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A "*LOT*" For Less

Innovative Economical and Technological Strategies for the Implementation of Limit of Technology (LOT) Nutrient Removal in the Chesapeake Bay Watershed

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EXECUTIVE SUMMARY

The living resources and water quality of the Chesapeake Bay are important to the economical well-being of Virginia, but it is unlikely they can be restored unless restoration efforts are accelerated considerably from the current pace. The key to restoration is the reduction of the quantity of nutrients entering the Bay, and the quickest reductions can be obtained by implementing limit of technology (LOT) nutrient removal at the significant wastewater treatment plants (WWTPs) throughout the Watershed. The primary obstacle to the implementation of LOT in Virginia is perceived to be cost, where it has been estimated that implementing LOT at Virginia's significant WWTPs would require $1.2 billion. However, first-cut area-wide cost estimates typically have overestimated the costs of nutrient removal upgrades compared to later, more detailed cost studies. For example, recently released studies of Maryland and Hampton Roads Sanitation District (HRSD) WWTPs were 32% (MD) and 23% (HRSD) lower than previous estimates. Furthermore, there is another way that the costs of rapid implementation of biological nutrient removal (BNR) and LOT wastewater treatment can be substantially reduced. Comparison of the combined design treatment capacities of the Bay Watershed's 304 significant WWTPs with the combined 2001 flows to those same plants shows that the WWTPs collectively have significant excess treatment capacity of 60 %. Considering that upgrading conventional activated sludge plants to BNR and to LOT BNR typically reduces capacity by only 10-20% and 20-30% respectively, most of the WWTPs could be rapidly upgraded at low cost using the excess capacities that already exist, thus avoiding major construction costs for the immediate future. Additionally, integrating innovative technologies such as fixed film media into the activated sludge (currently operating at the Annapolis, MD WWTP) would make rapid, economical upgrading possible at even more of the WWTPs.

This paper estimates that LOT implementation could be accomplished for 50 to 60% less than current projected costs while maintaining full treatment capacities, and certainly could be implemented in a much shorter time. Most of Virginia's significant plants could be rapidly and economically upgraded with LOT technologies if cost-share funds were available and plant managers/owners were willing to reduce their current excess treatment capacities. Unwillingness of the managers/owners to forfeit plant treatment capacity could be overcome by guaranteeing additional funding to finance future plant expansions when additional treatment capacity is needed. Since funding requirements would be spread over decades, savings resulting from reduced operating (O&M) costs should be included in economic evaluations of this approach. A permanent fund should be established in Virginia to implement LOT BNR at significant WWTPs utilizing existing excess capacities. Initial funding of $120 million in combination with long-term revenues from an annual user tax would both jumpstart rapid implementation and spread the implementation costs over a long period of time. This approach, if properly administered, could provide rapid reduction of point source nutrients to the Bay from Virginia in an affordable manner.

INTRODUCTION

The living resources and recreational resources of the Chesapeake Bay have substantially contributed to the economical well-being of Virginia in the past, and it is unlikely that the prosperity of bygone years can be restored without a healthy and productive Bay. It also is unlikely that it can be restored unless restoration efforts are accelerated considerably from the current pace. A critical need for the restoration of the water quality and living resources of the Chesapeake Bay is a reduction in the quantity of nutrients entering the Bay throughout the year. This has been widely accepted by the Bay community, and is based upon the results of Bay modeling efforts as well as the experience and observations of marine biologists. Recent proposals and strategies for significant restoration progress have focused on increased activity for the reduction of point source nutrients, i.e. nutrients discharged by wastewater treatment plants

(WWTPs), as the optimum action for progress. Specifically, some advocates have proposed that limit of technology (LOT) nutrient removal should be implemented at the WWTPs as soon as possible or conditions will continue to worsen, possibly at an accelerated rate. However, representatives of Virginia's WWTPs oppose this goal, citing significant economic impacts. For example, an Associated Press release published in the Roanoke Times, January 3, 2004, reported that upgrading eight of the nine major treatment plants owned and operated by the Hampton Roads Sanitation District (HRSD) would require an investment of $520 million dollars. The report further quotes an HRSD official as saying that this would cause a rate increase of 70 percent that would add about $100 per year to the average residential customer's sewage bill. Also, Virginia Secretary of Natural Resources, Tayloe Murphy, current Chairman of the Chesapeake Bay Program Principals' Staff Committee, has publicly stated that implementation of LOT at the significant WWTPs in the Virginia portion of the Chesapeake Bay Watershed has an estimated price tag of $1.2 billion (Murphy, 2003). The Secretary implied that, given the State's fiscal situation and economic conditions, the projected high cost has suppressed the current Administration's willingness to move forward with WWTP upgrades and LOT implementation.

However, lacking from such a cost-centered analysis is the fact that, historically, most initial area-wide estimated costs for biological nutrient removal (BNR) implementation have been over-estimated. For example, the recently revised cost estimate for the HRSD facilities mentioned above is 23% less than a previous, less detailed estimate. Also, a recently completed cost evaluation report for upgrading Maryland's WWTPs to LOT obtained costs that were 32% less than a preceding estimate. Further, this report concluded that it is more cost effective based on the cost per pound of nitrogen (N) removed to reduce nitrogen effluent concentrations from 8 to 3 mg/L than it has been to reduce concentrations from 18 to 8 mg/L (Gannett Fleming, et al., August, 2003).

It appears that the reluctance in Virginia to move forward at this time with accelerated WWTP upgrades is based on the assumption that the total amount of capital required for WWTP upgrades needs to be obtained and committed within a brief period of time, e.g., two to five years. Moreover, an inaccurate assumption appears to have been made that upgrading of the WWTPs will be an unrecoverable commitment of capital costs with additional increased operating and maintenance (O&M) costs. Such is not necessarily the case. In fact, there are options for biological nutrient removal (BNR) upgrades that would reduce the immediately needed capital to modest amounts at most WWTPs. Furthermore, BNR implementation commonly results in the reduction of operating costs at activated sludge treatment plants, which are by far the dominate type in use, with some payback times as low as three to five years.

I propose that the true immediate and long-term costs of nutrient removal implementation at Virginia WWTPs could be significantly lowered through implementation of innovative economical and technological solutions. The objective of this paper is to examine the projected costs of LOT BNR implementation at WWTPs, and propose economical and technological strategies that could be used in Virginia and other Bay states to reduce the overall costs and substantially reduce the immediate economical impacts of implementation.

FACTORS AFFECTING THE COST OF NUTRIENT REMOVAL

There are several factors that determine the overall costs of LOT implementation, e.g.:

1. the type of biological treatment process currently being used by the plant, i.e. activated sludge versus trickling filter or RBC,
2. the technological methodologies proposed to attain LOT,
3. the method of financing used, i.e. short-term versus long-term,
4. the inclusion or exclusion of operating and maintenance (O&M) costs in the overall economic analysis,
5. the availability of nutrient trading options, and,
6. the averaging period used to determine compliance with treatment regulations.

EXCESS TREATMENT CAPACITY – ACCOMMODATING POPULATION GROWTH

The current situation is that most of the municipally owned WWTPs throughout the Chesapeake Bay Watershed have excess treatment capacity that could be utilized for rapid, low cost implementation of LOT, or near LOT, nutrient removal at those facilities if appropriate technologies were selected. For example, Virginia Tech and the US EPA Chesapeake Bay Office have established that the watershed's 304 significant municipal WWTPS had an excess capacity of nearly 60% in 2001 (1,481 mgd 2001 flows vs. 2,365 mgd design capacity). The Chesapeake Bay Program's Nutrient Trading Committee has calculated, based on a 1% annual growth rate, that if the plants were all somehow interconnected, they could be operated for more than 100 years at current levels of treatment before population growth would exhaust their combined treatment capacities (Rose, 2004). Bay-wide interconnection is impossible, of course, but the exercise illustrates the potential for point-to-point nutrient trading, and the considerable room that currently exists at many plants for the implementation of BNR and LOT wastewater treatment. A similar examination of the previously mentioned HRSD plants shows that these eight plants have existing excess treatment capacity sufficient to accommodate a 35% increase in wastewater flow (125.71 mgd 2002 flows vs. 194.5 mgd design capacity). Fortunately, the cost of improved nutrient removal could be greatly reduced if owners were to forgo some of their current excess capacities and accept, for example, an excess capacity of only 10%. While Bay-wide interconnection may be only a theoretical exercise, some facilities, such as the HRSD facilities on the Peninsula, are, in fact, physically interconnected, thus offering a unique opportunity for more cost-effective implement of LOT nutrient removal at those facilities, if considered collectively.

The existence of excess treatment capacities of the magnitude stated above means there is a major opportunity to implement improved nutrient removal treatment at many (apparently a majority) of the WWTPs in the Watershed for low capital costs and substantial potential O&M savings.

However, conversion to BNR, particularly LOT, will reduce the rated treatment capacities of the plants, and therefore their "book" values. While some owners and managers might oppose such an approach because of the uncertainties regarding population growth and the ability to attract industries, such opposition can be overcome through creative financing arrangements with strong guarantees of future cost-share funding when plant expansion is needed to accommodate increased growth. For most plants, experience has shown that the influent flows are not likely to reach capacity limitations for one, two or even three decades after LOT BNR technology is implemented. This means the projected capital requirements can be spread out over a period of one to three or more decades rather than 100 percent being required immediately. Further, many of the plants currently not practicing BNR can realize substantial reductions of O&M costs through implementing such technologies, which will further reduce the upgrade costs over the life of the modified plant. Utilizing the excess capacities rather than maintaining current rated capacities is likely to reduce immediately needed capital costs by 50 to 60 % or more.

AVAILABLE TECHNOLOGIES

It is a technological fact that the typical municipal activated sludge plant can be modified for complete biological nutrient removal (BNR) to achieve effluent nitrogen concentrations less than 5 mg/L and phosphorus concentrations less than 0.5 mg/L. Such modifications would decrease the plant's treatment capacity on the order of 20 to 25%. The potential for using existing treatment capacity to implement BNR and achieve low level effluent nutrient concentrations at very low costs was demonstrated at the HRSD York River WWTP in 1986-90. For a cost of only $155,000, using in-house engineering and labor, 6.5 mgd of wastewater was treated by modifying only one third of the plant's aeration basin volume for complete BNR treatment. The modifications resulted in a process that could achieve year-round nitrogen

removal to less than 8mg/L, with summer values less than 6 mg/L, and, after the phosphate detergent ban, year-round effluent phosphorus concentrations less than 1 mg/L. More importantly, for less than $500,000 (in 1986 dollars using in-house engineering and labor and excess capacity) the same volume of wastewater could have been further treated to LOT levels using the modified Bardenpho configuration. If all of the aeration basin volume had been modified for LOT BNR, the plant would have lost only 13.3 % of its treatment capacity. Further, there are proven innovative technologies, such as integrated fixed film activated sludge (IFAS) methodologies, that make it possible to implement LOT BNR for little or no loss in treatment capacity. IFAS technology has been demonstrated at the 15 mgd Annapolis, MD, treatment plant, which is currently operating as a nitrogen removal IFAS process using Ringlace media (several other types of IFAS media are available). This technology reduced nitrogen levels to less than 8 mg/L far more efficiently, both physically and financially, than had been predicted if IFAS technology had not been used. The final project required no increase in aeration volume and only a one-third increase in clarification capacity, while it had been projected that the aeration volume would have to be increased by 50% and the clarification capacity by 150%. The costs of the Annapolis IFAS modifications were approximately $6.5 million in the mid 1990s. This technology could significantly increase the number of Bay Watershed plants that could be upgraded to LOT with little or no loss in treatment capacity.

INNOVATIVE TECHNOLOGIES

Another option for reducing the cost of nitrogen removal involves centralized sludge processing and treatment. This is best illustrated by the strategy developed by New York City. The City was mandated by the courts, following a lawsuit, to reduce the amount of nitrogen discharged to Long Island Sound and Jamaica Bay. This affected 11 of the City's 14 WWTPs. The initial projected cost of the necessary upgrades was $14.2 billion because the proposed plan assumed that each plant would process its own sludge. This approach would have necessitated construction of new land over the East River and the Bay to accommodate physical expansion of several plants. Alternatively, City staff and advisors devised a strategy wherein an innovative new nitrogen removal treatment process, Step-Feed BNR, was developed that minimized the basin volume needed for upgraded treatment. In addition, the alternative strategy included a water use reduction program and combined processing of all the waste sludges at only five of the plants. The centralized transportation of sludge to the five plants substantially reduced the amount of nitrogen that must be removed at the remaining plants, making it considerably easier for those plants to achieve low nitrogen concentrations. This revised strategy reduced the estimated costs of compliance from $14.2 billion to only $1.4 billion - a ten-fold cost savings. Currently, the City is seeking to further reduce the overall costs to $536 million by using a technology recently developed in The Netherlands for nitrogen reduction from the high strength waste streams generated during sludge dewatering and processing (NYC DEP, 2003). Through the innovative use of new technologies and processes the costs for New York City have been reduced 96 percent. Putting such an approach in perspective with the Bay nutrient reduction initiative, a similar centralized sludge processing strategy and use of innovative technologies could potentially be used in metropolitan areas throughout the Bay Watershed, such as Hampton Roads, Richmond, Washington, D.C., and possibly even in less metropolitan areas where several plants are reasonably close to each other. It is likely that implementation among different authorities and municipalities will require some centralized management, but such challenges could be accommodated.

O&M COST SAVINGS

The reduction of operating costs that can occur with BNR implementation has been documented at numerous locations, including some in the Chesapeake Bay Watershed. For example, in 1988 when complete BNR (combined nitrogen & phosphorus removal) was implemented at the Bowie, MD, WWTP, the need to add phosphorus precipitating chemicals and alkalinity for pH control was eliminated at a savings of nearly $68,000 per year. The total BNR

modification costs at this 2.2 mgd plant, including engineering and construction company fees, were $230,000, resulting in an O&M payback time of the capital costs of only 3.4 years (Sen, et al., 1990). This plant averaged an effluent phosphorus concentration of 0.16 mg/L during 2002 without chemical addition or effluent filtration, and typically discharges less than 4 mg/L nitrogen throughout the summers, and is capable of low nitrogen levels in the winters as well. The 15 mgd Moore's Creek WWTP, owned and operated by the Rivanna Water and Sewage Authority, Charlottesville, VA, was modified for nitrogen removal simply to eliminate the addition of alkalinity for pH control. The modification cost was approximately $100,000, including engineering, but it reduced the chemical costs by almost $55,000 per year, for a pay back period of less than 2 years. Although it was not a primary objective, the amount of nitrogen discharged was reduced by nearly 50%. Also in Virginia, modification of the HRSD York River WWTP's VIP process to include denitrification reduced waste activated sludge production by more than 40% (Waltrip, 1991). It was demonstrated at the Basingstoke, England (near London) WWTP that implementation of nitrogen removal from 30 to 8 mg/L reduced the aeration electrical costs by 22%, and the total energy costs for treatment by 19% (Best, et al., 1984). Then, it was demonstrated at the Yarra Glen WWTP near Melbourne, Australia, that implementation of alternating aeration nitrogen removal reduced the effluent nitrogen concentration from 25 to 7 mg/L, reduced aeration electrical costs by 35%, and reduced waste sludge production by 40% (Ip, et al., 1987).

INNOVATIVE FINANCING STRATEGY

It is proposed that a new strategy be developed for the implementation of LOT level point source nutrient removal throughout the Chesapeake Bay Watershed. The following recommendations are specifically proposed for the Virginia portion of the Watershed, but similar recommendations would apply to other governmental jurisdictions as well. It is further proposed that development of the strategy begin as soon as possible, i.e., within the current calendar year.

A successful strategy would result in: 1) relatively rapid implementation of BNR upgrades to LOT levels utilizing existing excess treatment capacities at WWTPs, 2) more accurate cost estimates by acknowledging and accounting for O&M cost savings that are possible through BNR implementation, and 3) stable and predictable funding for both near and long-term funding needs. Promotion and implementation of the strategy would best be accomplished through a combination of both regulatory and financial incentives.

Stable and predictable funding for such a strategy would best be accomplished through a separately budgeted State Administered Fund with its own fee-based income. Funds would be provided to WWTPs to fulfill two primary objectives: 1) funding at least 50% of the immediate capital costs associated with implementing LOT BNR and 2) funding at least 50% of the future costs associated with plant expansions designed to recoup losses in treatment capacity resulting from implementation of LOT BNR. Such long-term funding could be generated and dispersed over 20 years or more. A user fee similar to that recently adopted in Maryland could perpetuate funding, but the full cost of LOT at all facilities would not be needed immediately. A much smaller immediate appropriation of approximately 10% of the estimated LOT implementation costs would be needed to initiate the strategy. Based on the estimate quoted by Secretary Murphy, the amount needed would be a minimum of $120 million to jumpstart the suggested program. Spreading the total costs out over several decades makes it significantly more affordable. The program potentially could be administered through the Virginia DEQ Chesapeake Bay Office, with the appointment of design engineers to that office for decision-making regarding review and approval of proposed retrofit designs.

A further recommendation is that a program for point-to-point nutrient trading be established (i.e. nitrogen for nitrogen and phosphorus for phosphorus only) and the funding and trading programs be coordinated for optimum results. The purpose of both programs should be to facilitate and accomplish major reductions in nutrient loadings to waters within the Bay watershed in as short a time period as possible. It needs to be recognized that, just as the need for additional nutrient reduction increases with population and industrialization growth, so do the costs of effective technology controls. In parallel, the benefits from utilization of the Bay and the harvesting of its fisheries decrease the

longer that implementation of comprehensive, effective controls are delayed. The most costly strategy is the implementation of inadequate controls.

REDUCING COMPLIANCE COSTS – EFFLUENT AVERAGING

The primary objective of the nutrient control strategy for the Chesapeake Bay is to reduce the total loading (pounds) of nutrients that enter the Bay and its tributaries each year, with a secondary objective of specifically reducing the nitrogen loading at the beginning of the phytoplankton growing season (April), and during the late summer-early fall season when phytoplankton growth in the Bay is extremely nitrogen sensitive. It should be recognized that the amount of nitrogen in the Bay waters at the beginning of the growing season is primarily determined by non-point sources, whereas most of the nitrogen discharged to Bay waters during the late summer-early fall season is contained in the point sources, except during major storm events such as hurricanes. It further should be recognized that nitrogen removal efficiency by WWTPs is temperature sensitive, and removal efficiencies will be maximized during summer and fall conditions, if appropriately operated. Current permitting programs typically require short-term averaging periods (weekly, monthly) to determine compliance with effluent limits. Applying similar averaging periods to future nitrogen or phosphorus limitations will necessitate the need for large safety factors in plant designs, exacerbating operating problems and inflating costs. Therefore, to reduce costs and minimize compliance issues while maintaining sufficient resource protection, phosphorus effluent concentrations could be regulated by yearly averages, and nitrogen effluent concentrations could be regulated by either yearly averages, or by six-month averages with averaging periods from May through October and November through April if seasonal standards are selected. It should be noted that a recent memorandum (March 3, 2004) from the U.S. EPA headquarters in Washington, D.C. concurs that such longer-term averaging periods for nutrient effluent limitations are acceptable.

REFERENCES

Best, A.G., G.J. Hatton, A.J. Rachwal, and B. Hurley (1984). "Biological Phosphorus and Nitrogen Removal at an Experimental Full Scale Plant in the UK", *Proceedings, IAWPRC Post-Conference Seminar, Enhanced Biological Phosphorus Removal from Wastewater, Vol. 1,* Anjou-Recherche, 75389 Paris Cedex 08, France, pp. 270-289.

Gannett Fleming, Inc. and George Miles & Buhr, LLC (2003). *Refinement of Nitrogen Removal from Municipal Wastewater Treatment Plants Report.* Submitted to Maryland Department of the Environment, August, 2003.

Ip, S.Y., J.S. Bridges and N.F. Mills (1987). "Effect of Alternating Aerobic and Anaerobic Conditions on the Economics of the Activated Sludge Systems", *Water Science and Technology, 19:*911-918.

Rose, R.J (2004). *Point-to-Point Nutrient Trading: A Follow-On Presentation, January 9, 2004*. Chesapeake Bay Office, US EPA, Annapolis, MD.

Sen, D., C.W. Randall and T.J. Grizzard (1990). *Biological Nitrogen and Phosphorus Removal in Oxidation Ditch and High Nitrate Recycle Systems, CBP/TRS 47/90,* Chesapeake Bay Program, USEPA. 120 pages.

Waltrip, D (1991). *"Full Scale Nutrient Removal Demonstration Project at the York River Treatment Plant with the VIP Process,"* presented at the Virginia WPCF Conference, Williamsburg, VA. Hampton Roads Sanitation Authority, Virginia Beach, Virginia.

Dr. Clifford W. Randall **is an international authority on biological nutrient removal (BNR) technology and for nearly 20 years has conducted much of the leading research on nutrient pollution from wastewater treatment plants and other sources in the Chesapeake Bay.**

After beginning his academic career at the University of Texas, Dr. Randall joined the environmental engineering faculty of Virginia Polytechnic Institute and State University in 1968, where he has served as Professor, Endowed Professor and currently Charles Lunsford Professor Emeritus of Civil and Environmental Engineering.

Dr. Randall has spent much of his career developing and introducing biological nutrient removal (BNR) wastewater treatment systems to the East Coast and Chesapeake Bay region. His efforts have resulted in the development of a patented process now in use at two large Hampton Roads Sanitation District (HRSD) treatment plants and modifications to dozens of other plants in Virginia, Maryland, Delaware, North Carolina and other states and nations.

At the request of the Virginia State Water Control Board (SWCB), he established the Occoquan Watershed Monitoring Program in 1972 and developed the Occoquan Laboratory. He was the Director of the Monitoring Program until his retirement in 2001, and has continued to serve as the Chairman of the Occoquan Watershed Monitoring Subcommittee of the SWCB. He was appointed to the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) by the Governor of Virginia upon creation of the Committee in 1985, and has served continuously since then, including as the Chair from 1993-97, and as a member of STAC's Executive Committee since 1993. Other governmental appointments have included the US EPA Chesapeake Bay Nonpoint Pollution Committee; the Advisory Committee and the Technical Liaison Committee of the Virginia-North Carolina Chowan River Basin Commission; the Virginia State Board of Certification for Water and Wastewater Treatment Plant Operators; the Lower James River Water Quality Management Advisory and Technical Advisory Committees; Virginia State Water Control Board (SWCB) Nutrient Standards Technical Advisory Committee; the Science Advisory Committee of the Virginia SWCB; the Virginia-Israel Water Resources Management Cooperative Effort; and the Virginia Chesapeake Bay Project Partnership Council.

Among other awards, Dr. Randall has received the Governor's Salute to Excellence from the State of Maryland for his efforts to protect and improve the Bay; the Mathias Medal, named for former U.S. Sen. Charles "Mac" Mathias of Maryland and given in recognition of scientists making singular contributions to the Chesapeake Bay and its watershed; and Va. Tech's Public Service Excellence Award.