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## **Watershed Restoration Plan for Nitrogen and Selenium Impairments**

### **Plan de restauration d'un bassin versant contaminé en sélénium et en nitrates**

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#### **RÉSUMÉ**

Le plan stratégique du programme de gestion de l'azote et du sélénium (NSMP) et de mise en œuvre de bonnes pratiques de gestion (BMP) est l'aboutissement d'un long processus visant à restaurer le bassin versant de la baie de Newport en Californie. Le bassin hydrologique de la baie de Newport est affecté par les hautes teneurs en sélénium et en nitrates. Les changements hydrologiques sont responsables de la haute teneur en sélénium des couches géologiques supérieures du bassin. L'agriculture et l'utilisation d'engrais chimiques ont contribué à l'apparition de taux de nitrates relativement élevés. Le développement du plan stratégique de restauration est basé sur des activités de recherche et de tests dans le bassin versant, mais aussi sur une évaluation des technologies et ouvrages spécifiques de traitement du sélénium et des nitrates. Le développement du plan de restauration repose aussi sur la recherche et la modélisation d'alternatives pour la restauration du bassin versant, et l'évaluation des coûts associés aux techniques utilisées. L'approche définie par le plan stratégique vise à répondre au manque de connaissance des nappes phréatiques du bassin versant, et souligne que les bonnes pratiques de gestion pour le traitement du sélénium n'ont pas encore fait leurs preuves. Suivant les principes de gestion adaptative, le plan stratégique de restauration comporte deux phases : la première est dédiée à la validation des technologies, la seconde concerne la mise en œuvre grandeur nature des technologies sélectionnées.

#### **ABSTRACT**

The Nitrogen and Selenium Management Program (NSMP) Best Management Practice (BMP) Strategic Plan is the culmination of a multiple year process to develop a watershed restoration plan for nitrogen and selenium impairments in the Newport Bay watershed in Southern California. Hydrologic changes in the watershed have led to the mobilization of selenium and agricultural land uses, specifically from fertilizers, have led to elevated concentrations of nitrogen in the watershed. The development of the BMP Strategic Plan encompassed research, testing and evaluation of nitrogen and selenium BMPs and treatment technologies, the formulation of watershed restoration alternatives, watershed modeling of the developed alternatives, and identification of costs associated with technologies and watershed restoration alternatives. The approach of the BMP Strategic Plan takes into account that the BMPs for the treatment of selenium are not yet proven technologies and that better understanding of groundwater in the watershed is needed. Therefore, the BMP Strategic Plan uses a phased approach that incorporates adaptive management principles through two phases, Phase I – Technology Validation and Phase II – Full-Scale Implementation.

#### **KEYWORDS**

Selenium, watershed restoration, nitrogen, Best Management Practice, treatment technology

## 1 INTRODUCTION

The NSMP BMP Strategic Plan is a phased process for implementing treatment controls to meet prescribed water quality objectives for nitrogen and selenium in the Newport Bay watershed. An alternative compliance approach was implemented with the formation of a NSMP Working Group of watershed stakeholders to develop and implement a comprehensive Work Plan to address nitrogen and selenium discharges in the watershed. The United States Environmental Protection Agency promulgated numeric water quality criteria for priority toxic pollutants and other water quality standards provisions to be applied to waters in the State of California. These water quality criteria are defined under the California Toxics Rule (CTR), and are necessary to protect human health and the environment in the State of California. The Santa Ana Regional Water Quality Control Board issued an Order in 2004 for compliance with the CTR criteria for selenium and the Basin Plan water quality objective for nitrogen for discharges in the Newport Bay watershed. The alternative compliance approach of the NSMP Working Group encompassed a regional strategy as it was understood that while current groundwater levels in the watershed exceed the CTR limit of 5 µg/L selenium, a feasible treatment technology did not exist at the time of adoption of the Order to lower the levels in the discharges to the CTR standard. One of the tasks in the Work Plan was to develop and evaluate BMPs and treatment technologies for nitrogen and selenium and specify effective BMPs and treatment technologies capable of removing nitrogen and selenium in a BMP Strategic Plan. The purpose of the BMP Strategic Plan is to identify the types and locations of BMPs and treatment technologies to meet nitrogen and selenium water quality objectives to restore the watershed.

The Newport Bay watershed covers an urbanized area of approximately 154 square miles (399 square kilometers) in central Orange County, California. Land uses in the watershed are comprised of approximately 75% urban, about 5% agriculture, and about 20% open space located mainly in the foothills and headland areas. Mountains surround the watershed on three sides and runoff from these mountains drains across the Tustin Plain and enters Upper Newport Bay via San Diego Creek, the largest contributor (85%) of freshwater flow into Upper Newport Bay. The climate is Mediterranean, characterized by short, mild winters and dry summers. Average rainfall is about 13 inches per year (330 millimeters per year), with 90 percent of the rainfall typically occurring between November and April.

The hydrology of the watershed has been substantially altered compared to historical conditions. Selenium occurs naturally in the watershed and is present in many sedimentary formations. Natural precipitation and irrigation water that infiltrates through the geologic formations and soils oxidize the selenium to soluble selenate ( $\text{SeO}_4^{2-}$ ). Because of modifications to the hydrology in the watershed the selenium has become mobilized and is transported through shallow groundwater movement and surfaces into streams and channels in the watershed. The geology and hydrogeology of the watershed play an important role in the elevated concentrations of selenium in surface waters. While the geologic formations in the foothills and basins contain selenium-bearing minerals, the concentration of selenium by natural processes and subsequent mobilization by anthropogenic processes have resulted in the accumulation of selenium in surface waters, sediment, and biota in the watershed (Hibbs and Lee 2000). Nitrogen is also an issue in the watershed. The presence of nitrate in the shallow groundwater from historical agricultural uses within the watershed appear also to be helping to mobilize selenium and other trace elements from the old swamp deposits (Meixner et al., 2004). Nitrogen concentrations in many places are also in exceedance of the water quality objective and excessive nitrogen loading has caused algae blooms in Newport Bay.

The development of the BMP Strategic Plan included many sub-tasks, completed over a five-year period, that were designed towards supporting and ultimately developing the BMP Strategic Plan. One of the first tasks was identification and assessment of selenium and nitrogen treatment technologies and Best Management Practices. This task consisted of conducting a thorough literature review and technology survey of BMPs and treatment methods, beginning with the review of several papers in the peer reviewed literature. The result was the *Identification and Assessment of Selenium and Nitrogen Treatment Technologies and Best Management Practices Interim Report, March 2007*. This report summarizes BMPs and treatment technologies to reduce selenium and nitrogen concentrations that were considered for potential application in the Newport Bay watershed.

Based on the literature review and subsequent assessment of selenium and nitrogen treatment technologies candidate BMPs and treatment technologies were selected for pilot testing and potential application in the watershed. BMPs and technologies were selected based on criteria related to efficiency, reliability, cost-effectiveness, feasibility for application within the watershed, and

acceptability to stakeholders. The purpose of the testing was to pilot test promising candidate treatment technologies at a location in the watershed to understand primarily their nitrogen and selenium removal capabilities in a field situation in the watershed as well as have an understanding of their operation components and constraints. The following six BMPs were pilot tested at a location of impaired nitrogen and selenium in the watershed: reverse osmosis, Anaerobic Bacterial Removal (ABMet®/GE), Katchall Systems Heavy Metals Removal (HMR) Media, Ferrous Hydroxide Iron Treatment (Kemira/ORCA), constructed wetlands (Portable Wetlands System), Adsorption Media (MES). The results of the pilot tests showed that the Anaerobic Bacterial Removal (ABMet®/GE) and reverse osmosis had the most removal of nitrogen and selenium and the constructed wetlands had some removal. The other technologies did not show significant removal. The results of the pilot tests are provided in the *Pilot Test Report for Nitrogen and Selenium Removal Technologies, March 2007*.

Ongoing research, pilot testing and evaluation of nitrate and selenium technologies lead to the identification of viable technologies for the treatment of selenium and nitrogen that were used as basis for the development of the BMP Strategic Plan. The identified technologies include the anaerobic Bacterial Removal (ABMet®/GE) technology that was evaluated during the pilot test process. Economic considerations and technical aspects resulted in the identification of technologies capable of capturing and treating shallow groundwater, as well as volume source control technologies. Two identified technologies potentially capable of removing selenium and nitrate from shallow groundwater in the Newport Bay watershed include permeable reactive barrier (PRB), and groundwater pump and treat systems. Sewer diversion was identified as a potential long-term volume reduction source control. Ongoing survey of existing technologies potentially capable of removing nitrate and selenium identified two additional technologies: the Cienega Filtration system, and sub-surface flow wetlands (SSF wetlands). The results of research, testing, and evaluation of nitrogen and selenium BMPs identified six technologies potentially capable of removing selenium and nitrate in the Newport Bay watershed: volume reduction source controls including sewer diversion, the Cienega Filtration system, the ABMet® system, sub-surface flow wetlands (SSF wetlands), permeable reactive barriers (PRBs) and groundwater pump and treat systems. The BMP Strategic Plan was developed using these six identified technologies.

Sources, loadings, transport, and speciation data for the watershed were used to develop a simple model that predicts selenium and nitrogen concentrations at key locations from upstream inputs in the watershed. The NSMP Simple Treatment Model roughly evaluated the contributions of various sources to overall water quality and reflected important seasonality changes in those contributions. The model has been a key tool in developing and evaluating different BMP implementation alternatives, and it has been updated with treatment efficiency, locations, and cost information associated with different components of these alternatives. The details of the model are identified in the *Simple Treatment-Related Model Final Report, June 2007*.

BMP implementation alternatives were developed over a year period using BMP technologies that were identified in the initial literature review and assessment, subsequent literature reviews, the results of the pilot tests, and input from the NSMP Working Group stakeholders. The BMP implementation alternatives encompassed centralized and de-centralized BMP implementation, diversion to sanitary sewer, and groundwater BMPs. The different alternatives were modeled with the NSMP Simple Treatment Model to identify locations of BMPs, watershed compliance levels, and overall costs of each alternative. The details of the BMP implementation alternatives can be found in the following documents: *NSMP BMP Implementation Plan Alternatives, October 2007*; *NSMP BMP Implementation Plan Alternatives, December 2007*; *NSMP BMP Implementation Plan Modified Alternatives, April 2008*. The BMP implementation alternatives served as the basis for the BMP Strategic Plan. This paper describes the elements of the BMP Strategic Plan as of October 2009, however the Plan is a living document as water quality regulations are currently in flux.

## **2 BMP STRATEGIC PLAN APPROACH**

The primary objective of the stakeholders, members of the NSMP Working Group, is to achieve compliance with the water quality regulations by year 2024. The implementation of the present Strategic Plan is expected to be 15 years in duration with two phases. Two dynamic approaches are taken into consideration in the BMP Strategic Plan to incorporate the economic, technological, environmental, and strategic modifications, which may occur over the 15-year timeframe: a phased approach and an adaptive management approach. The BMP Strategic Plan must be adaptive so it can evolve over time as more information becomes available; it also needs to be phased in order to allow

for capitalization, refinement, and adaptation at set points in the process.

## 2.1 Rationale for a Phased Approach

Economic, technological, environmental, and strategic concerns resulted in a two-phased approach for the BMP Strategic Plan. Phase I of the Strategic Plan, with a duration of seven years (approximately 2010 to 2016), acts as a technology validation phase while Phase II, with a duration of eight years (approximately 2017 to 2024), will focus on full-scale implementation.

The rationale for Phase I – Technology Validation are numerous. The proposed technologies are not yet proven and must be verified with long-term demonstration-scale testing to confirm the removal of nitrogen and selenium to below the water quality standards. Since the technologies are very costly, implementing them without prior validation may result in significant costs without the required benefit or compliance. Finally, a better long-term understanding of proven technologies effective in removing other pollutants of concern in the watershed is critical prior to full-scale implementation.

The BMP Strategic Plan represents a major, long-term capital and resource investment to restore and maintain beneficial uses in the watershed. Therefore, the technologies that will serve as its foundation need to be validated as part of Phase I and prior to Phase II. Information obtained from five areas will be evaluated and incorporated into Phase I of the BMP Strategic Plan on a regular basis as part of the iterative approach:

- **BMP Effectiveness Program:** The observation and analysis of the demonstration-scale BMPs tested during Phase I of the BMP Strategic Plan provide information that can be used to evaluate the effectiveness and operational performance of the BMP, and refine cost projections of both Phase I and Phase II of the BMP Strategic Plan. The effectiveness program will also bring to light any potential negative side effects associated with implementing certain types of BMPs.
- **Groundwater-Surface Water Model:** The principal source of selenium loading in the Newport Bay watershed is shallow groundwater discharge to surface channels. Once completed, the groundwater-surface water model will help identify potential locations of groundwater remediation systems, such as permeable reactive barriers (PRBs) and groundwater capture and treatment systems. The model would also be used to calculate potential reductions in nitrogen and selenium loads based on the locations and projected performance data for the proposed treatment BMPs.
- **New monitoring data,** such as the TMDL-specific bird egg and fish tissue measurements, surface water quality, and groundwater quality in the watershed independent of the tested BMPs.
- **New BMP technologies:** New technologies capable of treating nitrogen and selenium will continue to be surveyed during Phase I. If such technologies are feasible and provide cost-effective selenium and nitrogen removal benefits, additional information can be developed for the technology and may be considered for Phase II.
- **Changes in water quality regulations** such as the adoption of a Site Specific Objective for selenium in the watershed or other regulations affecting nitrogen and selenium discharges in the Newport Bay Watershed.

Based on the information developed in Phase I the locations and types of BMPs and treatment technologies will be modified for Phase II with a potential reduction in the number of BMPs and volume of water to be treated depending on the groundwater information developed in Phase I. Phase II will build upon the work and information developed in Phase I so the most cost effective technologies and measures can be implemented at the most appropriate locations in the watershed. Phase II could ultimately be more cost effectiveness if the volume of water to be treated could be reduced by capturing groundwater before it surfaces.

## 2.2 Adaptive Management Approach

Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. This principle is incorporated within

the two-phased approach as the ongoing information and lessons learned during Phase I are integrated in the development of projects during both Phase I and Phase II. Five categories of information enter this dynamic process of adaptive management. The adaptive management process can be portrayed as a six-step cycle, and emphasizes that successful adaptive management requires completing all six of the following steps: Assess Problem, Design (Planning and Permitting), Implement (Construction), Monitor, Evaluate (Lessons Learned), and Adjust (Optimization).

In other terms, the adaptive management approach includes the allowance for refinement of decision making processes for Phase II, the re-evaluation of data and model projections based on data specific to the Newport Bay watershed, the evaluation of Phase I successes and challenges. The adaptive management approach integrates also the incorporation of new and additional information from recent studies and emerging technologies, and the reassessment of multiple lines of evidence based on additional field data.

Integrating both the phased and the adaptive management strategies in the BMP Strategic Plan provides a flexible approach to integrate new information and meet the nitrogen and selenium compliance objectives in the Newport Bay watershed.

### **3 PHASE I – TECHNOLOGY VALIDATION**

Phase I – Technology Validation includes assessing the following categories of information: the cost effectiveness of the demonstration-scale BMPs, the outcomes of the groundwater-surface water model, new monitoring data, new BMP technologies, and regulatory changes. The outcomes of Phase I will provide sufficient information to formulate recommendations on the most cost-effective, full-scale BMP projects to remove selenium and nitrogen from the Newport Bay watershed.

#### **3.1 Groundwater-Surface Water Model**

Since rising groundwater is the major contributor of nitrogen and selenium to surface waters within the Newport Bay watershed, capturing contaminated groundwater at high concentration locations would help to reduce the overall volume of water to be treated by BMPs. Finding the optimal locations for groundwater BMPs such as Permeable Reactive Barriers (PRBs) or groundwater pump and treatment systems will be possible once the groundwater in the watershed is better understood through the development of a three-dimensional groundwater-surface model.

A surface water model, such as United States Geological Survey (USGS) Hydrologic Simulation Program–Fortran (HSPF), could be used to evaluate the water quality benefits of different BMP implementation alternatives. The surface water model can be interfaced with a groundwater model such as MODFLOW where the ground-water flow is simulated using a block-centered finite-difference approach. Flow associated with external stresses, such as wells, recharge, evapotranspiration and drains can also be simulated using MODFLOW.

Completing the groundwater-surface water model constitutes a major step towards completing Phase I of the BMP Strategic Plan.

#### **3.2 Phase I - Demonstration-Scale Projects**

Six technologies will be evaluated through demonstration-scale projects during the seven-year duration of Phase I of the BMP Strategic Plan. Each of the technologies considered in Phase I is evaluated for its performance in removing selenium and nitrogen, as well as its operational effectiveness including durability, frequency of maintenance, and operation per design specifications.

##### **3.2.1 Cost Effectiveness of Tested Technologies**

The cost effectiveness of each of the six identified technologies is the major decision making parameter in determining which technologies may carry over to full-scale implementation in the Newport Bay watershed. The cost effectiveness may be determined by evaluating the cost per unit mass of pollutant removed. An initial cost-per-mass of pollutant removed analysis is presented and serves as a basis of comparison between Phase I demonstration-scale projects by including the estimated total cost of each demonstration-scale project and the estimated amount of selenium and nitrate removed over the duration of each demonstration-scale project.

Total costs were evaluated as the summation of the identified capital costs, land acquisition costs, and four years of O&M costs. Capital costs include construction, engineering, management, and permitting costs associated with each element of the Phase I projects. Land acquisition costs are also estimated at \$2.0 million per acre (\$495 per square meter) in the Newport Bay watershed (NSMP Working Group, 2009). Costs were updated to January 2009 considering the Construction, Material, and Skilled Labor indexes published by Engineering News Record (ENR, 2009). The expected total costs are summarized for each demonstration-scale BMP in Table 1.

The BMP Strategic Plan estimated the load removals of Phase I technologies over their four years of operation based on existing dry weather flow concentrations information collected in the watershed and available effectiveness data (NSMP Working Group, 2009). The present cost-per-mass of pollutant removed analysis may be revised at the completion of Phase I based on the effectiveness monitoring. The objectives of the effectiveness monitoring are presented in the next section.

For each demonstration-scale project  $i$ , the unit cost per mass of pollutant  $j$  removed can be computed by the following relation:

$$\eta_{i,j} = \frac{\Delta C_i}{\Delta m_{i,j}} \quad (\text{Equation 1})$$

Where:

$\eta_{i,j}$  = Unit cost per mass of pollutant  $j$  removed over the duration of the BMP demonstration-scale project  $i$

$\Delta C_i$  = Total cost of the BMP demonstration-scale project  $i$

$\Delta m_{i,j}$  = Estimated mass of pollutant  $j$  removed over the duration of the BMP demonstration-scale project  $i$

The results of the initial cost-per-mass of pollutant removed analysis are presented in Table 1. The sewer diversion and the ABMet® demonstration-scale projects are the most cost-effective Phase I – Technology Validation projects for selenium and nitrate, respectively. Permeable reactive barriers were not included in this analysis; the benefits of reducing selenium and nitrogen concentrations in groundwater cannot be correlated to reductions of selenium and nitrogen concentrations in surface waters of the Newport Bay watershed until completion of the groundwater-surface water model.

Best Management Practice	Technology Pilot Testing Site	Total Cost	Nitrate Cost-per-Mass (\$/kg)	Selenium Cost-per-Mass (\$/kg)
Cienega Filtration	Peters Canyon Wash at Valencia	\$ 3,655,600	618	288,808
ABMet®	Peters Canyon Warner at Warner	\$ 2,727,800	203	132,172
SSF Wetlands	Como Channel	\$ 2,546,700	605	295,623
PRBs	To be determined	\$ 1,483,900	n/a	
Groundwater Pump & Convey	To be determined	\$ 1,417,500	n/a	
Sewer Diversion	Santa Ana Delhi Channel Creek 3	\$ 665,900	298	90,738

Table 1 – Initial cost-per-mass of pollutant removed analysis – Results

### **3.2.2 Effectiveness Monitoring Protocol**

The effectiveness monitoring protocol will be implemented for the duration of Phase I. The protocol aims to evaluate both the effectiveness of BMPs in their ability to remove nitrogen and selenium, as well as the operational performance of the BMPs. The effectiveness of the different BMPs that may be implemented to reduce selenium and nitrogen concentrations in surface waters or groundwater should be understood to determine whether the BMP is performing as designed and to ensure that the BMP is not causing or contributing to water quality impairment due to changes in conditions. The BMP effectiveness monitoring protocol has the following objectives:

- Assess the effectiveness of the BMP for removal of nitrogen and selenium (water quality monitoring).
- Assess the operational performance of the BMP with regards to its engineering design (performance monitoring).
- Assess the performance of the BMP regarding potential impacts to water quality and beneficial uses (water quality monitoring).

A BMP effectiveness monitoring protocol was developed for each of the six Phase I demonstration-scale projects. This project specific protocol describes the types of monitoring to be implemented, such as the type of data collection, timing, frequency of monitoring, location of monitoring, and analytical methods.

Although the duration of Phase I is seven years, each demonstration-scale BMP is assumed to be tested for four years, which allows three years for design, permitting and construction of the demonstration-scale projects. The BMP effectiveness monitoring will be conducted over four years for each demonstration-scale BMP. The functionality of the BMP will be evaluated from the data obtained over the initial two years of testing, and the operation of the BMP will be monitored and optimized for a period of four years. After the initial two years of testing, the demonstration-scale project may be discontinued if the functionality of the BMP has not been proven. A demonstration-scale BMP is defined as functional if it provides a substantial reduction of selenium and/or nitrogen at the project location.

Specific parameters will be analyzed to ensure that each of the six demonstration-scale projects identified is operating efficiently and as designed. Engineering parameters like inflow and outflow volumes, electrical, plumbing, water quality monitoring data collection and mechanical performance will be analyzed. The engineering parameters will be monitored on a consistent basis with monthly reports being developed for each of the six BMP demonstration-scale projects.

A standard sampling and monitoring protocol applies to each of the demonstration-scale projects. The monitoring samples will be analyzed using standardized USEPA (United States Environmental Protection Agency) analytical methods for common constituents but also selenium speciation for selenium characterization. Monthly dry-weather water quality monitoring will be conducted for each of the six BMP demonstration-scale projects. The monitoring will include influent and effluent water quality samples and upstream and downstream ambient water quality samples.

### **3.2.3 Operation and Maintenance Activities**

The evaluation of the operation and maintenance activities is crucial in determining the cost-effectiveness of the demonstration-scale projects. Each of the BMPs tested during Phase I requires regular operation and maintenance. Several factors specific to operation and maintenance activities may impact the technology selection process: the frequency, the complexity or feasibility, and the associated costs of operation and maintenance activities for each demonstration-scale project will be evaluated during Phase I – Technology Validation. A preliminary assessment identified these factors for the demonstration-scale projects (NSMP Working Group, 2009). For each demonstration-scale project, the estimated operation and maintenance activities, their respective frequencies and annual costs are summarized in Table 2. The annual operation and maintenance costs were estimated using a 0.3 cubic feet per second design factor (8.5 litres per second). The duration of Phase I of the NSMP BMP Strategic Plan is seven years and testing of the technologies is identified for over four years. Maintaining the different technologies on a regular basis contributes to the performance of the different technologies but also increases the lifetime of the implemented BMPs, thus increases the cost-effectiveness of the projects.

Best Management Practice	Activities	Frequency	Annual Cost (\$/year)
Cienega Filtration	Control of metering pumps, refrigerator, and control and donor feeds	Weekly	\$ 163,900
	Crushed Rock Media Disposal	After completion of Phase I	
ABMet®	Control of feeds, pumps, inline mixers, sludge disposal, and carbon media replacement	Weekly	\$ 41,700
	Solids Flushing	Every 1 or 2 years	
SSF Wetlands	Control of the water-level and flow uniformity	After storm event	\$ 20,200*
	Maintenance of inlet and outlet structures, management of vegetation, odor, nuisance pests and insects control, and maintenance of berms.	Every 3 months	
PRBs	Compliance and performance monitoring	Routine	\$ 23,500**
Groundwater Pump & Convey	Operator check-ups of the conveyance pumps and pipeline network, and powering pumps	Daily	\$ 56,900
Sewer Diversion	Operator check-ups of the conveyance pumps and pipeline network, and powering pumps	Weekly	\$ 56,400

\* Flow discharge of 0.19 cfs (5.4 L/s)

\*\* Permeable Reactive Barrier of cross-section of 1000 ft<sup>2</sup> (92.9 m<sup>2</sup>)

Table 2: Summary of Phase I Operation and Maintenance Activities

### 3.3 Adaptive Management: Revisions to Phase II – Full Scale Implementation Projects

In the seventh year of Phase I information developed during Phase I will be compiled and a recommendation for changes to the Phase II projects will be developed. The information collected during the evolution of Phase I may also be critical to the continuation of Phase I projects. Four general types of information are identified:

- The outcomes of the groundwater – surface water model. The groundwater information will impact the locations of the Phase II projects. Results of the groundwater model also impact the evolution of Phase I with implementing the PRBs and groundwater pump and treatment system demonstration-scale BMPs at the appropriate locations.
- The effectiveness of the demonstration-scale BMPs tested during Phase I. The effective monitoring data for each tested technology will provide both an estimated pollutant load removal from the watershed and an estimated removal efficiency of each technology. Such information on technologies will help in determining what BMPs should be implemented during Phase II of the BMP Strategic Plan.
- Actual total cost, O&M costs, and cost effectiveness data will be assessed to compare the cost per load removed data for each of the BMP technologies. This will help the stakeholders determine if one technology is more cost-effective than another with the same load removal.



- Any additional data or information regarding the watershed, regulations, and new technologies that would be relevant to the dynamic process occurring during Phase I. The additional information includes new technologies for treating nitrogen and selenium, watershed information, such as water quality and groundwater data, changes in storm sewer permits or water quality regulations, and changes in other stakeholder agreements.

Integrating all this information as part of Phase I of the BMP Strategic Plan will be beneficial to identifying the most cost effective locations and BMPs for Phase II of the BMP Strategic Plan. A conceptual matrix of reports was developed to incorporate all the information identified in Phase I. This information may be synthesized into four particular types of reports:

- Three groundwater-surface water model reports are intended to provide both an understanding of groundwater in the Newport Bay watershed and the identified potential groundwater BMP locations in the watershed. Once the model is completed, one report will identify the locations for the PRBs and groundwater collection and treatment demonstration-scale systems. One report would discuss the surface water component and explain how it incorporates the NSMP Simple Treatment Model information. The last report completed near the end of Phase I would identify optimal groundwater locations of Phase II projects.
- For each technology tested during Phase I, two reports will be developed. The preliminary report would include a review of optimization studies, the design of the demonstration-scale BMP, and an effectiveness monitoring plan and be submitted prior to construction of the BMP. After completing the demonstration-scale BMP test, a technical report will summarize the characteristics relevant to a possible future implementation at full-scale and provide a thorough review of the water quality data. The technical report will also identify the potential for the tested BMP to be implemented in the impaired watershed.
- A summary of activities will be completed on an annual basis. The annual report will include changes in water quality regulations and changes to stakeholder agreements. The summary of activities will also provide an update on the different technologies undergoing testing as well as a short review of potential new technologies. In the case of a promising new technology for removal of nitrogen and selenium, investigation and potential demonstration-scale testing of the new technology may be considered by stakeholders. If approved, a report would investigate the specifics and applicability of the promising technology before a possible demonstration test.
- Two reports will be developed to identify new watershed data, one at the mid-term of Phase I and one near the end of Phase I. New watershed data includes but is not limited to ambient water quality and groundwater data in the watershed. A thorough analysis of new data will be performed and recommendations provided.

A Phase I General Report will be completed at the conclusion of Phase I of the BMP Strategic Plan. This report would include evaluation of the any new technologies with the potential to treat nitrogen and selenium, analysis of the tested technologies, the outcomes of the groundwater-surface water model, and recommendations for the Phase II projects of the BMP Strategic Plan. All the other reports previously mentioned will be completed at least six months before completing Phase I to provide a sufficient timeframe to analyze and complete this Phase I General report.

#### **4 PHASE II – FULL SCALE IMPLEMENTATION PROJECTS**

Phase II – Full-Scale Implementation will be developed based on the selection of the most cost-effective BMP implementation option to achieve compliance with water quality objective in the watershed. As of October 2009, four conceptual alternatives have been developed and are being considered by the stakeholders in coordination with the Orange County Sanitation District (OCSD) and the Irvine Ranch Water District (IRWD). The four alternatives being considered for Phase II of the BMP Strategic Plan include:

- Alternative 1 – BMPs Only: Surface water treatment BMPs would be implemented at major nodes and high concentration areas in the Newport Bay watershed.
- Alternative 2 – Sewer Diversion and BMPs: Surface water diversions to the sanitary sewer during off-peak hours would provide the primary treatment in the watershed. Where sewer diversion is not feasible surface water treatment BMPs would be implemented.
- Alternative 3 – Groundwater Replenishment System (GWRS) Diversion: The GWRS is a

treatment system installed in Orange County. The GWRS is designed to treat 100 MGD (0.38 Mm<sup>3</sup>/day) of secondary treated wastewater to replenish potable groundwater supplies through the following treatment processes: microfiltration, reverse osmosis, and purification UV light with hydrogen peroxide. Surface water diversion directly to a dedicated line to the GWRS would provide the treatment necessary in the watershed. If necessary to protect beneficial uses, replacement water would be supplied to the area of extraction.

- Alternative 4 – Cienega Filtration System Only: The demonstration-scale project would be scaled up to a ten cell full-scale system.

The Phase II alternatives will inevitably be revised at the conclusion of Phase I with more detailed information regarding effectiveness of BMPs, groundwater information, and other more detailed information about the watershed developed during the Phase I timeframe. The list of BMP projects, locations and associated costs will be determined by the NSMP Simple Treatment Model at the completion of Phase I – Technology Validation. The NSMP Simple Treatment Model identifies the most cost-effective method of compliance to be installed at the most appropriate identified locations in the Newport Bay watershed.

## 5 CONCLUSION

The NSMP BMP Strategic Plan provides a plan for restoring the Newport Bay watershed related to nitrogen and selenium impairments. The Plan is the result of five years of research, testing, and evaluation of nitrogen and selenium treatment technologies and of working with a diverse stakeholder group to develop BMP implementation alternatives that are acceptable, technically feasible, cost effective, and will result in compliance with nitrogen and selenium water quality objectives. Due to the infancy of effective selenium treatment technologies and the lack of groundwater data and information in the watershed the Plan provides an approach which allows for adaptive management. The results of the demonstration-scale testing of selenium and nitrogen BMPs in the watershed and the information developed through the groundwater-surface water model will allow the BMP Strategic Plan to be adaptively modified so that the most cost effective BMP alternative can be implemented in Phase II. Adaptive management also allows for modification of the BMP Strategic Plan as other technologies are discovered and more information and data is gathered in the watershed.

The NSMP BMP Strategic Plan provides a model for watersheds with similar pollutant issues as well as for impaired watersheds where treatment technologies for the pollutant of concern have not been firmly established. The Plan provides an opportunity to identify if a phased approach based on adaptive management principles is a valid approach to watershed restoration. Ultimately the NSMP BMP Strategic Plan provides a mechanism for watershed stakeholders to achieve compliance with the nitrogen and selenium water quality objectives based on a regional approach for restoration of the Newport Bay watershed.

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