



Tillamook County
PUBLIC WORKS DEPARTMENT
Department of Solid Waste
Waste Prevention and Recycling



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Land of Cheese, Trees and Ocean Breeze

July 7, 2021

TO: Solid Waste Advisory Committee

Prof. Jeffery Nason (OSU School of Chemical, Biological and Environmental Engineering) used our closed landfill challenge as the topic for his class of graduating engineering students. Five groups of students attempted to present a solution for cleaning our leachate of its two primary contaminants (iron and ammonia), first in a trial and then a full-scale plan.

Each of the teams prepared a "poster" for the Engineering Expo, as well as a summary video, in addition to their capstone papers. I am providing you with a list of links for their videos, and their posters follow this memo. Following all this is a summary table put together by Rick Malin, our consultant at Parametrix, who acted as a consulting expert for the students during this project.

I hope that you will take the time to watch the videos, read the posters, so that we can discuss the various proposals at our SWAC meeting.

If we wish, Professor Nason is willing to attend our September SWAC meeting and discuss further.

Team #1 video: <https://youtu.be/m8e6nTODuxk>

Team #2 video: <https://www.youtube.com/watch?v=75WX04oJ53I&t=4s>

Team #3 video: <https://youtu.be/ySk4ejGEOLl>

Team #4 video: <https://www.youtube.com/watch?v=oa4AAYq9gCk>

Team #5 video: (Sorry, I couldn't get a link for this one, and the file is quite large.)

Problem Statement

The Tillamook County Public Works Department (TCSW) is requesting a long-term, sustainable solution to treat 10-15 million gallons per year of dilute leachate from the Tillamook Closed Landfill (TCL). The solution should be able to treat excess ammonia and iron from the leachate to acceptable limits so that it may safely be discharged to a vegetated swale where it will eventually reach the Tillamook River. TCSW requests that the treatment process be low-maintenance, require little energy or chemical inputs, and need infrequent monitoring.

Project Significance

The leachate produced by the Tillamook Closed Landfill drains into Beaver Creek and is ultimately discharged into the Tillamook River. High concentrations of nitrogen within rivers will cause eutrophication, promote harmful algal bloom growth, and threaten aquatic life. Water from rivers containing high levels of iron will have an unpalatable rusty taste, odor, and color, and potentially clog pipes over time. To provide a safe and healthy environment for the local ecosystem, treating leachate before being discharged is necessary. This is an issue that many industries, including agricultural and municipal, have struggled with for decades, making the design of low-maintenance, low-cost solutions which minimize land requirements crucial.

Design of an Ammonia and Iron Removal Water Treatment System

A proposal for a treatment train which will be able to handle and treat leachate from the Tillamook Closed Landfill in Tillamook County.

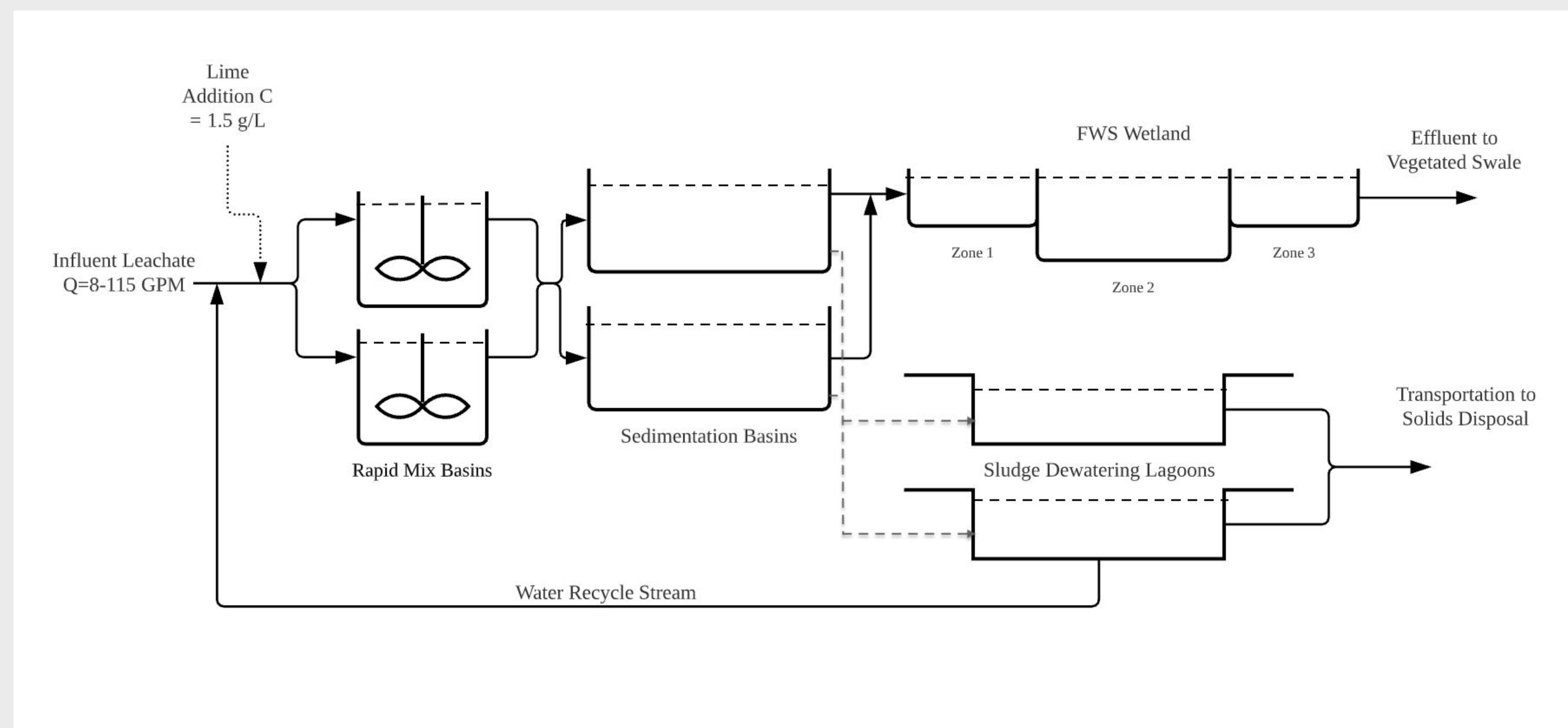


Figure: Process flow diagram showing arrangement of the unit operations in the proposed design: rapid mix basins, sedimentation basins, a FWS wetland, and sludge dewatering lagoons. Leachate and solids levels in each unit are shown as dashed lines, chemical additives as dotted arrows, and leachate pipelines as solid arrows. Grey dashed arrows leading to the dewatering lagoons represent sediment sludge flow.

Methodology

The full-scale flow was chosen as 113-115 GPM to reflect the maximum flow that the system would receive at the TCL (the pilot-scale was reduced to 8 GPM). The lime addition pond was designed as a continuous stirred-tank reactor (CSTR) at steady-state. The concentration of lime added to the mixer was determined by its solubility limit of 1.5g/L. The effect of hydrogen ions produced by ferrous oxidation (Eqn.1), leachate alkalinity, and pH changes from the lime addition were considered in the flow rate calculation for lime addition.



A material balance of ferrous iron determined the volume of the pond. Design criteria for vertical turbine flocculators, and power and pumping numbers for common impellers determined pond dimensions and impeller design. The sedimentation basin was designed for type II settling. Flow through the basin was determined

to be laminar because of its low Reynolds number. Basin dimensions were determined by calculating the critical settling velocity of particles. A free water-surface (FWS) wetland was chosen to treat ammonia levels via nitrification and subsequent nitrification. Temperature-dependent areal rate constants were calculated using site monitoring data data, then used to determine the wetland area which would be required to reach an effluent quality of 2.5mg ammonia per liter via the k-C* model presented by Kadlec and Knight (1996). The sludge dewatering lagoons, used in a batch cycle manner, were designed to have fill, settle, and decant stages. One lagoon would be filled for six months and left to dewater the sludge via gravity settling for another six months as the 2nd lagoon enters the fill stage. The supernatant layer would be decanted post-settling and directed back to the beginning of the treatment system, as dewatered solids would be disposed of off-site.

Design Description

- **Lime addition pond:** Two 3m x 3m x 3m basins were included for maintenance redundancy. The basins would receive an aqueous solution of 3.0 grams of lime per liter at 1.3 GPM. One pitched-blade turbine was included in each, with a diameter of 1m and speed of 20 rpm.
- **Sedimentation basin:** Following the rapid mix basin, two 10.1m x 2.0m x 5.0m sedimentation basins were included.
- **FWS Wetland:** A wetland with three zones and a total surface area of 6.8 acres would accept effluent from the sedimentation basins. Zones 1 and 3 would be fully vegetated with *Scirpus californicus* and *Typha latifolia*, and have dimensions of 185.0m x 37.0m x 0.75m. Zone 2 would have an open-water surface and dimensions of 262.0m x 52.0m x 3.0m.
- **Sludge Dewatering Lagoons:** Two lagoons, each with an area of 7m² and depth of 1.5 meters, would accept solids from the sedimentation basin for dewatering. The 6-month filling periods would be January-June for Lagoon 1, and July-December for Lagoon 2.

Conclusions

- A low-cost, low-maintenance treatment system capable of treating the TCL leachate to acceptable iron and ammonia levels was completed.
- Areal site restrictions (0.8 and 0.1 acres for the full-scale and pilot-scale, respectively) were exceeded in the final full-scale and pilot-scale designs. The unit operation which contributed to this the most by far was the FWS wetland, suggesting that the use of another method to reduce ammonia should be explored in the future.
- It is suggested that methods to handle the excess flow during winter months be implemented, i.e. via flow equalization, as this would lower the areal requirements significantly.
- A more conclusive design evaluation would be able to be given after pilot-scale testing, which would determine whether the models used for the design were accurate.

Motivation and Significance

10 - 15 million gallons of leachate flow from the Tillamook Closed Landfill (TCL) every year. The leachate is currently pumped to a field and disposed of via spray irrigation. This land application system is not a sustainable long-term solution. A treatment system with promising methods that enables direct discharge of leachate will be tested during the summer.

Methodology and Design Approach

Iron

- Aeration increases the dissolved oxygen available to oxidize the iron.
- Increasing the pH with lime will allow faster oxidation of the iron.

$$[Fe(II)] = [Fe(II)]_0 \exp(k[OH^{-1}]^2 K_H C_{O_2} t)$$

- Oxidized iron will be captured with a sedimentation basin.
- Allowing adequate time for sedimentation and oxidation to occur is critical to capturing all reacted iron.

Ammonia

- Nitrification is the targeted process for ammonia removal.
- Wetland nitrification rates are influenced by temperature, dissolved oxygen and contaminant concentrations, retention time, etc.
- Kinetic and volumetric models were used for wetland design and removal estimates.
- EPA wetland design guidelines were utilized.

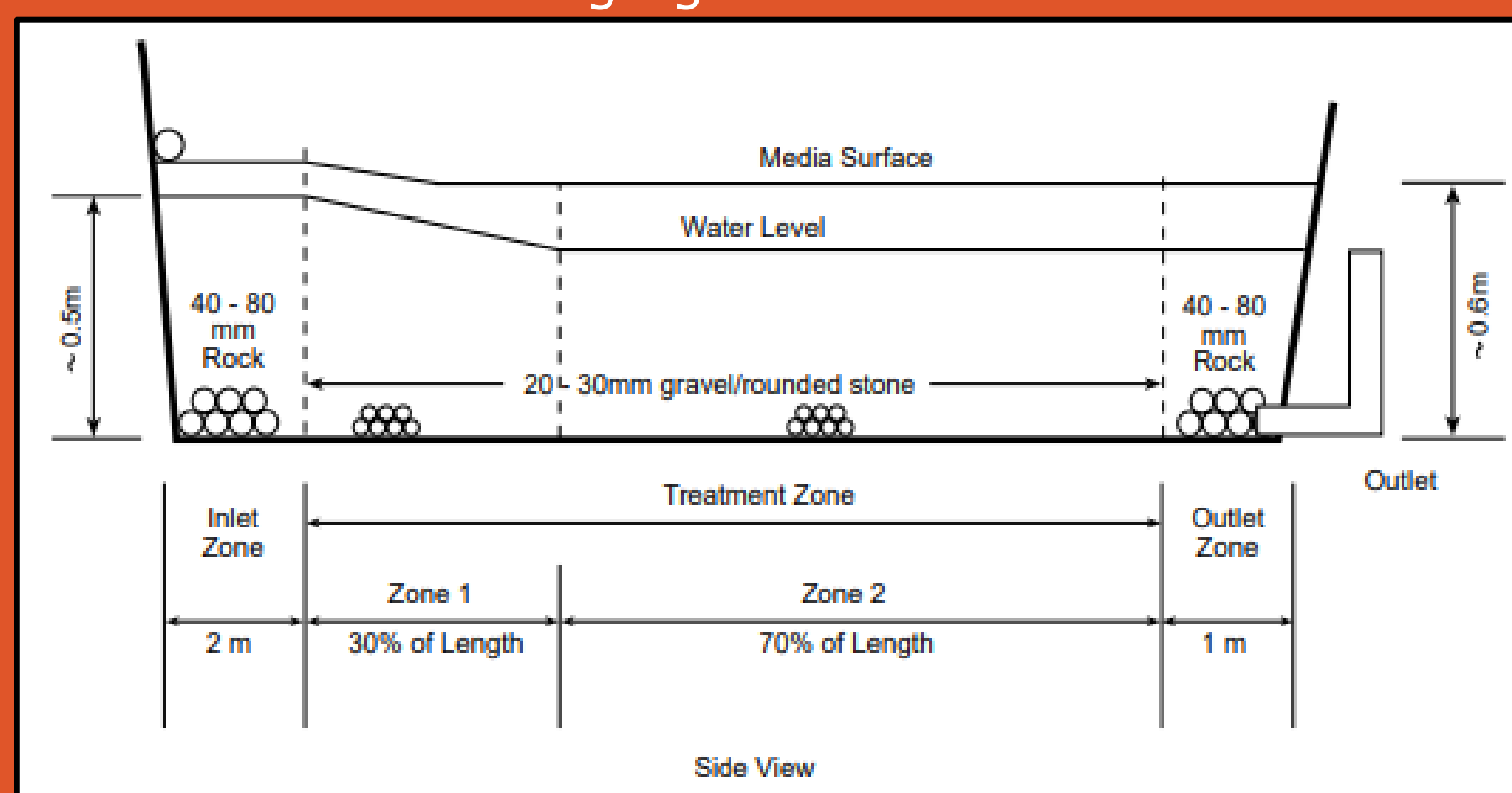


Figure 3. Design example of a HSSF wetland.

Landfill Leachate Treatment

The TCL requires development of a pilot-scale system targeting the removal of iron and ammonia is required to investigate treatment processes that allow for direct discharge of leachate from the landfill.



Figure 1. Site area available for a leachate treatment system at the landfill.

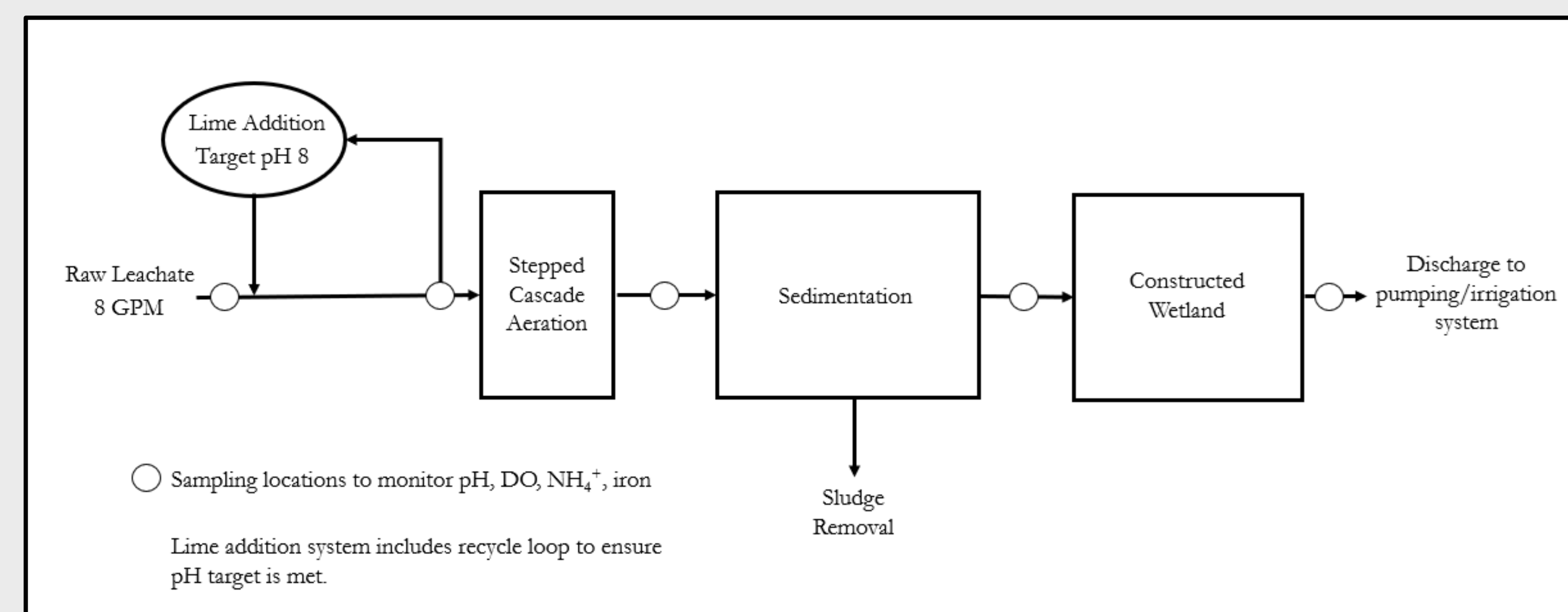


Figure 2. Process flow diagram of pilot-scale design.

Design Description

Cascade Aeration

A stepped cascade aerator is used to increase the dissolved oxygen content in the leachate.

Chemical pH Change

Chemical pH adjustment is achieved with lime dosing to reach a target pH of 8 and increase the rate of iron oxidation.

Sedimentation

A sedimentation basin facilitates iron removal via precipitation and settling.

HSSF Wetland

A horizontal subsurface flow wetland targets the removal of ammonia from the leachate prior to discharge.



Figure 4. Iron build up inside of previously tested treatment system.

Conclusion and Future Work Considerations

Ammonia

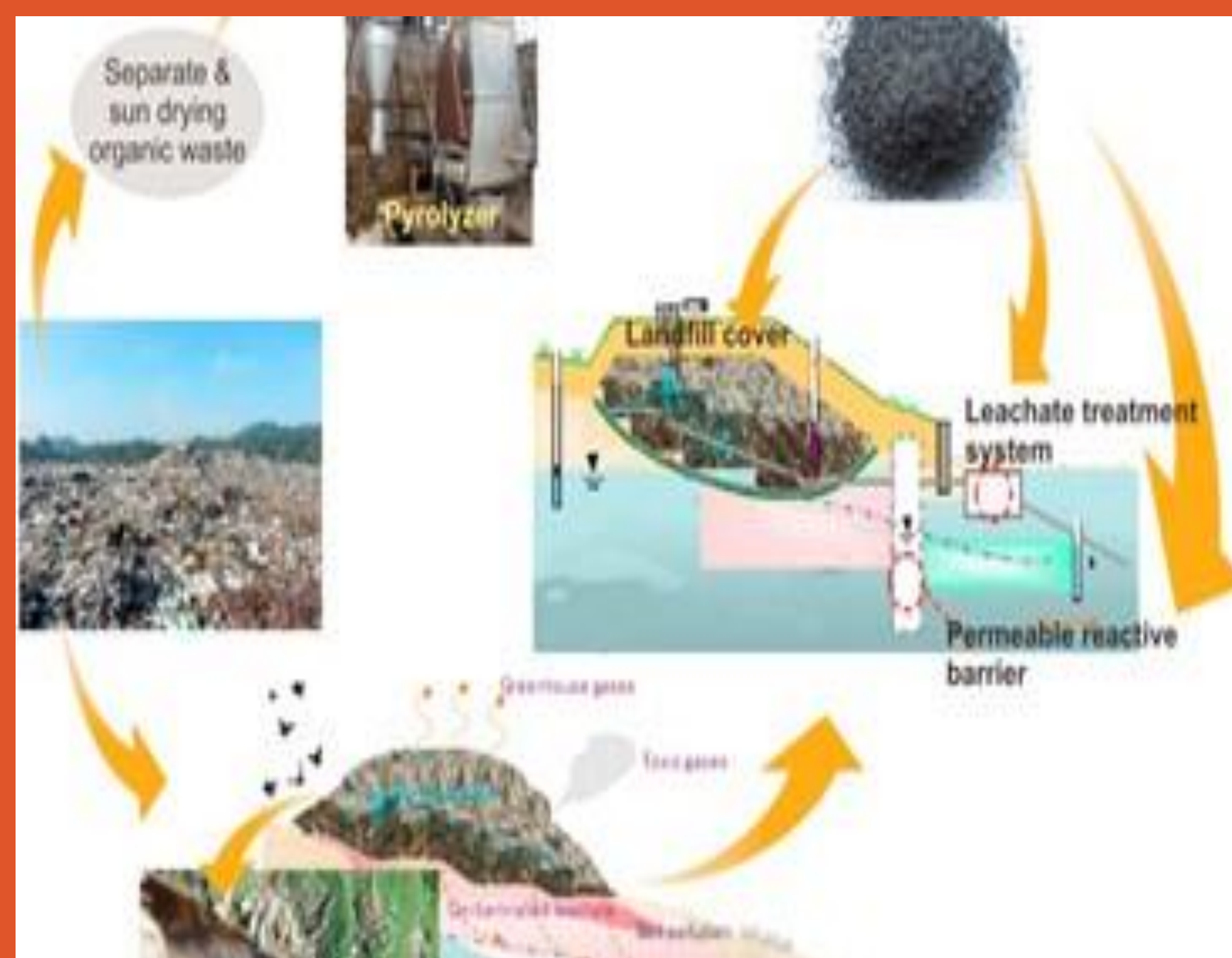
- The required full-scale wetland area is too large for the land available at the landfill
- A pilot-scale wetland could be used to more accurately determine the nitrification rate of ammonia
- A higher than predicted nitrification rate would reduce the land requirement

Iron

- Cascade aeration is predicted to sufficiently aerate the leachate
- Iron settling velocities are too slow, resulting in a required sedimentation basin volume that is too large.
- Polymer coagulation instead of chemical pH change will be investigated

BACKGROUND

- **How is leachate formed?**
 - Leachate is mostly formed from the process of biodecay of organic material, chemical oxidation of waste materials, escape of gas from landfill...etc. Those various formation process lead high concentration of ammonia, organic compounds, heavy metals and inorganic compounds.
- **Why do people need to treat leachate?**
 - Contaminated leachate can impact human health, soil composition, ground water and surface water quality.
 - Some general health problems caused by consuming leachate contaminated water are acute toxic allergies, respiratory disease, infection disease, blood disorders and cancer effects.
 - The heavy metals, degradable and non-degradable pollutants in leachate will affect soil strength and stability by the process of percolation.
 - The pollutants in leachate such as ammonia chloride, heavy metals and sodium will disseminate to surface and ground water and leave water undrinkable.



TREATMENT OF THE TILLAMOOK CLOSED LANDFILL LEACHATE

MELISSA COPPINI, ISAC CUSTER, NATALIE DUPUY, FUYUE TIAN

Problem Statement: Iron and ammonia concentrations present in leachate from Tillamook Closed Landfill are too high to discharge offsite and must be treated to below permit limits before release. Additionally, treatment system should be as passive as possible and require minimal chemical addition.

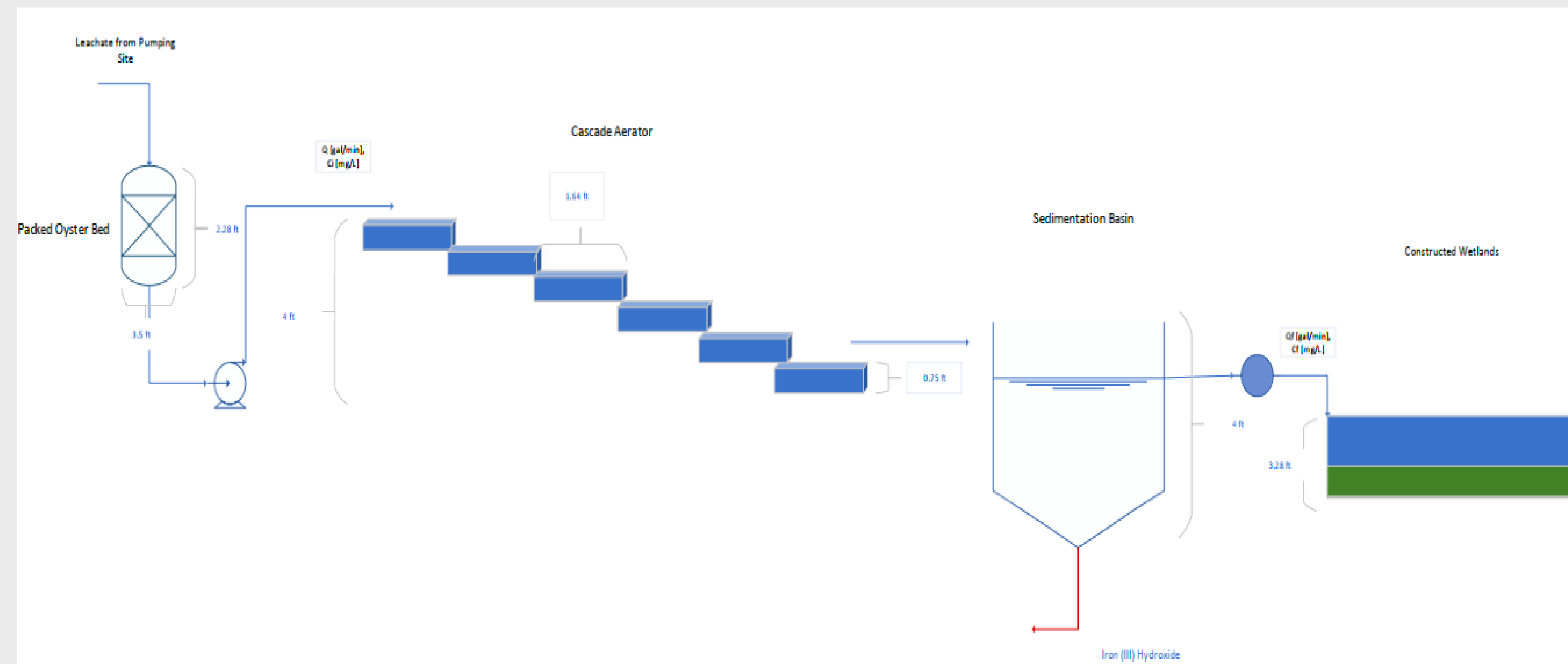


Figure 1: process flow diagram for pilot scale design

METHODOLOGY & APPROACH

The criteria for our design included high removal efficiency, limited chemical additives, passive or near-passive system, and ability to operate during high and low flows.

The team force-ranked these criteria and compared the values of four different alternatives for iron and ammonia treatment. The highest ranked methods were the ones we implemented in our design: Oyster shell packed bed, Cascade aerator with sedimentation basin, and vertical flow wetlands.

Advantages VS Disadvantages Of Approaches

- Oyster Shells Packed Bed
 - low cost for material sources/low land cover usage/low energy consumption/great design feasibility/pH adjustment
 - high maintenance requirement

- Cascade Aeration & Sedimentation
 - high iron removal efficiency/natural process/ low maintenance/inexpensive operation
 - odor emission to environment/high land usage/high cost for construction
- Vertical Flow Wetland
 - natural passive system/low maintenance/low-cost operation/high ammonia removal efficiency/tolerant different temperature/various loading rate
 - large land usage/high energy consumption of pumps implementation

DESIGN ELEMENTS

- Once leachate is collected, it is pumped up to an oyster shell packed bed for pH increase
- Once the pH has been increased to 9, the leachate is sent to a cascade aerator to oxygenate it and encourage iron floc formation
- The oxygenated leachate is then sent to a settling basin to allow the iron precipitate floc to leave the leachate
- Once settled, the semi-treated leachate is sent to a vertical flow wetland system to nitrify the ammonia present in the leachate
- The resulting treated leachate is released to a vegetated swale on the edge of the landfill property

FUTURE WORK

The next steps in our design process include:

- Refining hydraulics analysis for full treatment train
- Scaling up pilot design to full scale operation
- Complete cost analysis for pilot and full-scale design
- Lifecycle and sustainability assessment for the full-scale design

REFERENCES & ACKNOWLEDGEMENTS

- Thank you to Tillamook County Department of Solid Waste Prevention and Recycling for giving us this project!
- Additional thanks to Parametrix for sharing their expertise and initial pilot data with our team!



BACKGROUND

The Tillamook Closed Landfill (TCL) has seen the accumulation of dilute, low-strength leachate from spring water and stormwater intrusions. Due to detection of high iron and ammonia concentrations, the county has requested the development of a long-term treatment solution that is hydraulically capable of discharge onto a one-acre vegetated swale located below the landfill.

Specific objectives include meeting area constraints as well as anticipated permit requirements, as seen in Table 1. Both a pilot and full-scale implementation of the selected processes will be investigated. Approximately 0.8 acres are available for full-scale construction with an additional 0.1 acres for a pilot study. Maintaining system passivity is a key design priority.

Table 1. Anticipated permit effluent limits.

Constituent	Daily Maximum	Monthly Avg.
Total Recoverable Iron	1.6 mg/L	0.95 mg/L
Total Ammonia	5.3 mg/L	3.0 mg/L
pH	6.5-8.5	
TSS	< 100 mg/L	

PROCESS SELECTION

ALTERNATIVES ANALYSIS

Iron and ammonia removal methods were evaluated using a quantitative rating scale based on the following criteria, with higher associated weights defining relative importance:

- **Primary** (~15%): size, permit limits
- **Secondary** (~10%): maintenance, cost, energy, chemical, and operational requirements
- **Tertiary** (1-5%): aesthetics, local resources, safety, scaling capability

Table 2. Summary of process alternative scores.

Iron Removal Processes	Score	Ammonia Removal Processes	Score
Aeration/Flocculation/Filtration	3.83	FWS Wetlands	3.76
Electrocoagulation	3.4	Sequencing Batch Reactor	3.72
Vertical Flow Reactor	3.53	Rotating Biological Contactor	3.76
HSSF Wetlands	3.82	Trickling Filters	3.82

FINAL DECISION: Aeration/sedimentation, trickling filters, and HSSF wetlands were selected for further investigation based on superior treatment passivity and ability to meet discharge & space requirements.



DESIGN OF A LEACHATE TREATMENT SYSTEM FOR IRON AND AMMONIA REMOVAL AT THE TILLAMOOK COUNTY CLOSED LANDFILL

The Goal: Design of a passive leachate treatment system to meet iron and ammonia effluent requirements at the Tillamook Landfill.

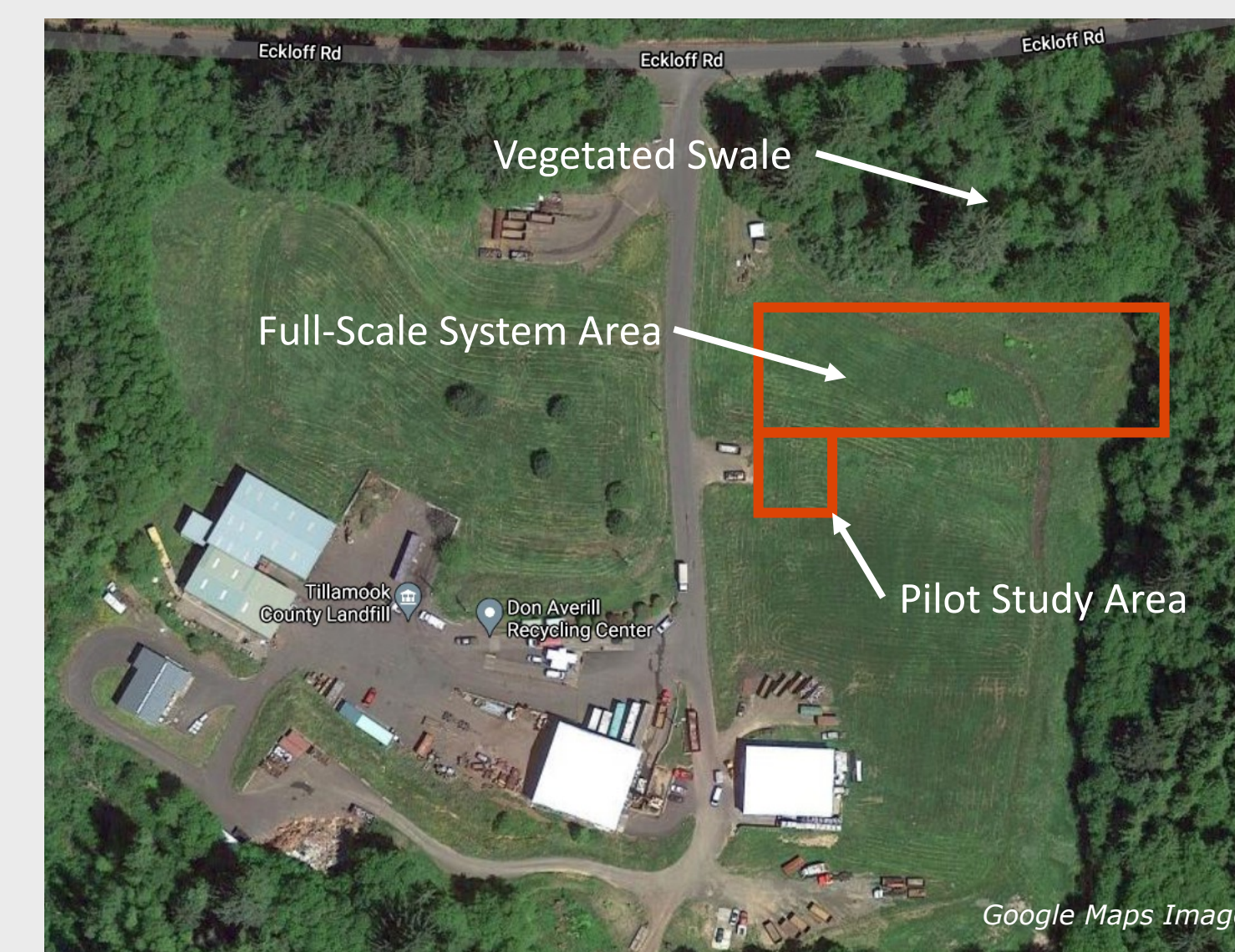


Image 1. Overhead view of the landfill, with the available space for the treatment system outlined.



Image 2. Abundant Tillamook wetlands allow access to emergent vegetation for constructed wetlands.



Image 3. Parametrix pilot study of cascade aeration, polymer flocculation, and settling experienced excess clogging and build-up from the iron precipitate.

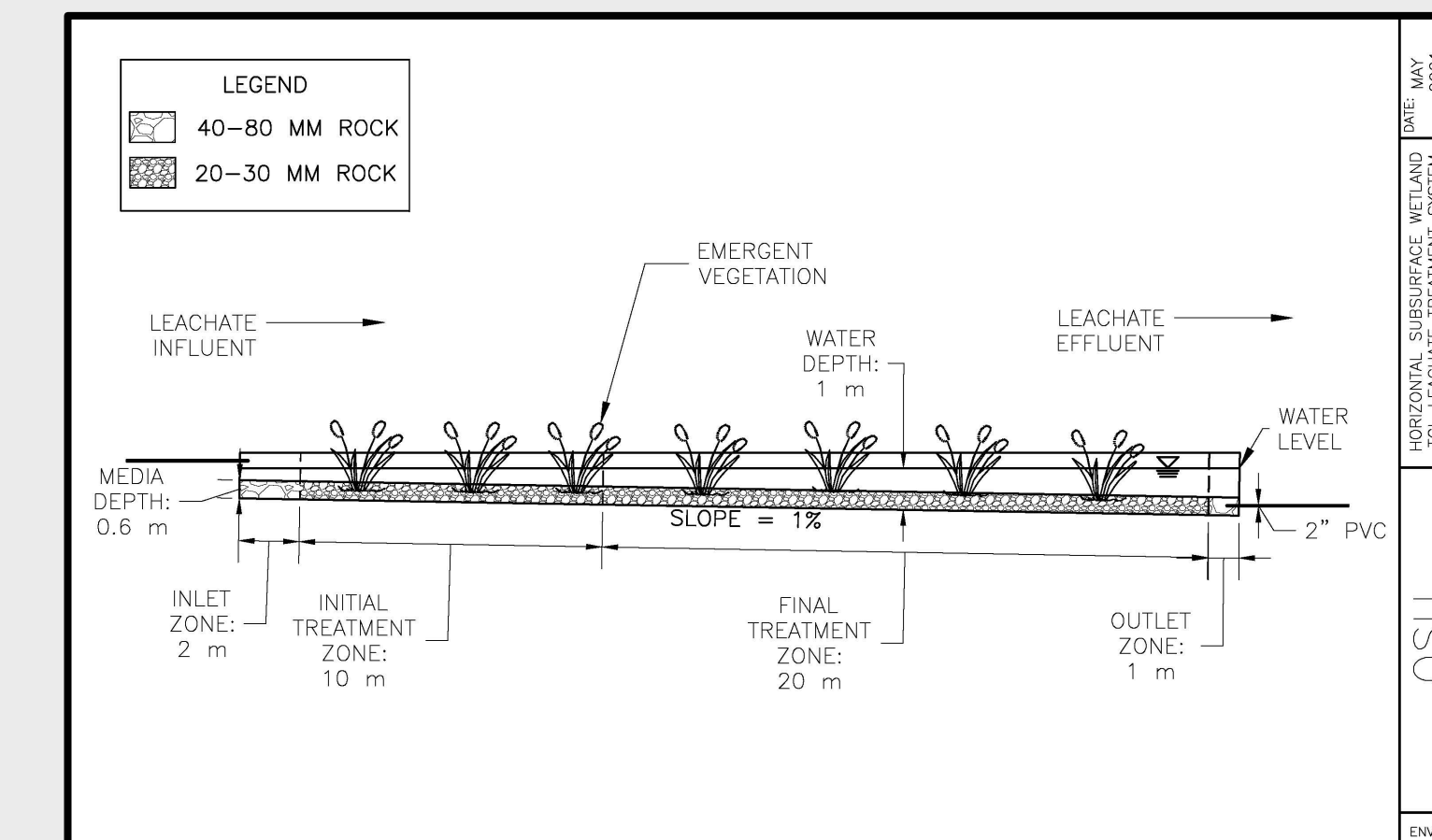


Figure 1. Design of a single horizontal subsurface flow wetland. Polishing step for iron and ammonia removal.

DESIGN METHODOLOGY

THE APPROACH

A performance-based process sizing approach used historical data to select raw leachate parameters:

- Max flow: 80 gpm
- Min flow: 5 gpm
- Temp: 10°
- Influent pH: 7
- Max influent iron: 12 mg/L
- Max. influent NH₃: 13 mg/L

Conservatism was integrated into design by selecting high temp. adjustment factors, high flow rates, low temperatures, and low rate constants from ranges.

AERATION/SETTLING: IRON REMOVAL

Oxygen transfer principles and PIRAMID (2003) guidelines for passive pollutant removal from metalliferous AMD were used to model 3 processes:

1. Oxidic limestone drain (OLD) to increase leachate pH, promoting iron precipitation
2. Cascade aeration to encourage iron oxidation
3. Settling lagoon to remove iron precipitate

TRICKLING FILTERS: AMMONIA REMOVAL

Adapted from Tchobanoglous et al. (2003), the NRC method was used to model nitrification in for ammonia removal with plastic packing media. Loading rates determined filter area and bed volume.

HSSF WETLANDS: POLISHING STEP

Constituent removal processes were modeled by plug flow first-order reactions, based on standardized kinetic parameters from Kadlec & Knight's (1996) *k-C** model. Darcy's Law governed characteristic wetland width to prevent overland flow within initial and final treatment zones (30% and 70% of the active surface area, respectively).

HYDRAULIC CONSIDERATIONS

An optimal configuration provides sufficient hydraulic head to overcome energy losses from friction, valves, and fittings for direct discharge to the vegetated swale. Pipes were sized to maintain flow velocities of 1-3 m/s to prevent clogging.

DESCRIPTION OF DESIGN

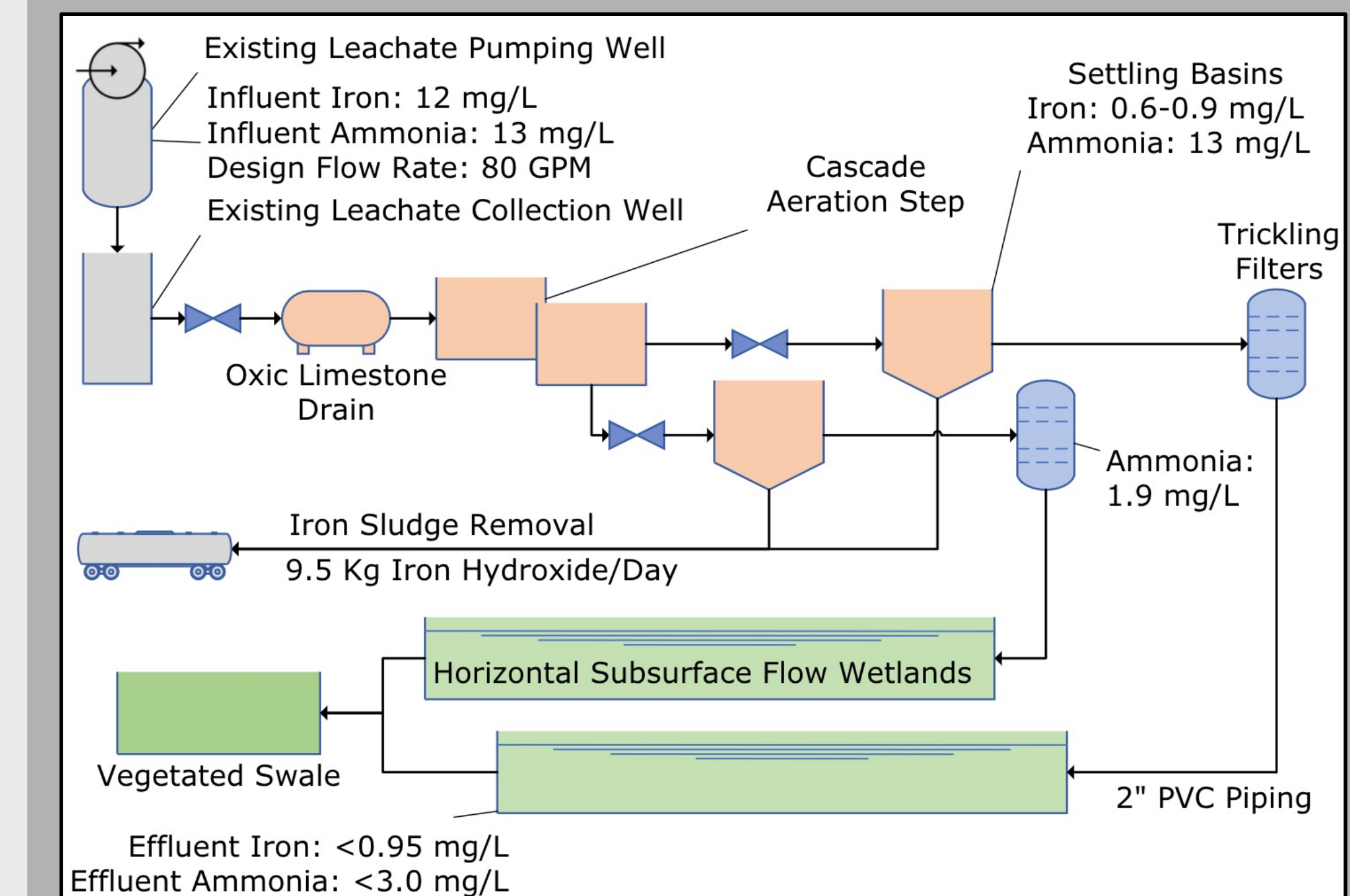


Figure 2. Full process flow diagram detailing chronological order of design elements, from influent to the collector well and discharge from wetlands.

Table 3: Design element purpose and sizing information

Design Element	Purpose	Dimensions
Oxic Limestone Drain	Alkalinity Generation	3 m x 1 m x 1 m
Cascade Aeration Step	Iron Oxidation	2 m x 1 m x 2 m
Settling Basin (2)	Iron Removal	Total Area - 500 m ² 25 m x 10 m x 1 m
Trickling Filter (2)	Ammonia Removal; Supply DO	Total Area - 84 m ² Diameter - 5.2 m Depth - 1 m
HSSF Wetlands (2)	Polishing	Total Area - 1500 m ² 30 m x 25 m x 1 m

CONCLUSIONS

The leachate treatment design is expected to meet iron & ammonia discharge limits and space constraint.

- Triangular trough in OLD design could prevent clogging
- Single-step cascade aeration system (0.8-m falling jet) provides aeration for 95% iron removal during settling
- Trickling filters sized to achieve ~86% nitrification, reducing effluent ammonia to 1.86 mg/L.
- Assuming 75% and 85% prior removal of ammonia and iron, monthly average limits are met for typical flows (10-30 gpm) and daily maximum limits are met for all flow rates through the 2 HSSF wetlands in parallel.

NEXT STEPS

Unit Process Considerations

- Hydraulic conductivity: limestone vs. crushed oysters
- Hydrolysis impacts on pH and iron removal efficiency
- Quantification of DO and carbon production by TFs to ensure ammonia removal in HSSF wetlands
- Analysis of bioconversion in the trickling filters
- Incorporate precipitation into wetland water balance

Overall System Consideration

- Finalize configuration of processes
- Hydraulic analysis to ensure gravity-driven flow:
 - Pipe lengths and associated major energy losses
 - Minor losses from fittings, valves, intake structures
- Design and layout of pilot study

ACKNOWLEDGEMENTS

Thank you to Dr. Jeff Nason for guidance and the Tillamook County Public Works Department for design input.

Please refer to attached document on project page for references.

Introduction

- Iron and ammonia concentrations in the leachate need to be reduced through passive treatments to meet permit limits to facilitate discharge into a vegetated swale.
- Constituent removal is important to ensure local water sources and aquatic systems remain unpolluted.
- Iron and ammonia reduction to below 0.95 mg/L and 3.0 mg/L, respectively.
- Key Constraints: area of 0.1 acres and seasonal flows ranging up to 100 GPM.

Methodology

- An alternatives analysis was conducted for iron and ammonia treatments to determine the project design.
- Decision matrices were used to rate and score alternatives based on team established criteria.

Table 1: Design Methodology

Design Element	Method
Aerator	Mass transfer and empirical formulas
Basin	Overflow rates
VFCW	Empirical formulas and loading rates



Pilot-Scale Design Proposal for Leachate Treatment at Tillamook Closed Landfill (TCL)

Capstone Team Members: Natalie Fowler, Chenxi Wu, Kamryn Smith

Advisor: Dr. Jeff Nason

Results

Iron removal:

- Stepped cascade aerator:
 - Mechanism of removal is oxidation and precipitation
 - Design increases dissolved oxygen (DO) concentration to promote oxidation
 - Aeration efficiency: 82.4%
- Sedimentation basin:
 - Removal of ferric hydroxide precipitates
 - Solids removal efficiency: 92.1%

Ammonia removal:

- Vertical flow constructed wetlands (VFCW)
 - Mechanism of removal is nitrification
 - Intermittent feeding for 6 hours
 - Ammonia removal efficiency: 97.1%

Full-scale consideration:

- Scale up flow rate of 100 GPM
- Design details:
 - 2 stepped cascade aerators
 - 2 sedimentation basins
 - 4 series of 4 wetland cells in parallel
- Area:
 - Project is limited to 0.8 acres
 - Design area requirement: 0.64 acres

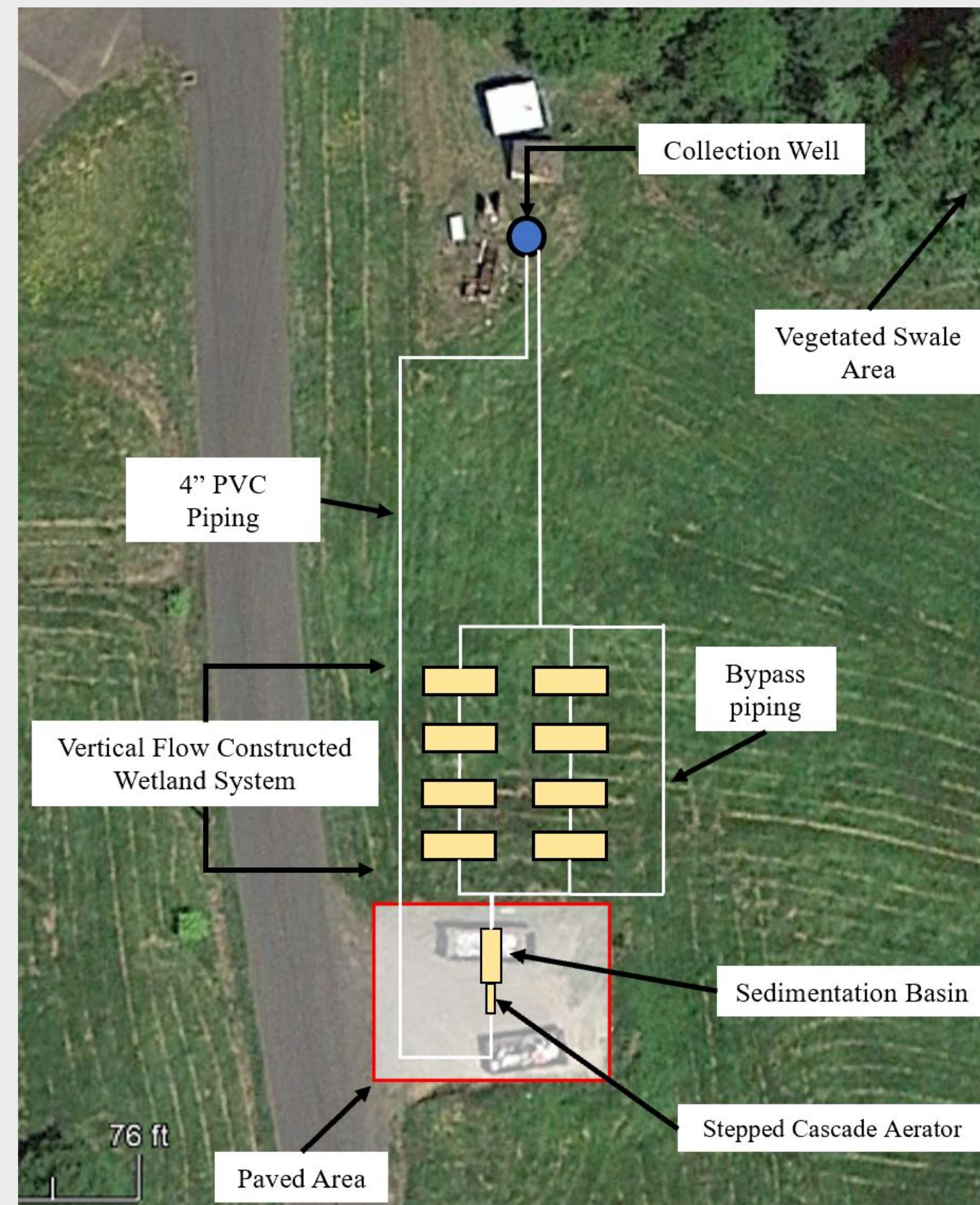


Figure 1: Pilot-scale on-site application

Pilot-scale consideration:

- Total required area is 0.0276 acres
- Effluent concentrations
 - Iron: 0.95 mg/L
 - Ammonia: 2.96 mg/L

Table 2: Design Specifications

Element	Length [ft]	Width [ft]	Height [ft]
Aerator	11.9	0.41	9.84
Basin	9.52	2.13	1.64
VFCW	25	5.9	2

Summary

The team developed a pilot-scale design that utilizes passive treatment methods for iron and ammonia removal. Both pilot and full scale designs are projected to fit within the allotted area. The team put an emphasis on developing a design that does not rely on chemical additives or continual energy use. The process consists of a stepped cascade aerator, sedimentation basin and VFCW system. This project is ongoing and is scheduled to conclude June 4th.

Future Works

- The engineering team will conduct a cost analysis and will consider the safety, regulatory and sustainability of the design.
- Head Losses through the wetland cells needs to be considered to ensure there are no system overflows.
- Pilot-scale assumptions need to be verified through pilot-scale testing.
- Data collection from pilot testing includes: iron, ammonia and DO concentrations, nitrification rate, and solids removal percentages.

Acknowledgements

- Special thanks to Dr. Jeff Nason for all the guidance on this project.
- Thanks to Rick Malin, TCL, and Parametrix for answering clarifying questions and providing preliminary data.

OSU Leachate Treatment System Design Comparisons - Pilot Scale
Tillamook County Landfill

Design Team Group #	Pilot System Assumed Flow Rate (gpm)	Treatment System Components - In order of application								
		pH Adjustment			Aeration		Sediment Basin		Constructed Wetland	
		Lime Dosing	Oyster Application	Description	Cascader	Description	Sediment Basin	Description	Type	Description
1	8	X		Lime is added to a concrete blade mixing basin. Auto lime dosing system used. Lime add rate is 1,500 mg/L.		Concrete blade mixing basin provides aeration.	X	Basin size: 6.16 ft long x 1.23 ft wide by 11.4 ft deep. 1 unit. Detention time not presented. Sludge formation rate = 1.73 Kg/day. Sludge dewater basin called out.	free water surface	Wetland consists of 3 zones (shallow & vege; deep & open; shallow & vege). Overall size: 223.4 ft long, 45.6 ft wide, and 1.7 - 6.8 ft deep. Estimated retention time is 55 days.
2	8	X		Packaged lime dosing system [Alar water treatment]. Lime add rate is 71.9 mg/L.	X	Cascader: 24.3 ft long by 1.64 ft wide by 9 ft high. 14 steps each 1.74 ft long with 0.48 foot drop.	X	Basin size: 13.6 ft long x 3.42 ft wide by 3.69 ft deep. 1 unit. Identified detention time is 8 hours. Sludge formation rate = 0.055 M3/day based on particulate size analys. Sludge management not presented.	horizontal subsurface	Wetland consists of 3 cells designed for different flow rates. Flow designed at 2 pgm with rest diverted to pump house. Size of each wetland cell: 27 ft long by 6 ft wide by 2.3+ ft deep. Estimated retention time is 3 days.
3	10		X	Oxic drain using crushed osyter shells.	X	Cascader: 12.5 ft long by 2 ft wide by 11 ft high. 9 steps each 1.42 ft long with 1.17 foot drop.	X	Basin size: 17 ft long x 3 ft wide by 4 ft deep. 1 unit. Identified detention time is 2.3 hours. Sludge formation rate not presented. Basin has a sludge collection zone. Sludge management is not presented.	vertical flow	Wetland size is 84.7 ft long by 20 ft wide by 3.28 ft deep consisting of 23 cells. Estimated retention time is 3 hours.
4	np		X	Oxic drain using crushed osyter shells.	X	No pilot scale analysis provided.	X	No pilot scale analysis provided.	horizontal subsurface	No pilot scale analysis provided.
5	10	X		Unidentified auto lime dosing system used. Lime add rate is 230 mg/L.	X	Cascader: 11.9 ft long by 0.42 ft wide by 9.8 ft high. 14 steps each 0.83 ft long with 0.67 foot drop.	X	Basin size: 13.2 ft long x 3.3 ft wide by 3.3 ft deep. 1 unit. Identified detention time is 1.76 hours. Estimated sludge formation rate is 19 Kg/day. Basin has a v shaped effluent structure. Sludge management is not presented.	vertical flow	Wetland consists of 2 parallel series of 4 cells. Intermittent feeding 2 times per day with resting periods of 6 to 8 hours. Size of each cell is 25 ft long by 5.9 ft wide by 2.1 ft deep.

Notes:
np - not presented. Pilot scale system not presented.