Demonstration Report No. 9

Addison County Demonstration Project - Alternative Sewage Disposal Technologies

Lake Champlain Basin Program

Prepared by
Judy Bond

for
Lake Champlain Management Conference

February 1997

PUBLICATION SERIES

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This demonstration report is the nineth in a series of reports prepared under the Lake Champlain Basin Program. Those in print are listed below.

Lake Champlain Basin Program Demonstration Reports

1. *Case Study of the Town of Champlain.* Yellow Wood Associates. October 1993.

2. *(A) Demonstration of Local Economic/Other Community Impacts.* Community Case Studies for Economic Plan Elements. The City of Vergennes, Vermont. Economic and Financial Consulting Associates, Inc. October 1993.

   (B) Demonstration of Local Economic/Other Community Impacts. Community Case Studies for Economic Plan Elements. Appendix. The City of Vergennes, Vermont. Economic and Financial Consulting Associates, Inc. October 1993.

3. *The Archeology on the Farm Project.* Improving Cultural Resource Protection on Agricultural Lands: A Vermont Example. Jack Rossen. May 1994.

4. (A) *The 1992 Fort Ticonderoga-Mount Independence Submerged Cultural Resource Survey. Executive Summary.* Arthur Cohn. May 1995.

   (B) *The 1992 Fort Ticonderoga-Mount Independence Submerged Cultural Resource Survey.* Arthur Cohn. May 1995.

   (C) *The Great Bridge "From Ticonderoga to Independant Point".* Arthur Cohn. May 1995.

   (D) *Geophysical Reconnaissance in the Mount Independence Area: Larrabee's Point to Chipman Point.* Patricia Manley, Roger Flood, Todd Hannahs. May 1995.

   (E) *Ticonderoga's Floating Drawbridge; 1871-1920.* Peter Barranco, Jr. May 1995.

   (F) *Bottom Morphology and Boundary Currents of Southern Lake Champlain.* Hollistir Hodson. May 1995.

5. *Implementation, Demonstration, and Evaluation of BMPs for Water Quality: Application Methods ("Manure Injections") for Improved Management of Manure Nutrients.* Bill Jokela, Sid Bosworth and Don Meals. September 1995.

6. (A) *Malletts Bay Recreation Resource Management Plan.* T.J. Boyle and Associates, Resource Systems Group, Associates in Rural Development and Engineering Ventures. October 1995.

   (B) *Malletts Bay Recreation Resource Management Plan. Executive Summary.* T.J. Boyle and Associates. October 1995.

   (C) *Review and Relevant Studies. Malletts Bay Recreation Resource Management Plan.* T.J. Boyle and Associates. October 1995.

   (D) *Natural and Built Resources Inventory: Data Documentation. Malletts Bay Recreation Resource Management Plan.* Associates in Rural Development. October 1995. **This report will not be published but data is available at the LCBP office.**

   (E) *Survey Implementation and Analysis. Malletts Bay Recreation Resource Management Plan.* Resource Systems Group. October 1995.

(F) *Institutional Review and Analysis. Malletts Bay Recreation Resource Management Plan.* Engineering Ventures. October 1995.

7. *The Best River Ever. A conservation plan to protect and restore Vermont's beautiful Mad River Watershed.* Mad River Planning District and Friends of the Mad River. December 1995.

8. *On Farm Composting Demonstration Project.* Clinton County Soil & Water Conservation District. December 1996.

9. *Addison County Demonstration Project - Alternative Sewage Disposal Technologies.* Judy Bond. February 1997.

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Steering Committee/Advisors

Dave Cotton -- VT DEC/Wastewater Technologies, Inc.
Rich Czaplinski -- Environmental Protection Consultant
Bruce Douglas -- VT DEC/Stone Environmental
Peg Elmer -- Vermont On-Site Sewage Committee
Spencer Harris -- VT Contours
Craig Heindel -- Vermont On-Site Sewage Committee
Alan Huizenga -- Addison County Regional Planning Commission
Jessanne Wyman -- VT DEC
Sandi Young -- Addison County Regional Planning Commission
Bill Zabiloski -- VT DEC

Participating Engineers

Gary Fern -- Phelps Engineering
Lance Phelps -- Phelps Engineering
Woody Reed -- EEC

Coordinator

Judy Bond -- GrassRoots GIS

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Table of Contents

Introduction 1

Basics of On-Site Wastewater Treatment 2

Constructed Wetlands for Wastewater Treatment 3

Sand Filters 5

At-Grade and Shallow-Placed Systems 7

The Demonstration Sites 8

Intermittent Sand Filter 8

Recirculating Sand Filter 8

Shallow-placed and At-grade Systems 10

Constructed Wetland 12

System Monitoring 14

Results summary 15

Results 16

Conclusions and Recommendations 18

Glossary 19

Bibliography & Journals 21

Web Sites about On-Site Wastewater Treatment 21

Introduction

In June, 1995 a partnership of the Vermont On-Site Sewage Committee, Addison County Regional Planning Commission and VT Agency of Natural Resources received a grant from the US E.P.A. through the Lake Champlain Basin Program install and monitor four innovative on-site sewage treatment systems and develop a broad educational component based on the results. The project goal was to demonstrate soil-based sewage treatment technologies that may be acceptable for sites having limited suitability for conventional treatment systems.

Vermont regulations regarding wastewater treatment are changing to include the use of additional technologies for both replacement of failed systems and new construction. The advantages are improved treatment, siting flexibility and more replacement options for sites not suitable for conventional subsurface or mound systems. The technologies used in the Demonstration Project: recirculating and intermittent sand filters, a constructed wetland, and a combined shallow-placed and at-grade systems, were selected because they were under consideration by the Vermont Department of Environmental Conservation for inclusion under the new state regulations.

The Addison County area was chosen because of the generally clay-rich, wet soil conditions. A steering committee consisting of the director of the Addison County Regional Planning Commission, ANR engineers, members of the Vermont On-Site Sewage Committee, on-site technicians and consulting engineers met to determine project layout and criteria. A coordinator was hired to oversee activities and ensure that the demonstration project moved forward on schedule. Local homeowners with failed on-site systems were recruited through media notices and mailings to local officials. Of the five requests, one was rejected immediately because of the need to obtain permits. The other four were considered and assigned the most appropriate technology. Engineering firms were requested to submit proposals through 'request for proposal' classified ads in local newspapers. A number, including firms from New York and New Hampshire, requested information, and four submitted complete proposals. Phelps Engineering from Middlebury was chosen because of a combination of experience, expertise and logistics.

The project provided an opportunity to:

- replace four failed domestic septic systems,
- better understand the technologies,
- explore Vermont-specific issues such as climate, soils and materials supply, and
- make demonstration sites available for educational purposes.

A videotape co-produced by Vermont ETV and the project coordinator has been aired on the 'Across the Fence' television show. Each site has also been visited by regulators, engineers, and students.

Monitoring was included in the project to provide background data regarding system effectiveness at removing pollutants such as coliform bacteria, phosphorus, nitrogen, solids, and biological oxygen demand. Sampling ports were designed into the systems where access would not otherwise be available. One to three effluent sample series were taken from each system at various times during the year by Vermont DEC staff and analyzed at the State of Vermont Agency of Natural Resources LaRosa Laboratory.

Basics of On-Site Wastewater Treatment

Approximately half of Vermont households utilize on-site disposal of wastewater. Systems are designed for the number of bedrooms in a house (minimum: three), which defines a theoretical number of gallons per day of wastewater. The designer must also take into account environmental factors such as slope, soil type and permeability, depth to seasonal groundwater and distances to drinking water supplies, roads, watercourses and property lines.

The basic concept of treatment in conventional sub-surface or mound systems and the alternatives included in the demonstration project are the same: eliminate pollutants such as pathogens, solids and nutrients by removing the solids from the effluent, treating the effluent by exposing it to physical filtration and the microbial community that has built up on the treatment media, and dispersing the liquid into the soil.

Household wastewater is piped to a septic or settling tank in which solids and grease are separated from the liquid. Soap, lighter materials and grease float to the surface to form *scum.* Bacterial action partially digests the solids into smaller pieces, which settle to the bottom of the tank as *sludge.* A septic tank should be pumped regularly to remove scum and sludge before they accumulate to the point of bypassing the baffles in the tank because they can clog gravel and soil pores in the leachfield and cause the system to fail. Internal baffles slow the passage of liquid through the tank, providing for longer in-tank treatment.

The relatively clear liquid in the middle of the tank is piped to the next phase of treatment (the sand filter, constructed wetland, mound, or leachfield), where it is exposed to oxygen, filtration and a bacteria/microbial community. The liquid constantly *trickles* or is pumped in *doses* uniformly over the porous material in the system for maximum efficiency and surface exposure. In conventional sub-surface and mound systems, which have been the standard in Vermont, the septic tank effluent infiltrates from the leachfield directly into the soil for final treatment and dispersal.

Treatment in sand filters and constructed wetlands occurs in an impermeable unit or box and is followed by a land-based dispersal system such as a subsurface leachfield, mound, or a spray distribution system. Because of the high degree of treatment in a sand filter or constructed wetland, the dispersal system can be smaller than would be allowed for conventional systems.

Septic systems should be pumped and maintained regularly by cleaning the effluent screens, dosing pumps and the distribution system. The septic tank needs to be monitored for accumulation of solids and grease and the float systems and timers need to be checked.

Constructed Wetlands for Wastewater Treatment

Adapted from an article in Alternative Technologies for Wastewater Treatment by S.C Reed, P.E. and Darryl Calkins. P.E.

Wetlands are defined as land where the water surface is near the ground surface long enough each year to maintain saturated soil conditions and support certain kinds of vegetation. Marshes, bogs, and swamps are all examples of naturally occurring wetlands. A constructed wetland (CW) is defined as a wetland specifically designed for the purpose of pollution control and waste management. There are two basic types of constructed wetlands: the free water surface wetland and subsurface flow wetland. Both types utilize emergent aquatic vegetation and a horizontal water flow path, and look similar to a native marsh.

The free water surface (FWS) wetland typically consists of channels or a basin with some type of impermeable liner to prevent seepage, soil to support roots of the vegetation, and water at a relatively shallow depth flowing through the system. The water surface is exposed to the atmosphere. These systems have a greater risk of exposure to the wastewater by the public, have a longer treatment time and require more land. They are typically designed for municipalities. Several communities in the U.S. have created FWS wetlands for treatment of municipal wastewater which have become locally valuable habitat for wetland birds and mammals. Orlando, Florida, Arcata, California and Columbia, Missouri are examples; Phoenix, Arizona and Albuquerque, New Mexico have such wetlands in the planning stage.

A subsurface flow (SF) constructed wetland, which is the type built as part of the Addison County Demonstration Project, consists of a basin or channel with a barrier to prevent seepage. The bed contains a greater depth of porous media such as sand, gravel or rock media than required for the growth of emergent vegetation. The media provides support for the vegetation. The subsurface position of the water and accumulated plant debris on the surface of the SF bed offer greater thermal protection in cold climates than the FWS CW. There is less chance of public contact with effluent, and fewer odors or mosquitoes. The greater surface area provided by the gravels allows for more efficient treatment, thus it can be smaller than a FWS CW.

Functional Components

The biological components in a wetland system include the vegetation and the microbial organisms suspended in the water or attached to the surfaces of the submerged plant parts and gravel media. The vegetation appears to be a major system component, but it actually plays a relatively minor role in the direct treatment of the wastewater. Uptake of nutrients and other pollutants does occur, but most of these materials eventually return to the water in less noxious forms due to the annual die-off and decomposition of the exposed portion of the plants. Harvesting the plant material could provide additional removal of nitrogen or phosphorus, but is usually not economical and is not typically included in system designs. Removal of persistent chemicals, such as chlorinated hydrocarbons, can be quite effective in these wetlands due to the relatively long detention time and the complex microbial environment which change these pollutants to less toxic forms.

Plants adapted to wetland conditions pump oxygen to their roots as part of their respiratory process. The bacteria which provide the essential aerobic reactions exist in this oxygen-rich area. The attached microbial organisms, believed to provide the major treatment action, occupy the surfaces of the media and plant roots. In effect, constructed wetlands utilize the same treatment mechanism as trickling filters and other conventional treatment systems.

The biological reactions in a constructed wetland proceed at the natural rate without the mechanical enhancements used in some types of conventional treatment such as aeration, mixing, recirculation or sludge management. As a result, operation and maintenance is simpler and less expensive than conventional treatments. Because they operate at their natural rate, the treatment time in a SF system might typically be 5 days as compared to 12 hours in a conventional wastewater treatment process.

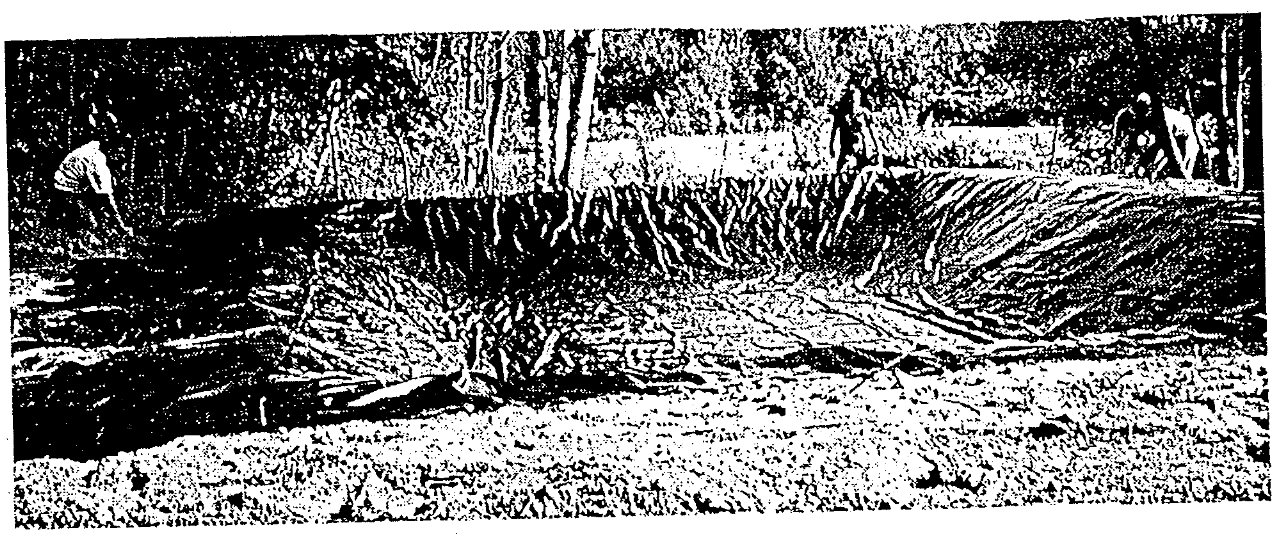
Physical and chemical processes are also important. In the type of household systems used in Vermont, the concentrations of BOD and TSS are first reduced by the septic tank and then by sedimentation, filtration and microbial activity in the CW. Removal of ammonia and other volatile organics can occur, as well as nitrification and denitrification of nitrogen forms. Precipitation and interaction with the plants and organic materials in the wetland are effective for removal of metals and similar substances, as well as partial removal of phosphorus. As systems are sensitive to the levels of toxics, homeowners must be careful not to dispose hazardous materials into septic systems.

Performance Expectation

Data from a community system in Kentucky show that constructed wetlands are effective at reducing biological oxygen demand (BOD), total suspended solids (TSS), fecal coliform and metals. Effluent concentrations of BOD were consistently less than 20 mg/L after only a few days in the CW, and total nitrogen concentrations in the effluent were less than 10 mg/L. Similar results are possible for these systems in Vermont if design adjustments are made for the cold winters.

Design Factors

Design equation factors include flow rates based on house size and local climate. A Florida system would be substantially smaller than an equivalent one in Vermont because most of the treatment processes are temperature dependent. It is necessary to design the system for cold weather effectiveness, and to ensure that the system does not freeze. The use of sand or sandy loam as a substrate might remove a greater amount of phosphorus than gravel, but would require a much larger area due to lower hydraulic conductivity of the sand.



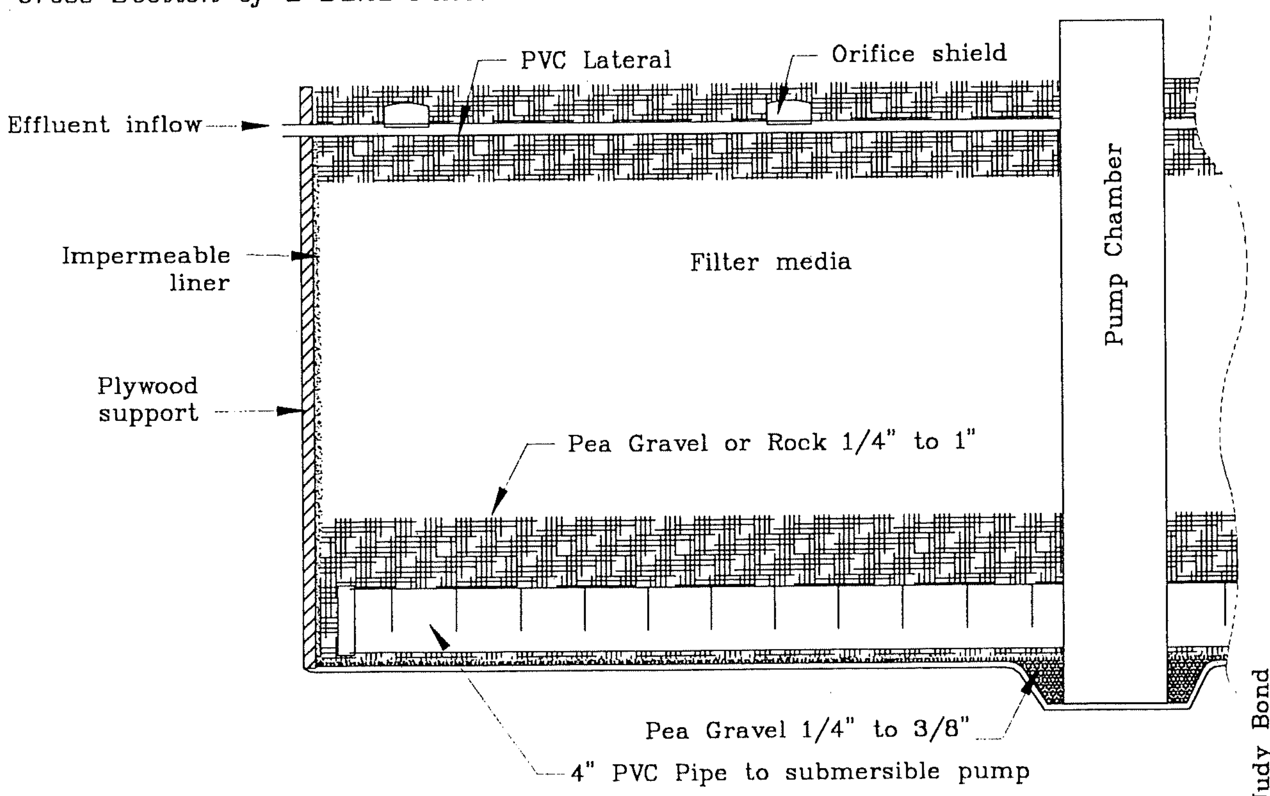
Sand Filters

Studies and 20 years of experience with installed systems in many areas throughout North America and Europe have shown that sand filters are an effective choice for small scale on-site wastewater treatment where municipal sewers are not available and the soils are not suitable for conventional treatment and dispersal. Filters are often used for small community systems and for high-strength applications such as restaurants or supermarkets. The high quality of treatment, even in cold climates, may allow on-site dispersal to be possible in marginal soils.

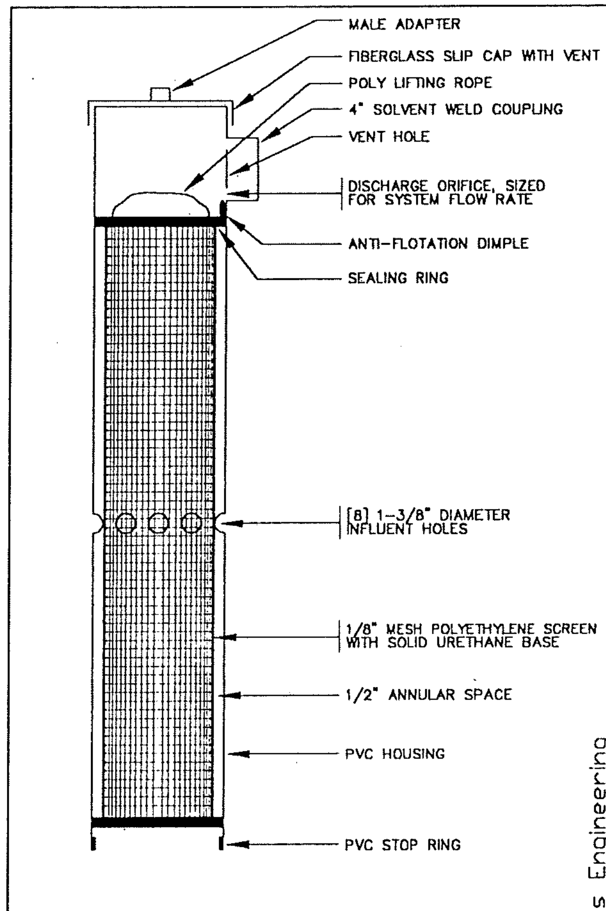
A sand filter system consists of a septic tank, the sand filter, pumping stations and a method for the treated effluent to infiltrate the soil. Filters come with a variety of controls, pumps, floats, circuit breakers, timers and alarms due to the need to pump septic tank effluent to the filter. A control box mounted near the system is connected to the residential electrical system. The sand filter is placed in an impermeable fiberglass, concrete, or plywood and PVC lined container. The depth and exact dimensions vary according to design size, slope and site.

The effluent is treated in a single pass through an intermittent sand filter (ISF). A recirculating sand filter (RSF) pumps much of the effluent back through a splitter valve placed between the filter and the dispersal field. With system usage lower than the design flows, the amount of retreated effluent will be greater than the design amount, resulting in a higher degree of treat-

Cross Section of a Sand Filter

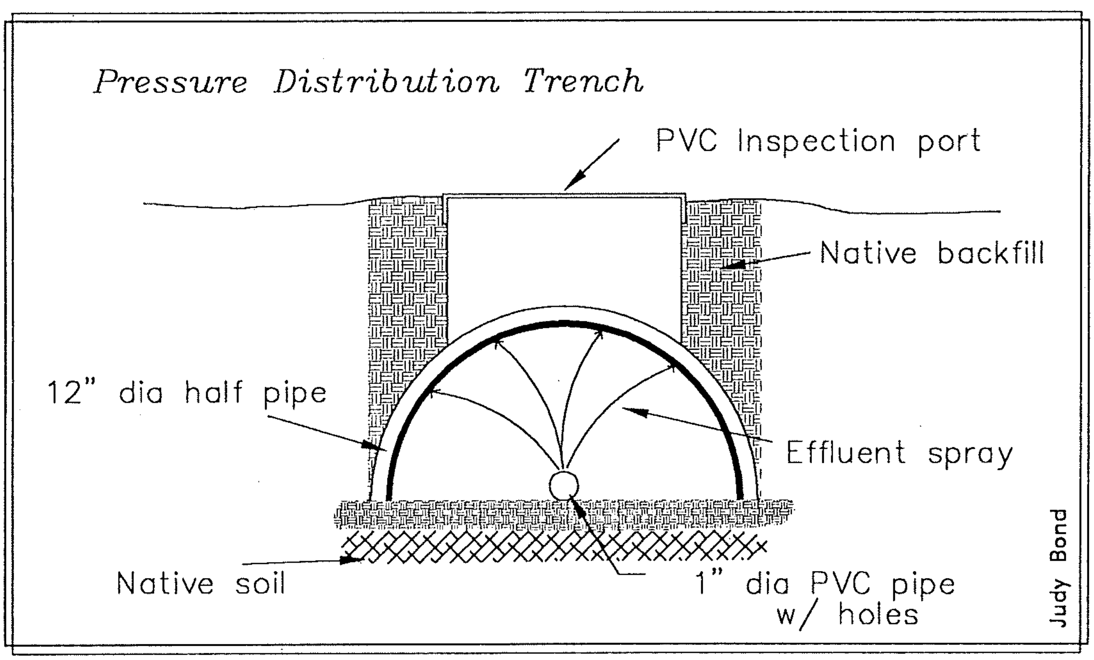


ment. An effluent filter with a 1/8" screen in the septic tank will improve treatment and reduce the risk of system clogging.



OSI EFFLUENT FILTER
NOT TO SCALE

Effluent is pumped from the 'clear zone' of the septic tank to a set of parallel lateral pipes near the top of the sand filter media. The pattern of the pipes allows the effluent to be dosed uniformly on the filter surface. The media, a coarse sand/fine gravel (1.22mm to 2.5mm), provides a surface for the growth of an attached microbial community. Effluent is treated as it passes through this algae and bacteria layer. Pulsed application of the effluent, rather than a constant trickling, reduces biomat clogging and uses the total volume of the filter more effectively. A sump at the low point of the intermittent sand filter allows the treated effluent to be pumped for dispersal. In an RSF, treated effluent returns to the recirculation tank or is pumped to the dispersal field. Because the system requires oxygen, it is covered with only a thin veneer of sod, or left exposed with a surface layer of coarse gravel. The filter can be placed fully below grade, or above grade with retaining walls or mounded soil.

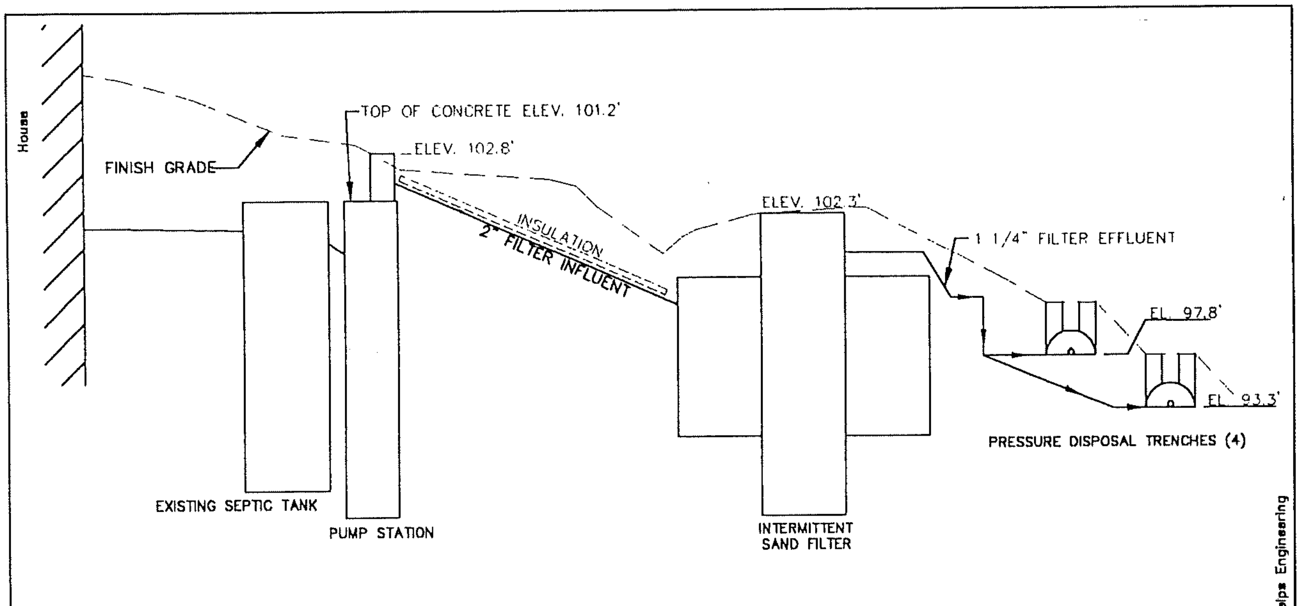


At-Grade and Shallow-Placed Systems

These two variations on a conventional mound are either placed at the surface of the ground or in a shallow excavation, depending on the distance from the system to ground water. In Vermont, a conventional mound requires 12" of sand fill material to be imported to provide the required 36" separation distance to the seasonal high water table. At-grade and shallow-placed systems allow for less than 12" of soil fill beneath the effluent dispersing medium if allowed by the site conditions. These systems may be built as one or more *trenches,* (a four foot wide leachfield as long as necessary to provide the design area), or a *bed* (wider and shorter than a trench), depending on the logistics of the site.

The native soil surface is furrowed by plowing along the contour of the land. A shallow-placed system is dug at least 6" deep on the downslope edge with a level floor, then 6" of stone, then pipe and 6" more stone. Sand is not required. With at-grade systems the sand layer is eliminated completely. This is followed with perforated small diameter pressure distribution pipes with orifices facing down, and another 2" of stone aggregate. The system is covered with filter fabric or similar material, then topsoil and seeded. The effluent flows from the septic tank to a pump station which discharges to the perforated pipe then through the stone and sand. The furrows capture the liquid, allowing it to infiltrate the soil. The effluent is treated as it passes through the stone aggregate, sand (if used) and into the soil.

At-grade and shallow placed on-site systems are valuable because of the flexibility of siting. The systems may consist of two lines installed end to end, rather than side by side, with the effluent inflow at the center. They may be placed at different depths to fit the space available or slightly angled to follow a contour. The systems are narrower, have a lower profile than standard mounds and require less imported material. This type of construction should ultimately be less expensive than conventional mound systems for the consumer.



HYDRAULIC PROFILE (ISF)
NOT TO SCALE

The Demonstration Sites

Intermittent Sand Filter; Sand Road, Ferrisburg

This site presented complicated logistics for access and design. The site, which does not have the space for a conventional system, is constrained by the floodplain of the Otter Creek, seasonal high water table, surface flow of water, a wet swale, a turtle migration corridor, close neighbors and steep slopes. In a January, 1996 flood, Otter Creek was within 120' of the distribution trenches. The soils consist of 30" of sand over clay with seasonal high water table at 24" to 36". Two people occupy the three bedroom house.

A 10' x 36' intermittent sand filter was constructed on an elevated area behind the house. Because of the anticipated quality of treatment, a pressure distribution system was installed with a reduced isolation distance to groundwater. A graywater system that previously drained into a nearby drainage swale was reconnected to the system for treatment by the intermittent sand filter. The filter was covered with a 12"-18" of soil and planted with grass.

Construction Notes

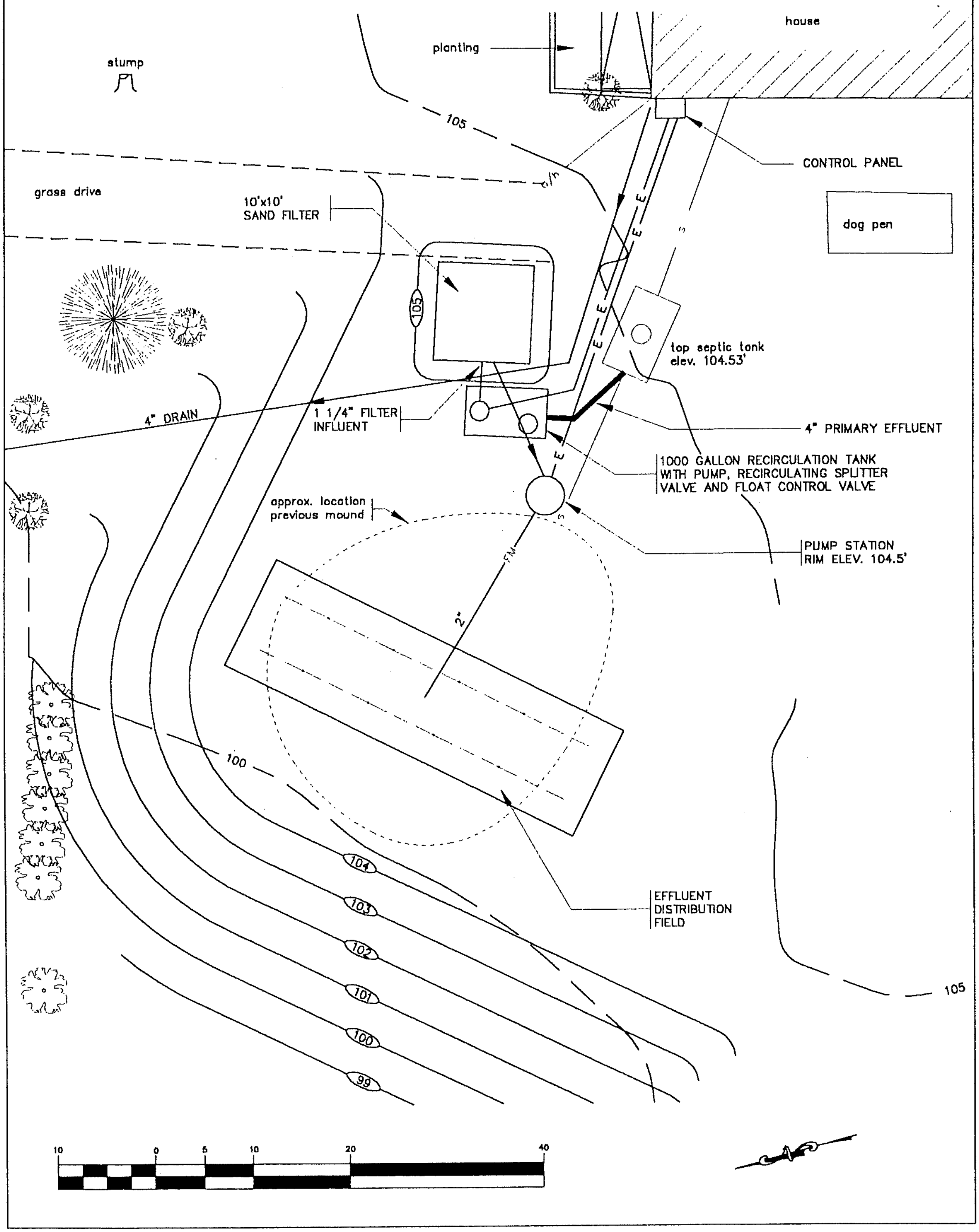
- Existing 1000 gallon septic tank was used after an inspection of its integrity.
- A five foot diameter pump station installed after the septic tank provides a secondary chamber.
- Second pump chamber installed in ISF.
- Pump control panel mounted to exterior of house with dedicated circuit breaker.
- Fiberglass covers over pump station allow for easy access and removal of pumps, floats and filters for maintenance.
- ISF design loading rate 1.25 GPD/sf; actual loading .35 GPD/sf. Design flow: 450 gpd.
- Air coil placed in ISF provides additional air if necessary to enhance treatment.
- Four 25' long pressure distribution dispersal trenches can be individually isolated to maximize loading to a specific trench.
- Pressure distribution dispersal field: design linear loading rate 4.5 gpd/lf; actual loading 1.25 gpd/lf.
- Access for monitoring through pump stations before and after the sand filter.

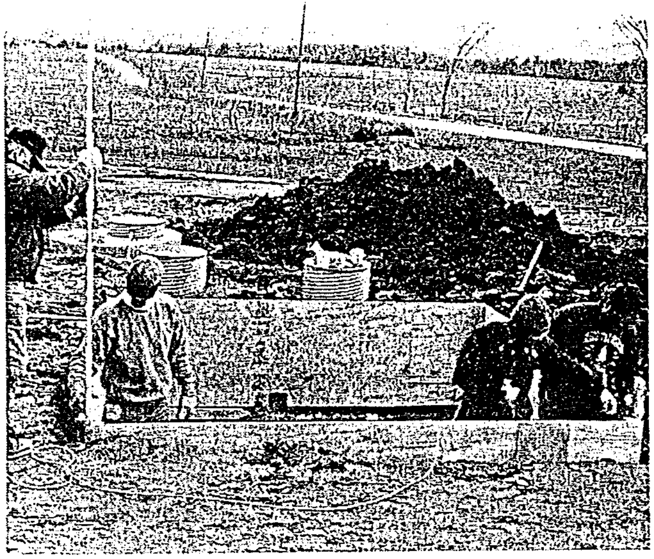
Recirculating Sand Filter; Crown Point Road, Bridport

This challenging site has a combination of seasonal surface flow and seasonal high water table within 12" of the surface of the ground, and heavy clay soils. A site to the west of the house with drier soils was considered and rejected because of surface sheet flow of water and the existence of a large vegetable garden. There are two adults, two children and a registered day-care serving two to six children on the premises.

The recirculating sand filter was selected because of the anticipated greater loadings from the family and day-care facility. The system, which was completed in late fall, 1995, is designed to retreat 80% of the effluent at full flow. At lower flows, there will be a higher percentage of retreatment. The top gravel surface of the filter has been left exposed to allow for more aeration of the system. The filter did not freeze during an extended period of below zero weather in January, 1996.

Recirculating Sand Filter Site





Prior to installation of the sand filter, the failed mound was removed. A foundation footing drain which had contributed to the failure was isolated from the wastewater treatment systems. A conventional mound for dispersal of the effluent was constructed to blend with the topography created by a house addition. Imported sand and stone fill was necessary to obtain the required 36" separation distance to groundwater.

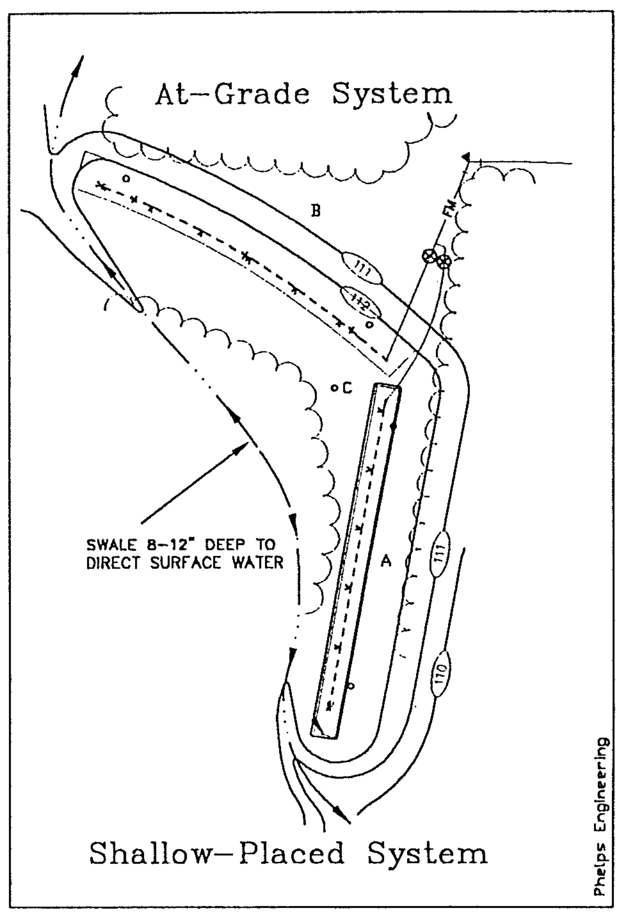
Construction Notes

- Existing septic tank used after inspection.
- Control panel mounted on house near filter, connected to electrical system with separate breaker.
- Initial readjustment of floats was required to 'fine-tune' the system .
- RSF design loading 6 gpd/sf; actual loading 1.2 gpd/sf. Design flow: 600 gpd.
- Filter media coarser than that of ISF.
- Air coil installed in RSF.
- Fiberglass covers allow access to pumps, floats and splitter valve.
- Conventional mound dispersal system: Design loading 1.25 gpd/sf; actual loading .266 gpd/sf
- Alarm system operates when there is a power outage, requiring resetting the alarm

Shallow-placed and At-grade Systems; N. Bingham Street, Cornwall

Two adults and two children occupy this old Victorian farmhouse, which had a typical substandard wastewater system. The 500 gallon steel septic tank was deteriorating, the leachfield site was not confirmed, and the system was close to failure. The replacement site, an old barnyard, has relatively suitable soils (for Addison County). While there is a swale with seasonal surface water and high water table nearby, the site is suitable for a standard mound system. The septic tank was replaced and an effluent filter installed as part of the demonstration project.

A dual dispersal system was installed in Oct. 1995, constructing both an at-grade and a shallow-placed system. After consideration of

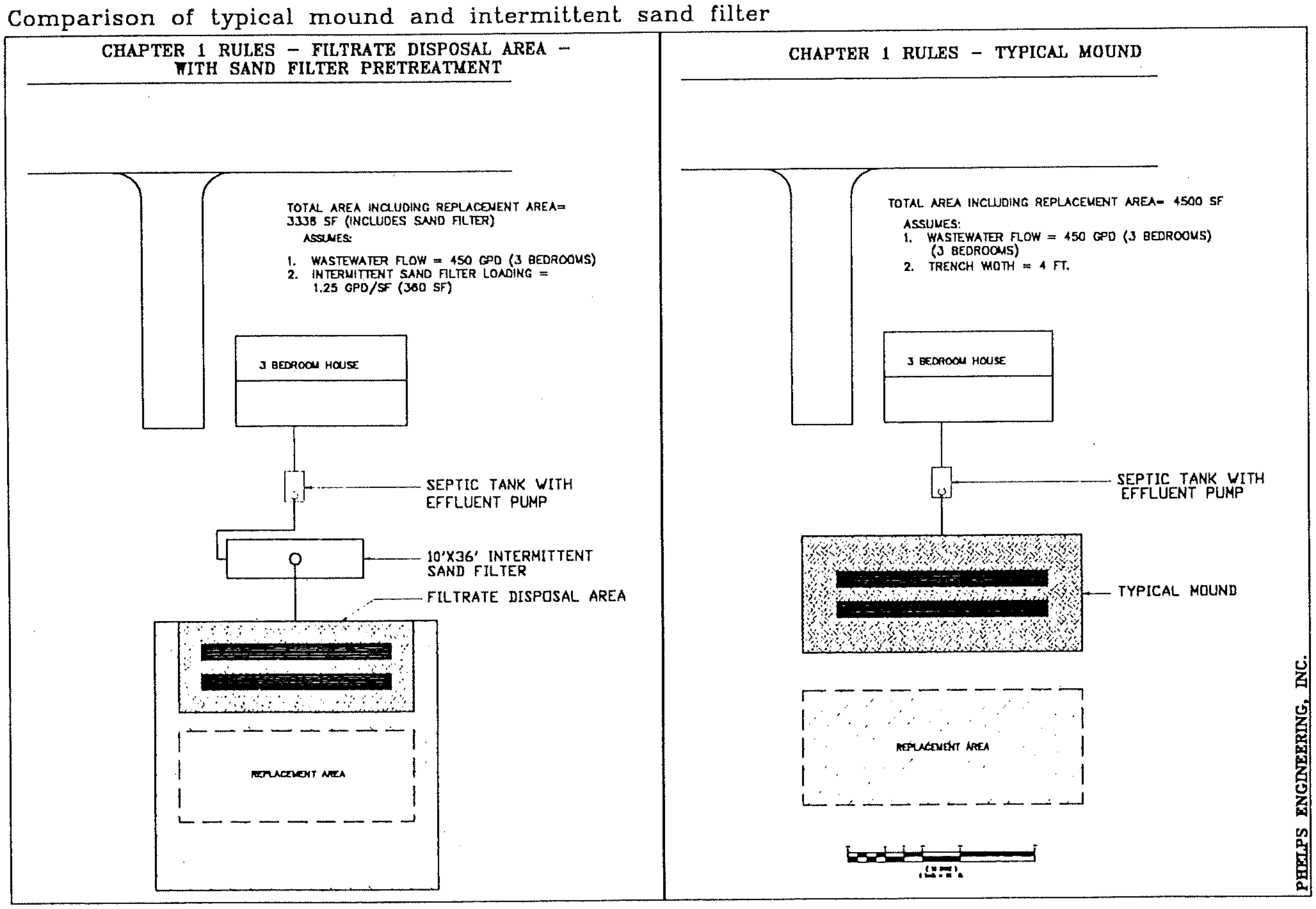


the site conditions, the separation distance of the disposal fields to the seasonal high ground water table was reduced from 24" to 18". The two units were angled slightly to fit the contour of the site. A valve at the effluent application point allows the effluent to be directed to one disposal system or the other.

Construction Notes

- New septic tank with filter used to monitor effectiveness.
- Site preparation included relocation of fir trees and removal of concrete debris and sumac shrubs.
- At-grade system required plowing an area 8-10 feet downslope of the bed.
- 3/4" stone was used to create at-grade and shallow placed trenches.
- Soil imported to continue the grade across the site.
- Observation ports allow viewing of ponding within the trenches.
- Owner landscaped around septic tank and pump station.
- Disposal area 532sf.
- Application rate (design) 1.127 gpd/sf; application rate (actual) 0.3 gpd/sf. Design flow: 600 gpd.
- Linear loading rate (design) 4.5 gpd/sf.
- Monitoring samples were taken from wells installed 3' down gradient of each system (effluent), 5' upgrade ('control') and from the septic tank filter (influent).
- The 'before' sample should show slight treatment due to filtration by the filter.

Comparison of typical mound and intermittent sand filter



Constructed Wetland; Burritt Road, Hinesburg

The leachfield of this approximately 15 year old house failed several years ago. The effluent was separated into black and gray water lines and discharged directly to a nearby wetland. The current owners, two adults and a teenage son, wanted to remedy the problem by installing a constructed wetland. The site includes a narrow lawn, a Class II wetland and a ledgey hillside with silty loam to 12" and silty clay to 36".

The treatment system consists of a septic tank, 1000 gallon pump station with 1HP pump, a 2" force main crossing the native wetland to the 25' by 49' lined constructed wetland, a siphon dosing chamber and a 120' single trench dispersal mound.

The constructed wetland treats effluent in a 30" deep gravel filled bed lined with 30 mil plastic and bermed with a substantial amount of native and imported soil. The first 15" of the apron was covered with a layer of gravel and the remainder seeded. The interior walls of the CW have a 2:1 slope which allows more room for the plants and removes the need for plywood support during construction. The gravel holds the liner in place in the completed system.

Native softstem bulrush (Scirpus acutus) was planted 18" on center in the gravel media, 6-8" deep to immerse the root zone in the effluent. Treatment will take place as the effluent passes over the microbial community in the highly oxygenated root zone. It is expected that the vegetation will be fully established in 3-5 years.

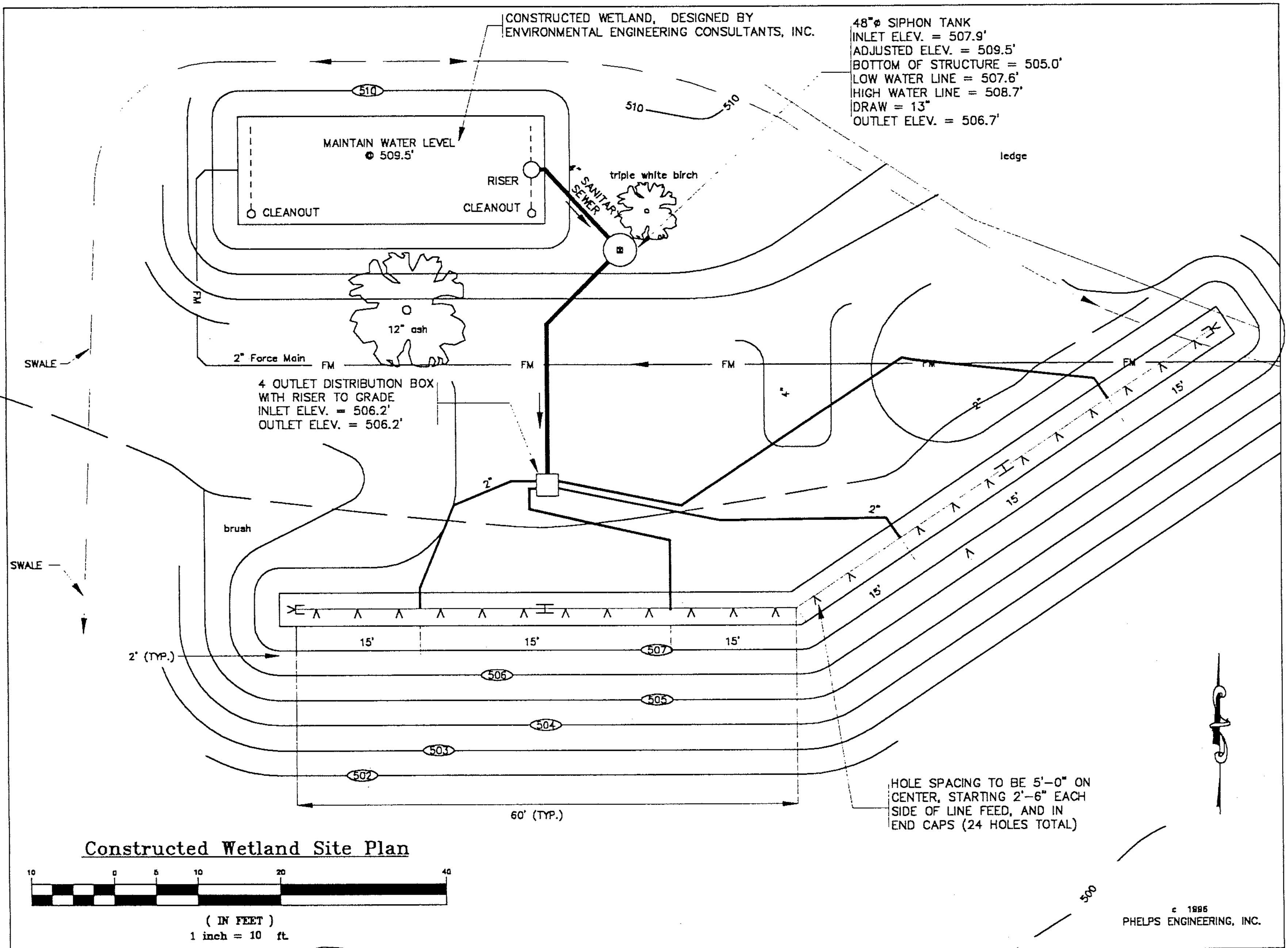
The use of reed grass (*Phragmites austrailis*) in the original design initiated a dialogue among various state agencies and the project partners regarding appropriate plant species to use in a constructed wetland. Engineers like using reedgrass for the same reason environmentalists hate it: it is invasive, fast growing, deep rooted and fierce when established. Softstem bulrush, which is preferred by wetlands biologists, (*Scirpus* sp.) is found in deeper water, is slower to get established but carries no risk of invasion to nearby upland wetlands.

The design of the outflow system controls the depth of water in the CW and allows the entire bed to serve as temporary storage in the event of a heavy rain, ensuring that the distribution system is not suddenly overloaded.

The homeowners will need to keep the apron mowed and the wetland weeded. Straw can be spread on the system in cold weather and removed in spring to provide extra insulation until the bulrush has matured. Weeds should not be allowed to build up in the bed or on the berm.

Construction Notes:

- An electrical box in the basement controls the pump station.
- The PVC liner for the CW was custom-made and the remaining materials were purchased locally.
- The final locations of both the dispersal field and constructed wetland were changed relative to the original design because of boulders and trees on the site.
- The siphon dosing chamber sends 100 gallons at a time into the dispersal mound.
- Two horizontal pipes w/ evenly spaced holes distribute the dosed effluent evenly throughout the mound.
- Samples will be taken from the pump station and the dosing chamber.
- Design flow: 450 gpd.
- Disposal area is 532 square feet; linear loading rate is 4.5 gpd/l.f.



Constructed Wetland Site Plan

System Monitoring

Each system was designed to allow "before" (influent) and "after" (effluent) samples to be analyzed for fecal coliform, nitrate, phosphorus, total Kjeldahl nitrogen (TKN), ammonia, biological oxygen demand (BOD), and total suspended solids (TSS) by the State of Vermont LaRosa lab in Waterbury, VT. Samples were collected on an intermittent basis to provide background information for evaluation of the systems' effectiveness under start-up conditions. The number of samples, however, do not provide a statistically valid sample size.

Vermont DEC field engineers were enlisted to obtain the samples with equipment supplied by Vermont DEC. Standard procedure was followed for obtaining and handling the samples. In several instances, the methods were slightly modified due to site constraints or the quantity of influent or effluent available.

The constructed wetland was installed during the fall of 1996 and a sample set obtained in December. The results will provide background information to relate to future monitoring.

Cornwall

The systems were installed in Oct. 1995, and three sets of samples taken in April and May, 1996. Monitoring wells were installed 5' upslope of the at-grade and shallow-placed systems (control) and 3' downgrade of the systems (effluent). The influent sample was taken from the effluent filter in the septic tank, which could result in slightly lower suspended solids (TSS) values.

When placed, each well was at least five inches into the water table. The groundwater level later subsided, creating problems for collecting samples until a wet period of time in spring, 1996. Due to the low hydraulic conductivity of the soil, it was necessary to evacuate the wells and return the following day to obtain a sample.

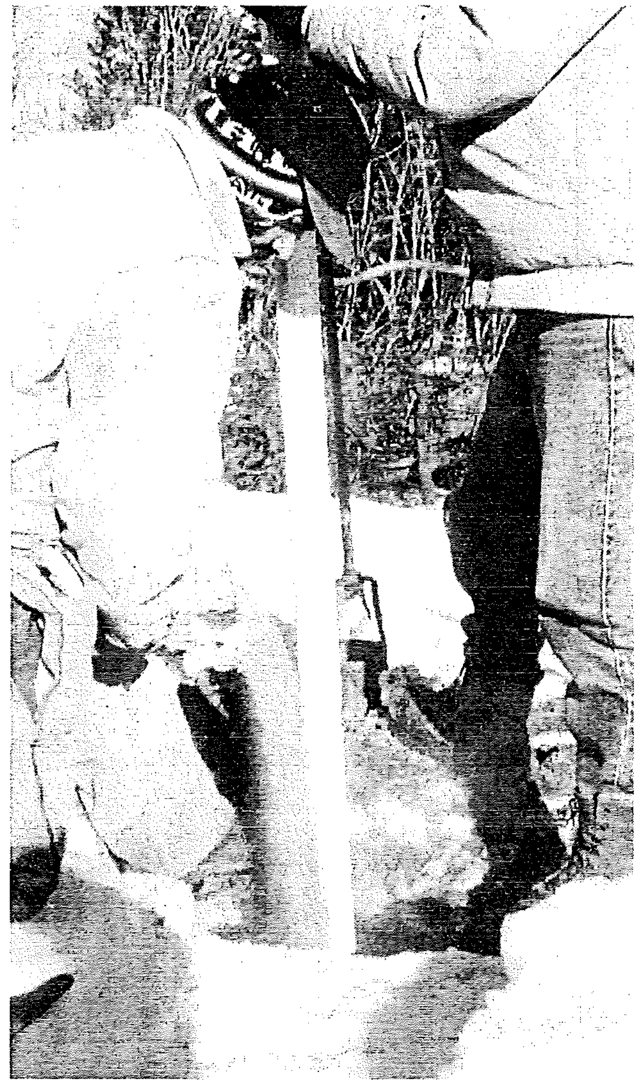
The systems are placed near an old barnyard, which may explain the higher than expected background ground values for phosphorus and nitrogen, both of which are nutrients found in animal waste.

Reduction of fecal coliform ranged from 99.83% to 99.99%. While this is an excellent result, it is slightly less than expected. Incomplete biomat development due to a short, cold life span for the systems could explain these results.

Bridport

The RSF was installed in late October, 1996 and samples taken six to nine months later. The samples were obtained from the septic tank (influent) and pump station containing the recirculation valve (effluent). It is possible that the effluent sample was slightly modified by the bailer touching the bottom of the pump chamber. This may disturb sediments, thus altering the results for nutrients and solids slightly.

Results show a removal range of 91.90% to 99.36% removal rate for fecal coliform, which is not unexpected for a recirculating sand filter. Apparent removal of nitrogen is good. There is a possibility of loss of nitrogen due to denitrification resulting from the alternating aerobic-anaerobic conditions. Phosphorus removal (25% to 70%) rates are also good.



Ferrisburg

The ISF was installed in September, 1995, and samples taken from seven to ten months later. Access for both samples was through the pump stations before and after the sand filter.

Intermittent sand filters tend to be very good at removing bacteria from wastewater, which is reflected in the very high reduction values (99.81% to 99.99%) for fecal coliform. Phosphorus removal rates (68% to 78% removal) and nitrification values are also very good. Nitrogen (TKN) removal values vary, possible due to sediment disturbance while collecting samples.

Result summary

Preliminary results show that the systems are working well. While there are several inconsistencies in the data, external influences provide scenarios that may explain them. It is important to note that the monitoring is taking place under 'real life' rather than strictly controlled conditions. The results may be used to get a general sense of how well the systems are working under start-up conditions but should not be used for comparisons of the systems.

The illustrations are provided for educational purposes only, and are not to be used for system design.

Monitoring Results -- Cornwall

Cornwall **4/25/96** Test	Unit	Pump Station Result	Shallow-placed A1 Result	*% Removal fro*	A2 Result	*% Removal from PS*	At-Grade B1 Result	*% Removal from PS*	B2 Result	*% Removal from PS*	Ground C1 Result
				from PS							
Fecal Coliform	Bact/100	48000	7	*99.99*	11	*99.98*	1	*100.00*	2	*100.00*	10
Nitrate +Nitrite	mg-N/l	0.02	14.6		2.6		23.3		26.5		4.73
Nitrogen, Ammonia	mg-N/l	45.5									
Phosphorus, Digested	mg/l	8.68									
Phosphorus -Filtered/Digested	mg/l	8.6	0.166	*98.07*	0.024	*99.72*	0.058	*99.33*	0.045	*99.48*	0.235
BOD - Total Uninhibited - 5day	mg/l	156									
Nitrogen, total Kjeldahl (TKN)	mg-N/l	53.2	8.6	*79.3*	24.4	*41.2*	8.28 **	*80*	17.1 **	*67.86*	22.8
Solids, Total Suspended (TSS)	mg/l	23.1									

5/15/96 Test	Unit	Pump Station Result	Shallow-placed A1 Result	*% Removal from PS*	A2 Result	*% Removal from PS*	At-Grade B1 Result	*% Removal from PS*	B2 Result	*% Removal from PS*	Ground C1 Result
Fecal Coliform	Bact/100		400		300		22		3		1
Nitrate +Nitrite	mg-N/l	<.02	0.89		0.02		9.25		19.4		6.2
Nitrogen, Ammonia	mg-N/l	45.3									
Phosphorus, Digested	mg/l	10.5									
Phosphorus -Filtered/Digested	mg/l	8.66	0.888	*89.75*	0.039	*99.55*	0.063	*99.27*	0.053	*99.39*	0.296
BOD - Total Uninhibited - 5day	mg/l	171 *									
Nitrogen, total Kjeldahl (TKN)	mg-N/l	56	15.4	*72.50*	4.96	*91.14*	6.35 **	*88.66*	6.35 **	*91.24*	6.06
Solids, Total Suspended (TSS)	mg/l	19									

5/22/96 Test	Unit	Pump Station Result	Shallow Trench A1 Result	*% Removal from PS*	A2 Result	*% Removal from PS*	At-Grade B1 Result	*% Removal from PS*	B2 Result	*% Removal from PS*	Ground C1 Result
Fecal Coliform	Bact/100	640000	80 E	*99.99*	1,090	*99.83*	1100	*99.83*	40	*99.99*	10
Nitrate +Nitrite	mg-N/l	0.04	1.05		0.02	*50.00*	2.35		9		7.25
Nitrogen, Ammonia	mg-N/l	44.6									
Phosphorus, Digested	mg/l	8.76									
Phosphorus -Filtered/Digested	mg/l	8.42	0.41	*95.13*	0.018	*99.79*	0.047	*99.44*	0.048	*99.43*	0.18
BOD - Total Uninhibited - 5day	mg/l	228									
Nitrogen, total Kjeldahl (TKN)	mg-N/l	41.5	17	*59.04*	6.11	*85.28*	14.5	*65.06*	17	*59.04*	5.4
Solids, Total Suspended (TSS)	mg/l	45.2									

See following page for notes

Monitoring Results -- ACDP

Bridport (RSF)		4/3/96			6/5/96			7/24/96		
Parameter	Unit	Influent	Effluent	% *removal*	Influent	Effluent#	% *removal*	Influent	Effluent	% *removal*
Fecal Coliform	Bact/100	1,150,000E	42,000	*96.35*	21,000	1700 E	*91.90*	250000	1600 E	*99.36*
Nitrate +Nitrite	mg-N/l	0.02	0.22		0.14	19.8		< 0.02	9.74	
Nitrogen, Ammonia	mg-N/l	60.40	41.10	*32.00*	96.8	0.42	*99.5*	42.5	0.14	*99.67*
Phosphorus -Digested	mg/l	15.60	7.70	*50.6*	8.34	4.02	*51.80*	9.37	5.25	*43.97*
Phosphorus -Filtered/Digested	mg/l	13.50	3.98	*70.5*	6.29	3.92	*37.68*	6.8	5.2	*23.53*
BOD - Tot Uninhibited - 5day	mg/l	0 (N)	0 (N)		320 j *	15.5 j *	*95*	510	39.7	*92.22*
Nitrogen, Total Kjeldahl (TKN)	mg-N/l	72.80	54.60	*25.00*	55.00	< 0.5	*>99.09*	44.2	1.79 **	*95.95*
Solids, Total Suspended (TSS)	mg/l	81.00	476.00		93.00	34.2	*63.23*	93	329	

Ferrisburg (ISF)		4/3/96			6/5/96			7/24/96		
Parameter	Unit	Influent	Effluent	% *removal*	Influent#	Effluent#	% *removal*	Influent	Effluent	% *removal*
Fecal Coliform	Bact/100	18000 E	<1	*100.00*	2000 E	<1	*99.90*	1,400,000	2600	*99.81*
Nitrate +Nitrite	mg-N/l	0.02	37		0.03	3.48		0.02	24.9	
Nitrogen, Ammonia	mg-N/l	34.8	5.09	*85.37*	33.3	<0.02	*99.90*	31.9	<0.02	*99.90*
Phosphorus -Digested	mg/l	8.13	1.73	*78.72*	8.53	1.53	*82.06*	8.9	2.82	*68.31*
Phosphorus -Filtered/Digested	mg/l	7	1.76	*74.86*	8	1.48	*81.50*	7.85	3.22	*58.98*
BOD - Tot Uninhibited - 5day	mg/l	0.0 (N)	0.0 (N)		57 j	6.5 j * ^	*88.60*	87.4	40.7	*53.43*
Nitrogen, Total Kjeldahl (TKN)	mg-N/l	44.3 **	12.4 **	*72.01*	41.8	< 0.50	*> 98.8*	40.7	0.5 **	*98.77*
Solids, Total Suspended (TSS)	mg/l	121	26	*78.51*	55	101		100	368	

Hinesburg (CW)		12/18/96		
Parameter	Unit	Influent	Effluent	% *removal*
Fecal Coliform	Bact/100	400,000	30 (E)	*99.99*
Nitrate +Nitrite	mg-N/l	<.02	<.02	
Nitrogen, Ammonia	mg-N/l	45.2	19.6	*56.64*
Phosphorus -Digested	mg/l	9.5	0.92	*90.32*
Phosphorus -Filtered/Digested	mg/l	8.9	0.689	*92.26*
BOD - Tot Uninhibited - 5day	mg/l	75.9	12.9	*83.00*
Nitrogen, Total Kjeldahl (TKN)	mg-N/l	46	22	*52.17*
Solids, Total Suspended (TSS)	mg/l	26	7.3	*71.92*

Notes:
j = value may be in error   ^ DO depletion <2mg/l for BOD5
*GGA Result Unacceptable E=Estimated
N=Outside estimated range
(N)=sample not processed, overhold
FCOL rosolic acid used for chl. sample
** High Nitrite >10 mg/l may cause negative interfereance

Nitrogen tends to change form during the treatment process, therefore % removal reflects this change.
Nitrate + Nitrite may increase.

Conclusions and Recommendations

The Addison County Demonstration Project has been successful in reaching the goals of educating the public, practitioners and regulators about new technologies for wastewater treatment and cleaning up sources of pollution to ground and surface water from failed septic systems. All four alternative replacement systems were installed successfully, and according to preliminary monitoring results, are working very well.

As a result of the project, new materials and expertise are available to designers and installers. Costs for design, materials and installation will vary on each site based on design size and site conditions. Based on experience with the demonstration project, expected costs for the systems are:

Technology	Design	Labor	Materials
Recirculating SF	$3500	$2000	$7500
Intermittent SF	3500	2000	7000
At-Grade	2500	2000	5000
Shallow-Placed	2500	2000	5000
Constr. Wetland	3000	2000	6200

The project has gained local, regional and international notice through tours and press coverage. *Small Flows Clearinghouse* and Vermont Technical College scheduled site visits for an operator training class. Visitors from Vermont, New York and Indonesia have been given site tours. Presentations have been given by the lead engineers, Steering committee members, Vermont DEC staff, and the project coordinator to engineers, water quality experts, regional planners, legislators and regulators.

The homeowners are grateful to have fully functional septic systems. They have allowed site visits to their yards, and have interacted well with the engineers regarding the working of their systems. Through a questionnaire, it has been determined that the homeowners understand how their system functions and how they should be maintained. Feedback regarding the expertise and professionalism of the designers and installers has been excellent. The homeowners are certainly more informed about on-site wastewater treatment than before the project started.

Vermont's standards for on-site systems have been revised, as a direct result of the research for this project, to allow at-grade systems and sand filters. WCAX-TV has been able to avoid pumping or storing the waste generated at their Mount Mansfield facility by installing a small sand filter. The Vermont On-Site Sewage Committee will continue in their efforts to comprehensively reform the way Vermont manages on-site sewage treatment.

The partners of the Addison County Demonstration Project: Addison County Regional Planning Commission, the Vermont Agency of Natural Resources, and the Vermont On-Site Sewage Committee, recommend that monitoring be continued for another year, especially for the constructed wetland and for the at-grade and-shallow placed systems. This will improve understanding of the long term effectiveness of these technologies. The partners are pleased to have been involved in a worthwhile project for the Lake Champlain Basin, the State of Vermont and New England.

"We now flush our toilets and know that it is not running into a Class II wetland. Also, our gray water system no longer backs up into our shower. These are simple things for most homeowners, but a real joy for us!"

Participating homeowner Alan Belcher

Glossary

Aerobic Wastewater treatment depending on oxygen for bacterial breakdown of waste.

Air coil Device that pumps external air to ensure adequate oxygen in a treatment system.

At-Grade A dispersal system installed so the bottom of the trench stone is at the natural grade of the soil.

Anaerobic Wastewater treatment in which bacteria break down waste without using oxygen.

Bed A dispersal field that is more than 48" wide. Requires less dispersal area, but sometimes fits the site better.

Biomat Microbe and bacteria buildup in a treatment system. Beneficial for the treatment process but can cause clogging if it becomes excessive.

BOD Biochemical Oxygen Demand. Decomposing organics require oxygen. The BOD_5 test measures the oxygen consumed by organisms as they decompose organics over a five day period. BOD is thus an indicator of the concentration of organics in water

Cold Climate Limitations Cold temperatures, ice cover, plant dormancy, equipment performance, ice buildup and reduced microbial action create design challenges for cold weather wastewater treatment.

Constructed Wetland A wetland constructed in an impermeable liner for the purpose of pollution control and waste management. The flow rate, residence time and other factors are controlled to enhance the removal of BOD, TSS, and N. A waterproof barrier is placed below the substrate to isolate the wastewater from the groundwater. Emergent wetland plants such as cattails, bulrushes and reeds provide a dense cover and an oxygenating substrate for bacteria in the root zone. Harvesting plant material is not required for treatment success.

Detention Time (retention time; residence time) The average period of time wastewater stays in a treatment system. Detention times vary for different types of wastewater treatment systems and can range from hours to weeks.

Effluent The liquid discharge from any component of a treatment system.

Effluent Filter A screen with varying mesh sizes placed over the outlet of the septic tank which removes solids from the septic tank effluent.

Emergent Vegetation A class of rooted wetland plants growing in shallow water or under periodic flooding conditions with stems and /or leaves emerging out of the water.

Free Water Surface Constructed Wetland (FWS) A lined basin or channel with porous plant substrate and wetland vegetation in which the shallow water is exposed to the air.

Gray Water All household wastewater not coming from toilets: *i.e.* showers, sinks and laundry.

Intermittent Sand Filter (ISF) Septic tank effluent is treated in a single pass through the filter before dispersal to soil.

Nitrogen (N) This nutrient is present in various forms in wastewater.

On-site Land-based wastewater treatment for a single house or small community.

Phosphorus (P) This nutrient, which is present in wastewater, acts as a fertilizer in surface waters.

Pressure Distribution Effluent is pumped under pressure into a leachfield to ensure even distribution of the liquid.

Recirculating Sand Filter (RSF) Eighty percent of the treated effluent is pumped from a recirculating tank back to the filter for retreatment. The high level of treatment makes this system suitable for use by small communities and other high strength applications.

Recirculation Valve (splitter valve) This valve, which is housed in an enclosure and buried between the circulating filter and dispersal system, divides the treated effluent into outflow pipes that lead out to the dispersal field or to return for additional treatment.

Sanitary Wastewater (domestic) Wastewater, including toilet, sink, shower and kitchen flows, originating from human domestic activities. An average of 50 to 100 gallons of wastewater is generated per person per day.

Shallow-Placed A dispersal system installed in a slight excavation in the soil.

Subsurface Flow Constructed Wetland (SF) A type of constructed wetland in which primarily treated waste flows through a deep gravel or other porous substrate planted with wetland vegetation. The water is not exposed to the air, avoiding problems with odor and direct contact.

Total Suspended Solids (TSS) Total suspended solids in wastewater.

Trench A long, narrow (four feet wide or less) dispersal system.

Trickling Filter A treatment system used by municipalities and small communities.,

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Constructed Wetlands Bibliography http://www.inform.umd.edu:8080/EdRes/Topic/AgrEnv/Water/Constructed_Wetlands_all Compiled by USDA, includes NPS pollution, agricultural waste, household wastewater, urban runoff, basic & general, and industrial waste.

NCSU Water Quality Group http://www2.ncsu.edu/bae/programs/extension/wqg/ General water quality information, monitoring and analysis.

Point Source Information and Provision Exchange System (PIPES) http://pipes.ehsg.saic.com/pipes.html watershed info

"Septic System Farm*A*Syst Fact Sheet" http://h2osparc.wq.ncsu.edu/info/farmassit/f_septic.html Fact sheet @ drinking water safety

Wastewater Engineering Virtual library (WWEVL) http://www.halcyon.com/cleanh2o/ww/welcome.html Bibliographies, info @ constructed wetlands, general ww treatment information

Water Environment WEB (Water Environment Federation) http://www.wef.org water resources info and hyperlinks

Water Quality and Land Treatment Informational Component http://h2osparc.wq.ncsu.edu/info/index.html Listing of many facets of water quality, NPS, metals, phosphorus, etc.

Web Sites of Interest http://www.ksmart.on.ca/WebSites.html To consulting engineers and planners

Welcome to Orenco Systems, Incorporated http://www.orenco.com/~osi/
Info on biotubes, sand filters, etc., and a list of available literature on sand filters, pressure dosing, effluent filters, etc.

Wetlands for waste treatment - Annotated Bibliography http://gus.nsac.ns.ca/~piinfo/resman/wetlands/anno/annobib.html Searchable index regarding wetlands and wastewater treatment, including agricultural wastewater