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Point Reyes Station Mesa Lot
Case Studies for Ecologically-Based Onsite Wastewater Treatment Systems

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Sherwood has prepared a slide deck presenting 12 case studies for ecologically-based wastewater treatment systems. This memo is intended to accompany the slide deck and provide a short description of the findings from each system. Some of these projects were completed by Sherwood, while some are representative projects completed by others. The case studies selected were chosen because: (1) they are potential technologies that could be implemented in Point Reyes Station to meet the excess wastewater treatment demand and (2) are similarly-sized to the demand flows calculated in the Needs Assessment study by Sherwood. The projects presented are small, decentralized wastewater treatment systems and representative of green and state-of-the-art technology. These projects include anaerobic treatment processes combined with vegetated systems that are typically lower-cost and simple to operate and maintain. Per request from the community, composting toilets have also been included.

	Project Name	Treatment & Disposal Process
1	San Lorenzo Valley Unified School District	Trickling Filter and Constructed Wetlands, Leach Field
2	Sidwell Friends School	Treatment Wetlands, On-site reuse for toilet flushing and cooling
3	Port of Portland	Treatment Wetlands, On-site reuse for toilet flushing and cooling
4	Old Trail School	The Living Machine, Subsurface disposal
5	Occidental Arts and Ecology Center (OAEC)	Composting toilets
6	Bronx Zoo	Composting toilets, wash water treated in greywater garden
7	The Bullitt Center	Composting toilets converted to vacuum flush toilet to sewer
8	Architectural Nexus SAC	Composting toilets, On-site treatment of greywater and reuse for toilets and irrigation
9	National Parks	Composting toilets

10	Xiaogan Service Area	Package MABR and on-site reuse
11	Caltrans RE Collier SRRA	ABR, anaerobic media tanks, recirculating sand filter, subsurface wetland, subsurface disposal field
12	Google Bay View	MBBR, horizontal subsurface treatment wetland, advanced treatment and on-site reuse for toilet flushing, irrigation and cooling

Each case study presented in the slide deck provides:

- Brief description of the project including any project challenges, and potential O&M requirements,
- Flow schematic (if available),
- Size of system in gallons/day or visitors/day,
- System loading for BOD and TSS (if available),
- Photo, and
- Source of information.

The following section contains supplemental information for the case studies. The advantages and disadvantages of each type of system are discussed in more detail in the alternatives analysis memo, also part of the Mesa Lot wastewater feasibility study. This report is titled Wastewater Treatment and Disposal Alternatives for Mesa Lot Restrooms and was delivered to the County in January 2023.

Treatment Wetlands (Case Studies 1-4)

Treatment wetlands require the most area of the technologies presented here, specifically horizontal wetlands, where effluent flows along the ground surface via a shallow gravel bed. Sherwood typically designs wetland systems as a final polishing step for a stormwater or wastewater treatment system, described in the Google Bay View project. As shown in the other case studies, they are combined with other treatment systems, like trickling filters, to meet effluent requirements. Treatment wetlands are limited by topography and space constraints, but the tradeoff is a low-maintenance system with an aesthetic benefit. A comparison of this type of system is discussed in more in the alternatives analysis report.

Composting Toilets (Case Studies 5-9)

Part of developing the composting toilet case studies included an interview with staff at two facilities using composting toilets: OAEC and the Arch Nexus office. They shared their experience and some lessons learned:

- OAEC installed composting systems from three manufacturers: Clivus Multrum, Phoenix, Eco-Carousel.
- Staff had to add a vacuum flush system due to elevation access issues. This added 4-6 oz of liquid to the system as opposed to the foam flush toilets which are part of the manufacturer's design. The additional liquid overwhelmed the system and the compost could not meet coliform standards required by the permit. Additionally, the vacuum flush system caused noticeable vibrations in the building when used.

- There was no urine diversion system, which the system may have benefited from.
- This system had issues meeting permits, but OAEC staff and Sherwood discussed several modifications that could rectify some of the issues. A proposed solution might be to convey all waste to a central location where the required volume and suitable thermophilic environment could be maintained.
- The permit allowed for an area in the forest to dispose of waste meeting the permit requirements, however this area was required to be fenced off, with signage that the area contained hazardous material.
- At the Arch Nexus office, they have had a good experience with the composting system, and have never discharged it to the sanitary sewer although they have a connection per code.
- The system is oversized, so they only have finished compost every couple years; however, their finished compost has been tested against EPA standards and is Class A. When it's available they deliver it to an educational farm in Placer County.
- They have a vacuum toilet system, which is necessary since the building does not have a basement so waste cannot enter the bins by gravity. A macerator pump within the vacuum system helps create a consistent product that can be distributed between the bins.
- The staff member operating the system typically adds wood chips and rotates the material in the bins on a weekly basis. The system distributes waste between the bins by automatically opening and closing them on a rotation.
- Fans are an integral part of the composting system run and one on each bin runs at half speed 24/7. The system vents odors to the roof while evaporating liquid from the bins. Operation of these fans at full speed led to failure one time over a holiday weekend led to odor issues and fungus gnats which were difficult to remove.

Additional lessons learned regarding composting toilets that would apply to this project were provided in the research around the Bullitt Center. The composting toilets were commissioned in 2013 but removed in 2020. The greywater system, however, is still operating and was modified to a three-stage media filtration treatment process to allow the water to be reused for toilet flushing as opposed to aquifer recharge. The lessons learned, summarized below, are helping to guide future designs such as engineering firm PAE's headquarters in Portland, OR.

- Various maintenance issues plagued the system. Limited access on the sides and top of the composters hindered routine weekly maintenance. High turnover of subcontractors maintaining the system led to gaps in training and maintenance of the system.
- Vacuum flush system improves the user experience compared to a foam flush system. Maintaining continuous negative pressure throughout the system is important to prevent odor issues, especially without a trap. Consider backup batteries for these systems.
- Distribute load the composters and design for urine diversion and drainage. An even load will prevent inefficiencies in emptying of composters and optimize truck trips.

Sherwood also consulted with the County of Marin to understand any permitting hurdles for a future wastewater treatment system. Currently, there is no permitting pathway for composting toilets in Marin County. In the case studies presented, the treatment systems were permitted by the owners.

- The County has no preference between proprietary or specialized engineering design.
- They do not want to permit more vault toilets. Additionally, a vault toilet would not be allowed within a 100-year flood zone, which may impact development of the B street lot discussed in the Needs Assessment.
- Precedent may exist for the Marin Carbon Project in Nicasio.

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Membrane aerated biofilm reactor (MABR), Moving bed biofilm reactor (MBBR), and Anaerobic Baffled Reactor (ABR) w/ Anaerobic Media Tanks (Case Studies 10-12)

Sherwood has extensive experience with these types of treatment systems, similar to the ones described in this case study. The level of treatment is high, while providing a compact footprint. The treatment train can be modified by working with the manufacturer to meet a variety of treatment goals. This type of system tends to be higher in capital cost than the other treatment systems described here.

Case Studies

Small-scale, decentralized wastewater treatment

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Treatment Wetlands

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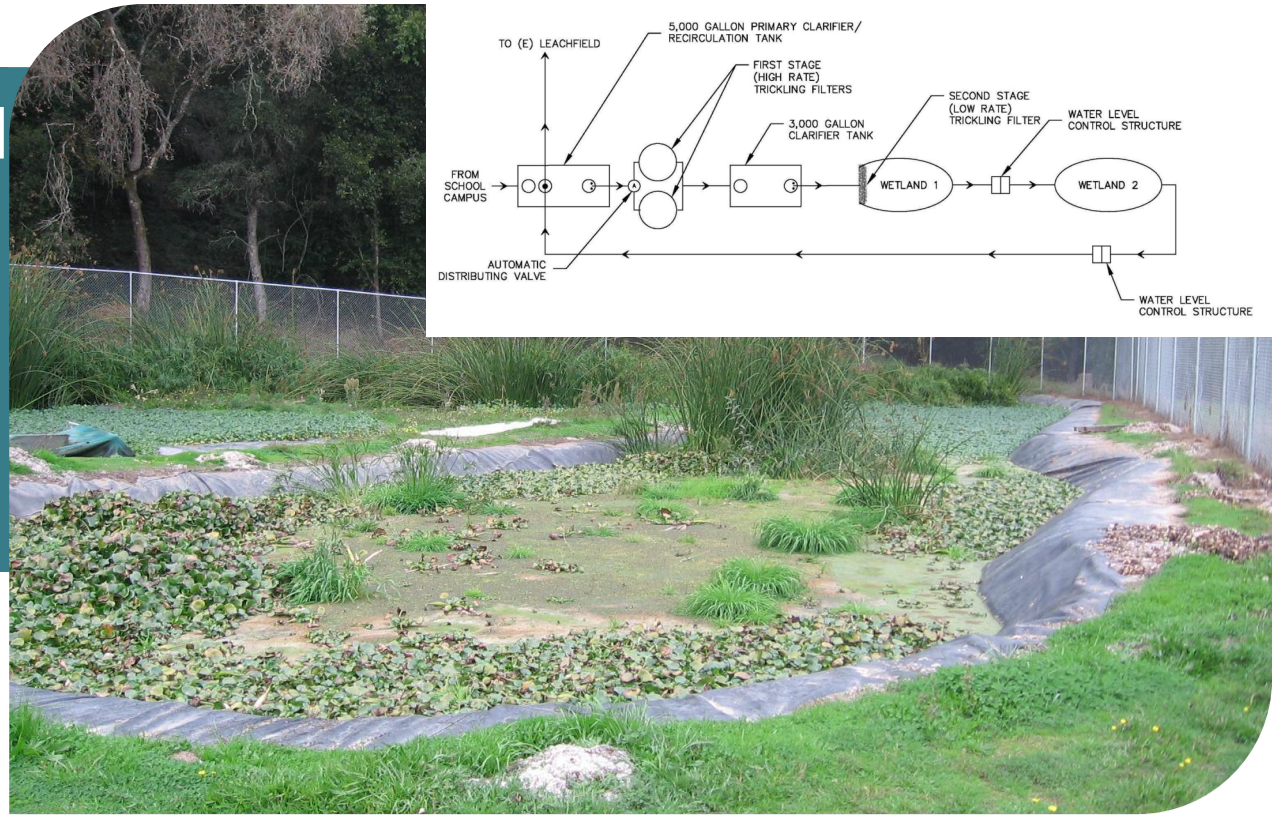
San Lorenzo Valley Unified School District

Santa Cruz, California

Treatment Type: Trickling Filter and Constructed Wetland
Disposal Type: Leach Fields



SYSTEM SIZE

Design Flow: 18,000 gpd under normal pumping conditions
Maximum Flow: 32,000 gpd

HIGHLIGHTS

The high school science classes monitor and run test on the wetland system and also maintain and cultivates wetland vegetation.

COST

Capital Cost: $270,000 (in 2005)
(Unit capital cost of $15 per gallon treated)

The system was installed in 2005. Regular maintenance activities include visual inspection and cleaning of biotube effluent pump vaults and pump systems. Other tasks include cleaning trickling filters monthly, and pumps the primary and secondary clarifiers annually.

Information obtained from Sherwood Engineers staff and San Lorenzo Valley Unified School District.

Sidwell Friends School

Washington DC

Treatment Type: Treatment Wetlands

Disposal Type: On-site reuse for toilet flushing and cooling

SYSTEM SIZE

Design Flow: 3,000 gpd
Project size: 1.5 acres
Wetland size: ~0.25 acres
Unused water passively overflows into municipal combined sanitary/storm system

HIGHLIGHTS

- Reduces potable water demand (toilets and cooling towers) on site.
- Incorporates embedded sensor network to monitor treatment performance.

COST

The EPA estimates the capital cost of a subsurface treatment wetland at about $178,000 per acre for the technology only. Wetlands at this site take up less than a quarter of an acre.

Onsite treatment of greywater and blackwater from a combined 72,000 sf existing and new buildings. Treatment process includes pretreatment tank to remove solids, subsurface flow wastewater wetlands, trickling filter, recirculating sand filter, and UV disinfection. Hydraulic residence time (HRT) in wetland is 3-5 days before entering storage tank in basement of building. When there is demand, water is then filtered and disinfected prior to reuse.

https://www.biohabitats.com/project/sidwell-friends-middle-school-natural-wastewater-and-stormwater-treatment-reuse-system/

https://pruned.blogspot.com/2009/06/wetland-machine-of-sidwell.html

Port of Portland

Portland, Oregon

Treatment Type: The Living Machine®

Disposal Type: Reuse for toilet flushing and cooling towers

PERFORMANCE

Units (mg/l)	Influent	Primary	Effluent
BOD	600	209	1.0
TSS	400	93	2.6
TKN	150	159	1.7
Turbidity (NTU)	-	-	0.6

SYSTEM SIZE

Design Flow: 5,000 gpd

HIGHLIGHTS

- Only uses 40,000 kWh annually
- Sludge pumped out every 4-5 years

COST

Per the EPA, these systems are typically cost competitive with more conventional wastewater treatment systems at flow volumes up to 1,000,000 gpd if they are located in a warm climate where a greenhouse is not necessary.

Completed in 2010, The Living Machine® system consists of interior tidal flow wetland and exterior vertical flow wetland cells. Wastewater from the Living Machine is pumped to a cartridge filter followed by UV and chlorine disinfection. The Living Machine® system was cited as a key innovative feature on Forbes.com's list of the world's greenest buildings, and the project attained a LEED Platinum certification. One of the challenges of these systems is clogging issues with some installations.

http://sustainablewater.com/wp-content/uploads/2013/07/POP-Case-Study-070213.pdf

https://www.puttman.com/utilities/port-of-portland-headquarters/

Old Trail School

Ohio

Treatment Type: The Living Machine(R)

Disposal Type: Pump to sand dunes

SYSTEM SIZE
Design Flow: 5,000 gpd

HIGHLIGHTS

- Only uses 40,000 kWh annually
- Sludge pumped out every 4-5 years

COST

- Estimated at $985,000 for a 40,000 gpd system

The Living Machine® system at Old Trail School in Ohio is an advanced wetland system, composed of primary settling, three different wetland processes (Horizontal Subsurface Flow, Tidal Flow and Vertical Flow), and UV disinfection which treat 5,000 gallons of wastewater per day.
One of the challenges of these systems is clogging issues with some installations.

https://theecologist.org/2010/jun/08/living-machine-ecological-approach-poo

Composting Toilets

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Occidental Arts and Ecology

Occidental, California

Treatment Type: Composting Toilets

Disposal Type: N/A

SYSTEM SIZE

An 80-acre ecological reserve in Sonoma County.
3 composting toilet systems, from Phoenix.

HIGHLIGHTS

- Installed in 2018.
- The project hopes to show that composting is effective in eliminating pathogens and prevents groundwater contamination. To show the value of the end project as nutrient-rich fertilizer, they are partnering with Stanford and UC Davis to analyze the finished compost.

COST

- Phoenix system:
- 3-stall building from Phoenix website estimated $65,000 - $100,000

Three commercial-grade systems including the Phoenix and EcoTech Carousel composting toilet systems. One system is used in a Meeting Hall, serving three toilets. Project consisted of a 2-year permitting process with Sonoma County Public Health Department and the North Coast Regional Water Quality Control Board. Originally tried foam-flush toilets but maintenance and ventilation issues led them to replace them with vacuum flush ones. First three years of operations involved troubleshooting of drainage and ventilation problems and adjusting permit with the County. Vacuum flush system is noisy. Working to develop best practices for visitors and maintenance staff.

Information from interview with Brock Dolman at OAEC and the case study: https://oaec.org/our-work/projects-and-partnerships/compost-toilet-project/

Bronx Zoo

Bronx, New York

Treatment Type: Composting toilets

Disposal Type: Wash water treated in greywater garden

SYSTEM SIZE

- 10 large-size commercial composting units from Clivis Multrum, housed in a full basement, that can accommodate more than 1/2 million visitors per year
- Design flow of greywater garden: 400 gpd

HIGHLIGHTS

- Saves over 1 million gallons of water each year
- The system required discussions with regulators to exempt the project from the New York requirement for all new construction to have a sewer connection.
- Positive reaction from public - project was named New York Construction's 2007 Eco Project of the Year.

COST

Large capacity systems for public facility use can cost as much as $20,000 or more per toilet.

Completed in 2006, the Eco Restroom at the Bronx Zoo replaced a failing septic system. The system has an educational component, with signs which explain the composting toilet process to the public. The system was selected as an alternative to an expensive connection to the combined sewer system, or a new septic system, which was rejected due to pollution concerns. The greywater garden irrigates approximately 1,000 sq. ft.

https://clivusmultrum.com/_media/BronxZooCase.pdf

The Bullitt Center

Seattle, Washington

Treatment Type: Composting Toilets (replaced w/ vacuum flush)
Disposal Type: Compost hauled off-site. Gray water treated in separate reuse process

SYSTEM SIZE

Design occupancy: 170 people, 52,000 sq. ft building.
Annual Water Use 50,400 gallons

HIGHLIGHTS

- Uses 96% less water than traditional toilets.
- 0.4 gal per flush.
- Keeping greywater system within the building footprint helped with permitting process.

COST

- Expect higher system maintenance costs from composting toilets vs. flush toilets.
- Compost from the Bullitt Center had to be hauled 52 miles round-trip, in a loaded diesel truck and trailer, ten times a year.

The Bullitt Center is a multi-tenant commercial building. The goals of installing the system were to reduce water and energy use, return nutrients to land, and reduce the burden on the municipal system. **However, the operations and maintenance of the system led to composting toilets (Phoenix) being replaced by vacuum flush system connected to municipal sewer. Lessons learned:**

- Without fans creating negative pressure, odors became a nuisance.
- Distribute load among multiple composters.
- Vacuum flush is superior to foam flush toilets for both user experience and maintenance.

The constructed wetland for greywater treatment is located on the third-level green roof area on the building's north terrace, and was used to recharge the aquifer under the building when the composting toilet system was in use (2013-2020). With the introduction of a vacuum-flush toilet system, greywater is now used to flush toilets after a three-stage filtration process and UV disinfection.

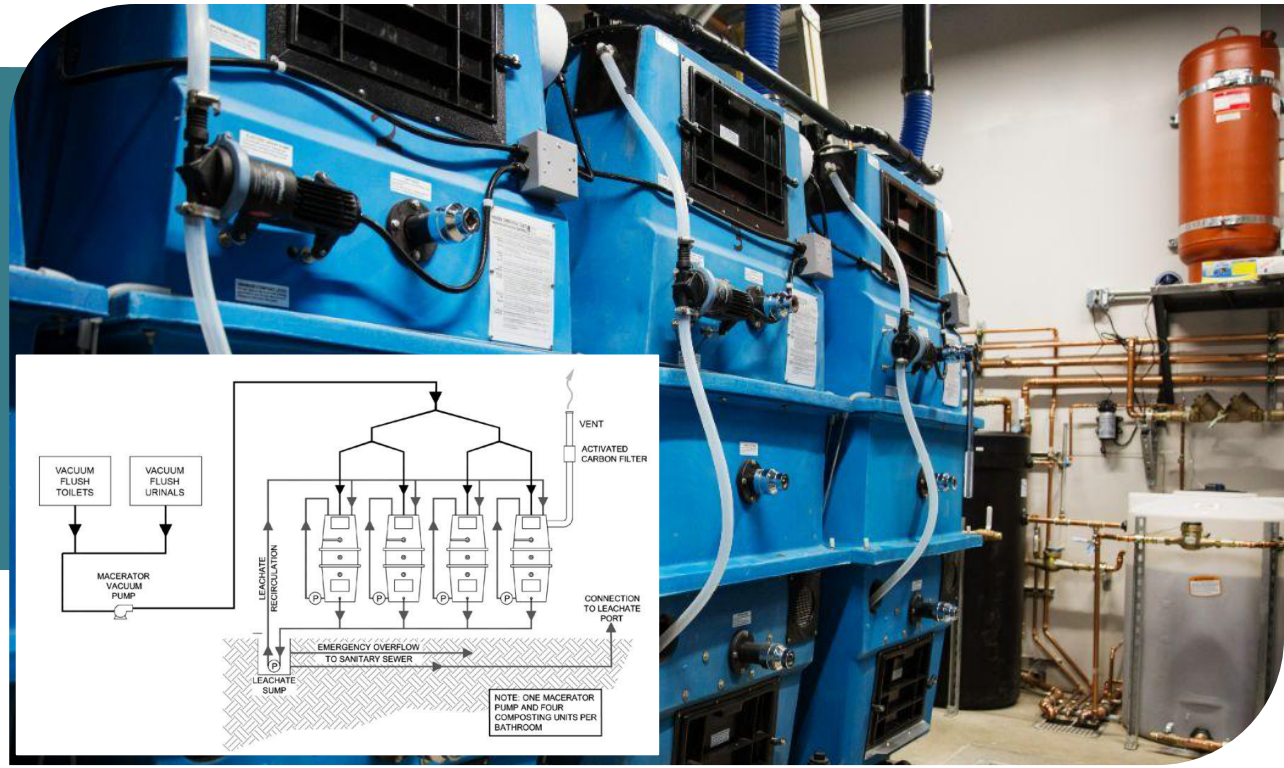
The information here comes from a Case Study Article and, a Lessons Learned memo written in 2021 describes the decision leading up to the replacement of the composting toilet system. The greywater system was modified during this replacement.

Architectural Nexus SAC

Sacramento, California

Treatment Type: Composting Toilets

Disposal Type: On-site treatment and reuse for toilets and irrigation



SYSTEM SIZE

8 Composters serve two restrooms: one women's and one men's.
Serves an 8,200 square foot office building.
40 full-time staff and 10 visitors per day.

HIGHLIGHTS

- All wastewater is treated on site. No discharge to City sewer. Compost meets Class A Standards and is sent to a educational farm in Placer County for use in a garden.
- Installed in 2016, it is California's first Living Building Certified building and is Net Zero Water.

COST

- Estimated cost is $100,000 for the full system which includes the composters, toilet fixtures, vacuum pump, control panel, and installation.

The building reduces water use by means of waterless urinals, composting toilets, and low flow fixtures, and harvests and stores rainwater on site. The composting toilet system (Phoenix) uses wall-mounted vacuum flush toilets (JETS) with a macerator pump which helps distributes material. The in-ground leachate tank is produced by Oldcastle. Operations staff adds wood chips and mixes bins weekly. System is oversized so they have only removed one batch of finished compost in the last three years.
The gray water system provides recycled water for toilet flushing and irrigation. Tenant education efforts encourage participation in energy savings and the buildings operations. The team also installed a system to convert rainwater to potable water but cannot operate it until California changes its water permitting laws.

Case study of the office building at:
http://www.archnexus.com/arch-nexus-sac/building/

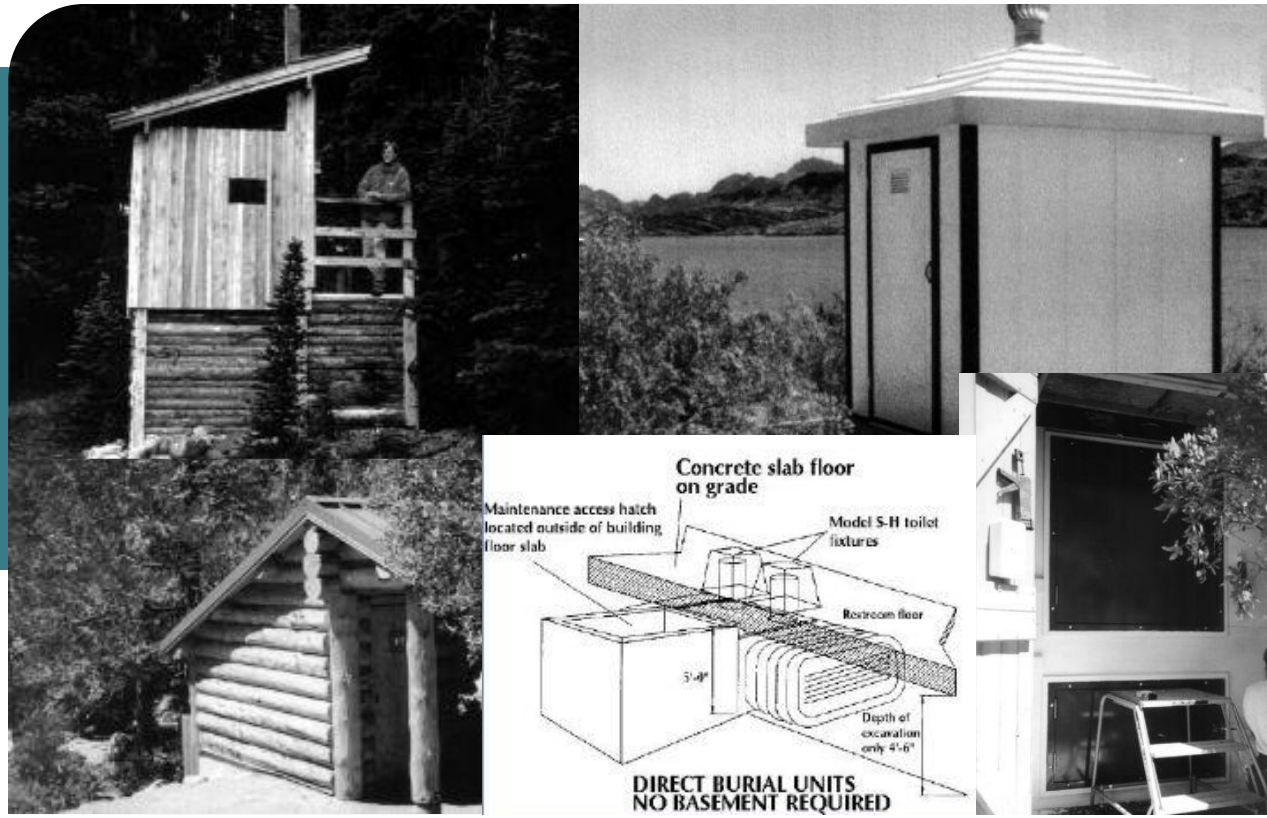
Composting Toilets at National Parks

Treatment Type: Composting Toilets
Disposal Type: N/A

SYSTEM SIZE
Various sizes to serve remote locations.

HIGHLIGHTS
- Composted material can achieve a Class A sludge rating, depending on level of maintenance, level of use, and climate.
- Recreational user acceptance of composting toilets is extremely high, since well-functioning units have no offensive odor and are considered an environmentally sound waste disposal method.

COST
Commercial composting toilets cost from $10,000 for smaller units to $30,000 for larger units (does not include labor and installation).



Compost toilets use a carbon source, preferably wood chips, added regularly to maintain the decomposition process. Maintenance is critical. The fecal cone must be knocked down and mixed with the carbon source regularly. The schedule of maintenance varies from once a month to twice a week, depending on digester tank size, level of use, temperature, and climate. Finished compost must be removed, generally about a bushel every 1 to 2 years, but some units have operated for 10 years without removing any material.

Examples of composting toilets at National Parks: https://www.fs.fed.us/t-d/pubs/html/95231202/95231202.html#COMP

MABR, MBBR, ABR

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Xiaogan Service Area

Hubei Province, China

Treatment Type: Aspiral™ Smart Package WWTP (MABR)
Disposal Type: On-site reuse

SYSTEM SIZE

Design Flow: 50,000 gal/day)
Influent TSS and BOD of 300 and 200 mg/L. Effluent <10 mg/L.

HIGHLIGHTS

- Design was near a popular service station, system had to be aesthetically pleasing with minimal noise or odors.
- Treats high nitrogen wastewater to China's strict Class 1A standard.
- Low energy consumption.

COST

- Economical CapEx and OpEx.
- Timeline: two months for installation and commissioning.

The service area, which includes restaurants, gas stations, mechanics, accommodations, shopping and parking, was upgraded to address growing traffic demand. This upgrade including its wastewater treatment capabilities to comply with new regulations. The system needed to be compact to fit within the footprint of the previous plant, and have minimal noise and odor. Rest areas typically have a high nitrogen concentration, which was removed to < 15 mg/L meet China's Class 1A standard. The system includes pretreatment with fine screen and selection tank, two Aspiral L4 units, a secondary clarifier, a media filter, and disinfection unit.

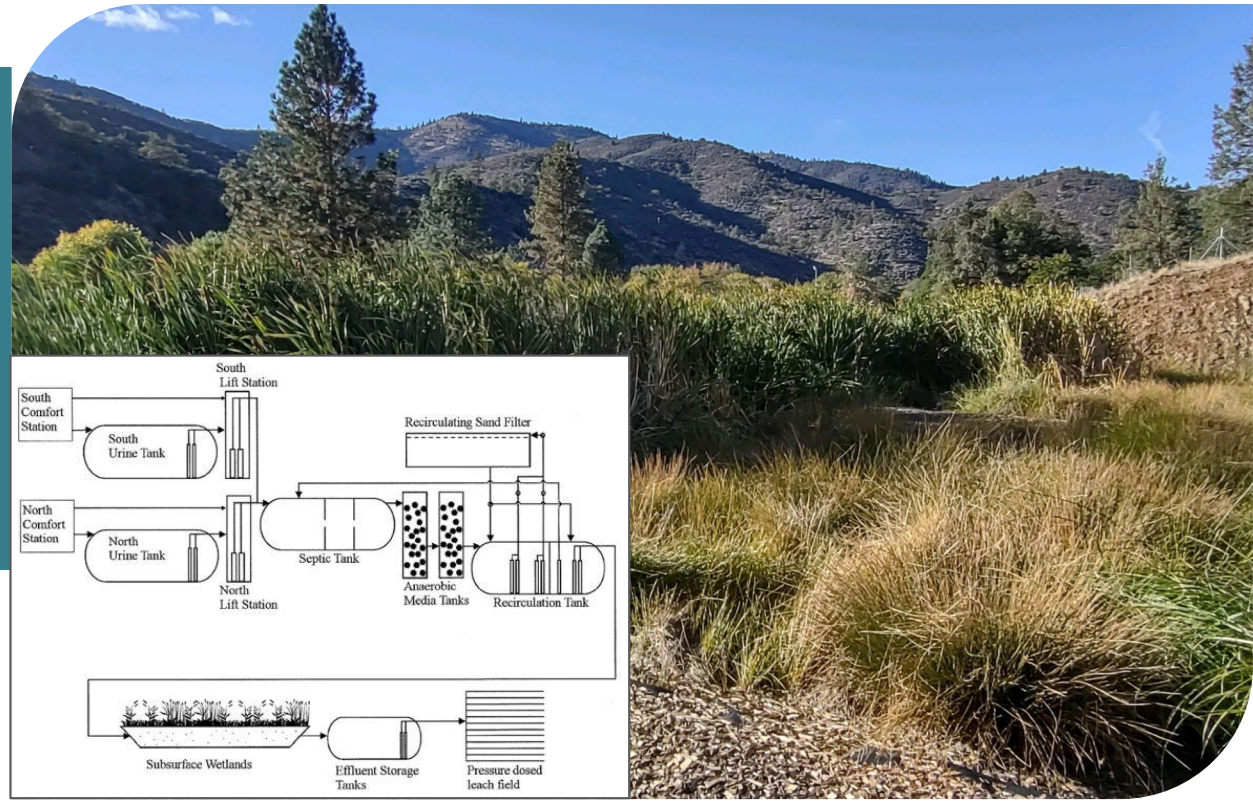
Case study provided by Fluence:
https://www.fluencecorp.com/wp-content/uploads/2019/07/HUBEI-CS_May19.pdf

Caltrans RE Collier SRRA

Location

Treatment Type: ABR, anaerobic media tanks, recirculating sand filter, subsurface wetland

Disposal Type: Subsurface disposal field



SYSTEM SIZE

Average Flow: 4,800 gpd
Peak Flow: 14,300 gpd

HIGHLIGHTS

- High strength wastewater, treatment complies with strict nitrogen limits
- Urine diversion tanks on urinals
- Low maintenance, with reliable remote monitoring, Caltrans not staffed for wastewater treatment operations

COST

The EPA estimates the capital cost of a subsurface treatment wetland at about $178,000 per acre for the technology only.

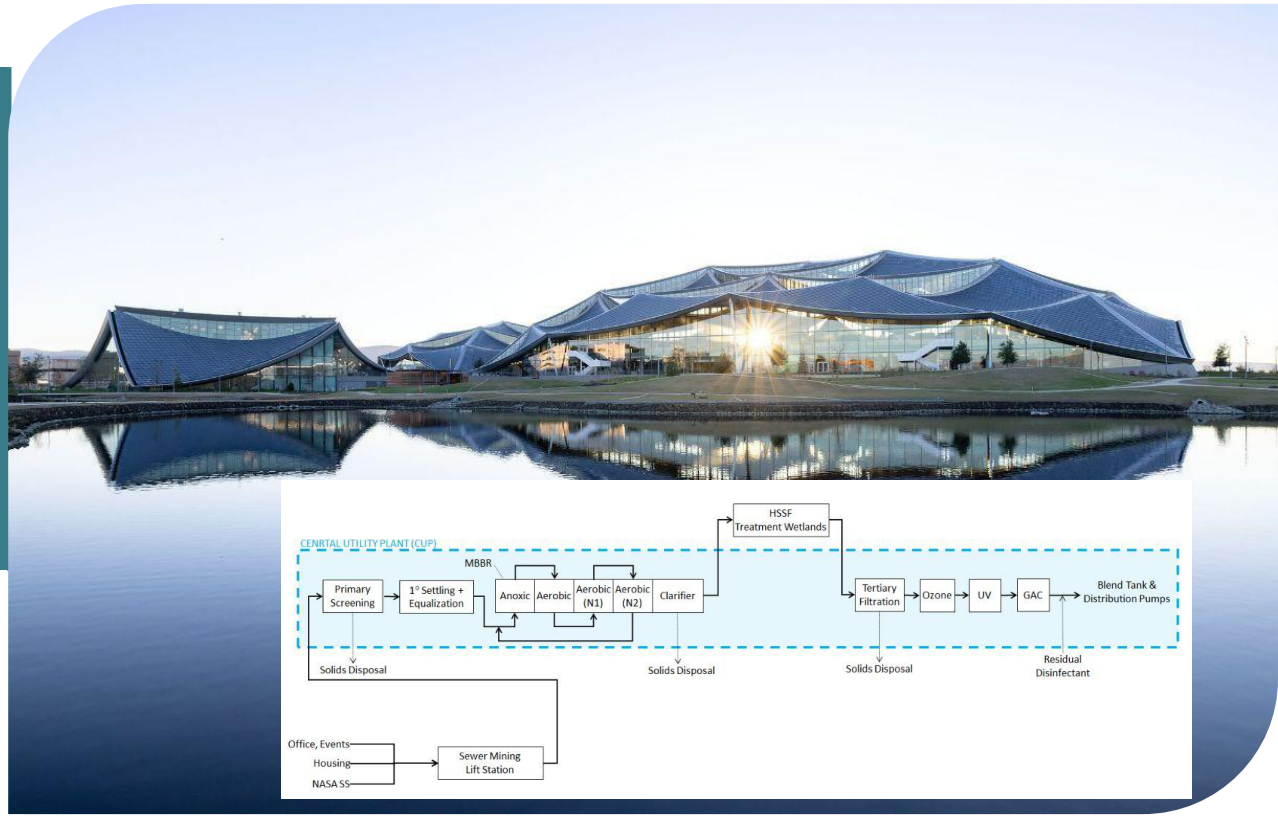
Rest areas typically have very high strength wastewater and nitrogen removal is key. The wastewater treatment system consists of ABRs, two anaerobic media tanks, recirculations tank, sand filter, two horizontal subsurface wetlands, an effluent storage tank and a subsurface pressure-dosed disposal field. There is a 100% redundant disposal field to meet the requirements of the General Order the system is regulated by. The system produces a backwash water volume of 1,500-5,000 gallons per month which is discharged into retention basins. Challenges include users flushing rags, diapers, and sometimes clothes. Influent grinder pumps are the biggest operational issue.

Information provided by Sherwood Design Engineers staff.

Google Bay View

Mountain View, California

Treatment Type: MBBR, horizontal subsurface treatment wetland
Disposal Type: Advanced treatment and on-site reuse



SYSTEM SIZE

Design Flow: 85,000 gpd
Sewer mining system with potential for future capacity.

HIGHLIGHTS

- Wetland provides nitrogen removal via denitrification.
- Incidental removal of other constituents.
- Recycled water used for irrigation, toilet flushing and washdown, and utility tower cooling makeup.
- Excess recycled water may be supplied to nearby NASA Research Park

COST

Approximately $5M for wastewater treatment system installed including subsurface flow polishing wetland

Treated roof and site stormwater is blended with onsite-treated wastewater to provided non-potable recycled water. Treatment consists of a moving bed bioreactor (MBBR) and subsurface treatment wetland. Advanced treatment includes tertiary filtration using compressible media filter, ozonation (disinfection and color removal), UV (disinfection), and organic carbon removal using GAC adsorption.

Information provided by Sherwood Design Engineers staff.