To: Lynn Small, Deputy Director
Environmental Compliance

Date: November 27, 2012

From: James A. Klang, PE, K&A
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cc: Dave Smith, Merritt Smith

RE: Nunes - Ocean View Dairy Summary of Best Management Practice Reduction Estimation Methods for City of Santa Rosa Nutrient Offset Program Credits

This memorandum provides details regarding the calculation methods used for estimating nitrogen and phosphorus credits from the Nunes - Ocean View Dairy site for the City of Santa Rosa Nutrient Offset Program. Credits were calculated for both current conditions as well as a future condition that includes the proposed Best Management Practices (BMPs). Tables and figures (located at the end of this memorandum) are provided for additional illustration and support of the crediting approaches.

Crediting methods were derived from approaches used by the Pennsylvania Department of Environmental Protection (PA DEP) Chesapeake Bay Water Quality Trading Program[1]. The following narrative presents the rationale for selecting this credit estimation method, a description of the calculations, and example credit computations for BMPs at the Nunes - Ocean View Dairy site. Computed credit values are consistent with the City of Santa Rosa Crediting Proposal for the Nunes - Ocean View Dairy BMPs dated October 23, 2012 (and submitted to the North Coast Regional Water Quality Control Board—Regional Board on October 30, 2012).

The City of Santa Rosa Nutrient Offset Program defines the term "offset" as an equal or greater load reduction that is adjusted to account for differences in nutrient bioavailability and introduced uncertainties. The term offset can be used interchangeably with the term "credit" (mass of nutrients reduced per year after accounting for bioavailability and uncertainty). Credits are generated by implementing a BMP that results in reducing the nutrient load to a water body.

Calculation Method Selection

The PA DEP nutrient credit calculation method was selected after comparing multiple empirical methods. In addition to the Pennsylvania method, the EPA Region V model and the USDA-NRCS Nutrient Tracking Tool (NTT) were examined. The EPA and USDA methods were removed from further consideration due to their limited applicability to the characteristics of the Laguna de Santa Rosa setting.

[1] PA DEP. 2007, 2008. Nitrogen and Phosphorus calculation spreadsheets. Accessed May 15, 2012; available at http://www.dep.state.pa.us/river/nutrienttrading/calculations/index.htm

The Region V model is limited in its ability to credit soluble nutrient parameters and lacks manure nutrient management considerations. NTT is expensive to calibrate for regional conditions, and without such calibration the local dairy BMP simulations cannot be adequately performed.

The strengths of the PA DEP method include ease of use, the ability to estimate load reductions for the soluble nutrient fraction, and the application of best available science during development. The Pennsylvania nutrient calculations were developed by representatives of PA DEP, the Pennsylvania Environmental Council, and the World Resources Institute. The equations were based on literature[2], agronomy guides[3], and the professional judgment of researchers at Pennsylvania State University (Dr. Doug Beegle, Dr. Peter Kleinman, and Dr. Barry Evans). These equations follow standard methods to estimate non-point source runoff. The calculations are performed on Microsoft Excel spreadsheets and a description of the calculation process is provided as follows.

Calculation Descriptions

The Nunes - Ocean View Dairy will be generating nutrient credits from three different BMP systems. The three systems described in the formal proposal are:

- Emptying manure lagoons and appropriately managing for future stormwater collection
- Implementing BMPs in heavy use areas to address accumulated manure
- Distributing 12,700 tons of manure solids for on-site land application

Credit calculation descriptions are provided for each of the three BMP systems. Each calculation process was based on the unique characteristics of the nutrient source.

BMP #1 – Manure Lagoon Cleanout and Management of Future Storage

BMP #1 addresses two full manure lagoons that have an imminent potential to contribute nutrients to Windsor Creek during precipitation events. As an interim measure, a berm will be established to prevent nutrient loading to Windsor Creek while cleanout is initiated. The crediting project will result in emptying the full lagoons and land applying the manure slurry at agronomic rates. The method used for emptying the lagoons will be either hauling the manure to forage fields on-site or land application on-site utilizing the reclaimed water irrigation system already available on the farm.

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[2] Evans, B.M., 2002. Development of an Automated GIS-Based Modeling Approach to Support Regional Watershed Assessments. Ph.D. dissertation in the Dept. of Crop and Soil Sciences, Penn State University, 231 pp.
Vadas et, al. Relating Soil Phosphorus to Dissolved Phosphorus in Runoff: A Single Extraction Coefficient for Water Quality Modeling. Published in J. Environ. Qual. 34:572–580 (2005).

[3] Pennsylvania State Agronomy Guide, available at http://extension.psu.edu/agronomy-guide (as of July 5, 2012); Penn State Agricultural Analytical Services Laboratory (AASL) Handbook, http://www.aasl.psu.edu/ (as of July 5, 2012); USDA Plant-Crop Nutrient Tool, available at http://plants.usda.gov/npk/main (as of July 5, 2012)

A typical lagoon cleanout process first empties the liquids in the lagoons by agitating the waste and pumping the liquid portion. The remaining solids then are stacked next to the lagoon to dewater. After dewatering, these solids will be similarly managed with the manure separated solids pile under BMP #3 of this crediting proposal. The production area contributing to the lagoons will be scraped and subsequently planted with cover crops in open areas. After manure removal, the lagoons will be temporarily closed allowing only Ag stormwater to enter.

To estimate the volume of runoff entering the lagoons, a local agricultural engineering firm was hired by the City of Santa Rosa to assess the Nunes Ocean View Dairy production area. Erickson Engineering, Inc. visited the site and developed runoff volume estimates based on the Soil Conservation Service Technical Release 55 (TR-55) method. The TR-55 runoff equation uses a coefficient called the Curve Number (CN), which is used to predict runoff from excess rainfall. The equation, as described in the TR- 55[4], is as follows:

$$Q = (P - 0.2S)^2 / (P + 0.8S)$$

S is the potential maximum retention after runoff begins, which is related to the soil and cover conditions of the watershed. The CN has a range of 0 to 100 and is selected based on rainfall and direct runoff. S is related to CN by:

$$S = 1000 / CN - 10$$

The runoff volume values applied by Erickson Engineering, Inc. were based on the 1983 isohyetal map provided by the Sonoma County Water Agency. The average annual rainfall applied was 36 inches a year. The results calculated by Erickson Engineering, Inc. are presented in Table 1. These estimates do not include dairy process water volumes because the milk parlor and barn flushing system will not be in use during the clean-up period as there will be no dairy herd onsite. Runoff estimates were divided into categories based on the surface characteristics of the contributing area. These categories include manured concrete, silage pad, manure storage (liquid), manured areas without concrete surfaces and crop/pasture areas.

[4]NRCS. 2009. Urban Hydrology for Small Watersheds, available at http://www.hydrocad.net/pdf/TR-55%20Manual.pdf pp. 2-1

Table 1. Runoff volume calculation based on SCS Technical Release - 55 runoff coefficients methods.

Surface Areas	Acres	Runoff coefficient Curve Number (CN)	Average Conditions (Acre-feet)	Wet Conditions (Acre-feet)
Manured Concrete	0.23	1.00	0.68	1.01
Silage Pad	0.52	1.00	1.57	2.33
Manure Storage, Liquid	2.09	1.00	6.26	9.33
Manured non-concrete	3.11	0.5	4.67	6.96
Crop/pasture	2.03	0.4	2.44	3.64
Totals	7.46	--	15.62	23.27

The results from the Erickson Engineering, Inc. assessment were used to estimate the credits generated by the proposed BMPs for the site. The crediting calculation used the volume estimate of 15.62 acre-feet of runoff expected under average conditions. This volume represents the flow into the two lagoons every year. The phosphorus and nitrogen load reduction was then calculated using this runoff volume combined with the manure lagoon nutrient concentrations. The 15.62 acre-feet value was first converted to 1,000-gallons in order for the units to correspond with those used in the nutrient concentration estimates provided by the Midwest Plan Service (Midwest Plan Service, 2004). This conversion is shown in EQ 1. The Midwest Plan Service provides estimates of dairy manure lagoon nutrient mass in lbs per 1,000 gallons (gals) of manure. The lagoon nutrient content is estimated to be 31 lbs of total nitrogen (TN) per 1,000 gallons and 15 lbs of phosphate (P_2O_5) per 1,000 gallons. Actual manure lagoon nutrient concentration samples have been collected and results are pending. Once available, calculations reported herein will be re-visited using site-specific information to adjust credit estimates.

15.62 (acre-ft) * 43,560 (sq ft/acre) * 7.48 (gals per foot^3) / 1,000 (gals) = 5,089 (1,000 gals) **[EQ 1]**

TN load reduction was calculated by combining the result from EQ 1 with the nutrient content estimates provided by the Midwest Plan Service, as shown in EQ 2.

5,089 (1,000 gals) * 31 (lbs TN/ 1,000 gals) = 157,773 (lbs) TN **[EQ 2]**

TP load reduction was calculated by first converting the P_2O_5 pounds into pounds of phosphorus, as shown in EQ 3. Next, the result from EQ 3 was converted to 1,000 gallon units, as shown in EQ 4.

15 (lbs) * 0.43 (molecular weight of P fraction in P_2O_5) = 6.5 (lbs / 1,000 gals) **[EQ 3]**

5,089 (1,000 gals) * 6.5 (lbs TP/ 1,000 gals) = 32,827 (lbs) TP **[EQ 4]**

A conservative assumption was added to address additional handling and storage losses after year one. Future stormwater directed to the ponds that are currently coming into contact with previously

accumulated manure will also be addressed. Because the BMP system applied to the temporary closure of the lagoons includes removing the manure in the manured areas exposed to rainfall and providing a conservation cover. Without this aspect of BMP #1, the 5,089 1,000 gallon units of runoff would still be coming into contact with legacy manure in corrals and open manured areas and contribute to nutrient loading. To illustrate the potential loading associated with stormwater runoff from manured areas, two papers were reviewed. The first paper was a literature review conducted by Koelsch *et al.* (2006)[5]. In this paper, runoff originating in open lots with beef cattle was estimated to be 5,800 ppm of nitrogen and 1,200 ppm of phosphorus. However, dairy cattle have higher nutrient content in their manure than beef cattle[6]. The second research paper was a study of runoff nutrient loadings by Gilley et al, (2012)[7]. The results of this study found that nutrient loads in runoff events decreased when there was no additional manure added between events.

Based on these studies, it is logical to assume that stormwater directed into the lagoons would have been in contact with legacy manure without the proposed open lot BMPs, but the nutrient content would diminish over time. However, no equation exists to estimate the rate of decrease in nutrient concentration. To address this unknown rate of reduction, two conservative factors were incorporated into the credit estimation process. First, the estimate of nutrient concentrations in liquids entering the lagoon used in equations 2 and 4 is substantially less than the estimated concentration of runoff mixed with manure. This is shown by comparing the results of equation 2 with 2a and equation 4 with 4a. Equations 2a and 4a are loading rate equations based on volume estimates in million gallons and pollutant concentrations in parts-per-million (ppm) times the weight of a gallon of water. In these equations, the density of the water is assumed not to change with the addition of pollutants. Stormwater coming into contact with manured open lots has an estimated nutrient load of 246,165 lbs of TN and 50,931 lbs of TP, which is 1.56 times greater than the load estimates used in the credit calculation. Based on this conservative margin of safety, the nutrient content of the stormwater coming into contact with manured open lots could be reduced by 36 percent before the concentration would reach the inputs selected for this credit calculation. The second conservative factor incorporated into the credit calculation method is a discount of 40 percent for nitrogen loading and 30 percent for phosphorus loading, as shown in equations 5 and 6. Adding in this margin of safety results in an edge-of-field loading estimate that, in subsequent years, is 62 percent less than the initial load estimate for nitrogen, and 55 percent less for phosphorus.

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[5] Koelsch, R.K., Lorimer, J., Mankin, K. 2006. Vegetative Treatment Systems for Open Lot Runoff: Review of Literature. Conference Presentations and White Papers: Biological Systems Engineering. Paper 5. http://digitalcommons.unl.edu/biosysengpres/5

[6] Midwest Plan Service, 2004. Manure Characteristics: Manure Management System Series. Second Edition. MWPS-18 S-1. Iowa State University. http://www.mwps.org/index.cfm?fuseaction=c_Products.viewProduct&catID=719&productID=6421&skunumber=MWPS18S1. Accessed March 1, 2011.

[7] Gilley, J.E., Vogel, J.R, Eigenberg, R.A., Marx, D.B., Woodbury, B.L. 2012. Nutrient losses in runoff from feedlot surfaces as affected by unconsolidated surface materials. J. of Soil and Water Conservation. May-June 2012. Vol. 67, pp 211-217

5,800 (ppm) TN * 8.34 (mass of a gallon of water) * 5.089 (million gallons) = 246,165 lbs of TN **[EQ 2a]**

1,200 (ppm) TP * 8.34 (mass of a gallon of water) * 5.089 (million gallons) = 50,930.7 lbs of TP **[EQ 4a]**

157,773 (lbs) TN * (1-40%) = 94,664 (lbs) TN reduced in years 2, 3, and 4 **[EQ 5]**

32,827 (lbs) TP * (1-30%) = 22,979 (lbs) TP reduced in years 2, 3, and 4 **[EQ 6]**

Introduced margins of safety are incorporated to adjust for delivery losses and differences in bioavailability. When a non-point source of nutrients is not adjacent to receiving water, the edge-of-field loading can be adjusted by an upland delivery ratio to represent overland transport losses. The Nunes - Ocean View Dairy manure lagoon calculation for BMP #1 incorporates the upland transport losses by using the equation presented in Figure 1 (located at the end of this document). The sediment delivery ratio (SDR) is taken from documentation discussing the development of the Minnesota Phosphorus Site Risk Index. The use of SDRs for upland field nutrient losses is considered a conservative assumption for nitrogen delivery. The fraction of soluble nitrogen lost in upland transport typically will be much lower on tight soils than the fraction of sediment loading lost under the same conditions. The nitrogen load reduction value for the field is multiplied by the delivery ratio to determine the edge-of-field delivered load per acre, as calculated in Equation 7. Several additional equations are applied that allow the total offset reductions to be calculated in Equation 13.

DR = NLR * SDR **[EQ 7]**

Where:

DR = Nutrient Load Reduction Edge-of-Field (lbs)
NLR = Nutrient Load Reduction (lbs); from Equation 5 and 6
SDR = Sediment Delivery Ratio as provided by Figure 1 (ratio)

Equation 7 was then applied to equations 8 and 9 for nitrogen and 10 and 11 for phosphorus to account for the distance between the manure lagoons and Windsor Creek on the Nunes Ocean View Dairy site. The lagoons are approximately 85 feet from Windsor Creek. The SDR discount factor resulted in a 60 percent reduction in the nutrient loading estimate from the site.

157,773 (lbs of TN in year 1) * 0.3988 (SDR) = 62,927 (lbs TN in year 1) **[EQ 8]**

94,664 (lbs of TN in years 2, 3 and 4) * 0.3988 (SDR) = 37,756 (lbs TN in years 2, 3 and 4) **[EQ 9]**

32,827 (lbs of TP in year 1) * 0.3988 (SDR) = 13,093 (lbs TP in year 1) **[EQ 10]**

22,979 (lbs of TP in years 2, 3 and 4) * 0.3988 (SDR) = 9,165 (lbs TP in years 2, 3 and 4) **[EQ 11]**

To account for differences in the bioavailability of nutrient forms released from wastewater effluent and manure sources, K&A completed a literature review, as directed by the offset Resolution (see Attachment A). This review assessed the nutrient bioavailability differences associated with multiple sources in order to incorporate these differences in the credit calculation process. Nutrients are present in the environment in a variety of forms, and not all of these forms are available for uptake by organisms. The fraction of the phosphorus or nitrogen that is or will become bioavailable for plant growth is the fraction of nutrient loading that is relevant to the Santa Rosa crediting project. Different sources release different forms (or varying fractions) of nitrogen and phosphorus. In order to facilitate crediting, a bioequivalence factor should be applied to account for these differences. This helps ensure that the credited reductions are equivalent in terms of environmental protection among all participating entities. The bioequivalence factor is a coefficient that is determined by taking the percent of the offset loading that is or will become bioavailable and dividing it by the percent of the wastewater discharge that is or will become bioavailable.

Phosphorus in dissolved form is considered 100 percent bioavailable, but the bioavailable fraction of particulate-attached phosphorus varies depending on the source. For manure-related non-point sources, it is estimated that 60 percent of particulate-attached phosphorus will become bioavailable. Combined with the dissolved fraction, the weighted average of bioavailable phosphorus is 80 percent. When the source is a domestic wastewater treatment plant, the particulate phosphorus fraction that will become bioavailable is estimated to be 70 percent. Combined with the dissolved fraction, the total fraction of bioavailable phosphorus from a domestic treatment facility is 85.5 percent. The bioequivalence factor for phosphorus from this manure-related non-point source and a domestic wastewater treatment plant is calculated by: 0.80/0.855. Therefore, the bioavailable coefficient is 93.5 percent.

For nitrogen, the dissolved inorganic forms (nitrate, nitrite and ammonia) are 100 percent bioavailable. The fraction of organic forms of nitrogen that are or will become bioavailable varies depending on the source. For agricultural non-point sources, the fraction of nitrogen that is or will become bioavailable has a weighted average of 80 percent. Domestic wastewater discharge has a higher fraction of nitrogen that is or will become bioavailable, with a weighted average of 94.5 percent. When these two fractions are entered into the bioavailability adjustment equation (0.80/0.945), the resulting nitrogen bioavailability coefficient is 85 percent. These bioavailability coefficients are used in the Nunes - Ocean View Dairy calculations.

Equations 12 through 15 present the final credit results after applying the bioavailability margin of safety.

62,927 (lbs TN in year 1) * 0.85 (ratio) = 53,488 TN credits in year 1 **[EQ 12]**

37,756 (lbs TN in years 2, 3 and 4) * 0.85 (ratio) = 32,093 TN credits in years 2, 3 and 4 **[EQ 13]**

13,093 (lbs TP in year 1) * 0.935 (ratio) = 12,242 TP credits in year 1 **[EQ 14]**

9,165 (lbs TP in years 2, 3 and 4) * 0.935 (ratio) = 8,569 TP credits in years 2, 3, and 4) **[EQ 15]**

BMP #2 – Heavy Use Area Restoration

For a 3.6-acre heavy use heifer loafing area situated adjacent to Mark West Creek Road, proposed activities will include scraping and closing this area, followed by the addition of a cover crop to increase nutrient uptake and reduce erosion. The heavy use area was historically used as a heifer loafing area. The heavy use history results in higher soil nutrient concentrations. Cows were released to this area daily and the cattle allowed to graze in the associated pasture. The total pasture is 19.4 acres, including the 3.6-acre loafing area. An adjacent 7.4-acre pasture also exists. Some 160 animals were kept 365 days per year in the open heifer barn and associated heavy use area and pastures. Animals were provided with supplemental feed bunkers and water near the barn.

The Pennsylvania Department of Environmental Protection (PA DEP) Chesapeake Bay Water Quality Trading Program[8] calculation method for pastures was adapted for heavy use areas here. The adjusted method calculates the reductions in phosphorus related to enriched soil concentrations from the past heavy use activities. The calculations estimate the reductions in phosphorus loading that result from implementation of a conservation cover BMP which will reduce surface erosion. This BMP will reduce both particulate and dissolved phosphorus loadings (but does not credit nitrogen). Site-specific credit calculations consider:

- Manure deposited in heavy use area
- Remnant manure after scraping
- Soil erosion rates for heavy use area
- Cover treatment efficiency

The crediting method developed by PA DEP involves conducting the calculations twice – once for present-day practices (before credit-generating BMPs are implemented) and a second time assuming new BMPs are installed. The difference in edge-of-field nutrient loading between the two scenarios provides the total load reduction value. Appropriate discount factors then are applied to calculate a final credit value eligible for offsetting City of Santa Rosa discharges.

To provide general background in preparation of the phosphorus calculation methods, a brief primer on phosphorus characteristics is provided here. Phosphorus is present in the environment in particulate attached and soluble forms[9]. Elemental phosphorus is very reactive and readily combines with oxygen

[8] PA DEP. 2007, 2008. Nitrogen and Phosphorus calculation spreadsheets. Accessed May 15, 2012; available at http://www.dep.state.pa.us/river/nutrienttrading/calculations/index.htm

[9] USDA ARS (1995). Fate and Transport of Nutrients: Phosphorus, Working Paper No. 8. Available at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/rca/?&cid=nrcs143_014203; Accessed July 5, 2012

when in contact with air to form phosphate[10]. Phosphate is a negatively charged ion and easily adsorbs to soil particles[11]. Therefore, substantial percentages of phosphorus are often attached to sediment, and eroded sediment can account for a large fraction of phosphorus loading to a water resource. Soluble phosphorus is released from sediments in increasing amounts when the soil content of phosphorus approaches the soil holding capacity[12]. In some settings, the soil holding capacity for phosphorus is approached or exceeded by the amount of phosphorus applied to a field and then soluble forms of runoff occur. The soluble fraction also can increase when inorganic and organically-bound phosphorus has a weakened or broken ionic bond with the soil's key ionic bonding minerals. Iron, aluminum, magnesium and calcium are the elements that bind phosphorus to the largest extent[13]. Bonds can be broken with exposure to anoxic conditions or changes in pH (e.g., when iron oxidizes in anaerobic conditions) (Sims et al., 1998)[14], (Sharply et al., 1981)[15], (Warwick et al., 2004)[16].

The credit equations used at the Nunes - Ocean View Dairy site require input values for:

- Current crop type (heavy use pad is comparable to a poor pasture stand)
- Acreage
- Soil type
- Field condition (poor, fair, and good depending on the stand density)
- Hydraulic condition (Poor – greater than average rainfall runoff and less infiltration, Good – less than average rainfall runoff and more infiltration)
- RUSLE2 soil loss for one-year period
- NRCS Curve Number
- Soil P test type
- Soil phosphorus test result
- Distance from the edge-of-field to the closest waterbody (feet)
- Number of 2-year, 24-hour storm events in one year (as provided by California Department of Water Resources website at ftp://ftp.water.ca.gov)
- Manure applications assumed to be zero
- Sediment Delivery Ratio

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[10] Busman, L., J Lamb, G. Randall, G. Rehm, M. Schmitt, (2002) The Nature of Phosphorus in Soils. Available at: http://www.extension.umn.edu/distribution/cropsystems/dc6795.html; Accessed July 5, 2012

[11] Id.

[12] Id.

[13] Id.

[14] Sims, J.T., Simard, R.R., Joern, B.C. (1998). Phosphorus Loss in Agricultural Drainage: Historical Perspective and Current Research. J. Environ. Qual. 27:227-293 (1998)

[15] Sharpley, A.N., Menzel, R.G., Smith, S.J., Rhoades, E.D., and Olness, A.E. (1981). The Sorption of Soluble Phosphorus by Soil Material during Transport in Runoff from Cropland and Grassed Watersheds. J. Envion.Qual. Vol. 10, no. 2, 1981

[16] Warwick, J.D., *Fleming, N.K., Cox, J.W., Chittleborough, D.J. (2004). Phosphorus Transfer in Surface Runoff from Intensive Pasture Systems at Various Scales: A Review. J. Environ. Qual. 33:1973-1988 (2004).

The PA DEP calculator allows for consideration of minimum site expectations. In the North Coast Regional Water Quality Control Board jurisdiction, these expectations are provided by the General Discharge Requirements or the Waiver requirements. Some BMPs are not required by the GWDR or Waiver and could generate credits each year for an extended period of time. Others will be required after a reasonable establishment period and can only receive credits until a point in time defined in the GWDR or Waiver. Therefore, the proposed heavy use area BMPs at the Nunes Ocean View Dairy are being requested for short-term credit generation, even though the dairy will achieve GWDR compliance for long-term requirements.

The PA DEP calculator can also addresses the total bioavailable nitrogen in manure and commercial fertilizer applications. However, this portion of the credit estimation process was not applied because the cattle have been removed from the site.

Applying the PA calculations to heavy use areas requires several additional modifications to the calculation methods. First, a heavy use area is not cropped. When a dairy is in operation, in the fall the livestock are limited to barns or sacrificial heavy use areas and access to the largest portions of heavy use areas is restricted. This is done in preparation for the winter wet season to limit loss of vegetation in saturated conditions and the associated water erosion and erosion stemming from cow traffic in this sensitive period. In addition, the heavy use areas are scraped to remove the manure that remained on the surface. Mulch and grass seed are then applied in preparation for the wet season. However, the cattle at this site were removed in 2012. Therefore, the estimated amount of manure remaining from previous use, including daily loafing of the milk cows prior to release into pastures, must be adjusted. These adjustments should incorporate the changes that occur when implementing the two existing practices used to prepare for the winter wet season (i.e., scraping and mulching). These practices represent the current nutrient loading conditions prior to implementation of the new BMPs proposed in the City's Nunes Ocean View Dairy crediting application.

The proposed quantification methodology for phosphorus management practices associated with proposed BMP #2 at the Nunes - Ocean View Dairy is described in the following narrative. Phosphorus computations for the edge-of-field loading are done twice – first for current site conditions and then for proposed nutrient management changes at the site. The difference in the results from these two calculations will reflect the edge-of-field reductions and the impact of the changes in nutrient management. The PA DEP calculator has a variety of agricultural application calculations, including development of mass balances for applied nutrients, particulate phosphorus losses associated with soil erosion, and dissolved phosphorus losses in runoff. The Nunes - Ocean View Dairy calculations only use equations for soil erosion sources and soluble phosphorus runoff estimates.

For manure applications, available phosphorus is determined by the timing, animal type, phosphorus concentration in the manure, rate of application, and application method. Because no additional manure is being applied during the crediting period, the only phosphorus losses that will be calculated are from sediment-attached phosphorus moving with eroded soil and soluble phosphorus releases during runoff events.

Discharge of soil phosphorus to waterways typically is controlled by reducing soil erosion and managing the soil phosphorus concentrations at levels well below the soil adsorption capacity. As such, the RUSLE2 annual soil erosion equation results are combined with the sediment-bound phosphorus concentrations per ton of soil to predict the phosphorus load moving within the field. Equation 16 provides this assessment converted into pound and acre units[17].

ESP = SPC * SEDE * 2.205 * EF **[EQ 16]**

Where:

ESP = Eroded Sediment Attached Phosphorus (lbs/yr)
SPC = Soil Phosphorus Concentration, from soil P test converted to total phosphorus (kg/ton)
SEDE = SEDiment Erosion, results for field from RUSLE2 calculation (tons/yr)
EF = Enrichment factor typical for the watershed, determined by GWLF modeling

The edge-of-field sediment-attached phosphorus load is calculated in Equation 17.

ESP-EoF = ESP * DR [**EQ. 17]**

Where:

ESP-EoF = Eroded Sediment Attached Phosphorus delivered to the Edge-of-Field (lb/yr)
ESP = Eroded Sediment Attached Phosphorus (Equation 16)
DR = Delivery Ratio (Figure 1)

The soil P test result conversion to total phosphorus has been modified to fit the Laguna setting. In Pennsylvania, the Mehlich – 3 test is used and applied in the PA DEP calculation spreadsheets. The soil tests recently collected at another approved dairy offset site were used to estimate total phosphorus content of typical soils here, and a back calculation was made using the PA converter based on a regression for Mehlich 3 and TP soil samples. (Note: Nunes - Ocean View Dairy site samples have been collected and the results are pending.)

SPC = SPT / 190 * 836 * 0.000909 [Mehlich - 3 TP] **[EQ 18]**[18]

Where:

SPC = soil total phosphorus concentration (ppm)
SPT = soil phosphorus test results (ppm)

[17] Equation recommended by Beegle, D., Klineman, P., and Evans, B., from Penn State University as supported by Evans (Evans, 2002).
[18] Vadas *et al*., 2005

The constants in this equation reflect the PA DEP calculation of the Area Weighted Value of lbs/acre as calculated by Evans[19] and a mass conversion from pounds to kilograms.

Dissolved soil phosphorus stream loading considers an estimate of non-point source runoff volume by adapting the SCS Curve Number (CN) for the site. The CN calculation, as quoted from the SCS Technical Release 55, indicates:

$Q = (P- 0.2S)^2 / (P +0.8S)$

S is the potential maximum retention after runoff begins, which is related to the soil and cover conditions of the watershed. The CN has a range of 0 to 100 and is selected based on rainfall and direct runoff. S is related to CN by:

$S = 1000 / CN – 10$

These runoff equations allow the potential maximum retention to be removed from the runoff estimate for the Sonoma County 2-year, 24-hour historic rain event, as determined based on CA Water Gov records. Equations 19 and 20 calculate the volume runoff for the Laguna de Santa Rosa as an example using a CN equal to 86.

$S = 1000 / 86 – 10$	result = 1.63	**[EQ 19]**
$Q = (3.34 – 0.2(1.63))^2 / (3.34 + 0.8 (1.63))$	result = 1.96	**[EQ 20]**

This runoff event volume can be multiplied by the estimated number of 2-year, 24-hour storm events in one year. According to Sonoma County long-term precipitation records (downloaded from CA Water Gov), the mean precipitation in the Santa Rosa Plain (where the Nunes - Ocean View Dairy is located) is 30.98 inches per year. The number of 2-year, 24-hour rain events that would equal that amount of precipitation is 9.28. Entering 9.28 into Equation 21 provides the estimated average annual rainfall runoff.

$AARR = Q * 9.28$ **[EQ 21]**

Where:

AARR = Average Annual Rainfall Runoff, in inches

Q = Annual Volume of Runoff, in inches

Equation 22 multiplies the total phosphorus concentration and the average annual runoff to obtain the total dissolved phosphorus loss from one acre.

$TDP = STP * SPRF * 0.000227$ **[EQ 22]**

[19] Evans, 2002

Where:

TDP = Total Dissolved Phosphorus, lost to runoff (lb/year)
STP = Soil Test Phosphorus
SPRF = Soluble Phosphorus Regression Factor[20]

SPRF = 2 * STP + 43.5 (μg/l), for the Mehilich test[21] **[EQ 23]**

Equation 24 calculates the total dissolved phosphorus from manure delivered to the edge-of-field.

TDP-EoF = TDP * DR **[EQ 24]**

Where:

TDP-EoF = Total Dissolved Phosphorus, to Edge-of-Field (lbs/ac)
TDP = Total Dissolved Phosphorus, lost to runoff (lbs/ac), from Equation 22
DR = Delivery Ratio (Figure 1)

The sum of the soil P loss from erosion, the total dissolved phosphorus loss, and the dissolved phosphorus from manure equals the phosphorus available in runoff, Equation 25

PFL = (TDP-EoF + ESP-EoF) * A **[EQ 25]**

Where:

PFL = Phosphorus Field Loss (lbs/ac)
TDP-EoF = Total Dissolved Phosphorus at the Edge-of-Field, from Equation 24
ESP-EoF = Eroded Sediment Attached Phosphorus at the Edge-of-Field, from Equation 17
A = Acres, in the field

For Equation 25, the long-term presence of past phosphorus applications will stay with the soil for many years and a new soil P test would have to be conducted to indicate a reduction in available soil phosphorus (ESP-EoF and TDP-EoF).

To illustrate how all of these equations, assumptions, and discounting factors are applied to calculate phosphorus credits at the Nunes - Ocean View Dairy site, the following inserts show applicable calculations for BMP #2. Equations cited above and as derived from the PA DEP credit calculator are denoted as to where they apply in this example illustration.

[20] Vadas *et al*., 2005 and Moncrief, 2002
[21] Vadas *et al*., 2005

Soil Information:					
	Classification:		Huichica	Loam	Htc
	Hydrologic Group:		D	**Soil C; Manure pack D**	
RUSLE estimate factors:					
	R Factor:	**120**	**From EPA Rainfall Erosivity Factor Fact sheet**		
	K Factor:	**0.37**	**Construction Sites at: http://cfpub.epa.gov/npdes/stormwater/lew/lewcalculator.cfm**		
	LS Factor	**2.2**	**From NRCS Web Soil Survey at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm**		
	C Factor	**0.05**	**From Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites and Reclaimed Lands, T.J. Toy and G. R. Foster, Co-editors J. R. Galetovic Publishing Editor. Accessed April 25, 2012 at: http://www.greenfix.com/Channel%20Web/pdfs/RUSLE%20Guidelines.pdf**		
	P Factor	**1**	**(no erosion practice)**		
	A= R*K*LS*C*P	**4.884**	**tons/acre/year**	**(if less than 1 ton/acre/year, use 1)**	

	Soil P		**3.0**	**kg/ton P**
Phosphorus Snapshot	**Background Soil P Loss from Erosion**		**64.6**	**lbs/acre**
Soluble P Concentration		1,544	ug/L (microgram/liter OR ppb)	
Average Annual Runoff		1,866,201	L/ac	Average Annual Runoff Conversion
Background Dissolved P Loss		2,880,480,541	ug/ac	
Background Dissolved P Loss		**6.3**	lbs/ac	
P Load Available from Soils:		**70.9**	lbs/ac	
P Load Available from Soils and Nutrient Applications:			70.9	lbs/acre
Site P Loading Available:			**255.4**	lbs P/yr

Introduced margins of safety are added to adjust for delivery ratio losses and differences in bioavailability.

When non-point sources of nutrients are not adjacent to receiving waters, the edge-of-field loading can be adjusted by an upland delivery ratio to represent overland transport losses. The Nunes - Ocean View Dairy heavy use area calculation (BMP #2) was adjusted for the upland transport losses by using the Minnesota Phosphorus Site Risk Index Sediment Delivery Ratio (SDR) equation presented in Figure 1, and as described in the calculations for BMP #1. The phosphorus load reduction value for the field is multiplied by the delivery ratio to determine the edge-of-field delivered load per acre, as calculated in Equation 26. The calculation for the total field reductions is provided in Equation 27.

DR = NLR * SDR **[EQ 26]**

Where:

DR = Nutrient Load Reduction Edge-of-Field (lbs)
NLR = Nutrient Load Reduction (lbs); from Equation 5 and 6
SDR = Sediment Delivery Ratio as provided by Figure 1 (ratio)

Equation 26 was applied for the site in equation 27 to account for the distance between the heifer heavy use area and a roadside water conveyance on the west side of this area. This conveyance connects to Windsor Creek a short distance south of the dairy site. The average distance to the conveyance is 100 feet. Equation 27 provides the application of the SDR to the phosphorus loading estimate. The SDR discount factor is 38.57 percent reducing the credit value by 61.43 percent.

255.4 (lbs of TP) * 0.3857 (SDR) = 98.48 (lbs TP) **[EQ 27]**

In addition to excluding the dairy milk cows, a conservation cover BMP will be added to the Nunes - Ocean View Dairy heavy use area. The cover, calculated here as a buffer, further reduces erosion and assimilates both soluble and sediment-attached phosphorus. The heavy use area cover introduced here is applied AFTER the SDR discount factor to determine the edge-of-field load. A study by Zhang *et al.* (2010)[22] presented the findings of a literature review focused on the treatment efficiency of vegetative buffers. In this review, nutrient loading reductions for a 30-meter buffer increased the percent reduction to 100 percent for phosphorus. Equation 28 presents the application of the addition of perennial cover to equation 27.

98.48 (lbs TP) * 1 = 98.48 lbs of TP reduced **[EQ 28]**

As presented in BMP #1, K&A completed a literature review (see attachment A) to address the nutrient bioavailability differences associated with various sources, as directed by the offset Resolution. For this manure-related non-point source site, it is estimated that 60 percent of particulate-attached phosphorus will become bioavailable. Combined with the dissolved fraction, the weighted average of bioavailable phosphorus is 80 percent. When the source is a domestic wastewater treatment plant, the particulate phosphorus fraction that will become bioavailable is estimated to be 70 percent, for a total of 85.5 percent when combined with the dissolved fraction. The bioequivalence factor for phosphorus from this manure-related non-point source and a domestic wastewater treatment plant is calculated by: 0.80/0.855. Therefore, the bioavailable coefficient is 93.5 percent. Equation 29 applies this margin of safety.

98.48 (lbs TP) * 0.935 (ratio) = 92.1 TP credits **[EQ 29]**

[22] Zhang, X., Liu, X., Zhang, M., Dahlgren, R.A., and Eitzel. M. 2010. A review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing non-point source pollution. J Environ Qual. 2009 Dec 30; 39(1):76-84. Print 2010 Jan-Feb.

In summary, the Nunes Ocean View Dairy edge-of-field loading calculations for nutrient applications include the following conservative assumptions: no further manure applications (of either nitrogen or phosphorus) will occur during the credit life and residual nitrogen releases from the site after dairy cows were excluded beginning in 2012 will not be credited. In addition, these credit calculations consider instream (channel) attenuation processes that occur between the Nunes - Ocean View Dairy site and the low flow pools in comparison with the relative location and timing of the Delta Pond discharges. The Nutrient Offset Program Resolution allows for the use of spatial and temporal considerations to be incorporated as an additional "margin of safety" factor when determining credits.

BMP #3 On-site Re-use of Stacked Manure Solids

The proposed credit-generating activity for BMP #3 will eliminate nutrient loading contributions to Windsor Creek by first constructing an interim containment berm, land applying on-site the manure separated solids, and then establishing a cover crop on exposed ground surfaces. During previous site visits, at least five areas were identified where manure stacking is persistent and nutrient and bacteria loading contributions to surface water are possible via runoff. The areas of activity will be consolidated into zones that provide protection against surface water nutrient loading with temporary berming until full land application of the solids is completed.

Three acres of manure separated solids are stacked on the dairy site. The stacking piles are estimated at 12,700 tons of solids. However, all of this manure is not expected to be released to Windsor Creek within the next four years. To calculate the credits for sediment-attached nutrient loading, the RUSLE equation was applied to the physical attributes of the stacking piles. The credit calculation insert below shows the application of RUSLE to the site. RUSLE supporting materials are listed alongside the applied coefficients. Using a topographic map of the site, the slope lengths of the manure stacking piles were found to average 12 feet, generating a LS factor of 1.84.

Area Served:	3	acres	
Soil Information:			
Classification:	Huichica	Loam	Htc
Hydrologic Group:	D		
RUSLE estimate factors:			
R Factor:	120		Soil identified as a C; manure pack/compaction assumed a D rating
K Factor:	0.1		From EPA Rainfall Erosivity Factor Fact sheet
LS Factor	1.84	12 foot length	Sites at: http://cfpub.epa.gov/npdes/stormwater/lew/lewcalculator.cfm
C Factor	0.42		From NRCS Web Soil Survey at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm
P Factor	1	(no practice)	From Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands
A= R*K*LS*C*P	9.27	tons/acre/year	From Guidelines for th (if less than 1 ton/acre/year, use 1)
Erosion Rate:	9.27	tons/acre/year	
Field Condition:	Poor		

Manure samples are pending at the site. However, dairy separated solids nutrient contents were estimated using the Pacific Northwest Extension publication PNW0533 (Pacific Northwest Extension, 2000). The nutrient content of manure separated solids is estimated to be 5 lbs per ton for nitrogen and 0.9 lbs per ton for phosphorus. In order to use the PA calculation method, the manure nutrient content was converted into metric units of 2.5 kg TN /ton and 0.45 kg TP /ton.

The eroded material is manure separated solids. Therefore, the sediment-attached nutrient calculations are derived by adjusting equation 16 to generate equation 16a, which can be used to calculate both nitrogen and phosphorus.

ESP = SPC * SEDE * 2.205 * EF **(EQ. 16a)**

Where:

ESP = Eroded Sediment Attached Nutrient (lbs/yr)
SPC = Soil Nutrient Concentration, from soil total nutrient test (kg/ton)
SEDE = SEDiment Erosion, results for field from RUSLE2 calculation (tons/yr)
EF = Enrichment factor typical for the watershed, determined by GWLF modeling

Next, equations 18 through 23, presented in the calculation discussion for BMP #2, are used to predict the soluble phosphorus loss from the manure separated solids stacking piles. The calculation of equation 16a and 18 through 23 is presented in the following insert.

Eroded/Particulate Attached			
TN	**306.7**	**lbs per year**	
TP	**55.2**	**lbs per year**	
Soluble	**TP**		
Soluble P Concentration	269	ug/L (microgram/liter OR ppb)	
Average Annual Runoff	1,866,671	L/ac	Using 18.16 inches annual average runoff
Background Dissolved P Loss	501,243,054	ug/ac	
Background Dissolved P Loss	**1.1**	lbs/ac	
Total TP	**56**	lbs/ac	
		Additional conservative assumption; soluble nutrient loading not credited	

The sediment delivery ratio and bioavailability factors were applied as margins of safety to the crediting equations. The distance from the manure separated solids stacking piles and Windsor Creek is 85 feet. The sediment delivery ratio is 39.88 percent. The sediment delivery ratio equation 26 was applied to both nutrients in equations 30 and 31.

306.7 (lbs of TN) * 0.3988 (SDR) = 122.3 (lbs TN) **[EQ 30]**

56.3 (lbs of TP) * 0.3988 (SDR) = 22.5 (lbs TP) **[EQ 31]**

The final step in calculating the credits for BMP #3 is to apply the bioavailability factor for nitrogen and phosphorus. The differences in nitrogen bioavailability between wastewater effluent and manure can be addressed by applying the 0.85 ratio, as described in BMP #1. The difference in phosphorus bioavailability between wastewater effluent and manure can be addressed by applying the 0.935 ratio, as described in BMP #1

122.3 (lbs TN) * 0.85 (ratio) = 104.0 TN credits per year **[EQ 32]**

22.5 (lbs TP) * 0.935 (ratio) = 21.0 TP credits per year **[EQ 33]**

This BMP #3 calculation summary completes the descriptions for all three proposed BMPs for the Nunes - Ocean View Dairy Site as part of this memorandum.

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Table 2. Manure Type and Average Nitrogen Concentrations.

Manure Type	Average N Concentration		Units
Dairy- Lactating Cows Liquid	28	lbs/1,000 gallons	1,000 gallons/ac
Dairy- Lactating Cows Solid	10	lbs/ton	tons/ac
Dairy- Dry Cow	9	lbs/ton	tons/ac
Dairy- Calf and Heifer	7	lbs/ton	tons/ac
Beef- Cow and Calf	11	lbs/ton	tons/ac
Beef- Steer	14	lbs/ton	tons/ac
Horse	12	lbs/ton	tons/ac

Table 3. Nitrogen Availability Factors.

Table 1.2-14. Manure nitrogen availability factors for use in determining manure application rates based on planning conditions.

A. Current Year

To use this table, find the ***planned manure application season*** in the left column, then move to the right in that row and select the ***target crop utilization***. Continue to the right in that row to find the ***nitrogen availability factor*** for the ***planned manure application management***.

			Nitrogen availability factor[1]		
Planned manure application season	*Planned manure target crop utilization*	*Application management*	*Poultry manure*	*Swine manure*	*Other manure*
Spring or summer	Spring utilization by grass hay and small grains. Summer utilization by corn, other summer annuals, and grass hay.	Incorporation the same day	0.75	0.70	0.50
		Incorporation within 1 day	0.50	0.60	0.40
		Incorporation within 2–4 days	0.45	0.40	0.35
		Incorporation within 5–7 days	0.30	0.30	0.30
		Incorporation after 7 days or no incorporation	0.15	0.20	0.20
Early fall[2]	Fall and spring utilization by grass hay and small grains.	Incorporation within 2 days	0.50	0.45	0.40
		Incorporation within 3–7 days	0.30	0.30	0.30
		Incorporation after 7 days or no incorporation	0.15	0.20	0.20
	Following summer utilization by corn and other summer annuals.	All situations	0.15	0.20	0.20
Late fall or winter[3]	Spring utilization by small grains and grass hay	All situations	0.50	0.45	0.40
	Following summer utilization by corn or other summer annuals	No cover crop	0.15	0.20	0.20
		Cover crop harvested for silage	0.15	0.20	0.20
		Cover crop used as green manure	0.50	0.45	0.40
Grazing	Late spring through early fall grazing	Manure deposited more or less continuously by grazing cattle	—	—	0.20
	Year-round grazing	Manure deposited more or less continuously by grazing cattle	—	—	0.30

1. Multiply this factor times the manure N content to estimate the manure N available for the planning conditions.
2. Early fall would be when it is still warm enough for plant growth and microbial activity to continue (soil temperature >50°F at 2 inches).
3. Late fall and winter is when it is so cold that there is no plant growth or microbial activity (soil temperature <50°F at 2 inches).

B. Historical Frequency of Manure Application on the Field

To use this table, determine the frequency of manure application and go across to the amount of residual N that is available from past manure applications. Deduct this amount of residual N from the basic N recommendation before determining any additional fertilizer or manure application rates.

Table 4. Available Nitrogen from Past Applications.

Frequency of Past Manure Application (followed by manure type)	N Available (lbs N/ac)
Never received manure in past	0
Rarely received manure in past (<2 out of 5 yrs)	0
Frequently received manure (2-3 out of 5 yrs)	20
Continuously received manure (4-5 out of 5 yrs)	35

Table 5. Phosphorus Application Factors.

	April-Oct	Nov-March
Application Method	Phosphorus Application Factor	
Placed or injected 2” or more deep	0.2	0.2
Incorporated less than 1 week following application	0.4	0.4
Incorporated more than 1 week following application	0.6	0.8
Not incorporated following application	0.6	0.8
Surface applied to frozen or snow-covered soil	1	1

Table 6. Nutrient Content of Manure and P Source Coefficients.

Manure Type	Average P Concentration				
	Phosphate	Phosphorus	Unit	P Source Coefficient	P Source Coefficient Applied[1]
Dairy- Lactating Cows Liquid	13	5.59	lbs P/1,000 gallons	0.8	0.6
Dairy- Lactating Cows Solid	4	1.72	lbs P/ton	0.8	
Dairy- Dry Cow	3	1.29	lbs P/ton	0.8	
Dairy- Calf and Heifer	2	0.86	lbs/ton	0.8	

[1] 20 percent margin of safety introduced

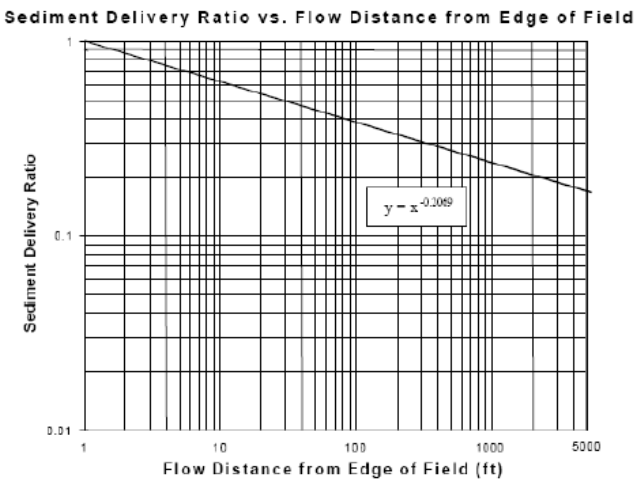

Figure 1. Sediment Delivery Ratio.

The SDR equation is:

$$SDR = D^{-0.2069}$$

Where:

SDR = Sediment Delivery Ratio

D = Distance of sediment source to nearest hydrologically connected water body

[Note: For distances greater than 5000 feet use 5000 feet]

(Delivery Ratio Explanation: To account for overland delivery of nutrients from the estimated edge-of-field location to an adjacent or nearby waterbody, Kieser & Associates, LLC recommends using information compiled by the University of Minnesota for sediment and particulate-attached nutrient reduction accounting. The University of Minnesota developed the Minnesota Phosphorus Site Risk Index in partial support of the Generic Impact Statement on animal agriculture (Moncrief, 2002). This method is applied in the Minnesota Phosphorus Index and water quality trading permits. The sediment delivery ratio (SDR) regression graph from the Minnesota Phosphorus Index is provided in Figure 1 above. The graph provides approximate SDRs based on distance from the edge-of-field to the nearest hydrologically connected water body.)