Compilation of external review comments by chapter/section and reviewer for the 3/19/09 Draft Report, Reactive Nitrogen in the United States: An Analysis of Inputs, Flows, Consequences, and Management Options"

General comments

From Dr. John Day

Review of EPA Nitrogen Report

The report is a detailed treatment of reactive nitrogen in the US. It is comprehensive and a wealth of detail is provided. But the report suffers because different topics are treated in different detail. Many of the conclusions and recommendations are so general that they don't provide a clear idea of what should be done next.

Climate change is dealt with very briefly in spite of the fact that climate will certainly have a dramatic impact on nitrogen dynamics. The loss of nitrogen from agricultural watersheds is strongly dependent on rainfall. Predicted increases and decreases in rainfall will likely have a dramatic impact on nitrogen export from ag fields. For example, precipitation is predicted to increase in the upper Mississippi watershed, and other factors being equal (but see below), N export should increase (e.g., Justic et al.). In the southwest, more winter precipitation is expected to fall as rain rather than snow. This may impact agriculture throughout the region and lower N export. The southeast may also have lower rainfall. Such topics should be dealt with in more detail because climate change may increase or decrease the need for dealing with excessive N in rivers. There is an extensive literature on this topic much of which is summarized in a series of PEW Center reports.

Energy is a topic that is not covered at all in the report but which will likely have dramatic impacts on both N dynamics and our ability to study them. There is a growing consensus that the world society is transitioning from a century of relatively cheap energy to a future where energy will be much more expensive and scarce. There is strong evidence that conventional world oil production has peaked or will peak soon. There is a quite robust literature on this subject that the report should refer to and analyze. In a time of energy scarcity, natural resource management will have to change to a less energy intensive approach. And the kinds of studies that scientists do will also be constrained by energy availability. For example, during the run up in oil prices last year, the price of fertilizer increased substantially. Although oil prices have fallen, the long-term trend is certainly for increasing energy prices. It is likely that in a decade or two, the price of fertilizer will be so high that farmers will be very efficient in its use resulting in greatly reduced fertilizer runoff from farm fields. When the economy of Eastern Europe collapsed in the 1990s, fertilizer use declined dramatically and Mee reported that hypoxic conditions in the Black Sea nearly disappeared in a short time period. It is likely that agriculture will return to what Boody et al. (Boody et al. 2005 BioScience) called multifunctional agriculture. The implication of this is that problems related to fertilizer runoff from ag fields (eutrophication of rivers, streams, and coastal waters, hypoxia, etc.) are likely to decrease. This information should be included in the report as possible future scenarios.

I suggest that the role of wetlands in controlling N pollution should be treated more extensively and comprehensively in the report. There is some mention of this subject but in not much detail and it is scattered throughout the report. I suggest that it should be treated in its own chapter and this could be referred to throughout the report. Mitsch and colleagues have proposed a comprehensive program for the Mississippi basin. This should be discussed as an example of what can be done.

From Dr. Elizabeth Holland:

The basic premise of moving towards a comprehensive holistic view of the environmental consequences of the ongoing dramatic increase in the use of nitrogen and the atmospheric-land-water exchanges of reactive nitrogen is one that I support enthusiastically. However, the draft report falls well short of its intended mark. Future versions of the report need to build more strongly on the published literature and must include a clearly articulated plan for integration of the work with strong emphasis on both models and data.

The report does not adequately take into account its ambitious holistic scope. Instead it comes across as series of research recommendations that interest the people who wrote the report. The report does not adequately build on the underlying science. Much of the science cited is old parts of the literature and has not been updated to the modern literature. Because agriculture is at the center of the problem, I suggest that subsequent versions of the report build strongly on interactions with the agriculture community laying the groundwork for the strong interactions with USDA called for in the report.

A striking omission of the report is the connection between the climate system and the nitrogen cycle. The EU is currently funding Nitro-Euro, a multi-million dollar project that was motivated by this connection. A Science paper by Hungate et al in 2002, a series of ongoing studies by MIT (Sokolov et al. Journal of Climate 2008), Princeton (Levy, and others) and NCAR (Thornton et al 2008) underscore the importance of the links between the carbon and nitrogen cycle. The centrality of the carbon cycle to climate change and the impact of the N cycle on carbon uptake are the top of the list, followed by N_2O, NO and its role in tropospheric ozone production, and the increasing importance of N containing aerosols that play a role in global warming make a compelling case for addressing the connection between the changing nitrogen cycle and climate change in this report.

Recent work suggests that the ongoing declines in fertilizer use throughout the mid-west are not sufficient to decrease the ongoing recurrence of hypoxia in the Gulf of Mexico. See particularly work by Laurie Drinkwater and Mark Davids of Cornell and a paper by Vitousek et al. submitted to Science (The manuscript may be available directly from Peter Vitousek at Stanford). The body of work suggests that years of excess fertilizer use may have sufficiently bolster soil organic nitrogen content to compensate for

reductions in fertilizer use and provide an ongoing source of reactive nitrogen N to downstream ecosystems.

The report requires a strong editorial hand to remove redundancy, increase the precision of the wording in the findings, recommendations and executive summary, and standardize the report throughout is needed. The current report is quite variable across the sections and needs considerable strengthening.

From Dr. Gregory McIsaac

General comments: The report compiles an extensive amount of information on Nr, which I consider to be largely accurate and the recommendations reasonable. I think the report could benefit from some thoughtful editing, with an eye towards organizing the technical information so that it most efficiently and effectively supports the recommendations. There are places where I found the text confusing or unnecessary, or providing potential for confusion.

I think this draft report represents a useful step in the process of improving understanding and management of Nr.

From Dr. Giles Randall

This was the most comprehensive, holistic document on nitrogen that I've read. It was quite well organized and for the most part was well written. After page 90, it did appear to be more hastily assembled with some sections repeated, poor agreement between figure citation in the text and the actual figure, incomplete sentences, unreferenced citations, etc.

From Dr. James Schauer

The subject report is well organized and well written. It contains excellent background material on the nitrogen cascade, sources of reactive nitrogen, and the flows and inventories of reactive nitrogen in the environment. The analysis appears sound and the recommendations are appear to be scientifically robust. As my expertise is in the atmospheric science and combustion related fields, my review and comments largely focused on these components of the report. I do have several comments that should be addressed before the report is finalized and distributed. I do have several comments that should be addressed before the report is finalized and distributed. These commented are as follows:

General Comments

1) The framework for discussing the transport and inventory of reactive nitrogen across environmental compartments is somewhat deceptive in terms of the atmosphere. Due to the timescale of mixing across the global troposphere, it is not reasonable to view the US atmosphere as a well defined entity. It appears that the export of reactive nitrogen from the US via the atmosphere is considered in the analysis and mass balance but that the import of reactive nitrogen to the US via the atmosphere is not considered. I think the reader would greatly benefit

from a clearer presentation of the atmosphere as only a global atmosphere, which provides a transport mechanism for deposition in other areas and transport to the stratosphere.

2) The inclusion of N2O in reactive nitrogen is understandable from a chemistry perspective but clearly the role of N2O in the context of the nitrogen cascade is very different from other species included in the report. N2O is basically inert until it reaches the largely isolated stratosphere, where it is an import species in stratospheric ozone depletion. The integration of N2O with all other reactive nitrogen species will be confusion to many readers. I think a separate section on N2O is needed to clearly explain N2O in the context of the nitrogen cascade and the report. This is particularly important in Figure 2 and 3, which implies that N2O has similar biogeochemistry to other species discussed in the report. As shown in Figure 2, the fate of NOy and NH3 are the same as N2O, which is not correct. It is unclear how the recommendations on page 18 related to N2O.

3) Throughout the report, one of the impacts of the nitrogen cascade is "global warming." I would strongly recommend to not use the term "global warming" as the impacts of the nitrogen cascade have important impacts on climate forcing that are positive and negative forcings. I would recommend the use of the term "climate change." As written, the report seems to use the term global warming with little explanation and some discussion of direct and indirect effects should be briefly discussed.

3) The discussion of mobile sources is a very stagnant perspective on emissions. The discussion of recommended reductions from mobile sources, and which feed into the overall recommendations, due not properly address the growth in mobile source VMT (Vehicles Miles Traveled) and already existing diesel engine emissions regulations that will go into place in 2010 for on-road engines and they are being phased in for off-road engines. The recommendations need to be placed into context of expected growth in emissions and existing regulations that are currently being implemented.

<u>From Dr. Stuart Weiss</u>

First, this document an excellent holistic view of the N-cascade and numerous negative environmental impacts of excess N in air, land, and water, and will be a foundation for finally addressing the issues in a comprehensive and effective manner.

As a reviewer, my main area of expertise is the impacts of atmospheric N-deposition on biodiversity (mainly in California) and the practical means to address the impacts in the short-term and long-term. I think a little more material on biodiversity impacts and policy responses would be a critical addition to the document, since the effects are a "1" in relevance. There is also some innovative processes, including Endangered Species Act consultations, underway that should be noted somewhere in the report (but I realize that I am providing far more background than could go into the document itself).

Review work by Fenn et al. (2003) compiled numerous impacts of N-deposition on biodiversity in the western US. Some of these include:

1) Loss of coastal sage scrub (CSS) in Southern California to invasions by annual grasses and subsequent changes in fire frequency, leading to losses of shrub cover and conversion to weedy annual grassland. CSS has already been reduced by ~90% due to urban and agricultural development and supports dozens of threatened and endangered species.
2) Invasion of desert scrub by annual grasses that create fine fuel loads that can carry fire across miles of desert lands, in places where such fires were nearly unheard of until recent decades. These fires threaten life and property in addition to converting rich desert scrub to weedy annual desert grassland.
3) Combined effects of ozone and N-deposition in Southern California montane conifer forests lead to changes in species composition, physiological disruption (needle lifetimes of < 1 year and continual buildup of litter), and increased fire risk, on top of climatic stresses.
4) Groundwater and surface discharges from heavily polluted watersheds in the LA Basin have extremely high levels of nitrate, including storm pulses and baseflow.
5) Atmospheric deposition on the order of 8-20 kg-N/ha/yr in the San Francisco Bay Area leads to annual grass invasions of nutrient-poor serpentine soils (Weiss 1999) that lead to losses of biodiversity, most notably the threatened Bay checkerspot butterfly (*Euphydryas editha bayensis*).
6) Montane meadows in Rocky Mountain National Park are losing wildflowers to native perennial grasses.
7) Aquatic biodiversity in ultra-oligotrophic lakes in western mountains is affected by quite low levels of atmospheric deposition (1.5 kg-N/ha/year wet).

A screening of the N-deposition exposure of listed (endangered, threatened, and rare) plants in California (Weiss 2006), suggests that a substantial fraction (~40%) of the listed flora in the state is exposed to > 5 kg-N/ha/year (from a 36 km CMAQ run for 2002). Many of these plants are on nutrient deficient soils such as serpentine. Many others are in vernal pools (seasonal wetlands). Grass and weed invasions are the primary mechanism of biodiversity loss. Many of the species are small annual forbs that are prone to being crowded out by increased grass and weed growth in many ecosystems.

There are many other examples outside of the Western US that need to be compiled, and I would suggest as a recommendation that a national N-deposition/biodiversity screening and assessment are needed.

Executive Summary

<u>From Dr. John Day</u>

13, fig 2. Denitrification doesn't seem to be a pathway.

16, Management strategies. Nutrient removal by wetlands should be specifically included in this list.

18, Recommenation C. Academic scientists should be included in the task force. It is clear from the literature that the great majority of work done on Nr has been done by academic scientists and they should be integrally involved in all stages of the effort.

19. Wetlands should be included in best mgt practices.

From Dr. Elizabeth Holland

The executive summary must refer to the correct section of the science portion of the report so that it is obvious to the reader where to find the supporting science. As written, it is not substantiated by the science.

While I agree with the intent of the N cascade framework—to integrate the various system components into a whole—I am unconvinced that continuing use of the term ***N cascade*** is useful to convey the importance and usefulness of a holistic N budgeting to the community outside of the relatively small community of scientists who are doing N cycling work.

From Dr. Gregory McIsaac

Page 6, line 9 (and throughout most of the report): The report identifies combustion of fossil fuels as a source of NOx, suggesting that combustion of non-fossil fuels is not a source of NOx. There are only one or two places (such as page 112, line 32) where combustion of biomass is identified as a source of NOx. Page 11, line 16: identifies stationary fossil fuel sources as power plants and industrial boilers. What about domestic heating?

Page 16, line 7: the claim is made that a "large part of the land surface in the northern hemisphere" has Nr deposition rates in the range of 10 to 20 kg N/ha-yr. This point could be made more explicit by estimating the proportion of land area in the US that receive deposition in this range.

Page 19, line 32: refers to "other unregulated mobile and stationary sources". This is elaborated in the body of the report but I think it would be helpful to give examples of these sources here (e.g., off road vehicles).

Comments from Dr. Giles Randall

6-20	all	The Executive Summary provides a good overview of the report. The sections dealing with "human activity creating reactive N", the "N cascade," and "sources of reactive N" were particularly helpful. The major findings and recommendations shown on pages 18-20 also set-the-stage quite well.

Comments from Dr. James Schauer

1) Page 11 lines 5-7 and Page 12 lines 1-3 – The text does not seem consistent with Figure 1. According to the Figure 1, Cultivated BNF seems to be the second largest sources and Fossil Fuel Combustion is the third largest source. This figure and associated text would gain from a clear discussion of the contributions by sector and process.

2) Page 17, line 1 – I am not sure what is meant by "more efficient diesel engines" but I think this should be engines with lower emissions or after-treatment controls. Engine efficiency usually does not mean the degree of NOX emissions.

3) Page 19, line 31 – The term "passenger cars" needs to be checked. I assume that this is on-road vehicles or mobile sources.

Chapter 1: Introduction

Comments from Dr. John Day

22. An discussion of the role of cheap energy, especially oil, in the agricultural revolution is completely lacking. The globalized food system uses about 10 cal of oil (or its equivalent) to produce one cal of food. N pollution is likewise a result of cheap energy. Energy is central to understanding this whole problem and it must be dealt with.

Comments from Dr. Gregory McIsaac

Page 25, Figure 3: All aquatic and terrestrial systems are identified as having some denitrification potential, except for oceans. But denitrification does occur in the oceans.

This seems to be an oversight because later on page 85, the report mentions that deposition of Nr to the oceans results in some N20 production, presumably from denitrification.

Page 26, lines 11-14 and 20 -22: These statements identify "losses" of Nr from aquatic and terrestrial systems that do not include conversion of Nr to N2, and then indicate that there is "potential" for conversion of Nr to N2. But conversion of Nr to N2 occurs in these systems and it does represent an important loss from those systems. The language is potentially confusing. I'd recommend changing the word "losses" to "transfers" or "exchanges" of Nr from one system to another, and conversion of Nr to N2 be considered a loss of Nr.

Comments from Dr. Giles Randall

25-26	all	Figure 3 and the accompanying text was well done.

Chapter 2 Behavior of Reactive Nitrogen in the Environment
2.1. Introduction

2.2. Sources of NR new to the US Environment
2.3. Nr Transfer and Transformation in and between Environmental Systems
2.4. Impacts, Metrics, and Current Risk Reduction Strategies

From Dr. John Day

79-80. Recommendations. A comprehensive scientific program of the role of wetlands as sinks should be included in this list. For example, Mitsch and colleagues (refs cited in the report) called for a comprehensive research effort in the Miss basin on the use of wetlands. This could be cited here as an example of what needs to be done.

In a broader sense, these recommendations will require considerable funds (and energy). In an energy scarce future, hard decisions will have to be made about what is done. Study efforts should be directed at energy efficient approaches for controlling N pollution.

89. Forests. The sentence on lines 22-23 "Changes in C…" is awkward. The statement is that the highest rate of tree growth is in the Pacific northwest. Is the rate of growth higher than cypress forests in the southeast. In addition, there is a climate aspect here. A recent study (van Mantgen et al. 2009. Science. 323:521) reported that tree mortality in the west had increased as a result of climate change. This is another way that climate may impact N dynamics if trees are dying more rapidly.

106. It is interesting to note that in fig. 21, the Everglades is treated as a separate unit while the Miss delta is grouped with arid south Texas. Likewise, the wet northwest is grouped with parts of arid southern CA.

From Dr. Elizabeth Holland

The atmosphere land section of the report is one of the better substantiated portion of the report, but the section is characterized by an overreliance on unpublished and unevaluated runs CEMAQ. The section also overlooks key papers like the US N budget done by Holland et al. 2005, published in Ecological Applications. The section also overlooks a series of important studies linking N deposition/fertilization to increased NO and N_2O emissions published by Butterbach-Bahl and Papen in the European literature.

From Dr. Gregory McIsaac

One of my main technical concerns involves the attempt to develop separate N budgets for Agricultural, Vegetated and Populated landscapes, discussed on pages 80-83. In this analysis manure and sewage N are treated as inputs, but they are really transformations of other inputs. Elsewhere in the report, claims are made about how much Nr is transported from agriculture to the environment but it is not always clear how these estimates were made.

Page 35, figure 4: The horizontal scale is not arithmetic. The 20 years from 1970 to 1990 represents 5 units (four years per unit), but after 1990, each year represents a one unit on the

horizontal scale. This appears to be an excel line graph. I'd recommend changing it and excel XY graph or some other format so that the horizontal scale is proportional to time.

Page 37, line 12: In discussing Table 5, the text refers to Louisiana even though data from Louisiana is not presented in Table 5.

Page 39, line 15: it would be nice to have a citation to the recommendations referred to.

Page 42, line 3: the statement is made that 7.6 Tg of Nr is transferred from agriculture to aquatic and atmospheric systems. It was not clear how this value was calculated.

Page 43, line 14: the statement is made that maize receives the largest share of fertilizer N in the US. It would be helpful to state this percentage.

Page 44, Figure 7: This figure is based on readily available USDA data, and could easily be extended from 2000 to include more recent years. This was apparently done to create Figure 25 on page 127.

Page 46, lines 4-6: It might be helpful to mention here that many legume crops will tend to scavenge inorganic N out of the soil before investing resources in N fixation. This is why they have some potential to be more efficient than inorganic fertilizer. I am not sure if this is the best place to mention this but I think it should be somewhere in the report.

Page 47, line 3: I think "prevention… of Nr applied to agricultural systems" is not the best word choice. Better choices might be "..prevention of unneeded Nr.." or "efficient use and mitigation of Nr…"

Page 51, line 28: there is an extra comma in this line.

Page 51, line 29: "will be used … in 2008" should be "…was used…"

Page 57, lines 15-16: explain how are aerosol formation and neutralization of acids produced by sulfur and nitrogen oxides are adverse effects.

Page 59: a table that shows how the N excretion has changed per animal would be useful.

Page 60, line 18-91: the language describing the ammonia equilibrium is presented as if volatilization is either "allowed" above pH 7, or not allowed below pH 7. I think it is more accurate to present it as a continuous function, with very low quantities of NH3 available for volatilization below ph 7 and increasing quantities above pH 7. Also, there is a reference to Arogo et al (2006) here but no Arogo et al. citation appears in the reference list at the end.

Page 61, line 18: the "finding" is made that there are no regulations to decrease Nr losses from manure, but many states do have laws governing the management of manure from larger farms. The report recognizes this on page 124, lines 14-15.

Page 64, Table 9: It looks like the left column is messed up. I think the top left box should say "Type of turf fertilized" the second box should say "nominal fertilization", the third "Professional lawn care" and the fourth "high maintenance areas".

Page 69, Figure 14: I think it is dangerous to presume a trend from two data points (the 1985 and 2005 maps). I have looked at the full series of maps available on the web, and I agree that there probably is a real trend, but I think it would be better to present and analyze the annual time series, as was done for nitrate.

Page 72, lines 14-15: I don't understand what is meant by foliar resistance to NO, nor how it explains why dry deposition of NO3- is 39% off the total NO3- deposition.

Page 73, lines 8-21: I think an additional source of uncertainty in these estimates of Nr deposition is locally recycled NH3/NH4 and perhaps some other N compounds. Plants emit NH3 but they also absorb it from the surroundings. Similarly a dust storm may lead to some local deposition of particulate N, but also some local removal. The monitored deposition may include some of this locally derived Nr, or be replacing Nr that is being emitted and thus in may not necessarily represent a net of new Nr input to the region. It may also be worth repeating in this section that the sampling networks have not been tested for spatial bias (as stated on page 68). I believe most of the monitoring locations are in rural areas, and thus may under represent deposition in and near urban areas.

Page 76, Figure 16. The legend on this graph is rather cryptic, and the graph basically provides only 4 percentages for each year, and there is not much difference between the two years. I think the essential information from the graph could just as easily be presented in the text or a small table.

Page 76, line 11: I think there is a need to insert after NHx the phrase "…emissions are…"

Page 76, line 21: delete "the" before 1985.

Page 77, line 24: I think "within" should be changed to "with" and probably should be preceded with a comma.

Page 78, line 9: "a fair fraction" ought to be changed to something more precise.

Page 79, line 22-23: this statement comes out of the blue. There was no discussion of this in the preceding text.

Page 80, lines 29-33: I think it is worth mentioning that much of the unharvested N is retained in the unharvested portions of the crop: leaves, stems and roots, which can protect the soil and contribute to soil organic matter, if properly managed.

Page 81, table 13 and line 15: Animals don't manufacture Nr, but they transform it. Grazing animals consume N in the grasslands and a portion of that N becomes manure. So, it is recycled N and not a separate input. Humans and confined livestock are consuming grain and feed

produced with fertilizer and BNF. To count manure and sewage as inputs involves double counting some of the Nr. Also, the portion of atmospheric deposition that is reduced may have derived from animal manure or fertilizer emissions, and thus would also be double counting. I can see the point of looking at transfers from one system to the other, but it seems that this analysis does not give enough attention to the difference between new Nr and recycled Nr. Adding up the totals in the far right column certainly involves double counting.

Page 81, line 8: I am not sure what the phrase "the remaining N" refers to. I am also not sure why 1.2 Tg of manure N in agricultural lands, and 3.8 Tg of manure in grasslands adds up to 6 Tg total. Maybe the difference is the "remaining" manure?

Page 82, line 16: section 3.2.5.1 appears to be incorrect.

Pages 82 and 83. I found this discussion rather confusing. Perhaps a diagram would help.

Page 85, line 4: "higher ranked consumers"? Maybe "animals and aerobic microorganisms"?

Page 86, line 2: insert "of" after movement

Page 87, line 34: ES = environmental system?

Page 88, lines, 27-39. The lengthy footnote found on page 91 that discusses this issue should be part of this section, rather than a footnote, except that the phrase "may need to be reconsidered" should be changed to "need to be reconsidered". Also, consider the following paper that showed no change in soil C over the last 50 years in central IL:

David, M.B., G.F. McIsaac, R.G. Darmody, and R.A. Omonode. 2009. Long-term changes in Mollisol organic carbon and nitrogen. Journal of Environmental Quality 38:200-211.

Page 94, line 28, through page 95, line 15 is a duplication of section 2.3.4.

Page 96, line 20: " the ideal framework" seems overly promotional for a scientific document. I think it would be better to state that it provides "a comprehensive framework"

Pages 97-8, section 2.4.2.2: I did not see much value or relevance to this section. I think it could be deleted.

Page 99, line 28: refers to Figure 20 should be Figure 19. From this point on, the figure numbers identified in the text does not match the actual figure number.

Page 106, Figure 21. I did not see much value in reproducing this figure.

Page 109, Table 18: I think it should be more clear what the percentages in the Nitrogen Management Target column represent. They seem to be percent reductions of current or recent Nr loadings, but it would be helpful to make that more explicit.

Page 109, line 15: is “disproportionate” the correct word? I think they meant “disappointing”

Page 110, lines 14-15: N causes “substandard levels of dissolved sewage treatment plants in LI Sound” ? Some words got deleted or mixed up there

Page 119, line 14: I think there should be the word “at” inserted after “aimed”.

Page 121, line 9-12: This sentence is confusing. I suggest it should be modified as follows: “The only way to determine the extent that critical thresholds are limiting is by overlaying them for different regions and determining by monitoring data or by model exercises where and which sources contribute to exceeding the critical threshold ~~is the limiting factor~~,and then identifying the best methods for putting caps on ~~losses from~~ relevant sources.”

Page 123, Table 21: In the middle column several of the entries are “NR” and should be Nr.

Page 125, line 4: delete “neither”

Page 126, line 2: Danish cereal crop yields are described as remaining relatively constant in Figure 24, but Figure 23 shows cereal crop production over time, and there appears to be an increasing trend.

Page 127, Figure 25: the figure caption references a 2002 publication but the data in the figure go through 2005. Several authors have presented similar analysis based on USDA data. I think the report can simply cite USDA data.

Figure 25 presents an updated version of a grain yield per unit of fertilizer input that was presented in Figure 7.

Page 128: It could perhaps be mentioned that Duvick et al (2005) and Duvick (1997) have reported declining protein content of corn hybrids in the US.

Duvick, D.N., J.S.C. Smith, and M. Cooper. (2005). Changes in performance, parentage, and genetic diversity of successful corn hybrids, from 1930 to 2000. In C. W. Smith, F.J. Betrán and E. Runge (eds). Corn: Origin, History, Technology and Production. John Wiley & Sons, Inc., New York.

Duvick, D. N. (1997). What is yield ? In Proceedings of a Symposium for Developing Drought and Low N-Tolerant Maize (Eds G. O. Edmeades, B. Banzinger, H. R. Mickelson & C. B. Pena-Valdivia), March 25±29, 1996, CIMMYT, El Batan, Mexico. CIMMYT, Mexico, D. F.

<u>Comments from Dr. Giles Randall</u>

38-41	all	Section 2.2.3.1 on “Nitrogen Fertilizer Use” was very informative and clearly sets the stage for Recommendation 1 on page 42. This is critical for enabling a better understanding of the cause and effects of N on a landscape scale.

41	Table 3	The table heading and column heading (Tg/year) indicates or at least implies that these data are the amount of N fertilizer (sources) and not the amount of N coming from each source. Because the N concentration in the sources ranges from <20 to 82% N, it is important to clearly indicate this is the amount of fertilizer N from each source. Changing "Tg/year to Tg N/year would help.
42	12-22	This paragraph can be very confusing to the non-N-trained audience. The lead sentence highlights nitrogen fertilizer use efficiency (NFUE). The second sentence (i) defines NFUE in terms of recovery efficiency (RE) in kg N uptake per kg N applied. However, (ii) describes physiological efficiency (PE), which is kg yield per kg N uptake where yield and N uptake are from both N fertilizer and soil N. Thus, (ii) really does not relate to NFUE because soil N taken up by the corn plant may account for anywhere between 25 and 100% of the yield given in the numerator. This is important for a couple of reasons. First, the proportion of corn yield produced by soil N is affected substantially by previous crop and geographic location. In Minnesota when using an optimum rate of fertilizer N, about 60% and 76% of the corn yield is produced by soil N for corn that follows corn and soybeans, respectively. In Illinois, those values are 54 and 64%, respectively. The means across 271 corn after corn sites and 427 corn after soybean sites in Illinois, Iowa, Minnesota, and Wisconsin are 56% for corn after corn and 70% for corn after soybean. (Reference = Sawyer, John, Emerson Nafziger, Gyles Randall, Larry Bundy, George Rehm, and Brad Joern. 2006. Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn. Iowa State Extension PM 2015 or on the web at www.extension.iastate.edu/Publications/2015.pdf). When RE is calculated, the N uptake in the corn from the zero fertilizer plots or area is subtracted from the total N uptake to get N uptake from the fertilizer. This is true NFUE and the term we need to address if we are to improve fertilizer N efficiency. In line 30, page 42, it states that "relatively few data that provide measurement of fertilizer N recoveries by our major field crops. . . .". This is because very few growers will leave an unfertilized area or two in their fields to provide this "zero fertilizer N" number. Also, few growers have the capability to measure N uptake; it is much easier for them to measure corn yield. Thus, a surrogate for NFUE can be kg yield per kg N applied. The confusing part of this surrogate is that it presents a yield value for only the fertilizer N per amount of applied N; whereas, PE described in (ii) presents a yield value for both soil N plus fertilizer N per amount of N. This is the second reason this distinction is important. This report (p.42 lines 12-22, p. 127 Figure 25, and p. 151 lines 4-15) and various reports in the literature have confused NFUE, which addresses efficiency of fertilizer N only, with NUE, which often addresses soil & fertilizer N.

42	23-29	I have no problem with what is said in this paragraph as long as one recognizes that RE can be affected greatly by previous crop and that RE is dependent on the rate of N applied because that term is in the demoninator. From a science perspective, it is always important to calculate RE and PE at the optimum rate of fertilizer applied (EONR) over a long period of time. Otherwise, one does not know if NFUE is truly being improved by management shifts or new genetic materials being planted.
43	9	Insert “may” between “that” and “improve”. The technologies that we currently have available and mentioned in lines 10-13 perform best in very site-specific instances and will not show N improvement across the board.
44	6-18	This paragraph contains some generalizations that need comment. Even though I am not a big fan of fall fertilization, due to our highest consistent yields occurring for spring preplant N application, I do recognize the logistical and economic factors that drive fall N application, especially in the Northern Corn Belt. Fall N application in late October or early November in Minnesota where the soils are frozen from early December through the end of March is much different than N being applied in mid-October in southern Iowa, Illinois, Indiana, Ohio and Missouri when the period of frozen soils is much shorter or absent. The potential for improving NFUE for spring compared to fall application is much greater in the mid-to southern Corn Belt than in the Northern Corn Belt.
44	14-18	The “smart” fertilizers work well when the risk of N loss is high. Unfortunately, weather, e.g. precipitation in the spring, has much to do with that risk; precipitation is an uncontrollable factor. These fertilizers are more expensive, which is huge factor reducing their acceptance among farmers.
45	1-3	See the reference mentioned earlier (p. 42, lines 12-22). This is not true in the Corn Belt (see the Corn N Rate Calculator on the Iowa State Extension Web site).
45	8-18	This paragraph illustrates the confusion between NFUE or RE and NUE or PE. The first line says NFUE yet the values are NUE/PE.
45	19-30	Hurricane Katrina had little to do with higher N costs. The greater N costs were due to higher natural gas prices and off-shore production and transportation. N prices are largely driven by energy costs.
45 46	35- 2	Cassman, who has done very good work, is frequently cited in this report. However, much of his work has been done on irrigated soils which are much different than rainfed crop production. The in-season decision-making tools described have a much greater probability of being

		successful in irrigated production, where N can be combined with water and delivered to the root system, compared to rainfed conditions where one needs to depend on Mother Nature to deliver that “timely rain”.
46	29-32	Zero-N control areas need to be implemented in production-scale fields to really get a handle on long-term N management.
46	33	include “land-grant Universities”
47	1-3	“ “ “ “
50	10-12	The values of 10% and 20% seem high to me considering the amount of each source that is incorporated during or soon after application.
51	9-12	include “land-grant Universities”
51	32	“increasing corn acreage by millions of acres” seems to be pulled out of the air. There are resources available to document how many acres of corn are planted each year. This statement is clearly an exception to the rest of this report.
57	16	“neutralization of acids produced by sulfur and N oxides”. Does this really occur to any significant amount?
57	20	I’m not aware of nitrate causing soil acidification.
58	28	NRC 2996?
52 61	all- all	Seems like a lot of attention to devoted to animal agriculture. Maybe that is fine from an atmospheric perspective, but in my opinion not from a water perspective.
64	Table 9	Table 9 is incomplete. The “High Maintenance Areas” has been omitted from the left-hand column.
67	15	“in” Recommendation D
80	25-33	This is the first place in the report where the mineralization of soil N is referred to as a source of N for plant use. This is a major source of non-controllable plant-available N, and it greatly affects NFUE. Thus, I feel that the concept should be introduced on page 42, lines 12-22 in addition to the few lines stated here.
81	Table 13	6.4 Tg N/y from N fixation in vegetated grasslands seems quite high when comparing it to the millions of acres of very efficient N fixing plants (alfalfa and soybeans) in agricultural systems! What leads to this high

		value. I know there are lots of areas of grasslands, but one does not visualize a significant amount of N fixation occurring in these grass-based systems.
83	16-23	I endorse this finding, the recommendation, and the inclusion of universities in the research effort.
86	3-24	This is a tricky section. The document has solely been directed toward N. Now P is being co-mingled with N. We know that algal growth is dependent on both N & P; but my knowledge indicates that N tends to be the driver in marine waters and P in fresh waters. Therefore, I'd recommend more text defining these differences. For most citizens who don't live next to marine waters, P is assumed to be the reason for algal blooms and associated taste and odor problems. Furthermore, aren't most of the 303 (d) listings and WQ nutrient pollution impairments due to P? The issue of N vs. P causing algal blooms is a real contentious issue among many, depending on how it affects their particular situation. This section as presently written only feeds that contensciousness. The section should be rewritten in a manner that focuses on N as a contributor to algal blooms and not using P to make the point. In my opinion, using P only discredits the report.
85	9-13	This section is fine as it concentrates on marine systems. Thus, distinguishing between marine and fresh water systems seems important.
86	2	sentence is unclear
86	18-20	For those of us who live in fresh water areas, chlorophyll *a* is always associated with P.
88	33	Recent information from Minnesota questions the role of conservation tillage as a factor for greater SOC accumulation.
91	Table 15	Table 15 and footnote 7 are valuable
93	9-13	This is an important paragraph. There are volumes of this information in the scientific literature, but perhaps it is too detailed and site-specific for this report.
94	2-27	A very important section!
94 95	28-15	This section was repeated earlier on p. 94.
95	16	Fig. 18 is not very instructive. Also, I could not find where it fits in or where it was discussed in the text.

98	2-20	Are cost: benefit ratios appropriate for measuring these impacts?
99 102	24- 18	Text Box 2, its text, figures and tables was an excellent instructive section.
125	15-18	"decreasing N fertilizer application rates 10 to 50% . . . . would decrease nitrate output to the river by 10 to 43%". Compared to what rate? One always needs to be careful when making these kinds of statements without defining the boundaries. We have data showing that when N application rate is reduced from 160 lb N/A to 120 lb N/A (a 25% reduction) that nitrate-N concentrations in drainage water are reduced by about 30% without losing crop yield. When reducing the N application rate to 80 lb/A from the Univ. of Minn. N recommendation of 120 lb/A, nitrate-N concentrations were reduced only about 10%, but crop yields were significantly reduced. Bottom line: one needs to state what the starting point or comparison value is to make these kinds of statements valid.
125	30	Jaynes and Karlen (2005) not found in Reference section.
126	2	Fig. 24 should correspond to Fig. 22 or 23
	18	" 25 " " " " 24.
	19	" 26 " " " " 25.
127	Fig. 25	Fig. 25 shows how corn grain yield per kg N changes with time. This "kg grain per kg N" relates to both the N from the soil and from the fertilizer. Thus, it does not specifically relate to NFUE (line 17, p. 126).
128	1-3	What is the N rate starting point or N rate range starting point? (same concern as above for p. 125 lines 15-18).
128	5	Fig. 27 should be Fig. 26.
129	14	" 28 " " 27.
131	2 & 7 8	" 30 " " 29. " 32 " " ??.
131	Fig. 28	no discussion found in text

<u>Comments from Dr. James Schauer</u>

4) Page 58, lines 10-12 - Recommendation 5 is really not a feasible recommendation. It is not really possible to measure trends in fugitive or areas sources. Networks like NADP are used as an assessment tool to study trends in emissions. A better recommendation may to be expand the locations or measurements of the NADP and STN networks.

Chapter 3: Integrated Risk Reduction Strategies for Reactive Nitrogen

From Dr. Elizabeth Holland

The recommendations as currently constructed are likely to result in a series of independent studies that do not make substantial progress towards solving problems on larger spatial scale. Careful thought and substantial revision of the current plan is required to ensure that the studies and integration achieve the desired environmental and policy outcomes.

From Dr. Gregory McIssaacs

Page 143, line 14: delete "for the WRP" as this was mentioned at the beginning of the sentence.

Page 151, line 11: The assessment of Cassman et al. (2002) was based on data collected from the 1995-1999 growing seasons, not the 2000 growing season as stated on line 12. It may also be relevant that Cassman was using a different definition of NFUE than was defined in this report on page 43 (footnote 5). As defined on page 43, NFUE has units of kg grain per unit of N fertilizer applied. Cassman et al. defined a recovery efficiency as the difference in above ground N between a fertilized and unfertilized crop divided by the quantity of fertilizer applied. A problem with this approach is the unfertilized baseline is an artificial condition influenced by the prior crop residues.

Page 152, lines 15-17: some citations that describe the storage systems would be valuable.

Page 152, line 21: "bemoaned" does not seem to be an appropriate descriptor of an NRC report.

Page 153, lines 29-30: there appears to be some words missing in the sentence starting with "Sommer".

Page 153, line 34-36: This sentence states that all unused fertilizer plus some of the N fixed by soybeans moves to surface and groundwater and ignores denitrification and long term storage. This statement, and the entire report also ignores the fact that soybeans in much of the Midwest are a net sink of N. Like many legumes, soybeans can reduce their investment in fixation if there is an abundant supply of soil N, and much of the plant N is transferred to the bean. In most years, soybeans remove more N from the soil than they leave behind in crop residues.

Page 156, line 2: "a side reaction for the … catalyst system is ammonia" probably should be "…produces ammonia"

Page 157, lines 5-7 are duplicated by lines 8-10.

Page 157, line 18, NR should be changed to Nr.

Page 159, Target Recommendation 2 seems to fit with the text of Target Goal 3 (page 161), and Target Goal 2 fits with the text of Target Recommendation 3.

Comments from Dr. Giles Randall

142	27	Fig.29 should be Fig. 32.
150	12	" the most leaky lands should be taken out of production ". I find this statement to be most interesting. In this whole document it is the only sentence that relates to changing from a row-crop (corn & soybean) system to a non-row crop system (perhaps a perennial grass or alfalfa system. Minnesota research has shown nitrate-N losses to drainage water to be reduced by 30 to 50 times when converting from a corn and soybean system to a perennial grass or alfalfa system. The effect of changing to a different cropping system has a greater effect on reducing nitrate losses to drainage water than combining all BMP factors for N management mentioned in this report.
150	23-39	It is not surprising that watersheds of the MRB with the highest rates of fertilizer runoff had the lowest amount of land enrolled in federal conservation programs. Lands enrolled in conservation programs are usually highly erodible with significant sediment loss potential; whereas the MRB watershed with higher nitrate runoff are generally flat and "non-erodible". So this could be an issue of taking flat non-erodible areas out of production to minimize nitrate loss and then replacing corn production on to areas much more vulnerable to soil erosion. It would be exchanging nitrate loss for sediment and P loss. Not a good trade.
151	7-10	This wording suggests that this is a NFUE calculation (kg grain produced per kg of N applied). However, the values of 42 to 57 kg grain/kg of N convert to 0.75 bu to 1.00 bu of grain per pound of applied N; these values far exceed NFUE values and lead me to suspect that they are merely NUE (PE) values, which combines the yield from soil N with that from fertilizer N. Thus, this is <u>not</u> an illustration of NFUE. It is a 35% yield efficiency gain but it cannot be specifically related to improved N fertilizer use efficiency (NFUE).
151	10-12	The next sentence relates this as NFUE and compares it to NFUE of 37%; it is like comparing apples and oranges. Furthermore, in Fig. 25 on page 127, Fixen and West did not subtract grain produced from soil N from the grain produced from soil + fertilizer N – a requirement for NFUE.
151	10	Fixen and West (2002) was not found in References section.
151	37-39	More than a "large investment in research, extension education, and

		technology transfer" will be needed to obtain substantial improvements in NFUE. In 1991, the State of Minnesota appointed a Nitrogen Fertilizer Task Force, which developed a N Management Plan for the state. This consisted of a 3-phase plan leading up to N regulations and the development of BMPs for N in six different areas of the state. Seven UM Extension bulletins (one for each of the areas and one for overall N mgmt) based on University research were published in 1993. Countless N management extension meetings were held and thousands of bulletin/fact sheets were distributed over the next 15 years with astonishing little implementation. The bulletins were revised in 2008. In my opinion one needs more than "volunteerism" before BMPs are widely practical. Incentives, disincentives and a "stick" approach is needed in conjunction with state-of-the-art research. The increased price of fertilizer N did more to change grower behavior with respect to N than did all of the extension bulletins distributed and meetings held.
153	29	sentence unclear
153	32	BMPs to minimize NH_3 emissions were not found in section 3.2
153	34-41	More N is removed in harvested soybean grain than is fixed by the plant. Also nitrate leached into drainage under soybeans comes primarily from the soil N and from fertilizer applied to corn the previous year. Nitrate leaching losses in a corn-soybean system are more complex than described in this paragraph.
153	38-39	Del Grosso et al. (2006) not found in Reference section.
154	35-39	This is an extremely important statement.
155	6	Section 3.3.1 did not address NO_X emissions declining in the U.S.
156	14	include "Universities"
157	20-28	BMPs based on excellent research and vigorously extended are not enough to change grower behavior AND industry sales/marketing when it comes to N. Tradition and the strong role of the fertilizer dealer are powerful forces opposing the implementation of N BMPs. As stated earlier incentives and disincentives are needed to accompany the BMP process.
159	6-7	There is lots of talk and enthusiastic, optimistic marketing for improved tile-drainage systems, but in my opinion, there are numerous practical and logistical obstacles that are not discussed. Reducing tile drain depth from 3.5' to 2.5' will be helpful due to the large area of drained soils where this kind of management is suitable. But, I am not that optimistic about

		significant nitrate mitigation across the landscape with controlled drainage, wood chips for denitrification in the tile lines, and riparian buffers in most Corn Belt land.
159	10-11	Advances in fertilizer technology will be helpful in certain specific areas but in the big picture will have a limited effect on mitigating nitrate loss to water.
159	22	Simpson et al. (2008) not found in Reference section.
159	36-41	Target recommendation 2 text should be under Target recommendation 3.
160 161	34- 10	Target rec. 3 text should be under target rec 2.
161	7-9	Decreasing Nr by up to 20% may be possible on average but the range is likely 0 to 100%. Again, what is the starting or reference point for the 20% reduction?
170	12-18	Does not agree with Target Goal 2.
170	20-34	Agrees with Target Goal 2.

<u>From Dr. Stuart Weiss</u>

Policy responses:

Overall, the ongoing critical loads process (CLAD) provides a means for addressing this problem in the long run. Note regional efforts like that at Rocky Mountain National Park to reduce emissions are starting, based on a finding of critical load for alpine lakes.

Impacts on threatened and endangered species fall under the jurisdiction of the US Fish and Wildlife Service. Since 1999, mitigation for impacts of powerplants, road widening, and urban development on Bay checkerspot butterflies and serpentine grasslands include land acquisition and management/monitoring endowments and the development of a regional Habitat Conservation Plan. The Endangered Species Act may be a powerful means for identifying and mitigating N-deposition impacts on protected species

It is the short-term mitigation and management needs of these ecosystems that desperately need attention, especially control of invasive species. In California cattle grazing has been effective in maintaining serpentine grasslands and vernal pools. Management of many ecosystems remains problematic- wildland weeds are hard to control and substantial resources are needed on the ground.

The emissions of ammonia from vehicles (catalytic converters) along heavily traveled roads creates high deposition corridors. Vehicular ammonia may be one of the more readily controllable sources, and the call for ammonia to be considered as a regulated pollutant

Measurement and modeling of N-deposition loads is critical for understanding highly local effects, such as roadsides, as well as regional plumes. Passive samplers provide inexpensive means for monitoring time-averaged concentrations. A 4 km CMAQ run for the California (Tonnesen et al 2006) has proven immensely valuable for N-deposition assessments at regional levels. Standards for project-based and cumulative impact assessments need to be developed.

Fenn, M. E., J. S. Baron, et al. (2003). "Ecological Effects of Nitrogen Deposition in the Western United States." Bioscience **53**: 404-420.

Tonnesen, G., Z. Wang, et al. (2006). Assessment of Nitrogen Deposition: Modeling and Habitat Assessment. Sacramento, CA, California Energy Commission, PIER Energy Related Environmental Research CEC-500-**2006**-032.

Weiss, S. B. (1999). "Cars, Cows, and Checkerspot Butterflies: Nitrogen Deposition and Management of Nutrient-Poor Grasslands for a Threatened Species." Conservation Biology **13**(6): 1476-1486.

Weiss, S. B. (2006). Impacts of nitrogen deposition on California ecosystems and biodiversity. Sacramento, CA, California Energy Commission, PIER Energy- Related Environmental Research CEC-500-2005-165.