Response to Comments

Nitrogen Dynamics at a Manured Grass Field Overlying the Sumas-Blaine Aquifer in Whatcom County

March 2014

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Purpose of This document

The Department of Ecology distributed a draft report to selected interested entities on March 29, 2013. In this Response to Comments document, we attempted to capture and respond to all comments received. Some electronic comments from reviewers made in the margins of the draft report were not included.

Significant revisions to the draft report have now been incorporated, including reorganization of the final report.

General Responses

This section offers responses to general comments on aspects of the study from one or more reviewers.

General Response 1: Recharge and precipitation estimates

One reviewer questioned the accuracy of the precipitation data. In the draft report we used data from the Lynden www.wundergound.com site for precipitation data on dates when the weather station at the study site was not working. At the suggestion of the commenter, we used precipitation data estimated from the Abbotsford, B.C. Airport climate station (Environment Canada) 7 miles east and slightly north of the study site. Precipitation data for 1,072 dates when precipitation data are available at both the on-site weather station and Abbotsford Airport were significantly correlated ($r^2 = 0.764$). The precipitation at the study site according to regression of the two data sets was 70.7% of that at Abbotsford Airport. Therefore, for dates when the on-site weather station was down, precipitation at the study site was estimated as 70.7% of the Abbotsford Airport value for that date.

In the final report we used the combined precipitation data (1,262 values from the on-site weather station and 418 values estimated from Abbotsford Airport) to estimate monthly recharge using a water balance method similar to methods used in Kuipers et al. (2012) and Malekani (2012) near Abbotsford, B.C.

Another commenter suggested we use the Water Table Fluctuation Method (WTF) for estimating recharge (Healy and Scanlon, 2010), but we found that this method overestimates recharge where the vadose zone is less than 3.5 m (11.5 feet) thick. Because the vadose zone at the study site varied from 0 to 11 feet thick during the study, the WTF Method was not applicable.

General Response 2: Estimating nitrogen loading

Several comments suggested using "plant-available nitrogen" for loading estimates rather than total N, because not all of the applied total N is immediately available to the crop. In the draft report we used only the total N method. In the final report we present and compare the 3 methods listed below. Mass balance results using the 3 methods varied widely. We selected the Sullivan (2008) method to estimate plant-available N because it is the most up-to-date and best-documented method for western Washington.

1. Sullivan (2008).
2. Sullivan (2008) does not account for the effect of higher than average soil organic matter concentration at the study site, which can affect soil mineralization. For this reason we used the part of the Sullivan method that estimates the nitrogen contribution for the current year and substituted 150 lb/acre for the amount mineralized from previous years (20 lb/acre for each 1% of organic carbon (OC) based on the average OC of 7.5% measured in the field during the study).
3. The method used in the draft (total nitrogen) except that the contribution from soil organic matter was deleted. This method uses total nitrogen, not all of which is available the year it is applied. However, this method assumes that the amount of nitrogen that is not available in the current year's applications is balanced out by the amount that becomes available from the soil from past years.

General Response 3. Soil nitrate was not designed to be an indicator of groundwater effects.

A few commenters noted that the post-harvest soil nitrate test (PSNT; Sullivan and Cogger, 2003) was not designed to be an indicator of groundwater nitrate leaching effects. We recognize that the test was not designed as an indicator of groundwater effects. However, the PSNT is one of the tools used to decide how to adjust future nutrient loading to a field. In this way it influences the potential leaching by guiding the amount and timing of future nutrient applications.

General Response 4: Show mean shallow groundwater nitrate concentrations (not just results for well AKG725) for comparisons with nitrogen mass balance (N_{Excess}) estimates and soil nitrate.

Two reviewers suggested including nitrate concentrations not only for the most affected monitoring well but also the mean of all 6 shallow monitoring wells in comparisons with nitrogen mass balance and soil nitrate results. We shifted the emphasis of groundwater analyses to the mean concentrations in the final report

General Response 5: Influence of upgradient groundwater on monitoring well samples

Dr. Thomas Harter (UC, Davis) suggested adding an explanation in the *Discussion* section of the influence of upgradient activities based on the velocity estimates in the draft report and the impact of recharge on vertical velocity.

We used this method to calculate the average age of the groundwater sampled and the average distance upgradient that the samples represented as described in the final report.

General Comments

This section offers general comments on aspects of the study from individual reviewers.

General Comment 1: Avoid spring manure applications

Dr. Thomas Harter (UC, Davis) offered these suggestions based on the groundwater response to spring manure applications described on p. 59:

> "From an agronomic perspective, this seems to indicate a strong recommendation for avoiding spring applications altogether, given that
> * there is substantial soil organic matter anyway
> * higher temps will mineralize SOM and make some nitrogen plant available
> * N uptake by the grass is still limited"

Wet conditions that postponed the first grass harvest until April 2, 2006 and the first manure application until April 27, (6 to 10 weeks later than in previous years) prompted this comment**:**

> "This indicates the need to recommend that annual application of manure must be allowed to vary according to the crop uptake and to consider the coldest/wettest conceivable year as the limiting case for sizing dairies/creating DNMPs.
>
> Dairies should be planning to either keep the herd size small enough to allow for complete manure disposal even in a relatively cold/wet year with a relatively short growing season, or have sufficiently large application area for that type of year, or have alternative export mechanisms for those years."

In another section, TH recommends that based on the climate and shallow water table, manure only be applied from May through August.

Response to General Comment 1: Comments were noted.

General Comment 2: Winter soil nitrate as an indicator of leachate concentration

Dr. Bernie Zebarth (Agriculture Canada) wrote (p. 19 comment) "there is considerable new evidence that winter nitrogen processes are more important than previously thought." In email correspondence, Zebarth (2013) describes agricultural research studies at 10 sites across Canada (including the Abbotsford, B.C. area) that indicates that winter mineralization can increase in the winter. They have found that the soil nitrifier and denitrifier communities are functioning throughout winter. They also found that bacterial community composition changes during the winter, suggesting adaptation strategies to cope with cold conditions.

Zebarth questioned using winter soil nitrate values to estimate leaching to groundwater, because the soil nitrate concentrations used do not include the nitrate mineralized during the late winter/spring that has already leached and so would underestimate the amount leached.

"In the winter period, any nitrate formed is leached as quickly as it is produced. Thus, winter soil sampling is of limited benefit as an indicator of leaching during the winter period. We have done winter sampling and so have the evidence of this. "(Comment on p. 67, last paragraph)

A related comment from Dr. Zebarth on p. 67, 3rd paragraph**:** "In the Pacific Northwest, it is unlikely the post-harvest test will over-estimate nitrate leaching. It is much more likely to under-estimate because when you measure at any one time, you do not measure all the nitrate that will leach. It (post harvest soil nitrate testing) is primarily a useful tool for identifying fields with excessive N inputs."

Response to General Comment 2: We recognize that the winter soil nitrate values used in this section of the report are probably an underestimate of the leaching potential. We removed this analysis, because the BACKCAST model provides a more accurate representation of nitrate movement in the January-March period.

General Comment 3: Incorrect locations for monitoring wells

Chris Clark, Whatcom Conservation District, noticed that the monitoring well locations in the draft report were not accurate and that this may have affected estimates for the hydraulic gradient and groundwater velocity.

Response to General Comment 3: On June 18, 2013, Ecology used a more sensitive GPS instrument (Trimble GeoExplorer 2005) than originally used to record the monitoring well locations. The more accurate measurements were used in the final report to re-draw water table contours, recalculate the horizontal groundwater gradients and recalculate groundwater velocity. The revised well locations do not affect the hydraulic conductivity calculations, because hydraulic conductivity is only a function of the soil properties at the specific location.

We used March 2, 2005 for the typical spring water level contours instead of March 28, 2007 in the draft report, because the 2007 elevations were the highest observed during the four years. The water table elevations in March 2005 were more representative of spring conditions observed.

Comments from Chris Clark, Whatcom Conservation District

p. x, 6th paragraph. Comment: The number of dairies has declined. The average size has decreased. The intensity has decreased due to:

- Requirements of farm plans
- Requirements of nutrient balance
- Reduced competition
- Switch to berry production allows use of ground in longer rotation

Response: We removed the reference to changes in dairy intensity and nutrient loading over the SBA per Whatcom CD's comment. A more detailed analysis would be needed to quantify nutrient loading over the aquifer.

p. xiv, Figure ES-3. Comment: This pie chart leaves out the contribution from the soil organic matter released. OM at 120 lbs is a substantial part of the nitrogen.

Response: Soil organic matter (SOM) contribution to the system was not measured. However we developed a pie chart using an estimate for soil organic matter contribution described in the final report, *Discussion* section.

We do not see a reference for 120 lb/acre contribution from SOM.

Comment: Each year is different, please indicate 1 year with 2 of the 4 years being quite different

Response: The amounts of nitrogen applied changed from year to year, but the percentages were very similar. Therefore we kept one chart as in the draft report.

p. xiv, last paragraph. Comment: PSNT (Post-harvest soil nitrate test) protocols ppm, see assumptions that are incorrect #--the conversion to lbs/acre at 3.5 is incorrect for this soil

Response: We changed the conversion factor to 3.1 (this assumes the soil bulk density at the site for 1-foot deep samples was 1.13 g/cc).

Throughout the rest of the report, the target nitrate level for the post-harvest soil nitrate concentration (Sullivan and Cogger 2003) is referred to as either 15 mg/kg (ppm) or 47 mg/kg for this site.

p. xv, 2nd paragraph. Comment: Fall soil nitrate test is REQUIRED by nutrient management plans.

Response: This point was added to the final report.

p. xvi. Comment: water sampled from wells at .1 pgm for ½ hour removes 3 gallons. The top recharge volume + nitrate.

Response: We used industry standard methods for low-flow purging and sampling. See *Methods* section for references.

Comment: Deep Groundwater wells tested were always low.

Response: Comment noted.

p. xvii, 1st paragraph. Comment: Incorrect

Response: (assuming the comment refers to 55 lb/acre target) All references in the draft to the 15 ppm target for post-harvest soil nitrate have been changed to 47 lb/acre based on the soil bulk density at the site (1.3 g/cm^3).

Comment: When the PSNT was followed, 20/24 of the tests are above the 15 ppm.
see assumptions that are incorrect 3e

Response: Only 10 out of 110 fall soil nitrate samples that we collected met all of the protocols in Sullivan and Cogger (2003) (sample 30 days after the last harvest and before 5 inches of precipitation beginning September 1). Two out of the 10 collected within the timing window recommended in the above guidance were collected after an additional manure application, which means the results do not represent the annual nitrogen loading for the year. All of the 10 samples exceeded the 15 ppm nitrate target. We added a table showing these data in the *Results* section.

Last paragraph. Comment: when too much was applied, or at the wrong time

Response: Comment noted.

p. xviii, 1st paragraph. Comment: extreme grass protein (nitrogen) levels give false crop demand.

Response: Comment noted.

2nd paragraph. Comment: incorrect, nitrate in manure is very low

Response: We agree that manure contains negligible nitrate. We changed the wording to clarify that some or all of the ammonium, and a portion of the organic nitrogen, would be mineralized at some point during the non-growing season, when recharge can quickly move it downward.

Comment: only if mineralization exceeds uptake

Response: Comment noted (that excess nitrate mineralized during the non-growing season will leach to groundwater if mineralization exceeds uptake). Recharge plays a role by moving at least a portion of the mineralized nitrate below the root zone before plants can take it up.

3rd paragraph. Comment: Indicating a lag time of recharge

Response: This comment refers to the evidence of nitrate, but not chloride, leaching to groundwater in January and February. The lag time between precipitation and recharge reaching the groundwater during the winter is typically short. Samples from our monitoring wells represented the most recent recharge. Comments from Dr. Zebarth substantiated that from their experience, nitrate left over from manure application during the growing season is quickly moved to groundwater with such a shallow water table. Nitrate at the top of the water table late in the winter represents nitrate mineralized after the growing season (in an on-going process).

In addition, the ratio of nitrate-to-chloride in groundwater samples should not diverge if the source of nitrate in the winter samples is from recently applied manure.

Comment: In Excess of needs and organic matter mineralization supply nitrate available for leaching if mineralization occurs

Response: See General Comment 2 and Response to General Comment 2 above for recent research on winter nitrate mineralization.

4th paragraph. Comment: Nitrate moves with recharge water, layer down layer, filling pore space with nitrate loaded leachate. Upon reaching saturation point moves down to the next layer. Only above the holding capacity does water move down. Only above saturation point does it move rapidly.

Response: The referenced sentence is no longer in the Executive Summary. Recharge is the mechanism by which residual nitrate is transported to the water table. Nimmo (2013) indicates that much, if not most, of vadose zone flow (unsaturated) is through preferential flow paths and can be very rapid. Recharge is discussed in the *Results* and *Discussion* sections of the final report.

Comment: Fall recharge 5.57" by Oct. 2, 2007? Check weather data.

Response: Figure ES-7. Correlation between the on-site weather station data and that from Abbotsford Airport indicated 29.3% less precipitation at the study site during the study. The *Results* section has been revised to reflect this.

p. xix, Figure ES-7. Comment: Abbotsford recharge #'s precip-et

Response: See preceding response regarding revised recharge numbers.

p. xx, 2nd paragraph. Comment: It was never meant to be

Use proper protocols to access. It is spelled out in procedures.

Taget is 15 ppm

Response: This comment refers to the statement in the draft report that the PSNT was not intended as an estimator of groundwater impacts. The authors agree. However, it has been used as a low-cost surrogate measurement. We did not set out to evaluate this test, but we believed it was important to point out our observations that the PSNT test is not effective for indicating groundwater impacts.

PSNT protocols used in the study are addressed in the *Methods* and *Results* sections of the final report.

p. xxi. Comment: nitrogen mineralized in the top foot, time to concentration, saturation and testing show movement when nutrients are applied or available at high rates.

Response: Comment noted.

p. xxii, 2nd paragraph. Comment: Neither method used proper protocols or calculations.

Response: These analyses have been revised. See the *Discussion* section in the final report.

p. xxiii, 4th paragraph. Comment: 15 ppm soil @24" of recharge = 10ppm for this soil.

Response: The conversion of 15 ppm soil nitrate, if mixed with 24 inches of recharge with Hale silt loam soil, would be around 8.7 mg/L nitrate-N. However, fall recharge (September through December) ranged from 0.98 feet to 1.57 feet, which would convert to 11 to 18 mg/L nitrate-N.
See the *Discussion* section for more detail.

p. xxiii, 6th paragraph. Comment: Your soil samples show the 2-4ft samples have fines, however deeper samples show coarse. Same as Kickerville.

Areas where manure applied similar soil to study.

Response: Comment noted. We did not investigate denitrification above the water table, but it is likely that a portion of the nitrogen loss that occurred was in the shallower, finer-grained soil zone either above or below the water table.

8th paragraph. Comment: Precip assumption not accurate.

Response: Statement regarding precipitation variation across the aquifer noted and removed.

p. xxiv, 2nd paragraph. Comment: monitoring does not reduce contamination. It is a tool to demonstrate the reversal.

Response: Comment noted and wording changed.

p. xxiv, Recommendation #1: Strikeout**:** Manure should not be applied during months with a significant water surplus and low soil temperatures. Stick to the study please.

Response: Comment noted.

Recommendation #2. Comment: Always

Response: We assume that this comment suggests adding "always" to the recommendation**:** "Where groundwater is well-oxygenated and denitrification rates are low, take special care to apply manure at the proper times and amounts." Comment noted.

Recommendations #4 and 5. Comment: More study needed
More frequent tillage and proper irrigation may reduce huge pool of OM.

Response: Comment noted.

Recommendations #6. Comment: Lag of nitrate does not equal mineralization.

Response: We revised this recommendation to state that manure application during the high recharge period (September through mid-March) is likely to increase nitrate leaching to groundwater. (Another commenter, Dr. Zebarth, commented that winter groundwater samples at the top of the water table in the Abbotsford, B.C. area represented winter mineralization.)

Additionally, nitrate and chloride from manure below the root zone move in tandem with recharge. Neither one lags relative to the other (with heavy fall/winter recharge). Both move quickly to the water table.

Recommendation #7. Comment: By following protocol, possibly before last application.

Response: Comment suggests that soil nitrate sampling may be improved by following the Sullivan and Cogger (2003) protocol and possibly sampling before the last manure application. Comment noted.

Recommendation #8. Comment: Strikeout**:** "Encourage cultivation of grass and perennial crops that can take up significantly more nitrogen than corn. " Corn was not part of the study.

Response: Recommendation regarding crop rotation has been removed.

p. xxv, Recommendation #10. Comment: Strikeout**:** "10. Track off-site manure transport and application and ensure that application is included in target field's nutrient management plan."

Response: Recommendation has been removed.

Recommendation #11. Comment: Strikeout**:** "11. Compare results from this study with results of the current Whatcom Conservation District's Application Risk Management System study."

Response: This recommendation was removed. However, the Whatcom CD ARM study results will provide a large base of information, together with this study, upon which to continue improving our understanding of nitrogen dynamics.

Last paragraph. Comment: Evaluate water table or top of water table?

Response: We changed the wording of this paragraph to refer to measuring near the top of the water table.

Comment: APPLY AT AGRONOMIC RATES

Response: Comment noted.

p. 2, 3rd paragraph. Comment: Incorrect statement.

If comparing to the 1997 #'s that decreased by 30%, the dairy MANURE is applied to more land. With no regulations on the Canadian side.

Response: We researched the statement referred to in this comment**:** "Fields formerly planted in grass to feed dairy cows are being converted to crops that take up less nitrogen and as a result, contribute a surplus of nitrogen similar to that on the Canadian side of the aquifer".

This statement is based on extensive Canadian research on nutrient balance at raspberry fields. Much more nitrogen is (or was) applied to raspberry fields than is (or was) removed in the crop. The point was that berry production is inherently imbalanced, because the crop removes so little nitrogen compared to the amount applied to the crop. Therefore the statement was retained.

The statement about the number of dairy farms and intensity was deleted for lack of data on the number of acres to which manure is applied.

p. 2, bullet list. Comment: available nitrogen

Response: "Methods for estimating plant-available nitrogen" was added.

Last paragraph. Comment: Not – calculatable?

Response: Comment questioned whether finding a balance between inputs and outputs of nitrogen to protect groundwater quality is calculable. The margin of error for mass balance calculations is probably large with current methods, but improvements in groundwater quality have been made in areas where greater attention has been focused on achieving a balance.

p. 6, 1st paragraph. Comment: Study site drained by surface ditches/waterways. (Listing of ditches)

Response: The fact that the site is drained by surface ditches and waterways was added to the text to provide a better perspective on site hydrology. .

2nd paragraph. Comment: Strikeout**:** "However the loading rate (lb/acre) was probably lower than it is currently, because the amount of cropland available for manure application was higher than today."

Response: The sentence was removed.

Last paragraph. Comment: 60 inches

Response: Comment that Abbotsford, B.C. Airport precipitation is 60 inches. The 30-year precipitation record for Abbotsford Airport (1973 to 2003) was 61 inches. The text was changed to 60 inches for the area around Abbotsford.

p. 7, 1st paragraph. Comment: Incorrect. Clearbrook is 47

Response: The comment refers to the average precipitation. Instead of Clearbrook, WA, all precipitation comparisons were changed to Abbotsford, B.C, because the records for that station are more complete.

p. 7, 2nd paragraph. Comment: Frequent malfunctions.

Response: Comment that weather station equipment malfunctions were "frequent" instead of "occasional." Precipitation details have been moved to the *Results* section and the number of days that equipment was down (418) is compared with the number of days working (1,262).

Comment: Should be 90+% of abbotsford

Response: Regarding the percentage of precipitation falling at the study site compared to Abbotsford Airport. See *Results* section for description of correlation between precipitation data for 1,072 days indicating that precipitation at the study site was 70.7% of that at Abbotsford, B.C. Airport.

p. 7, last paragraph. Comment: should be over 50 inches

Response: See *Results* section for description of annual precipitation estimates during the study based 75% on-site data and 25% from estimates based on the correlation with Abbotsford Airport**:** 40.0 to 46.2 inches/year.

p. 11, last paragraph. Comment: 120 lbs from soil organic matter

of the TKN applied ~50% was NH3 and 50% Organic. If 85% of the TKN is retained after volatilization. 50% is Organic N+35% NH3 N is retained only NH3 is volatilized.

It is assumed that the organic N will convert to nitrate during the growing season. From NRCS only a % will.

Response: As noted in General Comment 2 above, we have revised the analysis for plant-available nitrogen to the method used in Sullivan (2008). The *Discussion* section describes how this method is used and also provides comparison estimates using 2 other methods for estimating plant-available nitrogen.

p. 12, 3rd paragraph. Comments: Protocols dictate before 5 inches on medium to fine textured soils. And PSNT is only one tool

Response: This comment refers to the post-harvest soil nitrate test (PSNT) and collecting the soil sample according to the guidance in Sullivan and Cogger (2003) for timing before 5 inches of precipitation. Comment noted and addressed in the *Results* section.

The PSNT, when conducted according to the protocols in Sullivan and Cogger (2003), is a helpful tool for obtaining a rough estimate of how much nitrate is left over at the end of the season. However, the PSNT is probably always an underestimate of the amount of nitrate that was left over at the end of the season, because what already leached is gone. Nitrate at greater depths in the soil is not included. Also the PSNT is not sensitive enough to give a useful indicator of the resulting groundwater effect.

Comment. Depends on soil temperature and mineralization rate.

Response: The comment refers to the citation of Hirsch's (2007) finding that soil nitrate sampling after harvest did not capture all of the nitrate leached below the root zone. Comment noted.

p. 13, 4th paragraph. Comment: In the following sentence, "In addition to manure, dairy producers may supplement manure applications with commercial inorganic ~~nitrogen~~ fertilizer ~~during the summer~~.)

Response: The point of the sentence is to explain that inorganic nitrogen may also be added to manured fields. Therefore "nitrogen" was retained, and "during the summer" was deleted.

Paragraph 6. Comments: (Regarding the name of the method used to apply manure and referenced the 2009 VanWieringen report)**:** NOT SUBSURFACE DROP TUBES AND SPLASH PLATE

Response: VanWieringen and Harrison (2009) did not reference "drop tubes and splash plate". The report says**:** *"Manure was primarily applied using an aerator (also referred to as subsurface deposition or SSD)…. If possible, the neighboring dairy will apply manure using an injector (this happened in 2005 and 2008)."*

The terms aerator and splash plate were added to the description of the manure application method per VanWieringen and Harrison's (2009) description and reviewer's suggestion. The information regarding injecting manure in 2005 and 2008 was added.

p. 14, Figure 7. Comments: the manure still goes on top, the slit allows some to go down. But is not always fully inserted.

Response: Wording was added to indicate tines are not always fully inserted.

p. 16, Figure 8. Comment: recharge from

Response: Cox and Kahle (1999) provide several recharge estimates for the local area. The 16-30 inch estimate represents the Sumas-Blaine Aquifer as a whole. The map on p. 37 of Cox and Kahle (1999), based on modeling by Vaccaro et al. (1996), indicates that recharge in the study area could be 21 to 30 inches. We changed the figure to 21 to 30 inches.

p. 17, 2nd paragraph. Comment: You were referred to NRCS table. Do not mix or compare references on this subject.

The method was not subsurface deposition

Response: This comment refers to estimates for volatilization loss of ammonia. The NRCS Table WA 11-6a does not specifically address the type of manure application used in the study. Therefore we used Table 1 in Sullivan (2008) for the directed method**:** surface band (partial incorporation), which suggests 15% volatilization loss (of applied ammonium).

4th paragraph. Comment: significantly slower

Grass growth, Evapo-Transpiration rate coincides with mineralization rate if conditions allow.

Response: This comment refers to winter nitrogen mineralization rates compared to summer. See the winter mineralization explanation under general comments.

Comment noted regarding grass growth, ET.

p. 18, 1st paragraph. Comment: From October 1 to April 1, ET for Abbotsford averages 6 inches. The crop growth equals 2 tons DM requiring 120 lb N, 6 inches at 10 ppm nitrate only provides 12 lb of nitrate.

Response: Comment noted. This section was intended to provide general background for the reader.

p. 19, 2nd paragraph. Comment: Clarify high and above 5C, to the comparison to the reference document

Response: This comment refers to nitrogen mineralization rates. The reference cited is for a maize crop, where the winter temperatures were ~9 to 11°C, and the annual daily mean mineralization rates in the top 10 cm was 0.6 to 0.7 mg N kg^{-1} $day.^{-}$ The mineralization rate during the cold season was 27-48% of the yearly total.

The average winter temperature (November-January) measured during our study was 3°C. The range was 5.0° to 7.2°C. Because only one measurement was made during the months of December and January and weekly measurements in November, we do not have a good sense of the soil temperature during the winter. We did not feel that a high level of detail was appropriate; therefore, it is not included in the final report.

p. 20, bottom group of bullets (2nd bullet). Comment: One time during a dry April.

Response: Aquifer tests to characterize aquifer hydraulic characteristics provide information on the physical properties of the aquifer (saturated zone). These properties are not affected by moisture content of the overlying vadose zone and do not vary over time.

Bottom group of bullets (3rd bullet). Comment: One sample ran in triplicate.

Response: Triplicate subsamples for the split spoon soil sample from monitoring well AKG726 (40.0 to 41.5 feet depth) were analyzed for grain size as a quality assurance measure. We especially wanted to evaluate the precision of the hydrometer analyses for the samples with more fine-grained material. No change made.

p. 24, 3rd paragraph. Comment: Strikeout**:** "Therefore monthly soil nitrate sampling was sufficient to characterize availability to the crop during the spring and summer."

Response: Sentence was deleted.

4th paragraph. Comment: Spike in mineralization is driven by fall rains.

Response: This point is made in the *Discussion* section of the final report.

p. 28, last paragraph. Comment: April 2006 was not typical rainfall.
Why were these test not ran more than 1 time?
Well depths were 1-2 feet below typical

Response: See response above for similar comment on p. 20.

p. 34, Figure 16. Comment: please split this chart to include an estimate of OM nitrogen contribution.

Response: The chart has been revised in the final report *Discussion* section to show contribution of organic matter.

p. 36, mid-page. Comment: A discussion about late applications leading to nitrate in forages is needed. Applications late in the season, higher loss rates for ammonia part, higher mineralization rate from Organic N part at a time such as drought stress then rain leads to nitrate in the feed.

Response: This is outside the scope of the study.

p. 36, 1st paragraph under "Soil nitrate". Comment: 2 exact 60 ppm results are questionable.

Response: (Regarding duplicate soil nitrate results for 11/8/2006 in Figure 26 and Appendix Table I.5), WSU project lead checked QA for data collection and analysis for this date and found no anomalies. On 6 out of 111 other sampling dates, duplicate samples also had the same value. No change made.

Comment: Bulk density or assumptions based on OM determine soil weight. 3.1 should be used for this soil and OM%.

Response: All soil nitrate conversions were changed to reflect this (bulk density for this soil (0-10 inches)--1.3 g/cc) according to SCS Soil Survey for Whatcom County Area, Washington.

3rd paragraph. Comment: 20/24 soil nitrate samples were above 15 ppm following protocol.

Response: According to recommendations in Sullivan and Cogger (2003), 10 samples fit the recommended sample timing (30 days after the last manure application and before 5 inches of precipitation starting September 1). See *Results* section. All 10 samples exceeded 15 mg/kg.

p. 37, 2nd paragraph. Comment: variability when outside protocol

Response: Comment noted.

7th paragraph. Comment: use the nrcs reference, strikeout Clark, 2012 reference

Response: Implemented comment and corrected NRCS reference.

p. 40, 3rd paragraph. Comment: hydographs are inaccurate due to well locations.

Response: Well locations were updated and water level contours redrawn. Hydrograph elevations were not affected by updated well locations, because well elevations are based on the assumed elevation of

AKG721 (134.00 feet—NAVD88). Surveyed elevations of the other wells are relative to the elevation of AKG721 (Appendix G).

p. 41, 1st paragraph. Comment: Or Jackman Rd ditch was draining the other side of the field

Response: This comment refers to influences on groundwater flow during the low water table season. Comment noted.

Equation 3. Comment: Incorrect measurement

Response: This comment refers to the distance shown in the draft report between the most upgradient and downgradient wells being inaccurate. In the final report, a more accurate method was used for calculating hydraulic gradient that takes into account the variation across the site. The revised method is described in the report in the *Results/Groundwater Conditions* section.

p. 42, Equation 5. Comment: inaccurate because dh/dl is wrong

Response: This comment refers to the groundwater velocity calculations. Well locations were revised as described in General Comment 3. Velocity estimates were revised based on updated well locations.

Table 5. Comment: Porosity ranges

Response: This comment refers to the ***effective*** porosity value used to calculate groundwater velocity, 0.25. This is the most commonly used value for similar aquifers in Puget Sound glacial outwash deposits. Higher effective porosity values shown in Cox and Kahle (1999) may represent areas with substantial clay material. Comment noted.

p. 43, Equation 6. Comment: Specific yield is questionable.

Response: Comment noted. Specific yield and effective porosity are interchangeable terms. See preceding response.

1st paragraph. Comment: not December, usually January,

Response: This comment refers to the highest water table elevation used in the draft report for the recharge calculation. After further research into the water table fluctuation method for estimating recharge (Healy and Cook, 2002), we found that this method is not reliable for very shallow water table settings. Therefore we used the recharge estimation method used by Malekani (2012) and Healy and Scanlon (2010). See *Results* section for details.

2nd paragraph. Comment: Splitting recharge is inaccurate

Response: This comment refers to separating recharge into fall and spring seasons. Comment noted.

p. 51, 3rd paragraph. Comment: Incorrect. All over the county, but minimal dairy acres

Response: This comment refers to the low hydraulic conductivity at the site compared to other parts of the SBA. We do not have data to quantify the number of acres of coarse vs. fine-grained soils and aquifer material. Comment noted.

5th paragraph. Comment: Incorrect due to incorrect hydraulic gradient

Response: Hydraulic conductivity is a property of the aquifer and is not affected by hydraulic gradient.

p. 52, 4th paragraph. Comment: velocity incorrect due to wrong hydraulic gradient

Response: The velocity has been updated in the final report to reflect the revised hydraulic gradient.

6th paragraph. Comment: mass balance used incorrect loss values, math is incorrect.

Response: The mass balance analysis has been revised in the *Discussion* section of the final report.

p. 53, Equation 8. Comment: Are you assuming all manure TKN is mineralized?

Response: We have revised the *Mass balance* section in the final report. Three methods for calculating plant-available nitrogen input are presented. Method 3 in the final report is similar to the draft report method (assumes that the amount of N mineralized from soil organic matter balances out the TKN from the current year's manure application that is not available), but in Method 3, unlike the method shown in the draft report, no additional nitrate is added.

1st and 2nd bullets. Comment: Use NRCS references, computer for each application type.

Do not use my name unless you are using my numbers. You are bringing in different reference values to add onto a complex set of assumptions.

Response: Comments noted and implemented.

p. 54, Table 8. Comment: this is not the correct calculation. Do not use my name unless you follow the process. It is spelled out in Chapter 11 AWMFH.

Response: Comment noted. Three new calculation methods for plant-available nitrogen are presented in the *Discussion* section.

p. 57, 3rd paragraph. Comment: assumptions affecting flow rate need to be addressed.

Response: This comment refers to the average groundwater flow velocity estimate in the draft report. We revised this section based on extensive comments from Dr. Thomas Harter, U. of California, Davis.

3rd bullet. Comment: Assumptions incorrect due to error in measuring hydraulic gradient.

Response: This comment refers to the time of travel estimate. All distances have been re-calculated based on revised well locations.

p. 58, 4th paragraph. Comment: Add mineralization rate of soil om and manure organic nitrogen sources (to the bullet list).

Response: Mineralization rate of soil organic matter (OM) and manure organic nitrogen sources are difficult to measure and were not measured during the study. We agree that these nitrogen sources are very important for a reliable nitrogen balance. The plant-available nitrogen contribution from soil and manure organic matter was estimated in the final report using the Sullivan (2008) method and is in *Discussion* section.

Last paragraph. Comment: these calculations are not based on AWMFH and differ from those used to base agronomic rates for DNMP's.

Response: Comment noted. The revised report provides 3 estimates of plant-available nitrogen as recommended by reviewers. The revised calculations (Method 3) are similar to AWMFH methods, although atmospheric nitrogen is not included as an input in AWMFH. The estimated annual atmospheric input used, however, was very small (8 lb/acre).

p. 59, 4th paragraph. Comment: Mineralization of soil and manure organic sources of N contribute to fall spike in nitrogen. This has been documented, usually grass will keep up.

Response: The influence of wetting on mineralization spikes was added to the text.

6th paragraph. Comment: minimal

Response: This comment refers to information in the draft report regarding mineralization of nitrate in the February-March period. Our analysis added in the final report, using the groundwater BACKCAST model, estimated an average of 49 lb/acre of nitrate leached in the January-March period during the study.

Dr. Bernie Zebarth commented that nitrate loading to the water table during the winter becomes a good estimate of the over-winter mineralization. See Kuipers et al. (2012) for an example.

Comment: Plant needs are more than mineralization of organic matter.

Response: Comment noted.

Comment: Quantify substantial, during the study first cutting used

Response: This comment refers to the sentence in the draft report, "Applying manure before the crop can efficiently take up nitrogen in the earliest days of the growing season risks leaching substantial nitrate to groundwater." The groundwater BACKCAST model indicated that an average of 49 lb/acre of nitrate leached in the January-March period during the 5 wet weather seasons monitored.

p. 62, 1st paragraph. Comment: GDUS

Response: Correction made.

Last paragraph. Comment: Rainfall data is incorrect

Response: See General Response 1 above and explanation in the *Results* section of the final report.

p. 65, Equation 10. Comment: Recharge does not reach test well in September.

Response: Comment noted. Recharge may or may not reach the test well in September, but recharge by definition is water not taken up by ET that eventually reaches the water table. Equation 10 (draft report, Equation 20 in the final report) averages leaching for the fall period and assumes that the available soil nitrate mixes with the total amount of recharge for the fall/early winter period (September through December).

p. 66, Table 9. Comment: Weather data incorrect; recharge volume incorrect

Response: See General Comment 1 above.

1st and 2nd paragraphs. Comments: Use of protocols removes variability

Calculating mass balance is step 1
Soil test 2
Reviewing when nutrient applications were made 3
Adjusting 4

Response: This comment refers to use of protocols described in Sullivan and Cogger (2003). As noted previously, only 10 out of 110 soil samples during the study met the protocols. Comment noted.

p. 67, 1st paragraph. Comment: fluctuation in soil moisture, from dry to wet, spurs mineralization then causes leaching.

Response: Comment added.

5th paragraph. Comment: Characterize # of nitrate from the study, including temperatures where they saw the biggest.

Response: This comment refers to the Trindade et al. (2001) reference regarding winter nitrate mineralization. The amount of N mineralized during the winter (November-February) at site PF was 58 kg N/ha (52 lb/acre) in 2 years. At the VC site, 64 and 60 kg/ha (57 and 55 lb/acre) of N were mineralized in 2 years. Air temperatures at the 2 sites during the winter (November-February) were 7-12 C° (PF site) and 10-15 C° (VC site). Soil temperature at 5 cm depth was similar to air temperature during the winter months. This degree of detail was not considered appropriate for inclusion in the report. Therefore no change was made.

p. 68, Table 11. Comment: This assumes that the plant only takes up water as ET? the concentration of nitrate in the water with 6 inches of et during the winter time would remove 2/3 of the nitrate in the water if perfectly dissolved. The plant could use 120 lbs.

Response: This comment refers to Table 11 in the draft report, which showed estimated leachate nitrate concentrations based on soil nitrate concentrations observed and recharge. Dr. Bernie Zebarth (Agriculture Canada) advised us that this mid-winter analysis is not valid, because nitrate leaches so quickly in the winter that soil nitrate concentrations only represent what has not already leached and are therefore underestimates of the actual amount of nitrate leaching.

We did not measure crop removal of nitrogen during the winter.

p. 69, Top of page. Comment: Or immobilized by the root structures that die back that create a lag in the timeline.

Response: This comment refers to the title of the subsection in the draft report**:** "Estimating the mass of nitrate left over at the end of the growing season." Comment noted.

p. 69, Table 12. Comment: Incorrect calculation-- 2006-2007 are negative numbers…even though I don't agree because of the late application.

Response: The nitrogen mass balance methods have been revised in the final report. See General Comment 2 above. All 3 methods in the final report show negative values for 2006 and 2007.

Equation 11. Comment: Fall recharge starts in November, soil reaches saturation and movement occurs. Water testing high concentration nitrate fingers if anything.

Response: Recharge was calculated as the difference between (precipitation + irrigation) and (ET). When (precipitation + irrigation) exceeds ET, then recharge occurs. Saturation is not required for soil pore-water to move to the water table (Nimmo, 2013). The recharge period, September to December, represents the water that reaches the water table during the fall/early winter period and represents the amount of water to theoretically mix with the end-of-season residual nitrate. Therefore no change was made.

p. 72, 1st paragraph. Comment: untrue-dairy fields in the aquifer are typically on the finer grained soils.

(In separate written comments**:** the majority of farm plans are not over coarse-grained soils only ~3,000 acres out of ~30,000 acres in farm plans.)

Response: Comments noted. We did not evaluate soils relative to dairy field locations. The study site appears to be a typical soil type for dairy fields in the county. We changed the wording to reflect this.

p. 73, 2nd bullet. Comment: early applications are specific to managers showing test results and ability to manage.

Response: This comment refers to the sentence in the draft report, "This indicates that the application of manure during the months when precipitation exceeds evapotranspiration (September through March) presents a high risk for nitrate leaching to groundwater." It is not clear which test results the comment refers to. Results from this study indicate that nitrate was leaching to groundwater during the January-March period at the study field (when no manure was applied) at an average of 49 lb/acre/year under model assumptions which are relatively conservative (the mixing depth was probably larger than 2 feet, which would increase the estimated mass of nitrate leached). If manure were applied during the late winter period, at least a portion would likely become available for rapid leaching even with crop uptake. No change was made.

p. 75, 3rd paragraph. Comment: 15 ppm in a soil test with 24 in recharge = 10 mg/L

Response: This comment refers to the statement in the draft report, "The current fall soil nitrate target recommendation of 15 mg/kg was not developed to account for groundwater quality and may consistently produce fall/early winter leachate concentrations that are greater than the groundwater quality standard of 10 mg/L nitrate-N."

With soil bulk density of 1.13 g/cc, then 15 ppm nitrate = 47 lb/acre nitrate. 15 ppm then translates to 11-18 mg/L nitrate-N using the fall/early winter recharge (September-December) during the study (0.98 to 1.57 feet) as described in the *Discussion*. This does not include soil nitrate available below one foot depth. No change was made.

6th paragraph. Comment: If Cox and Kahle recharge numbers are correct that 15 ppm is protective.

Response: Cox and Kahle (1999) report several recharge estimates for the Abbotsford-Sumas Aquifer area. The recharge map (Figure 11 of Cox and Kahle (1999)) based on a regression model for recharge across Puget Sound indicates an annual estimated 26-30 inches recharge at the site. This compares favorably to the annual recharge estimates that we reported (Appendix J, Table J.5). However, the amount of recharge that carries the nitrate left over at the end of the growing season is only a portion of the annual recharge (12 to 19 inches during the study). No change was made.

p. 76, 2nd paragraph. Comment: not if recharge is calculated correctly.

Response: This comment refers to the statement in the draft report, "Increasing precipitation from west to east over the SBA translates into increasing recharge to groundwater from west to east. Increasing recharge can hasten nitrate movement below the root zone which increases the load of nitrate to groundwater."

The point of the sentence was that increasing recharge could hasten leaching of soil nitrate before the crop can take it up, compared to lower recharge areas where nitrate would linger longer in the root zone. This sentence was removed, because it was not a key finding.

p. 77-78. Comments: Strike-outs suggested:

a. Improving the monitoring needed to evaluate the effectiveness of measures to reduce nitrate loading
b. Manure should not be applied during months with a significant water surplus (October through March)
c. Minimize the use of inorganic fertilizer on manured fields.
d. Avoid applying manure to forage crops during the first season following tillage
e. Improve soil nitrate sampling by taking multiple samples in late September
f. Track off-site manure transport and application to ensure that application is included in target field's nutrient management plan. Encourage cultivation of grass and perennial crops that can take up to 4 times more nitrogen annually than corn.
g. Compare results from this study with results from the current Whatcom CD's ARM study

Response: Recommendation a was moved; b was reworded; c, e, f, and g were removed.

p. 78. Comment: following protocols

Response: This comment refers to the recommendation for improving soil nitrate sampling. The recommendation was revised.

Comment in letter from Chris Clark, May 16, 2013

Comment: Finally it is important for me to register my concern about the failure to follow sampling protocols. Chief among them was leaving the well head open to a manure application. We are all human. So, I can understand that it can happen. In my professional opinion, which I believe represents the larger scientific community, it can significantly negatively affect sampling accuracy, our credibility and future collaborations. Such lapses call into question the validity of studies. As we have seen recently folks take legal actions predicated upon the results. Given what can be at stake, it is critical that folks follow protocols precisely every time.

Response: This comment regarding the effect of the cap for monitoring well AKG727 being left off during a manure application in 2005 is addressed in the *Quality Assurance* section of the final report.

Comments from Bernie Zebarth, PhD, Agriculture and Agri-Food Research Canada

Dr. Zebarth provided many detailed, specific comments electronically on a copy of the draft report. We have included the main comments in this summary. The complete comments are available from the lead author.

p. xv, Figure ES-4. Comment: It is important to note that you are comparing two different things here. The red bar indicates the residual nitrogen as nitrate at the end of the growing season in a given year under the management and environmental conditions for that year.

The blue bars are a nitrogen surplus calculated on a TOTAL nitrogen basis. Much of the N inputs are in the organic form in the manure, and consequently, the timing of the conversion of this organic N to mineral N (and consequently to nitrate) is uncertain.

Such mass balances do not consider internal soil N cycling, and as a result are commonly applied over time periods longer than one year. That is, they assume the system is at an equilibrium, such that the internal N cycling can be ignored.

In some ways, the nitrogen surplus, calculated from the mass balance over the four year study period might be more meaningful than the nitrogen surplus in any given year. In fact, what you may want to compare is the N balance over the four years against the average residual nitrate over the same four years. That might be a more helpful comparison.

Response: In the final report, we conducted an annual mass balance analysis over 4 years. We also calculated the average mass balance over 4 years. See General Comment 2.

p. 12, 2nd paragraph. Comment: Or more correctly, the balance between the amount of N which is available to the plant, and the amount removed by the crop.

Much of the N supply in a given year comes from the soil itself, not necessarily a nitrogen input in that particular year.

Response: This comment refers to the sentence in the draft report**:** "Results of the fall soil nitrate test are used to evaluate the balance between the amount of nitrogen applied and the amount removed by the crop." We changed the wording and used plant-available nitrogen in most analyses in the final report.

p. 73. Comment: Bullet--Rate and timing of recharge—The timing of the recharge is clearly important. I am less convinced that the amount of recharge is all that important. At least on the Canadian side, the nitrate in the soil profile is leached out relatively quickly by the fall/winter rainfall events. Additional recharge after that doesn't necessarily increase the quantity of nitrate leached.

It is possible that there are indirect relationships. For example, do winters with greater recharge also have, for example, warmer temperatures which include more mineralization?

Response: The comment refers to the statement in the draft report, "the more recharge that moves through the root zone, the more the nitrate stored in the soils will be transferred to the dissolved phase…" The statement has been deleted.

p. 75, 6th paragraph. Comment: This will be an interesting point for discussion. You can change the guideline, but whether one can realistically achieve a reduced guideline is the question. You could easily mineralize more than enough nitrate to exceed the guideline from re-wetting of dry soil in some fields…"

Response: This comment refers to the statement in the draft report**:** "These points suggest that the post-harvest soil nitrate guidance for the amount of soil nitrate considered acceptable with no changes in management needed should be reviewed and revised to take groundwater impacts into account." This conclusion brings attention to the connection between the soil and groundwater that is not recognized in the guideline as currently used. The current "acceptable" level for post-harvest soil nitrate by the Washington State Department of Agriculture is 45 mg/kg, triple the guideline in Sullivan and Cogger (2003).

Comment noted.

p. 77, 1st recommendation. Comment: This is tough. We can discuss how one might do this, but there are significant challenges.

Response: This comment refers to the recommendation**:** "Ensure that nitrogen inputs (manure, fertilizer, irrigation water) and outputs (crop removal) are measured accurately for use in mass balance calculations. This is especially important in areas where groundwater nitrate already does not meet the drinking water standard OR areas with limited denitrification potential."

Comment noted.

3rd recommendation. Comment: Which is most of the aquifer?

Response: This comment refers to the recommendation**:** "Where groundwater is well-oxygenated and denitrification rates are low, take special care to prevent overapplication or application during the high recharge season."

We do not have data on the denitrification/oxygenation state of the aquifer. We don't know how these conditions vary across the aquifer.

Comment noted.

5th recommendation. Comment: I'm not sure it is that simple. The irrigation both increases N supply but also N demand.

Response: Comment noted.

Comments from Thomas Harter, PhD, University of California, Davis

Dr. Harter provided many detailed, specific comments electronically on a copy of the draft report. We have included the main comments in this summary. The complete comments are available from the lead author.

p. xxiv, Recommendations. Comment: You might want to insert a short section here that identifies the key challenges that recommendations have to address/overcome:

- Availability of proper management practices
- Knowledge of proper management practices
- (to me, it appears that a key challenge is that) the pasture growing season overlaps with the groundwater recharge season, which means that nutrients must be available at the same time when groundwater recharge occurs…..

Response: Comment noted. These points have been added to the *Recommendations* section of the final report.

p. xxv, last paragraph. Comment: On-farm mass balance is also the most important tool to help the farmer with managing nutrients and identifying potential courses of action to address high nitrate in groundwater. Monitoring wells by themselves cannot do that. Hence, mass balance would ideally be an intrinsic part of a monitoring program.

Response: This has been added to the *Recommendations* section.

p. 18, 5th paragraph. Comment: I am not an agronomist. So I don't understand the DNMP target of 55 lb N/ac for agronomic purposes, in the fall.

It seems to me, it would be best if the nitrate and ammonium N in the fall was close to zero (much less than 55) with new N applied at the beginning of the next growing period, in the spring? Perhaps you can explain in the above nutrient cycle or in the agronomic section. And also drop a note in the above section on DNMPs to explain the 55 lbs/acre rationale (to answer the question what is it used for?)

Response: The history of the 55 lb/acre (15 mg/kg) target for post-harvest soil nitrate was added to the DNMP description in the final report.

Comments from the U.S. EPA

General Comments

Comment:

1. The central theme of the report is evaluating the use of annual excess nitrogen mass balance as a nutrient management tool. This is in effect a partial mass balance, created by calculating input N minus that portion of the output N which is not made up of nitrogen leaching out of the soil; the difference is assumed to be nitrogen that can eventually leach. However, the difference can also be due to that plus artifacts caused by mis-estimates of mineralization, volatilization, or denitrification processes that vary year to year and across the site. The report tries to correlate these calculated annual excess nitrogen values to the "winter mean" (i.e., Nov-Dec) ground water nitrate values, and the results are mixed. In one portion of the report (page 56) you describe a fairly good comparison, because you made (and described) the decision to select one well (AKG725, Figure 46) because it was located in a portion of the site with the lowest potential impact from denitrification. We noted a contradiction in other sections of the report (e.g., page 70) where you show the same data but conclude that this approach is not a reliable method of predicting ground water nitrate. Because the annual excess nitrogen value is a single estimate considering all available data throughout the year, the question arises as to why you chose to compare it just to winter mean ground water nitrate values, and not each of the ground water nitrate values since some leaching occurs yearlong, especially after periodic land application events.

   The report concludes that this is not a reliable tool for predicting ground water impact from nitrate, but then states it may still be useful for balancing plant needs with manure application. How would this calculated value be used? Considering all of the monitoring, measurements and assumptions required to produce this calculated estimate, wouldn't it be more efficient and economical to instead just monitor water table nitrate concentrations periodically, especially in this region where the water table is shallow and easily accessible? This study shows that the amount of manure/fertilizer nitrogen that was applied each year was directly proportional to the annual excess nitrogen mass estimate with good correlation ($y = 0.77x - 304$; $r^2 = 0.9729$). Examination of Equation 8 and Table 8 shows that manure/fertilizer loading was the main driver-atmospheric deposition, soil matter mineralization, ammonia volatilization, and denitrification were all assumed to be constant year to year, and even crop production did not vary much year to year in this case. Another question would be that if this annual excess nitrogen is not proportionately impacting ground water nitrate levels, where is it all going?

   In summary, we are left with the understanding that while the annual excess nitrogen mass estimate may not be a good predictor of ground water quality, it may be useful for better matching manure/fertilizer nitrogen loadings to crop demand. However, it is unclear how exactly this would be used and whether the end result would justify the expense of the extensive annual monitoring required.

Response: We agree with the comment that nitrate leaching probably occurs year-round. We chose to compare annual nitrogen loading only to winter groundwater nitrate concentrations, because previous studies in the area indicated that the largest movement of nitrogen to the water table occurs in the fall, when rainfall is heavy and after the warm, dry summer period. Indications of nitrate leaching effects on groundwater during the spring are also included in the *Discussion* section.

We added comparisons of the mean winter nitrate concentration for all 6 shallow monitoring wells.

It was beyond the scope of this report to evaluate whether groundwater monitoring is more cost effective than detailed mass balance analysis.

Comment:

2. We suggest that the report clearly state upfront that the assessment of direct ground water impact is restricted to the upper reaches of the aquifer only, and may not represent the aquifer as a whole. This is a fairly unique hydrogeological setting in that the shallow water table ranges by about seven feet annually and that each year the soil is saturated in the winter up to near the ground surface (Figure 28). This allows for saturation dissolution of soil nitrate which can cause very high nitrate values, and may allow substantial organic carbon to be transported along with the nitrate. The ground water sample inlets and the low-flow sampling techniques are designed to acquire ground water samples as close to the water table as possible. Assuming that Figure 12 is correct, any high concentrations of nitrate in shallow ground water should "dive" downward as bulk ground water flows beneath the region. If unmitigated by dilution or other processes, nitrate levels measured at the top of the water table that are above the MCL could potentially cause nitrate levels in downgradient drinking water wells to exceed the MCL. According to the data collected from the one deep well beneath the site, nitrate is absent, but ammonium levels are higher than those in the shallow wells.

   There is no nitrate (but again minor levels of ammonium) in the upgradient deep private wells. One explanation for this could be dissimilatory nitrate reduction to ammonium, which occurs when nitrate becomes limiting relative to utilizable organic carbon. The amounts of ammonium produced are so minor that this would not have much impact on the nitrate loading, but if this process were occurring then it would be reasonable to assume substantial denitrification occurring in the aquifer matrix above. It would have been interesting if some downgradient private wells had been sampled, or if some other wells had been installed within the mid-levels of the aquifer or downgradient of this site to evaluate whether high nitrate levels observed in the shallow aquifer have migrated deeper into the aquifer.

Response: Comment noted. We added a statement in the *Conclusions* section of the final report that the study was designed to characterize groundwater quality near the top of the aquifer and that we cannot make inferences about the water quality in the aquifer between the shallow and deep wells sampled.

This was not an unusual water table situation for agricultural areas in Washington that either: (1) receive relatively high precipitation in the winter (western Washington) or (2) receive irrigation water for forage crops (eastern Washington).

Comment:

3. The stated purpose of the study on page xi was to "... conduct a field study to evaluate the effectiveness of Dairy Nutrient Management Plans (Chapter 90.64 RCW) in protecting the quality of the Sumas-Blaine Aquifer." The results of the field study indicate that the post- harvest soil benchmark used in Nutrient Management Plans is ineffective in preventing groundwater contamination. The study's conclusions do not circle back around to this central question and clearly state whether NMPs are or are not effective as currently implemented, even though the data support a clear conclusion. Presenting a clear, conclusive response to the initial question that was posed would strengthen the report.

Response: We added a paragraph in the *Conclusions* section of the final report, stating that the post-harvest soil nitrate test is not a valid method to predict groundwater nitrate effects and the reasons. We did not have access to any Dairy Nutrient Management Plans as such. Therefore we were not able to evaluate how they are implemented.

Comment:

4. The report concludes that "estimated excess nitrogen" is a more reliable predictor of groundwater impacts than measuring soil nitrate levels. It is not clear to EPA that this conclusion is supported by the data. However, if the conclusion is supportable, it is an important concept that should be highlighted. Similarly, the concept that the current soil nitrate target recommendation of 55 lb/acre criteria does not take into account groundwater impacts, and the conclusion that it significantly underestimates the risk to groundwater should be highlighted since that rate is mentioned as "guidance" in the report. The installation of groundwater monitoring wells should be more clearly called out in the recommendations section. In a geographic area like Whatcom County where the water table is very close to the ground surface, monitoring wells would be relatively inexpensive and easy to install, and would provide direct information about aquifer conditions, rather than having to rely on surrogate data with significant uncertainties such as soil nitrate tests.

Response: We removed statements that "estimated excess nitrogen" was a more reliable predictor of groundwater impacts than post-harvest soil nitrate. We added a recommendation that the post-harvest soil nitrate test (PSNT) protocols and recommended target concentrations be reviewed and revised to take into account groundwater quality.

We recommended groundwater monitoring as the only reliable way to evaluate impacts of nutrient management activities on underlying groundwater.

Comment:

5. The text should more clearly explain how the level of post-harvest soil nitrate recommended in the guidance could be revised so its use would ensure the protection of groundwater.

Response: We emphasized in the final report that the amount of recharge should be taken into account when establishing target soil nitrate concentrations. We recommended that experts from land grant universities as well as state and local scientists work together to revise the PSNT.

Comment:

6. Overall, the Executive Summary (ES) doesn't stand on its own. Recommend adding a project setting section to the ES. The ES currently lists three bulleted items on page x, 5th paragraph, but this discussion should be broadened (i.e, briefly discuss land use and setting of study area and SBA; regional hydrology, briefly explain how manure is handled, etc.). On the other hand, some of this information could be put in an Appendix showing what was and what was not measured.

Response: Comment noted. The Executive Summary has been edited for the final report**.**

Comment:

7. It would be helpful to add a figure depicting a cross section of the aquifer and vadose zone showing the property boundary, groundwater flow direction, the water table, and the location and depths of the shallow and deep wells.

Response: In the final report, Figure 5 shows a cross-section of the aquifer including the water table and monitoring well locations and depths. A new Figure 12 shows the location of all wells sampled during the study and the typical groundwater flow direction.

Specific Comments

Comment 1: Page xi, Figure ES-1. The figure should have another note on the legend which defines what appear to be generally incorporated or more urban areas shown in a red tone.

Response: Legend was added to Figures ES-1.

Comment 2: Pages xi, 3, and 73. The objective(s) of the study are stated several times, but are not stated consistently. Suggest reviewing, and revising where appropriate.

Response: We have edited to make objectives consistent throughout the final report.

Comment 3: Page xii. Recommend separating program objectives from technical objectives and outcomes or how to use the study. Even though this is the Executive Summary, it would be helpful to state how the objectives support the goal of evaluating the effectiveness of nutrient management plans.

Response: We edited the objectives as suggested.

Comment 4: Page xii, third paragraph from bottom. Mass balance implies that all outputs and inputs are considered and weighed against each other. This is actually a partial mass balance, because a key component (nitrogen output through leaching) is not directly measured. This should be noted.

Response: We have added leaching to the list of outputs in the mass balance description in the *Discussion* section of the final report.

Comment 5: Page xiii, first line. The word "seven" is spelled out here but elsewhere numbers are referred to numerically. Also, it becomes confusing when sometimes the report refers to seven vs six wells. Suggest this sentence be rewritten to refer to six shallow wells and one deep well.

Response: We made the suggested change.

Comment 6: Page xiii, Figure ES-2. Arrows should be added to and from ammonia (soil block) box to indicate the direction of the process. It would help to write out "denitrification" to identify the arrow leading to N_2 gas, and "volatilization" to identify the arrow leading to atmospheric ammonia. Why are there two boxes for ground water nitrate? What is the significance of multiple arrows and an (errant?) arrowhead in the aquifer matrix?

Response: We implemented these suggestions. The arrows in the aquifer matrix represent flow that has a horizontal as well as vertical component.

Comment 7: Page xiv, Figure ES-3. The colors in this and other figures could be adjusted so that if the document is printed in black and white, the figures can still be interpreted.

Response: We made the suggested change.

Comment 8: Page xiv, bottom paragraph. The statement, "These values provide an approximation of the amount of nitrogen that could reach groundwater if the soil was flushed by water recharging the aquifer in the months following the end of the growing season." <u>This assumes that none of this nitrogen has already leached out during the growing season prior to this flush</u>. Because the data shows nitrate spikes following manure application events during the growing season, we can assume that some nitrogen does leach out during this time, hence the annual excess nitrogen would be much higher than fall soil nitrate.

Response: Comment noted. See response to EPA General Comment 1.

Comment 9: Page xv, Figure ES-4. The left axis may be better labeled Total Nitrogen. It is unclear that "mean fall soil nitrate" as shown on the figure is "excess" from this graph or discussion.

Response: Figure ES-4 has been removed in the final report.

Comment 10: Page xv, first paragraph. Specify that the target amount is for fall soil nitrate, not excess nitrogen.

Response: Figure ES-4 has been removed in the final report.

Comment 11: Page xv. The second paragraph from the bottom refers to green bars in Figure ES-4, but there are no green bars in this figure.

Response: Figure ES-4 has been removed in the final report.

Comment 12: Page xvi, bottom paragraph. Define winter mean range as Nov-Dec.

Response: We added this definition.

Comment 13: Page xvii, first paragraph. Can the report really make any definitive statement about comparing fall soil nitrate with annual excess nitrogen as a better predictor of winter ground water nitrate, at least without doing some statistics? In the absence of numerical values for fall soil nitrate, a best guess analysis does not show a much better correlation with excess nitrogen ($r^2 = 0.41$) than with fall soil nitrate ($r^2 = 0.28$). Page xvii, Figure ES-6 – This figure could be misleading. Suggest the report state that the ground water mean is for one well (AKG725). The excess nitrogen values are incorrectly graphed in Figure ES-6. See Figure 46 for actual values and better graphical representation.

Response: In the final report, comparisons of fall soil nitrate and mass balance analysis indicators of groundwater impacts are compared to the mean early winter groundwater nitrate concentrations in all 6 shallow monitoring wells instead of only AKG725. The figure referred to in the draft report has been updated and statistical correlations added in the figure title.

Comment 14: Page xvii, Figure ES-6. The left axis label should be Total N (lb/acre), not per year since the years are shown by the different bars.

Response: We made this change in the revised Figure ES-6.

Comment 15: Page xvii, Figure ES-6. See comment 7 above and specifically it would be good to have some description or cross hatching so that even if a black and white printer is used the bars could be better defined (one approach would be to use a label – blue bar is left bar, or use of hatches in one of the bars). In addition, this figure and descriptions deal with mass balance, but the axis is "Excess total nitrogen" and MCL for refererence. Overall the point being made comes through, but it could use a few more touches on the figure to make it clearer (would changing left axis to "total nitrogen" vs. "Excess total nitrogen" resolve this issue?).

Response: We replaced Figure ES-6.

Comment 16: Page xvii, bottom section. Factors affecting groundwater nitrate concentrations-This sections seems to address NMPs but not directly. The text should clarify that the topics below are core elements of a NMP.

- Nitrogen application rate
- Timing of manure applications
- Recharge
- Tillage
- Temperature and Soil Moisture
- Denitrification

Response: The elements of an NMP are listed here**:**
http://agr.wa.gov/FoodAnimal/Livestock-Nutrient/DairyNutrientMgmtPlans.aspx.
We do not know which of these are the core elements of an NMP.

Comment 17: Page xviii, third paragraph. Chloride will leach out of manure well before nitrate does, so why couldn't the nitrate come from the previous year's manure?

Response: This comment refers to the statement in the draft report**:** "We saw indications of nitrate leaching to groundwater during January and February in two years but not manure-associated chloride, indicating a source other than the previous year's manure. The most likely source of this late winter nitrate is from soil organic matter that was bacterially converted to ammonium and then nitrate."

Based on discussions with and citations from Dr. Bernie Zebarth and Dr. Cathy Ryan, nitrate in the Sumas-Blaine Aquifer moves quickly in the fall and winter due to the heavy precipitation that continues through January. All of the nitrate (and chloride) remaining from the recent growing season's manure applications should have reached the water table by the time the water table has reached its peak for the year. Therefore we propose that increases in nitrate in shallow groundwater in January and February (without a corresponding increase in chloride) indicate a source of nitrate other than the flush of nitrate in the beginning of the fall/winter season. No change was made.

Comment 18: Page xviii, last paragraph. Define fall recharge range (Sept-Oct?). Recommend that you provide support for the inference (to avoid appearing arbitrary) – that decreasing fall recharge rates may be contributing to decreasing year-long ground water nitrate values. The overriding driver could be annual rainfall rates, which show a much different trend, being very low in 2005 and high in 2006-2007.

Response: We removed this paragraph in the ES and did not include this subject in the text of the final report. We need to do more research on this subject.

Comment 19: Page xix, first paragraph. Can you specify when tilling occurred and in what year?

Response: We added this information to the final report (April 2004).

Comment 20: Page xix, Tillage Section. This seems like a very important relationship, but there seems to be some disconnect with the figures and its importance may be overlooked. Should this section reference figure ES-5? While similar to ES-7 the reference to "Nitrate-N concentrations in groundwater the winter after tillage were as high as 45 mg/L-N" seems to more closely match figure ES-5 than ES-7 (which is the last figure referenced and is located above the tillage section). Also note that figure ES-5 does have concentrations that go to 45 mg/L.

Response: The former Figure ES-5 is Figure ES-3 in the final report and is referred to in the tillage paragraph of the Executive Summary. See the *Discussion* section of the final report for more detail.

Comment 21: Page xx, Figure ES-8. It is difficult to figure out what the green bars mean. Suggest this text**:** "Range of soil nitrate concentrations measured during September-October fall sampling period.

Response: We have made this change in the final report.

Comment 22: Page xxi, first paragraph. On page 13 it says that tilling was done in 2004, not 2005. Also, it seems like selective data are used to support the point. Feb 2005 and Jan 2008 soil nitrate data are listed as high. Why not use Feb 2008 data, which is half the value of Jan 2008? Is it because no Jan 2005 data were available and you are using just the first data point for each year?

Response: The date indicated in this paragraph in the draft report for tillage was incorrect. Tillage occurred in 2004.

Based on suggestions from Dr. Bernie Zebarth (Agriculture and Agri-Food Research Canada), we removed the reference to soil nitrate concentrations in January and February as an indication of late winter nitrate mineralization. Soil nitrate moves so quickly with winter recharge that it is not a reliable measure of the amount of nitrogen available for leaching.

Comment 23: Page xxi, Figure ES-9. These charts are too small to read. Also, the nitrate MCL line is missing in the AKG727 graph.

Response: Figure ES-9 has been removed from the Executive Summary.

Comment 24: Page xxii, second paragraph. Statement contradicts previous observation that the annual excess nitrogen method is better than the fall soil nitrate method for predicting winter ground water nitrate. Figure ES-10 – Yellow and blue bars represent ground water nitrate by different methods. Need to add the word "method" after descriptors for these bars. Otherwise it looks like the yellow bar represents mean fall soil nitrate.

Response: This figure was replaced in the final report.

Comment 25: Page xxii, last paragraph. The second sentence is not clear as written ("concentration of groundwater mixing"). Suggest "...uncertainties regarding mixing of ground water and leachate, and ongoing generation of soil nitrate past the end of the growing season."

Response: We changed this section in the final report and revised the wording.

Comment 26: Page xxiii. Implications for other parts of the SBA. This section could more clearly state the implications for other parts of the SBA. We assume that you are trying to say that this study site has the potential for much greater rates of denitrification than would be found in other parts of the SBA, which would suggest that nitrate levels would be expected to be higher and more persistent at other locations. Text should be clarified. Page xxiii, at the top of page**:** "..using estimates of excess nitrate in the soil at the end of the growing season is an unreliable substitute for direct groundwater monitoring ..." is correct, but it seems to conflict with other statements and figures in the report which imply that the use of the excess nitrate in soil method is a good indication of potential contamination from nitrogen loading Figure ES-6 seems to indicate that the "estimated excess nitrogen" correlates with the potential for contamination. That is confusing when compared to the following statement made about Figure ES-6 in the top of page xvii –

"....The figure indicates that the mass balance method of calculating the end-of-season nitrogen residual is a better predictor of the overall groundwater concentration pattern." These issues create potential for confusion about some very useful concepts presented in this report, and we suggest that some word changes may minimize potential reader confusion. Under the section "Use of current soil nitrate 55lbs/acre target to protect groundwater," we concur with the report's conclusion that the established end-of-season nitrate concentration recommendations still pose a risk to groundwater. This conclusion is significant and should be emphasized.

Response: Comment noted. We revised the wording on these items in the final report.

Comment 27: Page xxiii, third paragraph. There appears to be insufficient evidence to conclude that the maximum fall soil nitrate value is better than the mean fall soil nitrate value for estimating the amount of nitrate that can be leached.

Response: We removed the comparison of maximum and mean fall soil nitrate from the final report. However, because the measured amount of nitrate in the top one foot of soil does not include the amount of nitrate already leached below one foot or to be leached during the winter as an on-going process, we feel that the maximum is a better estimate (although still an underestimate) of the amount actually reaching the water table than is the mean in this setting.

Comment 28: Page xxiv, first sentence. Instead of using the phrase "worst-case scenario", we recommend the phrase-"potential for ground water contamination by nitrate would be greater in other regions" to make this point more clear.

Response: We revised this wording in the final report.

Comment 29: Page xxiv and page 77, Recommendations. Suggest that the report relate the recommendations back to the goal of determining the effectiveness of NMPs.

Response: See response to EPA General Comment 3.

Comment 30: Page xxiv, second paragraph. These actions may <u>reduce</u> contamination, but will not reverse contamination.

Response: We changed the wording in the final report.

Comment 31: Page xxiv, third paragraph. Bullets are used elsewhere... why number these recommendations?. Recommendation #8 regarding corn seems to be outside the scope of this study. Recommendation Number 7, sentence seems to be missing the phrase "manure application" after the word "last".

Response: We removed numbers and the reference to corn. We changed the wording in the final report. The recommendation that was missing "manure application" has been revised in the final report.

Comment 32: Page xxv, last paragraph. Monitoring is needed to evaluate the effectiveness of management practices, and not just improvements. EPA would suggest that routine ground water monitoring be conducted, in which case there is no need to go through the expense of generating an annual excess nitrogen mass estimate as a screening tool.

Response: Comment noted.

Comment 33: Page 4. The list of questions that seem important; however, the significance of these questions as they relate to the study goal isn't clear.

Response: The questions have been removed.

Comment 34: Page 4. We do not recall any discussion of estimating the lag time between nitrogen application and arrival of nitrate at the water table in this report. It is assumed that the lag time could vary significantly since application occurs at different times during the entire growing season. Should this objective be dropped?

Response: This objective was not included in the final report.

Comment 35: Page 8, first sentence. Data are shown in Table T.3, not T.2. But T.3 was not included in this report. What is the purpose of the temperature information summarized in Table 1? Suggest referencing the full dataset in an Appendix or providing a more comprehensive summary (e.g., daily or monthly maximum and minimum temperatures).

Response: The air temperature data summary has been moved to the *Results* section. The daily temperature data are included in an appendix in the final report.

Comment 36: Page 8, Table 1. Units should be included.

Response: Units are included in final report table.

Comment 37: Page 11. A table outlining what's required in an NMP would be helpful.

Response: The list of requirements for an NMP is quite long. The Washington Department of Agriculture provided the following link which we added to the section on *Dairy Nutrient Management Plans* in the final report:
http://agr.wa.gov/FoodAnimal/Livestock-Nutrient/DairyNutrientMgmtPlans.asp

Comment 38: Page 12. In the dairy nutrient management plans section, the Sullivan and Cogger soil nitrate threshold (15 mg/Kg (55 lb/acre)) appears, and since it is used in other sections and figures it may be good to reference those sections or figures to this section or page. Also in this section there appears to be a key statement concerning the critical effect of timing of soil sampling with the weather. Perhaps these two sentences should be printed in **bold** since they are considered as some baseline references.

Response: We added the following to the section *Dairy Nutrient Management Plans***:** "For fine-grained soils in Whatcom County, like Hale soils at the study site, the recommended time for post-harvest soil nitrate testing is after the last harvest and before 5 inches of precipitation has fallen after September 1."

Comment 39: Page 13, first paragraph. It seems like this first sentence should go into the preceding footnote, since it addresses a technicality for this calculation.

Response: We removed this sentence in the final report.

Comment 40: Page 13, Field Management section. Additional information would be helpful here. Does this farmer follow a DNMP? Is there guidance that the farmer is using to determine loading rates? Why did he apply almost double the amount of manure nitrogen in 2008 and, to a lesser extent, in 2005? Does he apply all of the manure he has, or does he get it from off-site and why doesn't he apply less? Did he apply at the upper loading rate in 2003 and 2004 or do anything else different that might have caused the large ground water nitrate spike, other than tilling? Were livestock ever permitted in the field?

Response: We did not have access to the producer's DNMP. According to the producer, the nutrient application rate had been consistent for the past 20 years. We assume that means that livestock had not grazed on the field.

Comment 41: Page 15, third paragraph. If known, provide the depth of the screened interval for the well used for irrigation, and show its location on one of the maps.

Response: The location and depth of the irrigation well were not available.

Comment 42: Page 15, Nitrogen Cycle. The concepts of "fall soil nitrate", "excess nitrogen", and "mass balance nitrogen" seem to first come up in detail after this section of the report. Later on the term "excess total nitrogen" appears. What is the base datum for calculating "excess"? EPA would suggest having a short discussion of all those definitions and calculations at around this section to set the framework for those terms used in the rest of the report. This may be related to our confusion with Figure ES-6 mentioned above.

Response: The various terms used for nitrogen are defined in the final report in mathematical terms as they are introduced.

Comment 43: Page 18, last paragraph. On page 15 the water table is listed as rising from 1 to 3 ft instead of 0 to 3 ft. Pick one and be consistent.

Response: We have changed all references to the water table maximum to 0 to 3 feet.

Comment 44: Page 20, Study Design. Suggest that you relate the results back to the goals of the study.

Response: We revised the introductory sentence to link back to the goal of the study

Comment 45: Page 20. On the "Residual" bullet section, the text implies that soil fall nitrate is measured as well as mass of nitrogen? According to Figure 10 and Appendix C, only nitrate was routinely measured in the soil. Is the latter text just intended as a definition of soil nitrate? If so, it should clearly state nitrate-nitrogen. Otherwise suggest that you delete it.

Response: We deleted "mass of nitrogen remaining in the upper root zone at the end of the growing season" from the Soil bullet.

Comment 46: Page 21, Figure 9. Arrow needed for soil organic matter. Otherwise same observations as noted for Figure ES-2.

Response: We removed the box for soil organic matter, because the "Organic N" box includes soil organic matter.

Comment 47: Page 22, Figure 10. In this figure the ammonia and organic nitrogen boxes are pink, indicating that they are measured. They are not. By the way, it took awhile searching through this report to locate the table listed as Appendix C. It would help to have this table in the main body of the report because of its importance.

Response: Appendix C has been moved to the main body of the final report (Table 1). Pink boxes in Figure 10 (draft report) do not refer to measured constituents in this figure (numbered 9 in the final report), only in the previous figure (numbered 8 in the final report).

Comment 48: Page 23, Methods. More detail should be provided on how the bucket sampling was done, and the relationship of the buckets to the irrigation methods. Also, how does the timing of the sampling and delay between the water entering the bucket and when that water is placed in sample containers affect the concentrations that were in the samples that arrived at the laboratory? Overall the method of collecting the water and then the delay between collection and taking the measurements and analyses merits a discussion of the potential uncertainties.

Response: We assume that the delay between the water entering the buckets and samples being placed in bottles did not result in significant effects on results for the constituents sampled, because the delay was a few hours at most. The concentration of volatilizable ammonia-N (NH_3) would be negligible at the pHs measured in the monitoring wells (roughly 5.0-6.5). Therefore little inorganic nitrogen would have been lost to volatilization. Most of the ammonia at these pHs is in the ammonium form (NH_4^+). Some of the ammonium may have converted to nitrate-N before samples were transferred to sample containers. However, this would not have significantly affected the total nitrogen concentrations used to estimate the nitrogen contribution to the mass balance.

Appendix D gives details of the irrigation water sampling and bucket placement.

Comment 49: Page 23. Describe how the grower decided how much N to apply. Were N application rates within WSU recommended fertilizer rates for the crop being grown? Were they within the recommendations of the Western Fertilizer Guide? More detail is needed here.

Response: We did not discuss the producer's management practices or application rates. Our agreement was that we were allowed to measure and sample all nutrients and irrigation water applied, and he was very forthcoming with access and information on those subjects.

Comment 50: Page 27, first sentence. It would enhance clarity to state that the monitoring well network consisted of six shallow and one deeper well. Because it is not quite clear from Figure 13 where the top of the well is relative to ground surface, it would also help to list the approximate distance between the ground surface and the top of the screen for the shallow wells.

Response: We added the suggested information to the final report.

Comment 51: Page 35, first paragraph. The last line on dairy manure treatment should be stated earlier in the farm management discussion.

Response: We added this information to the Local dairy field management description earlier in the report.

Comment 52: Page 35, last paragraph. What is the rational basis for assuming that chloride in a shallow well in an agricultural region is negligible? Is there regional shallow water quality data to support this assumption?
Response: We did not assume that chloride in shallow groundwater was negligible. We assumed that the groundwater that we were sampling near the top of the water table was derived from the most recently recharged water and represented mainly chloride from recent management practices in the overlying field. This is described in more detail in the *Discussion* section of the final report.

Comment 53: Page 36, middle paragraph. The observation that nitrogen crop uptake appeared to be inversely correlated with nitrogen applied to the field is an important finding and should be highlighted in the conclusions. It should provide further incentive to use less manure when the objective is to maximize yield (as opposed to maximizing disposal). By the way, some of the numbers in the text again do not match with the numbers listed in the figure (434 vs. 436, 716 vs. 736).

Response: Comment noted and figures were revised.

Comment 54: Page 36, last paragraph. In 2005, the last grass crop was not removed from the field, but the estimate of nitrogen harvested assumed crop removal. This would mean that this estimate is biased low because the nitrogen in this grass is subtracted out even though it never left the field and the real annual excess nitrogen mass would be higher because the grass will decompose and then re-enter the system as part of the original load.

Response: The estimate for the grass crop harvested is actually biased high, but the resulting estimated N_{Excess} in the mass balance calculations (Table 11 in the final report) is estimated low for the reasons stated in the comment. We added an explanation in this section of the final report that the 102 lb/acre that was included in the crop removal estimate for 2005 (but was not removed), biased the crop uptake high. We also added a section in the *Discussion* of the nitrogen mass balance calculations that the 2005 estimates for N_{Excess} are biased low.

Comment 55: Page 38, third paragraph. The sentence is missing "of" before fine-grained- "Samples below 7.5 feet in the other wells had varying amounts *of* fine-grained material."

Response: We added "of" to the sentence.

Comment 56: Page 43. Equation 7 missing ( ).

Response: In the final report we do not use this equation. Instead of surplus water, we discuss only recharge.

Comment 57: Page 45, Dissolved Oxygen section. It is inaccurate to categorically state that denitrification does not occur at dissolved oxygen concentrations greater than 2 ppm. Denitrification is more correctly described as a microaerophilic process rather than as an anaerobic process, and can occur at oxygen concentrations greater than 2 ppm. It is facilitated by lower oxygen levels and is expected to be more active at lower oxygen levels, and this has led some to establish a reasonable upper limit of 2 ppm dissolved oxygen. But in soil and aquifer matrics there can exist a variety of anaerobic microsites with oxygen levels much lower than the bulk water, and so care should be taken not to dismiss this process in aquifer or soil matrices where ground water sampling may indicate higher oxygen values.

Response: We added the following sentence to this section in the final report: Denitrification can also occur at microsites in soil and aquifer materials, where the bulk DO is higher than 2 mg/L but is generally more significant where the bulk water is also low in DO.

Comment 58: Page 50. Effects of drain tiles. The report recognizes the use of drain tiles throughout the SBA even though there were none in the study area. On page 50, in the last paragraph, the last sentence states: "The remaining 83% of soil nitrate was presumed to leach to groundwater." That presumption applies in this study field however it may not be true in fields that do have drain tiles. Nitrogen loss via tile drains will have an adverse environmental impact on surface waters.

Response: Comment noted.

Comment 59: Figure 44 (Plate 6). The term "excess total nitrogen" seems to only appear on a word search on this figure and in Figure ES-6. Is it different than excess nitrogen?

Response: Both of these figures have been changed in the final report. We have tried to be consistent with terms.

Comment 60: Page 53, Equation 8. Need parentheses around Equation 8 label

Response: We have added parentheses to all equation labels.

Comment 61: Page 53, equation legend. For "S", text should read "from", not "form". Note that the sentence below describes the need for this equation to assume a steady state, which "normally" happens for the crop 3 to 5 years after growth. It seems like that is not the case for this site, based on the water quality data indicating a perturbation in 2004 or prior.

Response: In the final report we use a different equation to estimate N_{Excess}, where S is part of the plant-available N.

Comment 62: Page 54. Table 8 displays the input requirements and expected outputs from a mass balance analysis. This study conducted by researchers at Washington State University was conducted with the full cooperation of the producer that operates that tract of land. The text recognizes that a challenge of conducting an accurate mass budget analysis is that it relies on the accurateness of records kept by the producer. Some of the information that a producer would be expected to maintain, then provide to Ecology includes, but is not limited to:

- Listing of all fields where land application occurs.
- When applications are made.
- How applications are made (injected, broadcast, mixed with irrigation water and sprinkled etc.)
- What kind of waste (liquid, solid, compost, etc.) and bedding content if applicable.
- The nutrient content of all waste applied.
- Application method and length of time between application and incorporation.
- The volume of applied waste, tons or cfs.
- The current crop and crop rotation. If irrigated, timing and volume of applications.
- If commercial fertilizer is applied, rate, form and method of application.
- The yields for all crops.

Response: Comment noted. We did not have access to the DNMP. Producers are not required to submit these records to Ecology.

Comment 63: Page 55, Figure 45. Previously the report refers to mean fall soil nitrate, which we assume is the average of all of the soil nitrate values across the site from September through November for any given year (is that correct?), and it provides a graphical representation of the values in Figure ES-4. Why then does Figure 45 introduce a separate set of numbers describing fall soil nitrate derived from maximum values? Why provide this estimate at all, since fall soil nitrate is not a parameter measured or estimated for use in Equation 8, which this Figure is supposed to represent?

Response: In the final report we have removed Figure ES-4. Figure 45 in the draft report is Figure 55 in the final report and is intended to provide a perspective on the relative contribution of the main components of the nitrogen cycle at the field. We chose to use the maximum fall soil nitrate value for the fall flush period (September 1 through October 31), because fall soil nitrate is typically an underestimate of nitrate that actually leaches to groundwater (Zebarth, 2013). The previous version of this graph did include 2 additional weeks for the soil nitrate period (November 1-15) in order to include any additional nitrate that may have been available for leaching; however, we removed that period in the final report to be consistent with the bulk of the report.

Comment 64: Page 57, first bullet. Is this saying that because of the time of travel, any high nitrate concentrations in ground water upgradient of this study at the time of this study would not reach the wells during this study? What about possible high concentrations upgradient of the study 5 to 10 years ago which could now theoretically be upgradient of these wells but within the study site boundaries during the time of the study?

Response: We have revised the analysis of upgradient influences in the final report. Using the recharge and effective porosity at the site to estimate the velocity of vertical flow, we estimated that groundwater flows 7 to 11 feet downward/year. Because our wells are screened in the top 10 feet of the aquifer, influences from upgradient activities greater than one year ago (or 285 feet) are unlikely to significantly affect the water quality in the samples we collected. See the final report *Discussion* section for more details.

Comment 65: Page 57, third bullet. How long has this upgradient site been receiving manure application? Twenty years, like the study site? Could nitrate from previously applied manure make it to this study site within this time period? These arguments don't appear to be supported. Additionally, it would be helpful to describe the current and historical land use around the study site and plot the locations where manure is being applied.

Response: See previous response and comment noted.

Comment 66: Page 59, third paragraph. Nitrate is like chloride only in that it has minimal sorptive properties and both are anions. It is not conservative because it is easily transformed to other nitrogen species. It may be "associated with manure application" like chloride, but indirectly so, since it is absent in manure and is only formed from manure ammonia through nitrification when oxygen is available. Chloride and nitrate plumes originating from manure do not necessarily coincide.

Response: We recognize that nitrate is the result of a series of transformations of ammonium and organic nitrogen. In the paragraph referenced, we are noting that elevated chloride concentration in the most recently recharged groundwater is an indicator of recent manure application.

Comment 67: Page 59, second paragraph from bottom. The wrong figure is referenced; Figure 29a shows October water table contours in 2007.

Response: The reference to this figure was removed in the final report.

Comment 68: Page 62, first paragraph. Should be "GDUs" in parentheses instead of "Gus"?

Response: This was changed in the final report.
Comment 69: Page 62. Equation 8 is on page 53. This should be Equation 9, and the equation label needs to be in parentheses and the text modified accordingly.

Response: Equation numbers and parentheses were revised in the final report.

Comment 70: Page 65, second paragraph. Some of this discussion on chloride and tillage already took place on page 59 and need not be repeated.

Response: We revised the text to avoid duplication.

Comment 71: Page 65, Equation 10. The equation label needs to be in parentheses, and the text at the bottom of the page needs to refer to this as Equation 10.

Response: Equation numbers and parentheses were revised in the final report.

Comment 72: Page 68, Figure 54. Is this mean fall soil nitrate? What is the significance of the green circled areas in relation to the target fall soil nitrate? Does it matter whether it was above · the target level just before the growing season in January? In other instances it was way above the target level a month or so earlier, but still ended up being pushed down by high rainfall in those earlier winter months. Under either circumstance, the load is being pushed down during cold weather when microbial activity is minimal. Note that 2006 and 2008 had very heavy November rainfalls (~11 inches) that drove this mass down earlier than observed in the green circled areas.

Response: We removed this figure in the final report, because we realized that the soil nitrate data for the late winter, which is what we were focusing on in this figure, was not a good indicator of the amount of nitrate leaching to groundwater.

Comment 73: Page 69, Equation 11. The equation label needs to be in parentheses, and the text above it to refer to this as Equation 11.

Response: Equation numbers and parentheses were revised in the final report.

Comment 74: Page 70. There is an "eith" highlighted which needs correction.

Response: This text has been removed in the final report.

Comment 75: Page 71, Figure 55. Same comments as for Figure ES-10.

Response: This figure has been removed in the final report.

Comment 76: Page 71, first paragraph. This discussion in this section does not relate to the title regarding the protectiveness of current guidelines. The report does not address the current guidelines or propose changes based on the study; it simply references an alternative based on recharge provided by another researcher and questions the validity of setting a guideline based on recharge. The focus should be tightened or the section title should to be changed.

Response: This section has been revised to address these concerns in the *Discussion* section of the final report.

Comment 77: Page 72, top paragraph. Again, the stated dissolved oxygen threshold for denitrification is too definitive and is misleading.

Response: We have removed the reference to a threshold value for denitrification and moved this paragraph to the *Conclusions* section in the final report.

Comment 78: Page 73. The conclusions section could be shortened to enhance its impact. The purpose of the study changes in the conclusions section: "The purpose of this study was to document the impacts of manure application on groundwater beneath a dairy field overlying the SBA." This conflicts with an objective stated earlier which is to determine the effectiveness of NMPs. This inconsistency should be reconciled.

Response: The conclusions have been edited in the final report.

Comment 79: Page 73, first paragraph. This should state 22 acres instead of 20 acres to be consistent with the rest of the report.

Response: This has been changed in the final report.

Comment 80: Page 73, Conclusions. Reiterating the definitions of the factors in the conclusions section detracts from the presentation of the conclusions. Perhaps just briefly list the factors prior to the discussion of the conclusions.

Response: Comment noted.

Comment 81: Page 74, last paragraph. Should be modified to "...the use of soil nitrate predicts..." A qualifier should be added stating that these preclude the use of soil nitrate for *reliably* predicting ground water impacts. In general, soil nitrate can indicate trends.

Response: We revised this section and attempted to address these comments in the final report.

Comment 82: Page 75, second paragraph. EPA concurs with the conclusion "that direct monitoring of groundwater using monitoring wells screened across the water table is needed to accurately characterize impacts of manure application on aquifer water quality" and suggests that this conclusion be articulated in the Executive Summary as well.

Response: We moved this point to the *Recommendations* section. It is also in the *Executive Summary*.

Comment 83: Page 76, last paragraph. "Worst case" and "best case" are vague phrases subject to interpretation. Perhaps a better way of phrasing this would be "These points suggest that the results observed during the study might be unique to this portion of the aquifer and that the same manure application practices would most likely lead to greater nitrate contamination in other regions of this aquifer".

Response: We revised this sentence in the final report to reflect this improved terminology.

Comment 84: Page 77, second paragraph. This general recommendation for conducting excess mass balance analyses does not seem to be supported by the evidence in the report, which shows it to be a poor predictor of leachate nitrate concentrations.

Response: Nitrogen mass balance analysis was left in the recommendations, because this is the only tool that producers have for evaluating how to adjust their practices.

Comment 85: Page 77, third paragraph. Suggest using bullets instead of numbers for consistency with the rest of the report (or at least start with number one instead of number twelve). Some of these recommendations seem to be more common-sense rather than being generated as a result of this study. One could easily add many more recommendations like "make sure that manure is distributed evenly" or "don't let livestock into the fields" when these are not experimental variables being addressed in this study. Recommendation No. 16 is an example; nowhere in this study was there an analysis of any deleterious effects caused by using fertilizer in those instances where it was used. It is common sense to not use fertilizer when one does not have to, but there is no data in this report that says one should not substitute fertilizer for manure. Also, in this recommendation, the second sentence is essentially identical to recommendation No.17. Some recommendations could be combined, like Nos.18 and 19.

Response: We have attempted to combine similar recommendations and remove those that are not directly related to the study.

Comment 86: Page 77, Recommendation No. 13. While the mass budget process addresses the application rates of nutrients, this recommendation gets to the root problem of migration of nitrogen to groundwater. Land application of waste during high precipitation periods, especially when crops are dormant or at least have reduced growth activity, encourages the migration of nitrogen through the root zone where it is lost to the environment. EPA supports limiting winter land application in this environmental setting and recognizes that facilities may need to construct additional storage capacity. Since waste is predominately handled as a slurry, construction or modification of concrete or similar storage containers may be required.

Response: Comment noted.

Comment 87: Page 78, last section. These monitoring strategies should be in place for routine operation, not just when management improvements are made. If a case is to be made for conducting annual excess nitrogen mass balance evaluations, it should be placed in this section, rather than in the section on reducing nitrate loading, because it does not seem to correlate with nitrate loading to ground water and is in essence an extensive monitoring program.

Response: We added wording that aims the monitoring program toward both current and future manure management evaluations. We also included a recommendation for reviewing nitrogen mass balance evaluation in this section of the final report.

Comment 88: Page 138, Table M.3. Relocate footnote 2, because 2005 is not an estimate, but the gallons applied may be an estimate. The units for the displayed N loadings should be indicated.

Response: We made this correction in the final report.

Comment 89: Plate 1, Figure 26. This figure should be clarified. It appears that the tops of the wells are a few feet below ground surface, which does not correspond with the well logs or Figure 13. Considering the annual rise of the water table, it is important to depict where the screened intervals are relative to ground surface. Is the red line intended to represent the ground surface? It would be helpful to expand this figure horizontally so that well AK725 can be displayed alongside of deep well AKG726. The well pairs could be placed more closely together to better reflect the B'-B transect line.

Response: We revised the figure to better represent the locations of the tops of the wells relative to the ground surface.

Comments from Bonda Habets, Natural Resources Conservation Service (NRCS)

Comment 1: The document tries to be both a research paper and a guidance document with the guidance based on findings from this field study. NRCS suggests using the data collected from this field study to prepare a research paper for submission to an appropriate peer reviewed scientific journal. If the authors would like to prepare a guidance document for application of manure from dairy operations, they should consider doing that separate from this field study.

Response: Comment noted.

Comment 2: The field study lacks a control against which the findings from nutrient application can be compared. This lowers the value of the findings by increasing the uncertainty about which factors are critical and which are not. Consider presenting the data in a manner that does not over represent its value.

Response: We have tried not to over-state or under-state our findings in the final report.

Comment 3: The field study measures nitrate concentrations based on one management system. The field study does not compare multiple management systems as stated in the project Purpose. Drawing conclusions and making recommendations based on the evaluation of one management system is not technically defensible and likely to fail. Consider clarifying the Purpose statement to accurately reflect the nature of the study and also, consider confining the conclusions and recommendations to the narrow scope of this study.

Response: We have changed the wording in the purpose statement to explain that the study was designed to evaluate the land application portion of DNMPs at one location. We removed conclusions and recommendation that were not related to the study.

Comment 4: The field study does not report any baseline conditions. Again, it is the lack of information regarding controlling factors that raises uncertainty and limits the conclusions that can be drawn by the findings. Consider strengthening the report by more clearing defining the scope of the study and the limitations of the data.

Response**:** Comment noted.

Comment 5: The study does not include a statistical analysis of the data. A statistical analysis and evaluation of uncertainty would offer critical support in favor of any findings and recommendations. In attempting to complete a statistical evaluation of the data, you may discover that the degree of variance and the level of uncertainty are too great to support the proposed findings and recommendations. As it stands, the findings are based on visual interpretation of graphical plots without any critical analysis. All claims should be supported and reproducible. Carefully consider how the paper states the certainty of findings based on the limited data.

Response: We have added a general analysis of the uncertainty in the mass balance analysis in the final report. We have also added correlation analyses of prediction methods for groundwater nitrate concentrations (soil nitrate and mass balance methods).

Comment 6: In arguing for use of a mass balance method of estimating residual soil nitrate, the authors simply state that soil sampling is not reliable without substantiating the claim. The variability of nitrate values observed from soil testing may be explained by complexity in the system of application, plant uptake and leaching. To demonstrate unreliability, one would have to show a problem with the sampling and/ or testing methods which this paper does not do. Consider either strengthening the argument in favor of using mass balance estimates or further investigating potential approaches for using direct measurements. Perhaps statistical analyses will yield fresh insights.

Response: We agree with the statement: "The variability of nitrate values observed from soil testing may be explained by complexity in the system of application, plant uptake and leaching." However, neither the post-harvest soil nitrate results nor the nitrogen mass balance results were accurate indicators of groundwater nitrate concentrations in our study.

The final report presents a modeling method using groundwater nitrate concentrations to back-calculate the mass of nitrate required to produce those concentrations.

Comment 7: It is suggested to adjust the Recommendations to "Reduce nitrate loading to groundwater" by rewording #5 to "account for residual nitrate from soil organic matter in manure application rates". Remove the first of #3, #4, and #9 and change #8 as manure applications apply about three times the amount of phosphorus for grass and corn has a very high uptake of phosphorus. A rotation of both grass and corn is ideal. Both nutrients need to be taken into consideration when applying manure. By taking corn out of the rotation, water quality impacts from phosphorus could become a concern.

Response: We have deleted the recommendation regarding encouraging grass over corn and revised the other recommendations in the final report.

Comment 8: The excessive amount of references tends to make the report a literary research paper and takes focus off of what is being studied. It is suggested to use references from the Western region of the US and Canada rather than the Midwest US or Europe. Since some of the document states information from 2012, I would use the data from the updated NRCS Ag Waste Management Field Handbook and remove the references prior to 2000. It would be helpful to select a few that reflect the project site.

Response: We have tried to use the latest NRCS references. The references cited are intended to explain and substantiate the methods, results and conclusions presented in the report.

Comments from Lynn VanWieringen, PhD, Washington State University

General Comments

Comment 1: There is a lot of focus in this paper about fall soil nitrate tests not being a good indicator of groundwater nitrate concentration. Why such a heavy focus? It was never meant to be an indicator of groundwater nitrate concentrations.

Response: See General Response 3 above.

Comment 2: Executive Summary → Conclusions made at beginning?

Response: The Executive Summary is a synopsis of the report and includes the Conclusions.

Comment 3: How deep are most private wells set? Do they draw the water right off the top of the groundwater table? These were low. This is a good thing.

Response: We did not survey private wells in the area. The groundwater quality standards apply to all groundwaters of the state (Chapter 173-200 WAC).

Comment 4: Is it correct to assume that the private wells tested in the study were well below the 10 mg/L drinking water limit?

Response: Yes, nitrate concentrations in samples collected on March 11 and April 2, 2008, from the two upgradient private wells were 0.014 to 0.021 mg/L-N.

Comment 5: What is the difference between unconfined and confined aquifer?

Response: An unconfined aquifer is not under pressure due to an overlying lower permeability layer. A confined aquifer is under pressure due to an overlying low permeability layer. Unconfined aquifers are therefore less protected from infiltration of contaminants from overlying land use.

Comment 6: It would be nice to see more focus on practices that dairy farmers could focus on to reduce nitrogen contamination in ground water.

Response: Comment noted. We have tried to note the practices that resulted in lower groundwater nitrate concentrations.

Comment 7: Can't control climate.

Response: Comment noted.

Comment 8: Definition of evapotranspiration.

Response: Evapotranspiration (ET) is the sum of evaporation and transpiration. Evaporation is the loss of water to the atmosphere from the ground surface down to the capillary fringe of the water table. Transpiration is the evaporation of water from plant leaves. This has been added to the Glossary.

Comment 9: Maybe some of the discussion should be that we learned as we went through this study as we collected data. Like you discussed with me on Friday. When this field was selected we didn't know as much as we know now. Then go on to discuss the characteristics of the soil that contributed to some of the groundwater results. Then discuss how these differences are different than other areas of the aquifer. Some this information we did not know when we started. In my opinion I wouldn't spend a lot of the discussion focused on what wasn't able to be measured and focus most of the discussion on what was measured, and what we learned.

Response: Comment noted.

Comment 10: I think figures 46 and 53 show how management practices can improve groundwater nitrate concentrations. I think this should be the main focus of the paper. I would center all discussion around this graph. It tells a different story than is being told currently.

Response: Comment noted.

Comment 11: There is very little weather data or crop data shown in this paper. However, it is discussed throughout the paper. I really think some of this data should be presented in the paper to support your conclusions.

Response: Comment noted.

General Comments

p. x, 2nd last paragraph. Comment: What does this mean? Is this a true statement? My guess is that cow numbers have either stayed the same or decreased. Farm numbers have decreased.

Response: This comment refers to the statements in the draft report**:** Recent shifts in the size and number of dairies overlying the SBA have also led to a higher intensity of nutrient loading than in past years. We have deleted this statement. A more detailed analysis would be needed to quantify changes in nutrient loading over the aquifer.

p. xii, bullets. Comment: What is measured vs. what is estimated? Volatilization estimate

Response: This comment refers to the listing of measured and estimated results for the study. The Executive Summary was intended to give a general description of the highlights of the study. Therefore we included the measured and estimated components together. Figure 8 in the main body of the report illustrates the components of the study that were monitored and those that were estimated.

p. xiv., Figure ES-3. Comment: We didn't measure atmospheric input.

Response: We have added a reference to the atmospheric input figure in the final report.

p. xv, Figure ES-4. Comment: ?

Response: We have removed Figure ES-4 from the final report.

p. xvi, 2nd paragraph. Comment: This is put in the 1st paragraph to outline the negative, so it's the focus. However if the groundwater nitrate decrease over time when mass balance was closer to target was emphasized it could send a more positive message that dairies can change practices and have an impact on decreasing nitrate in groundwater.

Response: Comment noted.

p. xvii, last sentence in 1st paragraph. Comment: These statements concern me.

Response: This comment refers to the sentence**:** "It is notable that although the nitrogen excess amount calculated by the mass balance analysis was below the 55 lb/acre target guidance value, groundwater nitrate concentrations, on average, remained above (did not meet) the drinking water standard." This part of the report has been revised.

p. xviii, 3rd paragraph. Comment: ?

Response: The comment refers to the paragraph related to winter manure application and evidence of mineralized nitrate produced during January and February. This paragraph has been revised in the final report.

p. xix, Figure ES-7. Comment: (Line pointing to the monthly mean groundwater nitrate-N concentration on the graph.) below 10 mg/L. How come other graph is above 10 mg/L?

Response: This figure was referring to the mean nitrate concentration in all 6 shallow monitoring wells. Several of the other graphs in the draft report only showed the nitrate concentration in well AKG725, one of the 2 wells that did not have DO concentrations indicative of significant denitrification occurring. The final report focuses on the mean of the 6 shallow monitoring wells. Nitrate concentrations in individual wells are also shown.

p. xx, Figure ES-8. Comment: ?

Response: This comment refers to the highest point on the soil nitrate graph, 210 lb/acre. In the final report we used a conversion factor of 3.1 from mg/kg to lb/acre based on the soil bulk density at the site. The revised soil nitrate concentration for the point is now 186 lb/acre.
The result is based on duplicate samples.

p. xxi, Figure ES-9. Comment: Are these individual wells?

Response: Yes, each graph represents an individual well. This graph is not included in the Executive Summary in the final report.

p. xxii, 2nd paragraph, last sentence. Comment: What happened the other half of the time?

Response: This comment refers to the sentence in the report**:** "Neither method of predicting the leachate concentration produced values that reliably matched the measured groundwater condition, underestimating the true condition half the time."

This analysis was not included in the final report.

p. xxiii, 4th paragraph. Comment: If the fall soil nitrate mean was never below 55 N lb/acre how can you be making all these conclusions. You didn't have a situation where you could analyze this because there is no comparison at or below 55 lb N/care. They are all above, and groundwater nitrate 1 year was below 10 mg/L even with fall soil nitrate above 55 lb N/acre. Why is this not discussed?

Response: The analysis referred to is described in detail in the body of the report. The purpose of including the analysis of the target post-harvest soil nitrate concentration for grass (15 mg/kg or 47 lb/acre N at the study site) is to provide a perspective on the calculated nitrate concentration of the water reaching the water table under recharge conditions like those observed during the study.

p. xxiii, last 3 paragraphs. Comment: I don't think this should be in this study. This was 1 study and 1 field. It should stick to that.

Response: Comment noted. We have modified the statements regarding implications for other parts of the Sumas Blaine Aquifer.

p. xxiv, No. 7. Comment: Can this be practically implemented?

Response: This comment refers to the recommendation regarding improving soil nitrate sampling. We have deleted the recommendation to sample soil nitrate in the spring.

p. xxv, last paragraph. Comment: What does this mean? That all fields need groundwater monitoring?

Response: This comment refers to the recommendation to conduct groundwater monitoring to evaluate the amount or concentration of nitrate that actually reaches the water table. The recommendation did not specify a particular monitoring network design. We have modified this recommendation in the final report to include dedicated monitoring wells. However, any monitoring network would be based on the objective(s) for monitoring, which would need to be clarified before suggestions about well locations were made.

p. 7, 2nd paragraph and Figure 2. Comment: Were WSU and Ecology precip estimates similar both years? Is this Ecology or WSU data?

Response: Few data were available from the WSU weather station. In the final report we used Ecology precipitation data for the dates when available. Based on a correlation between the Ecology weather station data and precipitation at Abbotsford, B.C. Airport, we filled in the dates where the Ecology weather station was down with the estimated precipitation. This is explained in the final report.

p. 8, 5th paragraph. Comment: What does this mean?

Response: This comment refers to the statement in the draft report**:** "The subsoil at the site (11-27 inches) is mottled, indicating periodic reducing conditions. " Reducing conditions refers to anaerobic conditions that occur in soils typically due to saturation, flooding, or ponding. Many chemical and microbial reactions are greatly affected by the presence or absence of reducing conditions.

p. 11, last sentence. Comment: Is this a measurement or estimate?

Response: This comment refers to the sentence in the draft report regarding the percentage of nitrogen that was plant-available. We removed this sentence in the final report.

p. 19, 1st paragraph. Comment: We didn't measure this.

Response: This comment refers to the reference in the draft report to leaching in the summer normally being negligible unless irrigation water, which is used on some fields over the SBA in the summer, is overapplied. In the final report we removed this sentence and added the following**:** Leaching during the summer due to irrigation and preferential flow was not addressed in this study but could be a significant factor in the annual nitrogen cycle at the field (Nimmo, 2013).

p. 24, 3rd paragraph. Comment: No

Response: This comment refers to the sentence in the draft report**:** "The frequency and timing of soil sampling rounds were scheduled to correspond with manure application and precipitation events." This sentence was modified in the final report to better explain that the high frequency of soil nitrate sampling was related to the end of the manure application season and the beginning of the high precipitation season.

p. 39, Table 3. Comment: What do these abbreviations stand for?

Response: This comment refers to the Soil Classes in Table 3 in the draft report (Table 5 in the final report. The abbreviated soil classes are defined in Footnote 1).

p. 43, last paragraph. Comment: You used these #'s for your calculations but adjusted the precipitation #'s for 2005. Wouldn't evapotranspiration #'s need to be adjusted as well?

Response: This comment refers to the use of evapotranspiration data measured at Abbotsford, B.C. Airport, 6 miles northeast of the study site. Evapotranspiration is calculated using data for radiation, air temperature, air humidity and wind speed. We assumed that these measurements at Abbotsford would be similar at the study site and therefore did not need to be adjusted.

p. 52, 3rd paragraph. Comment: A lot of discussion about other areas of the aquifer. Can't we stick to what was measured at the field and not predict what is happening at other locations in the SBA. That is not within the scope of the study.

Response: Comment noted.

p. 55, Figure 45. Comment: Why are we using means in some cases and maximums in others? I think you need to stick with means all the way through or present the data as maximum and minimum values. There are 2 sides to the data if you go that route instead of just focusing on the side that demonstrates the "worst" case scenario.

Response: This is Figure 56 in the final report. The figure has been revised. The figure for manure is the amount of plant-available nitrogen estimated as shown in Equation 15. The mean groundwater nitrate concentrations for the 6 shallow wells for November and December are shown as well as the values for the well with high DO, AKG725. The statistics used in this figure were considered the most representative for that media during the late fall/early winter period, when a large portion of the annual loading of nitrate to the water table occurs. The maximum soil nitrate concentration was chosen, because soil nitrate only represents the nitrate that has not already leached below 1 foot. It is therefore inherently an underestimate of the nitrate loading to the water table. Dr. Bernie Zebarth (Agriculture and Agri-Food, Canada) advised that soil scientists typically use the maximum fall soil nitrate as an estimate of the amount available for leaching to groundwater in the Pacific Northwest.

p. 56, 1st sentence. Comment: You need to make this clear that you are focusing entirely on maximum and worst case scenario and not the avg or best case scenario.

Response: This comment refers to the sentence in the draft report**:** "Monitoring well AKG725 was chosen to most clearly represent the maximum effect of surplus nitrogen on groundwater."

In the final report we have mainly used the mean groundwater nitrate concentration for all of the shallow wells.

p. 57, 1st bullet. Comment: What? Ag practices have been occurring for decades. They didn't just start at the beginning of this study. There could certainly be contribution.

Response: This comment refers to the description of the time of travel estimate for groundwater from upgradient. Comment noted. This analysis has been revised in the final report.

p. 58, 2nd last paragraph. Comment: This point needs to be highlighted. It can't be a zero balance.

Response: This comment refers to the sentence in the draft report**:** "some leaching of nitrate is unavoidable when growing a crop." Comment noted.

p. 60, 1st paragraph. Comment: If you don't know why say

Response: This comment refers to the sentence in the draft report**:** "When the water table is so close to the surface, most nitrate in the soil that might have been available for crop uptake is probably lost to groundwater when the water table recedes."

We added a reference to Plate 7, which demonstrates the point.

p. 60, 6th paragraph. Comment: This is a paragraph demonstrating something dairies could implement to improve groundwater nitrate levels. It would be nice to put some focus on this.

Response: This comment refers to the description of the lower groundwater nitrate concentrations following an early last manure application compared to increased groundwater nitrate concentrations following a late last manure application. Comment noted.

p. 61, 2nd paragraph. Comment: (circled**:** 60 mg/kg (210 lb/acre))—This seems excessively high. I would like to double check.

Response: This comment refers to the highest soil nitrate value observed. Comment noted.

p. 62, 2nd last paragraph. Comment: Would have to study more

Response: This comment refers to the discussion of too much irrigation contributing to nitrate leaching during the growing season. Comment noted.

p. 66, Table 9. Comment: I don't understand this completely. On the year with the least recharge there is a higher nitrate concentration in water. Wouldn't it be the opposite or is this not groundwater—but the water traveling from soil to groundwater

Response: This comment refers to Table 9 in the draft report (Table 14 in the final report) which shows the calculated concentration of nitrate in water leaching to the water table if 15 mg/kg of nitrate were mixed with the recharge that occurred during the fall. When less recharge occurs, there is less water to mix with the same amount of nitrate, so the concentration would be higher than when recharge is higher.

p. 67, last paragraph and Figure 54. Comment: I am having a hard time seeing this with our data. This seems like a stretch of the data.

Response: This comment refers to the discussion of winter soil nitrate as an indicator of nitrate leaching. We removed this analysis from the final report, because we were advised that the soil nitrate leaches so quickly from the soil in this area during the late winter months that it is not a good estimator for the mass leaching (Zebarth, 2013).

p. 70, Table 13. Comment: These are drastically different numbers between method A & B. What is the most correct?

Response: This comment refers to the table comparing the mean annual nitrate leachate concentration predicted using a mass balance method and the mean fall soil nitrate method. This analysis was modified in the final report.

p. 70. Comment: I think this is something that needs to be highlighted.

Response: This comment refers to the sentence**:** "The mean soil nitrate method predicted a leachate concentration similar to the measured groundwater concentration in 2006 and 2007." In the final report we used a different method to evaluate the suitability of fall soil nitrate and mass balance for predicting groundwater effects. Neither method was reliable as a predictor of groundwater nitrate concentrations, but both are still key tools for evaluating nutrient balance and comparing conditions over time at a particular field.

p. 71, Figure 55 caption. Comment: I think this should be a mean of all wells, instead of 1 well. How does soil type impact nitrate leaching potential? Is this soil type in CA similar to soil type in Whatcom Co.?

Response: This comment refers to the graph in the draft report showing estimated leachate nitrate concentration and actual winter groundwater nitrate-N. This graph is not included in the final report. However, most analyses involving groundwater nitrate in the final report include the mean for all shallow wells.

Soil type should not impact nitrate leaching potential unless there is an extensive, obstructive, low-permeability layer (like clay) that would prevent nitrate-bearing leachate from reaching the water table. There is no such low-permeability layer at the study site. Because nitrate is dissolved in the percolating water and does not react with the soil, it goes wherever the percolating water goes.

p. 73, 2nd paragraph. Comment: I think you should show Figures 46 and 53 if you're going to make this statement, because there were many improvements made in groundwater when management practices were altered. This is going to be the take-home message of this whole report.

I'm not sure this is the best take-home message of this whole report, because this average could have been different if the mass balance would have been closer to balance. This would be a completely different take-home message.

I think the focus should be on things that helped reduce nitrate concentration in groundwater and areas still of concern.

Response: This comment refers to the statement in the *Conclusions* section of the draft report that 65% of 308 shallow groundwater nitrate-N results were above the groundwater standard of 10 mg/L-N. We have added reference to the lower groundwater nitrate concentrations in 2006 and 2007 as a result of lower nitrate loading in the conclusions section and in the Executive summary.

p. 73, 2nd bullet. Comment: I don't think there is enough supporting data to make this comment.

Response: This comment refers to the portion of the *Conclusions* section of the draft report**:** "Likewise manure application early in the year may add to the recently mineralized (nitrate) and lead to significant transport to groundwater. This indicates that the application of manure during the months when precipitation exceeds evapotranspiration (October through March) presents a high risk for nitrate leaching to groundwater." The *Conclusions* section has been revised in the final report and does not include this statement.

p. 73, 3rd bullet. Comment: This is confusing to me because of the multiple factors affecting groundwater nitrate concentration. Groundwater nitrate levels were higher in 2008 when recharge was lowest. The lower the recharge the higher the estimated nitrate concentrations (Table 9). Table 9 does not follow Figure 46 groundwater nitrate concentration. I do not understand this conclusion. Recharge was highest in 2005 and groundwater nitrate was highest. But in 2008 recharge was lowest and groundwater nitrate was 2nd highest.

Response: This comment refers to the conclusion in the draft report regarding the rate and timing of recharge as a controlling factor for nitrate leaching. In the final report we have removed the statement that the amount of recharge is directly proportional to the amount of nitrate leached.

p. 74, 1st bullet. Comment: This statement doesn't talk about weather data or soil temp and soil moisture data and is confusing. Where is the soil moisture and soil temp data? It would be nice to refer to this data.

Response: This comment refers to the statement in the draft report**:** "In 2008, lower crop uptake and the highest applied excess nitrogen resulted in winter groundwater nitrate increases."

The soil temperature and soil moisture data were described in the *Results* and *Discussion* sections of the draft report, which have both been revised. These results are also referred to in the *Conclusions* section.

p. 74, 3rd bullet. Comment: I would make this the 1st statement in the conclusions.

Response: This comment refers to the bullet in the *Conclusions* section of the draft report with the heading**:** *Decrease in groundwater nitrate concentration over the 1st 3 years***-**

We have moved a portion of this item to the first page of the *Conclusions* section.

p. 74, 2nd last paragraph. Comment: Highlight this comment.

Response: This comment refers to the statement**:** "However when sampled more than one time immediately after the last harvest, and if no additional manure applications are made, the fall soil nitrate test can be a useful tool for producers to assess the general range of nitrate left in the soils."
We have tried to express this message in appropriate parts of the report.

Comments from Jay Gordon, Washington Dairy Federation

Comment: I am not a scientist, I am a farmer and a trade association representative. This report hopefully went to a diverse group of folks with the qualifications to evaluate the science, assumptions and conclusions. We would be most interested in seeing those thoughts. My observations come from 30 plus years of farming and working with farmers.

Response: The report was sent to various reviewers with expertise in agronomy, soil science and hydrogeology. This responsiveness summary lists comments received and our responses.

Comment: There is a very confusing array of information in this report and I think it would be good to schedule a day to sit down with folks right up in the Lynden area to walk through this. For example, You list wells and soil test areas, with many wells showing high nitrate levels, yet there are references to deeper wells that are very low.

Page 73 pp2- The shallow wells you established are not drinking water wells, they are somewhere around 9 feet deep. Earlier in the report you mention deeper wells in the .1-.333 ppm level. This doesn't add up.
-The use of averages throughout the report tells and incomplete story, For example the references to 65% wells exceed state 10 pmm levels - first of all these are not drinking wells, they are study wells to be used appropriately to study how nitrates move, when and at what rates...the other thing this average misses is that the first year 2005 had the highest level and number of over 10 pmm levels, this was following the field plowing....the use of averages dilutes the importance of the fact that tillage of sod has a measurable effect.

Response: After receiving these comments, Ecology met with the Dairy Federation and with the Whatcom County Conservation District to walk through the report findings. The wells used in the study are monitoring wells, not drinking water wells; this is described in the report. The final report uses both averages and maximum values to describe nitrate dynamics. The effect of tillage on nitrate loading is acknowledged in the report. The report has been edited to improve clarity, considering the large amount of information it contains.

The objectives of the study were to observe the effects of manure management activities on the nitrogen cycle at the field. Shallow monitoring wells are the commonly used method for observing cause-and-effect relationships as part of the nitrogen cycle at a site. The results for the shallow and deep wells are explained in the final report.

Comment: As we talked about a while back, there appears to be an interesting bias built into the study. It is backward looking, Farmers don't have the luxury of looking back in time to evaluate how we farm, Yes we can learn from study like this, but when spring comes I need to fertilize based on my understanding of how a field grows feed crops, my estimates for the season, the stage of grass , how old the stand is, what kind of irrigation water I will have available. This study flat out considers an over application as an over application but in a retroactive sense labels it an over application. How is a farmer supposed to know what heat units will materialize during the course of a summer, or rain fall or drought. For example, We had a heat wave first week of August 2009. Those four days over 100 degrees cooked our grass- there was no way to add enough supplemental water to all the fields simultaneously. Those four days changed the uptake rates for the rest of the summer and winter and even the next spring. Your report seems to consider that if a farmer applied manure the 25th of July that year, and then the grass crop went into heat dormancy, that the farmer was at fault. This bias is spread throughout the report.

Response: The report focuses on the observed impacts to groundwater and attempts to describe the nitrogen loading that caused the groundwater impacts. In that sense, the report is 'backward looking.' The purpose of looking backward is to understand the current situation so that workable options can be developed to address the situation.

The report recommends that new tools be developed to help farmers to improve nutrient management using expertise of university, regional, and state scientists as well as agricultural producers.

Comment: In the recommendations there is a suggestion that well monitoring is the only real manner for determining how to fertilize. Yet in your results there are times a place where the monitoring doesn't match either the fall soil tests or the mass balance tests. My conclusion is that all three are tools that work sometime and don't at others. Wells only measure after the fact, and once again you have to know when to test of test every day....

Response: Our findings indicate that groundwater monitoring is the most reliable method to determine groundwater impacts, because both post-harvest soil nitrate testing and mass balance analyses are not accurate predictors of groundwater nitrate concentrations. However, accurate measurement of the amount of nitrogen applied (in manure+fertilizer) as well as the amount of nitrogen removed in the crop are critical components of a field mass balance. With this information a farmer can have a sense of how much excess nitrogen may be available for leaching. Likewise, soil nitrate can provide the farmer with useful information for decision-making on future nutrient applications.

Comment: Through out the report are statements and assumptions about mineralization during the cool season, the basis for these statements is not well documented in your report. There are two references to northern Hemisphere mineralization in winter, but the location of those two studies is not reported- are they in California or Minnesota. The assumptions about soil mineralization during cool season need backed up. It is our understanding in the farming community that below 40 degree soil temperature do not result in appreciable mineralization, this needs discussed. There are obvious concerns with wet cool season applications that farmers understand such as run off. But the assumption that winter manure results in significant impacts to the aquifer is in doubt in my mind. IE. See page xxiv line 6

Response: Further explanations and citations regarding winter nitrate mineralization were added to the final report. Dr. Bernie Zebarth (Agriculture Canada) provided information on recent studies across Canada, including Agassiz, B.C, indicating that winter mineralization is much more important than previously thought and also detailing biochemical mechanisms for this.

Our results indicate that a substantial portion of the nitrate leaching at the study site occurred between January and March. See the *Groundwater nitrate GWNO3-BACKCAST modeling* section of the final report.

Comment: On page xx section two second sentence. There seems a bias against fall soil testing. It is a tool, like any tool it has limitations. It can be used right and wrong. There is noting wrong with the test, just how it is used and when it is taken. Same mistakes can be made with Wells, Mass balance, and tissue testing.

For example the mass balance protocol assumes a 15% volitization and 15% denitrification. Where is the basis of those assumptions, when do those rules not apply. If we have a wetter warmer season then volitization will be higher than a cool dry pattern. if we have wet and cold then what.

Response: We are not judging the post-harvest soil nitrate test (PSNT) in and of itself. It is an important tool for tracking nutrients in soil. However, our results indicate that PSNT results are not reliable for predicting groundwater nitrate concentrations. The soil water system is complex and dynamic, and changes occur all along the flow path.

We explain and compare 3 methods for estimating annual plant-available nitrogen at the study site in the *Discussion* section of the final report. The method developed by Sullivan (2008), Method 1-PAN, is used in more detailed analyses. Volatilization is taken into account in the Sullivan (2008) method, and denitrification in the soil was assumed to be negligible, as suggested in this reference also.

Comment: Page 12 Fourth Paragraph. Generalized statement regarding WSDA. Why ? What is the basis of this statement?

Response: This sentence was changed to**:** "The Washington Department of Agriculture is responsible for overseeing dairies and DNMPs. The minimum elements of a Dairy Nutrient Management Plan are described in the Washington State Department of Agriculture web site**:** http://agr.wa.gov/FoodAnimal/Livestock-Nutrient/DairyNutrientMgmtPlans.aspx"

Comment: Once again, to repeat, there is a fair chunk of information in this study, and I know your intentions are good, and we have work to do in the Whatcom area, but our level of trust is pretty low right now. There needs to be a multidisciplinary group meeting to listen to you and other folks walk and talk through this. Ecology is not in the farming business, we are and there is a big gap between accepting this information - along with all the other information that we use as farmers- and then actually incorporating it into farming practices. AND then actually seeing a difference in the ecosystem is even farther out on the horizon...but one step at a time and we can work through it.

Response: In advance of publication of the final report, Ecology has made several formal and informal presentations to groups with agricultural interest and expertise, to discuss findings and exchange information. These presentations include:

- Feb. 22, 2013 – WA Dairy Federation briefing (with co-author)
- March 19, 2013 - Whatcom CD and land owner (with co-author)
- March 21, 2013 - WA Conservation Commission
- 2012 USDA-NIFA Land Grant/Sea Grant National Water Conference (with co-author)
- 2012 Abbotsford-Sumas Aquifer Groundwater Nitrate Science Forum
- 2013 Abbotsford-Sumas Aquifer International Task Force
- December 11, 2013, EPA Region 10 AFO/CAFO Workshop

Comments from Virginia Prest, Washington State Department of Agriculture

Page xiv: "This value is the end-of-season nutrient management target number that is currently recommended to farmers to optimize crop growth for grass and minimize nutrient loss. The 55 lbs/acre guidance value was not developed for the purpose of protecting groundwater."

Comment: might help to say where this recommendation came from – WSU? Reading further on I see you do reference WSU in the next figure but decided to leave the comment in as during my read, this is where the question came to mind.

Response: This sentence is not included in the final Executive Summary. We added an explanation for the 15 mg/kg target for post-harvest soil nitrate in grass fields in the *Results* section that came from WSU Puyallup.

Page xv: "An alternative, although less accurate, way of estimating the amount of residual nitrogen in a farm field relies on measurements of shallow soil-nitrate concentrations collected in the fall. This technique (which was developed primarily to optimize crop output) is commonly used by farmers to manage nutrient conditions in their fields, and it has become an informal, low-cost measure of risk to groundwater."

Comment: All dairy farms are required to complete a fall soil sample 0-12 inches. While I agree it is not perfect, it is what we require through the NMP. I am not sure that the term informal supports that.

Response: The description of the post-harvest soil nitrate test has been removed from the Executive Summary and is now in the *Dairy Nutrient Management Plans* section. The word informal is not used.

Page xvii: The figure indicates that the mass balance method of calculating the end-of-season nitrogen residual is a better predictor of the overall groundwater concentration pattern.

Comment: Better than what?

Response: In the final report we re-analyzed the data using "plant-available nitrogen" for the mass balance. This figure has been updated in the final report. The comparison in the draft report figure was with soil nitrate predictions of groundwater nitrate concentrations.

Page xviii. "This shortens nitrate transport distances and times. In combination with an overall decline in nitrogen loading between 2005 and 2007, the decrease in the amount of fall recharge that infiltrated through the soil column (due to climate variability) was probably a contributing factor in the steady decline in groundwater nitrate concentration (Figure ES-7)."

Comment: is recharge = precip

Response: Recharge is not equal to precipitation. Recharge is the amount or rate of water entering the groundwater over a period of time. Evapotranspiration and runoff are subtracted from precipitation. Recharge has been added to the Glossary in the final report.

Page xxiv. "Reversing groundwater contamination in the SBA will require Reducing nitrate loading to groundwater. Additionally it will be imperative to monitor and evaluate the effectiveness of measures to reduce nitrate loading. The following actions are suggested to improve groundwater quality."

Comment: monitoring will not reduce nitrate loading or reverse gw contamination but it is a important component to track – suggest changing –

Response: Comment noted and wording changed.

Page xxv: "10. Track off-site manure transport and application and ensure that application is included in target field's nutrient management plan.**"**

Comment: Not sure how this fits. It is required for dairies to track exports – unfortunately it is not required for non-dairy applications fields to maintain soil and manure analysis or field application records.

Response: This recommendation has been deleted in the final report.

Comments from Cathy Ryan, PhD, University of Calgary, Alberta, Canada

Comment: in pie charge of N inputs- suggest you include lbs/ac as well as percentages so reader can grasp magnitude

Response: Labels added.

Comment: even though it wasn't designed to protect gw, a quick calculation dividing your 55 lbs/ac guideline with the volume of rain you expect to fall per acre (given a precipitation estimate) will give you a 'first cut' at the resulting groundwater nitrate. If I use one metre of recharge, I get about 6.2 mg N/L.

Response: This calculation is included in the final report with recharge instead of precipitation to be more accurate and 15 mg/kg rather than 55 lb/acre.

Comment: I think your right to point at tillage as a possible culprit for the really high N03 at the beginning of the study... did they also apply manure at the same time? A high rate perhaps? We are thinking more and more that manure application, fumigation, and tillage cause these kinds of periodic high concentrations under raspberries... all this being said the close correlation between N03 and Cl suggests high rate of manure application is really the culprit

Response: Correlation of chloride and groundwater nitrate is discussed in the final report. We don't know how much manure was applied during the growing season following tillage.

Comment: I think you already get this, but given you have a relatively high horizontal flow component in your study area (as do we), the groundwater you sample from your wells may have migrated from (and represent agricultural management of) upgradient fields. I can't tell how far below the water table your screens start, but at our site, if screens started about a meter or two below the annual low water table elevation we would be sampling from the upgradient field. A seven-foot long screen (commonly used I realize) could mix water from more than one field also. Over the next year I think Shawn Loo's work will help understand this better. Personally, I'd love to install a single diffusion sampling well beside one of yours to compare and contrast the information we get from it. Maybe we can discuss this possibility sometime.

Response: The influence of upgradient groundwater is discussed in the final report.

Comment: low irrigation nitrate concentration is remarkable- wells must be deep? Gives me hope for water supply....

Response: Comment noted.

Comment: NICE that you've measured Cl input to field :-)

Response: Comment noted.

Comment: Biggest surprise for me is the strong seasonal signal in DOC and P04 in AKG-726. Never seen data like this before. I'd love to see a cross plot of DO vs DOC to see if there is a relationship... Are you continuing to sample? Very intrigued by these data.... I'm curious to know if it is 'labile' in the context of denitrification (I suspect not). Why does the DOC cycle annually without the same overall inter-annual pattern that nitrate has....

Response: This analysis was not done for this study; however, the study data are available for others to use.

Comment: Re**:** "The property further upgradient of the residence was cultivated during the study and probably received manure at a rate similar to those observed at the study field. However, it takes 2.8 years for groundwater at the downgradient edge of this field (324 feet from the upgradient edge of the study field) to reach AKG721, 5.3 years to reach AKG725 and 8.0 years to reach AKG723"**-** this is based on an average velocity. It's easy to imagine there are narrow lenses that have hydraulic conductivites (and hence velocities) that are 10 to 100 time greater. Should put 'average time' to reach....

Response: An explanation of the influence of upgradient groundwater is included in the *Discussion* section. Based on our calculations, it is unlikely that upgradient groundwater had a significant influence on study site groundwater results.

Comments from Reviewers in pdf

The following pages include comments from these reviewers:

- Chris Clark, Whatcom Conservation District
- Bernie Zebarth, PhD, Agriculture Agri-Food Research Canada
- U.S. Environmental Protection Agency
- Bonda Habets, Natural Resources Conservation Service
- Jay Gordon, Washington Dairy Federation
- Cathy Ryan, PhD, University of Calgary, Alberta, Canada
- Steve Hulsman, Washington State Department of Health
- Derek Pell, Washington State Department of Health

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Whatcom Conservation District
6975 Hannegan Road, Lynden, WA 98264 Phone: (360) 354-2035 x 3 Fax: (360) 354-4678
e-mail: wcd@whatcomcd.org

May 16, 2013

Via Email

Barbara Carey, LHg
Environmental Assessment Program
Washington Department of Ecology
300 Desmond Drive
Olympia, WA 98504-7710

Joe Harrison
Professor - Nutrient Management Specialist, PAS
Washington State University
2606 West Pioneer
Puyallup, WA 98371

Re: Comment on the draft document: Nitrogen Mass Balance: Manure, Soil, Crop Removal, and Groundwater at a Grass Field Overlying the Sumas-Blaine Aquifer in Whatcom County

Dear Barb and Joe,

Please consider these comments. When we started this we were looking at pulling together the amount of data that would help answer questions:

"The principal questions addressed in this study are:

- How much nitrogen in a field receiving dairy waste is taken up by the crop?
- How much nitrogen is in the soil when winter rains begin?
- How much nitrate leaches to groundwater, and
- How do nitrogen concentrations in the major components of the nitrogen cycle vary seasonally and from year to year?"

…from QAPP.

The study and the answers to the above questions are important to "get out there". There are important lessons to be learned from your work. We urge you to state them in a direct manner. This will facilitate the transfer of information to the farmer which should be the overarching goal:

1. When a farmer applies more nutrients than the crop needs, it ends up in the groundwater.
2. Calculating "Agronomic Rate" or formulas used in farm plans are difficult.
3. Tools such as the Post Harvest Nitrate Test include protocols that are difficult to use.
4. Soil organic matter mineralization is difficult to predict and leads to nitrate leaching.
5. Timing of nutrient applications to coincide with uptake, dependent on biological systems for mineralization processes and precipitation is difficult at best.
6. Because of these difficulties, it is essential that producers receive technical assistance and tools to best protect water resources.

Here are some incorrect measurements and assumptions that greatly influence the results, calculations and conclusions.

1. Measure between wells 723 and 727 is 660 feet not 925 feet (equation 3). This affects:
    a. hydraulic gradient

b. velocity
c. time of travel
d. flow direction and contour lines.
    i. contour maps are not to scale
    ii. June 26, 2006 map 119.0 and 119.5 lables are incorrect
e. mapping of wells
    i. southern well locations are well north of property line and bend in Bertrand Creek.

2. Measure of precipitation.
    a. This affects recharge calculation
    b. This affects concentration of leachate
    c. Weather station recording issues and use of multiple stations.
    d. Abbotsford Airport records, & 5 inches after Sept1. see attached map.

2004	2005	2006	2007	2008	2009
18-Sep	10-Oct	3-Nov	2-Oct	2-Nov	17-Oct
5.12	5.2	5.7	5.57	6.32	6.17
61.33	60.55	60.94	66.42	48.57	54.62

    e. The only hydraulic testing occurred in April 2006 when recharge was less than typical.

	April 4, 2006 Hydraulic Testing						
	2004	2005	2006	2007	2008	2009	Average
30 days	5.45	8.366125	2.944876	13.10	3.488182	5.31	6.44
7 days	0.57	2.614168	0.7874	0.67	0.417322	1.93	1.16
since jan 1	17.51	21.89366	23.73617	29.80	13.64171	17.54	20.69
level							

    f. Recharge (inches) into using Abbotsford precip-et (-#s)in red removed)

Monthly Recharge								
	2003	2004	2005	2006	2007	2008	2009	Average
September		2.88	0.40		1.73			0.10
October		4.22	6.55	0.57	4.74	2.13	6.52	4.12
November		10.31	5.91	15.90	3.05	9.04	10.87	9.18
December		9.44	6.00	6.06	9.02	6.16	2.81	6.58
January	7.09	9.34	16.66	9.11	6.11	8.15		9.41
February	2.45	1.60	2.61	5.16	2.04	1.74		2.60
March	4.31	5.88	0.61	11.77	2.38	3.69		4.77
April		3.07	1.00	1.84		0.78		0.72

    g.
    h. Recharge (inches) to December:

Accumualted Recharge								
	2003	2004	2005	2006	2007	2008	2009	Average
September	0.00	2.88	0.40	0.00	1.73	0.00	0.00	0.84
October	0.00	7.10	6.95	0.57	6.47	2.13	6.52	4.96
November	0.00	17.41	12.87	16.46	9.52	11.18	17.39	14.14
December	0.00	26.85	18.86	22.52	18.54	17.33	20.20	20.72
January	7.09	36.18	35.52	31.63	24.66	25.49		26.76
February	9.54	37.78	38.13	36.79	26.69	27.23		29.36
March	13.85	43.66	38.75	48.56	29.07	30.93		34.14
April	13.85	46.73	39.74	50.40	29.07	31.70		35.25

   i. assumption of east to west characterasation not correct. See map. or Cox and Kahle.pg9. Increase in precipitation to North is documented.

3. Post Harvest Nitrate Test (PHNT) protocols were not evaluated correctly
   a. soil bulk density of this soil type and organic matter would not result in a 3.5 million pounds per acre conversion. Thus 55 lbs/acre would not be the target #. 15ppm is.
   b. before 5"rainfall
   c. 30 days after last application
   d. recommendations for changes to application timing and ammounts were not given or follwed to determine effacacy of this recommendation.
   e. 20 out 24 samples were over 15ppm when proper protocols were used. With 13, 14, 14.3, & 15 ppm being the other results.
4. Timing of Manure applications.
   a. Mineralization Rate of manure nitrogen or soil OM not quantified in study
   b. Recharge carrying nitrate not used in loading calculations
5. Porosity and Specific Yield = .25 typically .38 for this soil Cox and Kahle pg 28
6. Recharge from Cox and Kahle is 26-30" figure 11
7. Soils, soil grain size test, soil map-Hale, drained
   a. surface waters drained by (134' your datum amd lidar)
      i. Bertrand Creek, west 800 ft., elevation 134-14feet
      ii. Jackman Rd. Ditch, east 800 feet, elevation 134-10 feet
      iii. Hst rd. Ditch north 150 feet, 134-4feet
   b. finer grained in top soil (typical of hale)
   c. coarser in 4+ feet
   d. one grain size sample was ran in triplicate? Report is unreadable p150
   e. soil map shows hydrological grouping, with coarser grain soils all over the watershed. The Majority of farm plan fields are not over these soils.
      i. 1/3 area (~30,000 acres are A and B soils only ~3,000 acres manured fields)
      ii. 1/3 area type C includes Hale study site
      iii. 1/3 type D heavier soil, finer grained, more denitrification than study site
8. Land base requirements have increased land used to apply manure since 1997 with a decrease in the number of herds and total cow numbers. Use WSDA or Ag Statistics for animal numbers.
9. Hydrogeology
   a. coarse grains are below fine grained for Hale
   b. 40 feet aquifer depth pg 10, you use 35 on the calculations (Appendix Q. Bradbury…)
   c. hydraulic gradient influenced by both Jackman Ditch and Bertrand Creek.
      i. summer low flow impacted by Canadian irrigation
      ii. winter time runoff from Canadian development

10. hydraulic Conductivity
    a. conductivity numbers from Cox and Kahle using higher porosity
    b. using correct hydraulic gradient calculations Kc is greater
    c. Kc affects velocity
11. Hydraulic Testing
    a. assumptions for using Bradbury are questionable
        i. unconfined aquifer
        ii. is the storage coefficient known
12. QA
    a. manure and soil samples should not be expecteced to meet standard deviation assumptons.
    b. Soil samples that do match exactly are questionable.
        i. the random soil sample procedure should not have repeated results.
        ii. soil sample on 11/8/2006 stands out as an extreme high soil nitrate.
            1. exact same result on 11/8/2006 is questionable
            2. exact same results on 8 other dates prior to 11/8/2006
            3. no exact same results there after
            4. sampling protocol called for 15 cores mixed together, bagged separately from 15 additional cores. Soil variations account for variable results.
        iii. Manure Samples if taken during the time of application (more than an hour apart) should show varitation in lagoon effluent
            1. agitation
            2. lagoon stratification
13. Winter Mineralization
    a. reference materials point to temperatures not seen in our area. T>10C. Trinidad
    b. -15C the soil is drying out, disceiation of soil microbes and heating while drilling the sample out can spur mineralization
    c. drying a soil sample out will spur mineralization (see PHNT protocols)
    d. Cookson reference applied 1240lbs of TKN with ~15 tons of clover that had 10 ppm mineral (NO3 or NH4) to start and it had a CN ratio of 11.5:1. At those high rates they found 90-215ppm of mineralized N after 90 days at 2-15C on a laboratory bench. Applying 1/10th would result in ~10ppm or 30 lbs/acre of nitrate, our grass systems can use that much in 90 day winter window.
    e. Grass uptake during the winter from October 1 to April 1 will grow ~120 pounds of nitrogen out. Providing 40 lbs with a last application of plant available, 60 more pounds in th early spring. with the assumption that 20 lbs will come from the soil OM.
14. Mass balance calculation does not follow NRCS protocol.

Will answers to questions within this study provide help to producers to protect water quality? Yes. Discussion of what the right numbers are may lead to more questions. We all make mistakes, identifying difficulties in the calculations and protocols including frustrations with collecting weather data may help others trying to answer these questions in the future.

Finally, it is important for me to register my concern about the failure <u>to follow sampling protocols.</u> Chief among them was leaving the well head open to a manure application. We are all human. So, I can understand that it can happen. In my professional opinion, which I believe represents the larger scientific community, it can significantly negatively affect sampling accuracy, our credability and future collaborations. Such lapses call into question the validity of studies. As we have seen recently folks take legal actions predicated upon the results. Given what can be at stake, it is critical that folks follow protocols precisely every time.

Thank you for your willingness to receive input. Attached are maps and the draft with edits and notes. Please consider these the districts comments. Call me if you have any question with these comments.

Sincerely yours,

Chris Clark
Agricultural Engineer, PE

Enc.
ReportCareyManureStudy cc comemnts
study map
PrecipandAquiferSoils

Carey, Barb (ECY)

From: Zebarth, Bernie [Bernie.Zebarth@AGR.GC.CA]
Sent: Tuesday, May 14, 2013 4:53 AM
To: Carey, Barb (ECY)
Subject: RE: Nitrogen study at a manured grass field

Thanks, I will try not to take too long.

Perhaps a few words on the post-harvest test to put it into context.

It is true, the post-harvest test will not necessarily address the risk of nitrate contamination of groundwater. But, perhaps it is useful to fully understand the intent of the approach. First, you need to understand that there is currently NO spring soil N test in these humid environments. The closest we have is the PSNT test for corn, but no test at all for forage grasses. Given the lack of a spring soil test (such as exists for P and K), how do we evaluate our current practices? For lack of a better approach, we started using the post-harvest test as a "report card" on how we did. Now, understand that this test will not tell us if we had optimal or below-optimal management. Rather, it will ONLY identify excessive inputs. You can argue if that is sufficient to protect groundwater or not, that is a slightly different discussion. What it will do, however, is identify fields with excessive N inputs which can become major contributors to nitrate leaching. Things have certainly changed since I worked in the Fraser Valley, but at that time we guessed that, at least for raspberries, a large proportion of nitrate leaching occurred from a small percentage of fields with very high loading. Such a test approach as this one would help identify such fields. If we can accomplish that, we can greatly decrease nitrate loading.

Now what you are considering, is can we get down to the drinking water guideline. This is a bit more tricky. It sounds like the recharge near this study site is quite a bit lower than in Abbotsford, closer to, say, 500 mm/yr. If that is correct, then you only need to leach about 50 kg N/ha to reach 10 ppm nitrate-N in groundwater. You are sampling to 1 ft depth. Chances are, you have similar nitrate concentration to at least 2 ft depth. If so, you only need to be in excess of 25 kg N/ha in each 1 ft depth to exceed this guideline for nitrate. But, is this achievable? Perhaps, but it is very challenging. These are high fertility soils, and they can mineralize N quite rapidly. For example, if you have a corn field that dries during the summer, it will have a flush of mineralization in the fall when the soils re-wet. That flush alone can generate sufficient nitrate to exceed the guideline. For grasses, if you consider the total N inputs, the margin of error (as a percentage) required to exceed the guideline is quite small. I do not say this to excuse current practices, but rather to put them into perspective – it is very challenging!

So, in the context of protecting groundwater quality, it will be difficult to use a post-harvest soil test alone. In addition, you must also be aware of the assumptions involved. This post-harvest test assumes negligible in-season nitrate leaching. But is this valid? If irrigated, perhaps not.

One further complication. I remember visiting a dairy farm in Oregon mid-summer when the soil was nice and dry. The producer was irrigating from their manure lagoon. Thanks to cracks and macropores in the soil, the irrigated manure was trickling out the end of the tile drain!! Water, manure and nutrients can move quickly and in unexpected ways!

Bernie

From: Carey, Barb (ECY) [mailto:bcar461@ECY.WA.GOV]
Sent: May-13-13 5:14 PM
To: Zebarth, Bernie
Subject: RE: Nitrogen study at a manured grass field

For you, Bernie, I will make an exception if you need it, take another week or 2 ☺
Barb

Carey, Barb (ECY)

From: Zebarth, Bernie [Bernie.Zebarth@AGR.GC.CA]
Sent: Tuesday, May 14, 2013 5:03 AM
To: Carey, Barb (ECY)
Subject: RE: Nitrogen study at a manured grass field

A word on N budgets.

Typically, such N budgets take two approaches.

1. They are applied over a longer time frame. In this approach, we assume that the system is at some equilibrium, and as a result, internal N cycling can be neglected. That is, we can ignore processes such as mineralization. In this case, you can simply consider the additions and losses to, for example, the root zone of an individual field. The surplus then represents the potential for leaching losses. Note that this is on average – the actual loss in any given year can vary widely because a) the system is likely not at equilibrium and b) although the N surplus may be valid on average, the actual surplus in any given year can vary widely due to variation in environmental conditions (for example, through influence on crop growth and N uptake and on soil N mineralization).
2. You can do an annual budget. In the case of the annual budget, you no longer have the luxury of assuming the system is at equilibrium. In this case, you need to account for all inputs and losses. This means you can no longer neglect the internal N cycling, and you would then have to make an assumption about, for example, how much mineralization is occurring.

For this reason, you might actually want to consider constructing the N budget over the 4 year study period, and use that as the best estimate of the surplus and associated risk of leaching? It is that surplus over the study period, and average groundwater nitrate concentrations (which also may reflect nitrate leached over a significant time period depending on your depth of sampling) which should be best related to each other.

In constructing your annual N budget, I think it would be useful to do this on the basis of plant available N as opposed to total N. For example, include all manure ammonium-N, but only a fraction of the manure organic N. This still leaves the problem of estimating net N mineralization – no easy solution for that. However, the plant available N will give a more meaningful surplus than total N in my opinion

Cheers

bernie

From: Carey, Barb (ECY) [mailto:bcar461@ECY.WA.GOV]
Sent: May-13-13 5:14 PM
To: Zebarth, Bernie
Subject: RE: Nitrogen study at a manured grass field

For you, Bernie, I will make an exception if you need it, take another week or 2 ☺
Barb

From: Zebarth, Bernie [mailto:Bernie.Zebarth@AGR.GC.CA]
Sent: Monday, May 13, 2013 12:22 PM
To: Carey, Barb (ECY)
Subject: RE: Nitrogen study at a manured grass field

Sounds good.

Carey, Barb (ECY)

From: Zebarth, Bernie [Bernie.Zebarth@AGR.GC.CA]
Sent: Tuesday, May 14, 2013 5:55 AM
To: Carey, Barb (ECY)
Cc: Cathy Ryan (cryan@ucalgary.ca)
Subject: chloride - a question

As you know, I am working my way through your report and sending lots of comments and questions.

I pass this one on and copy to Cathy, since chloride is such a friend of hers!

I was looking at the longer term trends in nitrate and chloride over time in plate 5. The temporal trend in nitrate makes sense if the field was broken and re-seeded at the start of the experiment. The breaking of forage grass sod can result in huge release of N (this is thought to be the source of a lot of contamination in the UK where they broke grasslands after the war....). What is interesting, though, is the longer term decline in chloride. There should be no "storage" of chloride in the soil or the crop residues. So, why the longer term decline in chloride over time? Any chance this reflects something up-gradient of the study site? Any other ideas on this? Perhaps this pattern reflects that previously much greater manure applications were made and the concentrations are being diluted over time? I find it quite puzzling....

Bernie

Bernie Zebarth
Potato Research Centre
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June 17, 2013

Martha Maggi, LHG
Environmental Assessment Program
Washington State Department of Ecology
P.O. Box 47775
Olympia, WA 98504-7775

Re: Review of Washington Department of Ecology (Ecology) Draft Report -- *Nitrogen Mass Balance: Manure, Soil, Crop Removal, and Groundwater at a Grass Field Overlying the Sumas-Blaine Aquifer in Whatcom County March 2013 – Review Draft dated March 29, 2013*

Dear Ms. Maggi:

As requested, the U.S. Environmental Protection Agency (EPA) has reviewed Ecology's report titled *Nitrogen Mass Balance: Manure, Soil, Crop Removal, and Groundwater at a Grass Field Overlying the Sumas-Blaine Aquifer in Whatcom County, March 2013 – DRAFT*. Our review was supported by scientists with expertise in hydrogeology and groundwater field studies.

Our comments are enclosed. General comments are presented first, followed by specific comments. Many of our comments pertain specifically to this study and would not apply in other settings. Please feel free to contact us if you have any questions or would like to discuss the comments. Thank you for the opportunity to review this interesting report and we look forward to seeing the final report in the future.

Sincerely,

Marie Jennings, Manager
Drinking Water Program

Enclosure

cc: Sheila Fleming, Risk Evaluation Unit

EPA Region 10 Review of Washington Department of Ecology (Ecology) Draft Report - *Nitrogen Mass Balance: Manure, Soil, Crop Removal, and Groundwater at a Grass Field Overlying the Sumas-Blaine Aquifer in Whatcom County March 2013 – Review Draft dated March 29, 2013*

General Comments

This report describes a complex and comprehensive four-year field study to evaluate nitrogen application and cycling for a grass field receiving dairy manure with a specific emphasis on the transport of nitrate into ground water. This research is very relevant and seeks to address whether current application guidelines are protective of ground water quality. We commend the authors for the effort that they undertook in trying to address all of the relevant parameters and in trying to extrapolate their findings to other regions of interest. We have noted some technical errors, inconsistencies, and issues with data presentation, including the use of inconsistent scientific units. Addressing these issues will strengthen the report.

1. The central theme of the report is evaluating the use of annual excess nitrogen mass balance as a nutrient management tool. This is in effect a partial mass balance, created by calculating input N minus that portion of the output N which is not made up of nitrogen leaching out of the soil; the difference is assumed to be nitrogen that can eventually leach. However, the difference can also be due to that plus artifacts caused by mis-estimates of mineralization, volatilization, or denitrification processes that vary year to year and across the site. The report tries to correlate these calculated annual excess nitrogen values to the "winter mean" (i.e., Nov-Dec) ground water nitrate values, and the results are mixed. In one portion of the report (page 56) you describe a fairly good comparison, because you made (and described) the decision to select one well (AKG725, Figure 46) because it was located in a portion of the site with the lowest potential impact from denitrification. We noted a contradiction in other sections of the report (e.g., page 70) where you show the same data but conclude that this approach is not a reliable method of predicting ground water nitrate. Because the annual excess nitrogen value is a single estimate considering all available data throughout the year, the question arises as to why you chose to compare it just to winter mean ground water nitrate values, and not each of the ground water nitrate values since some leaching occurs yearlong, especially after periodic land application events.

   The report concludes that this is not a reliable tool for predicting ground water impact from nitrate, but then states it may still be useful for balancing plant needs with manure application. How would this calculated value be used? Considering all of the monitoring, measurements and assumptions required to produce this calculated estimate, wouldn't it be more efficient and economical to instead just monitor water table nitrate concentrations periodically, especially in this region where the water table is shallow and easily accessible? This study shows that the amount of manure/fertilizer nitrogen that was applied each year was directly proportional to the annual excess nitrogen mass estimate with good correlation ($y = 0.77x - 304$; $r^2 = 0.9729$). Examination of Equation 8 and Table 8 shows that manure/fertilizer loading was the main driver – atmospheric deposition, soil matter mineralization, ammonia volatilization, and denitrification were all assumed to be constant year to year, and even crop production did not vary much year to year in this case. Another question would be that if this annual excess nitrogen is not proportionately impacting ground water nitrate levels, where is it all going?

In summary, we are left with the understanding that while the annual excess nitrogen mass estimate may not be a good predictor of ground water quality, it may be useful for better matching manure/fertilizer nitrogen loadings to crop demand. However, it is unclear how exactly this would be used and whether the end result would justify the expense of the extensive annual monitoring required.

2. We suggest that the report clearly state upfront that the assessment of direct ground water impact is restricted to the upper reaches of the aquifer only, and may not represent the aquifer as a whole. This is a fairly unique hydrogeological setting in that the shallow water table ranges by about seven feet annually and that each year the soil is saturated in the winter up to near the ground surface (Figure 28). This allows for saturation dissolution of soil nitrate which can cause very high nitrate values, and may allow substantial organic carbon to be transported along with the nitrate. The ground water sample inlets and the low-flow sampling techniques are designed to acquire ground water samples as close to the water table as possible. Assuming that Figure 12 is correct, any high concentrations of nitrate in shallow ground water should "dive" downward as bulk ground water flows beneath the region. If unmitigated by dilution or other processes, nitrate levels measured at the top of the water table that are above the MCL could potentially cause nitrate levels in downgradient drinking water wells to exceed the MCL. According to the data collected from the one deep well beneath the site, nitrate is absent, but ammonium levels are higher than those in the shallow wells.

   There is no nitrate (but again minor levels of ammonium) in the upgradient deep private wells. One explanation for this could be dissimilatory nitrate reduction to ammonium, which occurs when nitrate becomes limiting relative to utilizable organic carbon. The amounts of ammonium produced are so minor that this would not have much impact on the nitrate loading, but if this process were occurring then it would be reasonable to assume substantial denitrification occurring in the aquifer matrix above. It would have been interesting if some downgradient private wells had been sampled, or if some other wells had been installed within the mid-levels of the aquifer or downgradient of this site to evaluate whether high nitrate levels observed in the shallow aquifer have migrated deeper into the aquifer.

3. The stated purpose of the study on page xi was to "... conduct a field study to evaluate the effectiveness of Dairy Nutrient Management Plans (Chapter 90.64 RCW) in protecting the quality of the Sumas-Blaine Aquifer." The results of the field study indicate that the post-harvest soil benchmark used in Nutrient Management Plans is ineffective in preventing groundwater contamination. The study's conclusions do not circle back around to this central question and clearly state whether NMPs are or are not effective as currently implemented, even though the data support a clear conclusion. Presenting a clear, conclusive response to the initial question that was posed would strengthen the report.

4. The report concludes that "estimated excess nitrogen" is a more reliable predictor of groundwater impacts than measuring soil nitrate levels. It is not clear to EPA that this

conclusion is supported by the data. However, if the conclusion is supportable, it is an important concept that should be highlighted. Similarly, the concept that the current soil nitrate target recommendation of 55 lb/acre criteria does not take into account groundwater impacts, and the conclusion that it significantly underestimates the risk to groundwater should be highlighted since that rate is mentioned as "guidance" in the report. The installation of groundwater monitoring wells should be more clearly called out in the recommendations section. In a geographic area like Whatcom County where the water table is very close to the ground surface, monitoring wells would be relatively inexpensive and easy to install, and would provide direct information about aquifer conditions, rather than having to rely on surrogate data with significant uncertainties such as soil nitrate tests.

5. The text should more clearly explain how the level of post-harvest soil nitrate recommended in the guidance could be revised so its use would ensure the protection of groundwater.

6. Overall, the Executive Summary (ES) doesn't stand on its own. Recommend adding a project setting section to the ES. The ES currently lists three bulleted items on page x, 5th paragraph, but this discussion should be broadened (i.e, briefly discuss land use and setting of study area and SBA; regional hydrology, briefly explain how manure is handled, etc.). On the other hand, some of this information could be put in an Appendix showing what was and what was not measured.

7. It would be helpful to add a figure depicting a cross section of the aquifer and vadose zone showing the property boundary, groundwater flow direction, the water table, and the location and depths of the shallow and deep wells.

Specific Comments

Note that the following comments for the Executive Summary should be considered and addressed, if appropriate, throughout the main text of report for the corresponding sections and figures.

1. Page xi, Figure ES-1. The figure should have another note on the legend which defines what appear to be generally incorporated or more urban areas shown in a red tone.

2. Pages xi, 3, and 73. The objective(s) of the study are stated several times, but are not stated consistently. Suggest reviewing, and revising where appropriate.

3. Page xii. Recommend separating program objectives from technical objectives and outcomes or how to use the study. Even though this is the Executive Summary, it would be helpful to state how the objectives support the goal of evaluating the effectiveness of nutrient management plans.

4. Page xii, third paragraph from bottom –Mass balance implies that all outputs and inputs are considered and weighed against each other. This is actually a partial mass balance, because a key component (nitrogen output through leaching) is not directly measured. This should be noted.

5. Page xiii, first line. The word "seven" is spelled out here but elsewhere numbers are referred to numerically. Also, it becomes confusing when sometimes the report refers to

seven vs six wells. Suggest this sentence be rewritten to refer to six shallow wells and one deep well.

6. Page xiii, Figure ES-2. Arrows should be added to and from ammonia (soil block) box to indicate the direction of the process. It would help to write out "denitrification" to identify the arrow leading to N_2 gas, and "volatilization" to identify the arrow leading to atmospheric ammonia. Why are there two boxes for ground water nitrate? What is the significance of multiple arrows and an (errant?) arrowhead in the aquifer matrix?

7. Page xiv, Figure ES-3. The colors in this and other figures could be adjusted so that if the document is printed in black and white, the figures can still be interpreted.

8. Page xiv, bottom paragraph. The statement, "These values provide an approximation of the amount of nitrogen that could reach groundwater if the soil was flushed by water recharging the aquifer in the months following the end of the growing season", assumes that none of this nitrogen has already leached out during the growing season prior to this flush. Because the data shows nitrate spikes following manure application events during the growing season, we can assume that some nitrogen does leach out during this time, hence the annual excess nitrogen would be much higher than fall soil nitrate.

9. Page xv, Figure ES-4. The left axis may be better labeled Total Nitrogen. It is unclear that "mean fall soil nitrate" as shown on the figure is "excess" from this graph or discussion.

10. Page xv, first paragraph. Specify that the target amount is for fall soil nitrate, not excess nitrogen.

11. Page xv. The second paragraph from the bottom refers to green bars in Figure ES-4, but there are no green bars in this figure.

12. Page xvi, bottom paragraph. Define winter mean range as Nov-Dec.

13. Page xvii, first paragraph. Can the report really make any definitive statement about comparing fall soil nitrate with annual excess nitrogen as a better predictor of winter ground water nitrate, at least without doing some statistics? In the absence of numerical values for fall soil nitrate, a best guess analysis does not show a much better correlation with excess nitrogen ($r^2 = 0.41$) than with fall soil nitrate ($r^2 = 0.28$). Page xvii, Figure ES-6 – This figure could be misleading. Suggest the report state that the ground water mean is for one well (AKG725). The excess nitrogen values are incorrectly graphed in Figure ES-6. See Figure 46 for actual values and better graphical representation.

14. Page xvii, Figure ES-6. The left axis label should be Total N (lb / acre), not per year since the years are shown by the different bars.

15. Page xvii, Figure ES-6. See comment 7 above and specifically it would be good to have some description or cross hatching so that even if a black and white printer is used the bars could be better defined (one approach would be to use a label – blue bar is left bar, or use of hatches in one of the bars). In addition, this figure and descriptions deal with mass balance, but the axis is "Excess total nitrogen" and MCL for reference. Overall the point being made comes through, but it could use a few more touches on the figure to make it clearer (would changing left axis to "total nitrogen" vs. "Excess total nitrogen" resolve this issue?).

16. Page xvii, bottom section. Factors affecting groundwater nitrate concentrations – This sections seems to address NMPs but not directly. The text should clarify that the topics below are core elements of a NMP.

- Nitrogen application rate
- Timing of manure applications
- Recharge
- Tillage
- Temperature and Soil Moisture
- Denitrification

17. Page xviii, third paragraph. Chloride will leach out of manure well before nitrate does, so why couldn't the nitrate come from the previous year's manure?

18. Page xviii, last paragraph. Define fall recharge range (Sept-Oct?). Recommend that you provide support for the inference (to avoid appearing arbitrary) – that decreasing fall recharge rates may be contributing to decreasing year-long ground water nitrate values. The overriding driver could be annual rainfall rates, which show a much different trend, being very low in 2005 and high in 2006-2007.

19. Page xix, first paragraph. Can you specify when tilling occurred and in what year?

20. Page xix, Tillage Section. This seems like a very important relationship, but there seems to be some disconnect with the figures and its importance may be overlooked. Should this section reference figure ES-5? While similar to ES-7 the reference to "Nitrate-N concentrations in groundwater the winter after tillage were as high as 45 mg/L-N" seems to more closely match figure ES-5 than ES-7 (which is the last figure referenced and is located above the tillage section). Also note that figure ES-5 does have concentrations that go to 45 mg/L.

21. Page xx, Figure ES-8. It is difficult to figure out what the green bars mean. Suggest this text: "Range of soil nitrate concentrations measured during September-October fall sampling period.

22. Page xxi, first paragraph. On page 13 it says that tilling was done in 2004, not 2005. Also, it seems like selective data are used to support the point. Feb 2005 and Jan 2008 soil nitrate data are listed as high. Why not use Feb 2008 data, which is half the value of Jan 2008? Is it because no Jan 2005 data were available and you are using just the first data point for each year?

23. Page xxi, Figure ES-9. These charts are too small to read. Also, the nitrate MCL line is missing in the AKG727 graph.

24. Page xxii, second paragraph. Statement contradicts previous observation that the annual excess nitrogen method is better than the fall soil nitrate method for predicting winter ground water nitrate. Figure ES-10 – Yellow and blue bars represent ground water nitrate by different methods. Need to add the word "method" after descriptors for these bars. Otherwise it looks like the yellow bar represents mean fall soil nitrate.

25. Page xxii, last paragraph. The second sentence is not clear as written ("concentration of groundwater mixing"). Suggest "...uncertainties regarding mixing of ground water and leachate, and ongoing generation of soil nitrate past the end of the growing season."

26. Page xxiii. Implications for other parts of the SBA. This section could more clearly state the implications for other parts of the SBA. We assume that you are trying to say that this study site has the potential for much greater rates of denitrification than would be found in other parts of the SBA, which would suggest that nitrate levels would be expected to be higher and more persistent at other locations. Text should be clarified. Page xxiii, at the top of page: "...using estimates of excess nitrate in the soil at the end of the growing season is an unreliable substitute for direct groundwater monitoring ..." is correct, but it seems to conflict with other statements and figures in the report which imply that the use of the excess nitrate in soil method is a good indication of potential contamination from nitrogen loading Figure ES-6 seems to indicate that the "estimated excess nitrogen" correlates with the potential for contamination. That is confusing when compared to the following statement made about Figure ES-6 in the top of page xvii – "....The figure indicates that the mass balance method of calculating the end-of-season nitrogen residual is a better predictor of the overall groundwater concentration pattern." These issues create potential for confusion about some very useful concepts presented in this report, and we suggest that some word changes may minimize potential reader confusion. Under the section "Use of current soil nitrate 55 lbs/acre target to protect groundwater," we concur with the report's conclusion that the established end-of-season nitrate concentration recommendations still pose a risk to groundwater. This conclusion is significant and should be emphasized.

27. Page xxiii, third paragraph. There appears to be insufficient evidence to conclude that the maximum fall soil nitrate value is better than the mean fall soil nitrate value for estimating the amount of nitrate that can be leached.

28. Page xxiv, first sentence. Instead of using the phrase "worst-case scenario", we recommend the phrase – "potential for ground water contamination by nitrate would be greater in other regions" to make this point more clear.

29. Page xxiv and page 77, Recommendations. Suggest that the report relate the recommendations back to the goal of determining the effectiveness of NMPs.

30. Page xxiv, second paragraph. These actions may <u>reduce</u> contamination, but will not <u>reverse</u> contamination.

31. Page xxiv, third paragraph. Bullets are used elsewhere... why number these recommendations? Recommendation #8 regarding corn seems to be outside the scope of this study. Recommendation Number 7, sentence seems to be missing the phrase "manure application" after the word "last".

32. Page xxv, last paragraph. Monitoring is needed to evaluate the effectiveness of management practices, and not just improvements. EPA would suggest that routine ground water monitoring be conducted, in which case there is no need to go through the expense of generating an annual excess nitrogen mass estimate as a screening tool.

33. Page 4. The list of questions that seem important; however, the significance of these questions as they relate to the study goal isn't clear.

34. Page 4. We do not recall any discussion of estimating the lag time between nitrogen application and arrival of nitrate at the water table in this report. It is assumed that the lag time could vary significantly since application occurs at different times during the entire growing season. Should this objective be dropped?

35. Page 8, first sentence. Data are shown in Table T.3, not T.2. But T.3 was not included in this report. What is the purpose of the temperature information summarized in Table 1? Suggest referencing the full dataset in an Appendix or providing a more comprehensive summary (e.g., daily or monthly maximum and minimum temperatures).

36. Page 8, Table 1. Units should be included.

37. Page 11. A table outlining what's required in an NMP would be helpful.

38. Page 12. In the dairy nutrient management plans section, the Sullivan and Cogger soil nitrate threshold (15 mg/Kg (55 lb/acre)) appears, and since it is used in other sections and figures it may be good to reference those sections or figures to this section or page. Also in this section there appears to be a key statement concerning the critical effect of timing of soil sampling with the weather. Perhaps these two sentences should be printed in **bold** since they are considered as some baseline references.

39. Page 13, first paragraph. It seems like this first sentence should go into the preceding footnote, since it addresses a technicality for this calculation.

40. Page 13, Field Management section. Additional information would be helpful here. Does this farmer follow a DNMP? Is there guidance that the farmer is using to determine loading rates? Why did he apply almost double the amount of manure nitrogen in 2008 and, to a lesser extent, in 2005? Does he apply all of the manure he has, or does he get it from off-site and why doesn't he apply less? Did he apply at the upper loading rate in 2003 and 2004 or do anything else different that might have caused the large ground water nitrate spike, other than tilling? Were livestock ever permitted in the field?

41. Page 15, third paragraph. If known, provide the depth of the screened interval for the well used for irrigation, and show its location on one of the maps.

42. Page 15, Nitrogen Cycle. The concepts of "fall soil nitrate", "excess nitrogen", and "mass balance nitrogen" seem to first come up in detail after this section of the report. Later on the term "excess total nitrogen" appears. What is the base datum for calculating "excess"? EPA would suggest having a short discussion of all those definitions and calculations at around this section to set the framework for those terms used in the rest of the report. This may be related to our confusion with Figure ES-6 mentioned above.

43. Page 18, last paragraph. On page 15 the water table is listed as rising from 1 to 3 ft instead of 0 to 3 ft. Pick one and be consistent.

44. Page 20, Study Design. Suggest that you relate the results back to the goals of the study.

45. Page 20. On the "Residual" bullet section, the text implies that soil fall nitrate is measured as well as mass of nitrogen? According to Figure 10 and Appendix C, only nitrate was routinely measured in the soil. Is the latter text just intended as a definition of soil nitrate? If so, it should clearly state nitrate-nitrogen. Otherwise suggest that you delete it.

46. Page 21, Figure 9. Arrow needed for soil organic matter. Otherwise same observations as noted for Figure ES-2.

47. Page 22, Figure 10. In this figure the ammonia and organic nitrogen boxes are pink, indicating that they are measured. They are not. By the way, it took awhile searching through this report to locate the table listed as Appendix C. It would help to have this table in the main body of the report because of its importance.

48. Page 23, Methods. More detail should be provided on how the bucket sampling was done, and the relationship of the buckets to the irrigation methods. Also, how does the timing of the sampling and delay between the water entering the bucket and when that water is placed in sample containers affect the concentrations that were in the samples that arrived at the laboratory? Overall the method of collecting the water and then the delay between collection and taking the measurements and analyses merits a discussion of the potential uncertainties.

49. Page 23. Describe how the grower decided how much N to apply. Were N application rates within WSU recommended fertilizer rates for the crop being grown? Were they within the recommendations of the Western Fertilizer Guide? More detail is needed here.

50. Page 27, first sentence. It would enhance clarity to state that the monitoring well network consisted of six shallow and one deeper well. Because it is not quite clear from Figure 13 where the top of the well is relative to ground surface, it would also help to list the approximate distance between the ground surface and the top of the screen for the shallow wells.

51. Page 35, first paragraph. The last line on dairy manure treatment should be stated earlier in the farm management discussion.

52. Page 35, last paragraph. What is the rational basis for assuming that chloride in a shallow well in an agricultural region is negligible? Is there regional shallow water quality data to support this assumption?

53. age 36, middle paragraph. The observation that nitrogen crop uptake appeared to be inversely correlated with nitrogen applied to the field is an important finding and should be highlighted in the conclusions. It should provide further incentive to use less manure when the objective is to maximize yield (as opposed to maximizing disposal). By the way, some of the numbers in the text again do not match with the numbers listed in the figure (434 vs. 436, 716 vs. 736).

54. Page 36, last paragraph. In 2005, the last grass crop was not removed from the field, but the estimate of nitrogen harvested assumed crop removal. This would mean that this estimate is biased low because the nitrogen in this grass is subtracted out even though it never left the field and the real annual excess nitrogen mass would be higher because the grass will decompose and then re-enter the system as part of the original load.

55. Page 38, third paragraph. The sentence is missing "of" before fine-grained – "Samples below 7.5 feet in the other wells had varying amounts *of* fine-grained material."

56. Page 43. Equation 7 missing ( ).

57. Page 45, Dissolved Oxygen section. It is inaccurate to categorically state that denitrification does not occur at dissolved oxygen concentrations greater than 2 ppm. Denitrification is more correctly described as a microaerophilic process rather than as an anaerobic process, and can occur at oxygen concentrations greater than 2 ppm. It is facilitated by lower oxygen levels and is expected to be more active at lower oxygen levels, and this has led some to establish a reasonable upper limit of 2 ppm dissolved oxygen. But in soil and aquifer matrices there can exist a variety of anaerobic microsites with oxygen levels much lower than the bulk water, and so care should be taken not to dismiss this process in aquifer or soil matrices where ground water sampling may indicate higher oxygen values.

58. Page 50. Effects of drain tiles. The report recognizes the use of drain tiles throughout the SBA even though there were none in the study area. On page 50, in the last paragraph, the last sentence states: "The remaining 83% of soil nitrate was presumed to leach to groundwater." That presumption applies in this study field however it may not be true in fields that do have drain tiles. Nitrogen loss via tile drains will have an adverse environmental impact on surface waters.

59. Figure 44 (Plate 6). The term "excess total nitrogen" seems to only appear on a word search on this figure and in Figure ES-6. Is it different than excess nitrogen?

60. Page 53, Equation 8 – Need parentheses around Equation 8 label.

61. Page 53, equation legend. For "S", text should read "from", not "form". Note that the sentence below describes the need for this equation to assume a steady state, which "normally" happens for the crop 3 to 5 years after growth. It seems like that is not the case for this site, based on the water quality data indicating a perturbation in 2004 or prior.

62. Page 54. Table 8 displays the input requirements and expected outputs from a mass balance analysis. This study conducted by researchers at Washington State University was conducted with the full cooperation of the producer that operates that tract of land. The text recognizes that a challenge of conducting an accurate mass budget analysis is that it relies on the accurateness of records kept by the producer. Some of the information that a producer would be expected to maintain, then provide to Ecology includes, but is not limited to:

    - Listing of all fields where land application occurs.
    - When applications are made.
    - How applications are made (injected, broadcast, mixed with irrigation water and sprinkled etc.)
    - What kind of waste (liquid, solid, compost, etc.) and bedding content if applicable.
    - The nutrient content of all waste applied.
    - Application method and length of time between application and incorporation.
    - The volume of applied waste, tons or cfs.

- The current crop and crop rotation. If irrigated, timing and volume of applications.
- If commercial fertilizer is applied, rate, form and method of application.
- The yields for all crops.

63. .Page 55, Figure 45. Previously the report refers to mean fall soil nitrate, which we assume is the average of all of the soil nitrate values across the site from September through November for any given year (is that correct?), and it provides a graphical representation of the values in Figure ES-4. Why then does Figure 45 introduce a separate set of numbers describing fall soil nitrate derived from maximum values? Why provide this estimate at all, since fall soil nitrate is not a parameter measured or estimated for use in Equation 8, which this Figure is supposed to represent?
64. Page 57, first bullet. Is this saying that because of the time of travel, any high nitrate concentrations in ground water upgradient of this study at the time of this study would not reach the wells during this study? What about possible high concentrations upgradient of the study 5 to 10 years ago which could now theoretically be upgradient of these wells but within the study site boundaries during the time of the study?
65. Page 57, third bullet. How long has this upgradient site been receiving manure application? Twenty years, like the study site? Could nitrate from previously applied manure make it to this study site within this time period? These arguments don't appear to be supported. Additionally, it would be helpful to describe the current and historical land use around the study site and plot the locations where manure is being applied.
66. Page 59, third paragraph. Nitrate is like chloride <u>only</u> in that it has minimal sorptive properties and both are anions. It is not conservative because it is easily transformed to other nitrogen species. It may be "associated with manure application" like chloride, but indirectly so, since it is absent in manure and is only formed from manure ammonia through nitrification when oxygen is available. Chloride and nitrate plumes originating from manure do not necessarily coincide.
67. Page 59, second paragraph from bottom. The wrong figure is referenced; Figure 29a shows October water table contours in 2007.
68. Page 62, first paragraph. Should be "GDUs" in parentheses instead of "Gus"?
69. Page 62 . Equation 8 is on page 53. This should be Equation 9, and the equation label needs to be in parentheses and the text modified accordingly.
70. Page 65, second paragraph. Some of this discussion on chloride and tillage already took place on page 59 and need not be repeated.
71. Page 65, Equation 10. The equation label needs to be in parentheses, and the text at the bottom of the page needs to refer to this as Equation 10.
72. Page 68, Figure 54. Is this mean fall soil nitrate? What is the significance of the green circled areas in relation to the target fall soil nitrate? Does it matter whether it was above the target level just before the growing season in January? In other instances it was way

above the target level a month or so earlier, but still ended up being pushed down by high rainfall in those earlier winter months. Under either circumstance, the load is being pushed down during cold weather when microbial activity is minimal. Note that 2006 and 2008 had very heavy November rainfalls (~ 11 inches) that drove this mass down earlier than observed in the green circled areas.

73. Page 69, Equation 11. The equation label needs to be in parentheses, and the text above it to refer to this as Equation 11.

74. Page 70. There is an "eith" highlighted which needs correction.

75. Page 71, Figure 55. Same comments as for Figure ES-10.

76. Page 71, first paragraph. This discussion in this section does not relate to the title regarding the protectiveness of current guidelines. The report does not address the current guidelines or propose changes based on the study; it simply references an alternative based on recharge provided by another researcher and questions the validity of setting a guideline based on recharge. The focus should be tightened or the section title should to be changed.

77. Page 72, top paragraph. Again, the stated dissolved oxygen threshold for denitrification is too definitive and is misleading.

78. Page 73. The conclusions section could be shortened to enhance its impact. The purpose of the study changes in the conclusions section: "The purpose of this study was to document the impacts of manure application on groundwater beneath a dairy field overlying the SBA." This conflicts with an objective stated earlier which is to determine the effectiveness of NMPs. This inconsistency should be reconciled.

79. Page 73, first paragraph. This should state 22 acres instead of 20 acres to be consistent with the rest of the report

80. Page 73, Conclusions. Reiterating the definitions of the factors in the conclusions section detracts from the presentation of the conclusions. Perhaps just briefly list the factors prior to the discussion of the conclusions.

81. Page 74, last paragraph. Should be modified to "...the use of soil nitrate predicts..." A qualifier should be added stating that these preclude the use of soil nitrate for *reliably* predicting ground water impacts. In general, soil nitrate can indicate trends.

82. Page 75, second paragraph. EPA concurs with the conclusion "that direct monitoring of groundwater using monitoring wells screened across the water table is needed to accurately characterize impacts of manure application on aquifer water quality" and suggests that this conclusion be articulated in the Executive Summary as well.

83. Page 76, last paragraph. "Worst case" and "best case" are vague phrases subject to interpretation. Perhaps a better way of phrasing this would be "These points suggest that the results observed during the study might be unique to this portion of the aquifer and that the same manure application practices would most likely lead to greater nitrate contamination in other regions of this aquifer".

84. Page 77, second paragraph. This general recommendation for conducting excess mass balance analyses does not seem to be supported by the evidence in the report, which shows it to be a poor predictor of leachate nitrate concentrations.

85. Page 77, third paragraph. Suggest using bullets instead of numbers for consistency with the rest of the report (or at least start with number one instead of number twelve). Some of these recommendations seem to be more common-sense rather than being generated as a result of this study. One could easily add many more recommendations like "make sure that manure is distributed evenly" or "don't let livestock into the fields" when these are not experimental variables being addressed in this study. Recommendation No. 16 is an example; nowhere in this study was there an analysis of any deleterious effects caused by using fertilizer in those instances where it was used. It is common sense to not use fertilizer when one does not have to, but there is no data in this report that says one should not substitute fertilizer for manure. Also, in this recommendation, the second sentence is essentially identical to recommendation No.17. Some recommendations could be combined, like Nos.18 and 19.

86. Page 77, Recommendation No. 13. While the mass budget process addresses the application rates of nutrients, this recommendation gets to the root problem of migration of nitrogen to groundwater. Land application of waste during high precipitation periods, especially when crops are dormant or at least have reduced growth activity, encourages the migration of nitrogen through the root zone where it is lost to the environment. EPA supports limiting winter land application in this environmental setting and recognizes that facilities may need to construct additional storage capacity. Since waste is predominately handled as a slurry, construction or modification of concrete or similar storage containers may be required.

87. Page 78, last section. These monitoring strategies should be in place for routine operation, not just when management improvements are made. If a case is to be made for conducting annual excess nitrogen mass balance evaluations, it should be placed in this section, rather than in the section on reducing nitrate loading, because it does not seem to correlate with nitrate loading to ground water and is in essence an extensive monitoring program.

88. Page 138, Table M.3. Relocate footnote 2, because 2005 is not an estimate, but the gallons applied may be an estimate. The units for the displayed N loadings should be indicated.

89. Plate 1, Figure 26. This figure should be clarified. It appears that the tops of the wells are a few feet below ground surface, which does not correspond with the well logs or Figure 13. Considering the annual rise of the water table, it is important to depict where the screened intervals are relative to ground surface. Is the red line intended to represent the ground surface? It would be helpful to expand this figure horizontally so that well AK725 can be displayed alongside of deep well AKG726. The well pairs could be placed more closely together to better reflect the B'-B transect line.

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April 23, 2013

Barbara Carey
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Olympia, WA 98504-7710

Dear Barbara:

The Natural Resources Conservation Service is dedicated to the conservation and protection of our nation's resources through the voluntary application of conservation practices and management systems that have been demonstrated to achieve conservation goals. NRCS develops practice standards based upon the best available science and we welcome the opportunity to review field studies that offer the hope for improving the quality of our standards. In light of our interest of incorporating the best available science, we expect field studies to follow standard scientific methods and study designs, methods, analysis and findings to be capable of withstanding the rigors of vigorous peer review.

We hope that the following comments provided by Washington NRCS staff will be of help as you revise your paper.

1. The document tries to be both a research paper and a guidance document with the guidance based on findings from this field study. NRCS suggests using the data collected from this field study to prepare a research paper for submission to an appropriate peer reviewed scientific journal. If the authors would like to prepare a guidance document for application of manure from dairy operations, they should consider doing that separate from this field study.

2. The field study lacks a control against which the findings from nutrient application can be compared. This lowers the value of the findings by increasing the uncertainty about which factors are critical and which are not. Consider presenting the data in a manner that does not over represent its value.

3. The field study measures nitrate concentrations based on one management system. The field study does not compare multiple management systems as stated in the project Purpose. Drawing conclusions and making recommendations based on the evaluation of one management system is not technically defensible and likely to fail. Consider clarifying the Purpose statement to accurately reflect the nature of the study and also, consider confining the conclusions and recommendations to the narrow scope of this study.

4. The field study does not report any baseline conditions. Again, it is the lack of information regarding controlling factors that raises uncertainty and limits the conclusions that can be drawn by the findings. Consider strengthening the report by more clearing defining the scope of the study and the limitations of the data.

5. The study does not include a statistical analysis of the data. A statistical analysis and evaluation of uncertainty would offer critical support in favor of any findings and recommendations. In attempting to complete a statistical evaluation of the data, you may discover that the degree of variance and the level of uncertainty are too great to support the proposed findings and recommendations. As it stands, the findings are based on visual interpretation of graphical plots without any critical analysis. All claims should be supported and reproducible. Carefully consider how the paper states the certainty of findings based on the limited data.

6. In arguing for use of a mass balance method of estimating residual soil nitrate, the authors simply state that soil sampling is not reliable without substantiating the claim. The variability of nitrate values observed from soil testing may be explained by complexity in the system of application, plant uptake and leaching. To demonstrate unreliability, one would have to show a problem with the sampling and/or testing methods which this paper does not do. Consider either strengthening the argument in favor of using mass balance estimates or further investigating potential approaches for using direct measurements. Perhaps statistical analyses will yield fresh insights.

7. It is suggested to adjust the Recommendations to "Reduce nitrate loading to groundwater" by rewording #5 to "account for residual nitrate from soil organic matter in manure application rates". Remove the first of #3, #4, and #9 and change #8 as manure applications apply about three times the amount of phosphorus for grass and corn has a very high uptake of phosphorus. A rotation of both grass and corn is ideal. Both nutrients need to be taken into consideration when applying manure. By taking corn out of the rotation, water quality impacts from phosphorus could become a concern.

8. The excessive amount of references tends to make the report a literary research paper and takes focus off of what is being studied. It is suggested to use references from the Western region of the US and Canada rather than the Midwest US or Europe. Since some of the document states information from 2012, I would use the data from the updated NRCS Ag Waste Management Field Handbook and remove the references prior to 2000. It would be helpful to select a few that reflect the project site.

9. NRCS didn't peer review for typographical errors and such.

Sincerely,

Bonda Habets

Bonda Habets,
NRCS WA State Resource Conservationist

Cc: Joe Gasperi,
NRCS WA Geologist

Carey, Barb (ECY)

From: Washington State Dairy Federation -- [wsdf@msn.com]
Sent: Friday, April 26, 2013 2:40 PM
To: Carey, Barb (ECY); Dan Wood; Chris Sybrandy; Steve Vander Haak; Jon De Jong; Larry Stap; Fred Likkel; David Haggith
Cc: Joe Harrison
Subject: RE: Draft nitrogen balance report

Barb,

Please consider this note our comments.
First of all, thank you to you and Joe for your years of work on this effort. Careful consideration and broad diverse perspective will and are needed as we all try to find better ways to farm and raise food for a hungry planet, while protecting the natural resources around us.

I am going to list some of my observations, concerns, questions and suggestions. There are more questions than I could write about in this email.

1. I am not a scientist, I am a farmer and a trade association representative. This report hopefully went to a diverse group of folks with the qualifications to evaluate the science, assumptions and conclusions. We would be most interested in seeing those thoughts. My observations come from 30 plus years of farming and working with farmers.

2. There is a very confusing array of information in this report and I think it would be good to schedule a day to sit down with folks right up in the Lynden area to walk through this. For example, You list wells and soil test areas, with many wells showing high nitrate levels, yet there are references to deeper wells that are very low. Page 73 pp2- The shallow wells you established are not drinking water wells, they are somewhere around 9 feet deep. Earlier in the report you mention deeper wells in the .1-.333 ppm level. This doesn't add up.
-The use of averages throughout the report tells and incomplete story, For example the references to 65% wells exceed state 10 pmm levels - first of all these are not drinking wells, they are study wells to be used appropriately to study how nitrates move, when and at what rates...the other thing this average misses is that the first year 2005 had the highest level and number of over 10 pmm levels, this was following the field plowing....the use of averages dilutes the importance of the fact that tillage of sod has a measurable effect.

3. As we talked about a while back, there appears to be an interesting bias built into the study. It is backward looking, Farmers don't have the luxury of looking back in time to evaluate how we farm, Yes we can learn from study like this, but when spring comes I need to fertilize based on my understanding of how a field grows feed crops, my estimates for the season, the stage of grass , how old the stand is, what kind of irrigation water I will have available. This study flat out considers an over application as an over application but in a retroactive sense labels it an over application. How is a farmer supposed to know what heat units will materialize during the course of a summer, or rain fall or drought. For example, We had a heat wave first week of August 2009. Those four days over 100 degrees cooked our grass- there was no way to add enough supplemental water to all the fields simultaneously. Those four days changed the uptake rates for the rest of the summer and winter and even the next spring. Your report seems to consider that if a farmer applied manure the 25th of July that year, and then the grass crop went into heat dormancy, that the farmer was at fault. This bias is spread throughout the report.
4. In the recommendations there is a suggestion that well monitoring is the only real manner for determining

how to fertilize. Yet in your results there are times a place where the monitoring doesn't match either the fall soil tests or the mass balance tests. My conclusion is that all three are tools that work sometime and don't at others. Wells only measure after the fact, and once again you have to know when to test of test every day....
5. Through out the report are statements and assumptions about mineralization during the cool season, the basis for these statements is not well documented in your report. There are two references to northern Hemisphere mineralization in winter, but the location of those two studies is not reported- are they in California or Minnesota. The assumptions about soil mineralization during cool season need backed up. It is our understanding in the farming community that below 40 degree soil temperature do not result in appreciable mineralization, this needs discussed. There are obvious concerns with wet cool season applications that farmers understand such as run off. But the assumption that winter manure results in significant impacts to the aquifer is in doubt in my mind. IE. See page xxiv line 6

5. On page xx section two second sentence. There seems a bias against fall soil testing. It is a tool, like any tool it has limitations. It can be used right and wrong. There is noting wrong with the test, just how it is used and when it is taken. Same mistakes can be made with Wells, Mass balance, and tissue testing.
For example the mass balance protocol assumes a 15% volitization and 15% denitrification. Where is the basis of those assumptions, when do those rules not apply. If we have a wetter warmer season then volitization will be higher than a cool dry pattern. if we have wet and cold then what.

6. Page 12 Fourth Paragraph. Generalized statement regarding WSDA. Why ? What is the basis of this statement?

Once again, to repeat, there is a fair chunk of information in this study, and I know your intentions are good, and we have work to do in the Whatcom area, but our level of trust is pretty low right now. There needs to be a multidisciplinary group meeting to listen to you and other folks walk and talk through this. Ecology is not in the farming business, we are and there is a big gap between accepting this information - along with all the other information that we use as farmers- and then actually incorporating it into farming practices. AND then actually seeing a difference in the ecosystem is even farther out on the horizon...but one step at a time and we can work through it.

I am going to stop with this, there are more questions but this is the ones that are top of mind.
I suggest some sit down time to go over this.

thanks.
Have a good weekend

Jay Gordon

Washington State Dairy Federation
Elma, Washington
360-482-3485

From: bcar461@ECY.WA.GOV
To: wsdf@msn.com; danwood.wsdf@gmail.com
CC: jhharrison@wsu.edu
Subject: Draft nitrogen balance report
Date: Mon, 22 Apr 2013 21:12:35 +0000

Hello Jay and Dan,

Some reviewers just received the draft report last week, so we are accepting comments until April 26 if that is helpful to you.
Thank you for your input.

Barb

Barbara Carey, LHg
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(360) 407-6769

Carey, Barb (ECY)

From: Cathryn Ryan [cryan@ucalgary.ca]
Sent: Thursday, May 16, 2013 8:55 AM
To: Carey, Barb (ECY); Bittman, Shabtai; Zebarth, Bernie
Subject: Re: Groundwater report

Barb,
This report looks fascinating. I'm really sorry I haven't found the time to look at this, but I've been way too busy for my own good. I'm heading off to do field work next week, so have carved out an hour for the quickest of reviews..... This is very frustrating to me because I would really love to delve into the data and discuss at length. Not sure of your timeline, but if this is still possible after May 25th, please let me know. I may have overlooked lots of details her in my haste, for which I apologize....

- in pie charge of N inputs - suggest you include lbs/ac as well as percentages so reader can grasp magnitude
- even though it wasn't designed to protect gw, a quick calculation dividing your 55 lbs/ac guideline with the volume of rain you expect to fall per acre (given a precipitation estimate) will give you a 'first cut' at the resulting groundwater nitrate. If I use one metre of recharge, I get about 6.2 mg N/L
- I think your right to point at tillage as a possible culprit for the really high NO3 at the beginning of the study... did they also apply manure at the same time? A high rate perhaps? We are thinking more and more that manure application, fumigation, and tillage cause these kinds of periodic high concentrations under raspberries... all this being said the close correlation between NO3 and Cl suggests high rate of manure application is really the culprit
- I think you already get this, but given you have a relatively high horizontal flow component in your study area (as do we), the groundwater you sample from your wells may have migrated from (and represent agricultural management of) upgradient fields. I can't tell how far below the water table your screens start, but at our site, if screens started about a meter or two below the annual low water table elevation we would be sampling from the upgradient field. A seven-foot long screen (commonly used I realize) could mix water from more than one field also.Over the next year I think Shawn Loo's work will help understand this better. Personally, I'd love to install a single diffusion sampling well beside one of yours to compare and contrast the information we get from it. Maybe we can discuss this possibility sometime.
- low irrigation nitrate concentration is remarkable – wells must be deep? Gives me hope for water supply....
- NICE that you've measured Cl input to field :-)
- Biggest surprise for me is the strong seasonal signal in DOC and PO4 in AKG-726. Never seen data like this before. I'd love to see a cross plot of DO vs DOC to see if there is a relationship... Are you continuing to sample? Very intrigued by these data.... I'm curious to know if it is 'labile' in the context of denitrification (I suspect not). Why does the DOC cycle annually without the same overall inter-annual pattern that nitrate has....
- Re: • "The property further upgradient of the residence was cultivated during the study and probably received manure at a rate similar to those observed at the study field. However, it takes ~2.8 years for groundwater at the downgradient edge of this field (324 feet from the upgradient edge of the study field) to reach AKG721, 5.3 years to reach AKG725 and 8.0 years to reach AKG723" - this is based on an average velocity. It's easy to imagine there are narrow lenses that have hydraulic conductivites (and hence velocities) that are 10 to 100 time greater. Should put 'average time' to reach....

From: <Carey>, "Barb (ECY)" <bcar461@ECY.WA.GOV>
Date: Monday, April 29, 2013 11:13 AM
To: Cathy Ryan <cryan@ucalgary.ca>, "Bittman, Shabtai" <Shabtai.Bittman@AGR.GC.CA>, "Zebarth, Bernie" <Bernie.Zebarth@AGR.GC.CA>
Subject: RE: Groundwater report

And the last plate. Bernie, I don't think I sent this to you yet.

Carey, Barb (ECY)

From: Hulsman, Steve (DOH)
Sent: Wednesday, May 08, 2013 2:44 PM
To: Carey, Barb (ECY)
Cc: Pell, Derek (DOH); Weisman, Kitty (DOH)
Subject: RE: Request for technical review

Barb – thank you for the opportunity to look at this significant work. I don't have any significant comments to contribute. Your recommendations seem to me to be common sense in the big picture. But there are obviously a lot of parameters that dairy (and berry) farmers would need to track and continually analyze to tweak their fertilizer application rates and times. That will be a challenging balancing act for them every year, and is significantly complicated by the fluctuations in the conditions that affect NO3 uptake and leaching (e.g. unknown short term patterns in precipitation, and when air and soil temperatures will be conducive to plants being able to use the nitrogen). Farmers will have to balance having enuf (or more than enuf) nitrogen ready for plants to use so that yields will eventually be good but risk applying too much that results in infiltration into the aquifer, versus keeping application rates lower and risking lower yields. In any case, it would be useful to avoid applications from Sept to March, and otherwise for a bit of time before significant rainfall events.

While not the focus of your study, but certainly related, I wonder what the nitrate contribution into the aquifer is from inorganic (and organic) fertilizer application to berry fields. A couple of general anecdotal observations I have from nitrate monitoring results from public water system wells surrounded by (or down gradient of) berry fields:

1) Annually, NO3 levels are generally higher from November to April (and are often highest in Feb and March) and lower in June thru Aug - which can be explained by what your study found; and
2) Over years/decades, average NO3 concentrations rise and fall in different areas of north Whatcom – the rises may coincide with local installation of new fields, and lower levels may coincide with local fallow/change-over of fields.

I'm guessing the same general concepts would apply to berry farming as your study found for dairy....

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This message from:
Steve Hulsman
Dept of Health - NW Drinking Water Operations
20425 72ND AVE S Ste 310 KENT WA 98032
Ph: 253.395.6777 fax: 253.395.6760
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Drinking Water Web Page: www.doh.wa.gov/ehp/dw
Public Health - Always working for a safer and healthier Washington.

From: Carey, Barb (ECY)
Sent: Monday, April 29, 2013 11:04 AM
To: Pell, Derek (DOH)
Cc: Hulsman, Steve (DOH)
Subject: RE: Request for technical review

Thank you for your input, Derek! It's very helpful. Also if Steve Hulsman has thoughts, we would love to hear them too.
Barb

From: Pell, Derek (DOH)
Sent: Monday, April 29, 2013 9:43 AM
To: Carey, Barb (ECY)
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Carey, Barb (ECY)

From: Pell, Derek (DOH)
Sent: Monday, April 29, 2013 9:43 AM
To: Carey, Barb (ECY)
Cc: Hulsman, Steve (DOH)
Subject: RE: Request for technical review

Hi Barb.

I did a quick read a couple weeks ago with the hope that I'd get into it deeper later. Unfortunately, I did not get the chance to spend more time with the document.

My initial impression was that of being grateful that a technical report from North Whatcom County is telling the story of contamination of the shallow aquifer.

- I like your grassy field work identifying specific lessons learned.
- The WA agriculture community will be sensitive to being blamed for the problem. Probably, they are deserving of most of it, but nitrates from Canada and septic tank sources also contribute. Not sure how hard you want to push.
- I wonder about nitrate contamination being the tip of the iceberg. From drinking water quality monitoring, we are not seeing an empirical jump in coliform bacteria in systems with seasonal fluctuation in nitrate, but I can't help wondering what else is getting through that public water system don't monitor for (viruses?).

Thanks for your work. I cc'd Steve Hulsman on these notes. He may have more to say.

Derek
253-395-6763 | NW Regional Office of Drinking Water | WA State Dept of Health

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From: Carey, Barb (ECY)
Sent: Wednesday, April 17, 2013 9:21 AM
To: Pell, Derek (DOH)
Subject: RE: Request for technical review

Derek,

Thank you for your attention to this. I had aimed for tomorrow, but I have extended the date for some to April 26 if that helps.
I appreciate your thoughts on any part of the report.

-Barb

From: Pell, Derek (DOH)
Sent: Wednesday, April 17, 2013 8:06 AM
To: Carey, Barb (ECY)