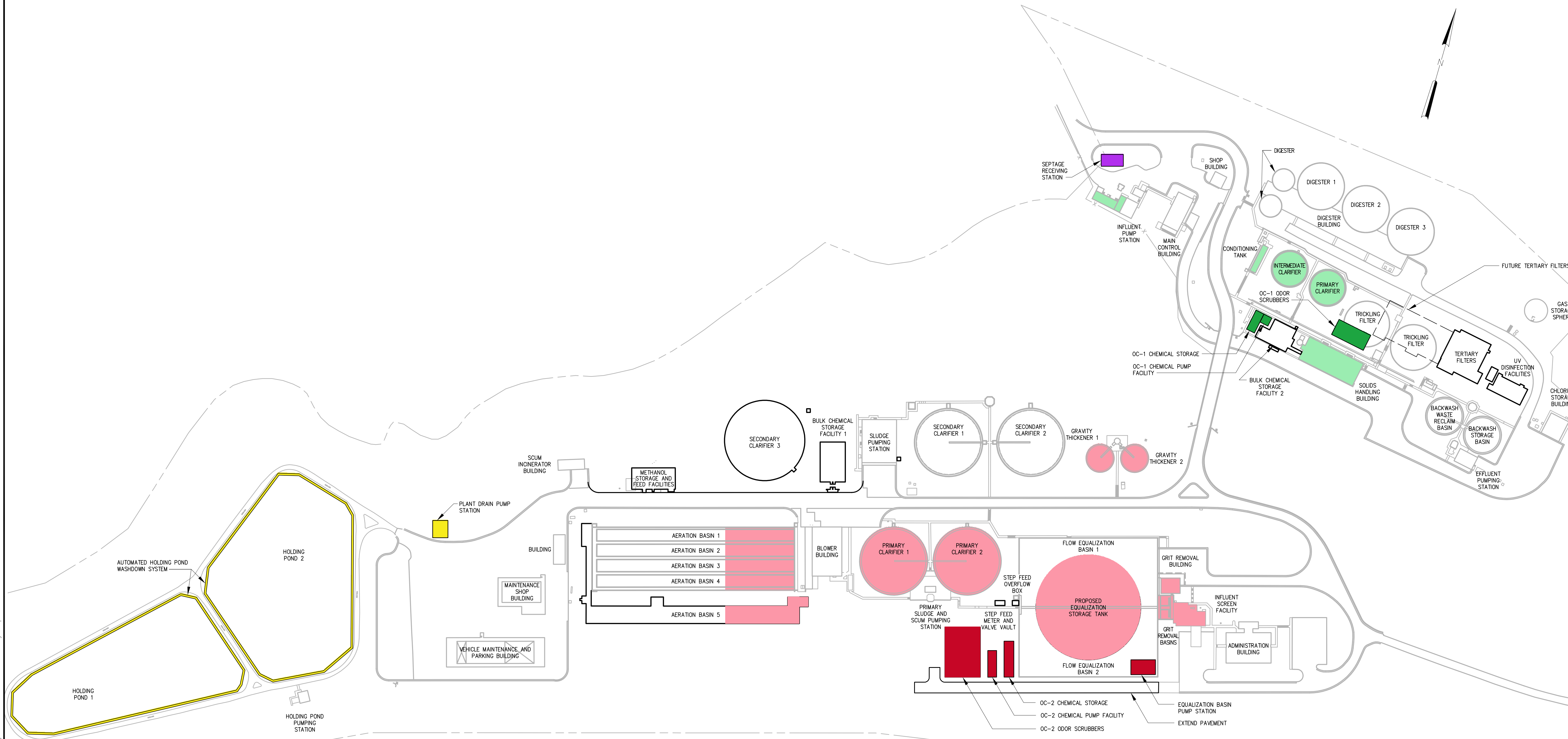
The air flow treated by each scrubber and the recommended scrubber diameter is included in Table 4-5.

Table 4-5

Characteristics of Scrubbers Recommended for Option 2 (99% Odor Removal)

Scrubber No.	Total Air Flow (cfm)	Number of Two Stage Scrubbers	Scrubber Diameter (ft)
1	39,900	1	12
2	94,000	3	12

The recommended site layout for Option 2 is shown in Figure 4-2. Capital, O&M and life cycle costs for Option 2 have been developed and are presented in Table 4-3 above.



LEGEND

(solid line)	NEW NUTRIENT REMOVAL FACILITIES
(green)	ODOR CONTROL SYSTEM 1 FACILITIES
(red/pink)	ODOR CONTROL SYSTEM 2 FACILITIES
(yellow)	NEW FACILITIES TO IMPLEMENT BMPs
(purple)	SEPTAGE RECEIVING STATION

1"=200'-0"

200 100 0 200'

MOORES CREEK WWTP
ODOR CONTROL EVALUATION

OPTION 2
99% REMOVAL

HAZEN AND SAWYER
Environmental Engineers & Scientists

4.4 95% Odor Removal (Option 3)

Option 3 represents a marked departure from Option 1, in that best management practices are incorporated wherever possible in lieu of providing active odor control facilities, with the goal of limiting migration of odors off site to 5% of the time (minor detection approximately 18 days per year). This approach is the most cost effective approach available to meet RWSA's odor reduction goals. Elements included in Option 3, by unit process, are listed below. The volume of foul air generated at each area is included in Table 4-6.

- Influent Pumping Station – Cease septage dumping at the influent pump station, and instead construct a separate septage receiving station on the north side of the plant that would allow for direct discharge to either the anaerobic digesters or the primary clarifiers. Cover the influent channels, aerated grit chambers, and wetwell associated with the influent pumping station and scrub the foul air.

- Flow Equalization Basins – Modify existing best management practices to minimize the potential for odors. Note that construction of improvements is required in order to implement the recommended BMP. Implementation of the modifications to the BMP will also provide a process benefit in terms of maximizing available carbon for the upcoming nutrient removal upgrade at the Moores Creek WWTP. Best management practices include:

    - Normally keeping the basins at a low level or empty (i.e. free of influent wastewater), clean and free of solids deposition, and restricting use primarily for storm flow equalization. Use of the basins for equalization of diurnal peaks would be minimized.

    - Bypassing influent flow around the equalization basins or operating the basins with a lower water surface elevation for flows other than storm flows. This will require construction of a bypass line around the equalization basins. Operation with a lower water surface elevation will decrease the retention time in the basin, which will minimize the potential for the flow to turn septic and generate odors.

    - Draining and cleaning the basins completely following their use during a storm flow event. Like the holding ponds, the equalization basins are large, are not easily accessible and are used to store untreated wastewater. As such, clean up by operations or maintenance personnel would be time consuming and dangerous. Therefore, to effect the recommended clean-up, while minimizing human risk, upgrades to the existing infrastructure, including construction of an automated wash down system for each of the equalization basins is recommended. The automated system will require a high volume and pressure in the plant's non-potable water system and thus will require upgrades to the pumping and piping associated with the existing non-potable water system.

- Installing and utilizing mixers and aerators in the equalization basins. The use of mixers as opposed to aerators will reduce the potential for generation of odors, while keeping the solids in suspension, which will enhance process performance while facilitating post-use basin clean-up.

- Holding Ponds –Modify existing best management practices to minimize the potential for odors. Note that construction of improvements is required in order to implement the recommended BMP. Best management practices would include:
    - Normally keeping the ponds empty (i.e. free of influent wastewater), clean and free of solids deposition, and restricting use to storm flow equalization or storage during scheduled or unscheduled plant maintenance activities. Use of the holding ponds for equalization of diurnal peaks would cease.
    - Construct a new plant drain pump station that would remove process drains from the holding ponds and allow for the holding ponds to normally be empty, except during storms or maintenance activities.
    - Diverting flow to the holding ponds downstream of the influent screen facilities and grit removal basins and primary clarifiers. This would be a change to the current diversion location, which can be either up or downstream of the influent screens. The change in location of diversion would serve to minimize rags and plastics conveyed to the holdings ponds, which will reduce the potential for odor generation. More significantly, the change in location would also reduce the solids conveyed to the holding ponds, which would minimize the potential for deposition of biological solids in the holding ponds, and facilitate cleanup of the ponds. This would require construction of new bypass facilities downstream of the primary clarifiers.
    - Cleaning the basins completely following each use. As noted previously under Option 1, construction of an automated wash down system for each one of the holding ponds is recommended. The automated system will required a high volume

and pressure in the plant's non-potable water system and thus will require upgrades to the pumping and piping associated with the existing non-potable water system.

- Influent Screen Facilities – Continue to implement existing best management practices for reduction of odor generation and migration potential. These management practices include:
    - Frequent dumpster changeout
    - Misting dumpster with an odor masking agent

- Grit Removal Facilities – Continue to implement existing best management practices for reduction of odor generation and migration potential. These management practices include:
    - Frequent dumpster changeout
    - Misting dumpster with an odor masking agent

- Primary Clarifiers – Cover the turbulent launder area of the two primary clarifiers, and scrub the foul air from the launders, as well as from the scum/grease pit. Covering and scrubbing of the air from the launder area of the primary clarifiers allows for containment of the major area of release of foul air in and around the primary clarifier while significantly reducing cover costs, scrubber size and O&M costs.

- Gravity Thickeners - Cover the turbulent launder area of the two gravity thickeners, and scrub the foul air. Covering and scrubbing of the air from the launder area of the gravity thickeners allows for containment of the major area of release of foul air in the gravity thickener while significantly reducing cover costs, scrubber size and O&M costs.

- Aeration Basins – Similar to Option 2 the aeration basin area to be covered and scrubbed would be limited to the initial stages of the aeration basin. The stages to be covered and scrubbed would include the initial anaerobic and anoxic stages, as well as the first two aerobic stages. It is in these stages that, due to the initial anaerobic/anoxic conditions, followed by introduction of air (oxygen), there is the highest odor generation potential.

- In-plant Clarifiers - Cover the entire surface of the two in-plant clarifiers and scrub the foul air. Note that due to the diameter of the clarifiers, use of a dome type cover, which increases the air volume to be scrubbed, is required.

- Conditioning Tank – Cover the tank, and scrub foul air. Note that the 16' width of the tank allows for use a flat cover, which minimizes the volume of air to be scrubbed.

- Solids Handling Building - Scrub foul air from the press/centrifuge room and truck loading area in the Solids Handling Building.

As noted previously, wet chemical scrubbing is the recommended odor control technology for the majority of the foul air generated on-site. To ensure satisfactory odor removal, two stage scrubbers, with ten feet of packing depth are recommended for all scrubber facilities. Since wet chemical scrubbers require scrubber towers with recirculation pumps, fans, chemical storage tanks for sodium hypochlorite and sodium hydroxide, containment, and a building for chemical metering pumps, the most cost effective means of providing scrubbing at a plant is often to centralize scrubbing operations. Given the natural divide in the Moores Creek WWTP created by the creek, the need for at least two scrubber facilities, one on the north side, for solids handling related facilities and one for the south side, for the liquid treatment facilities is evident. Therefore, two scrubber facilities are required for Option 3. The facilities served by each scrubber are listed below:

Scrubber 1 serves:

- Septage Receiving Station
- Moores Creek Influent Pump Station
- Conditioning Tank
- In-plant clarifiers
- Solids Handling Building

Scrubber 2 serves:

- Gravity Thickeners – launders only
- Primary Clarifiers – launders and scum/grease pit only
- Aeration Basins – anaerobic, anoxic and first two aerobic stages

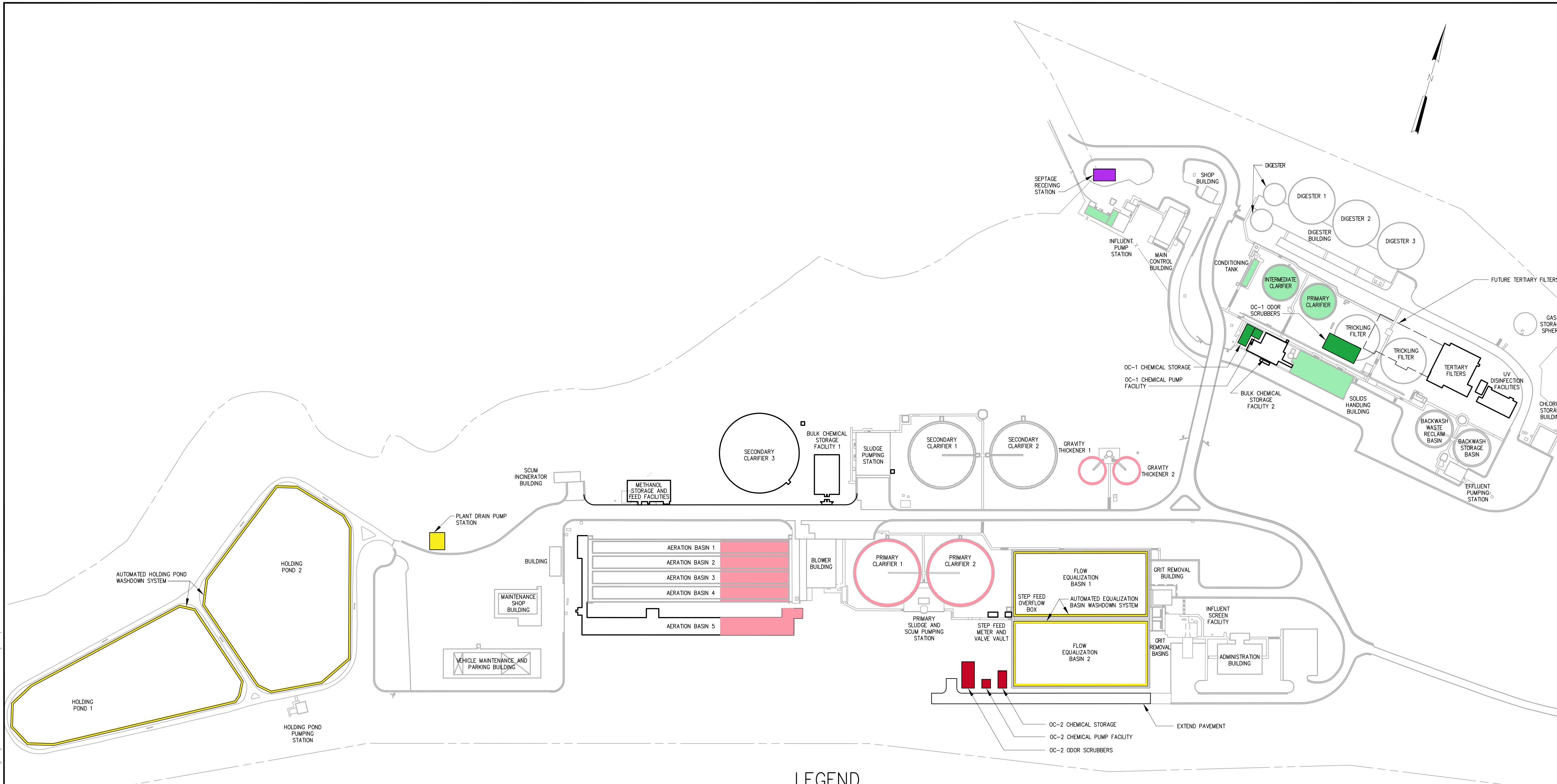
The air flow treated by each scrubber and the recommended scrubber diameter is included in Table 4-6.

Table 4-6

Characteristics of Scrubbers Recommended for Option 3 (95% Odor Removal)

Scrubber No.	Total Air Flow (cfm)	Number of Two Stage Scrubbers	Scrubber Diameter (ft)
1	39,900	1	12
2	20,000	1	9

The recommended site layout for Option 3 is shown in Figure 4-3. Capital, O&M and life cycle costs for Option 3 have been developed and are presented in Table 4-3 above.



LEGEND

- NEW NUTRIENT REMOVAL FACILITIES
- ODOR CONTROL SYSTEM 1 FACILITIES
- ODOR CONTROL SYSTEM 2 FACILITIES
- NEW FACILITIES TO IMPLEMENT BMPs
- SEPTAGE RECEIVING STATION

1"=200'-0"

200 100 0 200'

MOORES CREEK WWTP
ODOR CONTROL EVALUATION

OPTION 3
95% REMOVAL

HAZEN AND SAWYER
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4.5 Recommendations for Phasing

Recognizing that the costs for implementation of a comprehensive odor control plan are significant, and that RWSA has already committed to significant expenditures to meet the nutrient removal requirements, prioritization of odor control improvements is warranted. The goal of the phased approach recommended below is to provide a plan whereby odor detection off site is reduced as quickly as possible, and the largest return on investment, in terms of elimination of odors detected off-site for the funds expended, is achieved. Assignments of improvements to an implementation phase are based largely on the prioritization developed and presented in Section 2.7, combined with the strategic goals of: (1) implementing lower cost BMPs as a first step where possible, so as to maximize the odor reduction achieved for the available funding, and (2) giving priority to implementing odor control at areas where the installation of the associated scrubber will be required for an earlier phase. The elements included in each phase are described below and the phased implementation costs are included in Table 4-7. Figure 4-4 shows the phased implementation plan.

Phase I

- Construct the required capital improvements and then implement the modified BMP strategies for the equalization basins and holding ponds as described above under Option 3. This will require construction of two automated washdown systems, upgrades to the non-potable water system, a new plant drain pump station, the bypass around the equalization basins and modifications to the bypass to the holding ponds.
- Construct the separate septage receiving station and cease septage receiving at the influent pumping station. Scrub foul air from the septage receiving station.
- Cover the channels, aerated grit basins and wet well associated with the influent pumping station. Scrub foul air from the influent pumping station.
- Cover the conditioning tank and in-plant clarifiers and scrub the foul air.
- Construct odor control facility 1 and provide for scrubbing of foul air from the influent pumping station, the septage receiving station, the conditioning tank, the in-plant clarifiers and the solids handling building.
- Continue practicing BMPs for screening and grit facilities, which includes frequent dumpster changeout and use of odor masking agents.

Phase 2

- Cover the primary clarifier launders and scrub the foul air. Also scrub the foul air from the primary clarifier scum/grease pit.
- Cover the gravity thickener launders and scrub the foul air.

- Enclose the grit and screenings facilities and cover all associated channels and grit removal basins. The screenings facility enclosure would include the screens, compaction equipment and roll-off container. The grit enclosure would include the cyclones, classifiers and dumpster. Note that implementation of this element of Phase 2 should be coordinated with future expansion and projects at the Moores Creek WWTP. Specifically, the grit facilities will need to be replaced for the 20 mgd expansion and the screenings facilities may need to be expanded based upon the future peak flow determined in the ongoing wet-weather stub being conducted by others. Implementation of these upgrades will significantly increase the facilities required to provide enclosure of the grit and screenings unit processes. For the purpose of determining the estimated cost of phased approach, it is assumed that the existing facilities will be enclosed and scrubbed.
- Construct one 12' diameter two-stage scrubber and the required chemical storage and pumping building associated with Odor Control Facility-2 as described for Options 1 and 2 above. One 12' diameter scrubber will be oversized for treatment of the foul air collected under phase 2, but will facilitate modular expansion as recommended in subsequent phases.

Phase 3

- If odor complaints continue, cover the initial stages of the aeration basins, including the anaerobic, anoxic and first two aerobic stages and scrub the foul air. Construction of additional scrubber volume will not be required as the single 12' scrubber installed under phase 2 had sufficient capacity to treat the foul air generated under Phase 3.

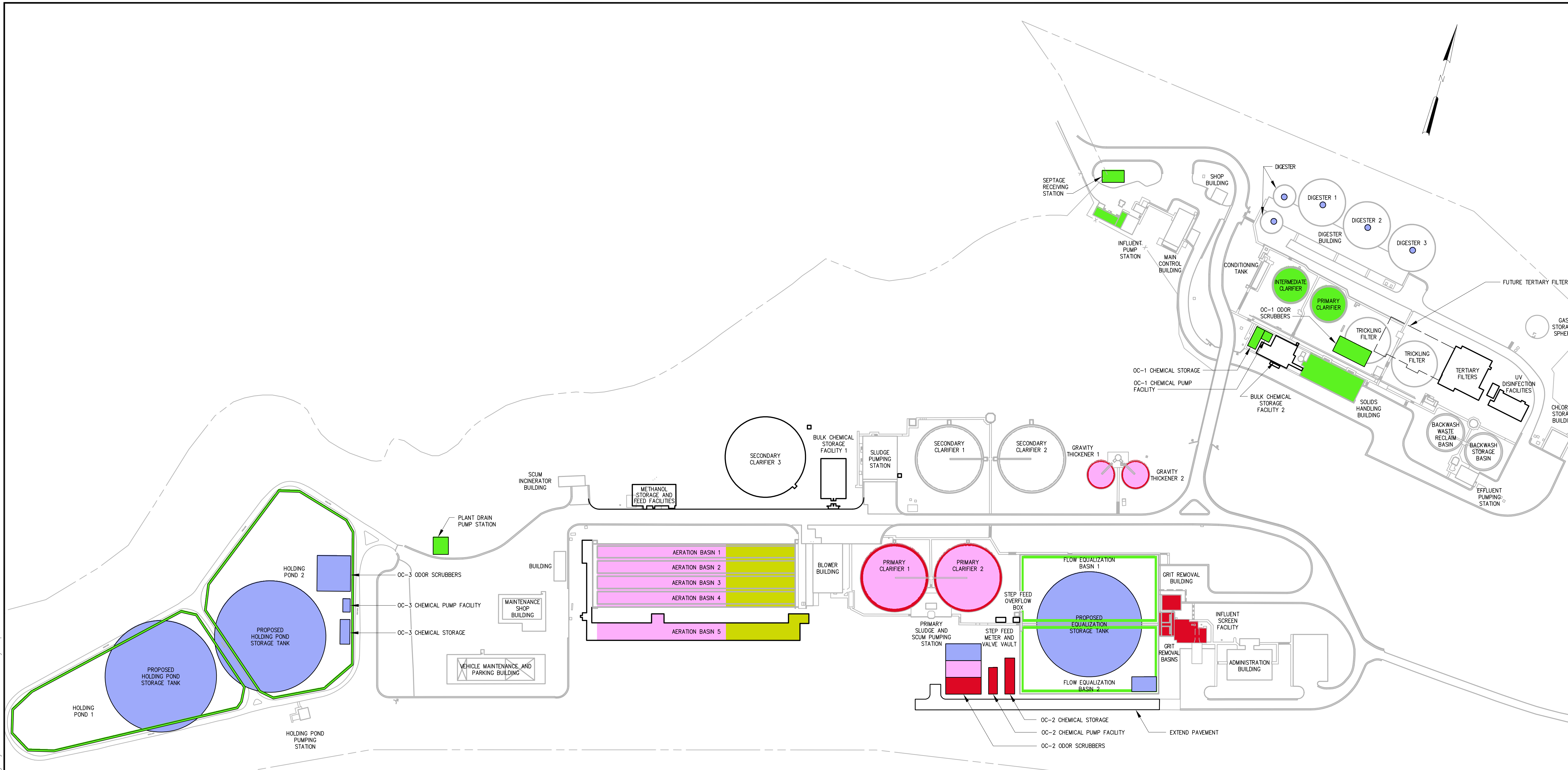
Phase 4

- Cover the entire surface of the primary clarifiers and scrub the foul air.
- Cover the entire surface of the gravity thickeners and scrub the foul air.
- Construct the second 12' diameter two-stage scrubber at Odor Control Facility 2.

Phase 5

- Decommission the equalization basins and construct a prestressed concrete storage tank. Note that this will require decommissioning of the automated washdown system constructed in Phase 1. Scrub foul air from the headspace in the tank.
- Construct the third 12' diameter scrubber at Odor Control Facility 2.
- Decommission the holding ponds and construct two prestressed concrete storage tanks. Note that this will require decommissioning of the automated washdown system constructed in Phase 1. Scrub foul air from the headspace in the tanks
- Construct Odor Control Facility 3 as described previously for treatment Option 1.
- Provide ductwork to connect digester PRVs to Odor Control Facility 1.

FIGURE 4-4



LEGEND

(line)	NEW NUTRIENT REMOVAL FACILITIES
(green)	PHASE 1
(red)	PHASE 2
(yellow-green)	PHASE 3
(pink)	PHASE 4
(blue)	PHASE 5

200 100 0 200'

1"=200'-0"

MOORES CREEK WWTP
ODOR CONTROL EVALUATION

PHASED IMPLEMENTATION PLAN

HAZEN AND SAWYER
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Table 4-7

Costs for Phased Implementation of Odor Control

Phase	Capital Cost[1] [2]
1	$5,963,000
2	$4,429,000
3	$3,012,000
4	$2,730,000
5	$17,609,000
Total	$33,743,000[3]

Notes: [1] Includes 30% contingency
[2] Estimated in November 2007 dollars, ENR CCI index = 8092.
[3] The total cost of the phased implementation plan exceeds that of Option 1 (99.7% removal) because the phased approach requires capital expenditures under Phase I for washdown systems at the Holding Ponds and Equalization Basins that would no longer be needed if Phase 5 is implemented to provide enclosed storage tanks with active odor control for these functions. If Option 1 were implemented in a single phase, the enclosed storage tanks with active odor control would be built up-front for the Holding Ponds and Equalization Basin functions, so the washdown systems would not be needed or built.

Implementation of the phased approach to providing odor control is recommended. Specifically, implementation of Phase 1 is recommended. Following completion of construction of the Phase 1 improvements, the impacts on odor reduction should be observed prior to entering the planning phase for implementation of Phase 2. This approach should be followed prior to implementation of each subsequent phase.

4.6 Additional Considerations

4.6.1 Operations at the Moores Creek WWTP

The ultimate goal of construction of odor control facilities will be to reduce the migration of detectable odors beyond the plant boundary. However, the implementation of constructed odor control will not only have capital and O&M cost implications, but will also have implications for the operation and maintenance of the Moores Creek WWTP. Specifically, up to three additional chemical storage and feed facilities will be required. This will result in transport of more chemicals (sodium hydroxide and sodium hypochlorite) to the plant. Additional operator and maintenance efforts will be required to control and maintain the odor control facilities and to provide washdown of the holding ponds and equalization basins. Up to one additional staff position could be required to address these additional duties; however, the additional responsibilities should be coordinated with the increased staffing requirements for operation and maintenance of the nutrient removal upgrades. Implementation of the BMPs in the holding ponds and equalization basins will also add additional load, as a recycle stream to the treatment process.

4.6.2 Construction of Odor Control Facilities

Given the magnitude of the upcoming nutrient removal project, RWSA will have the opportunity to include odor control facilities construction with the nutrient removal upgrades in the same construction package. Doing so will take advantage of economies of scale in construction and will reduce conflicts potentially caused by having multiple contractors on-site concurrently. Threrefore, inclusion of the Phase 1 elements of odor control in the nutrient removal upgrade project is recommended.

Appendix A

Sampling Location Characteristics

Table A-1

Sampling Location Characteristics

	Sample Location	Number	Dimensions	Surface Area (ft^2) Each	Total Area (ft^2)	Air Flow
1	Flow Equalization Tank (with floating type mechanical aerators)	2 (typically, only one unit in operation)	280' L x 140' W x (8.2'-14.2') D	39,200	78,400	motors= 60 hp 162 lb O_2/hr (high motor speed) 72 lb O_2/hr (low motor speed)
2	Primary Clarifier- Weir	2	130' Dia. (SWD= 8')	13,270	26,540	N/A
3	Primary Clarifier- Quiescent	2	130' Dia. (SWD= 8')	13,270	26,540	N/A
4	Influent Pumping Station- Bar Screen	1	8'-10' x 4'-7" W x 4.6' D	40	40	10 air diffusers in grit chamber at 8 CFM each (1)
5	Gravity Thickener	2 (only one unit in operation, 2nd unit is never in service)	52' Dia. (SWD= 10')	2,123	4,245	N/A
6	Conditioning Tank	1	58.5' L x 18' W x 10.5' SWD	1,053	1,053	
7	In-Plant Clarifier	2	70' Diam. (SWD= 6')	3,847	7,693	N/A
8	Grit Basin	2	23' L x 20' W x 15' D	460	920	5500-6000 CFM

Notes:

(1) See attached diagram for further description of the influent pump station

SWD =Sidewater Depth

The only plug flow occurred in the activated sludge aeration basins, which were not sampled.

Rivanna Water and Sewer Authority
Moores Creek Wastewater Treatment Plant

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