MEMORANDUM

NEWFIELDS

TO: Amanda Roa (Delta Diablo Sanitation District)

FROM: John Dickey, PhD, CPSS/Ag, RPSS[1] (with NewFields Agricultural & Environmental Resources)

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DATE: March 9, 2010

SUBJECT: Draft Monitoring and Reporting Plan for Lone Tree Golf Course

In consultation with the State Water Resources Control Board (SWRCB), Delta Diablo Sanitation District (District) has agreed to supplement the monitoring and reporting section of the *Operations & Maintenance Plan* (O&M Plan) for expansion of recycled water service to users in Antioch by the District. The purpose of this memo is to provide a draft of a new Monitoring and Reporting Plan (MRP). The MRP will be submitted to the SWRCB to address concerns about the potential for excessive nitrogen loading to recycled water irrigation sites.

1 MEMO ORGANIZATION

This MRP contains the following sections and content:

- MRP background, including the regulatory process context and objectives.
- Sampling, analysis, and interpretation, including sampling and analysis methodology (media, timing, frequency, sampling procedure, and analyses)
- Reporting monitoring results, including timing and content

2 MRP BACKGROUND AND OBJECTIVES

The applicable General Waste Discharge Requirements for Landscape Irrigation Uses of Municipal Recycled Water (SWRCB, 2009) includes the following to avoid environmental effects on water quality as partial mitigation for implementation:

- Application of recycled water at reasonable agronomic rates considering soil, climate, and nutrient demand.
- Implementation of a Monitoring and Reporting Program, which includes inspections and regular maintenance of areas irrigated with recycled water.
- Measurement of the volume of recycled water, total number of use areas/basin, total area of application, nitrogen application rate, and salinity application rate.

[1] CPSS/Ag stands for Certified Professional Soil Scientist and Agronomist (ARCPACS; #03223), and RPSS stands for Registered Professional Soil Scientist (National Society of Consulting Soil Scientists; #058)

Preliminary nitrogen (N) balances were developed for the project and reviewed with SWRCB. The N that can be supplied by reclaimed water will likely be at or below the needs of the turf. However, there is recognized uncertainty regarding actual, site-specific rates of N loss and uptake, and these assumptions influence planning-level calculations. Since the N balance and real potential for leaching of nitrate are most evident in the soil after a project is operating, it was agreed to sample site soil and to use results to refine project operation and management, as necessary. The MRP would be modified as conditions and our understanding of the site evolve. Therefore, soil monitoring would not necessarily be required in the long term.

The purpose of this MRP is to supplement the O&M Plan for expansion of the recycled water delivery system into Antioch by the District, and to supplement the specific monitoring requirements contained in SWRCB (2009). The site, water quality, water and N management, and N balance have been described previously (DDSD, 2009; Dickey, 2010). This MRP supplements those documents.

The results of monitoring will be used to determine the correct amount of N to apply to satisfy needs for plant uptake, while minimizing leaching of N below the root zone. The monitoring focus is on the Lone Tree Golf Course (Site), which comprises most of the project acreage, receives most of the water, and contains the broadest range of soil, landscape, plant community, and management conditions. Results of this Site-specific monitoring will serve to guide N fertility management throughout the whole irrigated area covered under this permit.

Monitoring results will be most useful to operators if they are provided at the beginning of the peak irrigation season (before June), and if the results of the previous year (through March) are fully considered. Therefore, the MRP will generally capture data from April of the previous year through March of the current year.

Planned sampling, analysis, and the approach to interpreting and reporting results are described in the following sections.

3 SAMPLING, ANALYSIS, AND INTERPRETATION

In general, sampling and analysis will proceed as follows:

1. Management activities at the Site during the preceding year will be documented.
2. Site operations and conditions will be characterized and evaluated by monitoring water and soil to determine the amount of N being applied, the extent to which applied N is being treated in the root zone, and whether conditions leading to leaching of N are being successfully avoided. Soil, landscape, climatic, and management parameters all influence the fate of applied and mineralizing N, and will thus be considered together.
3. Based on monitoring results, future N management and monitoring, including appropriate N management for the coming year, will be recommended.

It is anticipated that, as a result of implementing this MRP, the knowledge base regarding N management on the Site will evolve and improve. Sampling and analysis described throughout are based on experience to date, before commencement of irrigation with recycled water. Monitoring results may demonstrate that some sampling or analyses become unnecessary due to consistent results (e.g., consistent absence of organic N in recycled water), or new and important questions may develop. These circumstances will be documented, and sampling and analysis plans for the following year may be altered accordingly. If and when these changes occur, they will be described and justified as part of the annual monitoring report, providing appropriate opportunity for any needed review by and discussion with SWRCB staff.

3.1 DATA COLLECTION

Table A lists the climatic, irrigation, and N application parameters that will be measured as part of this MRP. The following sections describe the need for and means of developing each parameter.

CLIMATIC CONDITIONS

Annual rainfall and temperature influence plant growth and irrigation demands. Monthly total rainfall (depth), total evapotranspiration (ETo, depth), and average daily temperature will be tabulated (see Table A).

Rainfall and other parameters are measured at the Site and at nearby California Irrigation Management Information System (CIMIS) stations. These help to guide Site managers when planning irrigation throughout the year. Data collection and quality control at CIMIS are more rigorous, and will generally be used. Where climatic data collected at the Site are judged to be relevant and of adequate quality, they may also be tabulated.

Table A. Climatic, Irrigation, and N Application to Site[a]										
Month	Average	Total								
	Temperature	Precipitation	ETo	Applied Recycled Water	Other Applied Water	Organic -N Applied in RW[b]	Ammonia -N Applied in RW	Nitrate -N Applied in RW	N Applied as Fertilizer	Total Applied N
	(deg F)	*(inches)*				*(lb/a)*				
April										
May										
June										
July										
August										
September										
October										
November										
December										
January										
February										
March										
Annual Total										

[a]Site size = _____ acres
[b]RW = recycled water

IRRIGATION AND NITROGEN APPLICATION

Nitrogen can be applied to the Site in recycled water or as fertilizer. The total annual N application will be calculated as the sum of N contained in applied recycled water and fertilizer (see Table A).

NITROGEN IN RECYCLED WATER

The total monthly (depth) applied recycled water and other water will be tabulated (see Table A). Applied water will be estimated based on irrigation run time records and/or flow meter readings.

Recycled water N concentration will be determined by periodic (monthly) grab sampling. Samples will be analyzed for total Kjeldahl N (TKN), ammonia, nitrate, and total dissolved solids (TDS). The three N analytes allow distinction and quantification of the forms of N in the recycled water (organic N, ammonia-N, and nitrate-N). TDS is related to salinity, an important component of irrigation water from a management perspective that can also be helpful when interpreting N results in the system.

Samples will be placed in water sampling containers and analyzed by an outside laboratory. Samples to be analyzed for nitrate will be put on ice immediately and holding times for all constituents will be observed.

Concentrations of each form of N will be tabulated (see Table B). Monthly irrigation depths will be multiplied by N concentrations from the corresponding quarter, and the amount of each form of N applied each month will be tabulated (see Table A).

Table B. Recycled Water Quality

Quarter	TKN	Ammonia-N	Nitrate-N	Organic-N	Total Dissolved Solids
	(mg/L)				*(mg/L)*
April					
May					
June					
July					
August					
September					
October					
November					
December					
January					
February					
March					

FERTILIZER N APPLICATION

Nitrogen applied to the Site in the form of fertilizer will be logged and tabulated (see Table A).

3.2 SOIL SAMPLING AND ANALYSIS

The Site will be stratified (subdivided for sampling) according to several parameters affecting the N balance:

- Soil/landscape mapping unit
- Management unit (e.g. greens, fairways, etc.)
- Other factors judged to be significant (e.g., aspect [compass direction in which slope faces])

Several locations will be selected within each sampling stratum (area) at the Site. Within each location, subsamples will be collected at several depth increments from at least four locations and composited (by depth) for analysis. This method is standard practice (Self and Soltanpour, 1997) when sampling soil for nutrient content, producing results that better represent nutrient profiles in areas within the Site. Depths to be sampled are shown in Figure A: A) 0-6 inches B) 6-12 inches C) 12-24 inches and D) 24-(up to) 36 inches (as soil resistance to sampling equipment permits). These ranges were selected to characterize the upper 6 inches that is most intensively rooted by turf, as well as several deeper layers. The deepest samples are below the zone in which much N uptake by turf is expected to occur.

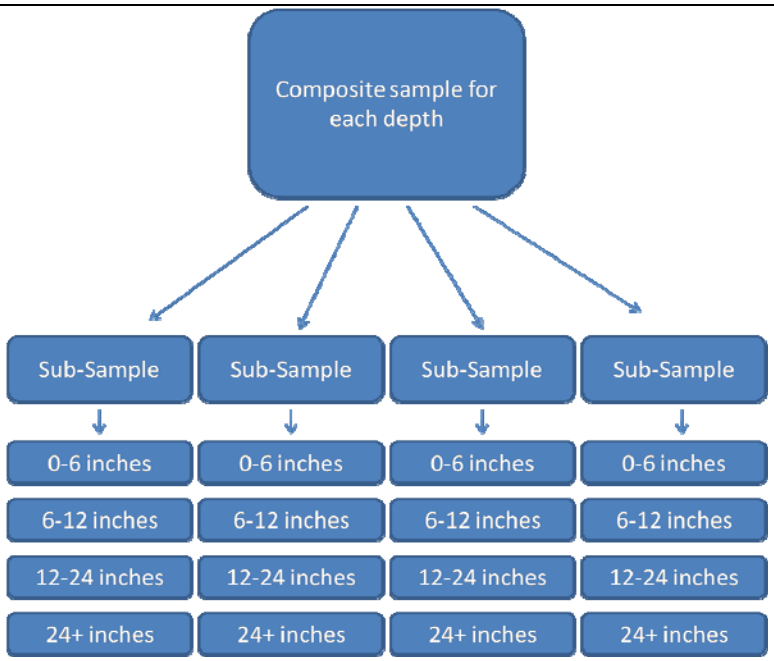

Figure A. Sampling schematic for a sampling area, showing subdivision of sample cores into depth increments. Subsample depth increments are to be composited (mixed and subsampled for analysis) across subsamples, within each sampling area. This is standard practice for evaluating fertility status of soils.

The soil samples will be collected with a handheld, manual-push type sampling probe (approximately 1 inch in diameter). Each soil core collected will be subdivided into depth increments, with each increment placed into the appropriate compositing bucket. Once all of the subsamples in an area are collected, soil in each depth increment composite bucket will be mixed thoroughly and placed into a labeled soil sample bag. Since sample analysis includes nitrate-N, soil samples need to be placed in a cooler immediately after sampling to slow biological activity and N transformations. All sample equipment (soil probe, sample buckets, etc.) will be cleaned thoroughly with fresh, potable water between sample areas to prevent cross contamination of samples.

Once sample collection is complete, samples will be shipped to a soil analytical laboratory where analyses for constituents listed in Table C will be performed. The two primary constituents of interest are the N species. Electrical conductivity (EC) is a measurement of soil salinity: the higher the conductance, the greater the concentration of dissolved ions (salts). Salinity (like nitrate) moves through the soil with water, but unlike nitrate, most of salt's mass is much less dynamic (i.e., less readily transformed to and from gas, and to and from plant and microbial biomass) than nitrogen species. Therefore the spatial distribution of salt provides a better indication of how water is moving solutes through the soil.

Table C. Soil Monitoring Results					
Sample No.	**Location**	**Depth Increment**	**Ammonium-N**	**Nitrate-N**	**Electrical Conductivity**
		(inches)	*(mg/kg)*		*(dS/m)*
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

ASSESSMENT OF BENEFICIAL USE OF NITROGEN

Applied N availability to plants depends on loss rates that vary widely. Therefore, the status (from deficient to excessive) and distribution of inorganic N in the soil will serve as the empirical criteria by which N loading during the preceding year will be evaluated.

Absent evidence to the contrary, organic N mineralization and immobilization rates will be assumed to be in equilibrium (i.e., generally balanced on an annual basis). This assumption will be re-examined if and when evidence of substantial net mineralization or immobilization emerges.

Results of the soil sampling will be evaluated for the following:

- Vertical distribution of N species and EC
- Comparison of inorganic, and specifically nitrate-N, in upper 6 and 12 inches

Conditions in each sampling area will be considered, and conclusions will be drawn relative to the following for each area:

- Minimization of nitrate leaching
- Residual N available for the coming year

- Influence of management

A general summary of beneficial N use on the Site during the past year will be developed.

From year to year, climatic and Site characteristics affecting N balances will vary and evolve. The area irrigated may change, and our understanding of the Site's capacity to beneficially use N will be increasingly informed by study of Site-specific monitoring results. Also, aspects of the N balance may prove to differ among areas of the Site. In these cases, area-specific management guidelines will be developed and implemented.

3.3 PLANNING NEXT YEAR'S NITROGEN LOADING

A plan for the next year's Site operation will be developed based on the assessment of beneficial N use during the past year. The following will be included in this plan:

- Projected N application, based on evidence of Site capacity to beneficially use N
- Projected N loading in recycled water
- Recommended management refinements
- Recommended monitoring refinements

4 REPORTING MONITORING RESULTS

Monitoring results from April of the previous year through March of the current year will be reported to the SWRCB by submitting a record of monitoring procedures, the results tables shown in the previous sections, and accompanying explanation and discussion.

To allow a month during which to draft, finalize, and submit the report, the report will be submitted to the SWRCB and reviewed with the Site supervisor by early May of each year.

5 REFERENCES

DDSD. 2009. *Recycled Water Program Manual and Notice of Intent for Compliance with San Francisco Bay Regional Water Quality Control Board General Water Reuse Order Board Order 96-011 and State Water Resources Control Board Order 2009-0006 DWQ General Waste Discharge Requirements for Landscape Irrigation Uses of Recycled Water.*

Dickey, J.B. 2010. *Nitrogen Loading Analysis for Antioch Recycled Water Project*. February 10 memo to Amanda Roa/Delta Diablo Sanitation District, and submitted to the SWRCB.

Self, J.R., and P.N. Soltanpour. 1997. *Soil Sampling*. Crop Series No. 0.500, Colorado State University, Boulder Colorado. http://www.extsoilcrop.colostate.edu/SoilLab/documents/0500Soilsamplingqualityfertilizerrecommendation.PDF.

State Water Resources Control Board. 2009. *Water Quality Order No. 2009-0006-DWQ: General Waste Discharge Requirements for Landscape Irrigation Uses of Municipal Recycled Water (General Permit)*.