TECHNICAL MEMORANDUM

Estimating Water Quality Benefits from Shellfish Harvesting; a Case Study in Oakland Bay, Washington

SEPTEMBER 25, 2009

PREPARED BY
SUSAN BURKE, PH.D.
FOR PACIFIC SHELLFISH
INSTITUTE

ENTRIX, Inc.
200 First Ave. West, Ste. 500
Seattle, WA 98119
Main: (206) 269-0104
Fax: (206) 269-0098

Technical Memorandum

Date: September 25, 2009

To: Dan Cheney, Pacific Shellfish Institute
Bobbi Hudson, Pacific Shellfish Institute

cc: Betsy Peabody, Puget Sound Restoration Fund,
Pete Becker, PACAQUA
Trina Wellman, NEI
Peter Steinberg, Herrera
Julie Hampden, Herrera

From: Susan Burke, ENTRIX

RE: **Estimating Water Quality Benefits from Shellfish Harvesting:**
A Case Study in Oakland Bay, Washington

1.0 OBJECTIVE

The objective of this task is to provide an assessment of the water quality benefits provided by shellfish harvest in Oakland Bay Washington.

2.0 BACKGROUND

Assessing whether there is an economic water quality benefit from shellfish is gaining interest by ecologists and economists. In September 2008 aquaculturist, economists and shellfish ecologists came together at the University of Rhode Island in September 2008. The goal of the two-day workshop was to identifying the kinds of services most likely to be of economic value or be conducive to being traded in markets (The Nature Conservancy). Workshop participants concluded that promoting denitrification (a process that removes nitrogen (N) from estuaries and coastal waters) may have particular economic value or could provide opportunities for developing markets that increase the demand for shellfish restoration and conservation.[1] In Sweden, a case is being made that it is less expensive to invest in expanding mussel farming operations than to invest in new waste water treatment capacity when controlling nitrogen in marine environments (Lindahl, et.al).

One method that has been used to control constituents of concern to water quality has been to treat water being discharged into a water body, for example with a wastewater treatment plant (WWTP). Although nearly all WWTPs provide a minimum of secondary treatment, conventional secondary biological treatment processes do not remove the phosphorus and nitrogen to any

---

[1] Workshop support was provided in part by the U.S. Environmental Protection Agency Office of Research and Development and by The National Partnership between The Nature Conservancy and NOAA Community-based Restoration Program

substantial extent. Tertiary treatment can remove nitrogen and phosphorous through carefully designed chemical reactions that generate easily isolated products such as precipitates and gases, though it is considered a costly technology (Carberry 1990). Despite the cost of removing nitrogen from waste water discharges development of such programs is occurring in multiple locations (Chesapeake Bay Foundation). One reason N is being controlled at discharges is well summarized in the Chesapeake Bay Foundation's (CBF) Program report (page 6)

> *… controlling N at point sources (such as wastewater effluents) is logistically easier than controlling inputs from more diffuse sources, such as agriculture and atmospheric deposition.*

Restoring shellfish beds and increasing shellfish harvest is another method of controlling N in estuarine environments. Rather than controlling at the source (e.g. through agricultural best practices), or controlling discharges (e.g. at WWTPs) shellfish remove N from the receiving waters, a relatively new concept. One reason to explore removing N from the receiving waters as a method to control water quality is that it may provide a least cost solution to tertiary treatment of WWTP effluent. Controlling point sources and treating effluent becomes relatively more costly, because they both face increasing marginal costs.

The cost of removing N using treatment at a WWTP increases with the volume of N being removed. For example, in 2005, 370 million pounds of N were introduced into the Chesapeake Bay, more than twice the restoration target of 175 million pounds (Chesapeake Bay Program 2006). Accordingly, to ameliorate N pollution (and its effects) in the Bay, the Chesapeake Bay 2000 agreement mandated 48% reductions in N loads from point sources to the Bay and its tributaries (based on 1990 input levels). This agreement has resulted in increasingly stringent effluent discharge limits for wastewater utilities discharging into the Chesapeake Bay watershed; down to as low as 3 mg/L total N by January 1, 2011. The capital cost to achieve this level of treatment by point sources discharging into Chesapeake Bay is estimated to be several billion dollars (Nutrient Reduction Technology Cost Task Force, 2002)**.** The report states (page 6)

> *…, the impact of implementing effluent guidelines down to 3 mg/L increases the cost of compliance substantially. The Nutrient Reduction Technology Cost Taskforce estimated that the capital cost to achieve effluent N levels of 5 mg/L at a 10 million gallon per day (MGD) plant that was not previously performing biological N removal was around $4.9 million. At the same plant, to implement limit of technology (LOT) treatment to achieve an effluent total N guideline of 3 mg/L would cost $9.6 million in capital costs. Operational costs also double for this scenario. Clearly, the economic impact of implementing LOT treatment levels is substantial.*

The report goes on to say that:

> *Consequently, the regulated community is unconvinced that reduction beyond that currently realized using conventional methods will provide substantial environmental benefits relative to the costs incurred..*

The purpose of this section of the report is to provide information from readily available sources about the cost – specifically the marginally cost – of removing N from waste water streams. Particularly the marginal cost as the LOT is reached. This marginal cost data can then be compared to the volumes and costs of N removed via aquaculture. Thereby providing data that can help suggest whether, at certain levels of N removal, it may be more cost effective to expand shellfish restoration and or aquaculture rather than implement relatively more costly treatment options.

3.0 ORGANIZATION

In addition to the Objective and the Background (above) the paper consists of four other sections. First, the Methodology used to quantify the benefit of N removed by shellfish is described. Second, the Cost of Engineering Nitrogen Removal is described including a discussion of the data sources. Third the water quality benefits of shellfish harvest in Oakland Bay, Wa is discussed. Lastly, a discussion of the uses, limitations and possible extensions of this research is discussed.

4.0 METHODOLOGY OF VALUING NITROGEN REMOVAL

There are a number of accepted methods used for valuing economic benefits. These methods vary in their application depending upon the type of benefit being measured, available information and the certainty of the physical effects of a proposed action. For this analysis the methodology used to value nitrogen removal is the **replacement cost** method.

This method does not provide a strict measure of economic values in the classical view of the term. The replacement cost method assumes that the costs of restoring a part of the ecosystem - in this case clean water through nitrogen removal technology (NRT) of wastewater - provides a useful estimate of the value of these ecosystems services – in this case the filtration and nitrogen capture provided by shellfish harvesting. For the research conducted in this paper use of the replacement cost methodology assumes that if shellfish are no longer harvested the nitrogen removal services they had been providing would have to be replaced. That is to say this analysis assumes the primary nitrogen removal mechanism is harvest rather than other sequestration by other means, such as increased nitrogen burial under active shellfish beds.

5.0 ESTIMATES OF COSTS OF NITROGEN REMOVAL TECHNOLOGY

Various methods of NRT are being employed by agencies responsible for improving the quality of water both alternative and traditional.

Alternative methods combine traditional and natural treatment systems to provide multiple barriers, improve source water quality, minimize treatment costs by lowering chemical doses, and improve finished water quality. Examples of natural treatment systems include natural and man-made wetlands, tree farms used for landfill leachate, and moving water through soil or aquifers (AWWA). For example the City of Albany Oregon is developing a 10-acre natural treatment area that makes treated wastewater safe for creating wetlands and irrigating parks. The 10 acres will be a demonstration area, the first step toward eventually creating a much larger system of integrated wetlands. The wetlands will mix treated wastewater from the two cities and two adjacent industries with natural lakes and wetlands, reestablishing habitat while further cleaning and cooling the wastewater before it rejoins the Willamette River farther downstream (City of Albany). Literature that synthesizes the costs of this type of natural treatment is not readily available yet. Although searched for, cost data could not be found within the budget allocated to this task.

Examples of traditional methods to remove N are system upgrades to WWTPs. Cost estimates for these treatment upgrades show a range on costs depending primarily on two factors (Chesapeake Bay Foundation, US Environmental Protection Agency (EPA)). The first factor is the capacity of the treatment plant, usually measured in the millions of gallons per day (MGD). The larger the WWTP design capacity the more expensive the treatment upgrade. The second factor is the degree to which N is removed.

The costs for NRT for each of the nine case studies, and relevant design criteria, from the EPA study are shown in **Table 1**. Of the nine WWTPs studied by the EPA the average concentration levels of N in the influent varied from 23.9 mg/L to 39.6mg/L. After treatment the average annual concentration levels of N in the WWTP effluent ranged from 0.9mg/L to 15.2mg/L. The capital costs of treatment ranged from $2,400 thousand to $71,600 thousand. On an annual basis the estimates of capital costs range from $302.7 thousand to $6,240.0 thousand. The estimate of annual O&M ranges from $109.0 thousand to $1,311.00 thousand.

Table 1 EPA Case Studies of Nitrogen Removal Costs (2007 dollars).

Case Study	Relevant Design Criteria	Total Cost		
		Total Capital	Annualized Capital	Annual O&M
	Capacity (MGD) Influent Concentrations and Effluent Concentration (mg/L)	Total Project Costs ($ 000s)	20 years at 6% ($ 000s)	Annual Costs (000s $/year
Central Johnston County WWTP, Smithfield, North Carolina	4.2 average MGD 31.2 mg/L influent 3.7 mg/L effluent	$2,400.0	$302.7	$301.7
Fiesta Village Advanced WWTP, Lee County Florida	3.2 average MGD 33.2 mg/L influent 1.71 mg/L effluent	$13,460.0	$1,174.0	$284.2
Kalispell Advanced wastewater treatment Kalispell, Montana	3.0 average MGD 39.6 mg/L influent 10.6 mg/L effluent	$4,310.0	$323.6	$57.8
Kelowna WWTP. Kelowna, British Columbia, Canada	8.5 average MGD 28.8 mg/L influent 4.4 mg/L effluent	$27,273.0	$2,378.0	$109.0
Marshall Street Water Reclamation Facility. Clearwater, Florida	10.0 avg MGD 28.0 mg/L influent 2.3 mg/L effluent	$18,600.0	$1,620.0	$509.0
Noman M. Cole, Jr., Pollution Control Plant. Fairfax County, Virginia	18.0 avg MGD 34.6 mg/L influent 0.9 mg/L effluent (a)	$71,600.0	$6,240.0	$1,243.0

Case Study	Relevant Design Criteria	Total Cost		
		Total Capital	Annualized Capital	Annual O&M
North Cary Water Reclamation Facility. North Cary, North Carolina	12.0 avg MGD 56.4 mg/L influent 3.67 mg/L effluent	$16,358.0	$1,426.0	$230.0
Western Branch WWTP. Upper Marlboro, Maryland	19.3 avg MGD 23.9 mg/L influent 1.63 mg/L effluent	$49,583.0	$4,324.0	$1,311.0

(a) Measured in terms of total Kjeldahl nitrogen

The Chesapeake Bay Foundation (CBF) study also estimated the costs of NRT (Chesapeake Bay Program 2002). The purpose of the study was to understand the additional investment needed to reduce the N concentration in the Chesapeake Bay to targeted levels. **Figure 1** shows the CBF's estimate of NRT costs to remove varying levels of N from significant municipal WWTPs located in the Chesapeake Bay watershed. The CBF report focuses on the *marginal investment* needed to reduce N, assuming that some treatment is already occurring. For example, in the case of a WWTP with a 2.0 MGD design capacity achieving N concentrations of 5.0 mg/L from 8.0mg/L is estimated to cost $2.2 million. Further reductions in N concentrations, from 5.0 mg/L to 3.0 mg/l are estimated to cost $3.1 million. In the case of a WWTP with a 20.0 MGD design capacity achieving N concentrations of 5.0 mg/L from 8.0mg/L is estimated to cost $11.5 million. Further reductions in N concentrations for the same WWTP, from 5/0 mg/L to 3.0 mg/l, are estimated to cost $24.0 million. The data in **Figure 1** shows how NRT costs increases both with increasing design capacity (in MGD) and as concentration levels are reduced (in mg/L).

Included on **Figure 1** are two data points representing planned investments by local WWTP in NRT. One data point represents investment in a WWTP located on Budd Inlet, in South Puget Sound. The plant, owned and operated by LOTT, treats wastewater from almost 50,000 homes, apartments, and commercial and industrial connections served by the sewer utilities of the cities of Lacey, Olympia, and Tumwater and Thurston County (www.LOTTonline.com (a))[2]. On average the plant treats 18.0 million gallons a day (MGD) of wastewater. In 1994 LOTT invested approximately $37 million in NRT, decreasing the N concentration in the effluent from an annual average of 18.0 mg/L to 4.0 mg/L. An upgrade is planned for 2017, reducing average N concentrations in the effluent to 2.25 mg/L at a cost of approximately $25.0 million (personal communication with Karla Folwer, LOTT).

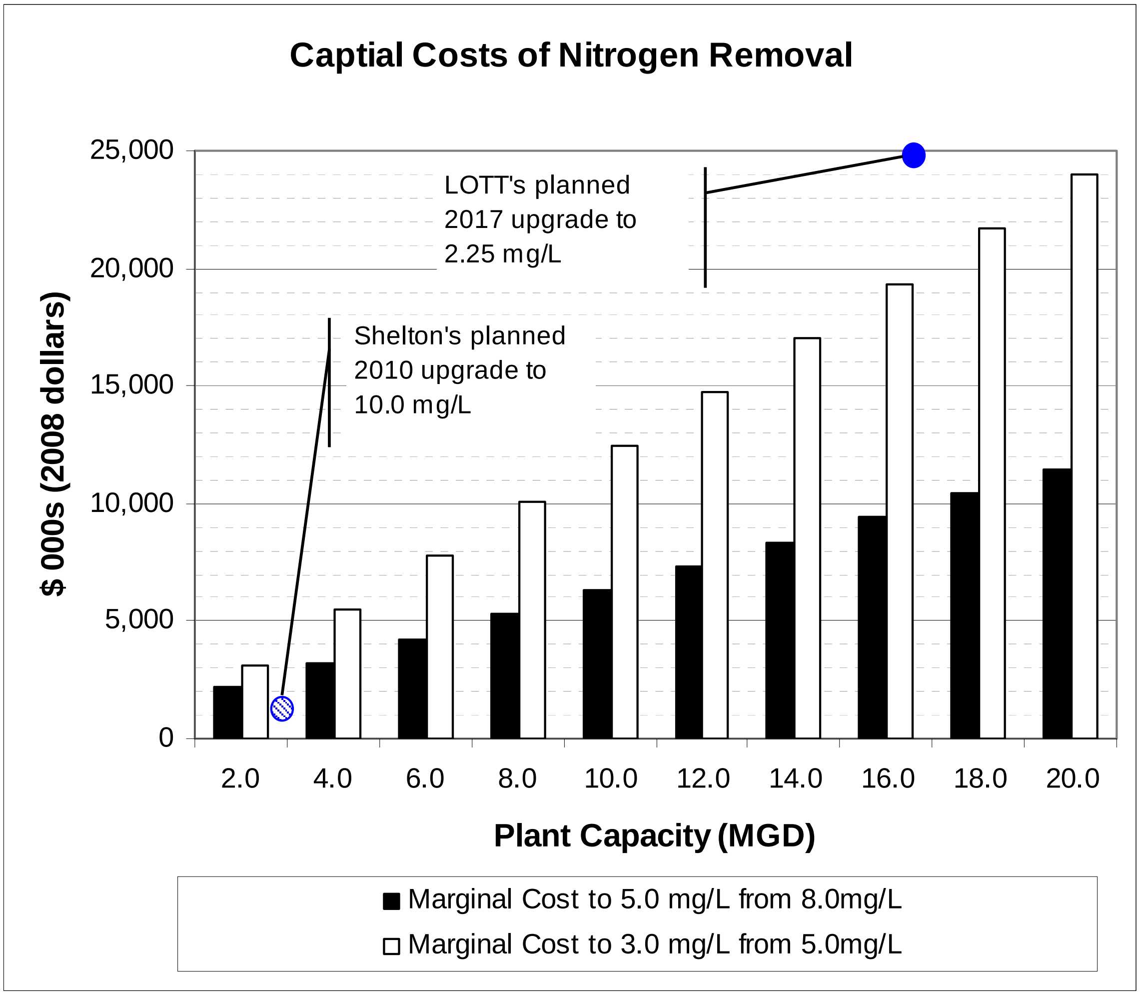
The second data point represents the City of Shelton's planned 2010 investment in NRT. The City of Shelton WWTP discharges into Oakland Bay in Puget Sound. The WWTP is designed to treat 4.0 MGD. The City is in the process of upgrading their plant to achieve concentration of 10.0 mg/L of N in its effluent, removing approximately 100 lbs per day of N (personal communication with John Ozga, City of Shelton). The cost of the anoxic basins for that upgrade is estimated to be between $1.1 million to $1.5 million (personal communication with Allan Maas, Parametrix). Although the data from LOTT and the City of Shelton does not equal the

---

[2] The LOTT Wastewater Alliance was incorporated as a non-profit organization on April 17, 2000 between the cities of Lacey, Olympia Tumwater and Thurston County. LOTT has full responsibility operating the waste water facilities that serve these communities.

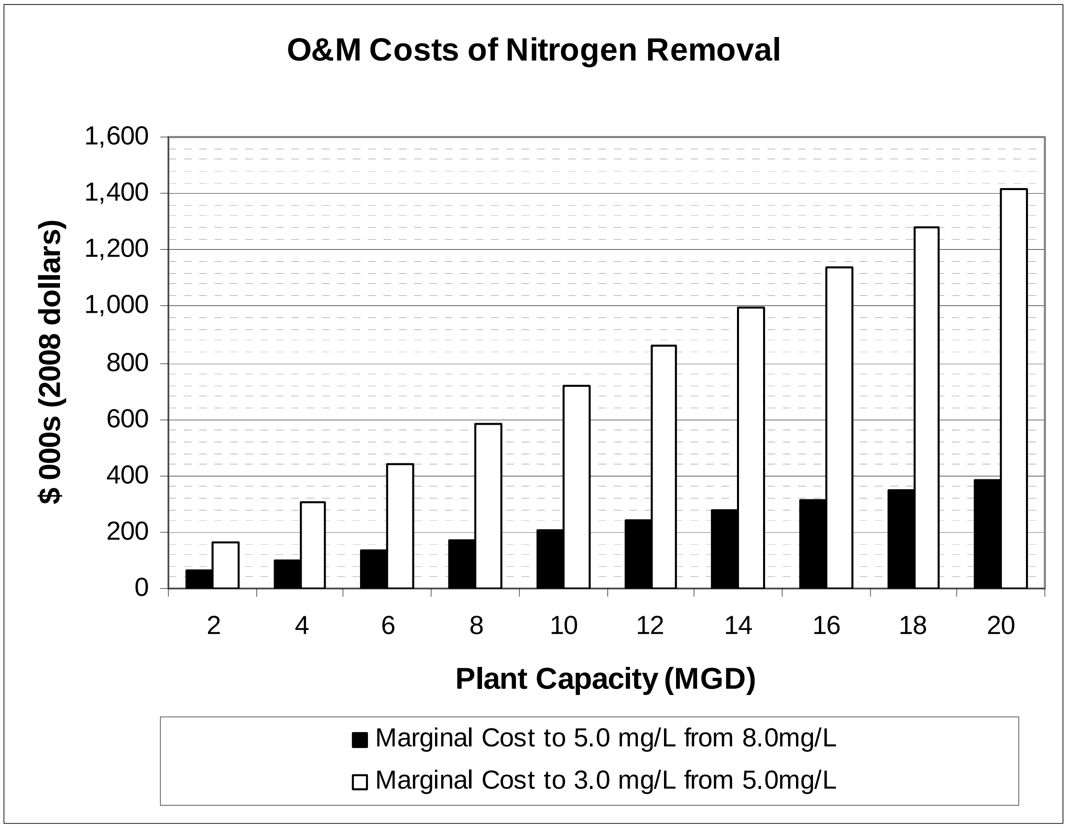
same concentration levels as estimated in the Chesapeake Bay study the data from the local WWTP tends to support the cost estimates from the Chesapeake Bay study.

Figure 2 shows a similar relationship of operations and maintenance (O&M) costs to reduce N concentrations. Here the increase in marginal costs of removing 3.0 mg/L of N when levels are at 8.0mg/L to removing 2.0 mg/L of N when levels are at 5.0 mg/L range from a 167 percent increase to a 370 percent increase.



Source: Chesapeake Bay Foundation, adjusted to 2007 dollars using ENR's construction indices

Figure 1 Estimate of Marginal Capital Cost of Nitrogen Removal, Case Study from the Chesapeake Bay, adjusted to 2007 dollars using ENR's construction indices.



Source: Chesapeake Bay Foundation, adjusted to 2007 dollars using ENR's construction indices.

Figure 2 Estimates of Operations and Maintenance Cost of Nitrogen Removal

Table 2 presents all the cost data described above in terms of dollars per pound of N removed from WWTP influent. Both the capital cost and the O&M costs are shown, the sum of which is the life cycle cost. The range of life cycle costs for the CBF study is $7.67/lb of N removed to $28.88/lb of N removed. The range of life cycle costs from the EPA report is $0.98/ lb to $4.78/lb. The life cycle costs for the City of Shelton's planned upgrade is $2.99/lb. The life cycle costs for Lott's two upgrades, the 1994 upgrade and the planned 2017 upgrade, are $7.56 and $25.24, respectively. The data from the various source tends toward corroboration. For example, the life cycle cost data from the CBF study for a WWTP with an 18.0 MGD capacity with 3.0 mg/L effluent concentrations of N is $28.88/lb of N removed. This estimate closely approximates the data from LOTT regarding the 2017 upgrade, when capacity is estimated to be 16.2 MGD with a 2.25 mg/L concentration of N; the life-cycle cost is estimated to be $25.24/lb of N removed.

Multiplying the per pound life cycle costs from **Table 2** by the estimate of the pounds of N removed by shellfish harvesting produces an estimate of water quality benefit provided from aquaculture (see **Table 3**). The shellfish harvested in Oakland Bay remove an estimated 25,787 pounds of N per year (Steinberg and Hampden, 2009).

The water quality benefit can be thought of as the investment needed in NRT that can replace the N removed by shellfish harvest. A range of benefits is to be expected because the actual benefit depends on many factors, capacity, concentration targets in the effluent, NRT used, upgrade feasibility, etc. For example, the costs of NRT increase as the concentration levels on the effluent decrease – these increasing marginal costs of NRT means, using the replacement cost valuation methodology, the water quality benefit will increase as regulations, like the NPDES, require reductions in concentrations of N.

Table 2 EPA Case Studies of Nitrogen Removal (2008 dollars).

Source / Case Study	Life-Cycle Unit Cost	Unit Cost		Relevant Design Criteria
		Capital	O&M	
	$/lb of TN removed	$/lb of TN removed	$/lb of TN removed	Capacity (MGD) Post-Project N Concentration (mg/L)
From the Chesapeake Bay Study (a)				
4.0 MGD design capacity upgrade from 8.0mg/L to 5.0mg/L	$10.33	$7.67	$2.65	Incremental upgrade removes 36,553 lbs N
4.0 MGD design capacity upgrade from 5.0mg/L to 3.0mg/L	$31.62	$19.35	$12.27	Incremental upgrade removes 24,369 lbs N
18.0 MGD design capacity upgrade from 8.0mg/L to 5.0mg/L	$7.64	$5.53	$2.11	Incremental upgrade removes 164,487 lbs N
18.0 MGD design capacity upgrade from 5.0mg/L to 3.0mg/L	$28.88	$17.23	$11.65	Incremental upgrade removes 109,658 lbs N
From the EPA study (b)				
Central Johnston County WWTP, Smithfield, North Carolina	$0.98	$0.49	$0.49	4.2 average MGD 3.7 mg/L N removes 619,000 lbs N
Fiesta Village Advanced WWTP, Lee County Florida	$4.78	$3.87	$0.91	3.16 average MGD 1.71 mg/L N removes 303,000 lbs N
Kalispell Advanced wastewater treatment Kalispell, Montana	$1.65	$1.46	$0.19	3.0 average MGD 10.6 mg/L N removes 258,000 lbs N
Kelowna WWTP. Kelowna, British Columbia, Canada	$3.19	$3.05	$0.14	8.5 average MGD 4.39 mg/L N removes 781,000 lbs N
Marshall Street Water Reclamation Facility. Clearwater, Florida	$3.15	$2.40	$0.75	10.0 average MGD 3.0 mg/L N removes 428,000 lbs N
Noman M. Cole, Jr., Pollution Control Plant. Fairfax County, Virginia	$1.76	$1.47	$0.29	18.0 average MGD 4.35 mg/L N removes 4,240,000 lbs N(a)
North Cary Water Reclamation Facility. North Cary, North Carolina	$2.95	$2.54	$0.41	12.0 average MGD 3.67 mg/L N removes 1.121,000 lbs N
Western Branch WWTP. Upper Marlboro, Maryland	$4.27	$3.27	$0.99	19.3 average MGD 1.63 mg/L N removes 1.320,000 lbs N
City of Shelton (c)				
Planned 2010 upgrade	$2.99	$2.99	Not available	3.3 average MGD 10.0 mg/L N removes 365,000 lbs N
LOTT (d)				
1994 Upgrade	$7.56	$7.56	Not available	10 average MGD 4.0mg/L n removes approx 426,449 lbs N
Planned 2017 Upgrade	$25.24	$25.24	Not available	16.2 average MGD 2.25mg/L N removes approx 86,356 lbs N

Sources: Base data obtained from: (a) Chesapeake Bay Foundation, 2002, (b) EPA, 2008, (c) Personal communications with John Ozga, City of Shelton and Allan Maas, Parametrix, 2009, (d) Personal communication with Karla Fowler, LOTT, 2009 and 2008 Annual LOTT Capacity Report. Calculations of per unit cost performed by ENTRIX as follows; Capital costs were annualized assuming a 6 percent discount rate over a 20 year life. The annualized capital and the annual O&M were divided by the lbs of N removed to obtain the per unit capital and O&M costs. Life cycle costs are the sum of the per unit capital and per unit O&M costs.

6.0 ESTIMATE OF WATER QUALITY BENEFITS OF SHELLFISH

The water quality benefit estimates of shellfish harvest are shown in **Table 3,** listed from the lowest benefit estimate to the highest benefit estimate. The benefits range from $25.3 thousand annually to $815.4 thousand annually. These estimates of annual benefit represent a range of capital investment from $144.9 thousand to $7,465.3 thousand.

An estimate of the water quality benefit from shellfish harvesting most applicable to Oakland Bay WA is based on the data of N removal obtained from the City of Shelton (bolded in Table 3). Using life-cycle costs data from the City of Shelton the annual water quality benefit of shellfish harvest from Oakland Bay is estimated to be $77.1 thousand. This estimate is based on capital costs only; the estimate of O&M costs was not available. The $77.1 thousand benefit represents a capital investment of $884.4 thousand.

Other estimates of the potential water quality benefit of shellfish removal in Oakland Bay can be developed using costs data from other sources. For example, the benefit estimate based on the case study from the EPA of the WWTP with the capacity and concentration levels most closely approximating the City of Shelton's WWTP. The Kalispell WWTP located in Kalispell Montana treats 3.0 MGD to a concentration of 10.6 mg/L N, a close approximation to the City of Shelton's WWTP which treats 3.3 MGD to 10.0mg/L concentration of N. The estimated annual water quality benefit based on the Kalispell WWTP case study is $42.5 thousand, representing a capital investment of $431.8 thousand.

Or, if the City of Shelton were considering treating effluent to achieve lower concentrations of N in its effluent, then another case study from the EPA study could be used. The Fiesta Village WWTP located In Lee County Florida is similar in size to the City of Shelton's WWTP and treats the water to a much lower concentration of N, 1.7mg/L. The annual water quality benefit is estimated to be $123.3 thousand representing a capital investment of $1,144.6 thousand.

Table 3 Estimates of Water Quality Benefit from Shellfish Harvest (2007 $ in 000s)

Study/ Source of Data	Name of Case Study	Reason for Selecting	Annual Life-Cycle	Annual Capital	Annual O&M	Total Capital
			($ 000s)	($ 000s)	($ 000s)	($ 000s)
EPA	Central Johnston County WWTP Smithfield, NC	Minimum per unit value from the EPA report	$25.3	$12.6	$12.6	$144.9
EPA	Kalispell advances WWTP, Kalispell, Montana	Design criteria close fit to the City of Shelton	$42.5	$37.6	$4.9	$431.8
City of Shelton	**City of Shelton WWTP, Shelton WA**	**Site of the study**	**$77.1**	**$77.1**	**N/A**	**$884.4**
EPA	Fiesta Village Advanced WWTP, Lee County Florida	Maximum from the EPA report	$123.3	$99.8	$23.5	$1,144.6
LOTT	1994 upgrade, Olympia WA	Located near the study site	$194.9	$194.9	N/A	$2,236.0
CBF	4.0MGD from 8.0mg/L to 5.0mg/	Capacity equals City of Shelton, suggest costs for further upgrades	$266.1	$197.8	$68.3	$2,268.6
LOTT	2017 planned upgrade, Olympia WA	Located near study cite suggests benefit for larger WWTP	$650.9	$650.9	N/A	$7,465.3
CBF	4.0MGD from 5.0mg/L to 3.0mg/L	Capacity equals City of Shelton, suggest costs for further upgrades	$815.4	$499.0	$316.4	$5,723.2

Source: ENTRIX calculations

Two other benefits estimates are based on data from LOTT. These benefits estimates can help frame the magnitude of benefit to LOTT if it were possible to expand shellfish harvesting to Oakland Bay's scale in Budd Inlet, where LOTT discharges its effluent. The cost data from LOTT provides an example of how costs increase as N concentration levels are reduced. Using the 1994 life-cycle cost data the water quality benefit of shellfish harvest is $194.9 thousand, representing $2,236.0 thousand in capital costs. The life-cycle costs data for the planned 2017 LOTT upgrade, with further reduction in N concentrations, results in a benefit estimate of $650.9 thousand and a capital investment of $7,465.3 thousand. This data provides an example of how the water quality benefits of shellfish harvest will increase as lower and lower concentration levels of N are required. The Marginal costs of N removal increase as concentrations levels in effluent decrease, which will change the water quality benefit calculations.

The two benefits estimates based on the CBF cost data provide another example of increasing marginal costs. The CBF cost data is based on the assumption that N concentration levels would be reduced first from 8.0 mg/L to 5.0 mg/L and then from 5.0 mg/L to 3.0 mg/L for a WWTP with a 4.0 MGD capacity. The annual water quality benefits, based on these two assumptions, are $266.1 thousand and $815.4 thousand, respectively. These annual benefits represent a capital investment of $2,268.6 thousand and $5,723.2, respectively.

7.0 USES, POSSIBLE EXTENSIONS AND LIMITATIONS OF THIS RESEARCH

7.1 Uses of this Research

The water quality benefits estimates can be useful in at least three ways.

- Regionally, in Oakland Bay, were there are productive shellfish beds and relatively little room to expand shellfish operations, these benefits can be used to assist in describing the benefits of protecting the existing operations.
- Outside of the region, in areas where historical shellfish operations have been closed due to water quality concerns, such as Drayton Harbor, Washington. The estimation of the benefits of removing N can be useful in developing a more complete understanding of the value of shellfish restoration activities.
- To inform policy makers about the feasibility of a market for water quality credits.

Each of these types of uses of the data is discussed below in more detail.

7.1.1 Regional applications, Benefits in Oakland Bay

The benefits of shellfish operations in Oakland Bay include (Oakland Bay Clean Water District);

- Annual total shellfish revenue not including the value of the seed beds is estimated at $9,220,000
- Annual production of at least 3.1 million pounds of manila clams
- Annual production of at least 190,000 dozen kumamoto and pacific oysters (150,000 Kumamoto and 40,000 Pacific)
- Annual production of 150,000 pounds of mussels
- 274 full or part-time local jobs
- This area is also a very important oyster seed bed area to Taylor Shellfish
- There are also hundreds of recreational harvesting efforts on State owned tidelands
- The regional is of great cultural importance to the Squaxin Island Tribe area to inform resource managers about the one of the environmental benefits of aquaculture.

The current classification status of shellfish in Oakland Bay is ‘Meets standards but threatened with a downgrade in classification’ (Washington State Department of Health). The estimates of the water quality benefits contribute to the existing understanding of the benefit of protecting shellfish operations.

7.1.2 Out-of-Region Benefits

In areas where the expansion of shellfish is possible, in areas that have historically supported shellfish harvesting, like Drayton Harbor, these benefit estimates can inform about additional benefits that would result from efforts to restore shellfish. In this example, if the water quality in Drayton Harbor indicated the need to regulate N loads then a comparison of the methods of water treatment can include expansion of shellfish production. The benefit estimates provide a way to make comparisons between other NRT and shellfish restoration.

7.1.3 Informing on the Feasibility of Water Quality Market Development

Water quality trading is a voluntary market-based approach that, if used in certain watersheds, might achieve water quality standards more efficiently and at lower cost than traditional approaches (EPA). In this example, costs for controlling N loads at a point source compared to restoring shellfish production can vary significantly in a watershed, creating the impetus for water quality trading. Through water quality trading, WWTPs that face higher NRT costs – particularly as N concentration limits are tightened the WWTP could meet their regulatory obligations by ‘purchase pollutant reduction credits’, e.g. restore shellfish harvesting if the cost is lower and the N reductions achieve targets. Thus achieving the same or better overall water quality improvement and providing other ecological and economic benefits. This is the case that is being made in Sweden, as was discussed at the beginning of the report (Lindahl, et.al). Water quality trading is an emerging market, increasingly considered as the Federal government begins to consider markets, such as Cap and Trade, as a management tool for many types of resources beyond carbon. For example the USDA’s new Department of Ecosystem Services and Markets (http://www.fs.fed.us/ecosystemservices/resources.shtml) lists numerous publications regarding market development.

7.2 Limitations of the Research

This research considers the benefit of shellfish aquaculture only as it relates to N removal. No attempt has been made to quantify the other types of ecosystem benefits, such as habitat creation with these benefits. For a description of many of the other types of benefits arising from shellfish restoration and harvest see Basin and Coast News, May 2008.

Conversely this research does not address possible water quality impacts that may occur as a result of shellfish aquaculture.

7.3 Extensions of the Research

This research could be improved in a number of ways. Considering other types of methods to remove N from water bodies, for example manmade wetlands would provide a broader comparison of the relative cost of various methods to remove N.

Another logical step would be to consider researching the criteria that would make using shellfish harvesting a viable option to other methods of NRT. For example, two of the criteria suggested by this research include; 1) areas where investment in NRT is reaching the limits of technology (for example LOTT’s planned 2017 upgrade to reduce N concentration in effluent to 2.25 mg/L) and 2) areas where there is sufficient undeveloped tidal area to expand shellfish production. Once a list of all the criteria was completed a search for regions that meet the criteria could be undertaken and the significance of expanding shellfish production to meet water quality goals could be undertaken.

This research suggest that if a tidal area existed where treatment for N was reaching limits of technology – an area where the marginal cost of N removal was high (e.g. the CBF’s estimate of $815.4 thousand/lb for life-cycle costs to reduce n concentrations from 5.0 mg/L to 3.0 mg/L) - then shellfish harvesting may provide an economically and environmentally viable N removal method. The question becomes whether those two criteria – space to expand shellfish production combined with the tighter constraints on N loads – exists for the same region.

The exercise to ascertain criteria for a successful water quality trading bank would also likely need to answer the question whether shellfish harvest in such a location would meet the Washington State Department of Health’s (SDH) criteria for food safety. A question that follows is, would production and harvesting of shellfish, solely for the purposes of removing N, and not for the sale of the food product, be a least-cost alternative to NRT? Or could the benefit from N removal be used to relay shellfish to other, clean waters, prior to sale for consumption? Answers to these questions in a feasibility study would contribute to developing new, least-cost, tools for resource managers as they face the challenges of restoring and protecting the environmental and provide needed services to people.

8.0 REFERENCES

American Water Works Association (AWWA) Organic Contaminants Control Committee. *Treating Water Nature's Way.* Citation: OPF, Vol. 34 Iss. 4, April 2008, Page Range 14-16.

Basin and Coast News, US Agency for International Development and Integrated Management of Coastal and Freshwater Systems Volume 2 Issue 2, May 2008. Accessed on June 10, 2009, http://www.imcafs.org/coastsheds/issues/article_2_2_2.swf.

Carberry, J.B. 1990. Environmental Systems and Engineering. Saunders College Publishing, Orlando, FL.

Chesapeake Bay Program Scientific and Technical Advisory Committee, *Establishing a Research Agenda for Assessing the Bioavailability of Wastewater Treatment Plant derived Effluent Organic Nitrogen in Treatment Systems and Receiving Waters*. February 27, 2009 Stac Report 09-002

Chesapeake Bay Program, *Nutrient Reduction Technology Cost Estimations for Point Source in the Chesapeake Bay Watershed*, November 2002.

City of Albany, Oregon website accessed June 10, 2009, http://www.cityofalbany.net/publicworks/sewer/wwtp_project/index.php.

City of Shelton website accessed June 11, 2009, http://www.ci.shelton.wa.us/public_works/public_works_sewerplan.php.

Engineering News Record (ENR) Construction Cost Index History, 2009.

Fowler, Karla, Community Relations & Environmental Policy Director, LOTT Alliance, phone call communication with Karla Fowler on March 4, 2009 and follow-up e-mail dated March 18, 2009.

LOTT online (a) http://www.lottonline.org/plant.htm accessed June 11, 2009.

LOTT 2008 Annual Capacity Report

Lindahl, O, R. Hart, B. Hernroth, S. Kollberg, L. Loo, L. Olrog, A. Rehnstam-Holm, J. Svensson, S. Svensson, and U. Syversen. *Improving Marine Water Quality by Mussel Farming: A Profitable Solution for Swedish Society.* AMBIO: A Journal of the Human Environment 34(2):131-138. 2005

Maas, Allan, Parametrix, consultant to the City of Shelton providing the engineering estimate of the planned upgrade. Personal phone conversation on July 9, 2009.

The Nature Conservancy’s Global Marine Initiative, Shellfish Restoration Clamor, April 2009.

Oakland Bay Clean Water District, Shellfish Growing Statistics for Oakland Bay, 2008.

Washington State Department of Health, Office of Shellfish And Water Protection Annual Growing Area Review for Oakland Bay, December 2008

U.S. EPA Office of Wastewater Management, Municipal Support Division, Municipal Nutrient Removal Technologies Reference Document Appendix A. EPA 832-R-08-006, Sept 2008.