To: Lynn Small, Deputy Director
Environmental Compliance

Date: July 6, 2012

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

RE: Beretta Dairy Summary of Best Management Practice Reduction Estimation Methods for City of Santa Rosa Offset Credits

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This memorandum provides details of the City of Santa Rosa Nutrient Offset Program calculations used for estimating nitrogen and phosphorus credits from the Beretta Dairy site under current conditions and under a future condition with proposed Best Management Practices (BMPs). Tables and figures (found at the end of this memorandum) are provided for additional illustration and support of crediting approaches. Crediting methods were derived from 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 Beretta site. Computed credit values are consistent with the City of Santa Rosa Crediting Proposal for the Beretta Dairy BMPs dated June 5, 2012 (and submitted on June 6, 2012).

The City of Santa Rosa Nutrient Offset Program defines the term "offset" to be an equal or greater load reduction obtained from a remote location whereby the pound for pound exchange is adjusted to account for differences in 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 implementation of a Best Management Practice (BMP) that results in a nutrient load reduction to a water body.

Selection of the Calculation Method

The PA DEP nutrient credit calculation method was selected based on comparisons of alternative methods. In addition to the Pennsylvania method, the EPA Region V model and the USDA-NRCS Nutrient Tracking Tool (NTT) were examined. These latter two methods were removed from further consideration due to limitations in their applicability with characteristics found in the Laguna de Santa Rosa setting. The Region V model has limited applicability related to crediting soluble nutrient parameters and lacks manure nutrient management considerations. NTT has a high cost for regional calibration without which the local dairy BMP simulations cannot be adequately performed.

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

The strengths of the PA DEP method include ease of use, load generation for soluble nutrient fraction load reduction estimates, and its 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). The calculations are performed on Microsoft Excel spreadsheets and are based on standard methods to determine non-point source runoff estimates. A description of the calculation process is provided as follows.

Calculation Description

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 are then applied to calculate a final credit value eligible for offsetting City of Santa Rosa discharges.

Nitrogen fate and transport dynamics within the land and river environments are different than phosphorus dynamics. The nitrogen water quality cycle includes conversion of organic forms of nitrogen into inorganic form ammonium and then nitrification (conversion of ammonia to nitrite and nitrates). In some settings denitrification can also occur (conversion of nitrates into N2). Phosphorus forms remain as dissolved or sediment attached forms within both soil and water media. Because of these different interactions, the credit calculation equations for nitrogen reductions and phosphorus reductions are different. As such, the nitrogen equations focus on the total nitrogen (organic forms) and their eventual breakdown and conversion into ammonium, while the phosphorus equations focus on particulate phosphorus loss associated with soil erosion and the soluble fraction in runoff. The following text provides a brief background on nitrogen and phosphorus dynamics, which establishes the rationale for focusing on specific forms of each nutrient.

Nitrogen is present in the environment in organic and inorganic forms[4]. Both organic and inorganic nitrogen can be present in dissolved forms as dissolved organic nitrogen (DON) and dissolved inorganic nitrogen (DIN)[5]. The DIN fraction includes the forms of nitrogen available for plant growth – nitrate and

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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)
[4] Understanding Nitrogen in Soils, Mike O'Leary, George Rehm and Michael Schmitt WW-03770-GO Reviewed 1994 Available at: http://www.extension.umn.edu/distribution/cropsystems/dc3770.html; Accessed July 5, 2012
[5] Wetzel, R. (2001). Limnology: Lake and River Ecosystems, Third ed. Academic Press, San Diego, CA.

ammonium[6]. Organic nitrogen becomes bioavailable over time as the particulate form of organic nitrogen is converted into DIN. The organic forms can be delivered to surface waters as eroded soil[7]. (See Attachment A of this memorandum for an additional discussion on bioavailability as applied to Santa Rosa credit proposals.)

When dealing with manure application on soils, total nitrogen testing focuses on Total Kjeldahl Nitrogen (TKN)[8]. This laboratory-measured nitrogen parameter is the sum of organic nitrogen and ammonium (NH_4^+)[9]. Additional laboratory procedures can be used to determine the ammonium concentration, which then can be used to calculate the organic nitrogen component from the TKN value[10]. The other forms of DIN – nitrite and nitrate –typically are present in smaller quantities in unsaturated soils, manure solids and/or biosolids. Therefore, the Beretta Dairy calculations can focus on TKN, which will release DIN components over time as organic matter decays.

Phosphorus is present in the environment in particulate attached and soluble forms[11]. Elemental phosphorus is extremely reactive and readily combines with oxygen when in contact with air to form phosphate[12]. Phosphate is a negatively charged ion and easily adsorbs to soil particles[13]. 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[14]. 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 three minerals that bind phosphorus to the largest extent[15]. The three ionic 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)[16], (Sharply et al., 1981)[17], (Warwick et al., 2004)[18].

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[6] USDA ARS (1995). Fate and Transport of Nutrients: Nitrogen. Working Paper No. 7. Available at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/rca/?&cid=nrcs143_014202. Accessed July 5, 2012

[7] Id.

[8] UC Davis (2010). California Analytical Methods Manual. Accessed July 3, 2012, available on line at: http://anlab.ucdavis.edu/docs/uc_analytical_methods.pdf

[9] UC Davis, College of Agricultural and Environmental Sciences (2010). California Analytical Methods Manual. Available at http://anlab.ucdavis.edu/docs/uc_analytical_methods.pdf; Accessed July 5, 2012.

[10] Id.

[11] 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

[12] 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

[13] Id.

[14] Id.

[15] Id.

[16] 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)

Beretta Project Applications - Nitrogen

The credit equations used at the Beretta 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 regarding density of stand)
- 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 1 year (as provided by CA Water Gov website at ftp://ftp.water.ca.gov)
- Manure applications
    - Time of year (spring or summer/early fall/late fall or winter)
    - Animal type
    - Recent nitrogen concentration in manure analysis (lbs N/ton manure)
    - Manure application rate
    - Days between application and incorporation
- Residual nitrogen information
    - Frequency of past manure applications (<2 out of 5 years, 2-3 out of 5-years, 4-5 out of 5 years)
    - Soil series
- Sediment Delivery Ratio

The methodology for quantifying nitrogen reductions from nutrient management projects in the Beretta Dairy site is provided as follows. The edge-of-field loading calculations are performed twice – first for current conditions and then with the assumption that BMPs are implemented. The difference between these two values yields the load reduction.

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

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[17] 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

[18] 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).

Waiver and could generate credits year after year for a length of time; others will be required after a reasonable establishment period and can only receive credits until a point of time that is defined in the GWDR or Waiver. Therefore, the three project sites where BMPs are proposed at the Beretta Dairy are separated into short-term credit generating BMPs and longer-term credit generation BMPs reflecting whether the Waiver requires the BMP or if the BMP is additional to the requirements, respectively.

Next, the PA DEP calculator addresses the total bioavailable nitrogen in commercial fertilizer applications. This step is performed for each application, and all applications are sequentially numbered. However, when working on an animal heavy use area, fertilizer is not applied and this step is not applicable. It is therefore not discussed here.

The PA DEP calculation method for estimating the total nitrogen from manure applications is calculated in Equation 1. The manure applications are sequentially numbered as well (e.g., the second manure application equals $_{m2}$). Nitrogen content in manure can be derived either by nitrogen manure testing (lbs/ton or lbs/1000 gallons of manure) or default values provided by the Midwest Plan Service (Midwest Plan Service, 2004) as shown in Table 1. (The sum of all manure applications is calculated in Equation 2.) Some of the following equations reference an “X”, which allows either “B” for Before or “A” for After BMP conditions to be selected.

$NA_{m1} = MAR_{m1} * ANC_{m1}$ **(EQ. 1)**

Where:

NA_{m1} = Nitrogen Applied, manure application #1 (lbs/ac)
MAR_{m1} = Manure Application Rate, application #1 (tons/acre)
ANC_{m1} = Average Nitrogen Concentration, manure application #1 (lbs/ton); from Table 1 or test

And;
$TNA_{M} = \Sigma NA_{m,\ 1\text{-}n}$ **(EQ. 2)**

Where:

TNA_{M} = Total Nitrogen Applied, manure applications (lbs/ac)
NA_{m}= Nitrogen Applied, manure application #X (lbs/ac); from Equation 1

The total available nitrogen from each manure application is calculated in Equation 3. This equation adjusts the TN applied by a nitrogen crop availability factor. The results of Equation 1 for each application must be multiplied by a coefficient for the crop available fraction. This coefficient is determined using Table 2, which considers the type of manure, season of application and the timing of incorporation (Penn State Cooperative Extension, 2011). Table 2 also takes into account the soil temperature and the period of time the manure remains on the surface, which affects exposure to soil bacteria, the bacteria’s metabolic rate and the related conversion to and loss of ammonium. The available nitrogen for a given manure application is calculated in Equation 3, and the sum of all available nitrogen from all applications is calculated in Equation 4.

$AN_{m1} = NA_{m1} * AF_{N1}$ **(EQ. 3)**

Where:

AN_{m1} = Available Nitrogen, from manure application #1 (lbs/ac)
NA_{m1} = Nitrogen Applied, in manure application #1 (lbs/ac); from EQ. 1
AF_{m1} = Available Fraction, in manure application #1 (ratio); from Table 2

And;

$TAN_M = \Sigma AN_{m,\ 1\text{-}n}$ **(EQ. 4)**

Where:

TAN_M = Total Available Nitrogen, in manure applications (lbs/ac)
AN_m = Available Nitrogen, in manure application #X (lbs/ac); from Equation 3

In the next step, all of the nutrient applications are summed to estimate the total nitrogen applied and total available nitrogen (Equation 5 and Equation 6, respectively).

$TNA_X = TNA_F + TNA_M$ **(EQ. 5)**

Where:

TNA_X = Total Nitrogen Applied (lbs/ac)
TNA_F = Total Nitrogen Applied, all fertilizer applications (lbs/ac); not applicable
TNA_M= Total Nitrogen Applied, all manure applications (lbs/ac); from Equation 2

$TAN = TAN_f + TAN_M$ **(EQ. 6)**

Where:

TAN = Total Available Nitrogen (as calculated for Before and After BMP implementation)
TAN_f = Total Available Nitrogen, all fertilizer applications (lbs/ac); not applicable
TAN_M = Total Available Nitrogen, all manure applications (lbs/ac); from Equation 4

Residual nitrogen is calculated from data on previous manure application rates and legume crops. The frequency of manure applications within the past five years determines the residual nitrogen from previous manure applications. Organically bound nitrogen in manure is released based on the decay rate of the organic particles. A fraction of residual manure nitrogen is assumed to be released for the three years following application. Table 3 provides the results of a PA DEP and Penn State assessment using professional judgment regarding manure application residuals. Table 4 provides the residual nitrogen contribution from legumes (Penn State Cooperative Extension, 2011). Summing the residuals from both manure and legumes is performed in Equation 7, which calculates the residual manure available from previous applications. Table 6 is provided for informational purposes only, as it is based on PA soils. Review of this table indicates that any "Somewhat Poorly Drained" soil or "Poorly Drained" soil receives a crop productivity rating of 4. Dairy operations within the Laguna de Santa Rosa are operating within the Santa Rosa plain and fall within these leaching and drain classifications. Therefore, a crop rating of 4 would be used on the Beretta fields included if they were cropped. This consideration does not apply to pastures or heavy use areas.

$RN = RNM + RNL$ **(EQ. 7)**

Where:

RN = Residual Nitrogen (lbs/ac)
RNM = Residual Nitrogen from Manure (lbs/ac; Table 3)
RNL = Residual Nitrogen from Legumes (lbs/ac; Table 4)

As noted previously, the above calculations are performed twice: once for the "before BMP" condition and again for the "after BMP" condition (Equation 8). Some of the following equations reference an X, which allows either B for Before or A for After BMP conditions to be selected.

$RAN = AN_B - AN_A$ **(EQ. 8)**

Where:

RAN = Reduction of Available Nitrogen (lbs/ac)
AN_B = Available Nitrogen (Before BMP)
AN_A = Available Nitrogen (After BMP)

The sum of the residual nitrogen and nitrogen available from commercial fertilizer and manure applications before and after implementing nutrient management measures provides an estimate of the total nitrogen available per acre as calculated in Equation 9 and 10. The field scale total available nitrogen is provided in Equation 11.

$AN_B = RN + TAN_{m\Sigma x} + TAN_f$ (Before BMP) **(EQ. 9)**
$AN_A = RN + TAN_{m\Sigma x} + TAN_f$ (After BMP) **(EQ. 10)**

Where:

AN_B = Available Nitrogen, Before BMP
AN_A = Available Nitrogen, After BMP
RN = Residual Nitrogen; from Equation 7
TAN_{FX} = Total Available Nitrogen from Fertilizer, not applicable for heavy use areas
TAN_{MX} = Total Available Nitrogen from Manure, for either Before or After; from EQ. 6

$NLR = A * RAN$ **(EQ. 11)**

Where:

NLR = Nitrogen Load Reductions, applied in the field (lbs)
A = Acres in the field
RAN = Reduction of Available Nitrogen (lbs/ac); from EQ 8

Applying these calculations to heavy use areas requires several modifications. (Note that all three BMP sites at the Beretta Dairy are located in heavy use areas (the manure lagoon solids stacking area is located in the heavy use area for BMP #2, and BMP #3 provides further reductions at a remote heavy use area.) First, a heavy use area is not cropped. In the fall of each year, after the livestock access has been removed, the heavy use areas are scraped to remove the manure that remained on the surface. Mulch is then applied in preparation for the wet season. Therefore, the estimated amount of dry season manure applied by daily loafing of the milk cows prior to release into pastures must be adjusted by 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 are representative of the current nutrient loading conditions prior to new BMPs being proposed in the City's Beretta Dairy crediting application.

To address how much manure remains on site associated with these current practices, and what then remains available to contribute to nitrogen loads, soil samples were collected in April of 2012. These soil samples represent the nitrogen content that remains available after the volatilization losses from non-incorporation during the dry season, the scraping that has been implemented, and any losses from wet season runoff has occurred. The soil test results from the three heavy use and lagoon solids stacking areas compare equally to fresh manure total nitrogen concentrations, after taking into account handling losses. When the BMP implementation does not change the field's intended use (i.e., the field remains a heavy use area for cows), a 5 percent increase in soil nitrogen concentration was added to estimate the fraction of applied nitrogen lost over the winter. This very low increase above the testing results acknowledges the many opportunities for winter season losses of the applied manure as described earlier and introduces a conservative safety factor into these calculations. One heavy use area (BMP #3) is being relocated to an interior field. The assumption to account for the wet season losses on this site uses 30 percent, which is less than the late fall, winter spring availability factor in the PA calculator of 40 percent. The soil nitrogen concentration was increased by 30 percent to adjust for the season's loss. An additional conservative safety factor for this site is applied in the buffer treatment efficiency estimate described below.

In summary, the Beretta Dairy edge-of-field loading calculations for current nitrogen applications include three conservative factors – spring-time sample collection, tests performed on the soil rather than manure, and a three-year averaging period allowed by the Nutrient Offset Program Resolution for crediting. The use of soil testing further dilutes the samples with inert materials (dirt). The three-year averaging period allows for mineralization (organic decay rates) to be taken into consideration. When the combination of all three factors are considered, (time of sample collection, soil tested instead of manure, and the long-term period for organic decay) this process for estimating available nitrogen can be considered conservative.

To compute offset credits, the edge-of-field available nitrogen as calculated above is multiplied by other coefficients to account for additional site characteristics such as overland delivery, bioavailability, and in-stream channel processes (losses). Thus, the offset amount (i.e., credit) is the difference in the edge-of-field available nitrogen value with and without BMPs multiplied by these coefficients (which serve as credit “discounting factors”). Consideration of these factors ensures that credits are equal to or greater than the nutrients discharged in the City’s wastewater. Each of these applicable factors are discussed as follows.

When a non-point source of nutrients is not adjacent to a receiving water, the edge-of-field loading can be adjusted by an upland delivery ratio to represent overland transport losses. The Beretta Dairy lagoon solid manure stacking area calculation (BMP Project #1) was adjusted for the upland transport losses by using the equation presented in Figure 1. 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 in 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 12. The calculation for the total field reductions is provided in Equation 13.

TNLREoF = NLR * SDR **(EQ. 12)**

Where:

TNLREoF = Total Nitrogen Load Reduction Edge-of-Field (lbs)
NLR = Nitrogen Load Reduction (lbs); from Equation 11
SDR = Sediment Delivery Ratio as provided by Figure 1 (ratio)

Equation 12 was applied to two of the Beretta BMPs. The first is BMP #1 for the manure lagoon solids stacking area. The second is BMP #3 where the remote heavy use area is being relocated to an interior field. The manure solid stacking area was 30 feet from the nearest water conveyance. The SDR discount factor resulted in a 50.5 percent reduction in the nutrient loading estimate from the current site conditions. BMP #3, the relocation of the remote heavy use area, also uses the SDR in its crediting computation. The SDR for relocating the area 200 feet away from Roseland Creek is 66.6 percent. Where a BMP is directly adjacent to a surface water body, the edge-of-field load is considered to be 100% delivered.

Though considered as an actual BMP and not a discount factor, additional nutrient reductions are expected at the Beretta dairy with the expected addition of vegetated buffers in the crediting proposal. These are introduced here as they are applied to the nitrogen loading AFTER the SDR discount factor is applied to the edge-of-field load. A study by Zhang[19] *et al.,* (2010) presented the findings of a literature review focused on the treatment efficiency of vegetative buffers. In this review, nutrient loading reductions for 10-meter mixed grass setbacks were estimated to be 71 percent for nitrogen and 69 percent for phosphorus. A 30-meter buffer increased the percent reduction to 98 percent for nitrogen and 100 percent for phosphorus. The Beretta BMPs #1 and #2 have a 10-meter buffer as part of the treatment system. The remote heavy use area relocation (BMP #3) also benefits from a 200-foot grass buffer. However, to introduce a conservative estimate for this BMP site, the treatment efficiency for a 10-meter buffer was applied.

A literature review (see attachment A) was completed by K&A to address the nutrient bioavailability differences from various sources, as directed by the offset Resolution. 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. However, 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 accounts for the differences in bioavailability between two sources. This coefficient 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 this non-point source, it is estimated that 60 percent of particulate-attached phosphorus will become bioavailable. Combined with the dissolved fraction, the weighted average result of bioavailable phosphorus is 80 percent. When the source is a domestic wastewater treatment plant, the particulate phosphorus fraction that will become bioavailable is higher and is estimated to be 70 percent. Combined with the dissolved fraction, the total is 85.5 percent. The bioequivalence factor for phosphorus from this 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 organic forms of nitrogen have variable bioavailability 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 bioavailable adjustment equation (0.80/0.945), the resulting nitrogen bioavailability coefficient is 85 percent. These bioavailability coefficients are used in the Beretta calculations.

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19 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.

Finally, these credit calculations consider instream (channel) attenuation processes that occur between the location of the offset discharge from the Beretta dairy and the location of the City's Delta Pond discharge location. The Nutrient Offset Program Resolution allows for the use of spatial and temporal considerations to be factored in as a "margin of safety" when determining credits. A margin of safety effectively becomes another potential discounting factor for calculating credits. For spatial considerations, the Beretta Dairy is located above several summer low flow pools targeted for protection under a forthcoming Laguna de Santa Rosa nutrient TMDL. In comparison, the City of Santa Rosa discharges treated wastewater from its Delta Pond situated downstream of the low flow summer pools.

When considering the possible temporal differences between Beretta Dairy nutrient contributions and City wastewater discharges, there are three temporal Laguna flow regimes that must be considered for margin of safety considerations for timing of discharges including:

1. Discharges during the dry season (there may dairy runoff from summer rain events affecting low flow pools while there are no dry weather discharges of wastewater from Delta Pond)
2. Discharges during the wet season when the Russian River does not create flow reversals in the Laguna (the dairy-related loading pathway is still through the low flow pools, while the Delta pond discharge pathway does not travel through these pools)
3. Discharge during the wet season when the Russian River backs up into the Laguna (Delta Pond discharges under this condition could result in nutrients associated with wastewater being transported upstream of summer low flow pond locations; however, predicting the deposition of discharged nutrients becomes very complex as the area of deposition includes the entire floodplain and not necessarily just the low flow pool areas as is the case in the other two flow scenarios)

The City's Delta Pond discharge will only impact low flow pool areas under the third flow condition. This assumes that what is typically a two to three week winter discharge event by the City, occurs during a Laguna flow reversal period. In some years, the City has no discharge to the Laguna. In comparison, nutrient contributions from the Beretta Dairy will affect low flow pools under all flow regimes. Thus, no location discounts/margins of safety are applied in the credit proposal. An argument could be construed that reductions at the Beretta Dairy could infinitely exceed equivalence in years with no City discharge, or only discharges under the first two flow scenarios. However, the City has only proposed credits with discounting that includes various conservative assumptions in edge-of-field load calculations, as well as bioavailability and application of a sediment delivery ratio.

To illustrate how all these equations, assumptions and discounting factors are applied to calculate nitrogen credits for the proposed BMPs at the Beretta Dairy site, the following text box shows 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.

	Location Information:			Description of watershed location:	
	Distance to nearest conveyance	1	feet	30	
	Delivery Ratio (Edge-of-Field)	100.00%	(Based on MN delivery ratio formula: distance$^{-0.2069}$)	49.47%	
	Area Served:	3.09	acres		
	Soil Information:				
	Classification:	Wright	(clay)	Woa	
	Hydrologic Group:	D			
	Fertilizer:	0	lbs N	0	lbs N
		0	lbs N available	0	lbs N available
	Manure Application Rates (repeated as necessary to account for all applications)				
	Season:	Spring and Summer			
	Manure Type:	Dairy- Lactating Cows Solid			
	Application Rate:	9.3	tons/acre		
	Application Method:	No Incorporation			
	N Availability Factor:	0.95	0.95 was selected based on the timing and results from the soil nutrient tests which were collected in late		
	Before:	10	lbs N/ton	After: 10	lbs N/ton
		9.5	lbs N available/ton	9.5	lbs N available/ton
		93	lbs N/acre	93	lbs N/acre
Equation 1		88.35	lbs N available/acre	88.35	lbs N available/acre
Equation 3					
	Total Nitrogen Applied	93	lbs N /acre	93	lbs N /acre
Equation 5		88.35	lbs N available/acre	88.35	lbs N available/acre
Equation 6					
	Residual Nitrogen	35	lbs acre every year becomes self canceling		
Equations 7	Nutrient Reductions from Manure Management				
		0	lbs/acre/year		
		0	lbs/acre/year		
Equation 11	Total N Loading	273	lbs/year		
Equation 12	Reduction from fencing	135	lbs per year		
	Contributing Area for Buffer	0.9	acres		
	Application of New Buffer:	Fenced	71%		
	Site N Loading Reduction From New Buffer:	59	lbs N/yr		
	Discount Factors		Description		
	Edge-of-field delivery:	100.00%	Next to conveyance		
	N Bioavailability:	85%	80% manure bioavailability/94.5% WWTP bioavailability		
	Fencing Nitrogen Credits with Bioavailability	115	N credits		
	Buffer Nitrogen Credits with Bioavailability	50	N credits		

Margin of Safety from implicit conservative assumptions (20% reduction in manure application rates and spatial and temporal location considerations for Delta Pond and Beretta Dairy)

Beretta Project Applications - Phosphorus

The proposed quantification methodology for phosphorus management practices at the Beretta Dairy is discussed here. Similar to nitrogen calculations, 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 edge-of-field reduction will reflect 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 Beretta 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. Equation 13 calculates the available phosphorus per acre and is repeated for every manure application occurring in a year. Equation 14 is used to sum all of the manure applications to calculate total available phosphorus (lbs/acres).

$AP_{M1} = PC_{M1} * PSC * AR_{M1} * AF$ (lbs/ac) **(EQ. 13)**

Where:

AP_{M1} = Available Phosphorus, in manure application number 1 (lbs/ac)

PC_{M1} = Phosphorus Concentration, from manure test or Table 8 (Penn State Agronomic Guide)

PSC = Phosphorus Source Coefficient, Table 8 (PA P-Index)

AR_{M1} = Application Rate, for manure applied in application (lbs/ac)
AF = Availability Factor, phosphorus availability regarding surface proximity

And;

$TAP_m = \Sigma AP_{MX,\,1\text{-}n}$ **(EQ. 14)**

Where:

TAP_m = Total Available Phosphorus, from all manure applications (lbs/ac)
AP_{MX} = Available Phosphorus, for each manure application event (lbs/ac)

Soil Phosphorus Loading Reductions

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 absorption 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 15 provides this assessment converted into pound and acre units[20].

ESP = SPC * SEDE * 2.205 * EF **(EQ. 15)**

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 16.

ESP-EoF = ESP * DR **(EQ. 16)**

Where:

ESP-EoF = Eroded Sediment Attached Phosphorus delivered to the Edge-of-Field (lb/yr)
ESP = Eroded Sediment Attached Phosphorus (Equation 21)
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

[20] Equation recommended by Beegle, D., Klineman, P., and Evans, B., from Penn State University as supported by Evans (Evans, 2002).

testing processed at the Beretta Dairy was for total phosphorus, and a back calculation can be made using the PA converter based on a regression for Mehlich 3 and TP soil samples.

SPC = SPT / 190 * 836 * 0.000909 [Mehlich - 3 TP] **(EQ. 17)**[21]

Where:

SPC = soil total phosphorus concentration (ppm)

SPT = soil phosphorus test results (ppm)

The constants in this equation reflect the PA DEP calculation of the Area Weighted Value of lbs/acre as calculated by Evans[20] 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 NRCS Technical Release 55 indicates:

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

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

S = 1000 / CN – 10

These 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 by the CA Water Gov records. Equations 18 and 19 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. 18)**
Q = (3.34 – 0.2(1.63))2 / (3.34 + 0.8 (1.63))	result = 1.96	**(EQ. 19)**

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 records (gathered on CA Water Gov), the mean precipitation in the Santa Rosa Plain (where the Beretta Dairy is located) equals 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 20 provides the estimated average annual rainfall runoff.

AARR = Q * 9.28 **(EQ. 20)**

Where:

AARR = Average Annual Rainfall Runoff, in inches

[21] Vadas *et al*., 2005

Q = Annual Volume of Runoff, in inches

Equation 21 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. 21)**

Where:

TDP = Total Dissolved Phosphorus, lost to runoff (lb/year)
STP = Soil Test Phosphorus
SPRF = Soluble Phosphorus Regression Factor[22]

SPRF = 2 * STP + 43.5 (*u*g/l), for the Mehilich test[23] **(EQ. 22)**

Equation 23 calculates the total dissolved phosphorus from manure delivered to the edge-of-field.

TDP-EoF = TDP * DR **(EQ. 23)**

Where:

TDP-EoF = Total Dissolved Phosphorus, to Edge-of-Field (lbs/ac)
TDP = Total Dissolved Phosphorus, lost to runoff (lbs/ac), from Equation 21
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 24

PFL = (TDP-EoF + ESP-EoF) * A **(EQ. 24)**

Where:

PFL = Phosphorus Field Loss (lbs/ac)
TDP-EoF = Total Dissolved Phosphorus at the Edge-of-Field, from Equation 21
ESP-EoF = Eroded Sediment Attached Phosphorus at the Edge-of-Field, from Equation 14
A = Acres, in the field

For Equation 24, 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 indicate a reduced available soil phosphorus reduction (ESP-EoF and TDP-EoF).

[22] Vadas *et al*., 2005 and Moncrief, 2002
[23] Vadas *et al*., 2005

To illustrate how all these equations, assumptions and discounting factors are applied to calculate phosphorus credits for the proposed BMPs at the Beretta Dairy site, the following text boxes 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.

Site Location Information: | **Description of watershed location:**

Distance to nearest conveyance: 1 feet | 30
Delivery Ratio (Edge-of-Field): 100.00% (Based on MN delivery ratio formula: distance^-0.2069) | 49.47%

Area Served: 3.09 acres

Soil Information:
Classification: Wright | (clay) | Woa
Hydrologic Group: D

RUSLE estimate factors:

R Factor:	117.22	From EPA Rainfall Erosivity Factor Calculator for Small Construction Sites at: http://cfpub.epa.gov/npdes/stormwater/LEW/erosivity_index-result.cfm
K Factor:	0.37	From NRCS Web Soil Survey at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm
LS Factor	0.15	From Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands
C Factor	0.42	From Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands
P Factor	1	(no erosion practice)
A= R*K*LS*C*P	2.73	tons/acre/year (if less than 1 ton/acre/year, use 1)

Erosion Rate: 2.73 tons/acre/year
Phosphorus Soil Test: 900 ppm Type: Mehlich - 3 As determined by TP soil test in cells I98:T104
Field Condition: Poor

Equation 19

Calculating Rainfall Runoff using the SCS Curve Number: Runoff from one 2yr, 24 hr storm event (in) 1.96

COUNTY	Climate Zone	Mean Precip (in/yr)	2 year, 24 hour rainfall event (in)	# of these events in 1 year:
Sonoma	3	30.98	3.34	9.275443102

Equation 20

Equations 18 & 25

County: Sonoma
Number of 2 year, 24 hour storm events in 1yr: 9.28
Average Annual Rainfall Runoff (in): 18.16 in
Hydraulic Condition: 0
Curve Number Based On: Pasture Poor Conditions
Curve Number: 89 S Value: 1.24 inches

2-year 24-hour rainfall event (in): gathered from CA Water Gov precipitation data available at:
Mean Precipitation (in/yr) is calculated from 30-yr record, missing data filled in using monthly long-term average.

Manure Application Rates

Season: Spring and Summer
Manure Type: Dairy- Lactating Cows Solid
Application Rate: 9.3 tons/acre
Application Method: No Incorporation
N Availability Factor: 0.95 — 0.95 was selected based on the timing and results from the soil nutrient tests which were collected in
Before: 4 lbs P2O5/ton | After
15.6 lbs P/acre
9.4 lbs P/acre; with potential to runoff

Equation 13

Phosphorus: 15.6 lbs P/acre
9.4 lbs P/acre; with potential to runoff

Equation 14

Phosphorus Snapshot

	Soil P	3.6	kg/ton P
Equations 15 & 17	Background Soil P Loss from Erosion	43.4	lbs/acre
	Soluble P Concentration	1043.50	ug/L (microgram/liter OR ppb)
Equation 21	Average Annual Runoff	1866200.54	L/ac
	Background Dissolved P Loss	3440340704.03	ug/ac
	Background Dissolved P Loss	7.57	lbs/ac
	P Load Available from Soils:	50.94	lbs/ac
Equation 24	P Load Available from Soils and Nutrient Applications:	60.31	lbs/acre
Equations 16 & 23	Site P Loading Available:	186.36	lbs P/yr
	Reduction Due to Fencing	92.20	
	Buffer Contributing Area	0.9	acres
	Application of New Buffer:	Fenced	69%
	Site P Loading Reduction From Application Changes:	36.33	lbs P/yr
	Field Total P Reduction:		lbs P/yr

List of Discount Factors

		Description
P Edge-of-field delivery:	100.00%	Next to conveyance
P Bioavailability:	93.5%	80% manure bioavailability/85.5% WWTP bioavailability
Bioavailability & Edge-of-Field		
Phosphorus Credits using Fencing:	86	P credits
Phosphorus Credits using Buffer:	34	P credits

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Table 1. Manure Type and Average Nitrogen Concentrations.

Manure Type	Average N Concentration		Units
Dairy- Lactating Cows Liquid	28	lbs/1000 gallons	1000 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 2. 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 >50ºF 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 <50ºF 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 3. 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 4. Residual Nitrogen Contribution from Legumes[1].

Previous crop	Percent Stand	High-productivity fields	Moderate-productivity fields	Low-productivity fields
		Soil productivity group[2] 1	Soil productivity groups[2] 2 & 3	Soil productivity groups[2] 4 & 5
		Nitrogen credit (lb/A)		
First year after clover or trefoil	>50	90	80	60
	25–49	60	60	50
	<25	40	40	40
First year after alfalfa	>50	120	110	80
	25–49	80	70	60
	<25	40	40	40
First year after soybeans harvested for grain.		---- 1 lb N/bu soybeans ----		

1. When a previous legume crop is checked on the Penn State soil test information sheet, the residual nitrogen for the year following the legume is calculated and given on the report. This credit should be deducted from the N recommendation given on the soil test report.
2. See table 1.1-1 in the basic soils section for information on soil productivity groups.

Table 5. Legume Crop Residual Nitrogen.

Legume Crop (no nitrogen application recommended)	Pounds of N Removed/Unit of Yield	Pounds of N Removed/Ac
Alfalfa (5 tons/A)	50	250
Soybeans (40 bu/A)	3.2	130
Trefoil (3.5 tons/A)	50	175
Clover (3.5 tons/A)	40	140

Comment: Although legumes will use N from manure and other sources, applying N may increase the competition from weeds and grasses. If you apply manure, limit it to an application rate that balances the crop's P requirement.

Table 6. Selected Properties and Typical Capabilities of Major Pennsylvania Soils.

Table 1.1-1. Selected properties and typical capabilities of major Pennsylvania soils (continued).

Soil series	*Depth class[1]*	*Drain class[2]*	*Leaching potential*	*Crop prod. group*	*Corn grain (bu/A)*	*Corn silage (T/A)*	*Alfalfa (T/A)*	*Clover (T/A)*	*Wheat (bu/A)*	*Oats (bu/A)*	*Barley (bu/A)*	*Sorghum/sudan (T/A)*	*Soybeans (bu/A)*
Hublersburg	D	WD	2	1	150	25	6	4	60	80	75	25	45
Huntington	D	WD	2	1	150	25	6	4	60	80	75	25	45
Klinesville	S	WD	2	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Kreamer	D	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Lackawanna	D[5]	WD	1[7]	2	125	21	5	3.5	60	80	75	21	40
Laidig	D[5]	WD	1[7]	2	125	21	5	3.5	60	80	75	21	40
Langford	D[5]	WD	1[7]	3	125	21	4	3	50	60	50	21	30
Lansdale	D	WD	2	2	125	21	5	3.5	60	80	75	21	40
Leck Kill	D	WD	2	2	125	21	5	3.5	60	80	75	21	40
Lehigh	D	MWD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Letort	D	WD	2	1	150	25	6	4	60	80	75	25	45
Lewisberry	D	WD	2	2	125	21	5	3.5	60	80	75	21	40
Lordstown	MD	WD	2	3	125	21	4	3	50	60	50	21	30
Manor	D	WD	2	2	125	21	5	3.5	60	80	75	21	40
Mardin	D[5]	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Meckesville	D[5]	WD	1[7]	2	125	21	5	3.5	60	80	75	21	40
Melvin	D	PD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Mertz	D	WD	1	2	125	21	5	3.5	60	80	75	21	40
Monongahela	D[5]	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Morris	D[4]	SWPD	2	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Morrison	D	WD	2	2	125	21	5	3.5	60	80	75	21	40
Murrill	D	WD	2	1	150	25	6	4	60	80	75	25	45
Neshaminy	D	WD	2	1	150	25	6	4	60	80	75	25	45
Opequon	S	WD	2	4	100	17	4[8]	2.5	40	60	40	17	30
Oquaga	MD	WD	2	3	125	21	4	3	50	60	50	21	30
Penn	MD	WD	2	3	125	21	4	3	50	60	50	21	30
Philo	D	MWD	2[7]	2	125	21	5	3.5	60	80	75	21	40
Platea	D[5]	SWPD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Pope	D	WD	2	1	150	25	6	4	60	80	75	25	45
Rainsboro	D	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Ravenna	D[5]	SWPD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Rayne	D	WD	2	1	150	25	6	4	60	80	75	25	45
Readington	D[5]	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Reaville	D	SWPD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Red Hook	D	SWPD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Sheffield	D[5]	PD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Shelmadine	D[5]	PD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Swartswood	D[5]	MWD	1[7]	2	125	21	5	3.5	60	80	75	21	40
Tunkhannock	D	WD[6]	3	2	125	21	5	3.5	60	80	75	21	40
Tyler	D	SWPD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Upshur	D	WD	1	2	125	21	5	3.5	60	80	75	21	40
Venango	D[5]	SWPD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Volusia	D	SWPD	1[7]	4	100	17	4[8]	2.5	40[8]	60	40[8]	17	30
Washington	D	WD	2	1	150	25	6	4	60	80	75	25	45
Watson	D[5]	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Weikert	S	WD[6]	2	4	100	17	4[8]	2.5	40	60	40	17	30
Wellsboro	D[5]	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Westmoreland	D	WD	2	2	125	21	5	3.5	60	80	75	21	40
Wharton	D	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Wheeling	D	WD	2	1	150	25	6	4	60	80	75	25	45
Wurtsboro	D[5]	MWD	1[7]	3	125	21	4	3	50	60	50	21	30
Wyoming	D	WD[6]	3	3	125	21	4	3	50	60	50	21	30

1. Depth classes: D = deep (>40 inches); MD = moderately deep (20 to 40 inches); S = shallow (<20 inches)
2. Drainage classes: WD = well drained; MWD = moderately well drained; SWPD = somewhat poorly drained; PD = poorly drained
3. Leaching ratings—these are only a relative rating of leaching potential. The higher the number, the greater the relative leaching potential.
4. A fragipan is present at 10 to 16 inches (0.25 to 0.40 meters) below the surface of the soil.
5. A fragipan is present at 16 to 40 inches (0.40 to 1 meter) below the surface.
6. These soils are well drained to excessively well drained.
7. These soils have a seasonal high water table that is less than 6 feet from the surface. Leaching potential may be a consideration of water resource use and water table following pesticide application.
8. Crop is not well suited for this soil.

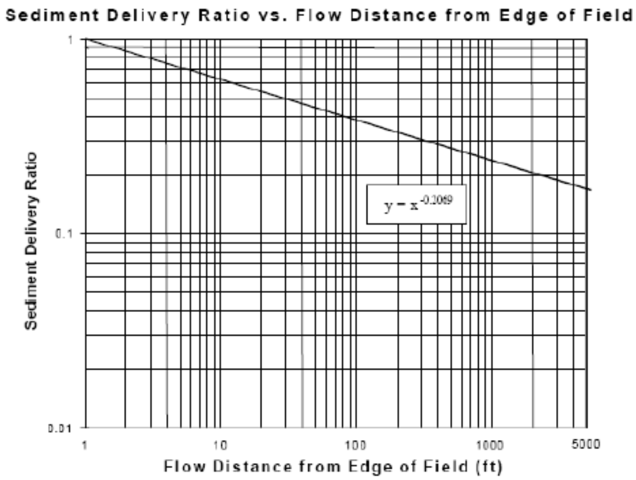
Table 7. Phosphorus Application Factors.

Application Method	Phosphorus App Factor (April-Oct)	Phosphorus App Factor (Nov-March)
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 8. 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/1000 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



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]

Figure 1. Sediment Delivery Ratio. (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.)

Attachment A

Santa Rosa Nutrient Offset Program Bioavailability Review

To: Lynn Small, City of Santa Rosa
Control Board

Date: July 3, 2012

From: James A. Klang, PE, K&A

cc: Dave Smith, Merritt Smith

RE: Santa Rosa Nutrient Offset Program Bioavailability Review

Addressing Nutrient Bioavailability in Offsets

This memorandum provides a brief review of published literature and selected water quality trading programs, analyzing various approaches for addressing nutrient (phosphorus and nitrogen) bioavailability between sources. This background information forms the basis for recommended bioavailability factors included in equations for calculating Santa Rosa nutrient offset credits. For water quality offsets, discount factors are often applied to nutrient load reductions to ensure that the environmental outcome from the offset is equivalent to the protection that would be achieved under conventional methods of additional wastewater treatment. Such factors are used in crediting proposals to account for bioavailability equivalence in the Santa Rosa Nutrient Offset Program for loading between non-point sources and the City's treated wastewater discharge.

Phosphorus:

The State of Minnesota addressed phosphorus bioavailability issues in the Statement of Needs and Reasonableness (SONAR) document written to support Water Quality Trading rule promulgation[1]. The Minnesota Pollution Control Agency (MPCA) based this document on a study entitled, "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" (Barr, 2004). An appendix to the 2004 study compiles phosphorus bioavailability by source. The table from this appendix is reproduced below as Table 1.

The literature reviewed for this memo most commonly determined bioavailability using a one-month period after release to a water environment. Applying the results of these bioavailability studies to longer time periods (as would be the case in the Laguna de Santa Rosa setting), provides a conservatively low range. The nutrients in the Laguna setting have substantially more time to undergo chemical and biological changes. To address bioavailability, a coefficient can be calculated that reflects the bioavailability of the different phosphorus forms discharged by each source.

[1] MPCA. 2010. A Scientifically Defensible Process for the Exchange of Pollutant Credits under Minnesota's Proposed Water Quality Trading Rules. Accessed July 3, 2012, available at: http://kieser-associates.com/uploaded/MPCA_Defensible_Processs_Exchange_Credits_072809.pdf

K&A used Table 1 to calculate recommended equivalence factors that incorporate phosphorus bioavailability considerations for the Laguna de Santa Rosa. An equivalence factor accounts for differences in phosphorus bioavailability from each type of source. For point source domestic wastewater treatment plants (WWTPs) using agricultural nonpoint source offsets (without presence of manure), the recommended equivalence factor is 58/85.5 (or 0.68). When working on agricultural sites that are seeking to improve manure management, this factor becomes 80/85.5 (or 0.94).

Table 1. Estimates of phosphorus bioavailability fractions for specific source categories (from Barr, 2004).

Phosphorus Sources		Fraction of PP that is Bioavailable (Range)	Fraction of PP that is Bioavailable (Most Likely)	Fraction of DP that is Bioavailable (Most Likely)	Fraction of TP that is Particulate (Most Likely)	Estimate of TP that is Bioavailable (Most Likely)
Publicly Owned WWTP for domestic use (effluent)		**0.6 - 0.8**	**0.7**	**1.0**	**0.5**	**0.855**
Privately Owned WWTP for domestic use (effluent)		**0.6 -0.9**	**0.8**	**1.0**	**0.3**	**0.94**
Commercial/Industrial WWTPs (effluent)		**0.2 - 0.8**	**0.6**	**1.0**	**0.3**	**0.88**
Agricultural Runoff						
	Manure Management	**0.5 -0.7**	**0.6**	**1.0**	**0.5**	**0.8**
	Cropland Runoff	**0.2 - 0.7**	**0.4**	**1.0**	**0.7**	**0.58**
Urban Runoff						
	Turfed Surfaces	**0.2 - 0.7**	**0.4**	**1.0**	**0.7**	**0.58**
	Impervious Surfaces	**0.10 - 0.5**	**0.2**	**1.0**	**0.5**	**0.6**
Forested Land		**0.2 - 0.8**	**0.3**	**1.0**	**0.8**	**0.44**
Roadway and Sidewalk Deicing Chemicals						
	salt	**0.2 - 0.8**	**0.6**	**1.0**	**0.2**	**0.92**
	sand	**0.1 - 0.3**	**0.2**	**1.0**	**0.8**	**0.36**
Stream Bank Erosion		**0.1 - 0.5**	**0.3**	**1.0**	**0.8**	**0.44**

Nitrogen:

Total nitrogen (TN) consists of dissolved and particulate nitrogen. Dissolved nitrogen can be further subdivided into inorganic and organic forms. Organic forms of particulate nitrogen also can be present. The dissolved inorganic nitrogen (DIN) forms (NO_2, NO_3 and NH_4^+) are commonly assumed to be 100 percent bioavailable (Berman, 1999). However, independent study findings regarding the bioavailability of organic nitrogen, dissolved organic nitrogen (DON) and particulate organic nitrogen (PON) suggest that the bioavailability of these forms might vary widely. The predictability of this range in bioavailability also might vary substantially, in part due to results based on algal bioassays (Seitzinger, 2002). DON in freshwater riverine systems was historically thought to be available only for bacterial uptake, rather than direct algal uptake. Research indicates that humic systems release more DON during summer periods than previously thought. Up to 20 percent of the DON can be photo-ammoniafied (Bushaw, 1996; Dagg, 2003).

The Laguna de Santa Rosa nitrogen loading affecting the low flow dissolved oxygen conditions, is likely in the forms of DON and PON that remain in the system for longer periods of time (e.g., when disconnected summer pools develop). These longer time periods likely expose the DON and PON to photochemical breakdown, zooplankton grazing and bacterial uptake resulting in NH_4-N or NO_3 release. Therefore, non-point source DIN is assumed to be 100 percent bioavailable (as discussed above) while DON and PON collectively are conservatively estimated at 20 percent bioavailable during the summer period for various Ag non-point sources. This is conservative because it does not include bacterial and zooplankton uptake. In the Laguna de Santa Rosa setting, the application of nitrogen bioavailability might be further complicated by limited laboratory or bioassay testing methods, which can use three-week incubation periods (Urgun-Demirtas *et al.*, 2008; Berman, *et al*. 1999). The use of this lab analysis is considered conservative due to the longer time periods and numerous chemical and biological activities that occur when the low flow polls trap nitrogen beyond the three-week timeframe of the lab tests.

Total Nitrogen to Dissolved Organic Nitrogen Ratios in Non-point Source Dominated Streams

Research indicates a broad range of ratios comparing stream TN to DON in non-point source dominated streams. Seitzinger (2004) conducted a literature review that suggested a range from 10 to 80 percent. Assessing the cropping and pasture runoff results from the Laguna de Santa Rosa TMDL source monitoring program, the 34-sample mean concentration was 2.6 mg/l TN. The dataset did not provide flow estimates. Therefore, a flow-weighted mean could not be generated. The mean concentration of the 34 samples of the total DIN fraction (NO_3- and NH_4-N) was 2.0 mg/l DIN.

A comparison of the two concentration means indicates approximately 76 percent of the total nitrogen is DIN. This can be roughly confirmed by solving for the DON fraction independently for each sampling event (TN - DIN = DON + PON) and then averaging the estimated percent of organic nitrogen results. The average organic nitrogen percentage of total nitrogen plus the 76 percent DIN fraction should be approximately 100 percent (not taking into account difficulties regarding sampling variability). The result of this calculation indicates approximately 29 percent of the total nitrogen is in the form of organic nitrogen. The 76 percent plus 29 percent is a reasonable indicator that these assumptions are within an acceptable range for the Laguna de Santa Rosa setting. Therefore, using a 75 percent bioavailable fraction as DIN and 25 percent as organic nitrogen form in non-point source runoff was deemed reasonable for nitrogen offset credits.

After combining the stream fractions of inorganic and organic nitrogen (and bioavailability of each), the TN bioavailability of crop and pasture sources can be estimated as follows: DIN bioavailability (75 percent times 100 percent bioavailable) plus organic nitrogen bioavailability (25 percent times 20 percent bioavailable) equals 80 percent total nitrogen bioavailability. This estimate is used in Ag settings with high organic content as a conservative estimate. However, as previously mentioned, in settings where there is a substantial presence of particulate organic nitrogen, the estimate is unreasonably low because it is based on three week lab analysis methods. In settings where the credit estimation method is dominated by PON, a higher bioavailability factor will be used.

The bioavailability of WWTP nitrogen also must be determined. Assessing the same forms of nitrogen (e.g., particulate and dissolved, further subdivided into inorganic and organic) the inorganic fractions are assumed to be 100 percent bioavailable. Literature indicates that secondary effluent WWTPs that denitrify have DON percentages around 10 percent of the TN discharged (Pehlivanoglu, 2004). However, advanced treatment with low total nitrogen levels (below 3 mg/l) increases the fraction of DON to 40-50 percent of TN (Chandran, 2010). Therefore, an analysis of the Laguna WWTP pond storage system sampling was performed. The results provided in Table 2 indicated that average concentrations were:

Table 2. Average nitrogen concentrations from Delta Pond samples (City of Santa Rosa, Delta Pond monitoring results, 2006-2010).

Nutrient Form	Concentration (mg/l)	Number of Samples
Nitrate Nitrogen	8.19	20 samples
Organic Nitrogen	1.34	24 samples
Ammonia nitrogen	0.48	14 samples
Total Nitrogen	9.8	Sum of nitrate, organic and ammonia samples (same day) from Delta Pond

These values indicate that approximately 89 percent of the discharged pond effluent was DIN (assumed to be 100 percent bioavailable). A conservative assumption for the Santa Rosa offset program would be to use a 50 percent bioavailable fraction of DON, assuming algal uptake is enhanced by bacteria (Pehlivanoglu, 2004). Therefore, the contributing DON bioavailable fraction is assumed to be 5.5 percent of the total nitrogen loading. The estimated wastewater bioavailable fraction result is 94.5 percent. The nitrogen bioavailability discount factor for cropping and pasture land offsets is determined by 0.8 non-point source bioavailability/0.945 WWTP bioavailability, or a discount factor of 0.85 times the credited loading reduction.

References:

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