APPENDICES

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Project Purpose

The Narragansett Bay Commission (NBC) prepared this Facility Plan Amendment for the Field's Point Wastewater Treatment Facility (FPWWTF) in order to determine the best alternative for providing Biological Nitrogen Removal (BNR) to meet the Rhode Island Department of Environmental Management (RIDEM) total nitrogen (TN) effluent discharge permit limit of 5 mg/L monthly average on a seasonal basis.

The general content of this plan includes background information for the FPWWTF, technical evaluations of various nitrogen removal alternatives, cost evaluations of the alternatives, recommendations, and implementation strategies. Appendices provide backup data and reference documents.

The planning period for this Facility Plan Amendment is from 2004 to 2024. Previous upgrades to the FPWWTF were implemented in the 1980's and were consistent with a 20-year planning period spanning 1983 through 2003.

Background

The planning area for this Facility Plan Amendment is the FPWWTF, which is located on Ernest Street in Providence, Rhode Island. The facility, which has a design average flow of 65 million gallons per day, currently treats wastewater with a complete-mix conventional activated sludge process. The facility's latest Rhode Island Pollution Discharge Elimination System (RIPDES) permit became effective on February 1, 2002 and expires on February 1, 2007. There were no nitrogen limits in the permit. On June 27, 2005, however, the Rhode Island Department of Environmental Management (RIDEM) issued final modifications to the permit that established a total nitrogen monthly average effluent concentration of 5 mg/L on a seasonal basis.

Evaluation of nitrogen removal alternatives occurred in two phases. The first phase occurred in 2001-2002, when the final RIPDES permit limit for effluent TN had not been finalized. Alternatives were developed and evaluated based on meeting three possible effluent TN limits - 8 mg/L, 5 mg/L, and less than 5 mg/L, all on warm season (May through October) and full year bases.

After the final effluent TN permit limit was issued alternatives that were initially evaluated were re-evaluated, but only for the final permit conditions.

Initial Evaluations

On June 5, 2001, the NBC held a BNR technology workshop with their consulting engineering team, Guertin Elkerton & Associates (GE&A) and CH2M Hill, to review current BNR and aeration technologies and to develop preliminary BNR alternatives for further evaluation.

The four basic BNR processes selected at the technology workshop for further evaluation were:

- Step Feed
- Modified Ludzak-Ettinger (MLE)
- Hybrid of Suspended and Attached Growth Processes, termed Integrated Fixed Film Activated Sludge (IFAS)
    - o IFAS-Fixed media
    - o IFAS-Floating media

Step feed is a biological process that is has been in use for nitrogen removal for many years. It consists of a plug flow biological nitrogen removal (BNR) reactor that includes several anoxic and aerobic zones arranged in series. Both types of zones contain a suspension of microorganisms referred to as "mixed liquor". Ammonia is biologically converted to nitrate in the aerobic zones and nitrate is biologically converted to nitrogen gas and released to the atmosphere in the anoxic zones. Wastewater from the primary clarifiers (primary effluent) is divided among the anoxic zones, hence the term "step feed."

The MLE process, in its simplest form, consists of one anoxic zone followed by one aerobic zone. Approximately 75% of the aerobic zone effluent, which is nitrate rich, is recycled back to the anoxic zone, where the nitrates are converted to nitrogen gas.

Both the floating and fixed media IFAS processes typically consist of an anoxic zone followed by an aerobic zone that contains mixed liquor and some type of media. IFAS processes are proprietary, which results in variations in the number of anoxic and aerobic zones. The media provides sites for nitrifying microorganisms to grow, thus providing a nitrifying population in addition to

that in the mixed liquor. Air is injected into the aerobic zones with diffusers typically mounted on the floor of the aerobic zone.

The floating IFAS processes use small floating sponges, or plastic disks or wagon wheel-shaped media along with mixed liquor in the aeration zone. Fixed media IFAS processes use rope-like or sheet-like media to provide microorganism sites. As with the MLE process, the nitrate rich mixed liquor at the downstream end of the aerobic zone is recycled back to the first anoxic zone where the nitrates are converted to nitrogen gas.

The step feed alternative was the recommended process at the end of this initial evaluation of alternatives. This process was the least costly and, at the time, had the longest history of successful operation.

Because the Rhode Island Department of Environmental Management had not issued the NBC effluent total nitrogen limits at the time of the initial evaluations, the Facility Plan Amendment could not be completed.

BNR Process Re-evaluation

Over the approximately three years during which RIDEM was developing the nitrogen limit for the FPWWTF, the United States wastewater treatment industry saw an increase in use of both the IFAS fixed and floating media processes with positive operating experiences for each. Because of this favorable recent experience, the NBC chose to re-evaluate these processes and compare them to the initially recommended step feed process once the effluent permit limit was issued.

The MLE process, which had been eliminated during the initial alternatives evaluations, was not re-evaluated. This process is mature, and no new MLE process developments occurred between the initial alternatives evaluations in 2001 and the issuance of the effluent permit limit in 2005.

In summary, the three alternatives that were re-evaluated were as follows:

- Step Feed for 5 mg/L TN, May-October
- Fixed media IFAS process for 5 mg/L TN, May-October
- Floating media IFAS process for 5 mg/L TN, May-October

The design data used for the re-evaluation are presented in Table ES 1.

Table ES 1: BNR Design Data

Parameter	Monthly Average	Maximum	Peak Hourly
BNR Influent Flow (mgd)	50	77	91
BNR Influent BOD (lb/day)	40,500	53,000	–
BNR Influent TSS (lb/day)	24,900	40,000	–
BNR Influent NH3-N (lb/day)	4,800	6,000	–
BNR Influent TKN (lb/day)	8,000	10,000	
Final Effluent BOD*, mg/l	30	—	—
lb/d	16,263		
Final Effluent TSS*, mg/l	30	—	—
lb/d	16,263		
Final Effluent TN*, mg/l	5	—	—
lb/d	2710		

* RIPDES Permit limits

Included in the re-evaluation process were the following:

- A pilot study at the FPWWTF using a floating media IFAS system treating FPWWTF primary effluent
- Visits by NBC staff to several step feed BNR systems and several floating media IFAS systems, one of which was in Westerly, Rhode Island
- Step feed and IFAS processes modeling to predict performance at 77 mgd (maximum daily flow) and 50 mgd (monthly average flow) under varying dissolved oxygen (DO) levels in the anoxic zone influent, various doses of supplemental carbon (ethanol), various water temperatures and internal recirculation rates.
- Cost evaluations of the three alternatives

The concentration of the total nitrogen from the pilot plant's floating media IFAS process achieved 5 mg/L under the conditions when the pilot plant was in operation (wastewater temperatures were between 15.3 and 27 deg. C). The samples collected during the pilot test were filtered which removed sources of nitrogen in the particulate matter that would normally not be removed in the full scale process at the FPWWTF. The BNR model evaluations indicated that the step feed and the floating media processes could also meet the 5 mg/L level but not necessarily under all conditions anticipated at the FPWWTF and not without the addition of a carbon source to enhance the denitrification process.

Modeling of the maximum daily flowrate of 77 mgd showed that the IFAS floating process will meet the permit limit with no carbon source addition at wastewater temperatures of 15 and 20 degrees C assuming no dissolved oxygen in the anoxic zone.

The modeling for an average daily flowrate of 50 mgd with low water temperature (14 degrees C) and the anoxic zone DO concentration of 6 mg/L, both the Step Feed and the IFAS-Floating processes show compliance with the TN permit limit if 1000 gallons per day of ethanol is added as a carbon source (see page 57 Table III.2.8.1-1 Runs 2c, 2d, 4c, and 4d).

All the model results incorporated a factor of safety to account for the fact that model runs were conducted under steady state conditions.

Modeling results indicated that wastewater temperatures below 14 deg. C could decrease the reliability of the step feed and floating media process for consistently meeting the 5 mg/L monthly average effluent TN. Typically, higher, more dilute flows associated with wet weather could be expected to also decrease the reliability of the BNR process. Periods of sustained flows up to, but not exceeding, 77 mgd are expected when the CSO tunnel system is activated (the tunnel system is now under construction).

The cost evaluation is summarized in Table ES 2.

Table ES 2: Present Worth Costs and Major Capital Cost Items

Present Worth Costs	Step Feed	IFAS-Floating Media	IFAS-Fixed Media
Capital Cost, $Million ($M)	21	28	85
Annual Operation and Maintenance (O&M) Cost, $M	1.7	1.8	1.9
Present Worth of O&M Cost, $M (5.125% discount rate, 20 yrs.)	21	22	23
Total Present Worth Cost, $M	42	50	108

As the table indicates, step feed is the least costly process, followed by the IFAS-floating media process. Both of these processes can be implemented using the existing aeration tanks. The most costly is the IFAS-fixed media process, which requires additional aeration tankage. The main difference in cost between the step feed and the IFAS floating media process are the costs of the media and other equipment specific to the floating media process.

Recommended Alternative

The IFAS-floating media is the recommended alternative which has the following process advantages outweighing the higher cost:

- The media retains nitrifying microorganisms under adverse conditions such as low wastewater temperatures and sustained high flows. This enhances start-up of the nitrifying process in May, when wastewater temperatures are relatively low.
- Mixed liquor solids concentrations are lower with IFAS than with step feed, thus enhancing clarifier performance
- Operation is simpler than step feed; very few process adjustments are required. With step feed, several process adjustments are required for maintaining process efficiency, including flow proportioning to the anoxic zones, mixed liquor concentration gradient from the influent to the effluent ends of the reactor, and air flow rates for the aerobic zones.
- Modeling results indicate from 0.5 to 1 mg/L less total nitrogen concentration in the effluent under similar operating conditions.

The estimated 20-year present worth cost of this process, which includes capital and annual operating costs for 20 years, is $50,000,000. The recommendation is based on detailed evaluations of the cost, reliability, and operational ease of several nitrogen removal technologies.

Implementing the Recommended Alternative

Construction Requirements

Implementing the floating media IFAS process would require that the aeration tanks be changed to BNR reactors. This would be accomplished by creating the necessary anoxic and aerobic zones in each tank using new baffle walls. A primary influent flow distribution system would be provided using new piping, flow control valves, and flow meters. This system would distribute the primary effluent flow among the new BNR reactors in a controlled manner.

Proprietary media would be placed in the aerobic zones of the new BNR reactors and proprietary ancillary equipment would be installed. Such equipment would include anoxic zone mixers, nitrate recycle pumps, the air diffusion equipment in the aerobic zones, and the media retention screens.

Because the BNR reactors would require more hydraulic head to pass flow than is required for the existing aeration tanks and the fact that the existing screw

pumps have a tendency to entrain air into the process, the existing pumps would be replaced with new propeller or centrifugal pumps with a higher head rating. Additionally, new fine screens, with bar spacing of approximately 1/4-inch, would be required upstream of the BNR reactors to minimize the amount of solids entering the reactors. The fine solids tend to accumulate in the aerobic reactors because they cannot pass through the media retention screens, and, therefore, must be removed upstream of the reactors.

The existing air blowers would be inadequate for supporting the BNR process. Three additional blowers, rated at 8,000 scfm, would be provided to supplement the existing blowers.

To support the BNR process, an auxiliary source of carbon is required along with a source of alkalinity. Carbon sources are typically methanol or ethanol (both are alcohols). The alkalinity source is typically sodium hydroxide (lye). A new chemical feed system, therefore, would be required that would include chemical storage tanks, chemical pumping equipment, piping, and a building.

If further treatment is required to meet the effluent nitrogen limits, additional process units could be provided as an add-on to the IFAS process. The technology evaluated in this facility plan to provide additional treatment was denitrification filters. These filters are anoxic biological units that are capable of producing effluent nitrogen concentrations in the 3-5 mg/L range. They would be installed on the site of the existing City of Providence garage property, which would require that the NBC compensate the City for the garage building and the land. The estimated additional capital cost of providing the denitrification filters to further reduce the effluent nitrogen is $48,000,000.

Financial Considerations

Funding for the recommended alternative would be provided through state bond issues or NBC revenue bonds or state revolving funds which are paid by sewer user fees.

Project Schedule

A Public Hearing will be scheduled within 30 days following acceptance by RIDEM of the draft Facility Plan Amendment. The public comment period will be open for 30 days following the hearing. The NBC will respond to comments received within 40 business days of the close of the comment period. The Final Facility Plan Amendment will be submitted to RIDEM within 15 business days following the response to comments. Design of the BNR facilities will commence upon RIDEM approval of the Final Facility Plan Amendment. An application for