Such a well managed forest would not only provide a substantial income to the rate payers, it would be a community recreational resource of inestimable value that could be completely accessible to the public, and would contribute a large number of jobs to a sector of our economy, namely the timber products industry, that has suffered in the last decades. 001 (cont.)

There are many other significant advantages that could be discussed that are not germane to the EIR. What is germane is that all the areas of concern raised in the EIR pertaining to "crop irrigation" are open to question because the most effective method currently in existence to implement wastewater irrigation was not included in the analysis. The exclusion of such a vital technology could be construed as unfairly weighting the EIR against the "crop irrigation" option and in favor of alternative disposal methods such as river discharge. It is essential that the city of Santa Rosa conduct a complete EIR so that they are not subject to legal challenge. They should direct the consultants to conduct a thorough and adequate study in the EIR of the implementation of subsurface transpiration forests as a supplement to the currently existing surface irrigation system.

The city's current irrigation system is beneficial and should continue. The limitations of the system are only relative and if water is applied at an appropriate rate and the system is well managed it can be effective. The subsurface transpiration component can be implemented in incremental fashion over an appropriate time period to supplement the current system to create a robust and better integrated wastewater treatment system which does not suffer from over-reliance on any single option.

Proposed Minimal Implementation

While it would be advantageous for the city of Santa Rosa to replace its entire current irrigation system with a subsurface forest we propose that the city undertake a limited implementation of the above system. Because we do not possess the details of the Santa Rosa system necessary to design such a system we include herein a water balance analysis of the city of Petaluma's system, for which data were available, which illustrates how a similar system would be assessed for Santa Rosa.

Petaluma faces the question of building a new reservoir capable of holding 1300 acre/feet of water costing $12 million. We prepared a preliminary analysis based on the data from the Martinez system and incorporated a transpiration forest component to the Petaluma system sized to avoid the necessity of adding the new reservoir. The forest was sized to move 1300 acre/feet/yr and was approximately 60 acres. The cost was estimated to be approximately $3.5 million for the transpiration forest. It is included here only as an example.

The water balance for Petaluma showed that the extra transpiration component worked to keep winter storage below the 1300 acre/feet of storage already used by the city.

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Table 1. Projected water balance for city of Petaluma with added transpiration component to eliminate addition of extra 1300 acre/feet storage reservoir and increased irrigation system. 001 (cont.)

	Inputs		Outputs				Amount in
Month	Flow	Rain	Irrigation	Evaporation	Discharge	Transpiration	Storage
Sept	600	0	900	90	0	101.5	0
Oct	600	0	600	50	200	117.7	0
Nov	600	200	0	30	300	87.5	382.5
Dec	750	200	0	10	400	87.5	835.0
Jan	600	250	0	10	800	87.5	787.5
Feb	650	200	0	30	750	52.9	852.1
Mar	750	250	0	60	550	140.4	846.3
Apr	700	50	250	80	300	191.2	775.1
May	700	0	700	100	0	122.0	553.1
Jun	650	0	1000	110	0	112.3	0
Jul	650	0	1100	110	0	110.2	0
Aug	650	0	1000	100	0	87.5	0

The critical feature of the above example is that one need only implement a minimal system for the transpiration forest to avoid new reservoir storage. This is because the system is used primarily to divert from storage during the time when storage would typically be filling to capacity. While the high winter months (Dec, Jan, Feb) display reduced transpiration rates this transpiration is additive in its effect on storage. River discharge is typically occurring during this period in any event so the transpiration is there as a safety valve or buffer to the system.

The Santa Rosa system will have its own seasonal dynamic and a transpiration component will need to be fitted to that dynamic. The primary advantage will be felt during the years when rainfall keeps the level of the Russian River low enough that either the 1,000 CFS requirement is not met or when the city needs to release more than 1% of river flow. These conditions do not occur except in low rainfall years. It is specifically those years in which transpiration disposal will be greatly increased over the conservative figures used in the Petaluma example. At that time even a minimally sized transpiration forest will extend storage capacity such that river discharge restrictions can be complied with under virtually any realistic weather scenario.

It is obvious from the above that the technology exists that can eliminate the need for the city of Santa Rosa to accept any of the options currently presented in the EIR prepared by the consultants. Not only does this technology make it possible to present to the Water Quality Control Board a weather-independent system that stays within the current discharge permit requirements, it does so at a cost well below any of the other alternatives. This includes both the "no-project" and the "20%" river discharge options because the consultants have not factored in the certain costs of continued litigation which would be faced by either of these options or the enormous potential for cost recovery.

We present the above analysis to the city council in the sincere hope that they act in the best interest of their constituents, the rate payers of the Santa Rosa system. This requires that at a minimum the city conduct an open-minded and thorough review of the alternative technologies that exist for dispersal of wastewater and reject the inaccurate representation in the current EIR that no system exists that can irrigate crops in the winter wet season. 001 (cont.)

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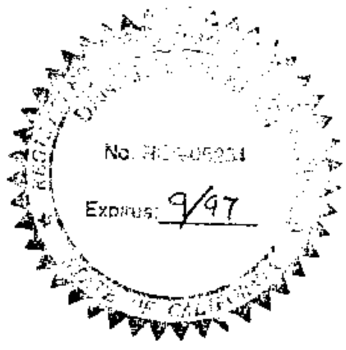

Wastewater Disposal in a Forest Evapotranspiration System

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Land application of treated wastewater as an alternative to discharge to natural watercourses is finding increasing acceptance in California and other areas. However, in many locations high land values limit the feasibility of this approach. In addition, concerns regarding the possible presence of pathogens and carcinogenic chemicals even in treated domestic wastewater have severely limited the allowable uses. In response to these concerns, a system was developed to maximize the water used per acre and the environmental benefit of the water while minimizing the potential for contact with pathogenic organisms or for undesirable elements to enter the food chain. The system disposes of wastewater through evapotranspiration/adsorption (ETA) by selected high-water-using trees. It is called the "marsh-forest ETA". **Wastewater is delivered to the trees from a marsh pond through an underground irrigation network.** A prototype was constructed at the Mt. View Sanitary District treatment plant in October, 1978. It has been monitored for the past nine years to determine the long term feasibility of the concept.

The marsh forest ETA is based on work done in two areas. The first of these is the use of natural and constructed wetlands for wastewater treatment and polishing. Research by others as well as work done at the Mt. View Sanitary District have shown that wetlands are effective in **polishing secondary effluent, especially in the removal of biologically degradable organics.** The removal of nutrients and suspended matter is less consistent and depends to a great extent on the control of algae growth in the open-water areas of the wetland.

The second research area is in silviculture and forest hydrology, based on the observation that trees are the dominant plants wherever rainfall is naturally abundant. While it is difficult to measure a tree's water uptake rate, water use rates of forested as opposed to non-forested areas can be compared by studying the water yield of watersheds with varying vegetative cover. Douglass (1965) monitored water yields from a watershed that was initially clearcut. Water uptake in the watershed increased proportionately with tree growth. Of particular interest to those looking at land disposal of wastewater using trees are the findings of Murphy (1982) and Emmingham (1977) that Douglas fir actively transpires water even during the fall and winter months along the west coast. It is likely that other evergreens such as redwoods that are adapted to the dry summers and mild wet winters of the west coast follow the same pattern.

Irrigation of trees using treated wastewater is not a new concept. Extensive experiments using wastewater for silviculture have been performed at Pennsylvania State University, Michigan State University and the University of Washington (EPA 1977). The principal limitations identified in these studies and in full scale applications of the practice are associated with the use of sprinklers to apply the water. First, large fixed sprinkler systems are expensive to install and energy intensive to operate. Second, even under favorable conditions it is impossible to evenly distribute the water to the trees by spraying, so the application rate is limited by the area that receives the highest volume of water. Third, spraying high volumes of water adversely affects the upper soil horizon leading to anaerobic conditions which kill the trees.

The successful operation of the marsh forest ETA system at the Mt. View Sanitary District since 1978 has shown that one can use the high year-round water demand of selected trees to

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maximize the application of treated wastewater per acre of irrigated area without adverse effects on the soil. The marsh forest ETA does this by circulating water from a marsh pond through irrigation chambers located under the trees. Thus the crucial soil-air interface is left undisturbed and the water coming in contact with the tree roots remains aerobic. Circulating the water through the forest area benefits the marsh by decreasing sunlight and nutrients to the algae in the water, thus reducing the occurrence of algal blooms and increasing water quality consistency in the marsh.

PROJECT DESCRIPTION

The marsh forest ETA demonstration project has operated since October, 1978 at the Mt. View Sanitary District's wastewater treatment plant in Martinez, California. The installation consists of a small marsh pond and approximately 4000 square feet of forest area. As shown in Figure 1, the forest area has 26 irrigation chambers (known as K-6 units) connected in parallel lines. Openings in the end of each chamber allow tree roots to penetrate into the chamber. The K-6 units are spaced at ten-foot intervals along the pipelines, which terminate in a distribution box at each end. Redwood trees were planted next to each of the K-6 units in October, 1978. A small eucalyptus was already on the site. Two alders and three Monterey pines were added in 1981.

Water for the Forest ETA demonstration system is obtained from the Mt. View Sanitary District's effluent water system. The water receives secondary treatment in a two-stage biofiltration plant and has been chlorinated. The influent to the marsh forest ETA is metered and passes through a float valve into the marsh pond. Originally, a float valve at the pond inlet controlled the amount of water that entered the pond to balance the water lost to evapotranspiration and discharge. Beginning in the spring of 1980, the water demand generated by the trees began to exceed the wastewater available and the system was modified to limit the amount of water going to the marsh forest ETA.

Water is pumped from the marsh pond to the forest area by a 1/10 horsepower pump which delivers 10 gallons per minute (gpm) to the upper splitter box. Adjustable weirs regulate the flow from the splitter box in proportion to the number of K-6 units on each line. After flowing through the forest area the water enters a second splitter box. Adjustable weirs in the effluent splitter box and a float valve on the pond return line control the proportion of the flow that is recycled through the marsh forest. Excess flow is discharged back to the treatment plant.

WATER QUALITY

Circulating the water through the forest serves not only to irrigate the trees and to dispose of water through ETA losses, but also to improve the water quality in the marsh pond and in the water discharged from the system.

The water quality parameters of biochemical oxygen demand, suspended solids, ammonia nitrogen, organic nitrogen, nitrate nitrogen, nitrite nitrogen, and phosphate were measured for the influent and effluent to the marsh forest ETA during the first three years of operation. The results of these measurements are summarized in Figure 2.

Biochemical oxygen demand (BOD) is a measure of the concentration of biodegradable organic material in the water. The BOD of the influent to the system averaged 30 milligrams per liter (mg/l), which meets the federal requirements for secondary treatment. The discharge from the marsh forest averaged 12 mg/l. Further sampling showed that approximately 90% of the BOD removal occurred in the marsh pond. However, the forest area was instrumental in maintaining a low discharge BOD in the summer months. Other marsh areas receiving wastewater typically exhibit higher BODs in the summer months due to algae blooms.

Suspended solids is a measure of the presence of particulate matter in the water. Typically marsh areas receiving treated wastewater exhi[illegible] wide swings of suspended solids levels due to algae blooms, with summertime levels frequently exceeding 100 mg/l. The marsh forest shows a different pattern with an average suspended solids of less than 10 mg/l and summertime values ranging from two to nine mg/l.

The nitrogen measurements were combined to give a graph of total nitrogen. The nitrogen in the marsh forest influent is about half in the form of ammonia and half in the form of nitrates with smaller amounts of nitrites and organic nitrogen. The marsh forest ETA system either nitrifies or uses most of the ammonia in the system. The concentration of all of the nitrogen compounds is reduced by about 40% as the water goes through the marsh forest ETA.

The results of the phosphate measurements are not shown here, but phosphate averaged a 12% to 15% decrease in concentration through the marsh forest ETA.

It must be noted that the values shown in Figure 2 illustrate the influent and effluent concentrations, not mass loadings. Since the water flow out of the marsh forest ETA is lower than the flow in, the mass removal rates are higher than the differences in concentrations. Water quality analyses were discontinued in 1982 because the system was operating without a discharge.

HYDROLOGY

In the marsh forest ETA system water is lost by the following processes:

1. transpiration — the use of water by the vegetation
2. evaporation — loss of water from the pond, soil, and plant surfaces
3. percolation — loss of water from the upper soil layer to the groundwater
4. runoff — water that flows off the site

Transpiration and evaporation from the soil and plant surfaces are often combined in one term, evapotranspiration, since it is difficult to measure them separately. The amount of water lost to evapotranspiration is difficult to measure directly, but it can be estimated by tracking all the measurable water flows into and out of the system and developing a water balance for the whole system. Water enters the system from the metered wastewater flow, and rain falling on the pond and forest area. Water leaves the system by evaporation from the surface of the pond, percolation down into the ground, evapotranspiration from the forest, and discharge. Runoff from the forest area returns to the marsh pond.

The evapotranspiration rates are summarized in Figure 3. Note that after April 1980 the water demand generally exceeded the available supply, so the rates reported reflect the actual evapotranspiration not the maximum possible evapotranspiration. In 1980, the system had been in operation for just over a year. The trees had recovered from transplant shock and were just starting to grow. In 1985, the trees averaged 15 feet tall and were growing vigorously.

Evapotranspiration ranged from a low of 7,000 gallons per day per acre (gpd/acre) in February to a high of 27,000 gpd/acre in April. It is likely that the summertime evapotranspiration rates would have been even higher if sufficient water had been available to satisfy the demand. This compares with typical pasture irrigation rates of 5300 - 7000 gpd/acre in the summer season under similar climate and soil conditions. Moreover, the system is still a net water user even in the wintertime when other irrigation systems are inactive.

SILVICULTURE

Twenty-eight redwood trees were planted at the Mt. View site in Martinez in November, 1978. The trees were two years old at time of planting and averaged 5 feet high with a DBH of less than 1/2 inch. (DBH stands for "diameter breast height" which is a standard measurement used along with height for estimating tree volumes.) As shown in Figure 4, the tree growth over the nine years since planting has averaged four feet/year in height and one inch/year in DBH.

The photograph in Figure 5 shows that the grove of trees successfully dominates the site with a complete crown cover and a healthy soil surface.

OPERATION

The marsh forest ETA requires only minimal operation and maintenance. The pump that circulates water to the forest area is checked and backwashed once a week, and weeds and grass are cleared from around the pond area twice a year.

The K-6 irrigation units at the Mt. View site have been in operation for nine years and show no sign of plugging or deterioration. Another smaller installation in Willits, California which receives basically primary effluent has been in operation for eight years with no problems.

SUMMARY AND CONCLUSIONS

Nine years' experience with a prototype marsh forest evapotranspiration system have shown that is possible to take advantage of the high water demand of selected trees without adverse effects on the soil. A review of past research has found that at least two tree species native to California consume large amounts of water and coninute to transpire actively year-round.

The results of the study have particular relevance to California communities faced with discharge prohibitions and a shrinking supply of agricultural land to accommodate land disposal. Disposal of wastewater in a forest ETA system has several advantages:

1. Less land is required per gallon of water.
2. The irrigation water is underground, reducing the chance of public contact.
3. Maintenance requirements are minimal.
4. In the long term, the trees can be harvested to provide offsetting revenue.
5. Seasonal discharges can be circulated through the forest for polishing.

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